Android-Based Drainage Information System with Daily Precipitation Forecasts for Community Inundation Monitoring in Malang City

Kukuh Yudhistiro[1,*], Evan Afdrianto Kota[2]

[1]Faculty of Teknologi Informasi, Universitas Merdeka Malang
[2]Magister Informatics Department, Universitas Islam Negeri Maulana Malik Ibrahim Malang
Corresponding Author: kukuh.yudhistiro@unmer.ac.id

***Abstract*—Rapid urbanization in Malang City has reduced natural infiltration surfaces and intensified localized inundation, while drainage condition data has remained confined to agency archives and inaccessible to the public it most affects. This study reports the design, implementation, and evolution of Sistem Informasi Banyu Malang (SIBAMA), an Android application backed by a Laravel REST service and a MySQL spatial datastore, developed to disseminate drainage-network profiles and inundation information to citizens of Malang. The system integrates the Google Maps API to render survey-derived drainage polylines and inundation pins ingested from KML/KMZ and GeoJSON sources, and provides multi-temporal access across annual survey layers together with live CCTV at flood-prone points. The current release (v.6, 2025) extends the system from a static archive to a forecast-coupled tool: a daily synchronization with the Open-Meteo API retrieves the 24-hour precipitation sum (R24) and maximum precipitation probability, and the current-day R24 drives a derived runoff status that recolors each channel segment as normal or inundation-prone and animates the cross-section overflow illustration. The release also integrates the municipal SAMBAT complaint channel, extends drainage coverage to all five districts, and is implemented in Kotlin. Functional verification used black-box testing with equivalence partitioning, complemented by a user acceptance testing instrument. The work contributes a replicable, low-infrastructure architecture that couples a multi-temporal survey record with public weather-forecast data for participatory municipal inundation monitoring.**

***Keywords*— urban drainage information system; Android application; precipitation forecast; runoff status; participatory inundation monitoring**

I. INTRODUCTION

Urban drainage performance is a determinant of road serviceability and flood resilience in tropical cities, where impervious expansion outpaces the hydraulic capacity of existing channels [1]. In Malang City, the progressive sealing of natural infiltration surfaces by concrete and asphalt has increased surface runoff that, when channels are silted or encroached upon, accumulates as localized inundation. The deterioration is not solely hydraulic; channel obstruction by waste disposal and unauthorized covering of channel tops for commercial use reflects a participation deficit that purely engineering interventions cannot resolve.

A recurring obstacle in municipal drainage governance is informational rather than structural: condition data collected through field inventories is retained in agency repositories and is rarely returned to residents in a form they can act on. Contemporary flood- and drainage-management research has converged on the position that situational information delivered to the community is a precondition for effective response and maintenance, not a peripheral add-on [2], [3]. Where citizens can observe the state of channels in their own neighborhood, the prospects for cooperative maintenance with the responsible agency improve materially [4]. This reasoning is codified locally in Malang Regional Regulation No. 4 of 2011 on Spatial Planning, which mandates the development of community-based drainage management.

The mobile phone is the natural delivery channel for such information in Indonesia, given high smartphone penetration and the spatial nature of drainage data, which is most legible when rendered on an interactive map rather than in tabular reports [5]. However, most reported drainage and flood systems are either desktop GIS tools oriented toward engineers [1] or sensor-centric IoT early-warning platforms that report a single live state without a navigable historical record [2], [6]. Few public-facing mobile systems expose multi-temporal survey data that lets a resident compare a channel's documented condition across successive years; fewer still couple those records with live visual confirmation at flood-prone points; and fewer again drive a forward-looking inundation indicator from openly available precipitation forecasts rather than from in-channel sensors.

This study addresses that gap through SIBAMA, an Android-based drainage information system commissioned by the Malang City Public Works agency and delivered incrementally across annual releases (2023–2025). The work pursues four objectives: (i) to design a geospatial mobile architecture that delivers agency drainage-survey data to citizens through an interactive map; (ii) to implement multi-temporal layering and live CCTV at inundation points; (iii) in the 2025 release, to couple the survey record with a daily public precipitation forecast (Open-Meteo) so that a derived runoff status recolors each channel segment and animates its cross-section overflow; and (iv) to verify the implemented system through black-box and user acceptance testing. The principal contribution is a replicable, low-infrastructure client–server–database architecture that fuses a multi-temporal survey record with forecast-driven status for participatory municipal inundation monitoring, deployable without a dedicated sensor network.

The remainder of this paper is organized as follows. Section 2 reviews related work on geospatial drainage systems, mobile flood-monitoring platforms, participatory e-government, and mobile software testing. Section 3 details the development methodology and system architecture. Section 4 presents the implementation and test results. Section 5 concludes and identifies directions for further development.

