ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep241

Smart Drains for Urban Flood Mitigation in Kolkata & Howrah: A Case Study

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Publication Date: 2025/09/18

Abstract: Urban flooding has emerged as one of the gravest challenges for Kolkata and Howrah, driven by heavy monsoon rains, silted canals, outdated pumps, and tidal backflow from the Hooghly River. Traditional drainage systems, largely dependent on manual interventions, have proved inadequate in addressing extreme rainfall events.

This DPR proposes a Smart Drainage System that integrates IoT-enabled sensors, automated sluice gates, predictive analytics, GIS-based mapping, and SCADA dashboards. A pilot DPR in the Behala–Taratala corridor demonstrates that smart drains can reduce waterlogging duration by up to 80%, prevent tidal ingress, and deliver socio-economic savings of ₹50–80 crores annually when scaled across the metropolitan region.

The report outlines system architecture, implementation strategies, comparative benefits, and phased deployment for a climate-resilient future.

Keywords: *Urban Flooding, Smart Drainage, IoT, Predictive Analytics, SCADA, Kolkata–Howrah, DPR.*

How to Cite: Gautam Bondyopadhyay (2025) Smart Drains for Urban Flood Mitigation in Kolkata & Howrah: A Case Study. *International Journal of Innovative Science and Research Technology,* 10 (9), 695-704. https://doi.org/10.38124/ijisrt/25sep241

I. INTRODUCTION

Kolkata's underground drainage remains largely manual, causing delays, blockages, and untreated sewage discharge of over 311 MLD into the Hooghly and Tolly's Nullah—creating serious environmental and health risks. With 14+ million people, the Kolkata–Howrah region suffers recurring floods as aging sluices, pumps, and silted canals fail under intense monsoons and tidal backflow, leading to heavy socio-economic losses.

Smart drainage offers a solution through IoT sensors, predictive analytics, automated gates, SCADA monitoring, and robotic cleaning. These enable real-time water and sewage flow regulation, early warnings, and quicker restoration of clogged networks. Global examples—Singapore's Smart Water Grid, Tokyo's flood discharge channel, and Copenhagen's cloudburst plan—prove that sensor-driven, automated systems greatly enhance urban flood resilience.

These examples show that sensor-driven, automated, and predictive drainage frameworks can transform urban resilience.

➢ *Objective of the Technical Report:*

To prepare a practical framework for Smart Drainage in Kolkata–Howrah with focus on pilot-scale Technical Report, city-wide applicability, and phased implementation.

II. BACKGROUND & NEED

With just 6–8 m elevation, Kolkata–Howrah's flat terrain, tidal backflow, and shrinking wetlands intensify flooding. Annual rainfall of 1,600–1,700 mm routinely overwhelms colonial-era drains, while blockages cut capacity by 20–40%. Aging pumps, silted canals, and rapid urbanization—boosting runoff by 30–40%—further strain the system. Climate change adds more short, intense downpours.

Smart drainage can forecast floods 30–120 minutes ahead, automate tidal exclusion, and cut flood duration by up to 80%. A predictive, sensor-based system is essential to replace outdated manual control, optimize pumping, and ensure resilient flood management.

➢ *Technical Inputs of the Terrain as Under:*

- Flat Terrain: Average slope <1:5000 results in sluggish runoff.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep241

- Monsoon Intensity: Rainfall often exceeds system capacity, causing ponding.
- Siltation: Canals carry large sediment loads, reducing conveyance.
- Tidal Backflow: High tide in Hooghly River blocks storm discharge.
- Bsolete Infrastructure: Several pumping stations >70 years old, running on manual control.
- Rapid Urbanization: Impervious areas rising, storm runoff surging by 30–40%.
- Climate Change: Short-duration high-intensity rainfall events increasing.

✓ Need: A digital, automated, and predictive system to supplement manual control, optimize pumping, and prevent backflow.

Fig 1 Kolkata–Howrah Natural Drainage Basin Map

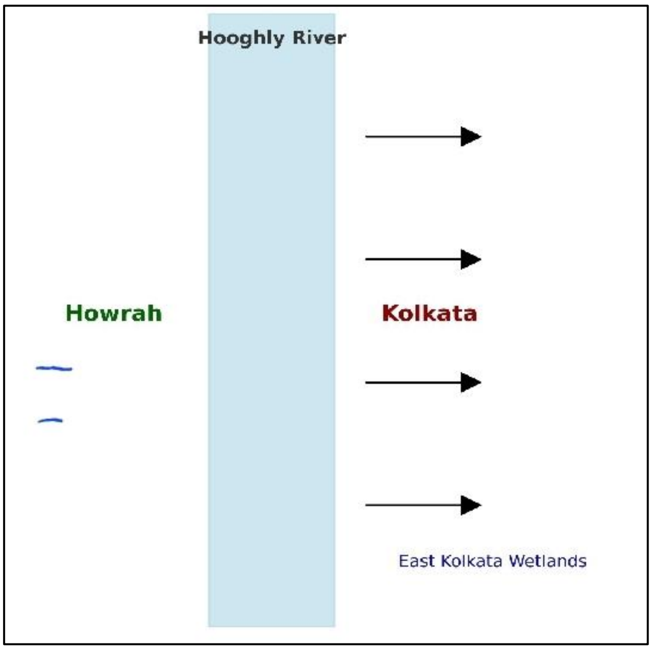

Fig 2 Kolkata–Howrah Natural Drainage Cross Section Profile

➢ *Proposed System Overview:*

The Smart Drainage framework is structured into four layers:

- Sensing Layer – Smart sensors to measure rainfall, canal levels, silt load, and tidal conditions.
- Control Layer – Automated sluice gates, pumps, and detention tanks.
- Decision Layer – AI/ML-based predictive models for rainfall–runoff response.
- Communication Layer – IoT devices, GSM/GPS modules, and SCADA dashboards.

