



“Terrain-Adaptive Multi-Level Urban Construction in Hilly Terrain”

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ABSTRACT

Conventional cast-in-situ drains are slow to build, vary in quality and are often found blocked only after flooding. This project proposes a **Smart Precast Drainage System with IoT-Based Monitoring and Automatic Blockage Management** for a hypothetical 250 m campus roadside drain. The civil part uses precast M30 U-shaped drain units of 600 × 600 mm clear opening, cover slabs and inspection chambers. A worked hydraulic design using the Rational Method and Manning's equation, with an assumed catchment of 1.5 ha and an assumed design intensity of 100 mm/h, gives a design discharge of 0.26 m³/s and a design flow depth of 0.318 m at a slope of 1 in 200.

The smart part uses three ultrasonic level sensors, a backup float switch and a rain gauge connected to ESP32-based nodes. Flow is estimated from level rather than measured directly. A rule-based method compares water levels upstream and downstream of a debris basket together with rainfall to classify normal flow, partial blockage, severe blockage, downstream backwater, heavy-rain overload and sensor fault. A stainless-steel basket lifted by a 24 V, 60 W worm-gear motor removes coarse debris, and a passive side-weir bypass of Ø450 mm gives relief when the main path is obstructed; at the assumed geometry it passes about 43 % of the design flow.

Illustrative costing gives about ₹ 23,97,340 for cast-in-situ, ₹ 17,71,000 for conventional precast and ₹ 19,34,405 for the smart precast drain. The smart features are not justified by maintenance savings alone but may be justified at sites where flood consequences are high. The design is a student concept: thresholds, rates and mechanism performance are assumptions that need prototype validation, and no novelty or patentability is claimed.

Keywords: precast drain, IoT, ultrasonic level sensor, blockage classification, debris basket, emergency bypass.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Surface drains carry storm runoff away from roads, buildings and open areas. In most Indian towns and campuses the common solution is a cast-in-situ open drain of masonry or reinforced concrete, often covered with slabs. Such drains are simple to understand and need only local labour, but their quality depends on site workmanship, weather and curing, and the work is slow because excavation, shuttering, steel fixing, concreting and curing must follow one another on the same trench.

1.2 PROBLEMS WITH CONVENTIONAL DRAINAGE

- **Blockage:** plastic waste, leaves, silt and construction debris collect at crossings, bends and outlets. A drain that is hydraulically adequate on paper can lose much of its capacity when blocked.
- **Flooding:** when blockage coincides with intense rain, water rises above the drain and spreads over the road or into adjoining property.
- **Slow, variable construction:** dimensional errors, honeycombing and poor curing are common in site-cast work.
- **Reactive maintenance:** blockages are usually found only after complaints or flooding; nobody knows the water level or flow in the drain between inspections.

1.3 PRECAST CONCRETE DRAINAGE

Precast drainage uses factory- or yard-made concrete units (U-shaped channels, box sections, pipes, inspection chambers and cover slabs) that are lifted into a prepared trench and jointed. Because units are cast in steel moulds and cured under control, dimensions and concrete quality are more consistent, and casting can proceed while the trench is being excavated. Design and erection of prefabricated concrete elements in India are covered by IS 15916:2010 [2], and concrete pipes by IS 458:2003 [4].

1.4 IoT-BASED MONITORING AND AUTOMATED BLOCKAGE MANAGEMENT

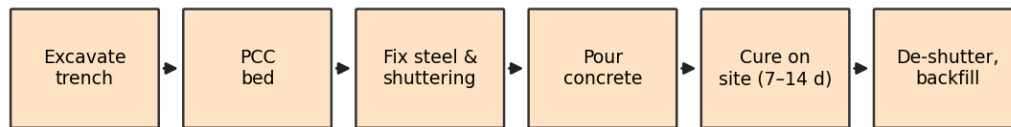
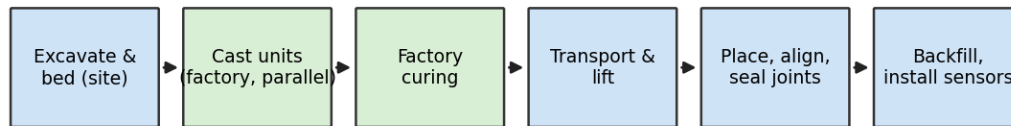
The Internet of Things (IoT) connects sensors and small controllers to a network so that field conditions can be seen remotely. For a drain, the most direct measurement is water level. Several published student and research prototypes use ultrasonic level sensors with a microcontroller to raise an alert when the level exceeds a threshold [15]–[18]. A single level threshold, however, cannot tell a blockage from heavy rain or from a high level in the receiving drain. This project therefore compares readings from several points together with rainfall, and adds a debris basket with an automatic lifting mechanism and a gravity bypass for the case where the main path is obstructed.

1.5 NEED FOR THE PROPOSED INTEGRATED SYSTEM

Precast construction improves how a drain is built; monitoring and blockage management improve how it performs afterwards. Treating the two together lets the precast geometry be designed with the sensors, basket guides, bypass and access openings already in mind, rather than retrofitting them into a finished drain.

1.6 PROJECT OVERVIEW

The project proposes a **Smart Precast Drainage System** for a hypothetical 250 m campus roadside drain. It combines (i) modular precast U-drain units, cover slabs and inspection chambers; (ii) three ultrasonic level sensors, a backup float switch and a rain gauge connected to an ESP32-based controller; (iii) a rule-based blockage-classification method; (iv) a removable stainless-steel debris basket with a motor-driven lifting arrangement; and (v) a passive emergency bypass. The report covers design, hydraulic calculation, components, manufacturing and installation, costing and a prototype test plan. **No part of the system has been built or tested as a full-scale installation; all performance statements are design expectations that need prototype validation.**

(a) Cast-in-situ construction**(b) Precast construction with smart integration (proposed)**

Green: off-site activities that run in parallel with site excavation

Fig. 1: Comparison of cast-in-situ and proposed precast construction workflow
 Source: Author's illustrative drawing (conceptual, not to scale)

CHAPTER 2: LITERATURE REVIEW

2.1 CONVENTIONAL CAST-IN-SITU DRAINAGE

Road and urban drainage practice in India is described in IRC:SP:42-2014 [9], IRC:SP:50-2013 [10] and the CPHEEO storm water manual [11]. These are the usual Indian references for runoff estimation, drain hydraulics, inlets and outfalls, and they treat open or covered drains as the normal solution. As far as this review went, they do not prescribe sensor-based monitoring; their text was not examined clause by clause.

2.2 PRECAST CONCRETE DRAINAGE TECHNOLOGY

IS 15916:2010 [2] is the Indian code of practice for design and erection of prefabricated concrete buildings and elements, including connections. Precast pipes are specified in IS 458:2003 [4] and their laying in IS 783:1985 [5]; manholes and similar structures are covered in IS 4111 (Part 1) [6]. Reported advantages of precast work are faster erection, factory curing and better dimensional control; limitations are the need for casting space, transport and a lifting appliance, and the risk of leakage at joints if bedding and sealing are poor.

2.3 EXISTING SMART DRAINAGE MONITORING APPROACHES

Published work on smart drains is mostly small-scale and level-based. Navia et al. [15] describe a stormwater-drain blockage detector with a LoRa/Wi-Fi sensor node, an ultrasonic distance sensor and a temperature/humidity sensor, a gateway, a cloud platform and a decision tree. Patil et al. [16] describe an ultrasonic level system with a Blynk-based remote interface and a control-room-initiated cleaning unit. Misra et al. [17] and Ghodmare et al. [18] are **preprints (not peer reviewed)** describing ultrasonic level sensing between manholes with alerts, and in [17] movable gates as actuators. These works show that ultrasonic level sensing with a low-cost controller is a common, feasible starting point; the review of their abstracts and available text does not show field-scale validation of automated cleaning.

2.4 SENSORS, IoT AND CLEANING APPROACHES

Level and flow sensing. Ultrasonic sensors measure the echo time of a sound pulse and are non-contact, but suffer from a blind zone near the transducer, temperature dependence of sound speed, and false echoes from walls or floating debris. Float switches are simple and reliable but give only one level. Turbine (Hall-effect) flow sensors suit closed, clean pipes and are not suitable for an open drain carrying debris; in open channels discharge is usually derived from level through a calibrated stage–discharge relation [12], [13]. **IoT architecture.** A typical node uses a microcontroller, a radio (Wi-Fi, GSM/4G or LoRa) and a message protocol such as MQTT [20] to a dashboard. **Debris handling.** Screens, trash racks and bar screens are widely used at pumping stations and treatment works [21]; cleaning in roadside drains is mostly manual. Automatic cleaning of narrow roadside drains is less documented, and any such arrangement must be treated as a design requiring trials.

