MEGHALAYA

# Stormwater Design Manual

Standards for the planning, design, construction, operation and maintenance of stormwater systems

Preserve | Retain | Detain | Convey | Maintain

**Draft v1.0**

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Prepared by

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# About this draft

**Status.** This is Draft v1.0 of the *Meghalaya Stormwater Design Manual*. It was prepared by Neer as a proposed stormwater design standard for Meghalaya.

**Not adopted.** This Manual has not been adopted, notified or endorsed by the Government of Meghalaya, by its Governor, its Council of Ministers or its Legislative Assembly, or by any of its departments, local bodies or agencies. In particular, it has not been adopted, notified or endorsed by the Urban Affairs Department, the Meghalaya Urban Development Authority (MUDA), the Shillong Municipal Board (SMB) or the Tura, Jowai, Williamnagar, Resubelpara or Baghmara Municipal Boards, the Shillong Cantonment Board, Shillong Smart City Ltd, the New Shillong Township Development Authority (NSTDA), any Town Committee, or any other agency. Nor has it been adopted, notified or endorsed by the Khasi Hills, Jaintia Hills or Garo Hills Autonomous District Councils (KHADC, JHADC and GHADC), by any building authority of a District Council, such as the Khasi Hills Building and Structure Regulatory Authority (KHBSRA), or by any Dorbar Shnong, Rangbah Shnong, Nokma or other traditional institution. Where it names a body, such as the Water Resources Department, the Public Health Engineering Department (PHED), the Public Works Department (PWD), the Soil and Water Conservation Department, the Forest and Environment Department, the Revenue and Disaster Management Department, the Meghalaya State Pollution Control Board (MSPCB), the Meghalaya State Disaster Management Authority (MSDMA), the Meghalaya Basin Development Authority (MBDA), the Meghalaya State Wetlands Authority, the Flood Zoning Authority under the Meghalaya Flood Plain Zoning Act, 2026 (when it is constituted), the Meghalaya Energy Corporation Ltd (MeECL) or the Meghalaya Power Generation Corporation Ltd (MePGCL), a Deputy Commissioner or a district administration, the High Court of Meghalaya, the National Green Tribunal (NGT) or the Supreme Court, or a body of the Union, such as the Central Water Commission (CWC), the India Meteorological Department (IMD), the Central Ground Water Board (CGWB), the Central Pollution Control Board (CPCB), the North Eastern Space Applications Centre (NESAC), the National Highways Authority of India (NHAI) or the Ministry of Environment, Forest and Climate Change (MoEF&CC), or a research body such as Integrated Research and Action for Development (IRADe), it describes the role that body would have if the Manual were adopted. It does not say the body has agreed to that role. Citing a body's document does not make this Manual that body's document.

**No legal force.** Until a competent authority adopts it, with or without changes, this Manual has no legal force. Until then, the Meghalaya Building Bye-Laws 2021 as amended (the Bye-Laws 2021), the Meghalaya Town and Country Planning Act, 1973 (the MTCP Act), the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015 and the instruments of the other District Councils, the Town Committee Acts, the Meghalaya Municipal Act, 1973, the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023 as amended (the Waterbodies Guidelines), the Meghalaya Flood Plain Zoning Act, 2026, the Shillong Master Plan 2041 and the other master plans, drainage schemes, orders of courts and tribunals and approval conditions in force continue to apply.

**Meghalaya and the Sixth Schedule.** Almost the whole State lies in three autonomous districts under the Sixth Schedule to the Constitution, and the power to regulate building and land is divided by area. The Bye-Laws 2021 apply to "all the Master Plan Areas, Municipal areas and Scheme Areas within the State", and name the "Authority" as "the Meghalaya Urban Development Authority / Autonomous District Councils as applicable". In those areas MUDA grants building permission and the Municipal Boards keep their own drains under the Municipal Act; the Shillong Cantonment Board acts in the Cantonment. Outside them, building and land are regulated by the District Councils, through the KHADC's Regulation of 2015 in the Khasi Hills, with permissions issued by the KHBSRA since 2020, as reported; the building instruments of the JHADC and the GHADC were not found [TBC]. Town Committees, Dorbar Shnongs and other traditional institutions act under the District Councils' rules. The CAG found that the Town Committees and census towns, "47 per cent of the total urban population", are "governed by the concerned ADCs" and not by the Urban Affairs Department, so nearly half of the urban

population lies outside the reach of the Bye-Laws 2021. Who regulates where is disputed: the KHADC's Executive Committee rejected the Bye-Laws 2021 in October 2021 for encroaching on the Sixth Schedule areas, as reported, and its present position is not known [TBC]; this Manual states the dispute and takes no side. This Manual therefore names its "competent authority" by area, as Chapter 1 sets out. The Urban Affairs Department could make it a condition under the Bye-Laws 2021 by an amendment under section 74 of the MTCP Act; a District Council's Executive Committee could adopt it for its district by amending its own building regulation, as the KHADC made its Regulation of 2015; a Municipal Board could adopt parts of it as bye-laws; the Flood Zoning Authority, once constituted, could use its corridor maps; and the Forest and Environment Department could align the setbacks of the Waterbodies Guidelines with it. None has done so, and the Manual can reach an autonomous district only through its District Council. Most land in the State is held by communities, clans or private owners, not by the State, so this Manual secures drainage corridors and easements by agreement with the landholding institution (a Dorbar Shnong, a clan or an owner) where they are not State land, or reserves them in a master plan; it does not assume that land can be taken. The paragraphs of the Sixth Schedule were not read for this Manual and are not quoted; the division is described by its effect, from the Bye-Laws 2021, the KHADC's Regulation and the CAG's audit.

**Names.** Some places, rivers and gauges have more than one name or spelling in statutes, sources and on IMD and CWC stations:

- **Cherrapunji**, **Cherrapunjee** and **Sohra** are the same place. IMD's station, with its record of 1,563.0 mm in 24 hours on 16 June 1995, is "Cherrapunji" (index 42515, rainfall data 1902–2012); the daily rainfall map of IMD's Meteorological Centre Shillong shows two gauges there, "Sohra" and "RKM Sohra". This Manual writes Sohra for the town and Cherrapunji for IMD's station and for the curve of IMD's national rainfall study (Das et al., 2022) that bears its name. Press reports give the 1995 fall as 1,563.3 mm; this Manual uses IMD's 1,563.0 mm;
- **Shillong (C.S.O.)** (index 42516, rainfall data 1957–2012) is the Shillong station in IMD's tables of extremes, with a record of 273.2 mm in 24 hours on 25 June 1988. The CWC flood estimation report for subzone 2(b) prints **Shillong (Obsy)** and **Upper Shillong** as separate ordinary rain gauges, each with a fall of more than 400 mm on 20 June 1934, and a **Shillong** self-recording gauge, with 347 mm on 14–15 September 1960. They need not be one gauge, and the 347 mm, which falls inside IMD's period of record but exceeds IMD's maximum, is not used until the two are reconciled [TBC]. This Manual names the gauge each figure comes from;
- CWC's flood estimation reports divide the State between two subzones. The plateau, the northern foothills and the Garo hills are in **subzone 2(b), South Brahmaputra**, whose revised report (No. SB-2(b)/R-4/44/99, March 2000) describes its area as "large parts of Assam and areas of Meghalaya, Nagaland and Arunachal Pradesh"; the southern escarpment facing Bangladesh, with Sohra, Mawsynram, Shella, Pynursla, Dawki and Baghmara, is in **subzone 2(c), Barak**, for which CWC has never published a report. The boundary on the report's plates runs west to east along the plateau, just south of Shillong and on or just north of Tura, as this Manual reads them. No part of the State is in **subzone 2(a)**, North Brahmaputra, though Chapter 2 uses that report's ratios of short to 24-hour rain on the plateau. These subzones are not the four rainfall zones (ML-Z1 to ML-Z4) and seven hydrologic sub-areas (ML-A, ML-A1, ML-B, ML-B1, ML-C, ML-C1 and ML-D) that this Manual sets in Annex 2A, nor Zones 1 and 2 of a waterbody setback in Chapter 7, nor a "flood zone" under the Flood Plain Zoning Act, 2026, which that Act defines by "the maximum probable floods";
- the FER for subzone 2(b) and other older sources use the districts of their time, **Khasi & Jaintia Hills** and **Garo Hills**, which were divided from the 1970s on. Today the State's districts are taken to be East Khasi Hills, West Khasi Hills, South West Khasi Hills, Eastern West Khasi Hills, Ri Bhoi, West Jaintia Hills, East Jaintia Hills and North, East, West, South and South West Garo Hills; this list was not confirmed against a current notification [TBC], and some sources count 11 districts. The State Language Act of 2005 names the districts of 2005, among them Jaintia Hills. IMD reports Meghalaya with Assam in its "Assam & Meghalaya" meteorological subdivision. A clause that names a district must be checked against the current list;

- the rivers are spelt in several ways: **Umiam** is Umium in the FER; **Umtru** is also Umtrew; **Digaru** is Digru in the FER; **Myntdu** is also Myntudu; **Jinjiram** is also Jingiram; **Umngot** is also the Wah Umngot; **Umkhrah** is also the Wah Umkhrah, Umkhra and Wahumkhrah; and **Umshyrpi** is also the Wah Umshyrpi. **Barapani** is the Umiam reservoir and its surroundings, and the reservoir is called Umiam lake. The Umkhrah and the Umshyrpi join below Shillong as the **Wah Roro** (or Roro) before they enter Umiam lake. **Nan Polok** is the Khasi name of Ward's Lake in Shillong, and **Pung Sajar Nangli** that of Thadlaskein, near Mukhla in West Jaintia Hills, as reported; these natural, historic and sacred waters keep their own names in this Manual;
- where a shared clause names the State's main city or its largest local body, this Manual names **Shillong**, the State capital, and the **Shillong Municipal Board (SMB)**. SMB is a Municipal Board under the Meghalaya Municipal Act, 1973, not a corporation, and its area is only part of Greater Shillong: only parts of the Umkhrah and the Umshyrpi lie in it, and the rest is under the KHADC, as the State told the NGT in 2023; the Cantonment, the census towns, New Shillong and the 54 villages of the Shillong Planning Area lie outside it. The State has six Municipal Boards: Shillong, Tura, Jowai, Williamnagar, Resubelpara and Baghmara;
- the State has four broad belts. The **northern foothills** of Ri Bhoi and the Garo Hills fall to the Brahmaputra plains, with valley fills and, on the north-western fringe of the Garo Hills and in the Jinjiram valley, thick alluvium whose water table lies 3–5 m below the ground. The **Shillong plateau**, of gneiss, quartzite and phyllite under thin red loams, carries Shillong, Mawphlang, Nongstoin, Mairang and, in the Jaintia uplands, Jowai. The **southern escarpment** drops from the plateau to the plains of Bangladesh over cavernous limestones, sandstones and coal measures; it holds the record-rainfall belt of Sohra and Mawsynram, and in the Jaintia Hills and parts of the Garo Hills it is honeycombed with rat-hole coal workings. The **Garo hills** to the west, of sandstone and shale, carry Tura and Williamnagar. The names describe regions, not administrative units;
- many levels in the sources are not in metric or not on a stated datum. MePGCL publishes some reservoir levels in **feet** (1 ft = 0.3048 m): the full reservoir level of Umiam–Umtru Stage III is 2,230 ft and its maximum water level 2,235 ft, about 679.7 m and 681.2 m; the level of Umiam lake behind the Stage I dam is known only from the press, as "3,220 ft", and on no stated datum [TBC]. Other MePGCL reservoirs are given in metres, such as the full reservoir level of 618.00 m of the Myntdu–Leshka Stage I dam. CWC's levels at its sites in the State, in metres, were read only in transcriptions by SANDRP, such as the highest flood level of 73.47 m for the Umngot at Dawki on 28 May 2006, and no source read states their datum [TBC]. This Manual names the gauge, the unit and the datum with every level; and
- in this Manual **"the monsoon" and "the monsoon season" mean the wet season of 1 April to 31 October**. That is not IMD's usage: IMD counts April and May as pre-monsoon months, and the south-west monsoon reaches the State in about the first week of June and withdraws in about mid-October. The Manual's season begins on 1 April because the April and May storms on the escarpment are among the State's largest (Chapter 2).

This Manual uses the first form and keeps the others where a title, a source or a station uses them. Some names of bodies and laws need a word of explanation:

- the **Meghalaya Building Bye-Laws 2021** (the **Bye-Laws 2021**) are the State's building rules, notified by the Urban Affairs Department under section 74 of the MTCP Act by Notification No. UAU.73/2016/Pt/402 of 9 March 2021 and published in the Gazette of Meghalaya of 25 March 2021. They have been amended at least eight times, from 2024 to May 2026, and the amendments are numbered inconsistently: two instruments are each called "(Amendment)" and two "Second Amendment", and the notification of 15 January 2025 amends "the Meghalaya Building Bye-Law, 2024". This Manual cites each amendment by its notification number and date, and clauses as "the Bye-Laws 2021 (as amended), B1(vii)" or "Section I(a), cl. 3". The earlier bye-laws of 2011 were made by MUDA. **MBBL 2016**, in Chapters 1 and 10, is the national Model Building Bye-Laws of 2016, not the State's bye-laws;
- the **Meghalaya Town and Country Planning Act, 1973** (the **MTCP Act**) is the Assam Town and Country Planning Act, 1959 as adapted, as the State's notifications cite it; MUDA is the Authority under it, and the Urban Affairs Department notifies the bye-laws and the master plans. The **Shillong Master Plan 2041** (**SMP 2041**) was notified by No. UAU.76/2022/Pt.I/74 of 27 November 2024, as cited in its amendment of

29 October 2025, and covers a planning area of 288.5 km², with NESAC's *Risk Informed GIS Based Master Plan* report of May 2023; no "Shillong Master Plan 2035" was found, and this Manual does not cite one. A draft risk-informed master plan for Tura was published for objections on 16 February 2024;

- the **Meghalaya Municipal Act, 1973** is the Assam Municipal Act, 1956 as adapted, amended by the Meghalaya Municipal (Amendment) Act, 2021. It vests "all public streams, channels, water-courses, springs tanks, reservoirs" and the public drains and sewers within municipal limits in the Board (section 62). Its penalties for unauthorised drains are ₹25 and ₹50;
- the **Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015** was made by the KHADC's Executive Committee by Notification No. DC.II/Genl/31/2015/9 of 4 August 2015, under the United Khasi-Jaintia Hills District (Establishment of Town Committee) Act, 1960, and extends to the whole Khasi Hills Autonomous District. It sets a duty to protect "catchment areas, water sources, spring sheds, streams and rivers" (section 15) and makes rainwater harvesting mandatory in all existing and new buildings (section 36). The Bye-Laws 2021 list the three Town Committee Acts, of 1960, 1975 and 1950, among their Acts;
- the **Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023** were issued by the Forest and Environment Department by No. FOR/CC/29/2019/Pt/688 of 25 August 2023, on the High Court's direction in a public interest case on the cleanliness of Umiam lake (PIL 10 of 2019), and amended in February 2024 and July 2026. They are executive guidelines. They bind building permissions under the Bye-Laws 2021, which refer to them since 2024; elsewhere they are to be implemented "in such manner as may be prescribed", and nothing prescribed was found. Their setbacks are measured from "the mean high flood level of a water body observed in the past ten years", and their "waterbody" excludes streams whose bed was dry for at least 240 days in each of the past ten years, which takes in most jhoras (Chapter 7). The High Court's interim bar on building within 50 m of a waterbody (24 May 2023) ended when the case was closed on 19 February 2024; this Manual does not cite it as a rule. The amendment of 2024 dates the Guidelines "18th July, 2023"; this Manual uses the gazetted date, 25 August 2023;
- the **Meghalaya Flood Plain Zoning Act, 2026** provides for a Flood Zoning Authority, surveys, notified flood zones and restrictions that "shall prevail" over other laws. Its Bill was read in the Gazette of 23 February 2026; the Act, as Act No. 4 of 2026 assented to on 6 March 2026, is known only from a search snippet of the State's law site [TBC]. No constitution of the Authority, rules or zone notification was found, and this Manual treats no zone as notified;
- **MSDMA** is the State's disaster management authority, under the Revenue and Disaster Management Department; the District Disaster Management Authorities are written in full. The **Meghalaya State Wetlands Authority** was constituted on 1 November 2017; no wetland notified under Rule 4 of the Wetlands (Conservation and Management) Rules, 2017 and no Ramsar site in the State was found. **MBDA** runs the State's spring-shed programme;
- the **Water Resources Department** holds the rivers and flood works, ran the floodplain zonation study of the Umkhrah and other stretches, and is named in this Manual as the State groundwater agency, through the committees that issue groundwater no-objection certificates; the State has no groundwater Act, and CGWB's North Eastern Region office at Guwahati keeps the observation wells. **PHED** supplies water and has been the nodal department for sanitation outside municipal areas since 2023. The **PWD** keeps the State's roads and their drains and culverts, and **NHAI** and the National Highways and Infrastructure Development Corporation Ltd (**NHIDCL**) the national highways;
- **MeECL** and its generating company **MePGCL** operate the Umiam–Umtru dams, the New Umtru dam and the Myntdu–Leshka dam (**MLHEP**); their guidelines for gate operation say that notice of releases is "not practicable" and that warnings go by siren, telephone or SMS;
- the **High Court of Meghalaya** (HC) and the **NGT** have shaped the State's rules on waterbodies, river pollution and mining. The NGT's case on Shillong's rivers (OA 192 of 2022) produced the State's action-taken report of 21 March 2023 that this Manual cites, and its order of 17 April 2014 (OA 73 of 2014) stopped rat-hole mining across the State; the Supreme Court decided the appeals from it on 3 July 2019 (Civil Appeal 10720 of 2018). This Manual cites court and tribunal orders with their status; and

- Meghalaya has no tehsils. Where a shared clause names a revenue subdivision, this Manual uses the **Community and Rural Development (C&RD) block**. A district is headed by a **Deputy Commissioner** (DC). In the Sixth Schedule areas most land records are held by the District Councils, the Dorbar Shnongs and the clans, not by the State's revenue staff (Chapter 7).

Where a shared clause calls for the local language on a sign, a form field or a basin name, this Manual writes "Khasi or Garo". **English is the official language of the State and the language of this Manual** (Meghalaya State Language Act, 2005, Act 10 of 2005, section 3). Under section 4 of that Act, Khasi is an associate official language in the East Khasi Hills, West Khasi Hills, Jaintia Hills and Ri Bhoi districts, and Garo in the East, West and South Garo Hills districts, as the districts were in 2005. The Meghalaya Official Languages Ordinance, 2026 reportedly makes English, Khasi and Garo official languages and repeals the 2005 Act, while one outlet reports that the associate status is kept; the sources conflict, and the Ordinance was not read [TBC]. So in this Manual "Khasi or Garo" means the language of the district: **signs and flood-depth markers are bilingual by district, in Khasi and English in the Khasi and Jaintia Hills districts and in Garo and English in the Garo Hills districts** (set by this Manual). Pnar, spoken in the Jaintia Hills, may be added there, though no official status for it was found; if the Ordinance is confirmed to make both languages official across the State, signs may carry all three. Khasi and Garo are both written in the Roman script, so where a shared clause says "script", it means the Roman spelling used in the district.

Some local words are used in the text, and are explained again where they first appear:

- a **pung** (Khasi and Pnar: pond, pool or small lake; Garo: *pokri*) is this Manual's general term for a pond, a pool or a small lake. Singh's *Khasi-English Dictionary* (1906) gives "Pung, ka, n. a pool" and his *English-Khasi Dictionary* (1920) gives *ka pung* first for both "Pond" and "Pool"; the word also names Pung Sajar Nangli. Khasi and Pnar mark the plural with the article *ki*, not with an ending, so the English plural *pungs* is a convention of this Manual. The same spelling also means "a joint" (Singh, 1906). The Garo *pokri* (pond, tank, pool) is a false friend of the Khasi *pukri*, which means a well. This Manual writes **detention pond** for engineered storage and never calls a detention basin a sacred or community pung;
- a **nan** (Khasi) is a tank, a built store of water, as in Nan Polok; in Pnar it is a small body of still water;
- **wah** (Khasi and Pnar) is a stream or river, as in the Wah Umkhrah; **um** is water, the prefix of many river names (Umiam, Umkhrah, Umshyrpi); and **umpohliew** (Khasi) is a spring;
- **nur** and **muri** (Khasi) are a channel, ditch or drain, *muri* also a culvert, and **dooid** (Pnar) is a drain that carries off rainwater or waste water;
- **chibima** (Garo) is a river and **chiring** (Garo) a brook or stream; *chi* is water;
- a **law kyntang** (Khasi) is a sacred grove, a patch of forest kept by custom; many lie at the heads of perennial streams, as reported;
- a **jhora** is a small hill stream, in the local English of Shillong, as reported; it is not in the Khasi dictionaries read, and this Manual glosses it where it first appears in a chapter; and
- a **Dorbar Shnong** is the village council of the Khasi and Jaintia Hills and a **Rangbah Shnong** its headman; the KHADC's rules on solid waste empower the Dorbar Shnong to fine polluters. A **Nokma** is the head of a Garo village, whose role in land and drainage was not researched for this Manual [TBC].

The dictionary page numbers behind these glosses were estimated from scanned text and are to be checked on the page images [TBC].

Some abbreviations have more than one meaning:

- AMC is the antecedent moisture condition in Chapters 2 and 3; this Manual does not use it for any municipal body;
- SMB is the Shillong Municipal Board, a Board and not a corporation. In other editions of this series and in some sources similar letters stand for other bodies; in this Manual SMB means only this one;
- ADC is an Autonomous District Council: the KHADC, the JHADC or the GHADC. DC is a Deputy Commissioner;

- "Bye-Laws 2021" is the Meghalaya Building Bye-Laws 2021 as amended, and "MBBL 2016" the national Model Building Bye-Laws 2016. Neither is the building rule of any other State;
- HFL is the highest flood level recorded at a gauge, as CWC uses it. It is not a design level. The Bye-Laws 2021 use the words "Highest Flood Level" for the line above which a stilt floor on a sloping site must rise (B1(v)(b)), and the KHADC's forms ask for "the highest flood level (HFL) reached above the street"; no HFL has been published for Shillong's streams, and Chapter 7 says how this Manual finds one. No CWC site in the State has a warning level (WL) or a danger level (DL);
- FRL (full reservoir level), MWL (maximum water level) and MDDL (minimum draw-down level) are used for MePGCL's reservoirs, in feet or metres as each guideline gives them;
- FPZ is flood plain zoning, under the Flood Plain Zoning Act, 2026; and
- SWD is a storm water drain.

The sense is clear from the context.

**Use with care.** Clauses and values may change after review. Designers remain responsible for their designs and for checking the data they use. Neer accepts no liability for decisions made on the basis of this draft.

**Disclosure.** Neer publishes the India Flood Atlas, a national map of modelled 1% AEP flood depth. Clause 6.11.3 names it as one example of a regional map that an Approving Authority may adopt for floor levels. The Manual does not require the Atlas; any map adopted under Clause 7.3.4 may be used.

**Comments.** Comments and corrections are welcome at info@neer.ai.

# Preface

Meghalaya's towns flood, and fail, for three reasons. June 2022 showed the first, when Mawsynram recorded 1,003.6 mm in the 24 hours to 08:30 on 17 June, a June record in IMD's tables, and IMD found the month's rainfall over Assam and Meghalaya the highest since 1901; the hill towns showed the second, when the rains of 30–31 May 2025 brought landslides near National Highway 6 in Umling block that were linked to hill cutting, as reported; and Shillong shows the third every day, because it has no sewers, and its drains and jhoras carry its sullage into the Umkhrah and the Umshyrpi, which CPCB lists in Priority I of its polluted river stretches.

1. **Rainfall that outruns every national product.** The State lies across two CWC subzones, and only one has a report. The revised report for subzone 2(b) (March 2000) covers the plateau, the northern foothills and the Garo hills; its plates give Shillong a 50-year day of about 560 mm, read by eye, which is 1.3 to 2 times every fall recorded at any Shillong gauge: IMD's record of 273.2 mm (25 June 1988), the 347 mm of the report's own self-recording gauge (1960) and the 415 mm and 437 mm of its ordinary gauges (20 June 1934). Its ratio of the 1-hour to the 24-hour rain, 0.48, the highest of any CWC report compared for this Manual, would give Shillong about 269 mm in an hour, 5.6 times the 48 mm that the self-recording gauge recorded in its largest hour. South of the plateau edge, the escarpment facing Bangladesh is in subzone 2(c), for which CWC never published a report, and the 2(b) plates draw no contour west of about 91.8°E. Yet that is where the rain is heaviest: Cherrapunji recorded 1,563.0 mm on 16 June 1995 and 985.5 mm on 13 September 1974, and its 48 hours of 15–16 June 1995, 2,493 mm, are reported as a world record. Its records in IMD's pre-monsoon months are each larger than the 50-year day that the 2(b) plates give anywhere in the Brahmaputra valley: 587.4 mm on 23 March 1994, 644.2 mm on 16 April 1990 and 812.0 mm on 25 May 1916. Sohra and Shillong are about 36 km apart, and their 24-hour records differ by more than five times. IMD's national set of rainfall intensity curves (Das et al., 2022) has a genuine panel for Cherrapunji, but its Shillong panel repeats a curve printed for many other cities, and the gridded rainfall of NIH-DHAARA gives Dawki a 50-year day of 1,423 mm, more than Mawsynram's. No hourly maximum for Cherrapunji or Mawsynram was found in any primary source, and the deaths of 2014 in the Garo Hills, where torrential rain on the night of 21 September was followed by 52 deaths by 28 September, and more than 60 by a later account, as reported, came with no rainfall measurement at all.
2. **Hill towns where water put into slopes, limestone or mine voids moves the ground, and jhoras narrowed by building and garbage that flood the valley floors.** Shillong is built on the plateau's thin red loams over gneiss and quartzite, on slopes that the Shillong Master Plan's report divides into a "Regulated Slope" of 40–50° (3.2 km²) and a "Restricted Slope/No Construction Zone" above 50° (0.53 km²); the IRADe plan for Shillong records landslides at Laitumkhrah (2008), Happy Valley (2007), Lawsohtun, Mccabe Road, Bethesda and Arbuthnot, "very high" susceptibility along NH-40 and near the Umshyrpi, and, citing the Revenue and Disaster Management Department, about 22 deaths from landslides in 2014. The great earthquake of 12 June 1897 brought down a landslide at Sohra that is reported to have killed 600 people. On the escarpment and in the Jaintia Hills the ground is cavernous limestone, which CGWB describes as a "discontinuous aquifer in the cavernous limestones", and rat-hole coal workings, into which "smaller streams and rivers either disappear or have become seasonal", as reported; water put into such ground goes to caves and voids, not to an aquifer. In the valleys of Shillong, NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong", that "the water tops the banks along most of the streams", and that Polo Market, Pynthorbah, Nongrim Hills and Dhankheti are "highly potential for flash flood"; under the 15th Finance Commission 49,612 m³ of waste were removed from the Umkhrah. The Bye-Laws 2021 forbid building on slopes above 50° and limit cuts to 3.00 m, but no rule restricts soak pits or recharge on slopes, limestone or mine ground.
3. **Storm drains that are the sewerage.** "The Shillong Planning Area has no sewerage system", NESAC records; septic tanks and soak pits take the sewage, and "the sullage from the kitchen and bathroom flows into the primary, secondary and natural drains and finally to the nearby rivers Wah Umkhrah in the north and Wah Umshyrpi in the south". MSPCB identified 32 outfalls, 20 on the Umkhrah and 12 on the Umshyrpi. In 2022–23 the biochemical oxygen demand reached 56 mg/L in the Umkhrah at Mawpdang and 59 mg/L in the Umshyrpi near the Law College, and the High Court found in 2023 that "Several of the rivers, including the Umkhrah in Shillong

itself are carrying such contaminated water that they may not be fit even to step into". The Smart City proposal of 2016-17, as quoted in the IRADe plan, gives Shillong 148.91 km of drains that "drain directly into the Umkhrah and Umshyrpi rivers", coverage of "less than 75%" of the city and "sewerage mixing in drains" of "almost 100%"; the same plan's table of service levels gives a coverage of 85%, and the two conflict. Both rivers flow, as the Wah Roro, into Umiam lake, which the Expert Committee constituted on the High Court's order found "serves as a cesspool of the waste materials of Shillong". In the Jaintia Hills the rivers also carry acid: a joint committee found the Lukha "to have become acidic", naming cement plants, power plants, breweries and ferro-alloy units as sources, and acid drainage from the coal mines is reported in the Kopili, the Myntdu and the Lukha; the biochemical oxygen demand (BOD), on which CPCB lists its stretches, does not measure it.

Over all three lies a regulatory field divided by the Sixth Schedule. The Bye-Laws 2021 reach the master-plan, municipal and scheme areas only; nearly half of the urban population, in the Town Committees and census towns, lives under the District Councils, as the CAG found. The Waterbodies Guidelines keep building only 3 m from an urban stream up to 3 m wide and 6 m from a wider one, and exclude the streams that are dry for 240 days a year, which most jhoras are. The Flood Plain Zoning Act of 2026 has, as far as was found, no Authority, no rules and no notified zone. And no State, municipal or District Council document fixes a design storm, a return period or a runoff coefficient for any town's drains.

Behind all of this lie the State's reservoirs, lakes, pungs, springs and sacred groves, which set the level at the outfall and the quality of the water downstream. Umiam lake, impounded in 1965 behind the Umiam Stage I dam, has a water spread of about 10 km² at its full level, as reported, and a catchment given as 221.5 km² and as over 220 km², though one source gives 547 km² for the river at the dam; its gross capacity was reported as 179.757 million m³ in 1965 and 159.206 million m³ in 2004, as sediment filled it, and its level, reported only as "3,220 ft", has no stated datum. MePGCL began releases from it at 3,216.15 ft in August 2024 on an IMD warning, as reported. Below the plateau, the Myntdu–Leshka dam has a spillway for 12,000 m³/s on a catchment of 350 km², about nine times the flow per km² of the New Umtru spillway (3,820 m³/s on 1,020 km²) on the northern slope, a measure of the escarpment's floods. The State has no Ramsar site and no wetland notified under the Wetlands Rules; the High Court accepted in April 2025 a report that 225 water bodies had been ground-truthed, as reported. Springs and streams, not wells, supply most towns, and the counts of mapped springs conflict, at 1,000 and 1,400, as reported; the sacred groves that sit at many stream heads are counted differently by every source, and no statute protects a spring or a grove, though the KHADC's Regulation charges its institutions with protecting "spring sheds".

Design for Meghalaya therefore has to cover a wet season that begins with the storms of April and May, before the south-west monsoon reaches the State in about the first week of June, and that runs past its withdrawal in about mid-October to storms such as those of 11 October 1975 at Cherrapunji (594.0 mm) and 8 October 2004 at Shillong (262.0 mm), and the Garo Hills floods of 4–6 October 2024; it is this Manual's monsoon season, 1 April to 31 October. Large falls come outside it too, as on 18 February 1993 (376.9 mm) and 23 March 1994 (587.4 mm) at Cherrapunji, so design statistics use the annual maxima of every month. The normal annual rainfall in the CWC report is 2,425 mm at Upper Shillong and 2,253 mm at Shillong (Obsy); the annual totals of about 11,430 mm for Cherrapunji and 17,800 mm for Mawsynram that CGWB quotes give no source or period and are not used as normals. There is no snow. Underground, every assessed unit of the State is safe, and the State draws 3.55% of its extractable groundwater (2022) or 4.60% (2024, as reported); there is "acute shortage of water during the summer as the major part of rainfall is lost as surface run-off", as CGWB found, so rainwater is worth storing for the dry season, not putting into the slopes.

National guidance sizes public drains but does not control the runoff that new building adds. This Manual makes stormwater a condition of development approval. Every development above a modest size must:

- hold frequent rainfall on site, in tanks for use in the dry season, and in the ground only where the ground can safely take it;
- release the large storms no faster than the undeveloped land did, or slower where catchments already flood; and
- show that its outfall still works when the receiving jhora, stream, river, pung or reservoir is high, when a dam upstream is releasing, or when a drain is choked with debris and garbage.

The Manual also sets how public drains, hill roads and their drains, jhoras, streams, rivers, pungs, reservoirs, springs and their recharge areas, outfalls and basin-wide master plans are designed, and how drains in steep catchments are protected against debris, sediment and garbage, so that private sites and public works aim at the same standard.

The Manual draws on leading stormwater standards from India and abroad. Each is adapted to Meghalaya's wet season of April to October, with its pre-monsoon storms and its June storms against the plateau and the southern escarpment; to the record-rainfall belt of Sohra and Mawsynram, where no CWC report applies; to the Umkhrah and the Umshyrpi, which join as the Wah Roro and flow into Umiam lake, and the Umiam–Umtru dams below it; to the Myntdu below the Myntdu–Leshka dam; to the Umngot at Dawki and the other rivers that flow south to Bangladesh; to the Ganol of Tura, the Simsang of Williamnagar and the Jinjiram of the Garo plains; to the jhoras of the hill towns; to the alluvium of the Garo foothills, the valley fills of Ri Bhoi, the thin red loams over the gneiss of the plateau, the cavernous limestones of the escarpment and the coal measures of the Jaintia and Garo coalfields; to the pungs, springs and sacred groves; and to towns built on community and clan land, whose roads and houses lie across the natural lines of drainage on the slopes.

1. **National base.** The CPHEEO *Manual on Storm Water Drainage Systems* (2019). This Manual builds on it and sets higher standards where it allows a State to do so. IRC road-drainage codes, including IRC:SP:42-2014 on hill roads, and the NDMA urban flood guidelines are also used. The drainage chapter of the IRC's hill road manual, IRC:SP:48, was not read for this Manual.
2. **Overall structure.** Kansas City Metro APWA Section 5600 (Version 2025.01), the most recent comprehensive regional standard. It supplies the preserve, retain, detain, convey and maintain sequence and the required retention volume.
3. **Design rainfall.** The CWC *Flood Estimation Report* for subzone 2(b), South Brahmaputra (revised, March 2000), as the interim source for the foothills, the plateau outside Shillong and the Garo hills. It rests on 14 gauged catchments, of which two, the Digaru and the Dudhnai, rise in Meghalaya, and its ratio of short to 24-hour rain was built from six recording gauges, Shillong's and five in the Assam valley; this Manual uses that ratio in the northern foothills only, and on the plateau and in the Garo hills uses the lower ratios of the CWC report for subzone 2(a), which still lie above every ratio recorded on the plateau. Inside the Shillong Planning Area it does not use the plate: the design day there comes from IMD's Shillong series, and is not less than the largest fall printed for any Shillong gauge, 437 mm, at 1% AEP. On the southern escarpment, where subzone 2(c) has no report and the plates no contour, the Cherrapunji curve of IMD's national study (Das et al., 2022) is the interim design rainfall, and every cross-drainage structure and outfall of more than 1 km² there needs a site-specific study. The design day is checked against the largest reliable days recorded nearby, but only within the same sub-area and not across a ridge or the plateau edge, so that Sohra's record never sets Shillong's design. NIH-DHAARA is reported beside the design value on the plateau and in the northern foothills only, and IMD's Shillong panel is not used.
4. **Monsoon practice.** The PUB Singapore *Code of Practice on Surface Water Drainage* (7th ed., 2025), for the fixed-coefficient route for small sites and drainage reserves. Malaysia's MSMA 2 (2012), for monsoon design storms and simplified on-site detention.
5. **Runoff reduction and treatment.** The Georgia Stormwater Management Manual (2016), for runoff reduction and downstream analysis. CIRIA C753 *The SuDS Manual* (2015), for the treatment train. The Mile High Flood District criteria manual, for outlet and storage design.
6. **Local rules.** The Meghalaya Building Bye-Laws 2021 and their amendments to 7 May 2026; the MTCP Act; the Shillong Master Plan 2041 with NESAC's report of May 2023, and the draft master plan for Tura (2024); the KHADC's Regulation of 2015; the Meghalaya Municipal Act, 1973 and its amendment of 2021; the Waterbodies Guidelines of 25 August 2023 and their amendments of 13 February 2024 and 6 July 2026; the Bill of the Meghalaya Flood Plain Zoning Act, 2026; the Meghalaya State Language Act, 2005; the Wetlands (Conservation and Management) Rules, 2017 and the State's notification of 1 November 2017 constituting the State Wetlands Authority; and the orders of the High Court of Meghalaya in PIL 10 of 2019, of the NGT in OA 192 of 2022 and OA 73 of 2014, and of the Supreme Court of 3 July 2019. This Manual follows them or, where disclosed, makes them stricter. The building instruments of the JHADC and the GHADC were not found; the gazetted text of the Flood

Plain Zoning Act, the Official Languages Ordinance, 2026 and the Sixth Schedule itself were not read; the KHADC's present position on the Bye-Laws 2021 is not known; and the CAG's report number was not confirmed. Every rule cited must be checked against the current text.

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## Why this Manual is needed

**India has no uniform stormwater design standard.** The CPHEEO *Manual on Storm Water Drainage Systems* (2019) is the country's first manual dedicated to storm water drainage, but it is advisory. The Ministry of Housing and Urban Affairs lists it among advisory guidelines and treats urban flooding as a matter for State Governments and urban local bodies. None of the national rules or State building rules reviewed for this Manual makes runoff control a condition of building approval, and neither does the Model Building Bye-Laws 2016.

**The national documents leave key values open, or give different answers.**

- **Return periods.** CPHEEO recommends 5 years for drains in Class I cities and 2 years elsewhere, and lets a State committee adopt higher values. A 2023 CPHEEO presentation shows a different table. IRC:SP:50-2013 suggests 1–2 years for urban road drains; IRC:SP:42-2014 suggests 5–25 years for road drains and 10–50 years for culverts, by class of road and size of culvert. An engineer designing a drain in Meghalaya can cite 1, 2, 5, 10 or 25 years, depending on the code chosen.
- **Detention.** CPHEEO describes limiting peak outflow to pre-development rates as general practice. It uses no "shall" and names no storm frequencies.
- **Climate.** The NDMA Urban Flooding Guidelines (2010) call for detention and retention facilities and for rainfall curves adjusted for climate change, but give no sizing rule or return period. The State Action Plan on Climate Change of 2015, as quoted in the IRADe plan, projects 10–15% more precipitation in East Khasi Hills by 2050 and about 3% more in the Garo Hills, but gives no factor for design; its second edition (2023–2030) was not read.
- **Design rainfall.** No national document gives design rainfall that a designer can apply directly to a given town. Each project chooses its own source. The CWC report for subzone 2(b) (2000) covers only the northern part of the State, and its plates read about twice every record at Shillong; its 1-hour ratio of 0.48, built mostly from gauges on the Brahmaputra plains, gives an hour at Shillong more than five times the largest recorded there; and the escarpment, where the rain is heaviest, is in subzone 2(c), which has no report at all. IMD's 2022 national set of rainfall intensity curves has panels for Cherrapunji and Shillong: Cherrapunji's is its own, with a 50-year day of about 1,440 mm read by eye, but Shillong's repeats a curve printed for many other cities. The one design statement found for Shillong, in RMSI's multi-hazard assessment of 2019 as quoted in the IRADe plan, takes its rainfall from CWC's *Brahmaputra Basin PMP Atlas* (2014), a source of probable maximum precipitation, not of design storms; neither the assessment nor the atlas was obtained.

**Meghalaya has no drainage design standard of its own.** Research for this Manual found no standard, IDF relationship or circular of the Urban Affairs Department, MUDA, SMB or any other Municipal Board, the PWD, the Water Resources Department or any District Council that fixes a return period, a runoff coefficient or a design rainfall for town storm drains; the Bye-Laws 2021 say only that drainage "shall be as per National Building Code 2016". No IDF relationship with published constants was found for any station in the State. The Shillong Master Plan's report maps flash-flood and landslide susceptibility, finding 4.67% of the planning area highly and 1.01% very highly susceptible to flash floods, and proposes decentralised treatment of waste water, but sizes no drain. The Water Resources Department has resubmitted a detailed project report for embankments and channel works on the Umkhrah and the Umshyrpi after the Brahmaputra Board returned the first, as reported; the RMSI study of floodplain zonation of the Umkhrah and other stretches, begun in June 2021 and 80% complete by March 2023, has not been published; and the State's river works since 2022 have been led by pollution orders, not by flood capacity. These are projects and studies, not a State standard. This Manual is offered as a technical companion to the Bye-Laws 2021 and the MTCP Act, the master plans, the KHADC's Regulation of 2015 and the other District Councils' instruments, the Waterbodies Guidelines, the Flood

Plain Zoning Act, 2026 and the Municipal Act: it supplies the design storm, detention, slope, water-level and buffer values that they leave open. It has not been adopted by the Urban Affairs Department, MUDA, any District Council or any other body. In particular:

- **The building rules require rainwater harvesting, but size nothing.** Table G1 of the Bye-Laws 2021 requires rainwater harvesting for every plot category and use, "Ground water recharge for covered area more than 3000 sqft" on larger residential plots, and soft cover of 10% or 20% of the plot, and G2.1.2 rebates 10% of the permission fee for rainwater harvesting with recycling; the KHADC's Regulation makes "storing of water runoff including rainwater in all existing and new buildings" mandatory and asks plans to show "the system of storm water drainage along with points of collection of rain water" (section 36). Neither gives a storage volume or a rate per m² of roof. No rule requires on-site detention, limits peak runoff or sets a design storm; the nearest are the Bye-Laws' measures for hazard-prone areas, inserted in 2024, that "Construction should not obstruct existing surface drainage courses" and that diversion ditches and swales direct runoff "into designated sediment basins" (Section I(b)), and the KHADC's call for "Semi-pervious ground cover … as paving wherever possible";
- **The slope rules stop building, not infiltration.** The Bye-Laws 2021 forbid building on slopes above 50° and limit building on 40–50° (Section I(a), 2024), limit earth cutting to 3.00 m, or 6.00 m to the crest of a reinforced concrete wall, with a report of the Geological Survey of India beyond that (B1(vii)), and ask for "good drainage facilities to prevent excessive saturation of sub-surface formations" (Section I(b)); the KHADC's Regulation sets the same 3 m and 6 m. But no rule restricts soak pits, recharge pits or infiltration trenches on slopes, on limestone or over mine workings, and the recharge that Table G1 asks of larger plots applies on the slopes of Shillong and the limestone of Sohra as on the Garo plains;
- **The setbacks are small, and they leave out the jhoras.** The Waterbodies Guidelines, as amended in 2024, keep building 3 m from an urban stream up to 3 m wide and 6 m from a wider one; this Manual reads the amendment of 2024 as having cut the setback outside municipal and cantonment areas from 5 m and 10 m to the same 3 m and 6 m [TBC]. Rural streams have setbacks of 10–30 m, reduced in 2026 from up to 50 m, and lakes and ponds 10 m, 20 m or 50 m by area, with a regulated zone four times the setback around lakes and along rural streams. The distances are measured from "the mean high flood level of a water body observed in the past ten years", a field mark, not a modelled flood; and a stream whose bed was dry for 240 days in each of the past ten years is not a "waterbody" at all, which leaves most jhoras unprotected. The Bye-Laws' own 2.40 m from a stream was replaced in 2024, the High Court's interim 50 m ended in February 2024, and the 50 m and 300 m zones that the Expert Committee recommended around Umiam lake, and the 50 m and 100 m buffers of NESAC's report, are recommendations, not rules;
- **The floodplain law has no zones yet.** The Flood Plain Zoning Act, 2026 defines a "flood zone" as "the area which is required to carry the flow of the maximum probable floods", without a return period, and lets the Authority's restrictions prevail over other laws, with permission deemed granted after 90 days; no Authority, rules or zone notification was found. The Bye-Laws 2021 forbid building on land "liable to flooding" without protection, and set a stilt floor at least 1.20 m above the Highest Flood Level on a sloping site, but no HFL has been published for Shillong's streams. This Manual offers a technical method for drawing a design flood line and corridors (Chapter 7); it does not replace any zone that the Authority notifies, a line that a master plan draws or a court orders, and where such a line binds and is wider, it governs; and
- **No document sets the river, jhora or reservoir level for which an outfall is designed.** CWC has seven level-monitoring sites in the State and no forecasting site, and none has a warning or danger level; its highest flood levels, such as 73.47 m for the Umngot at Dawki (28 May 2006) and 47.0 m for the Myntdu at Kharkhana (23 April 1995), were found only in transcriptions, on no stated datum, and two of them fall before the south-west monsoon. The Umkhrah, the Umshyrpi, the Umiam and the jhoras of the towns are ungauged. MePGCL gives some of its reservoir levels in feet and others in metres, and the level of Umiam lake behind the Stage I dam is known only from the press. Highest flood levels are records, not design levels.

**So each agency and each local body interprets the central manual its own way.** SMB and the other Municipal Boards, MUDA, the Cantonment Board, NSTDA, the District Councils and the KHBSRA, the Town Committees and the Dorbar Shnongs, the PWD, NHAI and NHIDCL, the Water Resources Department, PHED, MePGCL, Shillong Smart City Ltd, their consultants and funding agencies fill the gaps differently. No rule divides the drains between them: in Shillong a jhora may be SMB's drain for part of its length and run on community land under the KHADC for the rest, take the drainage of

a PWD road and the sullage of a whole locality, and end in Umiam lake, which MePGCL controls; only part of the Umkhrah and the Umshyrpi lies within SMB's limits. In the autonomous districts outside the master-plan, municipal and scheme areas the Bye-Laws 2021 do not apply at all, and the Waterbodies Guidelines apply only "in such manner as may be prescribed". And a reviewer has no common basis against which to check a design.

**What this Manual does about it.** It turns those open choices into one State standard:

- one source and method for design rainfall across the State, in four rainfall zones and seven hydrologic sub-areas, with a checked station analysis to govern where one exists; the 2(b) plates and ratios in the northern foothills; the plates with the lower 2(a) ratios on the plateau and in the Garo hills; IMD's Shillong record, with floors above every recorded fall, in place of the plate inside the Shillong Planning Area; the Cherrapunji curve on the southern escarpment, where subzone 2(c) has no report, with site-specific hydrology for every crossing and outfall of more than 1 km²; and a check of the design day against the largest reliable days recorded nearby that never crosses a ridge or the plateau edge (Chapter 2);
- named return periods for every drainage element (Chapters 2 and 6);
- a required pre- versus post-development rule for private sites (Chapter 4);
- a required tailwater check for outfalls to jhoras, streams, rivers, pungs and reservoirs, against a design river or lake level: CWC's highest flood levels where they exist, MePGCL's reservoir levels, converted from feet where they are given in feet, and its release reaches, and, on the ungauged streams and jhoras of the towns, surveyed flood marks and a 1% AEP study that allows for debris and garbage; and, on the valley floors of Shillong that flood when the Umkhrah rises, a check with the outfall closed (Chapter 5);
- a design flood line, and corridors and setbacks along jhoras, streams and rivers and around pungs, lakes, reservoirs and springs, proposed by this Manual for use where nothing wider binds, with a corridor at least 15 m from the top of bank on every natural channel draining 8 ha or more, whether or not the Waterbodies Guidelines count it as a waterbody, and the Guidelines' setbacks, the regulated zones and any notified flood zone wherever those are wider; corridor land that is not State land secured by agreement with its landholding institution (Chapter 7);
- no deliberate infiltration on slopes steeper than 10°, on colluvium, fill or slide debris, in mapped landslide zones, or above a cut slope or retaining wall, unless a geotechnical certificate allows it; none at all, with no exception, on limestone, over coal workings or near caves and sinkholes; recharge only on the tested alluvium of the Garo foothills and the valley fills of Ri Bhoi; roof runoff to storage for the dry season, as the building rules already require, with its overflow to lined drains; the recharge areas of springs above town intakes kept free of paving and road runoff; and the interception of dry-weather flow before every outfall to the Umkhrah, the Umshyrpi, the Wah Roro and Umiam lake, where drains carry sewage (Chapter 8);
- debris racks and traps, allowances for sediment, garbage and blockage, energy dissipation in steep drains, and hill-road drainage that never discharges onto an unprotected slope (Chapters 6 and 9), with drains, jhoras, inlets, racks and culverts cleared and certified ready by 31 March, before the April storms, cleared again by 31 May before the south-west monsoon and by 15 November after it, and standby kept from 1 April to 31 October (Chapter 10); and
- basin-wide master plans, so that the agencies that share a basin, including the District Councils for the parts that lie in their areas, plan together (Chapter 11).

It uses the route the CPHEEO manual itself provides: a State may adopt standards higher than the national values (CPHEEO 2019, Table 4.1, Note 2). A Municipal Board, the Urban Affairs Department in a master plan or the bye-laws, or a District Council in its own building regulation can still adopt a stricter standard (Chapter 1).

*Sources: CPHEEO (2019) Part A §4.4–4.5 and Table 4.1; CPHEEO presentation to CSE (August 2023); IRC:SP:50-2013 §6; IRC:SP:42-2014 cl. 7.1.4 and 8.5.1; NDMA (2010) Urban Flooding Guidelines, para 6.6.2; MoHUA Model Building Bye-Laws (2016); Meghalaya Building Bye-Laws, 2021, Notification No. UAU.73/2016/Pt/402 of 9 March 2021 (Gazette of Meghalaya No. 12, Part IIA, 25 March 2021), A1.2, A2.5, A2.7, A2.8(j), B1, B1.1, B2(ii)(c), C12, D4.2, Section G and Table G1, and the amendments No. UAU.73/2016/Pt/55 of 29 February 2024 (Section I), No. UAU.73/2016/Pt.III/76 of 19 November 2024, No. UAU.73/2016/Pt.VIII/191 of 15 January 2025, No. UAU.73/2016/Pt.VII/97 of 18 June 2025, No. UAU.110/2020/208 of 13 August 2025, No. UAU.73/2016/Pt.III(A)/70 of 21 October 2025 (B10), No. UAU.73/2016/Pt*

*VIII-A/22 of 19 December 2025 and No. UAU.73/2016/Pt.VIII/203 of 7 May 2026; Shillong Master Plan 2041, notification No. UAU.76/2022/Pt.I/74 of 27 November 2024 as cited in No. UAU.76/2022/Pt.I/186 of 29 October 2025; NESAC, Formulation of Risk Informed GIS Based Master Plan, Shillong Planning Area (Ver 1.0, May 2023); Tura draft master plan notice No. UAU.76/2022/129 of 16 February 2024; Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015, KHADC Notification No. DC.II/Genl/31/2015/9 of 4 August 2015, ss. 15, 34, 35, 36 and 40; Meghalaya Municipal Act, 1973, ss. 62, 190, 204–206, and the Meghalaya Municipal (Amendment) Act, 2021 (Act No. 4 of 2021); Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, No. FOR/CC/29/2019/Pt/688 of 25 August 2023 (Gazette Part IIA, 7 September 2023, with the Expert Committee report), as amended by No. FOR/CC/29/2019/1140 of 13 February 2024 and No. FOR/CC/29/2019/Pt/771 of 6 July 2026; Meghalaya Flood Plain Zoning Bill, 2026 (Gazette Extraordinary Part V, 23 February 2026, No. LB.43/LA/2026/2); Meghalaya State Language Act, 2005 (Act No. 10 of 2005), ss. 3–4; Forest and Environment Department notification No. ENV.1/2007/Pt/110 of 1 November 2017 (State Wetlands Authority); High Court of Meghalaya, PIL No. 10 of 2019, In Re: Cleanliness of Umiam Lake, orders of 24 May 2023, 19 July 2023 and 19 February 2024; NGT OA 192/2022, State action-taken report of 21 March 2023 and CPCB–MSPCB Joint Committee report of 28 February 2023; minutes of the stakeholder meeting on the Wah Umkhrah, Wah Umshyrpi and Wah Umkhen, 14 April 2023, and the Chief Secretary's presentation; Supreme Court, State of Meghalaya v. All Dimasa Students Union, CA No. 10720 of 2018 (3 July 2019); CAG, Performance Audit on Solid Waste Management in Urban Areas of Meghalaya (2017-18 to 2021-22), executive summary; CPCB, Polluted River Stretches for Restoration of Water Quality (September 2025); IRADe/NMHS, Disaster Resilience Action Plan, Shillong, IRADe-PR-73(2020); CWC, Flood Estimation Report for South Brahmaputra subzone 2(b) (Revised), No. SB-2(b)/R-4/44/99 (March 2000), Table 4.1, Annexes 4.1 and 4.2 and Plates 8–10, read by eye, and Flood Estimation Report for North Brahmaputra subzone 2(a) (NB/18/1991); CWC, Regional Flood Estimation Report page (archived 20 March 2024); IMD, Extremes of Temperature and Rainfall for Indian Stations (up to 2012); IMD, Monthly Climate Summary, June 2022; Das et al. (2022), MAUSAM 73(4); NIH-DHAARA (queried 14 November 2026); CGWB, Dynamic Ground Water Resources of Meghalaya 2022; MePGCL gate-operation guidelines for Umiam–Umtru Stages III and IV, New Umtru and Myntdu–Leshka Stage I; U Nissor Singh, Khasi-English Dictionary (1906) and English-Khasi Dictionary (1920); D. S. Nengminza, The School Dictionary Garo to English (7th ed., 1978); Sajeki Passah, Pnar–English Dictionary (2013); CWC levels as transcribed by SANDRP (2018); reports of the floods of 2014, 2022, 2024, 2025 and 2026, of the KHADC's position on the Bye-Laws, of the Official Languages Ordinance, 2026, of Umiam lake and of springs and sacred groves (press and secondary sources).*

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# How to use this Manual

**Clauses and commentary.** Numbered clauses (for example 4.5.2) are the requirements of this Manual and use "shall". Paragraphs headed **Commentary** explain the reason for a clause and cite its precedent. They are guidance, not requirements. Where a value has no direct precedent elsewhere, the commentary says so and explains why this Manual sets it.

**Return periods.** Storms are described both by annual exceedance probability (AEP) and by return period. For example, "1% AEP (100-yr)" means a storm with a 1-in-100 chance of being equalled or exceeded in any year.

**Illustrative values.** Worked examples and figures marked "Illustrative — not design values" show method and scale only. Design values come from the sources set in Chapter 2.

**Annexes and forms.** Each chapter lists the annexes and forms it relies on. They follow the chapters, grouped by chapter, and hold the forms to submit, worked examples, templates, model text and standard drawings. Annexes that need data not yet collected are marked *To be prepared*. They say what they will contain, and the clause that depends on them states the rule that applies in the meantime.

**Figures.** All figures are original drawings prepared for this Manual. Where a figure follows a published concept, its caption credits the source.

**Where to start.**

| If you are… | Read first |
|---|---|
| A developer or architect | Chapter 1 (does it apply?), Chapter 4 (what to provide), Chapter 10 (what to submit) |
| A design engineer | Chapters 2–6, then 8 and 9 |
| A local body or approving authority | Chapters 1, 10 and 11 |
| A planner or waterbody manager | Chapters 7 and 11 |

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# Abbreviations

| Abbreviation | Meaning |
|---|---|
| ABC Waters | Active, Beautiful, Clean Waters (PUB Singapore's design guidelines) |
| ADC | Autonomous District Council (the KHADC, JHADC or GHADC) |
| AEP | Annual exceedance probability |
| AIDR | Australian Institute for Disaster Resilience |
| AMC | Antecedent moisture condition |
| AMRUT | Atal Mission for Rejuvenation and Urban Transformation |
| APWA | American Public Works Association |

| Abbreviation | Meaning |
|---|---|
| ARF | Areal reduction factor |
| ASABE | American Society of Agricultural and Biological Engineers |
| ASTM | ASTM International (standards) |
| AWS | Automatic weather station |
| BOD | Biochemical oxygen demand |
| BRE | Building Research Establishment (UK) |
| BSMP | Basin Stormwater Master Plan |
| Bye-Laws 2021 | The Meghalaya Building Bye-Laws 2021, as amended |
| C&RD | Community and Rural Development (a C&RD block is the subdivision of a district used in this Manual) |
| CAG | Comptroller and Auditor General of India |
| CGP | Construction General Permit (US EPA) |
| CGWA | Central Ground Water Authority |
| CGWB | Central Ground Water Board |
| CN | Curve number (SCS/NRCS method) |
| COD | Chemical oxygen demand |
| CPCB | Central Pollution Control Board |
| CPHEEO | Central Public Health and Environmental Engineering Organisation |
| CSE | Centre for Science and Environment |
| CWC | Central Water Commission |
| DC | Deputy Commissioner |
| DEWATS | Decentralised wastewater treatment systems |
| DL / WL | Danger level / warning level (CWC; no site in Meghalaya has them) |
| DPR | Detailed project report |
| DWF | Dry-weather flow |
| EIA | Environmental impact assessment |
| EN | European Standard (Norme Européenne) |
| EPD | Environmental Protection Division (Georgia, United States) |
| ESC | Erosion and sediment control |
| ETP | Effluent treatment plant |
| EV1 | Extreme value type I (Gumbel) distribution |
| FAR | Floor area ratio |
| FEPCC | Flood Estimation Planning and Coordination Committee (CWC) |
| FER | Flood Estimation Report (CWC) |
| FPZ | Flood plain zoning (under the Meghalaya Flood Plain Zoning Act, 2026) |

| Abbreviation | Meaning |
|---|---|
| FRL / MWL / MDDL | Full reservoir level / maximum water level / minimum draw-down level |
| FRP | Fibre-reinforced plastic |
| FSSTP | Faecal sludge and septage treatment plant |
| GHADC | Garo Hills Autonomous District Council |
| GWRA | Ground water resource assessment (CGWB) |
| HAT / MHWS | Highest astronomical tide / mean high water springs (coastal terms; not applicable in Meghalaya) |
| HC | High Court of Meghalaya |
| HEP | Hydro-electric project |
| HFL | High flood level (the highest level recorded at a gauge) |
| HGL | Hydraulic grade line |
| HSG | Hydrologic soil group |
| HY-8 | FHWA's culvert hydraulic analysis program |
| IDF | Intensity–duration–frequency |
| IIT | Indian Institute of Technology |
| IMD | India Meteorological Department |
| IMDAA | Indian Monsoon Data Assimilation and Analysis (a regional reanalysis) |
| IRADe | Integrated Research and Action for Development |
| IRC | Indian Roads Congress |
| ISO | International Organization for Standardization |
| IST | Indian Standard Time |
| JHADC | Jaintia Hills Autonomous District Council |
| KC | Kansas City (Kansas City Metro APWA Section 5600) |
| KHADC | Khasi Hills Autonomous District Council |
| KHBSRA | Khasi Hills Building and Structure Regulatory Authority (of the KHADC) |
| KLD | Kilolitres a day |
| LiDAR | Light detection and ranging (laser survey) |
| MBBL 2016 | Model Building Bye-Laws 2016 (MoHUA; not the State's bye-laws) |
| MBDA | Meghalaya Basin Development Authority |
| MeECL | Meghalaya Energy Corporation Ltd |
| MePGCL | Meghalaya Power Generation Corporation Ltd (operator of the Umiam–Umtru, New Umtru and Myntdu–Leshka dams) |
| MLD | Million litres a day |
| MLHEP | Myntdu–Leshka Hydro Electric Project |
| MoEF&CC | Ministry of Environment, Forest and Climate Change |

| Abbreviation | Meaning |
|---|---|
| MoHUA | Ministry of Housing and Urban Affairs |
| MSDMA | Meghalaya State Disaster Management Authority |
| MSPCB | Meghalaya State Pollution Control Board |
| MTCP Act | The Meghalaya Town and Country Planning Act, 1973 |
| MUDA | Meghalaya Urban Development Authority |
| NAQUIM | National Aquifer Mapping and Management programme (CGWB) |
| NDMA | National Disaster Management Authority |
| NEEPCO | North Eastern Electric Power Corporation |
| NESAC | North Eastern Space Applications Centre |
| NGT | National Green Tribunal |
| NH | National Highway |
| NHAI | National Highways Authority of India |
| NHIDCL | National Highways and Infrastructure Development Corporation Ltd |
| NIH | National Institute of Hydrology, Roorkee |
| NIT | National Institute of Technology |
| NMHS | National Mission on Himalayan Studies |
| NOC | No-objection certificate |
| NPDES | National Pollutant Discharge Elimination System (United States) |
| NRSC | National Remote Sensing Centre |
| NSTDA | New Shillong Township Development Authority |
| NWIA | National Wetland Inventory and Assessment (ISRO) |
| OA | Original Application (NGT) |
| OBPS | Online Building Permission System |
| OGC | Open Geospatial Consortium |
| ORG | Ordinary rain gauge |
| PHED | Public Health Engineering Department |
| PIL | Public interest litigation |
| PSD | Permissible site discharge |
| PWD | Public Works Department, Meghalaya |
| RDSO | Research Designs and Standards Organisation (Railways) |
| RMSE | Root-mean-square error |
| RRC | River Rejuvenation Committee (Forest and Environment Department) |
| RRV | Required retention volume |
| RWH | Rainwater harvesting |

| Abbreviation | Meaning |
|---|---|
| SANDRP | South Asia Network on Dams, Rivers and People |
| SAPCC | State Action Plan on Climate Change |
| SH | State highway |
| SIPMIU | the Urban Affairs Department's project unit in Shillong, headed by a Project Director (expansion [TBC]) |
| SLA | Sea-level allowance (coastal term; not applicable in Meghalaya) |
| SMB | Shillong Municipal Board |
| SMP 2041 | Shillong Master Plan 2041 |
| SoI | Survey of India |
| SRRG | Self-recording rain gauge |
| STP | Sewage treatment plant |
| SUH | Synthetic unit hydrograph (CWC) |
| SW monsoon | South-west monsoon (in IMD's sense; about the first week of June to mid-October in Meghalaya) |
| SWA | Meghalaya State Wetlands Authority |
| SWD | Storm water drain |
| SWM | Solid waste management |
| TBC | To be confirmed: a fact or value not yet found in a source |
| TCPO | Town and Country Planning Organisation (MoHUA) |
| TR-55 | Technical Release 55 (USDA SCS/NRCS) |
| UH | Unit hydrograph |
| ULB | Urban local body (in Meghalaya, a Municipal Board) |
| USACE | US Army Corps of Engineers |
| UT | Union Territory |
| UTM | Universal Transverse Mercator |
| VR | Value rating (of a BMP treating the WQv) |
| WQv | Water quality volume |
| WSUD | Water-sensitive urban design |

CHAPTER 1

# Policy, Applicability and Adoption

## 1.1 Purpose and objectives

1.1.1 This Manual sets the minimum standards for the planning, design, construction, operation and maintenance of stormwater systems in Meghalaya. It applies to private development and to public works, as set out in Clause 1.5.

1.1.2 The Manual has the following objectives:

- (a) to make stormwater management a **condition of development approval**, so that new development and redevelopment do not increase flood peaks or runoff volumes downstream;
- (b) to retain frequent rainfall on site, so that groundwater recharge is sustained and pollutant loads are reduced;
- (c) to size storage for the long-duration storms of the monsoon season, which on the southern escarpment bring more than 1,000 mm in a day (1,563.0 mm at Cherrapunji on 16 June 1995 and 1,003.6 mm at Mawsynram on 17 June 2022, IMD) and on the plateau fall for days on thin soils already saturated, from the pre-monsoon storms of April and May to the October storms that follow the withdrawal of the south-west monsoon, as well as for short-duration intensities;
- (d) to design outfalls for the streams, rivers and reservoirs into which the towns drain: the Umkhrah and Umshyrpi below Shillong, which flood the valley floors of Polo, Pynthorbah and Nongmynsong in heavy downpours and run on as the Wah Roro to Umiam lake; the jhoras and hill streams of every town, which rise within the hour and carry boulders, slide debris and garbage; the Myntdu at Jowai, the Umngot at Dawki, the Ganol at Tura, the Simsang at Williamnagar and the south Garo rivers at Baghmara and Dalu; the Jinjiram and the Krishnai under backwater on the Garo foothill plains; and the reservoirs and release reaches of MePGCL, Umiam (Barapani), Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka, held and released by their operator, including the case where the outfall is closed;
- (e) to protect tanks (pungs), marshes, rivers, supply channels and surplus courses as part of the drainage system;
- (f) to give every element of the drainage network a safe overland path for the 1% AEP (100-yr) storm;
- (g) to make design inputs, approvals and facility records public, so that designs can be checked and repeated; and
- (h) to make sure that facilities, once built, are maintained and remain effective.

1.1.3 This Manual does not replace the rainwater harvesting (RWH) mandate, the building bye-laws notified by the Government under section 74 of the Meghalaya Town and Country Planning Act, 1973 (the Meghalaya Building Bye-Laws 2021), or the statutes on waterbodies. It adds runoff control requirements to them (Clause 1.8).

> **Commentary.** Meghalaya's floods come from four sources, often together. The first is the rain of the southern escarpment, the wettest belt on record. IMD prints 1,563.0 mm in 24 hours at Cherrapunji on 16 June 1995 and 1,003.6 mm at Mawsynram in the 24 hours to 17 June 2022 (IMD), and the storms come before the south-west monsoon as well as during it: Cherrapunji's highest days for March, April and May are 587.4 mm (1994), 644.2 mm (1990) and 812.0 mm (1916) (IMD, *Extremes*). In June 2022, when IMD found the month's rainfall over Assam and Meghalaya the highest since 1901, 13 people died on 17 June in the Khasi and Garo Hills, landslides cut NH-6, and the deaths counted since 1 April were reported as 32 and as 34 on successive days (IMD; as reported; conflict). The second is the flash flood of the hill towns. In Shillong, Polo, Pynthorbah, Nongmynsong, Forest

Colony and Mawlai flood "with nearly every heavy downpour" when the Wah Umkhrah overflows, a flooding attributed to the "clogging of Wah Umkhrah and the decreasing width of the river due to human activities" (as reported; the same text in the IRADe/NMHS plan, 2020), and the NESAC report for the Shillong Planning Area names "Polo Market, Pynthorbah, Nongrim hills, Dhankheti" as highly prone to flash floods and "Encroachment and clogging of channels" as the main causes (NESAC, 2023). The IRADe/NMHS plan tabulates a flash flood at Polo, Forest Colony and Mawlai in July 2019, when Shillong received "more than 72.2 mm of rain on 9th July 2019", floods in July 2020 in which 5 people died and 1.5 lakh were affected, and floods in September 2020 in which 13 died and the Nongstoin roads were cut (IRADe/NMHS plan, Table 17, from the District Disaster Management Authority, the Geological Survey of India and the District Magistrate). The third, found in no plains State of the series, is slides, debris and unstable ground. The great earthquake of 12 June 1897 damaged every stone house in Shillong and brought down a landslide at Sohra in which 600 people were reported killed; Shillong's deaths are given as 13 in one account and 29 in another (as reported; conflict). Landslides in the State caused about 22 deaths in 2014 (IRADe/NMHS plan, citing the Revenue and Disaster Management Department). On 30–31 May 2025, before the south-west monsoon, floods and landslides struck 86 villages in 10 districts and killed 6 people (MSDMA, as reported), with a flash flood at Sumer Latara, slides in 15 villages of Umling block near NH-6 linked to hill cutting along the highway, and a drowning in the Umlew; in June 2026 the Shillong–Dawki road collapsed at Laitlyngkot while the Umngot at Dawki rose rapidly, submerging a labour camp and sweeping away an excavator (as reported). The fourth is the river flood of the Garo hills and plains. On the night of 21 September 2014 torrential rain began floods and landslides in the Garo Hills; the toll was reported as 52 by 28–29 September and as more than 60, with damage of more than ₹1,500 crore, in a year-end account that called it the "worst natural calamity that struck the state in the past century"; the Brahmaputra and the Jinjiram submerged more than 200 villages and NH-51 to Tura was blocked (all as reported; tolls differ by date and include the missing; no rainfall measurement of the storm was found [TBC]). The Brahmaputra and the Jinjiram had flooded more than 100 villages in September 2012 (IRADe/NMHS plan, Table 17). On 4–6 October 2024, after the south-west monsoon had withdrawn, 3 people drowned at Dalu and 7 died in a landslide at Hatiasia Songma in South Garo Hills, 15 deaths were reported by 6 October and 2,630 households were affected in Dalu block (as reported; no rainfall value found [TBC]). MSDMA's official tolls for these events were not found [TBC].

Missing design makes all four worse. No design storm, return period or drain standard was found for the drains of any town in the State: Shillong's 148.91 km of drains "drain directly into the Umkhrah and Umshyrpi rivers", their coverage is put at "less than 75%" of the city in one passage and 85% in another of the same plan, and "the incidence of sewerage mixing in drains is almost 100%" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan; conflict). The Bye-Laws 2021 control slopes, cuts, siting and rainwater harvesting, not runoff, and in the autonomous districts outside the master-plan, municipal and scheme areas, where the Town Committees and census towns hold 47 per cent of the urban population (CAG), they do not apply at all. Objectives (b) to (e) address the storage, outfall and building-level failures, which a drain-sizing manual alone cannot fix; the third source is answered by the siting, screening, infiltration and debris rules of Chapters 2, 4, 6 and 7, because no drain is sized to carry a debris flow, and the fourth by the corridors and floor levels of Chapters 6 and 7.

No national instrument requires on-site detention. CPHEEO (2019) is advisory and describes peak control only as typical practice. NDMA (2010) says detention and retention "will" be included but gives no sizing rule. MBBL 2016 and the Meghalaya Building Bye-Laws 2021 mandate RWH only. Objective (a) is therefore the main new step this Manual takes.

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## 1.2 Stormwater management hierarchy

1.2.1 Every development to which Chapter 4 applies shall consider stormwater measures in the following order. A designer shall not use a lower measure in place of a higher one that is practicable on the site.

1. **Preserve** — keep or restore natural drainage features, tanks, wetlands, permeable soils, trees and overland flow paths (Chapter 7).

2. **Retain** — hold the runoff from the retention depth of Annex 2E on site, by infiltration, reuse or evapotranspiration (Chapters 4 and 8).
3. **Detain** — store larger storms temporarily and release them at or below the rates in Chapter 4, checked against downstream and tailwater conditions (Chapters 4 and 5).
4. **Convey** — carry the remaining flow safely in the minor system, and the 1% AEP flow in the major system (Chapters 6 and 9).

1.2.2 **Maintenance** underlies all four measures. A measure that cannot be maintained by its owner under Chapter 10 shall not be credited.

1.2.3 Credits from higher measures reduce the requirements of lower ones. Preserved areas and retained volume reduce detention storage as set out in Chapter 4.

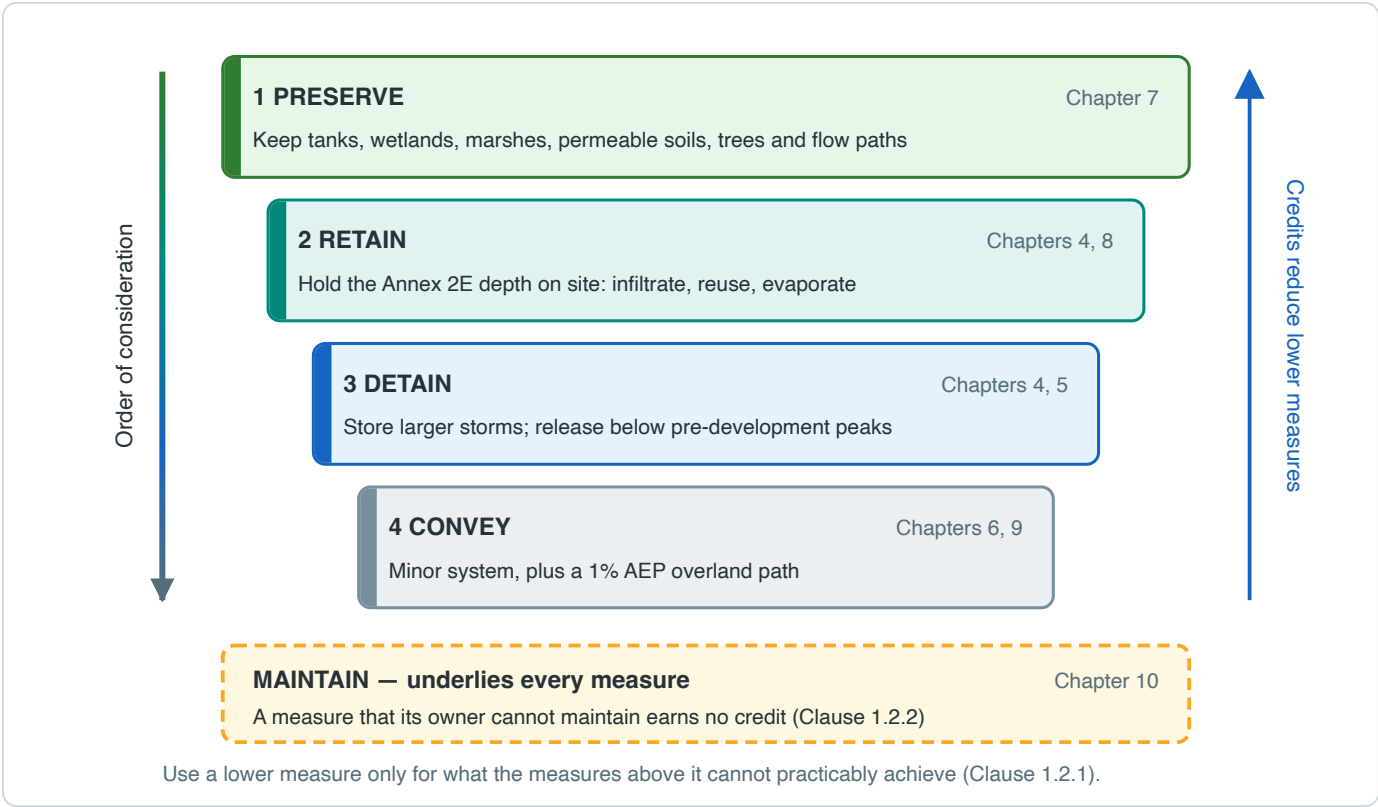


*Figure 1.1 — Stormwater management hierarchy: preserve, retain, detain, convey, with maintenance underlying each measure. Original drawing for this Manual, adapted from Mid-America Regional Council / Kansas City Metro Chapter APWA, "Layers of Stormwater Management", APWA 5600 Manual Factsheet, 2025 (concept).*

**Commentary.** The order follows the "layers" of Kansas City Metro APWA Section 5600, Version 2025.01: preserve or restore, retain, detain, convey, maintain (MARC factsheet, 2025). The same logic is behind Georgia's runoff-reduction standard and CSE's "attenuate and infiltrate first" principle (CSE, 2023). For Meghalaya, the top two layers have a particular meaning. Much of the State's natural storage and supply lies in its springs (*umpohliew*), which with the streams, not wells, supply most towns by gravity (CGWB, GWRA 2022); in its jhoras, the small hill streams that become the Umkhrah, the Umshyrpi and the other town rivers; in its pungs and small lakes, such as Thadlaskein (Pung Sajar Nangli) and Ward's Lake (Nan Polok), and its reservoirs, Umiam (Barapani) the largest; in the sacred groves (*law kyntang*) that stand at many stream heads (as reported); and in the alluvium of the Garo foothill plains and the valley fills of Ri-Bhoi. The counts of the State's springs conflict, an inventory of 1,400 in one account and "So far, we have mapped 1,000 springs across 11 districts" in another (both as reported), and the State reports the rejuvenation of 306 springsheds. The law protects some of this. The Meghalaya Municipal Act, 1973 vests "all public streams, channels, water-courses, springs tanks, reservoirs" within municipal limits in the Board (s.62(b)); the KHADC Regulation 2015 makes the Executive Committee, Town Committee or Dorbar Shnong

responsible for ensuring that land development does not damage "catchment areas, water sources, spring sheds, streams and rivers" (s.15(1)); the Waterbodies Guidelines set setbacks from lakes, ponds, rivers and streams, but exclude streams whose beds are dry for 240 days or more in each of the past ten years, which takes out most jhoras (para 2(e)); the Wetlands Rules 2017 apply to notified wetlands through the Meghalaya State Wetlands Authority, and no wetland of the State has been found notified under rule 4; and the Meghalaya Flood Plain Zoning Act, 2026 provides for flood zones, none of which has been notified. No statute protects springs or sacred groves as such. In the hills the second layer changes. Retention on a slope is storage and reuse, not infiltration: water put into colluvium, fill or slide debris raises the pressure in the slope, and water put into limestone or into old coal workings goes where no one can follow it, into caves and voids that can collapse ("smaller streams and rivers either disappear or have become seasonal" as water "disappears in the unfilled mine pits and caves", as reported). This Manual therefore bars deliberate infiltration on natural slopes of more than 10°, on colluvium, fill or slide debris, in mapped landslide zones and close upslope of a cut or retaining wall, unless a geotechnical certificate allows it (Clause 4.11, hill rule); bars it on limestone, within a coal-mining area and where caves or sinkholes are known, with no certificate to allow it (Clause 4.11, karst and mine rule); and allows recharge only on the tested alluvium of the Garo foothill plains and the tested valley fills of Ri-Bhoi, because every groundwater assessment unit of the State is "Safe" and recharge is not a design objective there (Clause 4.11, recharge rule; CGWB) (all set by this Manual). Rainwater harvesting elsewhere is storage for the dry season, when, CGWB notes, there is "acute shortage of water during the summer as the major part of rainfall is lost as surface run-off". Losing the springs and the stream heads cannot be offset by pipes, and in the hills drains that put water into a slope or a void can make it fail.

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## 1.3 Legal basis and status

1.3.1 **Notification.** This Manual shall be given statutory effect by the Government of Meghalaya through:

- (a) an amendment to the Meghalaya Building Bye-Laws 2021 that makes compliance with this Manual a condition of planning permission, building permit, layout approval and completion certificate, for development to which Clause 1.5 applies; and
- (b) bye-laws or standing orders of each urban local body (ULB), adopting the Manual for works executed or approved by that ULB, including the ULB's own drains and roads.

1.3.2 **Higher State standards.** The design return periods and performance criteria of this Manual exceed the national advisory minimums of the CPHEEO Manual on Storm Water Drainage Systems (2019). The State shall constitute, by notification, a high-powered committee (the **State Stormwater Technical Committee**, Clause 1.9) to adopt these higher standards. This is the route that CPHEEO (2019) provides for higher return periods.

1.3.3 **Precedence.** Within its scope, this Manual governs where it is stricter than CPHEEO (2019), IRC:SP:42-2014, IRC:SP:50-2013 or any departmental standard. Where a statute or statutory rule sets a stricter requirement (for example a waterbody setback), the statute governs.

1.3.4 **Design-practice standard for public works.** Departments and ULBs that procure drainage, road or waterbody works shall require compliance with this Manual in detailed project reports (DPRs) and contracts, from the dates in Clause 1.11.

Commentary. In Meghalaya the building rules are the Meghalaya Building Bye-Laws, 2021, notified by the Urban Affairs Department under section 74 of the Meghalaya Town and Country Planning Act, 1973 (the Assam Town and Country Planning Act, 1959, as adapted) and published under section 72(2) (Notification No. UAU.73/2016/Pt/402 of 9 March 2021; Gazette of Meghalaya No. 12, Part IIA, 25 March 2021). They "apply to all the Master Plan Areas, Municipal areas and Scheme Areas within the State" (A1.2), and their "Authority" is "the Meghalaya Urban Development Authority / Autonomous District Councils as applicable" (A2.5). They replaced the

bye-laws of 2011 made by MUDA, and have been amended at least eight times, each by a notification of the Urban Affairs Department under the same section: No. UAU.73/2016/Pt/55 of 29 February 2024 (Gazette, 9 May 2024), which inserted Section I on hilly and hazard-prone areas and tied stream setbacks to the Waterbodies Guidelines; No. UAU.73/2016/Pt.III/76 of 19 November 2024 (industrial buildings in Table D-2); No. UAU.73/2016/Pt.VIII/191 of 15 January 2025, which amends what it calls "the Meghalaya Building Bye-Law, 2024" (B1(i) and Table D10); No. UAU.73/2016/Pt.VII/97 of 18 June 2025 (Table D-2); No. UAU.110/2020/208 of 13 August 2025 (Gazette, 11 September 2025), which added Section J on the online building permission system; No. UAU.73/2016/Pt.III(A)/70 of 21 October 2025 (Gazette Extraordinary, 3 November 2025), which substituted B10 on septic tanks; No. UAU.73/2016/Pt VIII-A/22 of 19 December 2025 (green building certification above 10,000 m²); and No. UAU.73/2016/Pt.VIII/203 of 7 May 2026 (thresholds for special projects). Their short titles conflict: two notifications, of 15 January and 18 June 2025, each call themselves the "(Amendment) Byelaws, 2025", and two, of 2024 and of August 2025, a "Second Amendment", so this Manual cites each by number and date. The Bye-Laws 2021 forbid construction on slopes of more than 50° and regulate slopes of 40°–50° (Section I(a)); limit earth cutting to 3.00 m, relaxable to 6.00 m to the crest of an RCC wall, with a report of the Geological Survey of India beyond that (B1(vii)); require a site "properly drained or capable of being drained" and "not prone to land slide" (B1(ii), (iv)), a stilt at least 1.20 m above the Highest Flood Level on a sloping site beside a stream or river and a plinth of at least 0.90 m on a flat one (B1(v)(b)); bar the use of land "liable to flooding, except where protection measures are adopted" (B1.1(ii)); allow basements "only in flat terrain" and keep surface drainage out of them (A2.7, A2.8(j)); and, in hazard-prone areas, ask for "good drainage facilities to prevent excessive saturation of sub-surface formations", for construction that does not "obstruct existing surface drainage courses", for diversion ditches and swales into "designated sediment basins" and for silt fences (Section I(b)). They require rainwater harvesting for every plot category (Table G1) and defer drainage to the National Building Code 2016 (D4.2, D5.6), but set no design storm, return period, release rate or detention volume. The route of Clause 1.3.1(a) therefore runs through an amendment of the Bye-Laws 2021 under section 74 of the 1973 Act, which the Urban Affairs Department could make. It reaches only the areas to which the Bye-Laws 2021 apply. Outside them, in the autonomous districts, building and land are regulated under the Sixth Schedule by the District Councils: in the Khasi Hills by the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015 (KHADC Executive Committee Notification No. DC.II/Genl/31/2015/9 of 4 August 2015, Gazette Extraordinary No. 97 of 25 August 2015, made under the proviso to section 8, read with section 8(11), of the United Khasi-Jaintia Hills District (Establishment of Town Committee) Act, 1960), which extends to the whole of the Khasi Hills Autonomous District and under which the KHBSRA has issued building permissions since 2020 (as reported); the building instruments of the Jaintia Hills and Garo Hills Autonomous District Councils were not found [TBC]. The Comptroller and Auditor General found that the "jurisdiction of the Town Committees and Census Towns was not vested upon the Urban Affairs Department. Rather, these areas (47 per cent of the total urban population) are governed by the concerned ADCs" (CAG, performance audit on solid waste management in urban areas of Meghalaya, 2017-18 to 2021-22, executive summary; report number [TBC]), so nearly half of the State's urban population lies outside the reach of the Bye-Laws 2021. The boundary between the two regimes is disputed. The Urban Affairs Department notified the three District Councils to implement building bye-laws outside the municipalities on 1 February 2019 (as reported; number not found [TBC]); the KHADC Executive Committee "outright rejected" the Bye-Laws 2021 on 25 October 2021 for encroaching on Sixth Schedule areas (as reported), and their status in the District Council areas since then is not known [TBC]; and an earlier challenge concerned MUDA and the bye-laws of 2011 (as reported). This Manual states the dispute and takes no side in it. In a District Council area the Manual could take effect only through the District Council: its Executive Committee could adopt it for its district by amending its own building regulation, as the KHADC made its 2015 Regulation under the 1960 Act (Annex 1D). The KHADC Regulation already asks that plans show "the system of storm water drainage along with points of collection of rain water" (s.36) and "the highest flood level (HFL) reached above the street", which are the natural hooks for the drainage report there. This Manual is a draft; neither the Government, MUDA, any District Council nor any other authority has adopted it. MoHUA told Parliament in July 2026 that urban flooding "falls under the purview of the State Governments and the ULBs" and listed the CPHEEO manual among "advisory guidelines" (Lok Sabha AU1847). The State therefore needs no central approval to adopt higher standards.

> CPHEEO's Note 2 to Table 4.1 (§4.4.1.4) allows "a high powered committee constituted by State/UT Government through a notification" to adopt higher return periods. Clause 1.3.2 uses that route so that higher standards are on record for centrally funded schemes.

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## 1.4 Definitions

1.4.1 The following terms apply throughout this Manual. Chapter-specific terms are defined in each chapter (for example Clause 2.2).

| Term | Meaning in this Manual |
|---|---|
| Approving Authority (the Authority) | The body that grants planning permission, building permit or layout approval for a development, or that sanctions a public work: the competent authority for the area: MUDA (its Chairperson, or an officer to whom the power has been delegated) in the master-plan, municipal and scheme areas to which the Meghalaya Building Bye-Laws 2021 apply (A1.2, A2.3); the Municipal Board for its own drains and works and for the sanctions it gives under the Meghalaya Municipal Act, 1973; the Shillong Cantonment Board in the Cantonment; the New Shillong Township Development Authority (NSTDA) in New Shillong [TBC]; in the autonomous districts outside those areas, the District Council or its building authority (in the Khasi Hills, the Executive Committee of the Khasi Hills Autonomous District Council (KHADC) and the Khasi Hills Building and Structure Regulatory Authority (KHBSRA) under the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015; the building instruments of the Jaintia Hills and Garo Hills Autonomous District Councils were not found [TBC]); the Flood Zoning Authority in a flood zone notified under the Meghalaya Flood Plain Zoning Act, 2026 (none is constituted or notified); and the Forest and Environment Department for matters under the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, or a department for its own works. |
| Applicant | The owner, developer or department that seeks approval, and its successors in title. |
| Development | Any building, layout, sub-division, road, paving or land-use change that requires approval under the Meghalaya Building Bye-Laws 2021 or that is executed as a public work. |
| Redevelopment | Development on a site where impervious cover already exists. |
| Land disturbance | Clearing, grading, excavation, filling or paving of land, measured in plan area over the whole of a common plan of development (Clause 1.5.5). |
| Impervious area | Roofs, paving, compacted gravel, decks and other surfaces that prevent infiltration. Permeable paving designed to Chapter 8 is counted as pervious only for the area it treats. |
| New or replaced impervious area | Impervious area created, or removed and rebuilt down to the subgrade, by the development. Resurfacing that leaves the base in place is not "replaced". |
| Retention | Permanent removal of runoff from the drainage system on site, by infiltration, reuse or evapotranspiration (Chapter 4). |
| Detention | Temporary storage of runoff with a controlled outlet, emptied after the storm (Chapter 4). |
| Rainwater harvesting (RWH) | Collection of rainfall for supply or recharge under the RWH mandate. RWH storage is not detention unless Chapter 4 allows it. |
| Minor system | Drains, pipes and inlets designed for the minor-system AEP of Chapter 6. |
| Major system | The overland and floodway path that carries the 1% AEP (100-yr) flow (Chapter 6). |
| Pre-development condition | Greenfield: open land in good condition for the mapped hydrologic soil group. Existing impervious cover is not counted (Chapter 3). |

| Term | Meaning in this Manual |
|---|---|
| Flood-sensitive catchment | The catchments of Shillong's Umkhrah and Umshyrpi, with their jhoras, down to the Wah Roro and Umiam lake, including the valley floors of Polo, Pynthorbah, Nongmynsong, Mawlai, Forest Colony, Dhankheti and Nongrim Hills; the land on the shore of Umiam lake and along the release reaches of the Umiam–Umtru stages and of New Umtru down to Byrnihat; the land of Jowai that drains to the headwaters of the Myntdu, and the release reach of the Myntdu–Leshka dam to the Bangladesh border; the escarpment settlements of Sohra, Mawsynram and Shella; the land of Dawki that drains to the Umngot; the land of the Tura master-plan area that drains to the Ganol and the Ringrey and Rongkhon streams; the land of Williamnagar that drains to the Simsang; the land of Baghmara and Dalu on the rivers of the south Garo slopes; the Garo foothill plains on the Jinjiram and the Krishnai, at Phulbari and Tikrikilla; and the land of Nongpoh and Umling block that drains to the Umlew and the streams crossed by NH-6, and any catchment the Authority notifies (Chapter 4; Annex 1B). |
| Waterbody | A river, stream, canal, tank (pung), lake, pond, marsh, supply channel or surplus course, whether perennial or seasonal (Chapter 7). |
| Regional facility | A detention, retention or tank storage facility serving more than one development, built or restored under a basin plan (Chapter 4). |
| Tier A / Tier B authority | An Approving Authority classed under Clause 1.6. |
| Policy supplement | The set of adoptable alternative clauses in Clause 1.7 and Annex 1C. |
| Drainage report | The preliminary or final report required by Chapter 10. |
| Registered professional | A person registered under the Meghalaya Building Bye-Laws 2021 to prepare and sign the relevant plans, with any further qualification required by Clause 10.6. |
| Compliance calculator | The State-issued tool for computing and reporting compliance (Clause 10.5). |
| Maintenance declaration | The registered undertaking by an owner to maintain a stormwater facility (Clause 10.10). |
| Variance | Approval to depart from a numeric requirement, with equivalent performance shown (Clause 1.10). |
| Waiver | Approval that a requirement does not apply to a site, on the grounds in Clause 1.10. |
| Notified | Published by the Government or the State Stormwater Technical Committee in the Gazette of Meghalaya. |
| Competent authority for the area | The body that grants permission for the site under the instrument that applies there: MUDA in the master-plan, municipal and scheme areas of the Bye-Laws 2021; the Municipal Board for its drains, works and sanctions under the Meghalaya Municipal Act, 1973; the Shillong Cantonment Board in the Cantonment; NSTDA in New Shillong [TBC]; elsewhere in an autonomous district, the District Council or its building authority (in the Khasi Hills, the KHADC Executive Committee and the KHBSRA under the 2015 Regulation); the Flood Zoning Authority in a notified flood zone (none yet); and the Forest and Environment Department for matters under the Waterbodies Guidelines. Where this Manual says "the Authority", the competent authority for the area is meant. This Manual reaches an area of an Autonomous District Council only through that District Council. |
| Autonomous District Council (ADC), District Council | The Khasi Hills, Jaintia Hills and Garo Hills Autonomous District Councils (KHADC, JHADC, GHADC) under the Sixth Schedule to the Constitution, with their Executive Committees, Town Committees and building authorities. Outside the master-plan, municipal and scheme areas, building and land in their districts are regulated under their own instruments, not under the Bye-Laws 2021. |
| Traditional institution | The Dorbar Shnong (village council) and its Rangbah Shnong (headman) in the Khasi and Jaintia Hills, acting under the rules of the District Council, and the village institutions of the Garo Hills led by the Nokma [TBC: not researched for this Manual]. |
| Community land | Land held by a community, a clan or a private owner rather than by the State, which is most land in the State. Where this Manual reserves a drainage corridor, an easement or a regional facility site on such land, it is secured by agreement with the landholding institution (the Dorbar Shnong, the clan or the owner) or reserved in a master plan, not taken (set by this Manual). |

| Term | Meaning in this Manual |
|---|---|
| Jhora | A small hill stream (local English usage in Shillong). A jhora draining 8 ha or more is a natural channel under Chapter 7 whether or not it is a "waterbody" under the Waterbodies Guidelines. |
| Shillong Planning Area | The 288.5 km² of the Shillong Master Plan 2041: the Shillong urban agglomeration and 54 villages, 37 in East Khasi Hills and 17 in Ri Bhoi (NESAC, 2023), as notified from time to time. |

> **Commentary.** "Replaced" impervious area is defined to the subgrade so that redevelopment of a fully paved site is captured, while routine resurfacing is not. This follows the approach of the APWA 5600 (2025.01) redevelopment triggers (MARC Supplement, 2025).

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## 1.5 Applicability

1.5.1 **Who is covered.** This Manual applies to:

- (a) all development requiring planning permission, building permit or layout approval under the Meghalaya Building Bye-Laws 2021;
- (b) all drainage, road, bridge, culvert, waterbody and flood-mitigation works executed by a ULB, a State department, a board, or a State undertaking; and
- (c) works executed by Central agencies or their contractors within Meghalaya, to the extent that the Authority's approval or no-objection is required.

1.5.2 **Retention and detention threshold.** Chapters 4 and 5 (retention, detention, downstream and tailwater analysis) apply to any development that, over the common plan of development, involves:

- (a) land disturbance of **0.1 ha or more**; **or**
- (b) new or replaced impervious area of **500 m² or more**.

1.5.3 **RWH.** The existing RWH mandate continues to apply under Table G1 of the Meghalaya Building Bye-Laws 2021 to every plot category and use in the master-plan, municipal and scheme areas, with "Ground water recharge for covered area more than 3000 sqft" for residential plots of Category II, soft cover of at least 10% or 20% of the plot by category, and a 10% rebate of the permission fee where both rainwater harvesting and the recycling of waste water are provided (G2.1.2), but with no storage volume or roof-area rate; and under section 36 of the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015, which makes "storing of water runoff including rainwater in all existing and new buildings" mandatory in the Khasi Hills Autonomous District and asks that plans show "the system of storm water drainage along with points of collection of rain water", as now. This Manual does not change it.

1.5.4 **Provisions that apply at every size.** The following apply to all development under Clause 1.5.1, whatever its size, unless exempted by Clause 1.5.8:

- (a) no sewage connection to a storm drain (Chapter 8);
- (b) lowest habitable floor and openings at or above the 1% AEP level plus 0.5 m, where a 1% AEP level is mapped or determinable (Chapter 6);
- (c) waterbody setbacks and the no-fill zone (Chapter 7); and
- (d) no obstruction of a natural drainage path or major-system flow path (Chapter 6).

1.5.5 **Common plan of development.** The thresholds of Clause 1.5.2 apply to the total area of a development, including all phases, plots and sub-divisions under one layout approval or one ownership at the date of application. A development shall not be divided to avoid the thresholds.

1.5.6 **Redevelopment.** For redevelopment, the thresholds apply to new plus replaced impervious area. Retention and detention apply to the whole of the new and replaced impervious area, and the pre-development condition is greenfield (Clause 1.4). Where greenfield control cannot be achieved on a constrained redevelopment site, the relief route of Clause 4.5.6 applies: a minimum on-site cut of 50% from existing peaks, with the shortfall paid as fee-in-lieu into basin storage.

1.5.7 **Linear public works.** For roads, widening and other linear works, the impervious area threshold applies to the added impervious area within each drainage catchment crossed. Retention and detention shall be provided within the right of way, or in a regional facility under Chapter 4, where the right of way cannot hold them.

1.5.8 **Exemptions.** The following are exempt from Chapters 4 and 5:

- (a) a single dwelling on its own plot, where the thresholds of Clause 1.5.2 are not met; and
- (b) linear road resurfacing that adds no impervious area.

Exempt development remains subject to the RWH mandate and to Clause 1.5.4.

1.5.9 **Applicability determination.** The Applicant shall record the applicability decision on **Form 1-1** (Applicability Determination) with the first submittal under Chapter 10. The Authority may confirm or correct it at the pre-application stage.

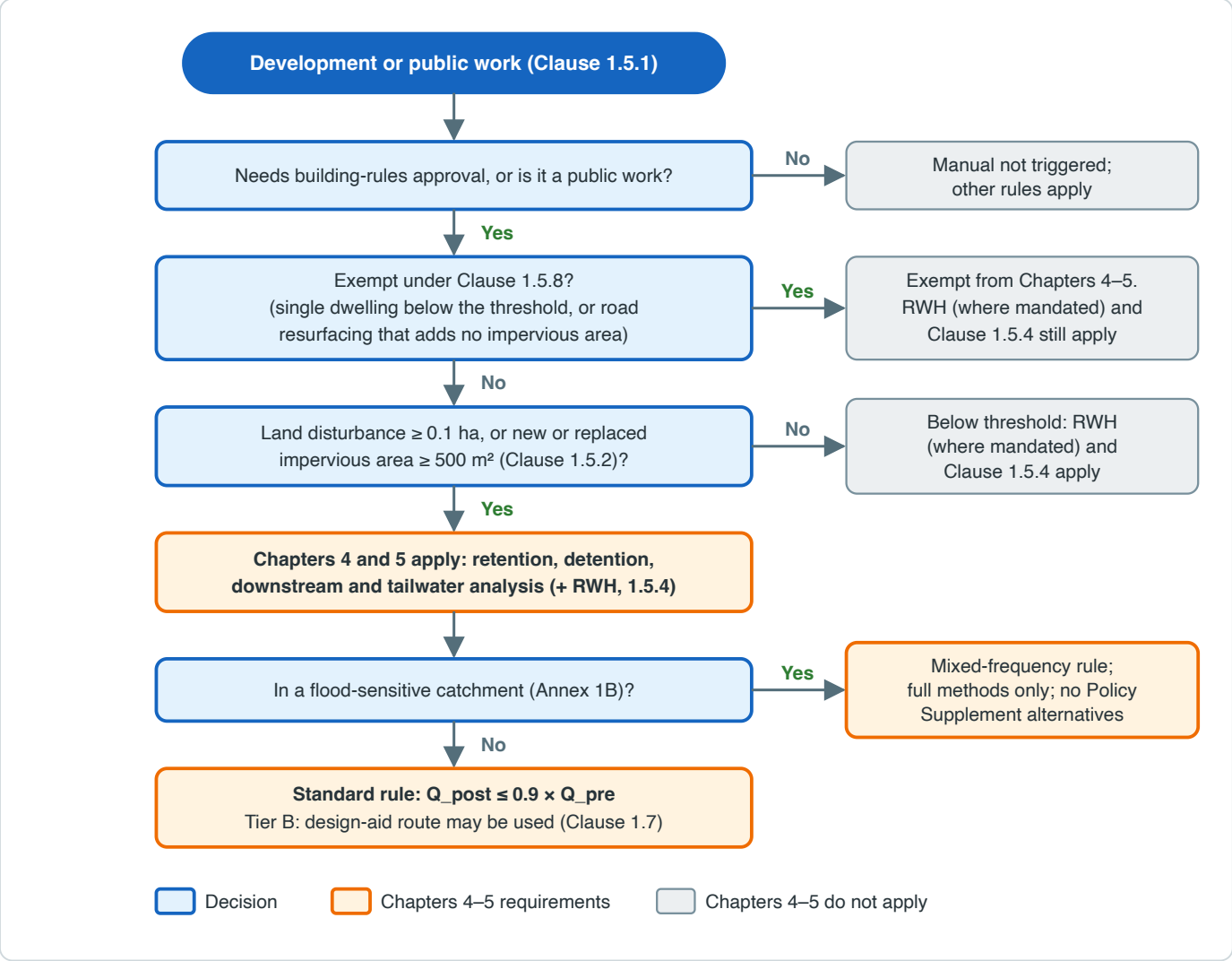


*Figure 1.2 — Applicability decision flowchart for Clause 1.5. Original drawing for this Manual.*

Commentary. The thresholds have no single direct precedent; they are set by this Manual. Precedents span a wide range:

- Singapore controls peak runoff from developments of 0.2 ha or more (PUB Code of Practice on Surface Water Drainage, 7th ed., cl. 7.1.5).
- Malaysia's 2008 DID checklist used on-site detention for sites up to 0.1 ha and community ponds above that.
- The APWA 5600 (2025.01) Policy Supplement offers alternative triggers of ¼ acre (about 0.1 ha) disturbed, or 1 acre (about 0.4 ha) with 10,000 sq ft (about 930 m²) impervious, and warns agencies not to exceed a 1-acre trigger.
- MBBL 2016 makes recharge mandatory for buildings over 500 m².

The 0.1 ha / 500 m² trigger sits at the strict end of these, because typical Meghalaya plots are small and the cumulative effect of many small plots is what fills Shillong's drains. For small buildings in Meghalaya, the Bye-Laws 2021 already reach every plot category in the master-plan, municipal and scheme areas with rainwater harvesting and a soft cover of 10% of the plot or more (Table G1), and the KHADC Regulation makes rainwater storage mandatory for every building in the Khasi Hills Autonomous District and asks for a storm-drainage layout with the points of collection (s.36). Neither sets a volume, and the tank is full when the season's storm arrives, so none of it limits what leaves the plot in a design storm. Outside the areas of the Bye-Laws 2021, where the Town Committees and census towns hold 47 per cent of the urban population (CAG), small buildings follow the District Councils' instruments, of which only the KHADC's was read for this Manual [TBC]. No rule asks a single building to carry the water from uphill around its foundations or to discharge its roof water to a lined drain or stable channel rather than down the slope, and both sets of rules show the septic tank and the soak pit on the site plan without forbidding the soak pit on a slope, on limestone or over old mine workings. Clause 1.5.4(b) applies to every building whatever its size for this reason. A small building on a hill slope, or on the limestone of the escarpment and the Jaintia hills, is also where a soak pit or soakaway can do most harm, and an Authority may make the hill rule and the karst and mine rule of Clause 4.11 a condition of every building permit in its area, whatever the size of the site (a recommendation of this Manual, not a requirement of Clause 1.5.4). Where Table G1 asks a residential plot of Category II for groundwater recharge, the recharge rule of Clause 4.11 allows it only on the tested alluvium of the Garo foothill plains and the tested valley fills of Ri-Bhoi, and storage takes its place elsewhere (Table 1.3).

Clause 1.5.4(b) has no direct precedent; this Manual sets it because floor levels are the cheapest protection a building can have, and it would be perverse to protect only large developments. Where no 1% AEP level is mapped, Chapter 6 gives the method for small sites.

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## 1.6 Tiered adoption

1.6.1 **Tier A authorities.** The following are Tier A:

- (a) the Shillong Municipal Board (SMB);
- (b) every Approving Authority within the Shillong Planning Area of the Shillong Master Plan 2041, as that area is notified from time to time under the Meghalaya Town and Country Planning Act, 1973, whichever has jurisdiction over a site: MUDA, the Shillong Cantonment Board, NSTDA in New Shillong [TBC] and, for the parts of the planning area under the Khasi Hills Autonomous District Council, its building authority, if the District Council adopts this Manual (this Manual does not decide where MUDA's jurisdiction ends and the District Council's begins); and
- (c) the Tura Municipal Board, with MUDA in the Tura master-plan area.

1.6.2 **Tier B authorities.** All other Municipal Boards, Town Committees and District Council building authorities are Tier B.

1.6.3 **What differs between tiers.** All criteria of this Manual apply in both tiers. The tiers differ only in method and review:

**Table 1.1 — Differences between Tier A and Tier B authorities**

| Item | Tier A | Tier B |
|---|---|---|
| Performance criteria (Chapters 2–9) | Apply in full | Apply in full |
| Hydrologic method for storage | Hydrograph method (Chapter 3) | Hydrograph method, or the design-aid route of Clause 1.7 where eligible |
| Compliance calculator (Clause 10.5) | Required as a summary | Required; may be the sole calculation on the design-aid route |
| Policy supplement alternatives (Clause 1.7) | Only with State Stormwater Technical Committee concurrence | May be adopted by council resolution |
| Technical review | By the Authority | By the Authority, with Urban Affairs regional support or an empanelled reviewer (Clause 10.7) |
| Flood-sensitive catchment rule | Applies | Applies |

1.6.4 **Moving between tiers.** A Tier B authority may opt into Tier A by council resolution. The Government may notify a Tier B authority as Tier A when it becomes a Corporation, joins the Shillong Planning Area of the Shillong Master Plan 2041, or another master-plan area under the Meghalaya Town and Country Planning Act, 1973, or is found by a post-event review (Clause 10.16) to need the full methods.

1.6.5 **Flood-sensitive catchments override tier.** In a flood-sensitive catchment, whatever the tier, the alternatives of Clause 1.7 are available only as Table 1.2 allows: S-1 (the design-aid route) for sites of 0.5 ha or less (Clause 4.14.1), and S-5 fee-in-lieu where a basin plan has been notified (Clause 1.10.3(d)). S-2, S-3 and S-4 are not available.

> Commentary. Shillong Municipal Board, with 148.91 km of drains that run directly into the Umkhrah and Umshyrpi, whose coverage of the city is put at "less than 75%" in one passage and at 85% in a table of the same plan (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan, 2020; conflict), and with only part of Greater Shillong within its limits, and a small Town Committee with one assistant engineer cannot be asked to review the same hydrograph models. The Kansas City solution was to keep one regional standard and publish adoptable alternatives for the most contested criteria, so that smaller agencies can "opt down" without leaving the standard (MARC Supplement, Nov 2025). The tiers here keep the performance criteria the same in both tiers and vary only the method, so that a building in a Tier B town is protected to the same level as one in Shillong.

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## 1.7 Policy supplement: adoptable alternatives

1.7.1 The Government shall publish, with this Manual, a **Policy Supplement** (Annex 1C) of alternative clauses. An Approving Authority may adopt one or more alternatives under the conditions in Clause 1.7.3.

1.7.2 The alternatives are:

**Table 1.2 — Policy supplement: adoptable alternatives S-1 to S-5**

| No. | Main-text requirement | Adoptable alternative | Eligibility |
|---|---|---|---|
| S-1 | Storage sized by hydrograph method (Chapter 3) | **Design-aid route:** retention and detention volumes taken from the unit-storage tables (m³ per ha, by rainfall zone, soil group and impervious fraction) in Annex 4 and the compliance calculator | Sites ≤ 2 ha outside flood-sensitive catchments; ≤ 0.5 ha within them (as Clause 4.14.1) |
| S-2 | Release rate Q_post(T) ≤ 0.9 × Q_pre(T), computed for the site | **Permissible site discharge (PSD):** a tabulated unit-area release rate (m³/s/ha) by zone and AEP, derived from the 0.9 × Q_pre rule | Any site outside flood-sensitive catchments |
| S-3 | Waterbody setback extended to the mapped 1% AEP flood extent plus margin (Chapter 7) | **Fixed-width setback table** by waterbody class, where no 1% AEP extent is mapped. Never less than the Zone 1 minimum of Clause 7.4.7 | Waterbodies with no mapped 1% AEP extent |
| S-4 | Downstream analysis by hydraulic model (Chapter 5) | **Screening checklist** of downstream capacity and known flooding, with a model only where the screen fails | Sites < 1 ha, outside flood-sensitive catchments, not discharging to a tidal outfall |
| S-5 | On-site detention | **Fee-in-lieu** toward a regional facility or restored tank storage in a master-planned basin (Chapter 4) | Where a basin plan has been notified |

1.7.3 **Conditions on adoption.**

- (a) An alternative shall not lower any criterion below the values of this Manual. S-1 and S-2 are simplified methods for meeting the same criterion. They are not lower criteria.
- (b) A Tier B authority adopts an alternative by council resolution, sent to the State Stormwater Technical Committee within 30 days. A Tier A authority needs the Committee's concurrence before adoption.
- (c) The adopted alternatives shall be published on the Authority's website and in the register of Clause 10.17.
- (d) Retention (Annex 2E depth) cannot be replaced by any alternative, except where fee-in-lieu under S-5 funds equivalent retention in the same basin.
- (e) The tables for S-1, S-2 and S-3 shall be issued by the State Stormwater Technical Committee, and reviewed with Chapter 2 (Clause 2.14).

> Commentary. The supplement follows the model of the APWA 5600 (2025.01) Policy Supplement, which gives alternatives for the four most contested criteria (applicability, Rational Method limits, stream setback trigger, and Zone 2 setback width). Two of those map onto S-3 and onto the applicability threshold of Clause 1.5.2. Alternative S-3 copies the APWA answer to the same problem: the 1% AEP extent is not mapped for small drainage areas, so a fixed-width table is offered. S-2 follows the Kansas City 2011 shift from "match existing" to fixed unit-area release rates. Local agencies preferred a set rate because existing conditions were hard to determine consistently (MARC Evolution deck). It also reflects the Sydney Water permissible site discharge (PSD) method. The 2 ha / 0.5 ha limits for S-1 (matching Clause 4.14.1) and the 1 ha limit for S-4 have no direct precedent; they are set by this Manual.

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## 1.8 Relationship with other instruments

1.8.1 This Manual shall be applied together with the instruments below. Where they overlap, Clause 1.3.3 governs.

**Table 1.3 — Relationship with other instruments**

| Instrument | Relationship |
|---|---|
| Meghalaya Building Bye-Laws, 2021 (Notification No. UAU.73/2016/Pt/402 of 9 March 2021), made under section 74 of the Meghalaya Town and Country Planning Act, 1973, as amended by Nos. UAU.73/2016/Pt/55 of 29 February 2024, UAU.73/2016/Pt.III/76 of 19 November 2024, UAU.73/2016/Pt.VIII/191 of 15 January 2025, UAU.73/2016/Pt.VII/97 of 18 June 2025, UAU.110/2020/208 of 13 August 2025, UAU.73/2016/Pt.III(A)/70 of 21 October 2025, UAU.73/2016/Pt VIII-A/22 of 19 December 2025 and UAU.73/2016/Pt.VIII/203 of 7 May 2026 (all read) | Continue. They apply to the master-plan, municipal and scheme areas (A1.2), with MUDA or the District Councils "as applicable" as the Authority (A2.5). They forbid construction on slopes of more than 50° and regulate slopes of 40°–50° (Section I(a)); limit earth cutting to 3.00 m, or 6.00 m to the crest of an RCC wall, with a report of the Geological Survey of India beyond (B1(vii)); require a stilt at least 1.20 m above the Highest Flood Level on a sloping site beside a stream or river and a plinth of 0.90 m on a flat site (B1(v)(b)), and keep septic tanks and soak pits "as far away as possible from the stream/river" (B1(v)(a)) and, beside a waterbody, at least 6 m or half the plot depth from it (B10, 2025); bar land "liable to flooding, except where protection measures are adopted" (B1.1(ii)); define natural hazard prone areas to include "back flow in drains, inadequate drainage" (A2.37); ask for drainage that prevents "excessive saturation of sub-surface formations", for construction that does not "obstruct existing surface drainage courses", for diversion ditches, swales, sediment basins and silt fences (Section I(b)) and for "Storm water inlet protection" on water-logged plains (Section I(c)); and require site plans to show "Surface drains, position and sizes of septic tank and soak pit", roof drainage and rainwater harvesting, and large projects a services plan with the "drainage and storm water disposal system". Drainage is "as per National Building Code 2016" (D4.2, D5.6). They set no design storm, release rate, detention volume or rule on infiltration on slopes, limestone or mine ground. The design criteria of Chapters 2–6, the hill, karst and mine and recharge rules of Clause 4.11 and the corridors of Chapter 7, whose Zone 1 is at least 15 m, are this Manual's proposals; they are not statutory values, and no authority has adopted them. Where the Bye-Laws 2021, a master plan or a statute are stricter, they govern (Clause 1.3.3). |
| Rainwater harvesting: Bye-Laws 2021, Table G1, G2.1.2 and D8.2; KHADC Regulation 2015, sections 35(iii) and 36 | Continue unchanged. Table G1 requires rainwater harvesting for every plot category and use, "Ground water recharge for covered area more than 3000 sqft" for residential plots of Category II and soft cover of at least 10% or 20% of the plot by category; G2.1.2 rebates 10% of the permission fee where both rainwater harvesting and recycling of waste water are provided; and new buildings in the City Centre Zone adopt rainwater harvesting with 30% of the plot as soft-covered open space (D8.2). Section 36 of the KHADC Regulation makes "storing of water runoff including rainwater in all existing and new buildings" mandatory and asks plans to show "the system of storm water drainage along with points of collection of rain water"; section 35(iii) sets soft cover of at least 15% of the plot where the covered area is 500 m² or more, and 10% otherwise, and asks for semi-pervious paving "wherever possible". Neither sets a storage volume or a roof-area rate. This Manual counts the stored water against its retention requirement only as reuse (Clause 4.4.3), never as detention. Where Table G1's recharge requirement falls on a site where the hill rule or the karst and mine rule of Clause 4.11 forbids infiltration, the two conflict: this Manual requires storage in place of recharge there, and the applicant seeks the Authority's relaxation of the recharge requirement; the Manual does not override the bye-law. |
| Meghalaya Town and Country Planning Act, 1973 (the Assam Town and Country Planning Act, 1959, Assam Act 2 of 1960, as adapted; as cited in the notifications under it); the Shillong Master Plan 2041 (notified by No. UAU.76/2022/Pt.I/74 of 27 November 2024, as cited in its amendment; amended under section 10(2) by No. UAU.76/2022/Pt.I/186 of 29 October 2025, Gazette of 13 November 2025, read) and the transit-oriented development corridors of 2025; the NESAC report for the plan; the draft risk-informed master plan for Tura (notice No. UAU.76/2022/129 of 16 February 2024) | Continue. The Shillong Planning Area covers 288.5 km², against 174 km² in the plan of 1991–2011: the urban agglomeration and 54 villages, bounded on the west by the Umiam river and lake and on the east by the Umkhen, and "drained mainly by the upstream reaches of Wah Umiam, Wah Umkhen, and Wah Tamdong"; the NESAC report maps 3.2 km² of "Regulated Slope" at 40°–50° and 0.53 km² of "Restricted Slope/No Construction Zone" above 50°, places the area in seismic zone V and gives its flash-flood susceptibility as 18.38% very low, 55.44% low, 20.5% medium, 4.67% high and 1.01% very high (NESAC, *Formulation of Risk Informed GIS Based Master Plan, Shillong Planning Area*, Ver 1.0, May 2023). The Tura draft covers 54.65 km² bounded by the Ringrey stream, the Ganol river and the Rongkhon stream. No drainage chapter of the notified plan of 2041 was read [TBC], and no master plan states a design storm. Master plans would show the flood-sensitive catchments, drainage reserves and regional facility sites of this Manual (Chapter 11). The plan in force is the plan of 2041. |

| Instrument | Relationship |
|---|---|
| Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015 (KHADC Executive Committee Notification No. DC.II/Genl/31/2015/9 of 4 August 2015; Gazette Extraordinary No. 97 of 25 August 2015), made under the United Khasi-Jaintia Hills District (Establishment of Town Committee) Act, 1960, and the permissions of the KHBSRA (since 2020, as reported); the Jaintia Hills Autonomous District (Establishment and Administration of Town Committees) Act, 1975 and the Garo Hills District (Administration of Town Committees) Act, 1950, which the Bye-Laws 2021 list as Acts (A2.1); the building instruments of the JHADC and the GHADC (not found [TBC]) | Continue in the autonomous districts, outside the master-plan, municipal and scheme areas. The 2015 Regulation, which sets out to "codify our ancient traditional conventions on built forms", extends to the whole of the Khasi Hills Autonomous District and is enforced through "the Executive Committee/Town Committee/Dorbar Shnong or Executive Dorbar"; it makes them responsible for ensuring that development does not damage "catchment areas, water sources, spring sheds, streams and rivers" (s.15(1)), with restoration costs on the polluter (s.15(2)); treats river edges as a zone where "No development should normally be allowed" (s.2.101); limits cuts to 3 m and 6 m (s.34(v)); requires rainwater storage (s.36) and drawings that show the highest flood level "reached above the street" and the drains; and forbids septic effluent in a drain or body of water "without adequate treatment" (s.40.3(b)). It sets no design storm. Whether the Bye-Laws 2021 apply in the District Council areas is disputed (Commentary to Clause 1.3); this Manual takes no side, and could take effect in a District Council's area only if that District Council adopted it. |
| Meghalaya Municipal Act, 1973 (the Assam Municipal Act, 1956, as adapted), as amended by the Meghalaya Municipal (Amendment) Act, 2021 (Act No. 4 of 2021) | Continue. The Act vests in the Board the drains of public roads, "all public streams, channels, water-courses, springs tanks, reservoirs" and the public sewers and drains (s.62); regulates the line of buildings on public roads and drains (s.164) and forbids building without sanction (s.171); lets the Board require an owner "to improve bad drainage" within 15 days (s.190), require land within one hundred feet of a drain to be drained (s.206) and drain a block of houses together (s.208); forbids a drain into a Board drain or water-course without written consent (s.204, fine up to ₹50) and sullage on a public road or into a road drain (s.205, fine up to ₹25); and provides for a sewerage scheme (s.212) and a drainage tax (s.68, as substituted in 2021), which is not leviable until a drainage scheme is approved and made (s.73). Its penalties are nominal. The State has six Municipal Boards: Shillong, Jowai, Tura, Williamnagar, Resubelpara and Baghmara. In 2023 the SMB served notices under section 201 and the Environment (Protection) Act on 47 of the 1,169 households it inspected along the Umshyrpi and the Wahumkhrah (State action-taken report, 21.03.2023), and by public notice No. SMB/PW/40/2023/10 of 17 February 2023 told residents "to not discharge untreated sewage directly into drains and water bodies". Only part of the Umkhrah and the Umshyrpi lies within the SMB's limits; the rest is under the KHADC (same report). |
| Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023 (No. FOR/CC/29/2019/Pt/688 of 25 August 2023; Gazette Part IIA, 7 September 2023), as amended by No. FOR/CC/29/2019/1140 of 13 February 2024 and No. FOR/CC/29/2019/Pt/771 of 6 July 2026; the earlier (Preservation and Conservation) Guidelines, No. FOR/CC/29/2019/Pt/637 of 18 July 2023 (superseded) | Apply as executive guidelines. The Forest and Environment Department made them on the High Court's direction in PIL 10/2019, and the Bye-Laws 2021 apply them in the areas the bye-laws cover (B2(ii)(c), Section I(a)4 and I(f), 2024); elsewhere they are to be implemented "in such manner as may be prescribed" (para 10(2)), and nothing prescribed was found [TBC]. Setbacks are measured from "the mean high flood level of a water body observed in the past ten years" (para 2(f)): 3 m from a stream up to 3 m wide in an urban area and 6 m from a wider one (Appendix 3 as merged in 2024; that the merger cut the setback in urban areas outside the municipalities and cantonments from 5 m and 10 m to 3 m and 6 m is a NEER reading [TBC]); 10 m from a rural stream up to 4 m wide and 10, 20 or 30 m from a wider one by plot size (Appendix 2A, 2026); 10, 20 or 50 m from lakes and ponds of up to 1 ha, 1–500 ha and more than 500 ha; and a regulated zone four times the setback for lakes and rural streams (para 7(1A)). Their "waterbody" excludes streams whose bed "remained dry for a period not less than 240 days during each of the past ten calendar years" (para 2(e)), which takes out most jhoras, and they exempt works permitted under the Bye-Laws 2021 and in progress (para 10(3)). The 2.40 m of the original B2(ii)(c) was replaced in 2024. The Pt/688 notification is dated 25 August 2023 in its gazette text and in the 2026 amendment and "18th July, 2023" in the 2024 amendment; this Manual uses 25 August 2023. This Manual's corridor of Chapter 7 applies to every natural channel draining 8 ha or more, whether or not the Guidelines treat it as a waterbody, with a Zone 1 of at least 15 m from top of bank, five times the 3 m and two and a half times the 6 m urban setback; it is stricter than the Guidelines, applies to development approved under this Manual and not to existing buildings, and where the Guidelines' line lies further out, theirs governs (Clause 7.4.5). |

| Instrument | Relationship |
|---|---|
| Meghalaya Flood Plain Zoning Act, 2026 (Bill read: Gazette Extraordinary Part V, 23 February 2026, No. LB.43/LA/2026/2; the Act, as quoted from the State law site, "Act No. 4 of 2026 … received the assent of the Governor on the 6th March, 2026", notification No. LL(B)14/2026/2) | Apply in a flood zone once it is notified; none has been. The Act provides for a Flood Zoning Authority, surveys, objections and the notification of limits, defines a "flood zone" as "the area which is required to carry the flow of the maximum probable floods" (s.2(g)), without a return period, and makes restrictions notified under it prevail over any other law (s.12(2)), with permission deemed granted if not refused within 90 days (as in the Bill). No constitution of the Authority, rules or zone notification was found [TBC]. This Manual maps the 1% AEP corridor of Chapter 7 and reads it as the "maximum probable floods" for its own purpose only; where a zone is notified, its restrictions prevail. |
| Wetlands (Conservation and Management) Rules, 2017; the Meghalaya State Wetlands Authority (Notification No. ENV.1/2007/Pt/110 of 1 November 2017; Gazette, 16 November 2017); the officers empowered to take cognizance of offences (No. ENV.I/2007/Pt-II/102 of 15 September 2023) | Continue. The Authority is chaired by the Minister in charge of Forests and Environment, with the Principal Chief Conservator of Forests as Member Secretary and the Secretaries of Urban Affairs and Water Resources, the Director of NESAC and a hydrology expert among its members. The State has no Ramsar site, and no wetland was found notified under rule 4; the High Court accepted in April 2025 that 225 water bodies had been ground-truthed and that none qualified as a Ramsar site (as reported). Reservoirs, lakes and pungs are governed by Chapter 7. |
| High Court of Meghalaya, PIL No. 10 of 2019, *In Re: Cleanliness of Umiam Lake* (orders of 24.05.2023, 19.07.2023 and 19.02.2024); the suo motu PIL on wetlands (disposed of on 29 April 2025; number not found, as reported); PIL 2/2024 (tree felling) and PIL 13/2022 (the Shillong–Dawki road) (as reported) | Apply where they bind; none sets a current setback. On 24.05.2023 the Court barred construction "within 50 metres of the high-water mark of the relevant waterbody without the express previous leave of this Court"; on 19.07.2023 it found the guidelines of July 2023 to "fall woefully short" and observed that "Several of the rivers, including the Umkhrah in Shillong itself are carrying such contaminated water that they may not be fit even to step into"; and on 19.02.2024 it took the amendment of 13.02.2024 on record and closed the PIL, with six general directions on retrieved public property, circulated by the Forest and Environment Department on 5 March 2024. **The 50 m bar ended with the PIL.** The Expert Committee's "Restricted Zones of 50m + 300m" around Umiam, annexed to the Guidelines, and the NESAC report's "buffer as per NGT" along the town streams, 50 m from Umiam lake and 100 m from protected forests, are recommendations, not rules; no NGT order fixing a buffer for Shillong's streams was found. |
| National Green Tribunal, OA 192/2022 (*In re: News item, The Shillong Times, 23.02.2022, "Poison flowing in Shillong's rivers"*; orders of 28.04.2022 and 22.11.2022), OA 673/2018 (polluted river stretches) and OA 172/2016/EZ (*Sanjay Laloo*) | Apply where they bind. On 22.11.2022 the Tribunal recorded that the Additional Chief Secretary, Urban Development, "is required to ensure that the raw fecal matter is not discharged into fresh water streams and Umkhrah and Umshyrpi rivers"; the State's action-taken report of 21.03.2023 and the joint committee report of 28.02.2023 set out the interception and treatment works, and the State ring-fenced ₹109 crore for liquid and solid waste (letter of 22.12.2023). OA 673/2018 requires full treatment of sewage and in-situ remediation meanwhile (as recited in the action-taken report), and OA 172/2016/EZ required ₹10 crore in a ring-fenced account (as recited in the joint committee report). CPCB lists the Umkhrah (Demthring to Mawpdang, Mawlai) and the Umshyrpi (Umshyrpi Bridge to Law College, Dhanketi) as Priority I stretches (CPCB, *Polluted River Stretches*, September 2025). Sewage in storm drains is dealt with in Chapter 8. |
| National Green Tribunal, OA 73/2014 (order of 17.04.2014, as recited by the Supreme Court) and Supreme Court of India, *State of Meghalaya v. All Dimasa Students Union*, CA No. 10720 of 2018 (judgment of 03.07.2019); Meghalaya Minerals (Prevention of Illegal Mining, Transportation and Storage) Rules, 2022 (as reported) | Apply where they bind. The Tribunal directed that "rat-hole mining/illegal mining is stopped forthwith throughout the State of Meghalaya"; the Supreme Court's judgment of 2019 deals with mining on private and community land under the mining laws, and its directions were not extracted for this Manual [TBC]. Rat-hole mining is reported to continue (as reported). The karst and mine rule of Clause 4.11 and the outfall checks of Chapter 8 apply in coal-mining areas whatever the status of the workings. |
| Groundwater: no State groundwater Act; the no-objection certificates of the District Level Committee and the CGWA portal; the Meghalaya State Water Policy, 2019 (as reported) | Continue. No State law regulates groundwater; abstraction for commercial use needs a no-objection certificate through the District Level Committee and the portal of the Central Ground Water Authority (as quoted in the State's procedure; not read [TBC]). Every assessment unit of the State is "Safe", with a stage of extraction of 3.55% (CGWB, GWRA 2022), so recharge is not a design objective of this Manual (Clause 4.11, recharge rule). |

| Instrument | Relationship |
|---|---|
| Environment (Protection) Act, 1986; Water (Prevention and Control of Pollution) Act, 1974; the Meghalaya State Pollution Control Board | Continue. MSPCB monitored 64 locations on 35 rivers in 2022–23 (CPCB, 2025) and consents industrial effluent before it is let into "a watercourse or drain" (Bye-Laws 2021, D4.6). Sewage and acid drainage in storm drains are dealt with in Chapter 8. |
| Disaster Management Act, 2005; MSDMA, the Revenue and Disaster Management Department and the District Disaster Management Authorities | Continue. No urban flood plan or standard operating procedure of MSDMA was read for this Manual [TBC], and no order of the State fixing a date for pre-monsoon desilting was found; the works calendar of Chapter 10 sets this Manual's dates, beginning with 31 March. |
| IRC:SP:42-2014, IRC:SP:48 (Hill Road Manual) and the practice of the Public Works Department, NHAI and NHIDCL on hill-road drainage | Apply to the drainage of hill roads, cross-referenced from Chapter 6, where they do not conflict with it; the drainage clauses of IRC:SP:48 were not read for this Manual [TBC]. |
| CPHEEO Manual on Storm Water Drainage Systems (2019) | Engineering reference. This Manual sets higher return periods under Clause 1.3.2. |
| NDMA Guidelines on Management of Urban Flooding (2010) and MoHUA SOP (2017) | This Manual puts into effect the NDMA directives on catchment-based design, detention and retention, waterbody protection and climate-adjusted IDF. |
| NDMA Urban Flood Risk Management Programme (UFRMP) and AMRUT 2.0 | Works funded under these programmes shall comply with this Manual. The development controls of Chapters 4–5 protect the capacity those works create. |
| IRC:SP:42-2014 and IRC:SP:50-2013 | Apply to road drainage only where they do not conflict with Chapter 6. |
| MBBL 2016, Chapter 9 | Model for RWH and for the inspection regime in Chapter 10. |

Commentary. RWH in Meghalaya is framed as a water supply and recharge measure. It works well for that purpose. It cannot, however, be relied on for flood control in the monsoon, because RWH sumps are usually full or the ground saturated by the time a June monsoon storm against the plateau and the southern escarpment, such as those of 16 June 1995 and 15–17 June 2022, arrives after weeks of rain. The Manual therefore keeps harvest volume and attenuation volume apart, while letting recharge count as retention where it truly removes water from the system.

Meghalaya is spending on its town streams, but without a design basis. Under the NGT's supervision of the Umkhrah and Umshyrpi (OA 192/2022), the State reported 49,612 m³ of waste removed from the Wahumkhrah for ₹7.9 crore under the 15th Finance Commission, stone bunds and solid-waste traps for ₹3.60 crore, in-situ treatment of five drains, five on-site sewage treatment plants of 13.42 MLD and a diversion drain at Nongrah (State action-taken report, 21.03.2023); Shillong Smart City Ltd is reported to have sanctioned eleven projects worth ₹670.95 crore, among them "in-situ Nallah Treatment Technology", and rainwater harvesting at 52 locations (as reported; State action-taken report); and the Water Resources Department is reported to have resubmitted a DPR for embankments and channel improvement on the Wahumkhrah and the Umshyrpi after the Brahmaputra Board returned the first (as reported). The flood plain zonation of the Umkhrah and other stretches awarded to RMSI in June 2021 was reported 80% complete in March 2023 and has not been published (State action-taken report). None of the documents found states a design storm, and no development-control condition stops new plots in the same catchments from using up the capacity such works create. Linking Chapters 4–5 to approvals closes that gap.

The State's law holds some of the tools. The Bye-Laws 2021 forbid building above 50° of slope, limit cuts, set the stilt and plinth above the Highest Flood Level, bar building on land liable to flooding without protection, require rainwater harvesting on every plot and, in hazard-prone areas, drainage that keeps water out of the subsoil and sediment basins during construction; the KHADC Regulation 2015 protects "catchment areas, water sources, spring sheds, streams and rivers" (s.15), makes rainwater storage mandatory for every building (s.36) and forbids septic effluent in "an open channel, drain or body of water without adequate treatment" (s.40.3(b)); the Meghalaya Municipal Act, 1973 vests the public streams, springs and drains of a municipality in its Board and lets the Board require land within one hundred feet of a drain to be drained (ss.62, 206); the Waterbodies Guidelines set

setbacks from lakes, ponds, rivers and streams, measured from "the mean high flood level of a water body observed in the past ten years"; and the Meghalaya Flood Plain Zoning Act, 2026 lets restrictions in notified flood zones "prevail" over other laws (s.12(2), as in the Bill). The courts have acted too: the High Court's supervision of Umiam lake (PIL 10/2019) produced the Waterbodies Guidelines, and the NGT's orders on the Shillong rivers (OA 192/2022) produced the interception and treatment works above. What the law lacks is a design standard. None of these instruments says how large a drain must be, which storm it must carry, how much water a hill site may put into its slope or a limestone or mine area into its voids, how the flood level of a jhora is to be fixed, or how much storage a paved plot removes; the Guidelines' setback from a stream in a municipal area is only 3 m or 6 m, and most jhoras fall outside them under the 240-day rule; and no flood zone has been notified under the 2026 Act. This Manual's checks are framed as part of the permission given by the competent authority for the area, under the Bye-Laws 2021 or a District Council's regulation, not as a separate no-objection certificate. This Manual is offered as a technical companion to these instruments, to the orders of the courts and to the drainage and river works of the towns: it supplies the design storm, detention, hill-site drainage, infiltration and corridor numbers they do not set, as a proposal for the Government, the District Councils and the other authorities to consider. Neither the Urban Affairs Department, MUDA, any Municipal Board, any District Council, the Water Resources Department nor any other body has adopted it.

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## 1.9 Roles and responsibilities

1.9.1 The responsibilities below apply under this Manual. They do not change any agency's statutory powers.

**Table 1.4 — Roles and responsibilities under this Manual**

| Agency | Role under this Manual |
|---|---|
| Urban Affairs Department (Urban Affairs) | Notifies the Bye-Laws 2021 under the Meghalaya Town and Country Planning Act, 1973 and the master plans of Shillong, Tura and the other towns, prepared with NESAC, and oversees the Municipal Boards and the State's urban programme unit (SIPMIU). Would prepare the amendment of Clause 1.3.1(a), show flood-sensitive catchments, drainage reserves and regional facility sites in the master plans (Chapter 11), issue the model bye-law of Clause 1.3.1(b) to the Municipal Boards, and give regional support to Tier B authorities (Table 1.1). Its jurisdiction does not reach the Town Committees and census towns governed by the District Councils (CAG). |
| Meghalaya Urban Development Authority (MUDA) | The "Authority" of the Bye-Laws 2021 in the master-plan, municipal and scheme areas, acting through its Chairperson or an officer to whom the power is delegated (A2.3). Would require the drainage report of Chapter 10 with each application, check the hill rules at the plinth inspection, and record drainage reserves and easements in the permissions it grants. Whether its jurisdiction reaches the District Council parts of a master-plan area is disputed; this Manual does not decide it. |
| State Stormwater Technical Committee (Clause 1.3.2) | Would adopt higher standards, issue Annexes, tables and the compliance calculator, concur with Tier A alternatives, decide variances referred to it and review the Manual (Clause 1.12). |
| Shillong Municipal Board (SMB) and the Municipal Boards of Jowai, Tura, Williamnagar, Resubelpara and Baghmara | Hold the public drains, streams, springs and tanks of their areas under section 62 of the Meghalaya Municipal Act, 1973, give consent for drains into them (s.204) and may require land to be drained (ss.190, 206). Would apply this Manual to their own works, keep the drain-and-jhora register of their area, receive handed-over assets (Clause 10.14), and inspect and enforce (Clauses 10.12–10.15). SMB would also keep the solid-waste traps on the drains it maintains clear before each season. |
| Shillong Cantonment Board | Governs building and drainage in the Shillong Cantonment, where "each house in the civil areas of cantonment has their own septic tank" (State action-taken report, 2023). Would apply this Manual to the works it approves and executes in the Cantonment. |

| Agency | Role under this Manual |
|---|---|
| New Shillong Township Development Authority (NSTDA) [TBC] and Shillong Smart City Ltd | Plan and build the New Shillong township (NSTDA; its powers not read for this Manual [TBC]) and drains, rainwater harvesting and in-situ nallah treatment in Shillong under the Smart Cities Mission (Shillong Smart City Ltd, as reported). Would design their drainage works to this Manual from the dates of Clause 1.11 and hand them over under Clause 10.14. |
| Khasi Hills, Jaintia Hills and Garo Hills Autonomous District Councils (KHADC, JHADC, GHADC), their Executive Committees and building authorities (KHBSRA in the Khasi Hills), and the Town Committees | Regulate building and land in their districts outside the master-plan, municipal and scheme areas: in the Khasi Hills under the 2015 Regulation, with permissions from the KHBSRA (as reported); the JHADC and GHADC instruments were not found [TBC]. The Manual has no force in their areas unless a District Council adopts it. A District Council's Executive Committee could adopt it for its district by amending its own building regulation; if it did, its building authority would require the drainage report of Chapter 10, or the simplified drainage layout of section 36 of the KHADC Regulation for small buildings, and the District Council would be the competent authority for the area. |
| Dorbar Shnong and Rangbah Shnong (Khasi and Jaintia Hills); the village institutions of the Garo Hills led by the Nokma [TBC] | Act under the rules of the District Councils; the KHADC Solid Waste Management Rules, 2022 empower the Dorbar Shnong to fine polluters (as recorded in the minutes of 14 April 2023), and the 2015 Regulation names the Dorbar Shnong among the bodies that protect water sources and streams (s.15(1)). Hold or speak for much of the community land on which jhoras and corridors lie. Would agree the drainage corridors, easements and regional facility sites on community land (Chapter 7) and keep village jhoras and drains clear under the District Council's rules. |
| Water Resources Department | Builds and maintains flood works on the rivers, carries out the flood plain zonation study awarded to RMSI, and issues groundwater no-objection certificates through the District Level Committee. Would supply river levels and flood marks for Chapter 5, approve the site-specific hydrology of Clause 2.3.6(i) for rivers, and apply this Manual to its flood works, among them the works proposed on the Wahumkhrah and the Umshyrpi. |
| Public Health Engineering Department (PHED) | Supplies water to the towns, mostly by gravity from streams and springs, and has been the nodal department for sanitation outside the municipalities since 2023 (minutes of 14 April 2023). Would protect the spring-recharge areas above its intakes under Chapter 8 and keep septic and sullage overflows out of the storm drains it serves. |
| Public Works Department (PWD (Roads)), NHAI and NHIDCL | Build and maintain the roads, their side drains, catch-water drains and culverts, which in the hill towns are much of the minor drainage system; NHAI and NHIDCL on NH-6 and the Shillong–Dawki road. Would apply Chapter 6 and the hill-road rules to them and never discharge a road drain onto an unprotected slope. |
| Soil and Water Conservation Department | Treats catchments. Would apply the hill rules of Clause 4.11 to its works and coordinate catchment treatment above the flood-sensitive catchments of Annex 1B. |
| Forest and Environment Department | Made and administers the Waterbodies Guidelines, provides the Member Secretary of the Meghalaya State Wetlands Authority and constituted the River Rejuvenation Committee (No. ENV.5/2018/44 of 24.01.2019, reconstituted by No. ENV.5/2018/172 of 9 October 2020). Would be the competent authority for matters under the Guidelines, could align their setbacks with the corridors of Chapter 7, and the Wetlands Authority's consent would be needed before a notified wetland is used for storage or as an outfall (Chapter 7). |
| Meghalaya State Pollution Control Board (MSPCB) | Monitors rivers (64 locations on 35 rivers in 2022–23) and identified the 32 outfalls of the Umkhrah and the Umshyrpi. Would receive the records of sewage and acid drainage found in storm drains under Chapter 8. |
| MSDMA, the Revenue and Disaster Management Department, the Deputy Commissioners and the District Disaster Management Authorities | Prepare for and respond to floods, flash floods and landslides and report their tolls. Would supply the landslide and flash-flood inventories used in the screening of Clause 2.3.6(i) and lead post-event reviews with the Authority (Clause 10.16). In the Sixth Schedule areas most land is community, clan or private, and its records are not held by the State's revenue staff. |
| Meghalaya Basin Development Authority (MBDA) | Runs the State's spring-shed programme (as reported). Would supply spring locations and recharge areas for the spring rules of Chapter 8. |
| MeECL and MePGCL | Operate the Umiam–Umtru dams, New Umtru and Myntdu–Leshka, whose gate-operation guidelines give their levels and release reaches. Would supply reservoir levels, release rules and release records for Chapter 5 and the screening of Clause 2.3.6(i). |

| Agency | Role under this Manual |
|---|---|
| NESAC, a centre of the Department of Space | Prepared the risk-informed master plans of Shillong and Tura with their flash-flood and landslide susceptibility maps. Its maps would be used in the screening of Clause 2.3.6(i) and in Chapter 11. |
| Flood Zoning Authority (Meghalaya Flood Plain Zoning Act, 2026; not constituted) | Once constituted, would survey rivers, notify flood zones and grant permissions in them; it could use the corridor maps of Chapter 7 in its notifications. Until then no flood zone exists. |
| Central Water Commission (CWC), a body of the Union | Publishes the Flood Estimation Report for subzone 2(b) used in Chapters 2 and 3 and monitors river levels at seven sites in the State, none with a warning level. Would supply river stage records for Chapter 5 and confirm whether a report for subzone 2(c) is in preparation. |
| Central Ground Water Board (CGWB), North Eastern Region, Guwahati, a body of the Union | Assesses the State's groundwater (every unit "Safe"; stage of extraction 3.55% in 2022) and holds the observation wells. Would supply groundwater levels and quality with the Water Resources Department. |
| IMD (Meteorological Centre Shillong), and road and rail owners | IMD's stations supply the rainfall records of Chapter 2; Cherrapunji (42515) and Shillong (C.S.O.) (42516) are the first data request of Clause 2.3.6(a). Road and rail owners would apply this Manual to road drainage (Chapter 6), culverts and linear works (Clause 1.5.7). |

**Commentary.** Stormwater in Meghalaya is split, first, by the Sixth Schedule. In the master-plan, municipal and scheme areas the Urban Affairs Department makes the Bye-Laws 2021 and the master plans, MUDA grants permission and the Municipal Boards hold the drains; in the rest of each autonomous district the District Council regulates building and land under its own instruments, the Town Committees and Dorbar Shnongs act under its rules, and the land is mostly community, clan or private. The Comptroller and Auditor General found that the Town Committee and census-town areas, 47 per cent of the urban population, are governed by the District Councils and not by the Urban Affairs Department (CAG). The split is then repeated among the bodies that drain the land: the Water Resources Department for the rivers and flood works, the PWD, NHAI and NHIDCL for the road drains that are much of the minor system in the hill towns, MePGCL for the reservoirs that hold outfalls up and release floods down the valleys, PHED for the water supply and, outside the municipalities, sanitation, and the courts, which have acted on Umiam lake and on the Shillong rivers. Shillong shows why the split matters. The Umkhrah and the Umshyrpi are at once trunk storm drains, the city's sewers, since the Shillong Planning Area "has no sewerage system" and its sullage flows through "the primary, secondary and natural drains and finally to the nearby rivers" (NESAC, 2023), and Priority I polluted stretches (CPCB, 2025). Only part of their length lies within the SMB's limits; the rest is under the KHADC (State action-taken report to the NGT, 21.03.2023), and the Cantonment, the census towns, New Shillong and the 54 villages of the planning area lie outside the Board. The Municipal Act vests the public drains and streams of a municipality in its Board (s.62), but no rule or order found divides the jhoras and streams outside the municipalities, or the road drains from the town drains, between the bodies concerned [TBC]. Until such a rule is made, this Manual assigns the drainage elements as in Table 1.5, as Chapter 6 does for the drains themselves, and recommends that each town keep a **drain-and-jhora register** giving every reach its owner, its land status (community, clan, private or State) and whether it is a "waterbody" under the Waterbodies Guidelines, that is, whether the 240-day rule excludes it (set by this Manual). The assignment is this Manual's working split for applying its clauses; it does not change any agency's powers, and on community land it is put into effect by agreement with the landholding institution, not by acquisition.

**Table 1.5 — Working assignment of drainage elements under this Manual**

| Element | Assigned to |
|---|---|
| Drains of public roads, public streams, channels, water-courses, springs and tanks, and public drains, within the limits of a Municipal Board | The Municipal Board (Meghalaya Municipal Act, 1973, s.62); in Shillong, SMB |
| Roadside drains, catch-water drains and culverts of State roads | PWD (Roads); on NH-6 and the Shillong–Dawki road, NHAI or NHIDCL |

| Element | Assigned to |
|---|---|
| Drains in the Shillong Cantonment | The Shillong Cantonment Board |
| Drains of the New Shillong township | NSTDA [TBC] |
| Rivers and the flood works on them | The Water Resources Department |
| Village drains and jhoras outside municipal limits | The District Council, and the Dorbar Shnong under the District Council's rules (the Nokma-led villages of the Garo Hills not researched for this Manual [TBC]) |
| Reservoirs, their gates and releases, and their release reaches | MePGCL |
| Catchment treatment | The Soil and Water Conservation Department |
| Drains and treatment works built by Shillong Smart City Ltd, until handed over in writing | Shillong Smart City Ltd (as reported), and the Municipal Board after handover |

This Manual names departments and authorities as the statutes, orders and records name them. A manual that names one owner for each task does not fix institutions by itself, but it removes ambiguity about who signs what.

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## 1.10 Variances and waivers

1.10.1 **Variance.** The Authority may grant a variance from a numeric requirement where the Applicant shows, through a report certified under Clause 10.6, that:

- (a) compliance is impracticable because of site conditions such as a high groundwater table, contaminated soil, rock, or a site area too small for the required facility; and
- (b) the proposed alternative gives equal or better performance at the downstream point of Chapter 5, or the shortfall is made up by fee-in-lieu or off-site works in the same catchment.

1.10.2 **Waiver.** The Authority may waive Chapter 4 detention requirements (not retention) where a hydraulic analysis certified under Clause 10.6 shows that the site discharges directly to the sea, or to a tidal reach with no flood-prone property downstream, and that undetained flow does not worsen the outfall-closed condition of Chapter 5. Meghalaya has no coast and no tidal reach, so no site in the State qualifies for this waiver. A site that drains to a stream in flood on a valley floor, such as the Umkhrah at Polo, to a reservoir or release reach of MePGCL, or to a river under backwater on the Garo plains, is in the outfall-closed condition of Chapter 5 whenever the receiving water is high, and detention is not waived for it; nor is it waived for a site because it drains to a steep jhora, a gorge or down the escarpment.

1.10.3 **No variance or waiver.** No variance or waiver shall be granted for:

- (a) a sewage connection to a storm drain;
- (b) the lowest habitable floor level of Chapter 6;
- (c) any reduction of a waterbody setback below the Zone 1 minimum of Clause 7.4.7, or any fill or construction in the no-fill zone of Chapter 7; or
- (d) the retention requirement in a flood-sensitive catchment, except by fee-in-lieu under Clause 1.7.

1.10.4 **Procedure.**

- (a) The request shall be made on **Form 1-2** (Variance / Waiver Request) with the preliminary drainage report.
- (b) A Tier B authority shall refer any variance on a site of 1 ha or more to the State Stormwater Technical Committee.
- (c) A decision shall state its reasons and any conditions, and shall be entered in the public register of Clause 10.17.
- (d) A variance runs with the approval. It lapses if the approval lapses.

> Commentary. The 2006 APWA 5600 included a waivers section (5601.6), and Georgia allows waivers where downstream analysis shows a peak control is unnecessary. The waiver of Clause 1.10.2 is narrow: on a tidal coast, undetained flow can help by passing through before the tide closes the outfall, but only an analysis can show that. This Manual requires every decision to be published because publication deters case-by-case erosion of the standard; in Meghalaya the High Court found the waterbody guidelines of July 2023 to "fall woefully short" and to "appear to be more of a formality" (PIL 10/2019, order of 19.07.2023); the guidelines that replaced them keep buildings only 3 m or 6 m from streams in municipal and cantonment areas, and their amendment of 2026 reduced the setbacks from rural streams on larger plots; and the NESAC report for the Shillong Planning Area found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" (NESAC, 2023).

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## 1.11 Transition provisions

1.11.1 **Effective date.** This Manual takes effect for new applications **6 months** after notification (the effective date).

1.11.2 **Applications in process.** An application filed complete before the effective date may be decided under the rules in force when it was filed, if a decision is issued within 12 months of the effective date. Otherwise, this Manual applies.

1.11.3 **Phased start for Tier B.** In Tier B authorities, Chapters 4 and 5 apply from **24 months** after notification, except in flood-sensitive catchments, where they apply from the effective date.

1.11.4 **Public works.** DPRs sanctioned before the effective date may proceed as sanctioned. Any DPR revised or re-tendered after the effective date shall comply. Departments shall report non-compliant works in progress to the State Stormwater Technical Committee within 12 months.

1.11.5 **Before the annexes are issued.** Until an annex referred to in this Manual is issued, the Applicant shall use the method stated in the clause, with values agreed with the Authority and recorded in the drainage report.

> Commentary. The 6-month lead time matches the lead time for NIH-DHAARA updates in Clause 2.14.2. Singapore gave a similar interval for its 2025 detention addendum (issued 16 Apr 2025, applied from 1 Oct 2025). The 12- and 24-month periods are set by this Manual to let Tier B authorities train staff and to let the State issue the design-aid tables (Clause 1.7).

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## 1.12 Review and amendment

1.12.1 The State Stormwater Technical Committee shall review this Manual every **10 years**, and after any event that exceeds the 1% AEP design depth as set out in Clause 2.14.1.

1.12.2 Amendments shall be notified in the Gazette, published with a change log, and take effect 6 months after notification unless the notification states otherwise.

1.12.3 Any person may propose an amendment to the Committee. Proposals and the Committee's decisions shall be published.

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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 1A | List of Tier A authorities, with the boundaries of the Shillong and Tura Municipal Boards and of the master-plan areas under the Meghalaya Town and Country Planning Act, 1973, among them the Shillong Planning Area and the Tura master-plan area |
| 1B | Maps of flood-sensitive catchments |
| 1C | Policy Supplement: text of alternatives S-1 to S-5 and model council resolution |
| 1D | Model Bye-Laws 2021 amendment and model ULB bye-law |
| Form 1-1 | Applicability Determination |
| Form 1-2 | Variance / Waiver Request |

CHAPTER 2

# Design Rainfall and Design Storms

## 2.1 Purpose and scope

2.1.1 This chapter sets the rainfall inputs for every hydrologic calculation in this Manual: drain and inlet sizing (Chapter 6), retention and detention sizing (Chapter 4), downstream and tailwater analysis (Chapter 5), and waterbody and tank works (Chapter 7).

2.1.2 It specifies:

- (a) the approved sources of design rainfall depth and intensity;
- (b) how depths are converted between durations, between point and area, and from present to future climate;
- (c) how design storms (hyetographs) are constructed; and
- (d) the storms that must be applied to pre- and post-development conditions.

2.1.3 This chapter applies throughout Meghalaya. Where a Municipal Board, MUDA, the Shillong Cantonment Board, NSTDA or a District Council has adopted a stricter rainfall standard under Chapter 1, the stricter standard governs.

> **Commentary.** Most past drainage failures in Meghalaya trace to the rainfall input, not the hydraulics. Meghalaya shows how. No design storm was found for any town's drains in the State: Shillong's 148.91 km of drains state none (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan), and the one method found, RMSI's for Shillong in 2019, took its design rainfall from a CWC atlas of probable maximum precipitation that was not obtained for this Manual (as quoted in the same plan). The published sources that seem to fill the gap do not. The CWC report for subzone 2(b) gives Shillong about 560 mm in 24 hours at 50 years, about twice IMD's record for the station, and its 1-hour ratio of 0.48 would give the city about 269 mm in an hour, 5.6 times the largest hour its recording gauge has measured; the escarpment, the wettest belt on record, lies in subzone 2(c), for which CWC has published no report at all. The Shillong panel of IMD Das et al. (2022) is a generic curve, not station data, and NIH-DHAARA gives Dawki 1,423 mm in a day at 50 years, more than Mawsynram (Clause 2.3.6). The rainfall figures that circulate after a flood often conflict: Cherrapunji's day of 16 June 1995 is 1,563.0 mm in IMD's tables and 1,563.3 mm in the press, Sohra's day to 15 June 2022 is reported as 811.6 mm and 811.2 mm, Mawsynram's previous June record as 945.4 mm by IMD and 944.7 mm in the press, and Shillong's highest day as 273.2 mm by IMD and 347 mm by the 2(b) report's recording gauge (IMD; CWC; as reported). Fixing one transparent source and method for the whole state is the main purpose of this chapter.

## 2.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Annual exceedance probability (AEP) | Probability that a given rainfall depth is equalled or exceeded in any one year. A 1% AEP storm is the "100-year" storm. Both forms are used here: T-year = 1/AEP. |

| Term | Meaning in this Manual |
|---|---|
| IDF / DDF | Intensity–duration–frequency and depth–duration–frequency relationships for a location. |
| Point rainfall | Rainfall at a single location, as measured by a rain gauge. |
| Design storm | A hyetograph (rainfall depth versus time) of stated AEP, duration and temporal pattern. |
| Critical duration | The storm duration that produces the largest peak flow, water level or storage requirement for the element being designed. |
| Areal reduction factor (ARF) | Ratio of catchment-average rainfall to point rainfall for the same AEP and duration. |
| Monsoon season (as used in this Manual) | 1 April to 31 October. In this Manual "the monsoon" and "the monsoon season" mean this wet season, which takes in IMD's pre-monsoon months of April and May as well as the south-west monsoon; it is the Manual's season, not IMD's. IMD's south-west monsoon reaches Shillong about the first week of June (its old normal date for Shillong was 1 June, as reported; the revised normals in use since 2020 were not read for this Manual [TBC]; in 2026 it reached "substantial parts" of the North East on 7 June, "two days later than its normal", as reported) and withdraws from the State about the middle of October (expected by 14 October in 2025, and from the North East on 15 October in 2026, "close to its normal date", as reported). The season begins on 1 April because the storms of April and May are among the State's largest: Cherrapunji's highest days are 644.2 mm in April (16 April 1990) and 812.0 mm in May (25 May 1916), each larger than the 50-year 24-hour value that the 2(b) plates give anywhere in the Brahmaputra valley (NEER reading), and its May total has reached 3,961.2 mm (1984) (IMD, *Extremes*); the CWC 2(b) report finds the rain "spread over a period of eight months, i.e. from March to October", with thunderstorms in April and May and "May rainfall … more than the September rainfall" (CWC, 2(b), p. 20); the highest levels at two of the State's CWC sites fell before June, on the Myntdu at Kharkhana (47.0 m, 23 April 1995) and the Umngot at Dawki (73.47 m, 28 May 2006) (CWC data as transcribed by SANDRP); and the floods and landslides of 30–31 May 2025 came before the south-west monsoon (as reported). A works deadline of 31 May would leave those storms uncovered, so the pre-monsoon deadline of 31 March is set before the season begins (Chapter 10). CGWB's reports say both that the monsoon "usually starts from the middle of May" and that the rainy season "commences with the onset of southwest monsoon in April" (CGWB, GWRA 2022); those are CGWB's statements, not IMD's dates, and they disagree. The wettest months on record are July 1974 at both IMD stations, 6,667.4 mm at Cherrapunji and 1,086.8 mm at Shillong (IMD, *Extremes*). Annual normals run from 225.3 cm at Shillong (Obsy) and 242.5 cm at Upper Shillong to 273.4 cm at Dalu (CWC, 2(b), Annex 4.1), and the monsoon rainfall "varies from 100 cm in the west central part to over 1000 cm in the south and southeast" (CGWB); the annual figures of 11,430 mm for Cherrapunji and 17,800 mm for Mawsynram quoted by CGWB give no source or period and are not normals. The antecedent moisture rule of Clause 2.11.4 and the standby period of Chapter 10 refer to this season. |
| Storms outside the season | Large falls come before and after the season, and the October storms that come about the time of the withdrawal fall inside it. Cherrapunji's highest days outside the season are 587.4 mm in March (23 March 1994), 376.9 mm in February (18 February 1993), 332.2 mm in November (1917) and 189.7 mm in December (1926); Shillong's are 48.0 mm in February (28 February 1973) and 138.2 mm in November (16 November 2007) (IMD, *Extremes*). In October, about when the south-west monsoon withdraws, Cherrapunji recorded 594.0 mm on 11 October 1975 and Shillong 262.0 mm on 8 October 2004, and the Garo Hills floods of 4–6 October 2024 came in IMD's post-monsoon season (IMD; as reported). The winter is close to dry, and December to February is this Manual's works window. Design statistics use annual maxima from all months, no works deadline or operating rule shall assume that heavy rain is confined to June–September, and the works calendar of Chapter 10 keeps standby to 31 October and a post-season clearance by 15 November for this reason. |
| Climate factor (CF) | Multiplier applied to present-day design depths to represent the design-life climate. |
| Approved source | A rainfall source listed in Clause 2.3. |

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## 2.3 Approved sources of design rainfall

2.3.1 **Primary source.** Design rainfall depths and intensities shall be taken from the National Institute of Hydrology, Roorkee **NIH-DHAARA** platform (Design Hydrology and Advanced Rainfall Analysis, nihdhaara.in). Use its IDF / frequency tools for the site's coordinates, for each duration and AEP required by Clause 2.4. In Meghalaya this clause is

suspended until Annex 2A is published: Clause 2.3.6 sets the interim source.

2.3.2 **Station IDF.** A station-specific IDF relationship may be used in place of 2.3.1 only if all of the following hold:

- (a) it is derived from at least 30 years of recording-gauge (hourly or finer) data;
- (b) it has been published or approved by IMD, the State Hydrology Authority or the approving authority; and
- (c) the gauge is within 10 km of the site, with no major change of terrain or coastal exposure in between.

Where a station IDF is used, the design value shall be the **greater** of the station value and the NIH-DHAARA value.

2.3.3 **Cross-checks (mandatory, not alternatives).** The designer shall report, but need not adopt, the following values for comparison:

- (a) the IMD isopluvial / IDF values of Das et al. (2022), *MAUSAM* 73(4), for durations of 1–24 h;
- (b) for catchments of 25–5,000 km², the 24-hour point rainfall from the CWC Flood Estimation Report for subzone 2(b) (South Brahmaputra), which covers the northern foothills, the plateau and the interior of the Garo hills but not the southern escarpment and the south Garo slopes, which lie in subzone 2(c) (Barak), for which CWC has published no Flood Estimation Report, as applicable.

Where the design value is lower than the CWC subzone 2(b) (South Brahmaputra) plate (outside the Shillong Planning Area, where Clause 2.3.6(c)(i) sets the floors instead, and outside sub-areas ML-C and ML-C1, which no CWC plate covers) value for the same AEP, the CWC value shall be adopted as a floor.

2.3.4 **Not permitted.** None of the following shall be used as a design rainfall source:

- (a) generalised all-India IDF formulae (for example Kothyari & Garde, 1992);
- (b) rainfall values that cite no source, including vendor or web-calculator tables;
- (c) single-event maxima; or
- (d) design intensities carried forward from a previous project without a stated AEP.

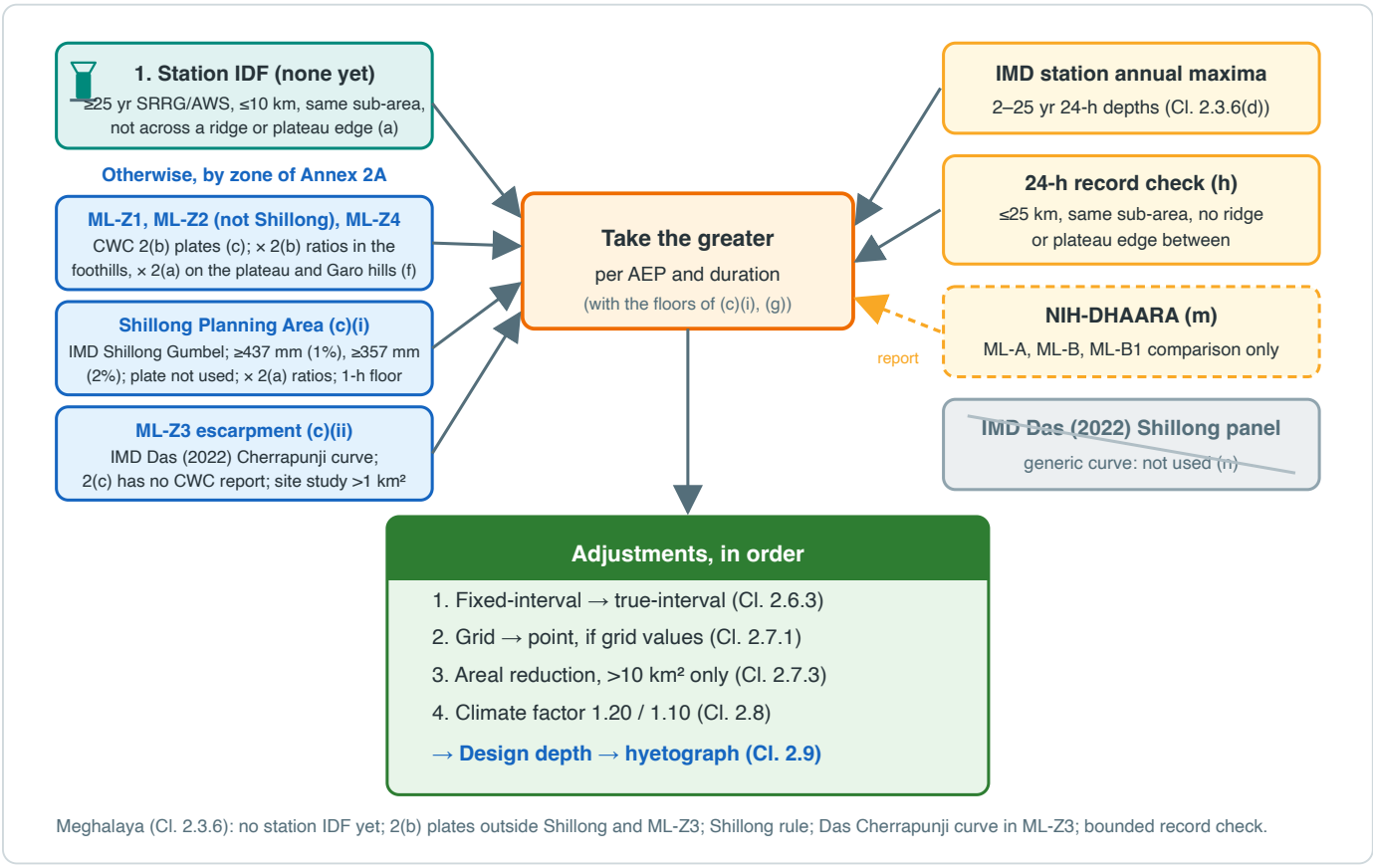


*Figure 2.1 — Design rainfall source hierarchy and adjustment sequence. Original drawing for this Manual.*

2.3.5 **Version control.** Every submittal shall record the source, its version or access date, the coordinates queried, and the values extracted (Clause 2.13).

2.3.6 **Interim source in Meghalaya.** Until Annex 2A is published and confirms NIH-DHAARA, or an approved station IDF, for a zone, Clause 2.3.1 does not apply in Meghalaya, and design rainfall shall be taken as follows:

- (a) **Station IDF.** Where a station IDF fitted to a checked IMD recording-gauge (SRRG) or automatic weather station record of at least 25 years has been published in Annex 2B, it governs, within 10 km of the station and in the same sub-area of Annex 2A, for the durations and AEPs it covers, in place of (f), and subject to the floors of (c)(i) and (g); the comparison of Clause 2.3.2 is then made with the 24-hour and longer depths of (c) to (e) and (h), and the CWC floor of Clause 2.3.3 still applies outside the Shillong Planning Area and outside sub-areas ML-C and ML-C1. A record is checked when its annual totals and annual maxima have been compared with the IMD normals and station extremes for the station, and every year that disagrees has been explained or removed. An IDF derived from daily data by the one-third rule (Clause 2.6.4) or by any other fixed ratio is not a station IDF. In Meghalaya Clause 2.3.2(a) is read with 25 years in place of 30, as in the mountain editions of this series, and the gauge shall not be separated from the site by a ridge or by the edge of the plateau (set by this Manual, because the State's rain changes several-fold over a few tens of kilometres: the highest day printed by IMD is 1,563.0 mm at Cherrapunji and 273.2 mm at Shillong, about 36 km apart (IMD, *Extremes*; distance a NEER reading)). No IDF has yet been published in Annex 2B, and no station IDF with constants was found for any station in the State: no IDF study of NEHU, IIT Guwahati, NIT Meghalaya or NERIST with published constants was found [TBC]; the "Eastern" constants of the zonal equations of Ram Babu et al. (2006) repeat the "Central" ones, a typesetting duplicate (NEER reading), and are not used (o); and IMD Das et al. (2022) has a genuine panel only for Cherrapunji (n). The first data request of this Manual is for the IMD recording-gauge and automatic weather station annual maxima and return-period tables of **Cherrapunji (Sohra, 42515)** and **Shillong (C.S.O.) (42516)**, the State's two stations in IMD's *Extremes*, to be fitted under this paragraph; then for Jowai or Khliehriat, whose plate value under (c) is probably high, Mawsynram, Barapani/Umiam (the agro-meteorological station of the ICAR Research Complex for NEH Region [TBC]), Tura, Shella, Nongstoin, Williamnagar, Baghmara and the gauges of the Dawki area; then for the other gauges on the daily rainfall map of the Meteorological Centre Shillong, among them Tikrikilla, Resubelpara, MeECL Lumjingshai, Mawphlang, Mawkyrwat, RKM Sohra and Ratacherra, whose types and record lengths are to be confirmed [TBC]; and for the hourly data of 15–17 June 2022, 4–6 October 2024 and June 2026.

- (b) **Reports, zones and sub-areas.** Two CWC areas cover the State. The northern foothills, the plateau and the interior of the Garo hills lie in **subzone 2(b), South Brahmaputra**, whose revised report (Design Office Report No. SB-2(b)/R-4/44/99, March 2000, approved by the Flood Estimation Planning and Co-ordination Committee at its 55th meeting on 13.3.2000, revising SB/8/1984) describes the subzone as bounded "on the south by Barak Subzone 2 (c)" and names Shillong and Tura among its towns (CWC, 2(b), p. 18). The southern escarpment facing Bangladesh, with Sohra, Mawsynram, Shella, Pynursla, Dawki and Baghmara, lies in **subzone 2(c), Barak, for which CWC has published no Flood Estimation Report**: the 2(b) report lists the 21 reports published by 2000 and none is for 2(c), and CWC's page of its reports, as captured on 20 March 2024, lists none (CWC). No part of the State lies in subzone 2(a), North Brahmaputra, on the north bank of the Brahmaputra; its report is used in (f) for its ratios only. On Plates 8 to 10 of the 2(b) report the dashed subzone boundary runs west–east along the plateau, just south of Shillong and on or just north of Tura, and no contour is drawn south of it west of about 91.8° E (NEER reading of the plates, about one town marker either way) [TBC]. The rainfall zone and sub-area of the site are those of Annex 2A: zone **ML-Z1 Northern foothills**, with sub-areas **ML-A Northern foothills and Ri-Bhoi (Nongpoh–Umsning–Byrnihat–Umiam)** and **ML-A1 Garo foothills and plains (Resubelpara–Mendipathar–Tikrikilla–Phulbari)**; zone **ML-Z2 Plateau**, with sub-areas **ML-B Shillong plateau (Shillong–Mawphlang–Nongstoin–Mairang)** and **ML-B1 Jaintia hills karst and mine belt (Jowai–Khliehriat–Sutnga–Ladrymbai)**; zone **ML-Z3 Southern escarpment**, with sub-areas **ML-C Southern escarpment (Sohra–Mawsynram–Shella–Pynursla–Dawki)** and **ML-C1 South Garo slopes (Baghmara–Siju–Gasuapara)**; and zone **ML-Z4 Garo hills**, with sub-area **ML-D Garo hills interior (Tura–Williamnagar–Rongjeng–Ampati–Dalu)**. ML-Z1 and ML-Z2 lie in subzone 2(b), ML-Z4 on the boundary of 2(b) and 2(c), and ML-Z3 in subzone 2(c). They fix the source of (c), the ratios of (f), the floors of (g), the bounds of the check of (h) and the rule of (i). A catchment that crosses the line between two

zones or two sub-areas of Annex 2A takes, at every duration, the higher value of the two (set by this Manual). The town lists of Annex 2A are a guide; their boundaries, and the side of the 2(b)/2(c) line on which Khliehriat, Mawkyrwat, Dalu and Ampati lie, are to be confirmed [TBC].

- (c) **24-hour depth, 2% and 1% AEP (50- and 100-yr).** Outside the Shillong Planning Area and outside sub-areas ML-C and ML-C1, the 24-hour point value at the site read from the 50- and 100-year isopluvial plates of the 2(b) report (Plates 9 and 10), whatever the catchment area. Where the site lies between two contours, the higher contour value is used; where it lies inside a closed contour with no higher contour within it, the value is that contour plus one contour interval, except that a contour that closes on the subzone boundary is read at its own value; and where the plate cannot be read at the site, the highest contour legible within 25 km of the site and in the same sub-area is used until the plate has been read for it [TBC] (all set by this Manual). The contours in this sector are 320, 400, 480, 560 and 680 mm, at intervals of 80–120 mm. Plates are read by the coordinates of the site, not by the town labels; on the copy used for this Manual the town markers fitted to the graticule fall about 20 px from the printed town dots on Plate 8 and about 0.15° from them on Plate 10, so those plates were read from the printed dots, and each reading is recorded on Form 2-1 with the contours on either side. For orientation only, read by eye to about one contour (low confidence), the 50-year plate gives **about 560 mm at Shillong (560–680 mm at 100 years)**; about 680 mm at Jowai, inside a closed 680 mm tongue that closes on the subzone boundary and is therefore read as 680 mm, not 680 mm plus one interval; about 560 mm at Nongstoin; about 280–320 mm at Nongpoh; about 320–400 mm at Tura, which lies in a closed 320 mm cell on Plate 8; and about 400 mm at Williamnagar. It is blank at Sohra, Mawsynram and Baghmara, and at Dawki the contours of the Jaintia south, extrapolated across the boundary, give about 560–680 mm (very low confidence) (CWC, 2(b), Plates 8–10; NEER reading). Where the Gumbel estimate of (d) for the station of the site is higher for the same AEP, it governs; the 24-hour depth is then checked under (h). At Jowai and Nongstoin the plate is probably high: NIH-DHAARA gives 335 mm and 285 mm at 50 years there (m), and Jowai's gauge is a priority of (a). Two departures from the plate are set by this Manual:
    - (i) **Shillong.** Within the Shillong Planning Area, the 288.5 km² of the Shillong Master Plan 2041 (NESAC, 2023), the plates are not used for design, because Plate 9 reads about 560 mm at 50 years, 1.3 to 2 times every fall recorded at any Shillong gauge: 273.2 mm at Shillong (C.S.O.) on 25 June 1988, in IMD's record of 1957–2012 (IMD, *Extremes*); 347 mm in 24 hours on 14–15 September 1960 at the Shillong recording gauge of the 2(b) report (CWC, 2(b), Annex 4.2); and 415 mm at Shillong (Obsy) and 437 mm at Upper Shillong, both on 20 June 1934 (CWC, 2(b), Annex 4.1). NIH-DHAARA gives 246 mm at 50 years and 276 mm at 100 years in the Shillong cell (m). The plates' 680 mm tongue just south-east of the town suggests that they carry the escarpment's values north over the plateau (NEER reading). Within the Shillong Planning Area the 24-hour depth at every AEP is therefore the Gumbel estimate of (d) from the daily annual maxima of IMD Shillong (C.S.O.), with 30 or more years of record (IMD's data period is 1957–2012), **and not less than 437 mm at 1% AEP**, the largest fall printed for any Shillong gauge (Upper Shillong, 20 June 1934), **and 357 mm at 2% AEP**, which is 437 mm less one 80 mm contour interval of the plates. The 25-year plate floor of (d) does not apply there, and the CWC floor of Clause 2.3.3 is not applied there. The plate value and the NIH-DHAARA value are recorded on Form 2-1 beside the design depth. This is a departure below the CWC plate, made because the plate stands at about twice the town's records; the two floors keep every design depth above every fall recorded at any Shillong gauge (all set by this Manual).
    - (ii) **Southern escarpment.** In sub-areas ML-C and ML-C1 no CWC plate applies: the escarpment lies in subzone 2(c), which has no report, and the 2(b) plates draw no contour there west of about 91.8° E. There the Cherrapunji curve of IMD Das et al. (2022), Fig. 4(v), is the interim design rainfall at every AEP and every duration it covers, read as in (f), in place of (c), (d) and (f) (set by this Manual, because no CWC report, no plate contour and no other station series exists for the escarpment, and because its flood yields show escarpment-scale rain well east of Sohra: the spillway of Myntdu–Leshka Stage I passes 12,000 m³/s from a catchment of 350 km², about 34 m³/s per km², against 3,820 m³/s from 1,020 km², about 3.7 m³/s per km², at New Umtru on the northern slope (MePGCL; ratios a NEER reading)). The curve may be replaced only by a station fit under (a), or by a site-specific study from the gauges of the Meteorological Centre Shillong agreed with the Authority and recorded on Form 2-1, and never by values below those of

the adjoining 2(b) sub-area for the same AEP and duration. The panel is used for no town outside ML-Z3. Every cross-drainage structure and outfall in ML-Z3 with a catchment of more than 1 km² also has the site-specific study of (i).

- (d) **24-hour depth, 50%, 20%, 10% and 4% AEP (2-, 5-, 10- and 25-yr).** The depth is the Gumbel (EV1) estimate from the annual maximum daily rainfall series, of all months, of the IMD station agreed with the Authority, with 30 or more years of daily record, checked as in (a), multiplied by the fixed-interval factor of Clause 2.6.3; outside the Shillong Planning Area and ML-Z3 the 4% AEP depth is not less than the 25-year plate value (Plate 8) read as in (c) (set by this Manual). The station is Shillong (C.S.O.) for the Shillong Planning Area and sub-area ML-B, and Cherrapunji for sub-area ML-C where a station fit is made under (c)(ii); for the other sub-areas it is agreed with the Authority from the gauges of (a), whose record lengths are to be confirmed [TBC]. No Gumbel fit to the annual maxima of any station in the State was found for this Manual [TBC]. A day of record excluded under (h) is left out of the series, and the fit with it is reported beside the fit without it on Form 2-1 (set by this Manual). The largest 48-hour fall reported for the State, 2,493 mm at Cherrapunji on 15–16 June 1995, recognised by WMO as a world record (as reported), is not a value printed by IMD: it is reported on Form 2-1 as the stress case for cross-drainage structures and outfalls in ML-C, not as a design value.

- (e) **48- and 72-hour depths.** The Gumbel estimate from the annual maximum 2-day and 3-day rainfall series of the same station, with the fixed-interval factors of Clause 2.6.3, and not less than the 24-hour depth for the same AEP, as checked under (h). In ML-Z3, until a station fit is made, they are those of the study of (i), and not less than the 24-hour depth of (c)(ii) [TBC].

- (f) **Durations of 1 to 24 hours.** The 24-hour depth of (c) or (d), before the check of (h), multiplied at every AEP by the ratios in Table 2B.1 for the site's sub-area, or in ML-Z3 the depths of the Cherrapunji curve (all set by this Manual):

    - in sub-areas **ML-A** (Northern foothills and Ri-Bhoi) and **ML-A1** (Garo foothills and plains), the ratios of the 2(b) report: 0.48 at 1 hour, 0.62 at 3 hours, 0.74 at 6 hours, 0.81 at 9 hours, 0.87 at 12 hours, 0.91 at 15 hours and 0.95 at 18 hours, the 10-year ratios averaged over the six recording gauges of the report, Shillong and five in the Assam valley (CWC, 2(b), Table 4.1);
    - in sub-areas **ML-B** (Shillong plateau), **ML-B1** (Jaintia hills karst and mine belt) and **ML-D** (Garo hills interior), the ratios of the CWC report for subzone 2(a), North Brahmaputra: 0.260 at 1 hour, 0.370 at 2 hours, 0.457 at 3 hours, 0.615 at 6 hours, 0.720 at 9 hours, 0.805 at 12 hours, 0.875 at 15 hours and 0.930 at 18 hours, averaged over the frequency analyses of 12 IMD recording gauges and printed for the 50-year depth (CWC, NB/18/1991, §3.1.2, p. 24, and Fig. 10, which gives the 2-hour value); and
    - in sub-areas **ML-C** (Southern escarpment) and **ML-C1** (South Garo slopes), the Cherrapunji curve of IMD Das et al. (2022), Fig. 4(v), read for every AEP and duration it covers: by eye, about 75, 117, 146, 182, 208 and 236 mm/h at 1 hour and 17, 31, 40, 51, 60 and 68 mm/h at 24 hours for 2, 5, 10, 25, 50 and 100 years, that is 24-hour depths of about 410, 745, 960, 1,225, 1,440 and 1,630 mm and a 1-hour ratio of about 0.14 at 50 and 100 years (readings ±5 mm/h at 1 hour and ±3 mm/h at 24 hours; NEER reading).

  The 2(b) ratios are kept for the northern foothills, which face the Assam valley whose convective gauges the ratio was built from; the single-event 1-hour ratios of the report's recording gauges in the Assam valley run from 0.21 to 0.50 (CWC, 2(b), Annex 4.2). They are not used on the plateau: applied to the Shillong plate, 0.48 gives about 269 mm in 1 hour, 5.6 times the 48 mm that the Shillong recording gauge recorded in its largest hour (15 September 1960; CWC, 2(b), Annex 4.2). Shillong's own single-event ratios are 0.14 at 1 hour, 0.32 at 3 hours, 0.48 at 6 hours and 0.64 at 12 hours (the storm of 14–15 September 1960), NIH-DHAARA's Shillong cell gives 0.23 and the Das et al. (2022) Cherrapunji panel about 0.14: the plateau's 24-hour totals are long orographic falls, more so than on the orographic fronts of the mountain editions of this series. Shillong's own 0.14 is not used either, because it comes from one storm at a gauge whose record length is not printed. The 2(a) set has the lowest 1-hour ratio of the CWC reports compared for this Manual (2(b) 0.48, zone 7 0.425, 1(g) 0.35, 1(e) 0.34, 2(a) 0.26) and lies above every observation on the plateau at every tabulated duration (0.26 against 0.23 and 0.14 at 1 hour, 0.457 against 0.32 at 3 hours, 0.615 against 0.48 at 6 hours and 0.805 against 0.64 at 12 hours). On the Shillong floors of (c)(i) it gives about 114 mm in 1 hour at 1% AEP and about 93 mm at 2% AEP, about twice the

recorded hour and NIH-DHAARA's 56 mm at 50 years, the same conservative margin that the mountain editions accepted on their orographic fronts. On Jowai's plate value of about 680 mm it gives about 177 mm in 1 hour at 50 years; that is probably high, and is why Jowai's gauge is a priority of (a). In ML-Z3 the Cherrapunji curve is the one genuine panel for the State: its curves bend between 9 and 12 hours, and the paper says that the region's values are highest "within the nearby periphery of Cherrapunji station and then sharply decreases away" (IMD Das et al., 2022, pp. 894–896). Its 1-hour values have no gauge check, because no hourly maximum for Cherrapunji or Mawsynram was found, and the record length behind the panel is not printed [U]. Between the tabulated durations the ratio is interpolated on logarithmic axes; the 2-hour ratio of 2(b), which the report does not give, is interpolated in the same way.

- (g) **Short storms.** No absolute floor in millimetres is set for any sub-area of the State, because the ratios and the curve of (f), applied to the depths of (c), already give 1-hour depths at or above the hours of record. Two floors guard against lower values where a station analysis or study governs (all set by this Manual):
    - (i) **Shillong.** Within the Shillong Planning Area the 1-hour depth for every AEP shall be not less than 48 mm multiplied by the ratio of the 24-hour depth of (c)(i) for that AEP to the 24-hour depth for the 10% AEP (10-yr), before the check of (h); that is, the largest hour of the Shillong recording gauge, 48 mm on 15 September 1960 (CWC, 2(b), Annex 4.2), is treated as the 10-year 1-hour depth and scaled to the other AEPs by the growth of the 24-hour depths, until the IMD Shillong recording-gauge and automatic weather station series is fitted under (a). The gauge's record length is not printed in the 2(b) report [TBC], which is why its largest hour is treated as a 10-year depth. With the 2(a) ratio the floor binds only where the 10-year 24-hour depth used is below about 185 mm (48 mm ÷ 0.26; NEER arithmetic); it guards against a light station fit.
    - (ii) **Southern escarpment.** In ML-C and ML-C1, where a station fit or a study replaces the Cherrapunji curve under (c)(ii), its 1-hour depth for every AEP shall be not less than 0.14 times its 24-hour depth for the same AEP, the curve's own ratio at 50 and 100 years.

  Where a floor of this paragraph governs the 1-hour depth, the 2-hour depth shall be not less than the value interpolated on logarithmic axes between the 1-hour and 3-hour depths for the same AEP. The floors are present-day, true-interval values: the fixed-interval factor of Clause 2.6.3 is not applied to them, and the climate factor of Clause 2.8 is. They are interim, to be revisited when Annex 2B publishes frequency analyses of the recording-gauge and automatic weather station records of the stations of (a), beginning with Cherrapunji and Shillong: if any shows 1- or 3-hour depths above those of (f) and (g) for a sub-area, a floor shall be set or raised for it; if together they show depths well below them, a reduction may be proposed to the State Stormwater Technical Committee. The depths of (f) and (g) are present-day, true-interval values once the fixed-interval factor has been applied to the 24-hour depth; the climate factor of Clause 2.8 is then applied.

- (h) **24-hour record check, bounded by sub-area.** The 1% AEP (100-yr) 24-hour depth of (c) or (d) shall be not less than the highest qualifying 24-hour rainfall recorded at any station within 25 km of the site, **in the same sub-area of Annex 2A and not separated from the site by a ridge or by the edge of the plateau**, where that record is higher; the record is used as printed, without the fixed-interval factor, and is treated as a 1% AEP depth; the 2% AEP (50-yr) 24-hour depth is then not less than the 1% AEP depth so raised less one contour interval of the plates, 80 mm (all set by this Manual). The radius of the mountain editions does not transfer to Meghalaya on its own: with 25 km and no other limit, Cherrapunji's 1,563.0 mm would set the 100-year depth at Mawphlang and Laitkor on the edge of the plateau, whose climate is the plateau's; Shillong itself lies about 36 km from Sohra and 42 km from Mawsynram (NEER distances). **Sohra's record never reaches sub-area ML-B.** A record qualifies only when it is printed by IMD (in *Extremes of Temperature and Rainfall for Indian Stations*, a climatological summary of the State, a monthly or seasonal climate summary, a later IMD table or an IMD press release that names the gauge and the day) or in Annex 4.1 or 4.2 of the 2(b) report, which CWC prepared jointly with IMD, RDSO and the Ministry of Surface Transport; the number of years of data at its gauge is confirmed by an IMD table as at least 20; it was made in 1901 or later, or IMD has confirmed that the gauge that made it stood where the present gauge

stands and was read in the same way; it falls in a month in which a fall of that size is plausible for the station; the location of its gauge is known; and it is not contradicted by another IMD table for the same gauge. A record that fails any test is excluded until IMD confirms what it lacks (set by this Manual). The outcomes at present are:

- **Cherrapunji, 1,563.0 mm on 16 June 1995** (IMD, *Extremes*, rainfall data 1902–2012; the press figure of 1,563.3 mm is not used), qualifies, and sets the 1% AEP 24-hour depth at not less than 1,563.0 mm within 25 km of the gauge in sub-area ML-C. The curve of (c)(ii) already gives about 1,630 mm at 100 years, so the record raises nothing unless a station fit or study under (c)(ii) comes in lower.
- **Mawsynram, 1,003.6 mm in the 24 hours to 08:30 IST on 17 June 2022**, qualifies. IMD prints it as a 24-hour record for June, against a previous June record of 945.4 mm on 7 June 1966 (IMD, Monthly Climate Summary, June 2022; the 944.7 mm of the press is not used), so its table shows the gauge to have more than 20 years of record, as the mountain editions read IMD's tables of previous records. IMD marks the 2022 value as based on real-time data, and does not say whether it is Mawsynram's highest day in any month [U]. It lies below the values of (c)(ii) and raises nothing.
- **Shillong (C.S.O.), 273.2 mm on 25 June 1988** (IMD, *Extremes*, rainfall data 1957–2012), qualifies, and lies below the floors of (c)(i).
- Excluded pending confirmation [TBC]: the **347 mm** of the Shillong recording gauge on 14–15 September 1960 (CWC, 2(b), Annex 4.2), because IMD's Shillong series, which begins in 1957, prints 273.2 mm as its highest day, so the two contradict each other unless they belong to different gauges or windows [U]; **437 mm at Upper Shillong and 415 mm at Shillong (Obsy) on 20 June 1934, and 320 mm at Dalu on 13 June 1956** (CWC, 2(b), Annex 4.1), whose gauges' years of record are not confirmed by an IMD table read for this Manual (437 mm is still the floor of (c)(i), which does not depend on this test); and the **811.6 mm** (also printed as 811.2 mm) and **972 mm** reported at Sohra for the 24 hours to 08:30 IST on 15 and 17 June 2022, which the press attributes to IMD but which were not found in an IMD table (as reported; the two figures for 15 June conflict).

Until Annex 2A is published, the designer lists on Form 2-1 every record within 25 km of the site, with its sub-area and the tests it passes or fails. The check raises the 24-hour depth and, through (e), the 48- and 72-hour depths. It does not raise the depths of (f) and (g) for 1 to 18 hours, because the records are daily totals of long orographic storms and no hourly record of any of them exists.