Table 1 Objectives of the Proposed Smart Drainage System

Sl. No.	Objective	Description
1	Intelligent Drainage System	Develop a system capable of sensing water levels, rainfall intensity, and blockages in real time.
	(a) Technical & Commercial	Cover design efficiency, cost-effectiveness, lifecycle optimization, and phased implementation strategies.
	(b) Technological (IT/IoT)	Integrate IoT, GIS, GSM, GPS, and SCADA for monitoring, automation, predictive analytics, and instant alerts.
	(c) Policy (Strategies & Goal Alignment)	Align with national/state flood management goals, Smart Cities Mission, sustainability targets, and institutional roles.
2	Automated Operations	Enable automatic control of sluice gates, pumps, and flow regulators based on live data inputs.
3	Technology Integration	Incorporate IoT, GSM, and GPS technologies for continuous monitoring and instant alerts to authorities.
4	Reduced Manual Dependency	Minimize reliance on manual interventions to reduce response time during flood emergencies.
5	Efficiency & Resilience	Enhance efficiency, cost-effectiveness, and resilience of the existing drainage network.
6	Cleaner Drains	Ensure regular detection of blockages and obstructions for cleaner and functional drains.
7	Smart City Alignment	Align the system with long-term urban resilience strategies and smart city development goals.

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➢ *City Context & Drainage Basin:*

- *Why Kolkata–Howrah Needs Smart Drainage*

Kolkata–Howrah's flat terrain and century-old drains, built for lighter rains, cannot handle today's intense monsoons. Tidal backflow, silt, and waste cut capacity by up to 40%, while manual pumps and gates fail in storms. Smart drainage with sensors, automated gates, and real-time alerts can sync with tides and regulate flows more effectively.

- *Flooding Challenges in Kolkata and Howrah*

Annual rainfall of 1,600–1,700 mm floods low-lying basins like Behala and Howrah Maidan. With no detention ponds, silted canals, aging pumps, power cuts, and wetland loss, discharge is slow and stagnation long. Narrow roads prevent expansion, and blockages worsen flooding, causing ₹6,429 crores in annual losses, hitting vulnerable communities hardest.

- *The City of Kolkata and Its Natural Drainage Basin*

Spread across 1,850 km² at just 6–8 m elevation, the region is highly flood-prone. Hooghly tides backflow into drains, silt clogs sluices, and intense bursts overwhelm undersized canals, sewers, and 25 pumping stations running at 60–70% efficiency. Fifty-five outfalls fail at high tide, while shrinking wetlands have lost buffer capacity, leaving hotspots like Behala, Ultadanga, Howrah Maidan, and Topsia chronically waterlogged.

✓ *Geography:*

Kolkata & Howrah lie on the east and west banks of Hooghly River. Low elevation (5–6 m above MSL) makes them flood-prone.

✓ *Historical Drainage:*

Began under British in 19th century, relying on canals, sluices, and outfalls.

✓ *Existing Assets:*

- 25 pumping stations
- 55 outfalls into Hooghly
- 280 km of canals (many silted)

✓ *Flood-Prone Wards:*

Behala, Tollygunge, Kidderpore, Ultadanga, Bally, and Howrah Maidan.