2.5 RESEARCH GAP AND PROPOSED CONTRIBUTION

Table 1: Comparison of the reviewed works with the proposed project

Source	Main focus (as reported)	Cleaning / bypass	Precast integration
Navia et al. [15]	Ultrasonic + temperature/humidity node, LoRa/Wi-Fi, decision tree	Not described	Not addressed
Patil et al. [16]	Ultrasonic level, Blynk, remote-operated cleaning unit	Remote cleaning unit	Not addressed
Misra et al. [17] (preprint)	Ultrasonic level between manholes; gates as actuators	Movable gates	Not addressed
Ghodmare et al. [18] (preprint)	Water-level, blockage and gas alerts by message	Not described	Not addressed
This project (proposal)	Multi-point level + rain comparison; classification; basket; bypass	Basket lift + passive bypass	Designed into precast units and chambers

Research gap. Within the sources reviewed, level sensing and alerts are common, while a combined design that compares upstream/downstream levels across a screen, ties the logic to a basket-cleaning mechanism and a bypass, and builds all of this into precast components is not described. This is a statement about the sources reviewed here; **no formal prior-art or patent search has been done, and the project makes no claim of novelty or patentability.** Items taken from established practice and items that are only proposed are separated in Table 2 (Chapter 3).

CHAPTER 3: PROPOSED SMART PRECAST DRAINAGE SYSTEM

3.1 OVERALL CONCEPT AND SYSTEM LAYOUT

The system is designed for a 250 m roadside drain collecting runoff from a 1.5 ha campus catchment (Chapter 5). Water flows through 1 m precast U-units with removable cover slabs. Inspection chambers are provided at 50 m spacing. Near the outfall, a larger **basket chamber (BC)** houses a debris basket across the flow path and a side weir leading to a bypass pipe. Level sensors sit at the upstream monitoring chamber IC-1 and on both sides of the basket in BC; a rain gauge sits on a pole near BC. Level sensors sit at the upstream monitoring chamber IC-1 and on both sides of the basket in BC; a rain gauge sits on a pole near BC.

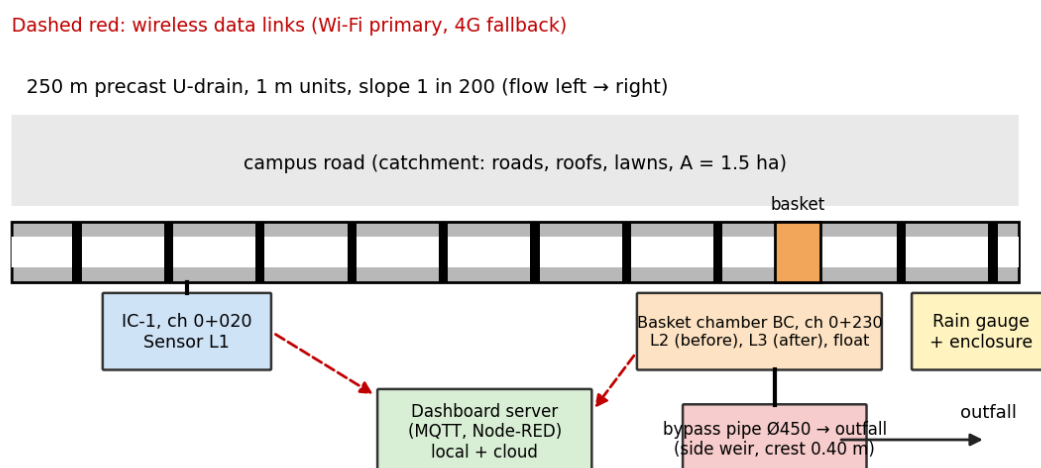


Fig. 2: Overall layout of the proposed system (plan)
Source: Author's illustrative drawing (conceptual, not to scale)

3.2 PRECAST DRAIN TYPES AND COMPONENTS

The base design uses a **U-shaped unit** of 600 × 600 mm clear opening, 1.0 m long, 100 mm walls and base, weight about 500 kg, which a small crane or backhoe with chains can place. A closed **box section** is an alternative where the drain must be covered along its full length. **Precast cover slabs** (1000 × 900 × 80 mm, about 180 kg) make the drain accessible for inspection. Pipes per IS 458 [4] are used for the bypass and crossings; chambers follow the intent of IS 4111 (Part 1) [6].

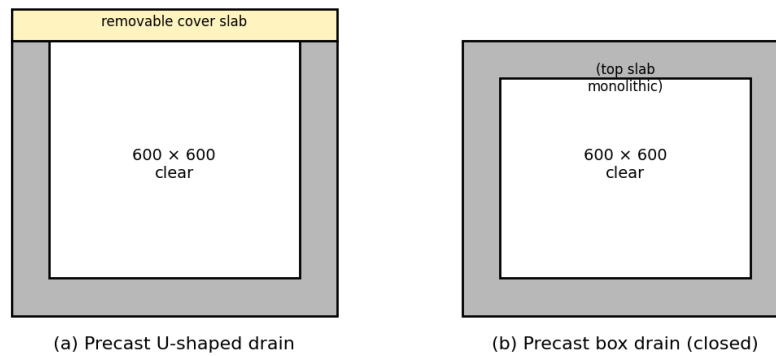


Fig. 3: Precast U-shaped and box drain sections
Source: Author's illustrative drawing (conceptual, not to scale)

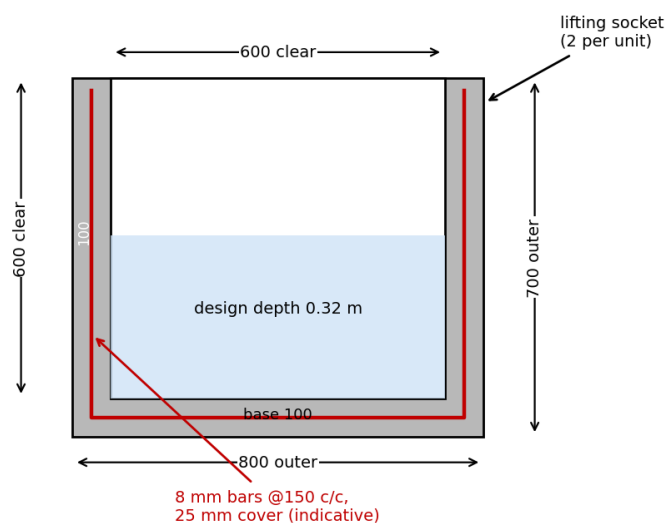


Fig. 4: Dimensioned cross-section of the precast U-unit with indicative reinforcement
Source: Author's illustrative drawing (conceptual, not to scale)

3.3 SENSOR AND IoT INTEGRATION

Each monitoring chamber is made taller than the drain (1.3 m internal depth) so that a sensor head can be fixed 1.00 m above the invert. This is needed because the ultrasonic modules considered have a blind zone of roughly 0.25 m; fixing the head directly under a cover slab 0.60 m above the invert would place the maximum water level inside the blind zone. Electronics are housed above flood level in a pole-mounted enclosure; only sensor heads and cables enter the chamber.

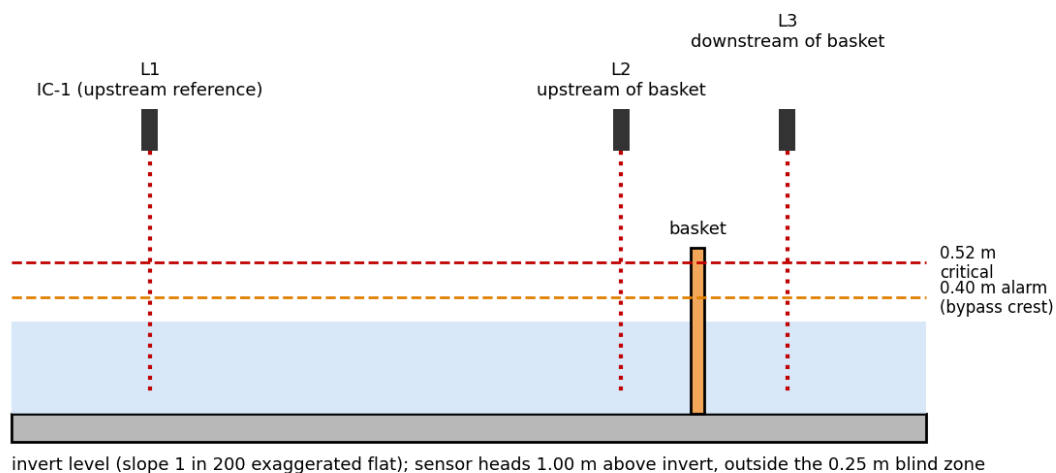


Fig. 5: Sensor locations and alarm levels (longitudinal section)
Source: Author's illustrative drawing (conceptual, not to scale)

3.4 BLOCKAGE CLASSIFICATION, BASKET AND BYPASS

Classification (Chapter 6) uses the water-surface level at three points and rainfall. The basket (Chapter 7) is lifted when a clogged screen is suspected. The side weir at BC spills to a Ø450 mm bypass pipe when the level reaches 0.40 m; it is passive and works without power or software. Sensor protection and maintenance access are described in Section 4.5 and Chapter 7.