- (i) **Hazard-first catchments.** Meghalaya has no snow-fed catchment. The design is hazard-first at every site in ML-Z3, and at any site in another sub-area that lies below a mapped landslide zone, a debris fan, a mine-spoil dump, a karst sink or cave entrance, or on the release reach of a reservoir of MePGCL (Umiam, Kyrdemkulai (Stage III), Nongkhyllem (Stage IV), New Umtru and Myntdu–Leshka): no design there is complete without a screening, recorded in the drainage report, that identifies them, from the landslide and flash-flood susceptibility maps of the NESAC risk-informed master plans and of the IRADe/NMHS plan for Shillong, the inventories of MSDMA where they exist [TBC] and the release reaches in MePGCL's gate-operation guidelines, and states whether the site lies on their path; where it does, the siting, setback and floor-level rules of Chapters 6 and 7 govern, because no drain is sized to carry a debris flow (set by this Manual). In ML-Z3 every cross-drainage structure and outfall with a catchment of more than 1 km² has a site-specific hydrology study, agreed with the Authority and recorded on Form 2-1: no CWC unit hydrograph applies in subzone 2(c); losses are taken as near zero in the monsoon season; multi-day storms are routed through the structure, because on the escarpment **duration and volume govern culverts and outfalls, not only the peak**; and the design rainfall is that of (c)(ii) (set by this Manual). The escarpment's disasters are as much slides and debris as rain: the earthquake of 12 June 1897 brought down a landslide at Sohra in which 600 people were reported killed, the Shillong–Dawki road collapsed at Laitlyngkot in June 2026, and the NH-6 tunnel at Sonapur was closed by mudslides in August 2023 (all as reported).

- (j) **Cloudbursts.** IMD calls a fall of 100 mm or more in one hour over a small area a cloudburst (as quoted; no IMD primary document was found for this Manual [TBC]). No design rule is drawn from the term. The press calls Meghalaya's storms "cloudbursts" ("Meghalaya lost 13 lives following incessant cloudbursts", 2022, as reported) without measured hourly rates, and the only hour recorded at any gauge of the State in a primary source is

Shillong's 48 mm (15 September 1960; CWC, 2(b), Annex 4.2). The 50-year 1-hour depth of the Cherrapunji curve, about 208 mm, is twice that threshold, so the design already covers such bursts on the escarpment; on the plateau the 1-hour depths of (f) on the Shillong floors, about 93–114 mm before the climate factor, are of the same order as the threshold. What a burst does in a steep catchment that a design storm does not represent is to bring down boulders, slope debris and garbage in its first minutes; in such catchments the capacity of inlets, debris racks and culverts to stay open governs more than the conveyance of the drain, and Chapters 6 and 9 size them for it.

- (k) **Durations below 1 hour.** No sub-hourly frequency analysis for any station in the State was found in research for this Manual. Until Annex 2B gives one, the ratio of the depth for a duration below 1 hour to the 1-hour design depth is agreed with the Authority, from a published recording-gauge analysis whose source is stated, and recorded on Form 2-1 [TBC]; the average intensity for a duration below 1 hour shall be not less than the 1-hour design intensity for the same AEP (set by this Manual). The time distribution of storms in the 2(b) report (Annexure 4.4) was not extracted for this Manual [TBC].

- (l) **Order of depths.** For the same AEP, no depth shall be less than the depth for a shorter duration.

- (m) **NIH-DHAARA.** NIH-DHAARA was queried at ten points in the State on 14 November 2026 (IMDAA dataset). In sub-areas ML-A, ML-B and ML-B1 its present-day values at the site are reported on Form 2-1 beside the interim values, for comparison only; they are never a design value, a floor or a check. Its 50-year 24-hour depths there are 246 mm at Shillong, 207 mm at Nongpoh, 285 mm at Nongstoin and 335 mm at Jowai. In ML-A1, ML-C, ML-C1 and ML-D it is not used or reported, because its cells there are erratic: 1,423 mm at Dawki, more than the 1,029 mm of the Mawsynram cell; 624 mm at Tura, against a plate value of about 320–400 mm and Dalu's 320 mm; 936 mm at Baghmara and 860 mm at Williamnagar, with no gauge to check them; and 922 mm at Sohra, below the curve of (c)(ii), about 1,440 mm (NIH-DHAARA, queried 14 Nov 2026). Its projected depths are not used under Clause 2.8.4.

- (n) **IMD Das et al. (2022).** The paper has two panels for the State. The Cherrapunji panel (Fig. 4(v)) is a genuinely different curve and is used in ML-Z3 under (c)(ii) and (f). The Shillong panel (Fig. 4(xxv)) repeats the generic curve that the paper prints for most of its cities, about 60, 73, 82, 93, 101 and 109 mm/h at 1 hour for 2 to 100 years, and is not station data: it is not used as a value, a check or a floor anywhere, and outside ML-Z3 the cross-check of Clause 2.3.3(a) is recorded on Form 2-1 as not available.

- (o) **Earlier design values.** No design storm, return period, runoff coefficient or drain standard was found for the drains of any town in the State. The one method found is that of RMSI's multi-hazard risk and vulnerability assessment of Shillong (2019), which used "the IMD rainfall station at Shillong", with design rainfall "adopted from the Brahmaputra Basin PMP Atlas developed by the Central Water Commission (CWC, 2014) using data from 1957-2010", and the rational formula, for return periods of 2 to 100 years (as quoted in the IRADe/NMHS plan, 2020; the RMSI report and the atlas were not obtained [TBC]); a designer who uses the atlas reports its values on Form 2-1, with the station and period. The 148.91 km of Shillong's drains state no design storm (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan). Road drains follow IRC:SP:42-2014 and IRC:SP:48 (Chapter 6). The zonal IDF equations of Ram Babu et al. (2006) are generalised formulae under Clause 2.3.4(a), and their "Eastern" constants repeat the "Central" ones, so they are not used. The return periods of Table 2.1 and the depths of this clause apply.

- (p) **Other clauses.** Where Clauses 2.3.2, 2.6.1, 2.7.1 and 2.13, Annexes 2A to 2C and Form 2-1 refer to the NIH-DHAARA value, the value under this clause is meant.

> Commentary. NIH-DHAARA is a national, publicly accessible product from a Government of India institution, and it can be queried at any point in the State. That makes it a reproducible default that an approving authority can check. NIH-DHAARA's sub-daily values are derived from hourly records, not disaggregated from daily totals. That makes it the only public source suitable for sizing drains, which depend on short-duration intensity. Its values should still be checked against the long IMD daily record at 24 hours and longer (Annex 2A). In Meghalaya the

platform has not yet been shown to meet that purpose. It was queried at ten points of the State for this Manual. On the plateau and the northern slope its cells are plausible: at Shillong its 50-year 24-hour depth, 246 mm, lies between IMD's record of 273.2 mm and the 1960 recording-gauge fall of 347 mm, and its 50-year 1-hour depth, 56 mm, is close to the 48 mm the Shillong recording gauge recorded in its largest hour. On the escarpment and in the Garo hills it is erratic: it gives Dawki 1,423 mm at 50 years, more than Mawsynram, and nearly twice Shillong's record even at 2 years (511 mm), Tura 624 mm against a plate of about 320–400 mm, and Sohra 922 mm against about 1,440 mm on the IMD Cherrapunji curve; there it errs high in some cells and low in others, unlike the hill cells of the mountain editions, which broke down only at short durations. A source that fails a check in part of the State cannot be adopted for any of it, so Clause 2.3.6 uses the CWC reports, the IMD station records and the one genuine IMD curve for the State until Annex 2A has been done, and reports NIH-DHAARA beside the design values on the plateau and in the northern foothills of Ri-Bhoi only. The Shillong panel of IMD Das et al. (2022) is not used anywhere, because it repeats the generic curve that the paper prints for most of its cities; the Cherrapunji panel, by contrast, is a curve of its own. Meghalaya is the first North-East hill edition of the series, and three things set its interim source apart. First, two CWC subzones cover the State and only one has a report: the 2(b) report of 2000 covers the plateau, the northern foothills and the Garo hills, while subzone 2(c), Barak, which holds the southern escarpment and the record-rainfall belt of Sohra and Mawsynram, has none, and the 2(b) plates stop at the boundary. The 2(b) report's gauges are mostly in the Assam valley: its six recording gauges are Shillong and five valley stations, and the two bridge catchments of its unit hydrograph that rise in Meghalaya, the Digaru and the Dudhnai, are gauged in Assam (CWC, 2(b), Annexes 3.1 and 4.2; where they rise is a NEER reading). Second, the 2(b) plates overstate the plateau. At Shillong the 50-year plate value, about 560 mm, is about 1.6 times the largest recording-gauge fall (347 mm, 1960), 1.3 times the largest fall printed for any Shillong gauge (437 mm at Upper Shillong, 1934) and twice IMD's record (273.2 mm, 1988), and the plate's 680 mm tongue round Jowai is drawn as if the escarpment's rain continued north of the boundary. Clause 2.3.6(c)(i) therefore replaces the plate inside the Shillong Planning Area by the IMD station with floors of 437 mm and 357 mm, a departure below the CWC value that keeps every design depth above every recorded fall, and Clause 2.3.6(f) uses the 2(a) ratios on the plateau, because the 2(b) ratio of 0.48 applied to the plate would give Shillong an hour 5.6 times its largest recorded hour. Third, the world's wettest belt has no plate. Cherrapunji recorded 1,563.0 mm on 16 June 1995 and Mawsynram 1,003.6 mm on 17 June 2022, while Shillong, about 36 km away, has never recorded 300 mm at its IMD station (IMD). Clause 2.3.6(c)(ii) takes the IMD Cherrapunji curve as the escarpment's design rainfall, and Clause 2.3.6(h) bounds the record check by sub-area, so that Sohra's record governs the escarpment and never the plateau. What the escarpment's totals change is volume and duration more than the peak: a 1,500 mm day does not mean a 1,500 mm design depth for a drain whose time of concentration is 10 minutes, but it does mean that culverts and outfalls run near their peak for many hours, that storage fills and soils stay saturated for weeks, and that slopes and debris decide the damage, which is why Clause 2.3.6(i) asks for a site study and a duration check on every structure of more than 1 km² there. The interim rules for the more frequent AEPs, the 48- and 72-hour depths, the reading of the plates, the Shillong and escarpment departures, the sub-area of each town, the three sets of ratios, the 1-hour floors, the bounded record check, the hazard-first screening and durations below 1 hour are set by this Manual. Several points are unresolved. The plate values were read by eye, to about one contour, with town markers on Plates 8 and 10 off their printed dots, and the 2(b)/2(c) line is known only to about one marker [TBC]. The Cherrapunji curve was read by eye from a printed figure, its 1-hour values have no gauge check and the record behind it is not printed [U]. The Shillong recording gauge's 347 mm of 1960 contradicts IMD's series for the same station, and the record lengths of the 1934 and 1956 gauges of the 2(b) annex are not confirmed (Clause 2.3.6(h)). The CWC Brahmaputra Basin PMP atlas used by RMSI for Shillong in 2019, and RMSI's report, were not obtained [TBC]. No storm-drain DPR for any town of the State with its design rainfall analysis was found for this Manual [TBC].

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## 2.4 Design return periods (summary)

2.4.1 Design AEPs are set in the chapters for each element. They are summarised here so that the correct rainfall is extracted at the start of design.

Table 2.1 — Design return periods (summary)

| Element | Design AEP (return period) | Check event | Chapter |
|---|---|---|---|
| Minor drains: Shillong, Tura and Jowai core and high-density areas | 10% (10-yr) | 1% (100-yr) overland path | 6 |
| Minor drains: other Class I urban areas | 20% (5-yr) | 1% overland path | 6 |
| Minor drains: other areas | 50% (2-yr) | 1% overland path | 6 |
| Arterial roads and crossings | 2–4% (25–50-yr) | next higher AEP | 6 |
| Collector / local roads | 4% / 10% (25 / 10-yr) | 2% / 4% (50 / 25-yr), plus the 1% overland path | 6 |
| Major (overland) system | 1% (100-yr) | — | 6 |
| Retention volume | Percentile daily rainfall (Clause 2.10) | — | 4 |
| Detention: standard catchments | 50%, 10%, 1% (2, 10, 100-yr) | 1% emergency spillway | 4 |
| Detention: flood-sensitive catchments | Mixed-frequency rule, Clause 2.11 | 1% | 4 |
| Building floor levels | 1% + 0.5 m freeboard | — | 6 |
| Detention emergency spillway | 1% with outlet blocked | 0.2% (500-yr) where high hazard | 4 |

> Commentary. These values exceed the CPHEEO (2019) national advisory minimums of 5-yr (Class I cities) and 2-yr (other areas). CPHEEO allows a State to set higher values. The values are set in Chapters 4 and 6, and the table is reproduced here for convenience.

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## 2.5 Design durations

2.5.1 **Conveyance elements** (pipes, open drains, inlets, culverts) shall be designed with the intensity for a duration equal to the time of concentration (Tc) of the contributing area (Chapter 3). The minimum duration is **10 minutes**.

2.5.2 **Storage elements** (detention, retention, tanks, pumped sumps) shall be checked for every duration in the set {1, 2, 3, 6, 12, 24, 48, 72 h}. The largest required storage or water level governs. The 24-, 48- and 72-hour storms are **mandatory** checks at every site, whatever the critical-duration result.

2.5.3 **Tidally influenced outfalls.** For storage draining to a tidally influenced outfall (Chapter 5), the 48- and 72-hour storms shall also be run with the tailwater boundary of Clause 2.12.

> Commentary. Meghalaya's worst floods have come when days of rain fill the soils and raise the streams and rivers. On the escarpment the storm of June 1995 brought 1,563.0 mm to Cherrapunji in 24 hours (IMD) and 2,493 mm in 48 hours on 15–16 June, recognised by WMO as a world record (as reported), and in June 2022 Mawsynram recorded 710.6 mm in the 24 hours to 15 June and 1,003.6 mm in the 24 hours to 17 June (as reported; IMD), in the wettest June over Assam and Meghalaya since 1901 (IMD). Cherrapunji's wettest month, July 1974, brought 6,667.4 mm, and Shillong had 1,086.8 mm in the same month (IMD, *Extremes*). The Garo Hills floods of September 2014 began with torrential rain on the night of 21 September and the toll was reported as 12 on 22 September and 52 by 28–29 September (as reported). The jhoras of the hill towns rise within an hour of a burst, but the landslides, the slide debris and garbage that block their culverts, and the rivers and reservoirs that

hold their outfalls up are set by the whole wet spell, not its peak hour; on the escarpment duration and volume govern culverts and outfalls (Clause 2.3.6(i)). A rule based only on critical duration, applied to a small site, picks a 1–2 hour storm and misses this failure mode. That is why the long-duration checks are mandatory.

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## 2.6 Sub-daily rainfall

2.6.1 Where NIH-DHAARA or an approved station IDF provides values directly for the required duration, those values shall be used.

2.6.2 Where only daily (24-hour) depths are available for a duration below 24 hours, the sub-daily depth shall be derived using the **ratio set of Annex 2B**. These are duration-to-24-hour ratios calibrated to Meghalaya recording gauges. They shall not be lower than the ratios that Clause 2.3.6 sets for the site's sub-area: those of the CWC Flood Estimation Report for subzone 2(b) in the northern foothills and the Garo plains, those of the CWC report for subzone 2(a) on the plateau and in the Garo hills, and the Cherrapunji curve of IMD Das et al. (2022) on the southern escarpment, for which subzone 2(c) has no CWC report. The subzone 2(b) ratios are not applied to plate depths on the plateau, and the IMD Das et al. (2022) Shillong panel repeats a generic curve and is not used.

2.6.3 **Fixed-interval adjustment.** Depths from fixed observation windows (for example 08:30–08:30 IST daily data, or clock-hour data) shall be converted to sliding-window ("true interval") depths:

- 1.13 for a single fixed observation interval;
- 1.04 for 2 intervals;
- 1.02 for 3–4 intervals.

This adjustment does not apply where the approved source already gives true-interval values.

2.6.4 The empirical relationship P(t) = P(24)·(t/24)^(1/3) shall not be used for design unless Annex 2B confirms it for the zone concerned.

> Commentary. The one-third power rule is common in Indian project reports, but no primary IMD source for it was found during research for this Manual. It applies one fixed curve shape everywhere: P(1h)/P(24h) = 0.35, P(3h) = 0.50, P(6h) = 0.63 and P(12h) = 0.79. It cannot represent the difference between a short convective burst and a long monsoon soak, and it tends to understate short-duration depths in convective coastal storms. Annex 2B shall tabulate the NIH-DHAARA ratios P(t)/P(24h) against these values by zone. That comparison shows whether the rule is acceptable anywhere in the State and corrects older daily-based analyses. The fixed-interval factors are the standard WMO (Hershfield) values. The IMD 2022 study applies similar clock-hour to any-hour corrections.

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## 2.7 Point, grid and areal rainfall

2.7.1 Design depths are point values. Where an approved source provides grid-average values (for example 0.25° cells), they shall be converted to point values with the grid-to-point factors in Annex 2C before use.

2.7.2 For catchments **≤ 10 km²**, ARF = 1.0.

2.7.3 For catchments **> 10 km²**, apply ARF as follows:

- for 25–5,000 km² in subzone 2(b) (South Brahmaputra): use the ARF curves of the applicable CWC Flood Estimation Report;
- for 10–25 km²: interpolate linearly between ARF = 1.0 at 10 km² and the CWC value at 25 km².

2.7.4 An ARF shall never be applied to storage design for a single development site.

> **Commentary.** Gridded and district-average return levels are much lower than point values. For example, IMD gives 858.1 mm for the whole of June 2022 over its Assam and Meghalaya subdivision, the highest since 1901, while Mawsynram alone recorded 1,003.6 mm in the single day to 17 June (IMD, Monthly Climate Summary, June 2022). The NIH-DHAARA cell of about 12 km over Sohra gives 922 mm for the 50-year 24-hour depth, against about 1,440 mm on the IMD Cherrapunji point curve and the 1,563.0 mm that the Cherrapunji gauge recorded on 16 June 1995 (NIH-DHAARA, queried 14 Nov 2026; IMD). Within about 40 km the State's highest days run from 1,563.0 mm at Cherrapunji to 273.2 mm at Shillong (IMD, *Extremes*), a range that no cell or district average can show. Neither error can be corrected without the factors of Annex 2C. Using grid values as point values without correction would make site-level design unsafe.

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## 2.8 Climate factor

2.8.1 Until a statewide future-climate rainfall product is adopted, present-day design depths shall be multiplied by the following interim climate factors:

**Table 2.2 — Interim climate factors**

| Duration | Climate factor (CF) |
|---|---|
| ≤ 6 h | 1.20 |
| > 6 h to 72 h | 1.10 |

2.8.2 The CF applies to all elements with a design life of more than 25 years. For temporary works (design life ≤ 5 years), CF = 1.0.

2.8.3 The climate factor does not apply to the retention depth (Clause 2.10) or to the water quality volume depth (Chapter 8). Those depths are percentile or frequent-event statistics of everyday rainfall, not AEP design values.

2.8.4 Where NIH-DHAARA, or a product adopted on review under Clause 2.14, provides projected future-climate depths, those depths shall replace the interim factors.

> **Commentary.** CPHEEO (2019) considers a fixed climate factor "not feasible" nationally and recommends trend testing instead. That leaves designers without a usable number. The 1.20 short-duration factor matches the UK value cited by CPHEEO itself. No design uplift factor has been adopted in Meghalaya. The State Action Plan on Climate Change of 2015, as quoted in the IRADe/NMHS plan for Shillong, projects an increase in precipitation in all districts, of "only about 3%" in East and West Garo Hills and of "10-15% in precipitation by 2050" in East Khasi Hills; the same passage says that the western districts gain less than the eastern ones while naming two western districts, so its east–west wording is inconsistent as printed (IRADe/NMHS plan, 2020). The State's second action plan, for 2023–2030, was not read [TBC]; a budget note of the State summarises it as projecting "rising heavy-rainfall events" (as reported). The observed record is short and mixed: a study of Shillong's daily maxima for 1985–2003 found a "non-significant … increasing trend" (as summarised); IMD found the rainfall of June 2022 over Assam and Meghalaya, 858.1 mm, "highest since 1901" (IMD, Monthly Climate Summary, June 2022); and the monsoon of 2026 was reported 60% below normal in the State, with the lowest seasonal rainfall in 125 years over the North East and East India, yet the same season brought the Dawki flood and the Laitlyngkot collapse (as reported). The case for an uplift rests on the size of recent extremes, not on trend statistics. The factor of 1.10 for durations above 6 hours lies within the 10–15% that the 2015 plan projects for East Khasi Hills by 2050, and the factor of 1.20 for short durations above it. As in the mountain editions of this series, they are applied after the

record check of Clause 2.3.6(h), including to the escarpment record where it governs, although the research for this Manual suggested leaving that record unscaled; this Manual keeps the series practice. NIH-DHAARA's projected depths are not used (Clause 2.3.6(m)). The factors of Table 2.2 are therefore interim values, not Meghalaya estimates.

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## 2.9 Temporal patterns (design hyetographs)

2.9.1 **Storms up to 24 hours.** Use the nested **alternating-block** method:

- construct the storm from the same IDF relationship (after the climate factor), at time steps no longer than Tc/3 and no longer than 15 minutes;
- place the peak block at **50%** of the storm duration.

2.9.2 **48- and 72-hour storms (monsoon pattern).** Construct as follows:

- (a) The total storm depth equals the design depth for the full duration (48 or 72 h).
- (b) The **final 24 hours** contain the 24-hour design depth for the same AEP, distributed by the alternating-block method of 2.9.1.
- (c) The remaining depth (total minus the 24-hour depth) is spread uniformly over the preceding 24 or 48 hours.

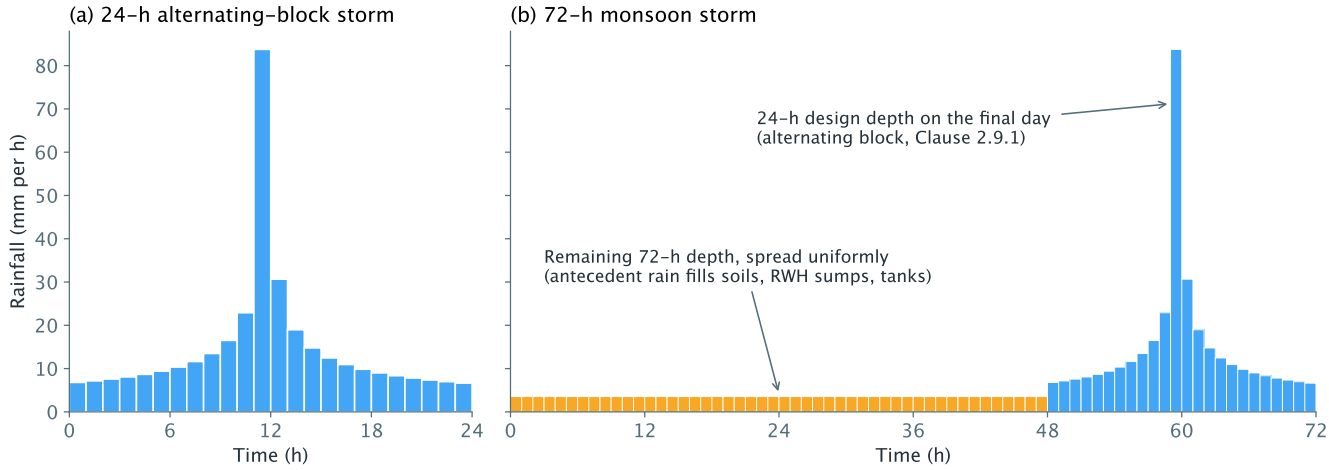


*Figure 2.2 — (a) 24-hour alternating-block design storm; (b) 72-hour monsoon design storm with the 24-hour design depth on the final day. Illustrative depths only. Original drawing for this Manual. The alternating-block method follows Chow, Maidment & Mays, Applied Hydrology (1988), §14.4.*

2.9.3 **Other temporal patterns.** Huff-type or mass-curve patterns derived from Meghalaya storms may be used instead of 2.9.1 and 2.9.2 only after they are published in Annex 2D. SCS Type I, IA, II and III distributions shall not be used.

2.9.4 **Large catchments.** For catchments of 25–5,000 km², the CWC Flood Estimation Report time-distribution curves may be used, and a sensitivity run with 2.9.1 shall be reported.

**Commentary.** The alternating-block storm embeds every shorter-duration design intensity in one hyetograph. That makes it conservative and consistent across durations. The 72-hour pattern puts the most intense day last. This reproduces the monsoon sequence of Meghalaya: by the time the largest falls arrive in June, after the storms of April and May, or in September and October, the thin soils of the plateau and the escarpment are saturated, the

springs are flowing, the small reservoirs of MePGCL are releasing water through their gates, and the Umkhrah, the Umshyrpi and the rivers of the Garo plains are already high. SCS distributions are excluded because they come from US convective and Gulf storm data and have no basis in Meghalaya records.

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## 2.10 Retention rainfall depth

2.10.1 The **retention design depth** is the 24-hour rainfall depth not exceeded on **90%** of days with rain (≥ 2.5 mm) in the long-term record, read from the zone value in Annex 2E.

2.10.2 The site must retain on site the runoff from this depth (Chapter 4). Retention earns a detention credit equal to the reduction in required detention storage found by routing with the retention in place (Clause 4.4.6). The credit is not the retained volume subtracted one-for-one.

> Commentary. This follows the Kansas City Metro APWA 5600 (2025.01) Required Retention Volume concept and Georgia's 1.0-inch runoff reduction standard. Both are based on percentile storms. A percentile depth is a statistic of everyday rainfall, not an AEP value, so it is computed from the daily record rather than from the frequency curves.

---

## 2.11 Design storms for pre- and post-development comparison

2.11.1 **Same storm for both scenarios.** Pre- and post-development runs shall use the same design storms:

- same AEP, duration, temporal pattern and climate factor;
- same antecedent moisture condition (Clause 2.11.4).

The two runs differ only in land surface parameters and Tc.

2.11.2 **Standard catchments.** For each of the 50%, 10% and 1% AEP storms and each duration in Clause 2.5.2:

> $Q_{post}(T) \le 0.9 \times Q_{pre}(T)$

2.11.3 **Flood-sensitive catchments** (as listed in Chapter 4: the catchments of Shillong's Umkhrah and Umshyrpi, of the Umiam lake shore and the Umiam–Umtru release reaches, of Jowai on the Myntdu, of the escarpment settlements of Sohra, Mawsynram and Shella, of Dawki on the Umngot, of Tura, Williamnagar, Baghmara and Dalu on their rivers, of the Garo foothill plains on the Jinjiram and the Krishnai, and of Nongpoh–Umling on NH-6 and the Umlew, and any catchment notified by the authority). The **mixed-frequency rule** applies:

> $Q_{post}$(1% AEP, 100-yr) ≤ $Q_{pre}$(10% AEP, 10-yr), and $Q_{post}$(50% AEP, 2-yr) ≤ $Q_{pre}$(50% AEP, 2-yr),

The post-development peak is checked for each duration in Clause 2.5.2. The caps are taken at the **pre-development critical duration**. The 10-yr cap is the largest pre-development 10-yr peak over all durations, and the 2-yr cap is the largest pre-development 2-yr peak over all durations. Each cap applies to every post-development duration.

2.11.4 **Antecedent moisture.** Use **AMC III** (wet conditions) for every design storm, whatever its duration, from 1 June to 15 October at a site in sub-area ML-A (Northern foothills and Ri-Bhoi), ML-A1 (Garo foothills and plains), ML-B (Shillong plateau), ML-B1 (Jaintia hills karst and mine belt) or ML-D (Garo hills interior) of Annex 2A, and from 1 April to 31 October at a site in sub-area ML-C (Southern escarpment) or ML-C1 (South Garo slopes). Use AMC III for every design storm at any time of year in a catchment that drains to a reservoir of MePGCL (Umiam, Kyrdemkulai, Nongkhyllem, New Umtru or Myntdu–Leshka) or to any other reservoir or its backwater, or to a reach below a dam into which the dam releases water. At any other site or time, use AMC III for a design storm that follows, or contains, a 5-day rainfall total of more than 53 mm. Use AMC II (average conditions) for every other storm. AMC I is not used for design.

2.11.5 **Pre-development condition.** Pre-development is defined in Chapter 3: greenfield, open land in good condition for the mapped hydrologic soil group. Existing impervious cover is not counted as pre-development.

> **Commentary.** Matching each site's post-development peak to its own pre-development peak does not protect the catchment. Denver's analysis found that 100% matching at every site still produced 106% of historic peak downstream, which led to the 90% rule. The mixed-frequency rule is stricter. It caps the 100-yr post-development release at what the undeveloped site produced in a 10-yr storm. Malaysia (DID 2008: all ARIs ≤ pre-development 2-yr) is a tropical precedent for this kind of cap. AMC III for long storms reflects that monsoon extremes arrive after weeks of rain. In Meghalaya the season, the ground and the receiving waters together decide how wet a catchment is. On the escarpment the monthly totals run to thousands of millimetres, 6,667.4 mm at Cherrapunji in July 1974 and 3,961.2 mm in May 1984 (IMD, *Extremes*), so the thin soils over sandstone and limestone stay saturated from April to October. On the plateau, the northern foothills and the Garo hills the soils are thin red loams and sandstone soils over hard rock (CWC, 2(b), §2.3.2; CGWB), and the infiltration tests of CGWB's aquifer mapping put the share of rain that reaches the groundwater at about 4–5% on the hard rocks and the Tertiary rocks and 10–13% on the alluvium and valley fills, so that most of the rain on most of the State leaves as runoff or evapotranspiration (CGWB, GWRA 2022; recharge fractions, not infiltration rates). The reservoirs of MePGCL are small and release water through their gates often, "during Monsoon as well as during Non-monsoon period" (MePGCL), so a catchment that drains to one, or to the reach below a dam, is wet whenever the reservoir is spilling. This Manual therefore uses AMC III for every design storm from 1 June to 15 October in sub-areas ML-A, ML-A1, ML-B, ML-B1 and ML-D, the main part of the south-west monsoon; from 1 April to 31 October in ML-C and ML-C1, the whole season, because the escarpment's April and May storms are as large as most monsoon storms elsewhere; at any time of year where the outfall is a reservoir of MePGCL or another reservoir, its backwater or a release reach; and otherwise after a 5-day total of more than 53 mm, the NRCS growing-season threshold for AMC III; AMC II otherwise (Clause 2.11.4). AMC I is not used, because no part of the State is dry enough during the season to justify it. These are interim choices set by this Manual; no study in the State has yet validated AMC classes against observed runoff.
>
> **Illustrative scale of the mixed-frequency rule.** The values below are not design values. They assume a 2 ha site in a colony draining to a jhora in Shillong with 24-h depths of 200 mm (10-yr) and 350 mm (100-yr), SCS-CN runoff with Ia = 0.2S, and CN 70 pre-development and CN 92 post-development:

**Table 2.3 — Illustrative scale of the mixed-frequency rule (not design values)**

| Case | Runoff depth | Runoff volume (2 ha) |
|---|---|---|
| Pre-development, 10-yr 24 h | 111 mm | 2,210 m³ |
| Post-development, 100-yr 24 h | 325 mm | 6,500 m³ |

The post-development 100-yr storm generates about three times the runoff volume of the pre-development 10-yr storm. A peak-rate cap at the pre-development 10-yr level means most of the difference must be stored and released slowly, so storage of the order of 0.2 m³ per m² of site may be needed. For this reason the rule applies only in flood-sensitive catchments (Clause 2.11.3); elsewhere the 0.9 × Q_pre rule of Clause 2.11.2 applies.

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## 2.12 Joint occurrence with tailwater

2.12.1 For outfalls under tidal or river backwater influence, the design rainfall of this chapter shall be combined with the tailwater conditions of Chapter 5 as follows. The more severe case governs.

- (a) Design rainfall (AEP as required) with a mean high water springs (MHWS) tailwater plus the sea-level allowance.
- (b) A 10% AEP (10-yr) 48-hour storm with the 1% AEP still-water level (tide plus surge) plus the sea-level allowance.

Meghalaya has no coast, so no outfall in the State is tidal and cases (a) and (b) do not arise. The tailwater is the jhora, stream, river, pung, lake or reservoir into which a town drains. For an outfall under river or reservoir backwater, the site storm is combined with the receiving-water level under Clause 5.8.4, which pairs a design event on one side with a 10-yr event on the other in the same way as case (b), and the river and reservoir levels are those of Clause 5.8.2. No CWC site in the State has a warning or danger level, and none is a forecasting site. CWC monitors levels at seven sites, all classed among the south-flowing rivers, and five have a highest recorded level: the Umngot at Dawki, 73.47 m (28 May 2006); the Umnohryngkew at Therriaghat, 20.62 m (15 June 1995); the Myntdu at Kharkhana, 47.0 m (23 April 1995); the Bugi at Dimapara, 29.75 m (27 July 2007); and the Dareng at Sibbari, 20.34 m (12 August 2017); the two sites of Myntdu Stage II have none (CWC data as transcribed by SANDRP, 2018). Two of the five highest levels fell before June, on 23 April and 28 May, the reason this Manual's season begins on 1 April. There is no gauge on the Umkhrah or the Umshyrpi, which carry Shillong's drains to the Wah Roro and Umiam lake, nor on the Umiam, the Umtru, the Kynshi, the Simsang, the Ganol, the Jinjiram or the Kopili within the State, so the receiving-water level of the towns on those streams is known only from surveyed flood marks or a hydraulic model. The reservoirs of MePGCL have operator levels: Myntdu–Leshka Stage I has a full and maximum water level of 618.00 m; New Umtru a full reservoir level of 130.10 m and a maximum water level of 132.78 m; Stage IV (Nongkhyllem) 503.00 m; and Stage III (Kyrdemkulai) 2,230 ft and 2,235 ft, published in feet and converted here at 0.3048 m per foot, about 679.7 m and 681.2 m (MePGCL, gate-operation guidelines); for Umiam (Barapani), Stage I, only a full level of "3,220 ft" in the press and a spillway crest of 969.5 m in another source were found, with no datum, and no gate-operation guideline of MePGCL for it was found [TBC]. The guidelines say that, the reservoirs being small and releases frequent, notice of each release is "not practicable" and warning is given by siren, telephone or SMS (MePGCL), so outfalls on their release reaches are checked against release scenarios, not notices. Where a river leaves the State into Assam, the levels of the Assam sites govern its reach there: the Kopili at Kampur has a warning level of 59.5 m, a danger level of 60.5 m and a highest level of 61.79 m (20 July 2004), and at Dharamtul 55.0 m, 56.0 m and 58.09 m (21 July 2004) (CWC data as transcribed by SANDRP). These levels are set by rain over the catchments upstream and by the releases of the dams, and on the escarpment and the plateau the jhoras and streams rise within the hour while the storm is still falling on the town, so storage and outfalls are checked for the outfall-closed condition with the local storm falling before, during or after the stream's peak. No document found in research for this Manual sets a design receiving-water level for the outfalls of any town in the State [TBC], and Chapter 5 sets the interim rule. Every level is stated on a named datum, as Chapter 5 requires; no source found states the datum of the CWC levels quoted here, presumably metres above mean sea level [TBC].

> Commentary. Meghalaya has no coast, so no outfall is tidal and there is no storm surge; the coincident load is the level of the jhoras, streams, rivers and reservoirs that receive the town drains. The coincidence is on record. In Shillong the valley floors of Polo, Pynthorbah and Nongmynsong flood "with nearly every heavy downpour" when the Wah Umkhrah, to which their drains discharge, overflows in the same storm (as reported). On 9 July 2019, when Shillong received more than 72.2 mm, Polo, Forest Colony and Mawlai flooded (IRADe/NMHS plan, Table 17). In June 2026 the Umngot at Dawki rose rapidly during the storm that collapsed the Shillong–Dawki road at Laitlyngkot (as reported), and in September 2014 the Brahmaputra and the Jinjiram submerged more than 200 villages of the Garo plains in the same spell of rain that set off the slides of the Garo Hills (as reported). The reservoirs of MePGCL release water by siren and SMS warning rather than notice (MePGCL), so a release reach can rise while a local storm is falling on the town beside it. These levels give no warning of a local storm that falls while they are high. The levels quoted by different sources differ, and none states its datum: the CWC highest

levels are transcribed by SANDRP, not read in a CWC bulletin, and Umiam's full level is known only as "3,220 ft" in the press, beside a spillway crest of 969.5 m in another source (as reported), which is why Chapter 5 requires every level to name its source and datum. Because rainfall and surge share a weather cause (in Meghalaya, which has no coast, the counterpart of surge is the stage of the streams, rivers and reservoirs that receive the town drains, raised by the same monsoon storms that bring the heaviest rain to the towns: on 17 June 2022, when Mawsynram recorded 1,003.6 mm in 24 hours (IMD), 13 people died in the Khasi and Garo Hills and landslides cut NH-6, and in June 2026 the Umngot at Dawki rose rapidly while the Shillong–Dawki road collapsed at Laitlyngkot (as reported)), they cannot be treated as independent. Case (b) is a simple joint-probability surrogate until a statistical joint analysis is adopted.

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## 2.13 Submittal requirements

Every hydrologic submittal shall include a **Design Rainfall Sheet** (Form 2-1) stating:

1. the site coordinates and zone;
2. the source (Clause 2.3), version or access date, and a screenshot or export of the values extracted;
3. a depth table for each AEP and duration used, before and after the fixed-interval factor, grid-to-point factor, ARF and climate factor;
4. the cross-check values of Clause 2.3.3 and the floor check;
5. the hyetographs used, as a table and a plot, for each design storm; and
6. the AMC and pre-development definition adopted.

Figure 2.3 shows the steps of this chapter in the order in which the sheet records them.

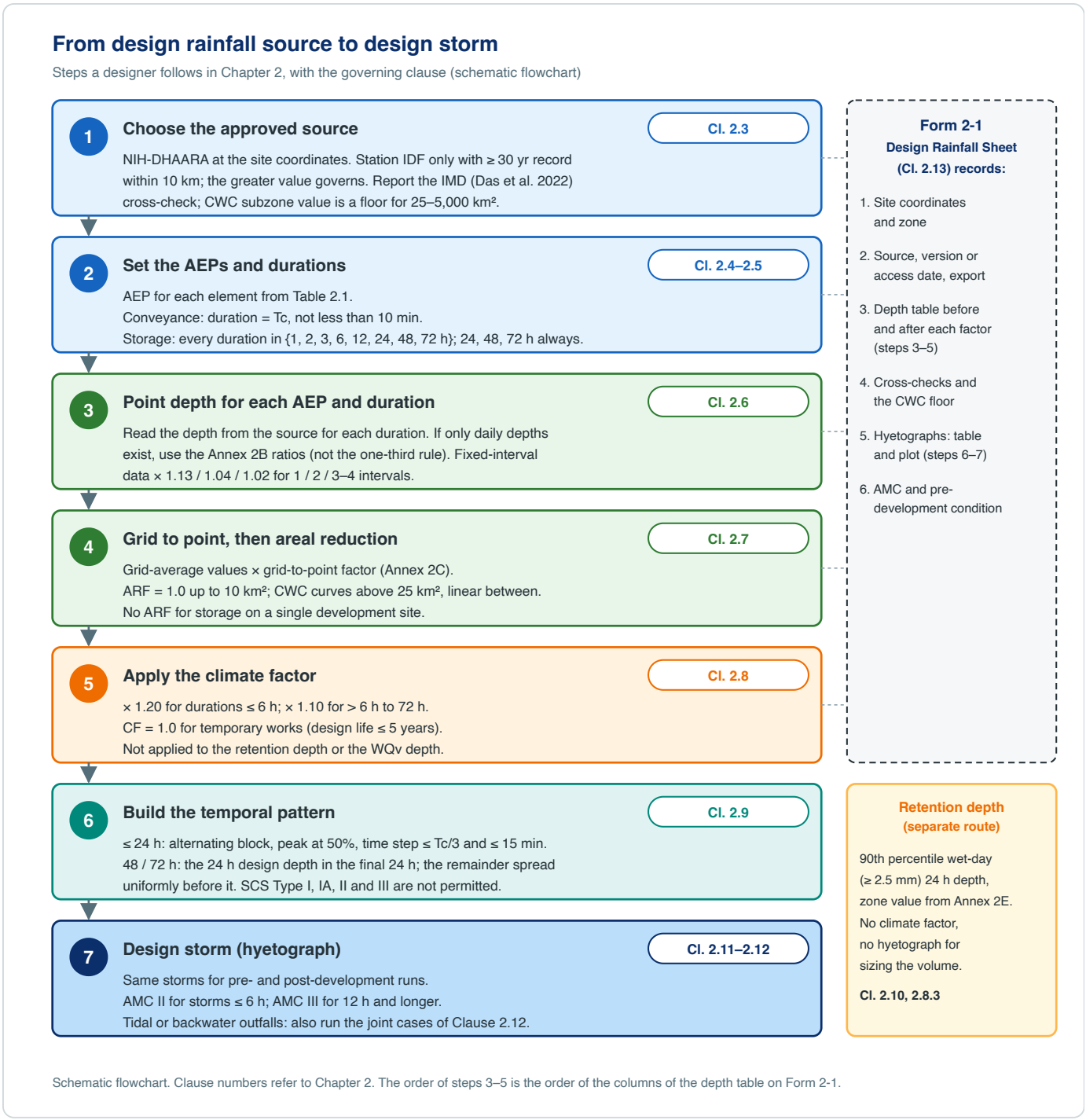


*Figure 2.3 — From design rainfall source to design storm: the steps a designer follows (source, AEPs and durations, point depth, grid-to-point and areal reduction, climate factor, temporal pattern, design storm), the clause that governs each step, what Form 2-1 records, and the separate route for the retention depth. Schematic. Original drawing for this Manual.*

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## 2.14 Review and update

2.14.1 The approving authority shall review this chapter **every 10 years**. It shall also review it within 2 years of any event in which recorded rainfall exceeds the 1% AEP 24-hour or 72-hour design depth at two or more approved gauges in the State.

2.14.2 Updates to NIH-DHAARA take effect for new submittals 6 months after release, unless the authority notifies otherwise.

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## References (chapter)


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- Ram Babu, Dhyani, B.L. & Nirmal Kumar (2006). Rainfall intensity–duration–return period equations for the zones of India (poster, 14th ISCO Conference; CSWCRTI, now ICAR-IISWC; not used).
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## Annexes

| Annex | Content |
|---|---|
| 2A | NIH-DHAARA vs IMD station and IMD gridded checks at benchmark points; zone map |
| 2B | Sub-daily ratios P(t)/P(24h) by zone: NIH-DHAARA (hourly-based) vs the one-third rule |
| 2C | Grid-to-point factors |
| 2D | Meghalaya temporal patterns (Huff curves) |
| 2E | Retention percentile depths by zone |
| Form 2-1 | Design Rainfall Sheet |

CHAPTER 3

# Hydrologic Methods

## 3.1 Purpose and scope

3.1.1 This chapter sets out how design rainfall from Chapter 2 is turned into runoff peaks, volumes and hydrographs for:

- (a) drain, inlet and culvert sizing (Chapter 6);
- (b) retention and detention sizing, and the pre- vs post-development comparison (Chapter 4);
- (c) downstream and tailwater analysis (Chapter 5); and
- (d) waterbody, tank (pung) and regional facility studies (Chapter 7).

3.1.2 It specifies:

- (a) which method may be used for which purpose and catchment size (Clause 3.4);
- (b) how the pre- and post-development land surfaces are defined (Clause 3.3);
- (c) the parameters of each method: runoff coefficients, time of concentration, soils, curve numbers, unit hydrographs and routing (Clauses 3.5–3.12);
- (d) when continuous simulation and model calibration are required (Clauses 3.13 and 3.15);
- (e) the step-by-step pre- vs post-development comparison (Clause 3.14); and
- (f) software acceptance and documentation (Clauses 3.16 and 3.17).

3.1.3 Rainfall inputs (depth, duration, areal reduction, climate factor, temporal pattern and antecedent moisture) are governed by Chapter 2 and shall not be varied in this chapter.

> **Commentary.** The CPHEEO (2019) Manual on Storm Water Drainage Systems gives a full Rational Method procedure and names SWMM for hydrograph work, but it is a drain-sizing guide. It does not say how a regulator should define "pre-development" or which method must be used to test a development against it (CPHEEO Part A §4.4, §8.5.1). APWA Section 5600 does both: it limits the Rational Method, names baseline hydrograph methods, and fixes the land-use assumptions for existing and proposed conditions (KC Metro APWA 5600, 2011, §5602.2–5602.3; Version 2025.01, §5603.4). This chapter follows that model.

## 3.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Pre-development condition | The reference land surface defined in Clause 3.3.2, against which post-development runoff is tested. It is not the existing condition. |
| Post-development condition | The land surface after the proposed works are complete, as defined in Clause 3.3.3. |
| Point of comparison (POC) | A location where site runoff leaves the site, at which pre- and post-development flows are compared (Clause 3.14). |

| Term | Meaning in this Manual |
|---|---|
| Time of concentration (Tc) | The time for runoff to travel from the hydraulically most distant point of the catchment to the point of interest. |
| Lag (tL) | The time from the centroid of rainfall excess to the peak of the runoff hydrograph. |
| Hydrologic soil group (HSG) | The NRCS classification (A, B, C, D) of a soil by its minimum infiltration rate when wet (USDA NRCS, NEH Part 630, Ch. 7). |
| Curve number (CN) | The NRCS parameter that combines soil group, land cover and antecedent moisture into a single runoff-potential index (USDA NRCS, NEH Part 630, Ch. 9–10). |
| Antecedent moisture condition (AMC) | The soil wetness at the start of a storm: AMC I (dry), II (average), III (wet). |
| Directly connected impervious area (DCIA) | Impervious surface that drains to a drain, pipe or channel without first flowing over a pervious surface. |
| Disconnected impervious area | Impervious surface whose runoff flows as sheet flow over a pervious surface before reaching the drainage system, and meets Clause 3.9.3. |
| Peak rate factor (PRF) | The constant in the unit hydrograph peak equation (484 in US customary units; 0.208 in the SI form of Clause 3.11.2). |
| Continuous simulation | A model run over a long rainfall record (years), with soil moisture, storage and tank levels carried forward between storms. |
| Tank cascade | A chain of tanks (pungs) in which the surplus of one tank feeds the next. |

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## 3.3 Pre-development and post-development land surface

3.3.1 **Same site, same storm.** Pre- and post-development runs shall cover the same area draining to each POC, and use the same design storms (Clause 2.11.1). They shall differ only in the land-surface parameters of this clause, the resulting Tc, and the stormwater controls.

3.3.2 **Pre-development condition.** The pre-development land surface shall be **greenfield: open land in good condition for the mapped hydrologic soil group**, as follows:

- (a) All land within the site, including land that is now built on, paved, compacted or cultivated, is treated as open land (grass cover > 75%) in good condition. **Existing impervious cover shall not be counted.**
- (b) The curve number is the TR-55 value for "open space, good condition" for the HSG of Clause 3.7: **CN 39 (A), 61 (B), 74 (C), 80 (D)** at AMC II (Table 3.5).
- (c) The HSG is the natural HSG of Clause 3.7, including the dual-group rule for high water table (Clause 3.10.1). No HSG improvement for drainage works is allowed.
- (d) Tc is computed on the pre-development ground surface using unchannelled overland and shallow concentrated flow and natural channels only (Clause 3.6). Existing pipes, lined drains and kerbs are ignored.
- (e) Existing waterbodies, tank waterspreads up to the full tank level (FTL), natural channels and supply or surplus channels are kept as they are, and modelled as water surfaces or channels, not as open land.

3.3.3 **Post-development condition.** The post-development land surface shall represent the proposed works at full build-out:

- (a) Impervious areas shall be measured from the site plan, separately for roofs, paved surfaces, roads and other sealed surfaces, and classified as directly connected or disconnected (Clause 3.9). Lot-size residential rows of TR-55 shall not be used for the site itself.

- (b) Pervious areas disturbed by construction (graded, filled or trafficked) shall be assigned one HSG lower in infiltration capacity than the natural HSG (A to B, B to C, C to D), unless post-construction infiltration tests (Clause 3.7.3) show otherwise. Soil disturbed by construction shall never be classed as HSG A.
- (c) Rainwater harvesting (RWH) sumps shall be treated as full at the start of storms of 12 hours or more, and the roof area draining to them as directly connected for those storms (Chapter 4).
- (d) Retention and detention facilities shall be represented explicitly as storage (Clause 3.12), not by lowering CN.

3.3.4 **Redevelopment.** The pre-development condition of Clause 3.3.2 applies to redevelopment as well. A site that is already fully paved is tested against greenfield, not against its existing state. For the constrained-redevelopment route of Clause 4.5.6, the existing condition shall also be modelled, with existing impervious areas as surveyed, so that the 50% minimum can be checked.

3.3.5 **Off-site areas.**

- (a) For conveyance design (Chapter 6), areas upstream of the site shall be taken at their ultimate land use under the approved master plan or development plan. Where no plan exists, upstream undeveloped land shall be assumed to be at least 35% impervious.
- (b) For the pre- vs post-development comparison, off-site run-on shall be modelled identically in both runs, at its existing condition (Clause 3.14.2).

> Commentary. A greenfield reference stops each redevelopment from being judged against an already degraded baseline. The UK non-statutory standards and KC APWA take the same approach in different forms: APWA caps existing agricultural land at no more than "good condition pasture, grassland or range (C = 0.30, CN = 74)" for HSG C, and forbids disturbed soils from being classed as HSG A or B (KC Metro APWA 5600, 2011, §5602.3A and E). The TR-55 "open space, good condition" values used in (b) are identical to TR-55's "pasture, grassland or range, good" values (USDA SCS TR-55, 1986, Tables 2-2a and 2-2c), so this Manual's pre-development CN equals the APWA cap on HSG C soils. The one-class downgrade for disturbed soils in 3.3.3(b) is set by this Manual as a simpler, less strict version of the APWA rule, suited to the alluvium and valley fills of the Garo and Ri-Bhoi foothills, the Garo Group sandstones and shales, the thin red loams over the gneiss, quartzite and phyllite of the plateau, the cavernous limestones, sandstones and coal measures of the southern escarpment and the Jaintia hills, and the laterite of the south-west, where an HSG A to C jump would be excessive. The 35% minimum imperviousness for unplanned upstream land in 3.3.5(a) is the APWA value (2011, §5602.3E.2). Using the master-plan land use for conveyance follows CPHEEO, which requires C to reflect "ultimate development of the catchment as per the master plan" (CPHEEO 2019, Part A §4.4.1.5).

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## 3.4 Selection of method

3.4.1 The method shall be selected from Table 3.1 by purpose and catchment size. Figure 3.1 shows the same rules as a flowchart.

**Table 3.1 — Permitted hydrologic methods**

| Purpose | Catchment / condition | Permitted method | Clause |
|---|---|---|---|
| Peak flow for one conveyance element (inlet, pipe reach, drain reach, culvert) | ≤ 16 ha contributing, no upstream storage, no backwater | Rational Method | 3.5 |
| Peak flow for conveyance | > 16 ha, or any upstream storage, tank or pond | Hydrograph method (SCS-CN with SCS unit hydrograph, SWMM or HEC-HMS) | 3.8–3.12 |

| Purpose | Catchment / condition | Permitted method | Clause |
|---|---|---|---|
| Retention, detention, any storage; pre- vs post-development comparison | Any size | Hydrograph method; **Rational Method not permitted** | 3.8–3.12, 3.14 |
| Pipe or drain network with backwater, tidal or tank tailwater | Any size | Hydrograph method with dynamic-wave hydraulic routing | 3.12.4; Chapter 5 |
| Catchment-scale flows | 25–5,000 km² in CWC subzone 2(b) (South Brahmaputra) | HEC-HMS or SWMM, benchmarked against the CWC synthetic unit hydrograph (SUH) | 3.11.4 |
| Regional facilities | Draining > 25 km² | Design-storm hydrograph method **plus** continuous simulation | 3.13 |
| Tank (pung) cascades | Any size | Design-storm hydrograph method **plus** continuous simulation | 3.13 |
| Tier B: small sites under Chapter 1 | Within the limits of the design aid | Design aids issued under Chapter 4, which are themselves derived by the methods of this chapter | 3.4.4 |
| Small sites, any authority | ≤ 1 ha, within the limits of Clause 4.14.3 | Fixed-coefficient route of Chapter 4 (fixed release coefficients, rainfall-mass storage) | 3.4.4; 4.14.3 |

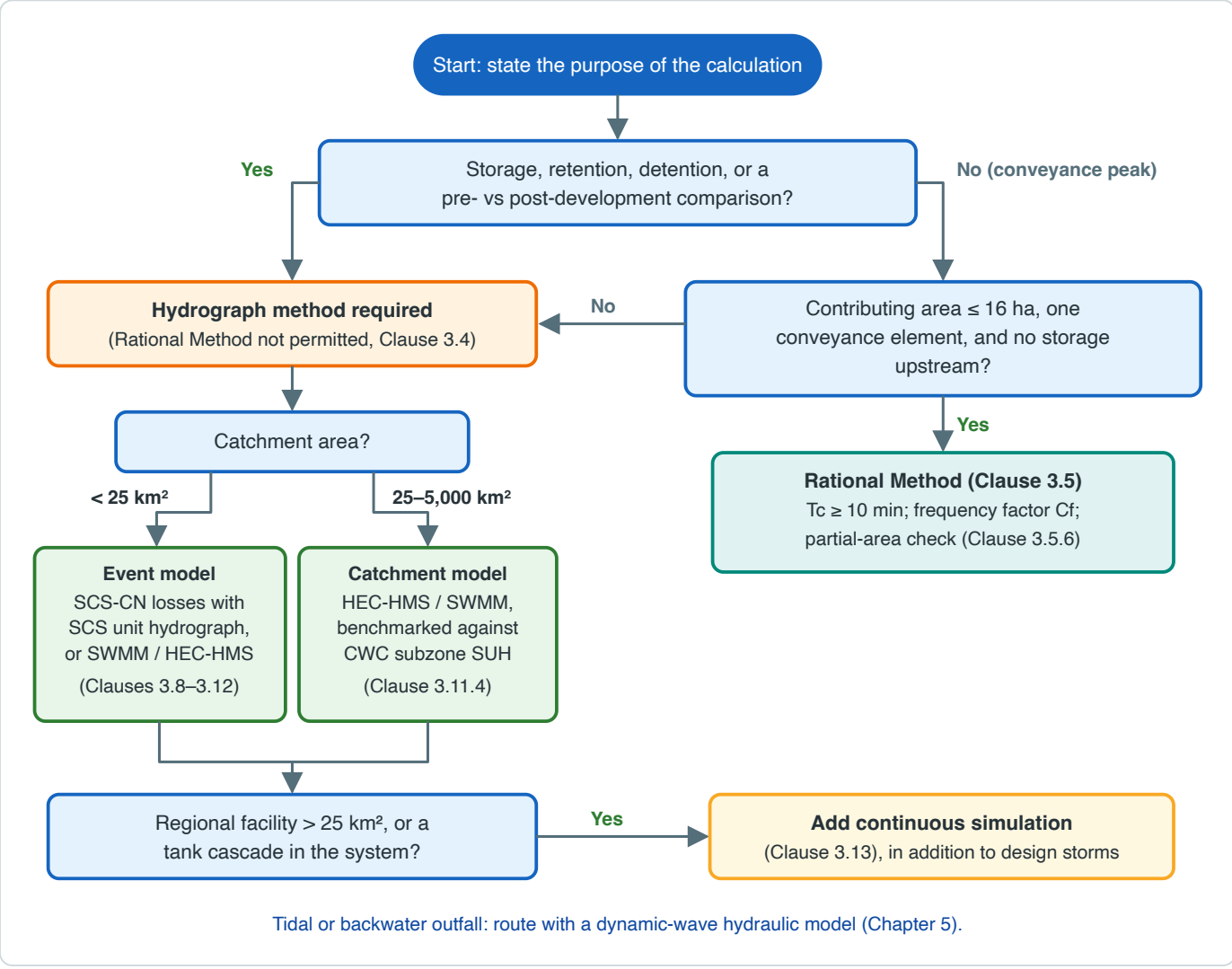


*Figure 3.1 — Selection of hydrologic method. Original drawing for this Manual, adapted from KC Metro APWA, Section 5600 Storm Drainage Systems and Facilities, 2011 (§5602.2) and Version 2025.01 (§5603.4, Policy Supplement, 2025).*

3.4.2 **Rational Method limits.** The Rational Method shall be used only for catchments of **16 ha or less** and only to compute the peak flow to a **single conveyance element**. It shall **never** be used to size retention, detention or any other storage, nor to derive a hydrograph or runoff volume.

3.4.3 **Hydrograph methods.** Above 16 ha, and for every storage calculation, a hydrograph method shall be used: SCS-CN losses with the SCS (NRCS) unit hydrograph, EPA SWMM, or HEC-HMS. For 25–5,000 km² the CWC synthetic unit hydrograph shall also be computed as a benchmark (Clause 3.11.4).

3.4.4 **Simplified routes.** In Tier B areas (Chapter 1), sites within the limits stated on a design aid issued under Chapter 4 may use that design aid in place of a site-specific hydrograph model. In any area, sites of 1 ha or less may use the fixed-coefficient route of Clause 4.14.3; it is the only exception to the rule in 3.4.2 that rainfall-based peak methods shall not be used for storage. The Rational Method remains available for conveyance under 3.4.2.

3.4.5 **Catchments above 5,000 km².** These are outside the scope of this Manual and require a basin study approved by the Water Resources Department.

> Commentary. The 16 ha limit and the single-element rule follow APWA 5600 Version 2025.01, which cut the Rational Method from 200 ac to 40 ac and restricted it to "a single pipe segment". The MARC Policy Supplement adds that it "cannot be used to size runoff reduction practices or determine retention volumes and detention volumes" (MARC, APWA Stormwater Standards Supplement, 2025). CPHEEO (2019, Part A §4.4.1.3) allows the Rational Method up to 8–10 km², which is too large for a method that assumes uniform rainfall intensity over the whole catchment for the whole of Tc and gives no volume. The Rational Method is excluded from storage design because it gives a peak, not a hydrograph, and storage depends on volume and timing.

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## 3.5 Rational Method

3.5.1 **Equation.** The peak flow shall be computed as:

$$Q = C \cdot Cf \cdot i \cdot A / 360$$

where Q is the peak flow (m³/s); C is the runoff coefficient (Table 3.2); Cf is the frequency factor (Table 3.3), with $C \cdot Cf \le 1.0$; i is the rainfall intensity (mm/h) for a duration equal to Tc, from Chapter 2 (with the climate factor of Clause 2.8); and A is the contributing area (ha).

> Commentary. This is the CPHEEO equation Qp = 10 C I A, with Qp in m³/h (CPHEEO 2019, Part A §4.4.1.1–4.4.1.3), converted to m³/s.

3.5.2 **Runoff coefficients.** C shall be taken from Table 3.2. Within a range, the designer shall use the upper half of the range unless site data justify a lower value.

**Table 3.2 — Runoff coefficient C (for AEP of 10% or more frequent)**

| Surface or land use | C | Source |
|---|---|---|
| Commercial | 0.70–0.95 | CPHEEO 2019, Table 4.2 |
| Industrial | 0.60–0.90 | CPHEEO 2019, Table 4.2 |

| Surface or land use | C | Source |
|---|---|---|
| Institutional | 0.70–0.95 | CPHEEO 2019, Table 4.2 |
| Residential, high density | 0.60–0.75 | CPHEEO 2019, Table 4.2 |
| Residential, low density | 0.40–0.60 | CPHEEO 2019, Table 4.2 |
| Recreational | 0.10–0.25 | CPHEEO 2019, Table 4.2 |
| Asphalt | 0.70–0.95 | CPHEEO 2019, Table 4.2 |
| Concrete | 0.80–0.95 | CPHEEO 2019, Table 4.2 |
| Brick paving | 0.70–0.85 | CPHEEO 2019, Table 4.2 |
| Roofs: tiles | 0.80–0.90 | CPHEEO 2019, Table 4.2 |
| Roofs: metal | 0.70–0.90 | CPHEEO 2019, Table 4.2 |
| Roofs: concrete | 0.70–0.90 | CPHEEO 2019, Table 4.2 |
| Lawns, sandy soil, flat (≤ 2%) | 0.05–0.10 | ASCE/WPCF 1969 |
| Lawns, sandy soil, average (2–7%) | 0.10–0.15 | ASCE/WPCF 1969 |
| Lawns, sandy soil, steep (> 7%) | 0.15–0.20 | ASCE/WPCF 1969 |
| Lawns, heavy (clay) soil, flat (≤ 2%) | 0.13–0.17 | ASCE/WPCF 1969 |
| Lawns, heavy soil, average (2–7%) | 0.18–0.22 | ASCE/WPCF 1969 |
| Lawns, heavy soil, steep (> 7%) | 0.25–0.35 | ASCE/WPCF 1969 |
| Undeveloped land (maximum for any condition) | 0.30 | KC APWA 5600 (2011), §5602.3E |

3.5.3 **Frequency factor.** For design AEPs rarer than 10%, C shall be multiplied by Cf from Table 3.3. The product C · Cf shall not exceed 1.0.

**Table 3.3 — Frequency factor Cf**

| Design AEP (return period) | Cf |
|---|---|
| 10% (10-yr) and more frequent | 1.00 |
| 4% (25-yr) | 1.10 |
| 2% (50-yr) | 1.20 |
| 1% (100-yr) | 1.25 |

3.5.4 **Composite C.** Where a catchment contains more than one surface, C shall be the area-weighted value $C = \Sigma(C_j \cdot A_j) / \Sigma A_j$, computed from the measured areas of each surface. Cf is applied to the composite C.

3.5.5 **Time of concentration and networks.**

- (a) Tc shall be computed by Clause 3.6 and shall not be less than **10 minutes**.
- (b) For each reach of a network within the 16 ha limit, the peak shall be computed with the cumulative $\Sigma(C \cdot A)$ upstream of that reach and the longest Tc to that reach. Peaks from upstream reaches shall not be added.

3.5.6 **Partial-area check.** Where a compact, highly impervious part of the catchment has a much shorter Tc than the whole, the peak shall also be computed for that part alone, using its own area, C and Tc. The larger peak governs.

> **Commentary.** The developed-surface coefficients in Table 3.2 are CPHEEO Table 4.2, which CPHEEO adapted from ASCE/WPCF (1969). CPHEEO keeps C constant for all return periods. Table 3.3 instead adopts the APWA antecedent-precipitation factors (KC Metro APWA 5600, 2011, §5602.2A: K = 1.1, 1.2 and 1.25 for 4%, 2% and 1% storms, with C·K ≤ 1.0). These factors matter here because Meghalaya's rare storms arrive on wet ground (Clause 2.11.4). The 10-minute minimum Tc matches the minimum design duration of Clause 2.5.1. APWA 2011 bounds inlet time between 5 and 15 minutes (§5602.7A). The partial-area check follows CPHEEO's treatment of "partial area effect" (CPHEEO 2019, Part A §4.4.1.7). This Manual requires the upper half of each range in 3.5.2 because Indian urban plots are typically more densely covered than the US land uses behind the ASCE ranges.

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## 3.6 Time of concentration

3.6.1 **General.** Tc shall be computed separately for the pre- and post-development conditions, along the flow path that gives the longest travel time to the point of interest, as the sum of travel times in each flow segment. Tc shall not be less than **10 minutes** for either condition.

3.6.2 **NRCS velocity (segment) method.** The NRCS segment method is the default for all catchments. Tc = Tt(sheet) + Tt(shallow) + Tt(channel), where:

- (a) **Sheet flow:**

  > Tt = 0.091 (n · L)^0.8 / (P2^0.5 · S^0.4)

  where Tt is in hours; n is the sheet-flow roughness from Table 3.4; L is the sheet-flow length (m); P2 is the present-day 50% AEP (2-yr) 24-hour rainfall (mm) from Clause 2.3, without the climate factor; and S is the land slope (m/m).

- (b) **Sheet-flow length.** In urban areas, and for all post-development conditions, the sheet-flow length shall not exceed **30 m**. For pre-development greenfield surfaces, up to 90 m may be used only where survey shows unchannelled planar ground; otherwise 30 m applies.

- (c) **Shallow concentrated flow:** Tt = L / (3,600 V), with V = 4.918 S^0.5 (unpaved) or V = 6.196 S^0.5 (paved), V in m/s, L in m and S in m/m.

- (d) **Channel and pipe flow:** Tt = L / (3,600 V), with V from Manning's equation at bank-full or pipe-full flow.

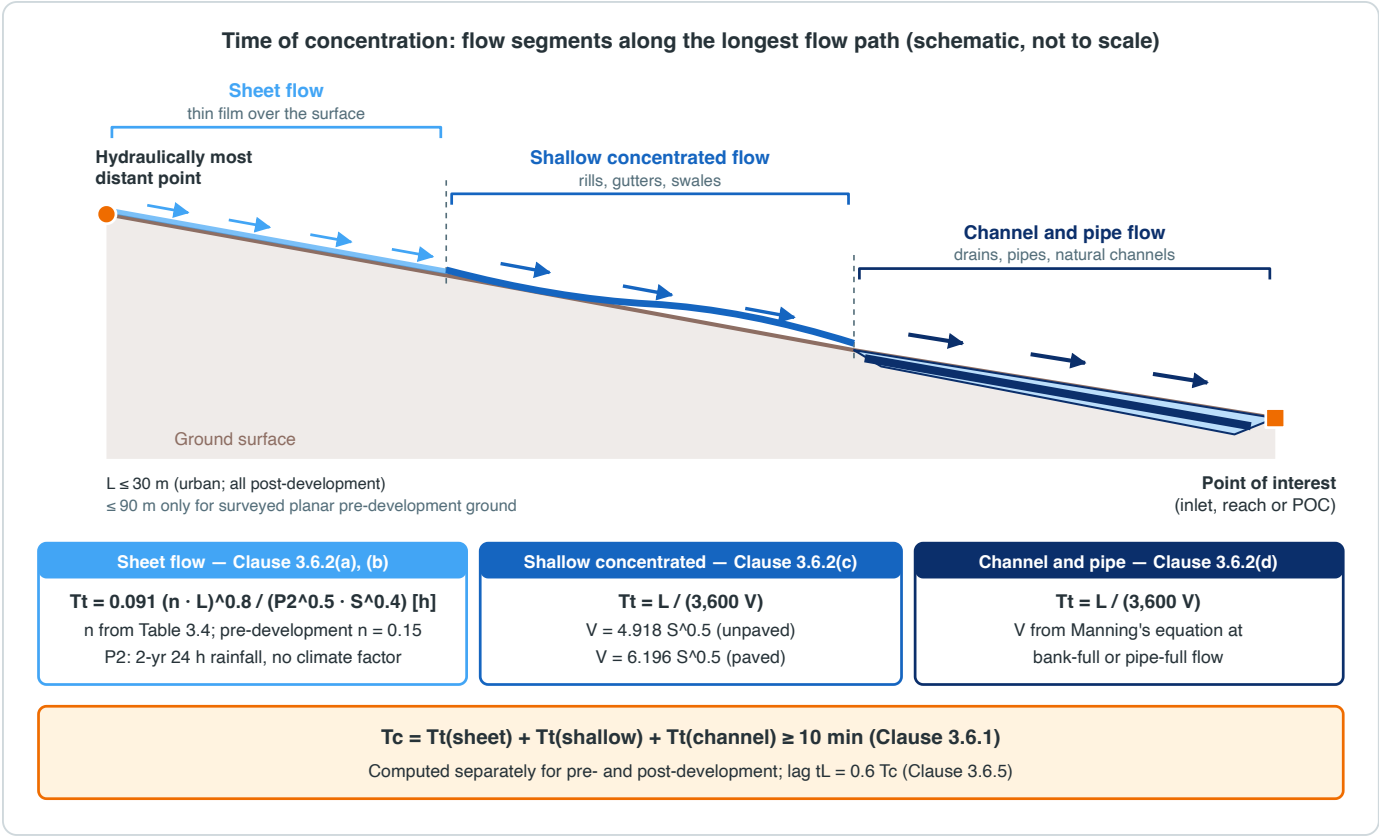


*Figure 3.2 — Time of concentration by the NRCS segment method: sheet flow, shallow concentrated flow and channel or pipe flow along the longest flow path, with the travel-time equations and limits of Clause 3.6. Schematic, not to scale. Original drawing for this Manual, adapted from USDA SCS TR-55 (1986), Ch. 3, and USDA NRCS, NEH Part 630, Ch. 15 (2010).*

**Table 3.4 — Manning's n for sheet flow (USDA SCS TR-55, 1986, Table 3-1)**

| Surface | n |
|---|---|
| Smooth surfaces (concrete, asphalt, gravel, bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated, residue cover ≤ 20% | 0.06 |
| Cultivated, residue cover > 20% | 0.17 |
| Grass: short-grass prairie | 0.15 |
| Grass: dense grasses | 0.24 |
| Range (natural) | 0.13 |
| Woods: light underbrush | 0.40 |
| Woods: dense underbrush | 0.80 |

3.6.3 **Pre-development roughness.** For the pre-development greenfield surface of Clause 3.3.2, sheet-flow n shall be **0.15** unless the designer justifies another Table 3.4 value from the natural vegetation of the area.

3.6.4 **Kirpich formula.** The Kirpich formula may be used only as a cross-check, or for pre-development rural catchments with a defined main channel:

> tc = 0.0195 L^0.77 S^−0.385

where tc is in minutes, L is the length of the main flow path (m) and S is its average slope (m/m). It shall not be used for urban or post-development catchments.

3.6.5 **Lag.** Where a unit hydrograph method requires lag, tL = 0.6 Tc.

3.6.6 **Check.** Post-development Tc shall normally be shorter than pre-development Tc. Where it is longer, the designer shall explain why in the submittal.

> Commentary. The segment method and its equations are from TR-55 (USDA SCS, 1986, Ch. 3) and NEH Part 630, Ch. 15 (USDA NRCS, 2010). The SI constants are direct conversions of the US equations: 0.007 becomes 0.091 with L in m and P2 in mm, and 16.1345 and 20.3282 ft/s become 4.918 and 6.196 m/s. TR-55 (1986) allowed sheet flow up to 300 ft (≈ 90 m). NEH 630 Ch. 15 states that sheet flow typically lasts no more than about 100 ft (≈ 30 m) before becoming shallow concentrated flow (citing Merkel, 2001), and many US agencies now cap it there. This Manual sets the 30 m urban limit in 3.6.2(b) on that basis: in Indian urban plots, flow reaches a drain, kerb or compound-wall weep hole within a few metres. The undisturbed P2 is used in the sheet-flow equation because P2 is a parameter of the travel-time relationship, not a design load. The default n = 0.15 for greenfield is the TR-55 short-grass value; this Manual adopts it to avoid long pre-development Tc values that would make Q_pre artificially low. The Kirpich formula is the SI form given by Chow, Maidment and Mays (1988, Table 15.1.2), from small agricultural catchments in Tennessee (Kirpich, 1940), so it does not suit urban surfaces. The lag ratio 0.6 is the NRCS value, also used by APWA (2011, §5602.7C).

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## 3.7 Soils and hydrologic soil groups

3.7.1 **Mapping.** HSG shall be assigned from the soil series mapped by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) or the Soil and Water Conservation Department (soil survey) [TBC], using the soil-series-to-HSG lookup of Annex 3A. The source map and its scale shall be stated.

3.7.2 **Assignment rule.** Where Annex 3A is not yet available for a series, the HSG shall be assigned from the measured saturated hydraulic conductivity and depth to an impermeable layer or water table using the criteria of NEH Part 630, Ch. 7. Until Annex 3A is published, this Manual sets the following interim groups for Meghalaya: the alluvium of the Garo foothill plains and the Jinjiram valley in sub-area ML-A1 and the valley fills of Ri-Bhoi in sub-area ML-A, HSG B on sandy or gravelly fills and HSG C on silty or clayey ones, with infiltration practices on them only where the seasonal high water table stands more than 2 m below ground in the monsoon season (Clause 4.11, recharge rule); the river terraces and floodplains elsewhere, HSG C; the sandstones of the Garo Group round Tura and Williamnagar, HSG C, and HSG D on clay or shale; the gneiss, quartzite, phyllite and schist of the plateau, with their thin red loams, at Shillong, Nongstoin, Mairang and Jowai, HSG D for design, whatever group the soil itself would take; the limestones, karst and coal measures of the southern escarpment and the Jaintia hills (Sohra, Shella, Lumshnong, Khliehriat, Sutnga) and of the Garo coalfields, with their mine spoil, HSG D for runoff, with no loss to caves, sinkholes or mine voids credited, however large it may be; the laterite of the south-west, HSG C, and HSG D where it is clayey; colluvium and slide debris, HSG D for design, with no infiltration credit; and urban fill, HSG C, and HSG D where it is clayey or compacted. A field infiltration test is required on every site larger than the limits of the simplified method of Clause 4.14.1, at the depth of the proposed facility; on smaller sites, a soil that has not been tested shall be given the less permeable of the groups listed for it. Whether an infiltration practice may be built at all is governed by the three infiltration rules of Clause 4.11 (the hill rule, the karst and mine rule and the recharge rule), not by its HSG. Clause 3.10.1 applies to all of these groups.

3.7.3 **Site verification.** For every site that relies on retention by infiltration (Chapter 4), the mapped HSG shall be verified by site infiltration tests at the location and depth of each infiltration facility. Where the tests show a lower infiltration capacity than the mapped HSG, the test result governs for both the retention design and the post-development CN. Where they show a higher capacity, the pre-development HSG shall not be changed without the approval of the authority.

3.7.4 **Disturbed and filled ground.** Clause 3.3.3(b) applies.

Commentary. NBSS&LUP soil maps are typically at 1:250,000 to 1:50,000 scale and classify soils by series and taxonomy, not by HSG. A lookup table is therefore needed (Annex 3A). Site tests matter most where one site can span two groups: at the edges of the Garo foothill plains and the Ri-Bhoi valley floors, where alluvium passes into weathered rock and the water table rises towards the streams; on the Garo hills, where sandstone, clay and shale alternate; at the contact of the plateau rocks with the limestones and coal measures of the escarpment and the Jaintia hills, where a test pit can stand on rock that drains to a void below; and on hill sites, where a high rate in a pit dug in colluvium or fill can be water entering a slope that cannot take it (Clause 4.11). No HSG map or table for Meghalaya, no SCS-CN calibration and no measured infiltration rate for any site in the State were found during research for this Manual [TBC]. The only field measures are the 60 infiltration studies of the CGWB's aquifer-mapping programme (NAQUIM), which gave rainfall infiltration factors of 5% on weathered granite and quartzite and on the valley fills and Tertiary rocks of East Khasi Hills (22 studies), 5% on hard rock and 13% on the alluvium and valley fills of Ri Bhoi (17), 4% on the weathered Tertiary rocks of East Garo Hills (8), and 5% on granite and Tertiary rocks and 10% on alluvium in East and West Jaintia Hills (13) (CGWB, *Dynamic Ground Water Resources of Meghalaya*, GWRA 2022, §4.4). These are fractions of the year's rainfall that reach the water table, not infiltration rates: they are not used to assign an HSG or to size an infiltration practice, but they show that on most of the State 87% or more of the rain runs off or evaporates. The interim groups follow the geology as the CGWB describes it: "hard massive rocks belonging to the Archaean gneissic complex … and Precambrian Shillong Group" over most of the State; Cretaceous–Tertiary "sandstones, shales, conglomerates, limestones etc." in the south-western, southern and south-eastern parts; and unconsolidated sediments "as thin veneer along rivulets and as valley-fills", of significant thickness "only along extreme north-western fringe of the state in South West Garo Hills district" (GWRA 2022). Water stands 3–5 m below ground in the alluvium, 4–9 m in the Garo Group, 2–4 m in the "cavernous limestones" and sandstones of the Jaintia and Khasi Groups, and 7–17 m in the weathered and fractured gneiss and Shillong Group (GWRA 2022, Table 1). The CWC subzone 2(b) report maps red loamy soil "upto Shillong in the southwest", laterite "in the southern corner and towards the southwest" and "red and yellow soils … between Tura and boundary of Bangladesh", and warns that "At micro level this broad classification may not hold good" (§2.3.2). The plateau soils may themselves test as HSG C, but they lie thin over rock on slopes, so they are designed as D. The limestones and coal measures are a new case in this series. Water that enters them can vanish into caves and voids: in the coal belt "smaller streams and rivers either disappear or have become seasonal in nature as surface water trickles into and disappears in the unfilled mine pits and caves" (as reported), and the Krem Liat Prah–Um Im–Labit cave system of the Jaintia hills is reported to run for 30.9 km (as reported). Their loss can therefore be very high, but where the water goes is unknown, it can reappear downslope or undermine the ground, and no karst map, sinkhole inventory or subsidence record was found [TBC], so the loss is never credited: they are D for runoff, and no infiltration is put into them (Clause 4.11, karst and mine rule). The only regional measure of losses is the design loss rate of the CWC subzone 2(b) report, 0.35 cm/h (3.5 mm/h), the modal value of 100 flood events on rural catchments gauged at bridges, two of them the Digru and the Dudhnai, which rise in Meghalaya (Annex 3E). It shall be used only in rural SUH runs under Clause 3.11.4, not to assign an HSG, not in an urban SCS-CN or SWMM model and not to size an infiltration practice. The interim groups of Clause 3.7.2, the 2 m water-table condition for infiltration on the alluvium and valley fills, the design of the plateau soils, colluvium, slide debris and mine spoil as group D, the rule that losses to voids are never credited and the rule for untested soil on small sites are set by this Manual pending a soil-series lookup for Meghalaya. Steep ground matters as much as soil: the Shillong Planning Area has 102.05 km² of slopes of 15–30°, 17.75 km² of 30–40°, 3.2 km² of 40–50° and 0.53 km² above 50° (NESAC, risk-informed master plan report for the Shillong Planning Area, 2023), and on the steep streets, jhoras and escarpment streams runoff from rock and thin soil reaches a channel within minutes. The following rules are set by this Manual. (a) Tc shall be found by the velocity-

based segment method of Clause 3.6.2, segment by segment, and shall not be taken below the 10-minute minimum of Clause 3.6.1, which matches the shortest design duration of Chapter 2; the Kirpich formula, derived from small farm catchments of moderate slope, shall not be used even as a cross-check where the average slope of the flow path exceeds 10%. (b) The sheet-flow segment over bare rock, a road cut or a paved hill street shall use the smooth-surface n of Table 3.4 and shall not exceed 30 m. (c) A catchment that runs from a hill flank onto a valley floor or a plain, such as the jhoras of Shillong onto the valley floors of the Umkhrah at Polo, Pynthorbah and Mawlai, the streams of the Garo hills onto the Jinjiram plains, or the escarpment streams onto the plains at Dawki, Shella and Baghmara, shall be split at the break of slope and the hill sub-area modelled on its own, so that a flatter lower reach does not average away the fast response of the hill. (d) In karst and coal-mining areas the surface catchment is used for conveyance design, whatever water it may lose or gain underground, and no loss to the ground is credited. (e) In sub-areas ML-C and ML-C1 the peak of a small catchment is limited by its channel and its debris as much as by the rain, and the duration of the storm, hours to days, governs culverts and outfalls: storms of 24 to 72 hours are routed with no storage credit (Clause 2.3.6 and Chapter 6). (f) Catchments that drain to a MePGCL reservoir, or to a reach below its dam, are modelled with storage routing and the operator's release scenarios, not by a peak-flow method alone (Clause 3.12; Chapter 5). (g) No method of this chapter predicts debris flow; in steep catchments the design flow is bulked for sediment and debris, and inlets and culverts are protected against blockage, under Chapters 6 and 9.

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## 3.8 SCS curve number (SCS-CN) loss method

3.8.1 **Runoff equation.** Runoff depth shall be computed by:

> $Q = (P - Ia)^2 / (P - Ia + S)$ for $P > Ia$; $Q = 0$ otherwise $S = 25{,}400 / CN - 254$

where Q is runoff depth (mm), P is the cumulative rainfall depth (mm), S is potential maximum retention (mm) and Ia is initial abstraction (mm). In hydrograph models the equation is applied to the cumulative rainfall at each time step to obtain incremental rainfall excess.

3.8.2 **Curve numbers.** CN at AMC II shall be taken from Table 3.5, for the HSG of Clause 3.7.

**Table 3.5 — Runoff curve numbers, AMC II, Ia = 0.2S (USDA SCS TR-55, 1986, Tables 2-2a and 2-2c)**

| Cover type | HSG A | HSG B | HSG C | HSG D |
|---|---|---|---|---|
| **Pre-development reference (Clause 3.3.2):** open space, good condition (grass > 75%) | 39 | 61 | 74 | 80 |
| Open space, fair condition (grass 50–75%) | 49 | 69 | 79 | 84 |
| Open space, poor condition (grass < 50%) | 68 | 79 | 86 | 89 |
| Impervious: roofs, paved parking, driveways, paved roads with kerbs and drains | 98 | 98 | 98 | 98 |
| Paved roads with open ditches (including right-of-way) | 83 | 89 | 92 | 93 |
| Gravel roads (including right-of-way) | 76 | 85 | 89 | 91 |
| Dirt roads (including right-of-way) | 72 | 82 | 87 | 89 |
| Newly graded areas (pervious, no vegetation) | 77 | 86 | 91 | 94 |
| Fallow, bare soil | 77 | 86 | 91 | 94 |

| Cover type | HSG A | HSG B | HSG C | HSG D |
|---|---|---|---|---|
| Meadow (continuous grass, protected from grazing) | 30 | 58 | 71 | 78 |
| Brush, good condition | 30 | 48 | 65 | 73 |
| Woods, good condition | 30 | 55 | 70 | 77 |
| Woods, fair condition | 36 | 60 | 73 | 79 |
| Woods, poor condition | 45 | 66 | 77 | 83 |
| Water surfaces, tank waterspreads, wet detention basins | Runoff = rainfall (no losses) | | | |

3.8.3 **Use of Table 3.5.**

- (a) Post-development CN shall be built up from measured surfaces (Clause 3.9). The TR-55 urban district and residential lot-size rows shall not be used for the site.
- (b) Pervious areas in the post-development condition shall use "open space" in the condition the landscape plan will achieve. Where no landscape plan is submitted, fair condition applies.
- (c) Cultivated rows of TR-55 may be used for off-site existing conditions, but never for the pre-development reference of Clause 3.3.2.

3.8.4 **Antecedent moisture.** AMC shall follow Clause 2.11.4: AMC III for every design storm, whatever its duration, from 1 June to 15 October at a site in sub-area ML-A (Northern foothills and Ri-Bhoi), ML-A1 (Garo foothills and plains), ML-B (Shillong plateau), ML-B1 (Jaintia hills karst and mine belt) or ML-D (Garo hills interior) of Annex 2A, and from 1 April to 31 October at a site in sub-area ML-C (Southern escarpment) or ML-C1 (South Garo slopes); AMC III for every design storm at any time of year in a catchment that drains to a reservoir of MePGCL (Umiam, Kyrdemkulai, Nongkhyllem, New Umtru or Myntdu–Leshka) or to any other reservoir or its backwater, or to a reach below a dam into which the dam releases water; at any other site or time, AMC III for a design storm that follows, or contains, a 5-day rainfall total of more than 53 mm; and AMC II for every other storm. AMC I is not used. CN for AMC I and III shall be obtained from AMC II by:

> CN(I) = 4.2 CN(II) / (10 − 0.058 CN(II)) CN(III) = 23 CN(II) / (10 + 0.13 CN(II))

The conversion shall be applied **to the pervious component only**. Impervious surfaces stay at CN 98 for all AMC. Composite CNs shall not be converted directly.

*Illustrative — not design values.* Pre-development reference CNs at AMC III are: HSG A 59.5; HSG B 78.2; HSG C 86.7; HSG D 90.2.

3.8.5 **Initial abstraction.**

- (a) **Default:** Ia = 0.2S, with the CNs of Table 3.5.
- (b) **Sensitivity run (mandatory):** every storage design shall also be run with Ia = 0.05S. For this run, S shall be converted as S0.05 = 1.33 · S0.20^1.15 (S in inches), which in SI is:

  > S0.05 = 25.4 × 1.33 × (S0.20 / 25.4)^1.15 (mm)

- (c) The design shall be based on the default run. The sensitivity results shall be reported on Form 3-2. Where the sensitivity run increases the required retention volume or water quality volume, the larger value governs for that volume.

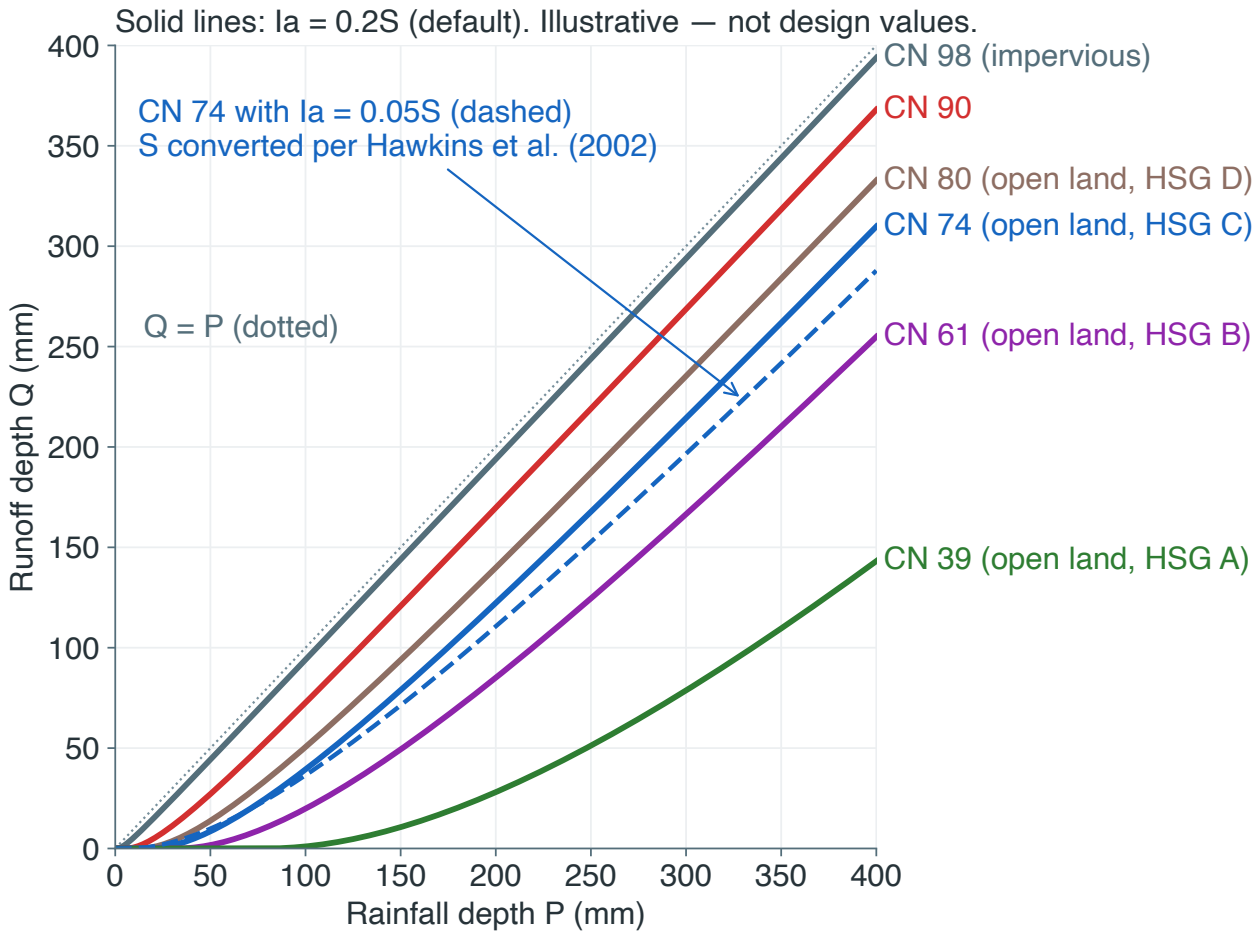


*Figure 3.3 — SCS-CN runoff depth versus rainfall depth for selected curve numbers at Ia = 0.2S, with the Ia = 0.05S sensitivity case for CN 74. Original drawing for this Manual, computed from the runoff equation of USDA NRCS, NEH Part 630, Ch. 10 (2004) and USDA SCS TR-55 (1986), and the S-conversion of Hawkins et al. (2002). Illustrative — not design values.*

**Commentary.** Table 3.5 reproduces standard NRCS TR-55 (1986) values. They were derived from US catchments and have not been calibrated in Meghalaya. The AMC conversion equations are the standard NEH-4 relationships as given by Chow, Maidment and Mays (1988, §5.5). Converting only the pervious component follows APWA, which states that "direct conversion of composite antecedent moisture conditions is not appropriate" (KC Metro APWA 5600, 2011, §5602.2C). Converting a composite CN would wrongly lower the CN of the impervious part.

Ia = 0.2S is the original NRCS ratio. Analysis of US rainfall–runoff data found that 0.05S fits better on average (Hawkins et al., 2002; Woodward et al., 2003), and gave the conversion of 3.8.5(b). NRCS has not formally replaced 0.2S, so this Manual keeps it as the default. Figure 3.3 shows why the sensitivity run is needed: for CN 74, the 0.05S case gives **more** runoff for small storms (about 2.0 mm vs 0.5 mm from 25 mm of rain) but **less** for large storms (about 242 mm vs 262 mm from 350 mm). *Illustrative — not design values.* The ratio therefore matters most for retention and water quality volumes, and the default 0.2S is the conservative choice for peak

and detention design. The rule in 3.8.5(c) that the larger retention or water-quality volume governs has no direct precedent; this Manual sets it because the 0.05S case gives more runoff from the small storms that set those volumes.

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## 3.9 Impervious connectivity

3.9.1 **Classification.** Every impervious surface in the post-development condition shall be classified as directly connected (DCIA) or disconnected, and shown on the drainage plan.

3.9.2 **Preferred representation.** In hydrograph models, DCIA and pervious areas shall be modelled as separate sub-areas (or as the separate impervious and pervious fractions of a SWMM subcatchment), each with its own loss parameters. The runoff from disconnected impervious areas shall be routed onto the receiving pervious area.

3.9.3 **Disconnection criteria.** An impervious area may be classed as disconnected only if all of the following hold:

- (a) its runoff discharges as sheet flow onto a pervious area, without a pipe, channel or kerb;
- (b) the pervious flow path is at least as long as the impervious flow path draining to it;
- (c) the pervious area is not compacted, not HSG D, and is protected from paving by the approved plan; and
- (d) for storms of 12 hours or more, it does not drain to an RWH sump or tank (Clause 3.3.3(c)).

3.9.4 **Composite CN.** Where a single composite CN is used instead of 3.9.2, it shall be computed as:

- for directly connected impervious area: $CNc = CNp + (Pimp / 100)(98 - CNp)$;
- where total impervious area is below 30% and part of it is disconnected: $CNc = CNp + (Pimp / 100)(98 - CNp)(1 - 0.5\,R)$,

where CNp is the pervious CN, Pimp is the percentage of impervious area and R is the ratio of disconnected to total impervious area. The composite CN shall not be used for retention or water quality volumes.

> **Commentary.** The composite equations are from TR-55 (USDA SCS, 1986, Ch. 2, Figures 2-3 and 2-4). This Manual prefers separate representation in 3.9.2 because a composite CN spreads the impervious response over the whole area, which suppresses runoff from small storms. For a site that is 50% directly connected impervious on HSG B open space (CNp 61), 25 mm of rain gives about 9.9 mm of runoff when the two parts are modelled separately, but only about 1.8 mm with the composite CN 79.5. At 200 mm the two methods agree (139.5 mm vs 138.4 mm). *Illustrative — not design values.* The error is largest for the frequent storms that set retention and water-quality volumes. The disconnection criteria of 3.9.3 are set by this Manual, drawing on common practice in US runoff-reduction manuals. Criterion (d) follows the rule of Clause 3.3.3(c) that RWH sumps are full at the start of monsoon storms.

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## 3.10 Groundwater, high water table and tank backwater

3.10.1 **High water table (dual HSG).** Where the seasonal high groundwater table is within 0.6 m of the ground surface, the soil shall be assigned HSG D for both the pre- and post-development runs, whatever its texture, unless it is permanently drained by works that are maintained under Chapter 10. This rule applies in every case to storms of 12 hours or more, which are run at AMC III (Clause 2.11.4).

3.10.2 **Water-table data.** The seasonal high water table shall be taken as the highest level recorded in the monsoon season (April–October), from site piezometers or trial pits, or from the nearest Central Ground Water Board (CGWB) or Water Resources Department observation well, adjusted for ground level.

3.10.3 **Infiltration-based losses.** Where Green–Ampt, Horton or soil-moisture-accounting losses are used instead of SCS-CN, the cumulative infiltration in any storm shall not exceed the storage available in the soil above the seasonal high water table.

3.10.4 **Tank and waterbody backwater.** Where a site or sub-catchment drains to a tank, pung, marsh or other waterbody:

- (a) the water level in the receiving waterbody shall be applied as the downstream boundary of the model, per Chapter 5 and Chapter 7;
- (b) land below the level of the receiving waterbody in the design event (including the tank foreshore below FTL) shall be modelled as water surface or storage, with no losses; and
- (c) where the outfall is submerged by the waterbody level, the routing shall use the dynamic-wave method of Clause 3.12.4.

> **Commentary.** The dual-group rule follows NEH Part 630, Ch. 7 (USDA NRCS, 2009), which places wet soils with a water table within 60 cm (24 in) of the surface in group D in their undrained state, with a dual group (A/D, B/D, C/D) where drainage is feasible. This Manual applies the undrained group to long storms because some land in Meghalaya is wet in the monsoon season, although most of the State is hard rock with deep water. The CGWB gives four depths to water: 3–5 m below ground in the alluvium, a "thick continuous aquifer" on the western, northern and southern fringes; 4–9 m in the sandstones, shales and clays of the Garo Group; 2–4 m in the "cavernous limestones" and sandstones of the Jaintia and Khasi Groups; and 7–17 m in the weathered and fractured zones of the gneiss and the Shillong Group (CGWB, GWRA 2022, Table 1). Thick unconsolidated sediment is found "only along extreme north-western fringe of the state in South West Garo Hills district"; elsewhere it lies "as thin veneer along rivulets and as valley-fills" (GWRA 2022). The wet land is therefore narrow but real: the alluvium of the Garo foothill plains and the Jinjiram valley, where the Brahmaputra and the Jinjiram "submerged over 200 villages" in September 2014 (as reported); the valley fills of Ri-Bhoi; the valley floors of the Umkhrah and Umshyrpi in Shillong, where Polo, Pynthorbah, Nongmynsong, Forest Colony and Mawlai flood "with nearly every heavy downpour" (as reported; the same text in the IRADe/NMHS plan) and the paddy near NEHU at Mawlai went under in July 2019 (IRADe/NMHS plan, Table 17); the margins of the pungs and lakes; and the shores of Umiam lake and the other reservoirs. On the limestone the shallow water of 2–4 m is in a discontinuous, cavernous aquifer that can rise fast after rain, and in the coal belt the mine pits hold water at unknown levels. No monsoon water-table depths for individual sites in Shillong, Tura, Jowai, Nongpoh or the Garo plains, and no map of the seasonal high water table, were obtained [TBC]; Annex 3A is to supply them. Clause 3.10.4 reflects the State's receiving waters, which are streams and jhoras with no gauges, a few rivers with level-monitoring sites, and reservoirs whose levels are published partly in feet. No CWC site in Meghalaya has a warning or danger level, and none forecasts floods. Of its seven level-monitoring sites, five have a highest flood level: the Umngot at Dawki, 73.47 m on 28 May 2006; the Umnohryngkew at Therriaghat, 20.62 m on 15 June 1995; the Myntdu at Kharkhana, 47.0 m on 23 April 1995; the Bugi at Dimapara, 29.75 m on 27 July 2007; and the Dareng at Sibbari, 20.34 m on 12 August 2017 (CWC, as transcribed by SANDRP); no datum is stated for any of them, presumably metres above mean sea level [TBC]. There is no gauge on the Umkhrah, the Umshyrpi, the Umiam, the Umtru, the Kynshi, the Simsang, the Ganol, the Jinjiram or the Kopili within the State. Shillong drains, through the Umkhrah and the Umshyrpi, which join as the Wah Roro, to Umiam lake (NESAC, 2023), a reservoir of MePGCL whose full level is known only from the press, as "3,220 ft" (Commentary to Clause 3.12); Byrnihat drains to the release reach of the New Umtru dam (full reservoir level 130.10 m, maximum water level 132.78 m), and Jowai, southward, to the Myntdu above the Myntdu–Leshka reservoir (618.00 m) (MePGCL). A site there drains to a water surface that the operator holds, and Clause 3.10.4(b) applies to the land below the starting level of the reservoir set in the Commentary to Clause 3.12. Ward's Lake (Nan Polok) in Shillong and Thadlaskein (Pung Sajar Nangli) near Mukhla are a small urban lake and a pung (as reported); no level or outlet data were found for either [TBC].

## 3.11 Unit hydrographs and runoff transformation

3.11.1 **Permitted transforms.**

- (a) SCS (NRCS) dimensionless unit hydrograph, curvilinear or triangular, for catchments below 25 km² and for any sub-area of a larger model;
- (b) the SWMM non-linear reservoir with kinematic overland flow;
- (c) Clark or ModClark unit hydrograph in HEC-HMS, where parameters are calibrated under Clause 3.15; and
- (d) the CWC synthetic unit hydrograph, for 25–5,000 km² (Clause 3.11.4).

3.11.2 **SCS unit hydrograph.** The peak and time to peak of the unit hydrograph shall be:

> qp = PRF' · A · Q / tp, with PRF' = 0.208 (SI form of the standard peak rate factor 484) tp = Δt / 2 + tL, tL = 0.6 Tc

where qp is the peak flow (m³/s); A is the area (km²); Q is the runoff depth (mm), equal to 1 mm for the unit hydrograph; tp is the time to peak (h); and Δt is the computation interval (h).

3.11.3 **Computation interval and sub-areas.**

- (a) Δt shall not exceed 0.133 Tc of the smallest sub-area, nor the hyetograph time step of Clause 2.9.1.
- (b) Sub-areas shall be reasonably uniform in HSG, land cover and slope. Pervious and directly connected impervious areas shall be separate sub-areas, per Clause 3.9.2.

3.11.4 **CWC synthetic unit hydrograph.** For catchments of 25–5,000 km² in CWC subzone 2(b) (South Brahmaputra), which covers the northern foothills, the plateau and the interior of the Garo hills but not the southern escarpment and the south Garo slopes, which lie in subzone 2(c) (Barak), for which CWC has published no Flood Estimation Report:

- (a) the SUH parameters, design storm duration, loss rate, base flow, areal reduction and time distribution shall be taken from the applicable CWC Flood Estimation Report, using the catchment's physiographic parameters measured from survey or a DEM;
- (b) the 24-hour design rainfall shall follow Clause 2.3.3(b) and Clause 2.7.3, and the climate factor of Clause 2.8 shall be applied;
- (c) the SUH result shall be reported alongside the HEC-HMS or SWMM result for the existing natural condition; and
- (d) where the hydrograph model gives a lower 1% AEP peak than the CWC SUH, the designer shall either justify the model by calibration under Clause 3.15 or adopt the CWC SUH peak.

3.11.5 **Peak rate factor for flat coastal land.** The standard factor (484; PRF' = 0.208) is the default. A lower factor may be used only:

- (a) for unchannelled, flat coastal-plain land without piped or lined drainage;
- (b) in the same way in both the pre- and post-development runs for any land that stays unchannelled; and
- (c) after the authority adopts calibrated values in Annex 3D.

Land drained by pipes, lined drains or kerbs in the post-development condition shall use the standard factor.

> Commentary. The SCS unit hydrograph, the 0.6 lag ratio and the 0.133 Tc interval are from NEH Part 630, Ch. 16 (USDA NRCS, 2007). The interval follows from the unit hydrograph geometry: with tp = Δt/2 + 0.6 Tc and Tc + Δt = 1.7 tp, Δt = 0.133 Tc. The SI constant 0.208 is the direct conversion of 484 (cfs, mi², in, h). APWA uses the SCS dimensionless unit hydrograph as its basis (2011, §5602.5). The CWC Flood Estimation Reports give regression equations for SUH parameters, a design storm duration, a constant loss rate and ARF and time-distribution curves for each subzone (CWC 2000; see Chapter 2). They were derived from natural, mostly rural catchments with data

that predate the report of 2000 (its 14 gauged catchments were observed between the 1960s and 1988; the two that drain Meghalaya, the Digru and the Dudhnai, rise in the State and were gauged at national-highway bridges in Assam in 1981–88), so they represent pre-development conditions, not urbanised ones. That is why the SUH is used as a benchmark rather than as the post-development model. Clause 3.11.4(d) mirrors the floor principle of Clause 2.3.3. HEC-HMS has been calibrated against CWC subzone SUH responses in Indian studies, which shows the two can be linked.

The lower-factor option of 3.11.5 is based on the NRCS Delmarva unit hydrograph, which uses a peak rate factor of 284 (PRF' ≈ 0.122) for flat, poorly channelled coastal-plain catchments on the Delmarva Peninsula (Welle et al., 1980, as adopted by NRCS; New Jersey Department of Agriculture, Delmarva bulletin, which uses 285). A lower factor gives a lower, later peak. Used only in the pre-development run, it would lower Q_pre and make the release cap stricter; used in a piped post-development run, it would understate Q_post. Clause 3.11.5(b) prevents both biases.

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## 3.12 Routing

3.12.1 **Storage routing.** Routing through detention and retention facilities, tanks, ponds and any storage behind embankments shall use level-pool (modified Puls, storage-indication) routing with:

- (a) a stage–storage relationship from the design grading or survey;
- (b) a stage–discharge relationship for every outlet (orifices, weirs, surplus weirs, pumps), including the minimum orifice and trash screen of Chapter 4; and
- (c) the tailwater boundary of Chapter 5, where the tailwater affects the outlet rating.

3.12.2 **Channel routing.** Routing through channels and drains shall use the Muskingum–Cunge method, or the Muskingum method with parameters K and X that are derived from channel geometry or calibration. For the Muskingum method, the routing interval $\Delta t$ shall satisfy $2KX \le \Delta t \le 2K(1 - X)$.

3.12.3 **Incidental storage.** Storage behind road embankments, culverts or boundary walls that is not part of an approved facility shall not be counted in the design unless the authority is satisfied that it will be maintained for the design life.

3.12.4 **Dynamic-wave routing.** Dynamic-wave (full Saint-Venant) routing, in SWMM or HEC-RAS unsteady flow, shall be used where:

- (a) the outfall is under tidal, river or tank backwater (Chapter 5, Clause 3.10.4);
- (b) flow can reverse, or the network has loops or overflow links; or
- (c) the network surcharges in the design event and the hydraulic grade line sets the design.

3.12.5 **Tank cascades.** Tanks in a cascade shall each be routed by Clause 3.12.1, with the surplus weir and sluice ratings and the documented operating rule of Chapter 7. The starting water level in each tank shall be FTL unless continuous simulation (Clause 3.13) supports a lower level.

Commentary. Modified Puls routing for storage and Muskingum–Cunge for channels are the APWA requirements (KC Metro APWA 5600, 2011, §5602.8). APWA also excludes "incidental detention" behind embankments unless it will be maintained, which 3.12.3 adopts. CPHEEO's detention procedure uses the same three inputs as 3.12.1: an inflow hydrograph, a stage–storage curve and a stage–discharge curve (CPHEEO 2019, Part A §8.5.3). The Muskingum stability limits are standard (Chow, Maidment and Mays, 1988, §8.4). This Manual starts pungs, lakes and reservoirs at their full or maximum level in 3.12.5 because Meghalaya's heavy rain falls on waterbodies that are already full or held up for power, not drawn down for drainage. The Manual's monsoon season runs from 1 April to 31 October, and the State's largest falls come in every month of it and beyond: at Cherrapunji the 24-hour records are 644.2 mm in April (16 April 1990), 812.0 mm in May (25 May 1916), 1,563.0 mm in June (16 June

1995), 838.2 mm in July, 853.4 mm in August, 985.5 mm in September (13 September 1974) and 594.0 mm in October (11 October 1975), with 587.4 mm in March (23 March 1994); at Shillong (C.S.O.) they are 227.0 mm in May (22 May 1988), 273.2 mm in June (25 June 1988), 244.0 mm in September (4 September 1979) and 262.0 mm in October (8 October 2004) (IMD *Extremes*). The wettest month on record at both stations was July 1974, 6,667.4 mm at Cherrapunji and 1,086.8 mm at Shillong (IMD *Extremes*). The MePGCL reservoirs are small, and their guidelines say that "Since the Reservoir capacity is very small, and the requirement of frequent release of water through the Gates during Monsoon as well as during Non-monsoon period, issuing the notification for release of water is not practicable"; warnings are given by siren, telephone or SMS (MePGCL guidelines for Stage III, Stage IV and New Umtru). The starting levels are as follows. MePGCL publishes the Umiam–Umtru levels in feet; they are converted here at 0.3048 m to the foot, and the datum of the gauges is to be confirmed with the operator [TBC].

- **Myntdu–Leshka Stage I (Myntdu).** Its full reservoir level and maximum water level are both EL 618.00 m, with the top of the dam at 620.00 m and the minimum drawdown level at 606.15 m (MePGCL, 2022). It shall be started at 618.00 m. Its spillway is designed for 12,000 m³/s from a catchment of 350 km², and the guideline records "very high discharge of about 10440 cumecs during high rainfall"; the release reach runs through the "Ravines and Plains of East & West Jaintia Hills" and reaches the Bangladesh border in about 24 km.
- **New Umtru (Umtru).** Its full reservoir level is 130.10 m and its maximum water level 132.78 m, with a storage of 3.55 MCM and a water spread of 0.537 km² at full level, a spillway of 3,820 m³/s and a catchment of 1,020 km² (MePGCL, 2025). It shall be started at its maximum water level, 132.78 m, the tailwater of Clause 5.8.5(d); its release reach runs for 9.80 km through a ravine to the bridge at Byrnihat.
- **Umiam–Umtru Stage III (Kyrdemkulai).** Its full reservoir level is 2,230 ft (679.70 m) and its maximum water level 2,235 ft (681.23 m), with the minimum drawdown level at 2,215 ft (675.13 m) and the spillway crest at 2,205 ft (672.08 m) (MePGCL, 2026). It shall be started at 2,235 ft (681.23 m).
- **Umiam–Umtru Stage IV (Nongkhyllem).** Its full reservoir level and maximum water level are both 503.00 m (MePGCL, 2025). It shall be started at 503.00 m.
- **Umiam lake (Umiam Stage I, Barapani).** No MePGCL guideline for Stage I was found, and no full or maximum level from the operator [TBC]. The press gives a full level of "3,220 ft" (about 981.46 m) and reports that releases began at 3,216.15 ft (about 980.28 m) in August 2024 on an IMD warning, and another document gives a spillway crest at EL 969.5 m (as reported); the datum of none of these is known. This Manual sets no starting level for Umiam lake from these figures: a site that drains to the lake or its backwater shall obtain the full and maximum levels and their datum from MePGCL in writing, and until it does the 3,220 ft figure is recorded in the submittal for information only and the outfall is treated as closed for the duration of Clause 5.8.5(d).
- **Kopili (NEEPCO).** No levels or release data for the Kopili project, which Meghalaya shares with Assam, were obtained [TBC]; it is started at the maximum water level published by its operator.
- **Lakes and pungs.** Ward's Lake (Nan Polok), Thadlaskein (Pung Sajar Nangli) and the other lakes and pungs have no published outlet level, operating rule or level record [TBC]; they shall be started at their surveyed spill or outlet crest level, and the small rain-fed and spring-fed pungs of the towns and villages are started full throughout the monsoon season.

A gated reservoir is modelled with its gate rule from its operator, and a waterbody is modelled below these levels only where a continuous simulation under Clause 3.13 or a notified operating rule supports it. The window of 1 April to 31 October in Clause 3.13.5(a) is set by this Manual and is the Manual's monsoon season. It starts on 1 April, not with the south-west monsoon, whose old normal date of onset at Shillong is 1 June (as reported; IMD's revised normals were not read [TBC]), because the pre-monsoon storms of April and May are among the State's largest, the CWC highest flood levels on the Myntdu at Kharkhana (23 April 1995) and the Umngot at Dawki (28 May 2006) fall in them (as transcribed by SANDRP), and the CWC subzone 2(b) report describes rainfall "spread over a period of eight months, i.e. from March to October", with "May rainfall … more than the September rainfall". It ends on 31 October because the monsoon leaves the State in about mid-October (expected by 14 October in 2025; 15 October in 2026 for the North East, as reported) and October storms are a real threat, such as

> Cherrapunji's 594.0 mm on 11 October 1975, Shillong's 262.0 mm on 8 October 2004 and the Garo Hills storm of 4–6 October 2024 (IMD *Extremes*; as reported). Pumps, gates and debris screens are on standby from 1 April to 31 October (Chapter 10).

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## 3.13 Continuous simulation

3.13.1 **When required.** Continuous simulation shall be carried out, in addition to the design-storm analysis, for:

- (a) regional facilities draining more than 25 km²; and
- (b) any system that includes a tank cascade whose storage is counted in the design (Chapter 7).

The authority may also require it for any facility where the starting storage level governs the design.

3.13.2 **Rainfall input.**

- (a) The longest available hourly record from IMD or another approved recording gauge representative of the catchment shall be used.
- (b) Where hourly data are shorter than 30 years, the record shall be extended with the IMD 0.25° gridded daily data. The full gridded record (1901 to present) should be used; at least the most recent 30 years shall be. The daily data shall be disaggregated to hourly by a method stated in the submittal and checked against the hourly gauge for the overlapping years. Grid values shall be converted to point values under Clause 2.7.1 where applicable.
- (c) A future-climate run shall scale the record by the climate factors of Clause 2.8.

3.13.3 **Model content.** The model shall include soil-moisture accounting with evaporation (IMD pan evaporation or equivalent), groundwater or base flow, tank storage with operating rules and irrigation withdrawals, and the tailwater series of Chapter 5 (predicted tides plus a surge allowance for coastal outfalls).

3.13.4 **Use of results.** Annual maxima of water level, storage and volume, and the duration of outfall closure, shall be extracted and fitted by frequency analysis. Results shall be compared with the design-storm results. The more severe result at each AEP governs. Peak flows in drains and channels with a response time of less than one day shall be taken from the design-storm analysis where the continuous record was disaggregated from daily data, because the disaggregated hourly peaks are synthetic.

3.13.5 **Two-step approach.** The continuous simulation need not use the full hydraulic model. It may use a simplified hydrologic and storage model, at a daily or hourly step, that represents the soil moisture, groundwater, tank storage, operating rules and tailwater of 3.13.3. Its results shall then be passed to the design-storm runs of the full hydraulic model as:

- (a) the **starting level of each tank**, taken as the level exceeded on 10% of the days from 1 April to 31 October over the record; and
- (b) the **antecedent soil-moisture condition**, taken from the same days and compared with the AMC rule of Clause 3.8.

The designer shall show that the simplified model reproduces the water balance of the full model for at least one recorded event.

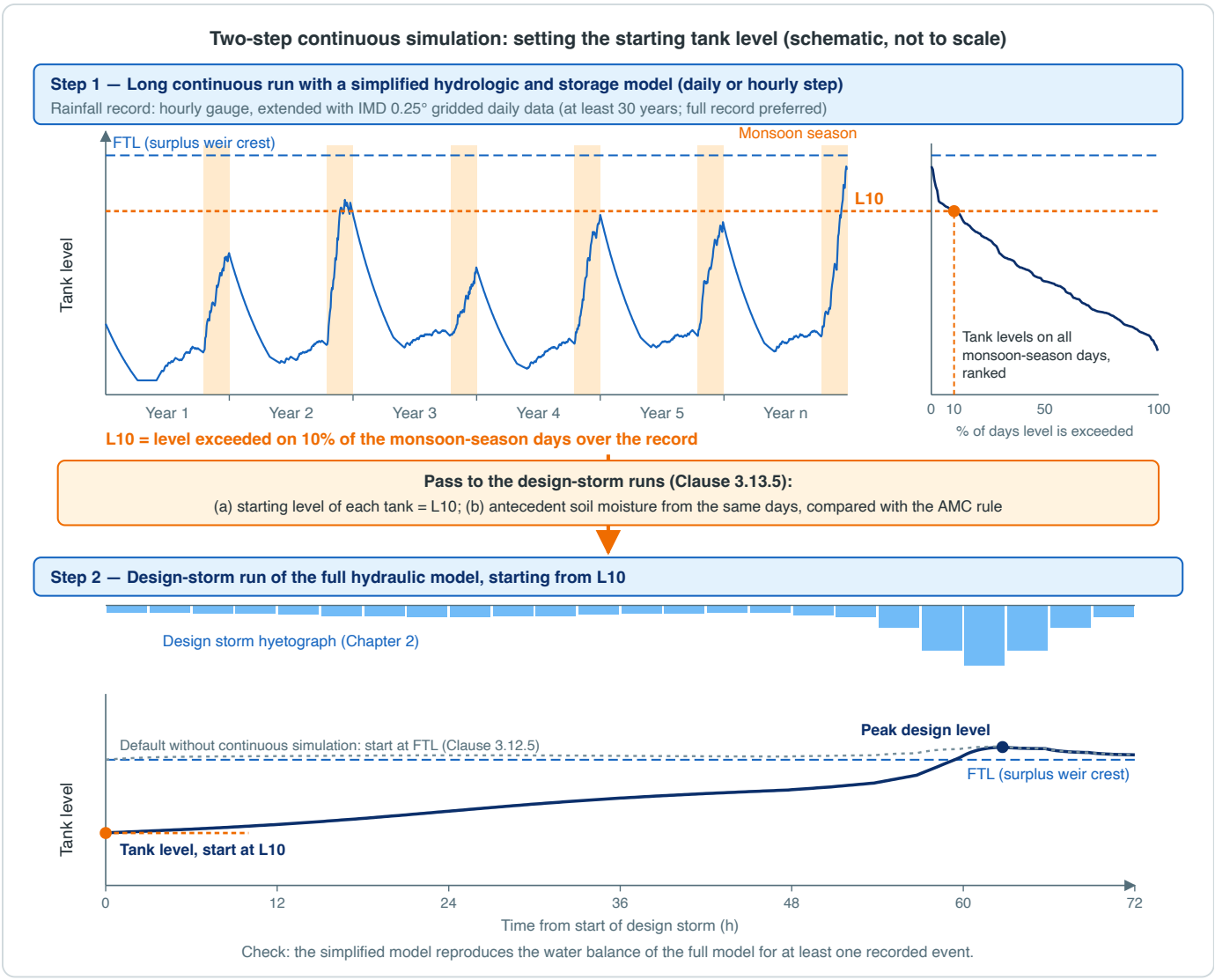


*Figure 3.4 — Two-step approach of Clause 3.13.5. Step 1: a long continuous run with a simplified hydrologic and storage model gives the tank level exceeded on 10% of the days from 1 April to 31 October (L10). Step 2: the design storms are run in the full hydraulic model from that starting level, in place of the default start at FTL of Clause 3.12.5. Schematic, not real data. Original drawing for this Manual, illustrating the two-step approach set by this Manual in Clause 3.13.5.*

**Commentary.** Design storms assume one starting condition, but in a tank cascade the governing variable is how full the tanks are when the storm arrives, which depends on the weeks of rain before it. An Australian study of 20 real on-site detention systems found that designs based on one temporal pattern, or even an ensemble of ten, "cannot reliably produce an OSD system design that will always be effective" under real rainfall, and continuous simulation showed frequent-event peaks exceeding pre-development levels (Water Science and Engineering, 2019). The 30-year minimum in 3.13.2(b) matches the station IDF rule of Clause 2.3.2; a longer record is better, and the IMD gridded daily record, which starts in 1901, is the practical long series for Meghalaya. The record length matters less than what the simulation is for. Its main purpose here is to find how full the tanks and soils usually are when a monsoon season storm arrives, and how often heavy rain coincides with a closed outfall. A design storm cannot answer either question, because it starts from one assumed condition. It is not intended to replace design storms for the peak flow in urban drains. Clause 3.13.5 therefore allows the long run to be made with a simple storage model, which takes minutes, and passes the starting tank levels to the detailed hydraulic model, which is then run only for the design storms. Running a detailed 1D–2D city model continuously for decades is rarely practical and is not required. The 10% exceedance level in 3.13.5(a) is set by this Manual: it

represents a wet but not exceptional monsoon, so that the design storm arrives on tanks that are already well filled, as they were in August 2024, when MePGCL began releases from Umiam lake at a level of 3,216.15 ft on an IMD warning (as reported).

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## 3.14 Pre- vs post-development comparison procedure

3.14.1 The comparison required by Clause 2.11 and Chapter 4 shall be carried out by the following steps. The results shall be recorded on Form 3-2.

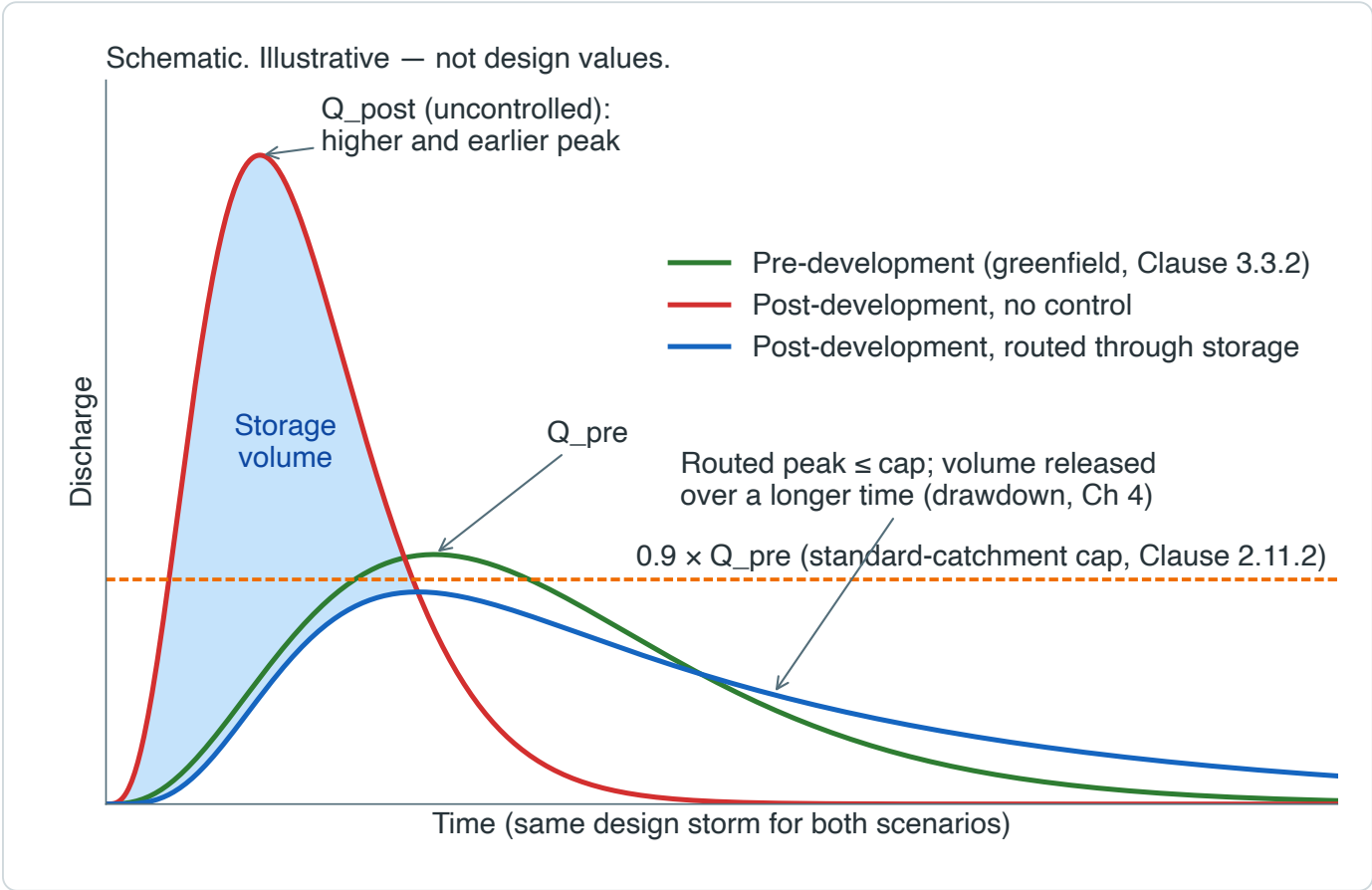


*Figure 3.5 — Pre-development, uncontrolled post-development and routed post-development hydrographs for the same design storm. Original drawing for this Manual, adapted from the pre- vs post-development detention concept in CPHEEO, Manual on Storm Water Drainage Systems, Part A §8.5, 2019, and KC Metro APWA Section 5600, 2025.01. Schematic. Illustrative — not design values.*

3.14.2 **Step 1 — Define the site, catchments and points of comparison.**

- (a) Delineate the site and every area that drains to it, from survey.
- (b) Identify each POC where runoff leaves the site. Each POC shall be tested separately. Runoff shall not be diverted from one natural catchment to another to meet the criterion.
- (c) Model off-site run-on identically in both runs, at its existing condition (Clause 3.3.5(b)). Where it passes through the site's storage, the criterion applies to the total outflow at the POC.

3.14.3 **Step 2 — Soils.** Map HSG (Clause 3.7), apply the high-water-table rule (Clause 3.10.1) and record the infiltration tests.

3.14.4 **Step 3 — Pre-development model.** Build the pre-development model per Clause 3.3.2: greenfield CN (Table 3.5), Tc (Clause 3.6, with n = 0.15), and existing waterbodies and channels. Compute CN at AMC II and AMC III.

3.14.5 **Step 4 — Post-development model.** Build the post-development model per Clause 3.3.3: measured impervious areas, connectivity (Clause 3.9), disturbed-soil HSG, CN, Tc, and the proposed retention, detention and outlets as storage (Clause 3.12.1).

3.14.6 **Step 5 — Design storms.** From Chapter 2, prepare for each required AEP (50%, 10% and 1%; 2-, 10- and 100-yr) and each duration in {1, 2, 3, 6, 12, 24, 48, 72 h}:

- the depth with the climate factor (Clause 2.8), ARF = 1.0 for the site (Clause 2.7.4);
- the hyetograph (Clause 2.9); and
- the AMC (Clause 2.11.4).

The same storms shall be used in both runs (Clause 2.11.1).

3.14.7 **Step 6 — Run the pre-development model** for every storm and tabulate $Q_{pre}(T, d)$. For flood-sensitive catchments, identify the largest 10% AEP pre-development peak over all durations; that value is the cap of Clause 2.11.3.

3.14.8 **Step 7 — Run the post-development model without controls** and tabulate $Q_{post}(T, d)$ and runoff volumes. This shows the size of the problem and is reported, not tested.

3.14.9 **Step 8 — Add retention and detention.**

- (a) Represent the retention volume of Chapter 4 as storage that is lost to infiltration or reuse (not released to the POC) within the period verified under Chapter 4.
- (b) Route the remaining hydrograph through the detention storage and outlets (Clause 3.12.1).
- (c) Apply the tailwater of Chapter 5, including the joint cases of Clause 2.12, where the outfall is tidal or under backwater.
- (d) Adjust storage and outlets until Step 9 is met.

3.14.10 **Step 9 — Test the criterion** at each POC, for every AEP and every duration:

- (a) standard catchments: $Q_{post}(T) \le 0.9 \times Q_{pre}(T)$ for the 50%, 10% and 1% AEP (Clause 2.11.2);
- (b) flood-sensitive catchments: $Q_{post}(1\%\ AEP) \le Q_{pre}(10\%\ AEP)$, and $Q_{post}(50\%\ AEP) \le Q_{pre}(50\%\ AEP)$ (Clause 2.11.3).

The governing duration for storage is the one that needs the largest storage or gives the highest water level; the 24, 48 and 72 h runs are always reported (Clause 2.5.2).

3.14.11 **Step 10 — Sensitivity runs.** Repeat Steps 6–9 for the governing storms with $I_a = 0.05S$ (Clause 3.8.5) and, where a lower peak rate factor is used, with the standard factor (Clause 3.11.5). Report the change in peaks and required storage.

3.14.12 **Step 11 — Associated checks.** Using the final routed model, check the drawdown times, minimum orifice and emergency spillway of Chapter 4, the outfall-closed storage check of Chapter 5, and the downstream analysis of Chapter 5.

3.14.13 **Step 12 — Document** the results on Forms 3-1 and 3-2 (Clause 3.17).

> Commentary. The step sequence follows the standard event-based workflow: delineate; set pre-development CN and Tc; set post-development CN and shorter Tc; run identical storms through a unit hydrograph or kinematic model; compare peaks and volumes; and size storage by modified Puls routing. It adds the Meghalaya elements: the 48–72 h storms, AMC III, and tailwater. Figure 3.5 shows why the long-duration runs matter: the routed peak

can meet the cap while the storage holds the volume difference between the post- and pre-development hydrographs, which must then drain within the Chapter 4 limits. The ban on diverting runoff between catchments in 3.14.2(b) stops a site meeting the rule at one POC by moving flow to a neighbour's drain.

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## 3.15 Model calibration and validation

3.15.1 **When required.** Calibration and validation are required for:

- (a) catchment models of 25 km² or more;
- (b) regional facilities and continuous simulation under Clause 3.13;
- (c) city or basin drainage master plans; and
- (d) any model whose parameters differ from the defaults of this chapter (for example a Clark transform or a lower peak rate factor).

3.15.2 **Data.** Calibration shall use observed rainfall (gauges, and radar where available) and observed flows or water levels (Water Resources Department gauging sites, SMB or MSDMA level sensors, tank gauges, or surveyed flood marks).

3.15.3 **Events.** At least three independent events shall be used for calibration and at least one further event for validation. At least one event shall be a long-duration monsoon or cyclone event (for example the storm of 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 IST on 17 June, IMD), the Shillong flash flood of 9 July 2019 (more than 72.2 mm in the day, as tabulated in the IRADe/NMHS plan), or the Garo Hills storm of 21–22 September 2014, for which no rainfall measurement was found [TBC], where data exist).

3.15.4 **Performance.** The submittal shall report, for each event, the observed and modelled peak, volume and time to peak, and for continuous models the Nash–Sutcliffe efficiency (NSE) and percent bias. As a guide, a calibrated model should reproduce event peaks and volumes within ±25%, and a continuous model should achieve NSE ≥ 0.5 and percent bias within ±25%.

3.15.5 **Limits on calibration.** Calibration shall not be used to justify design flows lower than those given by the default methods of this chapter, unless site-specific factors are thoroughly examined and documented and the authority agrees.

3.15.6 **Reasonableness check.** Design peak flows shall be plotted as discharge per unit area against catchment area and compared with the CWC SUH results, regional gauged estimates and known historical floods.

> Commentary. Clauses 3.15.5 and 3.15.6 follow APWA, which states that "model calibration shall not be used to justify discharge estimates that are lower than those provided by the baseline unit hydrograph method" and requires unit discharges to be plotted against tributary area and compared with regression, gauge and historical values (KC Metro APWA 5600, 2011, §5602.9). The event-count and performance values in 3.15.3 and 3.15.4 are set by this Manual. The NSE ≥ 0.5 and ±25% bias thresholds are the "satisfactory" streamflow ratings of Moriasi et al. (2007), which were developed for monthly continuous simulation; their use for event peaks and volumes here is an extension.

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## 3.16 Software acceptance

3.16.1 **Accepted software.** The following are accepted without further demonstration, in a version current at the time of submittal:

- (a) EPA Storm Water Management Model (SWMM 5.x);
- (b) USACE HEC-HMS and HEC-RAS;
- (c) USDA NRCS WinTR-55 and WinTR-20; and
- (d) spreadsheets for the Rational Method and single-area SCS-CN calculations, where every formula and input is shown.

3.16.2 **Other software.** Commercial packages built on the SWMM or HEC engines are accepted if the engine and version are stated. Any other method or software is accepted only if the designer reports, for every sub-area, the peak flow, lag, runoff volume and equivalent CN from both that method and a baseline method of 3.16.1, identifies every difference greater than 5%, and justifies every difference that gives a less conservative result.

3.16.3 **Benchmark problems.** The authority shall publish benchmark test problems (Annex 3C). Software not listed in 3.16.1 shall reproduce them within the stated tolerance.

3.16.4 **Model files.** Native model input and output files shall be submitted with every hydrograph-based design.

> Commentary. The 5% equivalence test is the APWA rule for alternative methods (KC Metro APWA 5600, 2011, §5602.2D). APWA names TR-55, TR-20, HEC-1 and HEC-HMS as baseline methods (§5602.2B). CPHEEO names SWMM for hydrograph and continuous modelling (CPHEEO 2019, Part A §4.4.2). Submitting native model files lets the authority rerun the model and is the main safeguard against unreviewable black-box results.

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## 3.17 Documentation

Every hydrologic submittal shall include:

1. **Form 3-1, Hydrologic Calculation Summary**, stating the method used and why (Table 3.1), the software and version, and the computation interval.
2. **Catchment maps** for the pre- and post-development conditions, showing sub-areas, flow paths used for Tc, POCs, and off-site run-on.
3. **Soils:** the HSG map and its source and scale (Clause 3.7), water-table data (Clause 3.10), and infiltration test results.
4. **Parameter tables** for each sub-area and condition: area, impervious area by type and connectivity, HSG, CN at AMC II and III (or C and Cf), Tc worksheets, and n values.
5. **Rainfall:** the Design Rainfall Sheet (Form 2-1) and the hyetographs used.
6. **Results:** hydrograph tables and plots for each storm; stage–storage and stage–discharge tables; routed outflows; and peak water levels.
7. **Form 3-2, Pre- vs Post-Development Comparison**, with Q_pre, Q_post (uncontrolled and routed) and the criterion for each POC, AEP and duration, and the sensitivity runs of Clause 3.14.11.
8. **Calibration report**, where Clause 3.15 applies.
9. **Model files** (Clause 3.16.4).
10. **A statement by the responsible engineer** that the methods and parameters of this chapter have been used, with any departures listed and justified.

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## References (chapter)


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- SANDRP, "Overview of CWC's flood monitoring & forecasting in North East India" (5 August 2018), transcribing CWC's site tables. https://sandrp.in/2018/08/05/overview-of-cwcs-flood-monitoring-forecasting-in-north-east-india/
- Reports on the reservoirs and caves of Meghalaya: the Umiam reservoir (full level, releases of August 2024, capacity surveys) and the Krem Liat Prah–Um Im–Labit cave system and the coal-mine pits of the Jaintia hills (Down To Earth; Mongabay; India Water Portal; as reported).
- US EPA. Storm Water Management Model (SWMM 5). US Army Corps of Engineers, Hydrologic Engineering Center. HEC-HMS and HEC-RAS.


## Annexes and forms

| Annex / Form | Content |
|---|---|
| 3A | Meghalaya soil series to HSG lookup; seasonal high water table map |
| 3B | Meghalaya CN calibration and supplementary land covers (forest and sacred groves, grassland and scrub, valley paddy, slide scars and hill-road cuts and fills, mine spoil and coal-mine pits, bare and cavernous limestone, boulder-bed jhoras, pung and reservoir beds) |
| 3C | Benchmark test problems for software acceptance |
| 3D | Peak rate factor study for flat coastal land |
| 3E | CWC SUH parameters for subzone 2(b), with worked example |
| Form 3-1 | Hydrologic Calculation Summary |
| Form 3-2 | Pre- vs Post-Development Comparison |

CHAPTER 4

# Site Runoff Control: Retention and Detention

## 4.1 Purpose and scope

4.1.1 This chapter sets the performance standard that every regulated development shall meet for runoff leaving the site. It covers:

- (a) the order in which runoff-control measures are to be applied (Clause 4.3);
- (b) retention of frequent rainfall, and how retained volume is credited against detention (Clause 4.4);
- (c) release-rate criteria for standard and flood-sensitive catchments (Clause 4.5);
- (d) the procedure for sizing detention storage and outlets (Clauses 4.6 to 4.9);
- (e) facility types, rainwater harvesting (RWH) accounting, and high-groundwater sites (Clauses 4.10 to 4.12);
- (f) regional detention and fee-in-lieu (Clause 4.13);
- (g) simplified methods for small sites: the Tier B tables and the fixed-coefficient route (Clause 4.14); and
- (h) public safety (Clause 4.15).

4.1.2 This chapter applies to land disturbance of **0.1 ha or more**, or new or replaced impervious area of **500 m² or more**, as set in Chapter 1. Single dwellings below that threshold, and road resurfacing that adds no impervious area, are exempt. The existing RWH mandate of the building rules (rainwater harvesting for every plot category and use under Table G1 of the Bye-Laws 2021 in the master-plan, municipal and scheme areas, with ground water recharge for residential covered area of more than 3,000 sq ft, and, in the Khasi Hills Autonomous District, the storing of water runoff including rainwater in all existing and new buildings under section 36 of the KHADC Regulation 2015; neither sets a volume, and both are discussed in the Commentary to Clause 4.11) continues to apply to every building it covers, whether or not this chapter applies.

4.1.3 Rainfall inputs come from Chapter 2. Hydrologic methods come from Chapter 3. Tailwater, downstream analysis and the outfall-closed check come from Chapter 5. Water quality volume (WQv) treatment comes from Chapter 8. Where this chapter and those chapters overlap, the more stringent requirement governs.

> Commentary. No Indian national rule or Meghalaya rule found during research for this Manual limits the rate of discharge from a site, and none requires on-site detention or "zero run-off". No Meghalaya document found sets a design storm, a return period, a runoff coefficient or a time of concentration for any drain. The building rules are the Meghalaya Building Bye-Laws 2021, notified by the Urban Affairs Department under section 74 of the Meghalaya Town and Country Planning Act 1973 (No. UAU.73/2016/Pt/402 of 9 March 2021), which apply to "all the Master Plan Areas, Municipal areas and Scheme Areas within the State" (A1.2) and name as the "Authority" "the Meghalaya Urban Development Authority / Autonomous District Councils as applicable" (A2.5). The text read is the notification of 2021 with its amendments of 29 February 2024 (No. UAU.73/2016/Pt/55, which inserted Section I), 19 November 2024, 15 January 2025, 18 June 2025, 13 August 2025, 21 October 2025, 19 December 2025 and 7 May 2026, cited here by number and date because two instruments are each called the " (Amendment)" and two the "Second Amendment", and the notification of 15 January 2025 amends "the Meghalaya Building Bye-Law, 2024". Outside those areas building and land are regulated by the District Councils: in the Khasi Hills Autonomous District by the Khasi Hills Autonomous District (Land Development and Building) Regulation 2015, with permissions issued by the KHBSRA since 2020 (as reported); the building instruments of the Jaintia Hills and Garo Hills District Councils were not found [TBC]. The Town Committees and census towns,

which hold 47% of the urban population, are "governed by the concerned ADCs", not by the Urban Affairs Department (CAG, *Performance Audit on Solid Waste Management in Urban Areas of Meghalaya*, executive summary), so nearly half of the State's urban people live outside the reach of the Bye-Laws 2021; the KHADC Executive Committee "outright rejected" the Bye-Laws 2021 on 25 October 2021 for encroaching on Sixth Schedule areas (as reported), and whether MUDA's jurisdiction reaches the District Council parts of a master-plan area is disputed (Chapter 1). This Manual takes no side in that dispute. The drainage provisions that can be found protect the building, the slope and the watercourse, not the catchment. The site shall be "properly drained or capable of being drained" and "not prone to land slide" (B1(ii), (iv)); where a plot lies along a stream or river, the septic tank and soak pit are to be "as far away as possible from the stream/river", the stilt at least 1.20 m above the Highest Flood Level on a sloping site and the plinth at least 0.90 m on a flat site (B1(v)); a soil report from a geotechnical expert is needed where the soil is weak (B1(vi)); earth cutting is limited to 3.00 m, relaxable to 6.00 m to the crest of an RCC wall, with a report of the Geological Survey of India beyond that (B1(vii)); and no land shall be used where "the proposed development falls in the area liable to flooding, except where protection measures are adopted" (B1.1(ii)). Since 2024 no construction is permitted on a slope of more than 50°, and building on slopes of 40–50° is limited (Section I(a)); "Buildings to be provided with good drainage facilities to prevent excessive saturation of sub-surface formations", "Construction should not obstruct existing surface drainage courses", and builders shall "Construct diversion ditches and swales to direct runoff away from sensitive areas and into designated sediment basins" and "Install silt fences, sediment barriers, or basins around the construction site" (Section I(b)); on water-logged plains, "Storm water inlet protection" is required (Section I(c)); and stream setbacks are governed by the Meghalaya Waterbodies (Conservation and Protection) Guidelines 2023 (B2(ii)(c) and Section I(a)4 and I(f), replacing the 2.40 m of 2021). The bye-laws define "Natural Hazard Prone Areas" to include areas flooded by "back flow in drains, inadequate drainage, etc., as to be identified through local surveys in the development plan" (A2.37), ask for "good drainage of water so that the saturation of the hill slope is avoided" (C12.1(iv)) and list flood-protection measures such as the "Clearing of clogged cross drainage works" (C12.3), and leave drainage itself to the National Building Code: "Requirements of water supply, drainage shall be as per National Building Code 2016" (D4.2, D5.6). The drawings show "Surface drains, position and sizes of septic tank and soak pit", the rainwater harvesting and the roof drainage, and large projects a services plan with the "drainage and storm water disposal system". Rainwater harvesting is required for every plot (Table G1; Commentary to Clause 4.11). None of these sets a design storm, a release rate, a detention volume or an overflow path. The KHADC Regulation adds a duty on the Executive Committee, Town Committee or Dorbar Shnong to ensure that development does not damage "catchment areas, water sources, spring sheds, streams and rivers" (s.15(1)), with restoration at the cost of the polluter (s.15(2)); a "Reserved Forest & Conservation Area", including the river edge, where "No development should normally be allowed" (s.2.101); the same 3 m and 6 m cut limits (s.34(v)); soft cover of at least 15% where the covered area is 500 m² or more and at least 10% otherwise, with "Semi-pervious ground cover … as paving wherever possible" (s.35(iii)(d)); and drawings that show "the highest flood level (HFL) reached above the street in front of the building" and the surface drains. Section I(b) and I(c) of the Bye-Laws and s.35(iii)(d) of the KHADC Regulation are the only provisions found that touch runoff from a site, and they are the hooks for this chapter. The Meghalaya Municipal Act 1973 vests "all public streams, channels, water-courses, springs tanks, reservoirs" and the public drains in the Board (s.62), lets it require an owner "to improve bad drainage" (s.190) and to drain land within 100 feet of a drain (s.206), and makes an unauthorised drain into a Board drain or water-course an offence (s.204, fine up to ₹50; s.205, up to ₹25), penalties too small to deter; its drainage tax (s.68, as substituted in 2021) cannot be levied until a drainage scheme is approved and made (s.73). The Meghalaya Flood Plain Zoning Act 2026 defines a "flood zone" as "the area which is required to carry the flow of the maximum probable floods" and makes the restrictions notified in it prevail over other laws (Bill, ss. 2(g) and 12(2)), but no Flood Zoning Authority, rules or zone notification was found, and no zone is notified (Chapter 7). No published highest flood level exists for Shillong's streams, so the stilt rule of B1(v)(b) and the KHADC's HFL above the street have no level to use; this Manual supplies the method (surveyed flood marks or the modelled 1% AEP level, Chapter 5). The only drainage design statement found is that of RMSI's multi-hazard assessment of Shillong (2019), which used the IMD station at Shillong, design rainfall "adopted from the Brahmaputra Basin PMP Atlas developed by the Central Water Commission (CWC, 2014) using data from 1957-2010" and the rational formula (as quoted in the IRADe/NMHS plan; the report and the atlas were not obtained [TBC]). Shillong's 148.91 km of drains "drain directly into the Umkhrah and Umshyrpi rivers", with coverage "less

than 75% of the city" and "the incidence of sewerage mixing in drains … almost 100%" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan, whose service-level table gives a coverage of 85%: the figures conflict); the plan recommends "Upgradation of the existing drains" and "Desilting to avoid flooding during monsoons"; and NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" (NESAC, 2023). Basements are limited by terrain, not for flooding. The Bye-Laws allow basements "only in flat terrain" (A2.7) and require that "surface drainage does not enter the basement / lower ground floor / cellar / underground floor" (A2.8(j)); no basement rule of the KHADC Regulation was read [TBC], and no Meghalaya rule found sets a level for a basement ramp or opening. This Manual therefore adds its own requirements for every basement: no detention storage in a habitable basement (Clause 4.10.1); the crest of every basement ramp and the sill of every basement opening at least 0.5 m above the 1% AEP flood level, with basement drainage pumped to the surface drain through a non-return valve (Clauses 6.11.1 and 6.11.4); and no basement in Zone 2 (Clause 7.5.2). In the flood-sensitive catchments of Clause 4.5.3.2, in any catchment notified under Clause 4.5.4, and on the plains, valley-floor, floodplain and waterbody-margin land of Clause 4.12.1, it recommends that no basement be permitted where the 1% AEP flood level stands above the surrounding ground; and wherever a basement or lower floor is cut into a slope, it shall carry the geotechnical certificate of the hill rule of Clause 4.11, with the water behind its walls drained to a lined drain and not to the ground, and none shall be cut into limestone or mine ground without a check for voids. For a sloping site, this chapter also supplies what the Bye-Laws leave open in Section I(b): runoff from the catchment above the site shall be intercepted and carried round the building in the design storms of Chapter 6, and every flow from the site shall discharge to a lined drain or a stable natural channel through an energy dissipator, never onto an unprotected slope or into fill. These are the Manual's proposals, not rules of the Bye-Laws 2021 or of the KHADC Regulation. This chapter is written so that it can supply, as a technical companion to the Bye-Laws 2021, the District Councils' building regulations, the master plans and the Municipal Act, the design storm, release rates and storage volumes that they leave open; a competent authority could adopt it for that purpose, but none has. In practice the storm drains of Shillong are its sewerage: "The Shillong Planning Area has no sewerage system", and "The sullage from the kitchen and bathroom flows into the primary, secondary and natural drains and finally to the nearby rivers Wah Umkhrah in the north and Wah Umshyrpi in the south" (NESAC, 2023); the MSPCB has identified 20 outfalls on the Wah Umkhrah and 12 on the Umshyrpi (minutes of 14 April 2023); and the CPCB places both rivers in Priority I among polluted river stretches, with a maximum BOD in 2022–23 of 56 mg/L at Mawpdang on the Umkhrah and 59 mg/L at the Law College on the Umshyrpi (CPCB, 2025) (Clause 8.9). Retention and detention apply in full on every site whatever the drain carries: every litre a site releases at the peak of a storm takes up capacity in a drain that is already part-filled with sewage. The CPHEEO (2019) manual describes limiting outflow to the pre-development peak as typical practice, but it uses no "shall" and names no storm frequencies (CPHEEO Part A §8.5.1). This chapter turns that description into a development-control requirement.

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## 4.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Retention | Permanent removal of runoff from the surface drainage system by infiltration, evapotranspiration or reuse, so that the water never reaches the outfall. |
| Retention depth | The 90th percentile wet-day 24-hour rainfall depth for the site's zone (Clause 2.10, Annex 2E). |
| Required retention volume (RRV) | The runoff volume from the retention depth over the post-development site (Clause 4.4.2). |
| Detention | Temporary storage of runoff, released through a controlled outlet at a rate set by Clause 4.5. |
| Retention credit | The reduction in required detention storage that results from retention practices, determined by routing under Clause 4.4.6. It is **not** the same as the retained volume. |

| Term | Meaning in this Manual |
|---|---|
| Permissible site discharge (PSD) | The maximum rate at which a site may discharge for a stated AEP, in L/s or L/s/ha. |
| Site storage requirement (SSR) | The detention storage required per hectare of site under the simplified method of Clause 4.14. |
| Multi-stage outlet | An outlet structure with separate openings at different levels, each controlling a different AEP (Figure 4.2). |
| Drawdown time | Time from the peak stored volume until the stated fraction of that volume has been released. |
| Emergency spillway | A secondary overflow that passes flows above the primary outlet capacity, or all flow when the primary outlet is blocked, without overtopping the embankment. |
| Freeboard | Vertical distance between the maximum design water level and the embankment crest or other critical level. |
| Flood-sensitive catchment | A catchment listed in Clause 4.5.3 or notified under Clause 4.5.4. |
| Authority | The approving authority under Chapter 1 (MUDA, through its Chairperson or the officer to whom the power is delegated, in the master-plan, municipal and scheme areas of the Bye-Laws 2021; the Municipal Board concerned for its own drains and works under the Meghalaya Municipal Act 1973; the Shillong Cantonment Board in the Cantonment; NSTDA in New Shillong [TBC]; and, in the autonomous districts outside those areas, the District Council or its building authority (in the Khasi Hills, the KHADC Executive Committee and the KHBSRA under the 2015 Regulation), as applicable). |
| Tier A / Tier B | Adoption tiers defined in Chapter 1. Tier A: the Shillong Municipal Board (SMB) and every approving authority within the Shillong Planning Area, whichever has jurisdiction over a site: MUDA, the Shillong Cantonment Board, NSTDA in New Shillong [TBC] and, for the parts of the planning area under the Khasi Hills Autonomous District Council, its building authority, if the District Council adopts the Manual (this Manual does not decide where MUDA's jurisdiction ends and the District Council's begins); and the Tura Municipal Board, with MUDA in the Tura master-plan area. Tier B: Municipal Boards, Town Committees and District Council building authorities. |

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## 4.3 Order of measures

4.3.1 Every site runoff-control design shall apply measures in the following order, and shall document in the submittal why each earlier step could not do more:

1. **Preserve.** Keep existing waterbodies, pungs, natural drainage lines, wetlands, and permeable soils and vegetation. Avoid fill in flood storage (Chapter 7).
2. **Retain.** Retain the RRV on site by infiltration, reuse or evapotranspiration (Clause 4.4).
3. **Detain.** Detain the remaining runoff so that the release-rate criteria of Clause 4.5 are met for every design storm and duration (Clauses 4.6 to 4.9).
4. **Convey.** Convey the 1% AEP (100-yr) flow safely through the site to the receiving system on a defined overland path (Chapter 6), and check the receiving system downstream (Chapter 5).

4.3.2 Preservation and retention reduce the detention required (Clauses 4.4.6 and 4.4.7). They do not relieve the site of the release-rate criteria of Clause 4.5 or of the downstream analysis of Chapter 5.

> **Commentary.** This order follows the "layers of stormwater management" adopted in the Kansas City Metro APWA Section 5600 Version 2025.01: preserve or restore, retain, detain, convey, maintain (MARC factsheet; MARC Supplement, Nov 2025). Maintenance is the fifth layer and is set in Chapter 10. The 2025.01 manual credits

retention and natural-area preservation against detention size (MARC Supplement, Nov 2025). Clause 4.4.6 adopts that credit, and defines it so that it cannot be claimed twice.

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## 4.4 Retention

### 4.4.1 Requirement

The site shall retain the RRV. Retention shall be achieved by one or more of the following:

- infiltration practices (soakaways, infiltration trenches, permeable pavement with an infiltration base, bioretention);
- rainwater reuse that is drawn down by a demonstrated non-potable demand;
- green roofs and landscape areas that do not drain to the outfall in the retention-depth storm.

The limits of Clause 4.4.4 apply.

### 4.4.2 Computation of the RRV

> RRV ($m^3$) = 10 × $Q_R$ × A

where:

- $Q_R$ (mm) is the runoff depth from the retention depth $P_R$ (Annex 2E). It is computed with the SCS-CN method for the post-development cover of each sub-area, at AMC II, with Ia = 0.2S (Chapter 3); and
- A (ha) is the area of the site that drains to the outfall.

$Q_R$ shall be computed for each sub-area separately and summed. An area-weighted CN shall not be used where impervious and pervious areas differ by more than 20 CN points.

The volumetric method RRV = 10 × $P_R$ × Rv × A, with Rv = 0.05 + 0.009 × I (I = percent impervious), may be used for sites under 0.5 ha and under the Tier B method.

> **Commentary.** The Rv formula is the one used in the KC water quality volume (MARC BMP Manual 2012). It is simple to review for small sites. The SCS-CN form is required for larger sites so that the retention computation uses the same runoff model as the detention routing. That keeps the credit computation of Clause 4.4.6 consistent.

### 4.4.3 Verification

Retention by infiltration shall be supported by:

- (a) site infiltration tests at the location and depth of each practice, at the frequency set in Chapter 8;
- (b) a design infiltration rate of no more than **half** of the measured rate; and
- (c) groundwater evidence showing the seasonal high groundwater table at least **1.0 m** below the base of the practice (Chapter 8).

Retention by reuse shall be supported by a demand calculation showing that the RRV is drawn down within 72 hours by a continuous non-potable use, such as toilet flushing, cooling or irrigation.

> **Commentary.** The factor of 2 on measured infiltration rate has no direct precedent; this Manual sets it to allow for clogging and for the difference between a test pit and a full-scale practice. Chapter 8 may set a different factor; if it does, Chapter 8 governs.

### 4.4.4 Limits on retention

4.4.4.1 Infiltration practices shall not be used:

- where the seasonal high groundwater table is less than 1.0 m below the base (Chapter 8);
- on contaminated land;
- within the setbacks from foundations, wells and septic systems set in Chapter 8; or
- on fill, unless tested after placement.

4.4.4.2 Where the RRV cannot be fully retained, the shortfall shall be stated in the submittal. The shortfall shall be treated as WQv under Chapter 8 and shall get no retention credit.

### 4.4.5 Drawdown of retention

Retention storage shall be emptied by infiltration or reuse within **72 hours** of the end of the retention-depth storm, verified by the tests of Clause 4.4.3.

### 4.4.6 Retention credit: definition and computation

4.4.6.1 **What the credit is.** The retention credit is the reduction in required detention storage that results when the retention practices are included in the post-development routing. It is computed. It is not assumed equal to the RRV.

4.4.6.2 **Tier A method (routing).** For each design storm and duration of Clause 4.6.3:

- (a) model each retention practice explicitly as a storage that is **empty at the start of the storm**, unless Clause 4.11 says otherwise;
- (b) let the practice fill from the front of the storm, and let it lose water during the storm only at the design infiltration or reuse rate of Clause 4.4.3;
- (c) once it is full, route its overflow to the detention facility; and
- (d) size the detention for the residual hydrograph.

The required detention storage is the largest storage over all storms and durations. The credit is the difference between that storage and the storage required with no retention. No further deduction shall be made.

4.4.6.3 **Tier B method (simplified).** The detention storage required by Clause 4.14 may be reduced by:

> $V_{credit} = C_R \times RRV_{provided}$

where $C_R$ is the retention credit factor from Annex 4B for the zone, soil group and drawdown rate. Until Annex 4B is published, **$C_R = 0$**.

4.4.6.4 Retention that is not verified under Clause 4.4.3 gets no credit.

> **Commentary.** "Credited against detention" (APWA 5600 2025.01) can be read in two ways. One reading subtracts the retained volume from the detention volume, cubic metre for cubic metre. The other routes the storms with retention in place and sees what detention is still needed. The two readings give very different answers in Meghalaya, because the mandatory 48- and 72-hour storms (Clause 2.5.2) fill any retention practice on the first day, long before the peak arrives on the last day (Clause 2.9.2). Unless the practice keeps infiltrating during the storm, it is full at the peak and does nothing to reduce the peak storage.
>
> The illustrative example in Clause 4.6.7 shows the size of the effect. A 2 ha site with 552 m³ of retention (no infiltration during the storm) needs 138 m³ less detention for the 24-hour storm. That is a credit of about a quarter of the retained volume. For the 48- and 72-hour storms, which govern, the credit is close to zero. Subtracting the retained volume directly would have under-sized the detention by about 545 m³ (about 19%).
>
> This Manual therefore defines the credit as the result of routing. Retention on fast-draining sandy soils, which keeps infiltrating through a multi-day storm, will earn a real credit. Retention that only fills will earn little. Both outcomes are physically correct. Setting C_R = 0 until Annex 4B exists is a safe default for Tier B, not a judgement that retention has no value: retention is still required for water quality and recharge (Chapter 8).

### 4.4.7 Preservation credit

Areas of the site that are permanently preserved in natural cover may be modelled at their pre-development CN in the post-development condition, provided that:

- they are protected by a registered covenant or dedication; and
- their runoff is not concentrated onto impervious surfaces.

This lowers both the RRV and the detention required. No other preservation credit applies.

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## 4.5 Release-rate criteria

### 4.5.1 General

4.5.1.1 Peak discharge from the site shall be computed by a hydrograph method (Chapter 3) for the pre-development and post-development conditions with identical design storms (Clause 2.11.1). The Rational Method shall not be used for any part of storage sizing.

4.5.1.2 Pre-development is greenfield: open land in good condition for the mapped HSG. Existing impervious cover is not counted (Clause 2.11.5, Chapter 3). This applies to redevelopment as well, subject only to the constrained-redevelopment route of Clause 4.5.6.

4.5.1.3 The criteria apply at each point where runoff leaves the site. Where a site drains to more than one outfall, the criteria apply to each outfall for the area draining to it. Runoff shall not be diverted between catchments.

### 4.5.2 Standard catchments

For each of the 50%, 10% and 1% AEP (2-, 10- and 100-yr) storms, and for every duration in {1, 2, 3, 6, 12, 24, 48, 72 h}:

> $Q_{post}(T, d) \le 0.9 \times Q_{pre}(T, d)$

### 4.5.3 Flood-sensitive catchments

4.5.3.1 In the catchments listed below, the **mixed-frequency rule** of Clause 2.11.3 applies, for every duration in Clause 2.5.2:

> Q_post(1% AEP, 100-yr) ≤ Q_pre(10% AEP, 10-yr), and Q_post(50% AEP, 2-yr) ≤ Q_pre(50% AEP, 2-yr).

Each cap is the pre-development peak at the duration that maximises it: the 10-yr peak for the 100-yr check, and the 2-yr peak for the 2-yr check. The cap applies to every post-development duration (Clause 2.11.3).

4.5.3.2 The flood-sensitive catchments are:

- (a) **Shillong's Umkhrah and Umshyrpi**: the catchments of the Wah Umkhrah and the Wah Umshyrpi, with their jhoras, down to the Wah Roro and Umiam lake, including the valley floors of Polo, Pynthorbah, Nongmynsong, Mawlai, Forest Colony, Dhankheti and Nongrim Hills, the land in the high and very high flash-flood susceptibility classes of the NESAC report for the Shillong Planning Area, and the landslide ground along NH-40 and near the Umshyrpi (Commentary to Clause 4.11);
- (b) **Umiam lake shore and the Umiam–Umtru release reaches**: the land that drains to Umiam lake below or near its starting level of Clause 3.12.5, and the land along the release reaches of the Umiam–Umtru stages and of New Umtru down to Byrnihat;
- (c) **Jowai on the Myntdu**: the land of Jowai that drains to the headwaters of the Myntdu, and the land along the release reach of the Myntdu–Leshka dam to the Bangladesh border;
- (d) **The escarpment settlements of Sohra, Mawsynram and Shella**: the land of Sohra, Mawsynram, Shella and the other settlements of the southern escarpment in sub-area ML-C, where the State's record rainfall falls on limestone and steep ground;
- (e) **Dawki on the Umngot**: the land of Dawki that drains to the Umngot, whose CWC level-monitoring site has a highest recorded level of 73.47 m;
- (f) **Tura on the Ganol**: the land of the Tura master-plan area that drains to the Ganol and to the Ringrey and Rongkhon streams;
- (g) **Williamnagar on the Simsang**: the land of Williamnagar that drains to the Simsang;
- (h) **Baghmara and Dalu on the south Garo rivers**: the land of Baghmara and Dalu that drains to the rivers of the south Garo slopes and the edge of the plains, among them the Simsang, the Bugi and the Dareng;
- (i) **The Garo foothill plains on the Jinjiram and the Krishnai**: the land of Phulbari, Tikrikilla and the other settlements of the Garo foothill plains that drains to the Jinjiram and the Krishnai under their backwater;
- (j) **Nongpoh–Umling on NH-6 and the Umlew**: the land of Nongpoh and Umling block that drains to the Umlew and the streams crossed by NH-6; and
- (k) any catchment notified under Clause 4.5.4.

The boundaries shall be those mapped in Annex 4A.

### 4.5.4 Notification of further flood-sensitive catchments

4.5.4.1 The Authority may propose that a catchment be notified as flood-sensitive where one or more of the following is documented:

- (a) buildings or arterial roads flooded in an event of 1% AEP or more frequent, on at least two occasions in the previous 20 years;
- (b) receiving drains or channels with capacity below the 10% AEP flow under existing conditions;
- (c) an outfall that is held up by a stream in flood, a river backwater or a reservoir, such as the Wah Umkhrah at Polo, Pynthorbah, Nongmynsong and Mawlai in Shillong, the Umngot at Dawki, the Jinjiram and the Brahmaputra backwater on the Garo plains, Umiam lake or another MePGCL reservoir held near its full level, or that is buried or

blocked by the boulders, debris and garbage of a jhora, for part of the monsoon season (Chapter 5);

- (d) loss of more than a quarter of the mapped tank and pung storage in the catchment since the earliest available survey; or
- (e) a basin master plan that relies on limiting site discharge.

4.5.4.2 The procedure shall be:

1. The Authority prepares a technical note with the catchment boundary in GIS form and the evidence for 4.5.4.1.
2. The State-level technical committee constituted under Chapter 1 reviews the note.
3. The draft notification and map are published for public comment for at least 60 days.
4. The Government notifies the catchment and the map is added to Annex 4A.
5. The rule applies to applications received **6 months** or more after notification. Applications received earlier are assessed under Clause 4.5.2.

4.5.4.3 A notified catchment may be de-notified only by the same procedure, and only after a basin study shows that the downstream system meets Chapter 5 with all development under Clause 4.5.2.

> Commentary. The 0.9 factor is derived from the Denver (MHFD) analysis. In that analysis, ten basins each releasing 100% of the historic 100-yr peak still produced 106% of the historic peak at the outlet; releasing 90% at each gave 97% (UDFCD Full Spectrum Detention Release Rate Memorandum, 2012). The mixed-frequency rule has no direct precedent; the nearest is the Malaysian DID (2008) checklist, which required post-development 2-, 10-, 50- and 100-yr peaks below the pre-development 2-yr peak. The specific "100-yr post ≤ 10-yr pre" form appears in a New Berlin, Wisconsin planning discussion (not an adopted rule). The Shillong entry follows the two city streams. The Umkhrah and the Umshyrpi drain the city and join as the Wah Roro before Umiam lake (NESAC, 2023); Shillong's 148.91 km of drains "drain directly into the Umkhrah and Umshyrpi rivers", and storm-water drainage covered "less than 75% of the city" in 2016-17 (Smart City Proposal, as quoted in the IRADe/NMHS plan, which elsewhere gives a coverage of 85%: the two figures conflict). NESAC classes 4.67% of the planning area as of high and 1.01% as of very high flash-flood susceptibility and names "Polo Market, Pynthorbah, Nongrim hills, Dhankheti" as "highly potential for flash flood"; Polo, Pynthorbah, Nongmynsong, Forest Colony and Mawlai flood "with nearly every heavy downpour" (as reported; IRADe/NMHS plan); a flash flood struck Polo, Forest Colony and Mawlai on 9 July 2019 after "more than 72.2 mm of rain" (IRADe/NMHS plan, Table 17); and the plan names historical landslides at Laitumkhrah (2008), Lawsohtun, Happy Valley (2007), Mccabe Road, Bethesda and Arbuthnot, and "very high susceptibility" along NH-40 and near the Umshyrpi. Neither stream has a gauge or a published flood level; the floodplain zonation of the Umkhrah and other stretches let to RMSI in June 2021 was "80%" complete in March 2023 and has not been published (State action-taken report to the NGT, 21.03.2023). The Umiam entry follows the reservoir and its release reaches: the lake receives the drainage of Shillong and "serves as a cesspool of the waste materials of Shillong" (Expert Committee report, 2023), releases are set by MePGCL, which began them at 3,216.15 ft in August 2024 on an IMD warning (as reported), and below the dams the Stage III reach runs 13.05 km through a ravine to the Stage IV reservoir, the Stage IV reach 33.5 km, and the New Umtru reach 9.80 km to the bridge at Byrnihat (MePGCL guidelines). The Jowai entry follows the Myntdu: Jowai lies inside the closed 680-mm contour of the CWC subzone 2(b) plate, the Myntdu at Kharkhana far downstream set its highest level, 47.0 m, on 23 April 1995 (CWC, as transcribed by SANDRP), and below the Myntdu–Leshka dam, whose spillway passes 12,000 m³/s from 350 km², the release reach runs about 24 km to the Bangladesh border past settlements and farms (MePGCL, 2022). The escarpment entry follows the record rainfall belt: Cherrapunji recorded 1,563.0 mm on 16 June 1995 (IMD *Extremes*) and Mawsynram 1,003.6 mm on 17 June 2022 (IMD), nine people were reported killed in Mawsynram block alone in that storm (as reported), the landslide at Sohra in the earthquake of 12 June 1897 is reported to have killed 600 people (as reported), and the ground is cavernous limestone on which no infiltration is allowed (Clause 4.11). The Dawki entry follows the Umngot, whose highest level at Dawki, 73.47 m, came before the south-west monsoon, on 28 May 2006 (CWC, as transcribed by SANDRP); in June 2026 the river "rose rapidly", submerging a labour camp of the bridge project and sweeping away an excavator, while the Shillong–Dawki road collapsed at Laitlyngkot (as reported). The Tura entry follows the streams of its draft risk-informed master plan, which bounds the 54.65 km² planning area by the Ringrey Stream, the Ganol River and the Rongkhon Stream (notice No. UAU.76/2022/129 of 16 February 2024); in

the Garo Hills floods of September 2014, which were reported to have killed more than 60 people and blocked NH-51 to Tura, no rainfall measurement was found (as reported) [TBC]. The Williamnagar entry follows the Simsang, which has no gauge and flows on to Bangladesh, in a sub-area where the reanalysis gives values (859.7 mm at 50 years in 24 hours, NIH-DHAARA) that no gauge checks. The Baghmara and Dalu entry follows the south Garo rivers: in the storm of 4–6 October 2024 three people drowned at Dalu, seven died in a landslide at Hatiasia Songma and 2,630 households were affected in Dalu block (as reported), the Bugi at Dimapara and the Dareng at Sibbari have highest levels of 29.75 m (27 July 2007) and 20.34 m (12 August 2017) (CWC, as transcribed by SANDRP), and the Dalu gauge recorded 32.0 cm in a day on 13 June 1956 (CWC subzone 2(b) report, Annex 4.1). The Garo plains entry follows the Jinjiram and the Krishnai, whose floods of September 2012 and September 2014 submerged over 100 and over 200 villages (IRADe/NMHS plan, Table 17; as reported), on alluvium with water 3–5 m below ground (CGWB, GWRA 2022); the reaches of these rivers in Assam are governed by the Assam edition of this series. The Nongpoh–Umling entry follows NH-6: in the storm of 30–31 May 2025 landslides hit 15 villages of Umling block "near National Highway 6", linked to hill cutting along the highway, and one person drowned in the Umlew (as reported). Nongstoin, where the storm of September 2020 cut the roads (IRADe/NMHS plan, Table 17), Mairang, Resubelpara, Khliehriat and New Shillong are candidates for notification under Clause 4.5.4. The notification triggers in 4.5.4.1 have no direct precedent and are set by this Manual. The 6-month lead time follows the update rule of Clause 2.14.2. Clause 4.16 explains why releases below pre-development are needed at all.

### 4.5.5 Minimum outlet and short-duration 2-yr checks

4.5.5.1 Where the PSD for any AEP and duration is less than the discharge of a **50 mm** orifice (Clause 4.8.2) at the corresponding stage, the 50 mm orifice is deemed to comply for that AEP and duration.

4.5.5.2 Where meeting the 2-yr criterion at a duration of 3 hours or less would require a low-flow orifice so small that the drawdown requirement of Clause 4.7 cannot be met, the designer shall:

- size the low-flow orifice as the smallest opening that meets Clause 4.7; and
- report the resulting 2-yr exceedance for those durations.

The Authority may accept the design if the exceedance is below the discharge of the 50 mm orifice at the 2-yr stage, or if the downstream analysis of Chapter 5 shows no adverse effect.

Commentary. Under AMC II, a greenfield site produces almost no runoff in a 1- or 2-hour, 2-yr storm, because most of the rain is lost to initial abstraction. A pre-development peak of a few litres per second, compared duration by duration, then forces a very small low-flow orifice. That orifice cannot release the 10-yr volume within 48 hours. Checked as if it were outside a flood-sensitive catchment, the illustrative example of Clause 4.6.7 would need a low-flow orifice of about 75 mm to match the 1-hour, 2-yr pre-development peak. 90% drawdown of the 10-yr volume would then take about 84 hours even with a clean orifice, against the 48-hour limit. The 170 mm orifice that meets drawdown with 50% blockage exceeds the 1-hour, 2-yr pre-development peak by about 11 L/s. Clause 4.5.5.2 resolves that conflict in favour of drawdown, because a basin that is still partly full when the next monsoon storm arrives fails in the event that matters more. KC APWA 5600 (2006) used a 75 mm (3 in) minimum orifice with trash racks. This Manual sets a 50 mm minimum (Clause 4.8.2).

### 4.5.6 Constrained redevelopment sites

4.5.6.1 **Eligibility.** The relief route of this clause is available only for **redevelopment** where all of the following hold:

- (a) the existing site is at least **60% impervious**, as surveyed before demolition;
- (b) the site is **1 ha or less**; and

- (c) the designer shows, in a Constraint Statement submitted with Form 4-1, that the greenfield criteria of Clauses 4.5.2 or 4.5.3 cannot be met on the site. The statement must show that every storage option of Clause 4.10 has been assessed: rooftop and podium storage, tanks under parking or landscape, permeable paving with sub-base storage, and landscape depressions. It must also give the storage each option can provide.

New development on undeveloped land is never eligible.

4.5.6.2 **Minimum on-site performance.** An eligible site shall provide all of the following on site:

- (a) the full retention volume (Clause 4.4) and the WQv treatment (Chapter 8), with no relief;
- (b) post-development peak discharge no more than **50% of the existing-condition peak** for the 50%, 10% and 1% AEP storms, at each duration of Clause 2.5.2. The existing condition is modelled under Clause 3.3.4; and
- (c) no increase in the 1% AEP water level at any building or road downstream (Chapter 5).

4.5.6.3 **Shortfall.** The shortfall is the detention storage required to meet the greenfield criteria (Clause 4.6) minus the storage provided on site under 4.5.6.2. The applicant shall pay for the shortfall as a fee-in-lieu at the unit rate of Clause 4.13.3. The fee shall be:

- (a) paid into the ring-fenced account of the basin in which the site lies;
- (b) spent only on regional detention or on restoring pung or tank flood storage identified in the basin stormwater master plan (Chapter 11); and
- (c) recorded in the public ledger of Clause 4.13.4, which shall show the volume owed and the volume delivered in each basin.

Where no basin master plan has yet been approved, the fee shall be held for up to **5 years**. If no plan is approved in that time, it shall be spent on restoring tank flood storage in the same basin, with Water Resources Department agreement.

4.5.6.4 **Flood-sensitive catchments.** In the catchments of Clause 4.5.3, the route is available under the same conditions. The Authority may, however, refuse it where the downstream analysis of Chapter 5 shows existing flooding of buildings in the 10% AEP event within the analysis extent.

> Commentary. Greenfield is the target for all redevelopment, because a dense city only reduces its runoff as it rebuilds. On small, fully built plots in areas such as Laitumkhrah, Mawlai, Polo and Pynthorbah in Shillong, or the old centres of Tura and Jowai [TBC], there is often no space for the full greenfield storage. A rule that cannot be met invites variances and non-compliance, which help no one downstream. This clause follows the approach of the UK Non-statutory Technical Standards for Sustainable Drainage (Defra, 2015, S2–S3). For previously developed sites, those standards require peak runoff "as close as reasonably practicable to the greenfield runoff rate" and never above the pre-redevelopment rate. The fixed 50% minimum reduction has no direct precedent; this Manual sets it to give reviewers a clear number in place of a "reasonably practicable" judgement. The fee-in-lieu turns the shortfall into regional storage in the same basin, so the basin still receives greenfield-equivalent control in total. Retention and water quality get no relief, because they are small volumes that almost every site can hold.

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## 4.6 Detention sizing procedure

### 4.6.1 Method

Detention shall be sized by hydrograph routing through the stage–storage–discharge relationship of the facility, by level-pool (Modified Puls) or an equivalent numerical method (SWMM, HEC-HMS). Fixed-ratio and Rational-based storage formulae shall not be used. The simplified methods of Clause 4.14 (the Tier B tables and the fixed-coefficient route) are the only exceptions.

### 4.6.2 Steps

1. Delineate the site and sub-areas. Map HSG and confirm by testing (Chapter 3).
2. Extract design rainfall for 50%, 10% and 1% AEP and every duration in Clause 2.5.2, with the climate factor (Chapter 2, Form 2-1).
3. Build design hyetographs: alternating block for ≤ 24 h; the "peak day last" pattern for 48 and 72 h (Clause 2.9).
4. Compute pre-development hydrographs (greenfield CN; AMC III for storms of every duration from 1 June to 15 October in sub-areas ML-A, ML-A1, ML-B, ML-B1 and ML-D and from 1 April to 31 October in sub-areas ML-C and ML-C1, at all times in catchments draining to a MePGCL or other reservoir, its backwater or a release reach below a dam, and at other sites and times after a 5-day total of more than 53 mm, AMC II otherwise).
5. Compute the release caps for each AEP and duration under Clause 4.5.2 or 4.5.3.
6. Compute post-development hydrographs with the same storms and AMC, including retention practices (Clause 4.4.6).
7. Choose a trial facility geometry (stage–storage) and a multi-stage outlet (Clause 4.6.5).
8. Route every storm and duration. Use a time step of no more than **5 minutes**, and no more than Tc/3 of the post-development catchment.
9. Check every release against its cap, and check drawdown (Clause 4.7). Adjust the outlet and storage and repeat.
10. Check the tailwater condition of Clause 4.6.6 and the downstream analysis of Chapter 5.
11. Size the emergency spillway and set freeboard (Clause 4.9).
12. Report the governing storm for storage, for each outlet stage, and for the spillway (Clause 4.17).

### 4.6.3 Storms to be routed

Every facility shall be routed for the full matrix:

**Table 4.1 — Design storms to be routed for detention sizing**

| AEP | Durations (h) | AMC |
|---|---|---|
| 50% (2-yr) | 1, 2, 3, 6, 12, 24, 48, 72 | II for ≤ 6 h; III for ≥ 12 h |
| 10% (10-yr) | 1, 2, 3, 6, 12, 24, 48, 72 | II for ≤ 6 h; III for ≥ 12 h |
| 1% (100-yr) | 1, 2, 3, 6, 12, 24, 48, 72 | II for ≤ 6 h; III for ≥ 12 h |

The 24-, 48- and 72-hour runs are mandatory whatever the critical-duration result (Clause 2.5.2). Where Ia = 0.05S sensitivity is required by Chapter 3, it shall be run for the governing storage case.

### 4.6.4 Initial conditions

Each run shall start with:

- detention storage empty, down to the invert of the lowest outlet;
- any permanent pool full;
- retention practices empty, except as limited by Clause 4.11; and
- RWH storage full (Clause 4.11).

The 48- and 72-hour storms already contain their antecedent rain, so no further pre-filling is applied.

### 4.6.5 Multi-stage outlet design

4.6.5.1 The outlet shall have a separate control for each criterion, normally stacked as in Figure 4.2:

- **Stage 1**, at the invert: the low-flow orifice. It releases the WQv over 24–48 h (Chapter 8) and controls the 2-yr release.
- **Stage 2**: an orifice or slot set at or near the maximum 2-yr level. It controls the 10-yr release.
- **Stage 3**: a weir, riser crest or larger orifice set at or near the maximum 10-yr level. It controls the 100-yr release.
- **Emergency spillway**: separate from the primary outlet (Clause 4.9).

Stages may be combined where routing shows that every cap is met.

4.6.5.2 Orifices shall be computed with a discharge coefficient of 0.60 unless a rated device is used. Weirs shall use a coefficient appropriate to their shape. Submerged-outlet and tailwater effects shall be included (Clause 4.6.6).

4.6.5.3 Vortex flow controls and other proprietary devices may be used where the supplier provides a certified head–discharge curve and the minimum clear opening is at least 50 mm.

### 4.6.6 Tailwater on the outlet

The outlet shall be routed against the tailwater of the receiving system, not free outfall, wherever the receiving water level can rise above the outlet invert. The tailwater shall be:

- for a receiving drain: its water level in the same storm, from the Chapter 5 analysis or, for Tier B, the drain obvert;
- for tidal or backwater-affected outfalls: the levels and joint cases of Clause 2.12 and Chapter 5, including the outfall-closed check (Clause 5.10).

Where tailwater governs, a flap gate shall be fitted to the outlet (Clause 5.11). The storage below the tailwater level shall not be counted as available unless the routing includes the gate closure.

### 4.6.7 Illustrative example

**Illustrative — not design values.** This example shows the procedure and the sizes it produces. The inputs are invented to be plausible for a colony draining to a jhora in Shillong. They are not NIH-DHAARA values and must not be used for design.

Inputs:

- Site: 2.0 ha, flood-sensitive catchment (Clause 4.5.3).
- Land cover: pre-development all pervious, CN 70. Post-development as two sub-areas (Clause 3.9.2): 1.57 ha of directly connected impervious surface at CN 98, never converted for AMC, and 0.43 ha of pervious open space at CN 70, on the same soil as pre-development; the area-weighted CN at AMC II is 92. For storms of 12 h and longer the pervious CN only is converted to AMC III: $CN_{III} = 23 \cdot CN / (10 + 0.13 \cdot CN) = 84.3$ (Clause 3.8.4).
- Time of concentration (Tc): 45 min pre-development, 15 min post-development (used for both sub-areas). SCS triangular unit hydrograph; 5-minute time step.
- 24-h depths: 110, 200 and 350 mm for 2-, 10- and 100-yr (the same 10- and 100-yr values as Clause 2.11).
- Shorter durations: $P(t) = P24 \cdot (t/24)^{0.40}$, an assumed ratio set and not Annex 2B.
- Longer durations: 48-h and 72-h depths taken as 1.25 and 1.40 × P24, laid out per Clause 2.9.2.
- Storage: vertical-walled, 2,500 m² plan area.
- Outlet, sized so that drawdown is met with the low-flow orifice 50% blocked (Clause 4.8.3). Annex 4C shows the trial outlet that failed this check.
    - Stage 1: 170 mm orifice at the invert.
    - Stage 2: 460 mm orifice with its invert 0.53 m above the floor.
    - Stage 3: none needed, because the 100-yr cap is met by Stages 1 and 2.

Results (discharges in L/s; storage in m³):

**Table 4.2 — Illustrative example: peak discharges and storage used, by duration (Illustrative — not design values)**

| Duration (h) | 2-yr pre | 2-yr post, detained | 10-yr pre | 10-yr post, detained | 100-yr post, uncontrolled | 100-yr post, detained | 100-yr storage used | 10-yr drawdown, 50% blocked (h) |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 15 | 51 | 28 | 922 | 42 | 1,426 | 31.3 |
| 2 | 14 | 20 | 84 | 34 | 961 | 79 | 1,911 | 32.1 |
| 3 | 19 | 22 | 104 | 37 | 981 | 139 | 1,999 | 32.8 |
| 6 | 32 | 25 | 150 | 41 | 1,010 | 194 | 2,154 | 34.2 |
| 12 | 127 | 30 | 302 | 46 | 1,074 | 276 | 2,512 | 39.0 |
| 24 | 149 | 32 | 327 | 49 | 1,081 | 320 | 2,766 | **45.3** |
| 48 | 173 | 34 | 349 | 82 | 1,087 | 343 | **2,913** | 44.8 |
| 72 | 180 | 34 | 356 | 84 | 1,089 | 343 | 2,911 | 44.7 |

How to read it:

- **100-yr cap.** The cap is the largest pre-development 10-yr peak, 356 L/s (72 h). Every 100-yr detained peak is at or below it; the largest is 343 L/s.
- **2-yr cap.** The site is flood-sensitive, so the 2-yr cap is the largest pre-development 2-yr peak, 180 L/s (72 h; Clause 4.5.3.1). The largest 2-yr detained peak is 34 L/s. At 1, 2 and 3 hours the detained 2-yr peak is above the pre-development peak of the same duration (15 against 4 L/s, 20 against 14 L/s, and 22 against 19 L/s). That comparison is not required here. It would be for a site under Clause 4.5.2, and Clause 4.5.5.2 would then apply.
- **Governing storage.** Storage is governed by the **48- and 72-hour** storms: 2,913 m³, which is 0.146 m³ per m² of site, at a maximum depth of 1.17 m. A design that checked only the critical-duration peak storm (1–3 h here) would have provided about 2,000 m³, roughly two-thirds of what is needed.
- **Drawdown.** With the low-flow orifice 50% blocked (Clause 4.8.3), 90% of the 10-yr storage drains in at most 45.3 h (the 24-hour storm), within the 48 hours of Clause 4.7. A 120 mm orifice would drain it in about 42 h when clean but 54 to 75 h when half blocked, so it fails. Annex 4C shows that trial and the routing step by step.
- **Retention credit.** With an illustrative retention depth of 40 mm, RRV = 552 m³, computed for each sub-area (Clause 3.9.4). Modelled as filling from the start of the storm with no infiltration during it, the retention reduces the 24-hour storage by 138 m³ and the 48- and 72-hour storage by 7 m³ or less. The credit under Clause 4.4.6 is therefore effectively zero for this site.

The order of magnitude, about 0.15 m³ per m² of site, is consistent with the indication in Clause 2.11.

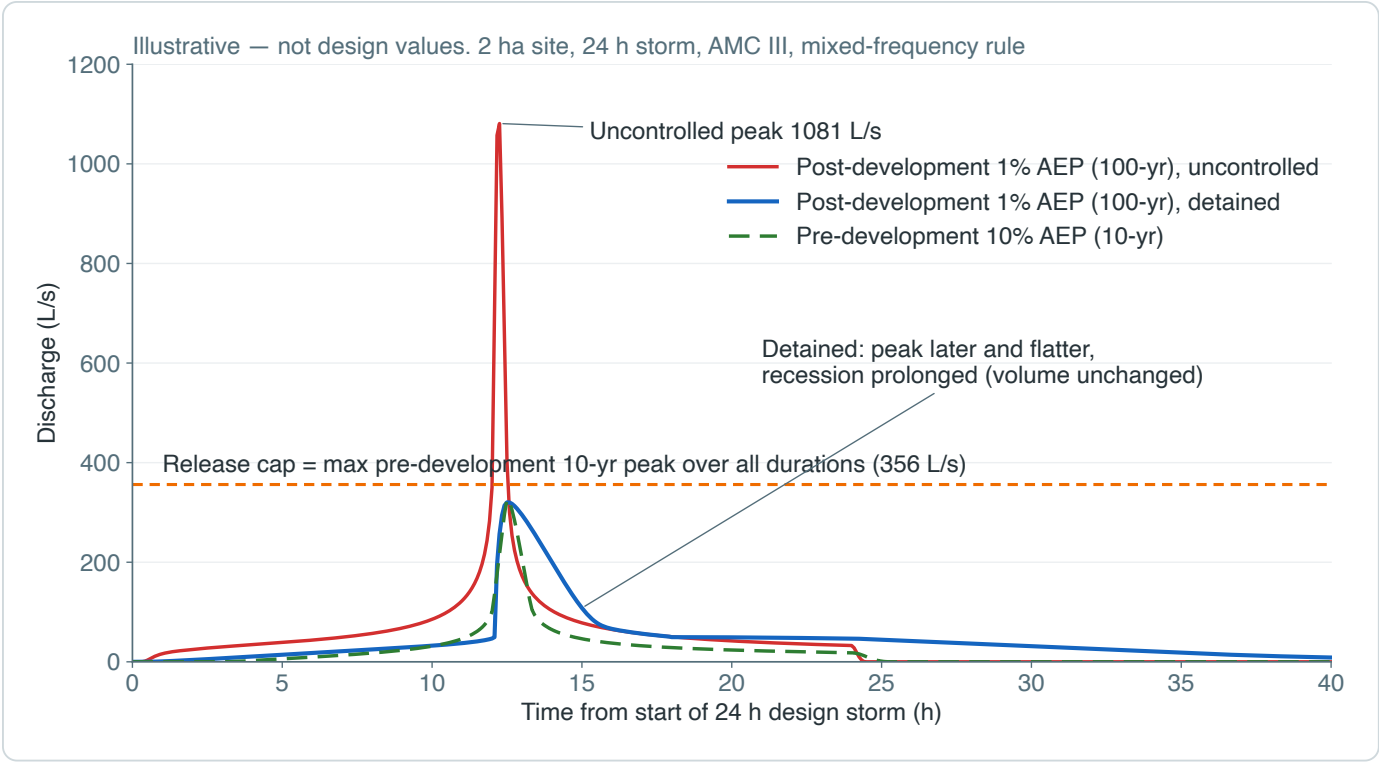


*Figure 4.1 — Pre-development 10-yr, post-development 100-yr uncontrolled and detained hydrographs for the 24-hour storm of the illustrative example (Clause 4.6.7). Illustrative — not design values. Original drawing for this Manual, adapted from the pre/post-development hydrograph concept in MARC/KC APWA Section 5600 and the Georgia Stormwater Management Manual (2016).*

> **Commentary.** Figure 4.1 shows what detention does and does not do. It cuts and delays the peak. It does not reduce the volume: the area under the detained curve equals the area under the uncontrolled curve, more than twice the pre-development 10-yr volume. The extra volume leaves the site over many hours after the storm. That prolonged release can coincide with the peak of the larger catchment downstream (Clause 4.16), and it must still drain when the outfall is tide-locked (Chapter 5).

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## 4.7 Drawdown

4.7.1 **Detention.** At least **90%** of the maximum volume stored in the 10% AEP (10-yr) storm of each duration shall be released within **48 hours** of the time of maximum storage, by gravity, with the tailwater of Clause 4.6.6.

4.7.2 **Water quality volume.** The WQv shall be released over not less than 24 hours and not more than 48 hours (Chapter 8).

4.7.3 **Retention.** Retention storage shall be emptied within 72 hours by infiltration or reuse (Clause 4.4.5).

4.7.4 **Tidal outfalls.** Where gravity drawdown is prevented by tide for part of each cycle, the 48-hour limit applies with the tidal tailwater modelled. Where it cannot be met by gravity, pumped drawdown shall be provided under Clause 5.12.