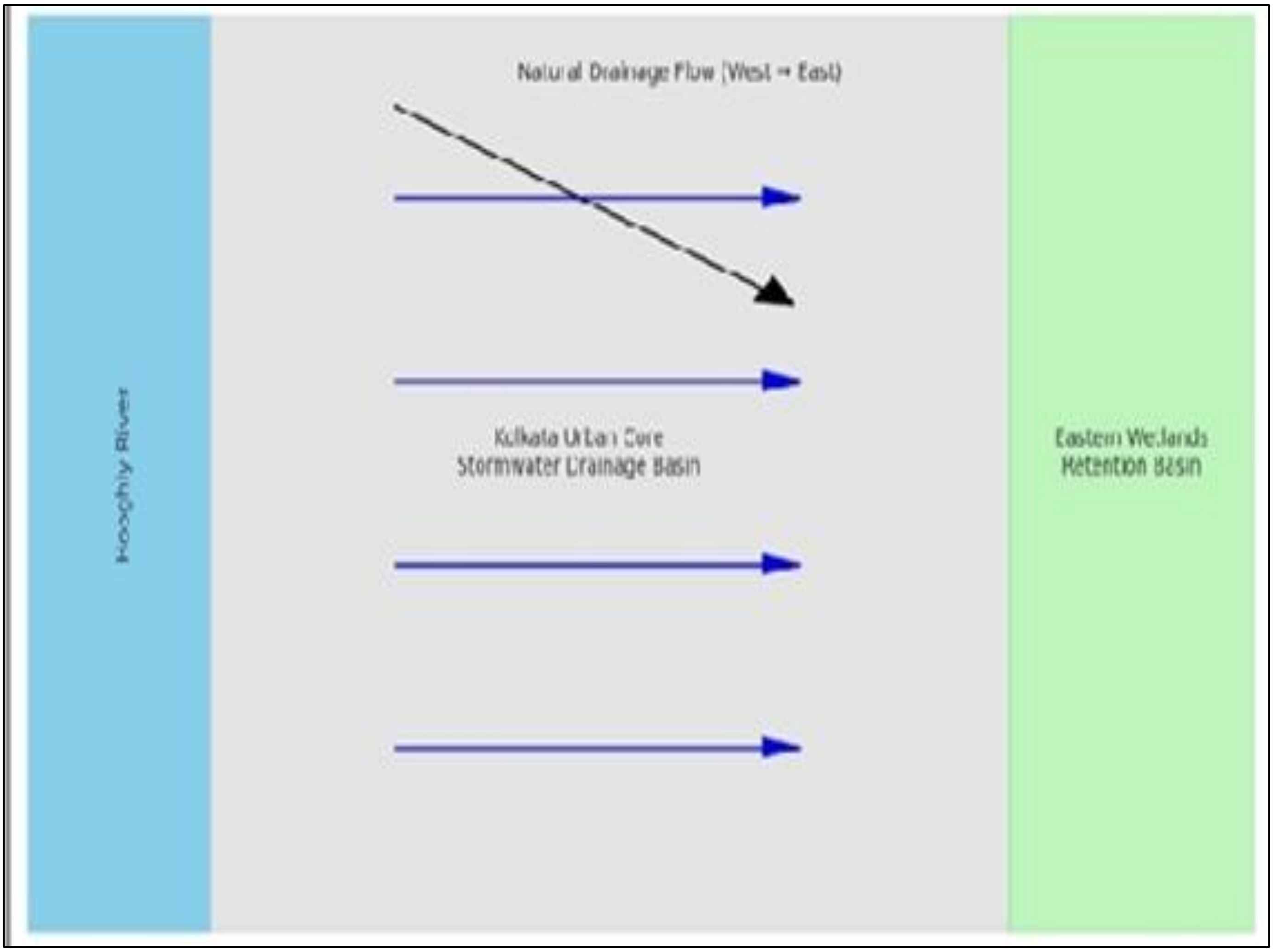

Fig 3 Kolkata Natural Drainage Basin

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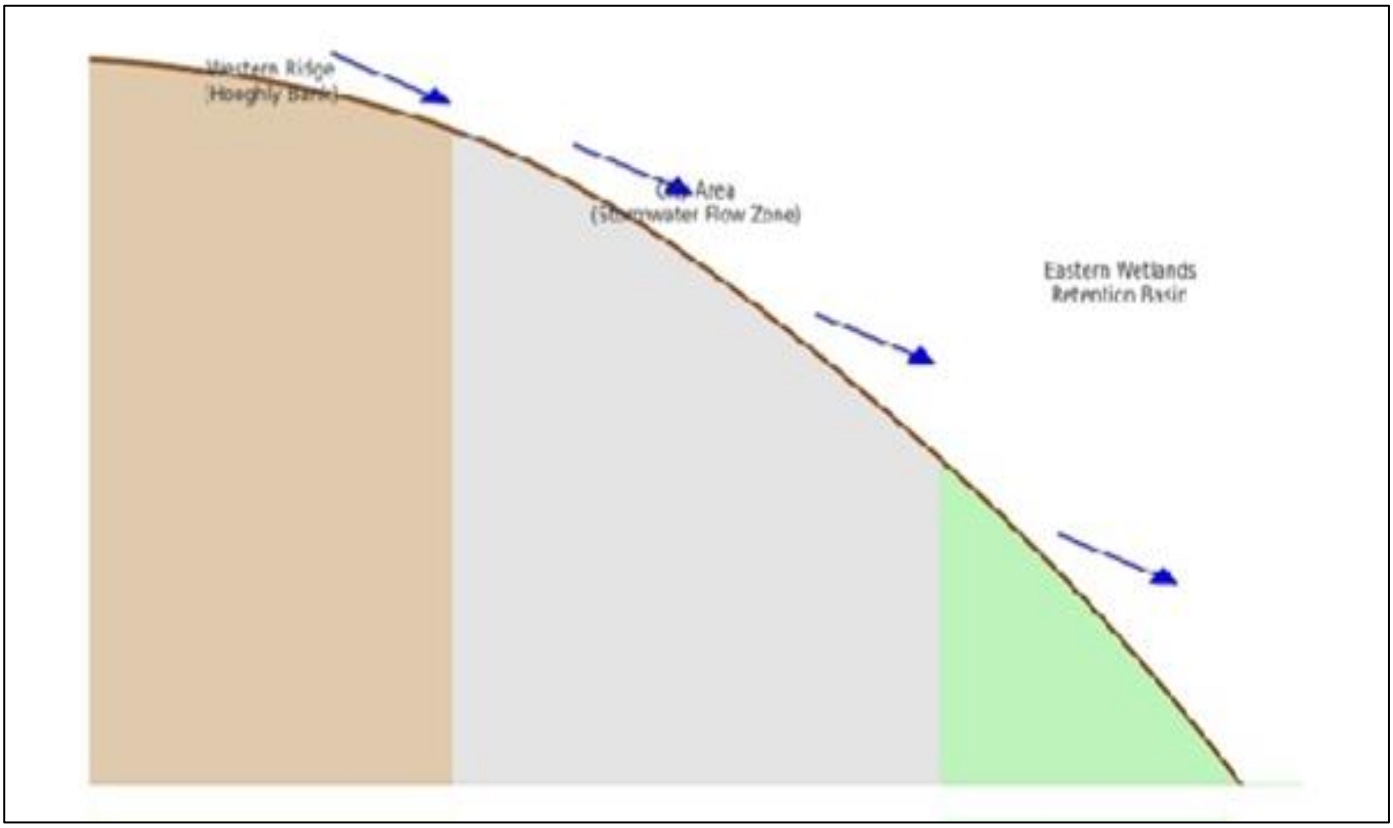

Fig 4 Basin Cross Section Profile

Table 2 Flood-Prone Zones in Kolkata–Howrah

Zone	Key Cause	Typical Waterlogging Duration	Impact
Behala–Taratala	Low-lying basin, weak pumping, clogged drains	24–48 hrs	Streets, homes, and local markets submerged
Ultadanga–Maniktala	Bowl-shaped topography, Palmer Bazar pumps fail under high tide	12–18 hrs	Severe traffic disruption, commercial losses
Howrah Maidan–Kadamtala	Flat terrain, silted Hooghly outfalls	18–24 hrs	Howrah Station and transport networks disrupted
Topsia–Tiljala–Dhapa	Chronic clogging, waste dumping near wetlands	12–20 hrs	Residential flooding, industrial areas affected

➢ *Core Components of Advanced IoT Drainage Systems:*

Modern systems blend civil, mechanical, electrical, and digital tech to sense, control, predict, and monitor drainage in real time.