Table 2: Status of the main features (established practice versus proposed integration)

Feature	Status	Needs validation
Precast U-drain, cover slabs, chambers, pipes	Established practice [2],[4],[6]	Structural check of chosen sizes; local manufacture
Manning-based drain design	Established practice [9]–[13]	Local rainfall data, levels, roughness
Ultrasonic level sensing with MCU and alert	Reported in student/research work [15]–[18]	Calibration, fouling, temperature effects
Differential-level (across-screen) classification	Proposed here	Thresholds, false-alarm rate, field trial
Motor-driven basket lifting	Proposed here	Jamming, corrosion, safety, duty cycle
Passive side-weir bypass	Common hydraulic device; sizing proposed here	Hydraulic check, discharge location

CHAPTER 4: MATERIALS, COMPONENTS AND SENSOR SELECTION

4.1 CONCRETE AND REINFORCEMENT

Precast units are proposed in **M30** concrete with Ordinary Portland Cement conforming to IS 269 and aggregates to IS 383, proportioned by IS 10262:2019 [3]. The maximum water–cement ratio and minimum cement content depend on the exposure condition chosen from IS 456:2000 [1] (Table 5); drains in contact with damp soil and wastewater are normally treated as at least moderate and often severe exposure, so $w/c \leq 0.45$ and cement ≥ 320 kg/m³ are assumed here and must be verified. Reinforcement is Fe 500 deformed bars to IS 1786:2008 [7]. An indicative cage of 8 mm bars at 150 mm centres each way is used in the quantities (about 80 kg/m³); **the actual reinforcement must come from a structural design** for handling, earth pressure and surcharge, with cover per IS 456.

4.2 MOULDS, LIFTING AND JOINTS

Steel moulds with a collapsible inner core allow early demoulding. Two cast-in lifting sockets per unit, located by the designer so the unit hangs level, are used in preference to chains round the unit. Joints are of the socket or rebated type with a flexible sealant or rubber gasket and a cement-mortar fillet. Bypass pipes are IS 458 [4] NP2 pipes laid per IS 783 [5].

4.3 SENSORS

Open-channel flow is not measured directly in the base design. It is **estimated from level** with the calibrated stage–discharge relation of Chapter 5, which is a standard open-channel technique [12], [13]. A Hall-effect turbine flow sensor is not used in the drain because debris would foul it. An optional radar or Doppler velocity sensor would give direct velocity but costs far more than this project budget.

Table 3: Sensors considered, with installation, limitations and maintenance

Sensor	Principle and location	Output / use	Approx. cost	Limitations and maintenance
Waterproof ultrasonic (JSN-SR04T class) ×3	Echo time; head down-facing 1.00 m above invert at IC-1 and both sides of basket (L1, L2, L3)	Distance (digital); level = 1.00 m – distance (temperature-compensated)	₹ 650 each	Blind zone ≈ 0.25 m; wide beam picks up walls; fouling and condensation; clean and re-check every 3 months
Float switch ×2	Magnetic float; at 0.52 m in BC and pre-basket	On/off; independent high-level backup	₹ 350 each	One level only; can stick in silt; test monthly
Tipping-bucket rain gauge ×1	Each tip = fixed rain depth (e.g. 0.2–0.5 mm); on pole near BC	Pulses → mm/h	₹ 6,000	Funnel blockage by leaves; clean monthly; calibrate once a year

Sensor	Principle and location	Output / use	Approx. cost	Limitations and maintenance
Temperature sensor (e.g. DS18B20), optional	Corrects speed of sound	°C	₹ 100	Place in shade; negligible cost
Turbidity sensor, optional	Light scattering; only if sediment monitoring is a project goal	NTU	₹ 1,500–3,500	Not required for blockage logic; fouls quickly; excluded from costs

4.4 CONTROLLER, COMMUNICATION, POWER AND DASHBOARD

An ESP32 development board is selected for the prototype (comparison in Chapter 6) with a Wi-Fi link to the campus network, an optional 4G/GSM fallback module, a 12 V sealed battery on a mains-fed charger, and an open-source dashboard on a Raspberry Pi 4 using an MQTT broker, Node-RED and Grafana. These are prototype-grade parts; a deployed system would need industrial-grade equivalents.

4.5 ENCLOSURES AND PROTECTION

Controller enclosures are specified as **IP65 minimum, IP67 preferred** under IS/IEC 60529 [8]; sensor cables enter through IP68 glands from the bottom with drip loops, and brackets are stainless steel or hot-dip galvanised. Moisture, sediment, vibration and corrosion all shorten sensor life, so access points and a calibration schedule are built into the design.

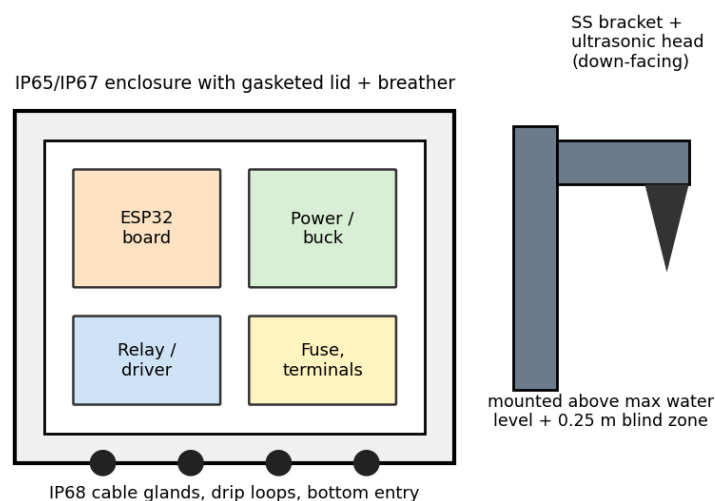


Fig. 6: Protection arrangement: controller enclosure and down-facing sensor bracket
Source: Author's illustrative drawing (conceptual, not to scale)

4.6 COMPONENT SELECTION TABLE

Table 4: Component-selection table (prices are illustrative estimates, not quotations)

Component	Function	Operating principle	Qty	Unit cost (₹)	Total (₹)	Justification
ESP32 DevKit	Acquisition, logic, Wi-Fi	Dual-core MCU, 12-bit ADC, Wi-Fi/BLE	2	600	1,200	Low cost, widely documented [19]
Ultrasonic level sensor	Level L1, L2, L3	Time of flight	3	650	1,950	Non-contact, waterproof head
Float switch	Backup high level	Magnetic reed float	2	350	700	Independent of software
Rain gauge	Rain intensity	Tipping bucket pulses	1	6,000	6,000	Needed to separate rain overload
4G/GSM module	Fallback comms	Cellular modem	1	2,200	2,200	Wi-Fi may fail in storms
Raspberry Pi 4 server	Local dashboard/log	MQTT, Node-RED, Grafana	1	7,500	7,500	Works without internet
Battery 12 V 7 Ah + SMPS	Backup power	Sealed lead-acid	2	1,700	3,400	Mains outage ride-through
Enclosure IP65/67 + glands	Protect electronics	Gasketed polycarbonate/ABS	2	2,400	4,800	Per IS/IEC 60529 [8]
SS304 basket	Collect debris	Perforated 3 mm sheet	1	9,000	9,000	Corrosion resistant

Component	Function	Operating principle	Qty	Unit cost (₹)	Total (₹)	Justification
24 V DC 60 W worm-gear motor	Lift basket	Self-locking gear reduction	1	6,500	6,500	Torque margin (Ch. 7)
Limit switches IP67	End positions	Mechanical/inductive	4	600	2,400	Position feedback
Flap valve 450 mm	Stop backflow in bypass	Hinged disc	1	9,500	9,500	Receiving water may rise

CHAPTER 5: DESIGN AND HYDRAULIC CALCULATIONS

5.1 HYPOTHETICAL SITE AND ASSUMPTIONS

This is a worked example for an assumed site, not a design for a real location. A 250 m roadside drain on a campus road carries runoff from the catchment in Table 5 to a natural stream. Longitudinal slope $S = 1$ in $200 = 0.005$; soil is ordinary soil; the design intensity $i = 100$ mm/h is an **assumed** value for a storm duration close to the time of concentration. Final design needs the local intensity–duration–frequency data, surveyed levels and the return period required by the relevant guidelines [9]–[11].

Table 5: Assumed catchment and runoff coefficients

Surface	Area (ha)	Runoff coeff. C	$C \times A$
Paved road and parking	0.60	0.85	0.510
Roofs	0.30	0.90	0.270
Lawns / open ground	0.60	0.25	0.150
Total / composite	1.50	0.62	0.930

5.2 DESIGN DISCHARGE (RATIONAL METHOD)

The Rational Method [14] gives peak discharge for small catchments, with Q in m^3/s , i in mm/h and A in ha :

$$Q = C \cdot i \cdot A / 360 \quad (5.1)$$

Composite $C = 0.930 / 1.50 = 0.62$. Therefore $Q = 0.62 \times 100 \times 1.5 / 360 = \mathbf{0.258 \text{ m}^3/\text{s}}$ (design discharge, taken as $0.26 \text{ m}^3/\text{s}$). Time of concentration is taken as an assumed 10 min inlet time plus travel time in the drain, 3.1 min at the velocity found below, giving 13.1 min, close to the duration assumed for i .