> **Commentary.** KC APWA 5600 (2006) required dry basins to release at least 80% of storage within 24 hours of the inflow peak and to empty within 72 hours. Singapore PUB requires detention to be restored within 4 hours. The 48-hour, 90% rule is longer than PUB's because Meghalaya storage must hold multi-day volumes. It is still short

enough that a basin filled by one monsoon depression will have most of its volume back before the next, which in June 2022, when the 24-hour falls of 15 and 17 June at Sohra (811.6 mm, also reported as 811.2 mm, and 972 mm, as reported) and of 17 June at Mawsynram (1,003.6 mm, IMD) came two days apart followed within days.

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## 4.8 Outlet structures

4.8.1 **General.** Primary outlets shall be:

- unattended, with no moving parts, valves or pumps, except where Clause 5.12 permits pumped drawdown;
- accessible for inspection and cleaning from the surface without confined-space entry, where practicable; and
- built of durable materials. In coastal areas these shall be corrosion-resistant (Clause 4.12.5).

4.8.2 **Minimum orifice.** No control orifice shall be smaller than **50 mm** in diameter, or 50 mm in least dimension for a slot.

4.8.3 **Trash racks and screens.** Every orifice and weir shall be protected by a trash rack or screen. The rack shall:

- have a clear bar spacing no greater than half the smallest opening it protects, and not less than 25 mm;
- have a clear open area at least **10 times** the area of the opening it protects;
- be inclined, or set as a cage around the riser, so that debris rises with the water and does not pin against the bars;
- be removable or hinged for cleaning; and
- for routing, be assumed **50% blocked** at the low-flow orifice when checking drawdown.

4.8.4 **Anti-vortex devices.** Riser crests and orifices that may run under more than 1.5 times their diameter of head shall have an anti-vortex plate or hood (Figure 4.2).

4.8.5 **Outlet barrels.** Outlet barrels through embankments shall:

- be at least 300 mm in diameter (Chapter 6);
- have watertight joints;
- have a filter diaphragm or seepage collars over the length within the embankment; and
- have an energy-dissipating outfall (Chapter 9).

4.8.6 **Isolation.** Facilities serving more than 1 ha shall have a means of isolating the outlet for maintenance, such as a stop-log slot or penstock. In normal service it shall be left fully open.

> Commentary. The 50 mm minimum is smaller than the 75 mm (3 in) of KC APWA 5600 (2006), so the trash-rack requirements are correspondingly stricter. The ratios in 4.8.3 (bar spacing at half the opening, open area 10 times the opening, 50% blockage for the drawdown check) have no direct precedent and are set by this Manual. The blockage factor matches the 50% grate clogging factor for sag inlets in Chapter 6. Indian urban drains carry heavy loads of solid waste, so a low-flow orifice without an effective rack will block within one season.

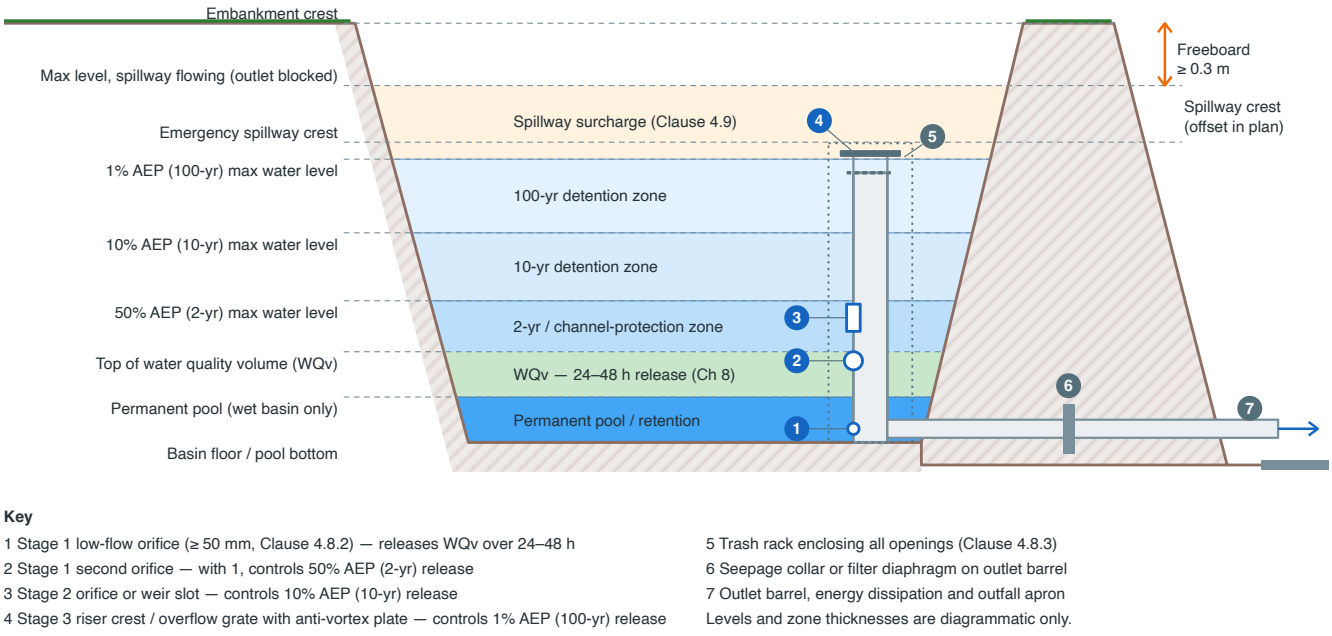


*Figure 4.2 — Detention storage stack (permanent pool, WQv, 2-yr, 10-yr and 100-yr zones, spillway surcharge and freeboard) and multi-stage riser outlet. Schematic, not to scale. Original drawing for this Manual, adapted from the multi-stage outlet and storage-zone concepts in MARC/KC APWA Section 5600 (2006, 2025.01) and the Mile High Flood District Urban Storm Drainage Criteria Manual, Volume 2 (full-spectrum detention).*

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## 4.9 Emergency spillway, freeboard and embankment safety

4.9.1 **Spillway capacity.** Every detention facility formed wholly or partly by an embankment, or whose overflow would reach buildings, shall have an emergency spillway that passes the **1% AEP (100-yr) peak inflow**:

- with the primary outlet assumed fully blocked;
- with the facility full to the spillway crest at the start of the storm; and
- with at least **0.3 m freeboard** from the maximum water level to the embankment crest.

4.9.2 **High-hazard facilities.** A facility is high-hazard if its failure or overflow could:

- endanger life;
- flood a habitable building or critical facility; or
- close an arterial road.

High-hazard facilities shall also be checked for the **0.2% AEP (500-yr)** peak inflow under the conditions of 4.9.1, with the embankment not overtopped.

4.9.3 **Spillway crest.** The spillway crest shall be at or above the 1% AEP maximum water level from routing with the primary outlet working. The recommended clearance is 0.15 m.

4.9.4 **Spillway location.** The spillway shall be:

- on natural ground or a reinforced section, not on fill, unless protected against erosion for the full design flow;
- discharging to the 1% AEP overland flow path of Chapter 6; and

- placed so that its flow does not reach a building.

4.9.5 **Underground and enclosed facilities.** Tanks, vaults and podium storage shall have an overflow route that operates when the outlet is blocked. The route shall carry the 1% AEP inflow to the overland path without surcharging any building, basement or lift pit.

4.9.6 **Embankments.**

- (a) Embankments more than **2 m** high (measured from the downstream toe to the crest) shall be designed by a qualified geotechnical engineer. The design shall include stability, seepage and settlement analysis.
- (b) Side slopes shall be no steeper than 3H:1V on any face that is mown or accessible to the public. Slopes shall be flatter where Clause 4.15 requires.
- (c) Embankments shall have:
  - a crest width of at least 3 m;
  - compacted, engineered fill with a core or cut-off where required by the seepage analysis; and
  - no trees or large shrubs.
- (d) An embankment structure that falls within the Dam Safety Act, 2021 is subject to that Act in addition to this Manual.

4.9.7 **Excavated facilities.** Facilities wholly below the surrounding ground, with no embankment, need not meet 4.9.6. They shall still meet 4.9.1, with the overflow route treated as the spillway.

> **Commentary.** The spillway criterion (1% inflow, outlet blocked, basin full, 0.3 m freeboard; 0.2% for high hazard) follows the KC APWA 5600 (2006) rule: the spillway passes the 1% storm with 1 ft (0.3 m) freeboard to the top of the dam, assuming zero storage and a clogged primary outlet, with the crest at least 0.5 ft (0.15 m) above the 1% maximum water surface. KC designed dams above 10 ft (3 m) to SCS TR-60 Class C. The 2 m embankment trigger, the 3H:1V slope (KC wet ponds), and the 3 m crest width have no direct precedent and are set by this Manual.

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## 4.10 Facility types

4.10.1 **General.** Any storage that meets Clauses 4.5 to 4.9 may be used. Surface storage that is visible and can be inspected without confined-space entry is preferred. Storage shall not be placed in a habitable basement or in any space whose flooding would endanger life.

4.10.2 **Underground tanks and vaults.**

- (a) Gravity outlet is required where the receiving drain allows it. Pumped outlets are permitted only under Clause 5.12, with a registered maintenance declaration (Chapter 10).
- (b) Access openings shall be provided over the outlet chamber and over every inlet. In tanks over 500 m², they shall be no more than 30 m apart.
- (c) The floor shall fall at least 1% to a sump at the outlet, with a sediment pocket below the low-flow orifice invert.
- (d) The tank shall be ventilated.
- (e) Inlets shall pass through a silt trap or gross pollutant trap (Chapter 8).
- (f) Flotation and groundwater ingress shall be checked under Clause 4.12.

4.10.3 **Rooftop detention.**

- (a) It is permitted on flat roofs designed for the full ponded load with the outlet blocked. The ponding depth shall not exceed **150 mm** unless a structural engineer certifies a greater depth.
- (b) Each roof outlet shall have a flow-control ring or weir with a certified rating, and every roof area shall have at least one overflow scupper, independent of the controlled outlets, that passes the 1% AEP inflow.

- (c) Roofs used for RWH collection may also provide rooftop detention. The detained volume is released through the control, not into the RWH sump.

4.10.4 **Podium and landscape-deck detention.**

- (a) It is permitted above ground level or above a basement car park, provided the structure is designed for full saturation and ponding, and waterproofed.
- (b) The release, overflow and safety rules for rooftop detention (4.10.3) apply.

4.10.5 **Parking-lot detention.**

- (a) It is permitted only on surface parking. Ponding depth shall not exceed:
  - **200 mm** in the 10% AEP storm and **300 mm** in the 1% AEP storm at any parking bay;
  - zero on accessible routes, ramps and pedestrian crossings; and
  - zero in the 10% AEP storm on fire-tender access routes.
- (b) Signs shall warn that the area floods.
- (c) Ponding shall not reach a building wall unless the wall is waterproofed above the 1% level plus freeboard (Chapter 6).

4.10.6 **Multi-use detention (parks, playfields, open space reservation).**

- (a) Open space land may be used for detention, provided its primary use remains available in at least the 50% AEP storm.
- (b) The storage areas shall be graded to drain fully within the times of Clause 4.7.
- (c) A low-flow channel or underdrain shall carry dry-weather and frequent flows, so that the park is not waterlogged.
- (d) The depth and slope limits of Clause 4.15 apply.
- (e) Play equipment and seating shall be placed above the 10% AEP level.

4.10.7 **Ponds and wet basins.**

- (a) A permanent pool shall be at least 1.2 m deep over most of its area to discourage weed growth and mosquito breeding, with a vegetated safety bench at the edge (Clause 4.15).
- (b) Only storage above the permanent pool counts as detention.

> Commentary.
>
> - The rooftop depth (150 mm) and parking depths (200 and 300 mm) have no direct precedent. This Manual sets them so that a blocked outlet is noticed before it becomes dangerous.
> - The 1.2 m pool depth equals the 4 ft minimum permanent pool of KC APWA 5600 (2006). This Manual adopts it mainly for weed and mosquito control.
> - Pumped detention tanks need maintenance declarations in Singapore (PUB Addendum No. 3, April 2025). This Manual adopts the same approach through Chapter 10.
> - Using open space for multi-use detention fits the soft-cover rules of the building rules, under which a plot keeps at least 10% of its area as soft cover in Category I (under 5,000 sq ft) and at least 20% in Categories II and III (Bye-Laws 2021, Table G1), a new building in the City Centre Zone earmarks 30% of the plot "for open space with soft cover and landscaping" (D8.2), and, in the Khasi Hills Autonomous District, a plot keeps at least 15% as soft cover where the covered area is 500 m² or more and at least 10% otherwise, with "Semi-pervious ground cover … as paving wherever possible" (KHADC Regulation 2015, s.35(iii)). On the tested alluvium of the Garo foothill plains and the valley fills of Ri-Bhoi, on flat ground, a detention area graded into the open space below the level of the road keeps it pervious and usable, which is what 4.10.6 requires, and can also infiltrate under Clause 4.11 (recharge rule). Everywhere else the position is different. Ground on a natural slope of more than 10°, a terrace held up by a retaining wall, land within twice the height of a cut or wall downslope of it, colluvium, fill and slide debris, mapped landslide ground, and any

limestone, cave or coal-mining ground are not to be used for ponding, because water held there soaks into the slope or into voids (Clause 4.11, hill rule and karst and mine rule). On such sites, detention is provided in lined tanks, open or closed, with an orifice outlet and an overflow to a lined drain, on rooftops and podiums under 4.10.3 and 4.10.4, or on a level open space only where it stands on rock or on ground that the geotechnical certificate of the hill rule covers (never on limestone or mine ground); an excavated pond or basin on a slope is not accepted, and semi-pervious paving there is laid on a lined or non-exfiltrating base with an underdrain. Four kinds of land are not open space for this purpose. A pung, lake or spring on the land is preserved under step 1 of Clause 4.3.1; a pung is modelled as a water surface (Clause 3.3.2(e)) that starts at its spill level (Clause 3.12.5), so only its flood storage above that level can count, and only as Chapter 7 allows; and a natural or sacred pung is never turned into a detention pond. The setbacks of the Meghalaya Waterbodies (Conservation and Protection) Guidelines 2023 (3 m or 6 m from urban streams, 10–30 m from rural streams, 10–50 m from lakes and ponds, measured from the mean high flood level of the past ten years) and the Manual's corridor of Chapter 7 are flood land already: water reaches them first, so they are not counted as detention for the development beside them. And land kept open on purpose, such as a sacred grove (law kyntang) at the head of a stream, a forest or other land with "No development" under s.2.101 of the KHADC Regulation, the 40–50° "Regulated Slope" and the > 50° "Restricted Slope/No Construction Zone" of the Shillong Planning Area (NESAC, 2023; Bye-Laws 2021, Section I(a)), or a spring-recharge area above a town's intake (Clause 4.11), is not graded or paved for detention.

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## 4.11 Rainwater harvesting versus detention accounting

4.11.1 **No double counting.** RWH storage (sumps, tanks, recharge pits and wells provided under the RWH mandate) shall **not** be counted as detention.

4.11.2 **RWH sumps assumed full.** For all routing under this chapter, RWH sumps and tanks shall be assumed **full at the start of every storm**, in every season. Their overflow shall be routed to the detention facility, or directly to the outfall if it bypasses detention. In the latter case the bypass flow counts against the PSD.

4.11.3 **Combined tanks.** A single tank may provide both RWH and detention only if:

- (a) the detention zone lies wholly **above** the RWH overflow level;
- (b) the detention zone is drained by its own gravity control orifice set at the RWH overflow level, meeting Clauses 4.7 and 4.8;
- (c) no pump, valve or user action can hold water in the detention zone; and
- (d) the two zones and the orifice level are shown on the drawings and in the maintenance declaration.

Only the volume between the RWH overflow level and the detention overflow level counts as detention.

4.11.4 **Recharge structures.** Recharge pits, trenches, shafts and wells may count as **retention** (not detention) if they meet Clauses 4.4.3 to 4.4.5. In particular, the seasonal high groundwater table shall be at least 1.0 m below their base. In the routing they are treated under Clause 4.4.6 with the groundwater level for the monsoon season.

4.11.5 **RWH remains mandatory.** Nothing in this chapter reduces the RWH requirement of Table G1 of the Bye-Laws 2021, section 36 of the Khasi Hills Autonomous District (Land Development and Building) Regulation 2015, any building rule of the Jaintia Hills or Garo Hills Autonomous District Council [TBC], the guidelines of the Central Ground Water Authority where they apply, any condition of a building permission, or any rainwater harvesting rule or direction of an approving authority.

Commentary. Rainwater harvesting in Meghalaya is required by two instruments, and neither sizes it. In the master-plan, municipal and scheme areas, Table G1 of the Bye-Laws 2021 lists "Rain Water Harvesting" for every plot category and use, adds "Ground water recharge for covered area more than 3000 sqft" for residential

buildings in Category II (plots of 5,001–25,000 sq ft), and requires soft cover of at least 10% of the plot in Category I and 20% in Categories II and III; G2.1.2 gives a 10% rebate of the building-permission fee to buildings that "Undertake both recycling of waste water and rain water harvesting structures", and new buildings in the City Centre Zone "shall adopt rain water harvesting systems" (D8.2). In the Khasi Hills Autonomous District, "Water harvesting through storing of water runoff including rainwater in all existing and new buildings shall be mandatory", and "The plans submitted shall indicate the system of storm water drainage along with points of collection of rain water in surface reservoirs or in recharge wells" (KHADC Regulation 2015, s.36). The State told the NGT that RWH is "Incorporated as one of the conditions while giving building permission", with RWH being installed at 52 locations under the Smart City Mission (action-taken report, 21.03.2023). Neither instrument gives a storage volume, a roof-area rate, a drawdown or an infiltration test [N]. **This Manual therefore sets a sizing rule for credit: RWH storage shall hold at least 25 L per m² of roof area** (about 25 mm of rain over the roof). This is set by this Manual. The 20 L per m² of the mountain editions of this series is the precedent. It is raised by a quarter because Meghalaya's towns are supplied by gravity from "streams and springs" and face "acute shortage of water during the summer as the major part of rainfall is lost as surface run-off" (CGWB, GWRA 2022), while December to February is "practically dry" (CWC subzone 2(b) report), so the store is for the dry season, not for the storm; and because, with an annual normal of 225.3–242.5 cm at Shillong (CWC subzone 2(b) report, Annex 4.1), a larger tank still refills many times in the season. The rule makes the bye-laws' requirement measurable; it does not replace it, and a larger tank is always allowed. This Manual credits these structures against its own retention requirement (Clause 4.4) as follows:

- An RWH tank under Table G1 or s.36 is RWH storage. It is not detention (Clause 4.11.1), and it is assumed full at the start of every storm (Clause 4.11.2), because in the monsoon season it is full after the first heavy rain. A tank may also provide detention only if it is built as a combined tank under Clause 4.11.3, with a detention zone above its RWH overflow level that drains through its own orifice; only that zone counts.
- An RWH tank counts toward the **retention** requirement of Clause 4.4 only to the extent that it is emptied within 72 hours by a continuous non-potable use, such as toilet flushing or washing, demonstrated under Clause 4.4.3; watering a garden is not a continuous use in the monsoon season. The tank is then modelled under Clause 4.4.6 like any other retention practice. Outside the two recharge areas below, storage and reuse is the way retention is provided, and the 25 L per m² is the first part of it.
- Recharge pits, trenches, shafts and wells count as retention only where they meet Clause 4.11.4 and the recharge rule below: they are credited only to the extent that they drain within 72 hours at half the rate measured in a site test (Clauses 4.4.3 and 4.4.5), with their base at least 1.0 m above the seasonal high water table, and the credit is found by routing under Clause 4.4.6, not by deducting their volume.
- **Hill rule.** No deliberate infiltration practice (soakaway, soak pit, recharge pit, shaft or well, infiltration trench, or permeable paving with an exfiltrating base) shall be built or credited: on natural ground sloping more than 10°; on colluvium, fill or slide debris, whatever its slope; in a mapped landslide zone or landslide locality, among them, in Shillong, Laitumkhrah, Lawsohtun, Happy Valley, Mccabe Road, Bethesda and Arbuthnot and the very-high-susceptibility ground along NH-40 and near the Umshyrpi named in the IRADe/NMHS plan; or upslope of a cut slope or retaining wall within twice the height of the cut or wall — unless a geotechnical certificate by a qualified geotechnical engineer or engineering geologist shows that the added water will not destabilise the slope. On such sites roof runoff goes to rainwater storage of at least 25 L per m² of roof, with overflow to a lined drain that discharges through a sediment trap and an energy dissipator to a stable natural channel, never onto an unprotected slope. The rule applies in every sub-area of Annex 2A except on the tested alluvium of sub-area ML-A1 and the tested valley fills of Ri-Bhoi on flat ground. The Bye-Laws 2021 are its hooks: no construction above 50° and a limited regime on 40–50° (Section I(a)), cuts of 3.00 m, or 6.00 m to the crest of an RCC wall, with a report of the Geological Survey of India beyond (B1(vii); the same limits in s.34(v) of the KHADC Regulation), and "good drainage facilities to prevent excessive saturation of sub-surface formations" (Section I(b)1). Where the geotechnical report of B1(vi) or the GSI report of B1(vii) is required, it shall also state whether the site's drainage, storage and any infiltration add water to the slope. On these sites, retention is provided by storage and reuse, and detention by lined tanks, not by ponds or basins on the slope (Commentary to Clause 4.10). The 1.0 m groundwater separation of Clause 4.4.3 does not make an infiltration practice acceptable on a slope: perched water and pore pressure in a slope are the hazard, not the depth to the water table.

- **Karst and mine rule.** No deliberate infiltration practice shall be built or credited, and no geotechnical certificate makes one acceptable, on limestone (the Sohra–Shella limestones of sub-area ML-C and the Jaintia limestones of sub-areas ML-B1 and ML-C round Khliehriat, Lumshnong and Sutnga), within a coal-mining area (the rat-hole workings of the Jaintia and Garo coalfields), or where caves or sinkholes are known. There drains are lined, routed away from cave entrances and checked for void collapse along their alignment; drainage from mine spoil is not routed to a drinking-water intake or to any infiltration device; and pH and metals are added to the outfall checks of Chapter 8. Water put into limestone or a mine void does not stay where it is put: the CGWB describes a "Discontinuous aquifer in the cavernous limestones and sandstones area" (GWRA 2022, Table 1); in the coal belt "smaller streams and rivers either disappear or have become seasonal in nature as surface water trickles into and disappears in the unfilled mine pits and caves" (as reported); and the Krem Liat Prah–Um Im–Labit cave system of the Jaintia hills is reported to run for 30.9 km (as reported). No karst map, sinkhole inventory or subsidence record was found [TBC], so no test can show where the water goes, and the rule has no certificate exception.
- **Recharge rule.** Recharge is not a design objective in Meghalaya: every assessment unit is safe, and the stage of groundwater extraction was 3.55% in GWRA 2022 (CGWB) and 4.60% in GWRA 2024 (as reported). Deliberate recharge is allowed only on the alluvium of sub-area ML-A1 (the Garo foothill plains and the Jinjiram valley, with water 3–5 m below ground) and on the valley fills of Ri-Bhoi in sub-area ML-A, where the NAQUIM tests gave a rainfall infiltration factor of 13% (GWRA 2022, §4.4), on ground sloping 10° or less, away from slide-prone slopes, after a field infiltration test, where the seasonal high water table stands more than 2 m below ground in the monsoon season and with the separation of Clause 4.12, and through a silt trap, a filter and a first-flush diverter ahead of the recharge structure. Everywhere else rainwater harvesting is storage and reuse for the dry season.
- **Where Table G1 asks for recharge on a forbidden site.** Table G1's "Ground water recharge for covered area more than 3000 sqft", and the "recharge wells" of s.36 of the KHADC Regulation, can fall on a site where the hill rule or the karst and mine rule forbids infiltration. This Manual does not override the bye-law or the regulation. It states the conflict plainly: on such a site the Manual requires storage and reuse in place of recharge, with the overflow to a lined drain, and the applicant seeks the relaxation of the recharge requirement from the Authority, citing this rule and, where one is required, the geotechnical or GSI report. Until the Authority relaxes it, the bye-law requirement stands, and a recharge structure that the bye-law forces on such a site earns no credit under this Manual.
- **Springs and sacred groves.** Springs and streams, not wells, supply most towns (GWRA 2022). The MBDA spring-shed programme is reported to have mapped 1,000 springs, or to hold an inventory of 1,400 (both as reported: the figures conflict), and the State reports work on 306 springsheds (State scheme page, as quoted). No spring statute was found; the hooks are s.62(b) of the Municipal Act, which vests "springs" in the Board, and s.15(1) of the KHADC Regulation, which protects "catchment areas, water sources, spring sheds, streams and rivers". In the recharge area of a spring above a town's intake, where it has been mapped, no surface shall be paved and no road or parking runoff shall be infiltrated; only clean roof runoff, passed through a filter, may be infiltrated, and only where the three rules above allow; and drains and fills shall not intercept or bury a spring outlet. A sacred grove (law kyntang) above a town is treated as a protected source catchment, with KHADC s.15 as the hook (all set by this Manual).
- **Polluted runoff.** Runoff from fuel stations, workshops, industrial premises and the like, from mine spoil, and from any drain or jhora that carries sewage, as most of Shillong's drains do (Commentary to Clause 4.1), shall not be recharged; road and parking runoff shall be recharged, where the recharge rule allows it at all, only through a surface practice with a filter, such as a vegetated basin or trench, never directly into a bore or well (Chapter 8).

In the hills, water put into the ground does not stay where it is put. The IRADe/NMHS plan records that in Shillong "due to increasing levels of urbanization and unregulated construction work the natural drainage system is blocked", and names the landslide localities above; Meghalaya's landslides caused "approximately 22 deaths in 2014" (as cited from the Revenue and Disaster Management Department); and the landslides in 15 villages of Umling block in May 2025 were linked to hill cutting along NH-6 (as reported). In the monsoon season an RWH tank is full after the first heavy rain, and on the alluvium a recharge pit can sit in the water table. Treating RWH as detention would therefore credit storage that does not exist when it is needed. That is why this Manual assumes

> RWH tanks are full at the start of every storm. Applying the assumption to every season keeps one simple rule. The combined-tank provision (4.11.3) lets an owner build one structure, as long as the detention part is empty when the storm arrives. The 25 L per m² sizing rule, the hill rule, the karst and mine rule, the recharge rule, the treatment of the Table G1 conflict, the spring and sacred-grove rules and the polluted-runoff rule are set by this Manual. No Meghalaya source sets a slope or distance threshold for infiltration: the slopes in the Bye-Laws 2021 (40° and 50°) and in the NESAC classes are limits on building. The 10° limit is set by this Manual, as in the mountain editions of this series, well below those slopes, because a slope that can carry a building can still be destabilised by water put into it, and the distance of twice the height of a cut or wall is set by this Manual as a precaution, pending guidance from a geotechnical study for the State [TBC]. The karst and mine rule is new in this series; it has no certificate exception because, unlike a slope, a void cannot be seen from the surface.

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## 4.12 High-groundwater and sandy coastal sites

4.12.1 **Design groundwater level.** Each site in the alluvium of the Garo foothill plains and the Jinjiram valley in sub-area ML-A1, where the water table stands 3–5 m below ground, the valley fills of Ri-Bhoi, the floodplains and low terraces of the rivers and the valley floors of the Umkhrah and Umshyrpi in Shillong, the limestone and sandstone ground of the escarpment and the Jaintia hills, where water stands 2–4 m below ground, the margins of Ward's Lake (Nan Polok), Thadlaskein (Pung Sajar Nangli) and the other pungs and lakes, the margins and backwaters of Umiam lake and the other MePGCL reservoirs, and hill sites with perched water or springs, or any area where the groundwater table lies within 3 m of the surface at any time of year shall establish a design groundwater level (DGWL) for the facility. The DGWL is the seasonal high level during or after the monsoon, from:

- (a) site piezometer readings over at least one full April–November season; or
- (b) where (a) is not available, the higher of the CGWB or Water Resources Department record for the nearest observation well, plus **0.5 m**, and the design flood level of any adjacent river, stream, jhora, pung, lake or reservoir.

For the flotation check of 4.12.3 at sites in the alluvium of the Garo foothill plains and the Jinjiram valley, the valley fills of Ri-Bhoi, the river terraces and floodplains, and the pung, lake and reservoir margins, where (a) is not available, the DGWL shall be taken as existing ground level.

4.12.2 **Lined storage.** Where the DGWL is less than 1.0 m below the base of a storage facility:

- (a) the facility shall be watertight (lined or of watertight concrete), and no infiltration credit applies (Clause 4.4.4); or
- (b) if unlined, the volume below the DGWL shall not be counted as detention, and groundwater inflow shall be added to the routed inflow.

4.12.3 **Uplift and flotation.** Every below-ground tank, vault, lined pond or chamber shall be checked for flotation:

- with the facility empty;
- with groundwater at the DGWL; and
- for coastal sites, with groundwater also at the major-system tailwater level of Chapter 5, where that is higher.

The factor of safety against uplift, counting only permanent dead loads and ignoring wall friction unless supported by geotechnical design, shall be at least **1.2**. Anchoring by ballast, toe extensions or tension piles may be used.

4.12.4 **Shallow and above-ground storage preferred.** On sites where the DGWL is within 1.5 m of ground, storage should be provided above ground where possible: rooftop, podium, landscape or surface storage. Deep tanks should be avoided.

4.12.5 **Durability.** Concrete and metal parts in contact with saline or brackish groundwater or tidal water shall be designed for the exposure class appropriate to coastal conditions under IS 456:2000. Outlet fittings, trash racks and gates shall be of stainless steel, HDPE, FRP or another corrosion-resistant material.

4.12.6 **Sandy soils with deep groundwater.** Where the DGWL is 1.0 m or more below the base, infiltration retention in sandy soils is encouraged. The design infiltration rate of Clause 4.4.3 applies, and the Chapter 8 requirements on pollution of shallow aquifers shall be met.

> Commentary. Meghalaya is landlocked, so the coastal provisions of this clause, the tidal water levels of 4.12.1 and 4.12.3, do not apply in the State, and no saline groundwater was reported in the assessments read for this Manual [TBC]. The CGWB reports groundwater with a pH of 5.4–8.2 and iron above the permissible limit at Shillong (11.25 mg/l), Nongpoh (5.7), Balat (7.2), Dawki (3.2), Bajengdoba (3.8) and Kharkutta (4.88 mg/l) (GWRA 2022), and runoff and seepage from the coal-mine spoil of the Jaintia and Garo hills is acid and metal-laden (as reported); in the coal-mining areas, and wherever a site test shows acid or iron-rich groundwater, the exposure provisions of 4.12.5 apply to concrete and metal parts as if the groundwater were aggressive, with the exposure class set from the test (set by this Manual). Groundwater lies at four kinds of depth (GWRA 2022, Table 1). In the alluvium of the Garo foothill plains it is shallow, 3–5 m below ground, in a thick continuous aquifer, and higher still beside the Jinjiram in flood. In the limestones and sandstones of the escarpment and the Jaintia hills it is at 2–4 m, in a discontinuous, cavernous aquifer, and in the coal belt the pits hold water at unknown levels. In the Garo Group of the Tura and Williamnagar hills it is at 4–9 m. On the plateau, in the gneiss and the Shillong Group, it is at 7–17 m in weathered and fractured rock, but perched water and springs occur in the slopes, and the valley floors of the Umkhrah and Umshyrpi in Shillong are wet when the streams rise. The Garo foothill plains, the valley fills of Ri-Bhoi, the river floodplains and low terraces, the valley floors of the Shillong streams, the margins of the pungs and lakes and of Umiam lake and the other reservoirs, and hill sites with perched water or springs are the wet cases. There an unlined tank fills with groundwater before the storm, and an empty lined tank can float, especially when a river in flood, a reservoir at its full level or a pung at its spill level raises the water table beside it. The design groundwater level of 4.12.1(b) therefore takes the design flood level of the adjacent river, stream, jhora, pung, lake or reservoir where that is higher than the well record, and on the alluvium of the Garo foothill plains and the Jinjiram valley, the valley fills of Ri-Bhoi, the river terraces and floodplains and the pung, lake and reservoir margins it is taken as existing ground level for the flotation check unless piezometers show otherwise. On a hill site, a deep tank is not preferred even where groundwater is deep, because a leaking tank on a slope is an infiltration practice by another name: storage on a slope or on limestone shall be lined and watertight, and its leakage and overflow taken to a lined drain (Clause 4.11). The April–November monitoring season of 4.12.1(a) is set by this Manual to cover the Manual's monsoon season of 1 April to 31 October, whose pre-monsoon storms can raise the water table in April and May, and the post-monsoon high after the withdrawal in mid-October; a reading taken in March understates the design level. Most of the State's observation wells are those of the CGWB, North Eastern Region, Guwahati. No monsoon water-table depths for individual town sites in Shillong, Tura, Jowai, Nongpoh or the Garo plains, and no map of the seasonal high water table, were obtained [TBC]. The factor of 1.2, the 0.5 m allowance, the "ground level" default for the plains, valley fills, floodplains and waterbody margins, and the exposure rule for acid groundwater have no direct precedent; this Manual sets them because no published site-scale seasonal groundwater depths for Meghalaya were found during research.

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## 4.13 Regional detention and fee-in-lieu

4.13.1 **Where permitted.** In a basin covered by a Basin Stormwater Master Plan approved under Chapter 11, a development may meet all or part of its detention requirement through:

- (a) a regional detention facility identified in the plan; or
- (b) a fee-in-lieu paid toward restoration of pung or tank storage identified in the plan.

4.13.2 **Conditions.** Regional detention or fee-in-lieu shall be accepted only where:

- (a) the regional facility or restored tank is operational, or is funded and scheduled to be operational within **3 years**. Until then, interim on-site detention is required.
- (b) the conveyance from the site to the facility carries the 1% AEP post-development flow without increasing water levels at buildings or roads between them (Chapter 5);
- (c) the storage credited at a tank is the **flood storage** only. This is the volume between full tank level (FTL) and the maximum water level the bund and surplus weir can safely hold, plus any volume below FTL that a notified operating rule commits to empty before the monsoon. Storage below FTL that is held for irrigation or supply through April to October shall not be credited.
- (d) the tank meets Chapter 7: surveyed FTL, a documented operating rule, and a maintained surplus weir;
- (e) the site still provides **retention** (Clause 4.4) and **WQv** treatment (Chapter 8) on site; and
- (f) in flood-sensitive catchments, the regional facility meets the mixed-frequency rule for its whole contributing area.

4.13.3 **Fee.** The fee-in-lieu shall be computed as:

> Fee = (detention volume required on site under Clause 4.6, m³) × (unit rate, ₹/m³, notified by the Authority)

The unit rate shall include land, construction and 10 years of maintenance. Fees shall be held in a ring-fenced basin account and spent only on the facilities named in the plan.

4.13.4 **Ledger.** The Authority shall keep a public ledger of:

- detention volume credited to each regional facility;
- volume delivered; and
- fees received and spent.

> Commentary. The Malaysian DID (2008) checklist favoured community ponds over on-site detention for sites above 0.1 ha. Studies of on-site detention show that its benefit depends on location and fades with distance downstream (Colorado State University thesis; McEnroe for Kansas City), and that a pond low in the catchment can synchronise with the main-stem peak (*Water* 2016). Regional storage therefore has to be sited by basin modelling, not simply aggregated.
>
> Meghalaya has no tank or lake Act, and no pung, lake or reservoir in its towns was found to be operated for flood control under a documented rule. The Meghalaya State Wetlands Authority was constituted on 1 November 2017 under the Wetlands (Conservation and Management) Rules 2017, with the Principal Chief Conservator of Forests as its member secretary (notification No. ENV.1/2007/Pt/110), but no wetland in the State was found notified under rule 4 of those Rules [TBC], and the State has no Ramsar site: of 225 waterbodies ground-truthed for the High Court in 2025, "none … qualify as a Ramsar site" (as reported). The State's regional storage is of five kinds: the reservoirs of MePGCL, Umiam lake (impounded in 1965; about 10.148 km² at full level, with a gross capacity reported to have fallen from 179.757 Mm³ in 1965 to 159.206 Mm³ in 2004, as reported), Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka; the small urban lakes, such as Ward's Lake (Nan Polok) in Shillong; the pungs (Khasi and Pnar: pond, pool or small lake; Garo: *pokri*), such as Thadlaskein (Pung Sajar Nangli) near Mukhla (as reported); the springs that supply most towns; and the river floodplains, which the Meghalaya Flood Plain Zoning Act 2026 can protect once zones are notified, as none yet is. Four points follow:
>
> - A pung on the record may not be a working pung, and a pung in the hills is not a detention basin. No inventory of the pungs, lakes and springs within the Municipal Boards and the Town Committees, with their beds, rims and outlets, was found [TBC]. A pung or lake is credited only after a survey shows its bed, rim

and outlet, and only for the storage above its spill level; a natural, community or sacred pung is never turned into a detention pond, and engineered storage is called a detention pond. A spring-recharge area is not storage for detention (Commentary to Clause 4.11).

- The reservoirs are not spare capacity for a site. They are small, held for power through the season and released "frequent[ly] … during Monsoon as well as during Non-monsoon period" (MePGCL guidelines); Umiam lake has lost storage to sediment since 1965 (as reported) and receives Shillong's sewage-laden streams; their storage below full level is not credited (Clause 4.13.2(c)); their releases are set by MePGCL for the whole river; and storm water spilled to a reservoir, or to a reach below a dam, can be relied on only with the written agreement of MePGCL, or of NEEPCO on the Kopili, for a stated flow and level.
- A pond or check dam in the bed of a jhora or hill stream is not regional detention unless it is designed for debris and garbage. The jhoras carry boulders, slide debris and solid waste in every large storm (49,612 m³ of waste was removed from the Wahumkhrah under the 15th Finance Commission, with stone bunds and solid-waste traps built for ₹3.60 crore; State action-taken report to the NGT, 21.03.2023); such a facility is credited only for the storage left after the sediment and debris volume of Chapter 6, with a debris rack or trap at its inlet, a geotechnical check of its bund and abutments, its failure path mapped, and a maintenance budget for clearing it after each large storm (Chapters 9 and 10). A regional facility on a slope is also subject to the hill rule, and one on limestone or in a coal-mining area to the karst and mine rule, of Clause 4.11; in sub-areas ML-C and ML-C1 no storage is credited against the 24- to 72-hour storms (Clause 2.3.6).
- No rule dividing natural streams from municipal drains was found [TBC]. Until one is made, this Manual follows the working assignment of Chapter 1: drains, public streams, springs and tanks within municipal limits as the Municipal Board's (Meghalaya Municipal Act 1973, s.62); roadside drains and culverts as the PWD (Roads)'s, and on NH-6 and the Shillong–Dawki road NHAI's or NHIDCL's; the Cantonment's drains as the Shillong Cantonment Board's; New Shillong's as NSTDA's [TBC]; rivers and flood works as the Water Resources Department's; village drains and jhoras outside municipal limits as the District Council's and the Dorbar Shnong's under the District Council's rules (the Garo Hills village institutions were not researched [TBC]); the reservoirs and release reaches as MePGCL's; catchment treatment as the Soil and Water Conservation Department's; and Smart City works as Shillong Smart City Ltd's (as reported). Each town keeps a drain-and-jhora register giving every reach its owner, its land status (community, clan, private or State) and whether it is a "waterbody" under the Waterbodies Guidelines (Commentary to Clause 6.9). This is the Manual's working assignment, not a statutory one; where land is community, clan or private, a drainage corridor or easement is secured by agreement with the landholding institution, not taken.

The first point is the basis of condition 4.13.2(c) in Meghalaya. A pung or lake gives flood storage only above its spill level, unless a notified operating rule commits it to be lowered before the monsoon season. The 3-year operational limit and the 10-year maintenance allowance have no direct precedent and are set by this Manual.

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## 4.14 Simplified methods for small sites

4.14.1 **Applicability.** Tier B local bodies may permit the simplified method for sites of **2 ha or less** outside flood-sensitive catchments. In flood-sensitive catchments, it may be used for sites of **0.5 ha or less**. All other sites shall use Clause 4.6. Until Table 4.3 (Annex 4B) is published, all Tier B sites shall also use Clause 4.6.

4.14.2 **Method.**

1. Read the PSD (L/s/ha) and SSR (m³/ha) for the site's zone, HSG and post-development imperviousness from **Table 4.3** (Annex 4B).
2. Required storage: V = SSR × A − V_credit (Clause 4.4.6.3).
3. Permissible discharges: Q_PSD,T = PSD_T × A for the 2-yr and 100-yr stages.
4. Select the low-flow orifice and upper control from the standard outlet table in Annex 4B (orifice sizes for the PSD at the stated depths), subject to the 50 mm minimum.

5. Provide a spillway or overflow under Clause 4.9, the RWH accounting of Clause 4.11, and the safety provisions of Clause 4.15.
6. Complete Form 4-2 (Tier B site sheet).

**Table 4.3 — Tier B permissible site discharge and site storage requirement (template)**

| Zone (Annex 2A) | HSG | Imperviousness | PSD 2-yr (L/s/ha) | PSD 100-yr (L/s/ha), standard | PSD 100-yr (L/s/ha), flood-sensitive | SSR (m³/ha), standard | SSR (m³/ha), flood-sensitive |
|---|---|---|---|---|---|---|---|
| ML-Z1 Northern foothills: ML-A Northern foothills and Ri-Bhoi (Nongpoh–Umsning–Byrnihat–Umiam) | B / C / D | 50% / 70% / 90% | [TBC] | [TBC] | [TBC] | [TBC] | [TBC] |
| ML-Z1 Northern foothills: ML-A1 Garo foothills and plains (Resubelpara–Mendipathar–Tikrikilla–Phulbari) | B / C / D | 50% / 70% / 90% | [TBC] | [TBC] | [TBC] | [TBC] | [TBC] |
| ML-Z2 Plateau: ML-B Shillong plateau (Shillong–Mawphlang–Nongstoin–Mairang) | C / D | 50% / 70% / 90% | [TBC] | [TBC] | [TBC] | [TBC] | [TBC] |
| ML-Z2 Plateau: ML-B1 Jaintia hills karst and mine belt (Jowai–Khliehriat–Sutnga–Ladrymbai) | C / D | 50% / 70% / 90% | [TBC] | [TBC] | [TBC] | [TBC] | [TBC] |
| ML-Z3 Southern escarpment: ML-C Southern escarpment (Sohra–Mawsynram–Shella–Pynursla–Dawki) | — | — | Not tabulated: Clause 4.6 applies (Clause 2.3.6(c)(ii)) | — | — | — | — |
| ML-Z3 Southern escarpment: ML-C1 South Garo slopes (Baghmara–Siju–Gasuapara) | — | — | Not tabulated: Clause 4.6 applies (Clause 2.3.6(c)(ii)) | — | — | — | — |
| ML-Z4 Garo hills: ML-D Garo hills interior (Tura–Williamnagar–Rongjeng–Ampati–Dalu) | C / D | 50% / 70% / 90% | [TBC] | [TBC] | [TBC] | [TBC] | [TBC] |

**Worked example (illustrative — not design values).**

A 0.4 ha residential layout in a Tier B Municipality, in a flood-sensitive catchment, with about 80% directly connected impervious area (area-weighted post-development CN about 92). Suppose Table 4.3 had been computed and gave the per-hectare equivalent of the Clause 4.6.7 example:

- PSD 100-yr = 356 / 2.0 = 178 L/s/ha
- SSR = 2,913 / 2.0 ≈ 1,460 m³/ha
- PSD 2-yr ≈ 17 L/s/ha

Then:

- Storage: V = 1,460 × 0.4 = **584 m³**. C_R = 0, so there is no retention credit.
- 100-yr release: 178 × 0.4 = **71 L/s**.

- 2-yr release: 17 × 0.4 = **7 L/s**. At about 1 m head this needs a low-flow orifice of about 60 mm, above the 50 mm minimum (Clause 4.8.2).
- Layout options:
  - a 400 m² underground tank 1.5 m deep; or
  - 250 m² of podium storage at 0.3 m (75 m³) plus a 350 m² tank 1.5 m deep (525 m³).
  - Rooftop storage at 150 mm over 1,200 m² of roof (180 m³) could replace part of the tank.
- RWH sumps are additional, and are assumed full (Clause 4.11).

> **Commentary.** Australian councils use permissible site discharge and site storage requirement tables in the same way (Sydney Water OSD guide; the Upper Parramatta River Catchment Trust handbook listed SSR of about 455 m³/ha). The illustrative SSR here, about 1,460 m³/ha, is much larger. That is the expected effect of combining a mixed-frequency cap with mandatory 48–72-hour storms at AMC III. MSMA 2 in Malaysia offers a similar simplified OSD method for sites under 5 ha. The MARC policy supplement offers smaller Kansas City municipalities adoptable alternatives within the regional standard; Clause 4.14 follows that model for Tier B.

4.14.3 **Fixed-coefficient route.** As an alternative to Clauses 4.6 and 4.14.2, the designer of any site of **1 ha or less**, under any Approving Authority and in any catchment, may size detention by Clauses 4.14.4 to 4.14.7. The route shall not be used where:

- (a) the site counts tank or waterbody storage in its design (Chapter 7);
- (b) any part of the site lies within a waterbody setback (Chapter 7); or
- (c) the site drains to a tank cascade whose storage is counted in a downstream design.

The route sets the release caps by fixed coefficients and does not need Table 4.3. It may therefore be used before Annex 4B is published. Retention (Clause 4.4), drawdown (Clause 4.7), outlets (Clause 4.8), the spillway (Clause 4.9), the downstream and tailwater checks (Chapter 5) and water quality (Chapter 8) still apply.

4.14.4 **Release caps.** Two caps apply at each point where runoff leaves the site:

$Q_{cap,10} = 2.78 \times C_{10} \times i_{10} \times A$ and $Q_{cap,2} = 2.78 \times C_2 \times i_2 \times A$

where $Q_{cap}$ is in L/s; A is the site area (ha); $i_{10}$ and $i_2$ are the 10% AEP (10-yr) and 50% AEP (2-yr) rainfall intensities (mm/h) for a **15-minute** duration at the site, from the sources of Chapter 2, with the climate factor of Clause 2.8; and $C_{10}$ and $C_2$ are the fixed coefficients of Table 4.3A for the site's hydrologic soil group (Clause 3.7). For a site with more than one soil group, the coefficients are area-weighted.

**Table 4.3A — Fixed release coefficients (provisional)**

| Hydrologic soil group | $C_{10}$ | $C_2$ |
|---|---|---|
| A (sandy, well drained) | 0.05 | 0.02 |
| B | 0.08 | 0.03 |
| C | 0.15 | 0.08 |
| D (clay, poorly drained) | 0.25 | 0.15 |

$Q_{cap,10}$ is the maximum release for **every storm up to and including the 1% AEP (100-yr) storm**, in every catchment. $Q_{cap,2}$ is the maximum release for the 50% AEP (2-yr) storm. Where a cap is smaller than the discharge of a 50 mm orifice at the corresponding stage, the 50 mm orifice is deemed to comply (Clause 4.5.5.1).

4.14.5 **Storage.** The detention storage V (m³) is the larger of $V_{100}$ and $V_2$, each the largest over the durations d of Clause 2.5.2 (1 to 72 hours):

V_100 = max over d of [ 10 × C_v × P_100(d) × A − 1.8 × Q_cap,10 × d ]

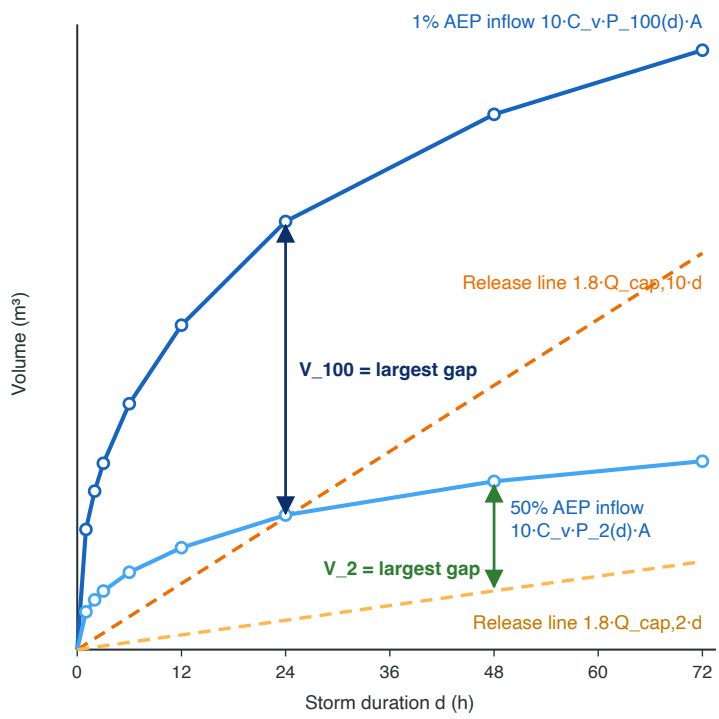
V_2 = max over d of [ 10 × C_v × P_2(d) × A − 1.8 × Q_cap,2 × d ]

where P_100(d) and P_2(d) are the 1% and 50% AEP rainfall depths (mm) for duration d (hours), with the climate factor; and C_v is the post-development volumetric coefficient: the composite C of Table 3.2 (upper half of each range), multiplied by Cf of Table 3.3 for the 1% AEP. For durations of 12 hours or more, C for every pervious surface shall be taken as not less than **0.50**. The factor 1.8 assumes an average release of half the cap over the storm (3.6 × 0.5).

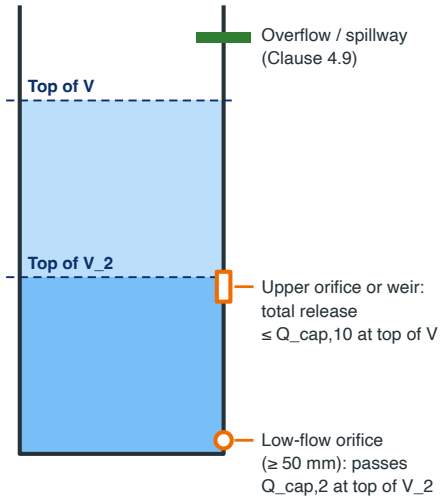
4.14.6 **Outlet.** The outlet shall be a two-stage control: a low-flow orifice that passes Q_cap,2 when the storage holding V_2 is full, and an upper orifice or weir that limits the total release to Q_cap,10 at the top of V. The outlet table of Annex 4B may be used once it is published.

4.14.7 **Retention.** The retention volume of Clause 4.4 is provided in addition to V. No retention credit (Clause 4.4.6) is taken under this route.

**Fixed-coefficient route for sites of 1 ha or less (Clauses 4.14.3–4.14.7) — schematic, not to scale**




**Two-stage outlet (Clause 4.14.6)**




Retention (Clause 4.4) is provided in addition; no retention credit (Clause 4.14.7)

Dots: durations of Clause 2.5.2 (1, 2, 3, 6, 12, 24, 48, 72 h). Pervious C ≥ 0.50 for d ≥ 12 h.

Q_cap,10 = 2.78 × C_10 × i_10 × A ; Q_cap,2 = 2.78 × C_2 × i_2 × A ; (L/s; A in ha; i in mm/h)

C_10, C_2 from Table 4.3A by soil group; i_10, i_2 for a 15-minute duration with the climate factor (Clause 2.8)

V = max(V_100, V_2); V_T = max over d of [ 10 × C_v × P_T(d) × A – 1.8 × Q_cap × d ] (m³) ; 1.8 = 3.6 × 0.5 (average release of half the cap)

*Figure 4.3 — Fixed-coefficient route for sites of 1 ha or less (Clauses 4.14.3 to 4.14.7): the release caps Q_cap,10 and Q_cap,2 from Table 4.3A; the storage V as the largest gap, over the durations of Clause 2.5.2, between the cumulative inflow 10·C_v·P(d)·A and the release line 1.8·Q_cap·d, for the 1% and 50% AEP storms; and the two-stage outlet that passes Q_cap,2 at the top of V_2 and Q_cap,10 at the top of V. Schematic, not to scale. Original drawing for this Manual, adapted from the rainfall mass-curve (inflow minus outflow) storage concept and the single-coefficient peak cap of the PUB Code of Practice on Surface Water Drainage, 7th ed. (cl. 7.1.5).*

> **Commentary.** The fixed-coefficient route follows Singapore, which caps the peak runoff from every development of 0.2 ha or more with one runoff coefficient, C = 0.55, applied to the 10-yr storm (PUB Code of Practice on Surface Water Drainage, 7th ed., cl. 7.1.5, Addendum No. 3, 2025). It is quick to apply and quick to check: the cap needs only the site area, the soil group and two intensities. PUB's 0.55 is not used here, because Singapore's baseline is the existing urban drainage system, while this Manual's baseline is greenfield land (Clause 4.5.1.2). The coefficients of Table 4.3A are set by this Manual from the greenfield curve numbers of Clause 3.3 (CN 39, 61, 74 and 80 for soil groups A to D). They are the ratios of runoff to rainfall that those curve numbers give for 1-hour depths typical of the Shillong plateau, rounded down. They are therefore **provisional**. The State Stormwater Technical Committee shall confirm or revise them against NIH-DHAARA values for each zone when it issues Annex 4B.
>
> The route is deliberately **stricter** than the full method, so that simplicity costs the developer storage rather than costing the people downstream. The 100-yr release is held to about the greenfield 10-yr peak everywhere, which is the flood-sensitive rule of Clause 4.5.3; the storage assumes the outlet releases only half the cap on average; pervious ground is assumed wet in long storms; and no retention credit is taken. A designer who wants a smaller tank can use the full method of Clause 4.6. The storage formula is the rainfall-mass (inflow minus outflow) method. Clause 3.4.2 otherwise forbids rainfall-based peak methods for storage, because they ignore the shape of the hydrograph; this route is a stated exception because its conservative assumptions cover that error for small sites, and the 24- to 72-hour durations are always checked.

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## 4.15 Safety, fencing and multi-use

4.15.1 **Depth limits for publicly accessible storage.** Where the public has access to a storage area (parks, playfields, open space, school grounds):

- (a) maximum depth in the 10% AEP storm: **0.45 m**;
- (b) maximum depth in the 1% AEP storm: **1.2 m**, except in a fenced zone under 4.15.3;
- (c) side slopes: no steeper than **4H:1V**, with at least a quarter of the perimeter at **6H:1V** or flatter for escape; and
- (d) no vertical drop greater than **0.3 m** within the storage area or at its edge.

4.15.2 **Wet basins.** Permanent pools shall have:

- a safety bench at least 3 m wide, no more than 0.3 m below the normal water level; and
- an emergent planting fringe that deters entry.

4.15.3 **Fencing.** A fence at least **1.2 m** high, of a non-climbable design with a lockable gate, is required around any part of a storage that:

- has a vertical wall or headwall drop greater than **0.6 m**;
- exceeds 1.2 m depth in the 1% AEP storm with slopes steeper than 4H:1V; or
- contains an outlet structure with an opening larger than 300 mm that is not grated.

4.15.4 **Outlets.** Every inlet and outlet opening larger than 300 mm accessible to the public shall be fitted with a grate or rack. The grate shall be designed so that a person pinned against it can escape: low approach velocity, inclined, with a large open area.

4.15.5 **Signs and depth markers.** Every publicly accessible storage shall have signs in Khasi or Garo and English stating that the area floods during rain, and a depth marker at the deepest point.

4.15.6 **Confined spaces.** Underground tanks shall have lockable covers. They shall be marked as confined spaces, and the maintenance declaration (Chapter 10) shall state the entry procedure.

4.15.7 **Vector control.** Dry storage shall drain completely (Clause 4.7) and have no low points that pond for more than 72 hours. Wet basins shall meet Clause 4.10.7.

> Commentary. The numeric limits in Clause 4.15 have no single direct precedent. They are drawn from common international practice, for example KC APWA 5600 (2006), which required at least a quarter of a dry-pond perimeter at 5:1 or flatter, a 20 ft (6 m) clearance from property lines and a 15 ft (4.6 m) maintenance strip. They are made somewhat stricter here because multi-use storage on open space land and in schools will be used by children during the monsoon. Standing water in dry basins is a mosquito-breeding risk, so complete drainage (Clause 4.15.7) is a public-health requirement, not an amenity.

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## 4.16 Basis: why peak matching alone fails

> Commentary. This section has no requirements. It records why this chapter requires release **below** pre-development rates, retention, long-duration checks and a downstream analysis, rather than simple peak matching.
>
> 1. **Timing.** Detention lowers a site's peak but stretches its hydrograph (Figure 4.1). Downstream, the stretched releases from many sites overlap with each other and with the main-stem peak. In Denver's study, ten basins each releasing 100% of the historic 100-yr peak produced 106% of the historic peak at the outlet. Only releasing 90% at each site brought it to 97% (UDFCD memo, 2012). A Colorado State University thesis found that location-blind on-site detention "can actually increase peak flows above post-development peaks". An optimisation study found that a downstream pond performed worse than upstream ponds because its outflow synchronised with the main stem (Water 2016, 8(7):290).
> 2. **Volume.** Detention does not remove volume. In the illustrative example, the post-development 100-yr storm produces about three times the runoff volume of the pre-development 10-yr storm (Clause 2.11). Only retention, or storage that empties to somewhere other than the receiving drain, reduces volume.
> 3. **Scale.** Kansas City modelling (McEnroe, 2005) found that uniform 3 cfs/ac control reduced Q100 by 36% in a 200-ac watershed. With the same control everywhere, Q100 still rose by 40% at 14 sq mi, and the benefit faded beyond about 1–2 sq mi. The KC committee concluded that "'match existing' can harm streams" (MARC Evolution deck). Georgia makes a ten-percent downstream analysis mandatory for the same reason: "Due to peak flow timing and runoff volume effects, some structural practices fail to reduce discharge peaks to pre-development levels downstream" (GSMM 2016).
> 4. **Design-storm dependence.** An Australian study of 20 real on-site detention systems found that designs using even ten temporal patterns "cannot reliably produce an OSD system design that will always be effective" under real rainfall (Water Science and Engineering, 2019). This is why Clause 4.6.3 routes the full duration matrix rather than one critical storm.
> 5. **Closed outfalls.** In Meghalaya the governing failure takes three forms. On the valley floors of Shillong it is a stream that rises faster than the drains can empty: Polo, Pynthorbah, Nongmynsong, Forest Colony and Mawlai flood "with nearly every heavy downpour" when the Wah Umkhrah overflows, a flooding attributed to "clogging of Wah Umkhrah and the decreasing width of the river due to human activities" (as reported; the same text in the IRADe/NMHS plan), and NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" and that "the water tops the banks along most of the streams" (NESAC, 2023). The Umkhrah and the Umshyrpi have no gauge, so how long they stay above a drain's outlet is not recorded anywhere. On the reservoirs and below the dams it is volume with no outlet: Umiam lake, Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka are held near their full levels for power, their releases are set by MePGCL and announced by siren, telephone or SMS rather than by notice (MePGCL guidelines), and when a reservoir is at that level every drain below it discharges to a water surface that cannot fall until the operator releases. On the Garo plains, the Jinjiram and the Brahmaputra back up into the foothill streams, as in September 2012 ("over 100 villages", IRADe/NMHS plan, Table 17) and September 2014, when the Brahmaputra and the Jinjiram "submerged over 200 villages" (as reported).

> Everywhere in the hills the outfall can also be closed by debris and garbage: the jhoras rise within minutes and carry boulders, slide debris and solid waste that bury outfalls and block culverts, and 49,612 m³ of waste was removed from the Wahumkhrah alone under the 15th Finance Commission (State action-taken report to the NGT, 21.03.2023). No hourly record of how long any river, reservoir or pung in Meghalaya stays above a town's outfalls was obtained [TBC], no CWC site in the State has a warning or danger level, and no document was found that sets a design river level for an outfall; Chapter 5 sets the design level and the closure to be assumed (Clause 5.8.5), and Chapters 6 and 9 the debris and blockage allowances. A perfectly orificed basin behind a closed outfall simply fills. No release-rate rule can fix that; it is handled by the outfall-closed check of Chapter 5.
>
> The response in this Manual is layered:
>
> - release below pre-development (Clause 4.5);
> - retain the frequent storms (Clause 4.4);
> - route long monsoon storms (Clause 4.6.3);
> - prefer regional storage in the pung system (Clause 4.13); and
> - check downstream and at the outfall (Chapter 5).
>
> Kansas City's own history shows the price. On a test site, peak matching needed 3.0 ac-ft of storage and the 2011 comprehensive criteria needed 4.9 ac-ft (MARC Evolution deck). Over-detention costs more storage. That is the cost of protecting the catchment rather than only the site boundary.

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## 4.17 Submittal requirements

Every site runoff-control submittal shall include a **Site Runoff Control Report** (Form 4-1) containing:

1. the Design Rainfall Sheet (Form 2-1) and the hydrology inputs (Chapter 3);
2. the evidence for the order of measures under Clause 4.3.1;
3. the RRV computation, infiltration tests, groundwater evidence and drawdown calculation (Clause 4.4);
4. the retention credit computation (Clause 4.4.6);
5. the release-rate criterion applied, standard or flood-sensitive, with the Annex 4A map extract (Clause 4.5);
6. a results table in the format of Clause 4.6.7 for every AEP and duration, with the governing case highlighted;
7. stage–storage and stage–discharge tables and plots, and inflow/outflow hydrographs for the governing cases;
8. the drawdown calculation (Clause 4.7);
9. outlet details, including orifice sizes and levels, trash racks and anti-vortex devices (Clause 4.8);
10. the spillway or overflow calculation, freeboard and hazard classification, and the geotechnical report where required (Clause 4.9);
11. the RWH and detention accounting, with tank sections showing zone levels (Clause 4.11);
12. the design groundwater level and flotation check (Clause 4.12);
13. the downstream and tailwater report (Chapter 5, Form 5-1); and
14. the safety provisions (Clause 4.15) and the draft maintenance declaration (Chapter 10).

Tier B sites using Clause 4.14.2 shall submit Form 4-2 in place of items 6 and 7. Sites using the fixed-coefficient route (Clause 4.14.3) shall submit Form 4-3 in place of items 6 and 7.

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## References (chapter)


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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 4A | Flood-sensitive catchment boundaries (GIS); shallow-groundwater zone map |
| 4B | Tier B tables: PSD and SSR (Table 4.3), retention credit factor C_R, standard outlet sizes; confirmed fixed release coefficients (Table 4.3A) |
| 4C | Worked example (Tier A) with full routing tables |
| Form 4-1 | Site Runoff Control Report |
| Form 4-2 | Tier B Site Sheet |
| Form 4-3 | Fixed-coefficient Route Sheet (Clauses 4.14.3 to 4.14.7) |

CHAPTER 5

# Downstream and Tailwater Analysis

## 5.1 Purpose and scope

5.1.1 This chapter sets two checks that every regulated development and every public drainage project must pass.

- **The downstream analysis** (Clauses 5.3 to 5.5) confirms that the project does not make flooding worse below its outfall.
- **The tailwater analysis** (Clauses 5.6 to 5.13) sets the water level the system discharges into, including tide, storm surge, sea-level rise, river backwater and sand-bar closure. It also requires the system to cope when its outfall is closed.

5.1.2 This chapter applies to:

- (a) every site to which Chapter 4 applies;
- (b) every minor- and major-system drainage project under Chapter 6; and
- (c) every regional detention or tank restoration project under Clause 4.13 and Chapter 7.

5.1.3 Rainfall and joint-occurrence inputs come from Chapter 2, in particular Clauses 2.5.3 and 2.12. Hydrologic methods come from Chapter 3. Site release criteria come from Chapter 4. Hydraulic design of gates, culverts and pumps follows Chapter 9.

5.1.4 **No tidal outfalls in Meghalaya.** Meghalaya is landlocked and hilly: it has no coast, no tide and no Coastal Regulation Zone, and the monsoon reaches it only as rainfall, driven against the plateau and the southern escarpment; that rainfall is dealt with in Chapter 2, not as a tidal or surge level. No outfall in the State discharges to the sea, a tidal creek or an estuary, so the provisions of this chapter that depend on tide, storm surge, sea-level rise or a river mouth do not apply in Meghalaya: Clause 5.7 and Annex 5A, cases J1 to J3 of Table 5.2, the tidal lock windows of Clause 5.10.3, the seawater requirement of Clause 5.11.3(a) (gates and seats shall still be of corrosion-resistant materials, and shall resist abrasion by gravel and boulders and attack by acid mine drainage in the coal belt), and Clause 5.13. They are kept so that the clause numbers of this Manual match its other State editions. In Meghalaya the receiving water is one of five kinds: a city stream, the Umkhrah or the Umshyrpi through Shillong, ungauged and narrowed by building and garbage, whose valley floors flood with nearly every heavy downpour; a river, reached directly, through a gate in a bank or through a pumping station, such as the Umngot at Dawki, the Myntdu below Jowai and the rivers that run into Assam or Bangladesh, which rise within hours on the escarpment and stay high for the days that a monsoon spell lasts; a jhora (a small hill stream) or other hill stream, ungauged, steep and laden with boulders, slide debris and garbage, whose bed rises and falls in a single flood; a reservoir of MePGCL held near its full level, such as the Umiam (Barapani) reservoir, or the reach of river below one of its dams, or a lake or pung (Khasi and Pnar: pond, pool or small lake; Garo: *pokri*), such as Ward's Lake (Nan Polok) or Thadlaskein (Pung Sajar Nangli); or a river of the Garo foothill plains, such as the Jinjiram, held up by the backwater of the Brahmaputra; and:

- (a) its tailwater is set by Clauses 5.6 and 5.8, including Clause 5.8.5;
- (b) where Clauses 5.10 to 5.12, Form 5-1 or Chapter 6 refer to the J1 tailwater or the J1 tidal curve, the minor-system tailwater of Clause 5.6.2 or 5.8.5 applies, as a time series where the receiving level varies; where they refer to the J2 tailwater or to HAT + surge + SLA, the major-system tailwater applies: the design-AEP river level of Clause 5.8.4(b), or the major-system tailwater of Clause 5.8.5, whichever is higher at the outfall; and

- (c) the outfall-closed check of Clause 5.10 applies where an outfall is closed by a city stream, a river, a jhora or hill stream, a reservoir, lake or pung, a river under backwater or a receiving drain, with the locks and closures of Clause 5.8.5(a) to (e) in place of the tidal lock windows.

**Commentary.** The drains of Meghalaya's towns fail in places that site design does not see, and in five different ways. The first is the city stream. Shillong's drains, 148.91 km of them, "drain directly into the Umkhrah and Umshyrpi rivers" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan, 2020); neither stream has a gauge; Polo, Pynthorbah, Nongmynsong, Forest Colony and Mawlai flood "with nearly every heavy downpour" when the Wah Umkhrah overflows, a flooding attributed to "clogging of Wah Umkhrah and the decreasing width of the river due to human activities" (as reported; the same text in the IRADe/NMHS plan); and NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" (NESAC, 2023). The second is the river. CWC has seven level-monitoring sites in the State and no forecasting site, and no site has a warning or a danger level (SANDRP, 2018, as reported); the highest levels at Dawki and Kharkhana were set on 28 May 2006 and 23 April 1995, before the south-west monsoon, and in June 2026 the Umngot at Dawki rose rapidly and submerged a labour camp of the bridge project (as reported). The third is the jhora. The jhoras are ungauged, many are dry for most of the year and so fall outside the Waterbodies Guidelines' definition of a waterbody, and they carry the slide debris of the slopes and the waste of the towns: 49,612 m³ of waste was removed from the Wahumkhrah alone (State action-taken report to the National Green Tribunal, 2023). The fourth is the reservoir and its release reach. The Umiam reservoir receives everything Shillong drains, and MePGCL's guidelines describe reservoirs so small that release notices are "not practicable", with warnings by siren, telephone or SMS; the escarpment's dams pass floods of a size the northern slope never sees, 12,000 m³/s from a catchment of 350 km² at Myntdu–Leshka against 3,820 m³/s from 1,020 km² at New Umtru (MePGCL guidelines). The fifth is the backwater of the plains: in September 2014 the Brahmaputra and the Jinjiram submerged over 200 villages of the Garo Hills (as reported). The outfalls also belong to one body while the drains above them belong to others: the rivers and flood works are the Water Resources Department's, the reservoirs MePGCL's, the city drains the Municipal Boards', the road drains PWD's, NHAI's or NHIDCL's, and the village drains and jhoras the District Councils' and the Dorbar Shnongs', and no rule divides them (Chapter 6, Clause 6.9). No document found during research sets a design level for any stream, river, reservoir, lake or pung outfall in the State, or a design standard for any town drain. A detention basin that meets every release rate in Chapter 4 still fails if the stream it drains to stands above its outfall, if the jhora has buried its outlet in boulders or garbage, or if the reservoir is full. This chapter makes these failure modes part of the design. Meghalaya has no tidal outfall, so Clause 5.1.4 says which of the chapter's coastal provisions fall away and what takes their place.

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## 5.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Analysis point | A location on the downstream system where pre- and post-project conditions are compared (Clause 5.3.3). |
| Contributing catchment | The whole area draining to an analysis point, on and off site. |
| Major drain | A channel listed as a major drain in the basin plan or Annex 5B, or any river, Water Resources Department canal, the Umkhrah (Wah Umkhrah) and the Umshyrpi (Wah Umshyrpi) through Shillong and the Wah Roro that they form, the Umkhen and the Wah Tamdong, the Myntdu at Jowai, the Ganol and the Ringrey and Rongkhon streams at Tura, the Simsang at Williamnagar, the Umngot at Dawki, the Umtru below the New Umtru dam, the Jinjiram and the Krishnai on the Garo foothill plains, any drain built or held by a Municipal Board, the Shillong Cantonment Board, NSTDA, Shillong Smart City Ltd, PWD (Roads), NHAI or NHIDCL with an internal width of 1.0 m or more, and every jhora or other natural stream that drains 8 ha or more, whether or not the Waterbodies Guidelines treat it as a waterbody, or a tidal creek. |
| Chart datum (CD) | The datum of the published tide tables and nautical charts, to which tidal heights are referred. |

| Term | Meaning in this Manual |
|---|---|
| Mean sea level (MSL) | Average sea level over a long period at a tide gauge. |
| MHWS | Mean high water springs: the average of high waters at spring tides. |
| HAT | Highest astronomical tide: the highest level predicted under average meteorological conditions over a full tidal cycle (18.6 years). |
| Storm surge | The rise in sea level above the astronomical tide caused by wind and low pressure, mainly during cyclones. |
| Still-water level | Astronomical tide plus surge, excluding individual waves. |
| Sea-level allowance (SLA) | The allowance added to present-day tidal levels for sea-level rise over the design life (Clause 5.7.4). |
| Tailwater | The water level at the downstream end of a drain, outlet or storage. |
| Tide-lock | The condition in which the tailwater is at or above the upstream water level, so a gravity outfall cannot discharge. |
| Lock window | A period during which the outfall-closed check of Clause 5.10 sets gravity discharge to zero. |
| Sand bar | A bar of beach sand that partly or fully closes a river mouth or creek inlet. |
| Project datum | The levelling datum used on the project drawings. It must be tied to a Survey of India benchmark (Clause 5.7.2). |

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## 5.3 Extent of the downstream analysis

5.3.1 The downstream analysis shall start at each site or project outfall. It shall continue downstream to the **first** of:

- (a) the point at which the project area is **10% or less** of the contributing catchment;
- (b) the next **tank, pung** or other waterbody with a surplus weir or controlled outlet; or
- (c) the next **major drain**, or the sea.

The end point itself shall be analysed (Figure 5.1).

5.3.2 Where the analysis ends at a tank or pung under 5.3.1(b), it shall report:

- the change in the tank's maximum water level; and
- the change in surplus-weir discharge, for the AEPs and durations of Clause 5.4.3.

If the maximum water level rises, the analysis shall continue below the surplus weir to the next end point.

5.3.3 Analysis points shall be set at least at:

- (a) each site outfall;
- (b) each confluence with a drain or channel whose contributing catchment is at least half that of the receiving drain at that point;
- (c) each culvert, bridge or road crossing;
- (d) each location recorded as flood-prone by the local body, SMB, MSDMA or Water Resources Department; and
- (e) each building or road segment lying within the 1% AEP flood extent along the route. Representative points may be used where buildings are closely spaced.

5.3.4 **Small sites.** For sites of less than **0.5 ha**, the Authority may accept a simplified downstream statement (Form 5-2) in place of the full analysis, where all of the following hold:

- the receiving public drain has documented capacity for its minor-system design flow (Chapter 6);
- no flood-prone location is recorded within 500 m downstream; and
- the site does not drain to a tidal or backwater-affected outfall.

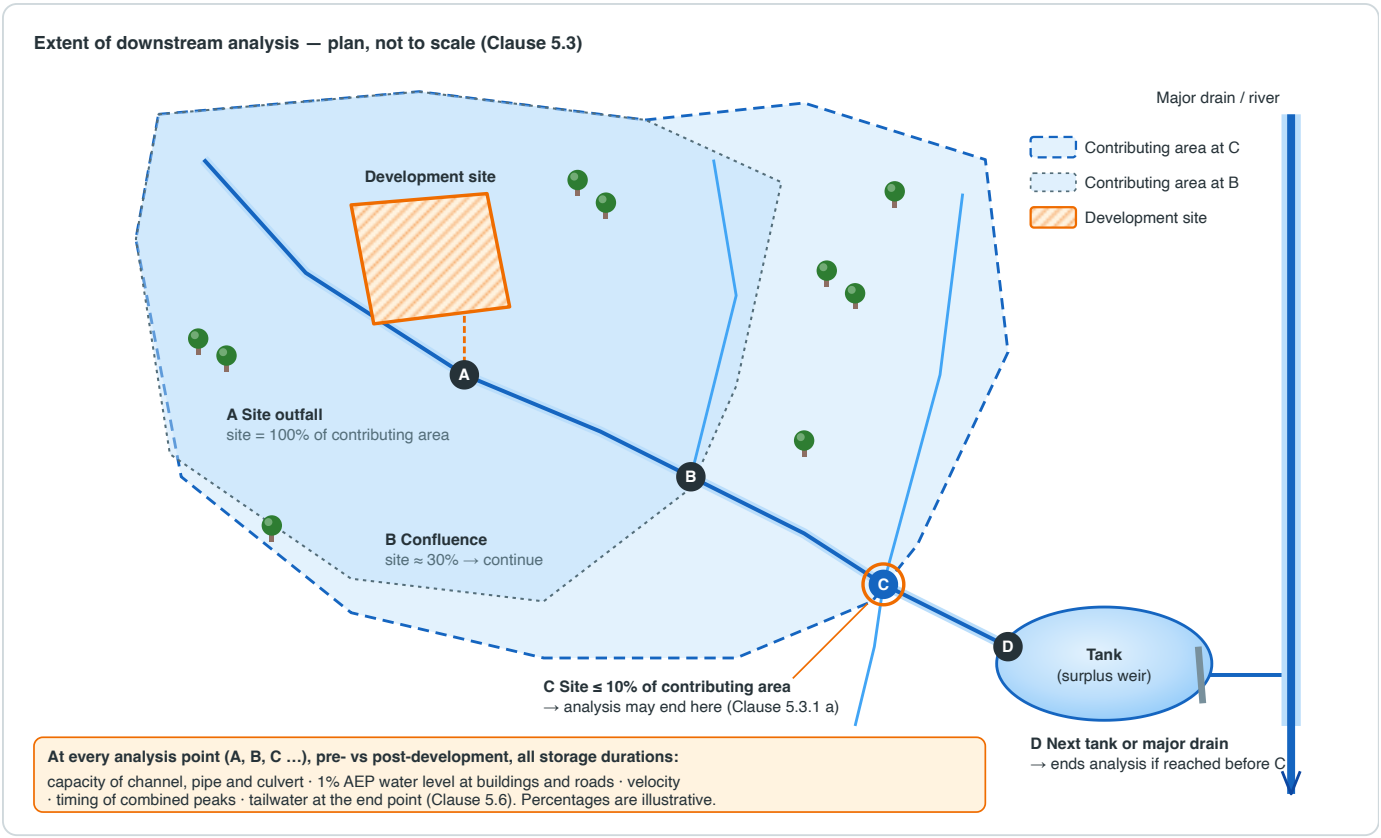


*Figure 5.1 — Extent of downstream analysis: analysis points A–D, the contributing area at each point, the 10% point, and the next pung or major drain as an alternative end point. Schematic; percentages are illustrative. Original drawing for this Manual, adapted from the ten-percent rule in the Georgia Stormwater Management Manual (2016, Vol. 2 §3.1.9) and KC APWA Section 5600 (2006, 5601.5).*

**Commentary.** The 10% rule has established precedent. KC APWA 5600 (2006) required the downstream system to be analysed "to the point the development's land mass is less than 10% of the total watershed". The Georgia manual makes the ten-percent analysis a mandatory standard (GSMM 2016, Standard #8). The tank or major-drain end point has no direct precedent; this Manual adds it for Meghalaya. In the hill towns, where a colony's drain runs down a jhora to a stream (wah), and the stream to a river or reservoir many kilometres below, as Shillong's drains run by the Umkhrah and the Umshyrpi to the Wah Roro and the Umiam reservoir, and on the Garo foothill plains, where the drains of Phulbari and Tikrikilla run to the Jinjiram and on to the Brahmaputra in Assam, the 10% point can lie many kilometres downstream, across several tanks. A tank with a working surplus weir changes the hydrograph completely, so the analysis is better ended there and the tank level reported. Clause 5.3.2 prevents that end point from hiding a rise in the tank level. The small-site statement (5.3.4) and its 500 m distance have no direct precedent and are set by this Manual.

## 5.4 What the analysis must check

5.4.1 **Scenarios.** Each analysis shall compare:

- (a) **Existing**: the present downstream system and present land use of the whole contributing catchment, with the project site at its pre-project state; and
- (b) **With project**: the same, with the project and all its controls (Chapter 4) in place.

Where the Authority's basin plan defines future land use, the Authority may also require:

- (c) **Future**: the catchment fully developed under the plan, all to Chapter 4 standards, with and without the project.

5.4.2 **Quantities to be checked at every analysis point:**

- (a) **Capacity**: peak flow against the capacity of every channel, pipe, culvert and crossing, for the minor-system AEP of that element (Chapter 6) and for 1% AEP;
- (b) **Flood levels**: 1% AEP maximum water level at buildings (at the lowest opening) and on roads (at the crown and at the deepest point);
- (c) **Velocities**: peak velocity for 50%, 10% and 1% AEP;
- (d) **Timing of combined peaks**: the hydrograph at each confluence, showing the time to peak of the project outflow and of the receiving drain; and
- (e) **Duration of inundation**: on roads and at buildings, the time above the Chapter 6 depth limits.

5.4.3 **Storms.** The analysis shall use:

- 50%, 10% and 1% AEP;
- the duration set of Clause 2.5.2, at least the durations that give the highest level at each analysis point (these will usually be longer than at the site); and
- the 24-, 48- and 72-hour storms in every case.

The AMC rule of Clause 2.11.4 applies. Areal reduction follows Clause 2.7, applied to the contributing catchment at each analysis point and never to the site storage.

5.4.4 **Method.** The analysis shall:

- use a hydrograph method that combines hydrographs at confluences (SWMM, HEC-HMS, or an equivalent);
- include a hydraulic model with backwater (SWMM dynamic wave, HEC-RAS, or equivalent) wherever tailwater or backwater affects any analysis point; and
- not use the Rational Method at any analysis point, because it cannot represent timing.

Off-site areas shall be modelled at their present land use. Upstream detention shall be included only where it is built, maintained and documented.

5.4.5 **Tailwater.** The downstream end of the model shall use the tailwater of Clauses 5.6 to 5.9 and the sand-bar condition of Clause 5.13 where applicable.

> **Commentary.** Clause 5.4.2(d) exists because detention changes when the site's water arrives, not only how much arrives (Clause 4.16). A Colorado State University thesis and a *Water* (2016) optimisation study both found that delayed site releases can coincide with the main-stem peak and raise it. Georgia's manual states the result directly: some structural practices "fail to reduce discharge peaks to pre-development levels downstream" because of "peak flow timing and runoff volume effects" (GSMM 2016). The duration-of-inundation check (5.4.2(e)) matters in the valley floors and plains of Meghalaya whose outfalls lie below streams, rivers and reservoirs held high for hours or days: Polo, Pynthorbah, Nongmynsong, Forest Colony and Mawlai in Shillong flood "with nearly every heavy downpour" when the Wah Umkhrah overflows (as reported; IRADe/NMHS plan, 2020), the Brahmaputra and the Jinjiram submerged over 200 villages of the Garo Hills in September 2014 (as

reported), and the shore of the Umiam reservoir drains to a lake held near its full level, from which releases were reported to have begun in August 2024 on an IMD warning (as reported). Detention that prolongs releases can lengthen that time even when it lowers the peak.

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## 5.5 Acceptance criteria

5.5.1 The project is acceptable if, at every analysis point and for every AEP and duration of Clause 5.4.3, comparing "with project" to "existing":

- (a) the 1% AEP maximum water level does not rise by more than **10 mm** at any habitable building, at any building's lowest opening, or on any road carriageway;
- (b) no building that is not flooded in the existing case is flooded with the project, and no building or road that meets the Chapter 6 freeboard or depth limits in the existing case fails them;
- (c) peak flow does not exceed the existing peak at the minor-system AEP of each element, or at 1% AEP;
- (d) peak velocity in lined channels stays within the permissible velocity for the lining (Chapter 6: 3.0 m/s maximum); and
- (e) in unlined or natural channels, peak velocity for 50% and 10% AEP does not increase by more than **10%**, unless protection is provided under Chapter 9.

5.5.2 The duration of inundation under 5.4.2(e) shall be reported. The Authority may refuse a project that increases the duration of road closure on an arterial or emergency route.

5.5.3 **Where the criteria are not met**, the project shall do one or more of the following:

- (a) reduce release rates or increase storage (Chapter 4);
- (b) build downstream improvements, with the consent of the owner of the downstream system. These shall not transfer the problem further downstream, and shall be re-analysed under this chapter;
- (c) contribute to a regional facility under Clause 4.13; or
- (d) under Clause 5.5.4, change the release strategy.

5.5.4 **Timing exception.** Where the analysis shows that detention raises downstream levels because of timing, the Authority may vary the site release-rate criteria of Clause 4.5. This applies only where the site discharges within the lower tenth of the contributing catchment, directly to a major drain, tidal creek or the sea, and only on the following conditions:

- (a) the varied strategy meets 5.5.1;
- (b) the retention requirement (Clause 4.4) and WQv treatment (Chapter 8) are met in full; and
- (c) the outfall-closed check (Clause 5.10) is met.

> **Commentary.** The 10 mm tolerance (5.5.1(a)) has no direct precedent. It is meant to be at or below the numerical precision of a typical one-dimensional model, so that "no increase" can be tested without arguing over rounding. The 10% velocity tolerance is likewise set by this Manual. The timing exception in 5.5.4 follows the Georgia manual, where the downstream analysis can show "that peak controls are not needed" and allow them to be waived (GSMM 2016, Standard #8). It is limited here to sites low in the catchment, which is where synchronisation with the main-stem peak is most likely (*Water* 2016, 8(7):290). It is not available above that, because the evidence on scale (Clause 4.16) shows that early release from many upstream sites raises peaks.

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## 5.6 Tailwater: general and non-tidal outfalls

5.6.1 Every drain, outlet and storage shall be designed against a stated tailwater. A free outfall shall be assumed only where the outlet invert is above the maximum receiving water level for the case being checked.

5.6.2 **Minor-system tailwater, non-tidal.** The tailwater is the receiving system's water level at the time of the minor-system peak, from the downstream model. Where no model exists, use:

- for a receiving pipe, its obvert; or
- for a receiving open drain, its full-bank level less freeboard (Chapter 6).

5.6.3 **Major-system tailwater, non-tidal.** The tailwater is the receiving system's 1% AEP water level, unless Clause 5.8 allows a coincident lower level.

5.6.4 **Tidal and backwater outfalls.** Clauses 5.7 to 5.13 apply in addition.

5.6.5 **Storage elements.** Detention, tanks and pumped sumps shall be routed with a time-varying tailwater (Clause 4.6.6), not a constant level, wherever the tailwater varies with tide or with the receiving system's hydrograph.

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## 5.7 Tidal tailwater: datums, surge and sea-level allowance

5.7.1 **Design tailwater levels.** For outfalls to the sea, tidal creeks, estuaries, backwaters and tidal reaches of rivers and canals:

**Table 5.1 — Design tailwater levels for tidal outfalls**

| Design case | Tailwater |
|---|---|
| Minor-system design (Chapter 6) | **MHWS + SLA** |
| Major-system design and storage design | **HAT + surge + SLA**, with the surge term defined in Clause 5.7.3 |
| Joint case (Clause 2.12(b)) | 1% AEP still-water level + SLA |

The SLA is **+0.3 m minimum** (Clause 5.7.4). The cases to be run are listed in Clause 5.9.

5.7.2 **Sources and datums.**

- (a) **Tidal levels.** MHWS, HAT and MSL shall be taken from the current edition of the Indian tide tables published by the National Hydrographic Office (NHO) or by the Survey of India, for the nearest standard or secondary port, or from the port authority's published tidal levels. The edition and port shall be stated.
- (b) **Datum conversion.** Tide-table heights are referred to chart datum. They shall be converted to the project datum through a documented connection between chart datum, the tide gauge zero and a Survey of India benchmark. The offset and its source shall be stated on Form 5-1.
- (c) **Estuaries, creeks and canals.** For outfalls inside estuaries, creeks, backwaters or tidal canals (for example the estuaries of the coastal States; there is none in Meghalaya, Clause 5.1.4), tidal levels may differ from the open coast. Open-coast levels shall be used unless measured levels over at least one spring–neap cycle, or a calibrated hydrodynamic model, justify a different value. No reduction below open-coast levels shall be taken without such evidence.
- (d) **Interim.** Until Annex 5A is published, the designer shall obtain the values directly from the sources in (a) and record them.

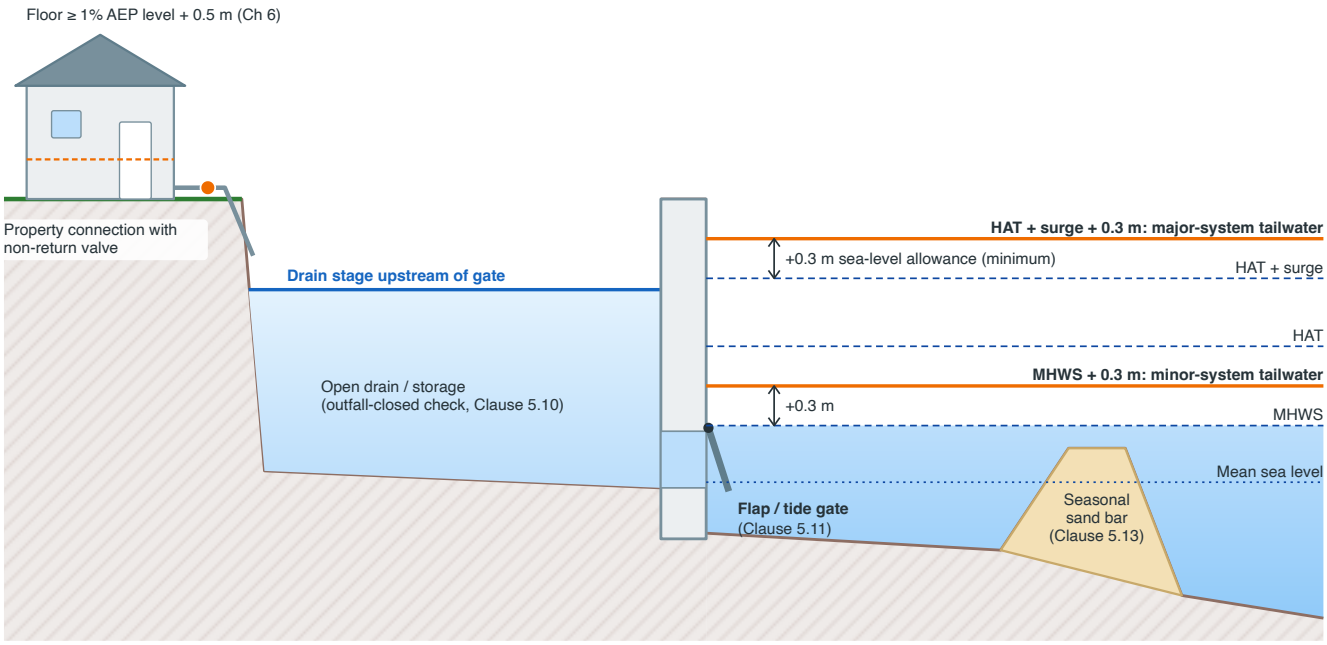
5.7.3 **Storm surge.**

- (a) **Major-system and storage design.** The surge term in "HAT + surge" is the **10% AEP (10-yr) storm surge** for the coastal segment, given in Annex 5A. The 1% AEP surge is used only in the joint case of Clause 2.12(b), with the 10-yr 48-hour storm. That keeps the two cases symmetric, so that a rare rainfall is never paired with a rare surge.
- (b) **Joint case.** The 1% AEP still-water level for Clause 2.12(b) is taken from Annex 5A.
- (c) Until Annex 5A is published, both values shall be taken from a site-specific study using INCOIS, IMD or NCCR surge hindcasts or return-level analyses. The study shall state its source, method and record length.
- (d) Wave set-up shall be added where the outfall faces the open sea without a protected entrance.

5.7.4 **Sea-level allowance.** The SLA shall be:

- (a) **+0.3 m** minimum for every element;
- (b) greater than 0.3 m where the State, MUDA or the Authority adopts a higher projection for the planning area; and
- (c) assessed for the design life of the element. For elements with a design life of more than 50 years, the designer shall report the effect of a sea-level rise of twice the SLA as a sensitivity run.

**Tidal outfall — schematic section, not to scale (Clauses 5.6–5.13)**




**Notes**
Levels are diagrammatic. Datums from the current NHO / Survey of India tide tables, reduced to the project datum (Clause 5.7).
Joint case (Clause 2.12 b): 10-yr 48 h storm with the 1% AEP still-water level + 0.3 m. Riverine reaches: see Clause 5.8.
Outfall invert below the 1% still-water level → flap or tide gate required; property connections need non-return valves.

*Figure 5.2 — Tidal outfall: flap gate, property non-return valve, and the design tailwater levels (MHWS + 0.3 m for the minor system; HAT + surge + 0.3 m for the major system), with a seasonal sand bar at the mouth. Schematic, not to scale. Original drawing for this Manual, adapted from the tidal tailwater table in MoHUA/CPHEEO Manual on Storm Water Drainage Systems (2019), Part A, Table 6.2.*

**Commentary.** CPHEEO (2019) Table 6.2 sets the design tailwater for coastal outfalls as:

- MHWN to MHWS for a minor storm (more frequent than 1 in 5 years);
- MHWS to HAT for a major storm; and
- "Effect of climate change: additional 0.3 m".

CPHEEO also says the joint probability of storm, tide and surge "should" be considered, with the state maritime board consulted. This Manual takes the upper end of each CPHEEO range, adds surge for the major system, and makes the joint case explicit (Clause 2.12). CPHEEO does not require surge to be added; this Manual adds it because the surge records of the coastal States showed why it is needed there; Meghalaya has no coast, and the surge term does not arise in the State, which the monsoon reaches only as rainfall, driven against the plateau and the southern escarpment (Chapter 2).

Indian tide tables have been published by the Survey of India since the nineteenth century (Survey of India, Tidal Predictions). Current Indian tidal predictions also appear in the NHO's tide tables. One port document describes the current edition as covering 95 Indian ports, based on NHO observations and on data from civil ports, NIO and INCOIS (Adani Ports, Dahej tide table 2025, citing NHO INP-12). INCOIS runs coastal tide gauges and issues storm-surge and swell-surge warnings. None of these is used for design in Meghalaya, which has no coast, and Annex 5A is not prepared for the State (Clause 5.1.4).

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## 5.8 Riverine backwater

5.8.1 **Where it applies.** Outfalls to rivers and canals whose water level in a storm can exceed the outfall invert shall be designed with riverine backwater. This includes:

- the **Umkhrah** (Wah Umkhrah) and the **Umshyrpi** (Wah Umshyrpi) through **Shillong**, with the jhoras that run to them and the valley floors of **Polo**, **Pynthorbah**, **Nongmynsong**, **Forest Colony**, **Mawlai**, **Dhankheti** and **Nongrim Hills**, and the **Wah Roro** that they form before Umiam lake (Clause 5.8.5(a));
- the **Umngot** at **Dawki**, the **Umnohryngkew** at **Therriaghat**, the **Myntdu** at **Jowai** and at **Kharkhana**, the **Bugi** at **Dimapara** and the **Dareng** at **Sibbari**, and the other rivers that run south to Bangladesh, among them the **Kynshi** and the **Simsang** at **Williamnagar** (Clauses 5.8.3 and 5.8.5(b));
- the **Kopili**, the **Digaru**, the **Kulsi**, the **Krishnai** (Dudhnai) and the **Umtru** below **Byrnihat**, where they run into Assam (Clause 5.8.5(b));
- the jhoras and hill streams of the towns, among them the jhoras of Shillong and the **Umkhen** and **Wah Tamdong**, the **Ganol** and the **Ringrey** and **Rongkhon** streams at **Tura**, the Myntdu headwater streams at Jowai, the **Umlew** at Nongpoh–Umling, and the streams of **Sohra**, **Mawsynram**, **Shella** and **Pynursla** on the southern escarpment (Clause 5.8.5(c));
- the **Umiam** (Barapani) reservoir, the **Kyrdemkulai** (Stage III), **Nongkhyllem** (Stage IV), **New Umtru** and **Myntdu–Leshka** reservoirs of MePGCL and their release reaches, among them the Umtru to the Byrnihat bridge and the Myntdu to the Bangladesh border, and the **Kopili** project of NEEPCO (Clauses 5.8.3 and 5.8.5(d));
- **Ward's Lake** (Nan Polok), **Thadlaskein** (Pung Sajar Nangli) and the other lakes and pungs (Clause 5.8.5(d));
- the **Jinjiram** and the **Krishnai** on the Garo foothill plains at **Phulbari** and **Tikrikilla**, under the backwater of the Brahmaputra, and the south Garo rivers at **Baghmara** and **Dalu** (Clause 5.8.5(e));
- any drain or channel of a Municipal Board, the Shillong Cantonment Board, NSTDA, Shillong Smart City Ltd, PWD (Roads), NHAI or NHIDCL, and any village drain or jhora held under a District Council's rules, that receives storm water (Clause 5.8.5(f)); and
- elsewhere: any river or Water Resources Department channel listed in Annex 5B.

5.8.2 **River levels.** River water levels shall be taken from:

- (a) Water Resources Department design flood levels or recorded highest flood levels for the reach, where published; or
- (b) a hydraulic model (HEC-RAS or equivalent) of the river reach. The model shall use:
  - the river design flood from a hydrograph method (Chapter 3), with continuous simulation where Chapter 3 requires it;
  - the tidal boundary of Clause 5.7 at the mouth; and
  - the sand-bar condition of Clause 5.13.

5.8.3 **Reservoir and tank releases.** Where a reservoir or tank upstream can release to the river (for example the Umiam dam (Stage I) at Barapani and the Kyrdemkulai (Stage III) and Nongkhyllem (Stage IV) dams of the Umiam–Umtru projects; the New Umtru dam on the Umtru above Byrnihat; the Myntdu–Leshka dam on the Myntdu downstream of Jowai; and the Kopili project of NEEPCO on the Kopili, shared with Assam), the river level shall include the release given by the reservoir's operating rule for the storm being checked. Where there is no published rule, it shall include the largest recorded release.

5.8.4 **Coincidence of site storm and river flood.** Unless a joint-probability study is accepted by the Authority, the more severe of the following governs:

- (a) the site design storm (AEP as required), with the river at its **10% AEP (10-yr)** level; and
- (b) the site **10% AEP** storm, with the river at its design-AEP level (1% AEP for the major system).

The two storms in each pair shall have the same duration and timing where they are generated by the same rainfall event.

5.8.5 **The Umkhrah and Umshyrpi, gauged and border rivers, jhoras, reservoirs and release reaches, pungs and lakes, the Garo plains, the drains of other bodies, and Water Resources Department consent.**

- (a) **Shillong's Umkhrah and Umshyrpi.** For an outfall to the Umkhrah (Wah Umkhrah) or the Umshyrpi (Wah Umshyrpi), to a jhora or drain that ends in either of them, or to the Wah Roro that they form before Umiam lake (NESAC, 2023):
  - **No gauge, no level.** Neither stream has a gauge of CWC or of any other body, and no flood level has been published for any reach of either [TBC]. The floodplain zonation of identified stretches, among them the Umkhrah, awarded to RMSI in June 2021 and reported 80% complete in March 2023 (State action-taken report to the National Green Tribunal, 21 March 2023), has not been published [TBC], and the levels of the embankment and channel scheme for the Wahumkhrah and Umshyrpi that the Water Resources Department is reported to have resubmitted were not obtained (as reported) [TBC]. The IRADe/NMHS plan for Shillong (2020) says that the two rivers reach "the danger mark during heavy rainfall", but no danger level is set for either.
  - **Design level.** The tailwater for the major-system and storage cases shall be the highest of: (i) the 1% AEP level at the outfall from a hydraulic model (Clause 5.8.2(b)) of the stream from the outfall to at least the next confluence downstream, with the rainfall of sub-area ML-B under the Shillong rule of Clause 2.3.6(c)(i), the AMC of Clause 3.8.4, the bulking factor of Clause 6.3.6(b) on the peak flow, the crossings downstream blocked as Clause 6.3.6(c) requires, and the channel as surveyed in its present condition, net of encroachment, silt, solid waste, stone bunds, waste traps and the interception works of Clause 8.9; (ii) the level at the outfall of any flood study of the stream made by or for the Water Resources Department or the State, among them the RMSI floodplain zonation, once it is published [TBC]; and (iii) the highest flood level surveyed at the outfall from flood marks, such as debris lines, silt marks and the accounts of residents, of the flash flood of 9 July 2019 at Polo, Forest Colony and Mawlai (IRADe/NMHS plan, 2020) or a later flood, and from the records of the Shillong Municipal Board, the Water Resources Department, the District Council, the Dorbar Shnong or the Deputy Commissioner, with its source stated. No outfall to either stream shall be designed without items (i) and (iii) (set by this Manual).
  - **Valley floors.** Polo, Pynthorbah, Nongmynsong, Forest Colony, Mawlai, Dhankheti and Nongrim Hills flood "with nearly every heavy downpour" when the Umkhrah overflows (as reported; the same text in the IRADe/NMHS plan, 2020), and NESAC's master-plan study names "Polo Market, Pynthorbah, Nongrim hills, Dhankheti" as "highly potential for flash flood" (NESAC, 2023). Every outfall on these valley floors, and every outfall elsewhere on either stream whose invert is below the design level of this item, is an **outfall-closed case**: the outfall-closed check of Clause 5.10 applies with a single lock that lasts for the duration of the design storm plus the stream's recession, computed with the model of item (i) for as long as the stream stays above the outfall invert, and **not less than 24 hours**; where the 48- and 72-hour storms of Clause 5.10.2 are run, the lock lasts for the whole storm (set by this Manual). A shorter lock may be used only where the outfall invert is above the 1% AEP level of this item.

    - **Two jurisdictions.** Only part of each stream lies in the area of the Shillong Municipal Board; the rest lies under the Khasi Hills Autonomous District Council (State action-taken report, 21 March 2023), and the Board was asked to prepare a geo-referenced map dividing the two [TBC]. The designer shall state on Form 5-1 which body holds the reach at the outfall and obtain its consent under item (f).
    - **Interception and waste traps.** An interception and diversion structure, an on-site treatment plant at a junction with the Umkhrah, an in-situ drain treatment work, a stone bund or a solid-waste trap on either stream or its jhoras (Clauses 6.3.6(i) and 8.9) shall not raise the design level of this item or reduce the capacity of the drain or stream; it shall stand above that level or be designed to be overtopped without damage. The 20 outfalls to the Umkhrah and 12 to the Umshyrpi identified by MSPCB (minutes of the stakeholder meeting, 14 April 2023) carry dry-weather sewage and sullage and are dealt with under Clause 8.9.
- (b) **Rivers with CWC level-monitoring sites, and rivers that leave the State.** For an outfall to a river directly, through a gate in a bank, a flood wall or an embankment, or through a pumping station, or into a drain that itself discharges in one of those ways, the designer shall identify the body that operates each gate and pumping station, and obtain the sill of each gate, the crest of the bank, wall or embankment, the installed pumping capacity and the operating levels, including the river level at which each gate is closed. Every level shall state its datum and its connection to the gauge datum of the nearest CWC gauge, or of the MePGCL or other gauge used, with its operator named.
    - **Design river level.** The river level of Clause 5.8.2 at the outfall shall be, for the major-system cases (Clause 5.8.4(b)), the **1% AEP river level at the outfall**, from a hydraulic model under Clause 5.8.2(b), with the releases of item (d). No floodplain zone has been notified under the Meghalaya Flood Plain Zoning Act, 2026 and no flood level has been published for any reach of any river in the State (Chapter 7), so no level is available from a floodplain study [TBC]. The level shall in no case be less than the **highest recorded level** at the nearest CWC gauge on the same river, transferred to the outfall. CWC has seven level-monitoring sites in Meghalaya and no forecasting site (SANDRP, 2018, a copy of CWC data, as reported); the highest levels found during research (Table 5B.1), with no datum stated and none read in a CWC site sheet [TBC], are: the Umngot at **Dawki 73.47 m** (28 May 2006); the Umnohryngkew at **Therriaghat 20.62 m** (15 June 1995); the Myntdu at **Kharkhana 47.0 m** (23 April 1995); the Bugi at **Dimapara 29.75 m** (27 July 2007); and the Dareng at **Sibbari 20.34 m** (12 August 2017). The two sites at the Myntdu Stage-II dam and power house have no published level, and two sites are listed as inactive and were not identified [TBC]. Where a later flood has exceeded the listed level, the later level governs: at Dawki, the level of the Umngot flood of June 2026, which submerged a labour camp of the bridge project (as reported), shall be surveyed from its flood marks, tied to a Survey of India benchmark, and used where it is higher (set by this Manual) [TBC]. The recorded level shall be transferred along the river with the water-surface slope of the flood that set it, from the gauge records or from the model; on these steep rivers, whose beds fall several metres in a kilometre where they leave the escarpment, a profile of the flood marks of the same flood, surveyed between the gauge and the outfall and tied to a Survey of India benchmark, may be used in place of the unchanged level, and the level of the nearest gauge downstream shall not be carried upstream (set by this Manual).
    - **Rivers and reaches with no gauge level.** No CWC site exists on the Umiam, the Umtru, the Kynshi, the Simsang, the Ganol, the Jinjiram or the Kopili within Meghalaya, or on the Myntdu at Jowai, where the Kharkhana site lies far downstream (SANDRP, 2018, as reported). On such a reach, and for an outfall upstream of every gauge on its reach, the river level shall be the higher of the level from a model under Clause 5.8.2(b) and the highest flood level surveyed at the outfall from flood marks, including those of June 2022, May 2025 and June 2026, and from the records of the Water Resources Department, the local body, the District Council or the Deputy Commissioner, with its source stated. Where a level is known only as a gauge reading, the designer shall tie the gauge zero to the project datum and a Survey of India benchmark by levelling. No outfall shall be designed on such a reach without one of these levels (set by this Manual).
    - **Rivers that leave the State.** The Kopili, the Digaru, the Kulsi, the Krishnai (Dudhnai), the Jinjiram and the Umtru below Byrnihat run into Assam, where the Assam edition of this Manual governs the plains reaches. CWC's sites on them in Assam are the Kopili at **Kampur** (warning level 59.5 m, danger level 60.5 m, highest level 61.79 m on 20 July 2004) and at **Dharamtul** (warning level 55.0 m, danger level 56.0 m, highest level

58.09 m on 21 July 2004), and level-monitoring sites with no published level on the Digaru at Sonapur, on the Kulsi and on the Dudhnai (SANDRP, 2018, as reported) [TBC]. For an outfall in Meghalaya on these rivers, the level at the State boundary from the Assam edition, or from those sites transferred upstream, is a lower bound on the downstream boundary of the model, not the level at the outfall. The Umngot, the Myntdu, the Kynshi, the Simsang, the Bugi and the Dareng run south into Bangladesh; no flood level of their lower reaches across the border was found [TBC], and the model of an outfall on them shall start far enough downstream that the boundary does not govern the level at the outfall (set by this Manual).

    - **10% AEP level.** No CWC site in Meghalaya has a warning or a danger level (SANDRP, 2018, as reported). For the cases with the river at its 10% AEP level (Clause 5.8.4(a)), the level shall be taken from the same model or from a frequency analysis of the gauge record; until such an analysis is accepted, the 10% AEP case shall use the design river level of this item (set by this Manual). The datum of every level is to be confirmed for each gauge; the levels are presumed to be metres above mean sea level [TBC].
    - **Tailwater.** The tailwater at the outfall shall be the higher of that river level beyond the gate, bank, wall or embankment, and the maximum level in the drain behind it, computed by routing the drain as a closed storage for as long as the river stands above the level behind it, with the inflow of the whole catchment that drains to it, its storage as surveyed in its present condition, net of silt, boulders, debris, encroachment, solid waste and weed, and an outflow of no more than the pumping capacity that the operator confirms in writing is available in a storm, and in no case more than the installed capacity of the permanent pumps less the largest pump (set by this Manual), with gravity discharge through the gate only while the river is lower than the level behind it. No pumped outfall was found in the State during research [TBC]. Pumps shall deliver against the design river level of this item, and every pump, panel and control shall remain operable with the river at that level (Clause 5.12.5).
    - **River lock.** Portable dewatering pumps brought in for an event, and capacity that has been sanctioned or proposed but not commissioned, shall not be counted. The outfall-closed check of Clause 5.10 applies with a single lock that lasts for as long as the river stays above the outfall invert, or above the level at which its gate is closed if that is lower, taken from the river model or from the stage record of the nearest CWC gauge in the flood that set the highest recorded level or in a comparable flood, with the releases of item (d), and **not less than 72 hours**, or, on a river below a dam, the time for which the largest release of the dams above stays above the flow at which the outfall is closed, from the operator's records, if that is longer (set by this Manual). The lock covers the whole of the 48- and 72-hour storms of Clause 5.10.2, so that storage and pumping handle the full storm volume (Clause 5.9.4) and the drawdown of Clause 5.10.5 is met by pumping until the lock ends. A shorter lock may be used only where the outfall invert is above the 1% AEP river level of this item, or where an analysis of the stage record of a CWC gauge under Clause 5.10.6, including the releases of the dams above, shows it and the Authority approves it.
    - **Gate failure and breach.** Floor levels and pumped outfalls behind a gate, flood wall or embankment shall also be checked for the failure of the gate and for a breach of the wall or embankment, with the land and drains behind it filled to the river level beyond it. Below a dam they shall also be checked for the release that results from a gate failing open.
- (c) **Jhoras and other ungauged hill streams.** For an outfall to a jhora (a small hill stream), a wah (stream) or another hill stream, such as the jhoras of Shillong that run to the Umkhrah, the Umshyrpi, the Umkhen and the Wah Tamdong, the streams of Jowai on the Myntdu headwaters, the Ringrey and Rongkhon streams and the Ganol at Tura, the streams of Williamnagar, Nongpoh and Nongstoin, and the streams of Sohra, Mawsynram, Shella and Pynursla on the escarpment, or into a drain that ends in one:
    - **No gauge.** None of these streams has a gauge or a published flood level [TBC]. They are steep and short, rise within minutes of a burst of rain, and carry boulders, gravel, slide debris and, below the towns, garbage: 49,612 m³ of waste was removed from the Wahumkhrah under the 15th Finance Commission at a cost of ₹7.9 crore, and stone bunds and solid-waste traps were built for ₹3.60 crore (State action-taken report to the National Green Tribunal, 21 March 2023). Many of them dry out for most of the year and are outside the Waterbodies Guidelines' definition of a "waterbody" (Chapter 7), but not outside this clause.
    - **Design level.** The tailwater for the major-system and storage cases shall be the highest of: (i) the 1% AEP level at the outfall from a study of the stream, made with a hydrograph method of Chapter 3 for the whole catchment above the outfall, with the rainfall of its sub-area in Annex 2A, the AMC of Clause 3.8.4 and the

bulking factor of Clause 6.3.6(b) on the peak flow, and routed through a hydraulic model (Clause 5.8.2(b)) of the channel as surveyed, net of encroachment, silt and solid waste, with the crossings downstream blocked as Clauses 6.3.6(c) and 6.3.6(i) require; in sub-areas ML-C and ML-C1 the study is the site-specific hydrology study of the ML-Z3 rule of Clause 2.3.6, with the 24- to 72-hour storms of Clause 6.3.6(j); (ii) the level at the outfall of any flood study of the stream made by or for the Water Resources Department or the local body, where it gives one [TBC]; and (iii) the highest flood level surveyed at the outfall from flood marks, such as debris lines, silt and scour marks and the accounts of residents, of the floods of June 2022, October 2024, May 2025 and June 2026 or a later flood, and from the records of the local body, the District Council, the Dorbar Shnong or the Deputy Commissioner, with its source stated. No outfall to such a stream shall be designed without items (i) and (iii) (set by this Manual).
    - **Bed level, scour and aggradation.** The designer shall survey the bed of the stream at the outfall and for at least 100 m upstream and downstream, and state the range within which the bed has moved, from past surveys, cross-sections, exposed foundations and pipes, and the records of the local body. The outfall invert, and the seat of any flap gate on it, shall stand at least **0.5 m above the highest bed level** found in that range within 50 m downstream of the outfall, and the foundation of the outfall structure and its apron shall be taken below the scour depth computed under Chapter 9 (Clause 9.6) for the 1% AEP flow with the bulking factor (set by this Manual).
    - **Siting.** An outfall shall be built into the bank and shall not project into the bed or the active channel, taken for this Manual as the land flooded once in 5 years (set by this Manual). It shall discharge in the direction of the stream's flow, with the bank protection that Chapter 9 requires, and no pipe, interceptor or chamber of the drainage system shall be laid along the bed of the stream. No muck, spoil or excavated material from the works shall be placed in the stream or where a storm can carry it into one (Clause 6.3.6(g)). No outfall shall discharge to a spring or its recharge area, into a sinkhole, a cave entrance or a mine pit, or to a reach of stream that sinks into one (Clause 4.11 (karst and mine rule)) (set by this Manual).
    - **Closed outfall.** Where the outfall invert is below the design level of this item, the outfall-closed check of Clause 5.10 applies with a single lock that lasts for as long as the level of the stream, computed under item (i) for the coincident cases of Clause 5.8.4, stays above the invert, and, where no hydrograph of the stream has been computed, for the whole storm (Clause 5.9.4) (set by this Manual).
    - **Interceptors and water sources.** An interception and diversion structure on a jhora or its drains (Clause 8.9) shall not raise the design level of this item or reduce the capacity of the drain; it shall stand above that level or be designed to be overtopped without damage. Where the stream or a spring on it supplies drinking water, as the streams and springs that supply most towns by gravity do (CGWB, 2022), Clause 8.9 and the spring rules of Chapter 7 also apply.
- (d) **MePGCL reservoirs and release reaches; lakes and pungs.** For an outfall to a reservoir, a lake or a pung (Khasi and Pnar: pond, pool or small lake; Garo: *pokri*), directly or through a drain, jhora or stream that ends in it, such as the Umiam (Barapani) reservoir, which receives the Umkhrah and Umshyrpi through the Wah Roro; the reservoirs of the Umiam–Umtru Stage III dam at Kyrdemkulai and Stage IV dam at Nongkhyllem; the New Umtru reservoir; the Myntdu–Leshka reservoir; Ward's Lake (Nan Polok) in Shillong; and Thadlaskein (Pung Sajar Nangli) and the other pungs; or to a reach of river below one of the dams:
    - **Consent.** Storm water shall not be discharged to a reservoir or its release reach without the written consent of MePGCL, which holds the Umiam–Umtru, New Umtru and Myntdu–Leshka projects, or, for the Kopili project on the Kopili, shared with Assam, of NEEPCO. Storm water shall not be discharged to a lake or pung without the written consent of its custodian, which was not confirmed during research for Ward's Lake, Thadlaskein or any other [TBC]; within municipal limits, public tanks and reservoirs vest in the Municipal Board (Meghalaya Municipal Act, 1973, s.62(b)), whose consent is also required, and a pung held by a community, clan or Dorbar Shnong needs the written consent of that institution (set by this Manual). No sacred or community pung shall be used as a detention pond. An outfall that carries dry-weather flow is dealt with under Clause 8.9; the Umiam reservoir already "serves as a cesspool of the waste materials of Shillong" (Expert Committee report annexed to the Waterbodies Guidelines, 2023).
    - **Design level.** The tailwater for the major-system and storage cases shall be the waterbody's **maximum water level (MWL)** as its custodian publishes it, or, where only the full reservoir level (FRL) is published, **FRL plus the surcharge in its design flood**, computed from the rating of its spillway and gates with the gates

operated only as the custodian's written rule provides. Where neither the MWL nor the surcharge has been published, or where the published MWL is not above the FRL, the tailwater is **FRL + 0.5 m** (set by this Manual) [TBC]. In every case it shall be not less than the highest level recorded at the waterbody. The minor-system tailwater is the FRL. The project's discharge shall be included in the level (Clauses 5.3.2 and 5.12.3).

- **The MePGCL reservoirs.** MePGCL's gate-operation guidelines give the levels in metres for three projects and in feet for one; every level in feet shall be converted at **1 ft = 0.3048 m** exactly, and the conversion and the datum stated on Form 5-1. No guideline states the datum of its levels, and this Manual takes them as above mean sea level, to be confirmed with MePGCL before final design [TBC]. Until MePGCL confirms the design-flood level, the tailwaters are (set by this Manual) [TBC]: **Myntdu–Leshka Stage I**, FRL and MWL both 618.00 m (top of dam 620.00 m): **618.50 m**; **New Umtru**, FRL 130.10 m and MWL 132.78 m: **132.78 m**; **Umiam–Umtru Stage III** (Kyrdemkulai), FRL 2,230 ft (679.70 m) and MWL 2,235 ft (681.23 m): **681.23 m**; and **Umiam–Umtru Stage IV** (Nongkhyllem), FRL and MWL both 503.00 m: **503.50 m** (MePGCL gate-operation guidelines, 2022–2026). For the **Umiam (Barapani) reservoir** of Stage I, no MePGCL guideline was found; its full level is reported only in the press as 3,220 ft (981.46 m), releases were reported to have begun at 3,216.15 ft (980.28 m) in August 2024 on an IMD warning, and a spillway crest at EL 969.5 m is given in another document, with no datum stated for any (as reported) [TBC]. These are not design levels, because their datum is unknown: no outfall to the Umiam reservoir or its shore shall be designed without MePGCL's FRL, MWL and spillway rating in writing, or, until it gives them, the higher of the highest water line surveyed on the shore and the top of the closed spillway gates surveyed at the dam, each tied to a Survey of India benchmark, plus 0.5 m, with the reported levels recorded beside it on Form 5-1 (set by this Manual). No level of the Kopili project was obtained [TBC].
- **Warnings are not notices.** The MePGCL guidelines for Stage III, Stage IV and New Umtru state that, because the reservoir capacity is very small and the gates must be opened often in and out of the monsoon, "issuing the notification for release of water is not practicable", and that warnings may be given by siren, telephone or SMS. No design shall rely on a notice or a warning of a release, on the reservoir being drawn down before a storm, or on a gate being opened early, late or partly: the release scenarios of this item govern (set by this Manual).
- **Closed outfall.** Where the outfall invert is below the design level of this item, the outfall shall be treated as closed for the **whole of the 72-hour storm** of Clause 5.10.2 and of every shorter storm (Clause 5.9.4), with storage and pumping handling the full storm volume, unless the custodian's stage record shows the waterbody below the invert at the start of comparable storms and the Authority accepts it (set by this Manual). Every reservoir starts every design storm at its FRL (Clause 7.7.3); the drawdown zone of a reservoir is part of the reservoir, and no outfall structure, pumping station or storage shall be built in it without MePGCL's consent.
- **Release reaches.** For an outfall to a river below a dam, such as the Umtru on its 9.80 km of ravine below the New Umtru dam to the bridge at **Byrnihat**, the 13.05 km of ravine below Stage III to the Stage IV reservoir, the 33.5 km of ravine below Stage IV, and the Myntdu below the Myntdu–Leshka dam, whose releases run through "Ravines and Plains of East & West Jaintia Hills" for about 24 km to the Bangladesh border (MePGCL guidelines), in addition to the cases of Clause 5.8.4, the site design storm (each AEP required) and the 72-hour storm shall be run with the river at the level that results from the largest release of the dams above, routed to the outfall, with the flow of the catchment below them as it occurred, and with the release placed before, during and after the site storm, and the lock of item (b) applies for not less than 72 hours (set by this Manual). No release record of any MePGCL dam was obtained during research [TBC]; until MePGCL states the largest recorded release and its duration, the release is the spillway design capacity in its guideline: **12,000 m³/s** at Myntdu–Leshka, which the guideline says has seen "very high discharge of about 10440 cumecs during high rainfall"; **3,820 m³/s** at New Umtru; 60,000 cusec (**about 1,699 m³/s**) at Stage III; and 75,000 cusec (**about 2,124 m³/s**) at Stage IV (set by this Manual). No attenuation by the storage of any reservoir shall be credited to the river below, because those guidelines describe reservoirs of very small capacity whose gates are opened often, and no written rule found commits any reservoir's storage to flood control [TBC], and no dam gate shall be assumed to open earlier or wider than the operator's records show.

    - **Lakes and pungs.** No level on a stated datum, and no outlet or overflow level, was found for Ward's Lake, Thadlaskein or any other lake or pung [TBC]. Until the custodian gives one, the tailwater is the level at which the lake or pung spills, from its outlet or overflow crest surveyed and tied to a Survey of India benchmark, plus the head over that crest needed to pass the 1% AEP inflow, and not less than the highest level recorded at it; the lake or pung starts every design storm at its spill level, and an outfall below the tailwater is closed for the whole storm (Clause 5.9.4) (set by this Manual). Every drain that discharges to a lake or pung shall pass a debris and solid-waste trap and a sediment trap (Clauses 6.3.6(a) and 6.3.6(i) and Chapter 8) before it reaches it, and no drain that carries sewage shall discharge to one (Clause 8.9).
- (e) **The Garo plains under river backwater.** For an outfall on the Garo foothill plains of sub-area ML-A1, such as those of Phulbari and Tikrikilla, to the Jinjiram or the Krishnai, or to a drain or stream that ends in them, and for an outfall at Baghmara or Dalu on the south Garo rivers where they leave the hills:
    - **Design level.** These rivers have no CWC site in Meghalaya with a published level (SANDRP, 2018, as reported), and their lower reaches are held up by the Brahmaputra, whose levels the Assam edition of this Manual governs. In September 2014 the Brahmaputra and the Jinjiram "submerged over 200 villages" (as reported), and in September 2012 floods on the Brahmaputra and the Jingiram affected "over 100 villages" (IRADe/NMHS plan, 2020, as tabulated from district records). The design level at the outfall shall be the higher of the 1% AEP level from a hydraulic model (Clause 5.8.2(b)) whose downstream boundary is the Brahmaputra or other receiving level that the Assam edition gives for the coincident case, and the highest flood level surveyed at the outfall from the flood marks of September 2012, September 2014 or a later flood, with its source stated. At Baghmara and Dalu the levels at Dimapara and Sibbari under item (b) apply where the outfall is on the Bugi or the Dareng, and a surveyed flood level, among them those of the floods of October 2024 at Dalu (as reported), elsewhere (set by this Manual) [TBC].
    - **Lock.** Every outfall whose invert is below the design level of this item is an outfall-closed case with a single lock of **not less than 72 hours**, covering the whole of the 72-hour storm of Clause 5.10.2, or longer where the river model or a stage record shows the backwater lasting longer (set by this Manual). The tailwater, pumping and gate-failure rules of item (b) apply.
- (f) **Consents, the drains of other bodies, and lines.** No outfall structure, gate, pumping station or drain shall be built in the bed, bank or floodplain of a river or in a flood-protection work without the consent of the Water Resources Department, or in a reservoir, its drawdown zone or a release reach without the consent of MePGCL; the procedure for the Department's consent was not found during research [TBC]. Storm water shall not be discharged to a drain of another body without the written consent of that body: to a drain or water-course vested in a Municipal Board, the Board's written consent under s.204 of the Meghalaya Municipal Act, 1973, without which the Board may demolish the connection; to a road drain or culvert, that of PWD (Roads), NHAI or NHIDCL; in the Cantonment, that of the Shillong Cantonment Board; in New Shillong, that of NSTDA [TBC]; and to a village drain or jhora outside municipal limits, that of the District Council and the Dorbar Shnong under the District Council's rules, for which no written procedure was found [TBC] (set by this Manual). Where consent is given, the discharge shall not exceed the rate the consent allows; the tailwater is the higher of the channel's design water level as its owner states it in writing and its level in the coincident case of Clause 5.8.4, computed from all the storm water it receives and with its downstream boundary at the level of items (a) to (e); the channel shall be taken in its present condition, net of silt, boulders, debris, encroachment, solid waste and weed and with its narrowest section as surveyed, and a widening, channelisation or restoration that has been proposed but not completed shall not be counted; and the outfall shall have a flap gate (Clause 5.11) where the design water level or the computed level is above the outfall invert. The designer shall also check the outfall against the lines that bind at the time of design (Chapter 7): the setbacks of the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, as amended, measured from "the mean high flood level of a water body observed in the past ten years", among them 3 m from an urban stream up to 3 m wide and 6 m from a wider one, and the regulated zone of four times the setback for lakes and rural streams, which bind in Bye-Laws areas through B2(ii)(c) and Section I(a)4 and I(f) and elsewhere only as may be prescribed; para 4 of the Guidelines lists the works permitted in a setback and does not name a drain outfall, so whether one is permitted within it is to be confirmed with the Forest and Environment Department before design [TBC]; the bar on the "discharge of untreated wastes and effluents from … cities, towns, villages and other human settlements" into a waterbody (para 3(e)); any flood zone notified under the Meghalaya Flood Plain Zoning Act, 2026, whose restrictions prevail over other laws (s.12(2)),

none of which has been notified; the Highest Flood Level above which the Bye-Laws 2021 set the stilt of a building on a sloping site along a stream or river (B1(v)(b)); and, in the Khasi Hills, the duty of the District Council, Town Committee or Dorbar Shnong that no land development damages "catchment areas, water sources, spring sheds, streams and rivers" (KHADC Regulation 2015, s.15(1)). The High Court's bar on construction within 50 m of the high-water mark of a waterbody (order of 24 May 2023 in PIL 10/2019) ended when the petition was closed on 19 February 2024, and the "Restricted Zones of 50m + 300m" round Umiam in the Expert Committee's report and NESAC's buffers are recommendations, not rules; none of them is applied by this clause.

No pump, gate or dam operation that helps drainage, such as pumping a drain down before a storm, lowering a reservoir, lake or pung before a storm, closing a gate late or opening dam gates early, shall be assumed unless the operator's written records show it. Where the outfall invert is below the tailwater of this clause, the outfall shall have its own flap gate (Clause 5.11) and, where the outfall-closed check requires it, pumping (Clause 5.12), with the pumped volume included in the routing of the drain, the waterbody or the river (Clause 5.12.3). Pumping shall not be used to move water into a pung, a lake, a reservoir or another catchment without the consent of its custodian, or onto a slope.

Commentary. In large continental river basins, a site storm and a river flood are usually treated as roughly independent. That is the basis of tables of coincident frequencies such as FHWA HEC-22 Table 7.3. Meghalaya's streams and rivers break that assumption, because their catchments are small and steep and the storms that fill them fall on the towns at the same time. The valley floors of Shillong flood when the Umkhrah overflows in the same downpour that falls on the streets above them (as reported; IRADe/NMHS plan, 2020); on 9 and 16 June 2022 IMD listed extremely heavy rainfall in East, South and South West Garo Hills and South West Khasi Hills, and on 17 June Mawsynram recorded 1,003.6 mm in 24 hours (IMD); and in June 2026 the Shillong–Dawki road collapsed at Laitlyngkot while the Umngot at Dawki rose rapidly (as reported). The highest levels at Dawki (28 May 2006) and Kharkhana (23 April 1995) were set by pre-monsoon storms (SANDRP's copy of CWC data, as reported), so the coincident case is not confined to the south-west monsoon. The two cannot be treated as independent, and a local storm can fall before, during or after the river peak. Clause 5.8.4 therefore pairs a design event on one side with a 10-yr event on the other, in the same way as Clause 2.12(b). This pairing has no direct precedent. It is more severe than an independence assumption would give.

Clause 5.8.3 reflects the dams above and below the State's towns, all of them MePGCL's except the Kopili project of NEEPCO, shared with Assam. MePGCL's gate-operation guidelines give their levels: Myntdu–Leshka Stage I, FRL and MWL 618.00 m, top of dam 620.00 m, minimum drawdown level 606.15 m and spillway crest 587.50 m, with a spillway of 12,000 m³/s on a catchment of 350 km² and releases running through the ravines and plains of the Jaintia Hills for about 24 km to the Bangladesh border (guideline of 4 April 2022); New Umtru, FRL 130.10 m and MWL 132.78 m, crest 124.00 m, a storage of 3.55 MCM at FRL over 0.537 km², and a spillway of 3,820 m³/s on 1,020 km², with 9.80 km of ravine to the Byrnihat bridge (2025); Umiam–Umtru Stage III at Kyrdemkulai, FRL 2,230 ft and MWL 2,235 ft, minimum drawdown level 2,215 ft and crest 2,205 ft, a spillway of 60,000 cusec on 150 km² and 13.05 km of ravine to the Stage IV reservoir (2026); and Stage IV at Nongkhyllem, FRL and MWL 503.00 m, a spillway of 75,000 cusec on an intermediate catchment of 52 km² and 33.5 km of ravine below it (2025). The guidelines for Stage III, Stage IV and New Umtru say that "Since the Reservoir capacity is very small, and the requirement of frequent release of water through the Gates during Monsoon as well as during Non-monsoon period, issuing the notification for release of water is not practicable; however warnings in the form of blowing the Siren, Telephone/SMS may be issued". The specific yields of the spillways, about 34 m³/s per km² at Myntdu–Leshka on the escarpment against about 3.7 m³/s per km² at New Umtru on the northern slope (NEER arithmetic), show how much harder the escarpment's rivers run. For the Umiam (Barapani) reservoir of Stage I, impounded in 1965, no MePGCL guideline was found: its full level is reported in the press as 3,220 ft, and releases were reported to have begun at 3,216.15 ft in August 2024 on an IMD warning; a spillway crest at EL 969.5 m, with two gated bays of 12.2 m, is given in another document; and its gross capacity is reported to have fallen from 179.757 Mm³ in 1965 to 159.206 Mm³ in 2004 with sediment (all as reported). No datum is stated for any of these levels, no release record or operating rule that bounds a release was obtained for any dam, and no level of the Kopili project was found during research [TBC]. Until they are available, the spillway design capacity applies as the

release, with the flow of the catchment below the dam as it occurred in the same event (Clause 5.8.5(d)). The river levels used in this Manual come from SANDRP's copies of CWC data; their datum and gauge zero are to be confirmed with CWC [TBC].

Clause 5.8.5 is set by this Manual. In Meghalaya the tailwater at a town outfall is set not by the tide but by a city stream that no one gauges, by a river held high by a monsoon spell or by the releases of a dam, by a jhora whose level no one has recorded and whose bed moves, by a reservoir, lake or pung at its full level, or by the backwater of the Brahmaputra on the Garo plains, and no document found during research gives a design level for any of them. No design standard for any town drain in the State was found: the only drainage-design statement found is that of a multi-hazard assessment of Shillong made in 2019, which took its design rainfall from the CWC Brahmaputra Basin PMP Atlas and used the rational formula (as quoted in the IRADe/NMHS plan, 2020; the assessment and the atlas were not obtained) [TBC]. The State has a floodplain zoning law, the Meghalaya Flood Plain Zoning Act, 2026, but no zone has been notified under it, and no flood level has been published for any reach (Chapter 7).

The first is the city stream. Item (a) treats the Umkhrah and the Umshyrpi as a case of their own because the State's capital drains into them, because they have no gauge, no flood study and no published level, and because their valley floors flood in ordinary storms. The design level must therefore come from a model and from flood marks, as for the ungauged hill streams of the mountain editions of this series, with the bulking and blockage of Clause 6.3.6, because the channels are narrowed by building and choked by waste: NESAC found "a drastic reduction in channel capacities in most streams due to encroachments along their banks by buildings" (NESAC, 2023). Polo, Pynthorbah, Nongmynsong and the other valley floors are named as outfall-closed cases because their drains cannot discharge while the stream is up. The lock there is the storm and the stream's recession, and not less than 24 hours, shorter than the 72 hours of the rivers, because the streams are small and fall within hours of the rain stopping; it is still long enough to cover a whole day's storm, because the plateau's 24-hour totals are long orographic falls (Chapter 2), and where the longer storms of Clause 5.10.2 are run, the lock lasts for all of them. The model of the stream also keeps the interception works, stone bunds and waste traps that the State has built for the National Green Tribunal (Clause 8.9) from raising the level at the outfalls they were built to protect.

The second is the river. Item (b) follows the interim river rule of the mountain editions: the design level is the 1% AEP level, and never below the highest level recorded at the nearest CWC gauge. No CWC site in Meghalaya has a warning or a danger level, and all seven of its sites record levels only (SANDRP, 2018, as reported), so the 10% AEP case uses the design level until a frequency analysis exists. Item (b) allows a surveyed profile of flood marks in place of the unchanged gauge level, because the escarpment's rivers fall several metres in a kilometre, and adds the surveyed flood mark of June 2026 at Dawki because the 2006 record there was set before that flood. The rivers that run into Assam are governed downstream by the Assam edition, and those that run into Bangladesh have no levels across the border, so item (b) makes the model start far enough downstream that the boundary does not decide the answer. The lock is not less than 72 hours because the storms that raise the rivers last for days, as on 15–16 June 1995 and 15–17 June 2022 (Chapter 2), and because no hourly stage record of any gauge in the State was obtained during research [TBC]. A designer who has the stage record of a CWC gauge can justify a shorter lock under Clause 5.10.6.

The third is the jhora. Item (c) follows the khad and nallah rule of the mountain editions: a study with the bulking factor of Clause 6.3.6(b), surveyed flood marks, the higher of the two, and an invert at least 0.5 m above the highest bed level surveyed downstream, a margin set by this Manual for the aggradation that a boulder bed can show in a single flood. Two things are added for Meghalaya. On the escarpment, where no CWC method applies and the storms run for days, the study is the site-specific study of the ML-Z3 rule of Clause 2.3.6, with the long storms of Clause 6.3.6(j). And in the karst and the coal belt, a stream can disappear underground: streams are reported to "disappear or have become seasonal in nature as surface water trickles into and disappears in the unfilled mine pits and caves" (as reported), so item (c) sends no outfall into a sinkhole, a cave or a mine pit, in line with the karst and mine rule of Clause 4.11.

The fourth is the reservoir, the release reach, the lake and the pung. A reservoir at its full level does not fall for the rest of the season but passes its inflow over its spillway, and its level rises above FRL by whatever head the flood needs. Item (d) therefore takes the MWL, or FRL plus the design-flood surcharge, and treats an outfall below it as closed for the whole of the 72-hour storm. Where MePGCL publishes an MWL equal to its FRL, as at Myntdu–Leshka and Stage IV, FRL + 0.5 m is set as the interim value: it is the freeboard that this Manual uses for floor levels (Clause 6.11.1), and it is a floor, not an estimate of the surcharge [TBC]. Stage III's levels are in feet and are converted at the exact factor of 0.3048 m. The Umiam reservoir, which takes all of Shillong's drainage, has no MePGCL guideline that was found and only a press level in feet with no datum, so item (d) does not use that level as a design level and requires MePGCL's figures or a surveyed shore line. The guidelines say that notices of release are not practicable and that warnings are given by siren, telephone or SMS; a warning helps people leave a reach but does not change the level an outfall must withstand, so item (d) designs for the release and not for the warning. No release record was obtained for any dam, so the spillway capacity stands in for the largest release until MePGCL gives one, which is conservative by design: a tailwater set too low floods the town, while one set too high only costs storage. Lakes and pungs have no published levels, so item (d) uses their surveyed spill level, as the mountain editions do for their lakes, keeps sewage out of them and does not let a sacred or community pung be used as a detention pond.

The fifth is the backwater of the plains, and the sixth is the consents and lines. On the Garo foothill plains the Jinjiram and the Krishnai are held up by the Brahmaputra for days, as in September 2012 and September 2014, so item (e) takes a lock of at least 72 hours and the Brahmaputra level of the Assam edition as the model's boundary. Item (f) asks for the owner's consent and design level because a design that discharges to a channel, a reservoir or a pung cannot be checked without them, and because the drains belong to several bodies, among them, outside municipal limits, the District Councils and the Dorbar Shnongs on land that is mostly community, clan or private. The lines of item (f) decide where an outfall can be built, not its level. The Waterbodies Guidelines set stream setbacks of 3 m and 6 m in urban areas, measured from a ten-year mean high flood level that was not found published for any stream, and exclude most jhoras from their protection; the Manual's own corridor (Clause 7.4) is wider and covers them. The High Court's 50 m bar of May 2023 ended in February 2024, and the Umiam and NESAC buffers are recommendations, so item (f) names them and does not apply them.

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## 5.9 Joint-probability cases

5.9.1 Every element draining to a tidal or backwater-affected outfall shall be checked for the cases below. The most severe governs each design quantity: storage, water level, pipe size and pump capacity.

**Table 5.2 — Joint-probability cases for tidal and riverine outfalls**

| Case | Rainfall | Tailwater | Applies to | Basis |
|---|---|---|---|---|
| J1 | Minor-system design AEP, Tc to 24 h | MHWS + SLA (tidal curve) | Minor system | Clause 2.12(a); Clause 5.7.1 |
| J2 | 1% AEP, all durations of Clause 2.5.2 | HAT + surge + SLA | Major system, detention, tanks, pumped systems | Clause 5.7.1 |
| J3 | 10% AEP, **48 h** | 1% AEP still-water level + SLA | Major system, detention, tanks, pumped systems | Clause 2.12(b) |
| J4 | Design AEP, **48 h** (72 h reported) | Tidal curve per J1 with two **6 h lock windows** (Clause 5.10) | All storage and every gated or tide-affected outfall | Clause 5.10 |
| R1 | Site design AEP | River at 10% AEP level | Riverine outfalls | Clause 5.8.4(a) |
| R2 | Site 10% AEP | River at design-AEP level | Riverine outfalls | Clause 5.8.4(b) |

5.9.2 For storage elements, the 48- and 72-hour storms shall be run with the J2 and J3 tailwaters (Clause 2.5.3).

5.9.3 For tidally influenced riverine outfalls, R1 and R2 shall be run with the river model's downstream boundary at the J1 tidal curve. The Authority may also require them at J2.

5.9.4 Where tailwater is constant at a level above the outfall invert for the whole storm, the case is treated as a fully closed outfall. Storage and pumps shall then handle the full storm volume.

> Commentary. Clause 2.12 sets two joint cases. Case (a) is design rainfall with MHWS plus the sea-level allowance. Case (b) is the 10-yr, 48-hour storm with the 1% still-water level. This Manual adds HAT plus surge for major-system design (Clause 5.7.1). Case J2 combines these. J4 is the outfall-closed check, which tests the timing of tide against the storm rather than a single level. Rainfall and surge share a cyclone cause, so they cannot be treated as independent (Clause 2.12 commentary). These cases are simple surrogates, to be replaced when a statistical joint analysis of IMD rainfall and tide-gauge records is adopted.

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## 5.10 Outfall-closed (tide-locked) storage check

5.10.1 **Where it applies.** The check applies to:

- every storage facility;
- every minor- and major-system element; and
- every pumped system

whose outfall invert is below HAT + surge + SLA, or which drains to a reach subject to tide-lock or sand-bar closure (Clause 5.13).

5.10.2 **Storm.** Use the 48-hour design storm built per Clause 2.9.2 (peak day last), at:

- the AEP of the element: 1% AEP for detention, tanks and the major system; the minor-system AEP for minor drains; and
- AMC III.

The 72-hour storm shall also be run and reported.

5.10.3 **Lock windows.** Unless a site study under 5.10.6 gives otherwise:

- (a) the outfall is closed for **two consecutive lock windows of 6 hours each**, centred on two consecutive high tides of the local tidal curve. For a semi-diurnal tide, the window starts are therefore about 12.4 hours apart.
- (b) During each lock window, gravity discharge is **zero**.
- (c) Between lock windows, gravity discharge is computed against the J1 tidal curve, including the head loss of the flap gate and any non-return valve.
- (d) The first lock window shall be placed so that it is centred on the peak 1-hour block of the final 24 hours of the storm. A second run with the first window **starting** at that peak block shall also be made. The more severe governs.

5.10.4 **Requirement.** Storage plus pumping (where provided) shall hold the inflow so that, throughout the check:

- (a) the maximum stage in any detention facility stays below its emergency spillway crest, so the spillway does not operate. Where the outfall-closed stage is higher than the 1% AEP maximum water level of the free-outfall design, it becomes the facility's 1% AEP maximum water level for Clause 4.9.3, and the spillway crest, freeboard and wall height are set from it;

- (b) the maximum stage in the minor and major systems meets the Chapter 6 limits: building floor levels, and street depths of no more than 150 mm at the crown and no more than 350 mm at the deepest point; and
- (c) no property connection surcharges above the lowest opening it serves, or a non-return valve is fitted under Clause 5.11.

In volume terms, over each lock window and the full storm:

> V_inflow ≤ V_storage available + V_pumped + V_gravity (between locks)

This shall be demonstrated by routing, not by a single volume balance. The release from each facility after a lock window ends may exceed the release caps of Chapter 4, because the facility is emptying into a drain that has just reopened. That release shall be included in the downstream analysis (Clauses 5.4 and 5.9).

5.10.5 **Drawdown after the storm.** After the second lock window, the storage shall drain under the J1 tidal curve. The drawdown requirement of Clause 4.7 shall be met, with pumping where gravity cannot meet it (Clause 5.12).

5.10.6 **Site study.** A longer or shorter lock may be used where a site study gives a time series of still-water level for the design case. The study may use a calibrated hydrodynamic model, gauge records of past events, or a surge hindcast. Locks shorter than the default require the Authority's approval. A longer lock shall be used where:

- sand-bar closure (Clause 5.13) or river backwater (Clause 5.8) keeps the outfall closed for longer; or
- the gauge record shows tailwater above the outfall invert for more than 6 hours per tide in comparable past events.

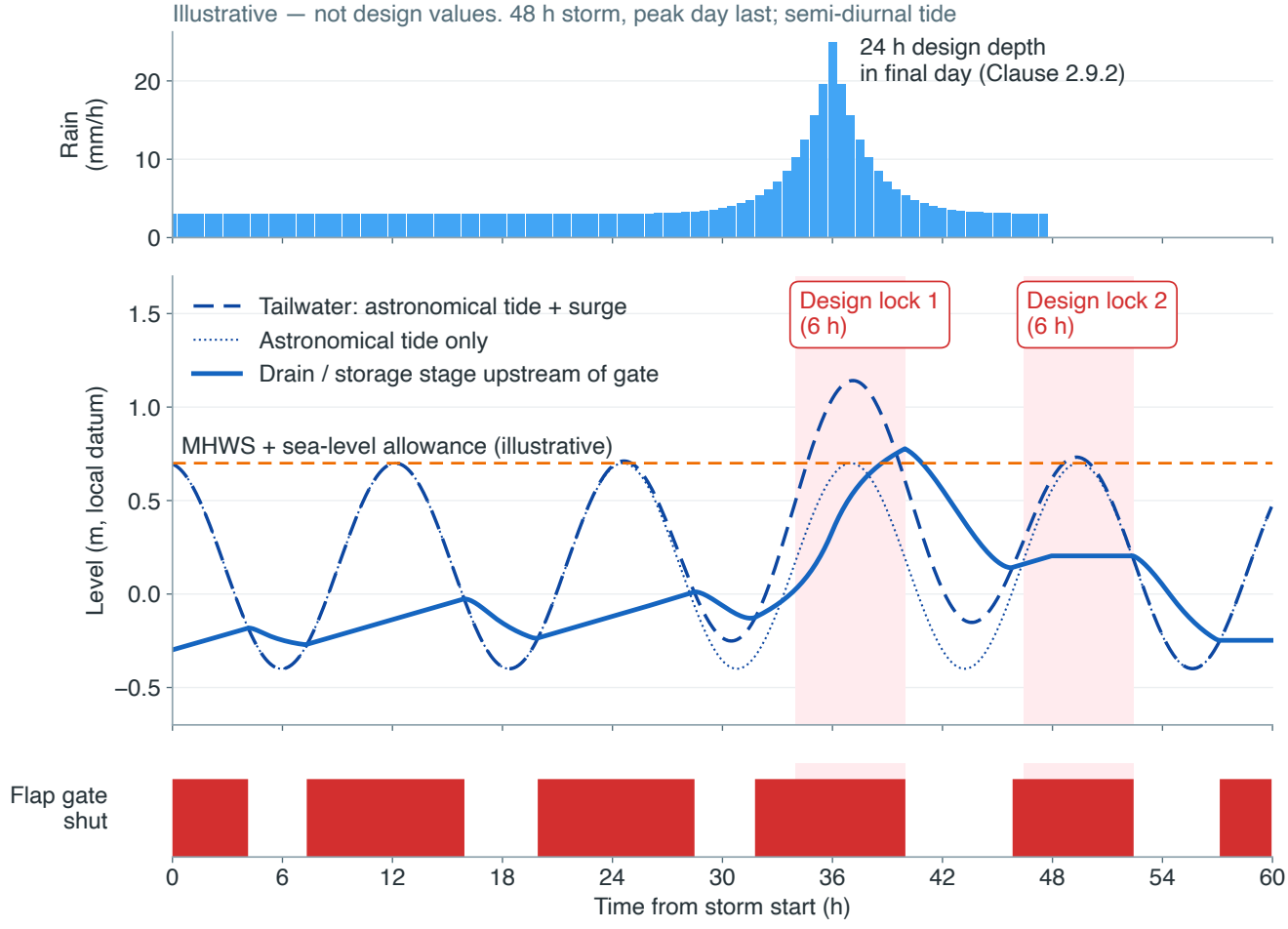

*Figure 5.3 — Outfall-closed check: 48-hour storm with the peak day last (Clause 2.9.2), tailwater of astronomical tide plus surge, two 6-hour design lock windows, and the resulting stage upstream of the flap gate. Illustrative — not design values. Original drawing for this Manual, adapted from the tidal tailwater and joint-probability concepts of MoHUA/CPHEEO Manual on Storm Water Drainage Systems (2019), Part A, §6.3.6.*

> **Commentary.** The outfall-closed check is the distinctive Meghalaya requirement in this Manual. In Meghalaya it applies where an outfall is shut not by the tide but by a city stream that has overtopped its banks, by a river held high by a monsoon spell or by the releases of a dam, by a jhora that has risen over the outlet or buried it in boulders and garbage, by a reservoir, lake or pung at its full level, or by the backwater of the Brahmaputra on the Garo plains. The valley floors of Shillong along the Umkhrah flood "with nearly every heavy downpour" (as reported; IRADe/NMHS plan, 2020); the storms that raise the escarpment's rivers last for days, as on 15–16 June 1995, when Cherrapunji is reported to have recorded 2,493 mm in 48 hours (as reported), and on 15–17 June 2022, when Mawsynram recorded 1,003.6 mm in the 24 hours to 0830 IST on 17 June (IMD); and in September 2014 the Brahmaputra and the Jinjiram submerged over 200 villages of the Garo Hills (as reported). A reservoir at its full level stays there for the rest of the season, and a jhora in flood can block an outlet with boulders and waste, which is why Clause 5.8.5 replaces the two 6-hour windows described below with a lock of at least 24 hours on the Shillong valley floors, at least 72 hours on the rivers, the release reaches and the Garo plains, and a closure for the whole storm at a reservoir, lake, pung or jhora outfall below its design level. A rate rule cannot help when there is no outlet: an orificed basin behind a closed gate simply fills.
>
> The default of two consecutive 6-hour locks has no direct precedent. It represents gravity outfalls failing to discharge for about half of each tidal cycle around the two high tides nearest the storm peak. Figure 5.3 shows why both windows matter. The first lock catches the storm peak. The second arrives before the storage has drained, so the stage rises again.
>
> Placing the first window on the rainfall peak is deliberately unfavourable. Cyclone rainfall and surge share a cause, and Clause 2.12 already treats them as dependent. The check replaces neither the J2 and J3 level checks nor the downstream analysis; it adds a test of timing and volume.

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## 5.11 Flap gates, tide gates and non-return valves

5.11.1 **Where required.** A flap gate, tide gate or equivalent non-return device is required on every outfall whose invert is below the **1% AEP still-water level** (Clause 5.7.3). It is also required on outfalls into irrigation channels under Clause 5.8.5.

5.11.2 **Hydraulics.** The design shall include:

- the gate's head loss and opening head, from the manufacturer's certified head–discharge curve; and
- the reduction in effective outfall capacity when the gate is partly open.

Gates shall not be assumed to seal perfectly in the outfall-closed check unless they are tested.

5.11.3 **Construction.**

- (a) Gates, hinges and seats shall be of corrosion-resistant materials suitable for seawater (Clause 4.12.5).
- (b) The gate shall be set so that sand, silt or debris on the downstream side cannot hold it shut or open. Where the bed is mobile, the gate invert shall be raised above the bed, or the approach shall be protected.
- (c) A trash screen shall be provided upstream where the gate could be jammed by debris.
- (d) A stop-log slot or penstock shall be provided upstream for maintenance isolation on outfalls larger than 600 mm.
- (e) The gate chamber shall be accessible at all tides, with its access above HAT + surge + SLA.

5.11.4 **Non-return valves on property connections.** A non-return valve, or a backwater valve with an accessible cleaning eye, is required on every property drainage connection where the lowest opening served is below:

- the major-system tailwater (J2) at the point of connection; or
- the maximum stage in the outfall-closed check (Clause 5.10).

Basement drainage shall in addition be pumped to a level above both, with its own non-return valve.

5.11.5 **Inspection.** Gates and valves shall be inspected and operated:

- before **31 March** each year;
- after every event in which they closed against a storm flow; and
- as set in the maintenance plan (Chapter 10).

> Commentary. The requirement for gates below the 1% still-water level is set by this Manual. The construction details follow common coastal-drainage practice. A gate that is jammed open by debris lets the tide into the drain. A gate held shut by a sand bank turns a gravity outfall into a dead end. In Meghalaya the outfalls do not cross a beach, but some of them end in a reach of river below a dam of MePGCL, or in a reservoir held near its full level. MePGCL's guidelines for its Stage III, Stage IV and New Umtru dams say that, because the reservoirs are very small and the gates are opened often, in the monsoon and out of it, "issuing the notification for release of water is not practicable", and that warnings may be given by siren, telephone or SMS; the Myntdu–Leshka dam has a spillway of 12,000 m³/s on a catchment of 350 km², whose releases run through the ravines and plains of the Jaintia Hills for about 24 km to the Bangladesh border (MePGCL guidelines); and the Umiam reservoir, which receives all of Shillong's drainage, was reported to have begun releasing water in August 2024 on an IMD warning (as reported). A gate opened in a hurry raises the river below; a gate held shut or jammed by debris raises the reservoir and every outfall that drains to it. The dams are held by MePGCL, and the Kopili project by NEEPCO, while the drains that reach the rivers and reservoirs below them belong to the Municipal Boards, PWD, NHAI and NHIDCL, the District Councils and the Dorbar Shnongs; no rule linking the operation of any of these gates to the levels of the drains was found during research, and no MePGCL guideline was found for the Umiam dam [TBC]. A gate and the drains behind it can therefore belong to different bodies. The 31 March inspection date is set ahead of the monsoon.

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## 5.12 Pumped outfalls

5.12.1 **When required.** Pumping shall be provided where gravity discharge cannot meet:

- the outfall-closed check of Clause 5.10;
- the drawdown requirement of Clause 4.7; or
- the J2 and J3 cases.

Pumping shall not be used where a gravity solution meets these requirements.

5.12.2 **Capacity.**

- (a) The duty pumps together, with the storage provided, shall pass every case of Clause 5.9 (including J4), demonstrated by routing.
- (b) **Standby** capacity at least equal to the largest duty pump shall be installed (duty + 1 standby as a minimum).
- (c) Pump capacity shall be stated at the static head for the **J2** tailwater, not at mean tide.

5.12.3 **Effect on the receiving water.** Pumped discharge to a river, canal or creek shall be included in the river or creek level analysis of Clause 5.8. Pumping that raises the receiving water level above the acceptance criteria of Clause 5.5 elsewhere is not permitted.

5.12.4 **Power supply.** Pumping stations shall have either:

- two independent power supplies; or
- standby generation for 100% of the duty capacity, with on-site fuel for at least **72 hours** of duty operation.

Changeover shall be automatic.

5.12.5 **Flood immunity.** Electrical panels, control equipment, generators and fuel storage shall be set above the higher of:

- the 1% AEP flood level + 0.5 m; and
- HAT + surge + SLA + 0.5 m.

Access to the station shall remain usable in the 1% AEP event.

5.12.6 **Discharge arrangement.** Rising mains shall discharge:

- over a level above the J2 tailwater; or
- through a non-return valve and a flap gate.

The arrangement shall prevent back-siphoning.

5.12.7 **Controls and monitoring.** Each station shall have:

- automatic level control;
- remote alarms for high level, pump failure and power failure, sent to the operator; and
- a level and run-time log kept for at least 5 years.

Wet wells shall be sized to keep pump starts within the manufacturer's limits.

5.12.8 **Screens.** Inlet screens shall be provided with a cleaning method that works during a storm (a mechanical rake, or duplicate screens).

5.12.9 **Testing.** Every pumped outfall shall be test-run at full duty, including on standby power, before **31 March** each year. Private pumped systems shall be covered by a registered maintenance declaration (Chapter 10).

> Commentary. Duty + standby, 72 hours of fuel and flood-immune electrics have no single direct precedent and are set by this Manual. The 72-hour fuel figure matches the longest mandatory design storm (Clause 2.5.2). A pump station that depends only on grid power can stop exactly when it is needed, because supply to flooded areas is often switched off for safety. Singapore's April 2025 amendments added annual maintenance declarations for pumped detention tanks (PUB Addendum No. 3). Clause 5.12.9 and Chapter 10 adopt the same approach. Clause 5.12.3 prevents pumping that simply moves water from one tide-locked drain into a tide-locked river.

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## 5.13 Sand-bar closure of river mouths

5.13.1 **Where it applies.** This clause applies to outfalls into any river or creek whose mouth is subject to seasonal sand-bar closure. That includes the mouths of the coastal States (there is none in Meghalaya: Clause 5.1.4), and any other mouth listed in Annex 5B.

5.13.2 **Assumption at the start of the monsoon.** The mouth shall be assumed **closed** by a bar at the start of the April–October season, at the crest level of the most recent pre-monsoon survey. This applies unless the Water Resources Department certifies that:

- a mouth-maintenance programme (dredging, bar cutting or training walls) has kept the mouth open at the start of each of the previous three monsoon seasons; and
- the programme is funded for the current season.

5.13.3 **Tailwater with a closed mouth.** With the mouth closed, the tailwater at the outfall shall be the higher of:

- (a) the tidal tailwater of Clause 5.7; and
- (b) the level in the river reach behind the bar, computed with the bar as a weir at its surveyed crest level. That level shall include the river flow of Clause 5.8 and the head needed to pass the flow over or through the bar.

5.13.4 **No credit for emergency cutting.** Bar cutting or breaching during the storm shall not be assumed in design, unless the Water Resources Department has a documented operating procedure, with equipment stationed for it. Where it does, the bar may be assumed lowered to the procedure's target level only after the time the procedure states.

5.13.5 **Outfall-closed check.** Where the closed-mouth level of 5.13.3(b) exceeds the outfall invert for longer than the default lock windows, the lock duration of Clause 5.10 shall be extended to that period.

> Commentary. Meghalaya has no coast and no river mouth, so Clause 5.13 does not apply in the State (Clause 5.1.4). Its nearest inland counterparts are the boulders, slide debris, silt and garbage that hill streams leave at an outfall or a gate. In Shillong 49,612 m³ of waste was removed from the Wahumkhrah, and ₹3.60 crore was spent on stone bunds and solid-waste traps (State action-taken report to the National Green Tribunal, 21 March 2023); the Umiam reservoir fell in gross capacity from 179.757 Mm³ in 1965 to 159.206 Mm³ in 2004 with sediment (as reported); and the IRADe/NMHS plan for Shillong (2020) found that "due to increasing levels of urbanization and unregulated construction work the natural drainage system is blocked". A flap gate held open or shut by gravel, debris or waste, an outlet buried by a rising bed or left hanging by scour, or a gate that cannot be moved, turns a designed outfall into a dead end or a back-flow path. MePGCL has written gate-operation guidelines for four of its dams, but no rule linking the operation of any gate to the levels of the drains above or below it was found during research [TBC]. Clause 5.8.5 deals with both by setting outfalls above the range of bed movement and by giving no credit for a gate operation or a storage that the operator's records do not show. Clause 5.13.2 has no direct precedent. It puts the burden of proof on showing that the mouth is open rather than assuming it.

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## 5.14 Documentation

Every project subject to this chapter shall submit a **Downstream and Tailwater Report** (Form 5-1). It shall contain:

1. a plan of the analysis extent showing:
    - the site;
    - each analysis point with its contributing catchment area and the site's percentage of it; and
    - the end point and the reason it was chosen (Clause 5.3);
2. the model description:
    - software and version;
    - the network schematic, with survey sources for the drains and crossings;
    - land use and CN for off-site areas;
    - any upstream detention included; and
    - calibration or validation evidence where available;
3. for each analysis point, AEP and duration, the existing and with-project:
    - peak flow;

    - time to peak;
    - maximum water level and velocity; and
    - duration of inundation (Clause 5.4);
4. the comparison against Clause 5.5, with each failure identified and the remedy adopted;
5. the tailwater derivation:
    - tide-table edition and port;
    - MHWS, HAT and MSL relative to chart datum;
    - the datum connection to the Survey of India benchmark and the project datum;
    - surge source and value;
    - SLA; and
    - river levels and their sources (Clauses 5.6 to 5.8);
6. the joint-case table of Clause 5.9 with results;
7. the outfall-closed check (Clause 5.10):
    - storm and lock alignment;
    - stage hydrographs; and
    - the volume balance for each lock window;
8. a schedule of flap gates, tide gates and non-return valves, with certified head–discharge data (Clause 5.11);
9. pumped outfall design, power supply, flood immunity and controls, where provided (Clause 5.12);
10. the sand-bar assumption and supporting Water Resources Department certification, where relevant (Clause 5.13); and
11. inspection and maintenance requirements for Chapter 10.

Small sites under Clause 5.3.4 shall submit Form 5-2 (Simplified Downstream Statement) instead.

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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 5A | Tidal datums (MSL, MHWS, HAT vs CD and Survey of India datum), surge allowances and 1% still-water levels by coastal segment |

| Annex / Form | Content |
|---|---|
| 5B | Major drains, riverine outfall reaches, and river mouths subject to sand-bar closure; map |
| 5C | Worked example: outfall-closed check for a site on a jhora draining to the Umkhrah in Shillong |
| Form 5-1 | Downstream and Tailwater Report |
| Form 5-2 | Simplified Downstream Statement (small sites) |

CHAPTER 6

# Minor and Major Drainage Systems

## 6.1 Purpose and scope

6.1.1 This chapter sets the level of service and the hydraulic criteria for the conveyance system that carries runoff from a development, a road or a public drainage scheme to a receiving waterway, tank or outfall. It covers:

- (a) the dual drainage concept: a minor system and a major system (Clause 6.3);
- (b) design return periods by land use and road class (Clause 6.4);
- (c) street hydraulics: spread, depth and flow hazard (Clause 6.5);
- (d) inlets, including clogging (Clause 6.6);
- (e) pipes and open and covered drains (Clause 6.7);
- (f) hydraulic grade line analysis (Clause 6.8);
- (g) overland flow paths, ponding at sags and building floor levels (Clauses 6.9 to 6.11);
- (h) culverts and road crossings (Clause 6.12); and
- (i) Meghalaya construction-practice requirements for covered drains, silt, solid waste, utilities and desilting access (Clause 6.13).

6.1.2 The detailed hydraulic design of individual structures (culverts, channels, energy dissipators, screens, pumps, gates, manholes) is in Chapter 9. Rainfall is in Chapter 2, runoff methods in Chapter 3, on-site storage in Chapter 4, tailwater in Chapter 5, waterbodies in Chapter 7 and water quality in Chapter 8.

6.1.3 This chapter applies to all public drains, all roads with kerbs or roadside drains, and all private drainage systems in developments that meet the applicability thresholds of Chapter 1. In Tier B local bodies, the simplified procedures and design aids referred to in Chapter 1 may be used for elements serving ≤ 16 ha, but the criteria of this chapter still apply.

> Commentary. Meghalaya's drains were not designed against any State or municipal standard: none was found during research, and no document found gives a design return period, runoff coefficient or drain size for any town; the Bye-Laws 2021 leave the requirements of drainage to the National Building Code 2016 (D4.2, D5.6). The only drainage-design statement found is that of a multi-hazard assessment of Shillong made in 2019, which divided the city into sub-watersheds, took its design rainfall from the CWC Brahmaputra Basin PMP Atlas and estimated flows by the rational formula (as quoted in the IRADe/NMHS plan, 2020; the assessment was not obtained) [TBC]. Shillong's count of its own drains is not settled: "The drains in the city run for 148.91 km and drain directly into the Umkhrah and Umshyrpi rivers … storm-water drainage network coverage is less than 75% of the city, the incidence of sewerage mixing in drains is almost 100%" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan), while the same plan's service-level table gives a coverage of 85% and waterlogging in 25% of the city, a conflict that the plan does not resolve. The plan recommends "Upgradation of the existing drains" and "Desilting to avoid flooding during monsoons", by PWD and the Shillong Municipal Board, without a design basis, and five drains entering the Umkhrah are reported to "account for 42% of Umkhrah's pre-monsoon discharge" (Chief Secretary's presentation, April 2023). The drains also work in a setting that the plains editions of this Manual do not meet. In the hill towns they collect water from slopes that deliver gravel, stones and slide debris with every storm, and, with no sewerage in Shillong, they carry the town's sullage and much of its waste; they end in jhoras and streams whose beds move and whose channels have been narrowed by building, and NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" (NESAC, 2023). The road drains of the

hills are the drains of the land above them. The drains are also divided among owners: the Municipal Boards, the Shillong Cantonment Board, NSTDA, Shillong Smart City Ltd, PWD, NHAI and NHIDCL, the Water Resources Department, MePGCL, and, outside municipal limits, the District Councils and the Dorbar Shnongs all build or hold drains and receiving waters, and no rule divides them (see the Commentary to Clause 6.9). Fixing the rainfall (Chapter 2) is only half the answer. The other half is a second, surface-level system that carries the flows the pipes cannot, without flooding buildings. That is the dual drainage concept of this chapter, taken from Kansas City Metro APWA Section 5600 (5601.8, Levels of Service), which requires every element to have a 1% AEP overflow path.

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## 6.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Minor system | Inlets, pipes, covered drains and open drains that carry runoff up to the minor design AEP of Table 6.1 without surcharge above the limits of Clause 6.8. |
| Major system | The surface flow paths (streets, overland flow paths, open channels, floodways and storage) that carry flow above the capacity of the minor system, up to the 1% AEP (100-yr) event. |
| Overland flow path | A defined surface route, in public land or a recorded easement, that carries major-system flow to a receiving waterway. |
| Spread (T) | Width of flow in the gutter and carriageway, measured from the face of the kerb. |
| Sag | A low point on a road or flow path from which water can leave only through an inlet or by ponding to an overflow level. A trapped sag has no surface overflow route. |
| Clogging factor | The fraction of an inlet's clean hydraulic capacity assumed lost to debris (Clause 6.6.3). |
| Hydraulic grade line (HGL) | The line joining the free-surface levels in a conduit system, or the piezometric levels where the system is under pressure. |
| Covered drain | A rectangular drain, usually beside a road, closed by cast-in-situ or precast cover slabs that form a footpath. |
| Sediment allowance | The depth or area of a drain or pipe assumed filled with silt when its design capacity is computed (Clause 6.7.8). |
| Check event | An AEP rarer than the design AEP at which the combined minor and major system must still meet the limits of Table 6.2. |
| High-density area | An area notified as such by the approving authority under Clause 6.4.4. |
| Class I area | An urban local body with a population of 1 lakh or more (the CPHEEO definition). |

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## 6.3 The dual drainage concept

6.3.1 Every drainage system shall be designed as two systems that work together:

- (a) a **minor system** that carries the minor design flow of Table 6.1 below ground or in drains, keeping streets usable and spread within Table 6.2; and
- (b) a **major system** that carries all flow above the minor-system capacity, up to the 1% AEP (100-yr) flow, on the surface without entering buildings and within the depth and hazard limits of Clause 6.5.

6.3.2 **Every element has a 1% path.** Every inlet, sag, pipe, drain, culvert and storage element shall have an identified 1% AEP overland flow path to a receiving waterway, tank or outfall. The path shall be shown on the drainage plan (Clause 6.15).

6.3.3 **Major-system design flow.** The major system at any point shall carry the 1% AEP peak flow less the minor-system capacity at that point. The minor-system capacity used in this subtraction is the capacity of the inlets after the clogging factors of Clause 6.6.3, or the pipe capacity, whichever is less. At sags and at any location used to set building floor levels, the major system shall also be checked with the minor system **fully blocked** (Clause 6.10.3).

6.3.4 **Rainfall and method.** Design flows shall use the rainfall of Chapter 2 (including the climate factor of Clause 2.8) and the methods of Chapter 3:

- (a) the Rational Method only for catchments ≤ 16 ha and a single conveyance element. It shall not be used to accumulate flows down a network whose total catchment exceeds 16 ha;
- (b) a hydrograph method with hydraulic routing (for example SWMM, HEC-HMS with a hydraulic model, or an equivalent 1D/2D model) for networks above 16 ha and for any network with storage, pumping or a tidal outfall;
- (c) a minimum time of concentration of 10 minutes.

6.3.5 **No transfer between catchments.** Neither the minor nor the major system shall divert flow from one natural catchment to another unless the approving authority accepts a catchment-wide study showing no adverse effect.

6.3.6 **Hill catchments: debris, garbage, sediment, steep drains and streets, hill roads, sloping sites and long storms.** This clause applies to every element of the minor and major systems that receives runoff from a hill catchment, which in this Manual means land in sub-area ML-A, ML-B, ML-B1, ML-C, ML-C1 or ML-D of Annex 2A, any catchment whose natural ground slopes more than 10% on average, and any jhora or other stream that comes down from the hills, including where it runs out across the Garo foothill plains of sub-area ML-A1. Such elements shall meet Clauses 6.4 to 6.14 and, in addition (all set by this Manual):

- (a) **Debris racks and traps.** Every inlet, drain or pipe entrance and culvert that receives flow from **1 ha or more** of unbuilt hill land (forest, scrub, cultivated or bare slope, a quarry or mine spoil, or a slide scar), or from a jhora or other hill stream whatever its catchment, shall have a debris rack or a debris trap upstream of it, designed under Chapter 9 (Clause 9.8), with machine access and a stable place to stockpile what it catches, which shall not be a slope, a jhora or a stream. With 50% of the rack blocked, the element it protects shall still pass its design flow, and the overflow route shall not send the flow onto a building or an unprotected slope. Racks and traps shall be cleared by 31 March, again by 31 May after the April–May storms, and after the season by 15 November (Chapter 10). The volume of a debris basin is to be set in Chapter 9 [TBC].
- (b) **Bulking factor.** The design flow of every channel, drain, pipe, culvert and crossing that receives flow from a hill catchment shall be the clear-water peak flow of Chapter 3 multiplied by a bulking factor of **1.25**, for the minor design flow, the check event and the 1% AEP flow; elsewhere the factor is 1.0. The factor applies to capacity, freeboard and velocity; it does not apply to the runoff volume used for storage (Chapter 4). A larger factor shall be used where a sediment study of the catchment gives one. A catchment that the screening of Clause 2.3.6(i) shows to be prone to debris flow, or that drains a mapped debris fan, landslide, slide scar or mine-spoil dump, is not designed by a bulking factor: no building, outfall, pumping station or storage shall be placed in the debris-flow path, and the drains are designed for the bulked flow only [TBC].
- (c) **Blockage.** The blockage check of Clause 6.12.4 shall assume 50% of the inlet area blocked for every culvert and pipe entrance with a span or diameter below **3.0 m**, and 20% for larger ones, whether or not a debris rack is provided. Grate inlets keep the clogging factor of Table 6.5, and kerb openings on grade take the sag value of 20%.
- (d) **Sediment and minimum velocity.** Drains and pipes that receive flow from a hill catchment, or that run across the foothill fans and valley fills of Ri-Bhoi and the Garo foothill plains, shall reach a velocity of at least **1.0 m/s** at the minor design flow, in place of the minimum of Clause 6.7.3(a). Where the gradient does not allow it, a sediment trap shall be provided upstream and the sediment allowance of Clause 6.7.8 doubled (Clause 6.7.4).

- (e) **Steep drains and energy dissipation.** Where the gradient of a drain gives a velocity above the limits of Clause 6.7.3(b), or a Froude number above 0.8, at the design flow, the drain shall be a lined chute, a stepped channel or a series of drop structures designed under Chapter 9 for the bulked flow of item (b), with the freeboard of Table 6.7 for steep channels and an energy dissipator at every change to a flatter gradient and at the outlet. No unlined drain shall be laid on a gradient on which the velocity exceeds the limit of Chapter 9 for its bed material, and no drain shall be unlined on limestone or in a coal-mining area (Clause 4.11 (karst and mine rule)).
- (f) **Steep streets.** On a street steeper than 5%, grate-only inlets shall not be used, and inlets shall be placed by the calculation of Clause 6.6.4 with the bypass flows of a steep gutter. On a street steeper than 10%, the flow shall be intercepted by transverse grated channels or kerb inlets at a spacing that keeps the street flow within the limits of Table 6.3 in the check and 1% AEP events. Where the 1% AEP flow cannot be kept within those limits on the carriageway, the excess shall be carried in a lined side channel or stepped drain under item (e), and the street, unless it is a notified evacuation route, is treated as closed in that event. Steps and footpaths that carry flow shall have a lined side channel.
- (g) **Hill roads as the minor system.** On every road and street in a hill catchment as this clause defines it, and on any road elsewhere that crosses one, the drainage of a road is the minor system for the land above it as well as for the road. Every such road and street shall have, as works of the road's owner, PWD (Roads), NHAI, NHIDCL, the Municipal Board or the District Council:
    - (i) a lined catch-water drain above every cut slope where the land above drains towards the road, discharging to a natural channel or a cross-drainage work and not over the cut;
    - (ii) lined side drains on the hill side (IRC:SP:42-2014, cl. 8.5.1);
    - (iii) a cross-drainage work at every jhora and stream, and culverts or scuppers at intervals such that no side drain exceeds its capacity at the design AEP of Table 6.1 with the factors of items (b), (c) and (i);
    - (iv) at the outlet of every scupper, culvert and side drain on the valley side, a lined chute, cascade or pipe carrying the flow to a stable natural channel, with an energy dissipator, so that road runoff is **never discharged onto an unprotected slope**, fill, retaining wall or the land of a building below, by PWD (Roads), NHAI, NHIDCL or any other owner of a road;
    - (v) culverts of at least the size of Clause 6.12.5, designed under Clause 6.12 and not less than IRC:SP:42-2014 cl. 7.1.4 requires for the road; where the drainage provisions of IRC:SP:48-1998, the Hill Road Manual, which were not read for this Manual [TBC], are stricter than this item, they apply; and
    - (vi) no muck, spoil or excavated material from the construction, widening or maintenance of the road, or from hill cutting beside it, placed in or beside a jhora, stream or other line of natural drainage, or on a slope from which a storm can carry it into one, and every natural drain or stream that such material has blocked cleared by 31 March so that the runoff of its catchment reaches the nearest stream or river.
- (h) **Sloping sites.** On a site where the land above drains towards a building, its cut or its retaining wall, the runoff of that land shall be intercepted above them by a lined diversion drain sized for the minor design flow of Table 6.1 from the land above it, with the factors of items (b), (c) and (i), with a 1% AEP flow path that does not pass through or against the building. The space between a building and the cut or retaining wall above it shall be paved or lined and drained so that water does not stand against the building or soak into the foot of the cut. Both shall discharge to a public drain or a stable natural channel as item (g)(iv) requires, not onto the slope below. Roof and paved-area runoff on such a site follows the hill rule and the karst and mine rule of Clause 4.11. During construction, runoff shall be kept off the existing drainage courses and led through diversion ditches and swales to sediment basins, with silt fences round the works, as Section I(b) of the Bye-Laws 2021 already asks in natural hazard prone areas (Chapter 8).
- (i) **Garbage-laden flows.** Every drain outfall to the Umkhrah, the Umshyrpi, the Wah Roro or the Umiam reservoir, and every public drain or culvert where a jhora below a settlement enters it, shall have a solid-waste trap or screen designed under Chapter 9 (Clause 9.8), with access for cleaning by hand or machine and a place to store what it catches that is not a jhora, a stream or a slope, cleared on the dates of item (a) and after every heavy-rainfall day (Chapter 10). The blockage of item (c) shall be taken to include solid waste whether or not a trap is provided, and the capacity of an existing drain or channel shall be taken net of the silt and waste surveyed in it (Clause 6.7.8). A trap, screen or stone bund placed in a stream or jhora shall not raise its 1% AEP level at any outfall (Clause 5.8.5(a) and (c)) and shall be designed to be overtopped without damage. A trap is not a treatment work: dry-weather flow is intercepted under Clause 8.9.

- (j) **Long storms in ML-Z3.** In sub-areas ML-C and ML-C1, where the 24-hour totals are long orographic falls, every culvert, cross-drainage work, chute and outfall shall also be checked for the 24-, 48- and 72-hour storms of the ML-Z3 rule of Clause 2.3.6, routed through it with no storage credit in the catchment above it (no detention, infiltration or loss to karst voids or mine workings), for the sustained flow near its peak for the whole duration of each storm, with the blockage of item (c) in place from the start: for the stability of its apron, the bed below it and the slope it discharges to under flow lasting many hours, for the abrasion of its lining, and for the volume that reaches its outfall. Every cross-drainage work and outfall that drains more than 1 km² there has the site-specific hydrology study of the ML-Z3 rule of Clause 2.3.6.

**Commentary.** The CPHEEO (2019) manual defines major and minor systems in its glossary but gives no return period for the major system. APWA 5600 (2006, 5601.8) requires the system to convey the 1% peak and, where in-system capacity is less, an overflow system to carry the remainder. Clause 6.3.3 subtracts only the *clogged* inlet capacity, not the full pipe capacity, because in practice the pipes cannot take more water than the inlets admit. The fully-blocked check at sags has no direct precedent; this Manual sets it because of the Shillong experience that drains under footpaths are often silted or blocked by solid waste when the heaviest rain arrives (CPHEEO 2019 Part A, Ch 1 and 2, Figures 1.2 and 2.1 on solid waste dumping in drains). The prohibition on inter-catchment transfer follows the DID Malaysia 2008 submission checklist, which prohibits inter-catchment diversion. Clause 6.3.6 is set by this Manual for Meghalaya, as for the mountain editions of this series, because the criteria of this chapter assume clear water on gentle ground. In the hills of Meghalaya the water is not clear and the ground is not gentle. The towns are built on slopes: the Shillong Planning Area has 102.05 km² between 15° and 30°, 17.75 km² between 30° and 40°, 3.2 km² of "Regulated Slope" between 40° and 50° and 0.53 km² of "Restricted Slope/No Construction Zone" above 50° (NESAC, 2023), and the Bye-Laws 2021 forbid building above 50° (Section I(a), 2024). The slopes fail: the IRADe/NMHS plan names landslides at Laitumkhrah (2008), Lawsohtun, Happy Valley (2007), Mccabe Road, Bethesda and Arbuthnot in Shillong and very high susceptibility along NH-40 and near the Umshyrpi, records about 22 deaths in landslides in the State in 2014 (citing the Revenue and Disaster Management Department), and finds that "due to increasing levels of urbanization and unregulated construction work the natural drainage system is blocked" (IRADe/NMHS plan, 2020). The streams that the drains end in have been narrowed: NESAC found that "the water tops the banks along most of the streams", aggravated "by a drastic reduction in channel capacities in most streams due to encroachments along their banks by buildings" (NESAC, 2023). No Meghalaya allowance for debris, bulking or blockage was found during research [TBC], and no Indian guidance on bulking factors, debris racks or debris basins [TBC], so each number in Clause 6.3.6 is an interim value with a stated reason, the same as in the mountain editions. The 1 ha trigger for a debris rack reflects the time of concentration on hill slopes, a few minutes, so that even a small unbuilt slope delivers stones, gravel and leaves to an inlet in the first burst of a storm. The bulking factor of 1.25 is the factor for a flow that carries a fifth of its volume as sediment (bulking factor = 1 / (1 − sediment fraction by volume)): about the most that a drain can carry and still behave as a water flood. A flow with more sediment than that behaves as a debris flow, which no drain can be sized for; that is why item (b) keeps buildings and outfalls out of a debris-flow path, among them the mine-spoil dumps of the coal belt, rather than sizing a drain for it, and why the factor is to be replaced by a sediment study as soon as one is made [TBC]. The 3.0 m limit in item (c) doubles the core's 1.5 m because boulders, timber and waste block openings that leaves alone do not. The 1.0 m/s minimum in item (d) replaces the 0.6 m/s of CPHEEO, which is based on carrying fine sand of 0.09 mm, because hill drains carry gravel. On a 10% street, the hazard limit of 2.0 m/s is reached when sheet flow on a concrete surface is only about 30 mm deep, which is why item (f) takes the flow off steep carriageways. IRC:SP:42-2014 (cl. 8.5.1) already treats hill roads differently: their side drains are "normally restricted to 60 cm" in width and lined because "rolling stones cause high friction", "culverts are required at closer intervals compared to those in plain areas", and "stepped chutes/baffles are to be provided where the longitudinal bed slope exceeds critical". Items (g) and (h) keep road and site runoff off unprotected slopes, because water discharged onto a slope raises its pore pressure (Chapter 4, Clause 4.11): on 30–31 May 2025 landslides in 15 villages of Umling block near NH-6 were linked to hill cutting along the highway (as reported); the NH-6 tunnel at Sonapur, along a stream feeding the Lubha, was closed by mudslides in August 2023 and reopened only in May 2024 (as reported); and in June 2026 the Shillong–Dawki road collapsed at Laitlyngkot, at chainage 25+200, while the Umngot at Dawki rose (as reported). The Bye-Laws 2021 already reach towards these rules without numbers: steep slopes are to be stabilised "by ensuring

good drainage of water so that the saturation of the hill slope is avoided" (C12.1(iv)), flood protection includes the "Clearing of clogged cross drainage works" (C12.3), and in natural hazard prone areas "Construction should not obstruct existing surface drainage courses" and builders shall "Construct diversion ditches and swales to direct runoff away from sensitive areas and into designated sediment basins" and "Install silt fences" (Section I(b), 2024); item (h) gives them a design standard of this Manual's own and Chapter 8 the construction-stage detail. Two items are added for Meghalaya. Item (i) deals with garbage, because in Shillong the drains and jhoras carry the town's waste as well as its water: 49,612 m³ of waste was removed from the Wahumkhrah under the 15th Finance Commission for ₹7.9 crore, and stone bunds and solid-waste traps were built for ₹3.60 crore (State action-taken report to the National Green Tribunal, 21 March 2023), and drains blocked by waste are reported to raise the susceptibility of the slopes to landslides (ICLEI, as reported). A trap catches waste only if it is placed where the waste arrives and cleared when it fills, and a trap or bund built in a stream must not raise the stream at the outfalls it protects. Item (j) deals with duration, because on the escarpment the rain does not stop: Cherrapunji's wettest month brought 6,667.4 mm (July 1974) (IMD *Extremes*), 2,493 mm is reported to have fallen there in 48 hours on 15–16 June 1995 (as reported), and the spillway of the Myntdu–Leshka dam is built for 12,000 m³/s from 350 km², about 34 m³/s per km², against about 3.7 m³/s per km² at New Umtru on the northern slope (MePGCL guidelines; NEER arithmetic). A culvert there sees near-peak flow for hours or days, so its apron, its outlet and the slope below must survive the duration as well as the peak, and no storage, infiltration or loss to karst can be counted on to shorten it. The clause deals with debris and garbage at the drain; it does not ask for the concrete channelisation of the streams, whose capacity has been lost to encroachment, not to roughness.

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## 6.4 Design return periods

6.4.1 The minor system, roads and crossings shall be designed for the AEPs of Table 6.1. Where both a land-use row and a road-class row apply to an element, the **rarer** AEP (longer return period) governs.

**Table 6.1 — Design AEPs for conveyance (matches Clause 2.4)**

| Element | Design AEP (return period) | Check event | Basis |
|---|---|---|---|
| Minor system: Shillong, Tura and Jowai core and other high-density areas | 10% (10-yr) | 1% (100-yr) overland path | This Manual (see Commentary) |
| Minor system: other Class I areas | 20% (5-yr) | 1% overland path | This Manual; CPHEEO Table 4.1 |
| Minor system: other areas | 50% (2-yr) | 1% overland path | This Manual; CPHEEO Table 4.1 |
| Arterial road drainage and crossings | 2% (50-yr) for arterials that are notified evacuation or emergency routes; 4% (25-yr) for other arterials | Next higher AEP: 1% for a 2% design; 2% for a 4% design | This Manual (25–50-yr); split set by this Manual |
| Collector road drainage and crossings | 4% (25-yr) | 2% (50-yr) | This Manual |
| Local road drainage and crossings | 10% (10-yr) | 4% (25-yr) | This Manual |
| Road underpasses and other trapped sags on public roads | 2% (50-yr) | 1% (100-yr) | This Manual (Clause 6.10.5) |
| Airports, railway stations, power stations and other critical infrastructure | 1% (100-yr) in Class I areas; 2% (50-yr) elsewhere | — | CPHEEO 2019 Table 4.1 |

| Element | Design AEP (return period) | Check event | Basis |
|---|---|---|---|
| Major (overland) system, every element | 1% (100-yr) | — | This Manual |
| Building floor levels | 1% level + 0.5 m freeboard | — | This Manual (Clause 6.11) |

6.4.2 **Check events.** At the check event of Table 6.1, the combined minor and major system shall carry the check-event flow within the 1% AEP limits of Table 6.2 and without water entering any building. The 1% overland path requirement of Clause 6.3.2 applies in addition to the check event.

6.4.3 **Higher standards.** An approving authority may adopt a rarer AEP for any element, including through the high-powered committee route in Note 2 of CPHEEO Table 4.1. It shall not adopt a more frequent AEP than Table 6.1.

6.4.4 **High-density areas.** The approving authority shall notify, by map, the high-density areas to which the 10% AEP minor-system standard applies. Until it does, the 10% AEP standard applies to:

- (a) in Shillong, the valley floors and localities that the sources name for flooding, Polo, Pynthorbah, Nongmynsong, Mawlai, Laitumkhrah and Dhankheti, and the older, densely built area within the Shillong Municipal Board's area that the Shillong Master Plan 2041 identifies as the core area or central business district; and the old towns of Tura and Jowai; with the boundary of each to be confirmed by the Municipal Board, MUDA and, for the parts under a District Council, its building authority [TBC];
- (b) in every other Municipal Board area and in the area of every Town Committee, the area that the applicable master plan identifies as the core area, old town or central business district, the main market of a hill town, and the old village settlements that have been taken into the built-up area; and
- (c) any area in a Tier A body where the master plan permits a floor space index above the base value for the zone.

6.4.5 **Retrofit.** Where an existing drain cannot practicably be enlarged to the Table 6.1 AEP, the shortfall shall be made good by upstream storage (Chapter 4), regional storage (Chapter 7) or an improved major-system path. The approving authority shall record the residual level of service.

> Commentary. The values in Table 6.1 match the Clause 2.4 summary and add rows for underpasses and critical infrastructure. They exceed the CPHEEO (2019) national advisory minimums of 5-yr for Class I cities and 2-yr elsewhere (CPHEEO Part A, Table 4.1). Note 2 of that table allows a State committee to adopt higher values. The 10-yr tier for high-density areas follows Gupta (IIT Bombay), who recommends "1 in 10 year for residential-high density", and Malaysia's MSMA 2, which uses 10-yr minor and 100-yr major systems for link houses, apartments, commercial and industrial land. The road values resolve a conflict in Indian codes. IRC:SP:50-2013 recommends 1–2 years for urban road drains. IRC:SP:42-2014 suggests 25 years for urban roadside drains and a check flood at the next higher return period. APWA 5600 (2006) uses 50-yr for arterial, 25-yr for collector and 10-yr for residential street crossings. Table 6.1 adopts the APWA tiers and the IRC:SP:42 check-flood concept. Splitting arterials into 50-yr evacuation routes and 25-yr others has no direct precedent and is set by this Manual. The 50-yr standard for underpasses is likewise set by this Manual, because an underpass is a trapped sag where the failure mode is deep water on a live carriageway. The default high-density areas in Clause 6.4.4 are set by this Manual and apply until the approving authority notifies a map.

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## 6.5 Street hydraulics: spread, depth and flow hazard

6.5.1 **Gutter flow.** Flow in a triangular kerb-and-gutter section shall be computed with the modified Manning (Izzard) equation:

> Q = (Ku / n) · Sx^(5/3) · SL^(1/2) · T^(8/3)

where Q is the gutter flow (m³/s), Ku = 0.376 (SI), n is the Manning roughness of the gutter (Table 6.6), Sx is the cross slope (m/m), SL is the longitudinal slope (m/m) and T is the spread (m). Composite and depressed gutter sections shall be analysed by the methods of FHWA HEC-22 (4th edition, 2024).

6.5.2 **Spread and depth limits.** Street flow shall not exceed the limits of Table 6.2.