- Sensors: Ultrasonic water-level meters, rainfall gauges, silt sensors.
- Smart Gates: Stainless steel (SS 316) sluice gates with FRP covers for corrosion resistance.
- Controllers: IoT-enabled PLCs connected to SCADA.
- Power Backup: Solar + grid + diesel generator redundancy.
- Data Integration: GSM/GPRS-based wireless transmission to command centre.

Fig 5 Cross Section of Automatic Open Smart Drain

Volume 10, Issue 9, September – 2025 International Journal of Innovative Science and Research Technology
ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep241

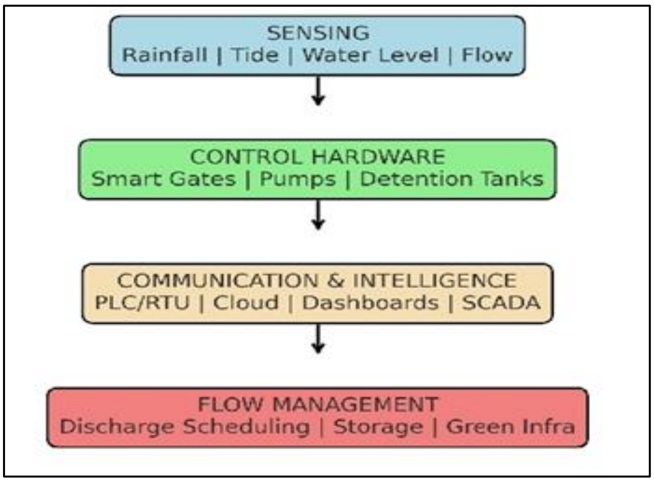

Fig 6 Smart Node Architecture

➢ *Smart Tech Enhancements:*

- Predictive Analytics: Rainfall–runoff modelling with 2–6 hr advance alerts.
- GIS Integration: Real-time flood hotspot visualization.
- Mobile Dashboards: Apps for KMC engineers and citizens (alerts, pump status, blocked drains).
- Digital Twins: Virtual model of drains for scenario analysis & predictive maintenance.

➢ *Smart Technologies for Drainage:*

IoT sensors and predictive tools give 30–120 minutes' flood warning, supported by four layers: sensing, control hardware, communication, and flow management. In Kolkata–Howrah, focus areas are tidal exclusion, rapid discharge, and resilient operation through automated SS/FRP gates, SCADA control, and hybrid power. Green features like bio-swales and permeable pavements cut runoff.

Implementation is phased—pilots in flood-prone wards, expansion with detention basins, and citywide SCADA. Sustainability depends on regular O&M and digital twins for predictive upkeep. Costs range from ₹4–8 lakh per smart node and ₹15–60 lakh per gate to several crores for basins and ₹50–150 lakh for SCADA pilots.

Table 3 Core Components of Smart Drainage Systems

Component	**Technical Features**	**Application**
Sensors & Instruments	Rain gauges (0.2 mm resolution), ultrasonic/radar water-level sensors (±5–10 mm), Doppler flow meters, tide gauges, debris detectors	Monitor rainfall, flows, tide levels, and clogging
Hydraulic Hardware	Self-closing flap gates, motorized sluice/weir gates with position feedback, detention tanks, mobile flood barriers	Control inflow/outflow and provide temporary storage
Controllers & Analytics	Local PLC/RTU for safety logic, central SCADA dashboards, open protocols (MODBUS, MQTT), AI/ML for short-term runoff forecasting	Decision support and automated operations
Communications	LoRaWAN, NB-IoT, LTE-M, or wired links; solar-powered with UPS backup	Reliable data transfer from nodes to central hub
Green Infrastructure	Permeable pavements, bio-swales, rain gardens, rooftop harvesting	Reduce source runoff and complement engineered measures
O&M & Monitoring Tools	IoT-based predictive maintenance, digital twin simulations, vibration/load sensors, AI-based service scheduling	Optimize performance and ensure long-term resilience

Table 4 Benefits of Smart Enhancements

Benefit	**Conventional System**	**Smart System**
Flood Reduction	Delays up to 24–48 hrs	Reduced by 60–80%
Maintenance	Reactive, breakdown-driven	Predictive digital twins
Power Resilience	Grid only	Hybrid grid + solar + DG
Monitoring	Manual	Real-time dashboards
Integration	Stand-alone	SCADA + GIS mapping

Table 5 Digital Technologies for Smart Drainage

Technology Layer	**Core Features**	**Functional Benefits**
Predictive Analytics	Rainfall–runoff models (SWMM, MIKE URBAN, HEC-HMS); ML-based depth forecasts; SCADA dashboard alerts	Forecast flooding hours in advance, enable pre-activation of pumps/gates
AI/ML Decision Support	Fuzzy logic, reinforcement learning; inputs: rainfall, tide, water levels; fail-safe PLC logic	Adaptive gate/pump operation, reduced human error, proactive interventions
GIS & Satellite Data	GIS mapping of drains, pump houses, outfalls; Sentinel-1 SAR flood maps; Landsat/INSAT rainfall layers	Identify hotspots, prioritize maintenance, overlay socio-economic vulnerability
Mobile & Web Dashboards	Mobile app alerts; remote gate/pump operation; SCADA-linked dashboards with role-based access	Improve institutional response, enable real-time coordination and decision-making