5.3 DRAIN SIZE USING MANNING'S EQUATION

For a rectangular section of width $B = 0.60$ m, Manning's $n = 0.015$ (smooth precast concrete, conservative), $S = 0.005$:

$$V = (1/n) \cdot R^{2/3} \cdot S^{1/2}, \quad R = A/P, \quad Q = A \cdot V \quad (5.2)$$

Trial depth $y = 0.318$ m: $A = B \cdot y = 0.1908 \text{ m}^2$; wetted perimeter $P = B + 2y = 1.236$ m; hydraulic radius $R = A/P = 0.1544$ m; $V = (1/0.015) \times 0.1544^{2/3} \times 0.005^{1/2} = \mathbf{1.357 \text{ m/s}}$; capacity $Q = A \cdot V = 0.2588 \text{ m}^3/\text{s} \geq 0.258 \text{ m}^3/\text{s}$, so the section is adequate. Froude number $Fr = V/\sqrt{g \cdot y} = 0.77$, i.e. sub-critical flow, so downstream levels (backwater) can affect upstream depths, which the classification logic must allow for. Freeboard at design depth is $0.60 - 0.318 = 0.28$ m. Brim-full capacity ($y = 0.60$ m) is $0.58 \text{ m}^3/\text{s}$, about 2.25 times the design discharge.

Table 6: Stage–discharge values used to set thresholds ($B = 0.60$ m, $S = 0.005$, $n = 0.015$)

Depth y (m)	Velocity V (m/s)	Discharge Q (m^3/s)	Remark
0.10	0.84	0.050	Low flow; V above 0.6 m/s
0.20	1.15	0.138	
0.32	1.36	0.261	Design depth
0.40	1.46	0.349	Alarm level; bypass crest
0.52	1.56	0.486	Critical level
0.60	1.61	0.580	Brim full

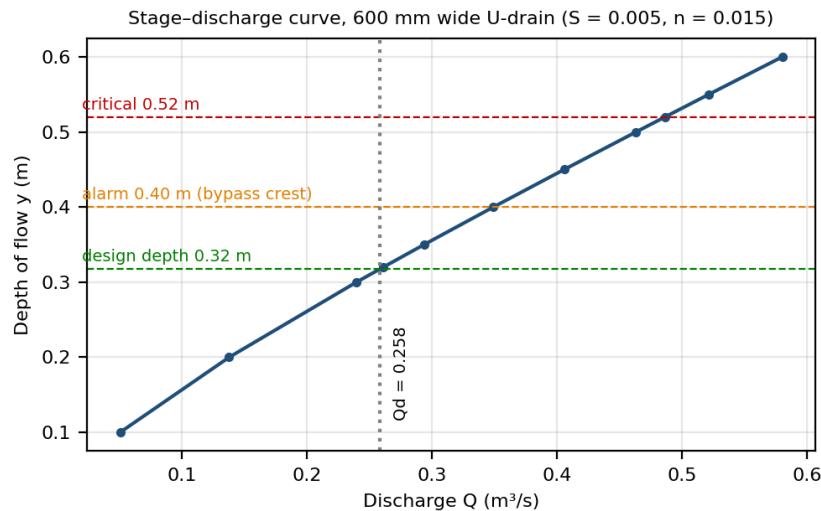


Fig. 7: Stage–discharge curve of the 600 mm U-drain with alarm levels

Source: Author's illustrative drawing (conceptual, not to scale)

At low flow ($y = 0.10$ m) the velocity is still 0.838 m/s, which is above the 0.6 m/s commonly used as a minimum for self-cleansing, so silt deposition is not expected at this slope for flows of that size; this must be checked against the local guidelines [9],[11]. The stage–discharge relation also gives the flow estimate used by the dashboard: Q is read from measured depth, valid only while flow is uniform and the drain is free of backwater and in good condition.

5.4 PRECAST UNIT, JOINTS AND QUANTITIES

Unit: $1.0\text{ m} \times 0.80\text{ m} \times 0.70\text{ m}$ high, wall and base 100 mm , concrete 0.2 m^3 (about 500 kg). Cover slab $1000 \times 900 \times 80\text{ mm}$ (0.072 m^3 , about 180 kg) bearing 150 mm on each wall. Joints are rebated with sealant and mortar fillet. Trench width 1.20 m (0.20 m working space each side), depth 0.80 m including a 100 mm PCC M10 bed. The wall and base thickness and the bar sizes are **indicative** and must be confirmed by structural design for handling, earth pressure and wheel surcharge.

Table 7: Quantities for 250 m of precast drain (hypothetical site)

Item	Unit	Quantity	Basis
Precast U-units	nos	250	1.0 m each
Precast cover slabs	nos	250	1.0 m each
Concrete in units (M30)	m^3	50	$0.20\text{ m}^3 \times 250$
Concrete in cover slabs (M30)	m^3	18	$0.072\text{ m}^3 \times 250$
Reinforcement in units (Fe 500)	kg	4,000	80 kg/m^3 assumed
Excavation	m^3	240	$1.20 \times 0.80 \times 250$
PCC M10 bed	m^3	25.0	$1.0 \times 0.10 \times 250$
Backfill beside units	m^3	70.0	$2 \times 0.20 \times 0.70 \times 250$
Inspection chambers (precast)	nos	6	50 m spacing + basket chamber

5.5 SENSOR LOCATIONS AND INDICATIVE ALARM THRESHOLDS

Level sensors L1, L2 and L3 and the rain gauge are placed as in Fig. 2 and Fig. 5. Depths are computed as $y = 1.00\text{ m} - \text{measured distance}$ (plus a calibration offset). Water-surface elevation (WSE) at L2 and L3 is the invert elevation plus depth; $\Delta h = \text{WSE2} - \text{WSE3}$ is the head loss across the basket, with Δh_0 its clean-basket value measured at commissioning.

Table 8: Indicative thresholds (illustrative; to be calibrated in the prototype and on site)

State / event	Condition (all values for BC unless stated)	Action
Normal	$y_2 \leq 0.35\text{ m}$ and $\Delta h < \Delta h_0 + 40\text{ mm}$	Log every 1 min; heartbeat
Watch	$0.35 < y_2 < 0.40\text{ m}$	Sample every 5 s; show on dashboard
Alarm (bypass active)	$y_2 \geq 0.40\text{ m}$ (side-weir crest)	Alert by app/SMS; check basket state
Critical	$y_2 \geq 0.52\text{ m}$ or float switch ON (80 mm below brim)	Urgent alert; local beacon and buzzer
Partial clogging	$\Delta h \geq \Delta h_0 + 40\text{ mm}$ for 2 min	Start cleaning cycle; warning
Severe clogging	$\Delta h \geq \Delta h_0 + 100\text{ mm}$ or $y_2 \geq 0.52\text{ m}$ with Δh high	Cleaning cycle; urgent alert

State / event	Condition (all values for BC unless stated)	Action
Heavy-rain overload	Rain $\geq$ 80 mm/h (80 % of design) and y1, y2, y3 rising together, Δh small	Notify; no cleaning
Sensor fault	Distance outside 0.25–4.0 m, no echo for 3 readings, value frozen for 30 min in rain, or WSE3 > WSE2 + 30 mm	Maintenance alert; use float backup

5.6 PRELIMINARY BYPASS CAPACITY

The side weir (crest 0.40 m, length $L = 1.5$ m) is treated as a rectangular weir with $C_d = 0.60$ (assumed):

$$Q_b = (2/3) \cdot C_d \cdot L \cdot \sqrt{2g} \cdot H^{3/2} \quad (5.3)$$

At $H = 0.12$ m (water at the 0.52 m critical level), $Q_b = (2/3)(0.60)(1.5)(4.43)(0.12)^{1.5} = 0.11 \text{ m}^3/\text{s}$, about 43 % of the design discharge. The Ø450 mm RCC bypass pipe at 1 in 100 and $n = 0.013$ has a full-flow capacity of 0.285 m³/s from $Q = (0.312/n) \cdot D^{8/3} \cdot S^{1/2}$, more than the weir passes, so the weir governs. **The bypass therefore does not remove the whole design flow if the basket is fully blocked;** it reduces flooding risk and buys time. A longer weir or larger pipe, a check of the real side-weir coefficient, and the capacity of the discharge point must be verified before any real use.

CHAPTER 6: IoT ARCHITECTURE AND BLOCKAGE-CLASSIFICATION LOGIC

6.1 SENSOR-TO-CONTROLLER ARCHITECTURE

Two ESP32 nodes are proposed: Node A at IC-1 (sensor L1) and Node B at BC (L2, L3, float switch, rain gauge, motor driver, limit switches). Each node validates its own readings, runs the classification locally and publishes results over MQTT [20]. Because the basket control runs on Node B, cleaning does not depend on the cloud or internet.