**Table 6.2 — Street flow limits**

| Road class | Minor design event (Table 6.1) | Check event and 1% AEP event |
|---|---|---|
| Arterial | Spread shall leave at least one through lane in each direction clear of water. No flow across the crown. | Depth ≤ 150 mm at the crown and ≤ 350 mm at the deepest point; hazard limits of Clause 6.5.3 |
| Collector | Spread T ≤ 3 m. No flow across the crown except at a sag intersection. | As above |
| Local | Spread T ≤ 3 m. Flow shall not overtop the kerb. | As above |
| All classes, at intersections | Cross-flow over the crown ≤ 0.03 m³/s at sag intersections and superelevation transitions; none at mid-block sags. | As above |

6.5.3 **Flow hazard limits.** In the check event and the 1% AEP event, the product of depth (D, m) and velocity (V, m/s) of street and overland flow shall not exceed the limits of Table 6.3.

**Table 6.3 — Flow hazard limits for streets and overland flow paths**

| Location | Required hazard class (Table 6.4) | Limits |
|---|---|---|
| Carriageways of all roads | H2 or better | D·V ≤ 0.6 m²/s; D ≤ 0.35 m (Table 6.2); V ≤ 2.0 m/s |
| Footpaths, pedestrian crossings, school, hospital and transit-stop frontages | H1 | D·V ≤ 0.3 m²/s; D ≤ 0.3 m; V ≤ 2.0 m/s |
| Notified evacuation and emergency routes | H1 | D·V ≤ 0.3 m²/s; D ≤ 0.3 m; V ≤ 2.0 m/s |
| Overland flow paths in public open space or easements, away from roads | H3 or better, with warning signs | D·V ≤ 0.6 m²/s; D ≤ 1.2 m; V ≤ 2.0 m/s |

**Table 6.4 — Combined flood hazard vulnerability classes (reproduced for reference)**

| Class | Description | D·V limit (m²/s) | Depth limit D (m) | Velocity limit V (m/s) |
|---|---|---|---|---|
| H1 | Generally safe for vehicles, people and buildings | ≤ 0.3 | 0.3 | 2.0 |
| H2 | Unsafe for small vehicles | ≤ 0.6 | 0.5 | 2.0 |
| H3 | Unsafe for vehicles, children and the elderly | ≤ 0.6 | 1.2 | 2.0 |
| H4 | Unsafe for vehicles and people | ≤ 1.0 | 2.0 | 2.0 |
| H5 | Unsafe for vehicles and people; buildings vulnerable to structural damage | ≤ 4.0 | 4.0 | 4.0 |
| H6 | Unsafe for vehicles and people; all buildings vulnerable to failure | > 4.0 | — | — |

Source: AIDR Guideline 7-3, *Technical flood risk management guideline: Flood hazard* (2014), Tables 1 and 2, modelled after Smith and Wasko (2012).

6.5.4 Depth and velocity for Clause 6.5.3 shall be taken from the gutter-flow calculation for simple sections, or from a 1D or 2D hydraulic model where flow leaves the kerb-and-gutter section.

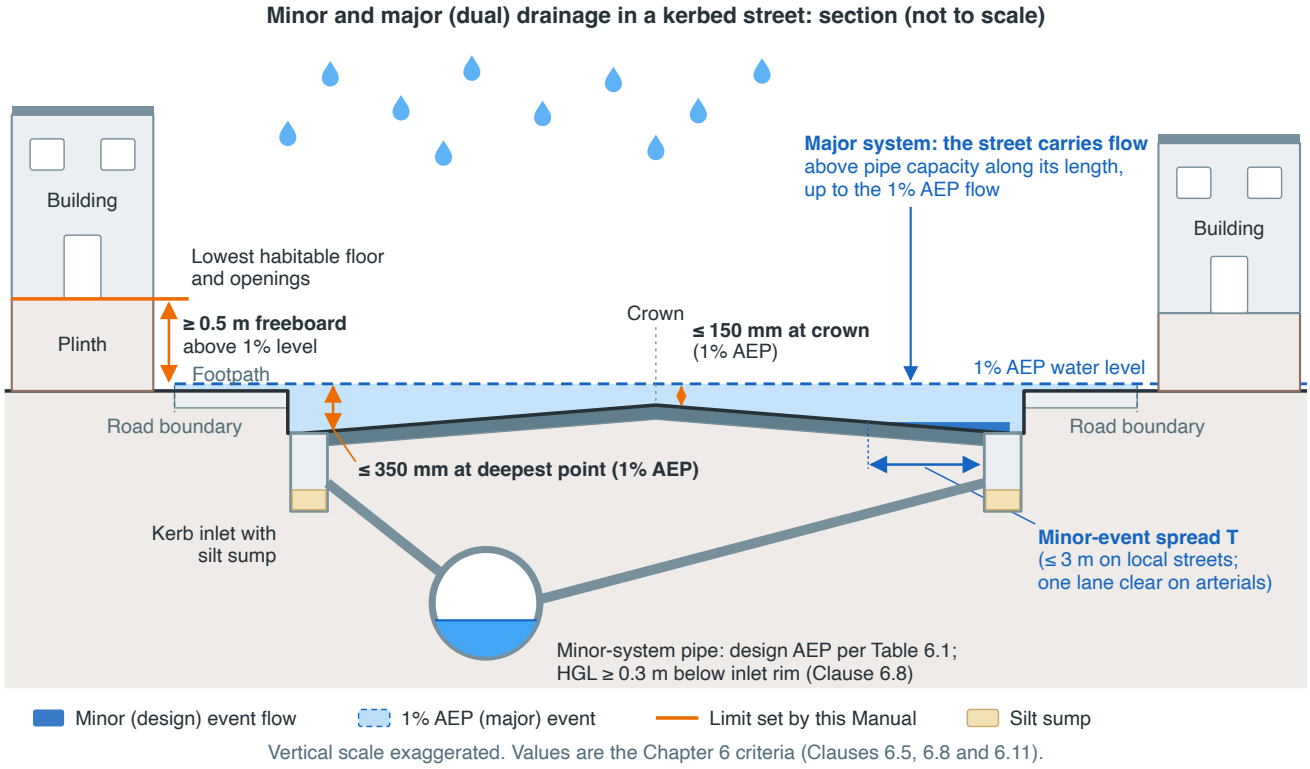


*Figure 6.1 — Minor and major drainage in a kerbed street. Original drawing for this Manual, adapted from Kansas City Metro APWA, Section 5600 (2006, 5601.8) and FHWA, HEC-22 Urban Drainage Design Manual (4th ed., 2024).*

**Commentary.** The Izzard form of Manning's equation with Ku = 0.376 is used both in FHWA HEC-22 and in the CPHEEO (2019) manual (Part A, Example 5.5, where the constant is written Kc = 0.376). The arterial spread rule (one lane clear) and the 3 m spread for local and collector streets are close to the APWA 5600 (2006, 5604.2) limit of 12 ft (3.66 m) from the back of kerb in each outside lane. The cross-flow limit of 0.03 m³/s is the SI equivalent of the APWA limit of 1.0 cfs at intersection sumps and superelevation transitions, with no cross-flow at mid-block sumps. The 150 mm and 350 mm depth limits are close to the APWA 5600 limits for 1% overflow at road crossings (7 in, about 180 mm, at the crown; 14 in, about 360 mm, at the deepest point). Mumbai's criterion of no flooding above 15 cm (IRC:SP:50-2013, §6.4.1) is a local precedent for the 150 mm crown value.

The hazard classes of Table 6.4 are the combined hazard curves published by the Australian Institute for Disaster Resilience (AIDR Guideline 7-3, 2014), which are modelled after Smith and Wasko (2012). Requiring H2 or better on carriageways means the 1% depth limit of 350 mm (Table 6.2) governs the depth, and the D·V product controls fast, shallow flow on steep streets. H2 is described as "unsafe for small vehicles". Two-wheelers are the dominant vehicles on Meghalaya streets, so the 1% event must be treated as a road-closure event on all roads except notified evacuation routes, which must meet H1. The assignment of hazard classes to locations in Table 6.3 has no direct precedent and is set by this Manual.

## 6.6 Inlets

6.6.1 **Inlet types.** Inlets may be kerb-opening inlets, grate inlets, combination inlets (a grate with a kerb opening) or slotted and trench drains. On public streets:

- (a) kerb-opening or combination inlets shall be used, unless the approving authority accepts grate-only inlets for a specific location;
- (b) inlet openings shall be set at road level, with a gutter depression where practicable, so that water is not held on the carriageway by a raised kerb or footpath;
- (c) grates in carriageways, cycle lanes and footpaths shall be of a bicycle- and pedestrian-safe pattern (Chapter 9, Clause 9.11).

6.6.2 **Inlet capacity.** The clean capacity of inlets on grade and in sags shall be computed by the methods of FHWA HEC-22 (4th edition, 2024), or from tested ratings published by the manufacturer for the exact grate and kerb-opening geometry. The empirical kerb-inlet equations of CPHEEO (2019) Part A §5.6.2 may be used as a cross-check only.

6.6.3 **Clogging factors.** The design capacity of every inlet shall be its clean capacity reduced by the clogging factors of Table 6.5:

**Table 6.5 — Inlet clogging factors (share of clean capacity assumed lost)**

| Inlet type | On grade | In a sag |
|---|---|---|
| Grate | 50% | 50% |
| Kerb opening | 10% | 20% |
| Combination | Apply the grate and kerb factors to each part separately | Apply the grate and kerb factors to each part separately |

Design capacity = (1 − clogging factor) × clean capacity.

6.6.4 **Inlet spacing.** Inlets shall be located by a sequential calculation that starts at the top of each gutter run. At each inlet, the intercepted flow is computed, and the bypass flow is added to the gutter flow arriving at the next inlet. Spacing shall be such that the spread limits of Table 6.2 are met everywhere in the minor design event. In addition:

- (a) inlet spacing shall not exceed 30 m on kerbed roads, whatever the calculation gives;
- (b) inlets shall be provided at every sag, immediately upstream of pedestrian crossings and intersections, upstream of bridge decks and superelevation transitions, and at the end of every gutter run;
- (c) bypass flow from the last inlet of a run shall not be passed onto a road of a higher class or into private land.

6.6.5 **Sag inlets.** At a sag on a kerbed road:

- (a) the sag inlet's design capacity (after clogging) shall be not less than the total minor design flow arriving at the sag;
- (b) flanking inlets shall be placed on each side of a sag on any road where ponding could spread beyond the Table 6.2 limits, and at every underpass;
- (c) the ponding at the sag shall comply with Clause 6.10.

6.6.6 **Inlet connections.** The pipe connecting an inlet to the main drain shall have a diameter of at least 300 mm and shall be laid at a gradient that gives at least 0.9 m/s at the inlet's design flow.

6.6.7 **Silt sumps.** Every inlet chamber on a public road shall have a silt sump at least 300 mm deep below the invert of its outlet pipe, accessible for cleaning from the surface.

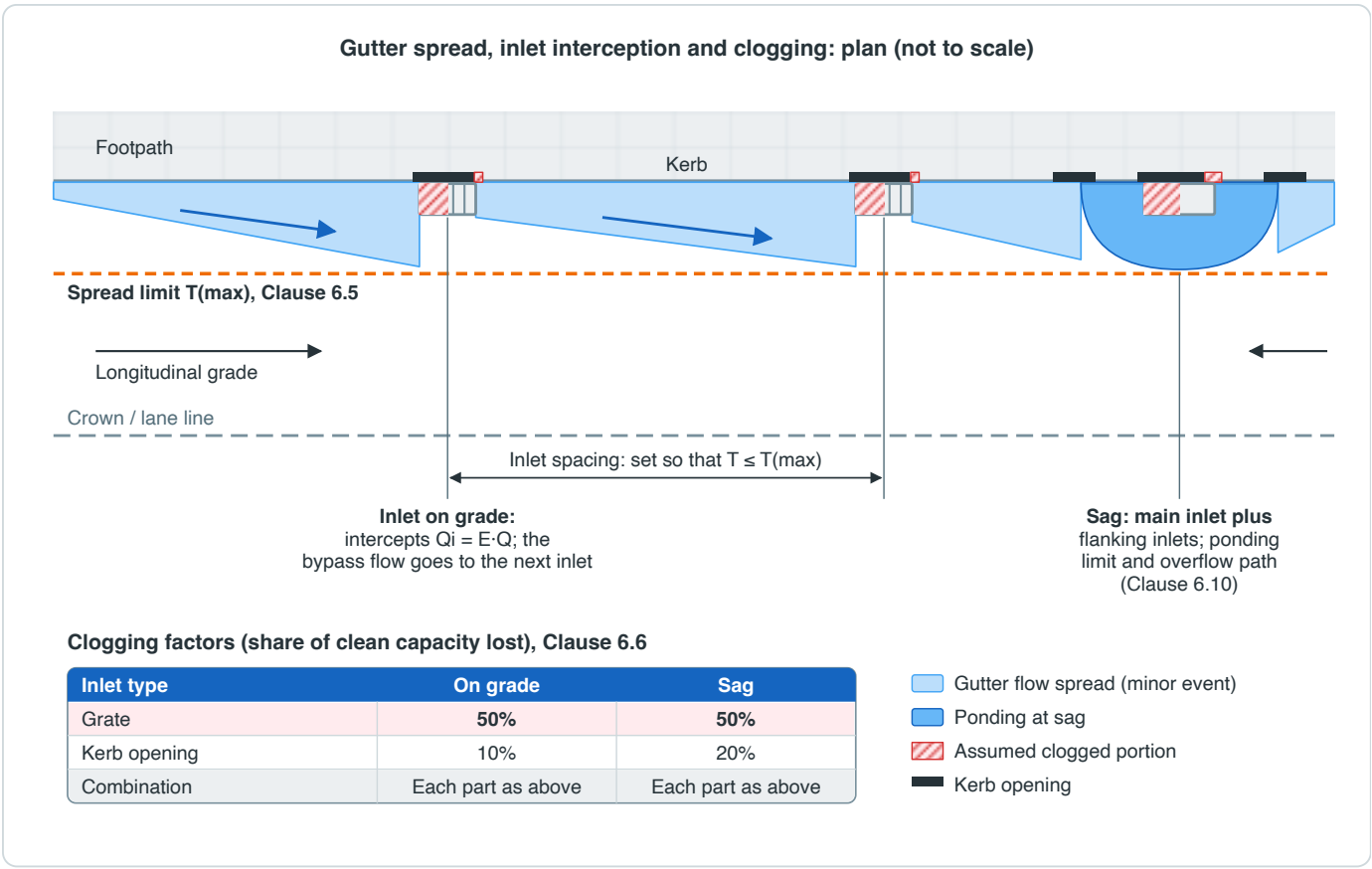


*Figure 6.2 — Gutter spread, inlet interception and clogging. Original drawing for this Manual, adapted from FHWA, HEC-22 Urban Drainage Design Manual (3rd ed., 2009; 4th ed., 2024) and CPHEEO, Manual on Storm Water Drainage Systems (2019).*

> **Commentary.** The clogging factors are more severe than the APWA 5600 (2006, 5604.2) rating of sump inlets at 80% of theoretical capacity (a 20% reduction), because grates in Meghalaya streets are routinely blinded by plastic and leaves. CPHEEO (2019) Part A shows solid waste dumped in drains as a primary cause of drain failure (Figures 1.2 and 2.1). APWA 5600 (2006) allows only kerb-opening inlets on public streets; Clause 6.6.1(a) is less strict because combination inlets are useful on flat roads. No standard inlet, kerb-channel or covered-drain detail of PWD, of the Shillong Municipal Board or of any other Municipal Board in the State was found during research [TBC]; the Bye-Laws 2021 ask that a site plan show its "Surface drains" and refer the requirements of drainage to the National Building Code 2016 (D4.2, D5.6). The 30 m maximum spacing and the treatment of combination inlets in Table 6.5 have no direct precedent and are set by this Manual. Roads on the Garo foothill plains of Phulbari and Tikrikilla and on the valley floors of Ri-Bhoi are flat, which shortens the calculated spacing anyway; on the steep streets of Shillong, Jowai and Tura gutter flow runs fast and passes inlets by, which Clause 6.3.6(f) deals with. A fixed cap stops a single blocked inlet from leaving a long dry gutter run. The 300 mm silt sump is set by this Manual. It matches the 0.3 m sump shown on the CPHEEO catch-basin detail (CPHEEO 2019, Figure 5.9).

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## 6.7 Pipes and open and covered drains

6.7.1 **Uniform flow.** Pipe and drain capacity shall be computed with Manning's equation:

> V = (1/n) · R^(2/3) · S^(1/2); Q = A · V

where V is the mean velocity (m/s), n is the Manning roughness (Table 6.6), R is the hydraulic radius (m), S is the friction slope (m/m), A is the flow area (m²) and Q is the discharge (m³/s). Where backwater from a tailwater, a junction or a structure affects the water level, a gradually varied flow (standard step) or hydraulic network model shall be used, and the HGL requirements of Clause 6.8 apply.

6.7.2 **Manning roughness.** Design values of n shall be taken from Table 6.6. For concrete pipes and masonry or concrete drains, the design value shall be not less than the "fair" or "rough" condition value listed, to allow for sediment, biofilm and ageing.

**Table 6.6 — Manning's n for design (from CPHEEO 2019)**

| Material | Condition | n (CPHEEO) | Minimum design n in this Manual |
|---|---|---|---|
| Cement concrete pipe (collar joints) | Good / fair | 0.013 / 0.015 | 0.015 |
| Spun concrete pipe (RCC, PSC) with S/S joints | Manufacturer's design value | 0.011 | 0.013 |
| HDPE / uPVC pipe | — | 0.010 | 0.011 |
| Plastic (smooth), asbestos cement | — | 0.011 | 0.011 |
| Concrete drain, steel trowelled / wood trowelled | — | 0.014 / 0.015 | 0.015 |
| Sand and cement plaster | — | 0.015 | 0.015 |
| Brick masonry | Good / rough | 0.015 / 0.017 | 0.017 |
| Masonry | Bad condition | 0.020 | 0.020 |
| Rubble set in cement | — | 0.017 | 0.017 |
| Earth channel | Regular, good / ordinary | 0.020 / 0.025 | 0.025 |
| Earth channel | With stones and weeds / poor | 0.030 / 0.035 | 0.035 |
| Earth channel | Partly obstructed by debris or weeds | 0.050 | 0.050 |
| Gutter: concrete | — | 0.013 | 0.013 |
| Gutter: hot-mix asphalt | — | 0.015 | 0.015 |
| Gutter: sprayed seal | — | 0.018 | 0.018 |

Source of the CPHEEO column: CPHEEO (2019) Part A, Table 5.1 (itself from the CPHEEO Manual on Sewerage and Sewage Treatment Systems, 2013) and Table 5.8 (gutters).

6.7.3 **Velocity limits.** At the minor design flow:

- (a) minimum (self-cleansing) velocity: **0.6 m/s** in open and covered drains and **0.9 m/s** in pipes;
- (b) maximum velocity: **3.0 m/s** in lined drains and in pipes, unless the drain or pipe is designed as a chute under Chapter 9. CPHEEO permits up to 6.0 m/s in plastic or plastic-lined pipes in hilly regions; this may be used in Shillong, Jowai, Tura, Nongpoh, Nongstoin, Mairang, Williamnagar, Sohra, Mawsynram, Khliehriat and Mawkyrwat and other hill towns with the approving authority's agreement;
- (c) maximum velocity in unlined and vegetated channels: Chapter 9, Table 9.2;

- (d) the Froude number of flow in open and covered drains shall not exceed 0.8 at the design flow, unless the drain is designed for supercritical flow under Chapter 9.

6.7.4 **Gradient.** Each pipe and drain shall be laid at a gradient that achieves Clause 6.7.3(a). Where flat terrain or a fixed outfall level makes this impossible, the designer shall:

- (a) report the velocity achieved;
- (b) double the sediment allowance of Clause 6.7.8; and
- (c) provide access for mechanical desilting at the spacing of Clause 6.13.2.

6.7.5 **Pipe flow condition.** Pipes shall be sized so that the minor design flow does not exceed the pipe-full capacity. The greater discharge that a circular pipe carries at about 0.95 of its depth shall not be relied on.

6.7.6 **Minimum sizes.**

- (a) Pipes: 300 mm internal diameter; **450 mm** for public mains.
- (b) Open drains: bed width 0.3 m.
- (c) Covered public drains (drains closed by cover slabs): clear internal width **0.6 m** and clear internal depth **0.6 m**.

6.7.7 **Cover to pipes.** Pipes shall have at least 0.6 m of cover to finished level, and at least 0.9 m under carriageways unless a structural design for the traffic load is submitted. Where the seasonal high groundwater table is within 1 m of the pipe crown, the pipe shall be checked for flotation with the pipe empty (CPHEEO 2019, Table 11.2) and anchored where necessary.

6.7.8 **Sediment allowance.** The design capacity of open drains, covered drains and pipes of 600 mm diameter or more shall be computed with the following depth of sediment at the invert:

- (a) open and covered drains: the greater of **75 mm** and **10%** of the clear internal depth;
- (b) pipes of 600 mm diameter or more: **5%** of the internal diameter;
- (c) pipes below 600 mm: no allowance, but Clause 6.7.3(a) shall be met.

The Manning n for the reduced section shall be that of the drain material in Table 6.6.

6.7.9 **Freeboard in open and covered drains.** At the minor design flow, the water surface (computed with the sediment allowance) shall be below the top of the drain wall, or below the soffit of the cover slab in a covered drain, by at least the freeboard of Table 6.7.

**Table 6.7 — Minimum freeboard in open and covered drains**

| Drain | Minimum freeboard | Source |
|---|---|---|
| Bed width up to 300 mm | 100 mm | CPHEEO 2019 Table 5.3 (from IRC:SP:50-2013) |
| Bed width 300–900 mm | 150 mm | CPHEEO 2019 Table 5.3 |
| Bed width 900–1,500 mm | 300 mm | CPHEEO 2019 Table 5.3 |
| Wider drains and engineered channels, Q < 3 m³/s | 450 mm | CPHEEO 2019 Table 5.12 (from IS 7784 (Part 1): 1993) |
| Q 3 to < 30 m³/s | 600 mm | As above |
| Q 30 to < 300 m³/s | 900 mm | As above |
| Q 300 to < 3,000 m³/s | 1,200 mm | As above |
| Q ≥ 3,000 m³/s | 1,500 mm | As above |
| Any roadside drain | Not less than 150 mm | IRC:SP:42-2014 |
| Steep (supercritical) channels | Equal to the flow depth | CPHEEO 2019 §5.3.2 |

At bends, the freeboard shall be measured from the water level on the outside of the bend, including the superelevation $\Delta y = V^2 T / (2\,g\,r_c)$, where T is the top width and $r_c$ the centreline radius (CPHEEO 2019, Eq. 5.29).

6.7.10 **Bends and junctions.**

- (a) The centreline radius of a bend in a drain shall be at least 3 times the drain width (CPHEEO 2019 §5.3.3). In engineered channels it shall be at least 2 times the top width and not less than 30 m (CPHEEO 2019 Table 5.11).
- (b) Where drains meet, a junction sump shall be provided with an internal width of at least twice the width of the outgoing drain. Incoming drains shall enter at less than a right angle to the outgoing flow, and the outgoing invert shall be below the sump floor so that water does not stand in the sump (CPHEEO 2019 §5.3.4).

6.7.11 **Manholes and access chambers on pipes.** Manholes shall be provided at every junction, change of size, alignment or gradient, and at the head of every pipe. Spacing on straight runs shall not exceed Table 6.8.

**Table 6.8 — Maximum spacing of manholes on straight pipe runs**

| Pipe diameter | Maximum spacing |
|---|---|
| 300–600 mm | 40 m |
| 700–1,000 mm | 100 m |
| 1,050–1,400 mm | 150 m |
| 1,500 mm and above | 300 m |

Source: CPHEEO 2019 Table 11.5. Manhole sizes, drops and covers: Chapter 9, Clause 9.12.

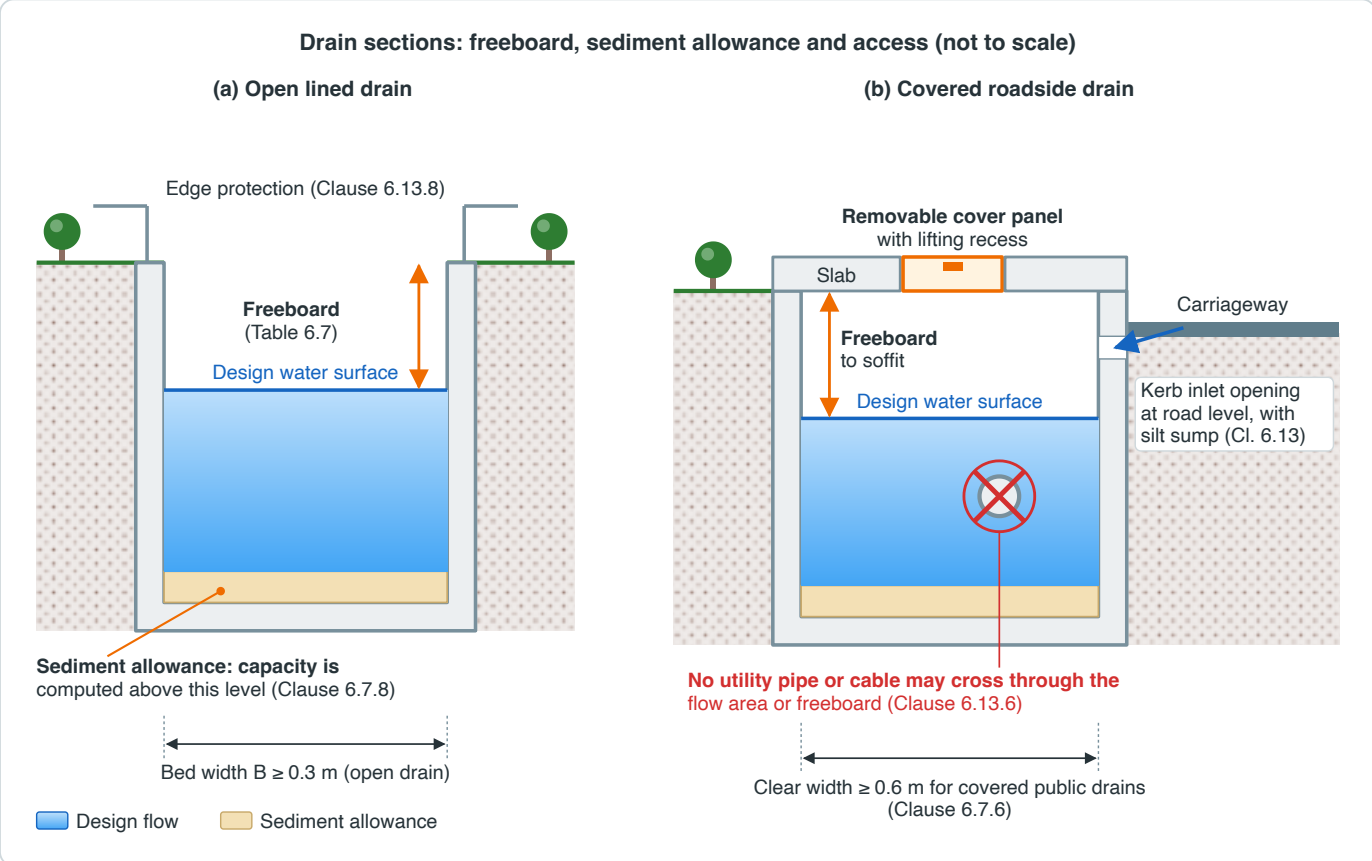


*Figure 6.3 — Drain sections: freeboard, sediment allowance and access. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Tables 5.3 and 5.12, and IRC:SP:50-2013.*

Commentary. The n values are those of CPHEEO (2019) Table 5.1. The higher minimum design values have no direct precedent; this Manual sets them because CPHEEO notes that the 0.011 value for spun pipes "may be taken as given by the manufacturer". That is a clean-pipe value, and Meghalaya drains carry heavy silt and solid waste. The 0.6 m/s minimum velocity is CPHEEO's (Table 5.2), based on carrying 0.09 mm sand (§5.3.1). The 0.9 m/s value for pipes is stricter, because a silted pipe cannot be cleaned as easily as an open drain. The 3.0 m/s maximum is from CPHEEO Table 5.2 (WPCF/ASCE 1982). The Froude limit of 0.8 is from CPHEEO §5.3, which advises avoiding critical flow because the water surface becomes unstable.

The 0.6 m × 0.6 m minimum for covered drains has no direct precedent and is set by this Manual. A covered drain narrower than this cannot be desilted by hand or by small machines through a cover opening, and silted, inaccessible drains were a recurring finding after the flash floods of Shillong, where the master-plan study found that "Encroachment and clogging of channels are the main causes of flooding" (NESAC, 2023) and 49,612 m³ of waste was removed from the Wahumkhrah alone (State action-taken report to the National Green Tribunal, 2023), and in a city whose drains carry its sullage, with "the incidence of sewerage mixing in drains … almost 100%" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan, 2020). The 0.6 m minimum cover is the value used in the CPHEEO (2019) worked pipe-design computation sheet (Part A, Chapter 5). The 0.9 m cover under carriageways is set by this Manual.

The sediment allowance values (75 mm or 10% for drains, 5% for large pipes) are set by this Manual. No Indian standard sets a sediment allowance for design. Shillong's experience is that drains run partly full of silt for much of the year, so a capacity computed for a clean section overstates the real capacity.

The CPHEEO freeboard table (Table 5.3) prints the first row as "Beyond 300 mm bed width". Read with the second row ("Beyond 300 mm & up to 900 mm"), the first row must mean "up to 300 mm"; Table 6.7 is written that way. The CPHEEO manhole spacing table (Table 11.5) gives overlapping ranges (700–1,050 mm and 1,000–1,400 mm); Table 6.8 removes the overlap by assigning 1,050 mm to the 150 m class.

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## 6.8 Hydraulic grade line

6.8.1 **HGL analysis.** For every pipe and covered-drain network, the designer shall compute the HGL for the minor design event and for the check event, starting at the outfall and working upstream. The analysis shall include friction losses and losses at junctions, manholes, bends, inlets, outlets and gates.

6.8.2 **Starting water level.** The starting (tailwater) level at the outfall shall be the higher of:

- (a) the tailwater level of Chapter 5: mean high water springs (MHWS) plus the sea-level allowance of +0.3 m for minor-system design at tidal outfalls, and the level in the receiving drain, river or tank for the coincident event at other outfalls; and
- (b) the level computed at the outlet pipe from the critical depth and the pipe diameter, (dc + D)/2, where the receiving water is lower.

6.8.3 **Minor-event limit.** In the minor design event, the HGL shall be at least **0.3 m below** the rim of every inlet and the cover level of every manhole and access chamber.

6.8.4 **Check-event and 1% limit.** In the check event and the 1% AEP event, the HGL may rise above the inlet rims. Water that leaves the minor system shall then be carried by the major system within the limits of Table 6.2 and shall not enter any building. Manholes that can surcharge above ground in these events shall have bolted or locked covers (Chapter 9, Clause 9.12).

6.8.5 **Structure losses.** Losses at manholes and junctions shall be computed by the energy-based access-hole method of FHWA HEC-22 (2009 or 2024 edition), or by an equivalent method in an approved hydraulic model. A simplified loss-coefficient method ($h = K V^2/2g$) with coefficients from HEC-22 may be used for Tier B networks below 16 ha.

6.8.6 **Invert and soffit levels.** Where pipe size increases at a manhole, the soffits (crowns) of the incoming and outgoing pipes shall be matched, or the outgoing soffit set lower. The outgoing invert shall not be higher than the lowest incoming invert. Vertical drops in manholes shall follow Chapter 9, Clause 9.12.

6.8.7 **Gates and valves.** The head loss through flap gates and non-return valves in the open position shall be included in the HGL (Chapter 9, Clause 9.10).

6.8.8 **Private connections.** Building drainage that connects to a public drain whose 1% HGL is above the building's lowest drainage fitting shall have a non-return valve.

> Commentary. The 0.3 m clearance between the minor-event HGL and the inlet rim is set by this Manual. It keeps a margin for losses that a model underestimates, and it stops water from bubbling out of inlets in the event the system is designed for. In Meghalaya many town drains end in a stream that no one gauges and that overtops its banks in ordinary storms, a jhora whose bed moves, a river below a dam, or a reservoir held near its full level (Clause 5.8.5). Shillong's drains end in the Umkhrah and the Umshyrpi, whose valley floors at Polo, Pynthorbah and Nongmynsong flood "with nearly every heavy downpour" when the Umkhrah overflows (as reported; IRADe/NMHS plan, 2020), and 32 of their outfalls also carry the sewage and sullage of a city with no sewerage (minutes of the stakeholder meeting, 14 April 2023); outfalls on the Umtru's 9.80 km of ravine to the Byrnihat bridge lie below the New Umtru dam; and the shore of the Umiam reservoir drains to a lake whose level is reported only in feet, with no datum (as reported). No flood level of any stream or jhora, and no design level of any outfall, was found during research. A drain whose HGL is started from a free outfall, or computed one length at a time without the stream, river or reservoir level, fails in exactly that way. An HGL computed from the outfall, with the tidal tailwater of Chapter 5, exposes those errors at design stage. The MHWS plus 0.3 m starting level is from CPHEEO (2019) Table 6.2. The access-hole method is described in HEC-22 from the 2009 edition onward.

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## 6.9 Major system: overland flow paths, easements and drainage reserves

6.9.1 **Streets as the primary major system.** Streets shall be graded so that the 1% AEP major-system flow is carried along the road reserve to a receiving waterway without being trapped, except at sags designed under Clause 6.10.

6.9.2 **Overland flow paths outside streets.** Where a major-system path leaves the road reserve, it shall be:

- (a) in public land, in the open space of a layout, or in an easement recorded on the layout approval and the title;
- (b) at least as wide as the 1% AEP flow top width plus 0.5 m on each side, and not less than 3.0 m;
- (c) kept free of buildings, compound walls, fences, fill, stored materials and planting that would obstruct flow;
- (d) graded to a continuous fall with no sag that lacks an outlet; and
- (e) within the hazard limits of Table 6.3.

6.9.3 **Compound walls.** A compound wall or fence shall not be built across a mapped overland flow path. Where a wall must cross one, it shall have openings with a total area that passes the 1% AEP flow with a 50% blockage, without raising the upstream water level above the limits of this chapter.

6.9.4 **Access along open drains.** Open drains with a top width of 2 m or more shall have a maintenance access strip at least 3.5 m wide along one bank, connected to a public road at intervals of not more than 500 m.

6.9.5 **Supply channels, surplus courses and tanks.** Tank supply channels and surplus courses are part of the major system and shall be protected under Chapter 7.

6.9.6 **Drainage reserves.** A drainage reserve is a strip of land, including the drain, kept free of buildings so that the drain can be maintained, widened and used as a flood path. A drainage reserve shall be provided:

- (a) along every public drain or channel with an internal width of 1.0 m or more that runs through or along a layout or site being developed or redeveloped;
- (b) along every drain or channel shown in an adopted Basin Stormwater Master Plan (Chapter 11), at the width of the future drain in that plan; and
- (c) along every new public drain with an internal width of 1.0 m or more built by a public body.

6.9.7 **Width.** The reserve shall be not less than the width in Table 6.9, measured from the drain's internal width W. The width is based on the **required** drain size (for a planned drain, the size in the master plan), not the existing size. Where the access strip of Clause 6.9.4 is wider than the margin in Table 6.9, the wider governs.

**Table 6.9 — Minimum drainage reserve width (adopted from PUB Singapore)**

| Internal width of drain, W | Open drain | Closed (covered) drain |
|---|---|---|
| 1.0 m to 1.2 m | 3.0 m | W + 0.6 m |
| more than 1.2 m to 3.0 m | W + 2.6 m | W + 1.6 m |
| more than 3.0 m to 4.5 m | W + 3.5 m | W + 1.6 m |
| more than 4.5 m to 6.0 m | W + 4.5 m | W + 3.0 m |
| more than 6.0 m to 9.0 m | W + 6.0 m | W + 3.0 m |
| more than 9.0 m to 25.0 m | W + 7.5 m | W + 3.0 m |
| more than 25.0 m | W + 12.0 m | W + 3.0 m |

For an open drain, the larger part of the margin shall be on the side used for maintenance access.

6.9.8 **Use and protection.**

- (a) The reserve shall be shown as a separate plot on the layout or site plan and transferred to the Approving Authority free of cost, as roads and open space reservations are. Where the drain is a Water Resources Department channel, the reserve is transferred to the Water Resources Department.
- (b) No building, compound wall, fence, ramp, step, fill or other structure shall be built in the reserve. Compound walls and boundary fences shall stand outside it.
- (c) The access strip in the reserve shall be level and continuous, and connected to a public road. Bollards or posts and chains may be used at entrances to keep out vehicles other than maintenance vehicles.
- (d) Where the reserve is not fenced off, its edge shall be marked with concrete markers at not more than 50 m spacing.
- (e) Services shall cross under the drain, with at least 1.0 m clearance below the invert, or over it on an approved structure. Services shall not run along the reserve inside the drain section.
- (f) A structure within 2 m of the edge of the reserve shall be designed to remain stable when the drain is excavated to 1.0 m below its invert. The design shall be signed by a qualified structural engineer.
- (g) The reserve counts toward the site's open space requirements only where the Approving Authority's rules allow it; it does not reduce any setback required by Chapter 7.

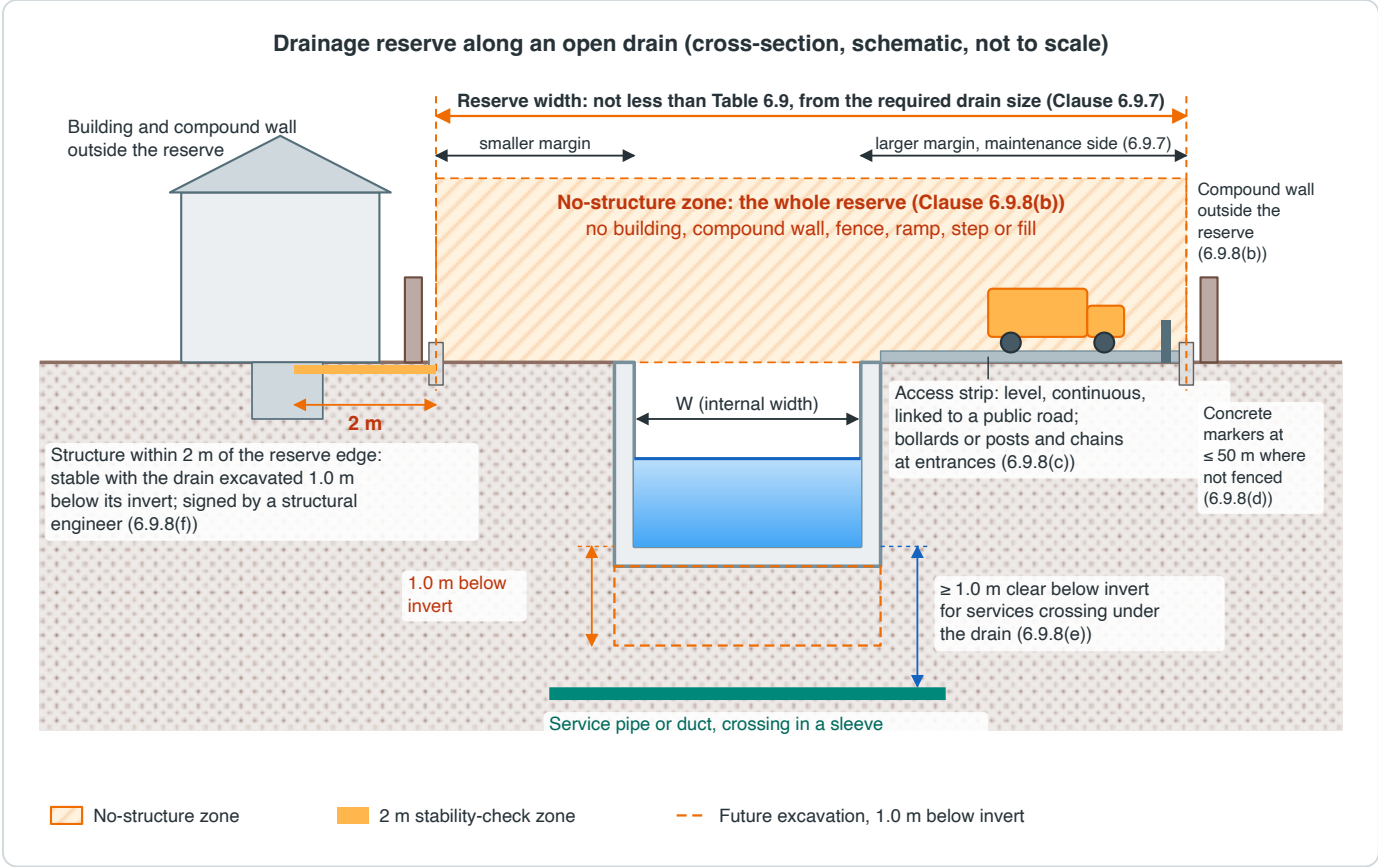


*Figure 6.4 — Drainage reserve along an open drain: reserve width from Table 6.9, no-structure zone, access strip on the maintenance side, the 1.0 m service clearance below the invert and the 2 m stability-check zone (Clauses 6.9.6 to 6.9.8). Original drawing for this Manual, adapted from PUB Singapore, Code of Practice on Surface Water Drainage (7th ed., with Addendum No. 3, 2025), clauses 5.1, 5.3, 9.6 and 9.7 and Appendix 1.*

**Commentary.** Drainage reserves follow Singapore, where "the width of a drainage reserve is based on the required drain size" and the reserve is set aside as a separate plot, "kept free of all encumbrances" (PUB Code of Practice on Surface Water Drainage, 7th ed. with Addendum No. 3, 2025, cl. 1.1). Table 6.9 reproduces PUB's Appendix 1 widths. Clauses 6.9.8(b) to (f) follow PUB clauses 5.1 (no structure within a drain or drainage reserve), 5.3 and 5.3.1 (stability for excavation 1.0 m below the invert; engineer's calculations within 2 m of the reserve), 9.6 (level, continuous access, with bollards or posts and chains) and 9.7 (markers at a maximum of 50 m). The 1.0 m clearance for services crossing under a drain is from PUB's development-plan guidance. In Meghalaya, buildings and compound walls are often built up to the edge of a drain, so it cannot be widened or desilted by machine. Reserving the land when a plot is developed or redeveloped is the cheapest time to secure it, because widening later needs land acquisition. Basing the width on the master-plan drain size (6.9.6(b)) protects the land a future drain will need. Meghalaya has statutory setbacks from water but no reserve width along a drain, and a floodplain law with no zone notified under it. The setbacks are those of the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023 (No. FOR/CC/29/2019/Pt/688 of 25 August 2023), as amended by No. FOR/CC/29/2019/1140 of 13 February 2024 and No. FOR/CC/29/2019/Pt/771 of 6 July 2026, executive guidelines made by the Forest and Environment Department on the High Court's direction in PIL 10/2019, which bind in Bye-Laws areas through B2(ii)(c), Section I(a)4 and I(f) of the Bye-Laws 2021 (2024) and elsewhere only "in such manner as may be prescribed" (para 10(2)), and nothing has been prescribed that was found. They are measured from "the mean high flood level of a water body observed in the past ten years" (para 2(f)), a level that was not found published for any stream, and are 3 m from an urban stream up to 3 m wide and 6 m from a wider one (Appendix 3 as merged in 2024; the NEER reading is that the merge cut the setback in urban areas outside the municipalities and cantonments from 5 m and 10 m to 3 m and 6 m [TBC]); 10 m from a rural stream up to 4 m wide and 10, 20 or 30 m from a wider one by plot size (Appendix 2A, 2026); and 10, 20 or 50 m from a lake or pond by its area, with a regulated zone of four times the setback for lakes and rural streams (para 7(1A)). The

2.40 m that the Bye-Laws 2021 first set beside a stream (B2(ii)(c)) was replaced in 2024 by a reference to the Guidelines. A "waterbody" excludes seasonal streams "where the entire bed remained dry for a period not less than 240 days during each of the past ten calendar years" (para 2(e)), which is most of the jhoras that town drains end in. The High Court's bar on building within 50 m of the high-water mark of a waterbody (24 May 2023) ended when the petition was closed on 19 February 2024. The Meghalaya Flood Plain Zoning Act, 2026 (Bill read; the Act, No. 4 of 2026, known from a search snippet) defines a flood zone as "the area which is required to carry the flow of the maximum probable floods" and lets restrictions notified under it prevail over other laws (s.12(2)), but no Authority, rule or zone notified under it was found. Within municipal limits, public streams, water-courses, springs and drains vest in the Municipal Board (Meghalaya Municipal Act, 1973, s.62), which may regulate the line of buildings on public roads and drains (s.164) and require land within one hundred feet of a drain to be drained (s.206); in the Khasi Hills, the KHADC Regulation 2015 treats a river edge as a zone where "No development should normally be allowed" (s.2.101). None of these gives a reserve width along a jhora or town drain. For this Manual, as its own proposal and not as the meaning of the rules, the bank of a channel is its top of bank, and the edge of a pung, lake or reservoir is the higher of its full or maximum level and its monsoon water line (Chapter 7, definitions after Clause 7.2); every jhora and other natural channel that drains 8 ha or more is a natural channel under Clause 7.4.1(b), whoever maintains it, whether or not it is lined, piped or covered, and whether or not the Guidelines treat it as a waterbody, so the corridor covers the jhoras that the 240-day rule excludes (all set by this Manual). This Manual therefore gives the reserve a width, as its own proposal and not as a statutory width: a **hydraulic corridor** made up of the reserve of Table 6.9, based on the drain size needed to carry the design flow with the bulking factor of Clause 6.3.6(b) (Clause 6.9.7), the access strip of Clause 6.9.4 on the access bank, and, along every natural channel that drains 8 ha or more, the setbacks of Clause 7.4 measured from its top of bank, with a Zone 1 of at least 15 m and a Zone 2 to the 1% AEP extent plus 10 m; where the Guidelines' setback, measured from the ten-year mean high flood level, a notified flood zone or a court sets a wider line, that line applies for as long as it binds, and the widest governs (Chapter 7). The corridor is stricter than the statute: beside an urban stream its 15 m Zone 1 is five times the Guidelines' 3 m and two and a half times their 6 m. It applies to new development and redevelopment approved under this Manual, not to existing buildings, and Clause 7.4.7 allows no variance below it. Land is mostly community, clan or private, and in the autonomous districts it is not the State's to take, so Zone 1 land and the reserve that is community, clan or private land is **secured by agreement with the landholding institution** (the Dorbar Shnong, the clan or the owner), recorded on the layout approval and the land record where one exists, or reserved in the master plan, and not taken; where it is so secured, the transfer of Clause 6.9.8(a) is made by that recorded agreement rather than by a transfer of title (set by this Manual). The corridor should be shown in the Shillong Master Plan 2041 and the Tura and other master plans as land kept free along drainage lines, and checked at building permission, where the site plan already has to show "Surface drains" under the Bye-Laws 2021 and, in the Khasi Hills, "the system of storm water drainage" under s.36 of the KHADC Regulation, rather than made a new NOC.

The reserve matters because the drains of Meghalaya's towns are divided among owners, and no rule divides them. Within municipal limits the public drains, streams, springs and tanks vest in the Municipal Board (s.62 of the Municipal Act), but in Shillong only part of the Umkhrah and of the Umshyrpi lies in the Board's area and the rest under the Khasi Hills Autonomous District Council (State action-taken report to the National Green Tribunal, 21 March 2023), and the Town Committees and census towns, with "47 per cent of the total urban population", are "governed by the concerned ADCs" (CAG, performance audit on solid waste management in urban areas, 2017-18 to 2021-22). PWD holds the roads and their drains, culverts and scuppers, which in the hills carry the runoff of the land above them, and NHAI and NHIDCL the national highways, among them NH-6 and the Shillong–Dawki road; the Shillong Cantonment Board holds the Cantonment, NSTDA New Shillong, and Shillong Smart City Ltd builds drains in the city (as reported); the Water Resources Department holds the rivers and flood works, MePGCL the reservoirs and their release reaches, and the Soil and Water Conservation Department works in the catchments; and outside municipal limits the village drains and jhoras are kept by the Dorbar Shnongs under the District Councils' rules. Shillong's count of its own drains is not settled: 148.91 km with a coverage of "less than 75%" in the Smart City Proposal 2016-17, and 85% in the same plan's service-level table (both as quoted in the IRADe/NMHS plan, 2020). No rule dividing the jhoras and streams from the municipal drains was found during research. For the purposes of this Manual, and until the State issues such a rule [TBC], the drains are assigned as follows: the drains, public streams, channels, water-courses, springs and tanks within municipal limits to the

**Municipal Board** (Meghalaya Municipal Act, 1973, s.62), in Shillong to the SMB for the reaches within its area; roadside drains, catch-water drains, scuppers and culverts to **PWD (Roads)**, and on NH-6, the Shillong–Dawki road and the other national highways to **NHAI** or **NHIDCL**; the drains of the Cantonment to the **Shillong Cantonment Board**; the drains of New Shillong to **NSTDA** [TBC]; rivers, with their beds, banks and floodplains, and flood works on any stream, to the **Water Resources Department**; village drains and jhoras outside municipal limits to the **District Council** and the **Dorbar Shnong** under the District Council's rules (the Nokma-led villages of the Garo Hills were not researched [TBC]); the reservoirs, their drawdown land and the reaches below the dams to **MePGCL**; catchment treatment to the **Soil and Water Conservation Department**; and works built by **Shillong Smart City Ltd** to that company until they are handed over in writing, and then to the Municipal Board (as reported) (set by this Manual). Each town shall keep a **drain-and-jhora register** that gives every reach its owner under this assignment, its land status (community, clan, private or State) and whether it is a "waterbody" under the Guidelines or is excluded by the 240-day rule (set by this Manual); the geo-referenced map dividing the SMB's reaches of the Umkhrah and Umshyrpi from the KHADC's, which the Board was asked to prepare (State action-taken report, 2023), is its first sheet [TBC]. Under Clause 6.9.8(a), the reserve along a channel assigned to the Water Resources Department is transferred to, or secured for, the Water Resources Department. Where a channel's status is disputed, the corridor follows the channel and not its name: Shillong's jhoras are at once storm drains, carriers of sewage and sullage, and the feeders of the Umiam reservoir (Clause 8.9). No approved city drainage master plan with a design return period was found for any town in the State, and no design storm for any town drain. A drain sized to fit the land left beside it cannot be enlarged, which is why the reserve is based on the required size. Until a Basin Stormwater Master Plan is adopted (Clause 6.9.6(b)), the required drain size of Clause 6.9.7 is the size computed by the designer under this chapter. This Manual does not prescribe a lined or an unlined section, except where Clause 6.3.6(e) and Chapter 9 require lining on steep gradients and the karst and mine rule of Clause 4.11 requires it on limestone and in the coal belt. It requires the section to meet the velocity limits of Clause 6.7.3 and Chapter 9, and a reserve wide enough for an unlined or vegetated section is a reserve that keeps both options open.

Commentary. Requirements 6.9.2(b)–(e), 6.9.3 and 6.9.4 have no direct precedent and are set by this Manual. Compound walls around individual plots are almost universal in Meghalaya and are one of the most common ways that overland flow paths get blocked. The 50% blockage assumption for wall openings is set to match the grate clogging factor of Clause 6.6.3. The 3.5 m access width is set by this Manual, sized for a small excavator or desilting vehicle. For comparison, APWA 5600 (2006, 5608.4) requires a 15 ft (about 4.6 m) maintenance access strip for detention facilities.

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## 6.10 Ponding at sags and low points

6.10.1 **Minor event.** At every sag, the minor design flow shall be removed by inlets (after clogging) with ponded spread within Table 6.2.

6.10.2 **1% AEP event.** At every sag:

- (a) the ponded depth shall not exceed 350 mm at the deepest point of the carriageway;
- (b) a surface overflow route shall be provided (for example over a lowered kerb and footpath into a designated overland flow path), so that the ponding level cannot rise above the overflow level; and
- (c) building floor levels around the sag shall comply with Clause 6.11.

6.10.3 **Fully-blocked check.** At sags, the 1% AEP ponding level shall also be computed with the minor system fully blocked and all flow leaving by the surface overflow route. Floor levels around the sag shall be set from the higher of the two ponding levels.

6.10.4 **Trapped sags.** Where a sag has no surface overflow route, the inlets and conduits (after clogging) shall carry the 1% AEP flow, and the approving authority shall agree the arrangement.

6.10.5 **Road underpasses.** Underpasses and other trapped sags on public roads shall:

- (a) be drained by a minor system (with pumping under Chapter 9, Clause 9.9, where gravity drainage is not possible) designed for the 2% AEP (50-yr) flow, checked at the 1% AEP flow;
- (b) have flanking inlets at both approaches to intercept flow before it reaches the low point;
- (c) be protected from inflow from surrounding streets by raised approach crests where practicable; and
- (d) have depth markers and automatic warning or closure signals that operate at 150 mm depth on the carriageway.

> Commentary. The fully-blocked check, the trapped-sag rule and the underpass requirements have no direct precedent and are set by this Manual. No record of a flooded road underpass in the State was found during research [TBC]. The roads already act as the major system, and in the hills as its steepest part: on 30–31 May 2025 landslides in 15 villages of Umling block near NH-6 were linked to hill cutting along the highway (as reported); the NH-6 tunnel at Sonapur in the Jaintia Hills, built along a stream, was closed by mudslides in August 2023 and reopened only in May 2024 (as reported); and in June 2026 the Shillong–Dawki road collapsed at Laitlyngkot, at chainage 25+200 (as reported). Clause 6.10.5(d) links the 150 mm crown depth limit of Table 6.2 to the point at which traffic should stop.

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## 6.11 Building floor levels

6.11.1 The lowest habitable floor, and every opening through which water could enter a building (doors, ventilators, basement ramps, lift pits and service entries), shall be at least **0.5 m above the 1% AEP flood level**.

6.11.2 The 1% AEP flood level is the highest of:

- (a) the 1% AEP major-system water level in the street or overland flow path next to the building (Clauses 6.9 and 6.10, including the fully-blocked check at sags);
- (b) the 1% AEP flood level of any river, channel, tank or waterbody (Chapter 7); and
- (c) the 1% AEP level with the tailwater of Chapter 5; and
- (d) where the Approving Authority has adopted a 1% AEP flood depth map under Clause 7.3.4, the ground level at the plot plus the mapped 1% AEP depth.

6.11.3 **Default where no level has been computed.** For a plot below the Chapter 1 thresholds, or where no 1% AEP level has been computed for the plot, the lowest habitable floor and openings shall be at least the higher of:

- (a) **0.65 m above the highest crown level of the road on which the plot fronts**; and
- (b) where an adopted 1% AEP flood depth map covers the plot, **the ground level plus the mapped 1% AEP depth plus 0.5 m**.

The Approving Authority may adopt a regional map, such as a State-approved map or a published national map of modelled 1% AEP flood depth (for example the India Flood Atlas), until a local study replaces it. A map that does not model storm surge shall not be used in place of Clause 6.11.6.

6.11.4 **Basements.** The crest of every basement ramp and the sill of every basement opening shall meet Clause 6.11.1. Basement drainage shall be pumped to the surface drain through a non-return valve.

6.11.5 **Services.** Electrical panels, transformers, standby generators, lift machinery and pumps that serve a building shall meet Clause 6.11.1.

6.11.6 **Coastal band.** The coastal band is the land within **500 m** landward of the High Tide Line along the sea front, as defined by the CRZ Notification, 2019, with the High Tide Line as demarcated in the approved Coastal Zone Management Plan. Where the Survey of India Hazard Line lies further inland than 500 m, the band extends to the Hazard Line. Within the coastal band, in addition to Clauses 6.11.1 to 6.11.5:

- (a) the lowest habitable floor and every opening shall also be at least **0.5 m above the coastal flood level**, which is the 1% AEP still-water level (Clause 5.7.3(b), Annex 5A) plus **twice** the sea-level allowance of Clause 5.7.4 (so at least 0.6 m), because buildings have a design life of more than 50 years (Clause 5.7.4(c));
- (b) where the plot fronts the open beach, the coastal flood level shall include wave set-up from a site study;
- (c) no habitable room, electrical service room or plant listed in Clause 6.11.5 shall be placed in a basement; and
- (d) every basement opening, ramp crest and ventilation opening shall meet Clause 6.11.6(a).

Clause 6.11.6 does not authorise any construction that the CRZ Notification prohibits. Where both apply, the stricter governs.

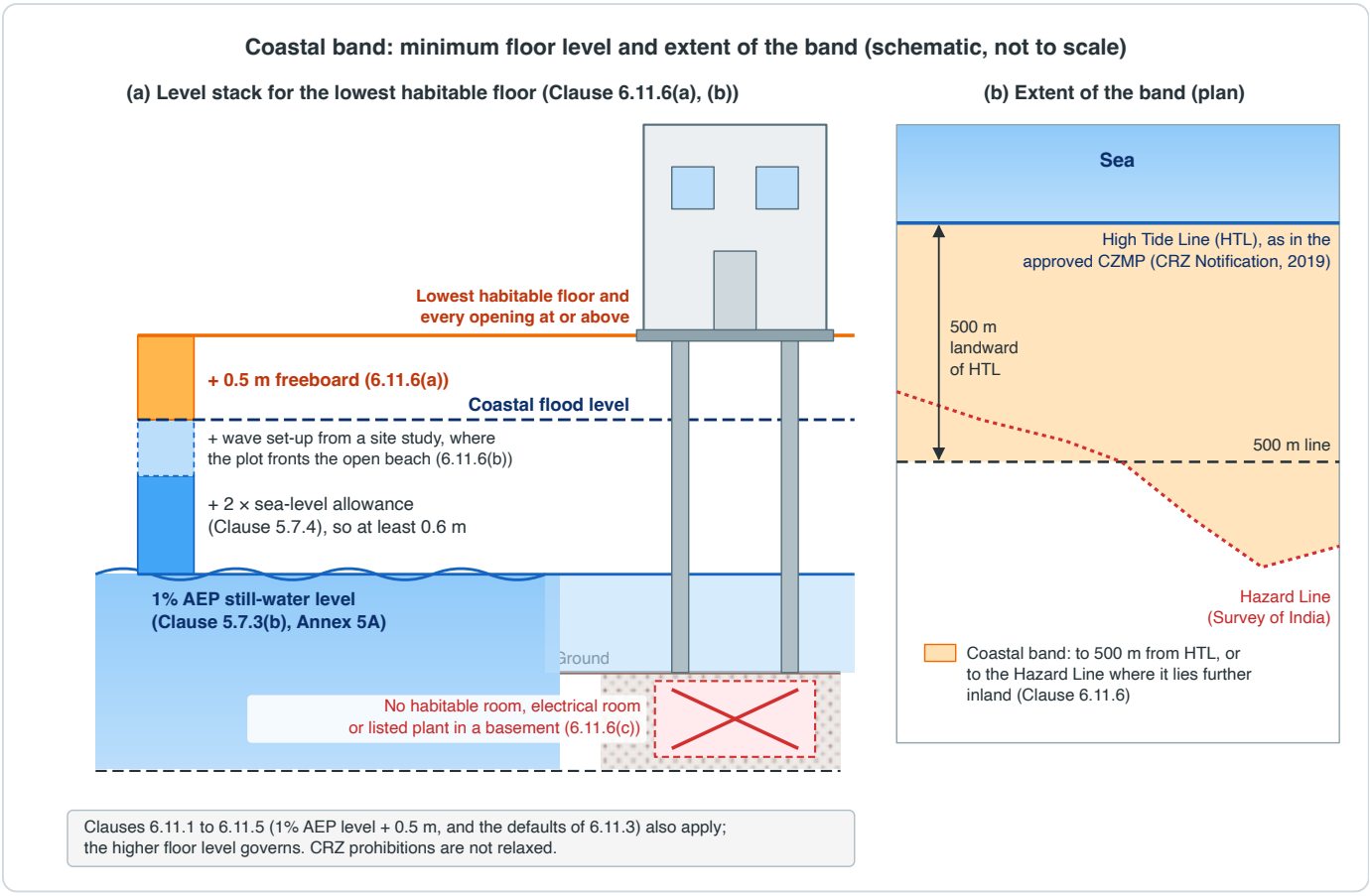


*Figure 6.5 — Coastal band: the minimum floor level built up from the 1% AEP still-water level, twice the sea-level allowance, wave set-up where the plot fronts the open beach and 0.5 m freeboard; and the extent of the band, to 500 m from the High Tide Line or to the Hazard Line where it lies further inland (Clause 6.11.6). Original drawing for this Manual, adapted from the CRZ Notification, 2019 (para 1(i) and Annexure IV) and PUB Singapore, Code of Practice on Surface Water Drainage (7th ed.), cl. 2.1.1.*

**Commentary.** The 0.5 m freeboard above the 1% AEP level follows the DID Malaysia 2008 checklist (platform and lowest floor at 100-yr ARI + 0.5 m). It is more than the APWA 5600 (2006, 5601.8 A2) requirement of 1 ft (about 0.3 m) above the 1% stage. The 0.65 m default in Clause 6.11.3 is derived from the other limits of this chapter, not separately sourced: the 1% water level at the crown may be up to 150 mm (Table 6.2), plus the 0.5 m freeboard. It has no direct precedent and applies to plots where no flood level exists. URDPFI (2015) also links minimum plinth levels to flood frequency in its flood-plain zoning, which is covered in Chapter 7.

Clause 6.11.3(b) lets a small plot use a mapped 1% AEP depth where no local study exists, instead of guessing from the road level alone. Modelled national maps are coarse (about 30 m), and most model rainfall and river flooding but not storm surge, which is why 6.11.3 keeps the road-crown check and Clause 6.11.6 sets a separate coastal rule.

The coastal band of Clause 6.11.6 uses the 500 m line of the CRZ Notification, 2019 (G.S.R. 37(E), para 1(i): "the land area from High Tide Line ... to 500 meters on the landward side"), because every coastal authority already maps it and it needs no new survey. The Hazard Line, demarcated by the Survey of India to show the extent of flooding and shoreline change, extends the band where it lies further inland (CRZ Notification, 2019, Annexure IV). The band takes the coastal level from the joint-case still-water level of Chapter 5 rather than from the rainfall map. The higher standard reflects the setting: a coastal flood rises with the sea, cannot be drained while the tide is up, and will rise further with the sea. Singapore takes the same approach with a fixed minimum platform level of 4.0 m above datum on its southern coast and 4.5 m on its northern coast, whatever the rainfall flood level (PUB Code of Practice on Surface Water Drainage, 7th ed., cl. 2.1.1). Each coastal State's tide and surge levels vary too much along its coast for one fixed level, so this Manual uses the computed still-water level instead. Using twice the sea-level allowance applies the sensitivity case of Clause 5.7.4(c) as the design case, because a building, unlike a drain, cannot easily be raised later. The basement restriction in 6.11.6(c) is set by this Manual: a basement in the coastal band fills from the sea as well as from rain, and cannot be pumped out to a tide-locked outfall. Meghalaya has no coast, no High Tide Line and no Coastal Regulation Zone, so the coastal band is empty in the State and Clause 6.11.6 does not apply there. Clauses 6.11.3 and 6.11.4 matter instead. The only flood-level building rules found are those of the Bye-Laws 2021: where a plot lies along a stream or river, the stilt of a building on a sloping site shall be "minimum 1.20m above the Highest Flood Level" and the plinth on a flat site at least 0.90 m (B1(v)(b)); no land shall be developed in an area "liable to flooding, except where protection measures are adopted" (B1.1(ii)); basements are "applicable only in flat terrain" (A2.7), and surface drainage shall not enter them (A2.8(j)); and, in the Khasi Hills, the drawings of a building shall show "the highest flood level (HFL) reached above the street" (KHADC Regulation 2015). No Highest Flood Level has been published for any stream in Shillong or any other town, so the rules give no level to build to. For this Manual, the Highest Flood Level of B1(v)(b) is taken as the 1% AEP flood level of Clause 6.11.2, or, where none has been computed, the highest flood level surveyed from flood marks, and the floor levels of Clause 6.11.1, 0.5 m above the 1% AEP level, govern where they are higher than the Bye-Laws' stilt and plinth (set by this Manual). Clause 6.11.3, which sets the lowest habitable floor and every opening 0.65 m above the road crown where no flood level has been computed, and Clause 6.11.4, which applies the same level, or 0.5 m above the 1% AEP flood level, to the crest of every basement ramp and the sill of every basement opening, are set by this Manual and add to the rules. On a hillside the road crown is not always the right reference: a building below a road takes the road's runoff, so Clause 6.11.2(a) sets its floor and openings from the 1% AEP level of the flow path past it, with the uphill diversion and the drained space against the cut of Clause 6.3.6(h) in place, and a floor or basement cut into a slope also needs the geotechnical certificate of the hill rule of Clause 4.11, the soil report of B1(vi) where the soil is weak, and the report of the Geological Survey of India that B1(vii) requires for a cut of more than 6.00 m; on limestone or in a coal-mining area, where the karst and mine rule of Clause 4.11 applies, no certificate makes infiltration acceptable. Along the streams, rivers and jhoras, near the pungs, lakes and springs and on the shores of the reservoirs, the lines of Chapter 7 also apply.

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## 6.12 Culverts and road crossings

6.12.1 **Design AEP.** A culvert or bridge that carries a road over a drain or waterway shall pass the design AEP flow of Table 6.1 for that road class without overtopping the road, and with the headwater limits of Chapter 9, Clause 9.4. Where the waterway is a State highway or national highway crossing, the design AEP shall also be not less than that of IRC:SP:42-2014 §7.1.4 for the span. The rarer AEP governs.

6.12.2 **Check event and 1% AEP.** At the check event and at the 1% AEP event, the crossing and the road together shall pass the flow:

- (a) with overtopping depth ≤ 150 mm at the road crown and ≤ 350 mm at the deepest point of the road;
- (b) within the hazard limits of Table 6.3;
- (c) with no overtopping at all of arterial roads that are notified evacuation routes; and
- (d) without raising the 1% AEP flood level at any upstream building or property boundary above the level for the existing condition, unless the affected owners and the approving authority agree.

6.12.3 **Where overtopping is not permitted.** Overtopping in the 1% AEP event is permitted only where the structure span is less than 6 m **and** the 1% AEP peak flow is not more than 7 m³/s, unless a guard rail is installed downstream of the overtopping section. Otherwise, the crossing shall pass the 1% AEP flow without overtopping.

6.12.4 **Blockage check.** The 1% AEP check shall be repeated with a blocked inlet:

- (a) 50% of the inlet area blocked for culverts with a span or diameter below 1.5 m; and
- (b) 20% blocked for larger culverts.

The results of this check shall meet Clause 6.12.2(a) and (d).

6.12.5 **Minimum size.** Culverts under public roads shall be at least 900 mm in diameter, or 900 mm × 900 mm for box culverts.

6.12.6 **Hydraulic design.** Culvert hydraulics, including inlet and outlet control, tailwater, road overtopping and outlet protection, shall follow Chapter 9, Clauses 9.4 and 9.6.

> Commentary. The design AEPs are those of Table 6.1. The overtopping limits are the street-depth limits of Table 6.2. The span and flow threshold in Clause 6.12.3 is the SI conversion of APWA 5600 (2006): overtopping allowed only where the structure span is under 20 ft and the 1% peak is 250 cfs or less, unless a downstream guard fence is installed. IRC:SP:42-2014 (§7.1.4) sets 25-yr for NH/SH culverts up to 2 m span and 50-yr for 2–6 m spans. The blockage percentages in Clause 6.12.4 and the 900 mm minimum size have no direct precedent and are set by this Manual. The 50% value matches the grate clogging factor.

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## 6.13 Meghalaya construction-practice requirements

6.13.1 **Covered roadside drains.** Where a roadside drain is covered by slabs that form a footpath:

- (a) it shall be designed as an open channel with the freeboard of Table 6.7 measured to the soffit of the cover slab, and its HGL shall meet Clause 6.8 measured to the footpath and inlet levels;
- (b) road runoff shall enter through openings in the drain wall at road level (Clause 6.6.1(b)), each with a silt sump (Clause 6.6.7), at the spacing of Clause 6.6.4;
- (c) footpath runoff shall enter through slots or grated openings in the cover, not by ponding on the footpath; and
- (d) the clear section shall meet Clause 6.7.6(c).

6.13.2 **Removable covers and access openings.** Covered drains shall have:

- (a) removable cover panels at not more than **10 m** centres, each at least 0.6 m long and spanning the full clear width, with recessed lifting points, liftable by two workers or by a hand-operated lifting device, and flush with the footpath;
- (b) access chambers with a clear opening of at least 0.6 m × 0.6 m at every junction, bend and change of section, and at not more than **30 m** centres on straight runs; and
- (c) covers rated for the traffic or pedestrian load at their location (Chapter 9, Clause 9.11).

6.13.3 **Silt traps.** In addition to the inlet sumps of Clause 6.6.7, silt trap chambers shall be provided:

- (a) upstream of every culvert under an arterial road;
- (b) upstream of every pump station and detention facility; and
- (c) at every outfall to a tank, river or other waterbody (with the gross pollutant trap required by Chapter 8).

Each silt trap shall be sized to hold the sediment expected between scheduled cleanings, using the sediment yield in Annex 6B, and shall be reachable by a desilting vehicle.

6.13.4 **Garbage and gross pollutant screens.** Screens shall be provided where an open drain enters a covered drain, a pipe or a culvert, and at outfalls under Chapter 8. Each screen shall:

- (a) be designed under Chapter 9, Clause 9.8;
- (b) have a bypass or overflow, so that a fully blinded screen does not flood properties or the road beyond the limits of this chapter; and
- (c) be checked hydraulically with 50% of its area blocked.

6.13.5 **No building over drains.** No structure other than an approved crossing or a removable cover shall be built over a public drain. Shop frontages, ramps and steps that cross a drain shall be removable or shall leave access openings that meet Clause 6.13.2.

6.13.6 **Utilities.** No water main, sewer, power or telecom cable, gas pipe or duct shall be laid along, or pass through, the flow area or freeboard of any drain. A utility that must cross a drain shall:

- (a) cross above the cover soffit or below the drain invert, inside a sleeve; and
- (b) be shown on the drainage plan with its level.

Where an existing utility crossing obstructs a drain, its area shall be deducted from the drain section, with a 50% blockage allowance for the debris it traps, until the utility is relocated. The utility owner shall relocate it when the drain is rebuilt.

6.13.7 **Sewage.** No sewage connection is permitted to a storm drain (Chapter 8). Covered drains shall be built with sealed joints where they run next to sewers.

6.13.8 **Edge protection.** Open drains deeper than 1.0 m beside a footpath, a carriageway or a public open space shall have railings or barriers. Open drains of any depth shall not be left uncovered across a footpath.

6.13.9 **As-built levels.** The as-built invert levels of every public drain, pipe and manhole shall be surveyed and submitted (Chapter 10). Inverts shall be within ±15 mm of design. An HGL re-check shall be submitted where they are not.

6.13.10 **Desilting.** Public drains shall be desilted before the monsoon season each year, as set out in Chapter 10.

> Commentary. Clause 6.13 has no direct precedent; this Manual sets it on the basis of Meghalaya practice. Most urban drains in the State are covered roadside drains under footpaths. They are often built with continuous cast-in-situ slabs and few openings, so they cannot be cleaned and fill with silt and solid waste within a season. CPHEEO (2019) notes that uncovered channels "are prone to the dumping of garbage" (Part A, Ch 2), which is why the drains are covered. Covering without access openings simply moves the problem out of sight. NDMA (2010) recommends that pre-monsoon desilting be complete by 31 March. In Meghalaya that date is also the start of the wet season. The south-west monsoon reaches Shillong at about the beginning of June (an old IMD normal of 1 June, as reported) and withdraws in mid-October (by 14 October in 2025, as IMD expected, and on 15 October in 2026 for the North East, as reported), but the storms come earlier: Cherrapunji's highest 24-hour falls for April and May are 644.2 mm (16 April 1990) and 812.0 mm (25 May 1916) (IMD *Extremes*), the CWC report for subzone 2(b) finds the rainfall "spread over a period of eight months, i.e. from March to October", and the highest recorded levels of the Umngot at Dawki and the Myntdu at Kharkhana were set on 28 May 2006 and 23 April 1995 (SANDRP's copy of CWC data, as reported). Storms also come after the withdrawal: 594.0 mm at Cherrapunji on

11 October 1975 and 262.0 mm at Shillong on 8 October 2004 (IMD *Extremes*). The only direction found is the IRADe/NMHS plan's recommendation of "Desilting to avoid flooding during monsoons", with no date; no desilting order of the Urban Affairs Department, a Municipal Board or a District Council with a completion date was found during research [TBC]. So Clause 6.13.10 refers to the monsoon season as this Manual defines it, 1 April to 31 October, and Chapter 10 requires desilting and the clearance of debris, garbage and slide material from drains, jhoras, inlets, racks, traps and culverts to be complete by 31 March, with inlets, debris racks, culverts, flap gates and pumps certified ready and test-run on the same date (Clauses 5.11.5 and 5.12.9); a mid-season clearance of racks, culverts, sediment traps and jhora inlets by 31 May, after the April–May storms and before the south-west monsoon sets in; standby from 1 April to 31 October; and a post-season clearance of debris and slide material in every town by 15 November, because every storm in the hills fills the racks and traps. These dates are set by this Manual. Meghalaya's towns have no snow regime.

No rule of the Bye-Laws 2021 on building over a drain was found. Within municipal limits the public drains, streams and water-courses vest in the Municipal Board (Meghalaya Municipal Act, 1973, s.62), which may regulate the line of buildings on public roads and drains (s.164); outside them, the KHADC Regulation 2015 treats a river edge as a zone where "No development should normally be allowed" (s.2.101). Natural jhoras and streams are open channels with a drainage reserve (Clause 6.9), and should not be covered, decked or built over: NESAC found the channel capacities of Shillong's streams drastically reduced "due to encroachments along their banks by buildings" (NESAC, 2023), and encroachment on the jhoras is reported to make them "more vulnerable to flooding" (ICLEI, as reported). Where a drain is covered, Clause 6.13.2 applies to it in full; where it is open beside a footpath or a carriageway, Clause 6.13.8 applies. In the hill towns many drains run beside steps and footpaths on steep ground, where an open drain is a fall hazard and a covered one cannot be cleared of stones and waste without its access openings.

Clause 6.13.7 is not yet the practice, and in Shillong it cannot be until sewers exist. "The Shillong Planning Area has no sewerage system": the sewage flows into septic tanks and soak pits, and the sullage "flows into the primary, secondary and natural drains and finally to the nearby rivers Wah Umkhrah in the north and Wah Umshyrpi in the south" (NESAC, 2023); MSPCB identified 20 outfalls to the Umkhrah and 12 to the Umshyrpi (minutes of the stakeholder meeting, 14 April 2023); and CPCB lists both streams in its first priority for pollution (CPCB, *Polluted River Stretches*, September 2025). The National Green Tribunal has required the State to ensure that "raw fecal matter is not discharged into fresh water streams and Umkhrah and Umshyrpi rivers" (O.A. 192/2022, order of 22 November 2022). Clause 8.9 sets how dry-weather flow in storm drains is surveyed and intercepted until the connections are removed, including the rule that interception shall not reduce the capacity of the drain (Clause 8.9.5(b)).

The 10 m and 30 m spacings and the ±15 mm tolerance have no direct precedent and are set by this Manual. Clause 6.13.6 responds to the common sight of water mains and cables running through drains. Each one traps debris and reduces the section. Mechanical cleaning through cover openings, rather than manual entry, is assumed throughout, consistent with the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013.

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## 6.14 Outfalls

6.14.1 Outfalls shall be designed for the tailwater conditions of Chapter 5. Outfalls below the 1% AEP still-water level shall have flap or tide gates or non-return valves (Chapter 5 and Chapter 9, Clause 9.10).

6.14.2 Outfall protection and energy dissipation shall be designed under Chapter 9, Clause 9.6. Outfalls to tanks and waterbodies shall also meet Chapters 7 and 8.

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## 6.15 Submittal requirements

Every conveyance submittal shall include a **Conveyance Design Report** (Form 6-1) containing:

1. a catchment plan showing sub-catchments, the minor system, inlet locations and the major-system overland flow paths for the 1% AEP event (Clause 6.3.2);
2. the land-use and road-class AEP adopted for each element (Table 6.1), and the high-density area status;
3. design flows, with the rainfall sheet of Chapter 2 and the method of Chapter 3;
4. gutter spread, depth and D·V checks for the minor, check and 1% events (Tables 6.2 and 6.3);
5. an inlet schedule with clean capacity, clogging factor, design capacity and bypass flow (Clause 6.6);
6. pipe and drain design tables with n, velocity, sediment allowance and freeboard (Clause 6.7);
7. HGL profiles for the minor and check events, with the tailwater used (Clause 6.8);
8. sag ponding levels, including the fully-blocked check (Clause 6.10);
9. a floor-level schedule for every building (Clause 6.11);
10. culvert and crossing calculations (Clause 6.12 and Chapter 9); and
11. a utilities-crossing schedule and access-opening layout for covered drains (Clause 6.13).

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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 6A | Standard inlet types for Meghalaya with capacity curves (on grade and sag) |
| 6B | Sediment yield for silt-trap sizing and calibration of the sediment allowance |
| 6C | Standard drawings: covered roadside drain with removable covers, access chamber, inlet with silt sump |
| Form 6-1 | Conveyance Design Report checklist |

CHAPTER 7

# Waterbodies, Pungs (Ponds and Lakes) and Setbacks

## 7.1 Purpose and scope

7.1.1 This chapter treats waterbodies as part of the drainage system. It sets the rules for:

- (a) identifying and mapping every waterbody that a development or public work affects;
- (b) the setback zones around waterbodies, and the uses allowed in each zone;
- (c) fill in flood-prone land, and the compensatory storage needed where fill is allowed;
- (d) counting tank (pung) storage, including tank cascades, as design storage;
- (e) restoring and desilting tanks and ponds;
- (f) protecting supply channels, surplus courses, inlets and outlets;
- (g) wetlands, marshes and estuaries, which in Meghalaya, a landlocked State with no Ramsar site, means the Umiam (Barapani) reservoir and the other reservoirs of MePGCL with their drawdown zones, the pungs and small lakes, such as Ward's Lake (Nan Polok) in Shillong and Thadlaskein (Pung Sajar Nangli), the bogs and seepage ground of springs, the marshes (chibol) and waterlogged ground of the Garo plains along the Jinjiram, any wetland notified under the 2017 Rules (none was found notified), and the 225 water bodies ground-truthed for the High Court in 2025 (as reported);
- (h) the interface with encroachment and its removal;
- (i) fee-in-lieu contributions to regional tank storage (with Chapter 4); and
- (j) the safety of tank bunds and other embankments.

7.1.2 This chapter applies to every development and public work to which this Manual applies under Chapter 1 and that:

- (a) adjoins a waterbody or lies wholly or partly within its setback (Clause 7.4);
- (b) discharges to a waterbody, directly or through a drain, within the downstream analysis extent of Chapter 5; or
- (c) alters a waterbody, its bund, sluice, surplus weir, supply channel or surplus course.

7.1.3 Where a statute or statutory rule sets a wider setback or a stricter restriction, the statute governs (Clause 1.3.3). Nothing in this chapter authorises any work that the Meghalaya Town and Country Planning Act, 1973 and the Meghalaya Building Bye-Laws, 2021 made under it, the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, the Meghalaya Flood Plain Zoning Act, 2026, the Meghalaya Municipal Act, 1973, the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015 and the other instruments of the District Councils, the Wetlands (Conservation and Management) Rules, 2017, or any other law, prohibits.

> Commentary. Meghalaya has no Act for the protection of lakes, tanks, ponds or springs as such. Its waterbodies are protected by executive guidelines, by its building bye-laws and the regulations of its District Councils, by its municipal law, by a new floodplain Act whose zones have not yet been drawn, by the wetland rules and by the courts, and in most of the State the land and water belong to communities, clans and private owners rather than to the State. The **Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023** (No. FOR/CC/29/2019/Pt/688 of 25 August 2023, as amended on 13 February 2024 and 6 July 2026) were made by the Forest and Environment Department on the direction of the High Court in PIL No. 10 of 2019, *In Re: Cleanliness of Umiam Lake*; they set setbacks from streams, lakes and ponds measured from "the mean high flood level of a water body observed in the past ten years", bind in the areas of the Bye-Laws 2021 through B2(ii)

(c) and Section I(a), cl. 4, and I(f), as amended in 2024, and elsewhere only "in such manner as may be prescribed" (para 10(2)) (Clause 7.4, Disclosure). The **Meghalaya Building Bye-Laws 2021** apply to "all the Master Plan Areas, Municipal areas and Scheme Areas within the State" (A1.2); they keep building off land "liable to flooding, except where protection measures are adopted" (B1.1(ii)) and raise stilts 1.20 m above the Highest Flood Level on sloping sites beside a stream or river (B1(v)(b)). Outside those areas building and land are regulated by the District Councils: in the Khasi Hills by the **Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015**, whose section 15(1) makes it the duty of the Executive Committee, Town Committee or Dorbar Shnong to ensure that land development does not damage "catchment areas, water sources, spring sheds, streams and rivers", and whose "Reserved Forest & Conservation Area", including a river edge, is a zone where "No development should normally be allowed" (s.2.101); the building instruments of the Jaintia Hills and Garo Hills Autonomous District Councils were not found [TBC]. Within municipal limits "all public streams, channels, water-courses, springs tanks, reservoirs" vest in the Municipal Board (**Meghalaya Municipal Act, 1973**, s.62(b)). The **Meghalaya Flood Plain Zoning Act, 2026** provides for a Flood Zoning Authority, the survey of rivers and the notification of flood zones whose restrictions "shall prevail" over other laws (s.12(2) of the Bill), but no Authority, rules or zone had been notified when this Manual was drafted (Clause 7.3, Commentary). Wetlands are the concern of the **Meghalaya State Wetlands Authority**, constituted on 1 November 2017 (Clause 7.12, Commentary); the State has no Ramsar site. In this chapter **MePGCL** means the Meghalaya Power Generation Corporation Ltd, which holds the reservoirs of the Umiam–Umtru and Myntdu–Leshka projects and is the only custodian in the State with written rules for its gates and levels; the custodians of the pungs and lakes are recorded one by one in the inventory (Annex 7A). Who regulates where in the Sixth Schedule areas, and who is the competent authority for each, is set out in Chapter 1.

**This Manual treats every recorded waterbody as drainage infrastructure.** Five features set Meghalaya apart. The first is the **jhora**: the small hill streams into which every town on the plateau drains, which in Shillong are also the sewerage (Clause 8.9, Commentary), which are narrowed by building and choked with garbage, and which the Waterbodies Guidelines do not protect where their bed is dry for 240 days a year. The second is the **reservoir**: the State's largest standing water is the Umiam (Barapani) reservoir, impounded in 1965, which receives Shillong's rivers through the Wah Roro and "serves as a cesspool of the waste materials of Shillong" (Expert Committee, 2023), with MePGCL's smaller reservoirs at Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka, whose levels are kept partly in feet. The third is the **spring** (umpohliew): the towns are supplied by gravity from streams and springs (CGWB), MBDA's counts of mapped springs conflict, and no statute keeps building or drains away from them. The fourth is the **sacred grove** (law kyntang), many of which stand at the heads of perennial streams (as reported) and which this Manual treats as protected source catchments. The fifth is the **ground**: limestone with caves on the southern escarpment and in the Jaintia hills, and rat-hole coal workings, into which water vanishes. The **pungs** and small lakes, such as Ward's Lake (Nan Polok) in Shillong and Thadlaskein (Pung Sajar Nangli) near Mukhla, are few, small and often sacred or communal, and Meghalaya has no irrigation tank cascades; the tank clauses of this chapter apply to pungs, small lakes and reservoirs. This chapter gives the design rules that protect the storage and conveyance of these waterbodies. It does not replace the Guidelines, the bye-laws, the District Councils' regulations, the customary rules of the Dorbar Shnongs and clans, the municipal, floodplain and wetland procedures that record and protect them, or the directions of the High Court of Meghalaya, the National Green Tribunal and the Supreme Court.

## 7.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Waterbody | A river or stream (wah in Khasi and Pnar; chibima, a river, or chiring, a brook, in Garo), such as the Umiam, the Umkhrah and the Umshyrpi, which join as the Wah Roro above the Umiam lake, the Umkhen and the Wah Tamdong at Shillong, the Myntdu at Jowai, the Umngot at Dawki, the Umtru, the Kynshi, the Simsang, the Ganol at Tura, the Bugi and the Dareng in the south Garo hills, and the Jinjiram and the Krishnai on the Garo plains; jhora (a small hill stream, perennial or seasonal, into which the drains of a hill town fall); drain (nur or muri in Khasi, dooid in Pnar); pung (a pond, pool or small lake, natural or dug, such as Thadlaskein, Pung Sajar Nangli, near Mukhla); lake or built tank (nan, such as Ward's Lake, Nan Polok, in Shillong); reservoir or pondage, such as the Umiam (Barapani) reservoir and the reservoirs of MePGCL at Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka; spring (umpohliew) with its recharge area; wetland, marsh or bog (chibol in Garo); supply channel or surplus course, perennial or seasonal (as in Chapter 1). |
| Tank (pung) | A waterbody impounded by an earthen bund, fed by its own catchment and/or a supply channel, with a surplus weir and one or more sluices. |
| Tank cascade | A chain of tanks in which the surplus or sluice outflow of one tank feeds the next (as in Chapter 3). |
| Full tank level (FTL) | The crest level of the surplus weir (spillway, overflow or outlet) of a tank, or the permanent crest of its regulating structure. The tank holds water up to FTL without spilling. |
| Maximum water level (MWL) | The highest water level in a tank when the surplus weir passes the tank's design flood. For this Manual, it is the greater of the level recorded by the Water Resources Department and the level computed for the 1% AEP (100-yr) inflow with the climate factor of Clause 2.8 (Clause 7.7.4). |
| Top bund level (TBL) | The crest level of the tank bund. |
| Waterspread | The area of a tank submerged at FTL. |
| Foreshore | The land around a tank between the FTL contour and the MWL contour. Foreshore land is flooded whenever the tank surpluses, and is part of the tank's flood storage. |
| Supply channel (stream, jhora or feeder channel) | A channel that brings water from a river, anicut or upstream tank into a tank. |
| Surplus course | The channel that carries the overflow of a surplus weir to the next tank, a river, a drain or the sea. |
| Sluice (sluice, spillway gate or regulator) | A controlled outlet through a tank bund, usually to an irrigation channel. |
| Top of bank | For a channel, the break in slope at the edge of the channel. Where it cannot be identified, the edge of the water surface at the 50% AEP (2-yr) flow. |
| 1% AEP flood extent | The land flooded by the 1% AEP (100-yr) flood with the climate factor of Clause 2.8, from a hydraulic model that meets Chapter 3 and Chapter 5, or from a map adopted by the Authority under Clause 7.3.4. |
| Floodway | The waterbody and the adjoining land that must be kept free of obstruction to pass the 1% AEP flood without raising the 1% AEP water level by more than **0.1 m** at any point (Clause 7.6.1). For a tank, all land below MWL. |
| Flood fringe | The part of the 1% AEP flood extent outside the floodway. |
| Zone 1 (waterbody protection zone) | The inner setback zone defined in Clause 7.4.3. |
| Zone 2 (flood fringe setback) | The outer setback zone defined in Clause 7.4.4. |
| Setback | Zone 1 and Zone 2 together. |

| Term | Meaning in this Manual |
|---|---|
| Compensatory storage | Excavated storage that replaces flood storage lost to fill, under Clause 7.6.4. |
| Flood cushion | Storage below FTL kept empty, under a documented operating rule, to absorb a flood (Clause 7.8). |

**Meghalaya terms.** The following terms are used in this chapter in addition to those above (see also Annex 7E):

| Term | Meaning in this Manual |
|---|---|
| Pung | A pond, pool or small lake, natural or dug: "Pung, ka, n. a pool" in Singh's *Khasi-English Dictionary* (1906), and the first equivalent of both "Pond" and "Pool" in his *English-Khasi Dictionary* (1920) (Annex 7E). First used in this Manual as "pung (Khasi and Pnar: pond, pool or small lake; Garo: *pokri*)". The plural "pungs" is this Manual's English form; Khasi and Pnar mark the plural with the article *ki*. A pung with a controlled outlet is a tank under Clause 7.2: its outlet gate is its sluice, and its FTL is the level at which it spills over its outlet with any gate closed, found by survey. A pung with an uncontrolled outlet has its FTL at the crest of that outlet. Natural, sacred and community waters keep their own names, such as Nan Polok (Ward's Lake) and Pung Sajar Nangli (Thadlaskein). Engineered storage built under this Manual is a "detention pond", never a sacred or community pung. |
| Recorded waterbody | A pung, lake, reservoir, stream, jhora, spring or wetland shown in any source of Clause 7.3.3(a): a Revenue or District Council record, a Municipal Board's record of what vests in it, a master-plan map, the Expert Committee's inclusion and exclusion lists, the 2025 ground-truthing list, MePGCL's records, an MBDA spring inventory or a town's drain-and-jhora register. A recorded waterbody is part of the drainage system for this Manual. Where it is proposed to be filled, in whole or part, a drainage assessment under Chapters 3 to 5 shall show the storage and flow paths lost and their effect upstream and downstream, and the lost storage shall be replaced under Clause 7.6.4 before any design relying on the filling is approved. This definition and rule are set by this Manual. |
| Boundary of a pung, lake or reservoir | For this Manual, the boundary of a pung or lake under Clauses 7.3.3 and 7.13.1 is the largest of its recorded boundary, its surveyed FTL and the outer edge of its water in the season of 1 April to 31 October shown by dated imagery or survey of recent years; and the boundary of a reservoir is the higher of its full reservoir level and the highest level its operator states, converted from feet at 1 ft = 0.3048 m and stated to the datum of Clause 7.3.5. For the Umiam (Barapani) reservoir no MePGCL guideline was found: its full level is given only in the press as 3,220 ft (about 981.5 m) and a spillway crest at EL 969.5 m in another document (both as reported; datum unknown), and until MePGCL states the level and datum the boundary is fixed by survey of the highest water line [TBC]. The drawdown land of a reservoir below that level is part of the reservoir. This reading is set by this Manual. |
| Stream (wah); jhora | A stream or river is a *wah* in Khasi and Pnar (Annex 7E). A jhora is a small hill stream, perennial or seasonal, the word used in Shillong for the streams into which the town's drains fall (as reported; no dictionary source was checked). Every stream or jhora that drains 8 ha or more is a natural channel under Clause 7.4.1(b), whatever its name, whether it is dry for most of the year, whether the Waterbodies Guidelines exclude it under their 240-day rule (para 2(e)), and whether it is lined, piped or covered. A jhora carries boulders, debris and garbage in flood: its inlets and culverts take the racks, bulking and blockage of Clause 6.3.6, and its top of bank is the edge of its active bed where that is wider than the edge of the 50% AEP flow. This definition is set by this Manual. |
| Reference lines for setbacks | Three lines are used, and the setback that reaches furthest from the water governs: (a) the Waterbodies Guidelines' line, "the mean high flood level of a water body observed in the past ten years" (para 2(f)), with the Guidelines' setback measured from it; (b) the FTL of a pung, lake or reservoir or the top of bank of a channel, with Zone 1 of Clause 7.4.3 measured from it; and (c) the 1% AEP flood extent of Clause 7.3.4, with the 10 m of Clause 7.4.4 added. Where the ten-year mean high flood level is not known, it is found by the survey of flood marks and the evidence of residents, recorded on Form 7-1. This rule is set by this Manual. |
| Spring (umpohliew); spring recharge area | A spring is a place where groundwater comes out at the surface: "Umpohliew, ka, n. a spring, a fountain" (Singh, 1906; Annex 7E). A spring is a waterbody for Clause 7.3, and its Zone 1 under Clause 7.4 is measured from its outlet or the edge of its tank or chamber. Its recharge area is the area upslope from which it is fed, as a hydrogeologist maps it; above a drinking-water intake that area is a no-paving zone, except for access, into which no road runoff is infiltrated, no drain is cut that would intercept the flow to the spring, and no fill is placed that would bury its outlet (Clause 8.8.1). No storm drain or sewer is laid within Zone 1 of a spring except a lined drain below its outlet that carries its overflow away. This definition and these rules are set by this Manual. |

| Term | Meaning in this Manual |
|---|---|
| Sacred grove (law kyntang); source catchment | A sacred grove is a forest kept by custom: "'lawkyntang, ka, n. a sacred grove" (Singh, 1906; Annex 7E). Where a grove stands at the head of a stream or above a spring that supplies a town or village, it is treated for this Manual as a protected source catchment: no drain discharges into it, no runoff from development is led through it, and no infiltration facility, soak pit or septic tank is placed in it. The grove's custodian decides what happens inside it; this Manual only keeps the drainage of development out of it. Counts of the State's groves conflict and none is used here without its source (Clause 7.12, Commentary). This rule is set by this Manual, with section 15 of the KHADC Regulation, 2015 as its hook in the Khasi Hills. |
| Limestone and mine areas | The limestone of the southern escarpment and the Jaintia hills (sub-areas ML-C and ML-B1 of Annex 2A), any coal-mining area with rat-hole workings, and any place where caves or sinkholes are known. No pung, retention basin or detention pond is excavated into them, no infiltration facility is placed in them (Clause 4.11, karst and mine rule), and no drain is designed to lose water into them. |
| Landholding institution | The body that holds the land of a waterbody or its setback where it is not State land: the Dorbar Shnong of a Khasi or Jaintia village, a clan, or a private owner (the village institutions of the Garo Hills, led by the Nokma, were not researched [TBC]). Zone 1 land that is not State land is secured for this Manual by a written agreement with the landholding institution, or reserved in a master plan, and is not taken. This rule is set by this Manual. |

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## 7.3 Inventory and mapping of waterbodies

7.3.1 **Statewide inventory.** The Authority, with the Water Resources Department and the Revenue and Disaster Management Department, shall maintain a GIS layer of every waterbody in its area (Annex 7A). For each waterbody it shall record:

- (a) its type (Clause 7.2), name and survey numbers;
- (b) its custodian (the Municipal Board (for the drains, public streams, springs, tanks and reservoirs within its limits, which vest in it under section 62 of the Meghalaya Municipal Act, 1973), the Shillong Cantonment Board (in the Cantonment), NSTDA (in New Shillong [TBC]), PWD (Roads), NHAI or NHIDCL (for the drains and culverts of their roads), the Water Resources Department (for rivers and flood works), MePGCL (for the Umiam, Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka reservoirs and the reaches below their dams), PHED (for water-supply sources and intakes), the Soil and Water Conservation Department (for catchment treatment works), the Forest and Environment Department (for forest land and for matters under the Waterbodies Guidelines), the District Council and the Dorbar Shnong under the District Council's rules (for the drains, jhoras, springs and pungs of a village outside municipal limits; the Nokma-led villages of the Garo Hills were not researched [TBC]), a clan or a private owner (for land and water held by them), a colony developer (for the drains of a layout until they are handed over), the Meghalaya State Wetlands Authority (for a notified wetland; none was found), or another body);
- (c) its boundary as recorded in Revenue records;
- (d) for tanks: FTL, MWL, TBL, the surplus weir crest length and type, sluices, the supply channel and the surplus course, each with its datum;
- (e) its position in any tank cascade, with the upstream and downstream tanks;
- (f) the 1% AEP flood extent, where mapped; and
- (g) known encroachments, with the date recorded.

7.3.2 **Project mapping.** Every drainage report shall include a Waterbody Sheet (Form 7-1) showing all waterbodies:

- (a) within the site;
- (b) within 100 m of the site boundary; and
- (c) downstream, to the extent of the downstream analysis of Chapter 5.

The sheet shall show, on a plan at a scale of 1:1,000 or larger for (a) and (b):

- the Revenue record boundary;

- the surveyed FTL or top of bank;
- the MWL contour (tanks) and the 1% AEP flood extent;
- Zone 1 and Zone 2 (Clause 7.4); and
- every supply channel, surplus course, sluice and surplus weir.

7.3.3 **Sources.** Waterbodies shall be identified from all of the following. Where they conflict, the larger waterbody extent governs:

- (a) Revenue records and maps of the Revenue and Disaster Management Department and the Deputy Commissioners, which are thin in the Sixth Schedule areas, because most land there is community, clan or private and is held, allotted and recorded by the District Councils, the Dorbar Shnongs and the clans rather than by the State's revenue staff (none of these records was read for this Manual [TBC]); the land records, permissions and conditions of the District Councils and their building authorities, such as the KHBSRA; the drains, public streams, springs and tanks that vest in each Municipal Board under section 62 of the Meghalaya Municipal Act, 1973; the land use, waterbody and flash-flood and landslide susceptibility maps of the Shillong Master Plan 2041 and of NESAC's risk-informed master plan report for the Shillong Planning Area (2023), and of the draft Tura master plan (2024); the "inclusion and exclusion lists of water bodies" that the Expert Committee under the Waterbodies Guidelines circulated to the Deputy Commissioners; the 225 water bodies ground-truthed for the High Court of Meghalaya in 2025 (as reported; the inventory of the Meghalaya State Wetlands Authority was not obtained [TBC]); MePGCL's records of reservoir levels and reservoir land; the spring inventories of MBDA (whose counts conflict, as reported); and each town's drain-and-jhora register (Chapter 6);
- (b) MePGCL and Dorbar Shnong or village council tank registers and records of FTL and MWL;
- (c) the Authority's inventory (Clause 7.3.1) and any list published under court directions;
- (d) historical topographic maps and satellite imagery, including the ISRO National Wetland Inventory and Assessment; and
- (e) a site survey by a licensed surveyor, levelled to the datum stated in Clause 7.3.5.

7.3.4 **Flood extent maps.** The Authority may adopt 1% AEP flood extent or flood depth maps for its area. A depth map adopted under this clause also sets floor levels under Clause 6.11. Where a map has been adopted, it shall be used unless a site hydraulic study under Chapters 3 and 5 shows a larger extent. Where no map has been adopted, the Applicant shall determine the 1% AEP extent by a hydraulic study for:

- (a) any site in a flood-sensitive catchment (Chapter 1);
- (b) any site of 1 ha or more adjoining a waterbody; and
- (c) any site where the Authority so requires.

For other sites, the fixed-width setback of Clause 7.4.6 may be used.

7.3.5 **Datum.** All levels in this chapter shall be stated to one datum, stated on every drawing. Where MePGCL records use a local or older datum, the conversion to the project datum shall be surveyed and stated.

> **Commentary.** Meghalaya has a floodplain Act but no flood line. The Meghalaya Flood Plain Zoning Bill, 2026 (Gazette Extraordinary, Part V, 23 February 2026, No. LB.43/LA/2026/2) was read for this Manual; it defines a "flood zone" as "the area which is required to carry the flow of the maximum probable floods" (s.2(g)), without a return period, and provides for a Flood Zoning Authority to survey rivers and for the State to notify their limits (ss. 3 to 11). The Act is known only from a snippet of the State law site, as "Act No. 4 of 2026 … received the assent of the Governor on the 6th March, 2026" (notification No. LL(B)14/2026/2, as quoted); its gazetted text was not obtained, and no constitution of the Authority, no rules and no notification of any zone were found. For its own purpose this Manual reads "maximum probable floods" as the 1% AEP extent with the climate factor of Clause 2.8; where a zone is notified under the Act, its restrictions prevail. A floodplain zonation of "identified river stretches including Umkhrah River" was awarded to RMSI Private Ltd in June 2021 and reported 80% complete in March 2023 (State action-taken report to the National Green Tribunal, 21 March 2023); it has not been published, and the return period it maps is not known [TBC]. NESAC's risk-informed master plan report for the Shillong

> Planning Area (2023) maps flash-flood susceptibility (very high 1.01% of the area, high 4.67%) and names "Polo Market, Pynthorbah, Nongrim hills, Dhankheti" as "highly potential for flash flood", but it draws no flood line. The rivers are hardly gauged: CWC has seven level-monitoring sites in the State and no forecasting site, none with a warning or danger level, and records highest levels only at a few, such as 73.47 m for the Umngot at Dawki (28 May 2006) and 47.0 m for the Myntdu at Kharkhana (23 April 1995); there is no gauge on the Umkhrah, the Umshyrpi, the Umiam, the Umtru, the Kynshi, the Simsang, the Ganol or the Jinjiram (all as reported by SANDRP; Chapter 5). MePGCL states some reservoir levels in feet and some in metres. No source read for this Manual states the datum of any of these levels. The Bye-Laws 2021 raise stilts above "the Highest Flood Level" (B1(v)(b)) and the KHADC Regulation's drawings show "the highest flood level (HFL) reached above the street", but no highest flood level has been published for any of Shillong's streams, and the Waterbodies Guidelines' reference line, the mean high flood level of the past ten years, is a field quantity that no one has mapped. The best evidence of flood extent in the towns is therefore on the ground: the flood marks at Polo, Pynthorbah and Nongmynsong on the Umkhrah, and those of June 2026 at Dawki. Clause 7.3.4 lets the Authority adopt flood maps once they exist; until then the Applicant must produce the 1% AEP extent for larger and flood-sensitive sites, with the bulking of Clause 6.3.6 on jhoras and streams and the surveyed flood marks of Clause 5.8.5(a) and (c), and a highest flood level stated in a permission or a plan is a minimum that the 1% AEP extent of this Manual, with the climate factor, may exceed but never reduce. Levels shall be stated to one datum (Clause 7.3.5), and reservoir levels converted from feet at 1 ft = 0.3048 m. Clause 7.3.3 makes the larger of the recorded and surveyed extents govern, because the Revenue boundary and the surveyed water edge often differ, and either may have been reduced by encroachment. The 100 m search band in Clause 7.3.2 is set by this Manual.

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## 7.4 Setbacks

7.4.1 **Waterbodies to which setbacks apply.** Setbacks apply to:

- (a) every waterbody recorded under Clause 7.3.1 or found under Clause 7.3.3, whatever its size; and
- (b) every natural channel, whether recorded or not, that drains **8 ha** or more at the site.

7.4.2 **Two zones.** The setback has two zones, shown in Figure 7.1:

- **Zone 1 (waterbody protection zone)**, next to the waterbody; and
- **Zone 2 (flood fringe setback)**, outside Zone 1.

7.4.3 **Zone 1 width.** Zone 1 is measured outward from the FTL contour (tanks, lakes and ponds) or from the top of bank (channels). Where both apply, use whichever gives the wider zone. Zone 1 extends to the **greatest** of:

- (a) **15 m**, the minimum set by this Manual along every natural channel draining 8 ha or more and round every pung, lake, reservoir and spring (wider lines govern under Clause 7.4.5 where they bind: the waterbody setback of the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, as amended, measured from the mean high flood level of the past ten years, is 3 m or 6 m along streams in urban areas, 10 to 30 m along streams in rural areas and 10, 20 or 50 m round lakes and ponds, with a regulated zone four times as wide round lakes and along rural streams; the Guidelines do not reach a seasonal stream whose bed was dry for 240 days or more in each of the past ten years, as most jhoras are, and this Manual's 15 m does; and no flood zone has been notified under the Meghalaya Flood Plain Zoning Act, 2026; see the Disclosure below);
- (b) the outer edge of the floodway (Clause 7.6.1); and
- (c) for a tank, the MWL contour.

7.4.4 **Zone 2 width.** Zone 2 extends from the outer edge of Zone 1 to the **1% AEP flood extent plus 10 m**. Where the 1% AEP flood extent lies inside Zone 1, Zone 2 is 10 m wide.

7.4.5 **Statutory and approval setbacks.** Where a statute, a statutory rule, a condition of planning permission or the waterbody setback or regulated zone of the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, as amended in 2024 and 2026, measured from the mean high flood level of the past ten years, where the Guidelines bind through the Bye-Laws 2021 or as later prescribed; a restriction notified in a flood zone under the Meghalaya Flood Plain Zoning Act, 2026 (none has been notified); the consent of the Water Resources Department for a work on or next to one of its flood works; the consent of MePGCL for a work that drains to, or lies next to, one of its reservoirs or the reach below its dam; the written consent of the Municipal Board for a drain into one of its drains or water-courses (section 204 of the Meghalaya Municipal Act, 1973); a condition of a District Council or its building authority, such as the "Reserved Forest & Conservation Area" along a river edge in the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015; the views or permission of the Meghalaya State Wetlands Authority or the Forest and Environment Department for a work in or next to a notified wetland or forest land; or a direction of the High Court of Meghalaya, the National Green Tribunal or the Supreme Court (the High Court's interim bar on building within 50 m of the high-water mark of a waterbody ended on 19 February 2024; Clause 7.4, Disclosure) sets a setback wider than Zone 1 or Zone 2, the wider setback governs for the uses it restricts.

7.4.6 **Fixed-width setback where no 1% AEP extent is available.** Where Clause 7.3.4 does not require a hydraulic study and no map has been adopted, the setback (Zone 1 plus Zone 2) shall be not less than the following, measured as in Clause 7.4.3:

**Table 7.1 — Fixed-width setback where no 1% AEP extent is available**

| Waterbody | Total setback (Zone 1 + Zone 2) | Of which Zone 1 |
|---|---|---|
| Channel draining 8 ha to 65 ha | 25 m | 15 m |
| Channel draining 65 ha to 20 km² | 40 m | 15 m |
| Channel draining more than 20 km², and rivers | 50 m | 20 m |
| Tank, lake or pond | MWL contour + 25 m | to MWL contour, and not less than 15 m from FTL |
| Marsh, estuary or backwater | as notified by the Authority, and not less than 50 m | 15 m |

This table is the alternative S-3 of the Policy Supplement (Annex 1C) and may be adopted under Clause 1.7.

7.4.7 **Minimum in all cases.** No setback under this chapter, and no variance under Clause 1.10, shall reduce Zone 1 below 15 m (Clause 1.10.3(c)).

> **Commentary.** The 15 m minimum is set by this Manual, as the floor of a hydraulic corridor where no wider line binds. Meghalaya's distances from water are executive guidelines of the Forest and Environment Department, the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023 (No. FOR/CC/29/2019/Pt/688 of 25 August 2023, as amended by No. FOR/CC/29/2019/1140 of 13 February 2024 and No. FOR/CC/29/2019/Pt/771 of 6 July 2026), made on the direction of the High Court of Meghalaya in PIL No. 10 of 2019. They bind in the areas of the Bye-Laws 2021, which have pointed to them since 2024 (B2(ii)(c); Section I(a), cl. 4, and I(f)), and elsewhere only "in such manner as may be prescribed" (para 10(2)); nothing prescribed was found. They measure the setback from "the mean high flood level of a water body observed in the past ten years" (para 2(f)): 3 m along a stream up to 3 m wide in an urban area and 6 m along a wider one, 10 m to 30 m along streams in rural areas, and 10, 20 or 50 m round lakes and ponds. The 15 m floor is five times the 3 m and two and a half times the 6 m of the urban streams, along which the towns' drains run; it also covers the seasonal streams, most of the jhoras, that the Guidelines exclude where the bed was dry for 240 days or more in each of the past ten years (para 2(e)), and the springs, which they do not name. It applies to new development and redevelopment approved under this Manual, not to existing buildings; and where Zone 1 land is community, clan or private, it is secured by agreement with the landholding institution (the Dorbar Shnong, the clan or the owner) or reserved in a master plan, not taken.

It is this Manual's proposal, not a statutory width, and it never reduces a wider line (see the Disclosure below). Extending the setback to the mapped 1% AEP extent plus a margin follows the Kansas City Metro APWA Section 5600 (2025.01) two-zone structure:

- APWA Zone 1 (streamside) is measured from top of bank, and only utility and road crossings are allowed in it.
- APWA Zone 2 is the 1% AEP flood extent plus 10 ft (about 3 m), for streams draining 20–40 acres.
- APWA lowered the trigger for stream setbacks from 40 acres to 20 acres (about 8 ha) in 2025.01.

(MARC, APWA 5600 Policy Supplement, Nov 2025.) Clause 7.4.1(b) adopts the 8 ha trigger. This Manual's 10 m margin is wider than APWA's 10 ft and has no direct precedent. This Manual sets it because Meghalaya flood maps are mostly coarser than US maps, the only level land in a Meghalaya town is usually a valley floor beside a stream, such as the Umkhrah's at Polo and Pynthorbah in Shillong, a river terrace, the margin of a pung, lake or reservoir, or the plains along the Jinjiram at the foot of the Garo hills (so a small error in level moves the flood edge a long way), and the margin gives room for maintenance access along the waterbody.

The fixed-width table in Clause 7.4.6 is set by this Manual. Its channel widths are scaled from the 2006 APWA default stream buffers, which were 40 ft, 60 ft, 100 ft and 120 ft (12, 18, 30 and 37 m) for drainage areas of less than 40 acres, 40–160 acres, 160–5,000 acres and more than 5,000 acres (KC APWA 5600, 2006, §5605.3). They are rounded up and floored at the 15 m minimum. APWA offered a fixed-width table for the same reason: communities objected that the 1% extent is often unmapped for small drainage areas (MARC Supplement, 2025). The table should be replaced by mapped extents as soon as the Authority adopts them.

URDPFI (2015) reserves the area flooded at a 10-year frequency for parks and playgrounds, and allows residential use in the 25-year flood zone only on stilts, with minimum plinth levels and no basements. This chapter is stricter. It keeps habitable buildings out of the whole 1% AEP extent plus margin, because the 1% AEP (100-yr) event is the major-system standard of this Manual (Chapter 6).

Meghalaya's setbacks from water come from executive guidelines, not from its building bye-laws. The Forest and Environment Department first issued the Meghalaya Waterbodies (Preservation and Conservation) Guidelines, 2023 (No. FOR/CC/29/2019/Pt/637 of 18 July 2023), which the High Court found "fall woefully short" and "more of a formality" (order of 19 July 2023); they were superseded by the **Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023** (No. FOR/CC/29/2019/Pt/688 of 25 August 2023; Gazette, Part IIA, 7 September 2023), amended by No. FOR/CC/29/2019/1140 of 13 February 2024 and No. FOR/CC/29/2019/Pt/771 of 6 July 2026 (the amendment of 2024 dates Pt/688 "18th July, 2023"; the gazette and the amendment of 2026 give 25 August 2023, which this Manual uses). Their "waterbody setback" is "an area located in immediate vicinity of the mean high flood level of a water body observed in the past ten years where no new construction of permanent nature" is permitted except the works of para 4, such as fencing "which does not hinder in any manner free flow of rain water", bank stabilisation, intakes, dams, weirs and footpaths (para 2(f)). The setbacks are: round lakes and ponds, 10 m up to 1 ha, 20 m from 1 to 500 ha and 50 m above 500 ha (Appendix 1); along streams outside urban areas, 10 m where the stream is up to 4 m wide and, where it is wider, 10, 20 or 30 m by plot size (Appendix 2A, 2026, which reduced the 15, 25 and 50 m of 2023); along streams in industrial areas, as MSPCB's consent guidelines of 2025 provide (Appendix 2B, 2026); and along streams "within urban areas", **3 m where the stream is up to 3 m wide and 6 m where it is wider** (Appendix 3, as merged in 2024). The merger of 2024 appears to have cut the setback along streams in urban areas outside the municipal and cantonment areas from 5 m and 10 m to 3 m and 6 m (NEER reading; to be confirmed with the Department [TBC]). Round lakes and ponds and along rural streams a regulated zone four times the setback, limited to the waterbody's catchment, caps coverage, FAR, floors and height (para 7(1A), 2024); a septic tank, STP or ETP stands at least 6 m, or half the depth of the plot, from the setback (para 7(3)); and "dense plantation of native species shall be undertaken in the waterbody setback" (para 5). Two exclusions matter for drainage. A "waterbody" does not include "seasonal rivers and streams or parts thereof where the entire bed remained dry for a period not less than 240 days during each of the past ten calendar years", nor ponds and lakes that dry in the same way (para 2(e)), which leaves out most jhoras; and buildings permitted under the Bye-Laws 2021 and works in progress are outside the Guidelines (para 10(3)). The Bye-Laws 2021 first gave 2.40 m from a stream (B2(ii)(c)), replaced in 2024 by a reference to the Guidelines (B2(ii)(c);

Section I(a), cl. 4, and I(f)); they also keep a septic tank and soak pit "as far away as possible from the stream/river" (B1(v)(a)). Outside the Bye-Laws' areas the Guidelines are to be implemented "in such manner as may be prescribed" (para 10(2)), and nothing prescribed was found; in the Khasi Hills the KHADC Regulation, 2015 keeps a river edge in its "Reserved Forest & Conservation Area", where "No development should normally be allowed" (s.2.101), without a width. Three wider figures are not rules. The High Court's order of 24 May 2023 that no construction be allowed "within 50 metres of the high-water mark of the relevant waterbody without the express previous leave of this Court" ended when the PIL was closed on 19 February 2024, after the amendment of 13 February 2024 was taken on record; the Expert Committee's "Restricted zones of 50m + 300m" round the Umiam lake, in its report annexed to the Guidelines, is a recommendation; and NESAC's "buffer as per NGT" along the Umkhrah and the Umshyrpi, 50 m from the Umiam lake and 100 m from protected forests, are recommendations of its master plan report (no order of the National Green Tribunal setting a buffer for Shillong's streams was found). The Guidelines leave gaps for drainage: their line is a ten-year mean flood level that no one has mapped; they give the urban streams, along which the towns' drains run, 3 m or 6 m; they exclude the seasonal jhoras; and they do not name springs. Clause 7.4.7 makes 15 m the floor of Zone 1 everywhere.

**Disclosure.** Meghalaya **has distances from water, but they are executive guidelines, measured from a line no one has mapped, narrow in the towns and silent on the jhoras**: the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, as amended, give **3 m along an urban stream up to 3 m wide and 6 m along a wider one**, 10 to 30 m along rural streams and 10, 20 or 50 m round lakes and ponds, measured from "the mean high flood level of a water body observed in the past ten years"; they exclude seasonal streams whose bed is dry for 240 days a year; they bind through the Bye-Laws 2021 in master-plan, municipal and scheme areas and elsewhere only as may be prescribed; and **no flood zone has been notified** under the Meghalaya Flood Plain Zoning Act, 2026. The **15 m minimum** Zone 1 of Clauses 7.4.3 and 7.4.7, and every value derived from it in Table 7.1, is **set by this Manual** as a hydraulic corridor where nothing wider binds: along every natural channel draining 8 ha or more, whether or not the Guidelines treat it as a waterbody, and round every pung, lake, reservoir and spring. So are the setback zones of Clause 7.4, the 1% AEP extent that governs Zone 2, this Manual's three reference lines and its reading of the boundary of a pung, lake or reservoir, and the rules on jhoras, springs, sacred groves and limestone and mine areas (definitions after Clause 7.2). They are **this Manual's proposal, not a statutory width or rule**, and no government body, District Council or traditional institution has adopted or endorsed them. Along an urban stream the 15 m Zone 1 is **five times the 3 m and two and a half times the 6 m** of the Guidelines. It applies to **new development and redevelopment approved under this Manual, not to existing buildings**; Clause 7.4.7 allows no variance below it; and where Zone 1 land is community, clan or private, it is **secured by agreement with the landholding institution** (the Dorbar Shnong, the clan or the owner) or reserved in a master plan, **not taken**. The setback is applied as **whichever of the three reference lines and its setback reaches furthest** (definitions after Clause 7.2), so the Manual is **stricter than statute** along the towns' streams and jhoras and round springs, and no less strict anywhere. What exists, and governs wherever it is wider or stricter (Clause 7.4.5), is:

- **The Waterbodies Guidelines (No. FOR/CC/29/2019/Pt/688 of 25 August 2023, as amended on 13 February 2024 and 6 July 2026).** 3 m or 6 m along urban streams (Appendix 3 as merged in 2024; whether the merger cut the non-municipal urban setback from 5 m and 10 m is to be confirmed [TBC]); 10 m along rural streams up to 4 m wide and 10, 20 or 30 m by plot size along wider ones (Appendix 2A, 2026); MSPCB's consent guidelines in industrial areas (Appendix 2B, 2026); 10, 20 or 50 m round lakes and ponds (Appendix 1); the regulated zone four times the setback round lakes and along rural streams (para 7(1A)); and the 6 m between a septic tank, STP or ETP and the setback (para 7(3)). The urban setbacks are narrower than Zone 1 and never govern alone; the Applicant states them on Form 7-1. Round the Umiam lake, if its water spread at full reservoir level, about 10.148 km² (as reported), is the basis of its class, the Guidelines give a 50 m setback and a regulated zone of 200 m, wider than this Manual's lines, and they govern (NEER reading [TBC]).
- **The Bye-Laws 2021 and the District Councils' regulations.** In the Bye-Laws' areas, the Guidelines through B2(ii)(c) and Section I(a), cl. 4, and I(f) (2024), with stilts 1.20 m above the Highest Flood Level on sloping sites beside a stream or river and plinths 0.90 m high on flat sites (B1(v)(b)), and no building on land liable to flooding without protection (B1.1(ii)); in the Khasi Hills, the "Reserved Forest & Conservation Area" along

a river edge of the KHADC Regulation, 2015 (s.2.101), and its duty to protect "catchment areas, water sources, spring sheds, streams and rivers" (s.15(1)); the instruments of the Jaintia Hills and Garo Hills District Councils were not found [TBC].

- **The Meghalaya Flood Plain Zoning Act, 2026.** Restrictions in a flood zone notified under the Act prevail over other laws (s.12(2) of the Bill). No zone has been notified; where one is, it governs as a statutory line under Clause 7.4.5.
- **Wetlands.** Any wetland notified under the Wetlands (Conservation and Management) Rules, 2017 (none was found) and the waters the Meghalaya State Wetlands Authority lists (Clause 7.12).
- **Courts, plans and custodians.** The orders of the High Court of Meghalaya, the National Green Tribunal and the Supreme Court as they stand; the lines of the Shillong Master Plan 2041 and other master plans (whose river buffers were not read [TBC]); MePGCL's lines at its reservoirs; the Water Resources Department's at its flood works. The High Court's interim bar on building within 50 m of the high-water mark of a waterbody (24 May 2023) **ended** on 19 February 2024; the Expert Committee's "Restricted zones of 50m + 300m" round the Umiam lake and NESAC's buffers of 50 m from the lake and 100 m from protected forests are **recommendations only**, cited in this Manual as expert guidance, never as binding; and no order of the National Green Tribunal setting a buffer for Shillong's streams was found.

This Manual sets 15 m as the floor because the Guidelines give the urban streams, which carry most of the towns' storm water and sewage, only 3 m or 6 m, from a flood level no one has mapped, and give the seasonal jhoras and the springs nothing; because 15 m is above the smallest APWA default stream buffer (12 m) from which Table 7.1 is scaled; and because a jhora needs room for the boulders, debris and garbage it carries in flood and for the people and machines that clear them. The reasons for the corridor are the record: NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" and that the water "tops the banks along most of the streams", "aggravated by a drastic reduction in channel capacities in most streams due to encroachments along their banks by buildings" (2023); 49,612 m³ of waste was removed from the Wahumkhrah for ₹7.9 crore (State action-taken report, 21 March 2023); and encroachment on the jhoras is reported to make them more vulnerable to flooding (as reported). Until a statute, rule, notification, master plan, District Council regulation or court adopts it, the 15 m minimum is this Manual's recommended standard, and the Guidelines, the bye-laws, the regulations and the orders above remain the only legal minimum. Approving authorities should state in each approval which was applied.

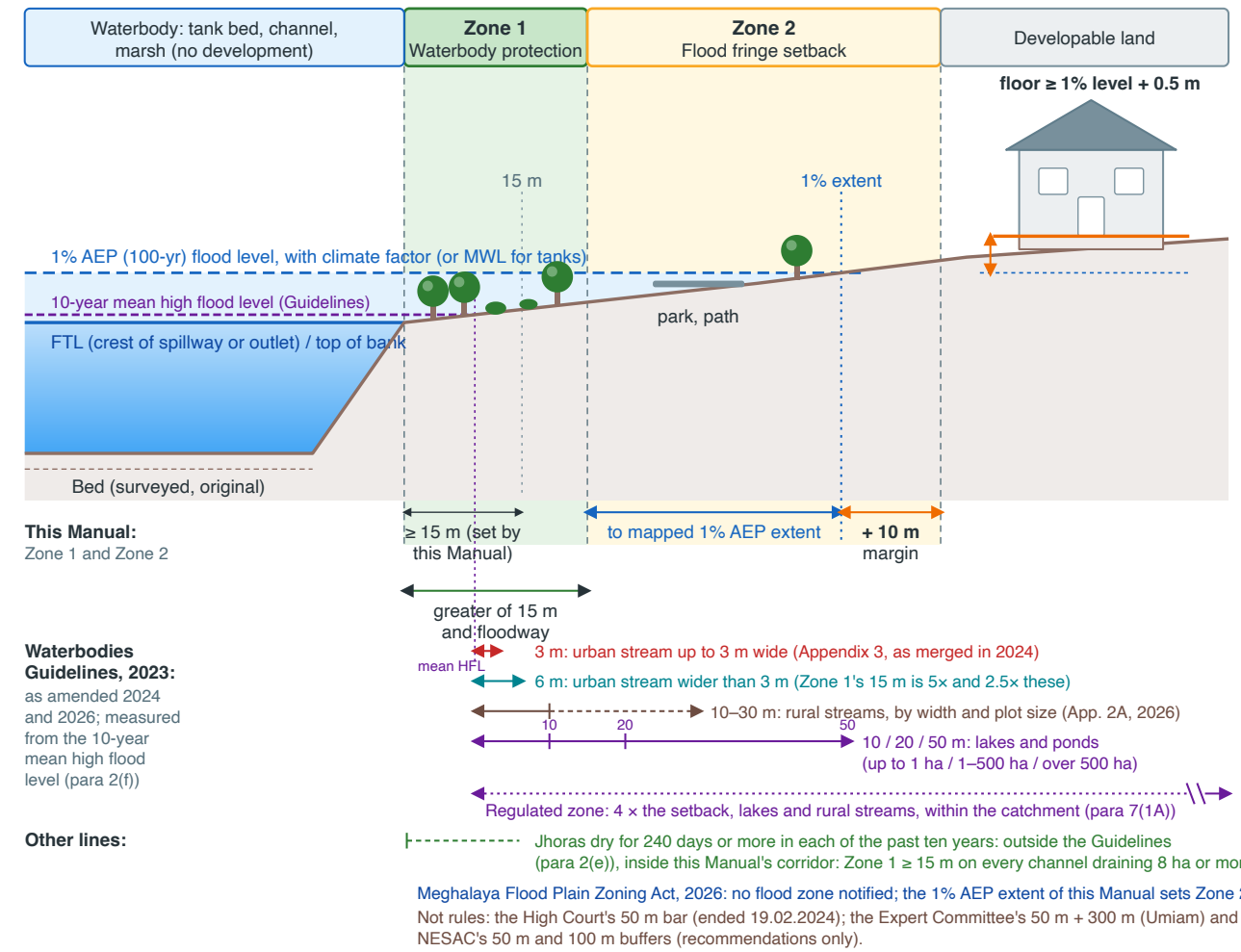


*Figure 7.1 — Waterbody setback zones: section through a tank or channel showing FTL, the 1% AEP flood level, the 15 m minimum line, Zone 1 and Zone 2. Original drawing for this Manual, adapted from Kansas City Metro APWA, Section 5600 Version 2025.01 and Policy Supplement (MARC, 2025).*

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## 7.5 Uses permitted in each zone

7.5.1 **Zone 1.** No building, fill, paving, retaining wall, boundary wall, compound wall, dumping of earth, debris or solid waste, storage of materials, or construction-stage stockpile shall be placed in Zone 1. Only the following are permitted, each subject to the custodian's NOC:

- (a) road, rail and utility crossings that meet Clause 7.10.3;
- (b) flood and drainage works: outfalls, inlet structures, gross pollutant traps, sluices, surplus weirs, bund strengthening and bank protection;
- (c) native vegetation, planting and habitat works;
- (d) unpaved or permeable footpaths and maintenance tracks at existing ground level; and
- (e) waterbody restoration under Clause 7.9.

7.5.2 **Zone 2.** No habitable building, basement, school, hospital, fuel store or hazardous-material store shall be placed in Zone 2. The following are permitted:

- (a) all uses permitted in Zone 1;
- (b) parks, playgrounds, open-air sports fields and urban agriculture;
- (c) open-sided structures (shelters, pavilions) with no walls that obstruct flow;
- (d) surface parking with permeable surfacing at existing ground level, where the 1% AEP flood depth is not more than 0.3 m;
- (e) retention, detention and water quality facilities under Chapters 4 and 8, provided they are outside the floodway and their storage is not counted twice (Clause 7.6.5); and
- (f) fill, only for (a) to (e) or for essential public infrastructure, and only with compensatory storage under Clause 7.6.4.

7.5.3 **Fences.** Fences in Zone 1 and Zone 2 shall be open (chain-link or railing) with no plinth wall above existing ground level, so that they do not obstruct flow or trap debris.

7.5.4 **Open space reservation.** Zone 2 land may be counted toward the open space required by the Meghalaya Building Bye-Laws 2021, where the Authority agrees. Zone 1 land shall be handed over to the custodian or kept free of private use, as the Authority decides.

> Commentary. The permitted uses follow APWA 2025.01: in Zone 1, only utility and road crossings; in Zone 2, linear utilities, trails and open-sided structures; no clearing, grading, fill or paving in either zone without approval (MARC Supplement, 2025). Clause 7.5.2 adds parks and playgrounds, the uses URDPFI (2015) allows in the 10-year flood zone. The ban on walls in Clauses 7.5.1 and 7.5.3 responds to hill-town practice: compound walls along channels and tanks act as dams in floods, and are often the first step toward encroachment. The 0.3 m depth limit for parking in Clause 7.5.2(d) has no direct precedent and is set by this Manual.

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## 7.6 Floodway, flood fringe and compensatory storage

7.6.1 **Floodway delineation.** The floodway shall be delineated by a hydraulic model of the 1% AEP flood (with the climate factor), using the encroachment method: the conveyance of the flood fringe is removed equally from both banks until the 1% AEP water level rises by 0.1 m. Where the floodway has not been delineated, the whole 1% AEP flood extent shall be treated as floodway. For a tank, all land below MWL is floodway.

7.6.2 **No fill in the floodway.** No fill, building, embankment, raised road or other obstruction shall be placed below the 1% AEP flood level within the floodway, except the works permitted in Zone 1 under Clause 7.5.1(a) and (b). Those works shall be shown by hydraulic analysis to raise the 1% AEP water level by no more than 0.01 m, upstream or downstream, outside the Applicant's land.

7.6.3 **Fill in the flood fringe.** Fill below the 1% AEP flood level in the flood fringe is permitted only:

- (a) for uses permitted under Clause 7.5.2, or outside the setback where the Authority has notified a developed-fringe area under Clause 7.6.6; and
- (b) with compensatory storage under Clause 7.6.4.

7.6.4 **Compensatory storage.** Where fill is placed in the flood fringe, compensatory storage shall be provided that (Figure 7.2):

- (a) replaces at least **1.0 m³ of storage for each 1.0 m³ of fill** placed below the 1% AEP flood level;
- (b) is provided at **equivalent levels**: the volume lost and the volume replaced shall be balanced in each elevation band of not more than **0.3 m**, from the normal water level (or the 50% AEP level, where higher) up to the 1% AEP flood level;

- (c) is in the same reach of the same waterbody, hydraulically connected to it, and not further downstream than the fill;
- (d) drains freely by gravity back to the waterbody as the flood recedes, with no pumping and no permanent pool below the normal water level;
- (e) is built before, or at the same time as, the fill is placed; and
- (f) is secured by a covenant or handover so that it is never filled later.

7.6.5 **No double counting.** Compensatory storage shall not be counted as detention or retention storage under Chapter 4. Detention and retention storage placed within the 1% AEP flood extent shall be counted only for the volume above the 1% AEP flood level, unless a model of the joint event (Clause 2.12) shows that it is available.

7.6.6 **Developed-fringe areas.** The Authority may notify, by map, areas of existing built-up land within the 1% AEP flood extent but outside the floodway, where it is impractical to apply Zone 2 to redevelopment. In a notified developed-fringe area:

- (a) redevelopment may be approved without the Zone 2 restriction;
- (b) the lowest habitable floor and all openings shall be at least 0.5 m above the 1% AEP flood level (Chapter 6);
- (c) basements are not permitted;
- (d) the redevelopment shall cause no net loss of flood storage below the 1% AEP flood level (Clause 7.6.4), and stilt construction may be used for this; and
- (e) Zone 1 continues to apply in full.

> **Commentary.** The 1:1 compensatory storage at equivalent levels is set by this Manual. A simple volume balance is not enough: storage excavated below the normal water level is full before the flood arrives and gives no flood benefit. Storage gained high up does not replace storage lost low down, because the low storage is used in every flood and the high storage only in the largest. Balancing volume within each elevation band avoids both problems. The 0.3 m band, the 0.01 m allowance for crossings, and the use of the encroachment method in Clause 7.6.1 are set by this Manual; the encroachment method is the standard way to delineate a floodway in a one-dimensional hydraulic model. The 0.1 m limit on the rise in the 1% AEP water level is tighter than the 1 ft (about 0.3 m) used by the US National Flood Insurance Program. The valley floors of Shillong along the Umkhrah and the Umshyrpi, the margins of the Umiam lake and of the pungs, and the Jinjiram plains at the foot of the Garo hills are flat, so a small rise in level spreads flooding over a wide area, and many small encroachments along the same channel add up.
>
> In Meghalaya the Guidelines measure a setback from "the mean high flood level of a water body observed in the past ten years", but that level has not been mapped for any pung, lake or reservoir, so the line from which a setback is measured must come from this Manual. The difference matters most at the reservoirs, whose levels move through the year: MePGCL operates its reservoirs between a minimum drawdown level and a maximum level, with frequent releases in and out of the season (Kyrdemkulai between 2,215 ft and 2,235 ft, Myntdu–Leshka between 606.15 m and 618.00 m; MePGCL), and the Umiam reservoir, whose full level is known only from the press, is reported to have lost more than a tenth of its gross capacity to sediment between 1965 and 2004 (as reported), so a line drawn from the edge of the water in the dry months would leave the reservoir's own bed open to building, and one drawn from today's edge would give up its lost area for good. This Manual gives every pung, lake and reservoir a boundary measured from a high level, not from the water's edge on the day of survey: the edge of a pung in the season and the operator's highest level of a reservoir are part of its boundary (definitions after Clause 7.2), and the foreshore up to MWL is its flood storage. Treating all land below MWL as floodway (Clause 7.6.1) means that no new building or fill is approved in a tank foreshore.
>
> The developed-fringe mechanism of Clause 7.6.6 is set by this Manual. Large parts of the valley floors of Shillong along the Umkhrah and the Umshyrpi, where Polo, Pynthorbah, Nongmynsong, Forest Colony, Mawlai, Dhankheti and Nongrim Hills flood "with nearly every heavy downpour" when the Wah Umkhrah overflows (as reported) and where NESAC found that "the water tops the banks along most of the streams", and of the Garo plains along the Jinjiram, where the floods of September 2014 submerged over 200 villages (as reported) already lie within the 1%

AEP extent. A blanket Zone 2 ban on redevelopment there would stop the replacement of older, lower buildings with buildings raised above flood level. The mechanism follows the URDPFI (2015) approach for the 25-year flood zone (stilts, minimum plinth, no basements), applied here to the 1% AEP extent.

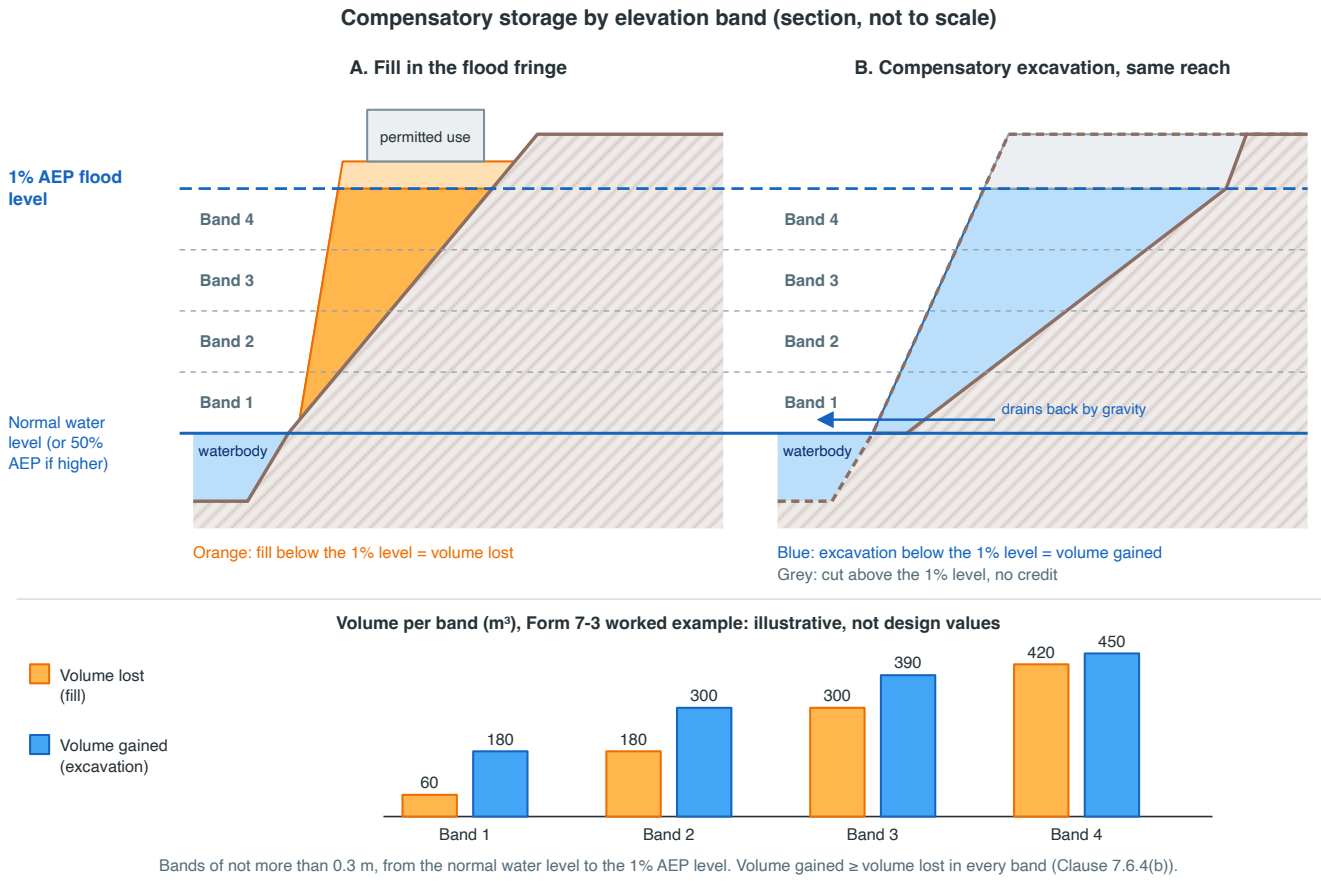


*Figure 7.2 — Compensatory storage by elevation band: section through the flood fringe showing fill placed below the 1% AEP flood level and an equal or greater volume excavated within each band of not more than 0.3 m, from the normal water level (or 50% AEP level) up to the 1% AEP level, with the excavation draining back to the waterbody by gravity. Band-by-band calculation on Form 7-3. Original drawing for this Manual, illustrating the method of Clause 7.6.4, which is set by this Manual.*

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## 7.7 Tank cascades as design storage

Meghalaya has no tank Act and no irrigation tank cascades, and its standing waters range from village pungs a few metres across to the Umiam reservoir. The storages that matter for urban drainage are of four kinds. The first is the reservoirs of MePGCL, the State's largest waterbodies: the Umiam (Barapani) reservoir, impounded in 1965 for Umiam Stage I, with a water spread of about 10.148 km² at full reservoir level, a catchment given as 221.5 km² (also about 220 and 225 km², and 547 km² for the whole river at the dam: the figures conflict), and a gross capacity reported to have fallen from 179.757 Mm³ in 1965 to 167.069 in 1990 and 159.206 in 2004 (all as reported), for which no MePGCL guideline and no level other than the press's 3,220 ft were found [TBC]; and, downstream, Kyrdemkulai (Stage III; full reservoir level 2,230 ft, about 679.7 m), Nongkhyllem (Stage IV; 503.00 m), New Umtru (full reservoir level 130.10 m, maximum 132.78 m, 3.55 MCM) and Myntdu–Leshka (618.00 m) (MePGCL gate-operation guidelines; feet converted at 0.3048 m). Their releases enter a design as inflow and tailwater (Clauses 5.8.3 and 5.8.5(d)), and they are not tanks for these clauses unless their storage is counted. The Kopili project shared with Assam is held by NEEPCO, and its levels were not obtained [TBC]. The second is the small lakes and pungs of the towns and villages: Ward's Lake (Nan Polok) in

Shillong, built about 1894 (as reported; who designed it is disputed), and Thadlaskein (Pung Sajar Nangli) beside the national highway near Mukhla, revered by the people of Raid Mukhla and the Niamtre community (as reported); no levels, areas or outlet records were found for either [TBC], so their storage is modelled as an existing feature and not counted unless Clause 7.7.1 is met. The third is the village pungs, which are modelled as existing features where they intercept runoff but are never counted as storage, because they are not surveyed, have no controlled outlet and are full by the time of the peak storm. The fourth is the springs, which are protected for their water and never counted as storage. These are the waterbodies for which Figure 7.3 and Clause 7.8 matter: in a plateau town every drain ends in a jhora and every jhora in a stream that runs to a reservoir or a river. Any pung, lake or reservoir whose storage is to be counted is subject to Clause 7.7.1 in full, with MePGCL or the other custodian, and the custodian of each pung and lake shall be confirmed for the inventory (Annex 7A) [TBC].

7.7.1 **When tank storage may be counted.** The storage of a tank or tank cascade may be counted as design storage (in a basin plan, a regional facility or a fee-in-lieu scheme under Clause 7.11) **only** where all of the following are met:

- (a) **Surveyed levels.** FTL, MWL, TBL, the surplus weir crest and length, and the sluice sill levels have been surveyed to the datum of Clause 7.3.5 within the previous 5 years.
- (b) **Stage–storage curve.** A stage–storage curve has been derived from a bathymetric and topographic survey of the waterspread and foreshore within the previous 5 years, or after the last desilting, whichever is later.
- (c) **Operating rule.** A documented operating rule has been agreed with the custodian (Clause 7.8).
- (d) **Maintained structures.** The surplus weir, sluices and bund are maintained under an O&M plan (Chapter 10), and the latest pre-monsoon inspection found them serviceable.
- (e) **Custodian concurrence.** MePGCL, or the other custodian, concurs in writing.

Storage in a tank that fails any of (a) to (e) shall not be counted, though the tank shall still be modelled as an existing feature (Chapter 3).

7.7.2 **Modelling.** Tank cascades shall be modelled under Clause 3.12.5 (level-pool routing of each tank, with surplus weir and sluice ratings) and Clause 3.13 (continuous simulation). The whole cascade, from the uppermost tank whose surplus can reach the site or facility to the next river, major drain or sea outfall, shall be modelled together, including, for a plateau town, every jhora that falls from the ridge and its slopes to the stream (wah) below, any pung with its inlets and outlet, the springs above the town's intakes, and the stream itself down to the reservoir or river whose level sets the tailwater of the jhoras (Clause 5.8.5), as shown in Figure 7.3.

7.7.3 **Starting level.** The starting level in every tank shall be **FTL** for the design-storm analysis. A lower starting level may be used only under a flood-cushion operating rule that meets Clause 7.8.

7.7.4 **Design maximum level.** For the 1% AEP inflow with the climate factor, routed through the cascade:

- (a) the computed maximum level shall be not higher than MWL (as defined in Clause 7.2); and
- (b) the freeboard from the computed maximum level to the lowest point of the bund (TBL) shall be not less than MePGCL's freeboard standard for the tank.

Where (a) or (b) fails, the tank storage above FTL shall not be counted until the surplus weir capacity is increased or the bund raised under Clause 7.7.6.

7.7.5 **Creditable volume.** The creditable design storage of a tank is the volume between the starting level (Clause 7.7.3) and the computed maximum level of Clause 7.7.4, less any volume already committed to another facility or scheme.

7.7.6 **Changes to FTL, weirs and bunds.** No surplus weir crest shall be raised or lowered, no shutters or falling boards shall be added, and no bund shall be raised, cut or breached except under a design approved by the custodian that:

- (a) routes the cascade under Clause 7.7.2;
- (b) shows the effect on flood levels in the foreshore and upstream, and on flows in the surplus course and downstream; and
- (c) checks the bund under Clause 7.14.

Commentary. This Manual allows tank cascades to be used as design storage subject to three basic conditions (surveyed FTL, a documented operating rule and maintained surplus weirs). Clause 7.7.1 adds the stage–storage survey and the custodian's concurrence, because the storage a tank actually offers depends on its silt level and on who controls the sluices. The 5-year survey interval is set by this Manual.

The FTL starting level follows Clause 3.12.5. Meghalaya's reservoirs are small for the floods they pass, and they are drawn on through the season. MePGCL's guidelines for Stage III, Stage IV and New Umtru say that "the Reservoir capacity is very small", with "frequent release of water through the Gates during Monsoon as well as during Non-monsoon period"; Myntdu–Leshka's spillway is built for 12,000 cumec from a catchment of 350 km², and its guideline records "very high discharge of about 10440 cumecs during high rainfall" (MePGCL). In August 2024 releases from the Umiam reservoir began at 3,216.15 ft on an IMD warning, close to its reported full level of 3,220 ft (as reported). The Manual's season begins on 1 April because the escarpment's largest falls come before the south-west monsoon as well as during it (Cherrapunji: 644.2 mm in 24 hours on 16 April 1990 and 812.0 mm on 25 May 1916, IMD), and storms follow its withdrawal (594.0 mm at Cherrapunji on 11 October 1975, and 262.0 mm at Shillong on 8 October 2004, IMD), so a reservoir or pung may be full at any time from April to October. No record of how long Ward's Lake, Thadlaskein or any village pung stays at or above its outlet level in a wet spell was found. While a pung or reservoir is full, it stores nothing more below FTL, the streams and jhoras that flow into it discharge against its level, and its release adds to the flow in the stream below it. A tank cascade passes floods from one tank to the next, so a design that counts storage in one tank and ignores the surplus arriving from the tank above it will overstate the benefit. That is why Clause 7.7.2 requires the whole cascade to be modelled.

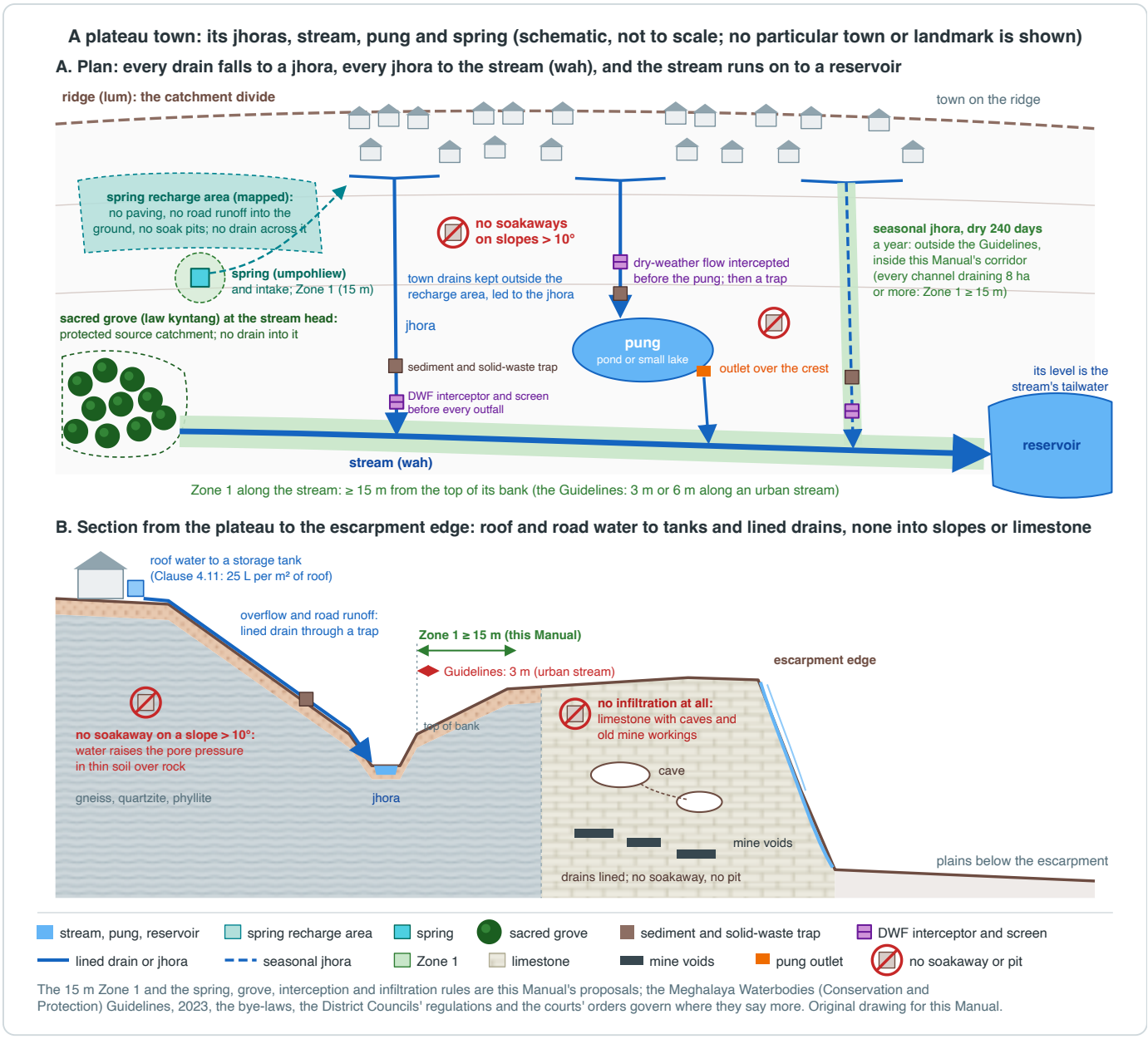


*Figure 7.3 — A plateau town: its jhoras, stream, pung and spring (schematic, not to scale; no particular town, lake, grove or landmark is shown). A: in plan, the town stands on a ridge, the catchment divide, and on the slopes below it, so every drain of the town ends in a jhora and every jhora in the stream (wah) in the valley, which runs on to a reservoir whose level is the stream's tailwater (Clause 5.8.5(d)). The drains are lined where they pass through the built-up area, and each jhora passes a sediment trap and a solid-waste trap before it reaches the stream, because a hill drain carries more silt, gravel and garbage than any other load (Clauses 6.3.6 and 8.12). At the head of the stream a sacred grove (law kyntang) is kept as a protected source catchment, into which no drain discharges. Upslope of the town's intake a spring (umpohliew) comes out; its recharge area, as a hydrogeologist maps it, is kept free of paving, road runoff and soak pits, and no drain crosses it or buries its outlet (Clause 8.8.1). A pung in the valley receives the jhoras only through traps, and the outfalls that reach it and the stream carry a dry-weather-flow interceptor and screen, because the drains carry sewage (Clause 8.9). Zone 1 along the stream is at least 15 m from the top of its bank, five times the Guidelines' 3 m along an urban stream up to 3 m wide; a jhora that is dry for 240 days a year is outside the Guidelines but inside this Manual's corridor. B: in section, from the plateau to the escarpment edge, roof water goes to a storage tank (Clause 4.11) and its overflow and the road runoff go by a lined drain through a trap to the jhora, because no soakaway is placed on a slope steeper than 10°; and where the plateau falls to the plains over limestone with caves and old mine workings, no water is put into the ground at all (Clause 4.11, karst and mine rule). The 15 m minimum, the spring, grove,*

*interception and infiltration rules are this Manual's proposals; the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, the bye-laws, the District Councils' regulations and the courts' orders govern where they say more. Original drawing for this Manual.*

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## 7.8 Operating rules and pre-monsoon flood cushion

7.8.1 **Operating rule content.** Every tank whose storage is counted under Clause 7.7 shall have a written operating rule, agreed by the custodian and kept with the O&M plan (Chapter 10). It shall state:

- (a) the levels and dates for filling, holding and drawdown through the year;
- (b) the sluice and regulator settings at each level;
- (c) who operates the sluices and regulators, and who may order a release;
- (d) the maximum release rate, set so that the release, added to the flow from the downstream catchment, does not cause flooding of buildings downstream;
- (e) the forecast and warning triggers (IMD district warnings, MSDMA alerts, and city forecast systems where available) and the actions taken at each trigger;
- (f) communication with downstream ULBs and residents before any release; and
- (g) the records to be kept: daily levels in the monsoon, releases, and gate settings.

7.8.2 **Flood cushion.** A tank may be operated with a flood cushion (a level below FTL during part of the monsoon), and the cushion counted under Clause 7.7.3, only where:

- (a) the tank has a gated sluice, regulator or other controllable outlet able to draw the tank down to the cushion level in the time stated in the rule;
- (b) the operating rule fixes the cushion level and the dates it applies;
- (c) continuous simulation (Clause 3.13) shows that the cushion is available at the start of a design storm in at least **90%** of monsoon seasons in the record, allowing for the rain that usually comes before the peak storm;
- (d) the custodian accepts any loss of irrigation or water-supply yield, and any agreed compensation is recorded; and
- (e) the release needed to create or restore the cushion meets Clause 7.8.1(d).

7.8.3 **No storage credit without control.** Where a tank has no controllable outlet, no flood cushion shall be assumed, whatever the past practice.

7.8.4 **Coordination.** For tanks under MePGCL control, the operating rule shall be MePGCL's rule. This Manual does not authorise any other body to operate a MePGCL tank.

> **Commentary.** No pung or lake in Meghalaya was found with a written operating rule, and most pungs have no gates to operate. MePGCL's guidelines for its Stage III, Stage IV, New Umtru and Myntdu–Leshka reservoirs set their levels and gate operations, and say that "issuing the notification for release of water is not practicable; however warnings in the form of blowing the Siren, Telephone/SMS may be issued"; no guideline for Umiam Stage I was found, and its full level is known only from the press. Without an agreed rule with dates, levels, release rates and a named operator, storage in a pung or reservoir cannot be relied on, and a release made without warning to the towns and villages downstream is itself a flood. Clause 7.8.2 turns that principle into a rule that can be checked, with a reliability test, because a cushion that is refilled by the April and May storms gives no protection when a June monsoon storm against the plateau and the southern escarpment, such as those of 16 June 1995 and 15–17 June 2022, arrives after weeks of rain. The 90% reliability in Clause 7.8.2(c) has no direct precedent and is set by this Manual.
>
> For a natural pung, Clause 7.8.3 is the governing condition: with no controllable outlet, no cushion is assumed, a design that relies on the pung routes the storm through it from its outlet level, and the outflow over the outlet is limited by the jhora or stream below it, which shall be shown to carry it with the debris of Clause 6.3.6. For a

reservoir, a design takes the operator's level and release for the storm being checked (Clause 5.8.3), not a drawdown the operator has not agreed to in writing. Many pungs and lakes are sacred or communal, and they belong to the Dorbar Shnong, a clan or another custodian rather than to the State, which is why Clause 7.8.2(d) requires the custodian to accept any drawdown, and why no detention pond built under this Manual is called a pung.

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## 7.9 Restoration, desilting and deepening

7.9.1 **Pre-works survey.** Before any desilting or restoration, the proponent shall:

- (a) survey the waterspread, foreshore, bund, weirs and sluices (Clause 7.7.1(a) and (b));
- (b) find the original bed level by test pits or augering on a grid, and from historical records where available; and
- (c) where the tank receives urban runoff or sewage, test the silt for heavy metals and other contaminants before disposal is planned.

7.9.2 **Desilting limit.** Desilting shall remove accumulated sediment down to the original bed level. It shall not deepen the tank below the original bed, except under Clause 7.9.3.

7.9.3 **Deepening.** Deepening below the original bed is permitted only where a hydrogeological report shows that:

- (a) it will not cut through a clay or silt layer that holds water in the tank or protects an aquifer from polluted water;
- (b) in coastal areas, it will not draw saline water into the tank or the aquifer; and
- (c) the extra storage will be refilled and used, and will not stand stagnant below the sluice sill.

Storage created below the lowest sluice sill shall not be counted as flood storage.

7.9.4 **Safe edges.** Where the public has access to the waterbody edge:

- (a) side slopes shall be no steeper than **1V:4H** from 0.5 m above FTL down to 1.2 m below FTL, or a level safety bench at least 3 m wide shall be provided between 0.3 m and 0.5 m below FTL; and
- (b) no isolated deep pit or vertical cut shall be left in the bed.

7.9.5 **Storage not to be reduced.** Restoration shall not reduce the storage below MWL. Islands, walkways, bund widening into the waterspread, ring roads, parking, buildings and "lake-front" platforms within the waterspread or foreshore shall be counted as lost storage and shall be offset under Clause 7.6.4.

7.9.6 **Silt disposal.** Desilted material shall not be placed within the setback, on the bund (except for approved bund strengthening), or on any flood path. Silt found to be contaminated shall be disposed of as the Meghalaya State Pollution Control Board (MSPCB) directs.

7.9.7 **Inlet treatment.** Every restoration of a tank that receives urban runoff shall include sediment and gross pollutant control at each inlet: a sediment forebay, a constructed wetland inlet zone, or a gross pollutant trap (Chapter 8), so that the restored storage does not silt up again.

7.9.8 **Timing.** Desilting shall be completed, and the waterbody made safe, by **31 March** each year (Chapter 10).

Commentary. No statewide order fixing a date for the pre-monsoon cleaning of drains, jhoras or pungs was found; the IRADe/NMHS plan for Shillong recommends "Desilting to avoid flooding during monsoons" by PWD and the Shillong Municipal Board, without a date. In the plateau towns the material to be removed is garbage and slide debris as much as silt: 49,612 m³ of waste was removed from the Wahumkhrah for ₹7.9 crore under the Fifteenth Finance Commission, and stone bunds and solid-waste traps were built for ₹3.60 crore (State action-taken report to the National Green Tribunal, 21 March 2023); and the Umiam reservoir is reported to have received 20.551 Mm³

of sediment between 1965 and 2004 (as reported). The date of 31 March in this Manual is set by this Manual, before the Manual's season begins on 1 April, because the escarpment's largest falls come in April and May as well as later (Cherrapunji: 644.2 mm in 24 hours on 16 April 1990 and 812.0 mm on 25 May 1916, IMD) and CWC's highest levels on the Myntdu and the Umngot were set in April and May (as reported); because storms also follow the season, the jhoras, racks and sediment traps are cleared again by 31 May, before the south-west monsoon arrives, and after it by 15 November (Chapter 10). Excavation to "increase capacity" is governed by Clause 7.9.3. In a pung fed by springs in its bed, deepening can cut the springs off or break the silt and clay that hold the water; on limestone it can open the bed to caves and voids. This Manual allows no spring-fed pung to be deepened below its original bed or its bed to be lined or cemented, and no pung or pond on limestone or in a mining area to be deepened at all. The 31 March deadline matches the pre-monsoon inspection date of Chapter 10. The limits on deepening are set by this Manual. Deepening tanks to "increase capacity" is common, but it can breach the silt and clay layer that holds water in the tank, it can let polluted urban water reach the aquifer, it can draw salt water toward the coast, and it creates storage below the sluice sill that never empties and gives no flood benefit. Deep pits with steep sides are also a drowning hazard. The slope and bench values in Clause 7.9.4 are adapted from common pond-safety practice; they have no Meghalaya precedent.

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## 7.10 Supply channels, surplus courses, inlets and outlets

7.10.1 **Part of the major system.** Supply channels and surplus courses are part of the major drainage system (Chapter 6). They shall be protected as waterbodies, with Zone 1 and Zone 2 setbacks under Clause 7.4.

7.10.2 **No closure or covering.** No supply channel or surplus course shall be closed, filled, diverted, covered, culverted along its length, or converted into a road or a closed drain, except under a design approved by the custodian that keeps or increases its 1% AEP capacity and its access for maintenance.

7.10.3 **Crossings.** Every road, rail, utility or access crossing of a waterbody, supply channel or surplus course shall:

- (a) pass the 1% AEP flow (with the climate factor), or the surplus of the upstream tank at its MWL, whichever is greater, with the freeboard required by Chapter 9;
- (b) not reduce the waterway width at the crossing below the full channel width as recorded in Revenue records or as surveyed, whichever is greater;
- (c) keep the channel bed level and grade; and
- (d) not raise the 1% AEP water level by more than the limit in Clause 7.6.2.

7.10.4 **Capacity.** The design capacity of a surplus course shall be the greater of the surplus weir discharge at MWL and the 1% AEP flow from its own catchment, combined as the cascade model (Clause 7.7.2) shows.

7.10.5 **Protection at structures.** Outlets of surplus weirs and sluices, and drain outfalls into waterbodies, shall have energy dissipation and scour protection designed under Chapter 9, so that the flow leaving them does not erode the bund, the bank or the channel bed.

7.10.6 **Drain outfalls into waterbodies.** A storm drain outfall into a tank, channel or wetland shall:

- (a) have its invert at or above the normal water level of the receiving waterbody, unless the drain is designed for submerged outfall under Chapter 5;
- (b) be located and aligned so that it does not cut through or weaken a tank bund;
- (c) have a gross pollutant trap and first-flush treatment (Chapter 8); and
- (d) not carry sewage or dry-weather flow (Chapter 8).

Commentary. This Manual protects supply channels and surplus courses as part of the major system. In urban areas they are often the first to be lost. Surplus courses are narrowed by culverts and compound walls, and supply channels are covered and turned into roads, which cuts the tank off from its source or leaves its surplus with nowhere to go. In Meghalaya the drains, public streams, springs and tanks within municipal limits vest in the Municipal Board (Meghalaya Municipal Act, 1973, s.62), which may require an owner "to improve bad drainage" (s.190), consents to any drain into its drains or water-courses (s.204) and may require land within 100 ft of a drain to be drained (s.206); outside municipal limits the village drains and jhoras are the concern of the District Council and the Dorbar Shnong under the District Council's rules, the roads' drains are PWD's or, on the national highways, NHAI's and NHIDCL's, and the rivers and flood works are the Water Resources Department's. Only part of the Umkhrah and the Umshyrpi lies within the Shillong Municipal Board's area; the rest is under the KHADC (State action-taken report, 21 March 2023). No rule or order dividing streams and jhoras from municipal drains was found; Chapter 6 gives this Manual's working split and each town's drain-and-jhora register. The record of Shillong shows a network that is partial and has become the streams themselves: the city's drains "run for 148.91 km and drain directly into the Umkhrah and Umshyrpi rivers", and storm-water drainage covers "less than 75% of the city" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan, whose own service-level table gives 85%: the figures conflict); NESAC found that the rivers' "tributaries are no more than drain now", and that the water "tops the banks along most of the streams … aggravated by a drastic reduction in channel capacities in most streams due to encroachments along their banks by buildings" (2023); and encroachment on the jhoras is reported to make them more vulnerable to flooding (as reported). The response has been to clean and confine the rivers: waste removal, stone bunds and solid-waste traps on the Wahumkhrah (Clause 7.9, Commentary), and a project report of the Water Resources Department for embankments and channel improvement on the Wahumkhrah and the Umshyrpi, resubmitted after the Brahmaputra Board returned the first (as reported). The Guidelines give an urban stream 3 m or 6 m from a ten-year mean flood level and exclude the seasonal jhoras; the Municipal Act's fines are ₹50 and ₹25 (ss. 204 and 205); neither keeps a stream or jhora at its recorded width once it has been lined, piped, covered, built over or filled with garbage, which is the failure Clauses 7.10.2 and 7.10.3 are written to prevent. Clause 7.10.3(b) prevents a crossing from narrowing a channel to its current, encroached width.

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## 7.11 Fee-in-lieu and regional tank storage

7.11.1 Where a basin plan has been notified, and the Authority has adopted alternative S-5 of the Policy Supplement (Clause 1.7), a development may pay a fee in lieu of on-site detention under Chapter 4. The fee shall be applied to restoring or creating storage in a tank, pond or regional facility in the same basin.

7.11.2 Tank storage funded by fee-in-lieu shall:

- (a) meet Clause 7.7.1 in full before it is counted;
- (b) be downstream of the contributing development and upstream of the flood-prone area it is meant to protect;
- (c) be created, or under construction, before the development it serves is occupied, or within a period the basin plan fixes; and
- (d) be recorded in the register of Clause 10.17 with the developments that funded it, so that the same volume is not sold twice.

7.11.3 Fee-in-lieu does not replace:

- (a) the retention requirement of Chapter 4, which is always met on site; or
- (b) the water quality requirement of Chapter 8, which is met on site or in a regional facility treating the same runoff before it reaches the tank.

> Commentary. Chapter 4 provides for fee-in-lieu toward restored pung or tank storage in master-planned basins. Malaysia's 2008 DID checklist allowed on-site detention only for small sites and required community ponds for larger areas (DID, 2008). In Meghalaya no shared form of storage is required by the building rules: Table G1 of the Bye-Laws 2021 requires rainwater harvesting on every plot but sets no volume, the soft cover of 10% or 20% of the plot is a landscape rule, and neither the Bye-Laws nor the KHADC Regulation, 2015 has a detention, peak-flow or design-storm rule (Chapter 4). The plans for Shillong's streams are for cleaning and conveyance, not storage: NESAC's master plan report proposes decentralised wastewater treatment, the Water Resources Department's project report for the Wahumkhrah and the Umshyrpi is for embankments and channel improvement (as reported), and the Smart City works include rainwater harvesting at 52 locations (State action-taken report, 2023). In the plateau towns there is little flat land on which a regional pond could be built, and none may be built on a slope where Clause 4.11 bars infiltration or on limestone or mine land; a regional facility there is a lined tank or a lined detention structure, not a pond, and it is never called a pung. None of these sets a technical standard for counting storage. Clause 7.11.2(b) matters because a tank downstream of the flood-prone area protects nothing. Clause 7.11.3 keeps retention on site: it is the volume-control layer of this Manual, and a regional tank cannot recharge the aquifer under the developed site.

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## 7.12 Wetlands, marshes and estuaries

7.12.1 **Scope.** This clause applies to marshes, swamps, backwaters, estuaries, and tidal creeks and lagoons, including:

- (a) wetlands notified under the Wetlands (Conservation and Management) Rules, 2017 or listed by the Meghalaya State Wetlands Authority;
- (b) any wetland notified under the 2017 Rules, to its notified boundary (Meghalaya has no Ramsar site, and none was found notified);
- (c) the Umiam (Barapani) reservoir and MePGCL's other reservoirs, with their drawdown zones; Ward's Lake (Nan Polok), Thadlaskein (Pung Sajar Nangli) and the other pungs and small lakes; the bogs and seepage ground of springs; the marshes (chibol) and waterlogged ground of the Garo plains along the Jinjiram; and the 225 water bodies ground-truthed for the High Court of Meghalaya in 2025 (as reported), within the 1% AEP extent of Clause 7.3.4 (a river, stream or reservoir itself is a waterbody under the rest of this chapter); and
- (d) any other pung, marsh or wetland that the Authority notifies, that the wetland authority lists, or that the High Court of Meghalaya, the National Green Tribunal or the Supreme Court directs to be protected.

7.12.2 **No drainage of wetlands.** No drain, channel, cut or pump shall be designed to drain a wetland, to lower its normal water level, or to reduce the period for which it is wet, except under a plan approved by the wetland authority.

7.12.3 **Inflows.** Every drain discharging into a wetland in Clause 7.12.1 shall:

- (a) meet Clause 7.10.6;
- (b) pass through water quality treatment for the WQv of its catchment (Chapter 8) before entering the wetland; and
- (c) where practicable, spread its flow across a vegetated margin rather than discharge at one point.

7.12.4 **Hydraulic connectivity.** Roads, embankments and utility corridors across or along a wetland shall have openings that:

- (a) pass the 1% AEP flow without raising the 1% AEP water level by more than the limit in Clause 7.6.2; and
- (b) keep the wetland's normal water exchange, including tidal exchange in estuaries, with openings spread along the crossing so that no part of the wetland is cut off.

7.12.5 **Storage counted at basin scale only.** Wetland storage shall be included in basin and regional models. It shall not be counted as detention for any individual development.

7.12.6 **Tidal wetlands and estuaries.** For estuaries and tidal wetlands:

- (a) tailwater shall be taken from Chapter 5 (Clause 2.12 joint cases);
- (b) works shall also comply with the Coastal Regulation Zone Notification in force; and
- (c) mouth-opening works, training walls and dredging are outside the scope of this Manual and need their own studies.

7.12.7 **No dumping.** No solid waste, construction debris or dredged material shall be placed in a wetland or its setback.

> Commentary. Meghalaya's wetlands are the concern of the **Meghalaya State Wetlands Authority**, constituted under rule 5(1) of the Wetlands (Conservation and Management) Rules, 2017 by notification No. ENV.1/2007/Pt/110 of 1 November 2017 (Gazette, 16 November 2017), chaired by the Minister in charge of Forests and Environment, with the Chief Secretary as Vice-Chair, the Secretaries of Urban Affairs, Water Resources and Revenue and Disaster Management and the Director of NESAC among its members, an expert in hydrology among its non-official members, and the Principal Chief Conservator of Forests and Head of Forest Force as Member Secretary. Officers who may take cognizance of offences under rule 4 of the Rules were notified on 15 September 2023 (No. ENV.I/2007/Pt-II/102). The State has **no Ramsar site**, and no wetland notified under rule 4 was found. In 2025, in a suo motu PIL, the State conceded that "an exhaustive survey of all waterbodies and wetlands had not yet been undertaken"; the High Court then accepted a report that 225 water bodies had been ground-truthed (66 lakes and ponds, 1 oxbow, 6 riverine wetlands, 18 waterlogged areas, 100 rivers and streams, 9 reservoirs and barrages and 25 tanks and ponds) and that "none of the above wetlands qualify as a Ramsar site", and disposed of the PIL on 29 April 2025 (all as reported; the PIL's number and the list were not obtained [TBC]). The wetland that matters most to drainage is the Umiam lake, which "serves as a cesspool of the waste materials of Shillong" (Expert Committee, 2023) and was "Not satisfactory" at all four of MSPCB's stations in June 2023, with cyanobacterial blooms and leachate from the Mawiong landfill; no data were found for Ward's Lake or the pungs. The sacred groves (law kyntang) that stand at the heads of many perennial streams (as reported) are counted differently by each source (125 in NESAC's report, which finds none in the Shillong Planning Area; "around 79" covering "close to 9,000 hectares" in another account; the Forest Department's documentation volumes in a third; all as cited), and none of these counts is used in this Manual. A drain outfall, desilting, diversion or gate operation in or next to a notified wetland or forest land therefore needs the views or permission of the Wetlands Authority or the Forest and Environment Department where the Rules reach it, as well as compliance with this chapter; for the pungs, springs, groves and marshes they do not reach, this chapter, the Guidelines and the District Councils' rules are the only controls. Clause 7.12.2 targets a specific risk: drains built to relieve flooding next to a marsh can drain the marsh itself, and once it is dry it is encroached. Sewage reaches Meghalaya's streams, pungs and the Umiam lake through the drains (Clause 8.9, Commentary). MSPCB has identified 32 outfalls to the Umkhrah and the Umshyrpi (minutes of 14 April 2023); the CPCB placed both rivers in Priority I in September 2025; and the Expert Committee found the lake to be the "cesspool" of Shillong (2023). Clauses 7.10.6(d) and 7.12.3 therefore cannot yet be met by most existing outfalls in Shillong. In Meghalaya they apply in full to every new outfall, and every existing outfall to the Umkhrah, the Umshyrpi, the Wah Roro, the Umiam lake or a pung is taken to carry dry-weather flow and comes under the annual survey and the interception of Clauses 8.9.4 and 8.9.5 until its sources are removed. On the shore of the Umiam lake and in the catchment of a pung, every drain that enters the water also passes a sediment trap and a solid-waste trap first (Figure 7.3; Clause 6.3.6), because the lake or pung is the end of the slope's drainage and has no other way to lose the silt and garbage.

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## 7.13 Encroachment interfaces

7.13.1 **Boundary.** For design under this Manual, the boundary of a waterbody is the larger of its Revenue record boundary and its surveyed FTL (or top of bank), as in Clause 7.3.3. Setbacks are measured from that boundary.

7.13.2 **No reliance on encroached land.** No design shall:

- (a) count, as storage or conveyance, land within a waterbody boundary that is occupied by encroachment, unless its removal is ordered and funded; or
- (b) treat the encroached width of a channel as its design width.

7.13.3 **Public works in encroached reaches.** Where a public drainage work passes through an encroached reach:

- (a) it shall be designed for the full waterbody width (Clause 7.13.1);
- (b) where the full width cannot be cleared before the work is built, the design report shall state the interim capacity and the flood risk until it is cleared; and
- (c) the work shall be built so that the full width can be restored later without rebuilding it.

7.13.4 **Boundary marking.** Every development adjoining a waterbody shall, before the completion certificate:

- (a) mark the outer edge of Zone 1 on the ground with permanent survey markers at intervals of not more than 30 m and at every change of direction; and
- (b) show the setback zones on the approved layout plan and in the sale documents of every plot that includes setback land.

7.13.5 **Retaining walls.** No retaining wall, bund or embankment shall be built along the edge of a waterbody, within Zone 1, to protect or reclaim land, except to protect existing public infrastructure under the custodian's approval.

> Commentary. Meghalaya's controls on building and dumping along its streams and lakes have come mostly from the courts. In PIL No. 10 of 2019, *In Re: Cleanliness of Umiam Lake*, the High Court of Meghalaya ordered on 24 May 2023 that "neither the State nor the local authorities will allow any construction to come up within 50 metres of the high-water mark of the relevant waterbody without the express previous leave of this Court"; on 19 July 2023 it found that the first guidelines did "not deal with the most serious aspect of buildings and construction mushrooming around waterbodies", that "Several of the rivers, including the Umkhrah in Shillong itself are carrying such contaminated water that they may not be fit even to step into", and that the State should persuade "the District Councils to abide by the same"; and on 19 February 2024 it closed the PIL, taking the amended Guidelines on record and laying down general directions on retrieved public property (display boards, no hawking or parking, removal of unauthorised structures, action against officials), which the Forest and Environment Department circulated by order No. FOR/CC/29/2019/Pt-I/7 of 5 March 2024 to the departments, MSPCB, the Deputy Commissioners, the Shillong Municipal Board, the KHADC, the Cantonment Board and the Rangbah Shnong of Mawlai and Umniam. In 2022 the Court ordered the removal of two buildings on the Umiam side of the national highway after the KHADC called them unauthorised, and the Deputy Commissioner of East Khasi Hills banned the dumping of trash in the lake (both as reported). Under NGT O.A. 192/2022 the Shillong Municipal Board inspected 1,169 households along the Umshyrpi and the Wahumkhrah and served notices on 47 under section 201 of the Municipal Act and the Environment (Protection) Act, issued a public notice (No. SMB/PW/40/2023/10 of 17 February 2023) "to not discharge untreated sewage directly into drains and water bodies", and the KHADC told "all headmen" on 13 March 2023 not to let "untreated waste, faecal matter and garbage" into the two rivers (State action-taken report, 21 March 2023). The KHADC's rules on solid waste let the Dorbar Shnong fine polluters (minutes of 14 April 2023). On building in flood land, NESAC found "Encroachment and clogging of channels" to be "the main causes of flooding over Shillong" (2023). The orders on rat-hole mining (NGT O.A. 73/2014, 17 April 2014; Supreme Court, C.A. 10720/2018, 3 July 2019) bear on the coal belt's streams (Chapter 8). This Manual cannot evict anyone. It can stop designs from treating encroachment as permanent (Clause 7.13.2), make public works restorable to full width (Clause 7.13.3), and make the setback visible on the ground and in property documents so that new buyers know it is there (Clause 7.13.4). The 30 m marker interval is set by this Manual.

## 7.14 Safety of tank bunds and embankments

7.14.1 **Dam Safety Act screening.** For every tank, and every embankment built or altered under this Manual, the designer shall determine whether it is a "specified dam" under the Dam Safety Act, 2021. Under the Act, a specified dam is a dam:

- (a) more than 15 m high, measured from the lowest point of the general foundation area to the top of the dam; or
- (b) between 10 m and 15 m high, where the crest length is not less than 500 m, or the reservoir capacity is not less than one million m³, or the maximum flood discharge dealt with by the dam is not less than 2,000 m³/s, or the dam has specially difficult foundation problems, or the dam is of unusual design.

Where it is a specified dam, the Act and the requirements of the State Dam Safety Organisation govern, in addition to this Manual.

7.14.2 **Hazard class.** Every tank bund and detention embankment that is not a specified dam shall be given a hazard class:

- **High hazard:** a breach could flood a habitable building, a school, a hospital, an arterial road or critical infrastructure.
- **Low hazard:** any other case.

7.14.3 **High-hazard embankments.** For high-hazard tank bunds and embankments:

- (a) the surplus weir or spillway shall pass the 1% AEP inflow at MWL with the freeboard of Clause 7.7.4(b), and shall be checked for the 0.2% AEP (500-yr) inflow without overtopping the bund (as for detention basins in Chapter 4);
- (b) a breach analysis shall map the area flooded by a breach at MWL;
- (c) an emergency action plan shall be prepared, with the warning and evacuation arrangements for the breach area; and
- (d) the design shall be certified and independently checked under Clause 10.6.

7.14.4 **Inspection.** Every tank whose storage is counted under Clause 7.7, and every high-hazard embankment, shall be inspected before the monsoon (by 31 March) and after every heavy-rainfall event (Chapter 10) for seepage, slips, cracks, animal burrows, trees on the bund, and blockage of the weir and sluices.

7.14.5 **No unauthorised cutting.** No person shall cut, lower or breach a tank bund or surplus weir during a flood except under the custodian's emergency procedure.

> **Commentary.** The definition of a specified dam is quoted from the Dam Safety Act, 2021 (Act 41 of 2021). The Act defines a "dam" as an artificial barrier constructed across rivers or tributaries to impound or divert water. It excludes flood embankments, dikes and guide bunds. No pung or lake in Meghalaya was found to be held by a bund high enough to be a specified dam, though the bunds and outlets of Ward's Lake and the other pungs were not surveyed for this Manual [TBC]; each outlet work or bund shall be screened under Clause 7.14.1. The dams of MePGCL's reservoirs are dams across rivers under the Act, and the Umiam (Barapani) dam, a concrete dam reported to be about 69 m high (as reported), is above the 15 m of Clause 7.14.1(a); the heights of the Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka dams were not obtained [TBC]. Where the storage of a pung or reservoir is counted under Clause 7.7, its bund, outlet works or dam is a tank bund for Clause 7.14.2 unless the Act applies. Whether a tank bund that is not across a river or tributary is a "dam" under the Act is not clear from its text. In Meghalaya the embankments that matter to the towns and villages are MePGCL's dams, and the hazard below them is the release. The release reaches are long and inhabited: below Myntdu–Leshka the Myntdu runs through "Ravines and Plains of East & West Jaintia Hills" for about 24 km to the Bangladesh border past settlements and farms; below New Umtru the river runs 9.80 km through a ravine to the Byrnihat bridge; and below Kyrdemkulai and Nongkhyllem the Umiam–Umtru reaches run 13.05 km and 33.5 km (MePGCL). Warnings are by siren, telephone and SMS, not by notification (MePGCL); releases from the Umiam reservoir in August 2024

began on an IMD warning (as reported). No breach map or emergency action plan for any dam, pung or lake was read for this Manual. A failed or overtopped bund floods the land below it, and a release made without warning floods it too, which is why Clause 7.14.3 asks for breach mapping and an emergency action plan for high-hazard embankments, and why Chapter 5 treats every release reach as a flood-sensitive outfall. The hazard classes, the breach analysis and the emergency action plan for high-hazard tanks are set by this Manual. They extend the Chapter 4 requirement for detention basins (1% AEP spillway with outlet blocked, 0.2% AEP for high-hazard basins) to tanks that are counted as design storage.

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## 7.15 Submittal requirements

Every drainage report for a development or work under Clause 7.1.2 shall include:

1. the **Waterbody Sheet (Form 7-1)** under Clause 7.3.2, with the setback zones and their basis (mapped extent, hydraulic study or fixed width);
2. the hydraulic study of the 1% AEP extent and floodway, where Clause 7.3.4 requires it;
3. the **Compensatory Storage Calculation (Form 7-3)**, by elevation band, where fill is proposed in the flood fringe;
4. for any tank storage counted: the **Tank Storage Credit Sheet (Form 7-2)**, with the survey, stage–storage curve, operating rule, cascade model results and custodian concurrence of Clause 7.7.1;
5. for any crossing, outfall or work in Zone 1: the custodian's NOC and the hydraulic analysis of Clause 7.6.2 or 7.10.3;
6. for restoration or desilting: the pre-works survey, silt tests and hydrogeological report of Clause 7.9; and
7. for any embankment: the Dam Safety Act screening and hazard class of Clause 7.14.

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## 7.16 Review and update

7.16.1 This chapter shall be reviewed with the rest of the Manual (Chapter 1). The fixed-width table of Clause 7.4.6 shall also be reviewed within 2 years of the Authority adopting 1% AEP flood maps for its area.

7.16.2 Where the Authority adopts new 1% AEP flood maps, they apply to new submittals **6 months** after adoption, unless the Authority notifies otherwise.

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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 7A | Statewide waterbody GIS layer and inventory fields |
| 7B | Fixed-width setback table (alternative S-3, with Annex 1C) |
| 7C | Template tank operating rule, with flood cushion |
| 7D | Desilting and restoration specification |
| 7E | Glossary of Khasi, Pnar and Garo waterbody terms and regional variants |

| Annex / Form | Content |
|---|---|
| Form 7-1 | Waterbody Sheet |
| Form 7-2 | Tank Storage Credit Sheet |
| Form 7-3 | Compensatory Storage Calculation (by elevation band) |

CHAPTER 8

# Water Quality and Recharge

## 8.1 Purpose and scope

8.1.1 This chapter sets the requirements for the quality of stormwater leaving a site or a public drainage system, and for groundwater recharge. It covers:

- (a) the water quality volume (WQv) and the water quality design flow;
- (b) the treatment train, and the selection and design of best management practices (BMPs);
- (c) the criteria for infiltration and recharge;
- (d) the exclusion of sewage and dry-weather flow from storm drains;
- (e) gross pollutant traps, first-flush treatment and screens at outfalls to waterbodies;
- (f) how rainwater harvesting (RWH) fits with retention and detention;
- (g) erosion and sediment control during construction; and
- (h) monitoring.

8.1.2 This chapter applies to every development and public work to which Chapter 4 applies (Chapter 1). Clauses 8.9 (sewage) and 8.12 (construction erosion and sediment control) apply to every development that needs a building permit or layout approval, and to every public drainage work, whatever its size.

8.1.3 Retention under Chapter 4 is the first and preferred form of water quality control. Runoff retained on site is treated in full. The rest of this chapter applies to the part of the WQv that is not retained.

> Commentary. CPHEEO (2019) is the only Indian manual that covers stormwater quality in any detail. Its Chapter 9 reproduces US event mean concentrations, but cautions that "in an Indian context the values would be much higher" because drains receive night soil, urine and food waste, and it sets no Indian numeric criteria (CPHEEO 2019, Part A §9.5). Its Chapter 10 describes water-sensitive urban design, LID and SuDS treatment trains (CPHEEO 2019, Part A Ch. 10). This chapter turns that guidance into requirements. It follows the treatment approach of the MARC/APWA BMP Manual (2012), now merged into APWA 5600 (2025.01), with the Malaysian 3-month ARI water quality storm (MSMA 2, 2012) and the Georgia water quality volume (GSMM, 2016) as tropical and US benchmarks.

## 8.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Water quality volume (WQv) | The runoff volume that must be retained or treated, from the water quality rainfall depth (Clause 8.4). |
| Water quality rainfall depth (P_wq) | The greater of the retention depth (Annex 2E, Clause 2.10) and the 24-hour 3-month ARI depth (Annex 8A). |

| Term | Meaning in this Manual |
|---|---|
| 3-month ARI depth | The 24-hour rainfall depth equalled or exceeded on average four times a year, from a partial-duration series of the long-term daily record. |
| Water quality design flow (Q_wq) | The peak flow from the 3-month ARI storm, used to size flow-through devices and diversion structures (Clause 8.4.5). |
| Runoff coefficient for WQv (Rv) | The volumetric runoff coefficient for small storms, Rv = 0.05 + 0.009·I. |
| BMP | A best management practice: a structural or non-structural measure that reduces pollutant loads or runoff volume. |
| Treatment train | Two or more BMPs in series, from source to site to regional scale (Clause 8.5). |
| Pretreatment | A BMP that removes coarse sediment, litter and oil before runoff reaches a filter or infiltration BMP. |
| First flush | The early part of a runoff event, which usually carries the highest concentrations of sediment, litter and oil. |
| Gross pollutant trap (GPT) | A device that captures litter, plastics, vegetation and coarse sediment, typically above about 5 mm. |
| Dry-weather flow (DWF) | Flow in a storm drain when it has not rained for at least 72 hours. In a separate storm system, DWF is evidence of sewage, sullage, groundwater infiltration or illicit discharge. |
| Cross-connection | Any pipe, channel or opening that lets sewage or sullage (grey water from kitchens, bathrooms and laundries) enter a storm drain. |
| Infiltration facility | A facility designed to store runoff below the ground surface, or in a depression, and let it soak into the soil: infiltration trenches and basins, unlined bioretention, permeable pavement with an open base, soakaways, recharge pits and recharge wells. |
| Seasonal high groundwater table | As defined in Clause 3.10.2: the highest level in the monsoon season. |
| Hotspot | A land use with a high risk of spills or contaminated runoff (Clause 8.8.8). |
| Level of Service (LoS) / Value Rating (VR) | The scoring system of Clause 8.6, from the MARC/APWA BMP Manual (2012). |

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## 8.3 Objectives and pollutants of concern

8.3.1 Stormwater treatment under this Manual shall aim to:

- (a) remove litter, plastics and other gross pollutants before they reach a waterbody;
- (b) remove suspended sediment, and the metals, nutrients and oil carried on it;
- (c) keep sewage and sullage out of storm drains and waterbodies;
- (d) recharge groundwater where soils and groundwater depth allow, without polluting it; and
- (e) prevent erosion and sediment discharge during construction.