Maintenance & Digital Twins	IoT diagnostics (vibration, load, sediment sensors); digital twin simulations; AI-based maintenance scheduling	Prevent failures, extend equipment life, optimize O&M budgets

III. COMPARATIVE OVERVIEW

➢ *Traditional Drainage versus IoT-Enabled Smart Solutions:*

Traditional drainage relies on manual inspection, reactive maintenance, and limited data, often causing delays and higher flood risks. IoT-enabled systems integrate sensors, automation, predictive analytics, and SCADA for proactive, real-time management. While conventional systems appear cheaper upfront, they incur high long-term costs from flood damage and inefficiencies. Smart drainage, by contrast, enhances resilience, reduces lifecycle costs, and supports sustainable, adaptive urban flood management.

Table 6 Comparative Assessment of Traditional and IoT-Enabled Drainage

Parameter	**Traditional Drainage**	**IoT-Enabled Smart Drainage**
Operation	Manual opening/closing of gates, visual monitoring by field staff	Automated real-time control through sensors, AI/ML, and SCADA
Response Time	Delayed (30 min–2 hrs depending on staff availability)	Instant (<30 sec) based on IoT triggers
Flood Risk Mitigation	Reactive; response begins after flooding occurs	Proactive; predictive analytics prevent flood formation
Energy Efficiency	Pumps run unnecessarily, leading to high wastage	AI-controlled pumps run only when required; 15–25% energy savings
Maintenance	Periodic and reactive (after clogging)	Predictive, IoT-based (silt/clog sensors issue alerts)
Data Availability	Minimal records, manual logs	Real-time digital records, trend analysis, historical datasets
Cost Perspective	Lower CAPEX but higher OPEX due to repeated flood losses	Higher CAPEX (20–30% more) but reduced lifecycle cost and avoided damages
Environmental Impact	Untreated overflows mix with sewage, creating sanitation hazards	Controlled discharge, reduced contamination, integration with wetlands for natural filtration

➢ *Case Snapshot – Palmer Bazar Flood (2018):*

Tidal backflow + pump failure flooded 3 km² for 36 hrs. Smart gates with predictive control could have reduced flood duration to <8 hrs.

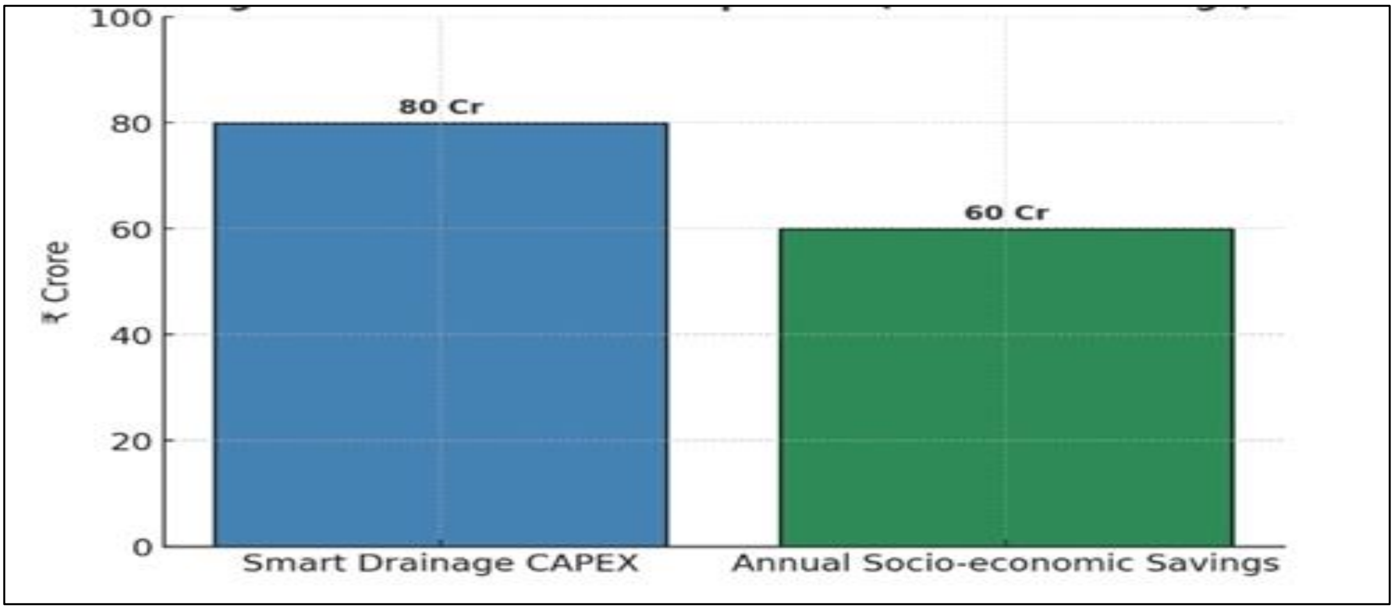

Fig 7 Cost–Benefit Bar Chart (CAPEX vs Socio-Economic Savings)

➢ *Case Study (Kolkata):*

- *Challenges*

✓ Tidal ingress from Hooghly
✓ Clogged inlets and canals
✓ Storm surges with 60–80 mm/hr rainfall

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep241

➢ *Methodology:*

- Site survey, LiDAR mapping, hydraulic modelling (SWMM)
- GIS-based hotspot identification
- Stakeholder consultation (KMC, HMC, Irrigation Dept.)