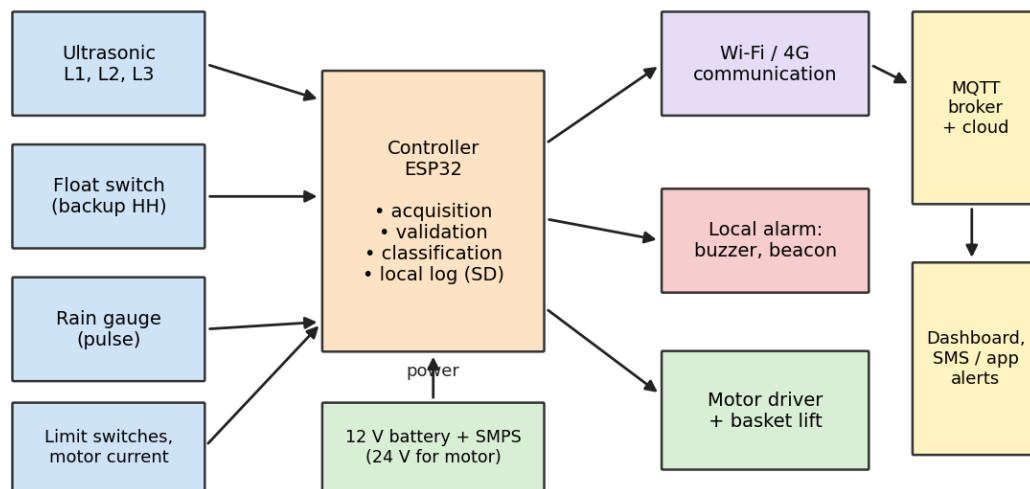


Fig. 8: IoT system block diagram

Source: Author's illustrative drawing (conceptual, not to scale)

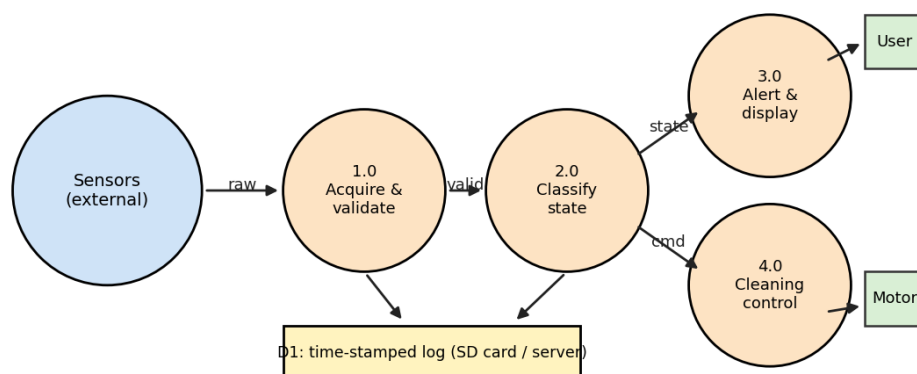


Fig. 9: Simple data-flow diagram (levels 0–1)

Source: Author's illustrative drawing (conceptual, not to scale)

6.2 CONTROLLER AND COMMUNICATION OPTIONS

Table 9: Comparison of controller options

Option	Key features	Suitability for this project
ESP32 (e.g. DevKit)	Dual-core MCU up to 240 MHz, built-in Wi-Fi and Bluetooth, 3.3 V logic [19]	Selected for prototype: integrated Wi-Fi, ample I/O, low cost; needs watchdog and careful power design
Arduino Uno R3	ATmega328P, 16 MHz, 5 V, 2 KB RAM, no built-in networking	Simple and robust for sensing and motor control, but needs add-on modules for communication; limited memory
Raspberry Pi Pico W	RP2040 dual-core, Wi-Fi	Good alternative; smaller community for some sensor and cellular libraries
Industrial PLC / STM32-based	Rugged I/O, certified power and EMC	Better for a real deployment; costly and harder for a diploma prototype

Table 10: Comparison of communication options

Option	Strengths	Weaknesses
Wi-Fi	Low cost, high data rate, campus network available	Short range; depends on access-point power and coverage
GSM / 4G	Wide coverage, works away from campus	Recurring data cost; high current peaks; module and antenna cost
LoRa	Long range, low power, licence-free band in India (865–867 MHz)	Low data rate; needs gateway; extra hardware

For the campus prototype, Wi-Fi is the primary link with an optional 4G fallback. If neither is available, the nodes still classify, drive the basket, sound the local alarm and store records on an SD card, sending the backlog when the link returns (store-and-forward).

6.3 BLOCKAGE-CLASSIFICATION LOGIC

Readings are taken every 10 s and the one-minute median is used to reject single false echoes. The logic compares three levels and rainfall. A blockage at the basket makes water pile up on the upstream side while the downstream side stays low, so Δh grows while y_3 remains low. Heavy rain raises y_1 , y_2 and y_3 together with a high rain-gauge reading and **small** Δh . A high level in the receiving drain raises y_3 close to y_2 (backwater), again with small Δh . Table 11 summarises these patterns; Fig. 10 gives the flowchart.

Table 11: Classification matrix (indicative)

State	y_2	Δh	y_3	Rain	Response
Normal	≤ 0.35	small	low	any	Log
Partial blockage	rising	$\Delta h_0 + 40$ mm	low	low/mod.	Clean, warn
Severe blockage	≥ 0.40 – 0.52	$\Delta h_0 + 100$ mm	low	any	Clean, bypass spills, urgent alert
Downstream backwater	high	small	high	any	Alert; inspect outfall
Heavy-rain overload	high	small	rising	≥ 80 mm/h	Notify only
Sensor fault	invalid	—	invalid or $WSE_3 > WSE_2$	any	Maintenance alert; float backup

Illustrative pseudocode

```

every 10 s: read L1,L2,L3,rain,float; keep 1-min medians
if any reading invalid or  $WSE_3 > WSE_2 + 30$  mm: state = FAULT; alert; exit
dh =  $WSE_2 - WSE_3$ 
if  $dh \geq dh_0 + 100$  or  $y_2 \geq 0.52$ : state = SEVERE; start_cleaning(); alert(urgent)
else if  $dh \geq dh_0 + 40$  for 2 min: state = PARTIAL; start_cleaning(); alert(warn)
else if  $y_3 \geq 0.35$  and  $dh < dh_0 + 40$ : state = BACKWATER; alert(inspect)
else if rain  $\geq 80$  and  $y_1, y_2, y_3$  rising: state = OVERLOAD; alert(info)
else: state = NORMAL
start_cleaning(): max 3 cycles per 30 min; if dh not  $< dh_0 + 20$  after cycle -> MANUAL_REQUIRED

```

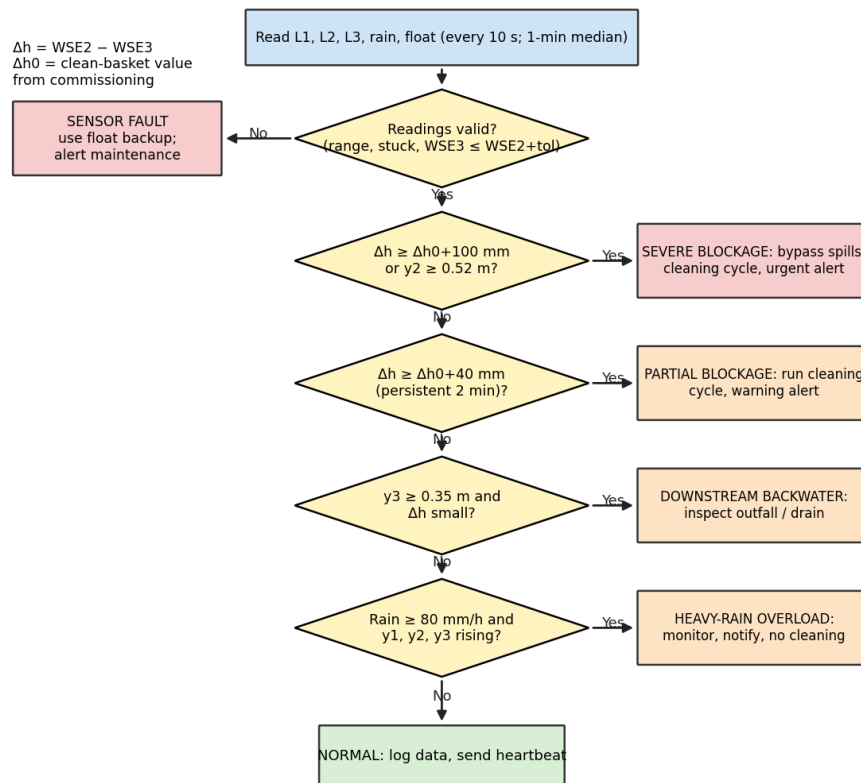


Fig. 10: Blockage-classification flowchart

Source: Author's illustrative drawing (conceptual, not to scale)

6.4 POWER, CONNECTIVITY, SECURITY AND RELIABILITY

- **Power:** an assumed average node load of 1.5 W (ESP32, sensors, 4G standby, regulator losses) from a 12 V 7 Ah battery (about 42 Wh usable) gives roughly 28 h of autonomy; the 60 W motor is used only during short cleaning cycles. A solar panel is a future option.
- **Connectivity loss:** local logic, local alarm and SD logging continue; the dashboard shows a "node offline" warning after missed heartbeats.
- **Security basics:** unique credentials per device, TLS-protected MQTT, no default passwords, signed over-the-air updates, access control on the dashboard, remote access through a VPN, and a hardware watchdog.
- **Reliability:** independent float switch for the highest level, sensor self-checks, and a rule that the bypass works without electronics.