8.3.2 The design shall address the following pollutants for every site, and the hotspot pollutants of Clause 8.8.8 where they apply:

**Table 8.1 — Pollutants of concern, sources and primary controls**

| Pollutant | Main sources in Meghalaya towns | Primary control |
|---|---|---|
| Gross pollutants (plastics, litter, vegetation) | Streets, markets, open dumping in drains | Source collection; GPTs and screens (Clause 8.10) |

| Pollutant | Main sources in Meghalaya towns | Primary control |
|---|---|---|
| Suspended sediment | Construction sites, unpaved roads and verges, road wear, drain silt | Erosion and sediment control (Clause 8.12); pretreatment; filtration |
| Oil, grease and fuel | Roads, parking, fuel stations, workshops, bus depots | Oil-grit separators at hotspots; bioretention |
| Pathogens and organic load (BOD) | Sewage and sullage cross-connections, animal waste | Exclusion and DWF interception (Clause 8.9) |
| Nutrients (N, P) | Sewage, fertiliser, food waste, detergents | Exclusion; bioretention; wetlands |
| Heavy metals | Roads, roofs, industrial yards | Filtration; sedimentation |

> **Commentary.** Gross pollutants and sewage come first in Clause 8.3 because they dominate the pollution of urban waterbodies in Meghalaya, and because no treatment BMP works for long if they are not removed. CPHEEO (2019) notes that Indian drains carry night soil, urine and food waste (Part A §9.5). In its WSUD procedure it lists TSS, total nitrogen, total phosphorus and gross pollutants as the key pollutants (Part A Ch. 10). AMRUT 2.0 funds the harvesting of rainwater "through storm water drains into water body (which is not receiving sewage/effluent)" (Lok Sabha unstarred question AU1419), which only works if sewage is first kept out of the drains.

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## 8.4 Water quality volume and design flow

8.4.1 **Water quality rainfall depth.** The water quality rainfall depth is:

$$P_{wq} = \max(P_{ret}, P_{3m})$$

where:

- $P_{ret}$ = the retention depth for the site's zone (Annex 2E, Clause 2.10), mm; and
- $P_{3m}$ = the 24-hour 3-month ARI depth for the site's zone (Annex 8A), mm.

8.4.2 **Water quality volume.** The WQv shall be computed as:

$$WQv = (P_{wq} / 1000) \times Rv \times A$$

where:

- WQv is in m³;
- A = the contributing area, m²;
- $Rv = 0.05 + 0.009 \cdot I$; and
- I = the impervious percentage of the contributing area (0–100), after the connectivity rules of Clause 3.9.

The Rv form above may be used only for sites under 0.5 ha and under the Tier B simplified method (Clause 4.14). This is the same limit as for the retention volume (Clause 4.4.2). For all other sites the WQv shall be computed with the SCS-CN method, as the retention volume is: WQv (m³) = 10 × $Q_{wq}$ × A, where $Q_{wq}$ (mm) is the SCS-CN runoff from $P_{wq}$ for each sub-area and A is in ha.

8.4.3 **Climate factor.** The climate factor of Clause 2.8 shall not be applied to P_wq. P_ret and P_3m are frequency statistics of ordinary rainfall, not AEP design depths.

8.4.4 **WQv met by retention.** The volume retained on site under Chapter 4 counts toward the WQv in full. Where the retained volume is equal to or greater than the WQv, no further treatment is required for that area, except:

- (a) pretreatment of inflows to each retention facility (Clause 8.5.3);
- (b) hotspot controls (Clause 8.8.8); and
- (c) the outfall requirements of Clause 8.10, where the site discharges to a waterbody.

8.4.5 **Water quality design flow.** Flow-through devices (swales, filter strips, oil-grit separators, GPTs) and diversion weirs for off-line BMPs shall be sized for Q_wq. Q_wq shall be computed from the 3-month ARI intensity at the time of concentration of the contributing area:

- (a) by the Rational Method, where Chapter 3 allows it (a single element draining no more than 16 ha); or
- (b) as the peak of a hydrograph method using the 3-month ARI 24-hour depth with the alternating-block pattern of Clause 2.9.1.

8.4.6 **Bypass.** Flows above Q_wq shall bypass flow-through and off-line treatment devices without washing out the material already captured. The bypass shall be part of the minor or major system (Chapter 6).

8.4.7 **Drawdown.** Where the WQv is held in an extended-detention BMP (wet pond, constructed wetland or dry extended-detention basin), it shall be released over **24–48 hours** (Chapter 4).

> Commentary. The WQv depth is the runoff from the 3-month ARI storm or the retention depth, whichever is greater. The 3-month ARI is the Malaysian water quality design storm (MSMA 2, 2012). The Malaysian 2008 checklist gave its depth as about 40 mm and said it captures 90% or more of 24-hour storm runoff volume (DID, 2008). The Meghalaya value must be computed (Annex 8A). Georgia sets its WQv as the runoff from 1.2 inches (about 30 mm), the depth that covers 85% of storms in an average year, and requires 80% removal of the average annual post-development TSS load (GSMM 2016, Vol 1, Standard #4). Kansas City's water quality storm is the 1.37-inch (about 35 mm) event that produces up to 90% of the runoff from all 24-hour storms in a year (MARC BMP Manual, 2012).
>
> The Rv formula is from the MARC/APWA BMP Manual (2012), which computes WQv = P × Rv with Rv = 0.05 + 0.009·I. Rv is used instead of the SCS curve number because the CN method greatly understates runoff from small storms on pervious ground. Not applying the climate factor (Clause 8.4.3) has no direct precedent; this Manual does so because it treats P_wq like the retention depth, as a statistic of ordinary rainfall. Bypass of larger flows and the 24–48 hour drawdown follow Chapter 4; MARC (2012) required at least 40 hours of extended detention of the WQv.
>
> **Illustrative — not design values.** For a 1.0 ha site with 80% impervious cover and an assumed P_wq of 50 mm:
>
> - Rv = 0.05 + 0.009 × 80 = 0.77
> - WQv = (50 / 1000) × 0.77 × 10,000 = 385 m³

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## 8.5 Treatment train and pretreatment

8.5.1 **Treatment train.** Water quality control shall be designed as a treatment train, in the order shown in Figure 8.1:

- (a) **source controls** on the plot: roof runoff to RWH, rain gardens, permeable paving, disconnection of impervious areas, and silt traps at inlets;

- (b) **site controls**: bioretention, swales, filter strips, infiltration, oil-grit separators at hotspots, wet ponds and extended detention; and
- (c) **regional controls**, for public drainage: GPTs and DWF interceptors at outfalls, constructed wetlands at tank inlets, and regional ponds.

8.5.2 A development shall meet the WQv on site, through (a) and (b). Regional controls under (c) may count toward a development's WQv only where a regional facility treating the same runoff has been built under a notified basin plan (Clause 7.11).

8.5.3 **Pretreatment.** Every bioretention cell, infiltration facility, permeable pavement receiving run-on, wet pond and constructed wetland shall have pretreatment at each concentrated inflow. Pretreatment shall be a sediment forebay, grass filter strip, silt trap or proprietary device that holds at least **10% of the WQv** of its contributing area, or that is sized for Q_wq for flow-through devices.

8.5.4 Pretreatment shall be accessible for cleaning without entering or disturbing the main BMP.

> **Commentary.** The treatment train follows CPHEEO (2019, Part A §10.2.3, SuDS treatment train) and CIRIA C753 *The SuDS Manual* (2015). It is also the order of priorities of this Manual: preserve, retain, detain, convey (Chapter 1). The 10% forebay volume has no Indian precedent; it is a common sizing rule for forebays in US manuals. In Meghalaya, unpaved verges, construction sites and drain silt deliver a heavy sediment load. Bioretention and infiltration facilities without pretreatment clog, often within a year or two.

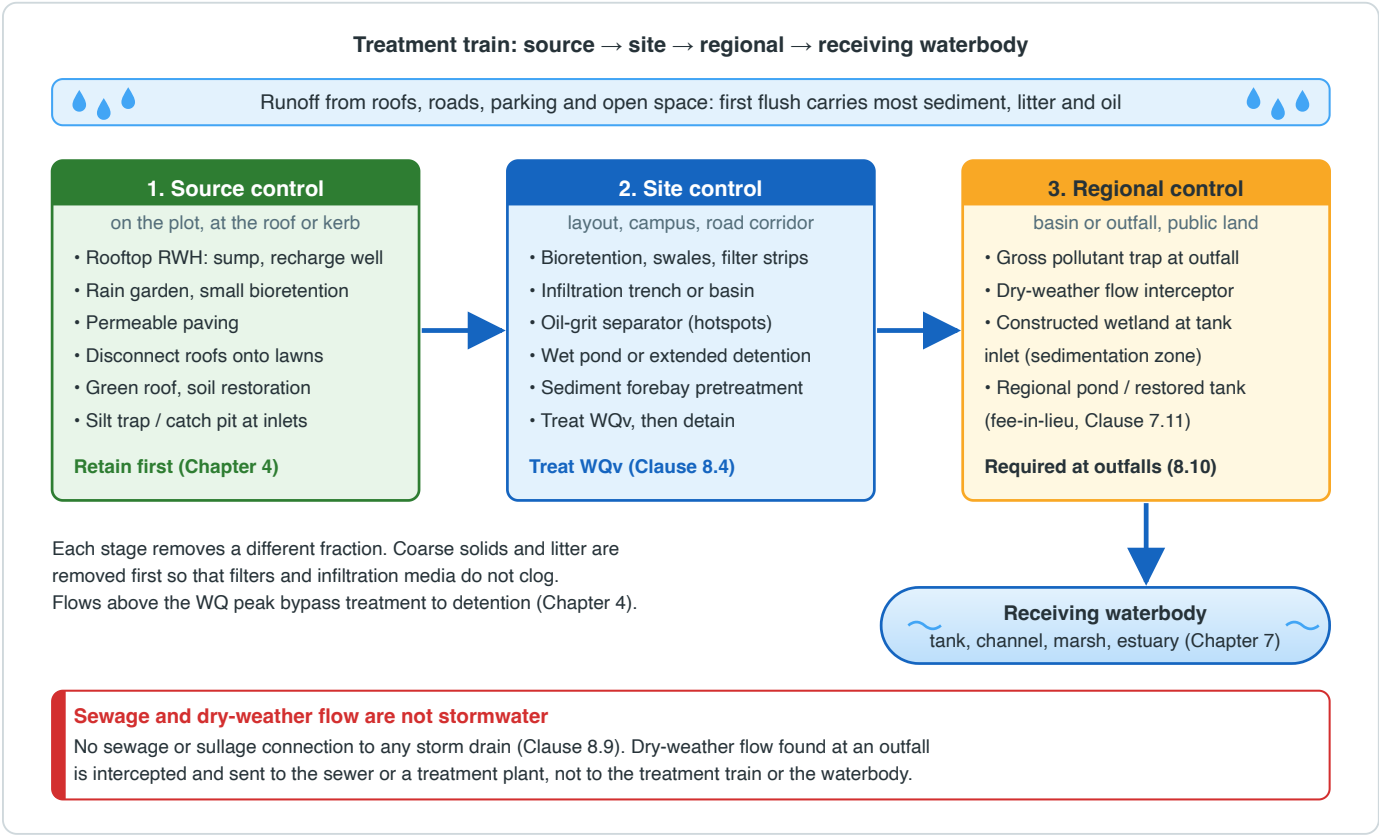


*Figure 8.1 — Treatment train: source, site and regional controls before the receiving waterbody, with sewage and dry-weather flow kept out of the system. Original drawing for this Manual, adapted from CIRIA, The SuDS Manual (C753), 2015, and MARC/APWA, Manual of Best Management Practices for Stormwater Quality, 2012.*

## 8.6 BMP selection: Level of Service and Value Rating

8.6.1 **Method.** In Tier A areas, the BMPs for each site shall be selected by the Level of Service (LoS) method of this Clause. In Tier B areas, the simplified route of Clause 8.6.5 may be used.

8.6.2 **Required Level of Service.** For a site that is not redevelopment, the required LoS depends on the change in curve number (ΔCN) from pre- to post-development (Chapter 3):

**Table 8.2 — Required Level of Service for sites that are not redevelopment**

| ΔCN | Impact | Required LoS |
|---|---|---|
| 17 or more | High | 8 |
| 7 to 16 | Moderate | 7 |
| 4 to 6 | Low | 6 |
| 1 to 3 | Minimal | 5 |

For redevelopment (existing impervious cover of 20% or more of the site), the required LoS shall be taken from Annex 8B.

8.6.3 **Value Rating.** Each BMP treating the WQv has a Value Rating (VR) from Table 8.3. The site's composite VR is the area-weighted average of the VRs of the BMPs serving each part of the site. Treatment trains get a composite VR under Annex 8B. The composite VR shall be equal to or greater than the required LoS.

8.6.4 **Conditions for a Value Rating.** A BMP earns its VR only if:

- (a) it is sized for the WQv (or Q_wq for flow-through devices) of the area credited to it;
- (b) it meets the design requirements of Clause 8.7 and, for infiltration, Clause 8.8; and
- (c) it has pretreatment under Clause 8.5.3.

8.6.5 **Tier B simplified route.** In Tier B areas, the requirement of Clause 8.6.3 is deemed met where the whole WQv of the site is either:

- (a) retained on site under Chapter 4; or
- (b) treated by a bioretention cell, rain garden or infiltration facility designed under Clauses 8.7 and 8.8, with pretreatment.

**Table 8.3 — BMP Value Ratings and suitability in Meghalaya**

| BMP | VR (MARC 2012) | Main pollutants removed | Volume reduction / recharge | Garo plains alluvium and Ri-Bhoi valley fills | Laterite / hard rock | Hill slopes, colluvium, limestone and mine areas / high water table | Meghalaya notes |
|---|---|---|---|---|---|---|---|
| Native vegetation (preserved) | 9.25 | All | High | Suited | Suited | Suited | Counts only for preserved, undisturbed area |
| Rain garden / infiltration | 9.0 | Sediment, metals, oil, nutrients | High | Suited if 1.0 m separation met | Conditional (test) | Not suited | Mosquito control: drain within 48 h |
| Bioretention | 8.5 | Sediment, metals, oil, nutrients | Medium–high (unlined); low (lined) | Suited | Suited, with underdrain | Lined, with underdrain | Media source and phosphorus content to be specified |

| BMP | VR (MARC 2012) | Main pollutants removed | Volume reduction / recharge | Garo plains alluvium and Ri-Bhoi valley fills | Laterite / hard rock | Hill slopes, colluvium, limestone and mine areas / high water table | Meghalaya notes |
|---|---|---|---|---|---|---|---|
| Permeable pavement | 7.5 | Sediment, metals, oil | Medium–high | Suited | Conditional | Lined only | Not where run-on carries heavy silt |
| Extended detention wetland | 7.0 | Sediment, nutrients, metals | Low | Conditional (water balance) | Suited | Suited | Good at tank inlets (Clause 7.9.7) |
| Media / sand filter | 6.0 | Sediment, metals | Low | Suited | Suited | Suited (lined) | Needs frequent cleaning |
| Extended wet detention (wet pond) | 5.0 | Sediment, metals, some nutrients | Low | Conditional (water balance) | Suited | Suited | Dry-season water balance (Clause 8.7.8) |
| Vegetated filter strip | 5.0 | Sediment | Low–medium | Suited | Suited | Suited | Mostly as pretreatment |
| Native vegetation swale | 4.0 | Sediment, oil | Low–medium | Suited | Suited | Suited | Not where Q_wq velocity is high |
| Extended dry detention | 4.0 | Coarse sediment | Low | Suited | Suited | Suited | Combine with detention (Chapter 4) |
| Proprietary / hydrodynamic devices | 3.0–5.0 | Coarse sediment, oil, litter | None | Suited | Suited | Suited | VR from verified test data only |
| Signage (public education) | +0.25 | — | — | — | — | — | Added to composite VR |

The VR column is from the MARC/APWA BMP Manual (2012), Table 4.4. The suitability columns and notes have no direct precedent and are set by this Manual.

> **Commentary.** The LoS and VR method is from the MARC/APWA Manual of Best Management Practices for Stormwater Quality (2012), Tables 4.2 and 4.4. The VRs combine a water quality score, based on effluent TSS concentrations in the International Stormwater BMP Database, with scores for volume reduction, temperature, and oils and floatables. The method suits Meghalaya for two reasons. It rewards volume reduction and preservation, which also serve recharge. It can also be checked by a reviewer without water quality modelling. Its weakness is that the scores come from US data. Meghalaya stormwater carries more litter and more sewage than the US runoff behind the scores (CPHEEO 2019, §9.5), so this Manual requires GPTs and DWF exclusion separately (Clauses 8.9 and 8.10) and does not let a VR stand in for them.

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## 8.7 BMP design summaries

8.7.1 **General.** Each BMP shall be designed to the requirements below and to Annex 8D (BMP design sheets). The dimensions given are **recommended starting values** where marked; the designer shall justify any departure. Every BMP shall be designed for safe passage of flows above Q_wq (Clause 8.4.6) and shall have access for maintenance (Chapter 10).

8.7.2 **Bioretention and rain gardens** (Figure 8.2).

- (a) Surface ponding depth not more than **300 mm** above the mulch, with an overflow at the maximum ponding level.
- (b) Surface ponding drained within **48 hours**.
- (c) Filter media 600–900 mm deep: an engineered sandy loam with low fines and low phosphorus content (Annex 8D), with a 50–75 mm mulch layer.
- (d) A transition (choker) layer and a gravel drainage layer below the media.
- (e) A perforated underdrain where the design infiltration rate of the native soil (Clause 8.8.4) is below the rate needed to meet (b), or where the cell is lined.
- (f) Unlined cells shall meet the infiltration criteria of Clause 8.8. Cells that cannot meet them, and cells at hotspots, shall be lined.
- (g) Plants: native or naturalised species tolerant of both waterlogging and long dry spells.

8.7.3 **Vegetated swales.**

- (a) Trapezoidal or parabolic section, with side slopes no steeper than 1V:3H.
- (b) Longitudinal slope 0.5% to 4%, with check dams where steeper.
- (c) Flow depth at Q_wq not more than the height of the grass, and velocity at Q_wq not more than 0.3 m/s.
- (d) The 1% AEP flow (or the bypass) shall not erode the swale (Chapter 9 permissible velocities).
- (e) Where longitudinal slopes are below 1% or the subsoil is poorly drained, an underdrained ("dry") swale with filter media.

8.7.4 **Vegetated filter strips.**

- (a) Receive sheet flow only, with a level spreader where flow arrives concentrated.
- (b) Length in the direction of flow at least 5 m, and slope 1% to 8%.
- (c) Used mainly as pretreatment for bioretention, infiltration and swales.

8.7.5 **Permeable pavement.**

- (a) Run-on from impervious areas not more than twice the permeable area, and no run-on from unpaved or eroding areas.
- (b) Base reservoir of clean, open-graded aggregate, sized to hold its share of the WQv in its voids.
- (c) An open base (infiltrating) only where Clause 8.8 is met; otherwise lined with an underdrain, and then counted as filtration only.
- (d) Structural design for the traffic loading by the road authority's standards.
- (e) Not at hotspots, and not where the surface will be resurfaced with impermeable material.

8.7.6 **Infiltration trenches and basins** (Figure 8.3).

- (a) Pretreatment under Clause 8.5.3 in every case.
- (b) Trenches filled with clean washed aggregate, with a void ratio confirmed by test, wrapped in geotextile on the sides and top, on a sand base.
- (c) An observation well to the base of each trench.
- (d) Storage volume = WQv (or the retention volume of Chapter 4, where greater) held in the voids; emptied within 72 hours at the design infiltration rate.
- (e) An overflow to the minor or major system at grade.
- (f) Not brought into service until the contributing area is stabilised (Chapter 10).

8.7.7 **Wet ponds (extended wet detention).**

- (a) A permanent pool of at least the WQv, plus extended detention of the WQv above the pool, released over 24–48 hours.
- (b) A sediment forebay at each inlet (Clause 8.5.3).
- (c) Length-to-width ratio of the flow path at least 3:1, with no short-circuiting.

- (d) Permanent pool depth 1.0–2.5 m, with a safety bench (Clause 7.9.4).
- (e) A dry-season water balance (Clause 8.7.8).
- (f) The detention storage of Chapter 4 may sit above the extended detention level.

8.7.8 **Water balance for permanent pools.** Wet ponds and wetlands shall be shown, by a monthly water balance using IMD rainfall and pan evaporation, to keep at least 50% of the permanent pool volume (or the minimum wetland depth) through the driest year in 10. They shall not be topped up with groundwater, potable water or sewage. Where the balance fails, a dry extended-detention basin or a constructed wetland with a smaller permanent pool shall be used instead.

8.7.9 **Constructed wetlands.**

- (a) An inlet sedimentation pond (forebay) followed by a shallow vegetated macrophyte zone.
- (b) Extended detention of the WQv above the normal water level, released over 24–48 hours, with an extended detention depth not more than 0.5 m.
- (c) A flow path length-to-width ratio of at least 3:1, with deep zones across the flow path to spread the flow.
- (d) A high-flow bypass so that floods do not scour the macrophyte zone.
- (e) Where built at a tank inlet, the wetland shall sit within the tank's setback but outside its waterspread, and its storage shall not be counted as tank storage.

8.7.10 **Gross pollutant traps.**

- (a) Sized to treat Q_wq, with all flows up to the 1% AEP passing without washing out captured material.
- (b) Capture of gross pollutants down to about 5 mm.
- (c) Head loss included in the hydraulic grade line of the drain (Chapter 9), with the screen assumed **50% blocked**.
- (d) Storage for captured material sized for the cleaning interval of the O&M plan, and not less than the 3-monthly cleaning of Chapter 10.
- (e) Vehicle access for cleaning by suction or grab.

8.7.11 **Oil-grit separators.**

- (a) Required at the hotspots of Clause 8.8.8 that involve fuel or oil: fuel stations, vehicle workshops and washing bays, bus and truck depots, and parking areas of more than 50 spaces.
- (b) Sized for Q_wq, with a high-flow bypass.
- (c) Not to be used as the only treatment: they shall be followed by a filtering BMP where the site needs a VR above 5.

8.7.12 **Silt traps and catch pits.**

- (a) At every inlet that receives runoff from unpaved ground, and at the inlet of every drain discharging to a BMP or waterbody.
- (b) A sump at least 300 mm below the outlet invert.
- (c) Silt traps are pretreatment only and earn no VR.

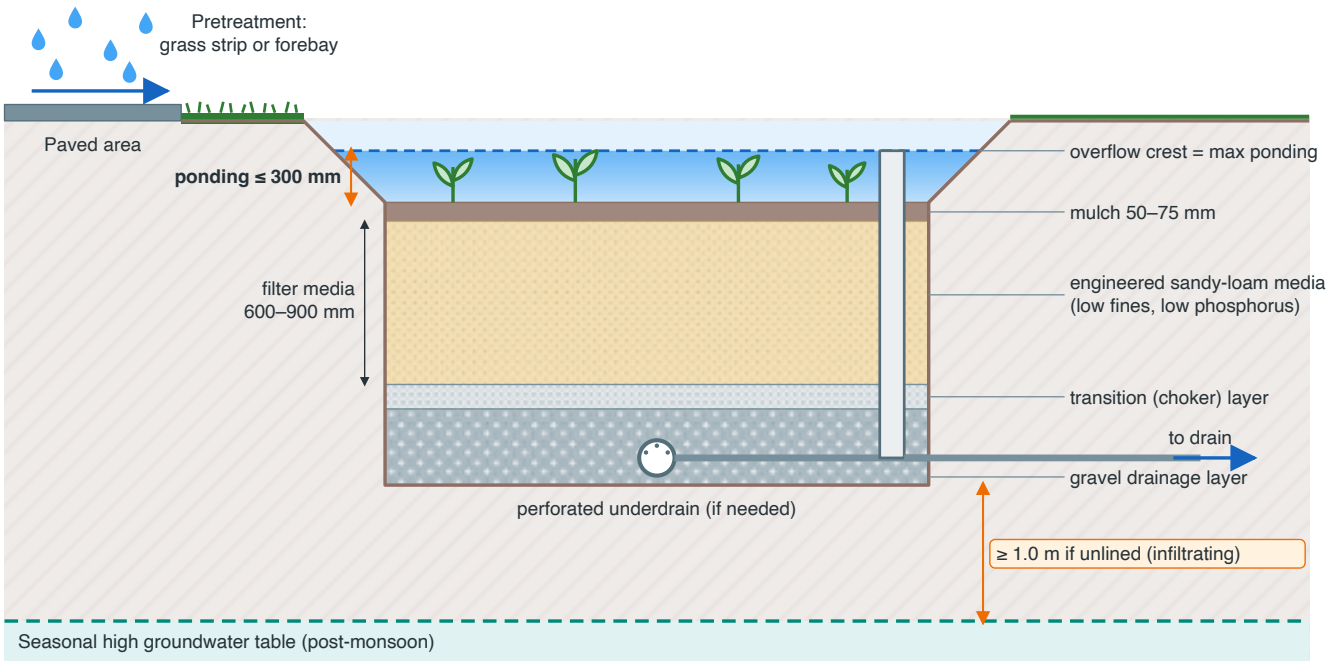
> **Commentary.** The design summaries draw on the MARC/APWA BMP Manual (2012), the Georgia Stormwater Management Manual (2016, Vol 2), CIRIA C753 *The SuDS Manual* (2015) and PUB Singapore's ABC Waters Design Guidelines. The dimensions are typical of those manuals but have not been calibrated in Meghalaya. Three local issues drive changes from the source manuals:
>
> - **Mosquitoes.** Dengue is endemic in Meghalaya. Surface ponding in bioretention and rain gardens must drain within 48 hours (Clause 8.7.2(b)), well inside the time mosquito larvae need to develop. This is consistent with the 24–48 hour WQv drawdown of Clause 8.4.7.
> - **Dry seasons.** Most of Meghalaya's rain falls in the monsoon season of 1 April to 31 October: the CWC report for subzone 2(b) describes rain "spread over a period of eight months, i.e. from March to October", with thunderstorms in April and May and "May rainfall … more than the September rainfall", and a winter

that is practically dry. The gauges of Shillong have annual normals of 225.3 cm and 242.5 cm (CWC, FER 2(b)), while Cherrapunji's wettest month brought 6,667.4 mm (July 1974, IMD). From November to March pungs fall and springs weaken, and the towns, supplied by gravity from streams and springs, face "acute shortage of water during the summer" (CGWB). In the towns the feed of a drain, jhora or pung in the dry months is often sewage, because the drains carry it (Clause 8.9, Commentary). A wet pond or constructed wetland whose water balance (Clause 8.7.8) cannot keep its permanent pool through the dry months on its own catchment's runoff is not to be used; in the plateau towns, where Clause 4.11 bars infiltration on slopes, limestone and mine land and there is little flat land, the practical forms are lined bioretention with an underdrain, swales on gentle ground, storage for use, and lined extended dry detention. Clause 8.7.8 applies to BMPs, which shall not be topped up with sewage; pungs, lakes, springs, sacred groves and wetlands are waterbodies or source catchments under Chapter 7 and are not to be used as treatment for a development. Wet ponds that dry out turn into stagnant pools or are used for dumping. Clause 8.7.8 requires a water balance and bans topping up with sewage, which is a common practice for keeping urban ponds "full".

- **Litter and silt.** GPTs and silt traps are treated as essential, not optional, because Meghalaya drains carry heavy litter and silt loads. The 50% blockage factor for screens matches the grate clogging factor of Chapter 6.

The 50-space threshold for oil-grit separators, the 5 mm GPT capture size, the 0.3 m/s swale velocity and the other dimensions in this Clause have no direct precedent and are set by this Manual.

**Bioretention cell (rain garden): section, not to scale**




Lined version (no infiltration): impermeable liner below the gravel layer. Required at pollution hotspots and wherever the 1.0 m separation to seasonal high groundwater cannot be met.

Dimensions as set in Clause 8.7.2.

*Figure 8.2 — Bioretention cell (rain garden) in section: pretreatment, surface ponding, filter media, transition and gravel layers, underdrain, overflow, and the 1.0 m separation to seasonal high groundwater for an unlined cell. Original drawing for this Manual, adapted from MARC/APWA, Manual of Best Management Practices for Stormwater Quality, 2012, and CIRIA, The SuDS Manual (C753), 2015.*

## 8.8 Infiltration and recharge criteria

8.8.1 **Groundwater separation.** An infiltration facility is permitted only where the **seasonal high groundwater table is at least 1.0 m below the base** of the facility. There is no exception in Meghalaya, which has no coastal sand areas (Clause 8.8.9). For this Clause the seasonal high groundwater table is the highest level found from April to November, which covers the season of 1 April to 31 October and the month after it (Clause 3.10.2). Meghalaya needs the three rules of Clause 4.11 here, and Clause 8.8.1 applies with the following. **(i) Recharge only on the tested alluvium and valley fills (Clause 4.11, recharge rule).** Recharge is not a design objective in Meghalaya: every assessment unit is Safe, and the State draws 3.55% of its extractable groundwater (CGWB, GWRA 2022; 4.60% in the assessment of 2024, as reported). Deliberate recharge is allowed only on the alluvium of sub-area ML-A1, where the water stands 3 to 5 m below ground, and on the tested valley fills of Ri-Bhoi in sub-area ML-A, on ground sloping 10° or less and away from slide-prone slopes, with pretreatment, the field test of Clause 8.8.3 and the separation of this Clause. The CGWB's 60 tests give rainfall infiltration factors of 4 to 5% on the weathered hard rock and Tertiary rocks and 10 to 13% on the alluvium and valley fills: they are fractions of rainfall, not infiltration rates, and no infiltration rate has been measured in the State. **(ii) No infiltration on hill slopes (Clause 4.11, hill rule).** No deliberate infiltration practice (soakaway, soak pit, recharge pit, shaft or well, infiltration trench, unlined bioretention, or permeable paving with an exfiltrating base) shall be built or credited on natural ground sloping more than 10°; on colluvium, fill or slide debris, whatever its slope; in a mapped landslide zone or landslide locality, among them, in Shillong, Laitumkhrah, Lawsohtun, Happy Valley, Mccabe Road, Bethesda and Arbuthnot and the very-high-susceptibility ground along NH-40 and near the Umshyrpi named in the IRADe/NMHS plan; or upslope of a cut slope or retaining wall within twice the height of the cut or wall — unless a geotechnical certificate by a qualified geotechnical engineer or engineering geologist shows that the added water will not destabilise the slope. On such sites roof runoff goes to rainwater storage sized under Clause 4.11 (25 L per m² of roof), with its overflow, and all other runoff, led by a lined drain through a sediment trap and an energy dissipator to a stable natural channel, never onto an unprotected slope; the exception for roof water in Clause 8.11.3(c) does not apply, and no infiltration is credited toward retention or the WQv. The Bye-Laws 2021 already ask for "good drainage facilities to prevent excessive saturation of sub-surface formations" in natural hazard prone areas (Section I(b), cl. 1) and for "good drainage of water so that the saturation of the hill slope is avoided" (C12.1(iv)), and the IRADe/NMHS plan for Shillong records that "due to increasing levels of urbanization and unregulated construction work the natural drainage system is blocked". **(iii) No infiltration at all on limestone or in mining areas (Clause 4.11, karst and mine rule).** No deliberate infiltration practice shall be built or credited, and no geotechnical certificate makes one acceptable, on limestone (the Sohra–Shella limestones of sub-area ML-C and the Jaintia limestones of ML-B1 and ML-C round Khliehriat, Lumshnong and Sutnga), within a coal-mining area (the rat-hole workings of the Jaintia and Garo coalfields), or where caves or sinkholes are known. There every BMP is lined, drains are lined, routed away from cave entrances and checked for void collapse along their alignment, drainage from mine spoil is not routed to a drinking-water intake or to any infiltration device, and pH and metals are added to the outfall checks of Clause 8.13. The CGWB describes the aquifer as "Discontinuous … in the cavernous limestones"; in the coal belt "smaller streams and rivers either disappear or have become seasonal in nature as surface water trickles into and disappears in the unfilled mine pits and caves", and the Krem Liat Prah–Um Im–Labit cave system is reported to run for 30.9 km (both as reported); no karst map, sinkhole inventory or subsidence record was found [TBC], so water put into the ground there goes where no designer can follow it. **(iv) No infiltration where the water is within 1 m.** On the marshes and waterlogged ground of the Garo plains, on the low terraces and floodplains of the rivers, and on the margins of pungs, lakes and reservoirs, no infiltration facility or recharge structure shall receive runoff of any kind where the seasonal high water table is within 1 m of the ground or the ground is waterlogged; the exception for roof water in Clause 8.11.3(c) does not apply there, and retention is met by storage for use and by detention under Chapter 4. **(v) Springs and their recharge areas.** Meghalaya has no statute that keeps building or drains away from a spring. Section 62(b) of the Meghalaya Municipal Act, 1973 vests public springs in the Municipal Board, and section 15(1) of the KHADC Regulation, 2015 makes it the duty of the Executive Committee, Town Committee or Dorbar Shnong to ensure that land development does not damage "catchment areas, water sources, spring sheds, streams and rivers". Within the recharge area of a spring (umpohliew) above a town's or village's drinking-water intake, as a hydrogeologist maps it, no paving is laid except for access, no road runoff is led into the ground, and no infiltration facility, soak pit or septic tank is placed; no drain, cut or fill intercepts the flow to a spring or buries its outlet; no infiltration facility, soak pit or septic tank lies within Zone 1 of the spring (Clause 7.4); and a sacred grove (law kyntang) at the head of a stream above an intake is treated as a protected

source catchment, into which no drain discharges and through which no runoff from development is led. These rules for springs and groves are set by this Manual, with section 15 of the KHADC Regulation as their hook in the Khasi Hills, not any statute on springs. **(vi) Quality.** No runoff from mine spoil, quarries, industrial yards or roads with heavy traffic is led to any recharge structure, and a recharge well or shaft on the alluvium or valley fills is used only for roof water or for runoff that has passed a filtering BMP, after a hydrogeologist's report confirming the depth to water, the receiving zone, and that no drinking-water well, spring or intake within 30 m will be harmed. Groundwater in the State already carries iron above the drinking-water limit at Shillong (11.25 mg/l), Nongpoh, Balat, Dawki, Bajengdoba and Kharkutta (CGWB). The 10° trigger, the distance of twice the wall height, the 1 m limit, the karst and mine rule and these conditions are set by this Manual; no Meghalaya rule on infiltration or soak pits on slopes, limestone or mine land was found. The seasonal high groundwater table shall be determined under Clause 3.10.2.

8.8.2 **Other separation.** The base of an infiltration facility shall also be at least 1.0 m above bedrock or any impermeable layer, unless the facility is designed to recharge a fractured or weathered rock aquifer under Clause 8.8.10.

8.8.3 **Infiltration tests.** The infiltration rate shall be measured at the proposed base level of the facility:

- (a) by a double-ring infiltrometer test (ASTM D3385) for basins, bioretention and permeable pavement;
- (b) by a falling-head borehole or trial-pit soakage test (for example BRE Digest 365) for trenches, soakaways, recharge pits and recharge wells;
- (c) with at least **2 tests per facility**, and at least 1 test per 100 m² of infiltration base area or per 50 m of trench length; and
- (d) by a person competent in geotechnical testing, with the results reported on the Infiltration Test Record (Form 8-2).

Tests made in the dry season shall be reported with the groundwater level at the time of test and the seasonal high level of Clause 8.8.1.

8.8.4 **Design infiltration rate.** The design infiltration rate is the measured rate divided by a safety factor:

- (a) **2.0** where the tests meet Clause 8.8.3(c) and the results vary by no more than a factor of 2; and
- (b) **3.0** otherwise.

8.8.5 **Minimum rates.**

- (a) Full infiltration (no underdrain) only where the design rate is at least **13 mm/h**.
- (b) Partial infiltration, with an underdrain, where the design rate is 3 mm/h to 13 mm/h. Only the volume that infiltrates within 72 hours is credited as retention.
- (c) No infiltration credit where the design rate is below 3 mm/h.

8.8.6 **Setbacks for infiltration facilities.** Infiltration facilities receiving runoff from roads, parking or other paved surfaces shall be at least:

- (a) **3 m** from building foundations, and **5 m** from a basement;
- (b) **1.5 m** from a property boundary, unless the neighbour agrees in writing;
- (c) **30 m** from a drinking-water well or borewell;
- (d) **15 m** from a septic tank or soak pit; and
- (e) **6 m** from the crest of a slope steeper than 1V:3H, unless a geotechnical report shows the slope remains stable.

Roof-only runoff to recharge structures is subject to (a) and (b) only, and to Clause 8.11.3.

8.8.7 **Drawdown and verification.** Every infiltration facility shall empty within **72 hours** at the design rate (Chapter 4), and shall be tested after construction (Clause 10.9.3).

8.8.8 **Hotspots.** Runoff from the following shall not be infiltrated without treatment, and shall not be infiltrated at all where (d) or (e) applies:

- (a) fuel stations;
- (b) vehicle workshops, washing bays, and bus and truck depots;
- (c) industrial yards and loading areas where hazardous materials are handled or stored;
- (d) solid waste transfer stations and landfill areas; and
- (e) land known or suspected to be contaminated.

Treatment for (a) to (c) shall include an oil-grit separator and a lined filtering BMP before any infiltration.

8.8.9 **Sandy coastal aquifers.** This Clause applies only to coastal sand aquifers. Meghalaya has none, so the Clause has no effect in the State; it is kept only so that the clause numbers stay unchanged. The alluvium of the Garo foothill plains and the Jinjiram valley and the valley fills of Ri-Bhoi are not coastal sand areas: Clause 8.8.1 applies there in full, and the reduced separation of item (d) does not. In coastal sand areas:

- (a) infiltration is the preferred means of meeting retention and the WQv wherever Clause 8.8.1 is met;
- (b) storm drains shall not be designed to lower the groundwater table: inverts below the seasonal high groundwater table shall be watertight, with no weep holes or subsoil drains that discharge groundwater to the outfall, unless a hydrogeological report shows no harm to the freshwater aquifer;
- (c) no long-term pumping of groundwater into storm drains shall be approved (for example basement dewatering); and
- (d) in notified coastal sand areas, **roof-only runoff** may be infiltrated with a separation of not less than **0.5 m** to the seasonal high groundwater table, provided a groundwater mounding check shows that the mound stays at least 0.3 m below the facility base and does not reach adjacent foundations or basements. No other runoff may use this reduced separation;
- (e) where neither the 1.0 m separation nor clause (d) can be met, the site shall use surface retention that does not infiltrate below ground (for example shallow vegetated depressions, disconnection of roofs onto lawns, and reuse), and detention under Chapter 4.

8.8.10 **Laterite and hard-rock areas.** In laterite and hard-rock terrain (for example the gneiss, granite, quartzite, phyllite and schist of the Archaean gneissic complex and the Shillong Group over most of the plateau, as at Shillong, Jowai and Nongstoin, where groundwater is held in weathered and fractured zones to about 150 m below ground and stands 7 to 17 m down, and the laterite of the south-west (CGWB); on any slope in these areas the hill rule of Clause 4.11 applies first under Clause 8.8.1, and on limestone or in a coal-mining area no infiltration is allowed at all (Clause 4.11, karst and mine rule)):

- (a) tests shall be made at the facility base, below any surface crust or hardpan;
- (b) recharge into weathered or fractured rock is permitted only for roof runoff, or for runoff that has passed through a filtering BMP, because fractures give little treatment; and
- (c) infiltration on or above slopes shall be checked for slope stability.

8.8.11 **Delta clays and black cotton soils.** In the clays and shales of the Garo Group, the marshes (chibol) and waterlogged ground of the Garo plains along the Jinjiram, the silted beds of pungs and the margins of reservoirs, and the clayey colluvium, fill and slide debris of the hills, and in expansive black cotton soils:

- (a) infiltration facilities will usually fail Clause 8.8.5 and need not be tested where the soil survey (Chapter 3) shows HSG D; and
- (b) where infiltration is used near buildings on expansive soils, the setback of Clause 8.8.6(a) shall be doubled.

> **Commentary.** The 1.0 m groundwater separation is a core requirement of this Manual. The other values in this Clause (the 1.0 m bedrock separation, test numbers, safety factors, minimum rates and setbacks) are typical of US and UK practice and have no Meghalaya precedent. The well setback in Clause 8.8.6(c) applies to runoff from

paved surfaces, not to roof water. Meghalaya RWH practice routes roof water into open wells and recharge wells, and Clause 8.11 keeps that practice.

No map of hydrologic soil groups for Meghalaya, and no measured infiltration rate anywhere in the State, was found. The CGWB's 60 infiltration tests under its aquifer mapping give rainfall infiltration factors, the share of the year's rain that reaches the water table, of 5% on the weathered granite and quartzite and the Tertiary rocks of East Khasi Hills, Ri-Bhoi and the Jaintia hills, 4% on the weathered Tertiary rocks of East Garo Hills, and 10 to 13% only on the alluvium and valley fills of Ri-Bhoi and the Jaintia hills (CGWB, GWRA 2022); these are not infiltration rates, and every infiltration design needs the tests of Clause 8.8.3. The State "is essentially occupied by hard massive rocks belonging to the Archaean gneissic complex … and Precambrian Shillong Group"; its south-western, southern and south-eastern parts are sandstones, shales, conglomerates and limestones of Cretaceous–Tertiary age; and unconsolidated sediments lie as a "thin veneer along rivulets and as valley-fills", thick only "along extreme north-western fringe of the state in South West Garo Hills" (CGWB). The water stands 3 to 5 m below ground in the alluvium, 4 to 9 m in the sandstones and shales of the Garo Group, 2 to 4 m in the "Discontinuous aquifer in the cavernous limestones and sandstones" of the Jaintia and Khasi Groups, and 7 to 17 m in the weathered and fractured gneiss and Shillong Group (CGWB, Table 1). Every assessment unit is Safe, and the State draws 3.55% of its extractable groundwater (GWRA 2022; 4.60% in the assessment of 2024, as reported); the towns are supplied by gravity from "streams and springs by tapping water source at higher altitudes", and still "there is acute shortage of water during the summer as the major part of rainfall is lost as surface run-off" (CGWB). Water put into the ground is a hazard as well as a resource: on the plateau it raises the pore pressure in thin soils over rock in a State where landslides caused "approximately 22 deaths in 2014" (IRADe/NMHS plan, citing the Revenue and Disaster Management Department); on the limestone and in the coal belt it disappears into caves and mine voids (as reported). This Manual's interim soil groups follow from these: the alluvium and valley fills B to C, the Garo Group sandstones C (D on clay or shale), the plateau gneiss, quartzite and phyllite with their thin red loam D for design, the limestone, karst and coal belt D with any loss to voids never credited, the laterite C to D, and urban fill C (D if clayey or compacted) (Chapter 3). **The State therefore needs three rules, not one** (Clause 4.11). On the tested alluvium of sub-area ML-A1 and the tested valley fills of Ri-Bhoi, recharge is allowed, with pretreatment, as a choice rather than a duty, because groundwater is not short. On hill slopes, on colluvium and fill and in landslide localities, no water is put into the ground on purpose, under the hill rule. On limestone and mine land, no water is put into the ground at all, under the karst and mine rule, whatever a certificate says. Everywhere, runoff from roads and open land goes to surface systems and never directly to a recharge well, borewell or shaft (Clause 8.11.3(b)). Clause 8.8.9 has no effect in Meghalaya, which has no coast.

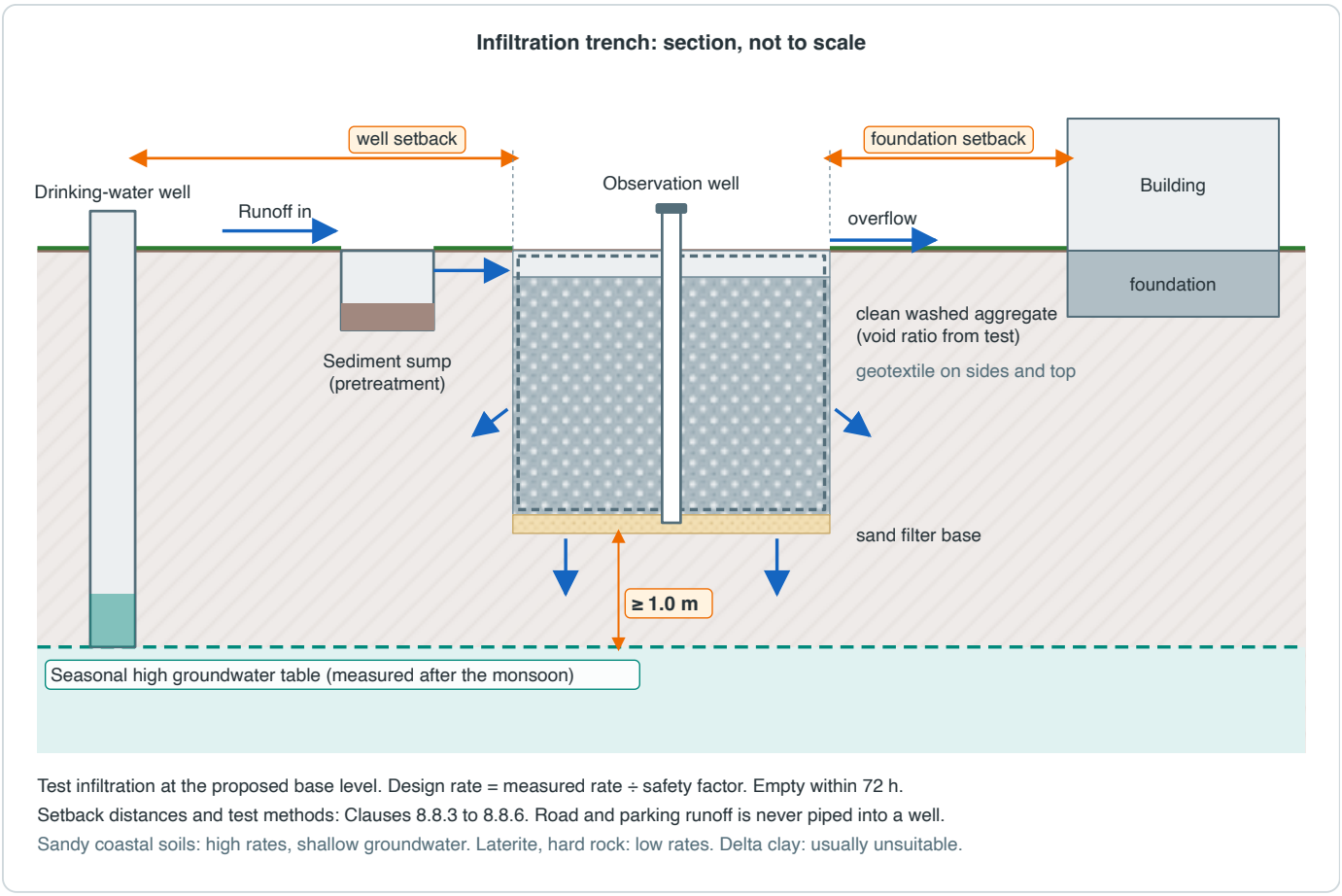



*Figure 8.3 — Infiltration trench in section: pretreatment sump, aggregate-filled trench in geotextile, observation well, overflow, the 1.0 m minimum separation to the seasonal high groundwater table, and setbacks to wells and foundations. Original drawing for this Manual, adapted from the Georgia Stormwater Management Manual, 2016 (Vol 2), and CIRIA, The SuDS Manual (C753), 2015.*

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## 8.9 Sewage cross-connections and dry-weather flow

8.9.1 **No sewage in storm drains.** No sewage or sullage (grey water from kitchens, bathrooms and laundries), septic tank effluent, or trade effluent shall be connected to, or discharged into, any storm drain, by any pipe, channel or opening.

8.9.2 **Condition of approval.** Before the completion certificate, the Applicant shall show, by a dye or smoke test witnessed by the Authority or the sewerage agency, that every sewage and sullage outlet on the site discharges to a sewer or to an approved on-site system, and that none discharges to a storm drain. Any existing cross-connection on the site shall be removed as a condition of approval, including on redevelopment and on additions to existing buildings.

8.9.3 **Where no sewer exists.** Where no sewer is available, sewage and sullage shall go to an approved on-site or decentralised treatment system. The treated effluent of such a system may be discharged to a storm drain only with the written consent of the Meghalaya State Pollution Control Board (MSPCB) and the drain owner.

8.9.4 **Public drains: DWF survey.** Every ULB in a Tier A area shall survey its storm drain outfalls to waterbodies for dry-weather flow at least once a year, before the monsoon, and record:

- (a) the outfalls with DWF;
- (b) the estimated DWF rate; and
- (c) the upstream sources found by tracing, CCTV, dye or smoke testing.

The results shall be published in the register of Clause 10.17.

8.9.5 **DWF interception.** Until the sources are removed, every outfall to a waterbody that carries DWF shall have a DWF interceptor that:

- (a) diverts the DWF to a sewer or a treatment plant;
- (b) does not reduce the capacity of the storm drain for the minor or major event (Chapter 6), with its weir or diversion head losses included in the hydraulic design (Chapter 9);
- (c) has a screen ahead of the diversion; and
- (d) is not a substitute for removing the source connections.

8.9.6 **Sewage overflows.** No new sewage overflow, emergency bypass or pumping station overflow shall be designed to discharge into a storm drain or waterbody, except where the sewerage agency shows that no alternative exists, and then only with screening and with the overflow frequency stated.

> **Commentary.** The prohibition of sewage connections and the removal of existing cross-connections as a condition of approval are core requirements of this Manual, and Clause 1.10.3 allows no variance from them. Sewage in storm drains is the single largest water quality problem of urban drainage in Meghalaya. It defeats every other measure in this chapter: BMPs designed for stormwater are overloaded, GPTs fill with sludge, and the receiving tanks and channels become sewage lagoons. CPHEEO (2019) notes that Indian drains carry night soil and urine (Part A §9.5). DWF interception (Clause 8.9.5) is an interim measure. It protects the waterbody while the sources are traced and removed, but it can become permanent if the source work is not done, which is why the annual survey and publication of Clause 8.9.4 are required. The annual survey frequency is set by this Manual.
>
> In Meghalaya's capital the storm drains are the sewerage. "The Shillong Planning Area has no sewerage system … the sewage flows into individual septic tanks and soaks pits. The sullage from the kitchen and bathroom flows into the primary, secondary and natural drains and finally to the nearby rivers Wah Umkhrah in the north and Wah Umshyrpi in the south" (NESAC, 2023), and the city's 148.91 km of drains "drain directly into the Umkhrah and Umshyrpi rivers", with "the incidence of sewerage mixing in drains … almost 100%" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan). MSPCB has identified 32 outfalls, 20 on the Wah Umkhrah and 12 on the Umshyrpi (minutes of the meeting of 14 April 2023), and five drains entering the Umkhrah "account for 42% of Umkhrah's pre-monsoon discharge" (Chief Secretary's presentation, April 2023). The CPCB's list of September 2025 places both rivers in Priority I, the only two of the State's 35 monitored rivers that fail: the Umkhrah from Demthring to Mawpdang, Mawlai, with a maximum BOD in 2022–23 of 52 mg/L at Demthring, 20 at Umkaliar, 55 near the slaughter house at Mawlai and 56 at Mawpdang, and the Umshyrpi from the Umshyrpi Bridge to the Law College, Dhanketi, with 59 and 39 mg/L; the Chief Secretary's table of 2023 shows no dissolved oxygen at all at Mawlai and total coliforms up to 1,50,000 MPN/100 mL. The five stretches listed in 2018 outside Shillong (the Kyrhukhla, Nonbah, Umtrew, Lukha and Myntdu) dropped out of the 2025 list on BOD, but BOD does not measure acid mine drainage (NEER reading): the joint committee before the National Green Tribunal found the Lukha "to have become acidic", with cement plants, power plants, breweries and ferro-alloy units among the sources (State action-taken report, 21 March 2023), phyco-remediation of the Lukha and the Lunar was minuted in February 2023, and acid discharge from the coal mines to the Kopili was the subject of the 2014 petition (as reported). The drains end in the Umiam lake, which "serves as a cesspool of the waste materials of Shillong and many other villages through Wahumkhrah, Umshyrpi and Umiam rivers" (Expert Committee, 2023), with a BOD of 4.8 to 5.6 mg/L, "Not satisfactory" at all four of MSPCB's stations in June 2023, cyanobacterial blooms and leachate from the Mawiong landfill. Under NGT O.A. 192/2022, in which the Tribunal held that the Additional Chief Secretary, Urban Development, "is required to ensure that the raw fecal matter is not discharged into fresh water streams and Umkhrah and Umshyrpi rivers" (order of 22 November 2022), the State reported in-situ treatment by CSIR-NEERI's ReNEU method in five drains (Pomdngiem or Wah Thangsiniang, Oakland, Lawmali, Wahingdoh–Raimohan and Polo Drain 2), five on-site sewage treatment plants of 13.42 MLD, 55% complete in February 2023, a faecal sludge and septage treatment plant of 0.35 MLD ("350 KLD" in the report, whose cost of "51 Cr" is probably a misprint; the figures conflict), a septage plant of 115 KLD at Marten, a diversion drain at Nongrah, and a survey of 1,169 households along the two rivers that found 47 with faulty septic tanks, served with notices

> under section 201 of the Meghalaya Municipal Act, 1973 and a fine of ₹500 a day (State action-taken report, 21 March 2023); a sewerage scheme for Shillong was not found, and NESAC's plan proposes decentralised treatment. The State's only distance between sewage and water is the 6 m, or half the depth of the plot, between a septic tank, STP or ETP and the waterbody setback (Waterbodies Guidelines, para 7(3); Bye-Laws 2021, B10, inserted in 2025), and in the Khasi Hills "Under no circumstance should effluent from a septic tank or toilet/latrine be allowed into an open channel, drain or body of water without adequate treatment" (KHADC Regulation, 2015, s.40.3(b)); the Municipal Act's fine for letting sewage run into a drain is ₹25 (s.205). In Meghalaya, therefore: **(i)** every storm-drain and jhora outfall to the Umkhrah, the Umshyrpi, the Wah Roro and the Umiam lake is taken to carry dry-weather flow until the survey of Clause 8.9.4 shows that it does not, and has a DWF interceptor and a screen under Clause 8.9.5 before it reaches the river or lake, and before any detention or infiltration device; **(ii)** no septic tank overflow, soak-pit overflow or sullage pipe is connected to a storm drain or jhora on any site approved under this Manual (Clauses 8.9.1 and 8.9.2), with section 40.3(b) of the KHADC Regulation and B10 of the Bye-Laws 2021 as the local hooks; **(iii)** until sewers exist, a jhora that receives the drains of a settlement is designed as a combined channel: for the velocities that keep sludge moving in dry weather as well as for the storm flow, with access for cleaning along it, and with covers or screens where it passes homes, because of the smell and the risk to health; and **(iv)** at every outfall in a coal-mining or limestone area of the Jaintia and Garo hills, the outfall survey and monitoring of Clauses 8.9.4 and 8.13 include pH and dissolved metals, as MSPCB directs, and no outfall carrying mine drainage discharges to a drinking-water intake. Every interceptor is sized from the measured dry-weather flow of its drain, does not reduce the drain's capacity for the minor and major events (Clause 8.9.5(b)), and passes the storm flow above its capacity on down the drain; on a jhora that carries boulders and garbage in flood, it and its chamber are placed above the stream's 1% AEP level found under Clause 5.8.5(c), or protected against the scour and debris of that flood (Chapter 9). These conditions are set by this Manual.

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## 8.10 Outfalls to waterbodies: first flush, gross pollutant traps and screens

8.10.1 **Requirement.** Every new storm drain outfall to a waterbody, and every existing outfall on a drain that is rebuilt, widened or extended, shall have:

- (a) a GPT designed under Clause 8.7.10; and
- (b) first-flush treatment: treatment of the WQv (or Q_wq) of the contributing catchment by the BMPs of Clause 8.7, either on the contributing sites or at the outfall.

8.10.2 **Where treatment at the outfall is impracticable.** Where land is not available at a public outfall, first-flush treatment may be provided by:

- (a) a proprietary first-flush or hydrodynamic device sized for Q_wq; or
- (b) a treatment wetland or forebay within the waterbody setback (Clause 7.5.1(b)), outside the waterspread.

8.10.3 **Screens and trash racks.** Screens at outfalls, culvert inlets and pump sumps shall:

- (a) be designed with **50% blockage** for hydraulic capacity;
- (b) have an overflow or bypass path so that a fully blocked screen does not flood property;
- (c) have bar spacing chosen for the hazard: closer spacing for litter capture, wider spacing where blockage would cause flooding; and
- (d) be cleanable from a safe platform, with vehicle access.

8.10.4 **Existing outfalls.** Each ULB shall prepare a programme to fit GPTs and DWF interceptors to its existing outfalls to waterbodies, starting with outfalls to tanks used for drinking water supply and to notified wetlands (Clause 7.12), and shall report progress in the register of Clause 10.17.

> Commentary. This Manual requires first-flush treatment and gross pollutant traps at outfalls to waterbodies. Gross pollutants are the most visible form of pollution in Meghalaya waterbodies, and plastics also block drains and culverts, which links water quality to flooding. The 50% screen blockage matches the grate clogging factor of Chapter 6. Clause 8.10.3(c) warns against fine screens on large drains, which block in the first hour of a storm and cause the flooding they were meant to prevent.

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## 8.11 Rainwater harvesting integration

8.11.1 **RWH mandate continues.** The rainwater harvesting required by the Meghalaya Building Bye-Laws 2021 (Table G1, which requires rainwater harvesting for every plot category and use, "Ground water recharge for covered area more than 3000 sqft" on residential plots of Category II, and soft cover of at least 10% or 20% of the plot, with a 10% rebate of the permission fee where both waste-water recycling and rainwater harvesting are provided (G2.1.2), but sets no storage volume or roof-area rate; and, in the Khasi Hills Autonomous District, section 36 of the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015, which makes "storing of water runoff including rainwater in all existing and new buildings" mandatory and asks the plans to "indicate the system of storm water drainage along with points of collection of rain water") continues to apply, subject to the limits of Clause 8.8.1: where the recharge that Table G1 asks for falls on a site where Clause 4.11 bars infiltration, this Manual states the conflict, requires storage for use in its place, and leaves the Applicant to seek the Authority's relaxation of the bye-law, which this Manual does not override (Chapter 1). This Clause sets how RWH structures are counted under this Manual.

8.11.2 **Three different functions.** The designer shall keep apart, on the drawings and in the calculations:

- (a) **harvesting**: storage for use (sumps and tanks);
- (b) **recharge**: recharge pits, trenches, shafts and wells that put water into the ground; and
- (c) **detention**: storage with an orifice outlet that is empty at the start of a storm (Chapter 4).

8.11.3 **Recharge structures.**

- (a) Roof runoff may be led to recharge wells, open wells, recharge pits and shafts after a filter or settling chamber.
- (b) Runoff from roads, parking and other paved areas shall not be led directly into any well, borewell or recharge shaft. It may be recharged only through an infiltration facility that meets Clause 8.8, with pretreatment.
- (c) Recharge structures shall meet the groundwater separation of Clause 8.8.1, measured from the base of the pit or the bottom of the filter media, except recharge wells that receive filtered roof water only.

8.11.4 **Credit toward retention and WQv.** A recharge structure counts toward the retention volume of Chapter 4 and the WQv only where:

- (a) its infiltration rate has been tested under Clause 8.8.3;
- (b) it empties within 72 hours at the design rate; and
- (c) it has pretreatment.

A harvesting sump counts toward retention only where its contents are used, by a demand stated in the drainage report, within 72 hours (Chapter 4).

8.11.5 **No credit as detention.** RWH storage does not count as detention unless it is a dedicated volume that is empty when a storm arrives, with an outlet. RWH sumps are assumed **full** at the start of every monsoon (April–October) design storm (Chapter 4).

8.11.6 **Overflow.** Every RWH structure shall have an overflow that discharges at grade to the site drainage, never onto a neighbouring plot or into a sewer.

8.11.7 **Surface-runoff recharge in public spaces.** Recharge trenches, shafts and percolation pits in roads, medians, parks and other public spaces shall meet Clause 8.8 in full, including the hotspot rules for roads with heavy traffic, and shall have a GPT or silt trap at each inlet.

> **Commentary.** The rule that RWH storage does not count as detention is set in Chapter 4. Meghalaya's building rules make rainwater harvesting compulsory, but none of them sets a volume or a detention rule. Under the Bye-Laws 2021, "All buildings while submitting the building plans for sanctions, shall mandatorily include the complete proposal for green buildings and sustainability norms" (G.1), and Table G1 lists "Rain Water Harvesting" for every plot category and use, "Ground water recharge for covered area more than 3000 sqft" on residential plots of Category II (5,001 to 25,000 sq ft), and soft cover of at least 10% of a plot of up to 5,000 sq ft and 20% of a larger one; new buildings in the City Centre Zone "shall adopt rain water harvesting systems" and keep 30% of the plot as open space with soft cover (D8.2); a rebate of 10% of the permission fee is given where both waste-water recycling and rainwater harvesting structures are provided (G2.1.2); and the drawings show the rainwater harvesting with the surface drains, septic tank and soak pit. In the Khasi Hills "Water harvesting through storing of water runoff including rainwater in all existing and new buildings shall be mandatory", and the plans "shall indicate the system of storm water drainage along with points of collection of rain water in surface reservoirs or in recharge wells" (KHADC Regulation, 2015, s.36), with soft cover of at least 15% of the plot where the covered area is 500 m² or more and "Semi-pervious ground cover" as paving "wherever possible" (s.35(iii)). The State told the National Green Tribunal in 2023 that rainwater harvesting is "Incorporated as one of the conditions while giving building permission" and that the Smart City programme was installing it at 52 locations (action-taken report, 21 March 2023); the State Water Policy of 2019 is reported to focus on rainwater harvesting (as reported; not read). None of these gives litres per m² of roof, a tank volume, a recharge rate, a test of a recharge pit or a limit on soak pits on slopes, limestone or mine land, and no audit of what has been built was found. This Manual credits storage sized at 25 L per m² of roof (Clause 4.11), more than the 20 L per m² of the mountain editions of this series, because Meghalaya's towns go short of water from November to March and the bye-laws set no volume. On the alluvium of sub-area ML-A1 and the tested valley fills of Ri-Bhoi, recharge may be one function of harvesting where Clause 8.8.1 allows it (Clause 8.11.2(b)); on hill slopes, on colluvium and fill, in landslide localities, on limestone and in mining areas, harvesting is for storage and use only, and its overflow goes to a lined drain; where the bye-law's recharge requirement falls on such a site, this Manual states the conflict and requires storage in its place (Clause 8.11.1). RWH serves water supply and recharge. It is usually full, or its soil saturated, by the time a June monsoon storm against the plateau and the southern escarpment, such as those of 16 June 1995 and 15–17 June 2022, arrives after weeks of rain, which is why it cannot be counted as detention.
>
> Clause 8.11.3(b) has no direct precedent; this Manual sets it because road runoff carries oil, metals and pathogens. A recharge shaft or borewell bypasses the soil that would otherwise filter it and delivers it straight to the aquifer that supplies wells nearby. The CGWB *Manual on Artificial Recharge of Ground Water* (2007) gives recharge structure types and filter designs; this Manual adds the source-water restrictions.

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## 8.12 Construction-stage erosion and sediment control

8.12.1 **ESC plan.** Every development with land disturbance of **0.1 ha** or more, and every public drainage or road work, shall have an Erosion and Sediment Control (ESC) plan, approved with the drainage report. It shall show:

- (a) the sequence of clearing, earthworks and stabilisation;
- (b) the area exposed at each stage;
- (c) the measures of Clause 8.12.3, with their locations and sizes;
- (d) the protection of infiltration and retention areas (Chapter 10);
- (e) stockpile, concrete washout and fuel storage locations; and
- (f) the inspection and maintenance schedule.

8.12.2 **Monsoon timing.** Earthworks shall be planned so that:

- (a) the area exposed during the monsoon (April to October) is as small as practicable;
- (b) all completed earthworks are stabilised by vegetation, mulch, matting or paving by **31 March**; and
- (c) any area exposed between 1 April and 31 October has sediment controls in place before it is cleared.

8.12.3 **Measures.**

- (a) **Silt fences** along the downslope edge of disturbed areas receiving sheet flow, with the area draining to each fence limited as set in Annex 8E.
- (b) **Sediment traps** for concentrated flow from disturbed areas of up to 2 ha.
- (c) **Sediment basins** for disturbed areas of more than 2 ha. The storage volume below the outlet shall be at least the greater of the runoff from the 50% AEP (2-yr) 24-hour storm and **250 m³ per hectare** of drainage area, with a dewatering outlet that draws water from the surface.
- (d) **Inlet protection** at every existing drain inlet that receives runoff from the site.
- (e) **Stabilised construction exits**, with wheel washing where vehicles enter public roads.
- (f) **Stockpiles** outside Zone 1 of any waterbody setback (Chapter 7), at least 10 m from any drain, and covered during the monsoon.
- (g) **Dewatering** discharges passed through a sediment basin, settling tank or filter bag, never pumped directly into a drain or waterbody.
- (h) **Concrete washout** in a lined pit, never into a drain.

8.12.4 **Design storm for temporary works.** Temporary ESC measures use the rainfall of Chapter 2 with a climate factor of 1.0 (Clause 2.8.2).

8.12.5 **Inspection.** ESC measures shall be inspected weekly and within 24 hours after every heavy-rainfall event (as defined in Chapter 10), repaired within 48 hours, and cleaned when half full of sediment.

8.12.6 **Removal.** Temporary measures shall be removed only after the area draining to them is stabilised. Sediment shall be removed from any permanent facility used for sediment control before its as-built survey (Chapter 10).

> Commentary. The 0.1 ha threshold is the applicability threshold of Chapter 1. The sediment basin volume of 250 m³/ha is the US EPA Construction General Permit minimum of 3,600 ft³ per acre drained, converted to SI (US EPA, 2022 CGP); the CGP allows the alternative of the 2-year, 24-hour runoff. This Manual requires the greater of the two, because Meghalaya's 2-year 24-hour depths are high and construction sites are commonly left exposed through the monsoon. The 2 ha division between traps and basins, the 31 March stabilisation date, the 10 m stockpile distance and the inspection frequency have no direct precedent and are set by this Manual. The 31 March date matches the pre-monsoon deadline of Chapter 10. Construction sediment is a direct flood hazard as well as a pollutant: it fills drains, culverts and tanks, and in Meghalaya garbage and slide debris travel with the sediment: 49,612 m³ of waste was removed from the Wahumkhrah (State action-taken report to the National Green Tribunal, 21 March 2023), drains blocked by waste are reported to raise the susceptibility of Shillong's slopes to landslides (as reported), the Umiam reservoir is reported to have received 20.551 Mm³ of sediment between 1965 and 2004, and the landslides of 30–31 May 2025 in Umling block, near NH-6, were linked to hill cutting along the highway (both as reported). The Bye-Laws 2021 already ask, in natural hazard prone areas, that "Construction should not obstruct existing surface drainage courses", that builders "Construct diversion ditches and swales to direct runoff away from sensitive areas and into designated sediment basins" and "Install silt fences, sediment barriers, or basins around the construction site" (Section I(b), cls. 2, 4 and 5, inserted in 2024), and on water-logged plains "Storm water inlet protection" (Section I(c), cl. 4); they give no size, date or inspection, which Clause 8.12 supplies. The stabilisation date of 31 March is set by this Manual, before its season begins on 1 April, because the escarpment's largest falls come in April and May as well as in June (Chapter 2). The reason given above for the larger basin volume, that the 2-year 24-hour depths are high, holds on the southern escarpment, where the Cherrapunji curve of IMD Das et al. (2022) gives about 410 mm, and on the plateau and the northern foothills, where the NIH-DHAARA reanalysis gives about 93 mm at Shillong, 121 mm at Jowai and 82

mm at Nongpoh (comparison values only, not design values; Chapter 2) and AMC III applies through the season (Chapter 3); no 2-year value was found for the Garo hills, and the rule of Clause 8.12.3(c) is kept unchanged everywhere. In Meghalaya the outlet of a sediment basin or trap under Clause 8.12 discharges to a lined drain or a stable channel and never onto an unprotected slope; no sediment basin or trap is designed to infiltrate where Clause 4.11 bars infiltration, which includes every slope steeper than 10° and all limestone and mine land; no spoil, debris or garbage from a site is placed in a jhora, stream or pung, within its Zone 1, or on the recharge area of a spring; and a construction site in the catchment of the Umiam lake or of a pung keeps its sediment out of every drain that reaches the water.

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## 8.13 Monitoring

8.13.1 **Outfall monitoring.** Each Tier A authority shall monitor water quality at a representative set of its outfalls to waterbodies, including every outfall to a drinking-water tank or notified wetland. Monitoring shall include:

- (a) dry-weather sampling (Clause 8.9.4), at least once a year before the monsoon; and
- (b) wet-weather sampling of at least three events each monsoon at a set of index outfalls.

8.13.2 **Parameters.** At minimum: TSS, BOD, COD, faecal coliform, total nitrogen, total phosphorus, oil and grease, and, for industrial catchments, heavy metals. Results shall be compared with the CPCB water quality criteria for the designated best use of the receiving waterbody.

8.13.3 **Gross pollutant records.** The mass or volume of material removed from each GPT and screen at each cleaning shall be recorded in the O&M records (Chapter 10).

8.13.4 **BMP performance monitoring.** The State Stormwater Technical Committee shall run a BMP performance calibration programme and shall revise Table 8.3 and Annex 8C from its results.

8.13.5 **Publication.** Monitoring results shall be published in the register of Clause 10.17.

> Commentary. No Meghalaya programme of stormwater quality monitoring was found during research for this Manual, and CPHEEO (2019) sets no Indian targets. The monitoring in Clause 8.13 is the minimum needed to calibrate Table 8.3 and to show whether DWF interception and source removal are working. The parameter list follows the key pollutants named in CPHEEO's WSUD procedure (TSS, nitrogen, phosphorus and gross pollutants), with BOD and faecal coliform added because of sewage contamination. The monitoring frequencies are set by this Manual.

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## 8.14 Submittal requirements

Every drainage report under this chapter shall include:

1. the **Water Quality Sheet (Form 8-1)**: P_ret, P_3m and P_wq; the WQv and Q_wq for each drainage area; the volume retained under Chapter 4; and the BMP serving each area;
2. for Tier A: the LoS calculation (ΔCN, required LoS) and the composite VR (Clause 8.6);
3. the design of each BMP to Clause 8.7 and Annex 8D, with pretreatment;
4. for infiltration and recharge: the **Infiltration Test Record (Form 8-2)**, the seasonal high groundwater level and its source, the design rate, the drawdown time, and the setbacks of Clause 8.8.6;
5. the sewage and sullage connection plan and the dye or smoke test record of Clause 8.9.2;
6. the GPT and first-flush design for any outfall to a waterbody (Clause 8.10);

7. the RWH layout, separating harvesting, recharge and detention (Clause 8.11); and
8. the ESC plan (Clause 8.12).

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## 8.15 Review and update

8.15.1 This chapter shall be reviewed with the rest of the Manual (Chapter 1). Table 8.3 shall also be reviewed when the calibration programme of Clause 8.13.4 reports, and in any case within 5 years of notification.

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## Annexes and forms

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| 8A | 3-month ARI 24-hour depth and IDF by zone |
| 8B | Redevelopment LoS table and treatment-train composite VR |
| 8C | Meghalaya BMP performance calibration |
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| Form 8-1 | Water Quality Sheet |
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CHAPTER 9

# Hydraulic Design of Structures

## 9.1 Purpose and scope

9.1.1 This chapter sets the hydraulic design methods for the structures used in the minor and major systems (Chapter 6), in retention and detention facilities (Chapter 4), at outfalls (Chapter 5) and at waterbodies (Chapter 7). It covers:

- (a) pipes and box drains (Clause 9.3);
- (b) culverts (Clause 9.4);
- (c) open channels (Clause 9.5);
- (d) energy dissipators, outlet protection and drop structures (Clause 9.6);
- (e) detention outlet structures (Clause 9.7);
- (f) trash racks and screens (Clause 9.8);
- (g) pumps and sumps (Clause 9.9);
- (h) tide gates, flap gates and non-return valves (Clause 9.10);
- (i) inlets and gratings (Clause 9.11);
- (j) manholes, junction chambers and access (Clause 9.12); and
- (k) materials and durability, including coastal and saline exposure (Clause 9.13).

9.1.2 **Structural design is outside the scope of this Manual.** Structures shall be designed structurally to the applicable Indian Standards and IRC codes, for example IS 456 (plain and reinforced concrete), IS 458 (concrete pipes), IRC:SP:13 (small bridges and culverts) and the IRC bridge codes. Where this chapter refers to a structural standard, it does so only for durability (Clause 9.13) or hydraulic performance.

9.1.3 Design flows, design AEPs and level-of-service limits come from Chapters 2 to 7. This chapter does not change them.

> **Commentary.** APWA Section 5600 places most structure hydraulics in its sections on inlets and manholes (5604), enclosed pipe systems (5606), engineered channels (5607) and detention (5608). CPHEEO (2019) spreads them across Chapters 5, 6, 8 and 11. This chapter gathers them in one place and points to the US Federal Highway Administration (FHWA) hydraulic circulars for methods that Indian codes do not cover in enough detail: HDS-5 for culverts, HEC-14 for energy dissipators, HEC-22 for inlets and access holes, and HEC-24 for pump stations. The FHWA editions cited are those listed in the FHWA hydraulics library as of October 2026.

## 9.2 General requirements

9.2.1 **Tailwater.** Every structure that discharges to a river, stream, jhora, pung, lake or reservoir whose level can rise above the outfall invert shall be analysed with the tailwater conditions of Chapter 5: the non-tidal tailwater of Clause 5.6 for minor- and major-system design; the riverine backwater of Clause 5.8, including the flood released from any dam upstream, such as Umiam–Umtru Stages III and IV (Kyrdemkulai and Nongkhyllem) and New Umtru on the Umtru above Byrnihat, and Myntdu–Leshka on the Myntdu below Jowai; the outfall-closed check of Clause 5.10 wherever the

receiving water can rise above the outfall invert, which is the case for the drains of the valley floors of Shillong that outfall to the Umkhrah and the Umshyrpi at Polo, Pynthorbah, Nongmynsong, Forest Colony, Mawlai, Dhankheti and Nongrim Hills (Clause 5.8.5(a)), for those of Dawki that outfall to the Umngot, for those of Byrnihat that outfall to the Umtru below New Umtru, for those of the Garo foothill plains, Phulbari and Tikrikilla among them, that outfall to the Jinjiram and the Krishnai under river backwater (Clause 5.8.5(e)), for those of Baghmara and Dalu that outfall to the south Garo rivers, and for the drains of the Umiam lake shore, which end in a reservoir; for an outfall to a reservoir, its maximum water level, or its full reservoir level plus the surcharge in the design flood, as Chapter 5 sets it, or, where neither is published, the full reservoir level plus 0.5 m (set by this Manual), with the levels of MePGCL (Myntdu–Leshka Stage I, full reservoir and maximum water level 618.00 m; New Umtru, full reservoir level 130.10 m and maximum water level 132.78 m; Umiam–Umtru Stage III, full reservoir level 2,230 ft and maximum water level 2,235 ft, about 679.7 m and 681.2 m at 0.3048 m per foot; Stage IV, 503.00 m), and for Umiam (Barapani) Stage I, whose full level is known only from the press as 3,220 ft (about 981.5 m, on an unknown datum) and for which no MePGCL guideline was found, the level that MePGCL states on a named datum [TBC]; for an outfall to a pung or lake, Ward's Lake (Nan Polok) and Thadlaskein (Pung Sajar Nangli) among them, its surveyed spill level (Clause 5.8.5(d)); for an outfall to a stream or jhora that has no gauge, which is every stream in the towns, among them the Umkhrah and the Umshyrpi in Shillong, the level of the 1% AEP flood in the reach, computed with the sediment, debris and garbage allowances of Chapter 6 (Clause 6.3.6) and checked against surveyed flood marks, with the outfall invert at least 0.5 m above the highest surveyed bed (Clause 5.8.5(c)); for a river reach without a CWC site, among them the Myntdu at Jowai, the Umtru at Byrnihat, the Simsang at Williamnagar and the Ganol at Tura, the flood-mark profile of the reach; the level held in a drain by any sluice, check dam, weir or pumping station downstream of the outfall, taken as a fixed control at its gate-closed level, its weir crest or the start level of its pumps; and the joint case of Clause 2.12. No CWC site in Meghalaya has a warning or a danger level, and none forecasts floods; CWC monitors levels at seven sites, five of which have a published high flood level: 73.47 m on the Umngot at Dawki (28 May 2006), 20.62 m on the Umnohryngkew at Therriaghat (15 June 1995), 47.0 m on the Myntdu at Kharkhana (23 April 1995), 29.75 m on the Bugi at Dimapara (27 July 2007) and 20.34 m on the Dareng at Sibbari (12 August 2017) (CWC levels as transcribed by SANDRP, as reported; the datum of none is stated [TBC]), and the levels of the Kopili at Kampur and Dharamtul are on reaches in Assam that the Assam edition governs; readings of a local gauge published in the press, on another zero, are never mixed with them. No document found sets a design river, reservoir, pung, lake, stream or jhora level at any outfall in Meghalaya, and no flood zone has been notified under the Meghalaya Flood Plain Zoning Act, 2026; until one is, the levels of Chapter 5 apply.

9.2.2 **Climate factor.** Design flows shall include the climate factor of Clause 2.8.

9.2.3 **Maintenance access.** Every structure shall be accessible for inspection and cleaning by the methods in Clause 9.12 and Chapter 10, without manual entry into confined spaces wherever practicable.

9.2.4 **Design life.** Structures shall be designed for a service life of at least 50 years for concrete and masonry works, and at least 25 years for mechanical and electrical equipment, unless the approving authority agrees otherwise.

9.2.5 **Blockage.** Where a structure can be blocked by debris, it shall be checked in the blocked condition set out in this chapter, and a safe overflow route shall exist for that condition (Chapter 6, Clause 6.3.2).

> Commentary. The design-life values in Clause 9.2.4 have no direct precedent; this Manual sets them because they are needed to decide when the climate factor applies (Clause 2.8.2 applies it to elements with a design life over 25 years).

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## 9.3 Pipes and box drains

9.3.1 **Capacity and roughness.** Pipe and box-drain capacity shall be computed by Manning's equation with the design n of Chapter 6, Table 6.6. For precast or cast-in-situ RCC box drains, the design n shall be at least 0.015.

9.3.2 **Partly full flow.** Depth, velocity and discharge in partly full circular pipes shall be computed from the hydraulic-element relationships for circular sections (for example CPHEEO 2019, Table 5.5). The minimum velocity of Clause 6.7.3 applies at the design flow.

9.3.3 **Pressure flow.** Where a pipe runs full or surcharged, the HGL shall be computed under Chapter 6, Clause 6.8, with friction and structure losses.

9.3.4 **Steep pipes.** Where the design flow in a pipe is supercritical (Froude number above 1), the designer shall:

- (a) locate any hydraulic jump and show that it occurs in a structure designed to contain it, not in a pipe run;
- (b) provide air venting where the jump can seal the pipe; and
- (c) meet the maximum velocity of Clause 6.7.3(b).

9.3.5 **Changes of size and direction.**

- (a) Pipe size shall not decrease downstream.
- (b) Pipes shall join only at manholes or junction chambers, except that inlet connections may join pipes of 1,200 mm or more through a factory-made junction.
- (c) Changes of direction greater than 90° in a single structure are not permitted.

9.3.6 **Flotation.** Pipes and box drains in high groundwater shall be checked for flotation (Chapter 6, Clause 6.7.7).

> **Commentary.** The design n of 0.015 for box drains is set by this Manual to match the "fair" concrete value in Table 6.6. Clauses 9.3.4 and 9.3.5 follow common practice in FHWA HEC-22 and other manuals. A jump inside a pipe run causes pressure surges and can blow off manhole covers.

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## 9.4 Culverts

9.4.1 **Method.** Culverts shall be designed by the methods of FHWA *Hydraulic Design of Highway Culverts*, HDS-5, 3rd edition (2012), or by software that implements them (for example FHWA HY-8). The design headwater is the **greater** of the headwater under inlet control (HWi) and the headwater under outlet control (HWo).

9.4.2 **Inlet control.** HWi shall be computed from the HDS-5 inlet-control equations or nomographs for the barrel shape, material and inlet edge condition actually built.

9.4.3 **Outlet control.** HWo shall be computed as:

> HWo = ho + H − L·S

> H = [1 + ke + (19.63 n² L) / R^1.33] · V² / 2g (SI units, full barrel)

> ho = the greater of TW and (dc + D)/2

where ho is the outlet water depth used for control (m), H is the total head loss through the barrel (m), L is the barrel length (m), S is the barrel slope (m/m), ke is the entrance loss coefficient (Table 9.1), n is the barrel roughness, R is the hydraulic radius (m), V is the barrel velocity (m/s), TW is the tailwater depth above the outlet invert (m), dc is the critical depth (m) and D is the barrel rise (m). Part-full barrels under outlet control shall be analysed by backwater calculation as set out in HDS-5.

**Table 9.1 — Entrance loss coefficients ke (outlet control, full or partly full)**

| Barrel and inlet | ke |
|---|---|
| Concrete pipe, projecting from fill, socket (groove) end | 0.2 |
| Concrete pipe, projecting from fill, square-cut end | 0.5 |
| Concrete pipe, headwall or headwall with wingwalls, socket end | 0.2 |
| Concrete pipe, headwall or headwall with wingwalls, square edge | 0.5 |
| Concrete pipe, headwall, rounded entrance (radius = D/12) | 0.2 |
| Concrete pipe, mitred to conform to fill slope | 0.7 |
| Concrete pipe, bevelled edges | 0.2 |
| Corrugated metal pipe, projecting from fill | 0.9 |
| RCC box, headwall parallel to embankment, square edge on three sides | 0.5 |
| RCC box, headwall parallel to embankment, three edges rounded or bevelled | 0.2 |
| RCC box, wingwalls at 30°–75° to barrel, square-edged crown | 0.4 |
| RCC box, wingwalls at 10°–25° to barrel, square-edged crown | 0.5 |
| RCC box, wingwalls parallel (extension of sides), square-edged crown | 0.7 |

Source: FHWA HDS-5 (2012), entrance loss coefficient table (Appendix C).

9.4.4 **Tailwater.** TW shall be the higher of:

- (a) the normal or backwater depth in the downstream channel at the design flow; and
- (b) the tailwater level of Clause 9.2.1, for culverts within tidal or river backwater reach.

9.4.5 **Headwater limits.** At the design AEP of Chapter 6, Table 6.1:

- (a) HW/D shall not exceed 1.2;
- (b) the headwater shall be at least 0.3 m below the edge of the road shoulder at the upstream face; and
- (c) the headwater shall not raise water levels at any upstream building or property boundary above the limits of Chapter 6, Clause 6.12.2(d).

9.4.6 **Road overtopping.** Flow over the road in the check and 1% AEP events shall be computed with the broad-crested weir equation:

> Qr = Cd · L · h^1.5

where Qr is the overtopping flow (m³/s), L is the length of the overtopping section (m) and h is the depth of the headwater above the road crest (m). Cd shall be taken from HDS-5 for the road surface and the ratio of h to road width, and shall not exceed 1.66 (SI). The culvert and overtopping flows shall be balanced at a common headwater. The overtopping depths and hazard shall meet Chapter 6, Clause 6.12.

9.4.7 **Outlet velocity.** The outlet velocity at the design AEP and at the 1% AEP shall be computed and the outlet protected under Clause 9.6.

9.4.8 **Barrels and debris.**

- (a) Multi-barrel culverts shall be avoided in debris-prone urban drains. Where they are used, one barrel shall carry the dry-weather flow, and the inlet shall have a debris fin or deflector.
- (b) Culverts shall meet the minimum size and blockage checks of Chapter 6, Clauses 6.12.4 and 6.12.5.
- (c) Culvert inverts shall match the bed of the drain. They shall not be set above the bed, which traps silt and water upstream.

9.4.9 **Headwalls and cut-offs.** Inlets and outlets shall have headwalls, wingwalls and cut-off walls designed to prevent piping and undermining.

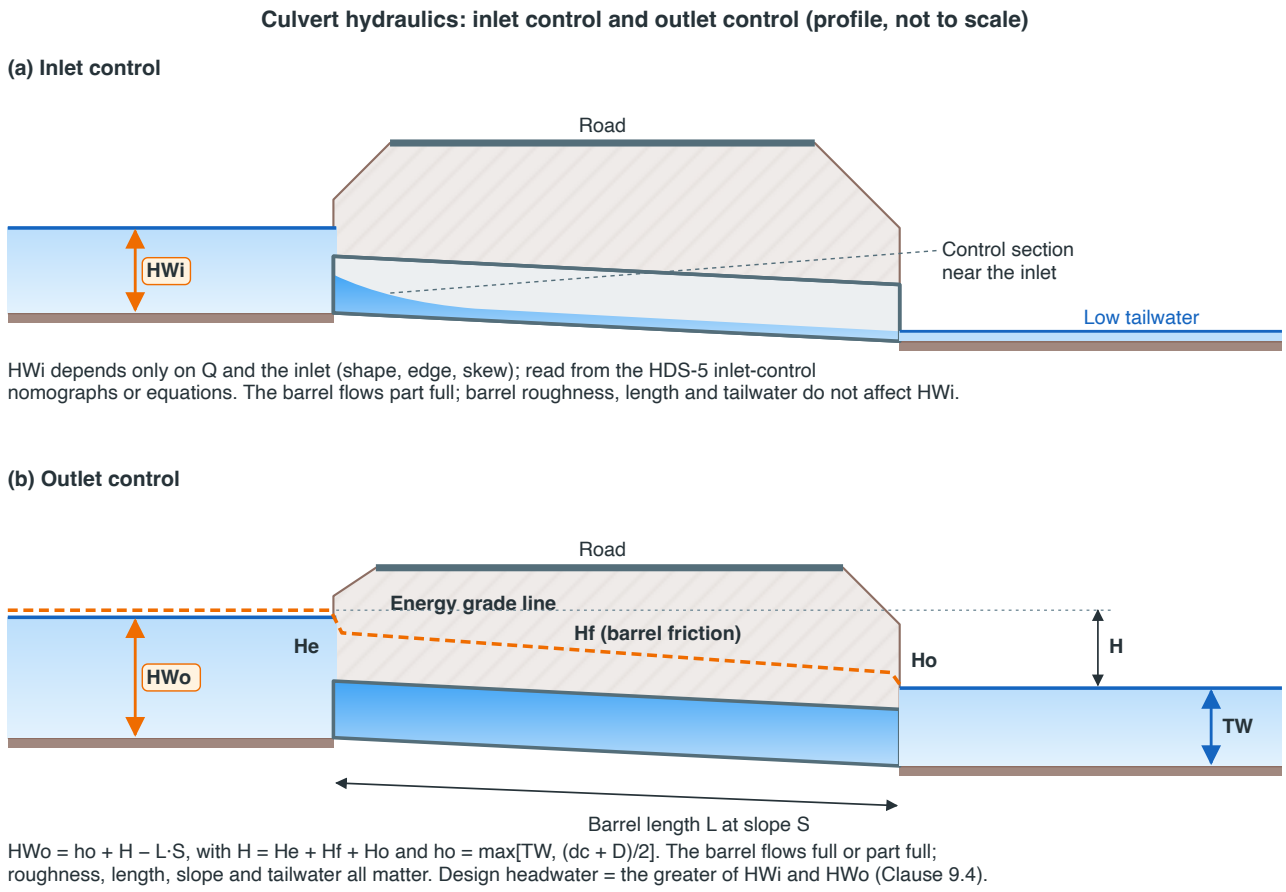


*Figure 9.1 — Culvert hydraulics: inlet control and outlet control. Original drawing for this Manual, adapted from FHWA, Hydraulic Design of Highway Culverts, HDS-5 (3rd ed., 2012).*

**Commentary.** HDS-5 (3rd ed., FHWA-HIF-12-026, April 2012) merged the culvert design material of HEC-5, HEC-10 and HEC-13 and is the current FHWA culvert manual. The outlet-control equation in Clause 9.4.3 is the HDS-5 energy equation in SI units: the friction coefficient 19.63 equals 2g. The ke values in Table 9.1 are reproduced from HDS-5. The weir coefficient cap of 1.66 (SI) is the conversion of the APWA 5600 (2006) limit of C ≤ 3.0 (US units) for overtopping calculations. The headwater limits of Clause 9.4.5 are set by this Manual: HW/D ≤ 1.2 keeps the inlet from operating far into submerged-orifice flow at the design event, where small increases in flow give large increases in headwater. Clause 9.4.8(c) has no direct precedent; it is included because raised culvert inverts are common in Meghalaya where a road is rebuilt on top of an old culvert, and they hold standing water and silt upstream.

## 9.5 Open channels

9.5.1 **Flow computation.** Open channels shall be designed by Manning's equation for uniform flow, with the n of Table 6.6. Water levels shall be computed by gradually varied flow (standard step) analysis where tailwater, bridges, culverts, bends or changes of section affect them, which on the drains of the valley floors of Shillong that outfall to the Umkhrah and the Umshyrpi, on the drains of the Umiam lake shore and of the towns below the dams of MePGCL, whose receiving levels the reservoirs and their releases set, on the flatter drains of the Garo foothill plains under the backwater of the Jinjiram and the Krishnai, and on the steep drains, jhoras and streets of Shillong, Jowai, Tura, Sohra and the other hill towns, stepped by drop structures and chutes and passing through critical depth at every step, is the normal case.

9.5.2 **Flow regime.** At the design flow, the Froude number shall not exceed 0.8 (CPHEEO 2019, §5.3), unless the channel is designed as a supercritical chute. Flows with a Froude number between 0.8 and 1.2 are not permitted at the design flow in any channel.

9.5.3 **Permissible velocities.** Mean velocity at the design flow shall not exceed the limits of Table 9.2.

**Table 9.2 — Maximum permissible mean velocities in channels**

| Lining or soil | Maximum velocity (m/s) | Source |
|---|---|---|
| Concrete lining | 3.0 | CPHEEO 2019 Table 5.11 |
| Riprap lining | 1.8 | CPHEEO 2019 Table 5.11 |
| Grassed lining | 1.2 | CPHEEO 2019 Table 5.11 |
| Stabilised earthen channel (modified natural channel) | 2.0, or the critical velocity if less | CPHEEO 2019 §5.10.3 |
| Unlined, fine sand | 0.46 | Fortier and Scobey (1926), clear water |
| Unlined, sandy loam | 0.53 | As above |
| Unlined, silt loam | 0.61 | As above |
| Unlined, firm loam | 0.76 | As above |
| Unlined, stiff clay | 1.14 | As above |
| Unlined, fine gravel | 0.76 | As above |
| Unlined, coarse gravel | 1.22 | As above |

Flexible linings (vegetation, riprap, geosynthetics) may instead be designed by the permissible shear stress method of FHWA HEC-15, *Design of Roadside Channels with Flexible Linings*, 3rd edition (2005).

9.5.4 **Longitudinal slope.** In engineered channels, the longitudinal slope shall not exceed 0.4% for natural linings and 0.2% for concrete linings, unless drop structures (Clause 9.6.6) or a chute are provided (CPHEEO 2019, Table 5.11).

9.5.5 **Freeboard and bends.** Freeboard shall meet Chapter 6, Table 6.7, measured above the water level that includes superelevation at bends. Bend radii shall meet Chapter 6, Clause 6.7.10.

9.5.6 **Side slopes.** Unless a structural or geotechnical design supports a steeper slope:

- (a) unlined earth channels shall have side slopes no steeper than 1V:2H; and
- (b) grassed channels that are mown shall have side slopes no steeper than 1V:3H.

9.5.7 **Low-flow channel.** Channels with a bed width of 3 m or more shall have a defined low-flow channel that carries the dry-weather flow at the self-cleansing velocity of Clause 6.7.3.

9.5.8 **Transitions.** Changes of section shall use gradual transitions. Abrupt expansions and contractions are not permitted in supercritical flow.

9.5.9 **Linings in high groundwater.** Lined channels in areas of high groundwater or tidal influence shall have weep holes with filters, or shall be designed to resist uplift with the channel empty.

9.5.10 **Natural channels.** Natural channels shall be preserved where possible (CPHEEO 2019, §5.10.3 note; Chapter 7). Where a natural channel must be modified, its capacity shall meet the design AEP of Chapter 6 and its velocities shall meet Table 9.2.

> Commentary. The lined-channel velocities and slopes are CPHEEO (2019) Table 5.11 values. The unlined-soil values are the classic Fortier and Scobey (1926) permissible velocities for clear water, as reproduced in Chow (1959). They are given for soils common in Meghalaya (the alluvium and valley fills of the Garo foothill plains and Ri-Bhoi, the sandstones, shales and mottled clays of the Garo Group, the thin red loams over the gneiss, quartzite and phyllite of the Shillong plateau, the laterite and the red and yellow soils of the south-west and of the country between Tura and the Bangladesh border, and the sandstones, shales, coal measures and cavernous limestones of the southern escarpment and the Jaintia hills, on which the boulders, gravel and garbage a flow carries, rather than the soil itself, decide what a channel bed must withstand (this Manual's reading)). The ban on Froude numbers between 0.8 and 1.2 extends CPHEEO's advice to avoid critical flow, where the water surface "becomes unstable and wavy" (§5.3). This extension is made by this Manual. The side slopes and the low-flow channel are also set by this Manual, because many Meghalaya urban channels carry sewage-mixed dry-weather flow until the cross-connections of Chapter 8 are removed. A wide flat bed then deposits sludge across its whole width, and a low-flow channel keeps the dry-weather flow concentrated.

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## 9.6 Energy dissipators, outlet protection and drop structures

9.6.1 **When required.** Outlet protection or an energy dissipator shall be provided at every pipe, culvert and channel outlet where the outlet velocity at the design AEP or the 1% AEP exceeds the permissible velocity of the receiving channel in Table 9.2, and at every outlet to an unlined channel, tank or waterbody.

9.6.2 **Method.** Energy dissipators and outlet protection shall be designed by the methods of FHWA HEC-14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*, 3rd edition (2006), selecting the dissipator type by its range of application.

9.6.3 **Riprap aprons.** For a circular outlet discharging to a flat apron, the median riprap size shall be computed with the HEC-14 apron equation:

$$D_{50} = 0.2 \cdot D \cdot \left[ Q / \left( g^{0.5} \cdot D^{2.5} \right) \right]^{(4/3)} \cdot (D / TW)$$

where $D_{50}$ is the median stone size (m), $D$ is the culvert diameter or rise (m), $Q$ is the design discharge (m³/s), $g = 9.81$ m/s² and $TW$ is the tailwater depth (m). Where $TW$ is not known, it shall be taken as $0.4D$.

Apron length and thickness shall follow the HEC-14 riprap-class table (Table 9.3). The apron width at the outlet shall be at least $3D$ and shall flare to the downstream channel.

**Table 9.3 — Riprap classes and apron dimensions (HEC-14)**

| Class | D50 (mm) | Apron length | Apron thickness |
|---|---|---|---|
| 1 | 125 | 4D | 3.5 D50 |
| 2 | 150 | 4D | 3.3 D50 |
| 3 | 250 | 5D | 2.4 D50 |
| 4 | 350 | 6D | 2.2 D50 |
| 5 | 500 | 7D | 2.0 D50 |
| 6 | 550 | 8D | 2.0 D50 |

Source: FHWA HEC-14 (2006), §10.2 and Table 10.1, as reproduced in state-agency design worksheets. Where the computed D50 exceeds Class 6, a riprap basin or a structural stilling basin shall be used.

9.6.4 **Riprap filter and grading.** Riprap shall be placed on a granular filter or a geotextile. Stone shall be angular, durable and graded so that the D50 of Clause 9.6.3 is met.

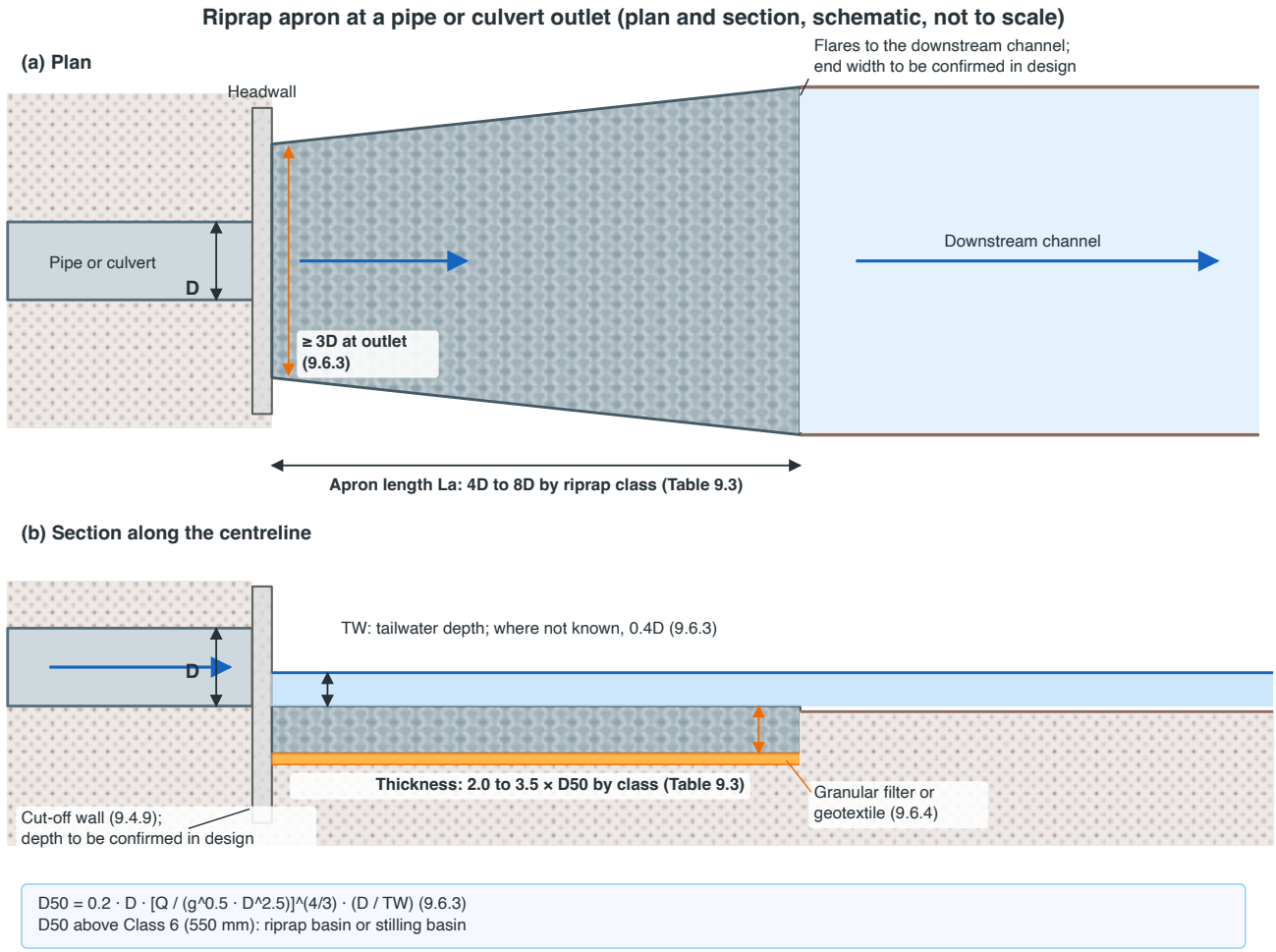


*Figure 9.2 — Riprap apron at a pipe or culvert outlet: apron width at least 3D at the outlet, flaring to the downstream channel; length and thickness from Table 9.3; stone on a granular filter or geotextile (Clauses 9.6.3 and 9.6.4). Original drawing for this Manual, adapted from FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, HEC-14 (3rd ed., 2006), §10.2.*

9.6.5 **Stilling basins.** Where velocities or Froude numbers are above the range of riprap aprons and basins, a structural stilling basin or impact basin shall be designed from HEC-14 or from the US Bureau of Reclamation basin types it describes.

9.6.6 **Drop structures.** Drop structures shall be used where the channel slope would otherwise exceed Clause 9.5.4 or the velocity limit of Table 9.2.

- (a) For a straight vertical drop, the drop number $D = q^2 / (g\,h^3)$ shall be computed, where q is the unit discharge ($m^2/s$) and h is the drop height (m). The pool geometry shall be set from the Rand (1955) relationships: drop length Ld/h = 4.30 D^0.27; pool depth Yp/h = 1.00 D^0.22; sequent depths y1/h = 0.54 D^0.425 and y2/h = 1.66 D^0.27.
- (b) Baffled chutes and stepped drops shall be designed by HEC-14 or US Bureau of Reclamation methods.
- (c) The height of a single vertical drop in a public drain shall not exceed 1.5 m. Drops shall have edge protection under Chapter 6, Clause 6.13.8.

9.6.7 **Coastal and beach outfalls.** Outfalls onto beaches or into estuaries shall be protected against wave action and scour. Where littoral sand can close the outfall, the outfall shall be designed so that it can be reopened by machine, and the drainage system shall be checked with the outfall closed under Chapter 5.

> Commentary. HEC-14 (3rd ed., FHWA-NHI-06-086, July 2006) is the current FHWA energy-dissipator manual. The apron equation and the class table are from HEC-14 §10.2 (Equation 10.4 and Table 10.1). The equation and table are given here as reproduced in secondary design documents (a Tennessee handbook and a state-agency riprap worksheet). The 3D apron width is from the same sources. A Purdue study (JTRP) found the HEC-14 apron method somewhat conservative within its range of application. The Rand (1955) drop relationships are standard and are reproduced in Chow (1959). The 1.5 m limit on a single vertical drop has no direct precedent; this Manual sets it for public safety in urban drains.

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## 9.7 Detention outlet structures

9.7.1 **Primary outlet.** The primary outlet of a detention facility shall:

- (a) produce the release rates and drawdown times of Chapter 4;
- (b) work without mechanical parts or operator action, except in pumped facilities (Clause 9.9);
- (c) have no orifice smaller than **50 mm**, and every orifice shall be protected by a trash screen (Clause 9.8.5); and
- (d) be accessible for cleaning from the surface.

9.7.2 **Orifices.** Orifice flow shall be computed as:

> $Q = C_d \cdot A \cdot (2\,g\,h)^{0.5}$

where A is the orifice area ($m^2$) and h is the head (m) on the centroid of the orifice, or the difference between the upstream and downstream water levels where the orifice is submerged. Cd shall be 0.60 for a sharp-edged orifice in a thin plate. Other edge conditions shall use published tested values.

9.7.3 **Weirs.** Weir flow shall be computed as $Q = C_w \cdot L \cdot H^{1.5}$, with:

- (a) sharp-crested rectangular weirs: Cw = 1.84 (SI), with the effective length reduced by 0.1 H for each end contraction;
- (b) V-notch weirs: $Q = 1.38 \cdot \tan(\theta/2) \cdot H^{2.5}$ (SI), where θ is the notch angle; and

- (c) broad-crested weirs and spillway crests: Cw = 1.44 to 1.70 (SI), selected from published tables for the crest shape and head.

Submerged weirs shall be corrected for submergence from published relationships.

9.7.4 **Stage–discharge rating.** For multi-stage outlets (orifices and weirs in a riser, with an outlet pipe), the designer shall compute, at each stage, the discharge under every possible control (each orifice, each weir, riser crest, and the outlet pipe under inlet and outlet control) and use the **smallest** combined value. The rating shall be tabulated from the outlet invert to the emergency spillway crest plus the design head.

9.7.5 **Tailwater.** Ratings shall be computed with the tailwater of Clause 9.2.1. Where the receiving water can rise above the outlet, the outlet shall have a flap gate or non-return valve under Clause 9.10, and the storage shall meet the outfall-closed check of Chapter 5.

9.7.6 **Emergency spillway.** The emergency spillway shall pass the 1% AEP inflow with the primary outlet assumed blocked and the basin full at the start, with **0.3 m** freeboard to the embankment crest. High-hazard basins shall also be checked for the 0.2% AEP inflow (Chapter 4).

9.7.7 **Outlet pipes through embankments.** Outlet pipes through embankments shall have a filter diaphragm or seepage collars to prevent piping along the pipe, and a flared or headwalled inlet.

9.7.8 **Anti-vortex.** Riser outlets with a design head above the riser crest greater than the riser diameter shall have an anti-vortex plate.

> Commentary. The 50 mm minimum orifice with a trash screen, the emergency-spillway criterion and the drawdown times are core criteria of this Manual (Chapter 4). The minimum orifice is smaller than the APWA 5600 (2006, 5608.4) minimum of 3 in (about 75 mm). It allows the low release rates of the Chapter 4 mixed-frequency rule on small sites, and it relies on a good screen (Clause 9.8.5). The "no mechanical parts" rule follows APWA 5600 (2006, 5608.4), which requires the primary outlet to function unattended. The orifice and weir coefficients are standard textbook values (for example Brater and King, *Handbook of Hydraulics*; Chow 1959). The 1.84 sharp-crested coefficient and the 0.1H end-contraction correction are the Francis formula in SI units. The broad-crested range 1.44–1.70 is the SI equivalent of the US range 2.6–3.1 commonly tabulated. Clauses 9.7.7 and 9.7.8 follow common dam and detention practice.

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## 9.8 Trash racks and screens

9.8.1 **Where required.** Trash racks or screens shall be provided:

- (a) where an open drain enters a pipe, covered drain or culvert longer than 30 m (Chapter 6, Clause 6.13.4);
- (b) at every detention outlet orifice (Clause 9.7.1);
- (c) at the inlet of every pump sump (Clause 9.9); and
- (d) at outfalls to waterbodies, as part of the gross pollutant trap of Chapter 8.

9.8.2 **Conduit-entrance racks.** Racks at the entrance to conduits and culverts shall have:

- (a) clear bar spacing not less than 75 mm and not more than half the smallest internal dimension of the conduit;
- (b) a gross area at least 4 times the conduit's cross-sectional area;
- (c) a mean velocity through the rack at the design flow, with 50% of the rack blocked, of not more than 1.0 m/s; and
- (d) an inclination no steeper than 1V:2H where the rack is to be raked by hand, with a working platform and handrail.

9.8.3 **Head loss.** Head loss through a clean rack shall be computed with the Kirschmer equation:

$$h_r = \beta \cdot (t / b)^{(4/3)} \cdot (V^2 / 2g) \cdot \sin\theta$$

where t is the bar thickness, b is the clear bar spacing, V is the approach velocity, θ is the angle of the rack from the horizontal, and β is the bar shape factor (2.42 for sharp-edged rectangular bars; 1.79 for circular bars). The HGL and headwater shall be checked with the rack **50% blocked** (head loss computed with half the open area).

9.8.4 **Overflow when blocked.** Every rack shall have an overflow route so that a fully blocked rack does not flood buildings or exceed the limits of Chapter 6.

9.8.5 **Detention outlet screens.** Screens over detention orifices shall have openings smaller than the orifice they protect, and an open area at least 10 times the orifice area.

9.8.6 **Pump sump screens.** Bar screens at pump-station inlets shall have a clear spacing smaller than the largest solid the pumps can pass, as stated by the pump manufacturer. Screens shall be built in removable modules, and a mechanically raked screen shall be used where the design inflow exceeds 1 m³/s.

9.8.7 **Safety.** Racks at the entrance to long conduits shall prevent people from being drawn in. They shall be designed for the hydrostatic load of a fully blocked rack.

> Commentary. CPHEEO (2019, §8.3.1.3) describes pump-station bar screens with a spacing of "approximately 58 mm", built in modules, with an emergency overflow in case of clogging. Clause 9.8.6 follows that approach but links the spacing to the pump's solids-passing size, which varies by pump. The 50% blockage check matches the grate clogging factor of Chapter 6. The Kirschmer equation and its shape factors are standard (Kirschmer 1926, as reproduced in hydraulic handbooks). The rack spacing, area ratio, through-velocity, the 30 m conduit length trigger, the 10× screen area for orifices and the 1 m³/s trigger for mechanical raking have no direct precedent and are set by this Manual.

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## 9.9 Pumps and sumps

9.9.1 **When pumping is used.** Pumping shall be used only where gravity drainage cannot meet the requirements of Chapters 5 and 6, for example at road underpasses (Chapter 6, Clause 6.10.5), basements, low-lying areas and outfalls that are tide-locked under the outfall-closed check of Chapter 5.

9.9.2 **Design inflow and storage.** The station shall be designed with the inflow hydrograph routed through the catchment and any upstream storage. Pump capacity and storage shall be chosen together:

- (a) the station shall meet the design AEP of the element it serves (for underpasses, the 2% AEP with a 1% AEP check);
- (b) where the station serves a tidal outfall, storage plus pumps shall hold the 48 h design volume with the outfall throttled for the tidal-lock duration (default: two consecutive high tides of 6 h each), as required by Chapter 5; and
- (c) the pumps shall be selected for the full range of static head between the lowest sump level against the lowest tailwater, and the highest tailwater (HAT plus surge plus 0.3 m).

9.9.3 **Wet-well volume.** The effective wet-well volume (between the pump-stop and the lowest pump-start level) shall be the greatest of:

- (a) where variable-speed drives and automatic controls are installed, 5 minutes of the minimum inflow (CPHEEO 2019, §8.3.3);

- (b) otherwise, 10 to 15 minutes of the peak inflow, or the volume needed for the pump manufacturer's minimum cycle time, from $V = Q \cdot t$ (CPHEEO 2019, Eq. 8.1); and
- (c) for constant-speed pumps, the volume $V = \Theta \cdot q / 4$ for each pump, where $\Theta$ is the minimum cycle time recommended by the motor manufacturer and q is the pump capacity (FHWA HEC-24, 2001).

9.9.4 **Duty and standby.**

- (a) Duty pumps shall be of the same size where practicable (CPHEEO 2019, §8.3.3).
- (b) Standby capacity shall be at least equal to the largest duty pump, and not less than 50% of the number of duty pumps.
- (c) Duty and standby roles shall alternate automatically.

9.9.5 **Pump type.** Pumps shall be solids-handling (non-clog) types suited to stormwater with sand and debris. Axial-flow pumps shall be used only behind a screen that meets Clause 9.8.6, because they cannot handle debris (CPHEEO 2019, §8.3.2).

9.9.6 **Sump and intake design.** Sump geometry, pump spacing, minimum submergence and approach flow conditions shall follow the pump manufacturer's requirements and ANSI/HI 9.8 (Rotodynamic Pumps for Pump Intake Design). A physical hydraulic model study shall be carried out where any pump exceeds 1 $m^3/s$, or where the sump does not follow standard ANSI/HI 9.8 geometry. The minimum clear space between adjacent pumps or motors is 0.6 m for small and medium units and 1.0 m for large units (CPHEEO 2019, §8.2.5).

9.9.7 **Silt and screens.** A silt trap and a bar screen shall be provided upstream of the wet well (Clause 9.8.6; Chapter 6, Clause 6.13.3).

9.9.8 **Controls and monitoring.**

- (a) Pumps shall be controlled by a primary level sensor (ultrasonic, radar or pressure) with an independent float-switch back-up.
- (b) High-level and pump-fault alarms shall be sent by telemetry to the local body's control room.
- (c) Sump levels, pump run hours and power status shall be logged and kept for at least 5 years.

9.9.9 **Power supply.**

- (a) The station shall have two independent power sources: the grid supply and a standby generator (or a second independent grid feeder) able to run all duty pumps at once (CPHEEO 2019, §2.4.2.3(j)).
- (b) Fuel for at least **72 hours** of continuous operation of all duty pumps shall be stored on site, above the flood level of Clause 9.9.10.
- (c) Changeover to standby power shall be automatic.

9.9.10 **Flood protection of the station.** The floor of the electrical and control room, the generator and the transformer shall be at least 0.5 m above the 1% AEP flood level at the station (Chapter 6, Clause 6.11). Access to the station for maintenance vehicles shall remain usable in the 1% AEP event.

9.9.11 **Discharge.** Each pump shall have its own rising main, or a non-return valve and an isolating valve where mains combine. Rising mains shall discharge into a delivery chamber or outfall fitted with a flap gate or non-return valve under Clause 9.10. Discharge piping shall be sized by a recognised friction formula (CPHEEO 2019, §8.3.9).

9.9.12 **Emergency connections.** Every station shall have a hard-standing area and a quick-coupling connection for mobile pumps to discharge into the delivery chamber.

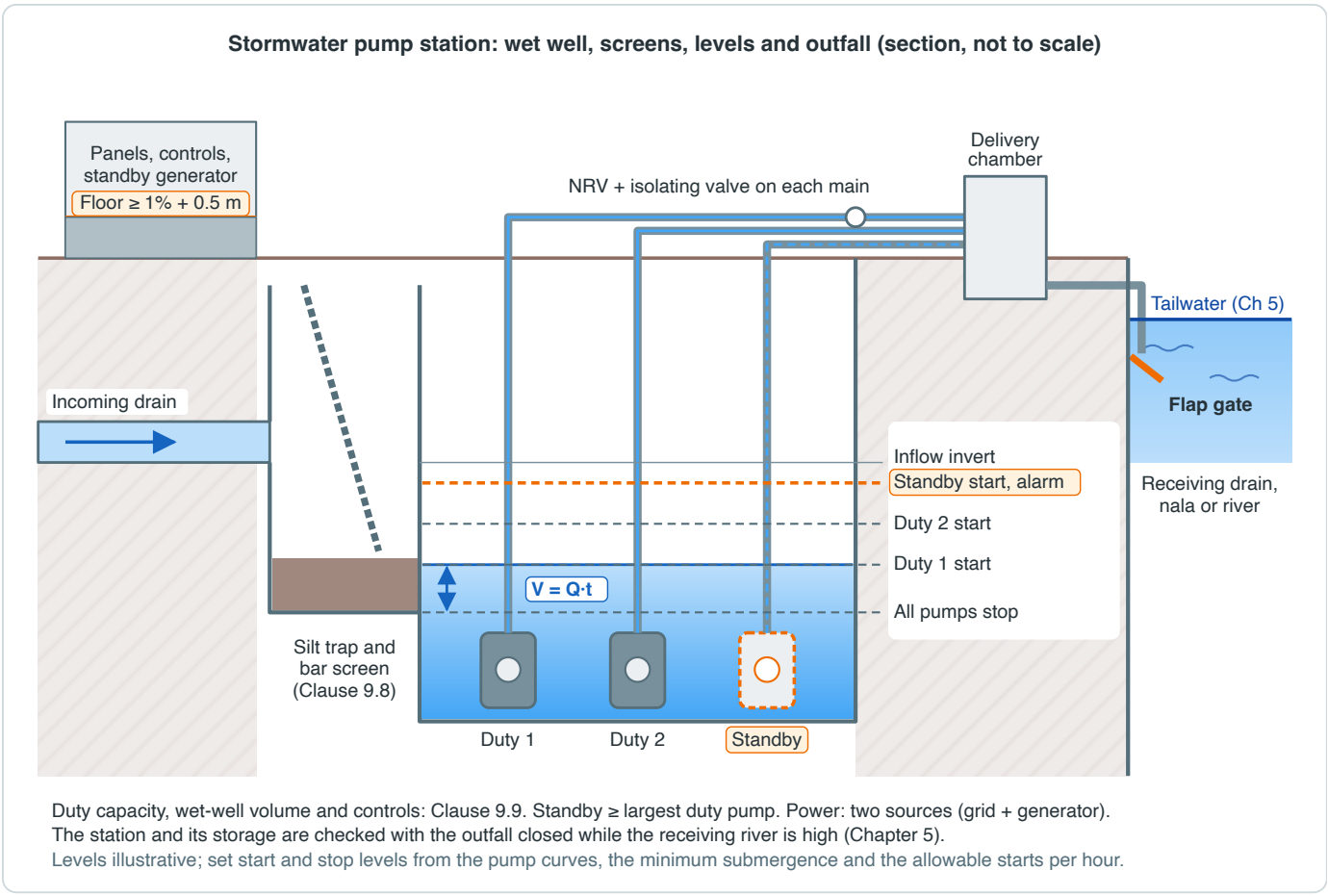


*Figure 9.3 — Stormwater pump station: wet well, screens, levels and outfall. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Chapter 8, and FHWA, Highway Stormwater Pump Station Design, HEC-24 (2001).*

> **Commentary.** CPHEEO (2019) Chapter 8 covers stormwater pumping: wet-well sizing (§8.3.3), pump types (§8.3.2), trash screens (§8.3.1.3), space requirements (§8.2.5) and the need for generator sets "as standby for emergency operation during failure of electricity" (§2.4.2.3). It recommends standby units of "minimum 50% of the duty pump units". Clause 9.9.4(b) is stricter: the standby must at least equal the largest duty pump, so the station still meets its design duty with its largest pump out of service. This stricter rule is set by this Manual. FHWA HEC-24 (*Highway Stormwater Pump Station Design*, FHWA-NHI-01-007, 2001) is the FHWA pump-station manual. The 72 h fuel storage is set by this Manual to match the 72 h design storm of Chapter 2. The model-study trigger, the telemetry and data-retention requirements, and the emergency connection have no direct precedent and are set by this Manual.

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## 9.10 Tide gates, flap gates and non-return valves

9.10.1 **Where required.** Flap gates, tide gates or non-return valves shall be provided on every outfall whose invert is below the 1% AEP still-water level of the receiving water (Chapter 5).

9.10.2 **Types.** Acceptable devices are:

- (a) hinged flap gates (cast iron, ductile iron, stainless steel, HDPE or composite);
- (b) elastomeric in-line or end-of-pipe check valves (duckbill type); and
- (c) penstocks or sluice gates, manual or motorised, as a secondary closure.

9.10.3 **Secondary closure.** Outfalls of 900 mm or more, and every outfall serving a pumped or storage system, shall have a penstock or stop-log slot upstream of the flap gate so that the gate can be maintained, and as a back-up if the gate jams open.

9.10.4 **Hydraulics.** The head loss through the device in the open position shall be taken from the manufacturer's tested data and included in the HGL (Chapter 6, Clause 6.8.7). Flap gates shall open at a small head difference (CPHEEO 2019, §6.3.10.1).

9.10.5 **Sand and debris.** At beach, estuary and creek outfalls where sand or debris can hold a gate open or shut:

- (a) the gate shall be housed in a chamber with surface access, or elastomeric check valves shall be used; and
- (b) the gate shall be inspected after every high-tide or surge event during the monsoon season (Chapter 10).

9.10.6 **Materials.** Hinges, pins, links and fixings shall be of corrosion-resistant material (CPHEEO 2019, §6.3.10.1). In coastal and tidal locations this means stainless steel grade 316, bronze or a non-metallic material (Clause 9.13).

9.10.7 **Storage behind gates.** Where gates close during a storm, the storage or pumping behind them shall meet the outfall-closed check of Chapter 5.

> Commentary. CPHEEO (2019, §6.3.10.1) describes flap gates and flood gates at outfalls to tidal waters. It notes that "adequate storage may be necessary if pumping is to be avoided during the closure of the gate" and that hinge pins and links "should be of corrosion-resistant materials". Meghalaya has no coast, so no outfall in the State is closed by the tide, and the beach, estuary, tidal and coastal provisions of Clauses 9.6.7, 9.9.2(b), 9.10.5 and 9.13.6, and the coastal and tidal rows of Table 9.5, do not arise; in Clause 9.9.2(c) the highest tailwater is the highest river, stream, reservoir, pung or lake level of Chapter 5. No pumping station on a storm drain was found anywhere in the State, and most outfalls fall freely to steep jhoras and gorges, so pumps and sumps under Clause 9.9 are needed only where the outfall-closed check of Chapter 5 shows that gravity cannot drain a site: on the valley floors of Shillong, at Polo, Pynthorbah, Nongmynsong, Forest Colony, Mawlai, Dhankheti and Nongrim Hills, which flood "with nearly every heavy downpour" when the Wah Umkhrah overflows (as reported; the same account is in the IRADe/NMHS plan for Shillong), and where NESAC maps the highest flash-flood susceptibility of the planning area (Clause 5.8.5(a)); on the Garo foothill plains of Phulbari and Tikrikilla under the backwater of the Jinjiram and the Krishnai (Clause 5.8.5(e)); and at Baghmara and Dalu on the south Garo rivers. Gates are still required below the 1% still-water level, because some town outfalls end in streams that rise above them and others in reservoirs. No CWC site in the State has a warning or a danger level; the Umngot at Dawki has a high flood level of 73.47 m on 28 May 2006 (CWC level as transcribed by SANDRP, as reported; the datum is not stated), on a pre-monsoon date, and in June 2026 it "rose rapidly", submerging a labour camp of a bridge project and sweeping away an excavator (as reported), so a drain of Dawki that outfalls below the river's flood level needs a flap gate, a penstock and either storage or a pumping station sized under Clause 9.9 and the outfall-closed check of Chapter 5. The drains of the Umiam lake shore end in the reservoir of Umiam (Barapani) Stage I, whose full level is known only from the press as 3,220 ft (about 981.5 m, on an unknown datum) and for which no gate-operation guideline of MePGCL was found [TBC], and Byrnihat lies on the Umtru 9.80 km below New Umtru (full reservoir level 130.10 m, maximum water level 132.78 m; spillway 3,820 m³/s on a catchment of 1,020 km²), whose release reach is a ravine to the Byrnihat bridge (MePGCL); an outfall to a reservoir or a release reach is checked against the maximum water level or the largest recorded release and, below it, needs a flap gate and storage, because MePGCL's guidelines say that notice of releases is "not practicable" and warn by siren, telephone or SMS instead. The escarpment rivers carry far larger floods per unit area than the northern slope: the spillway of Myntdu–Leshka Stage I is rated for 12,000 m³/s from 350 km², about 34 m³/s per km², against New Umtru's 3,820 m³/s from 1,020 km², about 3.7 m³/s per km² (MePGCL; ratios computed for this Manual). These dams are works of MePGCL, designed to dam-safety standards and not to this chapter, but their reservoir levels and releases are this chapter's boundary conditions. Most of the State drains steeply. The Shillong Planning Area has 102.05 km² of slopes of 15°–30°, 17.75 km² of 30°–40°, 3.2 km² of 40°–50°, which the master-plan report calls "Regulated Slope", and 0.53 km² above 50°, its "Restricted Slope/No Construction Zone" (NESAC, 2023), and the Bye-Laws 2021 forbid building only above 50° (Section I(a), 2024), far beyond the 0.4% and 0.2% of Clause 9.5.4, so drop

structures (Clause 9.6.6), stepped channels, baffled chutes and stilling basins (Clauses 9.6.5 and 9.6.6(b)) and supercritical chutes designed under Clause 9.5.2 are the normal case, not the exception, as IRC:SP:42-2014 (§8.5.1) already asks for lined, stepped or baffled drains on hill roads. In Meghalaya the following are set by this Manual, as in the mountain editions of this series, for a structure on a drain whose catchment includes an undeveloped hill slope, a jhora or a stream: (a) a drop or stepped channel shall have each pool shaped to drain dry and reachable by machine, and no single vertical drop shall exceed the 1.5 m of Clause 9.6.6(c); (b) where such a drain enters a pipe, covered drain or culvert, at the catchment size and with the sediment bulking and blockage factors that Chapter 6 sets (Clause 6.3.6), a debris rack, inclined so that the flow lifts debris onto it, shall stand upstream of the inlet, with a clear bar spacing chosen from a survey of the boulders and the garbage in the bed and not less than that of Clause 9.8.2(a), and a debris basin or sediment trap upstream of the rack; the basin volume shall be estimated from the debris and garbage deposited at the site in past floods and a stated debris-yield method, counting every slide scar, road cut, mine-spoil dump and garbage dump in the catchment as a source, because no Indian or Meghalaya guidance on sizing debris basins was found [TBC]; its spillway shall pass the 1% AEP inflow with the basin full of debris, as for Clause 9.7.6, and it shall have a ramp for the machines that empty it; (c) a culvert on a jhora shall have a single barrel where possible (Clause 9.4.8(a)), an armoured headwall and apron at the inlet with a deflector against boulders, an invert that follows the bed (Clause 9.4.8(c)), and an outlet protected under Clause 9.6 and led to a stable natural channel, never onto an unprotected slope, and in sub-areas ML-C and ML-C1 it shall also pass the 24-, 48- and 72-hour volumes of Clause 6.3.6(j), because on the escarpment near-peak flow lasts for hours; (d) every lined drain that receives runoff from unpaved slopes, hill roads, mine spoil or building sites shall have a sediment trap before it joins a public drain, a jhora, a pung or a reservoir, and every drain outfall to the Umkhrah, the Umshyrpi, the Wah Roro and Umiam lake, and every jhora below a settlement, a solid-waste trap or screen (Clause 6.3.6(i)); and (e) a lining in a steep drain shall be designed for the abrasion of the gravel and boulders it carries as well as for the velocity of Table 9.2. On limestone, within a coal-mining area and where caves or sinkholes are known, no structure of this chapter shall be built to exfiltrate, whatever a geotechnical certificate says: no soakaway, soak pit, exfiltrating chamber, perforated pipe or open-jointed drain; pipes, chambers and channels are watertight, routed away from cave entrances and checked for void collapse along their alignment (Clause 4.11, karst and mine rule), because water put into the "discontinuous aquifer in the cavernous limestones" (CGWB, 2022) or into the unfilled pits of the rat-hole workings, into which streams are reported to "disappear" (as reported), may go anywhere. The need is shown by the record. NESAC found that "Encroachment and clogging of channels are the main causes of flooding over Shillong" (2023); the IRADe/NMHS plan, that "the natural drainage system is blocked" by urbanisation and unregulated construction (2020); and drains blocked by waste are reported to raise the susceptibility of slopes to landslides, and encroachment to make the jhoras "more vulnerable to flooding" (ICLEI, as reported). The Bye-Laws 2021 already say that construction "should not obstruct existing surface drainage courses" (Section I(b), 2024) and list the "Clearing of clogged cross drainage works" among flood-protection measures (C12.3). The roads show the same failures: the repeated mudslides that closed NH-6 at the Sonapur tunnel, along a stream feeding the Lubha (August 2023; reopened May 2024), the landslides of 30–31 May 2025 in the Umling block near NH-6, linked to hill cutting, and the collapse of the Shillong–Dawki road at Laitlyngkot (chainage 25+200) in June 2026 (all as reported), so a road drain or culvert of PWD (Roads), NHAI or NHIDCL never discharges onto an unprotected slope. No structure of this chapter is designed to pass a debris flow or a landslide: in sub-areas ML-C and ML-C1, and on any drain below a mapped landslide zone, a debris fan, a mine-spoil dump, a karst sink or a reservoir release reach, the screening of Clause 2.3.6(i) comes first, and a structure is sited out of the hazard. Screens matter as much as gates, because the drains also carry garbage and sewage: Shillong has no sewerage, its drains and jhoras carry sullage and septic overflow to 32 outfalls on the Umkhrah and the Umshyrpi (MSPCB, as minuted on 14 April 2023), CPCB placed both rivers in Priority I of its polluted river stretches (2025), and 49,612 m³ of waste was removed from the Wahumkhrah under the 15th Finance Commission, with stone bunds and solid-waste traps built for ₹3.60 crore (State action-taken report to the National Green Tribunal, 21 March 2023), so a rack on a Meghalaya jhora is checked in the blocked case of Clause 9.8.4. No inventory of the sluices, flap gates, debris racks, solid-waste traps, sediment traps and pumping stations on the drains of any Meghalaya town, with their capacities and operating rules, no gate-operation guideline for Umiam Stage I, no operating rule for the gates of the State's dams that is linked to the towns below them, and no design river, reservoir, pung, lake, stream or jhora level at any outfall was found in the public domain. Clauses 9.10.3 and 9.10.5 are set by this

Manual because a flap gate, sluice or penstock that fails, or is jammed open by silt, gravel, boulders, slide debris, garbage or woody debris, lets a stream, river or reservoir in flood back into the drain network, and one jammed shut blocks it. The jhoras and streams of Meghalaya carry garbage and sewage as well as silt and debris: 49,612 m³ of waste was removed from the Wahumkhrah for ₹7.9 crore under the 15th Finance Commission, and stone bunds and solid-waste traps were built for ₹3.60 crore (State action-taken report to the National Green Tribunal in O.A. No. 192 of 2022, 21 March 2023); the Expert Committee annexed to the Waterbodies Guidelines found that Umiam lake "serves as a cesspool of the waste materials of Shillong" (2023); and the CAG found that none of the State's Municipal Boards had framed bye-laws under the Solid Waste Management Rules 2016 (performance audit of 2017-18 to 2021-22), so a gate, its screen and the debris rack above it are exposed to the same load and must be kept clear together; and because the reservoirs of MePGCL release water frequently, in the monsoon and outside it, with warnings by siren, telephone or SMS in place of notices (MePGCL gate-operation guidelines), a gate on an outfall to a reservoir or to a reach below a dam can be exposed without notice for the whole of a flood.

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## 9.11 Inlets and gratings

9.11.1 **Hydraulics.** Inlet capacity, spacing and clogging shall follow Chapter 6, Clause 6.6.

9.11.2 **Load class.** Gratings, covers and frames shall be rated for the traffic at their location. Load classes shall be those of IS 1726 (cast iron manhole covers and frames) or EN 124 (gully tops and manhole tops), at least:

- (a) carriageways and medians: EN 124 class D400 or the equivalent heavy-duty IS class;
- (b) kerb-side channel inlets within 0.5 m of the kerb: class C250 or equivalent; and
- (c) footpaths and cycle tracks: class B125 or equivalent.

9.11.3 **Grate pattern.**

- (a) Grates in carriageways, cycle tracks and footpaths shall not have openings parallel to the direction of travel wider than 25 mm.
- (b) Grate types without tested capacity data shall be rated by the weir and orifice methods of FHWA HEC-22 (2024), with the clogging factors of Chapter 6.

9.11.4 **Kerb openings.** Kerb-opening inlets shall have a clear opening height of at least 100 mm and a length of at least 1.0 m. Where a kerb inlet discharges through the wall of a covered drain (Chapter 6, Clause 6.13.1), the opening shall be at road level.

9.11.5 **Security.** Gratings and covers on public land shall be hinged or locked to their frames, so that they cannot be removed without a tool.

9.11.6 **Inlet chambers.** Inlet chambers shall have the silt sump of Chapter 6, Clause 6.6.7, and shall be sized so that the sump can be emptied by a suction or grab machine.

Commentary. NDMA (2010, §4.13) cites IS 5961 for cast-iron gratings for drainage inlets. The load classes are based on the EN 124 classes used internationally. The 25 mm limit on parallel openings is set for cyclist and pedestrian safety. APWA 5600 (2006, 5604.2) requires kerb openings of at least 4 ft (about 1.2 m) long and 6 in (about 150 mm) clear height. Clause 9.11.4 sets smaller minimums suited to the narrower roads and lower kerbs common in Meghalaya towns.

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## 9.12 Manholes, junction chambers and access

9.12.1 **Location and spacing.** Manholes shall be provided at the locations and spacings of Chapter 6, Clause 6.7.11 and Table 6.8. Where pipes are too large for a standard manhole, a junction chamber with a riser to the surface shall be used (CPHEEO 2019, §11.3.7.3).

9.12.2 **Minimum internal size.** Manholes shall have at least the internal dimensions of Table 9.4 (CPHEEO 2019, §11.3.7.6):

**Table 9.4 — Minimum internal size of manholes**

| Shape and depth | Minimum internal size |
|---|---|
| Rectangular, depth below 0.9 m | 900 mm × 800 mm |
| Rectangular, depth 0.9–2.5 m | 1,200 mm × 900 mm |
| Circular, depth above 0.9 m and up to 1.65 m | 900 mm diameter |
| Circular, depth above 1.65 m and up to 2.30 m | 1,200 mm diameter |
| Circular, depth above 2.30 m and up to 6.0 m | 1,500 mm diameter |
| Circular, depth above 6.0 m and up to 9.0 m | 1,800 mm diameter |

The manhole shall also be large enough to fit the largest pipe connected plus the benching on each side.

9.12.3 **Access openings.** The clear access opening of manholes and access chambers on public drains shall be at least 600 mm, so that cleaning equipment can be lowered.

9.12.4 **Drops.** Where the difference between incoming and outgoing inverts exceeds 0.6 m, a drop connection shall be provided. Below 0.6 m, the difference shall be taken up by adjusting the slope of the incoming pipe or the benching (CPHEEO 2019, §11.3.7.5). The invert drop across a manhole where pipe size changes shall be at least the following fraction of the difference in diameters (CPHEEO 2019, Table 11.6):

- conduits below 400 mm: one-half;
- 400 mm to 900 mm: two-thirds;
- above 900 mm: four-fifths.

9.12.5 **Benching.** Manhole floors shall be benched to at least the crown of the outgoing pipe, with channels shaped to guide flow from each incoming pipe.

9.12.6 **Surcharge.** Manholes on mains where the 1% AEP HGL can rise above the cover (Chapter 6, Clause 6.8.4) shall have bolted, locked or hinged covers designed for that pressure.

9.12.7 **Mechanical cleaning.** Manholes, chambers and covered drains shall be designed for cleaning by machine (suction, jetting, grab or robotic equipment) from the surface. Fixed ladders shall be of corrosion-resistant, encapsulated material where provided.

> **Commentary.** The size and drop requirements are from CPHEEO (2019) Chapter 11. The 600 mm access opening, the benching rule and the bolted covers are set by this Manual. Designing for mechanical cleaning supports the prohibition on hazardous manual cleaning under *The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013*.

## 9.13 Materials and durability

9.13.1 **Exposure classes.** Concrete structures shall be designed for the exposure class of IS 456: 2000, Table 3. In Meghalaya the minimum classes of Table 9.5 apply unless a site investigation shows a more severe condition:

**Table 9.5 — Minimum IS 456 exposure classes for Meghalaya locations**

| Location | Minimum IS 456 exposure class |
|---|---|
| Inland drains and structures | Moderate |
| Drains and structures in the coastal environment, and any drain that carries or may carry sewage-mixed flow | Severe |
| Structures exposed to sea-water spray, or in contact with saline or aggressive groundwater | Very severe |
| Structures in the tidal zone | Extreme |

9.13.2 **Concrete.** Minimum concrete grade, maximum water–cement ratio, minimum cement content and nominal cover to reinforcement shall be those of IS 456 for the exposure class. For the reader's convenience, IS 456 sets the minimum reinforced-concrete grades as M25 (moderate), M30 (severe), M35 (very severe) and M40 (extreme), and the nominal covers as 30, 45, 50 and 75 mm respectively.

9.13.3 **Aggressive ground.** Groundwater and soil at every structure in coastal and delta areas shall be tested for chlorides and sulphates. Cement type and concrete mix shall be chosen to suit the results under IS 456.

9.13.4 **Sewage-mixed flow.** Pipes and covered drains that carry, or may carry, sewage-mixed flow shall be protected against sulphide (crown) corrosion, by a sacrificial concrete thickness, a corrosion-resistant lining or a non-concrete pipe material.

9.13.5 **Pipes.** Concrete pipes shall comply with IS 458, with the class selected by structural design. Other pipe materials (for example ductile iron, HDPE or structured-wall plastic pipes) shall comply with the applicable Indian Standard and be approved by the approving authority.

9.13.6 **Metalwork.** Within 5 km of the coast, and in all tidal and saline locations:

- (a) fixings, hinges, ladders, handrails and screen frames shall be stainless steel grade 316, or hot-dip galvanised steel with a protective coating, or a non-metallic material; and
- (b) dissimilar metals shall be isolated from each other.

9.13.7 **Masonry.** New public drains in Tier A bodies shall be in reinforced or plain concrete. Brick or stone masonry may be used for drains in Tier B bodies only if it is plastered on the wetted face and meets the n value of Table 6.6.

> **Commentary.** The IS 456 exposure classes and the grade and cover values are quoted from IS 456: 2000 (Tables 3, 5 and 16) for convenience. The standard governs, and designers shall use its current amendment. Assigning Meghalaya locations to exposure classes, the sulphide-corrosion requirement and the ban on new masonry drains in Tier A bodies have no direct precedent and are set by this Manual. Drains that receive sewage cross-connections (a common condition, Chapter 8) generate hydrogen sulphide, which attacks unprotected concrete above the water line.

## 9.14 Submittal requirements

Every structure design shall be submitted with a **Hydraulic Structures Report** (Form 9-1) containing, as applicable:

1. culvert calculations (HDS-5 or HY-8 output) with HWi, HWo, outlet velocity, tailwater, overtopping and the blockage check;
2. channel water-surface profiles, velocities, Froude numbers and freeboard;
3. outlet protection and dissipator design, with riprap sizing;
4. detention outlet stage–discharge tables and the emergency spillway check;
5. screen and rack design with the 50% blocked check;
6. a pump station design report: inflow hydrograph, storage, pump curves and system curves, wet-well volume, controls, power supply and the Chapter 5 outfall-closed check;
7. gate and valve selection with head-loss data;
8. inlet, grate and cover load classes; and
9. an exposure class and materials statement (Clause 9.13).

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## References (chapter)


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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 9A | HDS-5 inlet-control coefficients and worked culvert example in SI units |
| 9B | Standard drawings: headwalls, riprap aprons, drop structures, trash racks, detention risers |
| 9C | Pump station design checklist and standard control philosophy |

| Annex / Form | Content |
| --- | --- |
| Form 9-1 | Hydraulic Structures Report checklist |

CHAPTER 10

# Submittals, Review, Operation & Maintenance and Enforcement

## 10.1 Purpose and scope

10.1.1 This chapter sets out how compliance with this Manual is shown, checked, built, kept working and enforced. It covers:

- (a) the submittal stages and their contents (Clauses 10.3–10.4);
- (b) the compliance calculator (Clause 10.5);
- (c) professional certification and review (Clauses 10.6–10.7);
- (d) construction inspection and as-built certification (Clauses 10.8–10.9);
- (e) maintenance declarations, O&M plans, inspection and access (Clauses 10.10–10.13);
- (f) handover of public assets (Clause 10.14);
- (g) enforcement (Clause 10.15); and
- (h) monitoring, post-event review and data publication (Clauses 10.16–10.17).

10.1.2 This chapter applies to every development and public work to which Chapters 4 and 5 apply under Clause 1.5.2. Clauses 10.3.1 (Stage 0), 10.15 and 10.17 also apply to development that is subject only to Clause 1.5.4.

> Commentary. A criterion that is not checked at approval, built as approved, and maintained afterwards has no effect. In Meghalaya the failure is one of missing criteria and of an approval system split by the Sixth Schedule. No document of the Urban Affairs Department, MUDA, a Municipal Board, a District Council, PWD or the Water Resources Department stating a design return period, intensity or runoff coefficient for the storm drains of any town was found; the Bye-Laws 2021 leave drainage to the National Building Code 2016 (D4.2, D5.6), and Shillong's 148.91 km of drains, which "drain directly into the Umkhrah and Umshyrpi rivers", covered "less than 75%" of the city with "sewerage mixing in drains … almost 100%" (Smart City Proposal 2016-17, as quoted in the IRADe/NMHS plan, whose own service-level table gives 85% coverage, a conflict). The approval route shapes this chapter. The Bye-Laws 2021 (Notification No. UAU.73/2016/Pt/402 of 9 March 2021, under s.74 of the Meghalaya Town and Country Planning Act, 1973, as amended to May 2026) apply only to "all the Master Plan Areas, Municipal areas and Scheme Areas within the State" (A1.2), and their "Authority" is "the Meghalaya Urban Development Authority / Autonomous District Councils as applicable" (A2.5); permissions are applied for through the Online Building Permission System, in force since 2025 (Section J, 13 August 2025). The Bye-Laws already ask for much of what a drainage submittal needs: a site plan showing "Surface drains, position and sizes of septic tank and soak pit in cubic dimensions" and rainwater harvesting, a roof plan "indicating drainage and roof slope", and for large projects a services and utilities plan with the "drainage and storm water disposal system"; a soil report from a geotechnical expert where the soil is weak (B1(vi)); cuts of not more than 3.00 m, or 6.00 m to the crest of an RCC wall, with a report of the Geological Survey of India beyond 6.00 m (B1(vii)); a stilt at least 1.20 m above the Highest Flood Level on sloping sites beside a stream or river (B1(v)(b)); the drainage and sediment measures of Section I(b) in hazard-prone areas, among them diversion ditches and swales "into designated sediment basins" and silt fences (2024); and the setbacks and regulated zones of the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023 (B2(ii)(c) and Section I(f), 2024). Outside those areas, which hold the Town Committee and census-town areas, "47 per cent of the total urban population", governed by the District Councils

(CAG, performance audit on solid waste management, 2017-18 to 2021-22), building is regulated in the Khasi Hills by the KHADC's Land Development and Building Regulation, 2015, with permissions issued by its building authority, the KHBSRA, since 2020 (as reported) on Forms I (application), II (commencement) and III (completion); its drawings show "the highest flood level (HFL) reached above the street in front of the building" and "adequate arrangements for proper drainage, sewerage and surface drains", and s.36 requires the plans to "indicate the system of storm water drainage along with points of collection of rain water". The building instruments of the JHADC and the GHADC were not found [TBC]. The two regimes are disputed: the Urban Affairs Department is reported to have notified the three District Councils to implement building bye-laws outside the municipalities on 1 February 2019 (number not found), and the KHADC's Executive Committee is reported to have "outright rejected" the Bye-Laws 2021 on 25 October 2021 as encroaching on Sixth Schedule areas (as reported; present status not known [TBC]); this Manual takes no side. Inside municipal limits no building may be put up without the Board's sanction (Meghalaya Municipal Act, 1973, s.171), and no drain may be led into a Board drain or water-course without its written consent (s.204). The Meghalaya Flood Plain Zoning Act, 2026 lets the Flood Zoning Authority require its permission for activities in notified restricted zones, deemed given if not refused within 90 days (s.12, as read in the Bill), but no Authority, rule or zone has been found. No rule asks for a drainage report, limits peak runoff, requires on-site detention or sets a design storm. Every stormwater item in this chapter is therefore written so that the architect or engineer on record can certify it on Forms 1-1, 2-1, 10-2 and 10-3, and the Authority can check it with the drawings that the Bye-Laws 2021 already require through the Online Building Permission System, beside the site plan with its surface drains and soak pits and with the Section I(b) measures; in the Khasi Hills, with the KHADC's Forms I–III, where the storm-drainage layout of s.36 is the hook for the simplified drainage plan of this chapter, if the District Council adopts the Manual; where cuts exceed 6.00 m, with the report of the Geological Survey of India, which shall then also confirm that no runoff is put into the ground (Clause 4.11); and at completion. This chapter is the process.

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## 10.2 Definitions

| Term | Meaning in this chapter |
|---|---|
| Submittal | A set of documents lodged with the Authority at one of the stages of Clause 10.3. |
| Drainage report | The preliminary (Stage 1) or final (Stage 2) report required by Clause 10.4. |
| Stormwater facility | Any retention, detention, water quality, conveyance, pumping, gate or outfall element required by this Manual, public or private. |
| Hold point | A construction stage at which work shall not proceed until the Authority or the certifying professional has inspected it (Clause 10.8). |
| As-built certificate | The certificate of Clause 10.9 that the facility was built as approved and performs as designed. |
| Owner | The person or body responsible for a facility under its maintenance declaration, or the ULB for a handed-over asset. |
| O&M plan | The operation and maintenance plan of Clause 10.11. |
| Facility register | The public register of facilities of Clause 10.17. |

Other terms are defined in Clause 1.4.

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## 10.3 Submittal stages

10.3.1 Submittals shall be made in the following stages, linked to the approval steps of the Meghalaya Building Bye-Laws 2021 (Table 10.1):

**Table 10.1 — Submittal stages and linked approvals**

| Stage | Submittal | When | Linked approval |
|---|---|---|---|
| 0 | **Pre-application** meeting and **Form 1-1** (Applicability Determination) | Before the planning permission or layout application | None (advisory record) |
| 1 | **Preliminary drainage report** | With the planning permission or layout application | Planning permission / layout approval |
| 2 | **Final drainage design** | Before building permit, or before commencement where the permit is issued with the planning permission | Building permit / commencement |
| 3 | **Construction inspections** at hold points | During construction | None (records filed) |
| 4 | **As-built certificate** and verification tests | Before the completion certificate | Completion / occupancy certificate |
| 5 | **Maintenance declaration** registered, or **handover** of public assets | Before or with the completion certificate | Completion certificate; asset acceptance |
| 6 | **Annual declarations** and inspection reports | Every year after completion | Continuing compliance |

10.3.2 **Stage 0 is mandatory** for:

- (a) sites of 2 ha or more;
- (b) sites in a flood-sensitive catchment;
- (c) sites proposing a variance, waiver, regional facility or fee-in-lieu; and
- (d) sites draining to a tidal outfall or adjoining a waterbody.

For other sites, Stage 0 is optional, and Form 1-1 is lodged with Stage 1.

10.3.3 **Combined stages.** For sites of less than 1 ha outside flood-sensitive catchments, the Authority may accept Stages 1 and 2 as one submittal.

10.3.4 **Public works.** For a public work, Stage 1 is the drainage section of the DPR and Stage 2 is the drainage section of the tender drawings. The sanctioning authority shall not sanction or tender the work until the relevant stage has been reviewed under Clause 10.7.

10.3.5 **Changes after approval.** Any change that alters impervious area, levels, storage, outlet or outfall after Stage 2 shall be resubmitted, with the compliance calculator re-run, before the change is built.

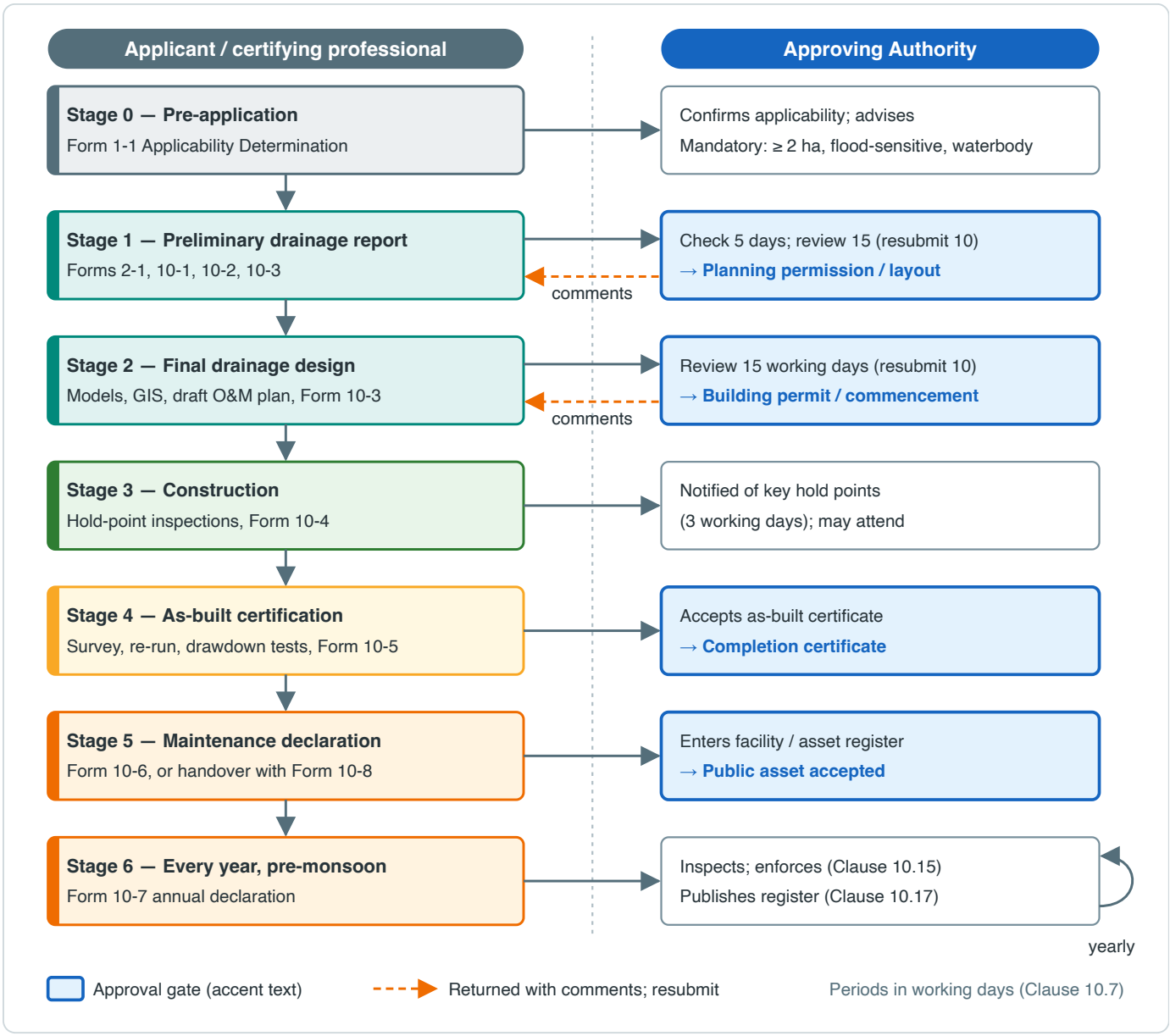


*Figure 10.1 — Submittal, review and approval workflow (Clauses 10.3–10.10). Original drawing for this Manual.*

> **Commentary.** The stages follow the APWA 5600 sequence of preliminary and final stormwater studies, construction inspection and maintenance agreements (APWA 5600, 2006, §5608 and §5609), mapped onto the Bye-Laws 2021 steps a Meghalaya applicant already follows. Linking Stage 4 to the completion certificate copies the MBBL 2016 RWH model, which requires inspection before the completion certificate (MBBL 2016, §9.6). The 2 ha and 1 ha limits in Clauses 10.3.2 and 10.3.3 have no direct precedent and are set by this Manual.

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## 10.4 Required contents and checklists

10.4.1 **Preliminary drainage report (Stage 1).** The report shall contain at least:

- (a) Form 1-1 and, where applicable, Form 1-2 (Variance / Waiver Request);
- (b) a site plan with existing and proposed levels, impervious areas, and the catchment boundaries draining to and through the site;
- (c) soils (HSG), the seasonal high groundwater table, and infiltration test results or a test plan (Chapter 3);

- (d) the **Design Rainfall Sheet (Form 2-1)**, completed as Clause 2.13 requires;
- (e) the pre-development condition and hydrologic method (Chapter 3);
- (f) how the hierarchy of Clause 1.2 has been applied: areas preserved, retention method, detention concept and conveyance;
- (g) preliminary retention, water quality and detention volumes, and release rates, from the compliance calculator (Clause 10.5);
- (h) the downstream extent and tailwater case (Chapter 5);
- (i) waterbodies, setbacks and the 1% AEP level (Chapters 6 and 7); and
- (j) the land reserved for facilities and maintenance access (Clause 10.13).

10.4.2 **Final drainage design (Stage 2).** The final design shall contain, in addition to updated Stage 1 contents:

- (a) the final calculations for every storage duration of Clause 2.5.2 and every AEP required by Chapter 4, including the outfall-closed check of Chapter 5;
- (b) stage–storage–discharge tables for each facility, and the emergency spillway design (Chapter 4);
- (c) hydraulic design of conveyance elements, inlets and structures (Chapters 6 and 9);
- (d) the water quality design and the first-flush or gross pollutant trap where required (Chapter 8);
- (e) construction drawings, details and specifications of every facility;
- (f) the construction sequence, including protection of retention and infiltration areas from sediment and compaction (Clause 10.8.3);
- (g) the hold-point schedule (Clause 10.8);
- (h) the draft O&M plan (Clause 10.11) and draft maintenance declaration (Clause 10.10);
- (i) the model input files and the GIS data of Clause 10.4.4; and
- (j) the certificates of Clause 10.6.

10.4.3 **Checklist.** Each submittal shall include the **Drainage Report Checklist (Form 10-1)**, showing for each item of Clauses 10.4.1–10.4.2 the page or sheet where it is addressed, or the reason it does not apply. The Authority shall not start technical review of a submittal without a completed Form 10-1.

10.4.4 **Digital submittal.**

- (a) Reports and drawings shall be submitted as searchable PDF.
- (b) Hydrologic and hydraulic models shall be submitted in their native, runnable format (for example SWMM .inp, HEC-HMS or HEC-RAS project files), with the version of the software used.
- (c) Facilities, outfalls, flow paths and catchment boundaries shall be submitted as GIS data (GeoPackage or shapefile) in WGS 84 (EPSG:4326) or the applicable UTM zone (46N for almost all of the State, and 45N west of 90° E, a strip about 18 km wide in West and South West Garo Hills that includes the Mahendraganj–Hallidayganj area (this Manual's reading; town coordinates not verified [TBC]); Tura, Williamnagar and Baghmara lie in 46N, Phulbari, Tikrikilla and Ampati are to be confirmed against Survey of India coordinates [TBC], and a project that crosses 90° E uses one zone for all its layers and states which), with attributes as listed in Annex 10B.
- (d) Levels shall be stated relative to a named vertical datum. The relationship to the river datums of the CWC level-monitoring sites on the receiving rivers (not stated in any source found), of the reservoir levels of MePGCL (published in metres for Myntdu–Leshka, New Umtru and Umiam–Umtru Stage IV, and in feet for Umiam–Umtru Stage III, converted at 0.3048 m per foot), and of the flood marks surveyed on ungauged streams, jhoras, pungs and lakes used in Chapter 5 shall be stated.

10.4.5 **Summary of forms used in submittals** (Table 10.2):

**Table 10.2 — Forms used in submittals**

| Form | Title | Stage |
|---|---|---|
| 1-1 | Applicability Determination | 0 or 1 |
| 1-2 | Variance / Waiver Request | 1 |

| Form | Title | Stage |
|---|---|---|
| 2-1 | Design Rainfall Sheet | 1, 2 |
| 10-1 | Drainage Report Checklist | 1, 2 |
| 10-2 | Compliance Calculator Summary | 1, 2, 4 |
| 10-3 | Professional Design Certificate | 1, 2 |
| 10-4 | Hold-Point Inspection Record | 3 |
| 10-5 | As-built Certificate | 4 |
| 10-6 | Maintenance Declaration | 5 |
| 10-7 | Annual Maintenance Declaration and Inspection Report | 6 |
| 10-8 | Asset Handover Certificate | 5 |

**Commentary.** Runnable models and GIS data cost the applicant little and let the Authority check the work, and later build a city-wide picture of private storage. Meghalaya has no notified design return period or design storm for its urban drains, and no document of the Urban Affairs Department, MUDA, a Municipal Board, a District Council, PWD, the Water Resources Department or Shillong Smart City Ltd stating a return period, a runoff coefficient or a drain standard was found; the Bye-Laws 2021 refer drainage to the National Building Code 2016 (D4.2, D5.6). The only drainage method found is that of RMSI's multi-hazard assessment of Shillong (2019), which used the IMD station at Shillong, design rainfall "adopted from the Brahmaputra Basin PMP Atlas developed by the Central Water Commission (CWC, 2014) using data from 1957-2010" and the rational formula (as quoted in the IRADe/NMHS plan; the report and the atlas were not obtained [TBC]); the plan itself recommends the "Upgradation of the existing drains" and desilting, without a design storm. The rainfall studies do not supply one either. No intensity–duration–frequency relation with constants was found for any Meghalaya station; the "Eastern" constants of Ram Babu and others repeat the "Central" ones and are not used; IMD's national study (Das et al., 2022) has a genuine panel for Cherrapunji but a Shillong panel that repeats the generic curve of most other cities, which is not used; and the 2(b) plate of the CWC Flood Estimation Report reads about 560 mm in 24 hours at 50 years at Shillong, 1.3 to 2 times every fall recorded there (273.2 mm on 25 June 1988 at Shillong (C.S.O.), IMD; 347 mm in 1960 at the self-recording gauge and 437 mm at Upper Shillong in 1934, CWC). The storms on record exceed anything the drains were built for: 1,563.0 mm in 24 hours at Cherrapunji on 16 June 1995 (IMD), 1,003.6 mm at Mawsynram on 17 June 2022 (IMD's June record), and 48 mm in one hour at the Shillong self-recording gauge on 15 September 1960 (CWC), the only hourly value on record in the State. The southern escarpment lies in subzone 2(c) (Barak), for which CWC has published no Flood Estimation Report. The State's design values are therefore those of Chapter 2: the 2(b) report in the northern foothills, on the plateau outside the Shillong Planning Area and in the Garo hills, the Shillong rule of Clause 2.3.6(c)(i) within it, and the Das et al. (2022) Cherrapunji curve on the escarpment (Clause 2.3.6(f)), and each submission must state its own design basis. Form 2-1 and Form 10-2 ensure that every design states its inputs.

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## 10.5 Compliance calculator

10.5.1 The State Stormwater Technical Committee shall issue and maintain a **compliance calculator**: a version-controlled spreadsheet or web tool that, for a given site:

- (a) applies the applicability tests of Clause 1.5;
- (b) computes the retention volume from the Annex 2E depth, and the water quality volume (Chapter 8);
- (c) applies the credits for preserved areas and retained volume against detention (Chapter 4);
- (d) on the design-aid route (Clause 1.7, S-1), gives retention and detention volumes from the unit-storage tables;

- (e) on alternative S-2, gives the permissible site discharge for each AEP; and
- (f) produces the **Compliance Calculator Summary (Form 10-2)**.

10.5.2 **Use.**

- (a) Every Stage 1, 2 and 4 submittal shall include Form 10-2 from the current version of the calculator.
- (b) On the design-aid route, the calculator may be the only storage calculation.
- (c) Outside the design-aid route, the calculator is a summary and a screening check. It does not replace the hydrograph analysis of Chapter 3. Where a model result differs from the calculator screen by more than the tolerance stated in the calculator guide, the report shall explain why.

10.5.3 **Version control.** The calculator shall record its version in every output. A new version applies to new submittals 6 months after release, in line with Clause 2.14.2. A submittal shall use one version throughout Stages 1 to 4, unless the Applicant elects a later one.

10.5.4 **Openness.** The calculator, its user guide, and the source of every table in it shall be published free of charge.

> Commentary. The Mid-America Regional Council issued a Compliance Calculator (.xlsm) and a Calculator Start-Up Guide with APWA 5600 Version 2025.01, together with a site activity plan template and the Policy Supplement (MARC stormwater management page, 2025). The calculator turns a layered standard with credits into one consistent set of numbers that a reviewer can check quickly. Singapore achieves a similar effect with a much simpler rule: a single allowable C value of 0.55 for 10-yr storms up to 4 h, applied by formula (PUB Code of Practice, cl. 7.1.5). A Meghalaya calculator serves Tier B authorities in particular, where it may be the whole calculation.

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## 10.6 Professional certification

10.6.1 **Who may sign.** Drainage reports and designs shall be prepared and signed by a registered professional (Clause 1.4) competent in hydrology and hydraulics. For any of the following, the signatory shall be a civil engineer **empanelled as a Stormwater Design Professional** by the Authority or Urban Affairs:

- (a) Tier A sites of 1 ha or more;
- (b) any site in a flood-sensitive catchment;
- (c) any facility with an embankment, or a high-hazard basin checked for the 0.2% AEP (Chapter 4); and
- (d) any pumped facility, tide gate or regional facility.

10.6.2 **Empanelment criteria** shall be issued by Urban Affairs and shall include a civil engineering degree, relevant experience in drainage design, and completion of a training course on this Manual.

10.6.3 **Certificate.** The signatory shall complete the **Professional Design Certificate (Form 10-3)**, certifying that:

- (a) the design complies with this Manual, except for variances listed and approved;
- (b) the rainfall, soils and tailwater inputs are as recorded in Forms 2-1 and 10-2; and
- (c) the models submitted reproduce the results reported.

10.6.4 **Independent check.** Facilities under Clause 10.6.1(c) and (d) shall be checked by a second empanelled professional who is independent of the designer. That professional shall sign Form 10-3 as checker.

10.6.5 **False certification.** A false or negligent certificate is an offence under Clause 10.15.

> Commentary. Singapore requires that its ABC Waters design features used for peak control be endorsed by an ABC Waters Professional who is also a Professional Engineer (Civil) (PUB Detention Tank Guide, 2024). India has no statutory register of professional engineers comparable to Singapore's, so this clause uses the Bye-Laws 2021 registration and adds empanelment for the higher-risk cases. The 1 ha limit is set by this Manual.

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## 10.7 Review procedure and timelines

10.7.1 **Completeness check.** The Authority shall check each submittal against Form 10-1 within **5 working days** and either accept it for review or return it with a list of missing items.

10.7.2 **Technical review.** The Authority shall complete technical review and issue approval, conditional approval or a single consolidated list of comments within:

- (a) **15 working days** of acceptance for a first submittal; and
- (b) **10 working days** of acceptance for a resubmittal.

10.7.3 **No new comments.** On resubmittal, the Authority shall not raise new comments on matters that were unchanged and not commented on in the earlier review, unless the matter affects safety.

10.7.4 **Review capacity.** A Tier B authority, or a Tier A authority for overflow work, may use an empanelled reviewer from the Urban Affairs list. The empanelled reviewer shall not have worked on the same site. The Authority remains the decision-maker.

10.7.5 **Concurrent clearances.** Where the approval of the Water Resources Department for a work on, or a discharge to, a river or flood-protection work in its charge, among them the Umkhrah and the Umshyrpi, the consent of MePGCL for a work that drains to Umiam, Kyrdemkulai, Nongkhyllem, New Umtru or Myntdu–Leshka or to a reach below one of their dams, the written consent of the Municipal Board to connect a drain to a Board drain or water-course (Meghalaya Municipal Act, 1973, s.204), the views of the Forest and Environment Department, or of the authority that implements the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023 in the area, for a work in the setback or regulated zone of a waterbody, and of the Meghalaya State Wetlands Authority for a work in or next to a wetland, the permission of the Flood Zoning Authority for an activity in a restricted zone, once one is notified under the Meghalaya Flood Plain Zoning Act, 2026 (none has been; the Act deems permission given if it is not refused within 90 days), the groundwater no-objection certificate of the District Level or State Level Committee on ground water, on which the Water Resources Department serves, for a well or abstraction, the consent of PWD (Roads), NHAI or NHIDCL for a discharge to a side drain, catch-water drain or culvert of one of their roads, the consent of MSPCB for a discharge that carries effluent, the consent of the District Council, or of the Dorbar Shnong under the District Council's rules, for a work on a jhora or village drain outside municipal limits, and the consent of the body that owns or runs the receiving drain where that body is not the Authority (for example the Shillong Cantonment Board, NSTDA in New Shillong [TBC] or Shillong Smart City Ltd until its drains are handed over), or another agency's concurrence is required (Chapter 7), the Authority shall forward the submittal on the day it is accepted for review, and the review periods shall run concurrently.

10.7.6 **Fit with permit timelines.** The periods in Clauses 10.7.1–10.7.2 run within, and do not extend, the overall time limits for planning permission and building permits set by the Government.

10.7.7 **Reasons.** Every refusal or condition shall state the clause of this Manual on which it is based.

> Commentary. The review periods have no direct precedent and are set by this Manual. A single consolidated comment list and the "no new comments" rule follow common good practice for engineering review.

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## 10.8 Construction inspection

10.8.1 **Hold points.** The approved hold-point schedule (Form 10-4) shall include at least:

- (a) the excavated base of each retention, infiltration and detention facility, before any media, liner or structure is placed;
- (b) the outlet structure, orifice and trash screen, before backfill or before the facility is first allowed to fill;
- (c) the infiltration tests of Clause 10.9.3;
- (d) the outfall, flap or tide gate and non-return valve, before the downstream connection is made; and
- (e) pumps and controls, at commissioning.

10.8.2 Each hold point shall be inspected by the certifying professional and recorded on Form 10-4 with dated, geotagged photographs. For sites under Clause 10.6.1, the Authority shall be given at least 3 working days' notice of hold points (a) and (b), and may attend.

10.8.3 **Protection during construction.**

- (a) Retention and infiltration areas shall be fenced off from construction traffic and stockpiles.
- (b) Infiltration facilities shall not be brought into service until the area draining to them is stabilised.
- (c) Sediment shall be removed from any facility used for temporary sediment control before the as-built survey.

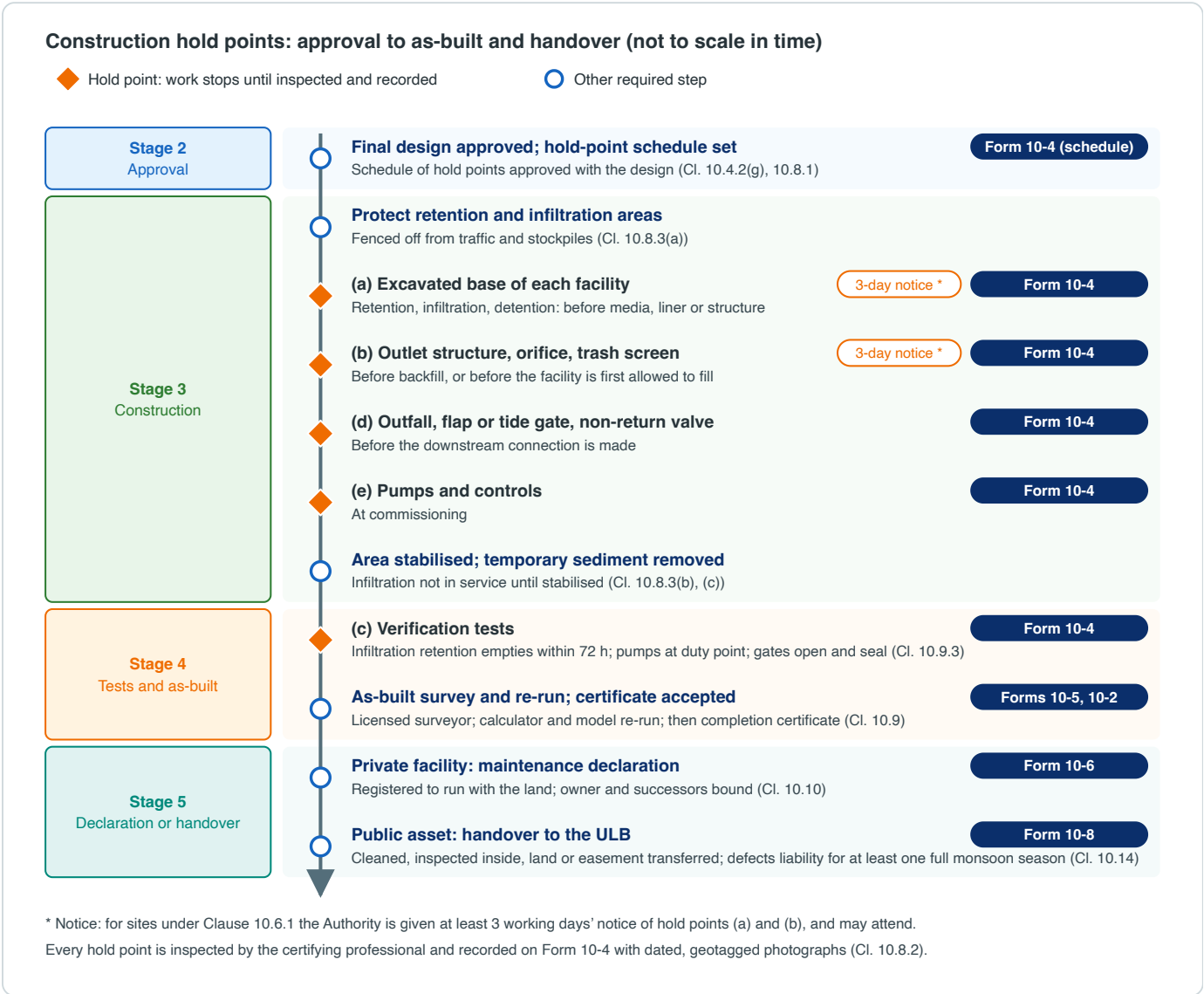

*Figure 10.2 — Construction hold points from approval to as-built certification and handover, with the form used at each step (Clauses 10.8–10.10 and 10.14). Hold points are lettered as in Clause 10.8.1. Original drawing for this Manual, adapted from the construction-inspection and maintenance-agreement sequence of APWA Section 5600 (2006), §5608.*

> Commentary. Infiltration facilities fail most often in construction, when they are compacted or filled with silt before they ever operate. Hold points (a) and (c) target that failure. The 3-day notice is set by this Manual.

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## 10.9 As-built certification

10.9.1 Before the completion certificate is issued, the certifying professional shall submit the **As-built Certificate (Form 10-5)** with:

- (a) an as-built survey by a licensed surveyor of each facility's levels, storage volume, outlet dimensions and inverts, and the outfall;
- (b) a re-run of the compliance calculator, and of the model where one was used, with as-built values;
- (c) the completed hold-point records (Form 10-4); and
- (d) the final O&M plan and the executed maintenance declaration or handover documents (Clauses 10.10 and 10.14).

10.9.2 **Acceptance.** The as-built facility is accepted where:

- (a) the as-built storage volume at each design level is not less than the volume required by Chapter 4;
- (b) the outlet dimensions and inverts match the approved design; and
- (c) the re-run shows compliance with every criterion of Chapters 4 and 5.

Any deviation shall be corrected, or re-certified as compliant under Clause 10.3.5.

10.9.3 **Verification tests.** Every retention facility that relies on infiltration shall be tested after construction to show that it empties within **72 hours**, as Chapter 4 requires. Pumped facilities shall be tested at their design duty point. Tide gates and non-return valves shall be shown to open and seal.

10.9.4 The Authority shall not issue the completion certificate until Form 10-5 is accepted.

> Commentary. The 72-hour retention drawdown is the criterion of Chapter 4. This Manual requires it to be tested after construction, rather than relying on pre-construction tests alone, because compaction during construction can cut infiltration rates far below the design values.

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## 10.10 Maintenance declarations and covenants

10.10.1 **Declaration.** The owner of every private stormwater facility shall execute a **Maintenance Declaration (Form 10-6)** before the completion certificate is issued. The declaration shall:

- (a) identify each facility, its location and the approved O&M plan;
- (b) bind the owner and successors in title to operate, inspect and maintain the facility under the O&M plan;
- (c) grant the Authority a right of entry to inspect, and to carry out works in default under Clause 10.15;
- (d) prohibit removal, filling, covering, reduction or change of use of the facility without the Authority's approval; and

- (e) be registered so that it runs with the land and is disclosed to purchasers.

10.10.2 **Multi-owner developments.** For apartments, layouts and gated communities, the declaration shall name the association or body responsible after handover by the developer. The developer remains responsible until that body is legally constituted and has accepted the declaration in writing.

10.10.3 **Annual declaration.** Every owner of a facility in a Tier A area, and of any pumped facility, tide gate or regional facility anywhere, shall submit an **Annual Maintenance Declaration and Inspection Report (Form 10-7)** by **31 March** each year. The report shall be signed by the owner and, for facilities under Clause 10.6.1(c) and (d), by an empanelled professional. It shall state that the pre-monsoon inspection of Clause 10.12 has been done and any defects corrected.

10.10.4 **Transfer.** On sale or transfer, the seller shall disclose the declaration and the latest Form 10-7. The purchaser takes on the obligations from the date of transfer.

> Commentary. Singapore requires owners of pumped detention systems to file yearly declarations and documents with PUB (PUB Detention Tank Guide, citing Code of Practice §13.2). Addendum No. 3 to the Code of Practice (16 Apr 2025) introduced annual maintenance declarations for flood barriers and pumped detention tanks, following amendments to the Sewerage and Drainage Act. APWA 5600 (2006, §5608) required easements and maintenance provisions for detention facilities. A registered declaration matters in Meghalaya because detention tanks under podiums and in basements are easy to convert to parking or storage once the building is occupied. The 31 March date is set by this Manual to fall before the monsoon season (April–October), when most Meghalaya extreme rainfall occurs.

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## 10.11 O&M plans

10.11.1 Every stormwater facility shall have an O&M plan, approved at Stage 2 and finalised at Stage 4. The plan shall include:

- (a) an inventory and a plan drawing of each facility, with design levels, volumes and outlet details;
- (b) routine tasks and their frequency: inspection, debris and sediment removal, vegetation care, screen cleaning;
- (c) the trigger for sediment removal, stated as a depth or a percentage of design volume;
- (d) inspection checklists matching Form 10-7;
- (e) for pumped systems, gates and valves: the operating rules, test schedule, standby power, and actions on a cyclone or heavy-rainfall warning;
- (f) actions to prevent standing water and mosquito breeding, consistent with the drawdown times of Chapter 4;
- (g) safety measures for confined spaces, deep water and public access;
- (h) access routes and equipment needed (Clause 10.13);
- (i) an annual cost estimate and who pays it; and
- (j) the records to be kept, and for how long.

10.11.2 **Public facilities.** For facilities owned by a ULB or department, the O&M plan shall be included in the asset register (Clause 10.14.3) and funded in the annual maintenance budget.

> Commentary. Meghalaya has no dated State order fixing pre-monsoon desilting: the IRADe/NMHS plan for Shillong recommends "Desilting to avoid flooding during monsoons" by PWD and the Shillong Municipal Board (2020), without a date. The drains are run by several hands, and no rule divides them: the Municipal Boards for the drains, public streams, springs and tanks vested in them within municipal limits (Meghalaya Municipal Act, 1973, s.62); PWD (Roads), and NHAI and NHIDCL on NH-6 and the Shillong–Dawki road, for the road drains and culverts, which carry much of the runoff of the hill towns; the Shillong Cantonment Board in the Cantonment, where "each house in the civil areas of cantonment has their own septic tank" (State action-taken report to the

National Green Tribunal, 2023); NSTDA in New Shillong [TBC]; the District Councils, and the Dorbar Shnongs under their rules, for the village drains and jhoras outside municipal limits, only parts of the Umkhrah and the Umshyrpi lying within the Shillong Municipal Board's area and the rest under the KHADC (the same report); the Water Resources Department for the rivers and flood works; PHED, nodal for sanitation outside the municipalities since 2023; and Shillong Smart City Ltd for its works, among them rainwater harvesting at 52 locations and "in-situ Nallah Treatment Technology" (as reported). The waste traps, stone bunds and in-situ treatment of five drains entering the Umkhrah, built since 2022 (the same report), need their own maintenance. The gates that matter most are run by rules made for other purposes: the reservoirs of MePGCL are operated for power, and their gate-operation guidelines for Umiam–Umtru Stages III and IV, New Umtru and Myntdu–Leshka say that, because the reservoirs are small and gates open often "during Monsoon as well as during Non-monsoon period", notice of releases is "not practicable" and warnings are given by siren, telephone or SMS; no guideline was found for Umiam Stage I, where releases were begun in August 2024 at 3,216.15 ft on an IMD warning (as reported). No operating rule for any sluice, flap gate or pumping station in a Meghalaya town, linking it to a stream level, a dam release or a rainfall warning, was found in the public domain. Every gate and pump in this Manual needs a written rule for what happens when a warning is issued.

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## 10.12 Inspection frequencies

10.12.1 **Owner inspections.** Owners shall inspect facilities at least as set out in Table 10.3:

**Table 10.3 — Minimum owner inspection frequencies**

| Facility type | Routine | Pre-monsoon (by 31 March) | After a heavy-rainfall event |
|---|---|---|---|
| Retention / infiltration (soakaways, trenches, bioretention, permeable paving) | Every 6 months | Yes | Yes |
| Surface detention basin or multi-use open space area | Every 6 months | Yes | Yes |
| Underground or podium detention tank, gravity outlet | Every 6 months | Yes | Yes |
| Pumped detention, pumps and controls | Monthly test run | Yes, with full duty test | Yes |
| Flap / tide gate, non-return valve | Every 3 months | Yes, with seal test | Yes |
| Gross pollutant trap / first-flush device | Every 3 months | Yes | Yes |
| Private drains and inlets | Every 6 months | Yes | — |

A heavy-rainfall event, for this Clause, is a day on which the nearest approved gauge records rainfall at or above the IMD "heavy rainfall" category, or a day for which a red alert is issued for the district. In Meghalaya, the pre-monsoon inspection of sluices, flap gates, non-return valves, debris racks, solid-waste traps, sediment traps, debris basins, culvert inlets and pumped facilities, including the gates on outfalls to Umiam lake and the other reservoirs, pungs and lakes and on outfalls that the Umkhrah and the Umshyrpi in Shillong, the Umngot at Dawki or the Jinjiram on the Garo plains can close, with the desilting and the clearance of debris, garbage and slide material from every drain, jhora, inlet, rack, trap, basin and culvert and the pump duty and gate seal tests, shall be completed by **31 March**; inlets, trash and debris racks, culverts, outfall gates and pumped facilities, with their standby generators, shall be certified ready on the same date, with every gate on an outfall to a river or reservoir operated through its full travel, because the season of this

Manual begins on 1 April and the storms of April and May are among the State's largest. Pumps, their standby power, gates and racks shall then be kept on standby, with the monthly test run, from **1 April to 31 October**, and at an outfall to a reservoir of MePGCL or to a reach below one of its dams until the releases have ended, if that is later. Racks, culverts, sediment traps and jhora inlets shall be cleared again by **31 May**, of the debris and garbage of the April and May storms, before the south-west monsoon arrives, and every public drain, jhora inlet, rack, trap, basin and culvert in every town shall be cleared of the sediment, slide debris and garbage of the season by **15 November**.

10.12.2 **Authority inspections.** The Authority shall inspect:

- (a) every facility on a site of 1,000 m² or more, or under Clause 10.6.1(c) or (d), at least once every 2 years, and every year in a flood-sensitive catchment; and
- (b) a random sample of at least 10% of other facilities each year.

10.12.3 The results of Authority inspections shall be entered in the facility register (Clause 10.17).

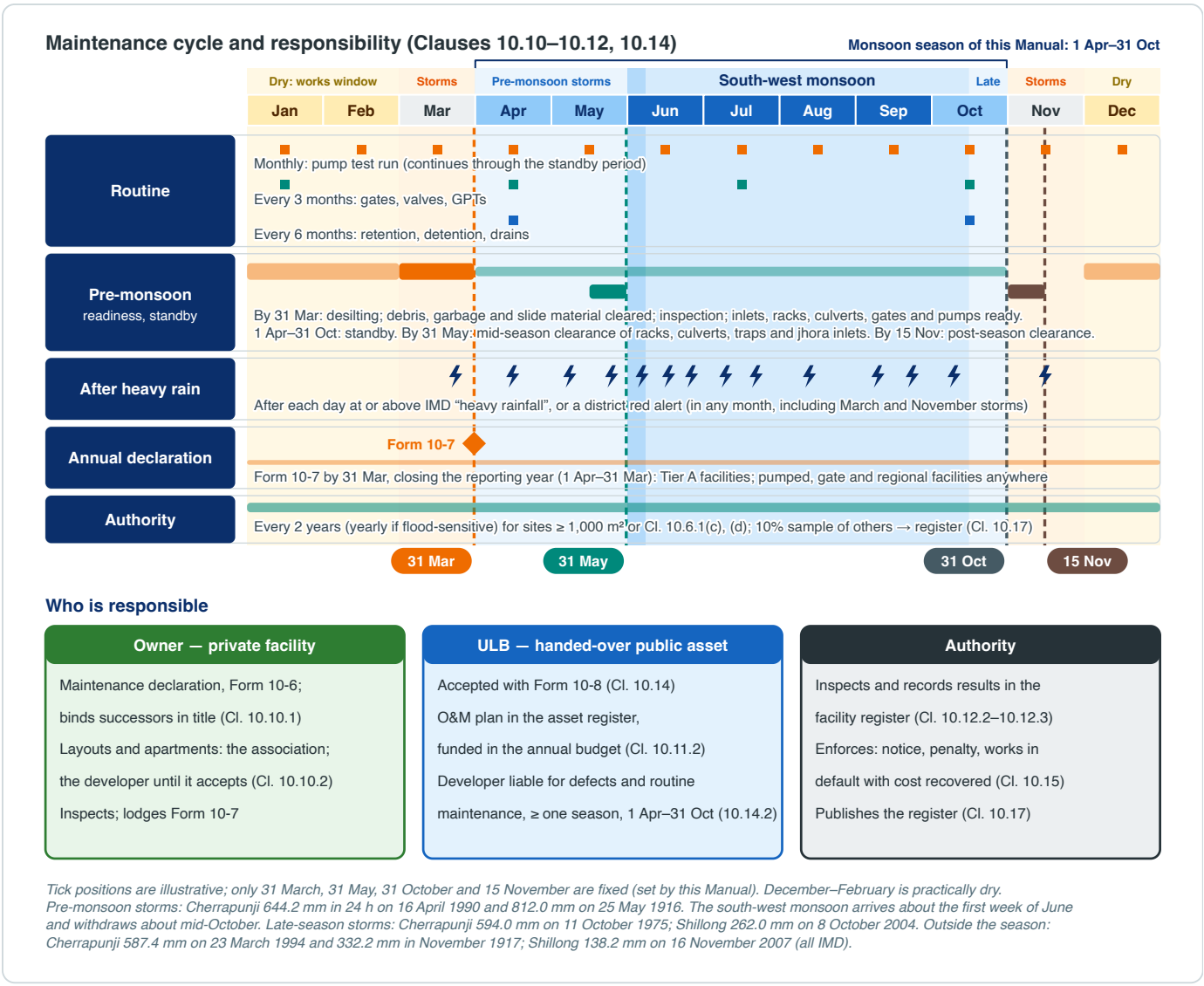


*Figure 10.3 — Annual maintenance cycle and who is responsible: routine, pre-monsoon (by 31 March) and post-event inspections, the annual declaration (Form 10-7) and Authority inspections (Clauses 10.10–10.12 and 10.14). Original drawing for this Manual. The timing follows the monsoon season (April–October); tick positions within the year are illustrative.*

Commentary. The split in Clause 10.12.2 follows the MBBL 2016 inspection regime for RWH, which requires 100% monitoring of buildings over 1,000 m² and a 10% random check below that (MBBL 2016, §9.6). The inspection intervals in Table 10.3 are set by this Manual. The 31 March deadline is set by this Manual for a wet season that begins before the south-west monsoon. In this Manual the monsoon season runs from 1 April to 31 October, and its first two months bring some of the State's largest storms: Cherrapunji recorded 644.2 mm in 24 hours on 16 April 1990 and 812.0 mm on 25 May 1916 (IMD, *Extremes*), more than the 50-year 24-hour depth of any plains State; CWC's high flood levels on the Myntdu at Kharkhana (47.0 m, 23 April 1995) and the Umngot at Dawki (73.47 m, 28 May 2006) fall on pre-monsoon dates (CWC levels as transcribed by SANDRP, as reported); the CWC Flood Estimation Report for subzone 2(b) finds the rainfall "spread over a period of eight months, i.e. from March to October", with thunderstorms in April and May and "May rainfall … more than the September rainfall"; and the floods and landslides of 30–31 May 2025 struck 86 villages in 10 districts before the monsoon arrived (as reported). NDMA (2010) sets 31 March for pre-monsoon desilting nationally, and this Manual keeps that date; the 31 May deadline of the mountain editions of this series would leave the April and May storms uncovered. December to February is "practically dry" (the same report) and is the works window. No dated State or municipal order fixing a deadline for desilting was found; the IRADe/NMHS plan for Shillong recommends desilting "to avoid flooding during monsoons" (2020), without a date. This Manual therefore takes 31 March for desilting and the clearance of debris, garbage and slide material, the pre-monsoon inspection, the annual declaration and the readiness of inlets, racks, culverts, gates and pumps, with no later readiness date. The south-west monsoon itself arrives about the first week of June: the old IMD normal date for Shillong is 1 June (as reported; IMD's revised normals for Shillong were not read [TBC]), and in 2026 the monsoon reached "substantial parts" of the North East on 7 June, "two days later than its normal" (as reported). Racks, culverts, sediment traps and jhora inlets are therefore cleared again by 31 May, after the April and May storms and before the onset. The monsoon withdraws from Meghalaya about mid-October (expected by 14 October in 2025 and reported for the North East on 15 October 2026, as reported), but storms continue after it: Cherrapunji recorded 594.0 mm on 11 October 1975 and Shillong 262.0 mm on 8 October 2004 (IMD), and the Garo Hills floods of 4–6 October 2024 drowned three people at Dalu (as reported); pumps, gates and racks are therefore kept on standby to 31 October (Figure 10.3). Large falls also come outside the season, 587.4 mm on 23 March 1994 and 376.9 mm on 18 February 1993 at Cherrapunji, and 332.2 mm there in November 1917 and 138.2 mm at Shillong on 16 November 2007 (IMD), and the jhoras fill with sediment, slide debris and garbage during the season, so every town clears its drains a second time by 15 November. The post-event inspections of Table 10.3 cover storms at any time of year. The reporting year runs from 1 April to 31 March, so that the annual declaration of 31 March closes it.