Table 7 Summarises the Physical and Operational Constraints that Shape the Design

Key Constraints	Description	References
Tidal influence of Hooghly	Tidal effects raise river levels above drain outfalls, forcing closure of sluice gates and risking backflow. Operations must align with tidal windows.	ResearchGate
Mixed sewer/storm system	Combined sewers with limited capacity; desilting and debris removal are critical.	ADB
Existing flood-control assets	KMC flood-control centres and pumping stations already exist; integration with these SOPs is essential.	KMC Gov
Frequent short intense storms	Sudden, high-intensity rainfall coinciding with high tides leads to severe waterlogging; real-time control and nowcasting are critical.	Times of India

➢ *Smart-Drain Architecture:*

- Field Layer – IoT nodes with sensors & gates
- Communication Layer – GSM/GPS transmission
- Central Layer – Control room with predictive analytics
- O&M Layer – Maintenance crew linked via dashboards

Table 8 Smart-Drain System Architecture

Layer	Components
Field Layer	Sensors (rain gauges, ultrasonic/tide level sensors, debris detectors); actuators (flap gates, motorised sluices, pumps); trash racks with mechanical rakes
Edge/Communication	LoRaWAN / NB-IoT for distributed nodes, LTE/fibre for large nodes; solar + battery + UPS backup
Central Layer	SCADA system, short-term rainfall nowcast, hydraulic optimisation engine, operational dashboards, alarms
O&M Layer	Preventive maintenance schedule, SOPs, emergency overrides, cleaning crews
Integration	KMC Flood Control Centre and KMDA masterplan for dredging and drainage upgrades

Node Design Summary:

Table 9 Outfall Node Components

Category	Specifications
Civil Layout	Upstream chamber with ultrasonic sensor and trash rack; motorised sluice gate with encoder; downstream flap gate; provision for pumps
Sensors	Tipping-bucket rain gauge (0.2 mm accuracy), ultrasonic/radar depth sensors, tide gauge, debris presence sensor
Actuators	Electric sluice motor (IP-rated, fail-safe), rubber-sealed flap gate, standby submersible pumps with VFD
Local Logic (RTU/PLC)	Automated gate closure during high tide, pre-emptive opening before heavy rain, debris-trigger alerts, manual override capability

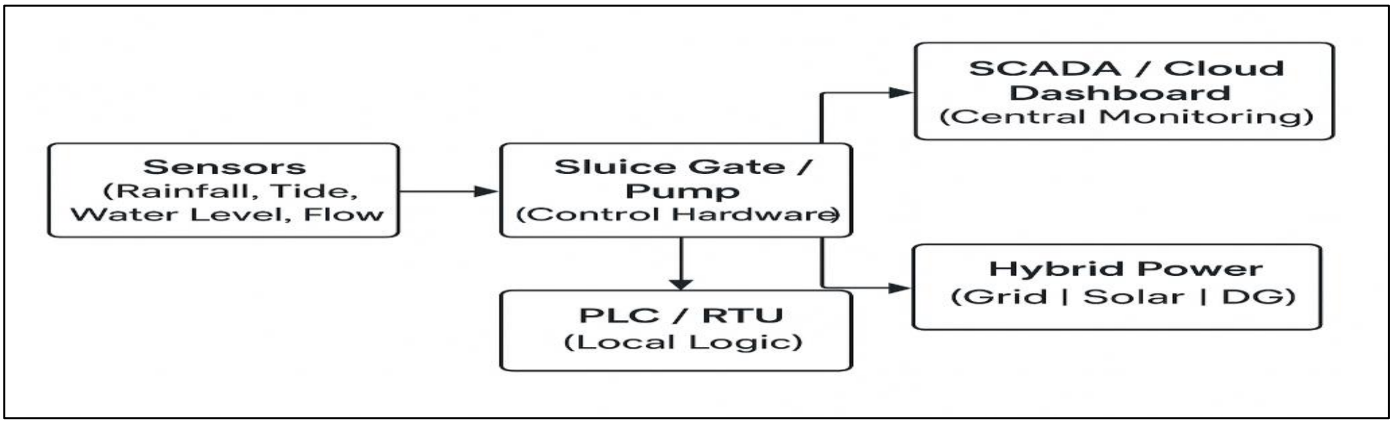

Fig 8 Integration of Sensors Sluice Gate, PLC & SCADA

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep241

- *Case Study: Kolkata Application*

- *Pilot Plan for The Report (Behala–Taratala Corridor):*
- ✓ Corridor Length: 3.2 km
- ✓ Nodes: 6 smart nodes with gates, sensors, detention tanks
- ✓ Storage: 5,000 m³ flood detention capacity
- ✓ Surveys Required: LiDAR, borehole logs, soil tests, CCTV drain mapping

- *Design Philosophy:*
- ✓ Prevent backflow at tidal gates
- ✓ Forecast rainfall & pump proactively
- ✓ Enable remote SCADA monitoring