CHAPTER 7: AUTOMATIC DEBRIS-BASKET CLEANING AND EMERGENCY BYPASS

7.1 BASKET DESIGN AND MECHANICAL ARRANGEMENT

The basket is a box of 3 mm SS304 perforated sheet with 20 mm holes (about 550 × 450 × 600 mm) that slides between two stainless guide rails fixed in BC. Holes of this size stop plastic bags, bottles, leaves and branches but pass fine silt. A motor with a worm-gear reduction drives a chain or strap that lifts the basket 0.9 m to a top position, where it tips its contents into a lidded 60 L bin; it then returns to the bottom. The worm gear is self-locking, so the basket stays in position if power fails. Hot-dip galvanised or stainless parts and a sealed motor are used because the chamber is humid and wet.

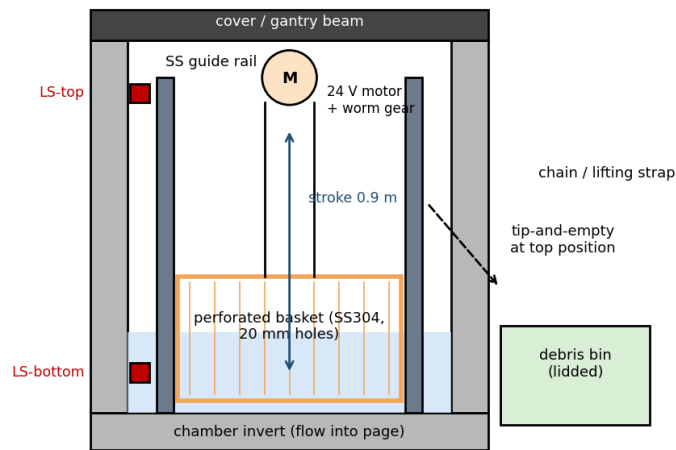


Fig. 11: Debris-basket lifting mechanism (section through basket chamber)

Source: Author's illustrative drawing (conceptual, not to scale)

7.2 MOTOR SELECTION

Assumed lifted mass (basket plus wet debris) $m = 25 \text{ kg}$, so $F = m \cdot g = 245 \text{ N}$. With a sprocket radius of 40 mm, torque $T = F \cdot r = 9.8 \text{ N} \cdot \text{m}$. Allowing a drive efficiency of 0.7 and a safety factor of 2 gives about $28 \text{ N} \cdot \text{m}$ at the output shaft. For a lifting speed of 0.03 m/s (0.9 m in 30 s) the output speed is 7.2 rpm and mechanical power $F \cdot v = 7.4 \text{ W}$; with an efficiency of 0.6 and a safety factor of 2, about 25 W electrical is the minimum. A **24 V DC, 60 W worm-gear motor** (rated current about 2.5 A) is selected to give margin for starting and stall torque. Catalogue torque at the required speed must be checked against the datasheet of the chosen motor.

7.3 TRIGGER LOGIC, FEEDBACK AND PROTECTION

- **Trigger:** $\Delta h \geq \Delta h_0 + 40 \text{ mm}$ for 2 min, or $y_2 \geq 0.40 \text{ m}$ with Δh high; not during maintenance lock-out.
- **Cycle:** lift until the top limit switch, dwell 10 s to tip, lower until the bottom limit switch. Time-out of 60 s for each stroke.
- **Jam / overload:** a current sensor trips the motor if current exceeds about 4 A for more than 0.5 s; the controller then reverses briefly once, and if the fault persists stops and raises a "manual attention" alert. A mechanical overload clutch or shear pin is recommended.
- **Result check:** after each cycle Δh is compared with $\Delta h_0 + 20 \text{ mm}$; if not recovered, repeat at most 3 times in 30 min, then flag manual cleaning.
- **Manual override and isolation:** a key-operated local switch and a lockable isolator allow safe manual operation; the basket can be lifted by hand with the chain after de-clutching.
- **Debris disposal:** the bin is emptied by maintenance staff and waste is disposed of as solid waste; removed debris is never discharged back into the drain.

Limitations. While the basket travels, the flow passes unscreened for about a minute; a twin-basket arrangement could avoid this but doubles cost. Sediment, large objects, compacted waste and blockages **downstream** of the basket will not be cleared by this mechanism and need manual cleaning.

7.4 EMERGENCY BYPASS

A side weir with crest 0.40 m opens from BC into a $\text{Ø}450 \text{ mm}$ bypass pipe that returns to the receiving stream through a headwall and a flap (non-return) valve. It operates only when the level reaches the crest, needs no power and is not controlled by software. The flap valve prevents backflow when the stream rises. Capacity and limits are in Section 5.6. The discharge point must be checked: the bypass moves water to the outfall and does not help if the blockage lies beyond the outfall or the receiving stream is already full. A removable grating and an inspection opening give access for clearing the bypass inlet.

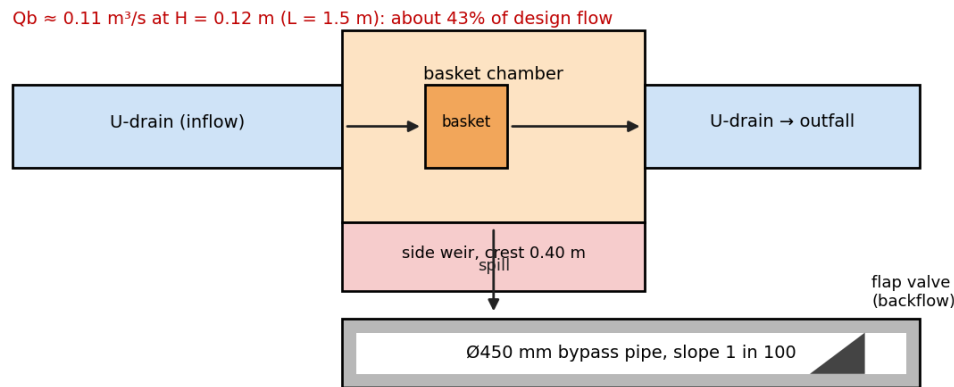


Fig. 12: Emergency bypass arrangement at the basket chamber (plan)

Source: Author's illustrative drawing (conceptual, not to scale)

7.5 FAILURE MODES AND SAFETY

Table 12: Failure modes and safeguards

Failure mode	Effect	Safeguard
Basket jam or heavy load	Motor stall	Current trip, reverse once, alert, manual override
Limit switch failure	Over-travel	Stroke time-out, mechanical stops, second switch
Corrosion, silt in guides	Seizure	Stainless parts, flushing/cleaning schedule, inspection
Sensor fouling or false echo	Wrong state	Median filter, float backup, quarterly cleaning
Power or comms loss	No remote view	Battery, local alarm, SD logging, passive bypass
Bypass inlet blocked or backflow	Reduced relief	Grating, flap valve, inspection after storms

CHAPTER 8: MANUFACTURING, INSTALLATION AND QUALITY CONTROL

8.1 PRECAST PRODUCTION

Steel moulds are cleaned, oiled and checked for dimensions. The reinforcement cage is tied with cover blocks and lifting sockets fixed; concrete is placed in layers and compacted by vibration. Units are demoulded after initial set, marked with an ID and date, and cured by spraying or ponding for 7–14 days, with cube specimens taken for strength tests. Each unit is inspected for dimensions, cracks, surface defects and joint profile before dispatch.

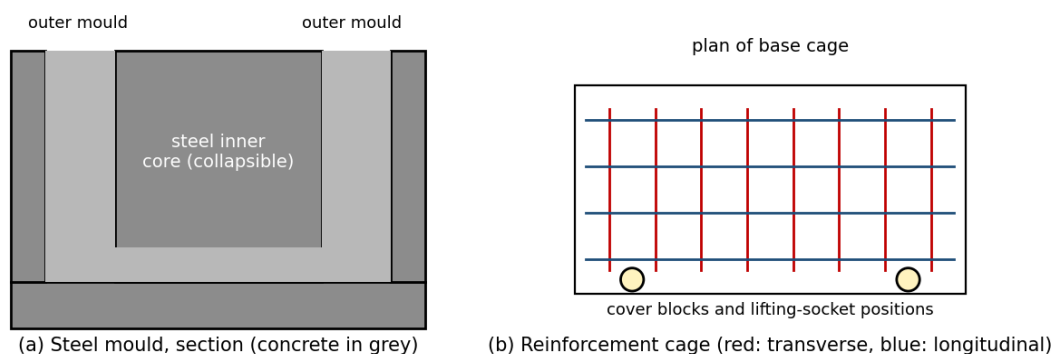


Fig. 13: Mould and reinforcement cage arrangement

Source: Author's illustrative drawing (conceptual, not to scale)

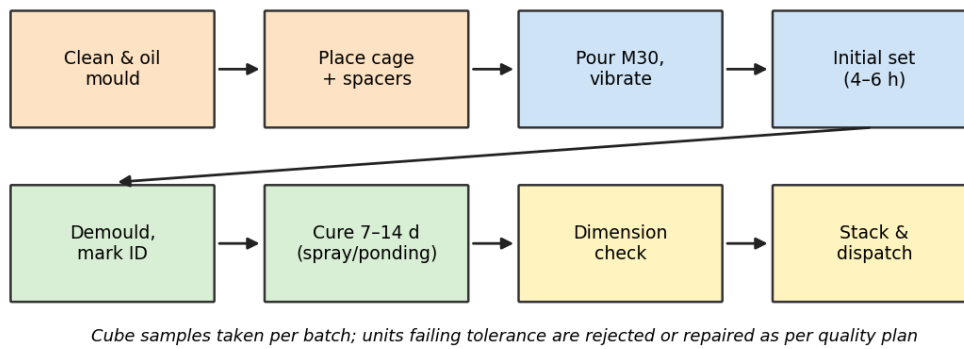


Fig. 14: Precast manufacturing and curing sequence
Source: Author's illustrative drawing (conceptual, not to scale)

8.2 TRANSPORT, LIFTING AND INSTALLATION

Units are lifted from their sockets, stacked on timber packing and moved only after the specified strength is reached. The trench is excavated to line and level, the bed placed and levelled, and units laid from the downstream end with the socket facing upstream, checking line and level at each unit. Joints are cleaned, sealant applied and mortar fillets finished. Backfill is placed evenly on both sides in 150 mm compacted layers to avoid pushing units sideways; cover slabs are placed last.