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## 10.13 Maintenance access

10.13.1 Every facility shall have permanent access for inspection and maintenance, shown on the approved drawings and protected by the maintenance declaration or, for public facilities, by an easement or land transfer.

10.13.2 **Surface facilities.** Basins, ponds and open channels shall have a vehicle access route to the inlet, the outlet and the base, and a maintenance strip along at least one side. Ramps into basins shall be suitable for the plant needed to remove sediment.

10.13.3 **Underground facilities.** Tanks shall have:

- (a) an access opening over the inlet, the outlet and each chamber;
- (b) fixed ladders or steps, and ventilation for confined-space entry;
- (c) a sump or low point for sediment removal; and
- (d) headroom sufficient for manual cleaning.

10.13.4 **Outlets.** Orifices and screens shall be reachable for cleaning without entering a full facility.

10.13.5 Access routes shall not be built over, fenced off or used for parking in a way that prevents access.

> Commentary. APWA 5600 (2006, §5608) required a 15-ft (about 4.5 m) maintenance access strip for detention facilities. Plot sizes in Meghalaya cities make a fixed width hard to apply to every site, so this Manual sets functional requirements. Annex 10C covers maintenance access dimensions.

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## 10.14 Handover of public assets to the ULB

10.14.1 Drains, roads, open space facilities, regional facilities and other stormwater assets that a developer builds for transfer to a ULB shall be handed over only when:

- (a) the as-built certificate (Clause 10.9) has been accepted;
- (b) the facility has been cleaned, and pipes and culverts have been inspected internally (for example by CCTV or manual entry), with the record handed over;
- (c) the land, or an easement over it, has been transferred to the ULB;
- (d) the O&M plan, drawings, GIS data and warranties have been handed over; and
- (e) the **Asset Handover Certificate (Form 10-8)** has been signed by both parties.

10.14.2 **Defects liability.** The developer shall remain responsible for defects and for routine maintenance for a defects liability period that includes at least **one full monsoon season, from 1 April to 31 October,** after handover. The ULB may hold a security deposit for this period.

10.14.3 **Asset register.** On acceptance, the ULB shall enter the asset in its GIS drainage asset register and in the facility register of Clause 10.17.

10.14.4 **Private facilities.** A private facility remains the owner's responsibility under its maintenance declaration unless the ULB formally accepts it under this Clause.

> Commentary. NDMA (2010) calls for a GIS inventory of drains. Requiring the developer's GIS data at handover builds that inventory as the city grows, at no cost to the ULB. The defects period spans one monsoon because many defects in Meghalaya drainage show up only in the first monsoon.

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## 10.15 Enforcement

10.15.1 **Offences.** The following are contraventions of this Manual:

- (a) building without an approved drainage design where one is required;
- (b) building a facility other than as approved;
- (c) removing, filling, covering, reducing or changing the use of a facility without approval;
- (d) failing to maintain a facility, or to submit Form 10-7;
- (e) a sewage connection to a storm drain;
- (f) building or filling in a waterbody setback or no-fill zone (Chapter 7);
- (g) obstructing a natural drainage path or major-system flow path; and
- (h) false or negligent certification.

10.15.2 **Graduated response.** The Authority shall respond in the following order, moving to a later step where an earlier one fails or where the contravention is serious (Table 10.4):

Table 10.4 — Graduated enforcement response

| Step | Action |
|---|---|
| 1 | Written notice stating the contravention, the clause breached, the remedy and a compliance period. |
| 2 | Stop-work order, or withholding of the completion certificate, for development not yet complete. |
| 3 | Penalty under the applicable Act or rules. |
| 4 | Works in default by the Authority, with the cost recovered from the owner. |
| 5 | Disconnection of the private drain connection to the public system, where this causes no hazard to others. |
| 6 | Report of the certifying professional to the registering authority, and suspension from the empanelled list. |

10.15.3 **Immediate action.** Where a contravention puts life or property at risk during a monsoon, the Authority may carry out works in default at once and recover the cost later.

10.15.4 **Security deposits.** For sites under Clause 10.6.1, the Authority may require a security deposit or bank guarantee, released after the as-built certificate is accepted, to cover works in default.

10.15.5 **Record.** Every notice and action under this Clause shall be entered in the facility register.

> **Commentary.** Penalties are referred to generically. This Manual cannot itself create offences or fines, and the powers come from the Acts under which the Meghalaya Building Bye-Laws 2021 are made and from the municipal Acts. The graduated steps are set by this Manual. In Meghalaya the courts and the National Green Tribunal have become the working regulators of the streams and lakes, and the District Councils and the Dorbar Shnongs act where the State's rules do not reach. The High Court, in *In Re: Cleanliness of Umiam Lake* (PIL No. 10 of 2019), barred any construction "within 50 metres of the high-water mark of the relevant waterbody without the express previous leave of this Court" (24 May 2023), found the waterbody guidelines of July 2023 to "fall woefully short" and "more of a formality", observing that "Several of the rivers, including the Umkhrah in Shillong itself are carrying such contaminated water that they may not be fit even to step into" (19 July 2023), and closed the PIL on 19 February 2024 once the amended Waterbodies Guidelines were taken on record, so the 50 m bar has ended. The Tribunal, on the report "Poison flowing in Shillong's rivers", directed that "the raw fecal matter is not discharged into fresh water streams and Umkhrah and Umshyrpi rivers" (O.A. No. 192 of 2022, 22 November 2022), and the State reported fencing, waste traps, in-situ treatment of five drains and on-site treatment plants (action-taken report, 21 March 2023) and undertook to ring-fence ₹109 crore for liquid and solid waste (letter of 22 December 2023); the Tribunal also supervises the polluted stretches (O.A. No. 673 of 2018) and stopped rat-hole mining throughout the State on 17 April 2014 (O.A. No. 73 of 2014), after which the Supreme Court allowed mining on private and community land subject to leases and mining plans under the MMDR Act (C.A. No. 10720 of 2018, 3 July 2019). The statutes carry weak powers. The Meghalaya Municipal Act, 1973 lets a Board require an owner "to improve bad drainage" within 15 days (s.190), have land within 100 ft of a drain drained (s.206) and demolish a drain led into a Board drain or water-course without consent, but the fines are nominal: up to ₹50 for such a drain (s.204) and up to ₹25 for letting sewage run onto a road or into a roadside drain (s.205). The Shillong Municipal Board inspected 1,169 households along the Umshyrpi and the Wahumkhrah and served notices on 47 under s.201 and the Environment (Protection) Act, 1986, with a fine of ₹500 a day for faulty septic tanks, and told the public not to discharge untreated sewage into drains and water bodies (notice No. SMB/PW/40/2023/10 of 17 February 2023). The Bye-Laws 2021 are enforced through the building permission and the completion stage. Outside the municipalities the District Councils' rules apply: the KHADC's Solid Waste Management Rules, 2022 empower the Dorbar Shnong to fine polluters (as recorded in the minutes of the meeting on the Wah Umkhrah, Wah Umshyrpi and Wah Umkhen, 14 April 2023), the KHADC told all headmen not to discharge "untreated waste, faecal matter and garbage" into the two rivers (notice of 13 March 2023, as recited in the action-taken report), and its Land Development and Building Regulation, 2015 makes the Executive Committee, the Town Committee and the Dorbar Shnong responsible for keeping development from damaging "catchment areas, water sources, spring

sheds, streams and rivers", with restoration at the polluter's cost (s.15). The Meghalaya Flood Plain Zoning Act, 2026 provides a fine of up to ₹10,000 and ₹500 a day for breaching a notified restriction (s.13, as read in the Bill), but no zone has been notified. The CAG's performance audit of solid waste management in urban areas (2017-18 to 2021-22) found that no Municipal Board, and neither the JHADC nor the GHADC, had framed bye-laws under the Solid Waste Management Rules 2016, while the KHADC had notified its Solid Waste Management Act, 2020 in February 2022 (report number [TBC]); no audit of storm drainage or flood works in Meghalaya was found. This shows that a rule without routine enforcement does little, and that where the State has not drawn a line on the ground the courts have. Professional accountability (step 6) is often more effective than fines on owners, because it acts on the person who signs the design.

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## 10.16 Monitoring and post-event review

10.16.1 **Monitoring network.** Tier A authorities shall maintain, or have access to, recording rain gauges and water-level gauges at their main outfalls and regional facilities. Data shall be archived at intervals of 15 minutes or less.

10.16.2 **Event reports.** After any event that floods buildings within a ULB area, the ULB shall prepare a short event report within **3 months**, recording:

- (a) rainfall at the nearest approved gauges, by duration, compared with the design depths of Chapter 2;
- (b) the level of the receiving river at the nearest CWC level-monitoring site (the Umngot at Dawki, the Umnohryngkew at Therriaghat, the Myntdu at Kharkhana, the Bugi at Dimapara or the Dareng at Sibbari, none of which has a warning or danger level) or of the receiving reservoir, pung or lake, with the level of a MePGCL reservoir as the operator records it, converted from feet where so published, and, where it is gauged, at the outfall, each on a named datum, with any reading of a local gauge kept apart from the CWC levels; for an ungauged stream or jhora, which includes the Umkhrah and the Umshyrpi in Shillong, the flood marks surveyed after the event and the boulders, slide debris and garbage deposited at crossings, racks and culverts; the state of every sluice, flap gate, debris rack, solid-waste trap, sediment trap, debris basin and pumping station on the outfall and on the drain upstream of it, with the volume of debris and garbage removed from each, the hours each pump ran and any loss of power; and the gate openings and releases of any MePGCL dam that sets the receiving level, such as Umiam–Umtru Stages III and IV, New Umtru or Myntdu–Leshka, with the times of its siren, telephone or SMS warnings;
- (c) flooded locations, depths and durations, with flood marks surveyed where possible;
- (d) the performance of public and inspected private facilities, including any blocked outlets, failed pumps or closed gates; and
- (e) recommended actions.

10.16.3 **Post-event review.** Where an event exceeds the 1% AEP 24-hour or 72-hour design depth at two or more approved gauges in the State (Clause 2.14.1), MSDMA, with the State Stormwater Technical Committee, shall lead a post-event review within **12 months**. It shall assess whether the criteria of this Manual were adequate, and shall feed into the review of Clause 1.12.

10.16.4 **Facility performance sampling.** The Authority shall, at least every 5 years, monitor a sample of private retention and detention facilities through a monsoon, to test whether they perform as designed.

Commentary. The post-event trigger is the review trigger already set in Clause 2.14.1. Meghalaya's floods and landslides have been counted more often than they have been reviewed, and the counts conflict. In the Garo Hills floods and landslides that followed the torrential rain of 21 September 2014, 52 deaths were reported by 28–29 September and more than 60 in a later account, with damage put at more than ₹1,500 crore and over 200 villages submerged by the Brahmaputra and the Jinjiram, in what was called the "worst natural calamity that struck the state in the past century" (all as reported); no rainfall measurement for the event was found. In June 2022, when

Mawsynram recorded 1,003.6 mm in the 24 hours to 08:30 on 17 June and the rainfall over Assam and Meghalaya was the highest since 1901 (IMD), 13 deaths were reported on 17 June and 32 or 34 since 1 April, depending on the date of the count (as reported). The floods and landslides of 30–31 May 2025 affected 86 villages in 10 districts and killed six people, by MSDMA's count as reported; the Garo Hills floods of 4–6 October 2024 killed 15 by 6 October, three of them drowned at Dalu and seven in a landslide at Hatiasia Songma (as reported); and the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki in June 2026 came with no rainfall value published (as reported). The IRADe/NMHS plan for Shillong tabulates the flash flood of July 2019 at Polo, Forest Colony and Mawlai after "more than 72.2 mm of rain on 9th July 2019", five deaths and 1.5 lakh people affected in July 2020, and 13 deaths in September 2020, and cites the Revenue and Disaster Management Department for "approximately 22 deaths" from landslides in 2014. MSDMA's official tolls for 2014, 2022 and 2025 were not found [TBC]. No review of any flood in a Meghalaya town, and no record of flood extents, depths or durations kept by any Municipal Board, District Council or MSDMA, was found, and for most of these events no gauge recorded the rain. NDMA (2010) called for automatic rain gauges at "1 in every 4 sq km" in Class I, II and III cities. Clause 10.16.1 asks only for gauges where they serve design and review. The report and sampling intervals are set by this Manual.

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## 10.17 Data publication

10.17.1 Each Authority shall publish, on a public website, and update at least quarterly:

- (a) a **facility register**: location, type, design volume, release rate, owner, date of as-built acceptance, and the latest inspection result for every facility approved under this Manual;
- (b) a summary of each approved drainage report, with Forms 2-1 and 10-2;
- (c) the register of variances and waivers (Clause 1.10);
- (d) the alternatives adopted under the Policy Supplement (Clause 1.7);
- (e) enforcement actions (Clause 10.15.5); and
- (f) event reports and post-event reviews (Clause 10.16).

10.17.2 The State Stormwater Technical Committee shall publish the compliance calculator, all Annexes, the flood-sensitive catchment maps and the State-level summary of facility registers as open data.

10.17.3 Personal data other than the name of a corporate owner or association shall not be published. Security-sensitive details of critical infrastructure may be withheld, with the reason recorded.

10.17.4 Published data shall be machine-readable (for example CSV and GeoPackage) and released under the Government Open Data Licence – India or an equivalent open licence.

Commentary. Transparency is a design criterion in its own right here. Much of Meghalaya's drainage record is public: the Bye-Laws 2021 and their amendments on the Urban Affairs Department's website; the Waterbodies Guidelines, the KHADC's Land Development and Building Regulation, 2015, the Flood Plain Zoning Bill, 2026 and the notification of the State Wetlands Authority in the Gazette of Meghalaya; the consolidated Meghalaya Municipal Act, 1973; NESAC's report for the risk-informed master plan of the Shillong Planning Area, the amendment of the Shillong Master Plan 2041 and the notice of the draft master plan for Tura; the State's action-taken report and the joint committee's report to the National Green Tribunal on the Shillong rivers, the minutes of the meeting of 14 April 2023 on their restoration and the Chief Secretary's presentation with its water-quality table; the High Court's orders on Umiam lake; CPCB's list of polluted river stretches (2025); the executive summary of the CAG's audit of solid waste management; the IRADe/NMHS plan for Shillong; MePGCL's gate-operation guidelines; and IMD's station extremes and monthly summaries. Much else could not be found in the public domain: the notified text of the Shillong Master Plan 2041 and any drainage chapter; the gazetted text of the Flood Plain Zoning Act, 2026, the constitution of the Flood Zoning Authority and any zone; the building

instruments of the JHADC and the GHADC, the KHBSRA's own rules and the notification of 1 February 2019 on the District Councils' role; RMSI's floodplain zoning study of the Umkhrah and other stretches and its multi-hazard assessment of Shillong; the design basis of any storm drain, including the Smart City and AMRUT works and the Water Resources Department's project report for the Wahumkhrah and the Umshyrpi; CWC's site sheets and gauge datums; the levels and gate rules of Umiam Stage I; MSDMA's operating procedures for urban floods and its official tolls; the number of the CAG's report; and an inventory of the gates, racks, waste traps and pumping stations of any town. Publishing inputs and facility records lets the public, researchers and other agencies check that the city's growing stock of private storage actually exists. The open-format requirement is set by this Manual.

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## 10.18 Review of this chapter

10.18.1 This chapter shall be reviewed with the Manual under Clause 1.12. The forms and the compliance calculator may be revised by the State Stormwater Technical Committee between reviews, under Clause 10.5.3.

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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 10A | Compliance calculator and user guide |
| 10B | GIS data specification and attribute schema |
| 10C | Maintenance access dimensions |
| 10D | Model O&M plans by facility type |
| 10E | Empanelment criteria for Stormwater Design Professionals and reviewers |
| Form 10-1 | Drainage Report Checklist |

| Annex / Form | Content |
|---|---|
| Form 10-2 | Compliance Calculator Summary |
| Form 10-3 | Professional Design Certificate |
| Form 10-4 | Hold-Point Inspection Record |
| Form 10-5 | As-built Certificate |
| Form 10-6 | Maintenance Declaration |
| Form 10-7 | Annual Maintenance Declaration and Inspection Report |
| Form 10-8 | Asset Handover Certificate |
| Form 2-1 | Design Rainfall Sheet (Chapter 2) |

CHAPTER 11

# Basin and City Stormwater Master Plans

## 11.1 Purpose and scope

11.1.1 Chapters 2 to 10 control one project at a time. This chapter sets the requirements for the plan that ties those projects together: the **Basin Stormwater Master Plan (BSMP)**. A BSMP is prepared for each drainage basin of a city or urban area. A city's set of BSMPs makes up its **City Stormwater Master Plan**.

11.1.2 A BSMP shall:

- (a) map flood hazard for the basin under existing and future conditions;
- (b) set the level of service each part of the drainage system must achieve (Clause 11.6);
- (c) identify the works, storage and land needed to reach that level of service, and rank them (Clauses 11.7 and 11.8);
- (d) reserve land for regional storage, pung and tank restoration, and major flow paths in the statutory land-use plan (Clause 11.9);
- (e) set the basin-specific inputs that site designs under Chapter 4 depend on: regional facilities, the fee-in-lieu unit rate, and any basin release rate stricter than Chapter 4 (Clause 11.8.3); and
- (f) recommend catchments for notification as flood-sensitive (Clause 4.5.4).

11.1.3 **Relationship to site design.** Site criteria (Chapters 4 to 8) apply whether or not a BSMP exists. A BSMP may make the site criteria **stricter** for its basin. It shall not relax them, except through the regional detention and fee-in-lieu routes of Clauses 4.13 and 4.5.6.

> Commentary. Meghalaya's towns have master plans, hazard maps and river projects, but no published storm-drainage master plan with a design storm. The Shillong Master Plan 2041 was notified by No. UAU.76/2022/Pt.I/74 of 27 November 2024 (as cited in its amendment, No. UAU.76/2022/Pt.I/186 of 29 October 2025, whose text was read); its notified text was not obtained [TBC]. NESAC's report for it covers a planning area of 288.5 km² (174 km² in the plan of 1991–2011), the Shillong urban agglomeration and 54 villages, "drained mainly by the upstream reaches of Wah Umiam, Wah Umkhen, and Wah Tamdong"; it maps flash-flood susceptibility (very low 18.38% of the area, low 55.44%, medium 20.5%, high 4.67% and very high 1.01%), finds that "Encroachment and clogging of channels are the main causes of flooding over Shillong" and that "Polo Market, Pynthorbah, Nongrim hills, Dhankheti is a highly potential for flash flood", records that the planning area "has no sewerage system", projects wastewater in 2041 of 10.35 MLD in the Board area, 18.28 MLD in the census towns, 0.97 MLD in the Cantonment and 6.52 MLD in the villages and proposes decentralised treatment (DEWATS), but sets no design storm and sizes no drain (NESAC, 2023). The draft risk-informed master plan for Tura (notice No. UAU.76/2022/129 of 16 February 2024) covers 54.65 km² bounded by the Ringrey stream, the Ganol river and the Rongkhon stream, with 0.58 km² of water bodies, and has no drainage design either; the earlier plans, Shillong 1991–2011, Tura 1990–2001 and Jowai 1991–2001, are listed by the Urban Affairs Department. River work in Shillong has been led by pollution rather than capacity: in-situ treatment of five drains, on-site treatment plants and waste traps on the Umkhrah under the Tribunal's supervision (State action-taken report, 21 March 2023), and an invitation of 2018 for project reports on seven polluted stretches favouring "low-cost, decentralized, wetland-based bio-treatment systems". The Water Resources Department is reported to have resubmitted a project report for embankments and channel improvement on the Wahumkhrah and the Umshyrpi

"to prevent flash floods" after the Brahmaputra Board returned the first (as reported; not read), and the floodplain zonation of the Umkhrah and other stretches awarded to RMSI in June 2021 was "80%" complete in March 2023 (the same report) but has not been published, so the flood it maps is not known [TBC]. No published document sets a design return period for the storm-drain network of any Meghalaya town. This chapter supplies the design storm, levels of service, storage and buffer criteria that such a plan needs, with the design storms of Chapter 2 and the levels of service of Clause 11.6; it has not been adopted by the Urban Affairs Department, MUDA, any Municipal Board, any District Council or its building authority, the Water Resources Department, MePGCL, MSDMA or any other body. A site-level manual cannot fix basin-level problems: lost tank storage, jhoras and streams narrowed by building and clogged with garbage, whose overflow floods the valley floors of Shillong, at Polo, Pynthorbah, Nongmynsong, Mawlai and Dhankheti, with nearly every heavy downpour, slopes that open drains and soak pits saturate, as in the landslide localities of Shillong along NH-40 and the Umshyrpi, drains that carry the sewage of a city with no sewers to the Umkhrah and the Umshyrpi and on to Umiam lake, drains that end in reservoirs or in reaches below the dams of MePGCL, and single streams split between a Municipal Board, PWD, a District Council and the Dorbar Shnongs of the villages they cross, and drains that are adequate on their own but overload the next reach. Comparable manuals pair site criteria with basin planning:

- Denver's Mile High Flood District prepares major drainageway master plans that set regional facilities and release rates.
- The Kansas City APWA criteria rest on regional watershed studies (MARC).
- England's Surface Water Management Plans (Defra, Surface Water Management Plan Technical Guidance, 2010) set a phased method of preparation, risk assessment, options and implementation.
- Malaysia's MSMA requires drainage master plans for urban areas.

This chapter adapts that method to Meghalaya, the first North-East hill State in the series and its first under the Sixth Schedule: to towns in three settings, the plateau towns, Shillong, Jowai and Nongstoin among them, built on slopes where open drains and soak pits saturate the ground and where jhoras narrowed by building and garbage flood the valley floors; the escarpment settlements of Sohra, Mawsynram, Shella and Dawki, in the world's wettest belt, on limestone and above gorges, where landslides and debris decide more than the design storm; and the towns of the Garo hills and plains, Tura, Williamnagar, Baghmara, Dalu, Phulbari and Tikrikilla, on rivers that back up; to two CWC subzones, of which the southern has no Flood Estimation Report, and rainfall records five times apart within 40 km, 1,563.0 mm in 24 hours at Cherrapunji and 273.2 mm at Shillong (IMD); to drains that are the sewerage of a city with no sewers and that carry it to the Umkhrah, the Umshyrpi and Umiam lake, a reservoir run for power by MePGCL; to a regulatory field split between MUDA and the Municipal Boards in the master-plan and municipal areas and the District Councils and Dorbar Shnongs elsewhere, on land that is mostly community, clan or private; to setbacks of 3 m and 6 m from urban streams that leave most jhoras out, and a Flood Plain Zoning Act with no zone yet; to springs and sacred groves that supply and protect the towns' water, and karst and mine voids into which no water may be put; and to a wet season that begins with the storms of April and May, so that on the escarpment and below the dams a BSMP begins with the hazard, not the storm (Clause 11.3.3).

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## 11.2 Definitions

| Term | Meaning in this Manual |
|---|---|
| Basin | The land draining to one outfall to the sea, a river, or a major waterbody, as delineated under Clause 11.3. |
| Basin Stormwater Master Plan (BSMP) | The plan for one basin prepared under this chapter. |
| Lead Authority | The body responsible for preparing a BSMP (Clause 11.4). |

| Term | Meaning in this Manual |
|---|---|
| Level of service (LoS) | The flood performance a part of the drainage system must achieve, expressed as an AEP and an outcome (Clause 11.6). |
| Flood hazard map | A map of flood extent, depth, velocity and hazard class (H1–H6, Chapter 6) for a stated AEP and scenario. |
| Regional facility | A storage, conveyance or outfall work serving more than one development, identified in a BSMP. |
| Capital Improvement Programme (CIP) | The ranked, costed list of works in a BSMP (Clause 11.8.4). |

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## 11.3 Planning unit: the basin, not the ward

11.3.1 BSMPs shall be prepared **by hydrological basin**, not by ward, zone or local-body boundary. Where a basin crosses local-body boundaries, one BSMP shall cover the whole basin.

11.3.2 Basin boundaries shall be delineated from the digital elevation model of Clause 11.5.2, checked against the drain network, road embankments, canals and tank supply channels. Diversions between basins, whether by canal, drain or surplus course, shall be mapped and represented in the model.

11.3.3 No basin delineation has been published for any Meghalaya town. For the urban areas where the evidence identifies them, the basins are at least the following, in the order of the flood-sensitive catchments of Clause 4.5.3.2:

- **Shillong, Umkhrah and Umshyrpi:** the catchments of the Umkhrah and the Umshyrpi to their junction as the **Wah Roro** and on to **Umiam lake**, with the valley floors of Polo, Pynthorbah, Nongmynsong, Mawlai, Forest Colony, Dhankheti and Nongrim Hills as outfall-closed cases (Clause 5.8.5(a)), NESAC's high and very-high flash-flood classes and the landslide localities along NH-40 and the Umshyrpi shown, the five drains that carry 42% of the Umkhrah's pre-monsoon discharge and the 32 outfalls of the two rivers in the 1D network, the stretches under the Board and under the KHADC marked, and surveyed flood marks and the 1% AEP level with its sediment, debris and garbage as the boundary condition, since neither river has a gauge;
- **Shillong, Umkhen and Wah Tamdong:** the catchments of the planning area that drain east to the **Umkhen**, its eastern boundary, and to the **Wah Tamdong** (NESAC), with the same boundary conditions;
- **Umiam lake shore and the Umiam–Umtru reaches:** the catchments that drain to **Umiam lake** and to the reaches below the dams of Stages III and IV and New Umtru, down the 9.80 km of the Umtru to **Byrnihat**, with the level of the lake, once MePGCL states it on a named datum [TBC], and the largest recorded releases as boundary conditions;
- **Jowai, Myntdu headwaters:** the catchments of Jowai that drain to the headwaters of the **Myntdu**, with the limestone, cave and mine-void areas of sub-area ML-B1 mapped, and a local survey of flood marks as the boundary, since the CWC site at Kharkhana is far downstream, and the release reach of **Myntdu–Leshka** below the dam to the Bangladesh border;
- **Sohra, Mawsynram and Shella, escarpment:** the catchments of the escarpment settlements of sub-area ML-C, under the hazard-first rule below;
- **Dawki, Umngot:** the catchments of Dawki that drain to the **Umngot**, with the high flood level at CWC's Dawki site (73.47 m, 28 May 2006; datum not stated) and a surveyed flood mark of June 2026 as the boundary, and the outfall-closed case a design case;
- **Tura, Ganol:** the catchments of Tura that drain to the **Ganol** and to the **Ringrey** and **Rongkhon** streams, which bound the draft master-plan area, with surveyed flood marks as the boundary;
- **Williamnagar, Simsang:** the catchments of Williamnagar that drain to the **Simsang**, with a surveyed level of the river as the boundary;
- **Baghmara and Dalu, south Garo rivers:** the catchments of the two towns, with the high flood levels of the **Bugi** at Dimapara (29.75 m) and the **Dareng** at Sibbari (20.34 m) where they apply, a survey of the Simsang at Baghmara, and the floods of October 2024 at Dalu as calibration evidence;

- **Garo foothill plains, Jinjiram and Krishnai:** the catchments of Phulbari, Tikrikilla and the other plains towns that drain to the **Jinjiram** and the **Krishnai**, with river backwater as the boundary for at least the 72-hour storm and the Assam edition governing the Brahmaputra reaches; and
- **Nongpoh–Umling, NH-6 and the Umlew:** the catchments along NH-6 that drain to the **Umlew** and the other streams of Ri-Bhoi, with the slides of the hill cuts of 2025 mapped.

**Hazard first on the southern escarpment (set by this Manual).** In sub-areas ML-C (Southern escarpment) and ML-C1 (South Garo slopes) of Annex 2A, and in any basin below a mapped landslide zone, a debris fan, a mine-spoil dump, a karst sink or a reservoir release reach, the BSMP begins with a hazard screening for landslides, debris flows, flash floods, karst collapse and dam releases, made with MSDMA's inventories where they exist [TBC], the susceptibility maps of NESAC and the IRADe/NMHS plan, and MePGCL's release reaches, and uses site-specific hydrology in place of a CWC report, which subzone 2(c) does not have (Clause 2.3.6(c)(ii) and (i)), with the duration check of Clause 6.3.6(j). The escarpment's floods are of another order: the spillway of Myntdu–Leshka Stage I is rated for 12,000 m³/s from 350 km², about 34 m³/s per km² (MePGCL; ratio computed for this Manual), Cherrapunji has recorded 1,563.0 mm in 24 hours (IMD) and 2,493 mm in 48 hours on 15–16 June 1995 (a world record, as reported, used only as a stress case), and the earthquake of 12 June 1897 is reported to have killed about 600 people in a landslide at Sohra (as reported). The hazard zones are shown on the 1% AEP map, no drain, storage or pumping station is sited in them, and no work in the CIP is sized to carry a debris flow or a landslide. Other Tier A bodies and the other Municipal Boards define their basins in the first BSMP that covers them. Where CWC, MePGCL, a master plan, the Flood Zoning Authority or a court has a high flood level, a reservoir level, a flood line or an operating rule for a dam, gate or pumping station, the BSMP shall take its boundary conditions from it and show those levels against its own 1% AEP map.

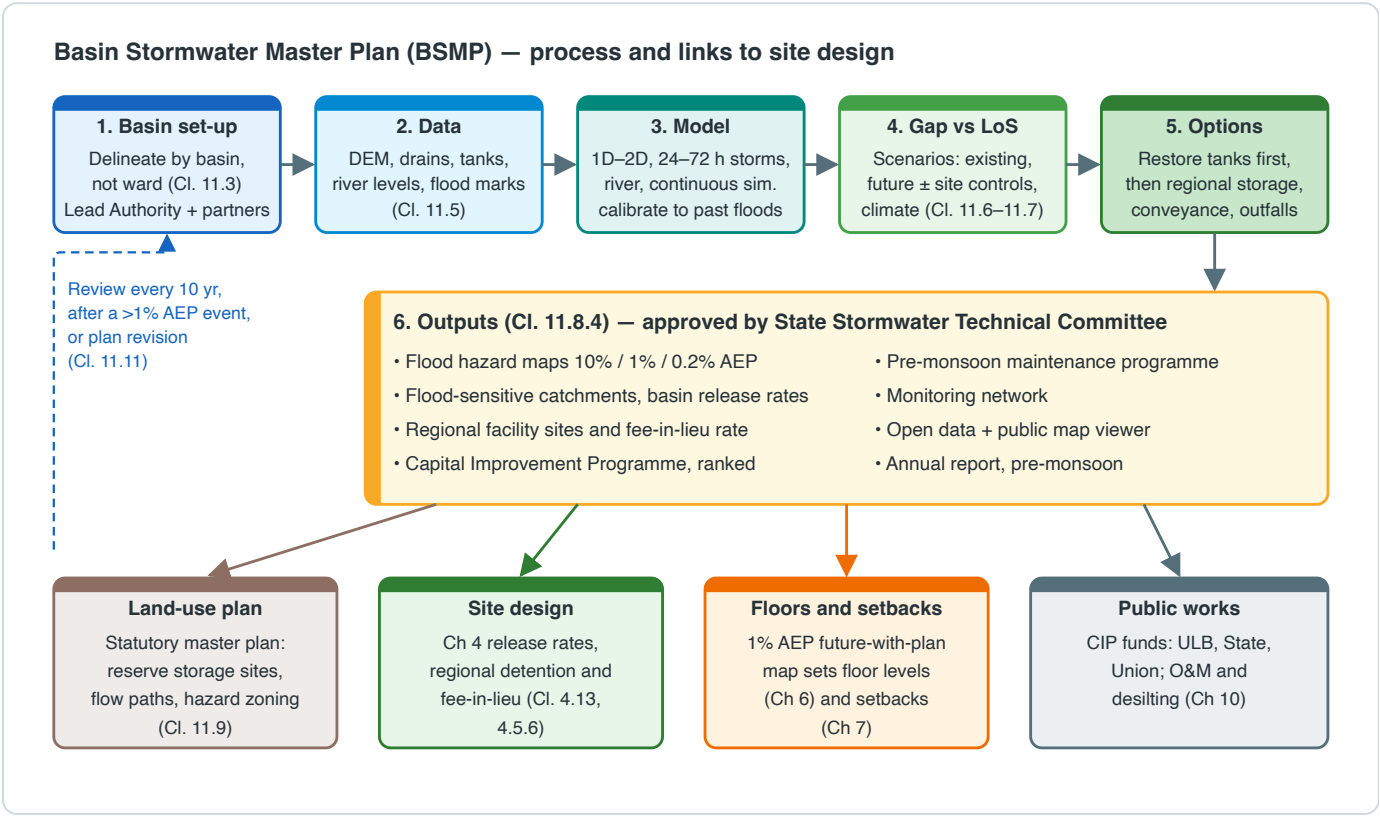


*Figure 11.1 — Basin Stormwater Master Plan process and its links to site design. Original drawing for this Manual. The phase structure is adapted from Defra, Surface Water Management Plan Technical Guidance (2010), and Mile High Flood District master planning practice.*

> **Commentary.** Water does not follow ward boundaries. A ward-by-ward drain plan can pass the problem to the next ward, and to the next local body. In Meghalaya a single stream passes through many hands, and through the Sixth Schedule line, on its way to a river. In Shillong the Umkhrah and the Umshyrpi are at once storm drains, sewers and the feeders of a reservoir: the drains and jhoras carry the city's sullage and septic overflow to 32

outfalls, 20 on the Umkhrah and 12 on the Umshyrpi (MSPCB, as minuted on 14 April 2023), five drains entering the Umkhrah "account for 42% of Umkhrah's pre-monsoon discharge" (the Chief Secretary's presentation, April 2023), and the two rivers join as the Wah Roro before flowing into Umiam lake, which the Expert Committee found "serves as a cesspool of the waste materials of Shillong" (2023). Only parts of the two rivers lie in the Shillong Municipal Board's area, "and remaining stretch falls under jurisdiction of Khasi Hills Autonomous District Council" (State action-taken report to the National Green Tribunal, 21 March 2023), which asked the Board to prepare a geo-referenced map dividing them; the drains in the Board's area are the Board's (Meghalaya Municipal Act, 1973, s.62), its road drains PWD's or NHAI's, the Cantonment's the Cantonment Board's, the village drains and jhoras the District Council's and the Dorbar Shnongs', and the lake MePGCL's. Most of the drainage lines of the planning area are "first, second, and third order reaches" (NESAC, 2023), and most jhoras fall outside the Waterbodies Guidelines, which exclude streams whose bed is dry for 240 days a year (para 2(e)). Beyond Shillong the rivers leave the State: the Umtru, the Digaru, the Jinjiram and the Kopili north to Assam, and the Umngot, the Myntdu, the Kynshi and the Simsang south to Bangladesh. No rule divides the jhoras and natural streams from the municipal drains (as this Manual reads the record). This clause makes the basin the planning unit, so that one model carries each jhora from its head on the ridge to the river or reservoir whoever owns each reach, whether or not the Guidelines treat it as a waterbody, and so that the sewage it carries is separated before it reaches the river or the lake (Chapter 8, Clause 8.9.5).

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## 11.4 Who prepares, and when

11.4.1 **Lead Authority.**

- For the basins of the Shillong Planning Area: the **Shillong Municipal Board (SMB)**, in which the drains, public streams and springs within its limits vest (Meghalaya Municipal Act, 1973, s.62), jointly with **MUDA**, the Authority under the Bye-Laws 2021 in the master-plan area, and the **Urban Affairs Department**, which notifies the Shillong Master Plan 2041 into which the BSMP is taken (Clause 11.9); and, for the parts of the planning area under the Khasi Hills Autonomous District Council, the **KHADC** or its building authority, if the District Council adopts the Manual. Each role is the one the body would have if the Manual were adopted. The **Shillong Cantonment Board** and **NSTDA** in New Shillong [TBC] are partners for their areas. For the basins of Tura: the **Tura Municipal Board** with **MUDA** in the Tura master-plan area. Where a basin extends beyond the Board's limits or the planning area, the District Council, the Dorbar Shnongs of the villages it crosses and the other local bodies in the basin are partners, and one BSMP covers the whole basin (Clause 11.3.1).
- No order dividing the jhoras and natural streams from the municipal drains, or the drains of the local bodies from the rivers and reservoirs, was found; until one is made, this Manual assigns the reaches within each BSMP as follows, each body being Lead Authority for the reaches and works it owns or runs and for the parts of the CIP on them: the **Water Resources Department** for the rivers and their beds, banks and flood works, among them the Umkhrah and the Umshyrpi, for which it has proposed embankments and channel improvement (as reported); the **Municipal Board** for the drains, public streams, springs and tanks within its limits; the **District Council**, and the **Dorbar Shnong** under the District Council's rules, for the village drains and jhoras outside municipal limits (the Nokma-led villages of the Garo Hills were not researched [TBC]); **Shillong Smart City Ltd** for the drains of its works, until handed over in writing; **PWD (Roads)** for the side drains, catch-water drains and culverts of the State roads, and **NHAI** and **NHIDCL** for those of NH-6 and the Shillong–Dawki road, with the spoil of their works; **PHED** for sanitation outside the municipalities; **MePGCL** for Umiam, Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka, their reservoir levels and releases; the **Soil and Water Conservation Department** for catchment treatment; the **Forest and Environment Department** and the **Meghalaya State Wetlands Authority** for the setbacks of the Waterbodies Guidelines, Umiam lake and the other wetlands; and **MSDMA**, with NESAC's susceptibility maps, for the mapping of landslide, flash-flood and debris hazards that a BSMP must show.
- In the other Municipal Boards (Jowai, Williamnagar, Resubelpara and Baghmara) and in Tier B bodies: the Lead Authority is named by the Urban Affairs Department, and in a District Council's area by the District Council, if it adopts the Manual. Basins draining to a common river reach or reservoir may be grouped into one district-level

plan.

MSDMA and the Deputy Commissioner shall be consulted on every BSMP; MePGCL on every BSMP whose basin drains to a reservoir or to a river below a dam; the Forest and Environment Department on every BSMP whose basin drains to Umiam lake or another waterbody with a setback or regulated zone; MSPCB on every BSMP that proposes works on a drain or stream that carries sewage or effluent, among them the Umkhrah, the Umshyrpi, the Wah Roro and the streams of the coal belt; the District Council and the Dorbar Shnongs on every BSMP that needs community, clan or private land for a corridor or storage, which is secured by agreement with the landholding institution; and, for a basin whose outfall lies on a river that flows into Assam, such as the Umtru below Byrnihat, the Digaru or the Jinjiram, Assam's water resources department, through the Water Resources Department.

The Water Resources Department shall be a partner in every BSMP that includes a river, canal or tank under its control.

11.4.2 **When a BSMP is required.**

- (a) Every Tier A body shall approve BSMPs covering its whole area within **3 years** of this Manual taking effect.
- (b) A BSMP is required before:
  - any regional detention or fee-in-lieu is accepted under Clause 4.13;
  - a fee held under Clause 4.5.6.3 is spent; and
  - a basin-specific release rate is applied under Clause 11.8.3.
- (c) A Tier B body shall prepare a BSMP where its Lead Authority, or the State Stormwater Technical Committee, finds recurrent flooding of buildings or arterial roads.

11.4.3 **Preparation.** BSMPs shall be prepared by, or under the direction of, an engineer empanelled as a Stormwater Design Professional (Chapter 10) with experience in basin-scale modelling.

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## 11.5 Data and surveys

11.5.1 Each BSMP shall assemble and publish (Clause 11.10) the data in Table 11.1:

**Table 11.1 — Minimum data and surveys for a BSMP**

| Data | Minimum requirement |
|---|---|
| Terrain | Digital elevation model from LiDAR or photogrammetry, with vertical accuracy of 0.15 m RMSE or better in urban areas, tied to the Survey of India datum |
| Drain network | Inventory of all public drains, culverts and outfalls with invert levels, sizes, condition and silt depth; private drains above 600 mm |
| Waterbodies | Survey of every tank, pung, pond and marsh under Chapter 7: FTL, MWL, bund level, stage–storage, sluices, surplus weirs, supply channels, encroachment |
| Rivers and canals | Cross-sections at no more than 200 m spacing and at every structure |

| Data | Minimum requirement |
|---|---|
| Outfalls, rivers, streams, jhoras, reservoirs, pungs and lakes | The datum of every level named; outfall invert levels against the high flood level of the receiving river at the nearest CWC level-monitoring site, where there is one (73.47 m on the Umngot at Dawki, 47.0 m on the Myntdu at Kharkhana, 20.62 m on the Umnohryngkew at Therriaghat, 29.75 m on the Bugi at Dimapara and 20.34 m on the Dareng at Sibbari; no site in the State has a warning or danger level; CWC levels as transcribed by SANDRP, as reported, with the datum not stated), with any local gauge kept as a separate series; for the Umkhrah and the Umshyrpi in Shillong and the other ungauged streams and jhoras, surveyed flood marks, the debris and garbage lines of past floods and the 1% AEP flood level with its sediment, debris and garbage; for outfalls to reservoirs, the maximum water level, full reservoir level and spillway and gate data from MePGCL, converted from feet where so published (for example Myntdu–Leshka Stage I, 618.00 m; New Umtru, full reservoir level 130.10 m and maximum water level 132.78 m; Umiam–Umtru Stage III, 2,230 ft and 2,235 ft, about 679.7 m and 681.2 m; Stage IV, 503.00 m; Umiam Stage I, 3,220 ft in the press only, on an unknown datum [TBC]), naming which is used, and pungs and lakes at their surveyed spill levels; the release records of the MePGCL dams; the landslide, flash-flood and debris hazards above the basin from the susceptibility maps of NESAC and the IRADe/NMHS plan and from MSDMA where mapped, the karst, cave and mine-void areas, and the mine-spoil dumps; and the sluices, flap gates, debris racks, solid-waste traps, sediment traps, debris basins and pumping stations on the outfalls, with their capacities and operating rules |
| Rainfall and levels | All available rain gauges (IMD, including its observatories at Cherrapunji and Shillong (C.S.O.) and the gauges reported by the Meteorological Centre Shillong, among them Tikrikilla, Resubelpara, Barapani, MeECL Lumjingshai, Shillong, Williamnagar, Nongstoin, Tura, Mawphlang, Mawkyrwat, Mawsynram, Sohra, RKM Sohra, Khliehriat, Baghmara, Shella and Ratacherra (types and record lengths [TBC]); the Shillong self-recording gauge and the ordinary gauges at Shillong (Obsy), Upper Shillong and Dalu used for the CWC Flood Estimation Report for subzone 2(b); the river gauges of CWC; the agro-meteorological station of the ICAR Research Complex for NEH Region at Umiam [TBC]; the rain and reservoir records of MePGCL at its dams [TBC]; and any gauges or sensors kept by the Municipal Boards, Shillong Smart City Ltd, MSDMA and the Water Resources Department [TBC]) and water-level records, including those for the 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 on 17 June, IMD, with 811.6 or 811.2 mm and 972 mm reported at Sohra and NH-6 cut by slides, as reported), 9 July 2019 (more than 72.2 mm at Shillong, with the flash floods of Polo, Forest Colony and Mawlai, as tabulated in the IRADe/NMHS plan), 21–22 September 2014 (the floods and landslides of the Garo Hills after the rain of the night of 21 September, with 52 deaths reported by 28–29 September and more than 60 in a later account, and more than 200 villages under the Brahmaputra and the Jinjiram, as reported, for which no rainfall measurement was found), 4–6 October 2024 (the floods at Dalu and the landslide at Hatiasia Songma in the Garo Hills, as reported, with no rainfall value found), 30–31 May 2025 (the flash flood at Sumer Latara and the landslides of the Umling block near NH-6, as reported, with no rainfall value found) and June 2026 (the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki, as reported, with no rainfall value found) events |
| Flood evidence | Surveyed flood marks and mapped flood extents from past events, including public reports |
| Land use | Existing land use and imperviousness; future land use from the statutory master plan |
| Soils and groundwater | HSG map (Annex 3A); seasonal high groundwater; aquifer and recharge zones |
| Sewer interaction | Known sewage cross-connections, dry-weather flow in drains, and solid-waste hotspots |

Commentary. The 0.15 m accuracy has no direct precedent; this Manual sets it because on the valley floors of Shillong along the Umkhrah and the Umshyrpi, where the water tops the banks of channels narrowed by encroachment, on the Garo foothill plains of Phulbari and Tikrikilla on the Jinjiram and the Krishnai, where slopes are gentle and the rivers back up, on the river terraces and floodplains below the dams of MePGCL, and on the pung, lake and reservoir margins, where a raised road, a dumped fill or a low wall can turn an overflow from one side of a valley floor to the other, a small error in ground level moves the flood edge a long way, and the 1% extent from the BSMP sets floor levels (Chapter 6) and setbacks (Chapter 7). Past flood marks matter as much as models. The 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 on 17 June, IMD, with 811.6 or 811.2 mm and 972 mm reported at Sohra and NH-6 cut by slides, as reported), 9 July 2019 (more than 72.2 mm at Shillong, with the flash floods of Polo, Forest Colony and Mawlai, as tabulated in the IRADe/NMHS plan), 21–22 September 2014 (the floods and landslides of the Garo Hills after the rain of the night of 21 September, with 52 deaths reported by 28–29 September and more than 60 in a later account, and more than 200 villages under the Brahmaputra and the Jinjiram, as reported, for which no rainfall measurement was found), 4–6 October

2024 (the floods at Dalu and the landslide at Hatiasia Songma in the Garo Hills, as reported, with no rainfall value found), 30–31 May 2025 (the flash flood at Sumer Latara and the landslides of the Umling block near NH-6, as reported, with no rainfall value found) and June 2026 (the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki, as reported, with no rainfall value found) events are the best calibration data Meghalaya has, and much of the evidence is held in photographs, news reports and residents' records that should be collected before it is lost.

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## 11.6 Levels of service

11.6.1 Each BSMP shall adopt the following minimum levels of service. A BSMP may adopt stricter levels.

**Table 11.2 — Minimum levels of service**

| Element | Minimum level of service |
|---|---|
| Minor system | The design AEP of Chapter 6 (Table 6.1) |
| Habitable buildings | No flooding above floor level in the 1% AEP (100-yr) event |
| Critical facilities (hospitals, emergency services, substations, water and sewage plants) | No flooding of the facility in the 0.2% AEP (500-yr) event; access road passable in the 1% AEP event |
| Evacuation routes and arterial roads | Passable (hazard class H2 or better, Chapter 6) in the 1% AEP event |
| Ponding drain time | Surface water cleared from roads within **6 hours** after rain ends in the 10% AEP (10-yr) event |
| Tank and pung storage | No net loss of flood storage below the MWL in the basin, measured against the earliest available survey |
| Outfalls | Functioning under the joint and outfall-closed cases of Chapter 5 |

Commentary. The building and road levels repeat Chapter 6, so that the basin plan and the site designs aim at the same outcome. The 0.2% AEP for critical facilities, the 6-hour ponding drain time and the no-net-loss rule for tank storage have no direct precedent and are set by this Manual. The drain time reflects what residents notice most after a storm. The no-net-loss rule reflects a loss of storage that has been reported but rarely measured. Meghalaya's storage is in its reservoirs, its few lakes and pungs, its valley floors and its springs more than in tanks; it has no irrigation tank cascades. Umiam (Barapani), impounded in 1965, has a water spread of about 10.148 km² at its full level and has lost part of its capacity to sediment (as reported); Ward's Lake (Nan Polok) in Shillong and Thadlaskein (Pung Sajar Nangli) near Mukhla are its best-known lake and pung (as reported). The Meghalaya State Wetlands Authority was constituted on 1 November 2017 under the Wetlands Rules 2017 (Notification No. ENV.1/2007/Pt/110), but no wetland has been found notified under Rule 4 and the State has no Ramsar site; in 2025 the High Court accepted a report that 225 water bodies had been ground-truthed, 66 of them lakes and ponds, 25 tanks and ponds and 9 reservoirs and barrages, and that none qualified as a Ramsar site (as reported). The Expert Committee annexed to the Waterbodies Guidelines circulated "inclusion and exclusion lists of water bodies" to the Deputy Commissioners (2023), and the Guidelines exclude ponds and streams whose bed is dry for 240 days in each of the past ten years (para 2(e)), so the jhoras that carry the hill runoff are outside them. The losses are visible in the water as well as at its edge: MSPCB found Umiam lake "Not satisfactory" at all four stations in June 2023, with cyanobacterial blooms each year and leachate from the Mawiong landfill reaching it (Expert Committee, 2023). No survey of the storage of any pung or lake, or of any floodplain inside a Municipal Board's limits, was found.

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## 11.7 Modelling and scenarios

11.7.1 **Model.** Each BSMP shall use a coupled 1D–2D hydraulic model of:

- the minor system;
- the major (overland) system;
- rivers, canals and tanks; and
- the outfalls.

Methods shall follow Chapter 3. Tidal and river boundaries shall follow Chapter 5.

11.7.2 **Design storms.** The model shall be run for the design storms of Chapter 2, including the 24-, 48- and 72-hour storms, for at least the 50%, 10%, 1% and 0.2% AEPs. Areal reduction shall be applied under Clause 2.7.3.

11.7.3 **Continuous simulation.** Basins with tank cascades shall also be run by continuous simulation (Clause 3.13), using the full IMD gridded daily record where available and at least 30 years, disaggregated by the temporal patterns of Annex 2D. This shows how full the tanks are when the design storms arrive, and how often heavy rain coincides with a closed outfall. The two-step approach of Clause 3.13.5 may be used: a simplified storage model is run for the whole record, and the coupled 1D–2D model of Clause 11.7.1 is run only for the design storms, starting from the tank levels the continuous run gives. A continuous run of the full 1D–2D model is not required.

11.7.4 **Scenarios.** Each BSMP shall model at least:

- (a) **Existing:** existing land use, network, tanks and outfalls;
- (b) **Future, uncontrolled:** future land use under the statutory master plan, with no site controls;
- (c) **Future, controlled:** future land use with the site controls of Chapter 4;
- (d) **Future, with plan:** scenario (c) plus the works of the CIP; and
- (e) **Climate:** scenarios (a) and (d), with the climate factors of Clause 2.8, used unchanged: no projection of heavy rainfall for Meghalaya has been adopted with a design factor; the State Action Plan on Climate Change (2015), as quoted in the IRADe/NMHS plan for Shillong, projects more precipitation in every district, 10–15% more in East Khasi Hills by 2050 and about 3% more in the Garo Hills (the passage's east–west wording is inconsistent as printed), and its second version (2023–2030) was not read [TBC]; the trend of Shillong's daily maximum over 1985–2003 is a non-significant increase; the rainfall of June 2022 over Assam and Meghalaya was the highest since 1901 (IMD), while the monsoon of 2026 was 60% below normal in Meghalaya (as reported), which is a reason to keep the factors, not to reduce them; and in sub-areas ML-C and ML-C1 the duration check of Clause 6.3.6(j) and the hazard screening of Clause 11.3.3 are made in every scenario.

11.7.5 **Calibration.** The model shall be calibrated and validated under Clause 3.15, using at least two of the 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 on 17 June, IMD, with 811.6 or 811.2 mm and 972 mm reported at Sohra and NH-6 cut by slides, as reported), 9 July 2019 (more than 72.2 mm at Shillong, with the flash floods of Polo, Forest Colony and Mawlai, as tabulated in the IRADe/NMHS plan), 21–22 September 2014 (the floods and landslides of the Garo Hills after the rain of the night of 21 September, with 52 deaths reported by 28–29 September and more than 60 in a later account, and more than 200 villages under the Brahmaputra and the Jinjiram, as reported, for which no rainfall measurement was found), 4–6 October 2024 (the floods at Dalu and the landslide at Hatiasia Songma in the Garo Hills, as reported, with no rainfall value found), 30–31 May 2025 (the flash flood at Sumer Latara and the landslides of the Umling block near NH-6, as reported, with no rainfall value found) and June 2026 (the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki, as reported, with no rainfall value found) events where data exist.

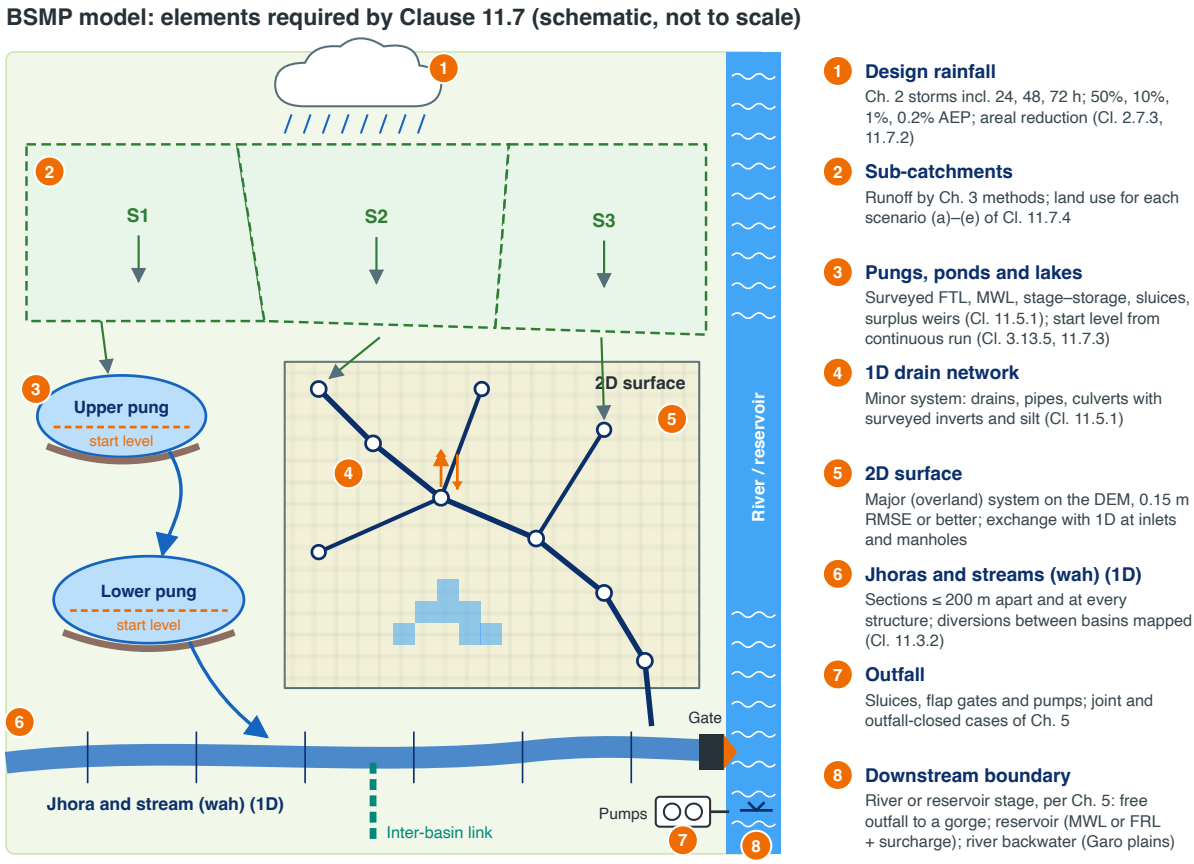


*Figure 11.2 — Elements of the BSMP model required by Clause 11.7: sub-catchments, the 1D drain and channel network, the 2D surface, tanks and pungs with starting levels from continuous simulation, and the tidal or river boundary at the outfall (schematic, not to scale). Original drawing for this Manual, adapted from common coupled 1D–2D urban flood modelling practice.*

> **Commentary.** Scenario (b) against scenario (c) shows what the site rules achieve on their own. Scenario (d) shows what the public works add. This comparison is also the evidence base for notifying flood-sensitive catchments (Clause 4.5.4) and for setting a stricter basin release rate (Clause 11.8.3).

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## 11.8 Options, outputs and the Capital Improvement Programme

11.8.1 **Options hierarchy.** Options shall be considered in the following order, the basin-scale form of the hierarchy in Clause 1.2:

1. **Protect and restore storage:** pungs, tanks, marshes and floodplains, including desilting to the original bed and recovering encroached area (Chapter 7);
2. **Regional retention and detention**, sited by modelling so that releases do not coincide with the main-stem peak (Clause 4.13);
3. **Conveyance** upgrades to drains, canals and culverts;
4. **Outfall works:** flap gates and penstocks on the outfalls of the valley floors of Shillong to the Umkhrah and the Umshyrpi, of Dawki to the Umngot and of the Garo plains towns to the Jinjiram and the Krishnai, and on the outfalls of the Umiam lake shore, with storage or pumping behind them where a stream in flood or a reservoir held near its full level can close an outfall; debris racks, solid-waste traps, sediment traps and debris basins

where jhoras and streams from the hills enter the towns and at every drain outfall to the Umkhrah, the Umshyrpi, the Wah Roro and Umiam lake, with ramps for the machines that empty them, and the removal of garbage and slide debris from the jhoras; drop structures, chutes, energy dissipators and protected outfalls where steep drains reach a jhora or river, never an unprotected slope; the interception and screening of dry-weather flow, and the separation of sewage, before the outfalls to the Umkhrah, the Umshyrpi, the Wah Roro and Umiam lake (Chapter 8, Clause 8.9); and the release rules of the MePGCL dams that set the receiving levels, agreed with MePGCL;

5. **Property-level protection** where works cannot reach the level of service; and
6. **Non-structural measures:** flood warning (for example IMD district rainfall warnings and nowcasts issued by the Meteorological Centre Shillong, the siren, telephone and SMS warnings that MePGCL gives before releases from its dams, level gauges with alarms on the Umkhrah and the Umshyrpi in Shillong, which have no gauge today, and the district emergency operation centres of MSDMA), flood-hazard zoning, emergency planning and public information.

11.8.2 **Option assessment.** Each option shall be assessed for:

- reduction in flood risk (buildings and people flooded; expected annual damage);
- capital and 30-year maintenance cost;
- land required;
- effect on the springs and streams that supply most towns by gravity, and their recharge areas above the town intakes, which this Manual keeps free of paving and of infiltrated road runoff, the sacred groves at the heads of perennial streams, the stability of hill slopes, where water put into colluvium, fill or slide debris raises the pore pressure, as in the landslide localities of Shillong, the cavernous limestones and coal-mine voids of the escarpment and the Jaintia hills, where water put into the ground may go anywhere and no infiltration is allowed (Clause 4.11, karst and mine rule), recharge on the alluvium of the Garo foothill plains and the valley fills of Ri-Bhoi, the only ground where it is allowed, although every assessment unit in the State is safe (stage of extraction 3.55%, CGWB, 2022), and the quality of the groundwater, which carries iron above the drinking-water limit at Shillong and other places, and of the streams, reservoirs, pungs and lakes that the runoff reaches (Chapter 8);
- effect on downstream basins and the receiving river, stream, jhora, reservoir or pung; and
- who benefits.

11.8.3 **Basin release rates.** Where scenario (c) does not meet the level of service, the BSMP may set a basin-specific **permissible site discharge** ($m^3/s/ha$) stricter than Chapter 4, by AEP and sub-catchment. The rate takes effect under the notification procedure of Clause 4.5.4.

11.8.4 **Outputs.** Each BSMP shall produce:

- (a) flood hazard maps (extent, depth, velocity, hazard class) for the 10%, 1% and 0.2% AEPs, existing and future-with-plan. The **1% AEP future-with-plan map** becomes the reference map for floor levels (Chapter 6) and setbacks (Chapter 7);
- (b) recommended flood-sensitive catchments and any basin release rates (Clauses 4.5.4 and 11.8.3);
- (c) regional facility sites, with storage volumes, land needs and the sites they serve;
- (d) the fee-in-lieu unit rate for the basin (Clause 4.13.3);
- (e) the **Capital Improvement Programme**: works ranked by risk reduction per rupee, with cost, phasing and agency;
- (f) a pre-monsoon **maintenance programme**: desilting, gate and pump testing, and tank operating rules (Chapter 10); and
- (g) monitoring needs: new rain gauges, level sensors and flood-mark survey points.

> Commentary. Restoring storage comes first because many of Meghalaya's town outfalls are closed or limited in the wettest hours, and because the storage left is on valley floors and in jhora beds that the towns are filling. In Shillong the valley floors of Polo, Pynthorbah, Nongmynsong, Forest Colony and Mawlai flood "with nearly every heavy downpour" when the Wah Umkhrah overflows, a flooding attributed to "clogging of Wah Umkhrah and the decreasing width of the river due to human activities" (as reported; the same account is in the IRADe/NMHS plan),

and NESAC found "a drastic reduction in channel capacities in most streams due to encroachments along their banks by buildings" (2023). Umiam lake, at the end of the city's rivers, is losing storage to sediment: its gross capacity is reported as 179.757 Mm³ in 1965, 167.069 Mm³ in 1990 and 159.206 Mm³ in 2004 (as reported). Concrete channels alone will not serve on a jhora that carries garbage, boulders and sewage, and on a hill slope, on limestone or over mine workings storage means a lined tank or a terrace, never a pond that soaks into the ground (Clause 4.11); the rainwater storage of at least 25 litres per m² of roof that Clause 4.11 sets, where the Bye-Laws 2021 and the KHADC's Regulation require rainwater harvesting without a volume, is the first of it, and it also serves the dry months, when the towns run short of water. The storms are large for drains with no stated design basis: Cherrapunji has recorded 1,563.0 mm in a day (16 June 1995) and Mawsynram 1,003.6 mm (17 June 2022), and even Shillong 273.2 mm (25 June 1988) (IMD). Conveyance upgrades on their own move water faster to an outfall that the Umkhrah or the Umshyrpi in flood, the Umngot at Dawki, the Jinjiram on the Garo plains, or Umiam lake or another reservoir held near its full level, may close, to a jhora or stream whose bed and banks shift with the boulders, slide debris and garbage it carries, or to an outfall limited by the capacity of its gate or pumping station. Groundwater in Meghalaya calls for storage and restraint, not recharge. Every assessment unit in the State is safe, with a stage of extraction of 3.55% in 2022 (CGWB) and 4.60% in 2024 (as reported), yet the State has "acute shortage of water during the summer as the major part of rainfall is lost as surface run-off", and its towns are supplied by gravity from "streams and springs" tapped at higher altitudes (CGWB, 2022). Little rain enters the ground: infiltration tests under the national aquifer mapping programme gave recharge of 4–5% of rainfall on weathered granite, quartzite and Tertiary rocks and 10–13% only on the alluvium and valley fills of Ri-Bhoi and the Jaintia hills (CGWB, 2022). Water put into the ground can do harm: on the slopes of Shillong, where the landslide localities named in the IRADe/NMHS plan lie, it raises the pore pressure; in the "discontinuous aquifer in the cavernous limestones" (CGWB, 2022) and in the rat-hole workings of the coalfields, into which streams are reported to "disappear" (as reported), it may go anywhere; and the groundwater of Shillong already carries 11.25 mg/l of iron (CGWB, 2022). The springs matter more than the wells: MBDA's spring-shed programme is reported to have mapped 1,000 springs in 11 districts, or to hold an inventory of 1,400 (both as reported; the counts conflict), and a State scheme for the revival of springs covers 306 springsheds under the National Adaptation Fund for Climate Change (as cited on the State's scheme page); many sacred groves stand near the sources of perennial streams (as reported). No State groundwater Act was found; abstraction needs the no-objection certificate of a District Level or State Level Committee on ground water. This is why springs and their recharge areas, slope stability, karst and mine voids, recharge on the only ground that can take it, and groundwater quality are all assessment criteria. This Manual ranks projects by risk reduction per rupee so that limited budgets go first where most people are protected.

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## 11.9 Integration with land-use planning

11.9.1 An approved BSMP shall be incorporated into the statutory land-use plan: the master plans of the master-plan areas notified under the Meghalaya Town and Country Planning Act, 1973, among them the Shillong Master Plan 2041 and, once notified, the risk-informed master plan for Tura, with their zoning regulations and the Bye-Laws 2021; in the autonomous districts outside those areas, the land-development and building regulations of the District Councils, among them the KHADC's Regulation of 2015, if the District Council adopts the Manual; the flood zones notified under the Meghalaya Flood Plain Zoning Act, 2026, once any are; and the layouts and buildings permitted under them. In particular:

- (a) regional facility sites, restored tank flood storage, and major flow paths shall be reserved in the plan;
- (b) the 1% AEP hazard map shall be shown, and Chapter 7 setbacks applied to it;
- (c) land in hazard classes H5–H6 in the 1% AEP event shall not be zoned for new habitable development; and
- (d) the open space of layouts within a basin should be located, where possible, to form part of the major flow paths or regional storage shown in the BSMP.

11.9.2 Where a land-use plan is revised before a BSMP is approved, the planning authority shall use the best available flood mapping and record the BSMP as pending.

> Commentary. Meghalaya draws its water lines by executive guideline and by bye-law, and has a floodplain Act with no zone yet. The Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, as amended in 2024 and 2026, set setbacks from "the mean high flood level of a water body observed in the past ten years" (para 2(f)): 3 m from an urban stream up to 3 m wide and 6 m from a wider one (Appendix 3 as merged in 2024), 10 m to 30 m from rural streams by width and plot size (Appendix 2A, 2026), and 10, 20 or 50 m from lakes and ponds by area, with a regulated zone four times the setback for lakes and rural streams (para 7(1A)); they bind in the Bye-Laws areas (B2(ii)(c) and Section I(f), 2024), elsewhere only "in such manner as may be prescribed" (para 10(2)), and nothing prescribed was found; and they exclude seasonal streams whose bed is dry for 240 days in each of the past ten years (para 2(e)), which is most jhoras. The Bye-Laws 2021 bar the use of land "liable to flooding, except where protection measures are adopted" (B1.1(ii)), set a stilt 1.20 m above the Highest Flood Level on sloping sites beside a stream (B1(v)(b)), and leave the areas of "back flow in drains, inadequate drainage" to be "identified through local surveys in the development plan" (A2.37); the KHADC's Regulation of 2015 puts the "river edge" in a conservation zone where "No development should normally be allowed" (s.2.101). The Meghalaya Flood Plain Zoning Act, 2026 defines the flood zone as "the area which is required to carry the flow of the maximum probable floods", without a return period, and its restrictions "shall prevail" over other laws (ss.2(g) and 12(2), as read in the Bill), but no zone has been notified. The High Court's bar on building within 50 m of waterbodies ended when PIL No. 10 of 2019 was closed on 19 February 2024; the Expert Committee's "Restricted Zones of 50m + 300m" round Umiam lake and NESAC's "buffer as per NGT" along the Umkhrah and the Umshyrpi (no such order of the Tribunal for Shillong's streams was found), 50 m from the lake and 100 m from protected forests are recommendations, not rules. Where a notified flood zone or a master-plan line governs, it applies; elsewhere the hydraulic corridor and setback zones of Chapter 7, with a Zone 1 of at least 15 m on every channel draining 8 ha or more, the Guidelines' setbacks from the ten-year mean high flood level and the 1% AEP extent plus 10 m apply, whichever is wider, as this Manual's proposal, with the 1% AEP corridor as this Manual's reading of "maximum probable floods" and Zone 1 land that is community, clan or private secured by agreement with the landholding institution. A BSMP gives the master plans and the Flood Zoning Authority the 1% AEP drainage-flood map, including the jhoras that no guideline covers, and the buffer widths of Chapter 7, that they need. Using open space land as storage or flow path has no direct precedent; this Manual adopts it because the Bye-Laws 2021 already require rainwater harvesting for every plot category and use, soft cover of at least 10% or 20% of the plot and, for new buildings in the City Centre Zone, 30% of the plot as open space with soft cover and landscaping (Table G1; D8.2), and ask for diversion ditches and swales that carry runoff into designated sediment basins (Section I(b)), and the KHADC Regulation 2015 asks for soft cover of 10–15% of the plot and for plans that show the storm-water drainage and the points where rainwater is collected (ss.35(iii) and 36), but no rule sets a detention or peak-runoff limit; storage placed in a layout's open space builds on these duties, and because that land still serves as open space, the storage must stay usable as one, and on a hill slope, on limestone or over mine workings it is a lined tank or a shallow terrace, never an infiltration basin (Clause 4.11). Placing it on the flow path costs the developer nothing extra and gives the basin storage it would otherwise have to buy.

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## 11.10 Consultation and publication

11.10.1 A draft BSMP shall be published for public comment for at least **60 days**, with public meetings in each affected local body.

11.10.2 After approval, the following shall be published as open data:

- the model files;
- the flood hazard maps;
- the data of Clause 11.5.1, except security-sensitive asset details; and

- the CIP.

They shall also be shown on a public map viewer.

> Commentary. Publishing the maps lets buyers, lenders, insurers and residents see flood hazard before they build or buy. Publishing the model lets designers use the same boundary conditions as the Authority, so site designs and the basin plan stay consistent. This matches the publication approach of Chapter 10.

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## 11.11 Approval, review and reporting

11.11.1 **Approval.** BSMPs shall be approved by the State Stormwater Technical Committee (Chapter 1), after review of the model and of the public comments.

11.11.2 **Review.** Each BSMP shall be reviewed:

- every **10 years**;
- within **2 years** of an event exceeding the 1% AEP design depth in the basin (Clause 2.14); and
- when the statutory land-use plan is revised.

11.11.3 **Annual report.** The Lead Authority shall publish an annual implementation report before each monsoon (by 31 March). The report shall show:

- CIP progress;
- the fee-in-lieu ledger (Clause 4.13.4);
- maintenance completed; and
- any flooding against the levels of service.

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## 11.12 Interim arrangements

11.12.1 Until a BSMP is approved for a basin:

- (a) all site criteria of Chapters 4 to 8 apply in full;
- (b) regional detention and fee-in-lieu under Clause 4.13 are not available, except the holding of fees under Clause 4.5.6.3;
- (c) floor levels and setbacks use the best available mapping, and the methods of Chapters 6 and 7 where no mapping exists; and
- (d) public drain projects shall include a basin-level check that their outfall and downstream reaches can take the design flow under the Chapter 5 tailwater cases.

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## References (chapter)


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## Annexes and forms

| Annex / Form | Content |
|---|---|
| 11A | BSMP terms of reference template |
| 11B | Basin lists and boundaries for Tier A bodies |
| 11C | Depth–damage curves for Meghalaya building types |
| 11D | BSMP data and model publication standard |
| Form 11-1 | Annual implementation report |

ANNEXES TO CHAPTER 1

# Policy, Applicability and Adoption

These annexes support Chapter 1. They hold the lists and maps that define where the Manual applies, the model text of the Policy Supplement and of the legal instruments that would give the Manual effect, and the two forms an Applicant files under Chapter 1. The Manual is a draft; it is not adopted by any government or agency: model legal text is offered for consideration by a competent authority and is not in force, and the forms are draft forms. An annex marked "To be prepared" states the data it needs and the rule to use until it is published (Clause 1.11.5).

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## Annex 1A — List of Tier A authorities, with the boundaries of the Shillong and Tura Municipal Boards and of the master-plan areas under the Meghalaya Town and Country Planning Act, 1973, among them the Shillong Planning Area and the Tura master-plan area

Supports Clauses 1.6.1 to 1.6.5 of Chapter 1.

1A.1 Clause 1.6.1 defines Tier A by class of authority. Table 1A.1 sets out the classes, and the authorities named in the clause, as Chapter 1 defines them. Every authority not in Table 1A.1 is Tier B (Clause 1.6.2).

**Table 1A.1 — Tier A authorities as defined in Clause 1.6.1**

| Item | Tier A authority | Clause |
|---|---|---|
| (a) | The Shillong Municipal Board (SMB) | 1.6.1(a) |
| (b) | Every Approving Authority within the Shillong Planning Area of the Shillong Master Plan 2041, whichever has jurisdiction over a site: MUDA, the Shillong Cantonment Board, NSTDA in New Shillong [TBC] and, for the parts of the planning area under the Khasi Hills Autonomous District Council, its building authority, if the District Council adopts this Manual (this Manual does not decide where MUDA's jurisdiction ends and the District Council's begins) | 1.6.1(b) |
| (c) | The Tura Municipal Board, with MUDA in the Tura master-plan area | 1.6.1(c) |
| — | A Tier B authority that opts into Tier A by council resolution, or that the Government notifies as Tier A | 1.6.4 |

1A.2 Whatever the tier, the design-aid route and the alternatives of Clause 1.7 are not available in a flood-sensitive catchment (Clause 1.6.5; Annex 1B).

**To be prepared.** This annex will contain the full list, by name, of every Approving Authority within the Shillong Planning Area and the Tura master-plan area, with the date from which each is Tier A, and the boundaries of those areas and of the Shillong and Tura Municipal Boards as a map and as a GIS layer. It needs the notified master-plan and scheme areas and their plans, among them the Shillong Master Plan 2041 and the Tura plan (the Urban Affairs Department, MUDA, NESAC); the limits of the six Municipal Boards and of the Shillong Cantonment (the Urban Affairs Department, the Cantonment Board); the area of the New Shillong township (NSTDA [TBC]); the parts of the Shillong Planning Area under the Khasi Hills Autonomous District Council, and the areas of its Town Committees and of the KHBSRA's permissions (the KHADC [TBC]); the line, within each master-plan area, between the areas in which MUDA and those in which a District Council grants permission, which is disputed and is to be shown as each body states it, without this Manual deciding it; and the district and C&RD block boundaries (Revenue and Disaster Management Department, Survey of India). Until it is published, the tier is decided by the classes in Clause 1.6.1 and recorded on Form 1-1, and the Authority confirms it at the pre-application stage (Clause 1.5.9).

**Table 1A.2 — Register of Tier A authorities (layout)**

| No. | Authority | Class (Municipal Board / Town Committee / MUDA / Cantonment Board / NSTDA / District Council building authority / other) | District | Basis (Clause 1.6.1(a), (b), (c) or 1.6.4) | Tier A from (date) | Notification or resolution reference |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |

1A.3 The Municipal Board and master-plan area boundary map shall be published as open data in a machine-readable format (Clause 10.17.4), with the date of the notification it shows.

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## Annex 1B — Maps of flood-sensitive catchments

Supports Clauses 1.4, 1.6.5 and 1.10.3(d) of Chapter 1, and Clauses 4.5.3 and 4.5.4 of Chapter 4.

1B.1 The flood-sensitive catchments are listed in Clause 4.5.3.2. Table 1B.1 repeats that list. The maps of this annex and the boundaries of Annex 4A are the same data set and shall be issued together.

**Table 1B.1 — Flood-sensitive catchments listed in Clause 4.5.3.2**

| Item | Catchment | Extent as described in Chapter 4 |
|---|---|---|
| (a) | Shillong's Umkhrah and Umshyrpi | The catchments of the Wah Umkhrah and the Wah Umshyrpi, with their jhoras, down to the Wah Roro and Umiam lake, including the valley floors of Polo, Pynthorbah, Nongmynsong, Mawlai, Forest Colony, Dhankheti and Nongrim Hills, the land in the high and very high flash-flood susceptibility classes of the NESAC report for the Shillong Planning Area, and the landslide ground along NH-40 and near the Umshyrpi. The valley floors flood "with nearly every heavy downpour" when the Wah Umkhrah overflows (as reported); "Encroachment and clogging of channels are the main causes of flooding over Shillong" (NESAC, 2023); the streams have no gauge, carry the city's sullage through 32 outfalls and are Priority I polluted stretches (MSPCB, as recorded in the minutes of 14 April 2023; CPCB, 2025) |

| Item | Catchment | Extent as described in Chapter 4 |
|---|---|---|
| (b) | Umiam lake shore and the Umiam–Umtru release reaches | The land that drains to Umiam lake below or near its starting level of Clause 3.12.5, and the land along the release reaches of the Umiam–Umtru stages and of New Umtru down to Byrnihat. New Umtru has a maximum water level of 132.78 m and a release reach of 9.80 km of ravine to the Byrnihat bridge, and MePGCL's guidelines warn of releases by siren, telephone or SMS because notice of each release is "not practicable" (MePGCL); no level of Umiam Stage I was found from its operator [TBC] |
| (c) | Jowai on the Myntdu | The land of Jowai that drains to the headwaters of the Myntdu, and the land along the release reach of the Myntdu–Leshka dam to the Bangladesh border, about 24 km of "Ravines and Plains of East & West Jaintia Hills" (MePGCL). The 2(b) plate reads about 680 mm at 50 years at Jowai, probably high; the CWC site at Kharkhana, far downstream, recorded its highest level, 47.0 m, on 23 April 1995 (CWC data as transcribed by SANDRP) |
| (d) | The escarpment settlements of Sohra, Mawsynram and Shella | The land of Sohra, Mawsynram, Shella and the other settlements of the southern escarpment in sub-area ML-C, where the State's record rainfall falls on limestone and steep ground: 1,563.0 mm at Cherrapunji on 16 June 1995 and 1,003.6 mm at Mawsynram on 17 June 2022 (IMD), in subzone 2(c), for which CWC has published no report |
| (e) | Dawki on the Umngot | The land of Dawki that drains to the Umngot, whose CWC level-monitoring site has a highest recorded level of 73.47 m (28 May 2006, a pre-monsoon date) (CWC data as transcribed by SANDRP); in June 2026 the river rose rapidly and submerged a labour camp while the Shillong–Dawki road collapsed at Laitlyngkot (as reported) |
| (f) | Tura on the Ganol | The land of the Tura master-plan area, 54.65 km² bounded by the Ringrey stream, the Ganol river and the Rongkhon stream, that drains to the Ganol and to the Ringrey and Rongkhon streams (draft master plan, 2024); NH-51 to Tura was blocked in the floods of September 2014 (as reported) |
| (g) | Williamnagar on the Simsang | The land of Williamnagar that drains to the Simsang, which has no CWC site within the State |
| (h) | Baghmara and Dalu on the south Garo rivers | The land of Baghmara and Dalu that drains to the rivers of the south Garo slopes and the edge of the plains, among them the Simsang, the Bugi and the Dareng (CWC sites at Dimapara, highest level 29.75 m, and Sibbari, 20.34 m); 3 people drowned at Dalu and 2,630 households were affected in Dalu block on 4–6 October 2024 (as reported) |
| (i) | The Garo foothill plains on the Jinjiram and the Krishnai | The land of Phulbari, Tikrikilla and the other settlements of the Garo foothill plains that drains to the Jinjiram and the Krishnai under their backwater, where the Brahmaputra and the Jinjiram submerged more than 200 villages in September 2014 (as reported) and more than 100 in September 2012 (IRADe/NMHS plan, Table 17) |
| (j) | Nongpoh–Umling on NH-6 and the Umlew | The land of Nongpoh and Umling block that drains to the Umlew and the streams crossed by NH-6, where landslides struck 15 villages near the highway on 30–31 May 2025, linked to hill cutting along it, and a person drowned in the Umlew (as reported) |
| (k) | Notified catchments | Any catchment notified under Clause 4.5.4 |

**To be prepared.** This annex will contain a map of each catchment in Table 1B.1 at a scale fit for deciding whether a plot lies inside it, and the same boundaries as a GIS layer. It needs catchment boundaries drawn from a digital elevation model and the drain and jhora network (SMB and the Municipal Boards of Jowai, Tura, Williamnagar, Resubelpara and Baghmara, MUDA, the Shillong Cantonment Board, NSTDA, the District Councils and the Dorbar Shnongs for the villages, Survey of India); the drains and jhoras with their outfalls and the dry-weather interceptions on them, with levels on a stated datum, among them the 32 outfalls of the Umkhrah and the Umshyrpi (the Municipal Boards, MSPCB); the flash-flood and landslide susceptibility maps of the risk-informed master plans of Shillong and Tura (NESAC, the Urban Affairs Department); the flood marks of the Umkhrah and the Umshyrpi at Polo, Pynthorbah and Nongmynsong, of the Umngot at Dawki (2006 and June 2026) and of the Garo plains (2012, 2014), and the flood plain zonation study of RMSI when it is published (the Water Resources Department, MSDMA, the Deputy Commissioners); the levels and release reaches of the reservoirs of MePGCL (MePGCL); the karst, cave and mine-void areas of the Jaintia hills and the escarpment, for which no map was found [TBC] (the Geological Survey of India); and the CWC levels at Dawki, Kharkhana, Dimapara and Sibbari (CWC). Nongstoin, Mairang, Resubelpara, Khliehriat and the coal-belt towns of the Jaintia hills are candidates for notification under Clause 4.5.4 once their catchment boundaries and flood record are documented [TBC]. The setbacks of the Waterbodies Guidelines from streams, lakes and ponds, and the corridors of Chapter 7, are governed by Chapter 7 and by the instruments that bind there rather than by this list. Until it is published, the Authority decides at the pre-application stage whether a site lies in a listed catchment, from the best boundary available, and the decision and its basis are recorded on Form 1-1 and in the drainage report (Clauses 1.5.9 and 1.11.5).

**Table 1B.2 — Attributes of the flood-sensitive catchment layer (layout)**

| Field | Content | Unit or format |
|---|---|---|
| catchment_id | Unique identifier | text |
| name | Catchment name | text |
| basis | Clause 4.5.3.2 item (a) to (j), or the notification under Clause 4.5.4 | text |
| notification_ref | Gazette notification number, where notified | text |
| notified_on | Date of notification | date |
| applies_from | Date from which the rule applies to applications (Clause 4.5.4.2, step 5) | date |
| boundary_source | Source and date of the boundary | text |
| area_km2 | Catchment area | km² |

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## Annex 1C — Policy Supplement: text of alternatives S-1 to S-5 and model council resolution

Supports Clauses 1.6.3, 1.6.5 and 1.7.1 to 1.7.3 of Chapter 1.

**Model text for consideration by a competent authority. Not in force.** The text below shows how the Policy Supplement of Clause 1.7 could be written. It has no effect unless and until it is issued by the Government and adopted by an Approving Authority under Clause 1.7.3.

## Part 1 — General provisions

P1.1 **Scope.** This Supplement sets out alternatives S-1 to S-5 to the requirements of the Meghalaya Stormwater Design Manual (the Manual) named in each alternative. An alternative applies within the area of an Approving Authority (the Authority) only from the date on which the Authority adopts it under P1.3.

P1.2 **No lower criterion.** No alternative lowers any criterion of the Manual. S-1 and S-2 are simplified methods for meeting the same criterion (Clause 1.7.3(a)).

P1.3 **Adoption.**

- (a) A Tier B authority adopts an alternative by council resolution in the form of Part 3, and sends a copy to the State Stormwater Technical Committee (the Committee) within 30 days of the resolution.
- (b) A Tier A authority adopts an alternative only after the Committee has concurred in writing.
- (c) The Authority publishes the alternatives it has adopted on its website and in the register of Clause 10.17.

P1.4 **Retention.** No alternative replaces the retention requirement (Annex 2E depth), except where fee-in-lieu under S-5 funds equivalent retention in the same basin (Clause 1.7.3(d)).

P1.5 **Tables.** The tables used by S-1, S-2 and S-3 are those issued by the Committee, and are reviewed with Chapter 2 of the Manual (Clauses 1.7.3(e) and 2.14). An alternative that depends on a table cannot be used until that table is issued.

P1.6 **Record.** An Applicant who uses an alternative states it on Form 1-1 and in the drainage report, with the resolution or concurrence under which it was adopted.

## Part 2 — The alternatives

### S-1 — Design-aid route for storage

S-1.1 *Replaces:* storage sized by a hydrograph method under Chapter 3.

S-1.2 *Alternative:* retention and detention volumes may be taken from the unit-storage tables issued for Annex 4B (m³ per ha, by rainfall zone, hydrologic soil group and impervious fraction) and the compliance calculator, by the method of Clause 4.14.2.

S-1.3 *Eligibility:* sites of 2 ha or less outside flood-sensitive catchments, and of 0.5 ha or less within them (Table 1.2; Clause 4.14.1).

S-1.4 *Conditions:* the post-development imperviousness used shall be that shown on the approved plans; the outlet, spillway, RWH accounting and safety provisions of Clause 4.14.2 apply; the compliance calculator may be the sole calculation (Table 1.1).

### S-2 — Permissible site discharge (PSD)

S-2.1 *Replaces:* the release rate $Q_{post}(T) \le 0.9 \times Q_{pre}(T)$ computed for the site (Clause 2.11.2).

S-2.2 *Alternative:* the release rate for each AEP may be taken as the tabulated unit-area release rate for the site's zone and AEP, multiplied by the site area. The tabulated rates are derived from the $0.9 \times Q_{pre}$ rule (Table 1.2).

S-2.3 *Eligibility:* any site outside a flood-sensitive catchment.

S-2.4 *Conditions:* storage is then sized to hold every duration of Clause 2.5.2 at the PSD; drawdown, minimum orifice and spillway rules of Chapter 4 apply unchanged.

### S-3 — Fixed-width waterbody setback

S-3.1 *Replaces:* the waterbody setback extended to the mapped 1% AEP flood extent plus margin (Chapter 7).

S-3.2 *Alternative:* where no 1% AEP extent is mapped, the setback shall be the fixed width for the class of waterbody in the table of Clause 7.4.6 (and Annex 7B), measured as in Clause 7.4.3.

S-3.3 *Eligibility:* waterbodies with no mapped 1% AEP extent.

S-3.4 *Conditions:* no setback under this alternative is less than the Zone 1 minimum of Clause 7.4.7 (Clause 1.10.3(c)); the no-fill zone of Chapter 7 applies; where a 1% AEP extent is later mapped and adopted, the mapped setback applies to new applications.

**S-4 — Downstream screening checklist**

S-4.1 *Replaces:* downstream analysis by hydraulic model under Chapter 5.

S-4.2 *Alternative:* the Applicant completes a screening checklist of downstream capacity and known flooding, covering at least the conditions of Clause 5.3.4: that the receiving public drain has documented capacity for its minor-system design flow (Chapter 6), and that no flood-prone location is recorded within 500 m downstream. A hydraulic model under Chapter 5 is required only where the screen fails.

S-4.3 *Eligibility:* sites of less than 1 ha, outside flood-sensitive catchments, not discharging to a tidal outfall.

S-4.4 *Conditions:* the checklist is signed by the registered professional who signs the drainage report (Clause 10.6); flood-prone locations are those recorded by the local body, the Deputy Commissioner and the District Disaster Management Authority, MSDMA, the Water Resources Department, or the Dorbar Shnong (Clause 5.3.3(d)).

**S-5 — Fee-in-lieu toward regional storage**

S-5.1 *Replaces:* on-site detention under Chapter 4.

S-5.2 *Alternative:* all or part of the detention requirement may be met by a fee-in-lieu toward a regional detention facility or restored pung or tank storage identified in the basin plan (Clause 4.13.1).

S-5.3 *Eligibility:* sites in a basin for which a basin plan has been notified (Table 1.2).

S-5.4 *Conditions:*

- (a) the conditions of Clause 4.13.2 apply, including interim on-site detention until the regional facility or restored tank is operational, and retention and WQv treatment on site;
- (b) the fee is computed under Clause 4.13.3 and held in the ring-fenced basin account;
- (c) the volume credited and the fee are entered in the public ledger of Clause 4.13.4; and
- (d) in a flood-sensitive catchment, fee-in-lieu is available only as allowed by Clause 1.10.3(d).

## Part 3 — Model council resolution

> **Model text for consideration by a competent authority. Not in force.**

**Resolution No. _____ of _____ (name of Municipal Board / Town Committee), dated _____**

*Subject:* Adoption of alternatives under the Policy Supplement to the Meghalaya Stormwater Design Manual.

The Council, having considered the report of the Executive Officer / Secretary dated _____, and noting that:

- (i) the Meghalaya Stormwater Design Manual and its Policy Supplement have been given effect by _____ (instrument and date);
- (ii) this local body is a Tier B / Tier A authority under Clause 1.6 of the Manual; and
- (iii) for a Tier A authority, the State Stormwater Technical Committee concurred on _____ (reference _____),

**resolves:**

1. to adopt the following alternatives of the Policy Supplement within its area, under the conditions of Clause 1.7.3 of the Manual:

**Table 1C.1 — Alternatives adopted by this resolution**

| Alternative | Adopted (Yes / No) | Area to which it applies (whole area, or wards / zones) | Applies from (date) |
|---|---|---|---|
| S-1 Design-aid route | | | |
| S-2 Permissible site discharge | | | |
| S-3 Fixed-width setback | | | |
| S-4 Downstream screening checklist | | | |
| S-5 Fee-in-lieu | | | |

2. that no adopted alternative shall apply within a flood-sensitive catchment except as the Manual allows (Clause 1.6.5);
3. that a copy of this resolution be sent to the State Stormwater Technical Committee within 30 days;
4. that the adopted alternatives be published on the local body's website and entered in the register of Clause 10.17; and
5. that this resolution be reviewed when the tables of Clause 1.7.3(e) are revised.

Chairperson: _____ Executive Officer / Secretary: _____ Date: _____

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## Annex 1D — Model Bye-Laws 2021 amendment and model ULB bye-law

Supports Clauses 1.3.1, 1.3.4, 1.11 and 1.12 of Chapter 1.

> **Model text for consideration by a competent authority. Not in force.** The text shows one way the instruments of Clause 1.3.1 could be drafted. Rule and section numbers are left blank.

> **Drafting note D1D.1.** The rule numbers of the Meghalaya Building Bye-Laws 2021 at which the new rule and the conditions would be inserted, and the enabling sections of the Meghalaya Town and Country Planning Act, 1973 and the municipal and panchayat Acts, are to be confirmed by the Government's legal advisers. None is stated here.

### Part A — Model amendment to the Meghalaya Building Bye-Laws 2021

A.1 **Short title and commencement.**

- (1) These rules may be called the Meghalaya Building (Stormwater Management) (Amendment) Bye-Laws, _____.
- (2) They shall come into force on the date six months after their publication in the Gazette of Meghalaya (Clause 1.11.1).

A.2 **Insertion of a new rule.** After rule [_____] of the building bye-laws notified by the Government under section 74 of the Meghalaya Town and Country Planning Act, 1973, the following rule shall be inserted:

> **Rule [_____]. Stormwater management.**
>
> (1) *Definitions.* In this rule, "the Manual" means the Meghalaya Stormwater Design Manual as notified by the Government, with its annexes and amendments; other words have the meanings given in Clause 1.4 of the Manual.
>
> (2) *Application.* This rule applies to every development for which planning permission, building permit or layout approval is required under these rules.
>
> (3) *Runoff control.* Where a development, over its common plan of development, involves land disturbance of 0.1 ha or more, or new or replaced impervious area of 500 m² or more, the development shall comply with Chapters 4 and 5 of the Manual (retention, detention, downstream and tailwater analysis).
>
> (4) *Provisions for every development.* Every development, whatever its size, shall comply with Clause 1.5.4 of the Manual: no sewage connection to a storm drain; floor levels; waterbody setbacks and the no-fill zone; and no obstruction of a drainage path.
>
> (5) *Exemptions.* A single dwelling on its own plot below the thresholds of sub-rule (3), and linear road resurfacing that adds no impervious area, are exempt from sub-rule (3) but not from sub-rule (4) or the rainwater harvesting provisions of these rules.
>
> (6) *Conditions of approval.* The competent authority shall not grant:
>
> - (a) planning permission or layout approval, unless a preliminary drainage report under the Manual has been accepted;
> - (b) a building permit, or permission to commence, unless the final drainage design has been accepted; or
> - (c) a completion certificate, unless the as-built certificate has been accepted and the maintenance declaration has been registered, or the public assets have been handed over,
>
> for a development to which sub-rule (3) applies (Manual, Clause 10.3).
>
> (7) *Certification.* Drainage reports and designs shall be signed by a registered professional, and, where Clause 10.6.1 of the Manual so requires, by an empanelled Stormwater Design Professional.
>
> (8) *Rainwater harvesting.* Nothing in this rule alters the rainwater harvesting provisions of these rules.
>
> (9) *Variances and waivers.* The competent authority may grant a variance or waiver only on the grounds and by the procedure of Clause 1.10 of the Manual, and shall publish each decision.
>
> (10) *Transition.* Applications filed complete before the commencement of this rule, and Tier B authorities, are governed by Clause 1.11 of the Manual.

## Part B — Model ULB bye-law

B.1 **Title and commencement.** These bye-laws may be called the _____ (name of local body) Stormwater Management Bye-laws, _____. They come into force on _____.

B.2 **Adoption of the Manual.** The Meghalaya Stormwater Design Manual, as notified by the Government, applies to:

- (a) every development approved by the local body; and

- (b) every drainage, road, culvert, waterbody and flood-mitigation work executed by the local body, including its own drains and roads (Clause 1.3.1(b)).

B.3 **Public works.** Every detailed project report and contract for a work under B.2(b) shall require compliance with the Manual, from the dates in Clause 1.11 (Clause 1.3.4).

B.4 **Tier and alternatives.** The local body is a Tier _____ authority under Clause 1.6 of the Manual. The alternatives of the Policy Supplement adopted by the local body are listed in the Schedule, with the resolution under which each was adopted.

B.5 **Submittals and review.** Submittals shall be made in the stages of Clause 10.3 of the Manual and reviewed within the periods of Clause 10.7.

B.6 **Maintenance, inspection and enforcement.** Maintenance declarations, inspections, handover of public assets and enforcement shall follow Clauses 10.10 to 10.15 of the Manual.

B.7 **Publication.** The local body shall publish the registers and reports of Clause 10.17 of the Manual.

B.8 **Review.** These bye-laws shall be reviewed whenever the Manual is amended under Clause 1.12.

**Table 1D.1 — Schedule: alternatives adopted (layout)**

| Alternative | Resolution number and date | Committee concurrence (Tier A only) | Applies from | Area |
|---|---|---|---|---|
| | | | | |
| | | | | |

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## Form 1-1 — Applicability Determination

Supports Clauses 1.5.1 to 1.5.9 and 1.6 of Chapter 1, and Clause 10.3 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Lodged at the pre-application meeting (Stage 0) or with the preliminary drainage report (Stage 1), as Clause 10.3.2 requires.

**Table 1F.1 — Form 1-1: Applicability Determination**

| No. | Item (clause) | Entry |
|---|---|---|
| | **A. Applicant and site** | |
| A1 | Applicant (owner, developer or department) | _____ |
| A2 | Site address and survey numbers | _____ |
| A3 | Site coordinates (latitude, longitude) | _____ |
| A4 | Approving Authority (Clause 1.4) | _____ |
| A5 | Tier of the Authority: A / B (Clause 1.6; Annex 1A) | _____ |
| A6 | Approval sought: planning permission / building permit / layout approval / public work (DPR) | _____ |
| A7 | Type of development: building / layout / sub-division / road / paving / land-use change / other (Clause 1.4) | _____ |
| A8 | Stage at which this form is lodged: Stage 0 / Stage 1 (Clause 10.3) | _____ |
| | **B. Coverage (Clause 1.5.1)** | |
| B1 | Development requiring approval under the Meghalaya Building Bye-Laws 2021 — 1.5.1(a): Yes / No | _____ |
| B2 | Public work by a ULB, State department, board or State undertaking — 1.5.1(b): Yes / No | _____ |
| B3 | Work by a Central agency needing the Authority's approval or no-objection — 1.5.1(c): Yes / No | _____ |
| | **C. Areas over the common plan of development (Clauses 1.4, 1.5.5)** | |
| C1 | Phases, plots and sub-divisions included (one layout approval or one ownership) | _____ |
| C2 | Total site area (ha) | _____ |
| C3 | Land disturbance (ha) | _____ |
| C4 | Existing impervious area (m²) | _____ |
| C5 | New impervious area (m²) | _____ |
| C6 | Replaced impervious area, removed to subgrade and rebuilt (m²) | _____ |
| C7 | New plus replaced impervious area, C5 + C6 (m²) | _____ |
| C8 | Plot area for the RWH mandate (m²) (Clause 1.5.3) | _____ |
| | **D. Thresholds and exemptions** | |
| D1 | Land disturbance 0.1 ha or more — 1.5.2(a): Yes / No | _____ |
| D2 | New or replaced impervious area 500 m² or more — 1.5.2(b): Yes / No | _____ |
| D3 | Redevelopment (existing impervious cover on the site) — 1.5.6: Yes / No | _____ |
| D4 | Constrained redevelopment route of Clause 4.5.6 proposed: Yes / No | _____ |

| No. | Item (clause) | Entry |
|---|---|---|
| D5 | Linear public work: added impervious area per drainage catchment crossed given in Table 1F.2 — 1.5.7: Yes / No / not applicable | _____ |
| D6 | Exemption claimed — 1.5.8(a) single dwelling below the thresholds / 1.5.8(b) resurfacing with no added impervious area / none | _____ |
| D7 | RWH mandate applies (Bye-Laws 2021, Table G1: every plot category and use in the master-plan, municipal and scheme areas; KHADC Regulation 2015, s.36: all existing and new buildings in the Khasi Hills Autonomous District) — 1.5.3: Yes / No | _____ |
| | **E. Site conditions** | |
| E1 | Site in a flood-sensitive catchment (Annex 1B; Clause 4.5.3): No / Yes — name | _____ |
| E2 | Source of the catchment boundary used | _____ |
| E3 | 1% AEP level mapped or determinable for the site (Clause 1.5.4(b)): Yes / No; source | _____ |
| E4 | Waterbody on or adjoining the site (Clause 1.5.4(c); Chapter 7): No / Yes — name | _____ |
| E5 | Natural drainage path or major-system flow path crossing the site (Clause 1.5.4(d)): No / Yes | _____ |
| E6 | Site drains to a tidal outfall (Clause 10.3.2(d)): Yes / No | _____ |
| E7 | Variance, waiver, regional facility or fee-in-lieu proposed (Clause 10.3.2(c)): No / Yes — Form 1-2 attached | _____ |
| | **F. Determination** | |
| F1 | Result: (i) Chapters 4 and 5 apply, with Clause 1.5.4 and the RWH mandate; (ii) Clause 1.5.4 and the RWH mandate only (below thresholds); (iii) exempt under 1.5.8, Clause 1.5.4 and the RWH mandate still apply | _____ |
| F2 | Stage 0 mandatory under Clause 10.3.2: Yes (state item (a) to (d)) / No | _____ |
| F3 | Storage method: hydrograph method (Chapter 3) / design-aid route S-1 (Clause 1.7, where adopted and eligible) | _____ |
| F4 | Other Policy Supplement alternatives relied on (S-2 to S-5), with the adopting resolution | _____ |
| F5 | Tier B phased start applies (Clause 1.11.3): Yes / No | _____ |
| | **G. Declaration** | |
| G1 | I declare that the information above is correct and covers the whole common plan of development. Applicant: name, signature, date | _____ |
| G2 | Prepared by (registered professional, Clause 1.4): name, registration number, signature, date | _____ |
| | **H. For the Authority (Clause 1.5.9)** | |
| H1 | Determination confirmed / corrected | _____ |
| H2 | Corrections and reasons | _____ |
| H3 | Officer: name, designation, signature, date | _____ |

### Table 1F.2 — Form 1-1: added impervious area by drainage catchment, linear works (Clause 1.5.7)

| Drainage catchment crossed | Chainage from – to | Added impervious area (m²) | 500 m² or more (Yes / No) | Storage location: right of way / regional facility |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

## Form 1-2 — Variance / Waiver Request

Supports Clause 1.10 of Chapter 1.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Lodged with the preliminary drainage report (Clause 1.10.4(a)), with one form for each requirement concerned.

**Table 1F.3 — Form 1-2: Variance / Waiver Request**

| No. | Item (clause) | Entry |
|---|---|---|
| | **A. Applicant and site** | |
| A1 | Applicant | _____ |
| A2 | Site address and coordinates | _____ |
| A3 | Form 1-1 reference and date | _____ |
| A4 | Tier of the Authority: A / B | _____ |
| A5 | Site area (ha) | _____ |
| A6 | Site in a flood-sensitive catchment: Yes / No | _____ |
| | **B. Request** | |
| B1 | Type: variance from a numeric requirement (1.10.1) / waiver of Chapter 4 detention (1.10.2) | _____ |
| B2 | Clause of the Manual concerned | _____ |
| B3 | Value required by the Manual | _____ |
| B4 | Value or arrangement proposed | _____ |
| | **C. Matters that cannot be varied or waived (Clause 1.10.3)** — confirm that the request does not concern any of them | |
| C1 | (a) a sewage connection to a storm drain | Not concerned: _____ |
| C2 | (b) the lowest habitable floor level of Chapter 6 | Not concerned: _____ |
| C3 | (c) a waterbody setback below the Zone 1 minimum of Clause 7.4.7, or fill or construction in the no-fill zone of Chapter 7 | Not concerned: _____ |
| C4 | (d) retention in a flood-sensitive catchment, except by fee-in-lieu under Clause 1.7 | Not concerned: _____ |
| | **D. Variance: grounds (Clause 1.10.1(a))** | |
| D1 | Site condition: high groundwater table / contaminated soil / rock / site too small for the required facility / other | _____ |
| D2 | Evidence (tests, surveys, plans), with references | _____ |
| D3 | Options assessed and why each is impracticable | _____ |
| | **E. Variance: equal performance or make-up (Clause 1.10.1(b))** | |
| E1 | Downstream point used (Chapter 5) | _____ |
| E2 | Performance at that point with full compliance and with the variance (peak flows, water levels) | _____ |

| No. | Item (clause) | Entry |
|---|---|---|
| E3 | Or: shortfall made up by fee-in-lieu or off-site works in the same catchment — volume (m³), works or fee | _____ |
| | **F. Waiver of detention: grounds (Clause 1.10.2)** | |
| F1 | Site discharges directly to the sea / to a tidal reach with no flood-prone property downstream | _____ |
| F2 | Analysis showing that undetained flow does not worsen the outfall-closed condition of Chapter 5 — reference | _____ |
| F3 | Retention still provided in full: Yes | _____ |
| | **G. Attachments (Clause 1.10.4(a))** | |
| G1 | Report certified under Clause 10.6 | _____ |
| G2 | Preliminary drainage report | _____ |
| | **H. Certification and declaration** | |
| H1 | Certified by (registered professional; empanelled professional where Clause 10.6.1 applies): name, registration or empanelment number, signature, date | _____ |
| H2 | Applicant: name, signature, date | _____ |
| | **I. For the Authority (Clause 1.10.4)** | |
| I1 | Referred to the State Stormwater Technical Committee (Tier B, site 1 ha or more): Yes / No; date | _____ |
| I2 | Decision: granted / granted with conditions / refused | _____ |
| I3 | Reasons and conditions | _____ |
| I4 | Entry number in the public register (Clause 10.17) | _____ |
| I5 | Note: a variance runs with the approval and lapses if the approval lapses (Clause 1.10.4(d)) | — |
| I6 | Officer: name, designation, signature, date | _____ |

ANNEXES TO CHAPTER 2

# Design Rainfall and Design Storms

These annexes support Chapter 2. Annexes 2A to 2E will hold the statewide rainfall tables that Chapter 2 refers to: the benchmark checks and zone map, sub-daily ratios, grid-to-point factors, temporal patterns and retention depths. Each needs analysis of NIH-DHAARA and IMD records that has not yet been done for this Manual, so each is marked "To be prepared" and gives its intended layout and the rule to use until it is published (Clause 1.11.5). Form 2-1 is a draft form for the Design Rainfall Sheet that every hydrologic submittal must include (Clause 2.13). The Manual is a draft; it is not adopted by any government or agency.

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## Annex 2A — NIH-DHAARA vs IMD station and IMD gridded checks at benchmark points; zone map

Supports Clauses 2.3.1 to 2.3.5 of Chapter 2.

**To be prepared.** This annex will compare, at benchmark points across the State, the NIH-DHAARA design depths with frequency analyses of long IMD daily station records and of IMD gridded daily data (converted to point values with Annex 2C), for 24 hours and longer and for the AEPs of Table 2.1. It will also contain the map of rainfall zones used by Annexes 2B, 2C and 2E and by the Tier B tables of Chapter 4. It needs NIH-DHAARA values at the benchmark coordinates (NIH), IMD daily and recording-gauge station records and IMD gridded rainfall (IMD), State rain-gauge records (the gauges on the daily rainfall map of the Meteorological Centre Shillong, among them Tikrikilla, Resubelpara, Barapani, MeECL Lumjingshai, Williamnagar, Nongstoin, Tura, Mawphlang, Mawkyrwat, Mawsynram, Sohra, RKM Sohra, Khliehriat, Baghmara, Shella and Ratacherra, whose types and record lengths are to be confirmed, the catchment gauges of MePGCL, the gauges of the Water Resources Department, and the agro-meteorological station of the ICAR Research Complex for NEH Region at Umiam [TBC]), and district and basin boundaries (Survey of India, Water Resources Department). Until it is published, design depths are taken from NIH-DHAARA under Clause 2.3.1, the cross-checks of Clause 2.3.3 are reported on Form 2-1, and the zone of a site is the one agreed with the Authority and recorded on Form 2-1.

**Table 2A.1 — Benchmark comparison of design depths (layout)**

| Benchmark point | IMD station ID | Latitude, longitude | Years of record | Duration (h) | AEP | NIH-DHAARA (mm) | IMD station analysis (mm) | IMD gridded, point value (mm) | NIH-DHAARA / IMD station | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 24 | | | | | | |
| | | | | 48 | | | | | | |
| | | | | 72 | | | | | | |

2A.1 The zone names below are the working names used in the Tier B table template of Chapter 4 (Clause 4.14.2). Their boundaries, and whether further zones are needed, are to be set by the analysis of this annex.

Table 2A.2 — Rainfall zones (layout)

| Zone (working name) | Extent (districts, basins) | Representative stations | Notes |
|---|---|---|---|
| ML-Z1 Northern foothills | The Brahmaputra-facing northern slope of the plateau in Ri Bhoi and the northern foothills and plains of the Garo hills, in CWC subzone 2(b), South Brahmaputra (Clause 2.3.6(b)); catchments that cross a zone line take the higher zone value | Barapani (Meteorological Centre Shillong map; the ICAR Research Complex for NEH Region at Umiam [TBC]); Tikrikilla and Resubelpara (Meteorological Centre Shillong map; types and record lengths [TBC]) | FER 2(b) 50-yr 24-h about 280–320 mm at Nongpoh; 2(b) ratios, 1-h ratio 0.48 (Clause 2.3.6(f)). NIH-DHAARA reported for comparison in ML-A only (Clause 2.3.6(m)). Weathered gneiss and granite with valley fills in Ri Bhoi; the alluvium of the north-western fringe of the Garo hills, the only thick unconsolidated deposit of the State (CGWB). Rivers that leave the State into Assam |
| ML-Z1 Northern foothills: ML-A Northern foothills and Ri-Bhoi (Nongpoh–Umsning–Byrnihat–Umiam) | Nongpoh, Umsning, Byrnihat, Umiam and Barapani, Umling, and the Umtru and Digaru valleys; boundaries [TBC] | Barapani; the agro-meteorological station of the ICAR Research Complex for NEH Region at Umiam [TBC] | FER 2(b) 50-yr 24-h about 280–320 mm at Nongpoh (25-yr about 280–320 mm, 100-yr about 320 mm; low confidence). NIH-DHAARA 50-yr 24-h 207 mm and 1-h 67 mm at Nongpoh (comparison only). No station record found. Weathered gneiss and granite (rainfall infiltration factor 5%) and valley fills (13% in Ri Bhoi), the tested valley fills being the only ground of ML-A where recharge is allowed (Clause 4.11, recharge rule) (CGWB). Receiving waters: the Umiam below the dams; the Umtru below New Umtru (full reservoir level 130.10 m, maximum water level 132.78 m), with 9.80 km of ravine to the Byrnihat bridge (MePGCL); the Digaru, whose bridge catchment of 1,270 km² in the 2(b) report rises in Ri Bhoi and is gauged in Assam (1981–88); the Kulsi and the Umlew. Landslides in Umling block near NH-6 on 30–31 May 2025, linked to hill cutting (as reported) |
| ML-Z1 Northern foothills: ML-A1 Garo foothills and plains (Resubelpara–Mendipathar–Tikrikilla–Phulbari) | Resubelpara, Mendipathar, Tikrikilla and Phulbari, the Jinjiram plains and the alluvial north-western fringe of the Garo hills; the strip west of 90° E lies in UTM zone 45N; boundaries [TBC] | Tikrikilla and Resubelpara (Meteorological Centre Shillong map) | FER 2(b) 50-yr 24-h about 400 mm near Resubelpara, at the subzone boundary (low confidence; NEER reading) [TBC]; 2(b) ratios. NIH-DHAARA not queried here and not used (Clause 2.3.6(m)). No station record found. Newer and older alluvium, a thick continuous aquifer with water 3–5 m below ground and yields of 30–100 m³/h, and the sandstones, shales and clays of the Garo Group, with water 4–9 m below ground (CGWB, GWRA 2022, Table 1); the tested alluvium is the only ground of ML-A1 where recharge is allowed (Clause 4.11, recharge rule). Receiving waters: the Jinjiram and the Krishnai (Dudhnai), whose bridge catchment of 476 km² in the 2(b) report rises in the Garo hills and is gauged in Assam (1981–88), under Brahmaputra backwater, governed by the Assam edition below the State boundary. The Brahmaputra and the Jinjiram flooded more than 100 villages in September 2012 (IRADe/NMHS plan) and more than 200 in September 2014 (as reported) |

| Zone (working name) | Extent (districts, basins) | Representative stations | Notes |
|---|---|---|---|
| ML-Z2 Plateau | The Khasi and Jaintia uplands on and just north of the 2(b)/2(c) boundary, in subzone 2(b) (Clause 2.3.6(b)); the edge of the plateau above the escarpment is a limit of the record check of Clause 2.3.6(h); catchments that cross a zone line take the higher zone value | Shillong (C.S.O.) (IMD 42516, rainfall data 1957–2012); the Shillong recording gauge of the 2(b) report; the Shillong (Obsy) and Upper Shillong gauges of the 2(b) annex (not necessarily the same gauge); Mawphlang, Nongstoin and Khliehriat (Meteorological Centre Shillong map); Jowai [TBC] | Annual normals 225.3 cm at Shillong (Obsy) and 242.5 cm at Upper Shillong (CWC, 2(b), Annex 4.1). FER 2(b) 50-yr 24-h about 560 mm at Shillong and Nongstoin and about 680 mm at Jowai, inside a 680 mm tongue that closes on the subzone boundary, values about twice the Shillong records; plates not used in the Shillong Planning Area (Clause 2.3.6(c)(i)); 2(a) ratios (Clause 2.3.6(f)). Archaean gneiss and Shillong Group quartzite, phyllite and schist with thin red loamy soils; the cavernous limestones and coal measures of the Jaintia hills in ML-B1 |
| ML-Z2 Plateau: ML-B Shillong plateau (Shillong–Mawphlang–Nongstoin–Mairang) | Greater Shillong (Upper Shillong, New Shillong, Mawlai, Nongthymmai, Laitumkhrah) and the rest of the Shillong Planning Area, Mawphlang, Sohiong, Nongstoin, Mairang and Mawkyrwat north [TBC]; boundaries [TBC] | Shillong (C.S.O.) (42516); the Shillong recording gauge (2(b) report); Mawphlang and Nongstoin (Meteorological Centre Shillong map) | Shillong Planning Area: the Shillong rule of Clause 2.3.6(c)(i), IMD Shillong (C.S.O.) Gumbel, not less than 437 mm at 1% AEP and 357 mm at 2% AEP; 1-h floor 48 mm × P24(T)/P24(10-yr) (Clause 2.3.6(g)(i)). Elsewhere in ML-B the plate: about 560 mm at 50 years at Nongstoin, probably high. Records: Shillong (C.S.O.) 273.2 mm (25 Jun 1988), qualifies under Clause 2.3.6(h); the Shillong recording gauge 347 mm in 24 hours (14–15 Sep 1960), 223 mm in 12 hours, 165 mm in 6 hours, 110 mm in 3 hours and 48 mm in 1 hour (15 Sep 1960), the 24-h value contradicting IMD's series; Upper Shillong 437 mm and Shillong (Obsy) 415 mm (20 Jun 1934), record lengths unconfirmed (CWC, 2(b), Annexes 4.1 and 4.2; IMD, *Extremes*); October 262.0 mm (8 Oct 2004) and May 227.0 mm (22 May 1988) (IMD). NIH-DHAARA 50-yr 24-h 246 mm and 1-h 56 mm at Shillong, 285 mm at Nongstoin (comparison only). Water in the weathered and fractured rock 7–17 m below ground, with iron up to 11.25 mg/l at Shillong (CGWB); landslide localities at Laitumkhrah, Lawsohtun, Happy Valley, Mccabe Road, Bethesda and Arbuthnot, and very high susceptibility along NH-40 and near the Umshyrpi (IRADe/NMHS plan); hill rule of Clause 4.11. Receiving waters: the Umkhrah and the Umshyrpi, ungauged, joining as the Wah Roro to Umiam lake (NESAC); the Umkhen and the Wah Tamdong; the Kynshi near Nongstoin |

| Zone (working name) | Extent (districts, basins) | Representative stations | Notes |
|---|---|---|---|
| ML-Z2 Plateau: ML-B1 Jaintia hills karst and mine belt (Jowai–Khliehriat–Sutnga–Ladrymbai) | Jowai, Khliehriat, Sutnga, Ladrymbai and the Jaintia uplands, inside the plates' closed 680 mm tongue round Jowai; the limestones and coal measures of the Jaintia hills; the side of the 2(b)/2(c) line on which Khliehriat lies is to be confirmed [TBC]; boundaries [TBC] | Khliehriat (Meteorological Centre Shillong map); Jowai [TBC: the second data request of Clause 2.3.6(a)] | FER 2(b) 50-yr 24-h about 680 mm at Jowai, read at the contour's own value because the tongue closes on the subzone boundary (Clause 2.3.6(c)); with the 2(a) ratio it gives about 177 mm in 1 hour at 50 years, probably high. NIH-DHAARA 50-yr 24-h 335 mm at Jowai (comparison only). No station record found. Barail, Kopili, Shella and Langer formations of the Jaintia Group, with a "Discontinuous aquifer in the cavernous limestones and sandstones area", water 2–4 m below ground and yields of 5–15 m³/h (CGWB); rat-hole coal workings; the Krem Liat Prah–Um Im–Labit cave system, 30.9 km (as reported); no karst map, sinkhole inventory or subsidence data [TBC]; karst and mine rule of Clause 4.11. Receiving waters: the headwaters of the Myntdu, whose CWC site at Kharkhana lies far downstream (highest level 47.0 m, 23 Apr 1995), and the Myntdu–Leshka dam and release reach; the Lukha, which the joint committee before the NGT found "to have become acidic" (State action-taken report, 2023), and the Myntdu, named in press reports as acidified (as reported), acid drainage that the BOD criterion of CPCB's list does not capture (NEER reading); tributaries of the Kopili to the north-east |
| ML-Z3 Southern escarpment | The Bangladesh-facing escarpment of the Khasi and Jaintia hills and the south Garo slopes, in subzone 2(c), Barak, which has no CWC report; the 2(b) plates draw no contour here west of about 91.8° E (Clause 2.3.6(b)); hazard-first under Clause 2.3.6(i); catchments that cross a zone line take the higher zone value | Cherrapunji (IMD 42515, rainfall data 1902–2012); Mawsynram, Sohra, RKM Sohra, Shella, Ratacherra and Baghmara (Meteorological Centre Shillong map; types and record lengths [TBC]) | The Cherrapunji curve of IMD Das et al. (2022) is the interim design rainfall at every AEP and duration (Clause 2.3.6(c)(ii)); no CWC unit hydrograph; site-specific study for every cross-drainage structure and outfall of more than 1 km² (Clause 2.3.6(i)). Monsoon rainfall "over 1000 cm in the south and southeast" (CGWB). NIH-DHAARA not used (Clause 2.3.6(m)). Cretaceous–Tertiary sandstones, shales, limestones and coal; karst and mine rule of Clause 4.11. Every river runs south to Bangladesh (NEER general geography — confirm) |

| Zone (working name) | Extent (districts, basins) | Representative stations | Notes |
|---|---|---|---|
| ML-Z3 Southern escarpment: ML-C Southern escarpment (Sohra–Mawsynram–Shella–Pynursla–Dawki) | Sohra, Mawsmai, Mawsynram, Shella, Pynursla, Dawki, Amlarem, Nongjri, Ranikor and Mawkyrwat south, and the Jaintia south (Lumshnong, Sonapur–Ratacherra); boundaries [TBC] | Cherrapunji (42515); Mawsynram; Sohra and RKM Sohra; Shella; Ratacherra | Das et al. (2022) Cherrapunji curve, read by eye: 24-h about 410, 745, 960, 1,225, 1,440 and 1,630 mm and 1-h about 75, 117, 146, 182, 208 and 236 mm for 2, 5, 10, 25, 50 and 100 years. Records: Cherrapunji 1,563.0 mm (16 Jun 1995) and Mawsynram 1,003.6 mm (17 Jun 2022), both qualifying under Clause 2.3.6(h) and below the curve at 100 years; Cherrapunji's highest days by month from 189.7 mm (December) to 1,563.0 mm (June), among them 587.4 mm in March, 644.2 mm in April, 812.0 mm in May and 594.0 mm in October; wettest month 6,667.4 mm (July 1974) (IMD); 48-h 2,493 mm (15–16 Jun 1995, as reported; stress case only). No hourly maximum found. NIH-DHAARA 922 mm at Sohra, 1,029 mm at Mawsynram and 1,423 mm at Dawki at 50 years, not used. The Sohra and Shella limestones, cavernous, with water 2–4 m below ground (CGWB); karst and mine rule. Specific flood yield of about 34 $m^3/s$ per $km^2$ at the spillway of Myntdu–Leshka Stage I (12,000 $m^3/s$ from 350 $km^2$; MePGCL). Receiving waters, all to Bangladesh (NEER general geography — confirm): the Umngot at Dawki (CWC highest level 73.47 m, 28 May 2006); the Umnohryngkew at Therriaghat (20.62 m, 15 Jun 1995); the Myntdu–Leshka reach (full reservoir level 618.00 m; about 24 km to the border); the Kynshi; the Lubha, along which the NH-6 Sonapur tunnel was closed by mudslides (as reported) |
| ML-Z3 Southern escarpment: ML-C1 South Garo slopes (Baghmara–Siju–Gasuapara) | Baghmara, Siju, Gasuapara and the south Garo slopes towards Bangladesh, wet and of lower relief; boundaries [TBC] | Baghmara (Meteorological Centre Shillong map); no long gauge record found [TBC] | Das et al. (2022) Cherrapunji curve, as in ML-C, until a station fit or study under Clause 2.3.6(c)(ii) replaces it; plates blank. NIH-DHAARA 936 mm at Baghmara at 50 years, unchecked and not used. Garo Group sandstones and shales; "red and yellow soils … between Tura and boundary of Bangladesh" (CWC, 2(b), §2.3.2); coal of the Garo coalfields. Receiving waters: the Simsang (to Bangladesh), the Bugi (CWC site at Dimapara, highest level 29.75 m, 27 Jul 2007) and the Dareng (Sibbari, 20.34 m, 12 Aug 2017). A landslide killed 7 people at Hatiasia Songma in South Garo Hills on 4–6 October 2024 (as reported) |
| ML-Z4 Garo hills | The interior of the Garo hills on the boundary of subzones 2(b) and 2(c), on or just north of which Tura lies (Clause 2.3.6(b)); catchments that cross a zone line take the higher zone value | Tura and Williamnagar (Meteorological Centre Shillong map); Dalu (2(b) annex; annual normal 273.4 cm) | FER 2(b) 50-yr 24-h about 320–400 mm at Tura and about 400 mm at Williamnagar; 2(a) ratios (Clause 2.3.6(f)). NIH-DHAARA not used (Clause 2.3.6(m)). Tertiary sandstones and shales of the Garo Group and laterite |

| Zone (working name) | Extent (districts, basins) | Representative stations | Notes |
|---|---|---|---|
| ML-Z4 Garo hills: ML-D Garo hills interior (Tura–Williamnagar–Rongjeng–Ampati–Dalu) | Tura, Williamnagar, Rongjeng, Dadenggre and Ampati, and Dalu at the edge of the plains [TBC: 2(b) or 2(c)]; Tura, Williamnagar and Baghmara are in UTM zone 46N, the strip west of 90° E in 45N; boundaries [TBC] | Tura and Williamnagar; Dalu | FER 2(b) 50-yr 24-h about 320–400 mm at Tura, in a closed 320 mm cell on Plate 8 (25-yr about 320 mm, 100-yr about 400 mm), and about 400 mm at Williamnagar (low confidence). Records: Dalu 320 mm (13 Jun 1956; CWC, 2(b), Annex 4.1), record length unconfirmed and excluded under Clause 2.3.6(h) [TBC]; no IMD record table for Tura found. NIH-DHAARA 624 mm at Tura and 860 mm at Williamnagar at 50 years, against the plate and Dalu's record; not used. Garo Group aquifers with water 4–9 m below ground (CGWB); red and yellow soils towards Bangladesh; laterite in the south-west. Receiving waters: the Ganol, with the Ringrey and Rongkhon streams, at Tura (draft master plan, 2024); the Simsang at Williamnagar, with no CWC site; the Dudhnai and Krishnai to the north. The Garo Hills floods of September 2014 (more than 60 dead and more than ₹1,500 crore of damage, as reported) and October 2024 (Dalu) |

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## Annex 2B — Sub-daily ratios P(t)/P(24h) by zone: NIH-DHAARA (hourly-based) vs the one-third rule

Supports Clauses 2.6.1 to 2.6.4 of Chapter 2.

**To be prepared.** This annex will tabulate, for each zone of Annex 2A, the ratios of the t-hour to the 24-hour design depth from NIH-DHAARA, which are derived from hourly records, against the ratios implied by IMD Das et al. (2022) and by the one-third rule. It needs NIH-DHAARA depths for each duration at representative points in each zone (NIH), IMD recording-gauge data and the IDF values of Das et al. (2022) (IMD). Until it is published, sub-daily depths are read directly from NIH-DHAARA or an approved station IDF (Clause 2.6.1). Where only daily depths are available, the ratios used are those agreed with the Authority, which in Meghalaya are those of Clause 2.3.6 for the site's sub-area in Table 2B.1 (the 2(b) ratios in ML-A and ML-A1; the 2(a) ratios, on the 2(b) plate depth or the Shillong depth of Clause 2.3.6(c)(i), in ML-B, ML-B1 and ML-D; and the depths of the Cherrapunji curve of IMD Das et al. (2022) in ML-C and ML-C1), with the 1-hour floors of Clause 2.3.6(g) in the Shillong Planning Area and in ML-C and ML-C1, applied to the 24-hour depth before the record check of Clause 2.3.6(h) (Clause 2.6.2), and are recorded on Form 2-1. The one-third rule is not used (Clause 2.6.4).

2B.1 The first row of Table 2B.1 gives the ratios of the one-third rule P(t) = P(24)·(t/24)^(1/3), for comparison only. The 1, 3, 6 and 12 h values are those stated in the commentary to Clause 2.6; the 2 h value is computed from the same formula. The rule shall not be used for design unless this annex confirms it for the zone concerned (Clause 2.6.4).

**Table 2B.1 — Ratios P(t)/P(24h) by zone (layout)**

| Zone | Source | 1 h | 2 h | 3 h | 6 h | 12 h | 24 h |
|---|---|---|---|---|---|---|---|
| All (reference only, not for design) | One-third rule | 0.35 | 0.44 | 0.50 | 0.63 | 0.79 | 1.00 |
| ML-Z1 (ML-A Northern foothills and Ri-Bhoi; ML-A1 Garo foothills and plains) | CWC FER 2(b), Table 4.1, 10-yr basis, six recording gauges (Shillong and five in the Assam valley) (interim design ratios, Clause 2.3.6(f); 2-h value interpolated on logarithmic axes) | 0.48 | | 0.62 | 0.74 | 0.87 | 1.00 |

| Zone | Source | 1 h | 2 h | 3 h | 6 h | 12 h | 24 h |
|---|---|---|---|---|---|---|---|
| ML-Z2 (ML-B Shillong plateau; ML-B1 Jaintia hills karst and mine belt) and ML-Z4 (ML-D Garo hills interior) | CWC FER 2(a), NB/18/1991, §3.1.2 and Fig. 10, 50-yr basis, 12 IMD recording gauges (interim design ratios, Clause 2.3.6(f), on the 2(b) plate depth or the Shillong depth of Clause 2.3.6(c)(i)) | 0.260 | 0.370 | 0.457 | 0.615 | 0.805 | 1.000 |
| ML-Z3 (ML-C Southern escarpment; ML-C1 South Garo slopes) | IMD Das et al. (2022), Fig. 4(v), Cherrapunji: depths read from the curve at every AEP and duration (Clause 2.3.6(c)(ii) and (f)); the 1-h ratio shown is the curve's at 50 and 100 years (about 0.18 at 2 years), by eye; other durations not tabulated here [TBC] | 0.14 | | | | | 1.00 |
| ML-Z2 (ML-B): Shillong Planning Area, every AEP | 1-hour floor of Clause 2.3.6(g)(i), set by this Manual: 48 mm × P24(T) / P24(10-yr), not a fixed ratio | | | | | | |
| ML-Z3 (ML-C, ML-C1), every AEP | 1-hour floor of Clause 2.3.6(g)(ii), set by this Manual, where a station fit or study replaces the Cherrapunji curve | 0.14 | | | | | |
| ML-Z2 (ML-B): Shillong | CWC FER 2(b), Annex 4.2: the recording-gauge maxima of the storm of 14–15 September 1960 as ratios to its 24-h total of 347 mm (record length not printed; comparison only) | 0.14 | | 0.32 | 0.48 | 0.64 | 1.00 |
| ML-Z2 (ML-B): Shillong cell | NIH-DHAARA, IMDAA, 50-yr (queried 14 Nov 2026; comparison only) | 0.23 | | | | | 1.00 |
| ML-Z1 (ML-A): Nongpoh cell; ML-Z2: Nongstoin and Jowai cells | NIH-DHAARA, IMDAA, 50-yr (comparison only) | 0.33 / 0.23 / 0.16 | | | | | 1.00 |
| ML-Z3 (ML-C): Sohra and Mawsynram cells | NIH-DHAARA, IMDAA, 50-yr (not used in ML-Z3; shown for comparison only) | 0.11 / 0.10 | | | | | 1.00 |

2B.2 Depths from fixed observation windows are converted to true-interval depths with the factors of Clause 2.6.3, repeated in Table 2B.2. They are the standard WMO (Hershfield) values and are not provisional.

**Table 2B.2 — Fixed-interval adjustment factors (Clause 2.6.3)**

| Number of fixed observation intervals in the duration | Factor |
|---|---|
| 1 | 1.13 |
| 2 | 1.04 |
| 3–4 | 1.02 |

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## Annex 2C — Grid-to-point factors

Supports Clauses 2.7.1 and 2.7.4 of Chapter 2.

**To be prepared.** This annex will give the factors that convert grid-average design depths (for example from 0.25° cells) to point depths, by zone, duration and AEP. It needs paired frequency analyses of IMD gridded rainfall and of the IMD and State gauges inside each cell (IMD, the catchment gauges of MePGCL, the gauges of the Water Resources Department and the agro-meteorological station of the ICAR Research Complex for NEH Region at Umiam (Barapani) [TBC]), the benchmark points of Annex 2A, and a stated method for deriving the factors. Until it is published, design depths are taken as point values from NIH-DHAARA or an approved station IDF (Clauses 2.3.1 and 2.3.2). Grid-average values are not used as design depths unless a conversion agreed with the Authority is recorded on Form 2-1 (Clause 1.11.5).

2C.1 The commentary to Clause 2.7 shows why the factors matter. In Meghalaya NIH-DHAARA was queried at ten points for this Manual, and its reanalysis cells, of about 12 km, smooth the escarpment's peak and scatter its edges: the Sohra cell gives 922 mm at 50 years in 24 hours, against about 1,440 mm on the IMD Cherrapunji point curve, while the Dawki cell gives 1,423 mm, more than the Mawsynram cell's 1,029 mm, with no gauge to support it, and the Tura cell 624 mm, 1.6 to 2 times the plate value (NIH-DHAARA, queried 14 Nov 2026). The averages that IMD publishes for a subdivision show the size of the gap between an area value and a point: for June 2022 the whole Assam and Meghalaya subdivision averaged 858.1 mm in the month, less than Mawsynram's single day of 1,003.6 mm (IMD). Within about 40 km the highest days printed by IMD fall from 1,563.0 mm at Cherrapunji to 273.2 mm at Shillong (IMD, *Extremes*). Values of this kind are grid- or area-average values and need these factors before any use as point depths; under Clause 2.3.6 they are not used as design depths in Meghalaya until this annex and Annex 2A are published, and NIH-DHAARA is used only for comparison on the plateau and in the northern foothills of Ri-Bhoi (Clause 2.3.6(m)).

**Table 2C.1 — Grid-to-point factors (layout)**

| Zone | Grid product and cell size | Duration (h) | AEP | Factor (point / grid) | Stations used | Years of record |
|---|---|---|---|---|---|---|
| | | 24 | | | | |
| | | 48 | | | | |
| | | 72 | | | | |

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## Annex 2D — Meghalaya temporal patterns (Huff curves)

Supports Clauses 2.9.3 and 2.9.4 of Chapter 2, and Clause 11.7.3 of Chapter 11.

**To be prepared.** This annex will give dimensionless time-distribution (mass) curves of Meghalaya storms, in the form introduced by Huff (1967), by zone, storm-duration class and quartile, at stated probability levels. It needs storm hyetographs from recording gauges and automatic weather stations (IMD, its automatic weather stations and automatic rain gauges in the State, under the Meteorological Centre Shillong, the Shillong recording gauge used by the CWC 2(b) report, and any recording gauges of MePGCL, MSDMA and Shillong Smart City Ltd [TBC]), separated into independent storms by a stated rule, and the storm recorded by the Shillong recording gauge of the CWC 2(b) report on 14–15 September 1960, with 48 mm in its largest hour, the Cherrapunji storm of 15–16 June 1995, the storms of 15–17 June 2022 at Mawsynram and Sohra, the Shillong storm of 9 July 2019, the Garo Hills storms of 21–22 September 2014 and 4–6 October 2024, the storms of 30–31 May 2025 and the Dawki storm of June 2026 among them. Until it is published, design storms use the alternating-block pattern of Clause 2.9.1 and the 48- and 72-hour pattern of Clause 2.9.2; for catchments of 25–5,000 km², the CWC Flood Estimation Report curves may be used with a sensitivity run under Clause 2.9.1 (Clause 2.9.4). SCS Type distributions are not used (Clause 2.9.3). For the disaggregation of daily records in continuous simulation (Clause 11.7.3), the method is agreed with the Authority and recorded (Clause 1.11.5).

**Table 2D.1 — Cumulative fraction of storm depth against cumulative fraction of storm time (layout, one table per zone, duration class and quartile)**

| Fraction of storm time | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10% probability curve | 0 | | | | | | | | | | 1.0 |
| 50% probability curve | 0 | | | | | | | | | | 1.0 |
| 90% probability curve | 0 | | | | | | | | | | 1.0 |

2D.1 Each table shall state the zone, the duration class, the quartile (the quarter of the storm in which most rain fell), the number of storms analysed and the period of record.

*Reference:* Huff, F.A. (1967). Time distribution of rainfall in heavy storms. *Water Resources Research* 3(4), 1007–1019.

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## Annex 2E — Retention percentile depths by zone

Supports Clauses 2.8.3 and 2.10.1 to 2.10.2 of Chapter 2, Clause 4.4 of Chapter 4 and Chapter 8.

**To be prepared.** This annex will give, for each zone of Annex 2A, the retention design depth P_R: the 24-hour rainfall depth not exceeded on 90% of days with rain (≥ 2.5 mm) in the long-term record (Clause 2.10.1). It needs long daily records at stations in each zone (IMD, the catchment gauges of MePGCL, the gauges of the Water Resources Department and the agro-meteorological station of the ICAR Research Complex for NEH Region at Umiam (Barapani) [TBC]) and IMD gridded data with the factors of Annex 2C where stations are sparse. Until it is published, P_R is computed by the definition of Clause 2.10.1 from the long-term daily record of a station agreed with the Authority, by the steps in 2E.1, and recorded on Form 2-1 (Clause 1.11.5).

2E.1 **Computing P_R from a daily record.**

1. Take the daily (24-hour) rainfall series of the station for its full record.
2. Keep only the days with rain of 2.5 mm or more (wet days).
3. Rank the wet-day depths and take the depth not exceeded on 90% of them (the 90th percentile).

4. Do not apply the climate factor (Clause 2.8.3) or the fixed-interval factor; P_R is a statistic of everyday rainfall, not an AEP design depth.
5. Record the station, the period of record, the number of wet days and P_R on Form 2-1.

**Table 2E.1 — Retention depth P_R by zone (layout)**

| Zone | Stations or grid cells used | Period of record | Number of wet days (≥ 2.5 mm) | P_R, 90th percentile (mm) | Issued on |
|---|---|---|---|---|---|
| ML-Z1 Northern foothills | | | | | |
| ML-Z2 Plateau | | | | | |
| ML-Z3 Southern escarpment | | | | | |
| ML-Z4 Garo hills | | | | | |

## Form 2-1 — Design Rainfall Sheet

Supports Clauses 2.3 to 2.13 of Chapter 2, and Clause 10.4.1(d) of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One sheet for each hydrologic submittal. The steps follow Figure 2.3 of Chapter 2.

**Table 2F.1 — Form 2-1: site, source and storms**

| No. | Item (clause) | Entry |
|---|---|---|
| | **A. Site (Clause 2.13, item 1)** | |
| A1 | Project and site | _____ |
| A2 | Site coordinates (latitude, longitude, decimal degrees) | _____ |
| A3 | Rainfall zone (Annex 2A, or as agreed with the Authority) | _____ |
| A4 | Contributing catchment area (km²) (Clause 2.7) | _____ |
| A5 | Design life: more than 25 years / temporary works, 5 years or less (Clause 2.8.2) | _____ |
| A6 | Outfall under tidal or river backwater influence: Yes / No (Clauses 2.5.3, 2.12) | _____ |
| | **B. Source (Clauses 2.3, 2.3.5; item 2)** | |
| B1 | NIH-DHAARA: version or access date | _____ |
| B2 | Coordinates queried | _____ |
| B3 | Screenshot or export of the values extracted attached: reference | _____ |
| B4 | Station IDF used (Clause 2.3.2): No / Yes — station, ID, distance from site (km) | _____ |
| B5 | Station IDF: years of recording-gauge data (30 or more); published or approved by | _____ |
| B6 | Station IDF: change of terrain or coastal exposure between gauge and site: None / describe | _____ |
| | **C. AEPs and durations (Clauses 2.4, 2.5)** | |
| C1 | Elements designed and their AEPs (Table 2.1) | _____ |
| C2 | Conveyance: Tc and design duration (not less than 10 min) (Clause 2.5.1) | _____ |
| C3 | Storage: durations checked from {1, 2, 3, 6, 12, 24, 48, 72 h}; 24, 48 and 72 h included (Clause 2.5.2) | _____ |
| C4 | Critical duration found for each storage element | _____ |
| | **D. Conversions** | |
| D1 | Sub-daily depths: read directly / from Annex 2B ratios / from ratios agreed with the Authority (Clauses 2.6.1, 2.6.2) | _____ |
| D2 | Fixed-interval factor applied: none (true-interval source) / 1.13 / 1.04 / 1.02 (Clause 2.6.3) | _____ |
| D3 | Grid-to-point factor: not needed (point source) / Annex 2C / agreed value (Clause 2.7.1) | _____ |
| D4 | ARF: 1.0 (10 km² or less; single-site storage) / CWC curve / interpolated (Clauses 2.7.2–2.7.4) | _____ |
| D5 | Climate factor: 1.20 (≤ 6 h) and 1.10 (> 6–72 h) / 1.0 temporary works / projected depths under Clause 2.8.4 | _____ |
| | **E. Cross-checks (Clause 2.3.3; item 4)** | |
| E1 | IMD Das et al. (2022) values for 1–24 h: reported in Table 2F.2 | _____ |

| No. | Item (clause) | Entry |
|---|---|---|
| E2 | CWC subzone 2(b) 24-hour point value, catchments of 25–5,000 km²: subzone used | _____ |
| E3 | CWC floor governs for any AEP: No / Yes — AEPs | _____ |
| | **F. Retention depth (Clause 2.10)** | |
| F1 | P_R (mm) and source: Annex 2E zone value / computed under Annex 2E, 2E.1 — station and period | _____ |
| F2 | No climate factor applied to P_R (Clause 2.8.3): confirmed | _____ |
| | **G. Design storms (Clauses 2.9, 2.11, 2.12; items 5 and 6)** | |
| G1 | Storms up to 24 h: alternating block, peak at 50%; time step (≤ Tc/3 and ≤ 15 min) | _____ |
| G2 | 48 and 72 h storms: built under Clause 2.9.2 (Table 2F.3) | _____ |
| G3 | Other pattern used: none / Annex 2D / CWC FER with sensitivity run (Clauses 2.9.3, 2.9.4) | _____ |
| G4 | Hyetographs attached as a table and a plot for each design storm: reference | _____ |
| G5 | AMC: III for every design storm of 1 June–15 October in sub-areas ML-A, ML-A1, ML-B, ML-B1 and ML-D and of 1 April–31 October in ML-C and ML-C1, whatever its duration, and at any time in catchments draining to a MePGCL or other reservoir, its backwater or a release reach; at any other site or time, III for a storm that follows or contains a 5-day total of more than 53 mm; II otherwise (Clause 2.11.4) | _____ |
| G6 | Pre-development condition: greenfield, open land in good condition for the mapped HSG (Clause 2.11.5) | _____ |
| G7 | Release criterion: standard, Q_post ≤ 0.9 × Q_pre (Clause 2.11.2) / flood-sensitive, mixed-frequency rule (Clause 2.11.3) | _____ |
| G8 | Tailwater joint cases run (Clause 2.12): case (a) MHWS + sea-level allowance; case (b) 10% AEP 48 h storm with 1% AEP still-water level + sea-level allowance; governing case | _____ |
| | **H. Prepared by** | |
| H1 | I confirm that the values above are those extracted and used in the submittal. Name, registration number, signature, date | _____ |

Design depth = source depth × fixed-interval factor × grid-to-point factor × ARF × climate factor. Where the design depth is lower than the CWC floor for the same AEP, the floor is adopted (Clause 2.3.3).

### Table 2F.2 — Form 2-1: depth table (Clause 2.13, item 3)

| AEP (T-yr) | Duration | Source depth (mm) | Fixed-interval factor | Grid-to-point factor | ARF | Climate factor | Design depth (mm) | IMD Das et al. (2022) (mm) | CWC floor (mm) | Adopted depth (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

### Table 2F.3 — Form 2-1: 48- and 72-hour storm construction (Clause 2.9.2)

| AEP (T-yr) | Duration (h) | Total design depth (mm) | 24 h design depth, final 24 h (mm) | Remainder (mm) | Hours before the final 24 h | Uniform intensity before the final 24 h (mm/h) |
|---|---|---|---|---|---|---|
| | 48 | | | | 24 | |
| | 72 | | | | 48 | |

ANNEXES TO CHAPTER 3

# Hydrologic Methods

These annexes support Chapter 3. Annex 3C sets out benchmark test problems for software acceptance, and Forms 3-1 and 3-2 are the submittal forms required by Clause 3.17. Annexes 3A, 3B, 3D and 3E need survey, gauging or published report data that this draft does not yet contain; each gives the intended layout and the interim rule of Chapter 3 that applies until it is published. The forms are draft forms and have no statutory status.

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## Annex 3A — Meghalaya soil series to HSG lookup; seasonal high water table map

Supports Clauses 3.7 and 3.10 of Chapter 3.

**To be prepared.** This annex will contain (a) a lookup from each soil series mapped in Meghalaya to its hydrologic soil group (HSG), in both the drained and the undrained state, and (b) a map of the depth to the seasonal high groundwater table in the monsoon season (April–October). It needs NBSS&LUP and Soil and Water Conservation Department (soil survey) [TBC] series maps with their scales, measured saturated hydraulic conductivity and depth to an impermeable layer for each series, and observation-well records from the Central Ground Water Board and the Water Resources Department, supplemented by piezometers in the alluvium of the Garo foothill plains and the Jinjiram valley, where the water table stands 3–5 m below ground, the valley fills of Ri-Bhoi, the Garo Group sandstones round Tura and Williamnagar (4–9 m), the limestone and sandstone aquifers of the escarpment and the Jaintia hills (2–4 m), the floodplains and low terraces of the rivers and the valley floors of the Umkhrah and Umshyrpi in Shillong, the margins of the pungs and lakes and of Umiam lake and the other reservoirs, and hill sites with perched water or springs. Until it is published, use the interim rules of Chapter 3: assign HSG from measured saturated hydraulic conductivity and depth to an impermeable layer or water table by the criteria of NEH Part 630, Ch. 7 (Clause 3.7.2); verify it by site infiltration tests wherever retention relies on infiltration (Clause 3.7.3); take the seasonal high water table from site piezometers, trial pits or the nearest observation well (Clause 3.10.2); and assign HSG D wherever that level is within 0.6 m of the ground surface (Clause 3.10.1).

**Table 3A.1 — Soil series to HSG lookup (layout)**

| Soil series | District(s) | Taxonomic class | Surface texture | Saturated hydraulic conductivity (mm/h) | Depth to impermeable layer (m) | HSG, drained | HSG, undrained | Source map and scale |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

**Table 3A.2 — Seasonal high water table, by mapping unit (layout)**

| Mapping unit or grid cell | Observation wells used | Years of April–October record | Highest April–October level below ground (m) | Within 0.6 m of ground (Clause 3.10.1)? | Data source |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

## Annex 3B — Meghalaya CN calibration and supplementary land covers (forest and sacred groves, grassland and scrub, valley paddy, slide scars and hill-road cuts and fills, mine spoil and coal-mine pits, bare and cavernous limestone, boulder-bed jhoras, pung and reservoir beds)

Supports Clauses 3.8 and 3.15 of Chapter 3.

**To be prepared.** This annex will contain (a) curve numbers calibrated against observed rainfall and runoff in Meghalaya catchments, compared with the TR-55 values of Table 3.5, and (b) curve numbers for land covers that Table 3.5 does not list: the forest that covers most of the hills (about 85% of the land of the CWC subzone 2(b) area, by the report's land use) and the sacred groves (law kyntang) at stream heads, with deep litter; the grassland and scrub of the plateau; the paddy and other fields of the valley floors, such as the fields of the Umkhrah valley at Mawlai, which flooded in July 2019 (IRADe/NMHS plan); the fresh scars, slide debris and fills of landslides and of hill-road cuts, such as those on NH-6 in Umling block in May 2025; the spoil heaps, pits and subsided ground of the coal-mining areas of the Jaintia and Garo hills, where runoff can vanish underground or turn acid; the bare and cavernous limestone of Sohra, Shella and Lumshnong, which can lose water to caves; the boulder beds of the jhoras and hill streams; and the beds of pungs, lakes and reservoirs that are drawn down at the start of a storm, such as the margins of Umiam lake. It needs paired rainfall–runoff records for small gauged catchments of known cover and soil, from Water Resources Department gauging sites, agricultural research stations and tank gauges, analysed by event and by antecedent moisture. Until it is published: the pre-development reference stays open space in good condition for every site (Clause 3.3.2), so these covers do not enter the pre-development run; for off-site existing conditions, use the nearest Table 3.5 or TR-55 cover row, including the cultivated rows (Clause 3.8.3(c)), and state the row chosen and the reason on Form 3-1; land under standing water at the start of the design storm is modelled as water surface with no losses (Table 3.5; Clause 3.10.4(b)). Any departure from these defaults requires calibration under Clause 3.15 (Clause 3.15.1(d)).

Table 3B.1 — Supplementary land covers, AMC II (layout)

| Cover type | HSG A | HSG B | HSG C | HSG D | Ia ratio | Basis (catchments, events, years) |
|---|---|---|---|---|---|---|
| Forest of the hills, with the litter recorded (broadleaf, pine or mixed); sacred grove (law kyntang) at a stream head | | | | | | |
| Grassland and scrub of the plateau, with the cover and the depth of soil over rock recorded | | | | | | |
| Paddy and other fields of the valley floors (Umkhrah valley at Mawlai; Ri-Bhoi valleys; Garo foothill plains), with the bunds recorded | | | | | | |
| Fresh landslide scar or slide debris; hill-road cut slope or fill | | | | | | |
| Coal-mine spoil heap, rat-hole pit area or subsided ground (Jaintia and Garo coalfields); losses to voids not credited | | | | | | |

| Cover type | HSG A | HSG B | HSG C | HSG D | Ia ratio | Basis (catchments, events, years) |
|---|---|---|---|---|---|---|
| Bare or cavernous limestone (Sohra, Shella, Lumshnong and the like); losses to caves not credited | | | | | | |
| Boulder bed of a jhora or hill stream, dry at the start of the storm | | | | | | |
| Pung, lake or reservoir bed dry or drawn down at the start of the storm (Umiam lake margins and the like) | | | | | | |
| Other (state) | | | | | | |

**Table 3B.2 — CN calibration catchments (layout)**

| Catchment | District | Area (km²) | Dominant HSG and cover | Events used | Table 3.5 CN | Calibrated CN | Calibrated ÷ Table 3.5 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

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## Annex 3C — Benchmark test problems for software acceptance

Supports Clauses 3.5, 3.6, 3.8, 3.9, 3.11, 3.12 and 3.16 of Chapter 3.

**Purpose.** Software not listed in Clause 3.16.1 shall reproduce the results of the five problems below (Clause 3.16.3). Each problem is fully specified and uses only the methods and tables of Chapter 3, so every answer can be checked by hand. The acceptance tolerance is ±5% on each tabulated result, the equivalence threshold of Clause 3.16.2; for closed-form results (Problems 3C-1 to 3C-4), software should agree to the rounding shown. The submittal shall report the software result next to each answer below.

*Illustrative — not design values.* The inputs (areas, intensities, rainfall depths, slopes and the basin) are chosen for testing only. They are not design data for any site.

### Problem 3C-1 — Rational Method peak (Clause 3.5)

**Inputs.** A 2.0 ha catchment draining to one inlet: 1.2 ha concrete paving and roofs, C = 0.90 (Table 3.2, upper half of 0.80–0.95); 0.8 ha lawns on sandy soil, average slope, C = 0.15 (Table 3.2, upper half of 0.10–0.15). Design AEP 1% (100-yr). Rainfall intensity at Tc, including the climate factor: i = 120 mm/h.

Part (b): a separate 0.5 ha fully paved catchment, C = 0.90, design AEP 1%, i = 150 mm/h.

**Table 3C.1 — Problem 3C-1 solution**

| Step | Calculation | Result |
|---|---|---|
| Composite C (Clause 3.5.4) | (1.2 × 0.90 + 0.8 × 0.15) / 2.0 | 0.60 |
| Frequency factor (Table 3.3) | 1% AEP | Cf = 1.25 |
| C · Cf (≤ 1.0) | 0.60 × 1.25 | 0.75 |
| Peak flow (Clause 3.5.1) | 0.75 × 120 × 2.0 / 360 | **Q = 0.500 m³/s** |
| Part (b): C · Cf | 0.90 × 1.25 = 1.125, capped at 1.0 (Clause 3.5.3) | 1.00 |
| Part (b): peak flow | 1.00 × 150 × 0.5 / 360 | **Q = 0.208 m³/s** |

## Problem 3C-2 — Time of concentration by the segment method (Clause 3.6)

**Inputs.** Pre-development flow path: sheet flow over greenfield, n = 0.15 (Clause 3.6.3), L = 30 m, S = 0.01; P2 (50% AEP 24-hour rainfall, no climate factor) = 80 mm. Shallow concentrated flow, unpaved, L = 200 m, S = 0.01. Channel flow, L = 400 m, bank-full velocity V = 1.0 m/s (given).

**Table 3C.2 — Problem 3C-2 solution**

| Segment | Calculation | Travel time |
|---|---|---|
| Sheet flow (Clause 3.6.2(a)) | 0.091 × (0.15 × 30)^0.8 / (80^0.5 × 0.01^0.4) = 0.2138 h | 12.83 min |
| Shallow concentrated (Clause 3.6.2(c)) | V = 4.918 × 0.01^0.5 = 0.4918 m/s; 200 / (3,600 × 0.4918) = 0.1130 h | 6.78 min |
| Channel (Clause 3.6.2(d)) | 400 / (3,600 × 1.0) = 0.1111 h | 6.67 min |
| **Tc** (Clause 3.6.1; ≥ 10 min) | 12.83 + 6.78 + 6.67 | **26.27 min** |
| Lag (Clause 3.6.5) | 0.6 × 26.27 | 15.76 min |

## Problem 3C-3 — SCS-CN runoff depth, AMC and Ia sensitivity (Clause 3.8)

**Inputs.** Pre-development reference on HSG C: CN = 74 at AMC II (Table 3.5), all pervious. Cumulative rainfall P = 100 mm; second case P = 25 mm.

**Table 3C.3 — Problem 3C-3 solution**

| Case | S (mm) | Ia (mm) | Runoff Q (mm), P = 100 mm | Runoff Q (mm), P = 25 mm |
|---|---|---|---|---|
| (a) AMC II, Ia = 0.2S: S = 25,400 / 74 − 254 | 89.24 | 17.85 | **39.38** | **0.53** |
| (b) AMC III, Ia = 0.2S: CN(III) = 23 × 74 / (10 + 0.13 × 74) = 86.75 | 38.80 | 7.76 | **64.93** | — |
| (c) AMC II, Ia = 0.05S: S0.05 = 25.4 × 1.33 × (89.24 / 25.4)^1.15 | 143.31 | 7.17 | **36.49** | **1.97** |

Runoff is Q = (P − Ia)² / (P − Ia + S). Case (c) gives less runoff than case (a) at 100 mm but more at 25 mm, as Clause 3.8.5 and Figure 3.3 describe.

## Problem 3C-4 — Separate vs composite impervious representation, and SCS unit hydrograph peak (Clauses 3.9 and 3.11.2)

**Inputs, part (a).** A site that is 50% directly connected impervious (CN 98) and 50% open space on HSG B (CNp = 61), AMC II, Ia = 0.2S, P = 25 mm.

**Inputs, part (b).** A sub-area of A = 2.5 km² with Tc = 1.0 h and computation interval Δt = 0.1 h.

**Table 3C.4 — Problem 3C-4 solution**

| Step | Calculation | Result |
|---|---|---|
| (a) Impervious half (Clause 3.9.2) | S = 5.18 mm, Ia = 1.04 mm; Q = 23.96² / (23.96 + 5.18) | 19.70 mm |
| (a) Pervious half | S = 162.39 mm, Ia = 32.48 mm > P | 0 mm |
| (a) Area-weighted runoff, separate sub-areas | 0.5 × 19.70 + 0.5 × 0 | **9.85 mm** |

| Step | Calculation | Result |
|---|---|---|
| (a) Composite CN (Clause 3.9.4) | 61 + 0.50 × (98 − 61) | 79.5 |
| (a) Runoff with composite CN | S = 65.50 mm, Ia = 13.10 mm; Q = 11.90² / (11.90 + 65.50) | **1.83 mm** |
| (b) Interval check (Clause 3.11.3(a)) | 0.133 × 1.0 = 0.133 h ≥ Δt = 0.1 h | satisfied |
| (b) Lag and time to peak (Clause 3.11.2) | tL = 0.6 × 1.0 = 0.60 h; tp = 0.1 / 2 + 0.60 | tp = 0.65 h |
| (b) Unit hydrograph peak, Q = 1 mm | 0.208 × 2.5 × 1 / 0.65 | **qp = 0.800 m³/s per mm** |

Part (a) reproduces the comparison in the commentary to Clause 3.9 (about 9.9 mm vs 1.8 mm).

## Problem 3C-5 — Level-pool (modified Puls) storage routing (Clause 3.12.1)

**Inputs.** A detention basin with vertical sides and plan area 500 m², with the stage–storage–discharge relationship of Table 3C.5. Triangular inflow hydrograph: 0 at t = 0, rising linearly to 0.50 m³/s at t = 30 min, falling linearly to 0 at t = 90 min. Basin empty at t = 0. Routing interval Δt = 10 min (600 s). No tailwater.

**Table 3C.5 — Problem 3C-5 stage–storage–discharge relationship**

| Stage (m) | Storage S (m³) | Outflow O (m³/s) |
|---|---|---|
| 0.0 | 0 | 0.00 |
| 0.5 | 250 | 0.05 |
| 1.0 | 500 | 0.10 |
| 1.5 | 750 | 0.15 |
| 2.0 | 1,000 | 0.20 |
| 2.5 | 1,250 | 0.25 |

**Method.** The storage-indication equation is (I1 + I2) + (2S1/Δt − O1) = (2S2/Δt + O2). The table gives O = S / 5,000 (S in m³, O in m³/s), so 2S/Δt + O = 17.667 O and 2S/Δt − O = 15.667 O, and each step is O2 = [(I1 + I2) + 15.667 O1] / 17.667. Software interpolating linearly in Table 3C.5 shall give the same result.

**Table 3C.6 — Problem 3C-5 routed outflow**

| Time (min) | Inflow I (m³/s) | Outflow O (m³/s) | Storage (m³) | Stage (m) |
|---|---|---|---|---|
| 0 | 0.0000 | 0.0000 | 0.0 | 0.000 |
| 10 | 0.1667 | 0.0094 | 47.2 | 0.094 |
| 20 | 0.3333 | 0.0367 | 183.3 | 0.367 |
| 30 | 0.5000 | 0.0797 | 398.4 | 0.797 |
| 40 | 0.4167 | 0.1226 | 612.8 | 1.226 |
| 50 | 0.3333 | 0.1511 | 755.7 | 1.511 |
| 60 | 0.2500 | 0.1670 | 835.2 | 1.670 |
| **70** | 0.1667 | **0.1717** | **858.6** | **1.717** |
| 80 | 0.0833 | 0.1664 | 832.1 | 1.664 |
| 90 | 0.0000 | 0.1523 | 761.5 | 1.523 |

| Time (min) | Inflow I (m³/s) | Outflow O (m³/s) | Storage (m³) | Stage (m) |
|---|---|---|---|---|
| 120 | 0.0000 | 0.1062 | 531.1 | 1.062 |
| 180 | 0.0000 | 0.0517 | 258.3 | 0.517 |

**Results.** Peak outflow 0.172 m³/s at 70 min; peak storage 859 m³; peak stage 1.72 m. The inflow peak of 0.50 m³/s is reduced to 34% of its value.

**Table 3C.7 — Benchmark results to be reported by the applicant**

| Problem | Result | Benchmark | Software result | Difference (%) | Within ±5%? |
|---|---|---|---|---|---|
| 3C-1 | Q, main case (m³/s) | 0.500 | | | |
| 3C-1 | Q, part (b) (m³/s) | 0.208 | | | |
| 3C-2 | Tc (min) | 26.27 | | | |
| 3C-3 | Q, case (a), P = 100 mm (mm) | 39.38 | | | |
| 3C-3 | Q, case (b), P = 100 mm (mm) | 64.93 | | | |
| 3C-3 | Q, case (c), P = 100 mm (mm) | 36.49 | | | |
| 3C-3 | Q, case (c), P = 25 mm (mm) | 1.97 | | | |
| 3C-4 | Runoff, separate sub-areas (mm) | 9.85 | | | |
| 3C-4 | Runoff, composite CN (mm) | 1.83 | | | |
| 3C-4 | qp (m³/s per mm) | 0.800 | | | |
| 3C-5 | Peak outflow (m³/s) | 0.172 | | | |
| 3C-5 | Peak storage (m³) | 859 | | | |

## Annex 3D — Peak rate factor study for flat coastal land

Supports Clauses 3.11.5 and 3.15 of Chapter 3.

> **Not required in Meghalaya.** Meghalaya is landlocked and hilly, so no land in the State meets Clause 3.11.5(a), and the standard factor 484 (PRF' = 0.208) applies to all land (Clause 3.11.5). The Garo foothill plains on the Jinjiram and the valley floors of Ri-Bhoi and of the Shillong streams are flat in places but are not coastal plain; their slow response is represented by storage and backwater (Clauses 3.10.4 and 3.12.4), not by a lower peak rate factor, while the plateau, the hills and the escarpment respond fast. The annex and the layout of Table 3D.1 are kept only so that the annex numbering is unchanged.

**Table 3D.1 — Calibrated peak rate factors (layout)**

| Catchment | Area (km²) | Mean slope (m/m) | Drainage condition | Events used | Calibrated PRF (US customary) | PRF' (SI) | Range of applicability |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

## Annex 3E — CWC SUH parameters for subzone 2(b), with worked example

Supports Clauses 3.4.3 and 3.11.4 of Chapter 3.

**To be prepared.** This annex will tabulate, for CWC subzone 2(b) (South Brahmaputra), the regression relationships for the synthetic unit hydrograph parameters, the design storm duration, loss rate, base flow, areal reduction and time distribution, each with its reference to the Flood Estimation Report, and a worked example for one catchment. It needs the one CWC Flood Estimation Report that covers part of Meghalaya, the South Brahmaputra subzone 2(b) report (Revised; Design Office Report No. SB-2(b)/R-4/44/99, March 2000), which covers the northern foothills (Nongpoh, Byrnihat, Umiam, Resubelpara, Tikrikilla, Phulbari), the plateau (Shillong just north of the subzone boundary, Nongstoin, Mairang, and Jowai on its edge) and the interior of the Garo hills (Tura and Williamnagar on or near the boundary), but whose plates draw no contour south of the boundary west of about 91.8°E (see the References of Chapter 3); a report for subzone 2(c) (Barak), which covers the southern escarpment (Sohra, Mawsynram, Shella, Pynursla, Dawki) and the south Garo slopes (Baghmara), and which CWC has never published, with written confirmation from CWC that none exists or is in preparation [TBC]; and, from the 2(b) report, the areal reduction curves of its Figs 12(a) and 12(b), the time distribution of its Annex 4.4, the regression formulae of its simplified approach (§3.5), which are not legible on the copy read, and the position of the subzone boundary at Tura, Williamnagar, Jowai, Khliehriat and Dalu, which is read by eye to within one marker and is still to be confirmed on a cleaner scan [TBC], transcribed and checked against the published reports, and a catchment with physiographic parameters measured from survey or a DEM. Until it is published, take all SUH inputs directly from the applicable Flood Estimation Report (Clause 3.11.4(a)), apply the 24-hour design rainfall of Clauses 2.3.3(b) and 2.7.3 with the climate factor of Clause 2.8 (Clause 3.11.4(b)), report the SUH result alongside the HEC-HMS or SWMM result for the existing natural condition (Clause 3.11.4(c)), and, where the hydrograph model gives a lower 1% AEP peak, either justify it by calibration under Clause 3.15 or adopt the SUH peak (Clause 3.11.4(d)).

Table 3E.1 — SUH relationships by subzone (layout)

| Parameter | Symbol | Unit | Subzone 2(b) (South Brahmaputra) relationship |
|---|---|---|---|
| Peak discharge of the 1-hour unit hydrograph | Qp | m³/s | Qp = 0.905 A^0.758 (Eq. 3.4.3.2); the peak depends on the catchment area alone |
| Peak discharge per unit area | qp | m³/s per km² | qp = Qp / A |
| Time from centre of unit rainfall to peak | tp | h | tp = 2.87 qp^−0.839 |
| Width of UH at 50% of peak | W50 | h | W50 = 2.304 qp^−1.035 |
| Width of UH at 75% of peak | W75 | h | W75 = 1.339 qp^−0.978 |
| Width of rising limb at 50% of peak | WR50 | h | WR50 = 0.814 qp^−1.018 |
| Width of rising limb at 75% of peak | WR75 | h | WR75 = 0.494 qp^−0.966 |
| Base width of UH | TB | h | TB = 2.447 tp^1.157 |

| Parameter | Symbol | Unit | Subzone 2(b) (South Brahmaputra) relationship |
|---|---|---|---|
| Time to peak from start of rise | Tm | h | Tm = tp + tr/2 |
| Unit duration | tr | h | 1 |
| Design storm duration | TD | h | TD = 1.1 tp |
| Design loss rate | — | mm/h | 3.5 (printed "0.35 cm/hr", the modal value of 100 flood events, as in the report of 1984; "The designer can adopt any other suitable value as per site conditions"); for rural SUH runs only |
| Design base flow | — | m³/s per km² | 0.05 (68 of 100 events in the range 0.01–0.09) |
| Ratio of t-hour to 24-hour rainfall | — | — | 10-yr, partial duration, mean of 6 self-recording gauges (Shillong and five in the Assam valley): 1 h 0.48; 3 h 0.62; 6 h 0.74; 9 h 0.81; 12 h 0.87; 15 h 0.91; 18 h 0.95; 24 h 1.00 (Table 4.1). Used in this Manual only in sub-areas ML-A and ML-A1 (Clause 2.3.6(f)) |
| Time distribution of rainfall | — | cumulative fraction by hour | Fig. 11 and Annex 4.4 (1,040 storms in five duration groups) not read [TBC] |
| Conversion of 1-day to 24-hour rainfall | — | factor | 1.15 (§4.3.1) |
| Areal reduction factor | ARF | % of point rainfall | Figs 12(a) (1, 3 and 6 h) and 12(b) (12 and 24 h), from about 25 storms at the 6 self-recording gauges; curve values not read [TBC] |
| 50-yr 24-hour point rainfall at Meghalaya towns (100-yr in brackets) | — | mm | Plate 9 (Plate 10), read by eye within about one contour (contours 320, 400, 480, 560 and 680 in this sector): Shillong about 560 (560–680), about 1.3–2 times every Shillong record, and not used for design inside the Shillong Planning Area (Clause 2.3.6(c)(i)); Jowai about 680, inside a closed 680 tongue (above 680); Nongstoin about 560 (480–560); Nongpoh about 280–320 (about 320); Tura about 320–400, in a closed 320 cell on Plate 8 (about 400); Williamnagar about 400 (about 400); Dawki about 560–680, extrapolated across the subzone boundary, very low confidence; Sohra, Mawsynram and Baghmara blank: no contour is drawn south of the boundary west of about 91.8°E |
| Gauged catchments that drain Meghalaya | — | — | 2 of the 14 used, both rising in Meghalaya and gauged at Ministry of Surface Transport bridges in Assam in 1981–88: the Digru (Digaru) at bridge MOT-4 (1,270 km²; L 84.47 km, Lc 41.19 km, S 6.34 m/km; 8 gauges) and the Dudhnai at bridge MOT-6 on the Krishnai–Dudhnai section (476 km²; L 60.18 km, Lc 27.35 km, S 6.98 m/km; 4 gauges) (Annexes 3.1 and 3.2) |
| Catchment area for which the relationships apply | A | km² | more than 50 to 1,500; up to 5,000 "judiciously" |
| Report reference | — | — | §§3.4–3.7, Table 3.3, Table 4.1, §4.3, Annexes 3.1, 3.2, 4.1 and 4.2, worked example, Plates 8–10 |

Note: relationships as printed in the CWC subzone 2(b) report (References of Chapter 3), read from a scanned copy and checked against the page images of Table 3.3. A is the catchment area in km², L the length of the main stream in km, Lc the length to the point nearest the catchment centroid in km and S the equivalent slope in m/km. **Coverage.** The report covers 73,556 km² "between longitude 89° 45' to 97° 15' East and latitude 25° 15' to 28° North approximately", comprising "large parts of Assam and areas of Meghalaya, Nagaland and Arunachal Pradesh"; "The northern ranges of Garo, Khasi, and Jaintia hills fall along the southern boundary of the sub-zone", which is bounded "on the south by Barak Subzone 2 (c)". On its Plates 8–10 the boundary runs west to east along the plateau, on or just north of Tura and just south of Shillong, and south-east past Jowai (NEER's reading, within about one marker). The northern foothills, the plateau and the interior of the Garo hills are in subzone 2(b); the southern escarpment (Sohra, Mawsynram, Shella,

Pynursla, Dawki) and the south Garo slopes (Baghmara) are in subzone 2(c), Barak, for which CWC has published no report: the 2(b) report's list of the 21 reports published by 2000 has none, and neither has CWC's download page of 2024. **Meghalaya is the first edition of this series in which part of the State has no CWC report. Basis.** The unit hydrograph rests on 14 catchments with 100 bridge-years of record, from 25 collected in 1961–83 and 29 bridge-years added for five catchments. The other twelve are bridges in the Assam valley and on the railway lines to the Barak divide; none lies on the Khasi–Jaintia plateau or the southern escarpment. The two catchments that drain Meghalaya, the Digru and the Dudhnai, have slopes of 6.34 and 6.98 m/km, against about 2.5 m/km on most of the others, and the report names their slope as "one of the factor for large variations" in its fit; the 50-yr peaks it reproduces err by "+ 40.72% − 57.84%", and "very small catchments have larger variation". **Area only.** Unlike the zone 7 relation of the mountain editions of this series, which uses L·Lc/S, the 2(b) peak depends on A alone: slope enters nowhere, so the SUH gives the same unit hydrograph to a steep Meghalaya catchment and a flat catchment of the same area on the plains. For the gauged catchments the printed relationships give Qp ≈ 204 m³/s, qp ≈ 0.16 m³/s per km², tp ≈ 13.3 h, TB ≈ 49 h and TD ≈ 14.6 h for the Digru, and Qp ≈ 97 m³/s, qp ≈ 0.20 m³/s per km², tp ≈ 10.9 h, TB ≈ 39 h and TD ≈ 12.0 h for the Dudhnai (NEER's computation; yardsticks, not design values). **Worked example.** The report's example is railway bridge 160, outside Meghalaya (470 km², L 56.35 km, Lc 31.40 km, S 2.02 m/km): Qp = 96.00 m³/s, qp = 0.20 m³/s per km², tp = 11.07 h, adjusted to 11.50 h, W50 = 12.19 h, W75 = 6.46 h, WR50 = 4.19 h, WR75 = 2.34 h and TB = 41.00 h, with a loss of 0.35 cm/h and a base flow of 0.05 × 470 = 23.50 m³/s; the copy read once gives the loss as "0.36 cm/hr", a misprint or a misreading of the scan for the 0.35 cm/h that the example applies [TBC]. **Use in the State.** The SUH applies only to the rural rivers of subzone 2(b) of more than 50 km² that leave the State or enter its towns, such as the Digaru, the Umtru and the tributaries of the Kulsi, the Umiam below Barapani, the Dudhnai or Krishnai and the headwaters of the Jinjiram, and is computed only as the benchmark of their natural condition (Clause 3.11.4); below the MePGCL dams the flood is set by releases (Chapter 5), and the Kopili and the reaches in Assam are outside it. The urban catchments of Shillong, Tura, Jowai and Nongpoh, and the wards and jhoras of the Umkhrah and Umshyrpi, are far smaller than 50 km² and steeper than the gauged catchments, and are designed by the Rational Method or SWMM under Clause 3.4, with Tc by the segment method and the rules for steep ground of the Commentary to Clause 3.7. **No SUH in subzone 2(c).** In sub-areas ML-C and ML-C1 no CWC unit hydrograph applies: every cross-drainage structure and outfall of more than 1 km² there needs a site-specific hydrology study with the design rainfall of Clause 2.3.6, losses near zero in the monsoon season (AMC III, Clause 3.8.4), and the routing of multi-day storms, because duration and volume govern culverts and outfalls there, not only the peak; the spillways of the escarpment show why: the Myntdu–Leshka spillway is designed for 12,000 m³/s from 350 km², about 34 m³/s per km², against 3,820 m³/s from 1,020 km², about 3.7 m³/s per km², at New Umtru on the northern slope (MePGCL; NEER's ratios). The design loss rate of 3.5 mm/h is a φ-index fitted to the floods of rural catchments, mostly on the Assam plains and foothills; it is used only in rural SUH runs, is not a soil infiltration capacity and is not used to assign HSG (Clause 3.7), in urban SCS-CN or SWMM models, or to size infiltration practices (Chapter 4). The 2(b) ratios are not to be used to derive intensities on the plateau: applied to the Plate 9 value at Shillong (about 560 mm) the 1-hour ratio of 0.48 gives about 269 mm in an hour, 5.6 times the 48 mm that the Shillong self-recording gauge recorded in its largest hour (15 September 1960; Annex 4.2), whose own single-event ratios are 0.14 at 1 hour, 0.32 at 3 hours and 0.48 at 6 hours (NEER's computation); Clause 2.3.6 deals with the difference. At 24 hours the Shillong records (273.2 mm, IMD, 25 June 1988; 347 mm on the self-recording gauge, 14–15 September 1960; 43.7 cm at Upper Shillong and 41.5 cm at Shillong (Obsy), 20 June 1934, Annex 4.1) all lie well below the plate, which probably carries the escarpment's values north over the plateau (NEER's reading), so the plate is not used inside the Shillong Planning Area, and Clause 2.3.6(h) decides which records count elsewhere.

**Table 3E.2 — Worked example outline (layout)**

| Step | Content | Clause |
|---|---|---|
| 1 | Catchment area, main stream length, length to centroid and equivalent slope, from survey or DEM | 3.11.4(a) |
| 2 | SUH parameters from Table 3E.1 and the plotted unit hydrograph | 3.11.4(a) |
| 3 | Design storm duration, point and areal 24-hour rainfall with climate factor, time distribution | 3.11.4(a), (b) |
| 4 | Effective rainfall after the design loss rate; convolution with the SUH; base flow added | 3.11.4(a) |

| Step | Content | Clause |
|---|---|---|
| 5 | 1% AEP peak compared with the HEC-HMS or SWMM peak for the existing natural condition | 3.11.4(c), (d) |

## Form 3-1 — Hydrologic Calculation Summary

Supports Clauses 3.4, 3.6, 3.7, 3.8, 3.10–3.13, 3.15–3.17 of Chapter 3.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One form per submittal. Attach the documents listed in Section H.

### A. Project

**Table 3F.1 — Form 3-1: project**

| Field | Entry |
|---|---|
| A1. Project name and applicant | |
| A2. Location (village or ward, survey numbers, district) | |
| A3. Site area (ha) and number of points of comparison (POCs) | |
| A4. Catchment class: standard (Clause 2.11.2) or flood-sensitive (Clause 2.11.3) | |
| A5. Design Rainfall Sheet reference (Form 2-1) | |

### B. Method and software (Clauses 3.4, 3.11, 3.12, 3.16)

**Table 3F.2 — Form 3-1: method and software**

| Field | Entry |
|---|---|
| B1. Purpose of each calculation (conveyance, storage, comparison, catchment study) | |
| B2. Contributing area for each purpose (ha or km²) | |
| B3. Method used and the row of Table 3.1 that permits it | |
| B4. Reason for the choice of method | |
| B5. Software and version; engine and version for packages built on SWMM or HEC (Clause 3.16.1, 3.16.2) | |
| B6. For other software: benchmark results of Annex 3C attached (Table 3C.7) and the 5% comparison of Clause 3.16.2 | |
| B7. Runoff transform (Clause 3.11.1) | |
| B8. Computation interval Δt (h), with 0.133 Tc of the smallest sub-area and the hyetograph time step (Clause 3.11.3(a)) | |
| B9. Storage routing and channel routing methods (Clauses 3.12.1, 3.12.2) | |
| B10. Dynamic-wave routing required? If yes, which condition of Clause 3.12.4 | |
| B11. CWC SUH benchmark required (25–5,000 km², Clause 3.11.4)? Result reference | |
| B12. Continuous simulation required (Clause 3.13.1)? Record used and starting tank levels (Clause 3.13.5) | |
| B13. Calibration required (Clause 3.15.1)? Calibration report reference | |

### C. Soils and groundwater (Clauses 3.3.3(b), 3.7, 3.10)

**Table 3F.3 — Form 3-1: soils and groundwater**

| Field | Entry |
|---|---|
| C1. HSG source map, scale and lookup used (Clause 3.7.1, Annex 3A) or NEH Part 630, Ch. 7 assignment (Clause 3.7.2) | |
| C2. Infiltration tests: number, locations, depths, results (Clause 3.7.3) | |
| C3. Seasonal high water table: depth below ground and source (Clause 3.10.2) | |
| C4. Areas within 0.6 m assigned HSG D (Clause 3.10.1) | |
| C5. Disturbed pervious areas and HSG downgrade applied (Clause 3.3.3(b)) | |

## D. Parameters by sub-area and condition (Clauses 3.3, 3.5, 3.8, 3.9; Clause 3.17 item 4)

**Table 3F.4 — Form 3-1: parameters by sub-area and condition**

| Sub-area | Condition (pre / post) | Area (ha) | Impervious: roofs / paved / roads (ha) | DCIA (ha) | Disconnected (ha) | HSG | CN, AMC II | CN, AMC III (pervious part) | C and Cf (if Rational) | Tc (min) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

## E. Time of concentration worksheet (Clause 3.6)

One worksheet per sub-area and condition.

**Table 3F.5 — Form 3-1: time of concentration worksheet**

| Segment | Flow type | Surface and n (Table 3.4) | L (m) | S (m/m) | P2 (mm) | V (m/s) | Tt (min) |
|---|---|---|---|---|---|---|---|
| 1 | Sheet | | | | | — | |
| 2 | Shallow concentrated | | | | — | | |
| 3 | Channel or pipe | | | | — | | |
| | **Tc (not less than 10 min)** | | | | | | |

E1. Is the post-development Tc shorter than the pre-development Tc? If not, explain (Clause 3.6.6): _____

## F. Rainfall and losses (Clauses 3.8.4, 3.8.5, 3.11.5, 3.12, 3.3.5)

**Table 3F.6 — Form 3-1: rainfall, losses and starting levels**

| Field | Entry |
|---|---|
| F1. AEPs and durations run; climate factor applied (Chapter 2) | |
| F2. AMC used for each duration (Clause 3.8.4) | |
| F3. Ia ratio for design runs; Ia = 0.05S sensitivity run made (Clause 3.8.5) | |
| F4. Peak rate factor used; if lower than 484, the Annex 3D value and the land it applies to (Clause 3.11.5) | |
| F5. Starting water level of each tank or waterbody, and its basis (Clauses 3.12.5, 3.13.5) | |

| Field | Entry |
|---|---|
| F6. Off-site run-on: land use assumed for conveyance and for the comparison (Clause 3.3.5) | |
| F7. Incidental storage counted? If yes, the authority's acceptance (Clause 3.12.3) | |

## G. Departures

### Table 3F.7 — Form 3-1: departures from Chapter 3

| No. | Clause departed from | Value used in place of the Chapter 3 value | Justification |
|---|---|---|---|
| 1 | | | |
| 2 | | | |

## H. Attachments (Clause 3.17)

### Table 3F.8 — Form 3-1: attachments

| Item | Attached (yes / no / not applicable) | Reference |
|---|---|---|
| H1. Catchment maps, pre- and post-development, with sub-areas, Tc flow paths, POCs and off-site run-on | | |
| H2. HSG map, water-table data and infiltration test results | | |
| H3. Parameter tables (Section D) and Tc worksheets (Section E) | | |
| H4. Design Rainfall Sheet (Form 2-1) and hyetographs | | |
| H5. Hydrograph tables and plots; stage–storage and stage–discharge tables; routed outflows; peak water levels | | |
| H6. Form 3-2 for each POC | | |
| H7. Calibration report (Clause 3.15) | | |
| H8. Native model input and output files (Clause 3.16.4) | | |

## I. Statement by the responsible engineer (Clause 3.17 item 10)

I state that the methods and parameters of Chapter 3 of the Meghalaya Stormwater Design Manual (Draft v1.0) have been used in this submittal, and that every departure is listed and justified in Section G.

### Table 3F.9 — Form 3-1: statement by the responsible engineer

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |
| Organisation | |
| Signature | |
| Date | |

## Form 3-2 — Pre- vs Post-Development Comparison

Supports Clauses 3.8.5, 3.11.5 and 3.14 of Chapter 3.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One form for each point of comparison (POC). Flows in $m^3/s$, volumes in $m^3$.

### A. Point of comparison (Clause 3.14.2)

**Table 3F.10 — Form 3-2: point of comparison**

| Field | Entry |
|---|---|
| A1. POC identifier and location | |
| A2. Area draining to the POC: site (ha) and off-site run-on (ha) | |
| A3. Off-site run-on passes through site storage? (Clause 3.14.2(c)) | |
| A4. Catchment class: standard (Clause 2.11.2) or flood-sensitive (Clause 2.11.3) | |
| A5. Tailwater applied, including joint cases of Clause 2.12 (Clause 3.14.9(c)) | |
| A6. Flood-sensitive only: largest 10% AEP pre-development peak over all durations, the cap of Clause 2.11.3 (Clause 3.14.7) | |
| A7. Flood-sensitive only: 50% AEP pre-development peak at the pre-development critical duration (Clause 2.11.3) | |

### B. Peak flows (Clauses 3.14.7–3.14.10)

Limit: standard catchments 0.9 × Q_pre for the same AEP and duration (Clause 3.14.10(a)); flood-sensitive catchments the caps A6 (for 1% AEP) and A7 (for 50% AEP) (Clause 3.14.10(b)).

**Table 3F.11 — Form 3-2: peak flows by AEP and duration**

| AEP | Duration (h) | AMC | Q_pre | Q_post, uncontrolled | Q_post, routed | Limit | Met? |
|---|---|---|---|---|---|---|---|
| 50% (2-yr) | 1 | II | | | | | |
| 50% (2-yr) | 2 | II | | | | | |
| 50% (2-yr) | 3 | II | | | | | |
| 50% (2-yr) | 6 | II | | | | | |
| 50% (2-yr) | 12 | III | | | | | |
| 50% (2-yr) | 24 | III | | | | | |
| 50% (2-yr) | 48 | III | | | | | |
| 50% (2-yr) | 72 | III | | | | | |
| 10% (10-yr) | 1 | II | | | | | |
| 10% (10-yr) | 2 | II | | | | | |
| 10% (10-yr) | 3 | II | | | | | |
| 10% (10-yr) | 6 | II | | | | | |

| AEP | Duration (h) | AMC | Q_pre | Q_post, uncontrolled | Q_post, routed | Limit | Met? |
|---|---|---|---|---|---|---|---|
| 10% (10-yr) | 12 | III | | | | | |
| 10% (10-yr) | 24 | III | | | | | |
| 10% (10-yr) | 48 | III | | | | | |
| 10% (10-yr) | 72 | III | | | | | |
| 1% (100-yr) | 1 | II | | | | | |
| 1% (100-yr) | 2 | II | | | | | |
| 1% (100-yr) | 3 | II | | | | | |
| 1% (100-yr) | 6 | II | | | | | |
| 1% (100-yr) | 12 | III | | | | | |
| 1% (100-yr) | 24 | III | | | | | |
| 1% (100-yr) | 48 | III | | | | | |
| 1% (100-yr) | 72 | III | | | | | |

## C. Volumes and storage (Clauses 3.14.8–3.14.10)

**Table 3F.12 — Form 3-2: volumes and storage**

| AEP | Governing duration (h) | Runoff volume, pre | Runoff volume, post uncontrolled | Retention volume | Detention storage required | Peak water level in storage (m) |
|---|---|---|---|---|---|---|
| 50% (2-yr) | | | | | | |
| 10% (10-yr) | | | | | | |
| 1% (100-yr) | | | | | | |

C1. Governing duration for storage, and the 24, 48 and 72 h results (Clause 3.14.10): _____

## D. Sensitivity runs (Clauses 3.8.5, 3.14.11)

**Table 3F.13 — Form 3-2: sensitivity runs**

| Run | Governing storm (AEP, duration) | Change in Q_post, routed (%) | Change in required storage (%) | Retention volume or WQv governing (Clause 3.8.5(c)) |
|---|---|---|---|---|
| Ia = 0.05S | | | | |
| Standard peak rate factor (only where a lower factor is used) | | | | — |

## E. Associated checks (Clause 3.14.12)

**Table 3F.14 — Form 3-2: associated checks**

| Check | Result | Reference in submittal |
|---|---|---|
| Drawdown times (Chapter 4) | | |
| Minimum orifice and trash screen (Chapter 4) | | |
| Emergency spillway (Chapter 4) | | |
| Outfall-closed storage check (Chapter 5) | | |
| Downstream analysis (Chapter 5) | | |

## F. Statement by the responsible engineer

I state that this comparison has been made by the procedure of Clause 3.14, with the same design storms in the pre- and post-development runs, and that no runoff has been diverted from one natural catchment to another to meet the criterion (Clause 3.14.2(b)).

**Table 3F.15 — Form 3-2: statement by the responsible engineer**

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |
| Signature | |
| Date | |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

ANNEXES TO CHAPTER 4

# Site Runoff Control: Retention and Detention

These annexes support Chapter 4. Annex 4C is a complete Tier A worked example with routing tables, built on the illustrative example of Clause 4.6.7. Annex 4B sets out the structure of the Tier B tables, the provisional fixed release coefficients and a standard orifice table computed from the Chapter 4 orifice equation; the values that need NIH-DHAARA depths are still to be derived. Annex 4A needs GIS and groundwater data that this draft does not yet contain; it gives the intended layout and the interim rules of Chapter 4. Forms 4-1 to 4-3 are the submittal forms required by Clause 4.17. They are draft forms and have no statutory status.

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## Annex 4A — Flood-sensitive catchment boundaries (GIS); shallow-groundwater zone map

Supports Clauses 4.5.3, 4.5.4 and 4.12 of Chapter 4.