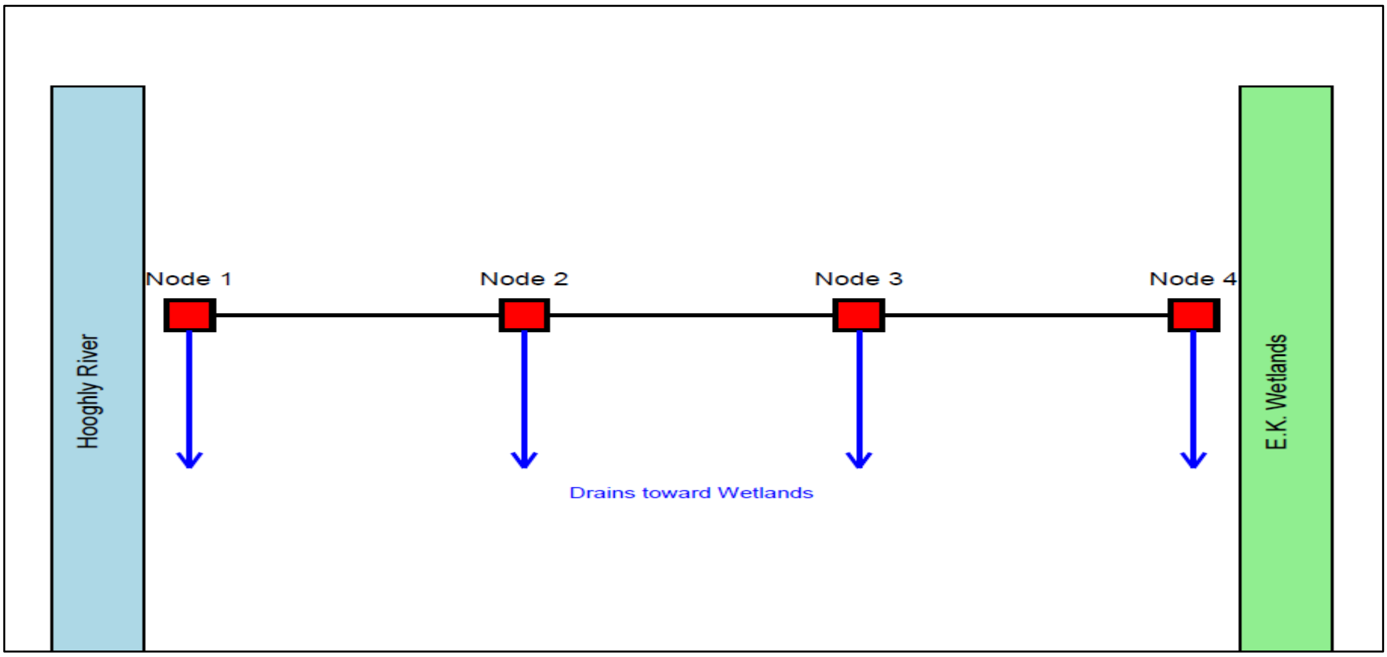

Fig 9 Pilot Layout Behala -Taratala

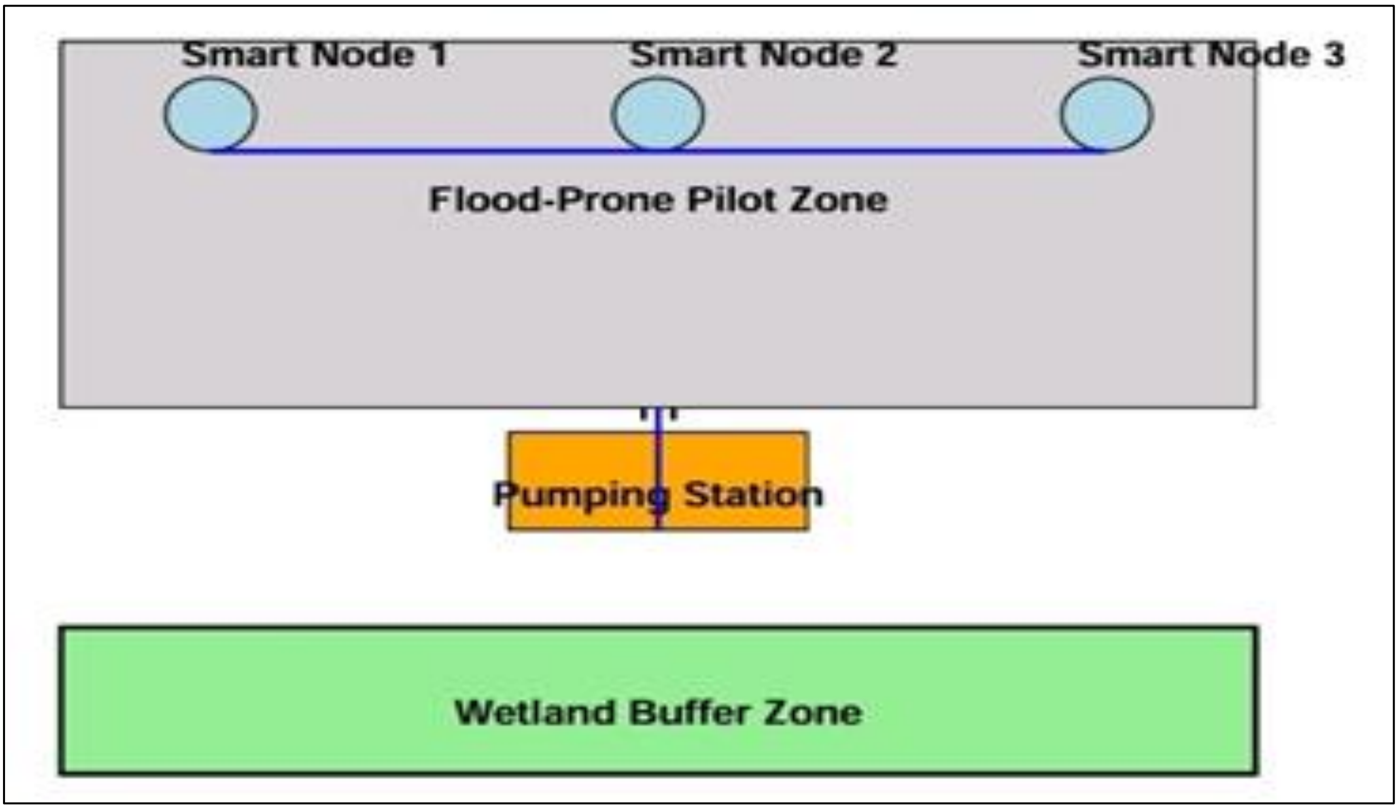

Fig 10 Outfall Nodes for Pilot Route Behala -Taratala

Table 10 Pilot Plan Highlights

Component	Details
Pilot Nodes	4–6 smart outfall nodes with sluice, flap, sensors, trash rack, RTU
Detention Cell	2,000–10,000 m³ modular underground or converted open basin
SCADA	Central dashboard with radar/gauge nowcast integration
Operations	6-month monitored trial across one monsoon season
Candidate Sites	Taratala–Behala corridor; Manicktala–Ultadanga drainage zone

➢ *Phased Implementation Strategy:*

The phased strategy also integrates community engagement, capacity building of municipal staff, and long-term maintenance contracts to ensure sustainability.

- *Phases*

✓ Short Term (0–3 yrs.): Pilot in Behala–Taratala, upgrade 5 key pumps.
✓ Medium Term (3–7 yrs.): Expand to 12 km network covering Bally, Howrah Maidan.
✓ Long Term (7–15 yrs.): City-wide rollout with 50+ smart nodes.

- *Institutional Framework*

✓ Formation of Kolkata Smart Drainage Cell (KSDC) under KMC.
✓ PPP-based O&M contracts with performance-linked payments.

Table 11 Phased Smart Drain Implementation Strategy for Kolkata

Phase	Duration	Scope	Key Investments	Estimated CAPEX
Short Term	0–3 years	Pilot nodes in hotspots (Behala–Taratala, Ultadanga, Topsia); mobile app + dashboard	4–6 smart nodes, selective pumping, SCADA link	₹100–150 Cr
Medium Term	3–7 years	Expansion to 15–20 wards; 50% pumping stations IoT-enabled; GIS integration	SCADA retrofits, GIS integration, 20–50 nodes	₹800–1,000 Cr
Long Term	7–15 years	Citywide coverage; integration with metro, flyover projects; AI-based digital twin	Full smart-drain network; PPP financing	₹3,000–4,000 Cr

Table 12 CAPEX Estimates for Smart Drainage Components

Component	Unit Cost (lakh)	Scale	CAPEX (Cr)
Smart Nodes	4–8	200–300	12–18
Motorized Gates	15–60	50–60	40–45
SCADA Pilot	50–150	3–4	2–5
Detention Basins	2–3 Cr	4–5	10–15
O&M Systems	~10% CAPEX annually	–	–

IV. RESULTS AND DISCUSSION

➢ *Bill of Quantities (BOQ) for Pilot Implementation:*

Table 13 Major Items

Code	Item	Qty	Notes	Code
A1–A7	Civil works (excavation, RCC chambers, steel, covers)	—	Chambers, pads, supports	A1–A7
B1–B5	Hydraulic works (sluice, flap gates, trash racks, rakes, hoists)	6 nos.	Smart control nodes	B1–B5
C1–C6	Electrical/SCADA (RTUs, panels, solar backup, comms, server)	—	IoT-enabled automation	C1–C6