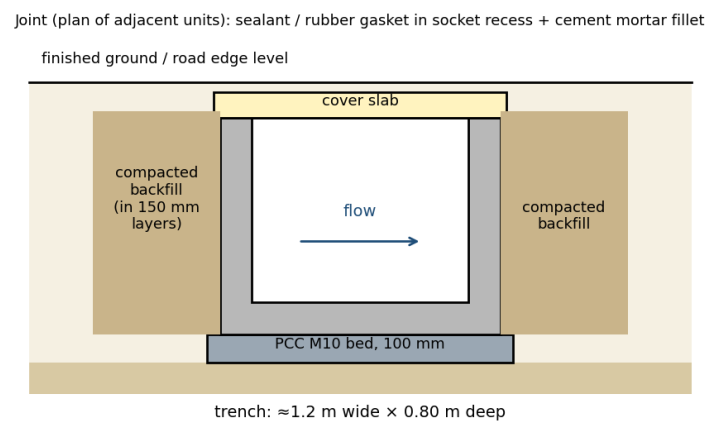


Fig. 15: Installation: trench, bed, unit, backfill and cover slab (cross-section)
Source: Author's illustrative drawing (conceptual, not to scale)

8.3 SENSOR INSTALLATION, CALIBRATION AND COMMISSIONING

- **Install:** fix brackets, set sensor heads exactly 1.00 m above the invert, route cables in conduit with drip loops, seal glands, and test the earthing and isolator.
- **Calibrate:** measure the real water depth with a scale at three levels (0.10, 0.30, 0.50 m) and fit an offset/scale correction; measure Δh_0 with a clean basket at steady flow.
- **Commission:** test each state by simulation (blocked basket, rainfall input, unplugged sensor, cut communication), operate the basket through full cycles, and confirm the bypass spills at the crest level.

Table 13: Inspection and quality-control checklist

Stage	Check	Acceptance (indicative)
Materials	Cement, aggregate, steel certificates	Conform to IS 269, 383, 1786
Casting	Cover, spacing, workability, cube tests	Per approved mix and IS 456
Dimensions	Length, width, wall thickness, squareness	Tolerance per IS 15916 / project spec
Curing	Duration and method records	7–14 days, no drying
Laying	Line, level, bedding, joint filling	Level within ± 5 mm; no leakage
Sensors	Calibration records, IP checks, cable sealing	Error within the set tolerance
Functional tests	Alarm, classification, basket cycles, bypass	All tests passed and recorded

CHAPTER 9: COST ESTIMATION AND COMPARATIVE ANALYSIS

9.1 BASIS AND ASSUMPTIONS

All rates are illustrative planning estimates for Western Maharashtra as of October 2026, assumed by the project team; they are not taken from any Schedule of Rates or supplier quotation, and they exclude GST, land, design fees, dewatering, road restoration and utility shifting. Before any real use, rates must be replaced from the current Maharashtra PWD / CPWD Schedule of Rates and written quotations. Quantities for the cast-in-situ option use the same hydraulic size with 150 mm walls and base (0.315 m³/m; 78.8 m³ in total). The same precast cover slabs and six chambers are included in all options so that the comparison isolates the effect of construction method and smart features. A 10 % contingency is added.

9.2 BILL OF QUANTITIES FOR THE SMART ADD-ON

Table 14: Bill of quantities: smart features added to precast drain (250 m site)

Item	Unit	Qty	Rate (₹)	Amount (₹)
A. Sensing and control				
ESP32 DevKit controller (2 nodes)	nos	2	600	1,200
Waterproof ultrasonic level sensor (JSN-SR04T class)	nos	3	650	1,950
Float switch, high-high level (stainless/PP)	nos	2	350	700
Tipping-bucket rain gauge	nos	1	6,000	6,000
Local alarm: buzzer, beacon, OLED display	set	1	1,700	1,700
B. Communication and dashboard				
4G/GSM fallback module with SIM antenna	nos	1	2,200	2,200
Raspberry Pi 4 local server (Node-RED, MQTT, Grafana)	set	1	7,500	7,500
Data plan and connectivity, first year	yr	1	1,200	1,200
C. Power and protection				
12 V 7 Ah sealed battery with 12 V SMPS and charger	set	2	1,700	3,400
IP65/IP67 enclosures, cable glands, DIN accessories	set	2	2,400	4,800
Sealed cable, conduit, earthing, MCB/RCCB isolation	LS	1	5,000	5,000
D. Debris basket and cleaning mechanism				
SS304 perforated basket (3 mm sheet), fabricated	nos	1	9,000	9,000
SS guide rails and brackets	set	1	6,000	6,000
Galvanised MS lifting gantry, chain and sprockets	set	1	16,500	16,500
24 V DC 60 W worm-gear motor	nos	1	6,500	6,500
Motor driver, current sensing, relays, 24 V SMPS	set	1	4,300	4,300
IP67 limit switches / proximity sensors	nos	4	600	2,400
Lidded debris bin (60 L) and IP66 control box	set	1	4,500	4,500
Fabrication, welding and anti-corrosion coating	LS	1	8,000	8,000
E. Emergency bypass				
450 mm RCC NP2 bypass pipe, laid (12 m)	m	12	1,350	16,200
Side-weir chamber, RCC (cast-in-situ)	LS	1	6,000	6,000
450 mm non-return (flap) valve	nos	1	9,500	9,500
Outfall headwall and stone pitching	LS	1	4,000	4,000
F. Installation and commissioning				
Installation, calibration, functional testing, commissioning	LS	1	20,000	20,000
Total smart add-on (before contingency)				1,48,550

Bills of quantities for the cast-in-situ and conventional precast options are given in Appendix A.

9.3 COST COMPARISON

Table 15: Comparative cost summary for 250 m of drain (₹, illustrative)

Item	1. Cast-in-situ	2. Conventional precast	3. Smart precast (proposed)
Civil works and drain units	21,79,400	16,10,000	16,10,000
Sensors, controller, communication, power	–	–	35,650
Debris basket and mechanism	–	–	57,200
Emergency bypass	–	–	35,700
Installation, testing, commissioning of smart items	–	–	20,000
Subtotal	21,79,400	16,10,000	17,58,550
Contingency (10 %)	2,17,940	1,61,000	1,75,855

Item	1. Cast-in-situ	2. Conventional precast	3. Smart precast (proposed)
Total capital cost	23,97,340	17,71,000	19,34,405
Capital cost per metre	9,589	7,084	7,738
Maintenance per year (assumed)	15,000	15,000	19,998
10-year maintenance (undiscounted)	1,50,000	1,50,000	1,99,985
Capital + 10-year maintenance	25,47,340	19,21,000	21,34,390
Construction time (assumed estimate)	45–55 days	25–30 days	30–35 days

Maintenance assumptions: manual desilting and cleaning at ₹ 15 per metre per round, four rounds a year for options 1 and 2; two rounds a year plus ₹ 6,000 sensor service, ₹ 3,000 power and data, 5 % of electronics cost and 3 % of mechanism cost for spares for option 3. Construction times are planning estimates, not measured values.