4A.1 **Flood-sensitive catchment boundaries.** The catchments are those listed in Clause 4.5.3.2, with any catchment notified under Clause 4.5.4. Their maps and GIS layer are the same data set as Annex 1B, which lists the catchments and gives the attribute layout of the layer. The two annexes shall be issued together.

4A.2 **Shallow-groundwater zone map.** This map shows the areas where Clause 4.12 applies: the alluvium of the Garo foothill plains and the Jinjiram valley in sub-area ML-A1, where the water table stands 3–5 m below ground, the valley fills of Ri-Bhoi, the floodplains and low terraces of the rivers and the valley floors of the Umkhrah and Umshyrpi in Shillong, the limestone and sandstone ground of the escarpment and the Jaintia hills, where water stands 2–4 m below ground, the margins of Ward's Lake (Nan Polok), Thadlaskein (Pung Sajar Nangli) and the other pungs and lakes, the margins and backwaters of Umiam lake and the other MePGCL reservoirs, and hill sites with perched water or springs, and any area where the groundwater table lies within 3 m of the surface at any time of year (Clause 4.12.1).

**To be prepared.** This annex will contain (a) the boundaries of the flood-sensitive catchments as a GIS layer and as maps at a scale fit for deciding whether a plot lies inside them, and (b) a map of the shallow-groundwater zone of Clause 4.12.1, with the seasonal high groundwater depth during and after the monsoon. It needs basin and sub-basin boundaries from a digital elevation model and the drainage network (Water Resources Department, NRSC, Survey of India), the flood works of the Water Resources Department, with their design levels, and its embankment and channel project report for the Wahumkhrah and the Umshyrpi (as reported) [TBC], the floodplain zonation of the Umkhrah and other stretches by RMSI (not published) [TBC] and any flood zone notified under the Meghalaya Flood Plain Zoning Act 2026 (none notified), the flash-flood and landslide susceptibility maps of the NESAC risk-informed master plan report for the Shillong Planning Area and the Tura draft risk-informed master plan, the levels of the Umiam, Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka reservoirs from MePGCL, converted to metres where they are published in feet, the waterbodies, setbacks and regulated zones of the Meghalaya Waterbodies (Conservation and Protection) Guidelines 2023, with the inclusion and exclusion lists of waterbodies circulated to the Deputy Commissioners, the waterbodies ground-truthed for the State Wetlands Authority (as reported), the spring inventory of MBDA, and any karst, cave or mine-void map [TBC], town boundaries (the Urban Affairs Department and MUDA for the master-plan, municipal and scheme areas, the six Municipal Boards, the Shillong Cantonment Board, NSTDA, and the District Councils for the Town Committees, census towns and villages), flood maps held by MSDMA, observation-well records of the CGWB and the Water Resources Department, and the extent of the alluvium of the Garo foothill plains, the valley fills of Ri-Bhoi, the Garo Group sandstones and shales, the thin red loams over the gneiss, quartzite and phyllite of the plateau, the limestones and coal measures of the escarpment and the Jaintia hills, the laterite of the south-west and urban fill, with the slopes of more than 10° to which the hill rule of Clause 4.11 applies and the limestone and coal-mining areas to which its karst and mine rule applies from soil survey maps (NBSS&LUP, the Soil and Water Conservation Department (soil survey) [TBC]). Until it is published: (a) the catchments named in Clause 4.5.3.2 apply, and whether a site lies in one is decided and recorded as set out in Annex 1B; and (b) every site to which Clause 4.12.1 may apply establishes its design groundwater level from site piezometer readings over one April–November season or, failing that, from the nearest CGWB or State observation well plus 0.5 m and the design flood level of any adjacent river, stream, jhora, pung, lake or reservoir (Clause 4.12.1(b)). For the flotation check in the alluvium of the Garo foothill plains and the Jinjiram valley, the valley fills of Ri-Bhoi, the river terraces and floodplains, and the pung, lake and reservoir margins without piezometer readings, the design groundwater level is existing ground level (Clause 4.12.1).

Table 4A.1 — Attributes of the shallow-groundwater zone layer (layout)

| Field | Content | Unit or format |
|---|---|---|
| zone_id | Unique identifier | text |
| zone_class | Garo foothill plains alluvium (Jinjiram valley, Phulbari–Tikrikilla or other); Ri-Bhoi valley fill; river floodplain, low terrace or urban valley floor (Umkhrah, Umshyrpi, Umiam, Umtru, Myntdu, Umngot, Ganol, Simsang, Jinjiram or other); limestone or sandstone ground of the escarpment or the Jaintia hills; pung or lake margin (Ward's Lake, Thadlaskein or other); reservoir margin or backwater (Umiam, Kyrdemkulai, Nongkhyllem, New Umtru, Myntdu–Leshka or other); perched water or spring on a hill slope; other area with groundwater within 3 m of the surface (Clause 4.12.1) | text |
| shgw_depth_m | Seasonal high groundwater depth below ground, monsoon season | m |
| shgw_basis | Wells or piezometers used, and period of record | text |
| tidal_influence | Whether the groundwater level follows an adjacent tidal water body (Clause 4.12.1(b)) | yes / no |
| source | Source agency and date of the data | text |
| geometry | Zone boundary | polygon |

## Annex 4B — Tier B tables: PSD and SSR (Table 4.3), retention credit factor C_R, standard outlet sizes; confirmed fixed release coefficients (Table 4.3A)

Supports Clauses 4.4.6.3, 4.14.1, 4.14.2 and 4.14.4 to 4.14.6 of Chapter 4.

4B.1 This annex will hold four tables. Their status in this draft is:

**Table 4B.1 — Contents of Annex 4B and their status**

| Table | Content | Clause | Status in this draft |
|---|---|---|---|
| 4B.2 | Tier B permissible site discharge (PSD) and site storage requirement (SSR), the values of Table 4.3 | 4.14.2 | To be prepared |
| 4B.3 | Retention credit factor C_R | 4.4.6.3 | To be prepared; C_R = 0 until published |
| 4B.4 | Standard outlet sizes | 4.14.2 step 4, 4.14.6 | Computed in this annex from the orifice equation of Clause 4.6.5.2 |
| 4B.5 | Fixed release coefficients C_10 and C_2 (Table 4.3A) | 4.14.4 | Provisional values of Table 4.3A; confirmed values to be prepared |

### 4B.2 PSD and SSR (Table 4.3)

**To be prepared.** This table will give, for each rainfall zone, hydrologic soil group and post-development imperviousness, the PSD for the 2-yr and 100-yr stages and the SSR, for standard and flood-sensitive catchments, in the layout of Table 4.3. It needs NIH-DHAARA design depths with the climate factor for each zone (Chapter 2, Annex 2A), the sub-daily ratios of Annex 2B, and routing of a set of standard sites by the full method of Clause 4.6 for every AEP and duration of Table 4.1. Each PSD shall be the governing release cap and each SSR the governing storage per hectare, with a margin so that the simplified method is never cheaper than routing. Until it is published, Tier B sites use Clause 4.6, or the fixed-coefficient route of Clause 4.14.3 where the site is 1 ha or less (Clauses 4.14.1 and 4.14.3).

**Table 4B.2 — Tier B PSD and SSR (layout of Table 4.3)**

| Zone (Annex 2A) | HSG | Imperviousness | PSD 2-yr (L/s/ha) | PSD 100-yr (L/s/ha), standard | PSD 100-yr (L/s/ha), flood-sensitive | SSR ($m^3$/ha), standard | SSR ($m^3$/ha), flood-sensitive |
|---|---|---|---|---|---|---|---|
| ML-Z1 Northern foothills: ML-A Northern foothills and Ri-Bhoi (Nongpoh–Umsning–Byrnihat–Umiam) | B / C / D | 50% / 70% / 90% | — | — | — | — | — |
| ML-Z1 Northern foothills: ML-A1 Garo foothills and plains (Resubelpara–Mendipathar–Tikrikilla–Phulbari) | B / C / D | 50% / 70% / 90% | — | — | — | — | — |

| Zone (Annex 2A) | HSG | Imperviousness | PSD 2-yr (L/s/ha) | PSD 100-yr (L/s/ha), standard | PSD 100-yr (L/s/ha), flood-sensitive | SSR (m³/ha), standard | SSR (m³/ha), flood-sensitive |
|---|---|---|---|---|---|---|---|
| ML-Z2 Plateau: ML-B Shillong plateau (Shillong–Mawphlang–Nongstoin–Mairang) | C / D | 50% / 70% / 90% | — | — | — | — | — |
| ML-Z2 Plateau: ML-B1 Jaintia hills karst and mine belt (Jowai–Khliehriat–Sutnga–Ladrymbai) | C / D | 50% / 70% / 90% | — | — | — | — | — |
| ML-Z3 Southern escarpment: ML-C Southern escarpment (Sohra–Mawsynram–Shella–Pynursla–Dawki) | — | — | Not tabulated: Clause 4.6 applies (Clause 2.3.6(c)(ii)) | — | — | — | — |
| ML-Z3 Southern escarpment: ML-C1 South Garo slopes (Baghmara–Siju–Gasuapara) | — | — | Not tabulated: Clause 4.6 applies (Clause 2.3.6(c)(ii)) | — | — | — | — |
| ML-Z4 Garo hills: ML-D Garo hills interior (Tura–Williamnagar–Rongjeng–Ampati–Dalu) | C / D | 50% / 70% / 90% | — | — | — | — | — |

## 4B.3 Retention credit factor C_R

**To be prepared.** This table will give C_R for each rainfall zone, hydrologic soil group and design infiltration or drawdown rate of the retention practice (Clauses 4.4.3 and 4.4.6.3). It needs routing of the full duration set of Clause 2.5.2 with NIH-DHAARA depths, with the retention practice modelled as in Clause 4.4.6.2, and the credit expressed as the reduction in governing storage per cubic metre of retention provided. Until it is published, **C_R = 0** (Clause 4.4.6.3).

**Table 4B.3 — Retention credit factor C_R (layout)**

| Zone (Annex 2A) | HSG | Design infiltration or drawdown rate (mm/h) | C_R (–) |
|---|---|---|---|
| | | | |
| | | | |

## 4B.4 Standard outlet sizes

4B.4.1 Table 4B.4 gives the largest circular orifice, in 5 mm steps, whose discharge does not exceed a stated permissible discharge at a stated head. It is computed from the orifice equation with the discharge coefficient of Clause 4.6.5.2:

$$Q = 0.60 \times (\pi d^2 / 4) \times \sqrt{(2 g H)}$$

where Q is the discharge (m³/s), d the orifice diameter (m), g = 9.81 m/s² and H the head from the water level to the centre of the orifice (m). Sizes are rounded **down**, so that the orifice never passes more than the permissible discharge. Where the computed size is below 50 mm, the 50 mm minimum of Clause 4.8.2 is shown; it is deemed to comply under Clause 4.5.5.1.

4B.4.2 The table assumes free discharge. Where the tailwater can rise above the orifice (Clause 4.6.6), H is the difference between the upstream and downstream water levels and the orifice shall be checked by routing. The State Stormwater Technical Committee may replace this table when it issues Annex 4B.

**Table 4B.4 — Largest orifice diameter (mm) for a permissible discharge at a given head (Cd = 0.60, free discharge)**

| Permissible discharge (L/s) | H = 0.5 m | H = 1.0 m | H = 1.5 m | H = 2.0 m |
|---|---|---|---|---|
| 5 | 55 | 50 | 50 | 50 |
| 10 | 80 | 65 | 60 | 55 |
| 15 | 100 | 80 | 75 | 70 |
| 20 | 115 | 95 | 85 | 80 |
| 30 | 140 | 115 | 105 | 100 |
| 50 | 180 | 150 | 135 | 130 |
| 75 | 225 | 185 | 170 | 155 |
| 100 | 260 | 215 | 195 | 180 |
| 150 | 315 | 265 | 240 | 225 |
| 200 | 365 | 305 | 275 | 260 |
| 300 | 450 | 375 | 340 | 315 |

Check: for 50 L/s at H = 1.0 m, the area is 0.050 / (0.60 × √(2 × 9.81 × 1.0)) = 0.0188 m², so d = √(4 × 0.0188 / π) = 0.155 m, rounded down to 150 mm.

## 4B.5 Fixed release coefficients (Table 4.3A)

4B.5.1 Table 4B.5 repeats the provisional coefficients of Table 4.3A. They may be used now under the fixed-coefficient route (Clause 4.14.4).

**Table 4B.5 — Fixed release coefficients C_10 and C_2 (provisional, Table 4.3A)**

| Hydrologic soil group | C_10 | C_2 | Clause | Status |
|---|---|---|---|---|
| A (sandy, well drained) | 0.05 | 0.02 | 4.14.4 | Provisional |
| B | 0.08 | 0.03 | 4.14.4 | Provisional |
| C | 0.15 | 0.08 | 4.14.4 | Provisional |
| D (clay, poorly drained) | 0.25 | 0.15 | 4.14.4 | Provisional |

**To be prepared.** The confirmed coefficients will replace Table 4B.5. They need NIH-DHAARA depths for each zone and the greenfield curve numbers of Clause 3.3, as described in the commentary to Clause 4.14. Until they are published, the provisional values of Table 4.3A apply.

## Annex 4C — Worked example (Tier A) with full routing tables

Supports Clauses 4.4 to 4.9, 4.15 and 4.17 of Chapter 4.

**Illustrative — not design values.** This example continues the illustrative example of Clause 4.6.7. Its inputs are invented to be plausible for a colony draining to a jhora in Shillong; they are not NIH-DHAARA values and must not be used for design. Part 1 sets out the inputs, hydrographs and routing step by step, for a trial outlet. Part 2 finds that the trial outlet fails the drawdown check with the blockage of Clause 4.8.3, and revises it to the outlet reported in Table 4.2. Part 3 completes the spillway, outlet, safety and retention checks. The outfall-closed check of Chapter 5 for the same facility on an outfall to a jhora draining to the Umkhrah in Shillong is in Annex 5C.

### Part 1 — Inputs, hydrographs and routing (Clauses 4.6.1 to 4.6.4)

4C.1 **Inputs.**

**Table 4C.1 — Inputs (Illustrative — not design values)**

| Item | Value | Basis |
|---|---|---|
| Site area A | 2.0 ha (0.02 km²), one outfall | Clause 4.6.7 |
| Catchment class | Flood-sensitive (Clause 4.5.3) | Clause 4.6.7 |
| Land cover and curve numbers, AMC II | Pre-development: all pervious, CN 70. Post-development, as two sub-areas: directly connected impervious 1.57 ha at CN 98, and pervious open space 0.43 ha at CN 70 (same soil as pre-development). Impervious fraction f = (92 − 70) / (98 − 70) = 0.786, so the area-weighted CN is 92 | Clauses 3.9.2, 4.6.7 |
| AMC III conversion | Pervious areas only, for storms of 12 h and longer: CN_III = 23·CN / (10 + 0.13·CN) = 84.3. The impervious CN 98 is not converted | Clause 3.8.4 |
| Initial abstraction | Ia = 0.2S; Ia = 0.05S as a sensitivity run | Clause 3.8.5 |
| Time of concentration Tc | 45 min pre-development; 15 min post-development, used for both sub-areas, because the open space is small and drains through the same site system | Clause 4.6.7 |
| Unit hydrograph | SCS triangular; tL = 0.6 Tc; tp = Δt/2 + tL; base 2.67 tp | Clauses 3.6.5, 3.11.2 |
| Time step Δt | 5 min (= Tc/3 of the post-development site) | Clause 4.6.2, step 8 |
| 24-h depths, 2-, 10-, 100-yr | 110, 200, 350 mm, taken as including the climate factor | Clause 4.6.7 |
| Shorter durations | P(t) = P24 · (t/24)^0.40 (assumed ratio set, not Annex 2B) | Clause 4.6.7 |
| 48-h and 72-h depths | 1.25 and 1.40 × P24, with the 24-h depth on the last day | Clauses 4.6.7, 2.9.2 |
| Storage | Open, vertical-walled, 2,500 m² plan area, excavated, no embankment, not publicly accessible | Clause 4.6.7 |
| Trial outlet | Stage 1: 120 mm orifice at the floor. Stage 2: 470 mm orifice, invert 0.533 m above the floor. No Stage 3 | Trial for this annex; Part 2 revises it |
| Outfall | Free outfall to a receiving drain whose level stays below the outlet invert | Illustrative input |

The example follows Clauses 3.8.4 and 3.9.2: the runoff of each sub-area is computed separately and the two are added before routing.

4C.2 **Design rainfall.** Table 4C.2 gives the depths. For example, the 100-yr 6-hour depth is 350 × (6/24)^0.40 = 350 × 0.574 = 201.0 mm.

**Table 4C.2 — Design rainfall depths, mm (Illustrative — not design values)**

| Duration (h) | 1 | 2 | 3 | 6 | 12 | 24 | 48 | 72 |
|---|---|---|---|---|---|---|---|---|
| 50% AEP (2-yr) | 30.9 | 40.7 | 47.9 | 63.2 | 83.4 | 110.0 | 137.5 | 154.0 |
| 10% AEP (10-yr) | 56.1 | 74.0 | 87.1 | 114.9 | 151.6 | 200.0 | 250.0 | 280.0 |
| 1% AEP (100-yr) | 98.2 | 129.5 | 152.3 | 201.0 | 265.3 | 350.0 | 437.5 | 490.0 |

4C.3 **Hyetographs.** Storms up to 24 h use the alternating-block method in 5-minute blocks with the peak block at mid-storm (Clause 2.9.1). The 48- and 72-hour storms spread the depth in excess of the 24-hour depth uniformly over the first 24 or 48 h and place the 24-hour alternating-block storm on the last day (Clause 2.9.2). For the 100-yr 72-hour storm: (490.0 − 350.0) / 576 blocks = 0.243 mm per 5 minutes for the first 48 h; the peak 5-minute block on the last day is 350 × (5/1440)^0.40 = 36.3 mm, at 60:00–60:05 h.

4C.4 **Losses.** Table 4C.3 gives S = 25,400/CN − 254 (mm) and Ia = 0.2S. The runoff depth for a rainfall depth P is Q = (P − Ia)² / (P − Ia + S) for P > Ia, and zero otherwise.

**Table 4C.3 — Curve numbers and abstractions (Illustrative — not design values)**

| Condition | AMC | CN | S (mm) | Ia = 0.2S (mm) |
|---|---|---|---|---|
| Pre-development | II (durations ≤ 6 h) | 70 | 108.9 | 21.8 |
| Pre-development | III (durations ≥ 12 h) | 84.3 | 47.3 | 9.5 |
| Post-development pervious open space (0.43 ha) | II (durations ≤ 6 h) | 70 | 108.9 | 21.8 |
| Post-development pervious open space (0.43 ha) | III (durations ≥ 12 h) | 84.3 | 47.3 | 9.5 |
| Post-development directly connected impervious (1.57 ha) | All durations (not converted) | 98 | 5.2 | 1.0 |

Check: 100-yr 24 h, post-development. Impervious: Q = (350.0 − 1.0)² / (350.0 − 1.0 + 5.2) = 343.9 mm. Pervious, AMC III: Q = (350.0 − 9.5)² / (350.0 − 9.5 + 47.3) = 299.0 mm. Site: 0.786 × 343.9 + 0.214 × 299.0 = 334.2 mm. The post-development columns of Table 4C.4 are these area-weighted site depths.

**Table 4C.4 — Storm runoff depth Q, mm (Illustrative — not design values)**

| Duration (h) | AMC | 2-yr pre | 2-yr post | 10-yr pre | 10-yr post | 100-yr post |
|---|---|---|---|---|---|---|
| 1 | II | 0.7 | 20.1 | 8.2 | 41.3 | 79.2 |
| 2 | II | 2.8 | 28.2 | 16.9 | 57.2 | 108.5 |
| 3 | II | 5.1 | 34.2 | 24.5 | 69.0 | 130.2 |
| 6 | II | 11.4 | 47.5 | 42.9 | 94.7 | 177.1 |
| 12 | III | 45.0 | 70.5 | 106.6 | 137.2 | 249.9 |
| 24 | III | 68.4 | 96.4 | 152.6 | 185.1 | 334.2 |
| 48 | III | 93.5 | 123.3 | 201.0 | 234.7 | 421.5 |
| 72 | III | 108.9 | 139.6 | 230.3 | 264.5 | 473.9 |

The runoff volume is 10 × Q × A = 20 × Q m³ for this 2.0 ha site: for example 9,478 m³ for the 100-yr 72-hour storm. The routed hydrographs carry up to 0.5% less, because the 5-minute alternating-block storm places 349.5 mm rather than 350.0 mm on the last day.

4C.5 **Unit hydrographs.** The runoff in each 5-minute block (for the post-development site, the sum of the two sub-areas) is convolved with the triangular unit hydrograph of Table 4C.5. The peak is qp = 0.208 × A × Q / tp, with A in km² and Q = 1 mm (Clause 3.11.2).

**Table 4C.5 — Unit hydrograph parameters (Illustrative — not design values)**

| Condition | Tc (h) | tL = 0.6 Tc (h) | tp = Δt/2 + tL (h) | Base 2.67 tp (h) | qp (L/s per mm of runoff) |
|---|---|---|---|---|---|
| Pre-development | 0.75 | 0.45 | 0.492 | 1.313 | 8.5 |
| Post-development | 0.25 | 0.15 | 0.192 | 0.512 | 21.7 |

4C.6 **Release caps (Clause 4.5.3).** The site is flood-sensitive, so the mixed-frequency rule applies. The 100-yr cap is the largest pre-development 10-yr peak over all durations: **356 L/s** (72 h; Table 4.2). The 2-yr cap is the largest pre-development 2-yr peak: **180 L/s** (72 h). Each cap applies to every post-development duration (Clause 4.5.3.1).

4C.7 **Stage–storage–discharge.** The basin is vertical-walled, so storage S = 2,500 × h (m³), where h is the stage above the floor (m). Outlet discharge follows Clause 4.6.5.2 with Cd = 0.60:

- Stage 1, for h ≥ d: Q1 = 0.60 × A1 × √(2g (h − d/2)). For h < d (orifice part-full), the head is taken as d/2 and the result is multiplied by h/d.
- Stage 2 is counted once the water is above its centre: Q2 = 0.60 × A2 × √(2g (h − z2 − d2/2)), where z2 is its invert. Below its centre its flow is ignored, which slightly over-states storage.

**Table 4C.6 — Stage–storage–discharge, trial outlet (Illustrative — not design values)**

| Stage h (m) | Storage (m³) | Stage 1, 120 mm (L/s) | Stage 2, 470 mm (L/s) | Total (L/s) |
|---|---|---|---|---|
| 0.00 | 0 | 0.0 | 0.0 | 0.0 |
| 0.06 | 150 | 3.7 | 0.0 | 3.7 |
| 0.12 | 300 | 7.4 | 0.0 | 7.4 |
| 0.20 | 500 | 11.2 | 0.0 | 11.2 |
| 0.30 | 750 | 14.7 | 0.0 | 14.7 |
| 0.40 | 1,000 | 17.5 | 0.0 | 17.5 |
| 0.50 | 1,250 | 19.9 | 0.0 | 19.9 |
| 0.60 | 1,500 | 22.1 | 0.0 | 22.1 |
| 0.70 | 1,750 | 24.0 | 0.0 | 24.0 |
| 0.80 | 2,000 | 25.9 | 83.0 | 108.9 |
| 0.90 | 2,250 | 27.5 | 167.8 | 195.3 |
| 1.00 | 2,500 | 29.1 | 222.3 | 251.4 |
| 1.10 | 2,750 | 30.7 | 265.8 | 296.5 |
| 1.20 | 3,000 | 32.1 | 303.2 | 335.3 |
| 1.30 | 3,250 | 33.5 | 336.4 | 369.9 |
| 1.40 | 3,500 | 34.8 | 366.7 | 401.5 |

Check at h = 1.00 m: Q1 = 0.60 × 0.01131 × √(19.62 × 0.94) = 0.0291 m³/s; Q2 = 0.60 × 0.1735 × √(19.62 × (1.00 − 0.533 − 0.235)) = 0.2223 m³/s.

4C.8 **Routing.** Each storm is routed by level-pool continuity (Clause 4.6.1): over each 5-minute step, the change in storage equals inflow volume minus outflow volume. The computation used six 50-second sub-steps per 5-minute step. Each row of Table 4C.7 can be checked by hand as ΔS ≈ (I − Ō) × 300 s, where I is the mean inflow over the 5-minute step ending at the time shown and Ō is the mean of the outflows at the start and end of the step. For example, between 60:15 and 60:20: ΔS = 2,853.0 − 2,613.3 = 239.7 m³, and (1.0891 − (0.2655 + 0.3069)/2) × 300 = 240.9 m³.

**Table 4C.7 — Routing of the 100-yr 72-hour storm through the trial outlet, around the peak (Illustrative — not design values)**

| Time (h:min) | Rainfall in step (mm) | Inflow I (L/s) | Outflow O (L/s) | Storage S (m³) | Stage h (m) |
|---|---|---|---|---|---|
| 60:00 | 8.44 | 286.3 | 169.5 | 2,164.0 | 0.866 |
| 60:05 | 36.33 | 354.2 | 184.1 | 2,216.9 | 0.887 |
| 60:10 | 11.61 | 703.3 | 218.0 | 2,367.1 | 0.947 |
| 60:15 | 6.88 | 1,066.0 | 265.5 | 2,613.3 | 1.045 |
| 60:20 | 5.23 | 1,089.1 | 306.9 | 2,853.0 | 1.141 |
| 60:25 | 4.34 | 897.5 | 334.8 | 3,025.0 | 1.210 |
| 60:30 | 3.77 | 653.2 | 349.9 | 3,117.6 | 1.247 |
| 60:35 | 3.36 | 403.6 | 353.8 | **3,132.9** | **1.253** |
| 60:40 | 3.05 | 301.5 | 352.3 | 3,117.3 | 1.247 |
| 60:45 | 2.81 | 254.8 | 348.6 | 3,088.7 | 1.235 |
| 60:50 | 2.61 | 224.9 | 343.7 | 3,052.4 | 1.221 |
| 60:55 | 2.45 | 203.3 | 337.9 | 3,011.3 | 1.205 |

Storage is greatest at the end of the step ending at 60:35. In the next step the mean inflow (302 L/s) is below the outflow (about 352 L/s), so storage falls.

**Table 4C.8 — Routing of the 100-yr 72-hour storm through the trial outlet, hourly (Illustrative — not design values)**

| Time (h) | Cumulative rainfall (mm) | Inflow (L/s) | Outflow (L/s) | Stage (m) | Storage (m³) |
|---|---|---|---|---|---|
| 12 | 35.0 | 14 | 8 | 0.130 | 325 |
| 24 | 70.0 | 15 | 12 | 0.215 | 536 |
| 36 | 105.0 | 16 | 14 | 0.264 | 660 |
| 48 | 140.0 | 16 | 15 | 0.294 | 736 |
| 54 | 181.7 | 47 | 19 | 0.469 | 1,172 |
| 57 | 213.5 | 69 | 23 | 0.623 | 1,559 |
| 59 | 248.5 | 120 | 91 | 0.789 | 1,971 |
| 60 | 293.3 | 286 | 170 | 0.866 | 2,164 |
| 61 | 378.0 | 187 | 332 | 1.187 | 2,967 |
| 62 | 399.3 | 106 | 237 | 0.968 | 2,421 |

| Time (h) | Cumulative rainfall (mm) | Inflow (L/s) | Outflow (L/s) | Stage (m) | Storage (m³) |
|---|---|---|---|---|---|
| 63 | 414.5 | 80 | 142 | 0.829 | 2,072 |
| 66 | 446.9 | 51 | 52 | 0.771 | 1,927 |
| 72 | 489.5 | 33 | 33 | 0.768 | 1,920 |
| 84 | 489.5 | 0 | 18 | 0.405 | 1,012 |
| 96 | 489.5 | 0 | 10 | 0.167 | 418 |
| 108 | 489.5 | 0 | 4 | 0.058 | 146 |

The routed outflow volume equals the inflow volume (about 9,470 m³): detention delays the volume but does not remove it.

4C.9 **Results, trial outlet.** Table 4C.9 gives the peaks, maximum stages and drawdown times for the trial outlet.

**Table 4C.9 — Results for the trial outlet (120 mm and 470 mm orifices) (Illustrative — not design values)**

| Duration (h) | 2-yr detained (L/s) | 2-yr max stage (m) | 10-yr detained (L/s) | 10-yr max stage (m) | 100-yr detained (L/s) | 100-yr max stage (m) | 100-yr storage (m³) | 10-yr 90% drawdown, clean (h) | 10-yr 90% drawdown, 50% blocked (h) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 0.15 | 15 | 0.30 | 22 | 0.59 | 1,468 | 27.2 | 54.2 |
| 2 | 11 | 0.20 | 18 | 0.42 | 89 | 0.79 | 1,966 | 28.3 | 57.0 |
| 3 | 13 | 0.24 | 20 | 0.50 | 135 | 0.82 | 2,058 | 29.3 | 59.1 |
| 6 | 15 | 0.31 | 23 | 0.64 | 190 | 0.89 | 2,229 | 31.1 | 63.4 |
| 12 | 17 | 0.40 | 49 | 0.77 | 279 | 1.06 | 2,647 | 36.2 | 69.2 |
| 24 | 19 | 0.45 | 87 | 0.79 | 334 | 1.20 | 2,991 | 42.8 | 75.4 |
| 48 | 20 | 0.51 | 144 | 0.83 | 353 | 1.25 | 3,129 | 42.5 | 72.7 |
| 72 | 20 | 0.52 | 147 | 0.84 | 354 | 1.25 | **3,133** | 42.5 | 71.9 |

The drawdown time is measured from the time of maximum 10-yr storage until 90% of that storage has been released (Clause 4.7.1).

## Part 2 — Checks and revision of the outlet (Clauses 4.5, 4.7 and 4.8)

4C.10 **Release caps.** Every 100-yr detained peak is at or below 356 L/s, and every 2-yr detained peak is far below the 2-yr cap of 180 L/s. Both caps are met. The 2-yr peaks are not compared duration by duration with the pre-development peaks: for a flood-sensitive site the 2-yr cap is the single largest pre-development 2-yr peak (Clause 4.5.3.1).

4C.11 **Drawdown.** Clause 4.8.3 requires the low-flow orifice to be assumed **50% blocked** when drawdown is checked. With the 120 mm orifice at half its area, 90% of the 10-yr storage takes 54 to 75 h to drain (Table 4C.9), against the 48-hour limit of Clause 4.7.1. **The trial outlet fails.** With a clean orifice it would drain in about 42 h.

4C.12 **Revised outlet.** The low-flow orifice was increased in 10 mm steps until the blocked drawdown met 48 h for every duration, and Stage 2 was then re-sized so that the 100-yr cap was still met. The result:

- Stage 1: **170 mm** orifice at the floor;
- Stage 2: **460 mm** orifice, invert 0.53 m above the floor (centre at 0.76 m);
- no Stage 3.

The larger low-flow orifice releases more in frequent storms. That is acceptable here because the 2-yr cap of a flood-sensitive site is the largest pre-development 2-yr peak (Clause 4.5.3.1). The WQv is assumed to be treated in a separate practice upstream (Chapter 8), so Stage 1 is not required to hold the WQv for 24–48 h (Clause 4.6.5.1); where Stage 1 also releases the WQv, Clause 4.7.2 must be checked as well.

**Table 4C.10 — Stage–storage–discharge, revised outlet (Illustrative — not design values)**

| Stage h (m) | Storage (m³) | Stage 1, 170 mm (L/s) | Stage 2, 460 mm (L/s) | Total (L/s) |
|---|---|---|---|---|
| 0.00 | 0 | 0.0 | 0.0 | 0.0 |
| 0.085 | 213 | 8.8 | 0.0 | 8.8 |
| 0.17 | 425 | 17.6 | 0.0 | 17.6 |
| 0.30 | 750 | 28.0 | 0.0 | 28.0 |
| 0.40 | 1,000 | 33.9 | 0.0 | 33.9 |
| 0.50 | 1,250 | 38.9 | 0.0 | 38.9 |
| 0.60 | 1,500 | 43.3 | 0.0 | 43.3 |
| 0.70 | 1,750 | 47.3 | 0.0 | 47.3 |
| 0.76 | 1,900 | 49.6 | 0.0 | 49.6 |
| 0.80 | 2,000 | 51.0 | 88.3 | 139.3 |
| 0.90 | 2,250 | 54.5 | 165.3 | 219.7 |
| 1.00 | 2,500 | 57.7 | 216.4 | 274.1 |
| 1.10 | 2,750 | 60.8 | 257.5 | 318.3 |
| 1.17 | 2,925 | 62.8 | 282.8 | 345.6 |
| 1.20 | 3,000 | 63.7 | 293.0 | 356.7 |
| 1.30 | 3,250 | 66.5 | 324.6 | 391.1 |

**Table 4C.11 — Results for the revised outlet (170 mm and 460 mm orifices) (Illustrative — not design values)**

| Duration (h) | 2-yr detained (L/s) | 2-yr max stage (m) | 10-yr detained (L/s) | 10-yr max stage (m) | 10-yr storage (m³) | 100-yr detained (L/s) | 100-yr max stage (m) | 100-yr storage (m³) | 10-yr 90% drawdown, 50% blocked (h) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 0.14 | 28 | 0.29 | 734 | 42 | 0.57 | 1,426 | 31.3 |
| 2 | 20 | 0.19 | 34 | 0.40 | 990 | 79 | 0.76 | 1,911 | 32.1 |
| 3 | 22 | 0.22 | 37 | 0.46 | 1,147 | 139 | 0.80 | 1,999 | 32.8 |
| 6 | 25 | 0.26 | 41 | 0.56 | 1,386 | 194 | 0.86 | 2,154 | 34.2 |
| 12 | 30 | 0.33 | 46 | 0.68 | 1,692 | 276 | 1.01 | 2,512 | 39.0 |
| 24 | 32 | 0.37 | 49 | 0.75 | 1,870 | 320 | 1.11 | 2,766 | 45.3 |
| 48 | 34 | 0.40 | 82 | 0.77 | 1,913 | 343 | 1.17 | **2,913** | 44.8 |
| 72 | 34 | 0.41 | 84 | 0.77 | 1,915 | 343 | 1.16 | 2,911 | 44.7 |

Findings:

- **100-yr cap:** largest detained peak 343 L/s ≤ 356 L/s. Met.
- **2-yr cap:** largest detained peak 34 L/s ≤ 180 L/s. Met.
- **Drawdown:** longest blocked drawdown 45.3 h ≤ 48 h (Clause 4.7.1). Met.
- **Governing storage: 2,913 m³** (100-yr, 48 h), at a maximum stage of **1.17 m**. The larger low-flow orifice releases more water early in the long storms, so the revised outlet needs about 220 m³ less storage than the trial outlet. Table 4.2 in Clause 4.6.7 reports this revised design.
- **Governing storms (Clause 4.6.2, step 12):** storage, the 100-yr 48-hour storm; Stage 1, the 10-yr 24-hour storm (drawdown); Stage 2, the 100-yr 48-hour storm (cap).

## Part 3 — Sensitivity, retention, spillway, outlet details and safety

4C.13 **Ia = 0.05S sensitivity (Clause 3.8.5).** With S converted as S0.05 = 25.4 × 1.33 × (S0.20 / 25.4)^1.15, the governing 100-yr 48-hour run gives 2,898 m³ of storage and a 341 L/s peak, slightly below the default run. The pre-development 10-yr peak, and so the 100-yr cap, falls to 344 L/s. The design is based on the default run (Clause 3.8.5(c)); the sensitivity results are reported on Form 3-2.

4C.14 **Retention and retention credit (Clauses 4.4.2 and 4.4.6).** With an illustrative retention depth P_R = 40 mm, Q_R is computed for each sub-area at AMC II, because a composite CN is not used for retention (Clause 3.9.4). Impervious, CN 98: S = 5.2 mm, Ia = 1.0 mm, Q_R = (40 − 1.0)² / (40 − 1.0 + 5.2) = 34.4 mm. Pervious, CN 70: S = 108.9 mm, Ia = 21.8 mm, Q_R = (40 − 21.8)² / (40 − 21.8 + 108.9) = 2.6 mm. RRV = 10 × (34.4 × 1.571 + 2.6 × 0.429) = **552 m³**. The retention is modelled as a store that is empty at the start of the storm and captures all runoff until full, with no infiltration during the storm (Clause 4.4.6.2).

**Table 4C.12 — Retention credit by routing, revised outlet (Illustrative — not design values)**

| 100-yr storm | Storage without retention (m³) | Storage with retention (m³) | Reduction (m³) |
|---|---|---|---|
| 24 h | 2,766 | 2,628 | 138 |
| 48 h | 2,913 | 2,906 | 7 |
| 72 h | 2,911 | 2,911 | 0 |

The governing storage falls from 2,913 to 2,906 m³, so the retention credit is 7 m³, about 1% of the RRV. The retention is still required in full for its own purposes (Clause 4.4.1, Chapter 8).

4C.15 **Emergency spillway (Clause 4.9).** The facility is excavated, with no embankment, so Clause 4.9.7 applies: the overflow route is treated as the spillway and must meet Clause 4.9.1.

- Design flow: the 1% AEP peak inflow, 1,089 L/s, with the outlet blocked and the basin full to the crest.
- Crest: the 1% AEP maximum water level with the outlet working is 1.17 m; with the recommended 0.15 m clearance (Clause 4.9.3) the crest is set at **1.35 m**.
- Crest length: a broad-crested weir with Q = C × L × H^1.5, C = 1.7 (an illustrative coefficient for a broad-crested weir in SI units; Clause 4.6.5.2 requires a coefficient suited to the shape). With L = 4.0 m: H = (1.089 / (1.7 × 4.0))^(2/3) = 0.295 ≈ **0.30 m**.
- Maximum level with the spillway flowing: 1.35 + 0.30 = 1.65 m. With 0.3 m freeboard (Clause 4.9.1), the top of the walls is at least **1.95 m** above the floor.
- The spillway discharges to the 1% AEP overland flow path, away from buildings (Clause 4.9.4).

4C.16 **Outlet details (Clause 4.8).**

**Table 4C.13 — Outlet checks, revised outlet (Illustrative — not design values)**

| Item | Requirement | Value | Result |
|---|---|---|---|
| Minimum orifice | ≥ 50 mm (Clause 4.8.2) | 170 mm | Met |
| Rack bar spacing | ≤ half the smallest opening and ≥ 25 mm (Clause 4.8.3) | ≤ 85 mm | Set at 75 mm |
| Rack open area | ≥ 10 × area protected (Clause 4.8.3) | 10 × (0.0227 + 0.1662) m² = 1.89 m² for one rack around both orifices | Provide ≥ 1.89 m² |
| Anti-vortex, Stage 1 | Needed if head > 1.5 d (Clause 4.8.4) | Head up to 1.08 m > 0.26 m | Required |
| Anti-vortex, Stage 2 | Needed if head > 1.5 d (Clause 4.8.4) | Head above centre up to 0.41 m < 0.69 m | Not required |
| Isolation | Facility serving > 1 ha (Clause 4.8.6) | Serves 2.0 ha | Stop-log slot or penstock, normally open |
| Outlet barrel | ≥ 300 mm (Clause 4.8.5) | Sized under Chapter 9 for 343 L/s | To be designed |

4C.17 **Safety (Clause 4.15).** The 10-yr depth (0.77 m) exceeds the 0.45 m limit for publicly accessible storage (Clause 4.15.1(a)), so the facility is not open to the public. It has vertical walls higher than 0.6 m and a depth of more than 1.2 m when the spillway flows, so a non-climbable fence at least 1.2 m high with a lockable gate is required (Clause 4.15.3). Signs and a depth marker are provided (Clause 4.15.5).

4C.18 **Summary of the design (Illustrative — not design values).**

**Table 4C.14 — Summary of the revised design (Illustrative — not design values)**

| Item | Value |
|---|---|
| Storage | 2,500 m² plan area; 2,913 m³ at the 1% AEP maximum level of 1.17 m |
| Stage 1 | 170 mm orifice at the floor, with trash rack and anti-vortex plate |
| Stage 2 | 460 mm orifice, invert 0.53 m |
| Spillway | Crest 1.35 m, length 4.0 m, maximum level 1.65 m |
| Top of walls | ≥ 1.95 m above the floor |
| 100-yr peak release | 343 L/s (cap 356 L/s) |
| 2-yr peak release | 34 L/s (cap 180 L/s) |
| 10-yr drawdown, 50% blocked | 45.3 h (limit 48 h) |
| Retention | RRV 552 m³ provided in addition; credit 7 m³ |
| Still to be checked | Outfall-closed check on an outfall to a jhora draining to the Umkhrah in Shillong (Annex 5C); downstream analysis (Chapter 5); groundwater and flotation (Clause 4.12); WQv (Chapter 8) |

## Form 4-1 — Site Runoff Control Report

Supports Clauses 4.3 to 4.17 of Chapter 4.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One form for each site. Where the site drains to more than one outfall, complete Sections E to J for each outfall (Clause 4.5.1.3). Tier B sites using Clause 4.14.2 attach Form 4-2 in place of Sections F and G; sites using the fixed-coefficient route attach Form 4-3 in place of Sections F and G (Clause 4.17).

### A. Site and route

**Table 4F.1 — Form 4-1: site and route**

| Field | Entry |
|---|---|
| A1. Project name and applicant | |
| A2. Location (village or ward, survey numbers, district) | |
| A3. Approving Authority and tier (Tier A / Tier B) | |
| A4. Site area, land disturbance and new or replaced impervious area (ha, ha, m²) (Clause 4.1.2) | |
| A5. Number of outfalls (Clause 4.5.1.3) | |
| A6. Sizing route: full method (Clause 4.6) / Tier B tables (Clause 4.14.2) / fixed-coefficient route (Clause 4.14.3) | |
| A7. Constrained redevelopment route used (Clause 4.5.6)? If yes, attach the Constraint Statement, the existing-condition model and the shortfall and fee computation | |

### B. Inputs (Clause 4.17, item 1)

**Table 4F.2 — Form 4-1: inputs**

| Field | Entry |
|---|---|
| B1. Design Rainfall Sheet reference (Form 2-1) | |
| B2. Hydrologic Calculation Summary reference (Form 3-1) | |
| B3. HSG of each sub-area and the tests that confirm it (Clause 4.6.2, step 1) | |
| B4. Pre-development condition and CN (Clause 4.5.1.2) | |
| B5. Post-development CN of each sub-area, and Tc pre and post | |
| B6. Routing method and software, with version; time step (Clauses 4.6.1, 4.6.2) | |

### C. Order of measures (Clause 4.3.1; Clause 4.17, item 2)

**Table 4F.3 — Form 4-1: order of measures**

| Step | What the design does | Why this step cannot do more |
|---|---|---|
| 1. Preserve | | |
| 2. Retain | | |

| Step | What the design does | Why this step cannot do more |
|---|---|---|
| 3. Detain | | |
| 4. Convey | | |

## D. Retention (Clause 4.4; Clause 4.17, items 3 and 4)

### Table 4F.4 — Form 4-1: retention

| Field | Entry |
|---|---|
| D1. Retention depth P_R (mm) and zone (Annex 2E) | |
| D2. Runoff depth Q_R (mm) by sub-area and RRV (m³) (Clause 4.4.2) | |
| D3. Retention practices and volume provided (m³) | |
| D4. Infiltration tests: number, locations and depths, measured rates (mm/h) (Clause 4.4.3(a)) | |
| D5. Design infiltration rate (mm/h), not more than half the measured rate (Clause 4.4.3(b)) | |
| D6. Seasonal high groundwater depth below the base of each practice (m), at least 1.0 m (Clause 4.4.3(c)) | |
| D7. Reuse demand calculation, where retention is by reuse (Clause 4.4.3) | |
| D8. Retention drawdown time (h), not more than 72 h (Clause 4.4.5) | |
| D9. Shortfall in RRV (m³), if any, treated as WQv (Clause 4.4.4.2) | |
| D10. Governing storage without and with retention, and the retention credit (m³) (Clause 4.4.6) | |
| D11. Preservation credit areas and covenant reference (Clause 4.4.7) | |

## E. Release criteria (Clause 4.5; Clause 4.17, item 5)

### Table 4F.5 — Form 4-1: release criteria

| Field | Entry |
|---|---|
| E1. Catchment class: standard (Clause 4.5.2) or flood-sensitive (Clause 4.5.3), with the Annex 4A map extract | |
| E2. Release caps by AEP (L/s), and the duration that sets each cap | |
| E3. Clause 4.5.5 used (50 mm orifice deemed to comply, or the short-duration 2-yr relief)? Report any 2-yr exceedance | |

## F. Results (Clause 4.6; Clause 4.17, item 6)

Complete one row for each duration, in the format of Table 4.2. Mark the governing case for storage, for each outlet stage and for the spillway (Clause 4.6.2, step 12).

### Table 4F.6 — Form 4-1: results by duration (L/s; m³)

| Duration (h) | 2-yr pre | 2-yr post, detained | 10-yr pre | 10-yr post, detained | 100-yr post, uncontrolled | 100-yr post, detained | 100-yr storage used |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |

| Duration (h) | 2-yr pre | 2-yr post, detained | 10-yr pre | 10-yr post, detained | 100-yr post, uncontrolled | 100-yr post, detained | 100-yr storage used |
|---|---|---|---|---|---|---|---|
| 3 | | | | | | | |
| 6 | | | | | | | |
| 12 | | | | | | | |
| 24 | | | | | | | |
| 48 | | | | | | | |
| 72 | | | | | | | |

## G. Facility, drawdown and outlet (Clauses 4.7, 4.8, 4.10; Clause 4.17, items 7 to 9)

### Table 4F.7 — Form 4-1: facility, drawdown and outlet

| Field | Entry |
|---|---|
| G1. Facility type (Clause 4.10) and storage provided ($m^3$) | |
| G2. Stage–storage and stage–discharge tables and plots; inflow and outflow hydrographs for the governing cases (attach) | |
| G3. 10-yr drawdown: time to release 90% of the maximum stored volume (h), with the low-flow orifice 50% blocked (Clauses 4.7.1, 4.8.3) | |
| G4. WQv release time (h), 24 to 48 h (Clause 4.7.2) | |
| G5. Tidal outfall: drawdown with the tidal tailwater, and any pumped drawdown (Clause 4.7.4) | |
| G6. Each outlet stage: type, size (mm), invert level (m) | |
| G7. Trash racks: clear bar spacing (mm) and open area ($m^2$) (Clause 4.8.3) | |
| G8. Anti-vortex devices (Clause 4.8.4); outlet barrel diameter and seepage control (Clause 4.8.5); isolation (Clause 4.8.6) | |
| G9. Proprietary devices: certified head–discharge curve and minimum clear opening (Clause 4.6.5.3) | |

## H. Spillway, freeboard and embankment (Clause 4.9; Clause 4.17, item 10)

### Table 4F.8 — Form 4-1: spillway and freeboard

| Field | Entry |
|---|---|
| H1. Hazard classification, with reasons (Clause 4.9.2) | |
| H2. 1% AEP peak inflow (L/s); 0.2% AEP peak inflow for high-hazard facilities (L/s) | |
| H3. 1% AEP maximum water level with the outlet working (m); spillway crest level (m) (Clause 4.9.3) | |
| H4. Spillway or overflow route: type, dimensions, maximum level with the outlet blocked (m) | |
| H5. Freeboard to the embankment crest or wall top (m), at least 0.3 m (Clause 4.9.1) | |
| H6. Spillway location and discharge path (Clause 4.9.4) | |
| H7. Embankment height (m); geotechnical report where more than 2 m (Clause 4.9.6) | |

## I. RWH accounting, groundwater and flotation (Clauses 4.11, 4.12; Clause 4.17, items 11 and 12)

**Table 4F.9 — Form 4-1: RWH, groundwater and flotation**

| Field | Entry |
|---|---|
| I1. RWH storage provided (m³), assumed full at the start of every storm (Clause 4.11.2) | |
| I2. Combined RWH and detention tanks: zone levels and the detention orifice level (Clause 4.11.3); attach tank sections | |
| I3. Design groundwater level and its basis (Clause 4.12.1) | |
| I4. Lined or unlined storage; volume below the design groundwater level not counted (Clause 4.12.2) | |
| I5. Flotation factor of safety, at least 1.2 (Clause 4.12.3) | |

## J. Downstream, tailwater, safety and maintenance (Clause 4.17, items 13 and 14)

**Table 4F.10 — Form 4-1: downstream, tailwater, safety and maintenance**

| Field | Entry |
|---|---|
| J1. Downstream and Tailwater Report (Form 5-1) or Simplified Downstream Statement (Form 5-2) reference | |
| J2. Tailwater used in routing, and flap gate where tailwater governs (Clause 4.6.6) | |
| J3. Public access, depths in the 10% and 1% AEP storms, slopes, fencing, grates, signs and depth markers (Clause 4.15) | |
| J4. Draft maintenance declaration reference (Chapter 10) | |

## K. Statement by the registered professional (Clause 10.6)

I state that this report has been prepared under Chapter 4 of the Meghalaya Stormwater Design Manual (Draft v1.0), that the results reported are reproduced by the models submitted, and that every departure from Chapter 4 is listed with its reason. The Professional Design Certificate (Form 10-3) is attached.

**Table 4F.11 — Form 4-1: statement by the registered professional**

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |
| Empanelment number, where Clause 10.6.1 requires it | |
| Organisation | |
| Signature | |
| Date | |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

## Form 4-2 — Tier B Site Sheet

Supports Clauses 4.4.6.3, 4.14.1 and 4.14.2 of Chapter 4.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* This sheet replaces items 6 and 7 of the Site Runoff Control Report (Form 4-1) for Tier B sites using Clause 4.14.2. It can be used only after Table 4.3 is published in Annex 4B; until then, Tier B sites use Clause 4.6 or, for sites of 1 ha or less, the fixed-coefficient route (Clauses 4.14.1 and 4.14.3).

### A. Eligibility (Clause 4.14.1)

**Table 4F.12 — Form 4-2: eligibility**

| Field | Entry |
|---|---|
| A1. Local body (Tier B) | |
| A2. Site area A (ha): 2 ha or less outside flood-sensitive catchments; 0.5 ha or less inside them | |
| A3. Catchment class: standard or flood-sensitive (Annex 4A) | |

### B. Table 4.3 values (Clause 4.14.2, step 1)

**Table 4F.13 — Form 4-2: values read from Table 4.3**

| Field | Entry |
|---|---|
| B1. Rainfall zone (Annex 2A) | |
| B2. Hydrologic soil group | |
| B3. Post-development imperviousness (%) | |
| B4. PSD 2-yr (L/s/ha) | |
| B5. PSD 100-yr (L/s/ha), for the catchment class | |
| B6. SSR (m³/ha), for the catchment class | |

### C. Storage and release (Clause 4.14.2, steps 2 and 3)

**Table 4F.14 — Form 4-2: storage and release**

| Line | Quantity | Computation | Value |
|---|---|---|---|
| C1 | RRV provided (m³) | Clause 4.4 | |
| C2 | C_R | Annex 4B; 0 until published | |
| C3 | V_credit (m³) | C2 × C1 (Clause 4.4.6.3) | |
| C4 | Required storage V (m³) | B6 × A − C3 | |
| C5 | Storage provided (m³) | From drawings | |
| C6 | Q_PSD,2 (L/s) | B4 × A | |

| Line | Quantity | Computation | Value |
|---|---|---|---|
| C7 | Q_PSD,100 (L/s) | B5 × A | |

## D. Outlet and other provisions (Clause 4.14.2, steps 4 and 5)

**Table 4F.15 — Form 4-2: outlet and other provisions**

| Field | Entry |
|---|---|
| D1. Low-flow orifice: diameter (mm) from the Annex 4B outlet table, head (m), at least 50 mm | |
| D2. Upper control: type, size and level | |
| D3. Spillway or overflow (Clause 4.9) | |
| D4. RWH accounting (Clause 4.11) | |
| D5. Safety provisions (Clause 4.15) | |

## E. Statement

I state that the values above are taken from Annex 4B for the site's zone, soil group, imperviousness and catchment class, and that the storage and outlets shown on the drawings match them.

**Table 4F.16 — Form 4-2: statement**

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |
| Signature | |
| Date | |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

## Form 4-3 — Fixed-coefficient Route Sheet (Clauses 4.14.3 to 4.14.7)

Supports Clauses 4.14.3 to 4.14.7 of Chapter 4.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* This sheet replaces items 6 and 7 of the Site Runoff Control Report (Form 4-1) for sites using the fixed-coefficient route. Complete it for each point where runoff leaves the site (Clause 4.14.4). Figure 4.3 shows the method.

### A. Eligibility (Clause 4.14.3)

**Table 4F.17 — Form 4-3: eligibility**

| Check | Yes / No |
|---|---|
| A1. Site area 1 ha or less | |
| A2. The design does not count tank or waterbody storage (Clause 4.14.3(a)) | |
| A3. No part of the site lies within a waterbody setback (Clause 4.14.3(b)) | |
| A4. The site does not drain to a tank cascade whose storage is counted in a downstream design (Clause 4.14.3(c)) | |

### B. Release caps (Clause 4.14.4)

**Table 4F.18 — Form 4-3: release caps**

| Line | Quantity | Source or computation | Value |
|---|---|---|---|
| B1 | Site area A (ha) | Survey | |
| B2 | Area of each hydrologic soil group (ha) | Clause 3.7 | |
| B3 | C_10 and C_2, area-weighted | Table 4.3A | |
| B4 | i_10 and i_2 (mm/h), 15-minute duration, with the climate factor | Form 2-1; Clause 2.8 | |
| B5 | Q_cap,10 (L/s) | 2.78 × C_10 × i_10 × A | |
| B6 | Q_cap,2 (L/s) | 2.78 × C_2 × i_2 × A | |
| B7 | Discharge of a 50 mm orifice at the corresponding stage (L/s), where a cap is smaller (Clause 4.5.5.1) | Orifice equation, Clause 4.6.5.2 | |

### C. Volumetric coefficient (Clause 4.14.5)

**Table 4F.19 — Form 4-3: volumetric coefficient C_v**

| Line | Quantity | Value |
|---|---|---|
| C1 | Composite C of Table 3.2 (upper half of each range) | |
| C2 | Cf of Table 3.3 for the 1% AEP | |
| C3 | C_v for durations below 12 h (C1 × C2) | |
| C4 | C_v for durations of 12 h or more, with C for every pervious surface not less than 0.50 | |

## D. Storage (Clause 4.14.5)

For each duration: inflow = 10 × $C_v$ × P(d) × A (m³); release = 1.8 × $Q_{cap}$ × d (m³); difference = inflow − release. $V_{100}$ and $V_2$ are the largest differences; V is the larger of the two.

**Table 4F.20 — Form 4-3: storage by duration**

| d (h) | $P_{100}(d)$ (mm) | 100-yr inflow (m³) | 1.8 × $Q_{cap,10}$ × d (m³) | 100-yr difference (m³) | $P_2(d)$ (mm) | 2-yr inflow (m³) | 1.8 × $Q_{cap,2}$ × d (m³) | 2-yr difference (m³) |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 6 | | | | | | | | |
| 12 | | | | | | | | |
| 24 | | | | | | | | |
| 48 | | | | | | | | |
| 72 | | | | | | | | |

**Table 4F.21 — Form 4-3: storage required and provided**

| Line | Quantity | Value |
|---|---|---|
| D1 | $V_{100}$ (m³) and governing duration | |
| D2 | $V_2$ (m³) and governing duration | |
| D3 | V = larger of D1 and D2 (m³) | |
| D4 | Storage provided (m³) | |

## E. Outlet, retention and other checks (Clauses 4.14.3, 4.14.6, 4.14.7)

**Table 4F.22 — Form 4-3: outlet, retention and other checks**

| Field | Entry |
|---|---|
| E1. Low-flow orifice: diameter (mm) and invert; discharge (L/s) with the storage holding $V_2$ full, not more than $Q_{cap,2}$ | |
| E2. Upper orifice or weir: size and level; total release (L/s) at the top of V, not more than $Q_{cap,10}$ | |
| E3. Retention volume of Clause 4.4 provided in addition to V (m³); no retention credit taken | |
| E4. Drawdown (Clause 4.7), trash racks (Clause 4.8), spillway (Clause 4.9): reference to Form 4-1 Sections G and H | |
| E5. Downstream and tailwater checks (Chapter 5) and water quality (Chapter 8): references | |

## F. Statement

I state that the site meets the eligibility conditions of Clause 4.14.3 and that the caps, storage and outlets above have been computed by Clauses 4.14.4 to 4.14.7.

**Table 4F.23 — Form 4-3: statement**

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |
| Signature | |
| Date | |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

ANNEXES TO CHAPTER 5

# Downstream and Tailwater Analysis

These annexes support Chapter 5. Annex 5C is a worked example of the outfall-closed check of Clause 5.10, for the illustrative facility of Annex 4C. Annexes 5A and 5B need tidal, surge, survey and river data that this draft does not yet contain; each lists what the chapter already sets, gives the intended layout and states the interim rule of Chapter 5 that applies until it is published. Forms 5-1 and 5-2 are the submittal forms required by Clause 5.14. They are draft forms and have no statutory status.

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## Annex 5A — Tidal datums (MSL, MHWS, HAT vs CD and Survey of India datum), surge allowances and 1% still-water levels by coastal segment

Supports Clauses 5.7, 5.9, 5.10, 5.11 and 5.12 of Chapter 5.

5A.1 Table 5A.1 shows how the values of this annex enter the design tailwater levels of Table 5.1. The sea-level allowance is set by Clause 5.7.4 and does not depend on this annex.

**Table 5A.1 — Use of the Annex 5A values in the design tailwater (Table 5.1)**

| Design case | Tailwater | Annex 5A values used | Chapter value |
|---|---|---|---|
| Minor-system design | MHWS + SLA | MHWS | SLA ≥ +0.3 m (Clause 5.7.4) |
| Major-system and storage design | HAT + surge + SLA | HAT; 10% AEP surge (Clause 5.7.3(a)) | SLA ≥ +0.3 m |
| Joint case (Clause 2.12(b)) | 1% AEP still-water level + SLA | 1% AEP still-water level (Clause 5.7.3(b)) | SLA ≥ +0.3 m |
| Datum conversion | Chart datum to project datum | Offset from chart datum to the Survey of India datum (Clause 5.7.2(b)) | — |

**Not prepared for Meghalaya.** Meghalaya has no coast, so no outfall in the State has a tidal tailwater, and this annex has no Meghalaya content (Clause 5.1.4). Its tables are kept, empty, so that the annex and table numbers match the other editions of this Manual. Rows F1 to F7 of Form 5-1 are entered as "not applicable", and the tailwater is derived under rows F8 to F10; for an outfall to the Umkhrah, the Umshyrpi or a jhora, row F10 records the model, the flood marks and the bed survey of Clause 5.8.5(a) or (c), and for an outfall to a MePGCL reservoir, the conversion of its levels from feet, where they are given in feet, of Clause 5.8.5(d).

**Table 5A.2 — Tidal datums, surge and still-water levels by coastal segment (layout)**

| Coastal segment | Reference port and tide-table edition | MSL (m CD) | MHWS (m CD) | HAT (m CD) | CD to Survey of India datum (m) | 10% AEP surge (m) | 1% AEP still-water level (m CD) | Wave set-up (m), open-sea outfalls | Sources |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

---

## Annex 5B — Major drains, riverine outfall reaches, and river mouths subject to sand-bar closure; map

Supports Clauses 5.2, 5.3, 5.8 and 5.13 of Chapter 5.

5B.1 Table 5B.1 lists the water bodies that Chapter 5 already names. It is not complete: the annex will add the extents of each reach, the other rivers, canals and mouths of the State, and a map.

**Table 5B.1 — Water bodies named in Chapter 5**

| Water body | Region | Listed as | Clause |
|---|---|---|---|
| Umkhrah (Wah Umkhrah) and Umshyrpi (Wah Umshyrpi) through Shillong, with their jhoras, to the Wah Roro and Umiam lake | Khasi Hills (Shillong) | Major drains and city streams; ungauged, no published flood level [TBC]; 1% AEP model with bulking and blockage and surveyed flood marks; valley floors of Polo, Pynthorbah, Nongmynsong, Forest Colony, Mawlai, Dhankheti and Nongrim Hills outfall-closed, lock not less than 24 hours; reaches divided between the Shillong Municipal Board and the KHADC; 32 outfalls carrying sewage (Clause 8.9) | 5.2, 5.8.1, 5.8.5 |
| Umngot at Dawki | Jaintia Hills (East Khasi Hills as listed by CWC) | Riverine outfall reach; design river level not below the transferred 73.47 m (Dawki, 28 May 2006) and the surveyed flood mark of June 2026 [TBC]; no warning or danger level; datum [TBC]; runs into Bangladesh | 5.8.1, 5.8.5 |
| Umnohryngkew at Therriaghat | Khasi Hills, foot of the escarpment | Riverine outfall reach; design river level not below the transferred 20.62 m (15 June 1995); datum [TBC] | 5.8.1, 5.8.5 |
| Myntdu at Jowai and at Kharkhana; the Myntdu–Leshka dam and its release reach to the Bangladesh border | Jaintia Hills | Riverine outfall reach and release reach; 47.0 m at Kharkhana (23 April 1995) far downstream of Jowai, so a modelled or surveyed level at Jowai [TBC]; two Stage-II sites with no level; reservoir tailwater 618.50 m (FRL and MWL 618.00 m + 0.5 m) [TBC]; release of 12,000 m³/s (spillway capacity) until MePGCL gives a recorded release [TBC] | 5.8.1, 5.8.3, 5.8.5 |
| Bugi at Dimapara and Dareng at Sibbari; the south Garo rivers at Baghmara and Dalu | Garo Hills (south) | Riverine outfall reaches; design river level not below the transferred 29.75 m (Dimapara, 27 July 2007) and 20.34 m (Sibbari, 12 August 2017) where the outfall is on those rivers; surveyed flood levels elsewhere, among them the floods of October 2024 at Dalu [TBC]; datum [TBC] | 5.8.1, 5.8.5 |
| Simsang at Williamnagar; Kynshi | Garo Hills; Khasi Hills (west) | Riverine outfall reaches; no CWC site; modelled or surveyed flood level required [TBC]; run into Bangladesh | 5.8.1, 5.8.5 |

| Water body | Region | Listed as | Clause |
|---|---|---|---|
| Kopili, Digaru, Kulsi and Krishnai (Dudhnai) where they leave the State | Eastern and northern fringes | Riverine outfall reaches; no site in Meghalaya; the Assam edition governs the plains reaches; the Kopili at Kampur (warning 59.5 m, danger 60.5 m, highest 61.79 m, 20 July 2004) and Dharamtul (warning 55.0 m, danger 56.0 m, highest 58.09 m, 21 July 2004) bound the model's downstream boundary only; Kopili project of NEEPCO, levels not obtained [TBC] | 5.8.1, 5.8.3, 5.8.5 |
| Jhoras and hill streams of the towns: the Umkhen and Wah Tamdong at Shillong; the Ganol and the Ringrey and Rongkhon streams at Tura; the Umlew at Nongpoh–Umling; the streams of Sohra, Mawsynram, Shella and Pynursla | Statewide | Jhoras and major drains; ungauged; 1% AEP study with bulking and blockage and flood marks; in ML-C and ML-C1 the site-specific study of the ML-Z3 rule with the 24- to 72-hour storms; outfall at least 0.5 m above the highest surveyed bed level; no outfall into a sinkhole, cave or mine pit | 5.2, 5.8.1, 5.8.5 |
| Umiam (Barapani) reservoir and its shore | Ri-Bhoi and Khasi Hills | Reservoir outfalls; no MePGCL guideline found; press level 3,220 ft (981.46 m), releases from 3,216.15 ft (980.28 m) in August 2024, crest EL 969.5 m, no datum (all as reported) [TBC]; not design levels: MePGCL's FRL, MWL and rating, or the higher of the surveyed shore line and the surveyed top of the closed spillway gates + 0.5 m; MePGCL's consent; the Waterbodies Guidelines' lake setback and regulated zone (Chapter 7) | 5.8.3, 5.8.5 |
| Kyrdemkulai (Stage III) and Nongkhyllem (Stage IV) reservoirs and their release reaches | Ri-Bhoi | Reservoir outfalls and release reaches; Stage III tailwater 681.23 m (MWL 2,235 ft; FRL 2,230 ft = 679.70 m), Stage IV 503.50 m (FRL and MWL 503.00 m + 0.5 m) [TBC]; releases of about 1,699 and 2,124 m³/s (spillway capacities) until MePGCL gives recorded releases [TBC] | 5.8.3, 5.8.5 |
| New Umtru reservoir and the Umtru to the Byrnihat bridge | Ri-Bhoi | Reservoir outfalls and release reach (9.80 km); tailwater 132.78 m (MWL; FRL 130.10 m) [TBC]; release of 3,820 m³/s (spillway capacity) until MePGCL gives a recorded release [TBC]; the Umtru runs into Assam below Byrnihat | 5.8.1, 5.8.3, 5.8.5 |
| Ward's Lake (Nan Polok), Thadlaskein (Pung Sajar Nangli) and other lakes and pungs | Statewide | Lake and pung outfalls; no level found [TBC]; spill level plus head; custodian [TBC]; debris, waste and sediment traps; no sewage; no sacred or community pung used as a detention pond | 5.8.5 |
| Jinjiram and Krishnai on the Garo foothill plains at Phulbari and Tikrikilla | Garo Hills (north-west plains) | Riverine outfall reaches under the backwater of the Brahmaputra (Assam edition); no CWC site in Meghalaya; modelled level and the flood marks of September 2012 and September 2014; lock not less than 72 hours | 5.8.1, 5.8.5 |
| Drains of the Municipal Boards, the Shillong Cantonment Board, NSTDA, Shillong Smart City Ltd, PWD (Roads), NHAI and NHIDCL 1.0 m wide or more; village drains and jhoras under the District Councils' rules | Meghalaya | Major drains; owner's consent (the Board's under s.204 of the Municipal Act within municipal limits), design water level and flap gate | 5.2, 5.8.5 |
| Umiam, Kyrdemkulai, Nongkhyllem, New Umtru and Myntdu–Leshka dams; the Kopili project | Umiam, Umtru, Myntdu, Kopili | Releases and gate operation to be included in river levels (release records and operating rules [TBC]); warnings by siren, telephone or SMS, not notices | 5.8.3, 5.8.5 |
| River mouths subject to sand-bar closure | None in Meghalaya | Not applicable (Clause 5.1.4) | 5.13.1 |

**To be prepared.** This annex will list and map (a) the major drains of each basin plan, (b) the riverine outfall reaches where backwater shall be modelled, with their upstream and downstream limits and the source of their design flood levels, and (c) the river mouths and creek inlets subject to seasonal sand-bar closure, with the most recent pre-monsoon bar crest levels and any Water Resources Department mouth-maintenance programme. It needs Water Resources Department river and canal records, design and recorded flood levels, reservoir operating rules, mouth-condition, dredging and bar-cutting records and pre-monsoon bar surveys (Water Resources Department), the drain inventories of SMB and other local bodies, basin stormwater master plans (Chapter 11), and base mapping from the Survey of India and NRSC. Until it is published: every river, Water Resources Department canal, the Umkhrah (Wah Umkhrah) and the Umshyrpi (Wah Umshyrpi) through Shillong and the Wah Roro that they form, the Umkhen and the Wah Tamdong, the Myntdu at Jowai, the Ganol and the Ringrey and Rongkhon streams at Tura, the Simsang at Williamnagar, the Umngot at Dawki, the Umtru below the New Umtru dam, the Jinjiram and the Krishnai on the Garo foothill plains, any drain built or held by a Municipal Board, the Shillong Cantonment Board, NSTDA, Shillong Smart City Ltd, PWD (Roads), NHAI or NHIDCL with an internal width of 1.0 m or more, and every jhora or other natural stream that drains 8 ha or more, whether or not the Waterbodies Guidelines treat it as a waterbody and every tidal creek is a major drain (Clause 5.2); the water bodies of Table 5B.1 are riverine outfall reaches (Clause 5.8.1); and the mouths of the coastal States' rivers (there is none in Meghalaya) are assumed closed at the start of the monsoon unless the Water Resources Department certifies otherwise (Clause 5.13.2).

Table 5B.2 — Attributes of the Annex 5B layers (layout)

| Field | Content | Unit or format |
|---|---|---|
| feature_id | Unique identifier | text |
| name | Name of the drain, river, canal, creek or mouth | text |
| category | Major drain; riverine outfall reach; mouth subject to sand-bar closure | text |
| clause | Clause of Chapter 5 under which it is listed | text |
| reach_limits | Upstream and downstream limits of the reach | text |
| design_flood_level_source | Water Resources Department design or highest recorded flood level, or hydraulic model (Clause 5.8.2) | text |
| reservoir_release | Upstream reservoir or tank and its operating rule, where any (Clause 5.8.3) | text |
| bar_crest_level | Most recent pre-monsoon bar crest level, for mouths | m (Survey of India datum) |
| mouth_programme | Water Resources Department mouth-maintenance programme and certification (Clause 5.13.2) | text |
| source | Source agency and date | text |
| geometry | Line (drains and reaches) or point (mouths) | line / point |

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## Annex 5C — Worked example: outfall-closed check for a site on a jhora draining to the Umkhrah in Shillong

Supports Clauses 5.9, 5.10, 5.11 and 5.12 of Chapter 5 and Clause 4.6.6 of Chapter 4.

**Illustrative — not design values.** This example applies the outfall-closed check of Clause 5.10 to the revised detention facility of Annex 4C. The site, its levels and its receiving drain are invented to show the method. No tidal level is used: the tide enters only through the illustrative statements in Table 5C.1 about whether the receiving drain is above or below the site outlet.

## Inputs

5C.1 The site is the 2.0 ha flood-sensitive site of Annex 4C. It discharges through its own outlet chamber and a flap gate to a public storm drain that joins a jhora running to the Umkhrah in Shillong, whose level rises when the jhora runs full and when the Umkhrah overflows onto its valley floor, as it does "with nearly every heavy downpour" at Polo and Pynthorbah (as reported), so Clause 5.10.1 applies to the facility. To show the method, this example uses the two 6-hour lock windows of Clause 5.10.3, as the coastal editions of this Manual do. In Meghalaya an outfall on the valley floors of the Umkhrah and Umshyrpi is closed for the design storm and the stream's recession, and for not less than 24 hours; an outfall to a jhora whose invert is below its design level is closed for as long as the computed level of the stream stays above it, or for the whole storm where no hydrograph of the stream has been computed; a river-locked outfall, an outfall to a release reach and an outfall on the Garo plains have a single lock of at least 72 hours; and an outfall below the design level of a reservoir, lake or pung is closed for the whole storm, under Clause 5.8.5. In each of those cases that lasts longer than the windows used here, the facility must store or pump the volume of the longer closure, up to the whole storm volume (Clause 5.9.4); that needs more storage, or pumping, than this example shows. The routing, the volume balance of Clause 5.10.4 and the assessment are the same. The public drain's own outfall to the jhora would also need the debris rack, the bulking factor and the solid-waste trap of Clause 6.3.6 and an invert above the range of bed movement of Clause 5.8.5(c); and on a slope in Shillong the facility itself would be a lined tank, not an infiltrating basin (Clause 4.11 (hill rule)).

**Table 5C.1 — Inputs (Illustrative — not design values)**

| Item | Value | Basis |
|---|---|---|
| Facility | Revised facility of Annex 4C: 2,500 m² plan area, vertical walls; 170 mm orifice at the floor; 460 mm orifice, invert 0.53 m | Annex 4C, Table 4C.14 |
| Storm | 1% AEP, 48 h, peak day last, AMC III; 72 h also run | Clause 5.10.2 |
| Inflow | Post-development 1% AEP hydrographs of Annex 4C (48 h: 8,420 m³; 72 h: 9,468 m³) | Annex 4C |
| Receiving drain levels at the connection, J1, J2 and J3 | Below the site outlet invert (from the drain owner's model) | Illustrative input |
| Receiving drain during each lock window | Backs up above the site outlet invert, so the site cannot discharge | Illustrative input; Clause 5.10.3(b) |
| Flap gate on the site outlet | Set 0.15 m below the orifice inverts in the outlet chamber, so that outside the lock windows its opening head and head loss do not affect the orifice control | Illustrative input; to be confirmed from the certified curve (Clause 5.11.2) |
| Lock windows | Two of 6 h each, starts 12.4 h apart (semi-diurnal tide) | Clause 5.10.3(a) |
| Pumps | None | — |

5C.2 **Cases of Table 5.2.** Because the receiving drain stays below the site outlet in J1, J2 and J3 (Table 5C.1), those cases give the free-outfall results of Annex 4C: in J2 the 1% AEP maximum water level is **1.17 m** (2,913 m³), and in J3 (10% AEP, 48 h) it is 0.77 m. R1 and R2 do not apply, because the site does not drain to a river. J4, the outfall-closed check, is worked below.

## Lock windows (Clause 5.10.3)

5C.3 The peak 1-hour block of the final 24 hours of the 48-hour storm is 35:35–36:35 h, with 98.2 mm (the 1-hour depth of Table 4C.2). Two runs are made:

- **Run A:** the first window is centred on that block: 33:05–39:05 h; the second starts 12.4 h later: 45:29–51:29 h.
- **Run B:** the first window starts at that block: 35:35–41:35 h; the second: 47:59–53:59 h.

For the 72-hour storm, every time is 24 h later.

5C.4 Gravity discharge is zero inside each window. Outside the windows the outlet discharges through the orifices of Table 4C.10. The routing is the same level-pool routing as in Annex 4C.

## Results

**Table 5C.2 — Outfall-closed check results (Illustrative — not design values)**

| Storm | Run | Lock windows (h:min) | Maximum stage (m) | Maximum storage (m³) | Time of maximum (h:min) | Largest release after a window (L/s) |
|---|---|---|---|---|---|---|
| 1% AEP, 48 h | A | 33:05–39:05; 45:29–51:29 | 2.01 | 5,019 | 39:05 | 566 |
| 1% AEP, 48 h | B | 35:35–41:35; 47:59–53:59 | **2.10** | **5,238** | 41:35 | 584 |
| 1% AEP, 72 h | A | 57:05–63:05; 69:29–75:29 | 2.00 | 5,012 | 63:05 | 565 |
| 1% AEP, 72 h | B | 59:35–65:35; 71:59–77:59 | 2.09 | 5,233 | 65:35 | 584 |

Run B of the 48-hour storm governs. The first window closes the outlet just as the storm peak arrives, so the whole peak is stored. The second window arrives when the facility has drained to about 0.7 m, below the Stage 2 orifice, and adds little.

5C.5 **Volume balance (Clause 5.10.4).** Table 5C.3 gives the balance for Run B. The outflow in each period is found by continuity: outflow = storage at start + inflow − storage at end.

**Table 5C.3 — Volume balance, 1% AEP 48-hour storm, Run B (Illustrative — not design values)**

| Period (h:min) | Inflow (m³) | Gravity outflow (m³) | Pumped (m³) | Storage at start (m³) | Storage at end (m³) |
|---|---|---|---|---|---|
| 0:00–35:35, before window 1 | 3,817 | 2,213 | 0 | 0 | 1,604 |
| 35:35–41:35, window 1 | 3,634 | 0 | 0 | 1,604 | 5,238 |
| 41:35–47:59, between windows | 941 | 4,423 | 0 | 5,238 | 1,756 |
| 47:59–53:59, window 2 | 28 | 0 | 0 | 1,756 | 1,784 |
| After 53:59 | 0 | 1,784 | 0 | 1,784 | 0 |
| Total | 8,420 | 8,420 | 0 | — | — |

Check for window 1: $V_{inflow}$ = 3,634 m³ ≤ $V_{storage\ available} + V_{pumped} + V_{gravity}$ = (5,238 − 1,604) + 0 + 0 = 3,634 m³. The facility therefore needs **5,238 m³** of storage, which the routing confirms.

**Table 5C.4 — Stage hydrograph, 1% AEP 48-hour storm, Run B (Illustrative — not design values)**

| Time (h) | Inflow (L/s) | Outlet | Outflow (L/s) | Stage (m) | Storage (m³) |
|---|---|---|---|---|---|
| 24 | 20 | Open | 18 | 0.18 | 445 |
| 28 | 39 | Open | 24 | 0.25 | 621 |
| 32 | 59 | Open | 32 | 0.36 | 906 |
| 34 | 85 | Open | 37 | 0.47 | 1,166 |
| 36 | 286 | Closed | 0 | 0.78 | 1,944 |
| 38 | 106 | Closed | 0 | 1.73 | 4,321 |
| 40 | 66 | Closed | 0 | 1.96 | 4,904 |
| 42 | 51 | Open | 529 | 1.79 | 4,472 |
| 44 | 42 | Open | 204 | 0.87 | 2,181 |
| 46 | 37 | Open | 49 | 0.74 | 1,854 |
| 48 | 33 | Open | 47 | 0.70 | 1,756 |
| 50 | 0 | Closed | 0 | 0.71 | 1,784 |
| 54 | 0 | Closed | 0 | 0.71 | 1,784 |
| 56 | 0 | Open | 43 | 0.58 | 1,459 |
| 60 | 0 | Open | 32 | 0.37 | 921 |
| 66 | 0 | Open | 16 | 0.16 | 397 |
| 72 | 0 | Open | 7 | 0.06 | 162 |

## Assessment

5C.6 **Clause 5.10.4(a).** The facility of Annex 4C reaches 1.17 m in J2, and its spillway crest is at 1.35 m (Annex 4C). In the outfall-closed check the stage reaches 2.10 m, so the spillway would operate. **The facility of Annex 4C fails the check.**

5C.7 **Remedy.** Pumping (Clause 5.12) does not help here: during the lock windows the receiving drain is itself closed, and pumping into it would raise its level, which Clause 5.12.3 does not permit. The remedy is more storage. Keeping the plan area of 2,500 m² and the outlets of Annex 4C:

- the facility must hold 5,238 m³, to a stage of **2.10 m**;
- the spillway crest is set above that stage, with the 0.15 m clearance recommended in Clause 4.9.3: **2.25 m**;
- with the 4.0 m spillway of Annex 4C (head 0.30 m), the maximum level with the spillway flowing is 2.55 m, and with 0.3 m freeboard the top of the walls is at least **2.85 m** above the floor.

The outfall-closed check therefore governs the storage: 5,238 m³ against 2,913 m³ from the release-rate checks, about 80% more. A larger plan area would make the facility shallower; the outlet, caps and drawdown would then have to be re-checked, because the stage–discharge relationship changes.

5C.8 **Release after the lock.** When the first window ends, the stored water is released under a head of about 2 m, at up to 584 L/s. This is above the 100-yr cap of 356 L/s. Clause 5.10.4 allows this, because the release reaches a drain that has itself just reopened, and requires it to be included in the J4 run of the downstream analysis (Clauses 5.4 and 5.9) and reported on Form 5-1, Section H.

5C.9 **Drawdown after the storm (Clause 5.10.5).** The J1 tidal curve stays below the site outlet (Table 5C.1), so the drawdown of Annex 4C applies: 45.3 h for 90% of the 10-yr storage with the low-flow orifice 50% blocked, within the 48-hour limit of Clause 4.7. In Run B, 90% of the maximum J4 storage is released 22.6 h after the maximum.

5C.10 **Other requirements.**

- The flap gate on the site outlet is inspected and operated before 31 March each year and after every event in which it closed against a storm flow (Clause 5.11.5).
- The deeper facility is checked for flotation with groundwater at the design groundwater level; in the alluvium of the Garo foothill plains and the Jinjiram valley, the valley fills of Ri-Bhoi, the river terraces and floodplains, and the pung, lake and reservoir margins without piezometer readings that level is existing ground level (Clauses 4.12.1 and 4.12.3).
- The fence and signs of Annex 4C apply to the deeper facility (Clause 4.15).

**Table 5C.5 — Summary (Illustrative — not design values)**

| Item | Value |
|---|---|
| Governing case | J4, 1% AEP 48-hour storm, Run B (first window starting at the peak 1-hour block) |
| Storage required | 5,238 m³ (Annex 4C release-rate design: 2,913 m³) |
| Maximum stage | 2.10 m, with 2,500 m² plan area |
| Spillway crest | 2.25 m |
| Top of walls | ≥ 2.85 m above the floor |
| Largest release after a lock window | 584 L/s, to be included in the downstream J4 run |
| Drawdown | Annex 4C result applies: 45.3 h with the low-flow orifice 50% blocked |

## Form 5-1 — Downstream and Tailwater Report

Supports Clauses 5.3 to 5.14 of Chapter 5.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One report for each project. Sites of less than 0.5 ha that meet Clause 5.3.4 may submit Form 5-2 instead, where the Authority accepts it. Attach the plans, model files and hydrographs referred to.

### A. Project

**Table 5F.1 — Form 5-1: project**

| Field | Entry |
|---|---|
| A1. Project name, applicant and location | |
| A2. Project type: site under Chapter 4; drainage project under Chapter 6; regional detention or tank restoration (Clause 5.1.2) | |
| A3. Site or project area (ha) and outfalls | |
| A4. Site Runoff Control Report reference (Form 4-1), where applicable | |

### B. Extent of the analysis (Clause 5.3; Clause 5.14, item 1)

**Table 5F.2 — Form 5-1: analysis points**

| Point | Location | Type (Clause 5.3.3 (a) to (e)) | Contributing catchment (ha) | Project area as % of it |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**Table 5F.3 — Form 5-1: end point**

| Field | Entry |
|---|---|
| B1. End point and reason: 10% point, tank or pung, or major drain or the sea (Clause 5.3.1 (a) to (c)) | |
| B2. Where the end point is a tank or pung: change in maximum water level (m) and in surplus-weir discharge ($m^3/s$); continuation below the weir if the level rises (Clause 5.3.2) | |
| B3. Plan of the analysis extent, showing the site, each point with its contributing area and percentage, and the end point (attach) | |

### C. Model (Clause 5.4.4; Clause 5.14, item 2)

**Table 5F.4 — Form 5-1: model**

| Field | Entry |
|---|---|
| C1. Software and version; hydrologic and hydraulic methods (Clause 5.4.4) | |
| C2. Network schematic, with the survey sources for drains and crossings (attach) | |
| C3. Land use and CN of off-site areas (present land use) | |

| Field | Entry |
|---|---|
| C4. Upstream detention included, with evidence that it is built, maintained and documented | |
| C5. Calibration or validation evidence, where available | |
| C6. Scenarios run: existing, with project, and future where the Authority requires it (Clause 5.4.1) | |
| C7. Storms run: AEPs and durations, AMC and areal reduction (Clause 5.4.3) | |

## D. Results at each analysis point (Clause 5.4.2; Clause 5.14, item 3)

Complete one row for each analysis point, AEP and duration. E = existing; P = with project.

**Table 5F.5 — Form 5-1: results by analysis point**

| Point | AEP | Duration (h) | Peak flow E / P ($m^3/s$) | Time to peak E / P (h) | Maximum water level E / P (m) | Peak velocity E / P (m/s) | Duration of inundation E / P (h) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## E. Acceptance (Clause 5.5; Clause 5.14, item 4)

**Table 5F.6 — Form 5-1: acceptance criteria**

| Criterion | Met at every point? | Where not met, the remedy adopted (Clause 5.5.3) |
|---|---|---|
| E1. 1% AEP water level rise ≤ 10 mm at buildings, lowest openings and carriageways (Clause 5.5.1(a)) | | |
| E2. No building newly flooded; no building or road newly failing the Chapter 6 limits (Clause 5.5.1(b)) | | |
| E3. Peak flow not above existing at the minor-system AEP of each element or at 1% AEP (Clause 5.5.1(c)) | | |
| E4. Velocity in lined channels within the lining limit, 3.0 m/s maximum (Clause 5.5.1(d)) | | |
| E5. Velocity in unlined channels, 50% and 10% AEP, not increased by more than 10% (Clause 5.5.1(e)) | | |
| E6. Change in duration of road closure on arterial or emergency routes (Clause 5.5.2) | | |
| E7. Timing exception requested (Clause 5.5.4)? Give the conditions met | | |

## F. Tailwater derivation (Clauses 5.6 to 5.8; Clause 5.14, item 5)

**Table 5F.7 — Form 5-1: tailwater derivation**

| Field | Entry |
|---|---|
| F1. Tide-table edition and port, or port authority source (Clause 5.7.2(a)) | |

| Field | Entry |
|---|---|
| F2. MHWS, HAT and MSL (m above chart datum) | |
| F3. Connection from chart datum to the Survey of India benchmark and the project datum: offset (m) and source (Clause 5.7.2(b)) | |
| F4. Estuary, creek or canal outfall: levels used and any evidence for a departure from open-coast levels (Clause 5.7.2(c)) | |
| F5. 10% AEP surge and 1% AEP still-water level: values, source, method and record length (Clause 5.7.3) | |
| F6. Wave set-up, for outfalls facing the open sea (Clause 5.7.3(d)) | |
| F7. SLA (m), at least +0.3 m; design life; sensitivity run at twice the SLA for design lives over 50 years (Clause 5.7.4) | |
| F8. Non-tidal tailwater: receiving-system level and source (Clauses 5.6.2, 5.6.3) | |
| F9. River levels and sources; reservoir or tank releases included (Clauses 5.8.2, 5.8.3) | |
| F10. City streams, gauged and border rivers, jhoras, reservoirs and release reaches, lakes and pungs, the Garo plains, and drains of other bodies: for the Umkhrah or Umshyrpi, the body that holds the reach (Shillong Municipal Board or KHADC), the 1% AEP model with the Shillong rainfall of Clause 2.3.6(c)(i), AMC, bulking and blockage, the channel as surveyed net of encroachment, waste and interception works, the surveyed flood marks and their sources, whether the outfall is on a valley floor (Polo, Pynthorbah, Nongmynsong, Forest Colony, Mawlai, Dhankheti, Nongrim Hills), and the lock (storm plus recession, not less than 24 hours); for a river, the operator of each gate and pumping station identified, gate sills, bank, wall or embankment crest, installed capacity, operating levels and gate-closing level obtained, with every level tied to the datum of the nearest CWC gauge or of the named gauge used; 1% AEP river level at the outfall from a model, with the dam releases, and not below the highest recorded level at the nearest CWC gauge transferred to the outfall (73.47 m at Dawki, with the surveyed flood mark of June 2026; 20.62 m at Therriaghat; 47.0 m at Kharkhana; 29.75 m at Dimapara; 20.34 m at Sibbari), with the profile or flood-mark survey used, or, where no gauge level exists (the Myntdu at Jowai, the Simsang, the Kynshi, the Ganol and other reaches), a modelled or surveyed flood level and its source; for a river leaving the State, the Assam-edition or Assam-site level used only as the model's downstream boundary; 10% AEP river level (no CWC danger level exists in the State: the design river level until a frequency analysis is accepted); drain behind the gate routed with its whole catchment and present storage, pumping confirmed available (permanent pumps only, not more than installed capacity less the largest pump), pumps operable at the design river level; single river lock of not less than 72 hours, or the duration of the largest release below a dam if longer, and its source; gate-failure and breach checks; for a jhora or hill stream, the 1% AEP study with the bulking, blockage and solid-waste rules of Clause 6.3.6 (in ML-C and ML-C1 the site-specific study of the ML-Z3 rule and the 24- to 72-hour storms), the surveyed flood marks and their sources, the bed survey and range of bed movement, the invert at least 0.5 m above the highest surveyed bed level, the scour depth of the foundation, and confirmation that no outfall discharges to a spring, a sinkhole, a cave or a mine pit; for a MePGCL reservoir, MePGCL's consent, MWL or FRL plus design-flood surcharge (FRL + 0.5 m where neither is published or the MWL equals the FRL: Myntdu–Leshka 618.50 m, New Umtru 132.78 m, Stage III 681.23 m, Stage IV 503.50 m), every level in feet converted at 1 ft = 0.3048 m with its datum stated, not below the highest recorded level, for the Umiam reservoir MePGCL's levels in writing or the higher of the surveyed shore line and the surveyed top of the closed spillway gates + 0.5 m, with the reported levels recorded, outfall below the tailwater treated as closed for the whole of the 72-hour storm, reservoir starting at FRL, no gate operation, drawdown, release notice or reservoir attenuation credited; for a release reach, the design storm and the 72-hour storm with the largest recorded release, or the spillway capacity until MePGCL gives one, placed before, during and after the storm; for Ward's Lake, Thadlaskein or another lake or pung, the custodian's consent (and the Municipal Board's or the landholding institution's), the surveyed spill level plus head, and the debris, waste and sediment traps before it; for the Garo plains, the model with the Brahmaputra boundary of the Assam edition, the flood marks of September 2012 and September 2014, and a lock of not less than 72 hours; Water Resources Department and MePGCL consent; owner's consent (s.204 of the Municipal Act within municipal limits; PWD, NHAI or NHIDCL; the Cantonment Board; NSTDA; the District Council and Dorbar Shnong), permitted rate, design water level or computed channel level, and flap gate; and the Waterbodies Guidelines' setback and regulated zone, any flood zone notified under the 2026 Act, the Bye-Laws' Highest Flood Level and the KHADC Regulation's s.15 duty checked (Clause 5.8.5) | |

## G. Joint cases (Clause 5.9; Clause 5.14, item 6)

### Table 5F.8 — Form 5-1: joint-case results

| Case | Rainfall | Tailwater used (m, project datum) | Applies? | Governing result (storage, level, pipe size or pump capacity) |
|---|---|---|---|---|
| J1 | | | | |
| J2 | | | | |

| Case | Rainfall | Tailwater used (m, project datum) | Applies? | Governing result (storage, level, pipe size or pump capacity) |
|---|---|---|---|---|
| J3 | | | | |
| J4 | | | | |
| R1 | | | | |
| R2 | | | | |

## H. Outfall-closed check (Clause 5.10; Clause 5.14, item 7)

### Table 5F.9 — Form 5-1: outfall-closed check

| Field | Entry |
|---|---|
| H1. Reason the check applies (Clause 5.10.1) | |
| H2. Storm: AEP, 48 h and 72 h, AMC III (Clause 5.10.2) | |
| H3. Lock duration and basis: default of two 6-hour windows, or site study (Clause 5.10.6); extension for sand-bar closure (Clause 5.13.5) | |
| H4. Lock windows of the two runs (start and end times) (Clause 5.10.3(d)) | |
| H5. Maximum stage in each facility, against its 1% AEP maximum water level (Clause 5.10.4(a)) | |
| H6. Maximum stage in the minor and major systems, against the Chapter 6 limits (Clause 5.10.4(b)) | |
| H7. Property connections: surcharge level, or non-return valves fitted (Clause 5.10.4(c)) | |
| H8. Stage hydrographs (attach) | |
| H9. Drawdown after the storm under the J1 tidal curve, and pumping where needed (Clause 5.10.5) | |

### Table 5F.10 — Form 5-1: volume balance for each lock window (Clause 5.10.4)

| Period | Inflow ($m^3$) | Gravity outflow ($m^3$) | Pumped ($m^3$) | Storage at start ($m^3$) | Storage at end ($m^3$) |
|---|---|---|---|---|---|
| Before window 1 | | | | | |
| Window 1 | | | | | |
| Between windows | | | | | |
| Window 2 | | | | | |
| After window 2 | | | | | |

## I. Gates and valves (Clause 5.11; Clause 5.14, item 8)

### Table 5F.11 — Form 5-1: schedule of flap gates, tide gates and non-return valves

| Location | Type | Size (mm) | Invert (m, project datum) | Certified head–discharge data (reference) | Stop-log or penstock (outfalls > 600 mm) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

## J. Pumped outfalls (Clause 5.12; Clause 5.14, item 9)

**Table 5F.12 — Form 5-1: pumped outfalls**

| Field | Entry |
|---|---|
| J1. Reason pumping is needed (Clause 5.12.1) | |
| J2. Duty capacity (m³/s) at the static head for the J2 tailwater; standby capacity (Clause 5.12.2) | |
| J3. Effect on the receiving water level (Clause 5.12.3) | |
| J4. Power supply: two independent supplies, or standby generation with 72 h of fuel; automatic changeover (Clause 5.12.4) | |
| J5. Level of electrical panels, controls, generators and fuel, against the higher of the 1% AEP flood level + 0.5 m and HAT + surge + SLA + 0.5 m (Clause 5.12.5) | |
| J6. Discharge arrangement (Clause 5.12.6); controls, alarms and logging (Clause 5.12.7); screens (Clause 5.12.8) | |

## K. Sand bar (Clause 5.13; Clause 5.14, item 10)

**Table 5F.13 — Form 5-1: sand-bar assumption**

| Field | Entry |
|---|---|
| K1. River mouth or creek inlet concerned | |
| K2. Mouth assumed closed, or open with Water Resources Department certification attached (Clause 5.13.2) | |
| K3. Bar crest level from the most recent pre-monsoon survey (m) and the closed-mouth tailwater (Clause 5.13.3) | |
| K4. Extension of the lock duration, where required (Clause 5.13.5) | |

## L. Inspection and maintenance (Clause 5.14, item 11)

**Table 5F.14 — Form 5-1: inspection and maintenance**

| Field | Entry |
|---|---|
| L1. Gate and valve inspection before 31 March and after closure events (Clause 5.11.5) | |
| L2. Pump test runs before 31 March (Clause 5.12.9) | |
| L3. Other requirements for the maintenance plan (Chapter 10) | |

## M. Statement by the registered professional (Clause 10.6)

I state that this report has been prepared under Chapter 5 of the Meghalaya Stormwater Design Manual (Draft v1.0), that the results reported are reproduced by the models submitted, and that every departure from Chapter 5 is listed with its reason. The Professional Design Certificate (Form 10-3) is attached.

**Table 5F.15 — Form 5-1: statement by the registered professional**

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |

| Field | Entry |
|---|---|
| Empanelment number, where Clause 10.6.1 requires it | |
| Organisation | |
| Signature | |
| Date | |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

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## Form 5-2 — Simplified Downstream Statement (small sites)

Supports Clause 5.3.4 of Chapter 5.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* For sites of less than 0.5 ha. The Authority may accept this statement in place of the full analysis only where every answer in Section B is "Yes". Otherwise submit Form 5-1.

### A. Site

**Table 5F.16 — Form 5-2: site**

| Field | Entry |
|---|---|
| A1. Project name, applicant and location | |
| A2. Site area (ha), less than 0.5 ha | |
| A3. Receiving public drain: name or reference, type and size | |
| A4. Site Runoff Control Report reference (Form 4-1) | |

### B. Conditions (Clause 5.3.4)

**Table 5F.17 — Form 5-2: conditions**

| Condition | Yes / No | Evidence |
|---|---|---|
| B1. The receiving public drain has documented capacity for its minor-system design flow (Chapter 6) | | |
| B2. No flood-prone location is recorded within 500 m downstream of the site outfall. Records checked: local body, SMB, MSDMA, Water Resources Department (Clause 5.3.3(d)) | | |
| B3. The site does not drain to a tidal or backwater-affected outfall | | |

### C. Route plan

**Table 5F.18 — Form 5-2: attachments**

| Attachment | Attached? |
|---|---|
| C1. Plan of the drainage route from the site outfall for 500 m downstream, with the receiving drain and any recorded flood-prone locations | |
| C2. Copy or reference of the drain capacity record | |

### D. Statement

I state that the site meets the conditions of Clause 5.3.4 as shown above, and that the records listed have been checked.

**Table 5F.19 — Form 5-2: statement**

| Field | Entry |
|---|---|
| Name | |
| Qualification and registration number | |
| Signature | |
| Date | |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

ANNEXES TO CHAPTER 6

# Minor and Major Drainage Systems

These annexes support Chapter 6. Annex 6A (standard inlets and their capacity curves) and Annex 6B (sediment yield) need test and survey data that are not yet available; each states what it will contain and the interim rule to use until it is published. Annex 6C gives standard drawings that carry only the dimensions Chapter 6 and Chapter 9 already set; every other dimension is marked "to be confirmed in design". Form 6-1 is a draft form: it lists what Clause 6.15 requires and does not add to it.

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## Annex 6A — Standard inlet types for Meghalaya with capacity curves (on grade and sag)

Supports Clauses 6.6.1 to 6.6.7 of Chapter 6 and Clause 9.11 of Chapter 9.

**To be prepared.** This annex will contain a short list of standard inlet types for Meghalaya streets (kerb-opening, grate and combination inlets, including the road-level wall opening into a covered drain) and, for each type, capacity curves on grade and in a sag. It needs a fixed set of standard inlet geometries agreed with the road-owning agencies, and rating tests of those geometries (laboratory or full-scale), or HEC-22 calculations for each geometry checked against tests (data and likely sources: Public Works Department (PWD), NHAI, NHIDCL and Shillong Municipal Board standard details, NIT Meghalaya, IIT Guwahati and NERIST, whose hydraulic testing capability was not confirmed during research [TBC], or other hydraulic laboratories, manufacturers' tested ratings). Until it is published, compute the clean capacity of the inlet actually proposed by the methods of FHWA HEC-22 (4th edition, 2024) or from the manufacturer's tested rating for that exact geometry (Clause 6.6.2), reduce it by the clogging factors of Table 6.5 (Clause 6.6.3), and meet the interim requirements of Table 6A.1.

**Table 6A.1 — Interim requirements for inlets until Annex 6A is published (from Chapters 6 and 9)**

| Item | Requirement | Clause |
|---|---|---|
| Inlet type on public streets | Kerb-opening or combination inlets, unless the Approving Authority accepts grate-only inlets for a location | 6.6.1(a) |
| Inlet level | Openings at road level; gutter depression where practicable | 6.6.1(b) |
| Clean capacity | FHWA HEC-22 (4th ed., 2024) or the manufacturer's tested rating for the exact geometry; CPHEEO §5.6.2 equations as a cross-check only | 6.6.2 |
| Clogging, on grade | Grate 50%; kerb opening 10% | 6.6.3, Table 6.5 |
| Clogging, in a sag | Grate 50%; kerb opening 20% | 6.6.3, Table 6.5 |
| Spacing | By sequential calculation from the top of each gutter run; not more than 30 m on kerbed roads | 6.6.4 |
| Kerb opening size | Clear height at least 100 mm; length at least 1.0 m | 9.11.4 |
| Grate pattern | Openings parallel to the direction of travel not wider than 25 mm | 9.11.3(a) |

| Item | Requirement | Clause |
|---|---|---|
| Load class | D400 in carriageways and medians; C250 within 0.5 m of the kerb; B125 in footpaths and cycle tracks (or the equivalent IS class) | 9.11.2 |
| Connection pipe | At least 300 mm diameter; gradient giving at least 0.9 m/s at the inlet's design flow | 6.6.6 |
| Silt sump | At least 300 mm deep below the outlet pipe invert, cleanable from the surface | 6.6.7, 9.11.6 |

The intended layout of the annex is given in Tables 6A.2 to 6A.4.

**Table 6A.2 — Register of standard inlet types (layout)**

| Type code | Description | Grate size or kerb opening (mm) | Gutter depression (mm) | Load class | Standard drawing |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ |

**Table 6A.3 — Capacity on grade (layout; one table per inlet type)**

| Cross slope Sx (m/m) | Longitudinal slope SL (m/m) | Gutter flow Q (L/s) | Spread T (m) | Clean intercepted flow (L/s) | Design intercepted flow after clogging (L/s) | Bypass flow (L/s) |
|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ |

**Table 6A.4 — Capacity in a sag (layout; one table per inlet type)**

| Ponded depth at the inlet (mm) | Clean capacity (L/s) | Clogging factor (Table 6.5) | Design capacity (L/s) | Flow regime (weir, orifice or transition) |
|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |

---

## Annex 6B — Sediment yield for silt-trap sizing and calibration of the sediment allowance

Supports Clauses 6.7.4, 6.7.8, 6.13.3 and 6.13.10 of Chapter 6.

**To be prepared.** This annex will contain sediment yields for urban drains in Meghalaya, by land use and drain type, for sizing the silt traps of Clause 6.13.3, and a calibration of the sediment allowance of Clause 6.7.8 against measured silt depths. It needs desilting records (volume or mass removed per drain length and per catchment area, with dates), silt-depth surveys before and after the monsoon season, and catchment land-use and soil data (data and likely sources: desilting records of Shillong Municipal Board and other urban local bodies, Water Resources Department records for channels, land cover from NRSC, soils from the Meghalaya soil survey and NBSS&LUP, rainfall from IMD). Until it is published, size each silt trap from the designer's stated estimate of the sediment expected between scheduled cleanings, based on the desilting records of the same drain or of similar drains in the same local body, and state the cleaning interval assumed; the interval shall not be longer than the yearly pre-monsoon desilting of Clause 6.13.10. Inlet silt sumps remain at least 300 mm deep (Clause 6.6.7), and the sediment allowance of Clause 6.7.8 applies unchanged.

The intended method is a simple volume balance, with every term to be stated in the design:

> $V_{trap} = Y \cdot A \cdot t_c$

where $V_{trap}$ is the sediment storage volume of the trap below its outlet invert ($m^3$), Y is the sediment yield for the catchment's land use and drain type ($m^3$/ha per year, from Table 6B.2 once published), A is the catchment area draining to the trap (ha), and $t_c$ is the scheduled cleaning interval (years). The annex will state whether a safety margin is added.

**Table 6B.1 — Sediment allowances already set by Chapter 6 (provisional, to be calibrated)**

| Element | Sediment allowance at the invert | Clause |
|---|---|---|
| Open and covered drains | Greater of 75 mm and 10% of the clear internal depth | 6.7.8(a) |
| Pipes of 600 mm diameter or more | 5% of the internal diameter | 6.7.8(b) |
| Pipes below 600 mm | No allowance; minimum velocity of Clause 6.7.3(a) applies | 6.7.8(c) |
| Drains and pipes that cannot reach the minimum velocity | Allowance doubled; mechanical desilting access provided | 6.7.4(b), (c) |
| Inlet silt sumps | At least 300 mm below the outlet pipe invert | 6.6.7 |

**Table 6B.2 — Sediment yield by land use and drain type (layout)**

| Land use or catchment type | Drain type | Sediment yield Y ($m^3$/ha per year) | Bulk density (t/$m^3$) | Local body and records used | Years of record |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ |

**Table 6B.3 — Calibration of the sediment allowance (layout)**

| Drain or pipe ID | Clear internal depth or diameter (mm) | Allowance under Clause 6.7.8 (mm) | Measured silt depth before pre-monsoon desilting (mm) | Measured silt depth at the end of the monsoon (mm) | Ratio of measured to allowance |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ |

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## Annex 6C — Standard drawings: covered roadside drain with removable covers, access chamber, inlet with silt sump

Supports Clauses 6.6, 6.7.6 to 6.7.10 and 6.13 of Chapter 6, and Clauses 9.11 and 9.12 of Chapter 9.

The drawings below are schematic standard drawings. They show only the dimensions that Chapter 6 and Chapter 9 set. Wall and slab thicknesses, reinforcement, concrete grade and cover, chamber plan sizes and frame details are to be confirmed in design: they come from the structural design (Clause 9.1.2) and the exposure class of Clause 9.13. Table 6C.1 lists the dimensions shown and their source clauses.

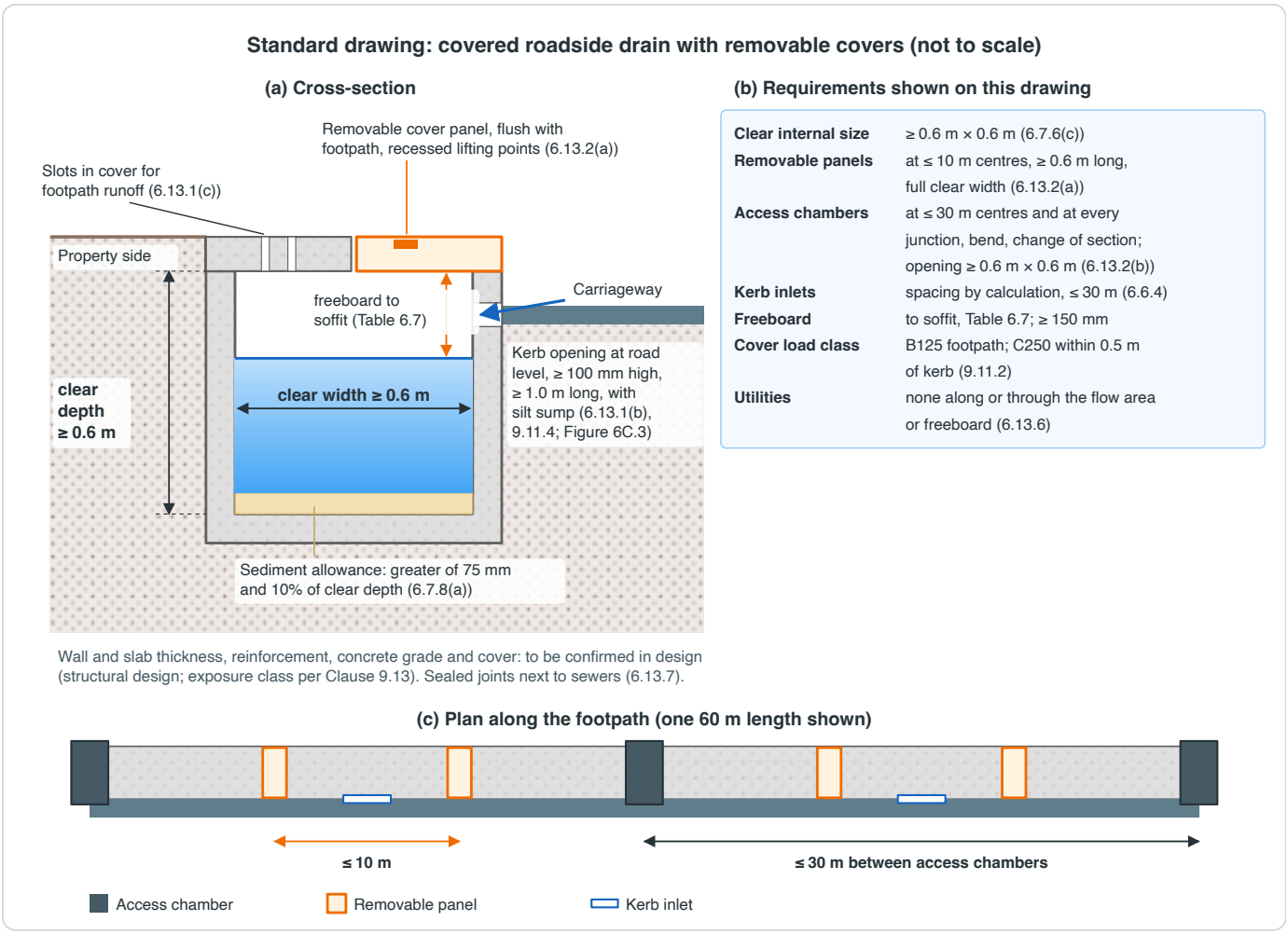


*Figure 6C.1 — Standard drawing: covered roadside drain with removable covers, kerb inlets at road level, footpath slots, freeboard to the soffit and sediment allowance, with a plan of cover panels and access chambers along the footpath. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Chapter 5, and IRC:SP:50-2013.*

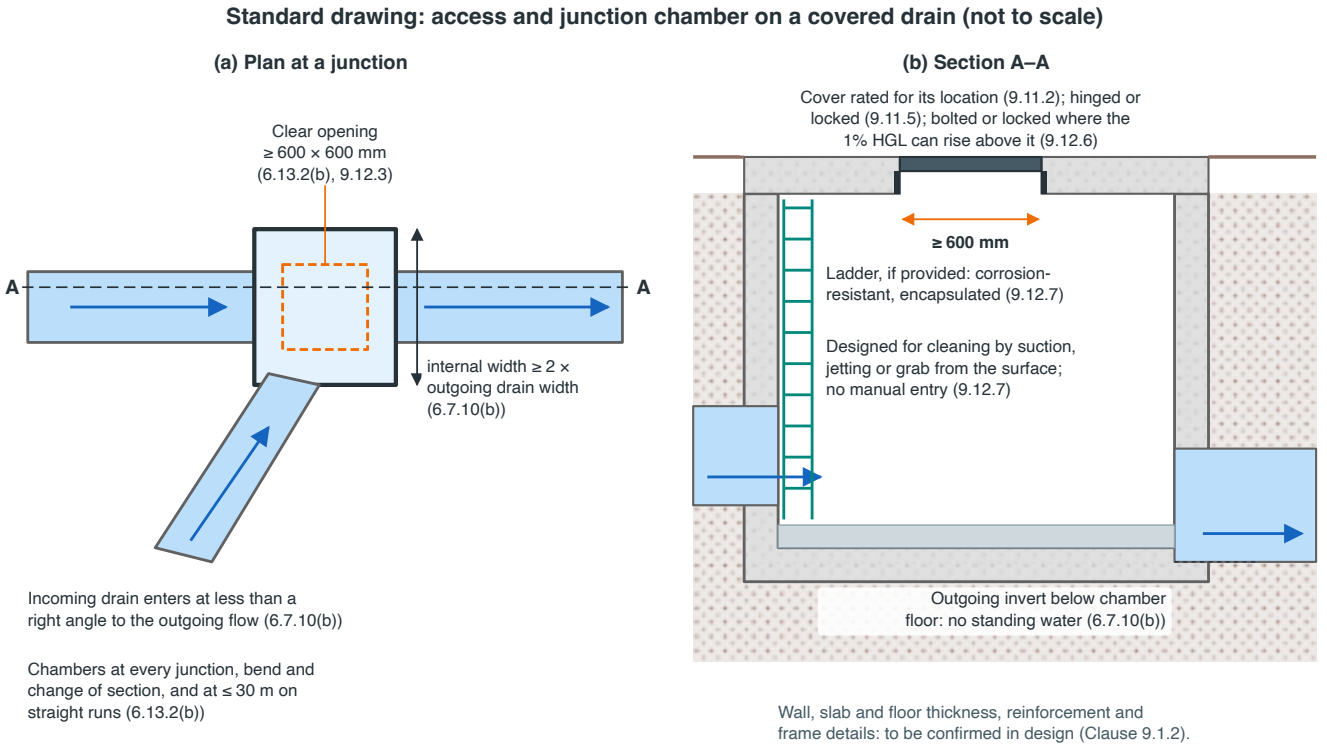


*Figure 6C.2 — Standard drawing: access and junction chamber on a covered drain, with the clear opening, junction width, entry angle of the incoming drain, outgoing invert below the chamber floor, and cover requirements. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), §5.3.4 and Chapter 11.*

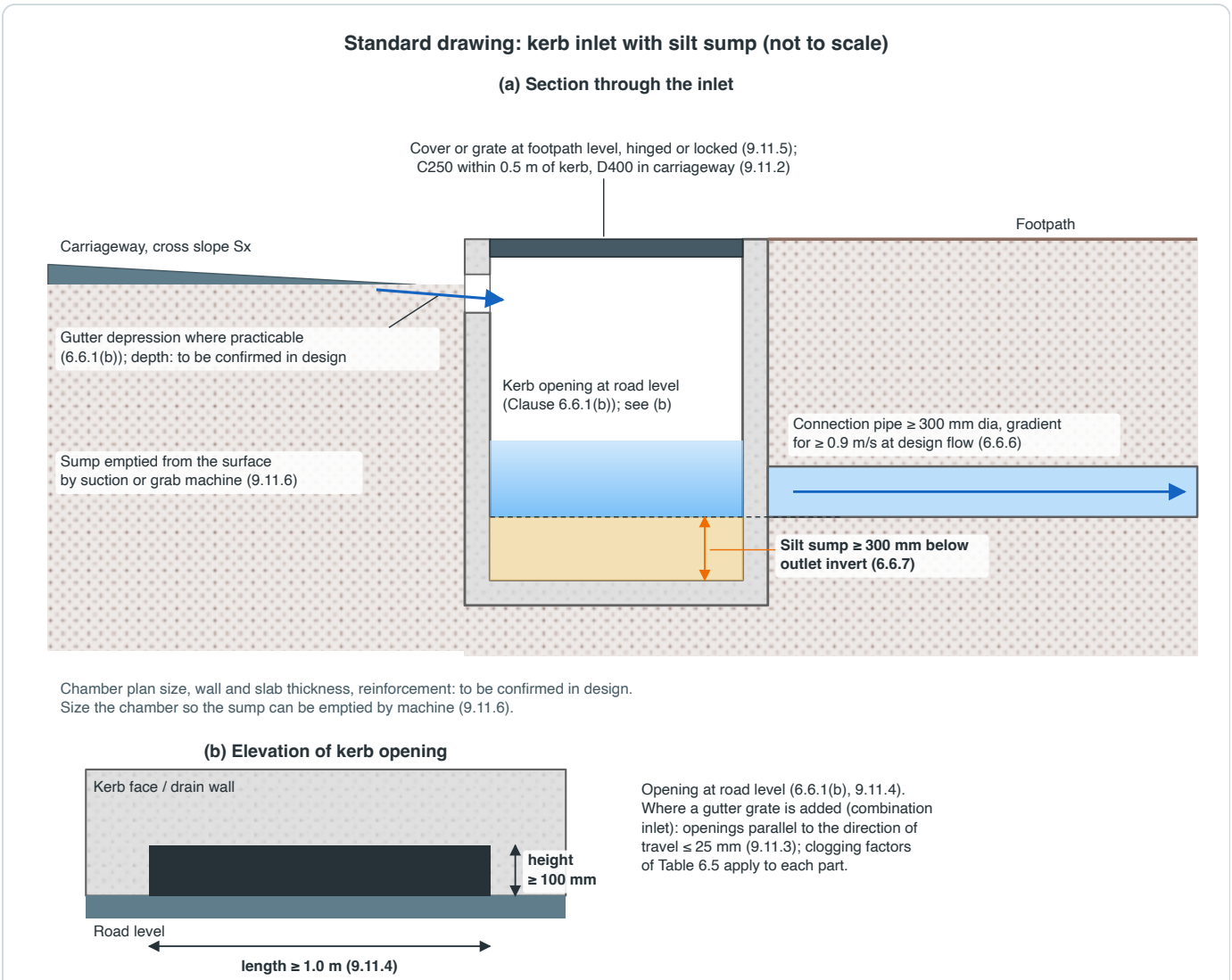


*Figure 6C.3 — Standard drawing: kerb inlet at road level with silt sump, connection pipe and cover, and an elevation of the kerb opening. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Figure 5.9, and FHWA, HEC-22 Urban Drainage Design Manual (4th ed., 2024).*

### Table 6C.1 — Dimensions on the standard drawings and their source clauses

| Drawing | Item | Dimension or rule | Clause |
|---|---|---|---|
| 6C.1 | Clear internal size of a covered public drain | At least 0.6 m wide and 0.6 m deep | 6.7.6(c) |
| 6C.1 | Freeboard to the cover soffit | Table 6.7; not less than 150 mm for any roadside drain | 6.7.9, 6.13.1(a) |
| 6C.1 | Sediment allowance | Greater of 75 mm and 10% of clear depth | 6.7.8(a) |
| 6C.1 | Removable cover panels | At not more than 10 m centres; each at least 0.6 m long and spanning the full clear width; recessed lifting points; flush with the footpath | 6.13.2(a) |
| 6C.1 | Footpath runoff | Through slots or grated openings in the cover | 6.13.1(c) |
| 6C.1 | Kerb inlets | Openings in the drain wall at road level, each with a silt sump; spacing by calculation, not more than 30 m | 6.13.1(b), 6.6.4 |
| 6C.1, 6C.2 | Access chambers | At every junction, bend and change of section, and at not more than 30 m centres on straight runs | 6.13.2(b) |

| Drawing | Item | Dimension or rule | Clause |
|---|---|---|---|
| 6C.2 | Clear access opening | At least 0.6 m × 0.6 m (600 mm) | 6.13.2(b), 9.12.3 |
| 6C.2 | Junction chamber | Internal width at least twice the outgoing drain width; incoming drains at less than a right angle; outgoing invert below the chamber floor | 6.7.10(b) |
| 6C.2 | Covers | Load class for the location; hinged or locked; bolted or locked where the 1% AEP HGL can rise above the cover | 9.11.2, 9.11.5, 9.12.6 |
| 6C.2 | Cleaning | By machine from the surface; ladders, where provided, corrosion-resistant and encapsulated | 9.12.7 |
| 6C.3 | Kerb opening | At road level; clear height at least 100 mm; length at least 1.0 m | 6.6.1(b), 9.11.4 |
| 6C.3 | Silt sump | At least 300 mm below the outlet pipe invert; emptied by suction or grab machine | 6.6.7, 9.11.6 |
| 6C.3 | Connection pipe | At least 300 mm diameter; at least 0.9 m/s at the design flow | 6.6.6 |
| 6C.3 | Grate in a combination inlet | Openings parallel to travel not wider than 25 mm; Table 6.5 clogging on each part | 9.11.3, 6.6.3 |
| All | Wall and slab thickness, reinforcement, concrete grade and cover, chamber plan size, gutter depression depth | To be confirmed in design | 9.1.2, 9.13 |

## Form 6-1 — Conveyance Design Report checklist

Supports Clause 6.15 of Chapter 6.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0. Not for statutory use.*

Attach this checklist to the front of the Conveyance Design Report. For each item, enter Yes, No or Not applicable, and the drawing or page where it is shown.

### Section A — Project

**Table 6F.1 — Form 6-1, Section A: project**

| Field | Entry |
|---|---|
| Project name and location | _____ |
| Local body, and Tier A or Tier B (Chapter 1) | _____ |
| Applicant | _____ |
| Designer (name and registration) | _____ |
| Total catchment area served (ha) | _____ |
| High-density area status for the 10% AEP minor system (Clause 6.4.4) | _____ |
| Within the coastal band of Clause 6.11.6 (Yes / No) | _____ |
| Date and revision | _____ |

### Section B — Contents required by Clause 6.15

**Table 6F.2 — Form 6-1, Section B: contents required by Clause 6.15**

| No. | Item | Clause | Provided (Yes / No / NA) | Drawing or page |
|---|---|---|---|---|
| 1 | Catchment plan: sub-catchments, minor system, inlet locations and the 1% AEP major-system overland flow paths | 6.3.2 | | |
| 2 | Land-use and road-class AEP adopted for each element, and the high-density area status | Table 6.1, 6.4.4 | | |
| 3 | Design flows, with the rainfall sheet of Chapter 2 and the method of Chapter 3 | 6.3.4 | | |
| 4 | Gutter spread, depth and D·V checks for the minor, check and 1% events | Tables 6.2, 6.3 | | |
| 5 | Inlet schedule: clean capacity, clogging factor, design capacity and bypass flow | 6.6 | | |
| 6 | Pipe and drain design tables: n, velocity, sediment allowance and freeboard | 6.7 | | |
| 7 | HGL profiles for the minor and check events, with the tailwater used | 6.8 | | |
| 8 | Sag ponding levels, including the fully-blocked check | 6.10 | | |
| 9 | Floor-level schedule for every building | 6.11 | | |
| 10 | Culvert and crossing calculations (with Form 9-1) | 6.12, Chapter 9 | | |

| No. | Item | Clause | Provided (Yes / No / NA) | Drawing or page |
|---|---|---|---|---|
| 11 | Utilities-crossing schedule and access-opening layout for covered drains | 6.13 | | |

### Section C — Design basis

### Table 6F.3 — Form 6-1, Section C: design basis

| Field | Entry | Clause |
|---|---|---|
| Minor-system design AEP adopted | _____ | Table 6.1 |
| Road class(es) and design / check AEPs for road drainage and crossings | _____ | Table 6.1, 6.4.2 |
| Rainfall source and climate factor applied | _____ | 6.3.4, Chapter 2 |
| Method: Rational Method (catchment ≤ 16 ha, single element) or hydrograph method with routing | _____ | 6.3.4(a), (b) |
| Minimum time of concentration used (not less than 10 min) | _____ | 6.3.4(c) |
| Tailwater at the outfall for the HGL (MHWS + 0.3 m at tidal outfalls, or the receiving level) | _____ | 6.8.2 |
| Any transfer of flow between natural catchments (none unless accepted under 6.3.5) | _____ | 6.3.5 |

### Section D — Compliance checks

### Table 6F.4 — Form 6-1, Section D: compliance checks

| No. | Check | Limit | Clause | Complies (Yes / No / NA) |
|---|---|---|---|---|
| D1 | Every inlet, sag, pipe, drain, culvert and storage element has a 1% AEP overland path | Shown on plan | 6.3.2 | |
| D2 | Major-system flow = 1% AEP peak less the clogged minor-system capacity | Computed at each point | 6.3.3 | |
| D3 | Spread in the minor event | Table 6.2 | 6.5.2 | |
| D4 | Depth in the check and 1% events | ≤ 150 mm at the crown; ≤ 350 mm at the deepest point | Table 6.2 | |
| D5 | Flow hazard (D·V) by location | Table 6.3 | 6.5.3 | |
| D6 | Inlet clogging factors applied | Table 6.5 | 6.6.3 | |
| D7 | Inlet spacing on kerbed roads | ≤ 30 m | 6.6.4(a) | |
| D8 | Sag inlet design capacity ≥ minor design flow arriving; flanking inlets where required | — | 6.6.5 | |
| D9 | Inlet connection pipes and silt sumps | ≥ 300 mm dia, ≥ 0.9 m/s; sump ≥ 300 mm | 6.6.6, 6.6.7 | |
| D10 | Manning's n not less than the minimum design values | Table 6.6 | 6.7.2 | |
| D11 | Minimum velocity at the minor design flow | 0.6 m/s drains; 0.9 m/s pipes | 6.7.3(a) | |
| D12 | Maximum velocity and Froude number | 3.0 m/s lined drains and pipes; Fr ≤ 0.8 | 6.7.3(b), (d) | |

| No. | Check | Limit | Clause | Complies (Yes / No / NA) |
|---|---|---|---|---|
| D13 | Where minimum velocity cannot be met: velocity reported, sediment allowance doubled, desilting access provided | — | 6.7.4 | |
| D14 | Pipes sized for pipe-full capacity, not the 0.95-depth peak | — | 6.7.5 | |
| D15 | Minimum sizes | Pipes 300 mm (450 mm public mains); open drain bed 0.3 m; covered public drains 0.6 m × 0.6 m | 6.7.6 | |
| D16 | Cover to pipes; flotation check where groundwater is within 1 m of the crown | ≥ 0.6 m; ≥ 0.9 m under carriageways | 6.7.7 | |
| D17 | Sediment allowance in capacity | 6.7.8 values | 6.7.8 | |
| D18 | Freeboard, including superelevation at bends | Table 6.7 | 6.7.9 | |
| D19 | Bend radii and junction sumps | 6.7.10 | 6.7.10 | |
| D20 | Manhole spacing on straight runs | Table 6.8 | 6.7.11 | |
| D21 | HGL below inlet rims and manhole covers in the minor event | ≥ 0.3 m | 6.8.3 | |
| D22 | Manholes that can surcharge above ground: bolted or locked covers | — | 6.8.4 | |
| D23 | Soffits matched or outgoing soffit lower; outgoing invert not above the lowest incoming invert | — | 6.8.6 | |
| D24 | Gate and valve losses included in the HGL; non-return valves on private connections where required | — | 6.8.7, 6.8.8 | |
| D25 | Overland flow paths outside streets: width, tenure, no obstruction, continuous fall | ≥ 1% top width + 0.5 m each side, ≥ 3.0 m | 6.9.2 | |
| D26 | Compound walls across mapped flow paths: openings pass the 1% flow at 50% blockage | — | 6.9.3 | |
| D27 | Access strip along open drains with top width ≥ 2 m | ≥ 3.5 m, linked to a road at ≤ 500 m | 6.9.4 | |
| D28 | Drainage reserve where required: width, separate plot, no structures, markers, services, 2 m stability check | Table 6.9 | 6.9.6–6.9.8 | |
| D29 | Sag ponding in the 1% event, overflow route, and fully-blocked check | ≤ 350 mm at the deepest point | 6.10.2, 6.10.3 | |
| D30 | Trapped sags and road underpasses | 6.10.4, 6.10.5 | 6.10.4, 6.10.5 | |
| D31 | Floor levels | ≥ 1% AEP level + 0.5 m; defaults of 6.11.3 where no level is computed | 6.11.1–6.11.3 | |
| D32 | Basements and building services | 6.11.4, 6.11.5 | 6.11.4, 6.11.5 | |
| D33 | Coastal band: floor ≥ 1% still-water level + 2 × SLA (+ wave set-up where applicable) + 0.5 m; no basement rooms or plant | — | 6.11.6 | |
| D34 | Culverts: design AEP, overtopping, 50% / 20% blockage check, minimum size | ≥ 900 mm | 6.12 | |

| No. | Check | Limit | Clause | Complies (Yes / No / NA) |
|---|---|---|---|---|
| D35 | Covered drains: removable panels and access chambers | ≤ 10 m; ≤ 30 m | 6.13.1, 6.13.2 | |
| D36 | Silt traps, screens with bypass and 50% blockage check | — | 6.13.3, 6.13.4 | |
| D37 | No building over drains; no utilities in the flow area or freeboard; existing crossings deducted with 50% blockage | — | 6.13.5, 6.13.6 | |
| D38 | No sewage connections; sealed joints next to sewers; edge protection on open drains deeper than 1.0 m | — | 6.13.7, 6.13.8 | |
| D39 | Outfalls: tailwater, flap gates or non-return valves below the 1% still-water level, outlet protection | — | 6.14 | |

### Section E — Variances

**Table 6F.5 — Form 6-1, Section E: variances**

| Clause | Requirement not met | Reason and proposed alternative | Approved by and date |
|---|---|---|---|
| _____ | _____ | _____ | _____ |

### Section F — Signatures

The report shall be prepared and signed by a registered professional, and the Professional Design Certificate (Form 10-3) attached (Clauses 10.6.1 and 10.6.3 of Chapter 10). Where a structure stands within 2 m of the edge of a drainage reserve, the stability design shall also be signed by a qualified structural engineer (Clause 6.9.8(f)).

**Table 6F.6 — Form 6-1, Section F: signatures**

| Role | Name | Registration or empanelment no. | Signature | Date |
|---|---|---|---|---|
| Designer | _____ | _____ | _____ | _____ |
| Structural engineer (Clause 6.9.8(f), where applicable) | _____ | _____ | _____ | _____ |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

ANNEXES TO CHAPTER 7

# Waterbodies, Pungs (Ponds and Lakes) and Setbacks

These annexes support Chapter 7. They give the inventory field specification, the fixed-width setback table, a template operating rule, the desilting and restoration specification, a glossary of Khasi, Pnar and Garo waterbody terms, and the three forms that Clause 7.15 requires. Where an annex cannot yet be completed it says so and gives the rule to use in the meantime. The forms are draft forms; the template and model text are for consideration by a competent authority and are not in force.

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## Annex 7A — Statewide waterbody GIS layer and inventory fields

Supports Clauses 7.3.1, 7.3.3 and 7.3.5 of Chapter 7.

**To be prepared.** This annex will contain the statewide GIS layer of waterbodies required by Clause 7.3.1, prepared by each Authority with the Water Resources Department and the Revenue and Disaster Management Department. It needs the Revenue records and maps of the Revenue and Disaster Management Department and the Deputy Commissioners, which are thin in the Sixth Schedule areas, because most land there is community, clan or private and is held, allotted and recorded by the District Councils, the Dorbar Shnongs and the clans rather than by the State's revenue staff (none of these records was read for this Manual [TBC]); the land records, permissions and conditions of the District Councils and their building authorities, such as the KHBSRA; the drains, public streams, springs and tanks that vest in each Municipal Board under section 62 of the Meghalaya Municipal Act, 1973; the land use, waterbody and flash-flood and landslide susceptibility maps of the Shillong Master Plan 2041 and of NESAC's risk-informed master plan report for the Shillong Planning Area (2023), and of the draft Tura master plan (2024); the "inclusion and exclusion lists of water bodies" that the Expert Committee under the Waterbodies Guidelines circulated to the Deputy Commissioners; the 225 water bodies ground-truthed for the High Court of Meghalaya in 2025 (as reported; the inventory of the Meghalaya State Wetlands Authority was not obtained [TBC]); MePGCL's records of reservoir levels and reservoir land; the spring inventories of MBDA (whose counts conflict, as reported); and each town's drain-and-jhora register (Chapter 6); the MePGCL and Dorbar Shnong or village council tank registers with FTL and MWL; surveyed levels on a common datum; the ISRO National Wetland Inventory and Assessment (NRSC); Survey of India topographic maps; and any list of waterbodies published under court directions. Until it is published, each Applicant identifies waterbodies from all the sources of Clause 7.3.3, with the larger extent governing, and records them on the Waterbody Sheet (Form 7-1).

The field specification below is complete. It is written so that every field the chapter asks for (Clause 7.3.1(a) to (g)) has a defined name, type and source, and so that the same fields can be filled from a project's Form 7-1.

### 7A.1 Layers

- **WB_POLY** — one polygon per waterbody: the Revenue record boundary (Clause 7.3.1(c)).
- **WB_FTL** — the surveyed FTL contour (tanks, lakes, ponds) or top of bank (channels), as a polygon or line.
- **WB_MWL** — the MWL contour of each tank, as a polygon.

- **WB_FLOOD** — the 1% AEP flood extent, where mapped (Clause 7.3.1(f)), with the floodway where delineated (Clause 7.6.1).
- **WB_STRUCT** — points for surplus weirs, sluices, regulators, inlets and drain outfalls.
- **WB_LINK** — lines for supply channels, surplus courses and the links between tanks in a cascade (Clause 7.3.1(e)).
- **WB_ENCR** — polygons of known encroachments, each with the date recorded (Clause 7.3.1(g)).
- **WB_SETBACK** — Zone 1 and Zone 2 polygons (Clause 7.4), derived from the layers above.

All layers shall carry the waterbody identifier (WB_ID) so that they can be joined. All levels shall be stated to one datum (Clause 7.3.5), named in the layer metadata.

**Table 7A.1 — Attribute fields of the waterbody inventory (WB_POLY)**

| Field | Type | Unit / domain | Required | Content | Clause |
|---|---|---|---|---|---|
| WB_ID | Text | District code + serial | Yes | Unique identifier, never reused | 7.3.1 |
| WB_NAME | Text | — | Yes | Name as in Revenue and MePGCL records, with local name | 7.3.1(a) |
| WB_NAME_LOC | Text | Khasi or Garo script | Yes | Name in Khasi or Garo | 7.3.1(a) |
| WB_TYPE | Code | Table 7A.2 | Yes | Waterbody type | 7.2, 7.3.1(a) |
| SURVEY_NOS | Text | Village, survey and subdivision numbers | Yes | Revenue survey numbers of the waterbody | 7.3.1(a) |
| VILLAGE | Text | — | Yes | Revenue village, C&RD block and district | 7.3.1(a) |
| CUSTODIAN | Code | Table 7A.2 | Yes | Custodian body | 7.3.1(b) |
| AREA_REC | Number | ha | Yes | Area within the Revenue record boundary | 7.3.1(c) |
| AREA_FTL | Number | ha | Tanks | Waterspread at FTL, surveyed | 7.2, 7.3.1(d) |
| FTL | Number | m (datum) | Tanks | Full tank level | 7.3.1(d) |
| MWL | Number | m (datum) | Tanks | Maximum water level (Clause 7.2 definition) | 7.3.1(d) |
| MWL_BASIS | Code | MePGCL record / 1% AEP computed | Tanks | Which value governs MWL | 7.2 |
| TBL | Number | m (datum) | Tanks | Top bund level, lowest point | 7.3.1(d) |
| WEIR_CREST | Number | m (datum) | Tanks | Surplus weir crest level | 7.3.1(d) |
| WEIR_LEN | Number | m | Tanks | Surplus weir crest length | 7.3.1(d) |
| WEIR_TYPE | Text | — | Tanks | Surplus weir type (for example fixed crest, with shutters or falling boards) | 7.3.1(d) |
| SLUICE_N | Integer | — | Tanks | Number of sluices; details in WB_STRUCT | 7.3.1(d) |
| SUPPLY_CH | Text | WB_ID(s) | Tanks | Supply channel(s) feeding the tank | 7.3.1(d) |
| SURPLUS_CS | Text | WB_ID(s) | Tanks | Surplus course(s) leaving the tank | 7.3.1(d) |
| UPSTR_WB | Text | WB_ID(s) | Cascades | Upstream tank(s) in the cascade | 7.3.1(e) |
| DNSTR_WB | Text | WB_ID | Cascades | Downstream tank, river, drain or sea outfall | 7.3.1(e) |
| CATCH_AREA | Number | ha | Channels | Drainage area at the downstream end of the reach (for the 8 ha trigger of Clause 7.4.1(b) and Table 7.1) | 7.4.1 |

| Field | Type | Unit / domain | Required | Content | Clause |
|---|---|---|---|---|---|
| DATUM | Text | — | Yes | Datum of all levels; conversion from any older MePGCL datum | 7.3.5 |
| LEVEL_DATE | Date | — | Tanks | Date of the level survey | 7.7.1(a) |
| SSC_DATE | Date | — | Tanks | Date of the latest stage–storage survey | 7.7.1(b) |
| FLOOD_SRC | Code | Adopted map / site study / none | Yes | Source of the 1% AEP extent | 7.3.4 |
| FLOODWAY | Code | Delineated / whole 1% extent / below MWL | Yes | Basis of the floodway | 7.6.1 |
| ENCR_KNOWN | Code | Yes / No | Yes | Known encroachment; details in WB_ENCR | 7.3.1(g) |
| CREDITED | Code | Yes / No | Tanks | Storage counted under Clause 7.7, with the scheme reference | 7.7.1 |
| WETLAND | Code | Notified / listed / other | Wetlands | Status under Clause 7.12.1 | 7.12.1 |
| SOURCES | Text | — | Yes | Sources used, from the list in Clause 7.3.3(a) to (e) | 7.3.3 |
| UPDATED | Date | — | Yes | Date of the last edit, and by whom | 7.3.1 |

### Table 7A.2 — Code lists

| Code list | Values | Clause |
|---|---|---|
| WB_TYPE | River or stream (wah, chibima, chiring); jhora (small hill stream; Guidelines waterbody or 240-day exclusion); drain (nur, muri, dooid); pung (pond, pool or small lake; natural, dug or sacred); lake or built tank (nan); reservoir or pondage (with its drawdown zone); spring (umpohliew) and its recharge area; source catchment (sacred grove, law kyntang, at a stream head); wetland, marsh or bog (chibol); supply channel; surplus course | 7.2 |
| CUSTODIAN | Municipal Board (Municipal Act, 1973, s.62); Shillong Cantonment Board; NSTDA [TBC]; PWD (Roads), NHAI or NHIDCL (road drains and culverts); Water Resources Department (rivers, flood works); MePGCL (reservoir and release reach); PHED (water-supply source or intake); Soil and Water Conservation Department; Forest and Environment Department (forest land; Waterbodies Guidelines); District Council with the Dorbar Shnong (or Garo village institution [TBC]); clan; private owner; developer (until handed over); Meghalaya State Wetlands Authority (wetland); other (name) | 7.3.1(b) |
| Structure (WB_STRUCT) | Surplus weir; sluice; regulator; inlet; drain outfall; gross pollutant trap; crossing | 7.3.1(d), 7.10 |
| Encroachment (WB_ENCR) | Building; fill; road; wall; dumping; cultivation; other — each with date recorded, area (m²) and source | 7.3.1(g), 7.13 |

### Table 7A.3 — Attribute fields of structures (WB_STRUCT)

| Field | Type | Unit | Content | Clause |
|---|---|---|---|---|
| STR_ID | Text | — | Unique identifier | 7.3.1(d) |
| WB_ID | Text | — | Waterbody served | 7.3.1(d) |
| STR_TYPE | Code | Table 7A.2 | Structure type | 7.3.1(d) |
| CREST_SILL | Number | m (datum) | Weir crest or sluice sill level | 7.7.1(a) |
| LENGTH_SIZE | Text | m | Weir crest length, or sluice opening size | 7.7.1(a) |
| GATED | Code | Yes / No | Controllable outlet (needed for a flood cushion, Clause 7.8.2(a)) | 7.8.2 |

| Field | Type | Unit | Content | Clause |
|---|---|---|---|---|
| CONDITION | Code | Serviceable / defective | Result of the latest pre-monsoon inspection, with date | 7.7.1(d), 7.14.4 |

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## Annex 7B — Fixed-width setback table (alternative S-3, with Annex 1C)

Supports Clauses 7.3.4, 7.4.3, 7.4.6 and 7.4.7 of Chapter 7, and alternative S-3 of the Policy Supplement (Annex 1C).

### 7B.1 When the table may be used

The fixed-width setback may be used only where all of the following apply:

- (a) the Authority has not adopted a 1% AEP flood extent map for the waterbody (Clause 7.3.4);
- (b) Clause 7.3.4 does not require the Applicant to determine the 1% AEP extent by a hydraulic study: the site is not in a flood-sensitive catchment, is not a site of 1 ha or more adjoining a waterbody, and the Authority has not asked for a study; and
- (c) the waterbody is one to which setbacks apply (Clause 7.4.1): any recorded or found waterbody, and any natural channel draining 8 ha or more at the site.

Where an Authority adopts alternative S-3 under Clause 1.7, the table below is the S-3 table. Clause 1.7.3(e) provides for the S-3 table to be issued by the State Stormwater Technical Committee. Until it is issued, the values are those of Clause 7.4.6, repeated here without change.

**Table 7B.1 — Fixed-width setback by waterbody class (alternative S-3)**

| Waterbody class | Drainage area at the site | Total setback (Zone 1 + Zone 2) | Of which Zone 1 | Measured from |
|---|---|---|---|---|
| Channel, small | 8 ha to 65 ha | 25 m | 15 m | Top of bank (Clause 7.4.3) |
| Channel, medium | 65 ha to 20 km² | 40 m | 15 m | Top of bank |
| Channel, large, and rivers | More than 20 km² | 50 m | 20 m | Top of bank |
| Tank, lake or pond | Any | MWL contour + 25 m | To the MWL contour, and not less than 15 m from FTL | FTL contour (Zone 1); MWL contour (total) |
| Marsh, estuary or backwater | Any | As notified by the Authority, and not less than 50 m | 15 m | The waterbody boundary of Clause 7.13.1 |

Values from Clause 7.4.6 (Table 7.1). Zone 2 is the total setback less Zone 1.

### 7B.2 Rules of application

- (a) **Measurement.** Measure horizontally on plan, outward from the boundary of Clause 7.13.1: the larger of the Revenue record boundary and the surveyed FTL (or top of bank). Where FTL and top of bank both apply, use whichever gives the wider zone (Clause 7.4.3).
- (b) **Drainage area.** For a channel, use the drainage area at the downstream end of the reach that adjoins the site. Where a reach crosses a class limit within the site, apply the wider setback to the whole reach within the site.
- (c) **Both banks.** The setback applies on each bank of a channel and all round a tank, lake, pond or marsh.
- (d) **Minimum set by this Manual.** Zone 1 is never less than 15 m (Clause 7.4.7). A wider statutory or approval setback governs for the uses it restricts (Clause 7.4.5).

- (e) **Stricter of the two.** Where a hydraulic study is made voluntarily, the setback is the wider of Table 7B.1 and Clauses 7.4.3 and 7.4.4.
- (f) **Record.** The basis of the setback (fixed width) shall be stated on the Waterbody Sheet (Form 7-1) and in the approval (Clause 7.4, Disclosure).
- (g) **Review.** The table shall be reviewed within 2 years of the Authority adopting 1% AEP flood maps (Clause 7.16.1).

### 7B.3 Source of the channel widths

The channel widths were set by this Manual with reference to the 2006 Kansas City APWA default stream buffers, rounded up and floored at the 15 m minimum (Clause 7.4.6, commentary). The source values, as cited in the chapter, are:

**Table 7B.2 — Source buffers cited in Clause 7.4.6 (KC APWA 5600, 2006, §5605.3)**

| Drainage area (source, acres) | Approximate SI equivalent | Source buffer |
|---|---|---|
| Less than 40 ac | Less than 16 ha | 40 ft (12 m) |
| 40–160 ac | 16–65 ha | 60 ft (18 m) |
| 160–5,000 ac | 65 ha – 20 km² | 100 ft (30 m) |
| More than 5,000 ac | More than 20 km² | 120 ft (37 m) |

The 65 ha and 20 km² class limits in Table 7B.1 are the SI equivalents of 160 ac and 5,000 ac. The 8 ha lower limit is the 20-acre trigger of APWA 2025.01 (Clause 7.4.1(b)).

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## Annex 7C — Template tank operating rule, with flood cushion

Supports Clauses 7.7.1(c), 7.7.3, 7.8 and 7.14.4 of Chapter 7.

*Model text for consideration by a competent authority. Not in force.* For tanks under MePGCL control, the operating rule is MePGCL's rule (Clause 7.8.4); this template sets out the content that Clause 7.8 asks for, so that the custodian's rule can be checked against it. Text in square brackets is to be completed for each tank.

### 7C.1 Identification

1. Tank: [name, WB_ID of Annex 7A, village, C&RD block, district].
2. Custodian: [MePGCL division / ULB / Dorbar Shnong or village council / other].
3. Cascade position: upstream tank(s) [ ]; downstream tank, river or drain [ ].
4. Datum: [ ]. Surveyed levels (Clause 7.7.1(a)), date of survey [ ]: FTL [ ] m; MWL [ ] m; TBL (lowest point) [ ] m; surplus weir crest [ ] m, length [ ] m; sluice sills [ ] m.
5. Stage–storage curve (Clause 7.7.1(b)): survey date [ ]; attached as Schedule 1.
6. Controllable outlets (Clause 7.8.2(a)): [gated sluice / regulator / none]; capacity at FTL [ ] m³/s.

### 7C.2 Purposes and priority

7. The tank serves [irrigation of a command area of [ ] ha / drinking water supply / recharge / flood storage]. Irrigation and water supply remain primary unless the custodian records otherwise (Clause 7.8.2(d)).

## 7C.3 Levels and dates through the year (Clause 7.8.1(a))

8. The tank shall be operated to the levels in Table 7C.1.

**Table 7C.1 — Rule levels by period (to be completed for each tank)**

| Period | Target level (m) | Upper limit (m) | Lower limit (m) | Purpose |
|---|---|---|---|---|
| [1 Jan – date] | [ ] | FTL | [ ] | Holding for irrigation / supply |
| [date – start of cushion period] | [ ] | FTL | [ ] | Holding |
| [Flood-cushion period, if any] | Cushion level [ ] | Cushion level [ ] | [ ] | Flood cushion (Clause 7.8.2) |
| [End of cushion period – 31 Dec] | [ ] | FTL | [ ] | Refilling |

9. Where no flood cushion is adopted, the starting level for design is FTL (Clause 7.7.3) and the row for the cushion period is deleted.

## 7C.4 Flood cushion (Clause 7.8.2)

10. Cushion level: [ ] m, which is [ ] m below FTL, giving a cushion volume of [ ] m³ from Schedule 1.
11. Dates: the cushion applies from [ ] to [ ].
12. Drawdown: the tank can be drawn down from FTL to the cushion level through [outlet] in [ ] hours, with a release not exceeding the maximum release rate of paragraph 18.
13. Reliability: continuous simulation (Clause 3.13) over the record [years] shows that the cushion is available at the start of a design storm in [ ]% of monsoon seasons, which shall be at least 90%. The simulation report is Schedule 2.
14. Yield: the custodian accepts the loss of irrigation or supply yield stated in Schedule 3 [and the compensation recorded there].
15. Where the tank has no controllable outlet, this section does not apply and no flood cushion is assumed (Clause 7.8.3).

## 7C.5 Releases (Clause 7.8.1(b) to (d))

16. Sluice and regulator settings at each level: Table 7C.2.
17. Operator: the sluices and regulators are operated by [post]. A release above [ ] m³/s may be ordered only by [post], or, in an emergency, by [post].
18. Maximum release rate: [ ] m³/s. This rate, added to the flow from the downstream catchment, does not flood buildings downstream (Schedule 4 gives the downstream check).
19. No person shall cut, lower or breach the bund or surplus weir except under the custodian's emergency procedure (Clause 7.14.5).

**Table 7C.2 — Outlet settings by level (to be completed for each tank)**

| Tank level (m) | Sluice 1 | Sluice 2 | Regulator | Expected outflow (m³/s) | Notes |
|---|---|---|---|---|---|
| Below cushion level | [ ] | [ ] | [ ] | [ ] | |
| Cushion level to FTL | [ ] | [ ] | [ ] | [ ] | |
| FTL (weir begins to spill) | [ ] | [ ] | [ ] | [ ] | |
| Above FTL to MWL | [ ] | [ ] | [ ] | [ ] | Check freeboard to TBL (Clause 7.7.4(b)) |

### 7C.6 Forecasts, warnings and communication (Clause 7.8.1(e) and (f))

20. The triggers and actions are in Table 7C.3.
21. Before any release under this rule, the operator shall inform the ULBs and the district administration downstream, and residents by the means stated in Schedule 5, at least [ ] hours before the release where the forecast allows.

**Table 7C.3 — Triggers and actions (to be completed for each tank)**

| Trigger | Source | Action | By whom |
|---|---|---|---|
| IMD district heavy-rainfall warning for the catchment | IMD | Read gauges [ ] hourly; check outlets are free; confirm the tank is at or below its rule level | [ ] |
| IMD or MSDMA red alert | IMD, MSDMA | Begin releases needed to reach the rule level, within the maximum release rate; notify downstream bodies (paragraph 21) | [ ] |
| City forecast system warning, where available | [ ] | [ ] | [ ] |
| Tank level reaches FTL | Gauge | Record outflow hourly; inspect bund and weir | [ ] |
| Tank level reaches [MWL − [ ] m] | Gauge | Emergency procedure; warning to the breach area of any emergency action plan (Clause 7.14.3(c)) | [ ] |

### 7C.7 Records and review (Clause 7.8.1(g))

22. During the monsoon (1 April to 31 October) the operator shall record daily: the tank level, every release (time, rate and duration), and every gate setting. Outside the monsoon, records shall be kept [weekly].
23. Records shall be kept with the O&M plan (Chapter 10) and given to the Authority on request.
24. The tank shall be inspected before the monsoon (by 31 March) and after every heavy-rainfall event (Clause 7.14.4).
25. This rule shall be reviewed after any event in which the tank surplused at a level above [ ] m, after any change to the weir, sluices or bund (Clause 7.7.6), and in any case with the review of the Manual.

Schedules: 1 stage–storage curve; 2 continuous simulation report; 3 yield and compensation; 4 downstream check of the maximum release; 5 communication list.

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## Annex 7D — Desilting and restoration specification

Supports Clauses 7.7.1(b), 7.9 and 7.14.4 of Chapter 7.

This specification applies to every desilting, restoration or deepening of a tank, pond or other waterbody under Clause 7.9. Values are those of Chapter 7. Where the chapter does not set a value, it is marked "to be confirmed in design" and shall be stated in the works design.

### 7D.1 Pre-works survey (Clause 7.9.1)

- (a) **Topographic and bathymetric survey** of the waterspread, foreshore (to the MWL contour), bund, surplus weir and sluices, levelled to the datum of Clause 7.3.5. Survey grid and point density: to be confirmed in design.
- (b) **Original bed level** found by test pits or augering on a grid (grid spacing to be confirmed in design), and from historical records where available. Each pit log shall show the silt thickness, the level of the original bed, and any clay or silt layer below it.

- (c) **Silt testing** where the tank receives urban runoff or sewage: samples from the pits of (b), tested for heavy metals and other contaminants before disposal is planned. The parameters and limits shall be those the Meghalaya State Pollution Control Board (MSPCB) directs.
- (d) **Structures:** condition of the bund (seepage, slips, cracks, animal burrows, trees), surplus weir and sluices, as in Clause 7.14.4.
- (e) **Existing stage–storage curve** from the survey of (a).

## 7D.2 Limits of excavation (Clauses 7.9.2 and 7.9.3)

- (a) Desilting removes accumulated sediment down to the original bed level of 7D.1(b), and no deeper.
- (b) Deepening below the original bed only with a hydrogeological report showing each of Clause 7.9.3(a) to (c).
- (c) Storage created below the lowest sluice sill is not flood storage, and shall not be shown as such in the revised stage–storage curve.
- (d) Excavation shall stay clear of the bund toe by a distance to be confirmed in design, so that the bund's stability is not reduced.

## 7D.3 Edges and safety (Clause 7.9.4)

Where the public has access to the edge:

- (a) side slopes no steeper than **1V:4H** from **0.5 m above FTL** down to **1.2 m below FTL**; or
- (b) a level safety bench at least **3 m** wide, between **0.3 m and 0.5 m below FTL**; and
- (c) no isolated deep pit or vertical cut left in the bed. Borrow pits shall be regraded to the bed.

## 7D.4 Storage not reduced (Clause 7.9.5)

- (a) Islands, walkways, bund widening into the waterspread, ring roads, parking, buildings and lake-front platforms within the waterspread or foreshore are lost storage.
- (b) Lost storage shall be offset by compensatory storage at equivalent levels, band by band, using Form 7-3.

## 7D.5 Silt handling and disposal (Clause 7.9.6)

- (a) Desilted material shall not be placed within the setback, on the bund (except approved bund strengthening), or on any flood path.
- (b) Contaminated silt shall be disposed of as the Meghalaya State Pollution Control Board (MSPCB) directs.
- (c) Haul routes and temporary stockpiles shall meet the construction erosion and sediment control rules of Clause 8.12, including stockpiles outside Zone 1.

## 7D.6 Inlets (Clause 7.9.7)

Every inlet that brings urban runoff shall have a sediment forebay, a constructed wetland inlet zone or a gross pollutant trap, designed under Chapter 8 (Annex 8D).

## 7D.7 Timing (Clause 7.9.8)

Desilting shall be complete, and the waterbody made safe, by **31 March**. No excavation shall be left open, and no sluice or weir left dismantled, during the monsoon.

### 7D.8 Completion records

- (a) As-built survey and revised stage–storage curve. The curve is the one that Clause 7.7.1(b) requires "after the last desilting".
- (b) Volume removed, its disposal site, and the silt test results.
- (c) Photographs of the bund, weir, sluices and inlet works.
- (d) Update of the inventory record (Annex 7A: SSC_DATE, LEVEL_DATE, CONDITION).

**Table 7D.1 — Hold points for desilting and restoration works**

| Hold point | Check | Clause |
|---|---|---|
| 1. Before excavation | Pre-works survey, pit logs, silt tests, and hydrogeological report if deepening | 7.9.1, 7.9.3 |
| 2. Original bed reached | Levels checked against pit logs; no excavation below the original bed unless approved | 7.9.2 |
| 3. Edges formed | Side slopes or safety bench as 7D.3 | 7.9.4 |
| 4. Inlet works | Forebay, wetland inlet zone or GPT built | 7.9.7 |
| 5. Completion (by 31 March) | As-built survey, stage–storage curve, silt disposal record | 7.9.8, 7.7.1(b) |

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## Annex 7E — Glossary of Khasi, Pnar and Garo waterbody terms and regional variants

Supports Clause 7.2 and Clause 7.3 of Chapter 7.

The terms below are Khasi, Pnar and Garo words for waterbodies, springs, channels and land in Meghalaya. All three languages are written in the Roman script, and many of the words appear in the names of rivers, lakes and places (Umiam, Wah Umkhrah, Pung Sajar Nangli, Nan Polok). The name used in the Revenue, District Council, municipal or MePGCL record for each waterbody, and the name the Dorbar Shnong or clan uses, should be recorded in the inventory (Annex 7A) alongside the Manual's term. A meaning is given below only where it was found in one of five dictionaries, read as Internet Archive copies of their scanned text: U Nissor Singh, *Khasi-English Dictionary* (1906); U Nissor Singh, *English-Khasi Dictionary* (1920), cited by headword only; Sajeki Passah, *Pnar–English Dictionary* (2013); D. S. Nengminza, *The School Dictionary Garo to English* (7th ed., 1978); and the American Baptist Garo Mission's *English-Garo Dictionary* (1905). **Two cautions apply.** The page numbers given for Singh (1906) are estimated from the page numbers nearest each entry in the scanned text, shown as "≈ p.", and are to be checked on the page images before this annex is relied on; and some headwords were misread in the scan (for example "Urn" for *um* and "TJmpohliew" for *umpohliew*), and are given here as the dictionary prints them. Meanings are the dictionaries' English glosses, and modern usage may be narrower or wider. Every term whose meaning or use was not confirmed in a dictionary is in Table 7E.4. The list is to be extended by the State Stormwater Technical Committee, with modern Revenue, District Council and municipal usage.

The Manual's term for a pond, pool or small lake in Meghalaya is **pung**, written on first use as "**pung (Khasi and Pnar: pond, pool or small lake; Garo: *pokri*)**". It is attested as "a pool" in Singh (1906) and is the first equivalent of both "Pond" and "Pool" in his English-Khasi dictionary (1920); it is used in Pnar place names as well as Khasi ones (Thadlaskein is also called *Pung* Sajar Nangli, as reported); and the alternatives are narrower: *nan* is "a tank", a built one, in Khasi, though "a fairly small body of still water" in Pnar, and Garo *chibol* includes bog and marsh. Because Singh (1906) also gives *pung* as "a joint", the word is always used of water in this Manual. Khasi and Pnar mark the plural with the article *ki*, not with an ending, so the English plural **pungs** is a convention of this Manual. Garo *pokri* (pond, tank, pool) is not the same word as Khasi *pukri*, which Singh (1906) gives as "a well": the two are false friends, and *pukri* is never used in this Manual for a pond. An engineered detention basin is not called a pung, and never a sacred or community pung: it is a detention pond. Natural, sacred and community waters keep their own names.

**Table 7E.1 — Waterbodies**

| Term | Language | Meaning (source) | Manual term (Clause 7.2) |
|---|---|---|---|
| pung | Khasi | "Pung, ka, n. a pool; a joint" (Singh, 1906, ≈ p. 164–165); "Pond … Ka pung"; "Pool … Ka pung; ka jinglang-um"; "Lakelet … i pung rit" (Singh, 1920) | Pung (pond, pool or small lake), see the definitions after Clause 7.2 |
| pung | Pnar | Used in place names, as *Pung* Sajar Nangli for Thadlaskein (as reported) | Pung |
| nan | Khasi | "Nan, ka, n. a tank" (Singh, 1906, ≈ p. 139–142); "Tank … Ka bir; nan; pipa; ka nan" (Singh, 1920) | A built tank or small lake; in names, as Nan Polok for Ward's Lake (as reported); a pung for this chapter |
| nan | Pnar | "nan [noun] a fairly small body of still water" (Passah, 2013) | A pung for this chapter |
| pokri | Garo | "Pokri (pok-kri), n. A pond; a tank; a pool" (Nengminza, 1978); "Tank … Pokri"; "Pond … Pokri, chibol" (English-Garo, 1905) | The Garo equivalent of pung |
| chibol | Garo | "Pond; bog; marshyland; swamp; fen; moor; morass; marsh" (Nengminza, 1978) | A pung, or a marsh under Clause 7.12 where it is one; always glossed |
| pukri | Khasi | "Pukri, ka, n. a well" (Singh, 1906, ≈ p. 164) | Not used for a pond (false friend of Garo *pokri*) |

### Table 7E.2 — Water, springs, streams and channels

| Term | Language | Meaning (source) | Manual term (Clause 7.2) |
|---|---|---|---|
| um | Khasi | "Um [printed 'Urn'], ka, n. water, juice" (Singh, 1906, ≈ pp. 241–243); compounds such as "Um-bah … having much water in a stream or river; — v. to overflow" | The prefix of river names (Umiam, Umkhrah, Umshyrpi, Umngot); not a defined term |
| um | Pnar | "um [noun] water"; "um changiar … a watery body that flows continuously" (Passah, 2013) | As Khasi |
| chi | Garo | "Chi, n. Water; liquid" (Nengminza, 1978); "Water … Chi" (English-Garo, 1905) | The prefix of Garo names; not a defined term |
| umpohliew | Khasi | "Umpohliew [printed 'TJmpohliew'], ka, n. a spring, a fountain" (Singh, 1906, ≈ p. 242); "Spring … ka um-poh-liew; ka jingmih ka um" (Singh, 1920) | Spring (umpohliew), see the definitions after Clause 7.2 |
| shyng-iar | Khasi | "a jet of water, a stream of water, a fountain" (Singh, 1906) | Local only; a spring or stream for this chapter |
| wah | Khasi | "Wah, ka, n. a stream, a river" (Singh, 1906, ≈ p. 244), with "Wah-bah, ka, n. a large river" and "Wah-duit, ka, n. a rivulet, a streamlet" on the same page | Stream (wah); in names, as Wah Umkhrah and Wah Roro |
| wah | Pnar | "wah [noun] a low lying area; a river" (Passah, 2013) | Stream (wah) |
| chibima | Garo | "River" (Nengminza, 1978; English-Garo, 1905) | River or stream |
| chiring | Garo | "Brook … Chiring"; "Stream … Chibima … chiring" (English-Garo, 1905) | Stream or brook; a jhora where it is a small hill stream |
| chirama, chirma | Garo | "The river-course; channel"; "Watercourse" (Nengminza, 1978) | Watercourse; a natural channel under Clause 7.4.1(b) |
| nur | Khasi | "Nur, ka, n. a channel, a ditch, a drain" (Singh, 1906, ≈ p. 147), with "Ruid-nur, v. to cut a drain" | Drain or ditch |
| muri | Khasi | "Muri, ka, n. a drain, a culvert" (Singh, 1906, ≈ p. 134); "Drain … Ka muri um; ka nur-um" (Singh, 1920) | Drain or culvert |

| Term | Language | Meaning (source) | Manual term (Clause 7.2) |
|---|---|---|---|
| kliap | Khasi | "a big drain in a paddy land or a ditch round a fence" (Singh, 1906, ≈ p. 27) | Local only |
| dooid | Pnar | "a channel carrying off surplus liquid esp. rainwater or liquid waste; drain" (Passah, 2013) | Drain (Jaintia hills) |
| kshait, kshaid | Khasi | "Kshait, ka, n. a waterfall, a cascade" (Singh, 1906, ≈ p. 49) | In names only |
| phud | Khasi | "the bed of a stream, a mountain gorge" (Singh, 1906, ≈ p. 158–168) | Local only; the bed of a stream or jhora |
| jingshlei-um | Khasi | "Flood … Ka jingshlei-um; v.t. Shlei; dap-um" (Singh, 1920) | Flood; local only |

### Table 7E.3 — Land, forest and institutions

| Term | Language | Meaning (source) | Use in this Manual |
|---|---|---|---|
| lum | Khasi | "Lum [printed 'Ltim'], u, n. a hill, a mountain" (Singh, 1906, ≈ p. 120); "Hill … U lum" (Singh, 1920) | A hill or ridge, and so a catchment divide; in names |
| ranap | Khasi | "the slope of a hill" (Singh, 1906, ≈ p. 171) | A hill slope; local only |
| a·bri | Garo | "A-bri, n. A hill; a highland" (Nengminza, 1978) | A hill; local only |
| law kyntang | Khasi | "'lawkyntang, ka, n. a sacred grove" (Singh, 1906, ≈ p. 111), with "Kyntang, a. consecrated, holy" | Sacred grove; a protected source catchment where it stands at a stream head or above a spring (definitions after Clause 7.2) |
| khlaw, law | Khasi | "Khlaw, ka, n. jungle"; "'law … (abbrev. of khlaw), jungle"; "law-bah … a dense forest" (Singh, 1906) | Forest; not a defined term |
| Dorbar Shnong; Rangbah Shnong | Khasi | The village council and its headman, as the KHADC Regulation, 2015, the KHADC's rules on solid waste and the State's orders use the terms (no dictionary source was checked) | The landholding institution of a Khasi or Jaintia village, with whom Zone 1 land is secured by agreement (definitions after Clause 7.2) |

### Table 7E.4 — Terms not yet verified

These terms or senses are in use but were not confirmed in a dictionary during research for this Manual. They shall not be used in a record or a drawing as defined terms until verified.

| Term | Reported meaning or use | Status |
|---|---|---|
| jhora | A small hill stream, perennial or seasonal; the word used in Shillong for the streams into which the town's drains fall | Local English, from the Bengali–Nepali word; Shillong usage per a city profile (ICLEI, as reported); not in the Khasi dictionaries, and no dictionary source was checked; used in this Manual only with the gloss "jhora: small hill stream" |
| chikare | Garo: a drain ("Drain … Chikare", English-Garo, 1905) | The scanned entry is partly garbled; to be verified before use |
| Nokma | The head of a Garo village, whose institution holds or manages village land | Not researched for this Manual [TBC]; the Garo village institution with whom Zone 1 land would be agreed is to be confirmed |
| A Garo word for a spring | — | None found in the two Garo dictionaries read [TBC] |
| Page numbers of Singh (1906) | As cited in Tables 7E.1 to 7E.3 ("≈ p.") | Estimated from the scanned text; to be checked on the page images |

| Term | Reported meaning or use | Status |
|---|---|---|
| Pnar and Garo dialect forms of the other terms | Regional words and spellings | Not checked beyond Passah (2013) and the two Garo dictionaries |

The Manual uses the terms in the last column of Tables 7E.1 and 7E.2, the land terms of Table 7E.3, and the Meghalaya terms defined after Clause 7.2.

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## Form 7-1 — Waterbody Sheet

Supports Clauses 7.3.2, 7.4 and 7.15(1) of Chapter 7.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One sheet per waterbody. Attach the plan of Clause 7.3.2 at 1:1,000 or larger.

### Table 7F.1 — Form 7-1, Section A: Project and waterbody

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Project name and Authority file number | _____ | — |
| A2 | Waterbody name (English and Khasi or Garo) and inventory ID (Annex 7A), if any | _____ | 7.3.1 |
| A3 | Waterbody type (Clause 7.2) | _____ | 7.2 |
| A4 | Position: within the site / within 100 m of the site boundary / downstream within the Chapter 5 extent | _____ | 7.3.2 |
| A5 | Survey numbers and village | _____ | 7.3.1(a) |
| A6 | Custodian | _____ | 7.3.1(b) |
| A7 | Sources checked (tick): Revenue and District Council records, Municipal Board (s.62) records, SMP 2041, NESAC and Tura plan maps, Expert Committee inclusion and exclusion lists, 2025 ground-truthing list, MePGCL records, MBDA spring inventories, drain-and-jhora register □; MePGCL / Dorbar Shnong or village council registers □; Authority inventory or court list □; historical maps and imagery, including NWIA □; site survey □ | _____ | 7.3.3 |
| A8 | Where sources conflict: which extent governs (the larger) | _____ | 7.3.3 |
| A9 | Datum of all levels, and conversion from any MePGCL datum | _____ | 7.3.5 |

### Table 7F.2 — Form 7-1, Section B: Levels and features

| No. | Field | Entry | Clause |
|---|---|---|---|
| B1 | FTL (tanks, lakes, ponds) or top of bank (channels), m | _____ | 7.2 |
| B2 | MWL (tanks), m, and basis (MePGCL record or 1% AEP computed) | _____ | 7.2 |
| B3 | TBL, lowest point (tanks), m | _____ | 7.3.1(d) |
| B4 | 1% AEP flood level, m, and source (adopted map / hydraulic study / not available) | _____ | 7.3.4 |
| B5 | Drainage area at the site (channels), ha | _____ | 7.4.1(b) |
| B6 | Supply channels, surplus courses, sluices and surplus weirs shown on plan (yes / no) | _____ | 7.3.2 |
| B7 | Known encroachments, with date recorded | _____ | 7.3.1(g) |

### Table 7F.3 — Form 7-1, Section C: Setback

| No. | Field | Entry | Clause |
|---|---|---|---|
| C1 | Basis of setback: mapped extent / hydraulic study / fixed width (Annex 7B) | _____ | 7.15(1) |
| C2 | Is a hydraulic study required under Clause 7.3.4 (a) / (b) / (c)? | _____ | 7.3.4 |
| C3 | Floodway outer edge, m from FTL or top of bank, and how delineated | _____ | 7.6.1 |
| C4 | Zone 1 width, m (greatest of 15 m, floodway edge, MWL contour) | _____ | 7.4.3 |

| No. | Field | Entry | Clause |
|---|---|---|---|
| C5 | Zone 2 width, m (to 1% AEP extent + 10 m, or 10 m) | _____ | 7.4.4 |
| C6 | Wider statutory or approval setback, if any, and its source | _____ | 7.4.5 |
| C7 | Setback applied: Manual standard / a wider statutory, plan or approval line: the waterbody setback or regulated zone of the Meghalaya Waterbodies (Conservation and Protection) Guidelines, 2023, as amended, from the mean high flood level of the past ten years (3 m or 6 m along urban streams, narrower than Zone 1, stated, never governing alone; 10 to 30 m along rural streams; 10, 20 or 50 m round lakes and ponds; the regulated zone four times the setback); a restriction in a flood zone notified under the Meghalaya Flood Plain Zoning Act, 2026 (none yet); a line of a District Council regulation, such as the "Reserved Forest & Conservation Area" of the KHADC Regulation, 2015; a line of the Shillong Master Plan 2041 or another master plan; the boundary of a notified wetland or forest land; a court or Tribunal line; a MePGCL or Water Resources Department line; or other (state which) | _____ | 7.4, Disclosure |
| C8 | Uses proposed in Zone 1 and Zone 2, and the custodian's NOC for any work in Zone 1 | _____ | 7.5, 7.15(5) |
| C9 | Fill proposed in the flood fringe (yes / no); if yes, Form 7-3 attached | _____ | 7.6.3 |
| C10 | Zone 1 marker positions shown (not more than 30 m apart) | _____ | 7.13.4 |

### Table 7F.4 — Form 7-1, Section D: Prepared by

| Field | Entry |
|---|---|
| Name, registration and empanelment number (Clause 10.6) | _____ |
| Signature and date | _____ |
| Licensed surveyor for the levels (name, licence number) | _____ |

## Form 7-2 — Tank Storage Credit Sheet

Supports Clauses 7.7, 7.8, 7.11, 7.14 and 7.15(4) of Chapter 7.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One sheet per tank whose storage is counted. Storage that fails any item in Section B shall not be counted (Clause 7.7.1).

### Table 7F.5 — Form 7-2, Section A: Tank and scheme

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Tank name and inventory ID (Annex 7A); custodian | _____ | 7.3.1 |
| A2 | Scheme in which storage is counted: basin plan / regional facility / fee-in-lieu (S-5) | _____ | 7.7.1, 7.11 |
| A3 | Cascade modelled: uppermost tank _____ to outfall _____ | _____ | 7.7.2 |
| A4 | Datum | _____ | 7.3.5 |

### Table 7F.6 — Form 7-2, Section B: Conditions for counting storage

| No. | Condition | Date / reference | Met (yes / no) | Clause |
|---|---|---|---|---|
| B1 | FTL, MWL, TBL, weir crest and length, sluice sills surveyed within the previous 5 years | _____ | _____ | 7.7.1(a) |
| B2 | Stage–storage curve from a bathymetric and topographic survey within 5 years or after the last desilting, whichever is later | _____ | _____ | 7.7.1(b) |
| B3 | Documented operating rule agreed with the custodian (Annex 7C) | _____ | _____ | 7.7.1(c), 7.8 |
| B4 | Weir, sluices and bund under an O&M plan; latest pre-monsoon inspection found them serviceable | _____ | _____ | 7.7.1(d), 7.14.4 |
| B5 | Custodian's written concurrence | _____ | _____ | 7.7.1(e) |

### Table 7F.7 — Form 7-2, Section C: Levels and creditable volume

| No. | Item | Value | Clause |
|---|---|---|---|
| C1 | Starting level: FTL, or cushion level under a rule meeting Clause 7.8.2, m | _____ | 7.7.3 |
| C2 | If a cushion is used: controllable outlet (type) and drawdown time, h | _____ | 7.8.2(a) |
| C3 | If a cushion is used: reliability from continuous simulation, % of monsoon seasons (≥ 90%) | _____ | 7.8.2(c) |
| C4 | Computed maximum level, 1% AEP inflow with climate factor routed through the cascade, m | _____ | 7.7.4 |
| C5 | MWL, m; is C4 ≤ MWL? | _____ | 7.7.4(a) |
| C6 | Freeboard C4 to TBL, m; MePGCL freeboard standard, m; met? | _____ | 7.7.4(b) |
| C7 | Storage between C1 and C4, from the stage–storage curve, $m^3$ | _____ | 7.7.5 |
| C8 | Volume already committed to another facility or scheme, $m^3$ | _____ | 7.7.5 |
| C9 | Creditable volume = C7 − C8, $m^3$ | _____ | 7.7.5 |
| C10 | Register entry under Clause 10.17 (fee-in-lieu storage) | _____ | 7.11.2(d) |

### Table 7F.8 — Form 7-2, Section D: Bund safety

| No. | Item | Entry | Clause |
|---|---|---|---|
| D1 | Specified dam under the Dam Safety Act, 2021? Height, crest length, capacity, maximum flood discharge | _____ | 7.14.1 |
| D2 | Hazard class: high / low | _____ | 7.14.2 |
| D3 | High hazard: weir passes 1% AEP at MWL with freeboard; 0.2% AEP check without overtopping | _____ | 7.14.3(a) |
| D4 | High hazard: breach analysis and emergency action plan (references) | _____ | 7.14.3(b), (c) |
| D5 | High hazard: independent check under Clause 10.6 (name) | _____ | 7.14.3(d) |

### Table 7F.9 — Form 7-2, Section E: Signatures

| Role | Name and designation | Signature and date |
|---|---|---|
| Designer (Clause 10.6) | _____ | _____ |
| Independent checker, where Clause 7.14.3(d) applies | _____ | _____ |
| Custodian's concurrence (Clause 7.7.1(e)) | _____ | _____ |

## Form 7-3 — Compensatory Storage Calculation (by elevation band)

Supports Clauses 7.6.3 to 7.6.5, 7.9.5 and 7.15(3) of Chapter 7.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

### Method

1. Fix the **lower limit**: the normal water level of the waterbody, or the 50% AEP (2-yr) level where higher (Clause 7.6.4(b)).
2. Fix the **upper limit**: the 1% AEP flood level (with the climate factor).
3. Divide the range into **bands of not more than 0.3 m**. The top band may be thinner.
4. For each level z at a band boundary, measure on plan:
    - A_fill(z): the area of the fill footprint where existing ground is below z; and
    - A_cut(z): the area of the excavation where finished ground is below z and existing ground was above z (new flooded area).
5. For each band, by the average end-area method: V = (A(z_bottom) + A(z_top)) / 2 × band thickness. Do this for fill (volume lost) and for excavation (volume gained).
6. **Check each band:** volume gained ≥ volume lost. A surplus in one band does not make up a shortfall in another (Clause 7.6.4(b)).
7. Check the other conditions of Clause 7.6.4(c) to (f) in Section C.

Figure 7.2 in Chapter 7 shows the method.

**Table 7F.10 — Form 7-3, Section A: Levels**

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Waterbody, reach, and inventory ID | _____ | 7.6.4(c) |
| A2 | Normal water level, m; 50% AEP level, m; lower limit (the higher), m | _____ | 7.6.4(b) |
| A3 | 1% AEP flood level with climate factor, m (upper limit) | _____ | 7.6.4(b) |
| A4 | Band thickness, m (≤ 0.3) and number of bands | _____ | 7.6.4(b) |
| A5 | Datum | _____ | 7.3.5 |

**Table 7F.11 — Form 7-3, Section B: Band-by-band balance**

| Band | From (m) | To (m) | A_fill bottom (m²) | A_fill top (m²) | Volume lost (m³) | A_cut bottom (m²) | A_cut top (m²) | Volume gained (m³) | Gained ≥ lost? |
|---|---|---|---|---|---|---|---|---|---|
| 1 | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| 2 | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| 3 | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| 4 | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Total | | | | | _____ | | | _____ | |

Add rows as needed.

**Table 7F.12 — Form 7-3, Section C: Other conditions**

| No. | Condition | Met (yes / no) and evidence | Clause |
|---|---|---|---|
| C1 | Fill is in the flood fringe, not the floodway, and for a permitted use | _____ | 7.6.2, 7.6.3 |
| C2 | Excavation is in the same reach of the same waterbody, hydraulically connected, and not further downstream than the fill | _____ | 7.6.4(c) |
| C3 | Excavation drains by gravity as the flood recedes; no pumping; no permanent pool below normal water level | _____ | 7.6.4(d) |
| C4 | Excavation built before, or at the same time as, the fill | _____ | 7.6.4(e) |
| C5 | Covenant or handover so that it is never filled (reference) | _____ | 7.6.4(f) |
| C6 | Not counted as detention or retention under Chapter 4 | _____ | 7.6.5 |
| C7 | Signature of designer (Clause 10.6) and date | _____ | 10.6 |

## Worked example

**Illustrative — not design values.** A site in the flood fringe of a channel needs a fill pad for a permitted Zone 2 use (Clause 7.5.2). The inputs are assumed.

- Normal water level 10.00 m; 50% AEP level 9.80 m. Lower limit = 10.00 m (the higher).
- 1% AEP flood level 11.20 m. Range 1.20 m, so four bands of 0.30 m.
- The fill footprint is 1,600 m². Existing ground across the footprint rises evenly from 10.00 m to 11.20 m, so the area of footprint below each level is: 0 m² at 10.00 m; 400 m² at 10.30 m; 800 m² at 10.60 m; 1,200 m² at 10.90 m; 1,600 m² at 11.20 m.
- The excavation is a graded cut beside the channel, with its floor at 10.00 m. The new flooded area below each level (first trial) is: 300 m² at 10.00 m; 900 m² at 10.30 m; 1,100 m² at 10.60 m; 1,500 m² at 10.90 m; 1,500 m² at 11.20 m.

Step 1 — volume lost, band by band (V = average area × 0.3 m):

- Band 1: (0 + 400) / 2 × 0.3 = 60 m³
- Band 2: (400 + 800) / 2 × 0.3 = 180 m³
- Band 3: (800 + 1,200) / 2 × 0.3 = 300 m³
- Band 4: (1,200 + 1,600) / 2 × 0.3 = 420 m³
- Total: 960 m³

Step 2 — volume gained, first trial:

**Table 7F.13 — Worked example: first trial (illustrative)**

| Band | From (m) | To (m) | Volume lost (m³) | A_cut bottom (m²) | A_cut top (m²) | Volume gained (m³) | Gained ≥ lost? |
|---|---|---|---|---|---|---|---|
| 1 | 10.00 | 10.30 | 60 | 300 | 900 | 180 | Yes |
| 2 | 10.30 | 10.60 | 180 | 900 | 1,100 | 300 | Yes |
| 3 | 10.60 | 10.90 | 300 | 1,100 | 1,500 | 390 | Yes |
| 4 | 10.90 | 11.20 | 420 | 1,500 | 1,500 | 450 | Yes |
| Total | | | 960 | | | 1,320 | |

Every band passes. Note that a simple total balance would hide a failure if, for example, the cut were made deeper and narrower: suppose the designer instead offers a cut with new flooded areas of 1,400 m² at 10.00 m, 1,400 m² at 10.30 m, 1,000 m² at 10.60 m, 600 m² at 10.90 m and 200 m² at 11.20 m.

**Table 7F.14 — Worked example: deeper, narrower cut (illustrative)**

| Band | From (m) | To (m) | Volume lost (m³) | A_cut bottom (m²) | A_cut top (m²) | Volume gained (m³) | Gained ≥ lost? |
|---|---|---|---|---|---|---|---|
| 1 | 10.00 | 10.30 | 60 | 1,400 | 1,400 | 420 | Yes |
| 2 | 10.30 | 10.60 | 180 | 1,400 | 1,000 | 360 | Yes |
| 3 | 10.60 | 10.90 | 300 | 1,000 | 600 | 240 | **No** |
| 4 | 10.90 | 11.20 | 420 | 600 | 200 | 120 | **No** |
| Total | | | 960 | | | 1,140 | |

The total gained (1,140 m³) exceeds the total lost (960 m³), but bands 3 and 4 are short by 60 m³ and 300 m³. The surplus low down cannot be counted against them: the low storage fills early in every flood and is not available when the fill takes away storage near the peak. This design fails Clause 7.6.4(b) and must be regraded so that the upper bands gain at least as much as they lose, as in the first trial.

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ANNEXES TO CHAPTER 8

# Water Quality and Recharge

These annexes support Chapter 8. They give the layout of the water quality rainfall tables, the Level of Service and Value Rating method in detail, the layout of the BMP calibration programme, design sheets for each BMP, standard details for construction erosion and sediment control, and the two forms that Clause 8.14 requires. Annexes 8A and 8C need data that are not yet available; they say so and give the rule to use in the meantime. The forms are draft forms.

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## Annex 8A — 3-month ARI 24-hour depth and IDF by zone

Supports Clauses 8.2, 8.4.1 and 8.4.5 of Chapter 8.

**To be prepared.** This annex will contain, for each rainfall zone of Chapter 2, the 24-hour 3-month ARI depth P_3m and the 3-month ARI intensity–duration relationship used for Q_wq. It needs long-term daily and sub-daily rainfall records (IMD station and gridded data, with NIH as the Chapter 2 primary source), analysed as a partial-duration series. Until it is published, the designer shall compute P_3m from the longest available daily record for the site's zone, as the 24-hour depth equalled or exceeded on average four times a year (Clause 8.2), state the record, its length and the method on the Water Quality Sheet (Form 8-1), and use P_wq = max (P_ret, P_3m) (Clause 8.4.1). The climate factor is not applied (Clause 8.4.3).

### 8A.1 Method to be used in preparing the annex

- (a) Use daily records of at least 30 years where available (as for station IDF in Chapter 2).
- (b) Form the partial-duration series of 24-hour depths, with independent events separated by at least one dry day.
- (c) Choose the threshold so that the number of events above it averages four per year; P_3m is that threshold.
- (d) Derive the 3-month ARI intensities for durations from 10 minutes to 24 hours from sub-daily records, or by the Chapter 2 method of scaling from the daily value, stating which.
- (e) Do not apply the climate factor (Clause 8.4.3).

**Table 8A.1 — Water quality rainfall depths by zone (layout)**

| Zone (Chapter 2) | Representative stations or grid | Record (years) | P_ret, Annex 2E (mm) | P_3m (mm) | P_wq = max (mm) |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ |

**Table 8A.2 — 3-month ARI intensity by duration (layout)**

| Zone | 10 min (mm/h) | 15 min (mm/h) | 30 min (mm/h) | 1 h (mm/h) | 2 h (mm/h) | 6 h (mm/h) | 24 h (mm/h) |
|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

| Zone | 10 min (mm/h) | 15 min (mm/h) | 30 min (mm/h) | 1 h (mm/h) | 2 h (mm/h) | 6 h (mm/h) | 24 h (mm/h) |
|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

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## Annex 8B — Redevelopment LoS table and treatment-train composite VR

Supports Clauses 8.6.2 to 8.6.5 of Chapter 8.

### 8B.1 Required Level of Service for redevelopment

**To be prepared.** This part will give the required Level of Service for redevelopment sites (existing impervious cover of 20% or more of the site, Clause 8.6.2). The MARC/APWA BMP Manual (2012, Table 4.3) sets the redevelopment LoS from the percentage of impervious cover within the disturbed area; the Meghalaya values need to be set by the State Stormwater Technical Committee and checked against local redevelopment cases. Until it is published, the required LoS for a redevelopment site is **6** for the disturbed area. Where Table 8.2, applied to the change in CN from the existing condition to post-development, gives a higher LoS, that higher LoS applies. This interim value is set by this Manual. A redevelopment site that retains its whole WQv on site under Chapter 4 needs no further treatment for that area, apart from pretreatment, hotspot controls and the outfall requirements (Clause 8.4.4).

Table 8B.1 — Required LoS for redevelopment (layout)

| Existing impervious cover within the disturbed area (%) | Change in impervious cover | Required LoS |
|---|---|---|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

### 8B.2 Composite Value Rating: area-weighted method

The composite VR of a site is the area-weighted average of the VRs of the BMPs serving each part of the site (Clause 8.6.3):

$$VR_{site} = \Sigma (A_i \times VR_i) / \Sigma A_i + VR_{signage}$$

where:

- $A_i$ = the area of part i of the site, ha;
- $VR_i$ = the Value Rating (Table 8.3) of the BMP serving part i, which counts only if the BMP meets Clause 8.6.4 for the whole of $A_i$;
- $\Sigma A_i$ = the whole site area: every part of the site is assigned to one BMP, or to preserved native vegetation; a part served by no BMP is entered with $VR_i = 0$; and
- $VR_{signage} = 0.25$ where public education signage is provided (Table 8.3), otherwise 0.

The site complies where $VR_{site} \geq$ required LoS (Clause 8.6.3).

**Illustrative — not design values.** A 1.0 ha site that is not redevelopment, with ΔCN = 18. Required LoS = 8 (Table 8.2).

**Table 8B.2 — Worked example: composite VR (illustrative)**

| Part | Area A_i (ha) | BMP | VR_i (Table 8.3) | A_i × VR_i |
|---|---|---|---|---|
| Roofs and paving draining to bioretention | 0.60 | Bioretention | 8.5 | 5.100 |
| Car park | 0.25 | Permeable pavement | 7.5 | 1.875 |
| Preserved strip along boundary | 0.15 | Native vegetation (preserved) | 9.25 | 1.388 |
| Total | 1.00 | | | 8.363 |

- Area-weighted VR = 8.363 / 1.00 = 8.36
- Signage provided: + 0.25
- VR_site = 8.61 ≥ 8. The site complies.

Without the permeable pavement (car park draining untreated, VR = 0): (5.100 + 0 + 1.388) / 1.00 + 0.25 = 6.74 < 8. The site would not comply.

### 8B.3 Treatment trains

**To be prepared.** This part will give the composite VR of BMPs in series (a treatment train), following the approach of the MARC/APWA BMP Manual (2012, Table 4.6), with values to be confirmed for Meghalaya by the calibration programme of Clause 8.13.4 (Annex 8C). Until it is published, each part of the site is credited with the VR of one BMP in the train that meets Clause 8.6.4 for that part, normally the last BMP before discharge, and no extra credit is given for BMPs in series. Pretreatment devices, silt traps and oil-grit separators upstream of the credited BMP earn no VR of their own (Clauses 8.6.4(c), 8.7.11(c) and 8.7.12(c)).

**Table 8B.3 — Composite VR of treatment trains (layout)**

| First BMP | Second BMP | Composite VR | Conditions |
|---|---|---|---|
| _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ |

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## Annex 8C — Meghalaya BMP performance calibration

Supports Clauses 8.6.3, 8.13 and 8.15.1 of Chapter 8.

**To be prepared.** This annex will report the BMP performance calibration programme of the State Stormwater Technical Committee (Clause 8.13.4): measured inflow and outflow concentrations and volumes for BMPs built in Meghalaya, and the revised Value Ratings that follow from them. It needs wet-weather monitoring of BMPs over several monsoon seasons, with laboratory analysis to the CPCB methods, and the outfall monitoring of Clause 8.13.1 published under Clause 10.17. Until it is published, the Value Ratings of Table 8.3 (MARC/APWA 2012) apply, and a proprietary device earns a VR only from verified test data (Table 8.3).