D1–D5	Sensors (rain, ultrasonic, tide, debris)	6–12 nos.	Real-time monitoring	D1–D5
E1–E3	Pumps & detention (30 kW sets, 5,000 m³ tank, pipes)	—	Storage + evacuation	E1–E3
F1–F5	Ancillary (reinstatement, coatings, testing, manuals)	—	Site restoration & training	F1–F5
G1	O&M (12 months)	LS	Preventive + reactive	G1

➢ *Expected Outcomes:*

- Flood duration reduction: from 24–48 hrs to <12 hrs.
- Waterlogging depth: reduced by ~40–50%.
- Energy efficiency: 20–25% pump energy savings.
- Economic impact: potential savings of ₹200–300 crores annually at city scale.
- Social benefit: improved mobility, reduction in health hazards, and improved quality of urban life.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/25sep241

V. CONCLUSION & POLICY RECOMMENDATIONS

The Smart Drainage Project for Kolkata–Howrah offers a paradigm shift in flood resilience. By integrating sensors, predictive analytics, SCADA, and green infrastructure, the system can cut flood duration by 60–80%, prevent tidal backflow, and yield ₹50–80 crore annual socio-economic savings city wide.

➢ *Recommendations:*

- Phased rollout: pilot in hotspots, expand citywide.
- Policy support: integrate into master plans, enforce wetland protection.
- Funding mix: public, PPP, climate resilience funds.
- Institutional O&M: digital twins, trained staff, citizen apps.

With strong governance, Kolkata and Howrah can emerge as global models for climate-proof urban drainage.

➢ *Closing Note:*

A resilient Kolkata–Howrah demands more than pumps and canals; it needs smart, predictive, and automated infrastructure. The Smart Drainage Project is both feasible and essential to climate-proof the twin cities for decades ahead.

ACKNOWLEDGMENT

The author acknowledges the support of the Kolkata Municipal Corporation (KMC), Howrah Municipal Corporation (HMC), and Kolkata Metropolitan Development Authority (KMDA) for providing data and technical insights.

➢ *Author Introduction:*

Prof. Gautam Bondyopadhyay, alumnus of Jadavpur University (1976), retired in 2024 as Professor of Practice and former Head of Civil Engineering, OmDayal Group of Institutions. With over four decades of leadership in EPC, contract management, and infrastructure design, he has authored several academic works and DPRs on water management.

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