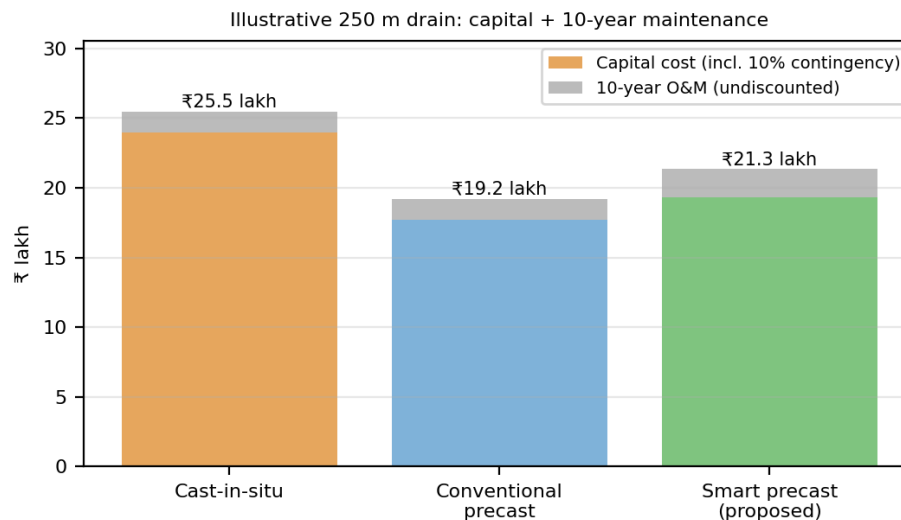


Fig. 16: Capital cost and 10-year maintenance, three options (illustrative)
Source: Calculated from Table 15 using assumed rates

9.4 DISCUSSION

Under these assumed rates, conventional precast is about 26.1 % cheaper than cast-in-situ in capital cost, mainly because of lower formwork, labour and excavation cost, and it is much faster. The smart system adds ₹ 1,63,405 (9.2 % above conventional precast). On these assumptions the reduced manual cleaning does **not** pay for the electronics and mechanism: the 10-year total is higher by ₹ 2,13,390. Thus the smart features are not justified by maintenance savings alone. They may be justified where flooding would be costly or dangerous (hospital approaches, underpasses, low points, critical access roads), where blockages recur, or where manual access is difficult, because the value then lies in avoided damage and faster response, which this report does not quantify. Results are sensitive to the assumed rates, cleaning frequency and the cost of flood loss.

CHAPTER 10: PROJECT INITIATION

10.1 PROBLEM STATEMENT

Roadside and campus drains are built slowly and with variable quality, and they block with plastic, leaves and silt; blockages are usually found only after flooding. The project asks whether precast construction combined with multi-point level monitoring, a debris basket with automatic lifting and an emergency bypass can reduce construction time and give early, reliable warning of blockage at an acceptable cost.

10.2 SCOPE AND OBJECTIVES

Scope: design, calculation, costing and a bench-scale prototype of the monitoring and basket subsystem for a hypothetical 250 m drain. Full-scale installation, structural detailing and long-term field trials are outside the scope.

- To study and design a modular precast concrete drainage system.
- To integrate suitable sensors for water-level and flow monitoring (flow derived from level).
- To develop a method to classify possible drainage blockage conditions from combined sensor readings.

- To propose an IoT dashboard and alert mechanism.
- To design a practical debris-basket cleaning mechanism with safety and maintenance provisions.
- To assess an emergency bypass for suitable overflow conditions.
- To estimate construction and smart-system costs and compare them with conventional alternatives.
- To evaluate expected performance through calculations, functional tests and, where feasible, a working prototype.

10.3 STAKEHOLDERS, RESOURCES AND TEAM

Stakeholders: campus or municipal maintenance staff, road users and residents, the institute, precast manufacturers, the project guide and the diploma programme. **Resources:** concrete laboratory and casting yard, workshop for the basket and frame, electronics laboratory, a transparent flume or PVC channel with a recirculating pump, a computer for the dashboard, and the components in Chapter 4. **Team roles:** [Team member 1 – civil design and hydraulics]; [Team member 2 – precast and quality control]; [Team member 3 – electronics and IoT]; [Team member 4 – mechanism and costing]; [Project guide – name to be filled].

10.4 METHODOLOGY AND ACTION PLAN

Table 16: Proposed action plan (16 weeks; to be adjusted to the institute calendar)

Weeks	Activity	Output
1–2	Literature review, site assumption, objectives	Problem statement, scope
3–4	Hydraulic design and quantities	Calculation sheets, drawings
5–6	Sensor and controller selection, bench tests	Component list, calibration data
7–9	Prototype: sensors, logic, dashboard	Working monitoring node
10–11	Basket frame, motor drive, limit switches	Working lifting mechanism
12–13	Flume tests of all states and cleaning	Test records
14–15	Costing, report writing	Draft report
16	Review, presentation	Final report and demonstration

10.5 FEASIBILITY, PROTOTYPE AND TEST PLAN

Technical feasibility: all parts are common and available. **Economic feasibility:** the prototype electronics cost a few thousand rupees; the full-scale add-on is about ₹ 1,48,550 before contingency (Chapter 9). **Prototype:** a 3 m channel of about 0.15 m width with a recirculating pump, one ultrasonic sensor pair across a small screen, a float switch, a rain input simulated by a pulse generator, and a small motor lift. **Tests:**

- Sensor calibration against a measured scale at several levels and temperatures.
- Repeatability of Δh_0 with a clean screen at fixed flows.
- Response to a gradually blocked screen (partial and severe) with injected plastic and leaves.
- Rain-overload simulation: all levels up, Δh small, no cleaning.
- Sensor-fault tests: unplugged sensor, frozen reading, noisy echo.
- Basket cycles: normal, jammed, limit-switch failure, power cut, comms loss.

10.6 EXPECTED OUTCOMES AND LIMITATIONS

Expected outcomes are a validated classification rule on the bench model, a working basket-lift prototype, calculation and cost sheets, and a clear statement of what remains unproven. Limitations: results come from a scaled bench model and assumed site data; the full-scale mechanism, long-term sensor fouling and field false-alarm rates are untested.

CHAPTER 11: ADVANTAGES, DISADVANTAGES AND FUTURE SCOPE

Table 17: Benefits and limitations

Feature	Advantages	Disadvantages / limitations
Precast drains	Faster erection, consistent quality, factory curing	Casting yard and crane needed; joint leakage risk; site-specific structural design
IoT monitoring	Early warning, data record, fewer blind inspections	Sensor fouling and calibration; depends on power and communication; false alarms possible
Automatic basket	Less manual cleaning of coarse debris	Jamming, corrosion, unscreened flow during travel; does not remove silt, large or compacted waste

Feature	Advantages	Disadvantages / limitations
Bypass	Passive relief when main path is obstructed	Limited capacity (about 43 % of design here); needs safe discharge and access
Whole system	Integrated and maintainable layout	Higher initial cost; need for manual inspection and cleaning continues

Future scope (possibilities, not completed features): improved analytics on logged data, solar-assisted power, remote maintenance diagnostics, duplicated sensors for redundancy, camera verification of blockages, and predictive-maintenance methods that must first be validated against real field data.

CHAPTER 12: CONCLUSION

The report presents a student design concept that combines modular precast drainage with multi-point level monitoring, rule-based blockage classification, a motor-driven debris basket and a passive bypass. For the assumed 250 m site, a 600 × 600 mm precast U-drain at 1 in 200 carries the 0.26 m³/s design discharge at a depth of 0.318 m. Precast construction is expected to be faster and, at the assumed rates, cheaper than cast-in-situ. The smart features raise capital cost by about 9.2 % over conventional precast and are not justified by maintenance savings alone; they make sense where flood consequences are high. The bypass in the present layout passes about 43 % of the design flow and the basket cannot remove sediment or large obstructions. Hydraulic data, thresholds, rates and mechanism performance are assumptions until local data, a prototype and field trials confirm them.

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Background reading used for this report: open-channel hydraulics [12], [13]; hydrology [14]; Indian storm water and sewerage manuals [11], [21]; and the Indian Standards and IRC guidelines listed under References [1]–[10].

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APPENDIX A: BILLS OF QUANTITIES FOR OPTIONS 1 AND 2

Table 18: Option 1: cast-in-situ RCC drain, 250 m (illustrative rates)

Item	Unit	Qty	Rate (₹)	Amount (₹)
Excavation in ordinary soil	m ³	297.5	350	1,04,125
PCC M10 bedding (100 mm)	m ³	25	6,200	1,55,000
RCC M25 cast-in-situ (concrete only)	m ³	78.8	7,800	6,14,250
Reinforcement Fe 500 (80 kg/m ³)	kg	6300	78	4,91,400
Formwork / shuttering	m ²	600	650	3,90,000
Backfill and compaction	m ³	93.8	300	28,125
Precast RCC cover slabs (supply and place)	nos	250	1,250	3,12,500
Inspection chambers (cast-in-situ)	nos	6	14,000	84,000
Subtotal				21,79,400

Table 19: Option 2: conventional precast drain, 250 m (illustrative rates)

Item	Unit	Qty	Rate (₹)	Amount (₹)
Excavation in ordinary soil	m ³	240	350	84,000
PCC M10 bedding (100 mm)	m ³	25	6,200	1,55,000
Precast M30 U-units: concrete (factory)	m ³	50	9,500	4,75,000
Precast units: reinforcement Fe 500 (80 kg/m ³)	kg	4000	75	3,00,000
Transport (about 15 km), per unit	nos	250	350	87,500
Lifting and placing, per unit	nos	250	250	62,500
Joint sealing, per joint	nos	250	150	37,500
Backfill and compaction	m ³	70	300	21,000
Precast RCC cover slabs (supply and place)	nos	250	1,250	3,12,500
Precast inspection chambers	nos	6	12,500	75,000
Subtotal				16,10,000