The layouts below set the minimum records the programme shall keep, so that results from different authorities can be pooled.

**Table 8C.1 — Monitoring site register (layout)**

| Site ID | BMP type (Table 8.3) | Location and authority | Catchment area (ha) | Impervious (%) | Soil and groundwater setting | Date commissioned | Pretreatment |
|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

**Table 8C.2 — Event record (layout; parameters of Clause 8.13.2)**

| Site ID | Event date | Rainfall (mm) | Inflow volume ($m^3$) | Outflow volume ($m^3$) | TSS in / out (mg/L) | BOD in / out (mg/L) | COD in / out (mg/L) | Faecal coliform in / out (MPN/100 mL) | TN in / out (mg/L) | TP in / out (mg/L) | Oil and grease in / out (mg/L) | Heavy metals (industrial catchments) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

**Table 8C.3 — Performance summary and proposed VR (layout)**

| BMP type | Sites | Events | Volume reduction (%) | Median effluent TSS (mg/L) | Other findings | VR in Table 8.3 | Proposed VR |
|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

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## Annex 8D — BMP design sheets, media specification, plant lists

Supports Clauses 8.5, 8.7, 8.8 and 8.11 of Chapter 8.

Each design sheet collects the requirements of Chapter 8 for one BMP. Values marked "recommended starting value" in Clause 8.7.1 may be departed from with justification. Values that the Manual does not set are marked "to be confirmed in design"; the designer shall state and justify them. Every BMP also needs: sizing for the WQv or Q_wq (Clause 8.6.4(a)), pretreatment (Clause 8.5.3), a safe bypass for flows above Q_wq (Clause 8.4.6) and maintenance access (Chapter 10).

### 8D.1 Design sheets

**Table 8D.1 — Pretreatment (all BMPs)**

| Item | Requirement | Clause |
|---|---|---|
| Where needed | Every bioretention cell, infiltration facility, permeable pavement receiving run-on, wet pond and constructed wetland, at each concentrated inflow | 8.5.3 |
| Types | Sediment forebay, grass filter strip, silt trap or proprietary device | 8.5.3 |
| Size | Holds at least 10% of the WQv of its contributing area; or sized for Q_wq (flow-through devices) | 8.5.3 |
| Access | Cleanable without entering or disturbing the main BMP | 8.5.4 |
| Silt traps and catch pits | At every inlet receiving runoff from unpaved ground, and at the inlet of every drain discharging to a BMP or waterbody; sump at least 300 mm below the outlet invert; earn no VR | 8.7.12 |

### Table 8D.2 — Bioretention and rain gardens (Figure 8.2)

| Item | Requirement | Clause |
|---|---|---|
| Ponding depth | ≤ 300 mm above the mulch, with an overflow at maximum ponding level | 8.7.2(a) |
| Ponding drawdown | Within 48 h | 8.7.2(b) |
| Filter media | 600–900 mm engineered sandy loam, low fines, low phosphorus (Table 8D.12) | 8.7.2(c) |
| Mulch | 50–75 mm | 8.7.2(c) |
| Transition (choker) and gravel drainage layers | Required; thickness and grading to be confirmed in design | 8.7.2(d) |
| Underdrain | Perforated; required where the design infiltration rate cannot meet the 48 h drawdown, or where lined; diameter to be confirmed in design | 8.7.2(e) |
| Lining | Required where Clause 8.8 cannot be met, and at hotspots | 8.7.2(f) |
| Plants | Native or naturalised, tolerant of waterlogging and long dry spells (Tables 8D.13 and 8D.14) | 8.7.2(g) |
| VR | 8.5 (rain garden / infiltration 9.0) | Table 8.3 |

### Table 8D.3 — Vegetated swales

| Item | Requirement | Clause |
|---|---|---|
| Section | Trapezoidal or parabolic; side slopes no steeper than 1V:3H | 8.7.3(a) |
| Longitudinal slope | 0.5% to 4%; check dams where steeper | 8.7.3(b) |
| Flow at Q_wq | Depth not more than grass height; velocity ≤ 0.3 m/s | 8.7.3(c) |
| 1% AEP or bypass flow | No erosion (Chapter 9 permissible velocities) | 8.7.3(d) |
| Underdrained ("dry") swale | Where slope < 1% or subsoil is poorly drained; filter media as Table 8D.12 | 8.7.3(e) |
| VR | 4.0 (native vegetation swale) | Table 8.3 |

### Table 8D.4 — Vegetated filter strips

| Item | Requirement | Clause |
|---|---|---|
| Inflow | Sheet flow only; level spreader where flow arrives concentrated | 8.7.4(a) |
| Length in flow direction | ≥ 5 m | 8.7.4(b) |
| Slope | 1% to 8% | 8.7.4(b) |
| Use | Mainly pretreatment for bioretention, infiltration and swales | 8.7.4(c) |
| VR | 5.0 | Table 8.3 |

### Table 8D.5 — Permeable pavement

| Item | Requirement | Clause |
|---|---|---|
| Run-on | Impervious run-on area ≤ 2 × permeable area; none from unpaved or eroding areas | 8.7.5(a) |
| Base reservoir | Clean open-graded aggregate holding its share of the WQv in its voids; void ratio confirmed by test | 8.7.5(b) |
| Open (infiltrating) base | Only where Clause 8.8 is met; otherwise lined with underdrain and counted as filtration only | 8.7.5(c) |

| Item | Requirement | Clause |
|---|---|---|
| Structure | Designed for traffic loading to the road authority's standards | 8.7.5(d) |
| Exclusions | Not at hotspots; not where it will be resurfaced with impermeable material | 8.7.5(e) |
| VR | 7.5 | Table 8.3 |

### Table 8D.6 — Infiltration trenches and basins (Figure 8.3)

| Item | Requirement | Clause |
|---|---|---|
| Pretreatment | Always (Table 8D.1) | 8.7.6(a) |
| Fill | Clean washed aggregate, void ratio confirmed by test; geotextile on sides and top; sand base | 8.7.6(b) |
| Observation well | To the base of each trench | 8.7.6(c) |
| Storage | WQv (or Chapter 4 retention volume, if greater) held in the voids | 8.7.6(d) |
| Drawdown | Empty within 72 h at the design infiltration rate | 8.7.6(d), 8.8.7 |
| Overflow | At grade, to the minor or major system | 8.7.6(e) |
| Commissioning | Not in service until the contributing area is stabilised | 8.7.6(f) |
| Criteria | All of Clause 8.8 (Table 8D.11) | 8.8 |

### Table 8D.7 — Wet ponds (extended wet detention)

| Item | Requirement | Clause |
|---|---|---|
| Permanent pool | ≥ WQv | 8.7.7(a) |
| Extended detention | WQv above the pool, released over 24–48 h | 8.7.7(a), 8.4.7 |
| Forebay | At each inlet | 8.7.7(b) |
| Flow path | Length-to-width ≥ 3:1; no short-circuiting | 8.7.7(c) |
| Pool depth | 1.0–2.5 m, with safety bench (Clause 7.9.4) | 8.7.7(d) |
| Water balance | Monthly balance with IMD rainfall and pan evaporation: ≥ 50% of pool volume kept through the driest year in 10; no top-up with groundwater, potable water or sewage | 8.7.8 |
| Flood detention | Chapter 4 detention may sit above the extended detention level | 8.7.7(f) |
| VR | 5.0 | Table 8.3 |

### Table 8D.8 — Constructed wetlands

| Item | Requirement | Clause |
|---|---|---|
| Layout | Inlet sedimentation pond (forebay), then shallow macrophyte zone | 8.7.9(a) |
| Extended detention | WQv above normal water level, released over 24–48 h; depth ≤ 0.5 m | 8.7.9(b) |
| Flow path | Length-to-width ≥ 3:1; deep zones across the flow path | 8.7.9(c) |
| Bypass | High-flow bypass so that floods do not scour the macrophyte zone | 8.7.9(d) |
| At a tank inlet | Within the tank's setback, outside its waterspread; not counted as tank storage | 8.7.9(e) |
| Water balance | As wet ponds (minimum wetland depth kept) | 8.7.8 |

| Item | Requirement | Clause |
|---|---|---|
| VR | 7.0 (extended detention wetland) | Table 8.3 |

### Table 8D.9 — Gross pollutant traps and outfall screens

| Item | Requirement | Clause |
|---|---|---|
| Treatment flow | Q_wq; all flows up to 1% AEP pass without washing out captured material | 8.7.10(a) |
| Capture size | Down to about 5 mm | 8.7.10(b) |
| Head loss | In the drain HGL (Chapter 9), screen 50% blocked | 8.7.10(c), 8.10.3(a) |
| Storage | For the O&M cleaning interval; not less than 3-monthly cleaning | 8.7.10(d) |
| Access | Vehicle access for suction or grab cleaning; safe cleaning platform | 8.7.10(e), 8.10.3(d) |
| Blocked screen | Overflow or bypass path so that a fully blocked screen does not flood property | 8.10.3(b) |
| Bar spacing | Chosen for the hazard: closer for litter capture, wider where blockage would cause flooding; to be confirmed in design | 8.10.3(c) |

### Table 8D.10 — Oil-grit separators

| Item | Requirement | Clause |
|---|---|---|
| Where | Fuel stations; vehicle workshops and washing bays; bus and truck depots; parking areas of more than 50 spaces | 8.7.11(a) |
| Sizing | Q_wq, with high-flow bypass | 8.7.11(b) |
| Not alone | Followed by a filtering BMP where the site needs a VR above 5; lined filtering BMP before any infiltration at hotspots | 8.7.11(c), 8.8.8 |

### Table 8D.11 — Infiltration and recharge criteria (all infiltrating BMPs)

| Item | Requirement | Clause |
|---|---|---|
| Groundwater separation | Seasonal high groundwater ≥ 1.0 m below base (roof-only runoff in notified coastal sand: ≥ 0.5 m with mounding check, mound ≥ 0.3 m below base) | 8.8.1, 8.8.9(d) |
| Bedrock or impermeable layer | Base ≥ 1.0 m above, unless designed for rock-aquifer recharge under Clause 8.8.10 | 8.8.2 |
| Tests | Double-ring (ASTM D3385) for basins, bioretention, permeable pavement; falling-head borehole or trial-pit soakage (e.g. BRE Digest 365) for trenches, soakaways, pits, wells; ≥ 2 per facility and ≥ 1 per 100 m² of base or per 50 m of trench; Form 8-2 | 8.8.3 |
| Design rate | Measured rate ÷ 2.0 (tests meet 8.8.3(c) and vary by no more than a factor of 2), otherwise ÷ 3.0 | 8.8.4 |
| Minimum rates | ≥ 13 mm/h full infiltration; 3–13 mm/h partial, with underdrain, credit only for volume infiltrated within 72 h; < 3 mm/h no credit | 8.8.5 |
| Setbacks (runoff from paved surfaces) | Foundations 3 m, basements 5 m; property boundary 1.5 m; drinking-water well or borewell 30 m; septic tank or soak pit 15 m; crest of slope steeper than 1V:3H 6 m | 8.8.6 |
| Expansive soils | Foundation setback doubled | 8.8.11(b) |

| Item | Requirement | Clause |
|---|---|---|
| Drawdown | Empty within 72 h at design rate; tested after construction | 8.8.7 |
| Hotspots | No infiltration without treatment; none at all for waste sites and contaminated land | 8.8.8 |
| Road runoff | Never led directly into a well, borewell or recharge shaft | 8.11.3(b) |

## 8D.2 Bioretention drawdown check

The 48-hour ponding drawdown (Clause 8.7.2(b)) and the minimum rates of Clause 8.8.5 together decide whether a cell needs an underdrain.

- Rate needed to drain the maximum ponding depth in 48 h = 300 mm / 48 h = 6.25 mm/h.
- Design rate ≥ 13 mm/h: full infiltration, no underdrain, provided Clause 8.8 is met.
- Design rate from 6.25 mm/h to 13 mm/h: the ponding drains in time, but Clause 8.8.5(b) applies, so an underdrain is required.
- Design rate below 6.25 mm/h: the ponding cannot drain in 48 h by infiltration; an underdrain is required (Clause 8.7.2(e)), and below 3 mm/h no infiltration credit is given.

**Illustrative — not design values.** Two tests at the base of a proposed cell give 30 mm/h and 22 mm/h. The two results differ by a factor of 30 / 22 = 1.36, which is not more than 2, and the number of tests meets Clause 8.8.3(c), so the safety factor is 2.0. Taking the lower result, the design rate = 22 / 2.0 = 11 mm/h. This is above 6.25 mm/h, so the ponding drains in 300 / 11 = 27 h, within 48 h. It is below 13 mm/h, so the cell is a partial-infiltration design with an underdrain (Clause 8.8.5(b)).

## 8D.3 Filter media specification

**Table 8D.12 — Bioretention filter media and layers**

| Layer | Requirement from Chapter 8 | Values to be confirmed in design |
|---|---|---|
| Mulch | 50–75 mm (Clause 8.7.2(c)); shredded hardwood or similar organic mulch that does not float away at the ponding depth | Material and source |
| Filter media | 600–900 mm engineered sandy loam with low fines and low phosphorus content (Clause 8.7.2(c)) | Particle size grading; fines (silt + clay) limit; organic matter content; phosphorus limit; saturated hydraulic conductivity of the compacted media; source and test certificate for each batch |
| Transition (choker) layer | Between media and gravel, to stop media washing into the gravel (Clause 8.7.2(d)) | Thickness and grading, matched to the media and gravel |
| Gravel drainage layer | Below the transition layer, surrounding the underdrain (Clause 8.7.2(d)) | Thickness, grading, washed |
| Underdrain | Perforated pipe where Clause 8.7.2(e) applies, with cleanouts | Diameter, slope, perforation, outlet level |
| Liner | Where Clause 8.7.2(f) applies (cannot meet Clause 8.8; hotspots) | Liner type and protection |

Media shall be tested before placing, and placed in lifts without heavy compaction. The State Stormwater Technical Committee should set numeric limits for grading, fines, organic matter and phosphorus, with local sources of sand and compost, when it reviews this annex.

### 8D.4 Plant lists

No Meghalaya source on planting for stormwater BMPs was found during research for this Manual, and none of the sources read names the native species to be used in bioretention, swales, filter strips or constructed wetlands in the State. The Waterbodies Guidelines ask that "dense plantation of native species shall be undertaken in the waterbody setback" (para 5), without naming any. This annex therefore lists **no species** for Meghalaya, and gives no Khasi, Pnar or Garo plant names, rather than carry over lists drawn up for other States or invent local names. Until the State Stormwater Technical Committee issues lists, the species for each BMP shall be chosen, and recorded on the BMP design sheet, by a horticulturist or the Forest and Environment Department for the site's sub-area of Annex 2A, its altitude, its soil and its water table, under the following rules (set by this Manual):

- (a) **Native or long naturalised species only**, as the Forest and Environment Department confirms for the site; no species named in Table 8D.15 or otherwise known to be invasive in the State.
- (b) **Wet and dry ground.** Species that stand saturated ground through the season of 1 April to 31 October, when monthly totals on the southern escarpment run to thousands of millimetres, and survive the dry months of December to February without irrigation once established.
- (c) **Slopes.** On the plateau and the escarpment, species chosen first to bind soil on banks, cut slopes and the margins of jhoras; bioretention on a slope is lined (Clause 8.8.1).
- (d) **Not in the waterway.** No planting in the bed or on the banks of a stream or jhora, or on an embankment, without the consent of its custodian (the Municipal Board, the Water Resources Department, the District Council or the Dorbar Shnong, as the case may be), and none that would obstruct the flow of a channel or the outlet of a pung.
- (e) **Not in the waterbodies or the groves.** No planting under this annex in a pung, lake, spring or sacred grove (law kyntang), whose vegetation is managed by its custodian under Chapter 7 and custom.

**Table 8D.13 — Indicative plants for bioretention, swales and filter strips**

| Use | Botanical name | Local name | Notes |
|---|---|---|---|
| All BMPs of Clause 8.7 | None listed for Meghalaya in this draft | — | Chosen under rules (a) to (e) above and recorded on the BMP design sheet (Annex 8D) |

**Table 8D.14 — Indicative plants for constructed wetlands and wet ponds**

| Zone | Botanical name | Local name | Notes |
|---|---|---|---|
| All zones | None listed for Meghalaya in this draft | — | Chosen under rules (a) to (e) above; constructed wetlands are built outside the waterspread of any natural waterbody (Clause 8.7.9(e)) |

**Table 8D.15 — Species not to be planted**

| Botanical name | Local name | Reason |
|---|---|---|
| Any species the Forest and Environment Department lists as invasive in Meghalaya | — | No list of invasive species for Meghalaya was read for this Manual [TBC] |

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## Annex 8E — Erosion and sediment control standard details

Supports Clause 8.12 of Chapter 8.

The details below show the arrangement of each measure. Dimensions set by the Manual are given. Dimensions the Manual does not set are labelled "to be confirmed in design" and shall be shown on the ESC plan (Clause 8.12.1). Temporary measures are designed with the rainfall of Chapter 2 and a climate factor of 1.0 (Clause 8.12.4).

**Table 8E.1 — Selection of measures (Clause 8.12.3)**

| Situation | Measure | Detail |
|---|---|---|
| Sheet flow leaving a disturbed area, along its downslope edge | Silt fence | Figure 8E.1 |
| Concentrated flow from a disturbed area of up to 2 ha | Sediment trap | Figure 8E.2 |
| Disturbed area of more than 2 ha | Sediment basin with surface dewatering outlet | Figure 8E.2 |
| Existing drain inlet receiving site runoff | Inlet protection | Figure 8E.4 |
| Vehicle exit to a public road | Stabilised construction exit, with wheel washing | Figure 8E.3 |
| Stockpiles | Outside Zone 1 of any waterbody setback; ≥ 10 m from any drain; covered in the monsoon | Notes to Figure 8E.1 |
| Dewatering | Through a sediment basin, settling tank or filter bag; never pumped directly to a drain or waterbody | Notes to Figure 8E.2 |
| Concrete washout | Lined pit; never into a drain | Notes to Figure 8E.3 |

## 8E.1 Silt fence

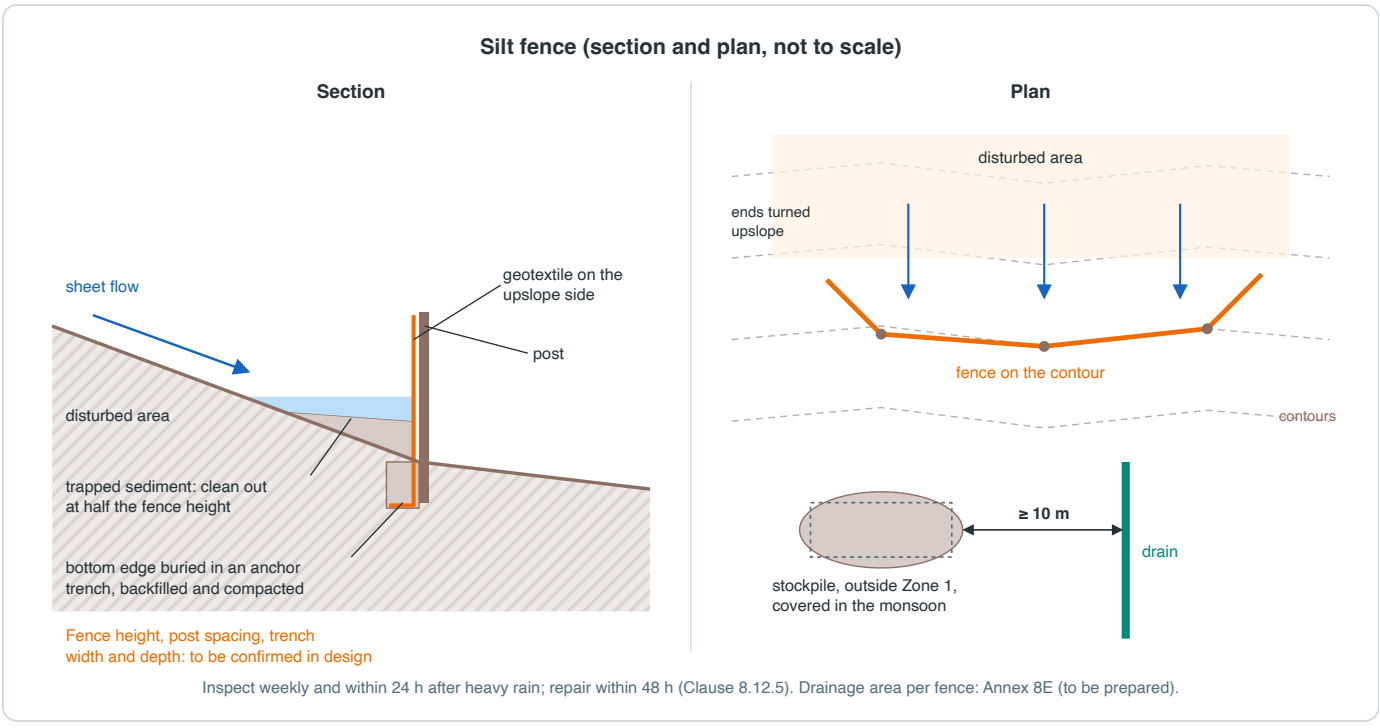



*Figure 8E.1 — Silt fence: section showing geotextile on posts with the bottom edge buried in an anchor trench on the upslope side, and plan showing the fence on the contour with returns at the ends. Dimensions not set by the Manual are to be confirmed in design. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022), and CIRIA, The SuDS Manual (C753), 2015.*

**To be prepared.** Clause 8.12.3(a) refers to this annex for the limit on the area draining to each silt fence. That limit, and the maximum slope length above a fence, need to be set by the State Stormwater Technical Committee for Meghalaya rainfall. Until they are published, the following interim limits apply, taken from common US practice (US EPA, Stormwater Best Management Practice fact sheet: Silt Fence):

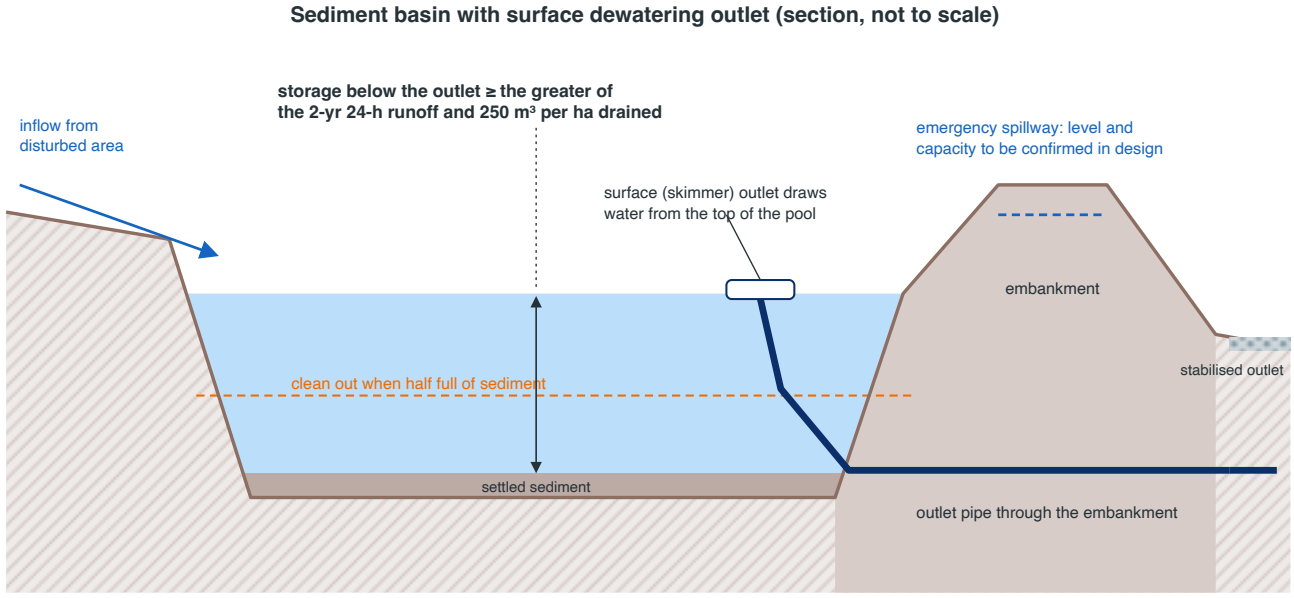
- drainage area: not more than **0.1 ha per 30 m** of fence;
- slope length above the fence: not more than 30 m on slopes under 2%, 23 m at 2–5%, 15 m at 5–10%, 8 m at 10–20% and 5 m steeper than 20%;
- wherever flow arrives concentrated, or a limit cannot be met, a sediment trap (Figure 8E.2) is used instead.

The designer shall show the drainage area and slope length served by each fence on the ESC plan.

Notes:

1. Place along the contour at the downslope edge of the disturbed area, never across a concentrated flow path.
2. Turn the ends upslope so that water cannot run round them.
3. Inspect weekly and within 24 hours after every heavy-rainfall event; repair within 48 hours; remove sediment when the deposit reaches half the fence height (Clause 8.12.5).
4. Remove only after the area draining to it is stabilised (Clause 8.12.6).
5. Stockpiles: outside Zone 1, at least 10 m from any drain, and covered during the monsoon (Clause 8.12.3(f)).

## 8E.2 Sediment trap and sediment basin




Sediment trap: disturbed area up to 2 ha. Sediment basin: more than 2 ha (Clause 8.12.3(b), (c)).
Design rainfall from Chapter 2 with climate factor 1.0 (Clause 8.12.4). Dewatering of excavations passes through the basin, a settling tank or a filter bag.

*Figure 8E.2 — Sediment trap or basin in section: inflow, storage volume below the outlet, surface dewatering outlet (skimmer) drawing water from the top of the pool, emergency spillway, and sediment cleanout level at half the storage. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022).*

Notes:

1. **Sediment trap:** for concentrated flow from disturbed areas of up to 2 ha (Clause 8.12.3(b)). Storage volume, depth and outlet: to be confirmed in design.

2. **Sediment basin:** for disturbed areas of more than 2 ha. Storage below the outlet ≥ the greater of (a) the runoff from the 50% AEP (2-yr) 24-hour storm and (b) 250 m³ per hectare of drainage area (Clause 8.12.3(c)).
3. The dewatering outlet draws water from the surface (Clause 8.12.3(c)).
4. An emergency spillway and its capacity: to be confirmed in design. Where the basin is also a permanent detention facility, the Chapter 4 spillway rules apply.
5. Clean out when half full of sediment (Clause 8.12.5). Remove sediment from any permanent facility before its as-built survey (Clause 8.12.6).
6. Dewatering of excavations shall pass through a sediment basin, settling tank or filter bag (Clause 8.12.3(g)).

**Illustrative — not design values.** A sediment basin serves 3.0 ha of disturbed land. Assume a 2-yr 24-hour rainfall of 100 mm (climate factor 1.0, Clause 8.12.4) and a curve number of 86 for bare compacted ground under the antecedent moisture condition of Chapter 2.

- $S = 25{,}400 / 86 - 254 = 41.35$ mm; $I_a = 0.2S = 8.27$ mm
- $Q = (P - I_a)^2 / (P - I_a + S) = (100 - 8.27)^2 / (100 - 8.27 + 41.35) = 8{,}414 / 133.08 = 63.2$ mm
- (a) Runoff volume = $10 \times Q \times A = 10 \times 63.2 \times 3.0 = 1{,}896$ m³
- (b) 250 m³/ha × 3.0 ha = 750 m³
- Required storage below the outlet = max (1,896, 750) = 1,896 m³. Here the 2-yr runoff governs.

## 8E.3 Stabilised construction exit and concrete washout

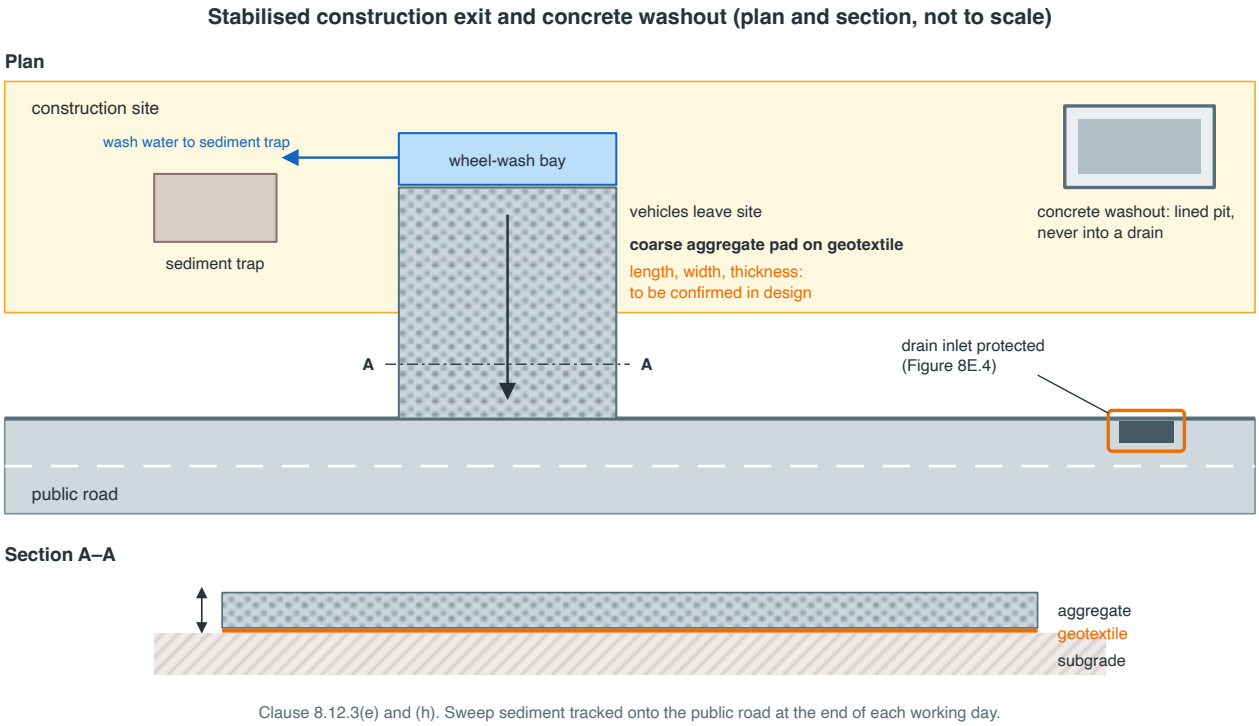



*Figure 8E.3 — Stabilised construction exit: plan and section showing a coarse aggregate pad on geotextile between the site and the public road, a wheel-wash bay draining to a sediment trap, and a lined concrete washout pit. Dimensions not set by the Manual are to be confirmed in design. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022).*

Notes:

1. Provide at every point where vehicles leave the site onto a public road, with wheel washing (Clause 8.12.3(e)).
2. Pad length, width, thickness and aggregate size: to be confirmed in design.
3. Wash water drains to a sediment trap or basin, never to a drain.
4. Concrete washout in a lined pit, never into a drain (Clause 8.12.3(h)).

5. Sweep any sediment tracked onto the public road at the end of each working day.

## 8E.4 Inlet protection

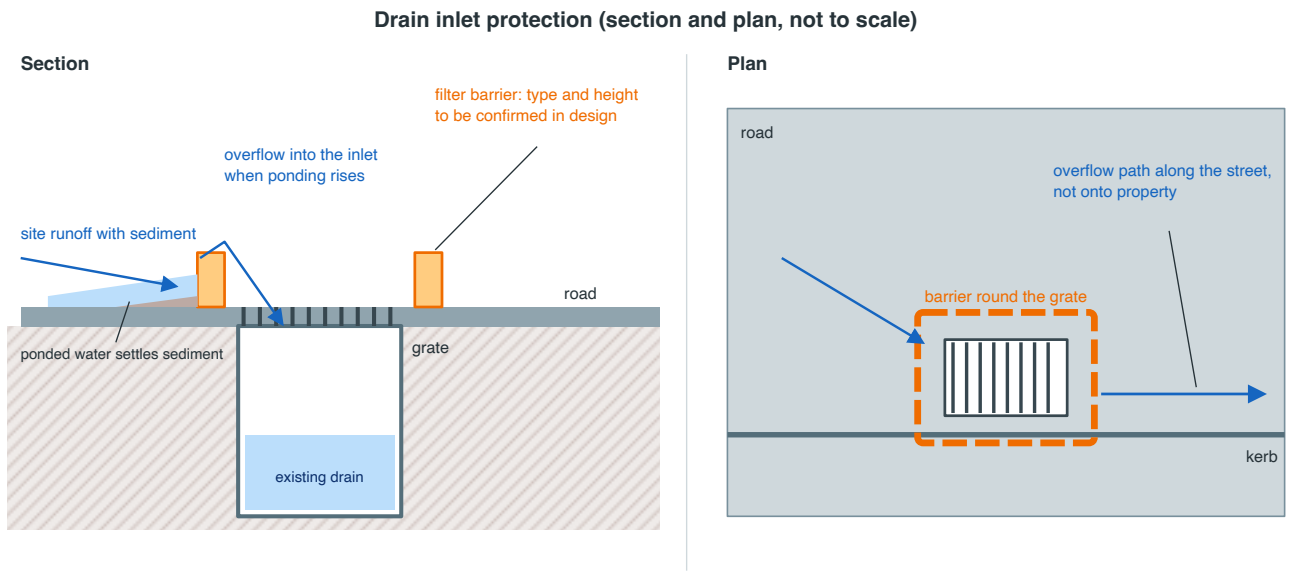



*Figure 8E.4 — Inlet protection at an existing drain inlet: a filter barrier around a grate or kerb inlet, with an overflow path so that ponding does not flood the road or property. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022), and CIRIA, The SuDS Manual (C753), 2015.*

Notes:

1. At every existing drain inlet that receives runoff from the site (Clause 8.12.3(d)).
2. The protection must not block the inlet: water ponding behind it must be able to overflow into the inlet or along the street.
3. Barrier type and height: to be confirmed in design.
4. Remove sediment after each heavy-rainfall event (Clause 8.12.5).

## 8E.5 Timing and inspection

**Table 8E.2 — ESC timing and inspection (Clauses 8.12.2 and 8.12.5)**

| Item | Requirement |
|---|---|
| Completed earthworks | Stabilised by vegetation, mulch, matting or paving by 31 March |
| Area cleared between 1 April and 31 October | Sediment controls in place before clearing |
| Area exposed in the monsoon | As small as practicable |
| Inspection | Weekly, and within 24 h after every heavy-rainfall event (Chapter 10) |
| Repair | Within 48 h |
| Cleaning | When half full of sediment |
| Removal | Only after the area draining to the measure is stabilised |

## Form 8-1 — Water Quality Sheet

Supports Clauses 8.4, 8.6 and 8.14 of Chapter 8.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

### Table 8F.1 — Form 8-1, Section A: Site and rainfall

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Project name and Authority file number | _____ | — |
| A2 | Tier (A / B) and site area, ha | _____ | 8.6.1 |
| A3 | Rainfall zone (Chapter 2) | _____ | 8.4.1 |
| A4 | P_ret, mm (Annex 2E) | _____ | 8.4.1 |
| A5 | P_3m, mm (Annex 8A, or the interim calculation: record, years, method) | _____ | 8.4.1 |
| A6 | P_wq = max (P_ret, P_3m), mm (no climate factor) | _____ | 8.4.1, 8.4.3 |
| A7 | WQv method: SCS-CN, or Rv (sites < 0.5 ha and Tier B simplified method only) | _____ | 8.4.2 |
| A8 | Redevelopment (existing impervious ≥ 20%)? | _____ | 8.6.2 |

### Table 8F.2 — Form 8-1, Section B: Water quality volume and flow by drainage area

| Area ID | Area (ha) | Impervious I (%) | Q_wq runoff depth (mm) or Rv | WQv ($m^3$) | Q_wq ($m^3/s$) | Volume retained, Chapter 4 ($m^3$) | WQv not retained ($m^3$) | BMP serving the area | Pretreatment |
|---|---|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Total | _____ | | | _____ | | _____ | _____ | | |

### Table 8F.3 — Form 8-1, Section C: Level of Service and Value Rating (Tier A)

| No. | Field | Entry | Clause |
|---|---|---|---|
| C1 | CN pre-development; CN post-development; ΔCN | _____ | 8.6.2 |
| C2 | Required LoS (Table 8.2, or Annex 8B for redevelopment) | _____ | 8.6.2 |
| C3 | Composite VR (Annex 8B calculation attached) | _____ | 8.6.3 |
| C4 | Composite VR ≥ required LoS? | _____ | 8.6.3 |
| C5 | Tier B: route used under Clause 8.6.5 (a) retained on site / (b) bioretention, rain garden or infiltration | _____ | 8.6.5 |

### Table 8F.4 — Form 8-1, Section D: Other submittals (Clause 8.14)

| No. | Item | Attached (yes / no / not applicable) | Clause |
|---|---|---|---|
| D1 | BMP designs to Clause 8.7 and Annex 8D, with pretreatment | _____ | 8.14(3) |

| No. | Item | Attached (yes / no / not applicable) | Clause |
|---|---|---|---|
| D2 | Infiltration Test Record (Form 8-2), seasonal high groundwater level and source, design rate, drawdown time, setbacks | _____ | 8.14(4) |
| D3 | Sewage and sullage connection plan; dye or smoke test record | _____ | 8.9.2, 8.14(5) |
| D4 | GPT and first-flush design for any outfall to a waterbody | _____ | 8.10, 8.14(6) |
| D5 | RWH layout separating harvesting, recharge and detention | _____ | 8.11, 8.14(7) |
| D6 | ESC plan | _____ | 8.12, 8.14(8) |
| D7 | Hotspot controls, where Clause 8.8.8 applies | _____ | 8.8.8 |

### Table 8F.5 — Form 8-1, Section E: Prepared by

| Field | Entry |
|---|---|
| Name, registration and empanelment number (Clause 10.6) | _____ |
| Signature and date | _____ |

## Form 8-2 — Infiltration Test Record

Supports Clauses 8.8.1 to 8.8.7 and 8.11.4 of Chapter 8.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* One record per facility. Attach a plan showing the test locations, and the readings for each test.

**Table 8F.6 — Form 8-2, Section A: Facility**

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Project and facility ID; facility type | _____ | 8.8.3 |
| A2 | Infiltration base area (m²) or trench length (m) | _____ | 8.8.3(c) |
| A3 | Proposed base level of the facility, m (datum) | _____ | 8.8.3 |
| A4 | Runoff source: roof only / paved surfaces / mixed; hotspot (yes / no) | _____ | 8.8.6, 8.8.8 |
| A5 | Ground setting: sandy coastal / laterite or hard rock / delta clay or black cotton / other | _____ | 8.8.9–8.8.11 |

**Table 8F.7 — Form 8-2, Section B: Tests**

| Test no. | Location (grid ref.) | Date | Method: double-ring (ASTM D3385) / falling-head borehole or trial-pit soakage (e.g. BRE Digest 365) | Test level, m | Groundwater level at time of test, m | Measured rate (mm/h) |
|---|---|---|---|---|---|---|
| 1 | _____ | _____ | _____ | _____ | _____ | _____ |
| 2 | _____ | _____ | _____ | _____ | _____ | _____ |
| 3 | _____ | _____ | _____ | _____ | _____ | _____ |

Minimum number of tests: 2 per facility, and 1 per 100 m² of base area or per 50 m of trench (Clause 8.8.3(c)).

**Table 8F.8 — Form 8-2, Section C: Design rate and drawdown**

| No. | Item | Entry | Clause |
|---|---|---|---|
| C1 | Number of tests made; number required | _____ | 8.8.3(c) |
| C2 | Highest and lowest measured rates; ratio (highest ÷ lowest) | _____ | 8.8.4 |
| C3 | Safety factor: 2.0 (tests meet 8.8.3(c) and ratio ≤ 2) or 3.0 | _____ | 8.8.4 |
| C4 | Design rate = measured rate used ÷ safety factor, mm/h (state which measured rate was used) | _____ | 8.8.4 |
| C5 | Category: ≥ 13 mm/h full infiltration / 3–13 mm/h partial with underdrain / < 3 mm/h no credit | _____ | 8.8.5 |
| C6 | Depth of water to infiltrate, mm; drawdown time = depth ÷ design rate, h (≤ 72 h) | _____ | 8.8.7 |

**Table 8F.9 — Form 8-2, Section D: Separation and setbacks**

| No. | Item | Entry | Clause |
|---|---|---|---|
| D1 | Seasonal high groundwater level, m, and its source (Clause 3.10.2) | _____ | 8.8.1 |
| D2 | Separation from facility base to seasonal high groundwater, m (≥ 1.0; ≥ 0.5 for roof-only runoff in notified coastal sand with mounding check) | _____ | 8.8.1, 8.8.9(d) |

| No. | Item | Entry | Clause |
|---|---|---|---|
| D3 | Depth to bedrock or impermeable layer below base, m (≥ 1.0 unless Clause 8.8.10) | _____ | 8.8.2 |
| D4 | Distances to: foundations / basement / property boundary / drinking-water well or borewell / septic tank or soak pit / crest of slope steeper than 1V:3H, m | _____ | 8.8.6 |
| D5 | Expansive soils: foundation setback doubled? | _____ | 8.8.11(b) |

### Table 8F.10 — Form 8-2, Section E: Declaration

| Field | Entry |
|---|---|
| Tester: name, qualification in geotechnical testing, organisation | _____ |
| I certify that the tests were made at the stated locations and levels, by the stated methods, and that the readings attached are complete. Signature and date | _____ |
| Designer (Clause 10.6): name and signature | _____ |

ANNEXES TO CHAPTER 9

# Hydraulic Design of Structures

These annexes support Chapter 9. Annex 9A gives the FHWA HDS-5 inlet-control equations in SI units, with published coefficients for common inlets, and a full worked culvert example. Annex 9B gives standard drawings that carry only the dimensions Chapter 9 and Chapter 6 already set; every other dimension is marked "to be confirmed in design". Annex 9C is a pump station design checklist with a standard control philosophy drawn from Clause 9.9. Form 9-1 is a draft form: it lists what Clause 9.14 requires and does not add to it.

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## Annex 9A — HDS-5 inlet-control coefficients and worked culvert example in SI units

Supports Clauses 9.4.1 to 9.4.7 of Chapter 9 and Clause 6.12 of Chapter 6.

### 9A.1 Inlet-control equations

FHWA *Hydraulic Design of Highway Culverts*, HDS-5, 3rd edition (2012), Appendix A, gives three inlet-control equations. In SI units:

> Unsubmerged, Form 1: HWi/D = Hc/D + K · [Ku · Q / (A · D^0.5)]^M + Ks · S

> Unsubmerged, Form 2: HWi/D = K · [Ku · Q / (A · D^0.5)]^M

> Submerged: HWi/D = c · [Ku · Q / (A · D^0.5)]² + Y + Ks · S

where HWi is the headwater depth above the inlet invert under inlet control (m), D is the interior height (rise) of the barrel (m), Hc is the specific head at critical depth, dc + Vc²/2g (m), Q is the discharge (m³/s), A is the full cross-sectional area of the barrel (m²), S is the barrel slope (m/m), K, M, c and Y are the constants of Table 9A.1, Ku = 1.811 in SI units (1.0 in US units), and Ks is the slope correction: −0.5, or +0.7 for mitred inlets.

Which equation applies depends on X = Ku · Q / (A · D^0.5):

- X ≤ 3.5: unsubmerged equation (Form 1 or Form 2 as listed in Table 9A.1);
- X ≥ 4.0: submerged equation;
- 3.5 < X < 4.0 (transition): use FHWA HY-8, which implements the HDS-5 transition. Where a hand calculation is used, take the higher of the unsubmerged and submerged results. This is a conservative simplification made by this annex, not an HDS-5 rule.

**Table 9A.1 — HDS-5 inlet-control coefficients for common inlets**

| Barrel | Inlet edge | Form | K | M | c | Y |
|---|---|---|---|---|---|---|
| Circular concrete | Square edge with headwall | 1 | 0.0098 | 2.0 | 0.0398 | 0.67 |
| Circular concrete | Groove (socket) end with headwall | 1 | 0.0018 | 2.0 | 0.0292 | 0.74 |
| Circular concrete | Groove (socket) end projecting | 1 | 0.0045 | 2.0 | 0.0317 | 0.69 |
| Circular corrugated metal | Headwall | 1 | 0.0078 | 2.0 | 0.0379 | 0.69 |
| Circular corrugated metal | Mitred to slope | 1 | 0.0210 | 1.33 | 0.0463 | 0.75 |
| Circular corrugated metal | Projecting | 1 | 0.0340 | 1.50 | 0.0553 | 0.54 |
| Rectangular box | Wingwalls flared 30° to 75° | 1 | 0.026 | 1.0 | 0.0347 | 0.81 |
| Rectangular box | Wingwalls flared 90° and 15° | 1 | 0.061 | 0.75 | 0.0400 | 0.80 |
| Rectangular box | Wingwalls at 0° (extensions of the sides) | 1 | 0.061 | 0.75 | 0.0423 | 0.82 |
| Rectangular box | 90° headwall with 19 mm (3/4 in) chamfers | 2 | 0.515 | 0.667 | 0.0375 | 0.79 |
| Rectangular box | 90° headwall with 45° bevels | 2 | 0.495 | 0.667 | 0.0314 | 0.82 |
| Rectangular box | 90° headwall with 33.7° bevels | 2 | 0.486 | 0.667 | 0.0252 | 0.865 |

Source: FHWA HDS-5 (2012), Appendix A, Table A.1 (the coefficients are dimensionless and apply in SI units with Ku = 1.811). The values were checked against HIF-12-026, Table A.1 (chart and scale numbers 1/1–1/3, 2/1–2/3, 8/1–8/3 and 10/1–10/3). Where a later edition of HDS-5 differs, the later table governs. Entrance loss coefficients for outlet control are in Table 9.1 of Chapter 9.

## 9A.2 Worked example: pipe culvert under a collector road

*Illustrative — not design values.* The inputs below are invented to show the method; the results are not design values for any site.

**Inputs.**

**Table 9A.2 — Inputs for the worked example**

| Item | Value | Source |
|---|---|---|
| Road class | Collector; design AEP 4% (25-yr), check event 2% (50-yr), and the 1% AEP check | Table 6.1, Clause 6.12.2 |
| Design flow, 4% AEP | 1.80 m³/s (including the climate factor) | Illustrative |
| Check flow, 2% AEP | 2.20 m³/s | Illustrative |
| 1% AEP flow | 3.00 m³/s | Illustrative |
| Barrel | One 1,200 mm RCC pipe with collar joints, n = 0.015 | Table 6.6 |
| Inlet | Square edge with headwall: ke = 0.5; K = 0.0098, M = 2.0, c = 0.0398, Y = 0.67, Form 1 | Tables 9.1 and 9A.1 |
| Length and slope | L = 20.0 m; S = 0.005 (inlet invert 20.00 m, outlet invert 19.90 m, local datum) | Illustrative |
| Road levels at the inlet | Shoulder edge 22.00 m; lowest point of the road crest 22.10 m | Illustrative |
| Tailwater above the outlet invert, TW | 0.60 m at 1.80 m³/s; 0.70 m at 2.20 m³/s; 0.85 m at 3.00 m³/s (normal depth in the downstream channel) | Illustrative; Clause 9.4.4 |
| Receiving channel | Unlined sandy loam | Table 9.2 |

Minimum size: 1,200 mm ≥ 900 mm (Clause 6.12.5). The span is below 1.5 m, so the blockage check uses 50% of the inlet area blocked (Clause 6.12.4(a)).

**Step 1 — Barrel properties.** A = π · 1.2² / 4 = 1.131 m²; full-barrel hydraulic radius R = D/4 = 0.300 m; D^0.5 = 1.095.

**Step 2 — Critical depth.** For each flow, dc is found by trial from the critical-flow condition for a circular section, $Q^2 \cdot T / (g \cdot Ac^3) = 1$, where Ac and T are the flow area and top width at depth dc.

**Table 9A.3 — Critical depth and specific head (D = 1.2 m)**

| Q (m³/s) | dc (m) | Ac (m²) | T (m) | Vc = Q/Ac (m/s) | Hc = dc + Vc²/2g (m) | Hc/D |
|---|---|---|---|---|---|---|
| 1.80 | 0.737 | 0.728 | 1.168 | 2.471 | 1.048 | 0.873 |
| 2.20 | 0.817 | 0.820 | 1.119 | 2.683 | 1.184 | 0.987 |
| 3.00 | 0.952 | 0.962 | 0.972 | 3.118 | 1.447 | 1.206 |

**Step 3 — Headwater under inlet control.** X = 1.811 · Q / (1.131 × 1.095) = 1.462 · Q.

**Table 9A.4 — Inlet-control headwater**

| Q (m³/s) | X | Equation | HWi/D | HWi (m) |
|---|---|---|---|---|
| 1.80 | 2.631 | Unsubmerged, Form 1: 0.873 + 0.0098 × 2.631² − 0.5 × 0.005 = 0.873 + 0.068 − 0.003 | 0.939 | 1.127 |
| 2.20 | 3.216 | Unsubmerged, Form 1: 0.987 + 0.0098 × 3.216² − 0.003 = 0.987 + 0.101 − 0.003 | 1.085 | 1.302 |
| 3.00 | 4.385 | Submerged: 0.0398 × 4.385² + 0.67 − 0.003 = 0.765 + 0.67 − 0.003 | 1.433 | 1.719 |

**Step 4 — Headwater under outlet control** (Clause 9.4.3). The friction term is 19.63 · n² · L / R^1.33 = 19.63 × 0.015² × 20.0 / 0.300^1.33 = 0.0883 / 0.2016 = 0.438, so H = (1 + 0.5 + 0.438) · V²/2g = 1.938 · V²/2g. L · S = 20.0 × 0.005 = 0.100 m.

**Table 9A.5 — Outlet-control headwater**

| Q (m³/s) | V = Q/A (m/s) | V²/2g (m) | H (m) | (dc + D)/2 (m) | TW (m) | ho (m) | HWo = ho + H − L·S (m) |
|---|---|---|---|---|---|---|---|
| 1.80 | 1.592 | 0.129 | 0.250 | 0.969 | 0.60 | 0.969 | 1.119 |
| 2.20 | 1.945 | 0.193 | 0.374 | 1.009 | 0.70 | 1.009 | 1.283 |
| 3.00 | 2.653 | 0.359 | 0.695 | 1.076 | 0.85 | 1.076 | 1.671 |

**Step 5 — Governing headwater** (Clause 9.4.1): the greater of HWi and HWo.

**Table 9A.6 — Governing headwater and checks**

| Event | Q (m³/s) | HWi (m) | HWo (m) | Control | HW (m) | HW level (m) | HW/D |
|---|---|---|---|---|---|---|---|
| Design, 4% AEP | 1.80 | 1.127 | 1.119 | Inlet | 1.127 | 21.13 | 0.94 |
| Check, 2% AEP | 2.20 | 1.302 | 1.283 | Inlet | 1.302 | 21.30 | 1.09 |
| 1% AEP | 3.00 | 1.719 | 1.671 | Inlet | 1.719 | 21.72 | 1.43 |

**Step 6 — Headwater limits at the design AEP** (Clause 9.4.5):

- (a) HW/D = 0.94 ≤ 1.2. Complies.
- (b) HW level 21.13 m ≤ shoulder edge 22.00 m − 0.30 m = 21.70 m. Complies.

- (c) Water levels at upstream buildings and property boundaries are compared with the existing condition under Clause 6.12.2(d). This needs the upstream survey and is not shown here.

**Step 7 — Road overtopping** (Clauses 6.12.2, 6.12.3 and 9.4.6). The 1% AEP headwater level, 21.72 m, is below the lowest road crest, 22.10 m, so the road is not overtopped in the check or 1% AEP events. Had the headwater exceeded the crest, the overtopping flow Qr = Cd · L · h^1.5 (Cd ≤ 1.66) would be balanced with the culvert flow at a common headwater, and the overtopping depth checked against Clause 6.12.2(a).

**Step 8 — Outlet velocity** (Clause 9.4.7). Under inlet control, the outlet velocity is the velocity at normal depth in the barrel. The barrel's full-flow capacity is (1/n) · A · R^(2/3) · S^0.5 = (1/0.015) × 1.131 × 0.448 × 0.0707 = 2.39 m³/s.

- 1.80 m³/s: normal depth 0.778 m, outlet velocity 2.32 m/s.
- 2.20 m³/s: normal depth 0.908 m, outlet velocity 2.40 m/s.
- 3.00 m³/s: above the full-flow capacity, so the barrel flows full at the outlet; velocity = Q/A = 2.65 m/s.

The receiving channel is unlined sandy loam, with a permissible velocity of 0.53 m/s (Table 9.2), so outlet protection is required (Clause 9.6.1). All barrel velocities are below 3.0 m/s (Clause 6.7.3(b)).

**Step 9 — Riprap apron** (Clause 9.6.3; Figure 9.2). D50 = 0.2 · D · [Q / (g^0.5 · D^2.5)]^(4/3) · (D/TW), with g^0.5 · D^2.5 = 3.132 × 1.577 = 4.941.

**Table 9A.7 — Riprap apron sizing**

| Q (m³/s) | TW (m) | Q / (g^0.5 · D^2.5) | [ ]^(4/3) | D50 (m) |
|---|---|---|---|---|
| 1.80 | 0.60 | 0.364 | 0.260 | 0.2 × 1.2 × 0.260 × 2.00 = 0.125 |
| 2.20 | 0.70 | 0.445 | 0.340 | 0.2 × 1.2 × 0.340 × 1.71 = 0.140 |
| 3.00 | 0.85 | 0.607 | 0.514 | 0.2 × 1.2 × 0.514 × 1.41 = 0.174 |

Clause 9.4.7 requires the outlet to be protected for the design AEP and the 1% AEP, so the apron is sized here for the largest D50, 0.174 m. From Table 9.3, Class 2 (D50 = 150 mm) is too small, so **Class 3** (D50 = 250 mm) is used:

- apron length 5D = 5 × 1.2 = 6.0 m;
- apron thickness 2.4 × D50 = 2.4 × 0.25 = 0.60 m;
- apron width at the outlet at least 3D = 3.6 m, flaring to the downstream channel;
- stone placed on a granular filter or geotextile (Clause 9.6.4).

**Step 10 — Blockage check** (Clause 6.12.4(a)). Steps 3 to 7 are repeated for the 1% AEP flow with 50% of the inlet area blocked, and the results must meet Clause 6.12.2(a) and (d). This Manual does not yet set a standard way of representing a partly blocked inlet, so this check is carried out in HY-8 or by a method agreed with the Approving Authority. It is not worked here.

**Table 9A.8 — Summary of the worked example (Illustrative — not design values)**

| Check | Result | Clause |
|---|---|---|
| Minimum size | 1,200 mm ≥ 900 mm | 6.12.5 |
| Design HW/D | 0.94 ≤ 1.2 | 9.4.5(a) |
| Design HW below shoulder edge | 21.13 m ≤ 21.70 m | 9.4.5(b) |
| Overtopping in the check and 1% events | None (21.72 m < 22.10 m) | 6.12.2, 9.4.6 |
| Outlet protection | Class 3 riprap apron, 6.0 m long, 0.60 m thick, 3.6 m wide at the outlet | 9.6.1, 9.6.3 |
| Blockage check | To be run in HY-8 or by an agreed method | 6.12.4 |

## Annex 9B — Standard drawings: headwalls, riprap aprons, drop structures, trash racks, detention risers

Supports Clauses 9.4, 9.6, 9.7 and 9.8 of Chapter 9.

The drawings below are schematic standard drawings. They show only the dimensions and rules that Chapter 9 and Chapter 6 set. Structural dimensions, reinforcement, foundations and fixings are to be confirmed in design (Clause 9.1.2). The riprap apron standard drawing is Figure 9.2 of Chapter 9, with dimensions from Table 9.3; it is not repeated here. Table 9B.1 lists the dimensions shown and their source clauses.

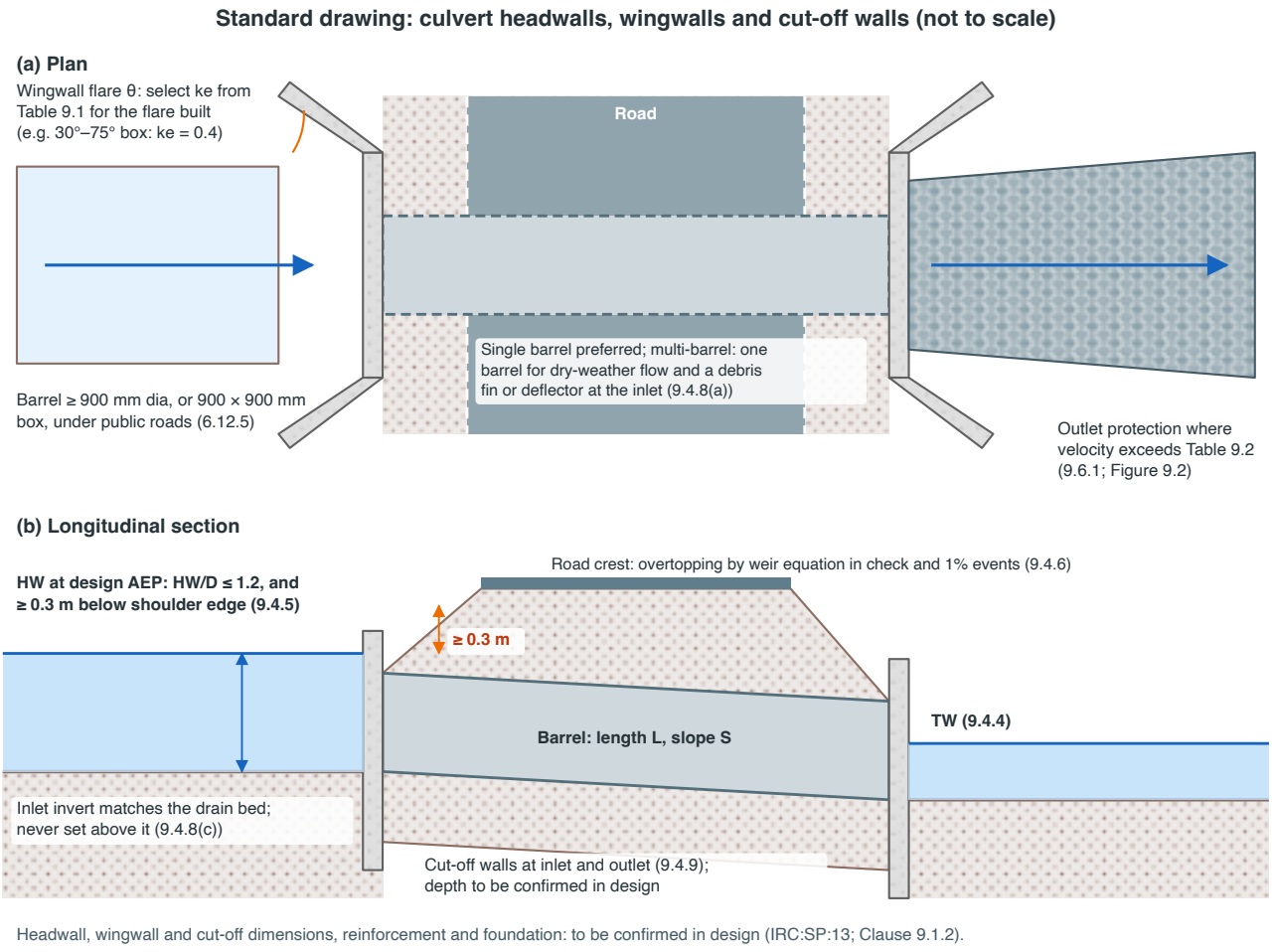


*Figure 9B.1 — Standard drawing: culvert headwalls, wingwalls and cut-off walls, in plan and long section, with the headwater limits, invert rule and debris provisions. Original drawing for this Manual, adapted from FHWA, Hydraulic Design of Highway Culverts, HDS-5 (3rd ed., 2012).*

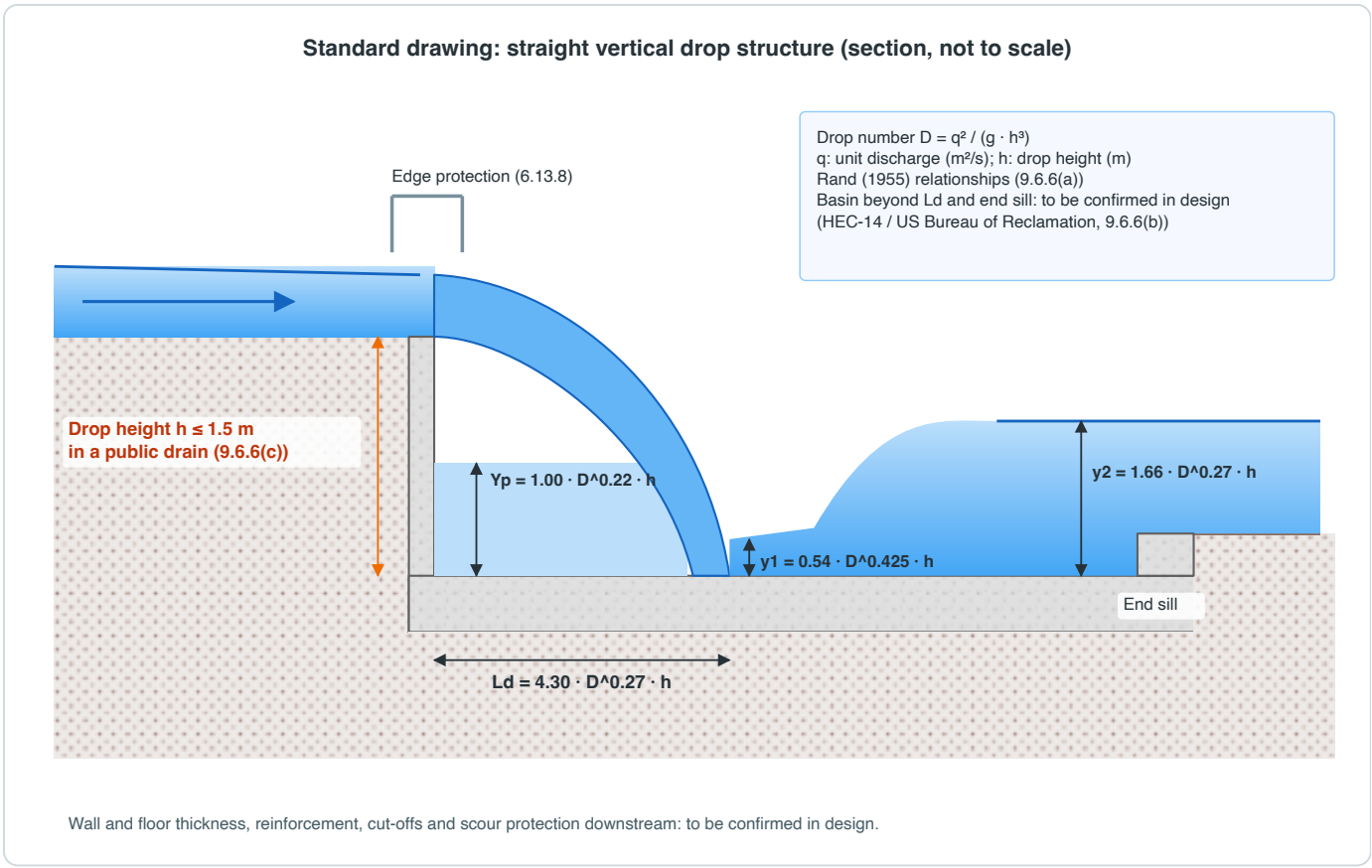


*Figure 9B.2 — Standard drawing: straight vertical drop structure with the Rand (1955) pool geometry and the 1.5 m height limit. Original drawing for this Manual, adapted from Chow, Open-Channel Hydraulics (1959), and FHWA, HEC-14 (3rd ed., 2006).*

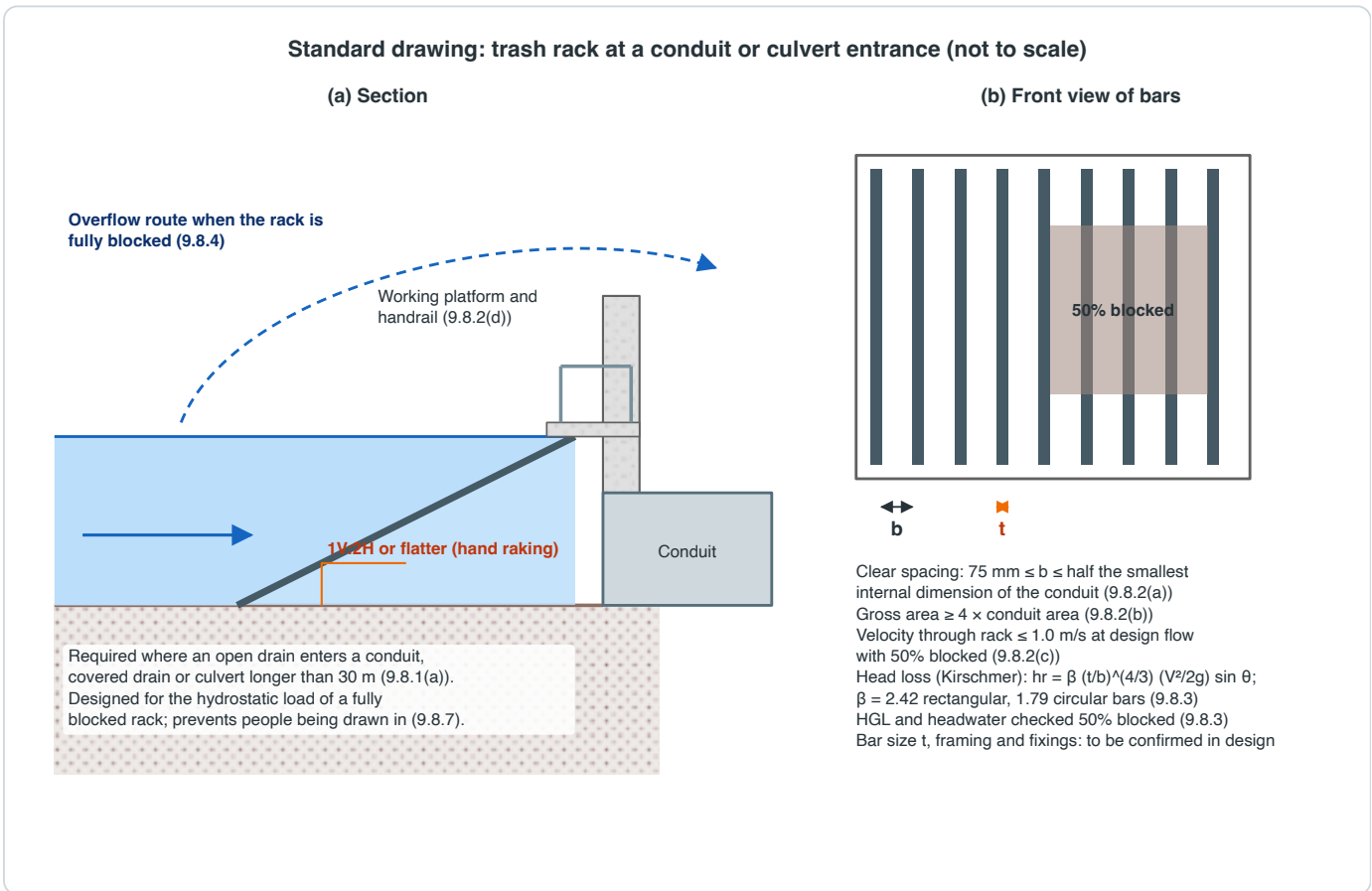

*Figure 9B.3 — Standard drawing: trash rack at a conduit or culvert entrance, in section and front view, with bar spacing, area, velocity, slope and overflow requirements. Original drawing for this Manual, adapted from CIRIA, Culvert, screen and outfall manual, C786 (2019), and CPHEEO, Manual on Storm Water Drainage Systems (2019), §8.3.1.3.*

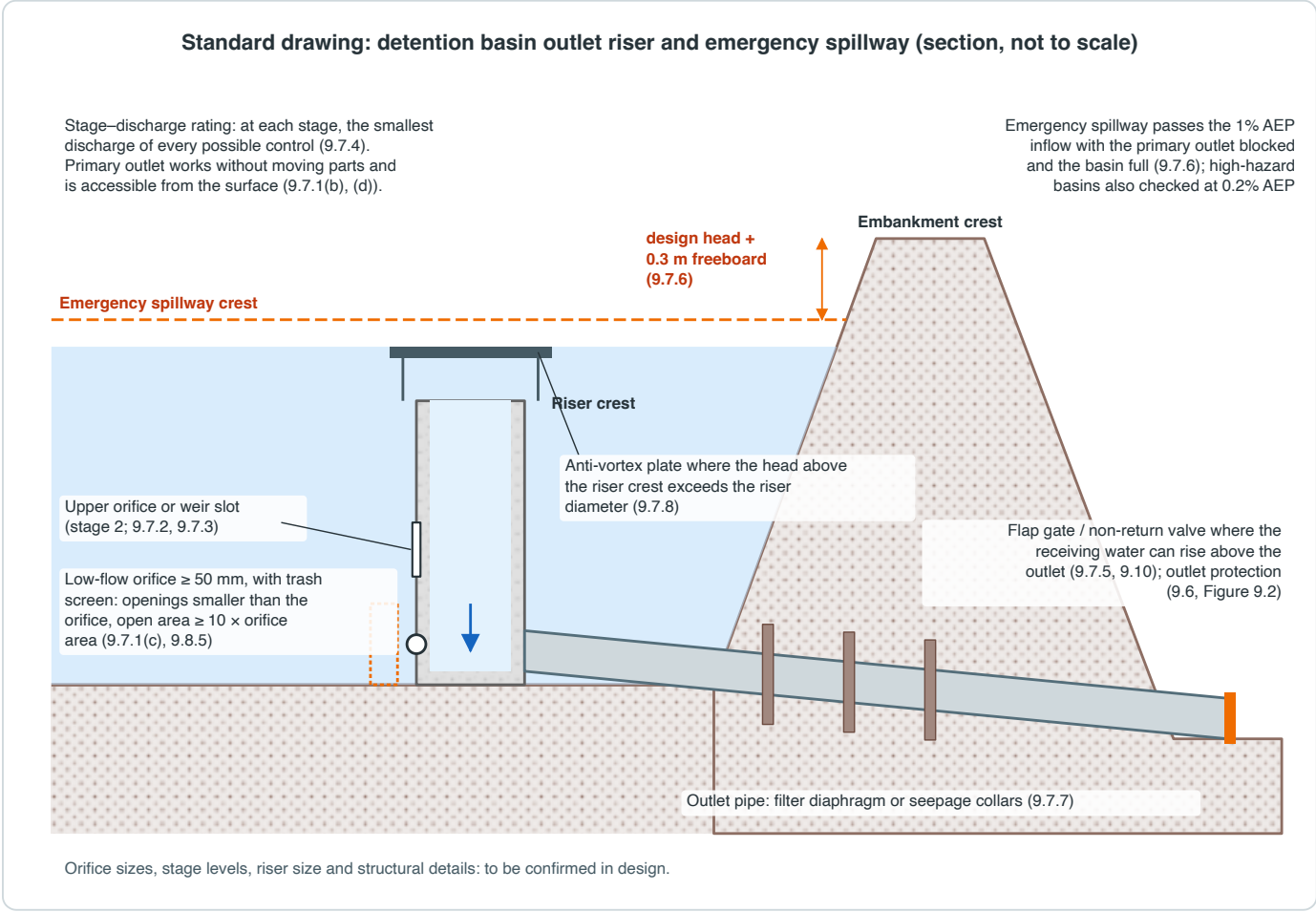


*Figure 9B.4 — Standard drawing: detention basin outlet riser with low-flow orifice and screen, upper stage, anti-vortex plate, outlet pipe through the embankment, flap gate and emergency spillway. Original drawing for this Manual, adapted from Kansas City Metro APWA, Section 5600 (2006, 5608.4).*

### Table 9B.1 — Dimensions and rules on the standard drawings and their source clauses

| Drawing | Item | Dimension or rule | Clause |
|---|---|---|---|
| 9B.1 | Minimum culvert size under public roads | 900 mm diameter, or 900 mm × 900 mm box | 6.12.5 |
| 9B.1 | Headwater at the design AEP | HW/D ≤ 1.2; at least 0.3 m below the shoulder edge at the upstream face | 9.4.5 |
| 9B.1 | Entrance loss coefficient | From Table 9.1 for the inlet built (for example 0.4 for a box with wingwalls at 30°–75°) | 9.4.3 |
| 9B.1 | Inverts | Match the drain bed; never above it | 9.4.8(c) |
| 9B.1 | Multi-barrel culverts | Avoided in debris-prone drains; where used, one barrel for dry-weather flow and a debris fin or deflector | 9.4.8(a) |
| 9B.1 | Headwalls, wingwalls, cut-off walls | Required; dimensions to be confirmed in design | 9.4.9 |
| 9B.1 | Road overtopping | Qr = Cd · L · h^1.5, Cd ≤ 1.66 | 9.4.6 |
| Figure 9.2 | Riprap apron | Width at the outlet ≥ 3D, flaring to the channel; length and thickness from Table 9.3; filter or geotextile | 9.6.3, 9.6.4 |

| Drawing | Item | Dimension or rule | Clause |
|---|---|---|---|
| 9B.2 | Single vertical drop in a public drain | Height h ≤ 1.5 m; edge protection | 9.6.6(c), 6.13.8 |
| 9B.2 | Pool geometry | D = q²/(g h³); Ld/h = 4.30 D^0.27; Yp/h = 1.00 D^0.22; y1/h = 0.54 D^0.425; y2/h = 1.66 D^0.27 | 9.6.6(a) |
| 9B.2 | Basin beyond Ld, end sill | To be confirmed in design (HEC-14 or US Bureau of Reclamation) | 9.6.6(b) |
| 9B.3 | Where required | Where an open drain enters a conduit, covered drain or culvert longer than 30 m | 9.8.1(a) |
| 9B.3 | Clear bar spacing b | Not less than 75 mm and not more than half the smallest internal dimension of the conduit | 9.8.2(a) |
| 9B.3 | Gross rack area | At least 4 times the conduit area | 9.8.2(b) |
| 9B.3 | Velocity through the rack | Not more than 1.0 m/s at the design flow with 50% blocked | 9.8.2(c) |
| 9B.3 | Inclination | No steeper than 1V:2H where raked by hand; working platform and handrail | 9.8.2(d) |
| 9B.3 | Head loss and blocked check | Kirschmer equation; HGL and headwater checked with 50% blocked | 9.8.3 |
| 9B.3 | Overflow and safety | Overflow route for a fully blocked rack; designed for the full hydrostatic load | 9.8.4, 9.8.7 |
| 9B.4 | Low-flow orifice | Not smaller than 50 mm; trash screen with openings smaller than the orifice and open area at least 10 times the orifice area | 9.7.1(c), 9.8.5 |
| 9B.4 | Orifice and weir flow | Q = Cd · A · (2gh)^0.5, Cd = 0.60 sharp-edged; weir coefficients of Clause 9.7.3 | 9.7.2, 9.7.3 |
| 9B.4 | Stage–discharge rating | Smallest discharge of every possible control at each stage | 9.7.4 |
| 9B.4 | Anti-vortex plate | Where the design head above the riser crest exceeds the riser diameter | 9.7.8 |
| 9B.4 | Outlet pipe through the embankment | Filter diaphragm or seepage collars; flared or headwalled inlet | 9.7.7 |
| 9B.4 | Flap gate or non-return valve | Where the receiving water can rise above the outlet | 9.7.5, 9.10 |
| 9B.4 | Emergency spillway | Passes the 1% AEP inflow with the primary outlet blocked and the basin full, with 0.3 m freeboard to the embankment crest; 0.2% AEP check for high-hazard basins | 9.7.6 |
| All | Structural dimensions, reinforcement, foundations, bar sizes, orifice sizes and stage levels | To be confirmed in design | 9.1.2 |

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## Annex 9C — Pump station design checklist and standard control philosophy

Supports Clauses 9.8.6, 9.9 and 9.10 of Chapter 9, with Clause 6.10.5 of Chapter 6 and the outfall-closed check of Chapter 5.

### 9C.1 Design checklist

Submit this checklist with the pump station design report of Clause 9.14, item 6.

**Table 9C.1 — Pump station design checklist**

| No. | Item | Requirement | Clause | Provided (Yes / No / NA) |
|---|---|---|---|---|
| 1 | Need for pumping | Gravity drainage cannot meet Chapters 5 and 6; reason stated | 9.9.1 | |
| 2 | Inflow | Inflow hydrograph routed through the catchment and any upstream storage | 9.9.2 | |
| 3 | Design standard | Design AEP of the element served; for underpasses, 2% AEP with a 1% AEP check | 9.9.2(a), 6.10.5(a) | |
| 4 | Tidal outfall | Storage plus pumps hold the 48 h design volume with the outfall throttled for the tidal-lock duration (default two high tides of 6 h each) | 9.9.2(b), Chapter 5 | |
| 5 | Head range | Pumps selected from the lowest sump level against the lowest tailwater to the highest tailwater (HAT + surge + 0.3 m); pump and system curves submitted | 9.9.2(c), 9.14 | |
| 6 | Wet-well volume | Greatest of: 5 min of minimum inflow (variable speed and automatic control); 10 to 15 min of peak inflow, or the manufacturer's minimum cycle volume; $V = \Theta \cdot q / 4$ for each constant-speed pump | 9.9.3 | |
| 7 | Duty pumps | Same size where practicable | 9.9.4(a) | |
| 8 | Standby | At least equal to the largest duty pump, and not less than 50% of the number of duty pumps | 9.9.4(b) | |
| 9 | Alternation | Duty and standby roles alternate automatically | 9.9.4(c) | |
| 10 | Pump type | Solids-handling (non-clog); axial-flow only behind a screen meeting Clause 9.8.6 | 9.9.5 | |
| 11 | Sump and intake | Manufacturer's requirements and ANSI/HI 9.8; clear space 0.6 m (small and medium) or 1.0 m (large units) | 9.9.6 | |
| 12 | Model study | Physical model where any pump exceeds 1 $m^3/s$ or the sump departs from ANSI/HI 9.8 geometry | 9.9.6 | |
| 13 | Silt trap and screen | Upstream of the wet well; screen spacing smaller than the pumps' solids size; removable modules; mechanical raking where inflow exceeds 1 $m^3/s$ | 9.9.7, 9.8.6 | |
| 14 | Screen overflow | Overflow route when the screen is fully blocked | 9.8.4 | |
| 15 | Level control | Primary level sensor (ultrasonic, radar or pressure) with an independent float-switch back-up | 9.9.8(a) | |
| 16 | Alarms | High-level and pump-fault alarms by telemetry to the local body's control room | 9.9.8(b) | |
| 17 | Records | Sump levels, pump run hours and power status logged and kept at least 5 years | 9.9.8(c) | |
| 18 | Power sources | Grid supply plus a standby generator or second independent feeder able to run all duty pumps at once | 9.9.9(a) | |
| 19 | Fuel | At least 72 h of all duty pumps, stored above the flood level of Clause 9.9.10 | 9.9.9(b) | |
| 20 | Changeover | Automatic changeover to standby power | 9.9.9(c) | |
| 21 | Flood protection | Electrical and control room floor, generator and transformer at least 0.5 m above the 1% AEP flood level; vehicle access usable in the 1% AEP event | 9.9.10 | |
| 22 | Discharge | Separate rising mains, or a non-return and an isolating valve where mains combine; delivery chamber or outfall with a flap gate or non-return valve; mains sized by a recognised friction formula | 9.9.11 | |

| No. | Item | Requirement | Clause | Provided (Yes / No / NA) |
|---|---|---|---|---|
| 23 | Gates | Flap or tide gate on outfalls below the 1% AEP still-water level; penstock or stop-log slot upstream for outfalls of 900 mm or more and every pumped outfall; head loss from tested data | 9.10.1, 9.10.3, 9.10.4 | |
| 24 | Sand and debris at the outfall | Gate in a chamber with surface access, or elastomeric check valves, at beach, estuary and creek outfalls | 9.10.5 | |
| 25 | Emergency connection | Hard-standing and quick-coupling connection for mobile pumps into the delivery chamber | 9.9.12 | |
| 26 | Materials | Exposure class of Clause 9.13; stainless steel grade 316, galvanised and coated steel, or non-metallic fixings within 5 km of the coast | 9.13 | |
| 27 | Design life | At least 50 years for civil works and 25 years for mechanical and electrical equipment | 9.2.4 | |
| 28 | Underpass stations | Depth markers and automatic warning or closure signals at 150 mm depth on the carriageway | 6.10.5(d) | |
| 29 | Certification | Designed by an empanelled professional and checked by an independent empanelled professional | 10.6.1(d), 10.6.4 | |

## 9C.2 Standard control philosophy

This is the standard control philosophy for a stormwater pump station designed under Clause 9.9. The designer adapts it to the station and submits it with the design report. Items marked "recommended" are good practice that Chapter 9 does not require; all others restate a clause.

**Table 9C.2 — Control levels (values to be set in design)**

| Level | Rule for setting it | Clause |
|---|---|---|
| Pump stop | Not below the minimum submergence required by the pump manufacturer and ANSI/HI 9.8 | 9.9.6 |
| Duty pump 1 start | Above the pump-stop level by at least the effective wet-well volume of Clause 9.9.3 | 9.9.3 |
| Duty pumps 2, 3 … start | Staged above duty pump 1 start; spacing to be confirmed in design | 9.9.2 |
| High-level alarm | Above the highest duty-pump start level; to be confirmed in design | 9.9.8(b) |
| Float back-up high | Independent float; starts the duty pumps | 9.9.8(a) |
| Float back-up low | Independent float; stops the pumps | 9.9.8(a) |

1. **Normal (automatic) operation.** As the wet-well level rises to the duty pump 1 start level, the lead pump starts. If the level keeps rising, each further duty pump starts at its start level. The pumps stop when the level falls to the pump-stop level. The primary level sensor controls this sequence (Clause 9.9.8(a)).
2. **Duty rotation.** The lead pump changes automatically, after each pump-down cycle or by run hours as set in the design, so that duty and standby roles alternate and wear is shared (Clause 9.9.4(c)).
3. **Pump fault.** A pump that trips or fails to start is locked out. The next available pump, including the standby pump, takes its place, and a pump-fault alarm is sent by telemetry (Clauses 9.9.4(b) and 9.9.8(b)).
4. **Level-sensor failure.** If the primary sensor fails, or disagrees with the float switches, control passes to the independent float back-up: at the float-high level the duty pumps run, and at the float-low level they stop. An alarm is sent (Clause 9.9.8(a), (b)).
5. **Power failure.** Supply changes over automatically to the standby generator or second feeder (Clause 9.9.9(c)). Recommended: pumps restart one at a time after changeover, to limit the starting load on the generator.

6. **High level.** At the high-level alarm level an alarm is sent by telemetry to the local body's control room (Clause 9.9.8(b)). At an underpass, the warning or closure signals operate at 150 mm depth on the carriageway (Clause 6.10.5(d)).
7. **Outfall and gates.** Rising mains discharge to a delivery chamber or outfall fitted with a flap gate or non-return valve (Clause 9.9.11). Flap gates open and close under head difference without control action. The upstream penstock or stop logs are closed only for maintenance, or if the flap gate jams open (Clause 9.10.3). Recommended: penstock position is shown at the control panel and logged.
8. **Tide-locked operation.** Where the outfall is tide-locked, storage and pumping together hold the 48 h design volume for the tidal-lock duration (Clause 9.9.2(b) and Chapter 5). Where the station also has a gravity outfall, gravity discharge resumes through the flap gate when the tide falls.
9. **Screens.** Mechanically raked screens (required where inflow exceeds 1 m³/s, Clause 9.8.6) are run automatically. Recommended: raking is started by a timer and by the level difference across the screen, with an alarm when the difference stays high.
10. **Manual operation.** Recommended: each pump has a hand–off–auto selector at the panel, and the float back-up high-level start remains active in hand mode.
11. **Mobile pumps.** When fixed pumps are out of service or overwhelmed, mobile pumps discharge into the delivery chamber through the quick-coupling connection (Clause 9.9.12).
12. **Records.** Sump levels, pump run hours and power status are logged and kept for at least 5 years (Clause 9.9.8(c)). Recommended: alarms, pump starts and stops, and changeovers are logged as well.
13. **Testing.** The controls, floats, alarms, telemetry, changeover and generator are tested in the pre-monsoon inspection of Chapter 10 (Clause 10.12), and the results reported in the Annual Maintenance Declaration (Form 10-7; Clause 10.10.3).

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## Form 9-1 — Hydraulic Structures Report checklist

Supports Clause 9.14 of Chapter 9.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0. Not for statutory use.*

Attach this checklist to the front of the Hydraulic Structures Report. For each item, enter Yes, No or Not applicable, and the drawing or page where it is shown.

### Section A — Project

**Table 9F.1 — Form 9-1, Section A: project**

| Field | Entry |
|---|---|
| Project name and location | _____ |
| Local body, and Tier A or Tier B (Chapter 1) | _____ |
| Applicant | _____ |
| Designer (name and registration) | _____ |
| Structures covered (culverts, channels, dissipators, outlets, screens, pumps, gates, inlets, manholes) | _____ |
| Tailwater conditions used: MHWS, HAT + surge, sea-level allowance, joint case (Clause 9.2.1) | _____ |
| Date and revision | _____ |

### Section B — Contents required by Clause 9.14

**Table 9F.2 — Form 9-1, Section B: contents required by Clause 9.14**

| No. | Item | Clause | Provided (Yes / No / NA) | Drawing or page |
|---|---|---|---|---|
| 1 | Culvert calculations (HDS-5 or HY-8 output) with HWi, HWo, outlet velocity, tailwater, overtopping and the blockage check | 9.4, 6.12 | | |
| 2 | Channel water-surface profiles, velocities, Froude numbers and freeboard | 9.5 | | |
| 3 | Outlet protection and dissipator design, with riprap sizing | 9.6 | | |
| 4 | Detention outlet stage–discharge tables and the emergency spillway check | 9.7 | | |
| 5 | Screen and rack design with the 50% blocked check | 9.8 | | |
| 6 | Pump station design report: inflow hydrograph, storage, pump and system curves, wet-well volume, controls, power supply and the Chapter 5 outfall-closed check (with Annex 9C) | 9.9 | | |
| 7 | Gate and valve selection with head-loss data | 9.10 | | |
| 8 | Inlet, grate and cover load classes | 9.11 | | |
| 9 | Exposure class and materials statement | 9.13 | | |

### Section C — Compliance checks

**Table 9F.3 — Form 9-1, Section C: compliance checks**

| No. | Check | Limit | Clause | Complies (Yes / No / NA) |
|---|---|---|---|---|
| C1 | Climate factor included in design flows | Clause 2.8 | 9.2.2 | |
| C2 | Blocked condition checked where debris can block; safe overflow route | — | 9.2.5 | |
| C3 | Pipes and box drains: design n (box drains ≥ 0.015); supercritical pipes: jump located in a structure, air venting | — | 9.3.1, 9.3.4 | |
| C4 | Pipe size does not decrease downstream; joins only at manholes or junction chambers; no change of direction over 90° | — | 9.3.5 | |
| C5 | Culvert design headwater = greater of HWi and HWo | — | 9.4.1 | |
| C6 | Culvert headwater at the design AEP | HW/D ≤ 1.2; ≥ 0.3 m below shoulder edge | 9.4.5 | |
| C7 | Road overtopping weir coefficient | Cd ≤ 1.66 | 9.4.6 | |
| C8 | Culvert inverts match the drain bed; headwalls, wingwalls and cut-off walls | — | 9.4.8(c), 9.4.9 | |
| C9 | Channel Froude number at the design flow | ≤ 0.8; none between 0.8 and 1.2 | 9.5.2 | |
| C10 | Channel velocity | Table 9.2 | 9.5.3 | |
| C11 | Channel slope in engineered channels | ≤ 0.4% natural, ≤ 0.2% concrete, or drops / chute | 9.5.4 | |
| C12 | Side slopes; low-flow channel where bed width ≥ 3 m; uplift or weep holes | — | 9.5.6, 9.5.7, 9.5.9 | |
| C13 | Outlet protection where outlet velocity exceeds Table 9.2 | Table 9.3 apron, or basin | 9.6.1, 9.6.3 | |
| C14 | Single vertical drop height | ≤ 1.5 m | 9.6.6(c) | |
| C15 | Detention primary outlet: no moving parts; minimum orifice | ≥ 50 mm with screen | 9.7.1 | |
| C16 | Emergency spillway | 1% AEP, outlet blocked, basin full, 0.3 m freeboard; 0.2% AEP for high-hazard basins | 9.7.6 | |
| C17 | Outlet pipe through embankment; anti-vortex plate where needed | — | 9.7.7, 9.7.8 | |
| C18 | Conduit-entrance racks | Spacing 75 mm to half the smallest conduit dimension; area ≥ 4×; ≤ 1.0 m/s at 50% blocked | 9.8.2 | |
| C19 | Detention orifice screens | Openings smaller than the orifice; open area ≥ 10× | 9.8.5 | |
| C20 | Pump station | Annex 9C checklist complete | 9.9 | |
| C21 | Gates on outfalls below the 1% AEP still-water level; secondary closure; corrosion-resistant fittings | — | 9.10 | |
| C22 | Grate load classes, parallel openings ≤ 25 mm, kerb openings ≥ 100 mm × 1.0 m, locked covers | — | 9.11 | |
| C23 | Manhole sizes (Table 9.4), 600 mm access openings, drops, benching, surcharge covers | — | 9.12 | |

| No. | Check | Limit | Clause | Complies (Yes / No / NA) |
|---|---|---|---|---|
| C24 | Exposure class (Table 9.5); chloride and sulphate tests in coastal and delta areas; sulphide protection; metalwork within 5 km of the coast | — | 9.13 | |

### Section D — Variances

#### Table 9F.4 — Form 9-1, Section D: variances

| Clause | Requirement not met | Reason and proposed alternative | Approved by and date |
|---|---|---|---|
| _____ | _____ | _____ | _____ |

### Section E — Signatures

The report shall be prepared and signed by a registered professional, and the Professional Design Certificate (Form 10-3) attached (Clauses 10.6.1 and 10.6.3 of Chapter 10). For a facility with an embankment, a high-hazard basin, a pumped facility, a tide gate or a regional facility, the signatory shall be an empanelled Stormwater Design Professional, and a second, independent empanelled professional shall sign as checker (Clauses 10.6.1(c), (d) and 10.6.4).

#### Table 9F.5 — Form 9-1, Section E: signatures

| Role | Name | Registration or empanelment no. | Signature | Date |
|---|---|---|---|---|
| Designer | _____ | _____ | _____ | _____ |
| Independent checker (Clause 10.6.4, where applicable) | _____ | _____ | _____ | _____ |

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.*

ANNEXES TO CHAPTER 10

# Submittals, Review, Operation & Maintenance and Enforcement

These annexes support Chapter 10. They give the specification and user-guide outline of the compliance calculator, the GIS data specification, the maintenance access dimensions that the Manual sets, model O&M plans for each facility type, model empanelment criteria, and the eight forms that Chapter 10 requires. The Design Rainfall Sheet (Form 2-1) is in the annexes to Chapter 2. The forms are draft forms. The model texts are for consideration by a competent authority and are not in force.

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## Annex 10A — Compliance calculator and user guide

Supports Clauses 10.4.1(g), 10.5 and 10.9.1(b) of Chapter 10.

> **Status.** The compliance calculator does not exist yet. Clause 10.5.1 requires the State Stormwater Technical Committee to issue and maintain it. This annex is the specification the calculator shall meet and the outline of its user guide. Until the calculator is issued, the designer completes Form 10-2 by hand from the calculations of Chapters 4, 5 and 8, enters "not issued" as the calculator version, and attaches the calculations.

### 10A.1 General requirements

The calculator shall:

- (a) be a spreadsheet or web tool, published free of charge with its user guide and the source of every table in it (Clause 10.5.4);
- (b) print its version number and release date on every output page and every exported file (Clause 10.5.3);
- (c) keep a public version log. A new version applies to new submittals 6 months after release; a submittal keeps one version from Stage 1 to Stage 4 unless the Applicant elects a later one (Clause 10.5.3);
- (d) work for one site at a time, with one or more drainage areas, each draining to its own outfall (Clause 4.5.1.3);
- (e) never apply a value that the Manual has not published. Where a table it needs has not been issued (for example Table 4.3 of Annex 4B, or the S-2 discharge tables of Annex 1C), the calculator shall show that route as "not available" rather than estimate the value; and
- (f) export its inputs and results as a machine-readable file (CSV or JSON) as well as Form 10-2, so that the Authority can load them into the facility register (Clause 10.17.1(b)).

### 10A.2 Inputs

**Table 10A.1 — Calculator inputs**

| No. | Input | Unit | Source |
|---|---|---|---|
| I1 | Authority, tier (A or B) and file number | — | Clause 1.6 |

| No. | Input | Unit | Source |
|---|---|---|---|
| I2 | Site area; land disturbance area | ha | Clause 1.5.2 |
| I3 | New impervious area; replaced impervious area; existing impervious area before demolition | m² | Clauses 1.5.2, 1.5.6, 4.5.6.1 |
| I4 | Development type: new, redevelopment, linear public work, single dwelling | — | Clauses 1.5.6–1.5.8 |
| I5 | Flood-sensitive catchment (yes / no), and basin with an approved BSMP (yes / no) | — | Clauses 4.5.3, 4.13, 11.12 |
| I6 | Rainfall zone | — | Annex 2A |
| I7 | Retention depth P_R; 3-month ARI 24-hour depth P_3m | mm | Annexes 2E, 8A |
| I8 | Design rainfall depths by duration (1–72 h) and AEP, with the climate factor, as recorded on Form 2-1 | mm | Clauses 2.5, 2.8, 2.13 |
| I9 | 15-minute intensities i_10 and i_2, with the climate factor (fixed-coefficient route only) | mm/h | Clause 4.14.4 |
| I10 | Drainage areas: for each, area, land cover, impervious percentage, HSG and curve number, pre- and post-development | ha, %, — | Clauses 3.3, 3.7, 3.9 |
| I11 | Areas preserved under a registered covenant | ha | Clause 4.4.7 |
| I12 | Seasonal high groundwater depth below the base of each retention practice | m | Clauses 4.4.3(c), 8.8 |
| I13 | Measured infiltration rate at each practice | mm/h | Clause 4.4.3 |
| I14 | Retention volume provided, by practice; reuse demand where retention is by reuse | m³, m³/d | Clauses 4.4.3, 4.4.5 |
| I15 | Route: full hydrograph method (Clause 4.6); design-aid S-1 (Clause 4.14.2); PSD S-2 (Clause 1.7); fixed-coefficient (Clause 4.14.3); constrained redevelopment (Clause 4.5.6) | — | Clauses 1.7, 4.5.6, 4.6, 4.14 |
| I16 | For the full method: model results for each AEP and duration — pre- and post-development peaks, storage used, retention credit found by routing | m³/s, m³ | Clauses 4.4.6.2, 4.6 |
| I17 | Outlet: low-flow orifice diameter or least slot dimension; drawdown times from routing | mm, h | Clauses 4.7, 4.8.2 |
| I18 | Outfall: tidal or non-tidal; outfall-closed check result | — | Chapter 5 |
| I19 | Fee-in-lieu unit rate notified for the basin, where the route applies | ₹/m³ | Clause 4.13.3 |
| I20 | Stage of submittal (1, 2 or 4) and, at Stage 4, the as-built values of I14, I16 and I17 | — | Clauses 10.5.2, 10.9.1(b) |

## 10A.3 Calculations, by clause

### Table 10A.2 — Calculations the calculator shall perform

| Step | Calculation | Clause |
|---|---|---|
| C1 | **Applicability.** Chapters 4 and 5 apply where land disturbance ≥ 0.1 ha or new plus replaced impervious area ≥ 500 m², over the common plan of development. Report exemptions. Flag that the universal provisions apply at every size, and that RWH applies under Table G1 of the Bye-Laws 2021 to every plot category and use in the master-plan, municipal and scheme areas, and under s.36 of the Khasi Hills Autonomous District (Land Development and Building) Regulation, 2015 to all existing and new buildings in the Khasi Hills Autonomous District, as storage of at least 25 litres per m² of roof (Clause 4.11, set by this Manual, since neither rule sets a volume); recharge is credited only where Clause 4.11 (recharge rule) allows it, which is on the tested alluvium of sub-area ML-A1 and the tested valley fills of Ri-Bhoi on flat ground, never on natural ground sloping more than 10°, on colluvium, fill or slide debris, in a mapped landslide zone or within twice the height of a cut slope or retaining wall upslope of it (unless a geotechnical certificate allows it), and never, whatever a certificate says, on limestone, in a coal-mining area or where caves or sinkholes are known (Clause 4.11, karst and mine rule). | 1.5.2–1.5.8 |
| C2 | **Process flags.** Stage 0 mandatory (≥ 2 ha, flood-sensitive, variance or regional route, tidal outfall or waterbody); Stages 1 and 2 may be combined (< 1 ha, not flood-sensitive); empanelled signatory required; independent check required. | 10.3.2, 10.3.3, 10.6.1, 10.6.4 |
| C3 | **Route eligibility.** Tier B simplified method: ≤ 2 ha, or ≤ 0.5 ha in a flood-sensitive catchment, and only once Table 4.3 is published. Fixed-coefficient route: ≤ 1 ha and none of the exclusions of Clause 4.14.3. Constrained redevelopment: existing ≥ 60% impervious and ≤ 1 ha. Regional detention or fee-in-lieu: only in a basin with an approved BSMP. | 4.5.6.1, 4.13.1, 4.14.1, 4.14.3, 11.12.1(b) |
| C4 | **Retention volume.** RRV = 10 × Q_R × A, with Q_R the SCS-CN runoff from P_R for each sub-area at AMC II, summed over sub-areas. The larger of the Ia = 0.2S and Ia = 0.05S results governs. The Rv form (RRV = 10 × P_R × Rv × A, Rv = 0.05 + 0.009 × I) is offered only for sites < 0.5 ha and the Tier B method. No climate factor. | 4.4.2, 3.8.5(c), 2.8.3 |
| C5 | **Preservation credit.** Preserved areas are modelled at their pre-development CN in the post-development condition. | 4.4.7 |
| C6 | **Retention checks.** Design infiltration rate ≤ half the measured rate; groundwater ≥ 1.0 m below the base; drawdown of the retained volume within 72 h at the design rate (or by the stated reuse demand). A practice that fails any check gets no credit; any shortfall is reported and treated as WQv. | 4.4.3–4.4.5, 4.4.6.4 |
| C7 | **Water quality volume.** P_wq = max(P_ret, P_3m); WQv = 10 × Q_wq × A by SCS-CN, or (P_wq / 1000) × Rv × A (A in m²) for sites < 0.5 ha and the Tier B method. The retained volume counts toward the WQv in full. No climate factor. | 8.4.1–8.4.4, 3.8.5(c) |
| C8 | **Retention credit.** Tier A: the credit found by routing is entered (I16); the calculator does not compute it. Tier B: V_credit = C_R × RRV provided, with C_R = 0 until Annex 4B is published. | 4.4.6 |
| C9 | **Design-aid route (S-1).** V = SSR × A − V_credit; Q_PSD,T = PSD_T × A for the 2-yr and 100-yr stages, from Table 4.3. Shown as "not available" until Table 4.3 is published. | 1.7.2, 4.14.2 |
| C10 | **Permissible site discharge (S-2).** Q = PSD (m³/s/ha) × A for each AEP, from the S-2 tables. Shown as "not available" until they are issued. | 1.7.2, 1.7.3(e) |
| C11 | **Fixed-coefficient route.** Q_cap,10 = 2.78 × C_10 × i_10 × A and Q_cap,2 = 2.78 × C_2 × i_2 × A (L/s); V_100 and V_2 = max over d of [10 × C_v × P(d) × A − 1.8 × Q_cap × d] for d = 1 to 72 h, with pervious C ≥ 0.50 for d ≥ 12 h; V = max(V_100, V_2); retention added without credit. Coefficients from Table 4.3A (provisional). | 4.14.4–4.14.7 |
| C12 | **Release-rate screen (full method).** For each AEP and duration: Q_post ≤ 0.9 × Q_pre (standard), or the two mixed-frequency caps (flood-sensitive). Report the governing duration and margin. | 4.5.2, 4.5.3 |
| C13 | **Constrained redevelopment.** Q_post ≤ 0.5 × Q_existing for 2-, 10- and 100-yr at each duration; shortfall volume = greenfield storage − storage provided; fee = shortfall × unit rate. | 4.5.6.2, 4.5.6.3 |
| C14 | **Minimum orifice.** Flag any orifice < 50 mm. Where a cap is below the discharge of a 50 mm orifice at the corresponding stage, report "50 mm orifice deemed to comply". | 4.5.5.1, 4.8.2 |
| C15 | **Drawdown.** Report the detention drawdown (90% of the 10-yr stored volume within 48 h), the WQv release time (24–48 h) and the retention emptying time (≤ 72 h). | 4.7 |
| C16 | **Fee-in-lieu.** Fee = detention volume required on site × notified unit rate. | 4.13.3 |

| Step | Calculation | Clause |
|---|---|---|
| C17 | **Model screen.** Where the full method is used, compare the model results (I16) with the calculator's screen values (C9 to C11, where available) and flag a difference above the tolerance stated in the user guide. | 10.5.2(c) |
| C18 | **As-built re-run.** At Stage 4, repeat C4 to C17 with the as-built values and report each change from Stage 2. | 10.9.1(b), 10.9.2 |

### 10A.4 Outputs

The calculator produces:

- (a) **Form 10-2**, filled in, with the calculator version and release date on every page;
- (b) a machine-readable export of every input and result of Tables 10A.1 and 10A.2; and
- (c) a list of the flags raised (C1 to C3, C6, C14, C17), each with the clause on which it is based (Clause 10.7.7).

### 10A.5 Testing before release

Before each release the State Stormwater Technical Committee shall check that the calculator reproduces, within rounding, the worked examples of the Manual that use the same method, including the illustrative examples of Clauses 4.6.7 and 4.14, and the benchmark problems of Annex 3C where they apply. The test results shall be published with the version log.

### 10A.6 Outline of the user guide

The user guide shall contain at least:

1. Purpose, status and limits of the calculator: a summary and screening check outside the design-aid route (Clause 10.5.2(c)).
2. How to obtain the current version, and the version rule of Clause 10.5.3.
3. Each input of Table 10A.1, with where to find it in the Manual and its annexes.
4. Each calculation of Table 10A.2, with its equation and clause.
5. The tolerance used in step C17, and what the drainage report must explain where it is exceeded (Clause 10.5.2(c)).
6. How to read and sign Form 10-2, and what to attach.
7. At least one worked example for each route, labelled "Illustrative — not design values".
8. The sources of every table in the calculator (Clause 10.5.4), and the version log.

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## Annex 10B — GIS data specification and attribute schema

Supports Clauses 10.4.4, 10.14.1(d), 10.14.3 and 10.17 of Chapter 10.

### 10B.1 Format and reference systems

- (a) **Format.** One OGC GeoPackage (.gpkg) per submittal is preferred. Shapefiles are accepted, one per layer, zipped with all component files. Field names shall be as in Tables 10B.2 to 10B.6; shapefile names are limited to 10 characters, and the names below meet that limit.
- (b) **Horizontal reference.** WGS 84 geographic (EPSG:4326), or WGS 84 / UTM zone 46N (EPSG:32646), or 45N (EPSG:32645) west of 90° E (a strip of West and South West Garo Hills; a project that crosses 90° E uses one zone for all its layers), whichever contains the site (Clause 10.4.4(c)). One system shall be used for all layers.

- (c) **Vertical reference.** All levels shall be in metres relative to a named vertical datum, stated in the metadata. The metadata shall also state the relationship between that datum and the river datums of the CWC level-monitoring sites on the receiving rivers (not stated in any source found), of the reservoir levels of MePGCL (published in metres for Myntdu–Leshka, New Umtru and Umiam–Umtru Stage IV, and in feet for Umiam–Umtru Stage III, converted at 0.3048 m per foot), and of the flood marks surveyed on ungauged streams, jhoras, pungs and lakes used in Chapter 5 (Clause 10.4.4(d)).
- (d) **Accuracy.** Positions shall come from the site survey or the approved drawings. At Stage 4 and at handover, positions and levels shall come from the as-built survey (Clause 10.9.1(a)).
- (e) **File name.** `<Authority file number>_<stage>_<yyyymmdd>.gpkg`, for example `MUDA–BP–2026–0123_S2_20261015.gpkg`.
- (f) **Identifiers.** Every feature has an identifier unique within the submittal (FAC_ID, OUT_ID, CAT_ID, FLP_ID). The Authority replaces them with register identifiers on acceptance and returns the mapping to the Applicant.

## 10B.2 Layers

**Table 10B.1 — Layers**

| Layer | Geometry | Content | Required at |
|---|---|---|---|
| SW_SITE | Polygon | Site boundary | Stages 1, 2, 4 |
| SW_CATCH | Polygon | Catchment boundaries draining to and through the site, pre- and post-development (Clause 10.4.1(b)) | Stages 1, 2, 4 |
| SW_FAC | Polygon (point for buried items smaller than 5 m across) | Every stormwater facility: retention, detention, water quality, pumping, gate, conveyance element designed under this Manual | Stages 2, 4; handover |
| SW_OUTF | Point | Every outfall from the site, and every public outfall | Stages 1, 2, 4; handover |
| SW_FLOW | Line | Major-system flow paths through and from the site, and natural drainage paths (Clause 10.15.1(g)) | Stages 1, 2, 4 |
| SW_CONV | Line | Drains and pipes designed under Chapter 6 | Stage 4 for public works; handover |
| SW_META | Table (no geometry) | Metadata of Table 10B.6 | Every stage |

## 10B.3 Attribute schema

Types: T = text, I = integer, R = real, D = date (ISO 8601, yyyy-mm-dd). "Req." marks fields that shall not be empty; other fields are filled where they apply.

**Table 10B.2 — Attributes of SW_FAC (facilities)**

| Field | Type | Unit | Req. | Content | Source |
|---|---|---|---|---|---|
| FAC_ID | T | — | Yes | Facility identifier | 10B.1(f) |
| FAC_TYPE | T | — | Yes | Code from Table 10B.7 | Clause 4.10, Table 10.3 |
| FAC_NAME | T | — | | Name on the drawings | — |
| OWNER_TYP | T | — | Yes | PRIVATE / ASSOC / DEVELOPER / ULB / DEPT | Clauses 10.10, 10.14 |
| OWNER_NM | T | — | Yes | Name of a corporate owner or association only; for an individual, "private individual" (Clause 10.17.3) | Clause 10.17.3 |

| Field | Type | Unit | Req. | Content | Source |
|---|---|---|---|---|---|
| CTRL_AREA | R | ha | Yes | Area draining to the facility | Clause 4.5.1.3 |
| V_RET | R | m³ | | Retention volume provided | Clause 4.4 |
| V_WQ | R | m³ | | Water quality volume provided | Clause 8.4 |
| V_DET | R | m³ | | Detention volume at the top design level | Clause 4.6 |
| Q_2 | R | L/s | | Release at the 50% AEP (2-yr) design level | Clause 4.5 |
| Q_10 | R | L/s | | Release at the 10% AEP (10-yr) design level | Clause 4.5 |
| Q_100 | R | L/s | | Release at the 1% AEP (100-yr) design level | Clause 4.5 |
| ORIF_MM | R | mm | | Low-flow orifice diameter or least slot dimension | Clause 4.8.2 |
| INV_OUT | R | m | | Outlet invert level | Clause 10.9.1(a) |
| TWL_DES | R | m | | Top design water level | Clause 10.9.2(a) |
| SPILL_LV | R | m | | Spillway or overflow crest level | Clause 4.9 |
| PUMPED | T | — | Yes | Y / N | Clause 10.10.3 |
| REGIONAL | T | — | Yes | Y / N | Clause 4.13 |
| EMPANEL | T | — | Yes | Y / N: facility under Clause 10.6.1(c) or (d) | Clause 10.6.1 |
| STATUS | T | — | Yes | Code from Table 10B.8 | Clause 10.17.1(a) |
| APPR_DATE | D | — | | Date of Stage 2 approval | Clause 10.3 |
| ASB_DATE | D | — | | Date the as-built certificate was accepted | Clause 10.9 |
| DECL_REF | T | — | | Registration reference of the Maintenance Declaration (Form 10-6) | Clause 10.10.1(e) |
| HAND_DATE | D | — | | Date of the Asset Handover Certificate (Form 10-8) | Clause 10.14 |
| LAST_INSP | D | — | | Date of the latest inspection | Clause 10.12 |
| INSP_RES | T | — | | Code from Table 10B.9 | Clause 10.17.1(a) |
| OUT_ID | T | — | Yes | Outfall to which the facility discharges | — |

### Table 10B.3 — Attributes of SW_OUTF (outfalls)

| Field | Type | Unit | Req. | Content | Source |
|---|---|---|---|---|---|
| OUT_ID | T | — | Yes | Outfall identifier | 10B.1(f) |
| RECEIVER | T | — | Yes | Receiving drain, channel, waterbody or sea, by name | Clause 4.5.1.3 |
| RECV_TYPE | T | — | Yes | PUBLIC_DRAIN / CANAL / RIVER / TANK / SEA / OTHER | Chapter 5 |
| INV_LEVEL | R | m | Yes | Outfall invert level | Clause 10.9.1(a) |
| SIZE_MM | R | mm | Yes | Diameter, or width × height written in the drawing | Chapter 6 |
| TIDAL | T | — | Yes | Y / N | Chapter 5 |
| GATE_TYPE | T | — | | NONE / FLAP / TIDE / DUCKBILL / PENSTOCK / NRV | Clauses 5.11, 9.10 |
| GATE_REQ | T | — | Yes | Y / N: invert below the 1% AEP still-water level | Clause 5.11.1 |
| GPT | T | — | | Y / N: gross pollutant trap fitted | Clause 8.10.1 |

| Field | Type | Unit | Req. | Content | Source |
|---|---|---|---|---|---|
| Q_100 | R | L/s | | Design 1% AEP discharge | Chapter 5 |

### Table 10B.4 — Attributes of SW_CATCH (catchments)

| Field | Type | Unit | Req. | Content | Source |
|---|---|---|---|---|---|
| CAT_ID | T | — | Yes | Catchment identifier | 10B.1(f) |
| CONDITION | T | — | Yes | PRE / POST / EXTERNAL (land outside the site draining through it) | Clause 10.4.1(b) |
| AREA_HA | R | ha | Yes | Area | — |
| IMPERV_PC | R | % | Yes | Impervious percentage | Clause 3.9 |
| HSG | T | — | Yes | A / B / C / D, or mixed with area shares in NOTES | Clause 3.7 |
| CN | R | — | | Curve number, AMC II | Chapter 3 |
| OUT_ID | T | — | Yes | Outfall to which it drains | Clause 4.5.1.3 |
| FLOODSENS | T | — | Yes | Y / N | Clause 4.5.3 |
| NOTES | T | — | | Free text | — |

### Table 10B.5 — Attributes of SW_FLOW and SW_CONV (flow paths and conveyance)

| Field | Type | Unit | Req. | Content | Source |
|---|---|---|---|---|---|
| FLP_ID | T | — | Yes | Line identifier | 10B.1(f) |
| LINE_TYPE | T | — | Yes | OVERLAND / NATURAL / OPEN_DRAIN / COVERED_DRAIN / PIPE / CULVERT | Chapter 6 |
| US_LEVEL | R | m | | Upstream invert or ground level | Chapter 6 |
| DS_LEVEL | R | m | | Downstream invert or ground level | Chapter 6 |
| SIZE_MM | R | mm | | Pipe diameter, or drain width (depth in NOTES) | Clause 6.7.6 |
| Q_DES | R | L/s | | Design discharge | Chapter 6 |
| AEP_DES | T | — | | Design AEP, for example "10%" or "1%" | Clause 6.4 |
| RESERVE_M | R | m | | Drainage reserve width, where one applies | Clause 6.9.7 |
| NOTES | T | — | | Free text | — |

### Table 10B.6 — Metadata (SW_META)

| Field | Content |
|---|---|
| FILE_NO | Authority file number |
| STAGE | 1, 2, 4 or HANDOVER |
| H_CRS | EPSG code of the horizontal reference system |
| V_DATUM | Name of the vertical datum |
| TIDE_REL | Relationship of the vertical datum to the Chapter 5 river datums of the CWC level-monitoring sites on the receiving rivers (not stated in any source found), of the reservoir levels of MePGCL (published in metres for Myntdu–Leshka, New Umtru and Umiam–Umtru Stage IV, and in feet for Umiam–Umtru Stage III, converted at 0.3048 m per foot), and of the flood marks surveyed on ungauged streams, jhoras, pungs and lakes (for example, MSL = x.xx m on the site datum) |

| Field | Content |
|---|---|
| SURVEYOR | Name and licence number of the surveyor |
| SURV_DATE | Date of the survey |
| PREP_BY | Name and registration number of the certifying professional |
| CALC_VER | Compliance calculator version (Annex 10A), or "not issued" |
| DATE | Date the file was prepared |

## 10B.4 Code lists

### Table 10B.7 — Facility type codes (FAC_TYPE)

| Code | Facility | Inspection row of Table 10.3 |
|---|---|---|
| RET_SOAK | Soakaway, recharge pit or shaft | Retention / infiltration |
| RET_TRENCH | Infiltration trench or basin | Retention / infiltration |
| RET_BIO | Bioretention or rain garden | Retention / infiltration |
| RET_PERM | Permeable pavement | Retention / infiltration |
| RET_REUSE | Retention by reuse (tank with demand) | Underground or podium detention tank, gravity outlet |
| DET_BASIN | Surface detention basin | Surface detention basin or multi-use open space area |
| DET_OSR | Multi-use detention in open space, park or playfield | Surface detention basin or multi-use open space area |
| DET_ROOF | Rooftop detention | Underground or podium detention tank, gravity outlet |
| DET_PODIUM | Podium or landscape-deck detention | Underground or podium detention tank, gravity outlet |
| DET_PARK | Parking-lot detention | Surface detention basin or multi-use open space area |
| DET_TANK | Underground tank or vault, gravity outlet | Underground or podium detention tank, gravity outlet |
| DET_PUMP | Pumped detention or pump station | Pumped detention, pumps and controls |
| WQ_POND | Wet pond or constructed wetland | Surface detention basin or multi-use open space area |
| WQ_SWALE | Swale or filter strip | Private drains and inlets |
| WQ_GPT | Gross pollutant trap, first-flush device or oil-grit separator | Gross pollutant trap / first-flush device |
| GATE | Flap or tide gate, non-return valve | Flap / tide gate, non-return valve |
| CONV | Private drain, inlet or culvert | Private drains and inlets |

### Table 10B.8 — Status codes (STATUS)

| Code | Meaning |
|---|---|
| PROPOSED | In a Stage 1 or Stage 2 submittal |
| APPROVED | Stage 2 approved; not yet built |
| ASBUILT | As-built certificate accepted (Clause 10.9) |
| HANDEDOVER | Accepted by the ULB (Clause 10.14) |
| ALTERED | Changed with the Authority's approval (Clause 10.3.5) |

| Code | Meaning |
|---|---|
| REMOVED | Removed with the Authority's approval |

Table 10B.9 — Inspection result codes (INSP_RES)

| Code | Meaning |
|---|---|
| OK | Working as designed; no defect |
| MINOR | Defect found and corrected; date in the inspection record |
| MAJOR | Defect affecting storage, outlet or safety; notice issued (Clause 10.15.2, step 1) |
| NOACCESS | Inspection could not be made |
| NOTFOUND | Facility missing, filled, covered or changed in use (Clause 10.15.1(c)) |

### 10B.5 Facility register extract

The public facility register of Clause 10.17.1(a) is an extract of SW_FAC: FAC_ID, FAC_TYPE, location (centroid), V_DET (and V_RET, V_WQ), Q_100 (and Q_2, Q_10), OWNER_NM, ASB_DATE, LAST_INSP and INSP_RES. It is published as CSV and GeoPackage under the licence of Clause 10.17.4. Personal data are not published (Clause 10.17.3).

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## Annex 10C — Maintenance access dimensions

Supports Clause 10.13 of Chapter 10.

Clause 10.13 sets access by function. This annex collects the access dimensions that the Manual already sets in other chapters, and lists the dimensions that it does not set. Where a dimension is not set by the Manual, the designer shall state it on the drawings, show that it suits the plant and equipment named in the O&M plan (Clause 10.11.1(h)), and mark it "to be confirmed in design".

Table 10C.1 — Access dimensions set by the Manual

| Element | Requirement | Clause |
|---|---|---|
| Open drains with a top width of 2 m or more | Maintenance access strip at least 3.5 m wide along one bank, connected to a public road at intervals of not more than 500 m | 6.9.4 |
| Drainage reserves | Width not less than Table 6.9, based on the required drain size; where the access strip of Clause 6.9.4 is wider, the wider governs | 6.9.7 |
| Covered drains, minimum section | 0.6 m × 0.6 m clear | 6.7.6 |
| Covered drains, removable covers | Panels at not more than 10 m centres, each at least 0.6 m long and spanning the full clear width, liftable by two workers or a hand-operated device | 6.13.2(a) |
| Covered drains, access chambers | Clear opening at least 0.6 m × 0.6 m at every junction, bend and change of section, and at not more than 30 m centres on straight runs | 6.13.2(b) |
| Manholes and access chambers on public drains | Clear access opening at least 600 mm | 9.12.3 |
| Inlet chambers on public roads | Silt sump at least 300 mm deep below the outlet pipe invert, cleanable from the surface | 6.6.7 |

| Element | Requirement | Clause |
|---|---|---|
| Underground tanks and vaults | Access openings over the outlet chamber and over every inlet; in tanks over 500 m², not more than 30 m apart; floor falling at least 1% to a sump at the outlet | 4.10.2(b), (c) |
| Detention outlets serving more than 1 ha | A means of isolating the outlet (stop-log slot or penstock) | 4.8.6 |
| Outfall gates | Stop-log slot or penstock upstream on outfalls larger than 600 mm (Chapter 5) and on outfalls of 900 mm or more or serving a pumped or storage system (Chapter 9); the gate chamber accessible at all tides, with its access above HAT + surge + sea-level allowance | 5.11.3(d), (e); 9.10.3 |
| Pump stations | Maintenance vehicle access usable in the 1% AEP event; hard standing and a quick-coupling connection for mobile pumps; clear space between adjacent pumps or motors of 0.6 m (small and medium units) or 1.0 m (large units) | 9.9.6, 9.9.10, 9.9.12 |
| Pretreatment devices | Cleanable without entering or disturbing the main BMP | 8.5.4 |
| Screens at outfalls, culvert inlets and pump sumps | Cleanable from a safe platform, with vehicle access | 8.10.3(d) |
| Infiltration trenches | Observation well to the base of each trench | 8.7.6(c) |
| Publicly accessible storage | Side slopes no steeper than 4H:1V, with at least a quarter of the perimeter at 6H:1V or flatter | 4.15.1(c) |
| Wet basins | Safety bench at least 3 m wide, no more than 0.3 m below normal water level | 4.15.2 |
| Fencing | At least 1.2 m high, non-climbable, with a lockable gate, where Clause 4.15.3 requires it | 4.15.3 |

### Table 10C.2 — Access dimensions not set by the Manual (to be confirmed in design)

| Element | What the designer shall state | Clause setting the function |
|---|---|---|
| Vehicle access route to the inlet, outlet and base of a basin, pond or open channel | Width, gradient, turning space and design load for the plant in the O&M plan | 10.13.2 |
| Maintenance strip beside a basin or pond | Width along at least one side | 10.13.2 |
| Ramp into a basin | Width, gradient and surface for the sediment-removal plant | 10.13.2 |
| Access openings of private tanks | Clear size of each opening over the inlet, outlet and each chamber | 10.13.3(a) |
| Ladders and steps | Type and spacing; ventilation for confined-space entry | 10.13.3(b) |
| Headroom in underground tanks | Clear height for manual cleaning | 10.13.3(d) |
| Reach to orifices and screens | How the outlet is cleaned without entering a full facility | 10.13.4 |

> **Commentary.** APWA 5600 (2006, §5608) required a maintenance access strip of 15 ft (about 4.5 m) for detention facilities. The Manual did not adopt a fixed width for private sites, because plot sizes in Meghalaya cities vary widely (Clause 10.13, Commentary). The State Stormwater Technical Committee may add standard values to Table 10C.2 when it issues the standard drawings of Annexes 6C and 9B.

# Annex 10D — Model O&M plans by facility type

Supports Clauses 10.11, 10.12 and 10.13 of Chapter 10.

The model plans below are starting points. The designer adapts them to each facility and completes the items marked "_____". Inspection frequencies are the minimum frequencies of Table 10.3; a plan may set more frequent inspection, never less. Where this annex leaves a value to the designer, the Manual does not set it.

## 10D.1 Contents of every O&M plan

Every plan shall contain the items of Clause 10.11.1:

**Table 10D.1 — Contents of an O&M plan**

| Item | Content | Clause |
|---|---|---|
| 1 | Inventory and plan drawing of each facility, with design levels, volumes and outlet details (from SW_FAC, Annex 10B) | 10.11.1(a) |
| 2 | Routine tasks and their frequency (Tables 10D.2 to 10D.8) | 10.11.1(b) |
| 3 | Trigger for sediment removal, as a depth (mm) or a percentage of design volume: _____ | 10.11.1(c) |
| 4 | Inspection checklist matching Form 10-7 | 10.11.1(d) |
| 5 | For pumps, gates and valves: operating rules, test schedule, standby power, and actions on a cyclone or heavy-rainfall warning | 10.11.1(e) |
| 6 | Actions against standing water and mosquito breeding, consistent with the drawdown times of Clause 4.7 | 10.11.1(f) |
| 7 | Safety: confined spaces, deep water, public access | 10.11.1(g) |
| 8 | Access routes and equipment (Annex 10C) | 10.11.1(h) |
| 9 | Annual cost estimate (₹ _____ per year) and who pays it | 10.11.1(i) |
| 10 | Records to be kept, and for how long: _____ years (pump records at least 5 years, Clause 9.9.8(c)) | 10.11.1(j) |

## 10D.2 Model plans

**Table 10D.2 — Retention and infiltration (soakaways, trenches, bioretention, permeable paving)**

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Inspect surface, inlets, pretreatment and overflow | Every 6 months; before 31 March; after each heavy-rainfall day | No blockage; overflow clear | Table 10.3 |
| Check drawdown at the observation well or surface | At each inspection after rain | Empties within 72 h of the end of rain; if not, investigate clogging | 4.4.5, 8.7.6(c) |
| Clean pretreatment (forebay, filter strip, silt trap) | When the sediment trigger (item 3) is reached | Pretreatment cleaned without disturbing the main BMP | 8.5.3, 8.5.4 |
| Bioretention: mulch, plants, ponding | Every 6 months | Ponding drains within 48 h; dead plants replaced; mulch 50–75 mm | 8.7.2 |
| Permeable paving: surface | Every 6 months | Sweep or vacuum; no resurfacing with impermeable material | 8.7.5(e) |
| Keep the contributing area stable | Each inspection | Bare soil stabilised; no sediment washing in | 10.8.3(b) |

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Keep the facility in place and in use | Each inspection | Not filled, covered, paved or built over without approval | 10.10.1(d) |

### Table 10D.3 — Surface detention basin or multi-use open space area

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Inspect inlets, outlet, orifice, trash rack and spillway | Every 6 months; before 31 March; after each heavy-rainfall day | Orifice and rack clear; spillway unobstructed | Table 10.3, 4.8, 4.9 |
| Remove debris and sediment | When the sediment trigger is reached, and after events | Design volume restored | 10.11.1(c) |
| Check that the basin drains | After rain | No low point ponds for more than 72 h | 4.15.7 |
| Vegetation | As set in the plan | Grass cut; no woody growth on embankments or in the outlet zone | 10.11.1(b) |
| Safety features | Every 6 months | Signs in Khasi or Garo and English and a depth marker in place; fences and gates sound where required | 4.15.3, 4.15.5 |
| Embankment (if any) | Every 6 months and after events | No cracks, slips, seepage or animal burrows | 4.9.6 |

### Table 10D.4 — Underground or podium detention tank, gravity outlet

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Inspect from the access openings: inlets, outlet, orifice, screen, sump, vents | Every 6 months; before 31 March; after each heavy-rainfall day | Clear; vents open | Table 10.3, 4.10.2 |
| Clean the sump and floor | When the sediment trigger is reached | Floor falls freely to the sump | 4.10.2(c) |
| Inlet silt trap or GPT | Every 3 months (Table 10.3 row for GPTs) | Cleaned | 4.10.2(e) |
| Overflow route | Each inspection | Operates when the outlet is blocked; route to the overland path unobstructed | 4.9.5 |
| Confined-space entry | Each entry | Entry procedure stated in the maintenance declaration followed; covers locked after | 4.15.6 |
| Use of the space | Each inspection | Not used for parking or storage; volume not reduced | 10.10.1(d) |

### Table 10D.5 — Pumped detention, pumps and controls

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Test run of each pump, duty and standby | Monthly | Each pump starts on level control; roles alternate | Table 10.3, 9.9.4(c) |
| Full duty test | Before 31 March | Station meets its design duty point | Table 10.3, 10.9.3 |
| Standby power | Monthly with the test run; full test before 31 March | Automatic changeover works; fuel for at least 72 h of all duty pumps on site | 9.9.9 |

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Level sensors, float back-up, alarms, telemetry | Monthly | High-level and fault alarms reach the control room | 9.9.8 |
| Screens and silt trap | Every 3 months and after events | Clean | 9.9.7 |
| Records | Continuous | Sump levels, run hours and power status logged; kept at least 5 years | 9.9.8(c) |
| Warning actions | On an IMD heavy-rainfall or cyclone warning | Actions written in the plan: _____ (for example staff on site, fuel topped up, mobile pump connection checked) | 10.11.1(e), 9.9.12 |

### Table 10D.6 — Flap or tide gate, non-return valve

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Inspect and operate | Every 3 months; after each heavy-rainfall day | Opens at a small head; no debris, sand or growth holding it | Table 10.3, 9.10.4 |
| Seal test | Before 31 March | Seals against the receiving water | Table 10.3, 10.9.3 |
| Beach, estuary and creek outfalls | After every high-tide or surge event in the monsoon season | Sand and debris cleared | 9.10.5(b) |
| Isolation | Before 31 March | Stop-log slot or penstock operable | 9.10.3 |
| Hinges, pins and fixings | Before 31 March | No corrosion that would stop the gate working | 9.10.6 |
| Property non-return valves | Every 3 months | Cleaning eye accessible; valve seals | 5.11.4 |

### Table 10D.7 — Gross pollutant trap or first-flush device

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Inspect and empty | Every 3 months; before 31 March; after each heavy-rainfall day | Emptied before the capture chamber is full; bypass clear | Table 10.3, 8.4.6 |
| Screens | Each inspection | Clean; overflow path clear | 8.10.3(b) |
| Disposal | Each cleaning | Material taken to an authorised solid-waste facility | — |

### Table 10D.8 — Private drains and inlets

| Task | Frequency | Standard or trigger | Clause |
|---|---|---|---|
| Inspect and clean drains, inlets and silt sumps | Every 6 months; before 31 March | Free of silt and debris | Table 10.3 |
| Check for sewage connections | Each inspection | None; any cross-connection removed | 1.5.4, 8.9 |
| Overland flow paths | Each inspection | Not obstructed by walls, fill or stored material | 6.9.2, 10.15.1(g) |

# Annex 10E — Empanelment criteria for Stormwater Design Professionals and reviewers

Supports Clauses 10.6, 10.7.4 and 11.4.3 of Chapter 10.

> *Model text for consideration by a competent authority. Not in force.* Clause 10.6.2 assigns the issue of empanelment criteria to Urban Affairs. The text below is a model. Values shown as "[ ]" are for the competent authority to set; the Manual does not set them.

## 10E.1 Model criteria

1. **Lists.** The competent authority shall keep three public lists:
   - (a) **Stormwater Design Professionals**, who may sign designs under Clause 10.6.1 and act as independent checkers under Clause 10.6.4;
   - (b) **Empanelled Reviewers**, who may review submittals for an Authority under Clause 10.7.4; and
   - (c) a **basin modelling endorsement**, held by a Stormwater Design Professional who may prepare or direct a BSMP under Clause 11.4.3.
2. **Eligibility for list (a).** An applicant shall:
   - (a) hold a degree in civil engineering, or an equivalent qualification recognised by the competent authority (Clause 10.6.2);
   - (b) be registered as a professional under the Meghalaya Building Bye-Laws 2021 (Clause 1.4);
   - (c) have at least [ ] years of experience in drainage design after graduation, shown by a list of at least [ ] projects with the applicant's role in each (Clause 10.6.2); and
   - (d) have completed a training course on this Manual, with an assessment, within the [ ] years before application (Clause 10.6.2).
3. **Eligibility for list (b).** As for list (a), with at least [ ] years of experience, of which at least [ ] years in the design or review of drainage under this Manual or an equivalent standard.
4. **Basin modelling endorsement (c).** A Stormwater Design Professional who shows experience in basin-scale 1D–2D modelling, including calibration, on at least [ ] studies (Clause 11.4.3).
5. **Independence of a checker.** A checker under Clause 10.6.4 shall not be employed by, or a partner of, the designer's firm or the Applicant, and shall not have worked on the design.
6. **Conflict of interest of a reviewer.** An Empanelled Reviewer shall not review a site on which the reviewer, or the reviewer's firm, has worked in any capacity (Clause 10.7.4), and shall declare any other interest before accepting a review. The Authority remains the decision-maker (Clause 10.7.4).
7. **Application.** The application shall include proof of degree and registration, the project list with references, the training certificate, and a signed declaration that the information is true.
8. **Term and renewal.** Empanelment is valid for [ ] years. Renewal requires evidence of continuing practice and of any refresher training issued after a revision of the Manual (Clause 1.12).
9. **Suspension and removal.** The competent authority may suspend or remove an empanelled person after a false or negligent certificate (Clause 10.6.5), on a report under step 6 of Table 10.4, or on loss of registration. The person shall be given notice and an opportunity to be heard. Every suspension and removal shall be published on the list.
10. **Publication.** The lists shall be published and kept current, with each person's name, registration number, list, endorsement and validity date.

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## Form 10-1 — Drainage Report Checklist

Supports Clauses 10.4.1 to 10.4.4 and 10.7.1 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Lodge with every Stage 1 and Stage 2 submittal. For each item give the page or sheet where it is addressed, or the reason it does not apply. The Authority does not start technical review without a completed Form 10-1 (Clause 10.4.3).

**Table 10F.1 — Form 10-1, Section A: Submittal**

| No. | Field | Entry |
|---|---|---|
| A1 | Authority and file number | _____ |
| A2 | Site name and address; survey numbers | _____ |
| A3 | Stage: 1 / 2 / combined 1 and 2 (Clause 10.3.3) / public work DPR or tender (Clause 10.3.4) | _____ |
| A4 | Applicant | _____ |
| A5 | Certifying professional (name, registration and empanelment number) | _____ |

**Table 10F.2 — Form 10-1, Section B: Stage 1 contents (Clause 10.4.1)**

| No. | Item | Clause | Page / sheet | Not applicable: reason |
|---|---|---|---|---|
| B1 | Form 1-1; Form 1-2 where a variance or waiver is sought | 10.4.1(a) | _____ | _____ |
| B2 | Site plan: existing and proposed levels, impervious areas, catchment boundaries to and through the site | 10.4.1(b) | _____ | _____ |
| B3 | Soils (HSG), seasonal high groundwater, infiltration tests or test plan | 10.4.1(c) | _____ | _____ |
| B4 | Design Rainfall Sheet (Form 2-1) | 10.4.1(d) | _____ | _____ |
| B5 | Pre-development condition and hydrologic method | 10.4.1(e) | _____ | _____ |
| B6 | Order of measures: areas preserved, retention method, detention concept, conveyance | 10.4.1(f) | _____ | _____ |
| B7 | Preliminary retention, WQ and detention volumes and release rates, with Form 10-2 | 10.4.1(g) | _____ | _____ |
| B8 | Downstream extent and tailwater case | 10.4.1(h) | _____ | _____ |
| B9 | Waterbodies, setbacks and the 1% AEP level | 10.4.1(i) | _____ | _____ |
| B10 | Land reserved for facilities and maintenance access | 10.4.1(j) | _____ | _____ |
| B11 | Professional Design Certificate (Form 10-3) | 10.4.5 | _____ | _____ |

**Table 10F.3 — Form 10-1, Section C: Stage 2 contents (Clause 10.4.2)**

| No. | Item | Clause | Page / sheet | Not applicable: reason |
|---|---|---|---|---|
| C1 | Updated Stage 1 contents (Section B) | 10.4.2 | _____ | _____ |
| C2 | Final calculations for every storage duration and AEP, with the outfall-closed check | 10.4.2(a) | _____ | _____ |

| No. | Item | Clause | Page / sheet | Not applicable: reason |
|---|---|---|---|---|
| C3 | Stage–storage–discharge tables; emergency spillway design | 10.4.2(b) | _____ | _____ |
| C4 | Hydraulic design of conveyance, inlets and structures | 10.4.2(c) | _____ | _____ |
| C5 | Water quality design; first-flush device or GPT where required | 10.4.2(d) | _____ | _____ |
| C6 | Construction drawings, details and specifications of every facility | 10.4.2(e) | _____ | _____ |
| C7 | Construction sequence, with protection of retention and infiltration areas | 10.4.2(f) | _____ | _____ |
| C8 | Hold-point schedule (Form 10-4, Section A) | 10.4.2(g) | _____ | _____ |
| C9 | Draft O&M plan and draft Maintenance Declaration (Form 10-6) | 10.4.2(h) | _____ | _____ |
| C10 | Model input files and GIS data | 10.4.2(i) | _____ | _____ |
| C11 | Certificates (Form 10-3, signed by designer and, where required, checker) | 10.4.2(j) | _____ | _____ |

### Table 10F.4 — Form 10-1, Section D: Digital submittal (Clause 10.4.4)

| No. | Item | Clause | Provided (yes / no) | Detail |
|---|---|---|---|---|
| D1 | Reports and drawings as searchable PDF | 10.4.4(a) | _____ | _____ |
| D2 | Models in native, runnable format; software name and version | 10.4.4(b) | _____ | _____ |
| D3 | GIS data to Annex 10B; horizontal reference system (EPSG code) | 10.4.4(c) | _____ | _____ |
| D4 | Vertical datum named; relationship to the Chapter 5 river datums of the CWC level-monitoring sites on the receiving rivers (not stated in any source found), of the reservoir levels of MePGCL (published in metres for Myntdu–Leshka, New Umtru and Umiam–Umtru Stage IV, and in feet for Umiam–Umtru Stage III, converted at 0.3048 m per foot), and of the flood marks surveyed on ungauged streams, jhoras, pungs and lakes | 10.4.4(d) | _____ | _____ |

### Table 10F.5 — Form 10-1, Section E: Declaration and completeness check

| Field | Entry |
|---|---|
| I confirm that this checklist is complete and correct. Certifying professional: name, signature, date | _____ |
| For the Authority: date received | _____ |
| Date of completeness check (within 5 working days, Clause 10.7.1) | _____ |
| Result: accepted for review / returned | _____ |
| Missing items, if returned | _____ |
| Officer: name, designation, signature | _____ |

## Form 10-2 — Compliance Calculator Summary

Supports Clauses 10.4.1(g), 10.5 and 10.9.1(b) of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Produced by the compliance calculator (Annex 10A) with Stage 1, 2 and 4 submittals. Until the calculator is issued, complete it by hand and enter "not issued" in A3. One column per drainage area where the site has more than one outfall.

**Table 10F.6 — Form 10-2, Section A: Site and route**

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Authority, file number, stage (1 / 2 / 4) | _____ | 10.5.2(a) |
| A2 | Site area, ha; land disturbance, ha; new + replaced impervious area, m² | _____ | 1.5.2 |
| A3 | Calculator version and release date | _____ | 10.5.3 |
| A4 | Tier (A / B); flood-sensitive (yes / no); approved BSMP for the basin (yes / no) | _____ | 1.6, 4.5.3, 11.12 |
| A5 | Route: full method / S-1 / S-2 / fixed-coefficient / constrained redevelopment / regional or fee-in-lieu | _____ | 1.7, 4.5.6, 4.13, 4.14 |
| A6 | Flags raised by the calculator (list) | _____ | Annex 10A.4 |

**Table 10F.7 — Form 10-2, Section B: Rainfall and soils**

| No. | Field | Entry | Clause |
|---|---|---|---|
| B1 | Rainfall zone; Form 2-1 reference | _____ | 2.13 |
| B2 | Retention depth P_R, mm; 3-month ARI depth P_3m, mm | _____ | 2.10, 8.4.1 |
| B3 | Climate factor applied (≤ 6 h; > 6–72 h) | _____ | 2.8 |
| B4 | HSG by sub-area; seasonal high groundwater, m below base | _____ | 3.7, 4.4.3 |
| B5 | Measured and design infiltration rates, mm/h | _____ | 4.4.3 |

**Table 10F.8 — Form 10-2, Section C: Volumes**

| No. | Quantity | Required (m³) | Provided (m³) | Clause |
|---|---|---|---|---|
| C1 | Retention volume (RRV) | _____ | _____ | 4.4.2 |
| C2 | Water quality volume (WQv) | _____ | _____ | 8.4.2 |
| C3 | Retention credit against detention | _____ | — | 4.4.6 |
| C4 | Detention volume | _____ | _____ | 4.6, 4.14 |
| C5 | Fee-in-lieu or regional volume, and fee (₹) | _____ | _____ | 4.5.6.3, 4.13.3 |

**Table 10F.9 — Form 10-2, Section D: Release rates (each outfall)**

| AEP | Q_pre or cap (L/s) | Q_post (L/s) | Governing duration (h) | Meets criterion (yes / no) | Clause |
|---|---|---|---|---|---|
| 50% (2-yr) | _____ | _____ | _____ | _____ | 4.5 |
| 10% (10-yr) | _____ | _____ | _____ | _____ | 4.5 |

| AEP | Q_pre or cap (L/s) | Q_post (L/s) | Governing duration (h) | Meets criterion (yes / no) | Clause |
|---|---|---|---|---|---|
| 1% (100-yr) | _____ | _____ | _____ | _____ | 4.5 |

Table 10F.10 — Form 10-2, Section E: Outlets, drawdown and stage comparison

| No. | Field | Entry | Clause |
|---|---|---|---|
| E1 | Low-flow orifice, mm (minimum 50 mm) | _____ | 4.8.2 |
| E2 | Detention: time to release 90% of the 10-yr stored volume, h (≤ 48 h) | _____ | 4.7.1 |
| E3 | WQv release time, h (24–48 h) | _____ | 4.7.2 |
| E4 | Retention emptying time, h (≤ 72 h) | _____ | 4.7.3 |
| E5 | Model result differs from the calculator screen by more than the guide tolerance? If yes, report section that explains it | _____ | 10.5.2(c) |
| E6 | Stage 4 only: changes from the Stage 2 values (list), and whether every criterion is still met | _____ | 10.9.2 |
| E7 | Prepared by (name, registration number), signature, date | _____ | 10.6.3(b) |

## Form 10-3 — Professional Design Certificate

Supports Clauses 10.6.1 to 10.6.5 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Signed by the designer with every Stage 1 and Stage 2 submittal, and by an independent checker for facilities under Clause 10.6.1(c) and (d).

### Table 10F.11 — Form 10-3, Section A: Project and signatory

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Authority, file number, stage | _____ | — |
| A2 | Site and facilities covered by this certificate | _____ | — |
| A3 | Designer: name, qualification, Bye-Laws 2021 registration number | _____ | 10.6.1 |
| A4 | Empanelment number, where required, and the reason: Tier A ≥ 1 ha / flood-sensitive / embankment or high-hazard basin / pumped, tide gate or regional facility | _____ | 10.6.1(a)–(d) |
| A5 | Variances or waivers approved (Form 1-2 references), or "none" | _____ | 10.6.3(a) |

### Table 10F.12 — Form 10-3, Section B: Certificate of the designer

| No. | I certify that: | Initials |
|---|---|---|
| B1 | the design complies with the Meghalaya Stormwater Design Manual, except for the variances listed at A5, which have been approved | _____ |
| B2 | the rainfall, soils and tailwater inputs are as recorded on Form 2-1 and Form 10-2 | _____ |
| B3 | the models submitted reproduce the results reported | _____ |
| B4 | I understand that a false or negligent certificate is a contravention under Clause 10.15 | _____ |

### Table 10F.13 — Form 10-3, Section C: Certificate of the independent checker (Clause 10.6.4)

| No. | Field or statement | Entry |
|---|---|---|
| C1 | Checker: name, registration and empanelment number | _____ |
| C2 | I am independent of the designer and the Applicant and have not worked on this design | _____ |
| C3 | I have checked the facilities listed: _____, and agree with the certificate in Section B | _____ |
| C4 | Matters on which I do not agree, if any | _____ |

### Table 10F.14 — Form 10-3, Section D: Signatures

| Role | Name | Signature | Date |
|---|---|---|---|
| Designer | _____ | _____ | _____ |
| Independent checker (where required) | _____ | _____ | _____ |

## Form 10-4 — Hold-Point Inspection Record

Supports Clauses 10.4.2(g), 10.8 and 10.9.3 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Section A is the hold-point schedule, approved at Stage 2. Section B is completed at each hold point, with dated, geotagged photographs (Clause 10.8.2). Work shall not proceed past a hold point until Section B is signed. See Figure 10.2.

**Table 10F.15 — Form 10-4, Section A: Hold-point schedule**

| Hold point | Facility (FAC_ID) | Stage of work | Planned date | Notice to Authority sent (date)* | Authority attended (yes / no) |
|---|---|---|---|---|---|
| (a) Excavated base, before media, liner or structure | _____ | _____ | _____ | _____ | _____ |
| (b) Outlet structure, orifice and trash screen, before backfill or first filling | _____ | _____ | _____ | _____ | _____ |
| (c) Infiltration and verification tests (Clause 10.9.3) | _____ | _____ | _____ | – | _____ |
| (d) Outfall, flap or tide gate and non-return valve, before downstream connection | _____ | _____ | _____ | – | _____ |
| (e) Pumps and controls, at commissioning | _____ | _____ | _____ | – | _____ |
| Other hold points added by the Authority | _____ | _____ | _____ | _____ | _____ |

* For sites under Clause 10.6.1, at least 3 working days' notice of hold points (a) and (b) (Clause 10.8.2).

**Table 10F.16 — Form 10-4, Section B: Inspection record (one per hold point)**

| No. | Field | Entry |
|---|---|---|
| B1 | Hold point and facility | _____ |
| B2 | Date and time of inspection; weather | _____ |
| B3 | Inspected by (certifying professional); others present | _____ |
| B4 | Approved drawing and revision checked against | _____ |
| B5 | Levels, dimensions and materials found, against approved values | _____ |
| B6 | For (a): retention and infiltration areas protected from traffic and stockpiles (Clause 10.8.3(a)) | _____ |
| B7 | For (b): orifice size and invert; screen in place | _____ |
| B8 | For (c): infiltration test result and emptying time (≤ 72 h); pump duty point; gate opening and sealing | _____ |
| B9 | For (d) and (e): gate type, seating and test; pump commissioning record | _____ |
| B10 | Photograph references (dated, geotagged) | _____ |
| B11 | Result: released / not released; corrective work required | _____ |
| B12 | Corrective work checked (date, by) | _____ |
| B13 | Signature of the certifying professional, date | _____ |

## Form 10-5 — As-built Certificate

Supports Clauses 10.9 and 10.3.5 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Lodged before the completion certificate. The Authority shall not issue the completion certificate until this form is accepted (Clause 10.9.4).

### Table 10F.17 — Form 10-5, Section A: Project and survey

| No. | Field | Entry | Clause |
|---|---|---|---|
| A1 | Authority, file number; Stage 2 approval reference and date | _____ | — |
| A2 | Licensed surveyor: name, licence number, date of survey | _____ | 10.9.1(a) |
| A3 | Vertical datum | _____ | 10.4.4(d) |
| A4 | GIS data to Annex 10B, as built (file name) | _____ | 10.4.4(c) |

### Table 10F.18 — Form 10-5, Section B: Approved against as built (one block per facility)

| Item | Approved | As built | Accepted (yes / no) | Clause |
|---|---|---|---|---|
| Storage volume at each design level, m³ | _____ | _____ | _____ | 10.9.2(a) |
| Outlet dimensions (orifice, weir), mm | _____ | _____ | _____ | 10.9.2(b) |
| Outlet and outfall inverts, m | _____ | _____ | _____ | 10.9.2(b) |
| Spillway or overflow level, m | _____ | _____ | _____ | 4.9 |
| Retention volume, m³ | _____ | _____ | _____ | 4.4 |

### Table 10F.19 — Form 10-5, Section C: Re-run and tests

| No. | Field | Entry | Clause |
|---|---|---|---|
| C1 | Compliance calculator re-run with as-built values: version, and Form 10-2 (Stage 4) attached | _____ | 10.9.1(b) |
| C2 | Model re-run with as-built values (where a model was used): file name | _____ | 10.9.1(b) |
| C3 | Every criterion of Chapters 4 and 5 met on re-run (yes / no; list any not met) | _____ | 10.9.2(c) |
| C4 | Infiltration retention: measured emptying time, h (≤ 72 h) | _____ | 10.9.3 |
| C5 | Pumps: duty point achieved (flow at head) | _____ | 10.9.3 |
| C6 | Tide gates and non-return valves: shown to open and seal | _____ | 10.9.3 |
| C7 | Deviations, and how corrected or re-certified under Clause 10.3.5 | _____ | 10.9.2 |

### Table 10F.20 — Form 10-5, Section D: Attachments and certificate

| No. | Field | Entry |
|---|---|---|
| D1 | Completed hold-point records (Form 10-4) | _____ |
| D2 | Final O&M plan | _____ |
| D3 | Executed Maintenance Declaration (Form 10-6) or handover documents (Form 10-8) | _____ |

| No. | Field | Entry |
|---|---|---|
| D4 | I certify that the facilities listed were built as approved, except as stated at C7, and perform as designed. Certifying professional: name, registration number, signature, date | _____ |
| D5 | For the Authority: accepted / returned; officer, date | _____ |

## Form 10-6 — Maintenance Declaration

Supports Clauses 10.10.1, 10.10.2, 10.10.4 and 10.13.1 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0. Model text for consideration by a competent authority. Not in force.* Executed by the owner of every private stormwater facility before the completion certificate is issued, and registered so that it runs with the land.

> **Drafting note D10A.1.** The instrument under which this declaration is registered, and the Act that gives the Authority its right of entry and its power to carry out works in default, are to be confirmed by the competent authority. This form does not cite statute sections.

**Table 10F.21 — Form 10-6, Section A: Parties and land**

| No. | Field | Entry |
|---|---|---|
| A1 | Owner (the declarant): name and address; for a company or association, its registration number | _____ |
| A2 | Authority | _____ |
| A3 | Land: survey numbers, village, C&RD block, district; extent | _____ |
| A4 | Approval reference (file number, Stage 2 approval date) | _____ |
| A5 | For multi-owner developments: the association or body that takes over after the developer (Clause 10.10.2) | _____ |

**Table 10F.22 — Form 10-6, Section B: Schedule of facilities**

| Facility (FAC_ID) | Type | Location on the attached plan | Design volume (m³) | Outlet | O&M plan reference |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ |

**Model declaration.** I/We, the owner named in Section A, declare and undertake, for myself/ourselves and for every successor in title to the land:

1. to operate, inspect and maintain each facility in Section B under the approved O&M plan, and to make the inspections of Clause 10.12 (Clause 10.10.1(b));
2. to give the Authority, its officers and its contractors a right of entry to inspect each facility and the access route shown on the plan, and to carry out works in default under Clause 10.15, with the cost recoverable from the owner (Clause 10.10.1(c));
3. not to remove, fill, cover, reduce or change the use of any facility, or obstruct its access route, without the Authority's written approval (Clauses 10.10.1(d), 10.13.5);
4. where Clause 10.10.3 applies, to lodge an Annual Maintenance Declaration and Inspection Report (Form 10-7) by 31 March each year;
5. for underground tanks, to follow the confined-space entry procedure stated here: _____ (Clause 4.15.6);
6. on sale or transfer of the land or any part of it, to disclose this declaration and the latest Form 10-7 to the purchaser, who takes on these obligations from the date of transfer (Clause 10.10.4); and
7. for a multi-owner development, that the developer remains responsible until the body named at A5 is legally constituted and has accepted this declaration in writing (Clause 10.10.2).

**Table 10F.23 — Form 10-6, Section C: Execution and registration**

| Field | Entry |
|---|---|
| Owner: signature, name, date | _____ |
| Witness 1: signature, name, address | _____ |
| Witness 2: signature, name, address | _____ |
| Acceptance by the association or body at A5 (when constituted): signature, date | _____ |
| Registration: office, document number, date | _____ |
| For the Authority: received and recorded in the facility register; officer, date | _____ |

## Form 10-7 — Annual Maintenance Declaration and Inspection Report

Supports Clauses 10.10.3, 10.11.1(d) and 10.12 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Due by **31 March** each year from every owner of a facility in a Tier A area, and from every owner of a pumped facility, tide gate or regional facility anywhere (Clause 10.10.3). See Figure 10.3.

**Table 10F.24 — Form 10-7, Section A: Owner and facilities**

| No. | Field | Entry |
|---|---|---|
| A1 | Reporting year (1 April to 31 March) | _____ |
| A2 | Owner or association; Maintenance Declaration registration reference | _____ |
| A3 | Facilities covered (FAC_ID and type) | _____ |
| A4 | Any facility under Clause 10.6.1(c) or (d) (yes / no). If yes, Section E is required | _____ |

**Table 10F.25 — Form 10-7, Section B: Inspections made during the year (Table 10.3)**

| Facility | Routine inspections (dates) | Pre-monsoon inspection (date) | After heavy-rainfall events (dates) | Monthly pump test runs (number) |
|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |

**Table 10F.26 — Form 10-7, Section C: Pre-monsoon checklist (one per facility)**

| No. | Item | Condition (OK / defect) | Defect and date corrected |
|---|---|---|---|
| C1 | Inlets, pretreatment and silt traps clear | _____ | _____ |
| C2 | Orifice, trash screen and outlet clear; orifice size unchanged | _____ | _____ |
| C3 | Sediment below the trigger in the O&M plan | _____ | _____ |
| C4 | Storage volume not reduced; no filling, covering or change of use | _____ | _____ |
| C5 | Overflow and spillway route clear | _____ | _____ |
| C6 | Retention drains within 72 h (observation well or surface) | _____ | _____ |
| C7 | Pumps: full duty test; standby pump and standby power tested; fuel for 72 h on site | _____ | _____ |
| C8 | Alarms and telemetry tested | _____ | _____ |
| C9 | Flap or tide gates and non-return valves: operated and seal tested | _____ | _____ |
| C10 | Safety: covers locked, fences, signs and depth markers in place | _____ | _____ |
| C11 | Access routes clear and not used for parking | _____ | _____ |

**Table 10F.27 — Form 10-7, Section D: Declaration of the owner**

| Field | Entry |
|---|---|
| I/We declare that the pre-monsoon inspection of Clause 10.12 has been made, that the defects found have been corrected as listed in Section C, and that the facilities are maintained under the approved O&M plan. Owner: name, signature, date | _____ |

### Table 10F.28 — Form 10-7, Section E: Empanelled professional (facilities under Clause 10.6.1(c) and (d))

| Field | Entry |
|---|---|
| I have inspected the facilities listed and confirm Section C. Name, empanelment number, signature, date | _____ |

### Table 10F.29 — Form 10-7, Section F: For the Authority

| Field | Entry |
|---|---|
| Date received; on time (by 31 March) yes / no | _____ |
| Entered in the facility register (Clause 10.17), date | _____ |
| Follow-up action, if any (Clause 10.15) | _____ |

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## Form 10-8 — Asset Handover Certificate

Supports Clause 10.14 of Chapter 10.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Signed by the developer and the ULB when drains, open space facilities, regional facilities or other stormwater assets built by a developer are handed over.

### Table 10F.30 — Form 10-8, Section A: Asset and parties

| No. | Field | Entry |
|---|---|---|
| A1 | Developer: name and address | _____ |
| A2 | ULB | _____ |
| A3 | Layout or project, approval reference | _____ |
| A4 | Assets handed over (FAC_ID, type, length or volume), with a plan | _____ |

### Table 10F.31 — Form 10-8, Section B: Conditions of handover (Clause 10.14.1)

| No. | Condition | Met (yes / no) | Reference or date |
|---|---|---|---|
| B1 | As-built certificate (Form 10-5) accepted | _____ | _____ |
| B2 | Facility cleaned; pipes and culverts inspected internally (CCTV or manual entry), record handed over | _____ | _____ |
| B3 | Land, or an easement over it, transferred to the ULB | _____ | _____ |
| B4 | O&M plan, drawings, GIS data (Annex 10B) and warranties handed over | _____ | _____ |

### Table 10F.32 — Form 10-8, Section C: Defects liability and register

| No. | Field | Entry | Clause |
|---|---|---|---|
| C1 | Defects liability period: from _____ to _____ (includes at least one full monsoon season, from 1 April to 31 October, after handover) | _____ | 10.14.2 |
| C2 | Developer responsible during the period for defects and routine maintenance | _____ | 10.14.2 |
| C3 | Security deposit held by the ULB, ₹, and release date | _____ | 10.14.2 |
| C4 | Entered in the ULB GIS drainage asset register and the facility register: date | _____ | 10.14.3 |

### Table 10F.33 — Form 10-8, Section D: Signatures

| Party | Name and designation | Signature | Date |
|---|---|---|---|
| Developer | _____ | _____ | _____ |
| Certifying professional | _____ | _____ | _____ |
| ULB | _____ | _____ | _____ |

ANNEXES TO CHAPTER 11

# Basin and City Stormwater Master Plans

These annexes support Chapter 11. They give a terms of reference template for a Basin Stormwater Master Plan (BSMP), the layout of the basin list and boundary layer, the layout and method for depth–damage curves, the standard for publishing BSMP data and models, and the annual implementation report form. Annexes 11B and 11C need data that are not yet available; they say so and give the rule to use in the meantime. The template and the form are a model and a draft form for consideration by a competent authority, and are not in force.

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## Annex 11A — BSMP terms of reference template

Supports Clauses 11.1 to 11.12 of Chapter 11.

> *Model text for consideration by a competent authority. Not in force.* The Lead Authority adapts this template for each basin. Items in "[ ]" are for the Lead Authority to complete. Clause references are to this Manual, which the consultant shall follow in full.

### 11A.1 Background and purpose

1. The [Lead Authority] intends to prepare a Basin Stormwater Master Plan for the [name] basin under Chapter 11 of the Meghalaya Stormwater Design Manual.
2. The BSMP shall (Clause 11.1.2):
    - (a) map flood hazard for the basin under existing and future conditions;
    - (b) set the level of service for each part of the drainage system;
    - (c) identify, cost and rank the works, storage and land needed to reach that level of service;
    - (d) identify land to be reserved in the statutory land-use plan for regional storage, pung and tank restoration and major flow paths;
    - (e) set the basin inputs for site design: regional facilities, the fee-in-lieu unit rate, and any basin release rate stricter than Chapter 4; and
    - (f) recommend catchments for notification as flood-sensitive.
3. The BSMP may make the site criteria of Chapters 4 to 8 stricter for the basin. It shall not relax them, except through the regional detention and fee-in-lieu routes of Clauses 4.13 and 4.5.6 (Clause 11.1.3).

### 11A.2 Client, partners and study area

1. **Client:** [Lead Authority] (Clause 11.4.1).
2. **Partners:** Water Resources Department, wherever the basin includes a river, canal or tank under its control, and [other local bodies, MUDA or Urban Affairs, MSDMA] (Clause 11.4.1).
3. **Study area:** the whole of the [name] basin, draining to [outfall], as delineated under Clause 11.3, including the parts outside the client's limits (Clause 11.3.1). The provisional boundary is in [Annex 11B / attached map]. The consultant shall confirm it in Task 2.

4. **Links to other basins:** [for example the receiving river, stream, jhora, reservoir or pung corridor]. Diversions between basins by canal, drain or surplus course shall be mapped and represented in the model (Clause 11.3.2).

## 11A.3 Team

1. The study shall be led by an engineer empanelled as a Stormwater Design Professional with the basin modelling endorsement of Annex 10E (Clause 11.4.3).
2. The team shall include at least: [a hydrologist; a hydraulic modeller; a coastal or tidal specialist where the basin has a tidal outfall; a GIS and survey lead; a planner; a cost engineer; a community engagement lead]. The client sets the minimum qualifications and experience of each.

## 11A.4 Tasks

**Task 1 — Inception.** Review existing studies, data and projects in the basin. Prepare a data inventory against Table 11.1, a gap list, a survey plan, a consultation plan, and the work programme. Deliver the inception report.

**Task 2 — Data and surveys.** Assemble, survey where missing, and quality-check every item of Table 11.1 (Clause 11.5.1):

- (a) terrain: DEM from LiDAR or photogrammetry with vertical accuracy of 0.15 m RMSE or better in urban areas, tied to the Survey of India datum, with the accuracy test reported;
- (b) drain network: every public drain, culvert and outfall, with invert levels, sizes, condition and silt depth; private drains above 600 mm;
- (c) waterbodies: every tank, pung, pond and marsh under Chapter 7: FTL, MWL, bund level, stage–storage, sluices, surplus weirs, supply channels and encroachment, in the fields of Annex 7A;
- (d) rivers and canals: cross-sections at no more than 200 m spacing and at every structure;
- (e) outfalls, rivers, streams, jhoras, reservoirs, pungs and lakes: outfall invert levels, on a named datum, against the high flood level of the receiving river at the nearest CWC level-monitoring site (none in the State has a warning or danger level), with any local gauge kept as a separate series and any conflict between published values stated; for ungauged streams and jhoras, the Umkhrah and the Umshyrpi among them, surveyed flood marks and the 1% AEP level with its sediment, debris and garbage; for outfalls to reservoirs, the maximum water level, full reservoir level and spillway and gate data from MePGCL, converted from feet where so published, and pungs and lakes at their surveyed spill levels; the release records of the dams that set the receiving levels; the landslide, flash-flood, karst, mine-void and mine-spoil hazards above the basin; and sluices, flap gates, debris racks, solid-waste traps, sediment traps, debris basins and pumping stations on the outfalls, with their capacities and operating rules;
- (f) rainfall and water levels: all available records (IMD, including its observatories at Cherrapunji and Shillong (C.S.O.) and the gauges reported by the Meteorological Centre Shillong, among them Tikrikilla, Resubelpara, Barapani, MeECL Lumjingshai, Shillong, Williamnagar, Nongstoin, Tura, Mawphlang, Mawkyrwat, Mawsynram, Sohra, RKM Sohra, Khliehriat, Baghmara, Shella and Ratacherra (types and record lengths [TBC]); the Shillong self-recording gauge and the ordinary gauges at Shillong (Obsy), Upper Shillong and Dalu used for the CWC Flood Estimation Report for subzone 2(b); the river gauges of CWC; the agro-meteorological station of the ICAR Research Complex for NEH Region at Umiam [TBC]; the rain and reservoir records of MePGCL at its dams [TBC]; and any gauges or sensors kept by the Municipal Boards, Shillong Smart City Ltd, MSDMA and the Water Resources Department [TBC]), including the 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 on 17 June, IMD, with 811.6 or 811.2 mm and 972 mm reported at Sohra and NH-6 cut by slides, as reported), 9 July 2019 (more than 72.2 mm at Shillong, with the flash floods of Polo, Forest Colony and Mawlai, as tabulated in the IRADe/NMHS plan), 21–22 September 2014 (the floods and landslides of the Garo Hills after the rain of the night of 21 September, with 52 deaths reported by 28–29 September and more than 60 in a later account, and more than 200 villages under the Brahmaputra and the Jinjiram, as reported, for which no rainfall measurement was found), 4–6 October 2024 (the floods at Dalu and the landslide at Hatiasia Songma in the Garo Hills, as reported, with no rainfall value found), 30–31 May 2025 (the flash flood at Sumer Latara and the

landslides of the Umling block near NH-6, as reported, with no rainfall value found) and June 2026 (the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki, as reported, with no rainfall value found) events;

- (g) flood evidence: surveyed flood marks and mapped extents of past events, including public reports, photographs and residents' records;
- (h) land use: existing land use and imperviousness; future land use from the statutory master plan;
- (i) soils and groundwater: HSG map (Annex 3A or Clause 3.7.2), seasonal high groundwater, aquifer and recharge zones; and
- (j) sewer interaction: known cross-connections, dry-weather flow in drains, solid-waste hotspots.

Confirm the basin boundary and the inter-basin diversions (Clause 11.3.2). Deliver the data report and the data in the formats of Annex 11D.

**Task 3 — Model build.** Build a coupled 1D–2D hydraulic model of the minor system, the major (overland) system, rivers, canals and tanks, and the outfalls (Clause 11.7.1; Figure 11.2). Use the methods of Chapter 3 and the tidal and river boundaries of Chapter 5. Run the design storms of Chapter 2, including the 24-, 48- and 72-hour storms, for at least the 50%, 10%, 1% and 0.2% AEPs, with areal reduction under Clause 2.7.3 (Clause 11.7.2). Where the basin has tank cascades, run continuous simulation under Clause 3.13 with the full IMD gridded daily record where available, and at least 30 years, disaggregated by the temporal patterns of Annex 2D. The two-step approach of Clause 3.13.5 may be used: starting tank levels and antecedent conditions from the continuous run are passed to the design-storm runs (Clause 11.7.3).

**Task 4 — Calibration and validation.** Calibrate and validate the model under Clause 3.15, using at least two of the 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 on 17 June, IMD, with 811.6 or 811.2 mm and 972 mm reported at Sohra and NH-6 cut by slides, as reported), 9 July 2019 (more than 72.2 mm at Shillong, with the flash floods of Polo, Forest Colony and Mawlai, as tabulated in the IRADe/NMHS plan), 21–22 September 2014 (the floods and landslides of the Garo Hills after the rain of the night of 21 September, with 52 deaths reported by 28–29 September and more than 60 in a later account, and more than 200 villages under the Brahmaputra and the Jinjiram, as reported, for which no rainfall measurement was found), 4–6 October 2024 (the floods at Dalu and the landslide at Hatiasia Songma in the Garo Hills, as reported, with no rainfall value found), 30–31 May 2025 (the flash flood at Sumer Latara and the landslides of the Umling block near NH-6, as reported, with no rainfall value found) and June 2026 (the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki, as reported, with no rainfall value found) events where data exist (Clause 11.7.5). Report the performance measures of Clause 3.15.4 and the reasonableness check of Clause 3.15.6.

**Task 5 — Scenarios and hazard maps.** Model the scenarios of Clause 11.7.4: (a) existing; (b) future, uncontrolled; (c) future, controlled; (d) future, with plan; and (e) climate, applied to (a) and (d). Produce flood hazard maps of extent, depth, velocity and hazard class (H1–H6, Chapter 6) for the 10%, 1% and 0.2% AEPs, existing and future-with-plan (Clause 11.8.4(a)).

**Task 6 — Level-of-service assessment.** Compare scenarios (a), (c) and (d) with the levels of service of Table 11.2 and any stricter levels the client adopts (Clause 11.6.1). Map every shortfall.

**Task 7 — Options.** Develop options in the order of Clause 11.8.1: protect and restore storage; regional retention and detention, sited by modelling; conveyance; outfall works; property-level protection; non-structural measures. Assess each option for the criteria of Clause 11.8.2: reduction in flood risk (buildings and people flooded, and expected annual damage using Annex 11C); capital and 30-year maintenance cost; land required; effect on the springs and streams that supply most towns by gravity, and their recharge areas above the town intakes, which this Manual keeps free of paving and of infiltrated road runoff, the sacred groves at the heads of perennial streams, the stability of hill slopes, where water put into colluvium, fill or slide debris raises the pore pressure, as in the landslide localities of Shillong, the cavernous limestones and coal-mine voids of the escarpment and the Jaintia hills, where water put into the ground may go anywhere and no infiltration is allowed (Clause 4.11, karst and mine rule), recharge on the alluvium of the Garo foothill plains and the valley fills of Ri-Bhoi, the only ground where it is allowed, although every assessment unit in the

State is safe (stage of extraction 3.55%, CGWB, 2022), and the quality of the groundwater, which carries iron above the drinking-water limit at Shillong and other places, and of the streams, reservoirs, pungs and lakes that the runoff reaches; effect on downstream basins and the receiving river, stream, jhora, reservoir or pung; and who benefits.

**Task 8 — Basin inputs for site design.** Where scenario (c) does not meet the level of service, propose basin release rates (m³/s/ha) by AEP and sub-catchment (Clause 11.8.3). Recommend catchments for notification as flood-sensitive, with the evidence of Clause 4.5.4.1. Identify regional facility sites, with storage volumes, land needs and the sites they serve, and compute the fee-in-lieu unit rate, including land, construction and 10 years of maintenance (Clauses 4.13.3, 11.8.4(c), (d)).

**Task 9 — Capital Improvement Programme.** Rank the works by risk reduction per rupee, with cost, phasing and responsible agency (Clause 11.8.4(e)).

**Task 10 — Maintenance and monitoring.** Prepare the pre-monsoon maintenance programme: desilting, gate and pump testing, and tank operating rules (Clause 11.8.4(f); Chapters 7 and 10). Specify monitoring needs: new rain gauges, level sensors and flood-mark survey points (Clause 11.8.4(g); Clause 10.16.1).

**Task 11 — Land-use integration.** Prepare the material for the statutory land-use plan required by Clause 11.9.1: sites to be reserved; the 1% AEP hazard map with the Chapter 7 setbacks; land in hazard classes H5–H6 in the 1% AEP event; and open space locations that can form part of flow paths or regional storage.

**Task 12 — Consultation.** Publish the draft BSMP for public comment for at least 60 days, with public meetings in each affected local body (Clause 11.10.1). Keep a log of comments and responses.

**Task 13 — Final BSMP and publication.** Revise the BSMP after consultation. Prepare the package for approval by the State Stormwater Technical Committee, including the model for review (Clause 11.11.1). Publish the data, models, maps and CIP under Annex 11D (Clause 11.10.2).

## 11A.5 Deliverables

**Table 11A.1 — Deliverables**

| No. | Deliverable | Task | Due (months from start) |
|---|---|---|---|
| D1 | Inception report, data inventory and survey plan | 1 | [ ] |
| D2 | Data report and data sets (Annex 11D) | 2 | [ ] |
| D3 | Model build report and model files | 3 | [ ] |
| D4 | Calibration and validation report | 4 | [ ] |
| D5 | Scenario results, hazard maps and level-of-service assessment | 5, 6 | [ ] |
| D6 | Options report, with basin inputs for site design | 7, 8 | [ ] |
| D7 | Draft BSMP with draft CIP, for consultation | 9–12 | [ ] |
| D8 | Final BSMP, consultation log, approval package and open-data release | 13 | [ ] |

## 11A.6 Ownership and publication

All data, models, maps and reports produced under these terms are owned by the Lead Authority and shall be published under Annex 11D. The consultant shall not use any software licence, data licence or format that prevents publication, or that prevents a third party from re-running the model with the stated software version.

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## Annex 11B — Basin lists and boundaries for Tier A bodies

Supports Clauses 11.3 and 11.4 of Chapter 11.

**To be prepared.** This annex will contain the list of basins for every Tier A body, with a GIS layer of basin boundaries delineated under Clause 11.3.2. It needs the list of Tier A bodies (Annex 1A), a DEM of the accuracy of Clause 11.5.1, flown again over the valley floors, the foothill plains and the slide-prone slopes after any large flood or landslide, the drain network of every drain-owning body (the Municipal Boards, the Shillong Cantonment Board, NSTDA, Shillong Smart City Ltd, PWD (Roads), NHAI and NHIDCL, and the District Councils and Dorbar Shnongs for the village drains and jhoras), a drain-and-jhora register giving every reach its owner, its land status (community, clan, private or State) and whether it is a waterbody under the Waterbodies Guidelines, the 32 outfalls of the Umkhrah and the Umshyrpi, the rivers and flood works of the Water Resources Department, the reservoirs of MePGCL with their levels, spillways, gates and release rules on a stated datum, the pungs and lakes with their spill levels, the springs and their recharge areas and the sacred groves above the towns, the karst, cave and coal-mine void areas, and the landslide, flash-flood and debris hazards mapped by NESAC, the IRADe/NMHS plan and MSDMA (other likely sources: Survey of India, CWC, CGWB, NIH, the Urban Affairs Department's master-plan maps and the District Councils' land records). No basin map of any Meghalaya town was found. Until the annex is published, the basins of Shillong (the Umkhrah and the Umshyrpi to the Wah Roro and Umiam lake; the Umkhen and the Wah Tamdong), the Umiam lake shore and the Umiam–Umtru reaches to Byrnihat, Jowai, the escarpment settlements of Sohra, Mawsynram and Shella, Dawki, Tura, Williamnagar, Baghmara and Dalu, the Garo foothill plains and Nongpoh–Umling named in Clause 11.3.3 are at least those named there; other Tier A bodies define their basins in their first BSMP (Clause 11.3.3); in sub-areas ML-C and ML-C1 the hazard screening of Clause 11.3.3 comes first; and the interim arrangements of Clause 11.12 apply in every basin without an approved BSMP.

### Table 11B.1 — Basins named in Clause 11.3.3 (provisional)

| Tier A body or area | Basin | Note from Chapter 11 |
|---|---|---|
| Shillong Planning Area (SMB, MUDA; the KHADC for its parts, if adopted) | Catchments of the Umkhrah and the Umshyrpi to the Wah Roro and Umiam lake | Valley floors outfall-closed (Clause 5.8.5(a)); five drains and 32 outfalls in the 1D network; Board and KHADC stretches marked; surveyed flood marks and 1% AEP level with debris and garbage as boundary |
| Shillong Planning Area (as above) | Catchments draining to the Umkhen and the Wah Tamdong | As above |
| Umiam lake shore and the Umiam–Umtru reaches | Catchments draining to Umiam lake and to the reaches below Stages III and IV and New Umtru, to Byrnihat | Lake level from MePGCL on a named datum [TBC]; largest recorded releases as boundary |
| Jowai (Municipal Board) | Catchments draining to the Myntdu headwaters | Limestone, cave and mine-void areas mapped; local flood-mark survey as boundary; Myntdu–Leshka release reach downstream |
| Sohra, Mawsynram and Shella | Catchments of the escarpment settlements (sub-area ML-C) | Hazard screening first; site-specific hydrology; duration check of Clause 6.3.6(j) |
| Dawki | Catchments draining to the Umngot | CWC Dawki high flood level (73.47 m, 2006) and June 2026 flood mark as boundary; outfall-closed case a design case |
| Tura (Municipal Board, MUDA) | Catchments draining to the Ganol and the Ringrey and Rongkhon streams | Surveyed flood marks as boundary |
| Williamnagar (Municipal Board) | Catchments draining to the Simsang | Surveyed river level as boundary |

| Tier A body or area | Basin | Note from Chapter 11 |
|---|---|---|
| Baghmara and Dalu | Catchments draining to the south Garo rivers | Bugi (Dimapara) and Dareng (Sibbari) high flood levels where they apply; Simsang survey; in sub-area ML-C1, hazard screening first |
| Garo foothill plains (Phulbari, Tikrikilla) | Catchments draining to the Jinjiram and the Krishnai | River backwater for at least the 72-hour storm; the Assam edition for the Brahmaputra |
| Nongpoh–Umling | Catchments along NH-6 draining to the Umlew and the streams of Ri-Bhoi | Slides of the hill cuts mapped |
| Other Tier A bodies and Municipal Boards, including Resubelpara | To be defined in the first BSMP | Clause 11.3.3 |

**Table 11B.2 — Attributes of the basin boundary layer (layout)**

| Field | Type | Content |
|---|---|---|
| BASIN_ID | Text | Basin identifier |
| NAME_EN, NAME_LOC | Text | Basin name in English and Khasi or Garo |
| TIER_A | Text | Tier A body or bodies in the basin |
| OUTFALL | Text | Outfall to the sea, river or major waterbody (Clause 11.2) |
| AREA_KM2 | Real | Basin area, km² |
| LEAD_AUTH | Text | Lead Authority (Clause 11.4.1) |
| PARTNERS | Text | Partners, including Water Resources Department where it applies |
| LINKS | Text | Diversions to and from other basins (Clause 11.3.2) |
| BSMP_STAT | Text | None / in preparation / draft published / approved |
| BSMP_DATE | Date | Date of approval of the current BSMP |
| REVIEW_DUE | Date | Date of the next review (Clause 11.11.2) |

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## Annex 11C — Depth–damage curves for Meghalaya building types

Supports Clause 11.8.2 of Chapter 11.

**To be prepared.** This annex will contain depth–damage curves for the main building types of Meghalaya cities, for structure and contents, for use in computing expected annual damage under Clause 11.8.2. It needs a building-type classification and building stock data (Census housing tables, property-tax records, Lead Authority GIS), damage surveys and claims from the 15–17 June 2022 (1,003.6 mm at Mawsynram in the 24 hours to 08:30 on 17 June, IMD, with 811.6 or 811.2 mm and 972 mm reported at Sohra and NH-6 cut by slides, as reported), 9 July 2019 (more than 72.2 mm at Shillong, with the flash floods of Polo, Forest Colony and Mawlai, as tabulated in the IRADe/NMHS plan), 21–22 September 2014 (the floods and landslides of the Garo Hills after the rain of the night of 21 September, with 52 deaths reported by 28–29 September and more than 60 in a later account, and more than 200 villages under the Brahmaputra and the Jinjiram, as reported, for which no rainfall measurement was found), 4–6 October 2024 (the floods at Dalu and the landslide at Hatiasia Songma in the Garo Hills, as reported, with no rainfall value found), 30–31 May 2025 (the flash flood at Sumer Latara and the landslides of the Umling block near NH-6, as reported, with no rainfall value found) and June 2026 (the collapse of the Shillong–Dawki road at Laitlyngkot and the Umngot flood at Dawki, as reported, with no rainfall value found) floods (Revenue and Disaster Management Department and MSDMA damage assessments, insurers), and replacement costs (Public Works Department schedules of rates). Until it is published, each BSMP shall state the depth–damage relations it uses and their source, and shall report the reduction in buildings and people flooded for every option (Clause 11.8.2), which does not depend on the curves.

**Table 11C.1 — Depth–damage curve (layout, one table per building type)**

| Depth of water above floor level (m) | 0 | 0.25 | 0.5 | 1.0 | 1.5 | 2.0 | 3.0 |
|---|---|---|---|---|---|---|---|
| Structure damage (% of replacement cost) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Contents damage (% of contents value) | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| Building type, source and year of costs | _____ | | | | | | |

### 11C.1 Use in option assessment

Expected annual damage (EAD) is computed for each scenario from the damages at the modelled AEPs. With damages D_1, D_2, … at annual exceedance probabilities P_1 > P_2 > …, using at least the 50%, 10%, 1% and 0.2% AEP results of Clause 11.7.2:

$$EAD \approx \Sigma \tfrac{1}{2} \times (D_i + D_{(i+1)}) \times (P_i - P_{(i+1)})$$

The reduction in EAD between scenario (c) and scenario (d), or between options, is the risk-reduction benefit used to rank works per rupee (Clause 11.8.4(e)). The BSMP shall state how damages beyond the 0.2% AEP and below the 50% AEP were treated.

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## Annex 11D — BSMP data and model publication standard

Supports Clauses 11.5.1 and 11.10 of Chapter 11, and Clause 10.17 of Chapter 10.

### 11D.1 What is published, and when

**Table 11D.1 — Items to be published**

| Item | Format | At draft (Clause 11.10.1) | At approval (Clause 11.10.2) |
|---|---|---|---|
| BSMP report, with the level-of-service assessment and options | Searchable PDF | Yes | Yes, final |
| Flood hazard maps: extent, depth, velocity, hazard class, for each AEP and scenario of Clause 11.8.4(a) | GeoTIFF rasters; extents also as GeoPackage polygons | Yes | Yes |
| Capital Improvement Programme | CSV and PDF | Draft | Yes |
| Basin release rates, recommended flood-sensitive catchments, regional facility sites, fee-in-lieu unit rate | GeoPackage and CSV | Yes | Yes |
| Data of Table 11.1 (terrain, drains, waterbodies, cross-sections, river, reservoir, pung and lake levels, slope, debris and garbage hazards and outfall structures, rainfall and levels, flood evidence, land use, soils and groundwater, sewer interaction) | GeoTIFF (terrain); GeoPackage (features); CSV (tables and time series) | Summary | Yes, except security-sensitive asset details |
| Model files: native, runnable, with all boundary-condition, rainfall and control files, the software name and version, and a run log | Native format, zipped | No | Yes |
| Calibration and validation report | Searchable PDF | Yes | Yes |
| Consultation log of comments and responses | PDF or CSV | — | Yes |

## 11D.2 Formats and references

- (a) Raster data shall be GeoTIFF, preferably cloud-optimised, with the cell size stated. Vector data shall be GeoPackage. Tables and time series shall be CSV in UTF-8, with a header row and units in the column names.
- (b) Horizontal and vertical references shall be as in Annex 10B.1(b) and (c). The vertical datum and its relationship to the Chapter 5 river datums of the CWC level-monitoring sites on the receiving rivers (not stated in any source found), of the reservoir levels of MePGCL (published in metres for Myntdu–Leshka, New Umtru and Umiam–Umtru Stage IV, and in feet for Umiam–Umtru Stage III, converted at 0.3048 m per foot), and of the flood marks surveyed on ungauged streams, jhoras, pungs and lakes shall be stated in every data set that carries levels.
- (c) Times shall be in Indian Standard Time, written as ISO 8601 (yyyy-mm-ddThh:mm+05:30). Units shall be SI.
- (d) Hazard map files shall be named `<basin>_<scenario>_<AEP>_<variable>.tif`, where scenario is a to e of Clause 11.7.4, AEP is written as 50, 10, 1 or 0p2, and variable is depth, velocity, hazard or extent; for example `umkhrah_d_1_depth.tif`.
- (e) Waterbody data shall use the fields of Annex 7A. Facility and outfall data shall use the fields of Annex 10B.

## 11D.3 Metadata

Every published data set shall carry: title; description; Lead Authority; source and method; date of capture; accuracy (for the DEM, the measured vertical RMSE); horizontal and vertical reference; scenario and AEP, where relevant; BSMP version; licence; and a contact.

## 11D.4 Withholding and personal data

- (a) Security-sensitive details of critical assets may be withheld, with the reason recorded and published (Clauses 10.17.3, 11.10.2). The flood hazard maps and the model shall still be published; only the sensitive attributes are removed.
- (b) Personal data shall not be published (Clause 10.17.3). Flood evidence collected from residents shall be published without names or contact details unless the person consents.

### 11D.5 Licence, viewer and versions

- (a) Published data and models shall be released under the Government Open Data Licence – India or an equivalent open licence (Clause 10.17.4).
- (b) The hazard maps, regional facility sites and CIP shall also be shown on a public map viewer (Clause 11.10.2).
- (c) Each approved BSMP shall carry a version number and date. Superseded versions shall stay available, marked as superseded, so that designs approved under them can be checked.
- (d) The published model package shall allow a third party with the stated software version to reproduce the published results. Designers may use its boundary conditions for site designs in the basin (Clause 11.10, Commentary).

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## Form 11-1 — Annual implementation report

Supports Clause 11.11.3 of Chapter 11, with Clauses 4.5.6.3 and 4.13.4 of Chapter 4.

*Draft form — Meghalaya Stormwater Design Manual, Draft v1.0.* Published by the Lead Authority for each basin with an approved BSMP before each monsoon season, by **31 March** (Clause 11.11.3).

### Table 11F.1 — Form 11-1, Section A: Basin and plan

| No. | Field | Entry |
|---|---|---|
| A1 | Basin; Lead Authority; partners | _____ |
| A2 | BSMP version and date of approval | _____ |
| A3 | Reporting year (1 April to 31 March) | _____ |
| A4 | Date of publication (by 31 March) and web address | _____ |

### Table 11F.2 — Form 11-1, Section B: CIP progress

| CIP rank | Work | Agency | Cost in CIP (₹) | Spent this year (₹) | Spent to date (₹) | Status | Expected completion |
|---|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

### Table 11F.3 — Form 11-1, Section C: Fee-in-lieu ledger (Clauses 4.5.6.3(c) and 4.13.4)

| Regional facility or tank | Volume credited to sites (m³) | Volume delivered (m³) | Fees received (₹) | Fees spent (₹) | Fees held, with year received |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |
| Basin total: volume owed and delivered | _____ | _____ | _____ | _____ | _____ |

### Table 11F.4 — Form 11-1, Section D: Maintenance completed (Clause 11.8.4(f))

| No. | Item | Planned | Done | Date completed |
|---|---|---|---|---|
| D1 | Desilting of drains and canals (length, km; volume, m³) | _____ | _____ | _____ |
| D2 | Tank and pung desilting and restoration (tanks, number; storage restored, m³) | _____ | _____ | _____ |
| D3 | Gate tests (number of gates) | _____ | _____ | _____ |
| D4 | Pump station duty tests (number of stations) | _____ | _____ | _____ |
| D5 | Tank operating rules reviewed with the custodian (number) | _____ | _____ | _____ |
| D6 | Monitoring added: rain gauges, level sensors, flood-mark points (Clause 11.8.4(g)) | _____ | _____ | _____ |

### Table 11F.5 — Form 11-1, Section E: Flooding against the levels of service

| Event (dates) | Rainfall compared with the design depths (Clause 10.16.2(a)) | Level-of-service element (Table 11.2) | Location | Met (yes / no) | Event report reference (Clause 10.16.2) |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |

### Table 11F.6 — Form 11-1, Section F: Review triggers and sign-off

| No. | Field | Entry |
|---|---|---|
| F1 | Event exceeding the 1% AEP design depth in the basin this year (yes / no). If yes, review due within 2 years (Clause 11.11.2) | _____ |
| F2 | Statutory land-use plan revised this year (yes / no) (Clause 11.11.2) | _____ |
| F3 | Next 10-year review due (date) | _____ |
| F4 | Officer of the Lead Authority: name, designation, signature, date | _____ |