II. THEORY

a. Geospatial information systems for urban drainage

Geographic Information Systems have long served as the analytical backbone for drainage and water-network management, supporting spatial integration of channel geometry, catchment delineation, and asset inventories [1]. Recent reviews report that GIS integration reduces design time and improves locational accuracy in drainage modeling [1], and smart GIS platforms have been proposed to digitalize integrated urban drainage systems end-to-end [29]. The dominant orientation of this body of work, however, is the engineering workflow: modeling, simulation, and capital planning, with the human interface assumed to be a trained operator at a desktop. SIBAMA inherits the spatial data model from this tradition but reorients the consumption endpoint toward the non-expert citizen on a mobile device.

b. Mobile and IoT flood and inundation-monitoring systems

A second thread emphasizes real-time monitoring. IoT-based early-warning systems instrument channels with water-level and rainfall sensors and push alerts to operators or residents [2], [8], and machine-learning models have been layered on sensor and satellite inputs to predict flood severity and map inundation extent [6], [7], [27]. Community-scale smart flood resilience frameworks argue for harnessing distributed data for rapid impact assessment and situational awareness [3], and reviews of flood-warning technology stress that situational intelligence must reach affected communities to be actionable [4]. These systems excel at conveying the present state but generally lack a persistent, navigable archive of surveyed channel condition; SIBAMA is complementary, prioritizing a multi-temporal survey record with live CCTV as a confirmatory layer rather than a sensor-prediction pipeline.

c. Participatory e-government and public service delivery

A third strand frames such tools as instruments of participatory governance. Stakeholder engagement is repeatedly identified as decisive for the adoption and sustained effectiveness of disaster-management systems [4], [20]. Citizen empowerment and satisfaction studies of municipal smart-city applications show that perceived service quality and trust drive sustained use [21], [22]. SIBAMA operationalizes this at the municipal level, treating information disclosure as the mechanism that converts passive residents into co-maintainers of public drainage assets.

d. Geospatial mobile architecture

On the engineering side, the relevant literature concerns map-centric mobile clients consuming server-side spatial data. The prevailing pattern couples a native Android client and the Google Maps API for rendering with a documented REST API and a relational store, exchanging geometry through interchange formats such as KML/KMZ and GeoJSON [9], [23]. Comparative evaluations of backend frameworks indicate that Laravel offers a workable performance-to-productivity balance for REST services [15], [16]. SIBAMA follows this pattern, contributing a concrete instantiation of multi-year layer management on the client.

e. Rainfall-threshold and forecast-driven inundation indicators

A distinct line of work derives inundation likelihood from precipitation rather than from in-channel instrumentation. Empirical rainfall-threshold methods classify flood or flash-flood risk by comparing observed or forecast rainfall against depth–duration thresholds, and are attractive precisely because they avoid complex hydrodynamic models and dense sensing, at the cost of dependence on historical calibration data [31]. Operational flood forecasting increasingly translates quantitative precipitation forecasts into threshold-exceedance warnings [4], [27]. SIBAMA adopts a deliberately lightweight instance of this idea in its 2025 release: it consumes a free public precipitation forecast and applies a daily-rainfall criterion to set a per-segment runoff status, trading hydrodynamic fidelity for zero sensing cost and city-wide coverage, a trade-off whose limitations are examined in Section 4.9.

f. Software testing for mobile applications

Finally, the validation of mobile systems is itself an active area. Black-box testing, assessing behavior from inputs and outputs without reference to source code, frequently realized through equivalence partitioning and boundary-value analysis [9], [18], and is commonly paired with user acceptance testing to confirm fitness for operational use [10], [18]. Black-box verification of feature increments is widely reported for fixed-scope information systems [17]. SIBAMA adopts black-box testing with equivalence partitioning together with a UAT instrument, consistent with this established practice.

g. Research gap

Across these threads, engineering-grade GIS tools are not citizen-facing [1], [14]; IoT early-warning platforms report present state without a navigable historical survey record [2], [6]; rainfall-threshold methods supply a forecast signal but are seldom embedded in a public, map-based municipal tool [31]; and participatory frameworks establish the rationale but rarely specify a deployable mobile architecture for drainage [3], [4]. SIBAMA addresses this intersection: a public-facing Android system that fuses multi-temporal, segment-level survey data, live inundation-point confirmation, and a forecast-driven per-segment runoff status, on a replicable and low-cost stack.

III. METHODS

3.1 Development Method

SIBAMA was delivered incrementally across annual releases (2023, 2024, 2025), with each release executing the Waterfall phases: requirements, design, implementation, integration, and testing, over a scope fixed by a municipal procurement contract for that cycle. Describing the overall programme as a single Waterfall pass would be inaccurate; the appropriate characterization is incremental delivery in which Waterfall governs each increment, the requirements of a given year being stable once contracted, while the system as a whole accretes new capability between years. The five phases instantiated per release were:

1. *Requirements analysis*

   Functional needs were elicited jointly with the Malang City Public Works agency. Across releases, these grew from public dissemination of drainage-survey profiles, multi-year access, inundation-point visualization, and live CCTV, to the 2025 additions: forecast-driven runoff status, a dynamic cross-section overflow illustration, integration of the municipal SAMBAT complaint channel, and CCTV zoom.

2. *System design*

   The three-tier architecture (Section 3.2), the data pipeline including the precipitation-forecast synchronization (Section 3.3), the relational schema (Section 3.4), and the runoff-status rule (Section 3.5) were specified.

3. *Implementation*

   The current (2025) client was built in Android Studio Otter 2025.2.1 in Kotlin against the Google Maps SDK; the administrative backend is a Laravel REST API over a MySQL datastore. Earlier releases used Android Studio Electric Eel (2022.1.1).

4. *Integration and testing*

   Modules were integrated and verified through black-box testing complemented by a user acceptance testing instrument (Section 3.6).

5. *Maintenance*

   Deployment to Google Play, administrator training, and corrective maintenance for defects not surfaced during testing.

3.2 System Architecture

The system follows a three-tier client–server model that cleanly separates presentation, application, and data concerns, a separation that is standard for map-centric mobile systems consuming server-side spatial data [1].

1. *Presentation tier*

   A native Android application (minimum API level corresponding to Android 7.0; recommended Android 10) renders drainage geometry and inundation points on a Google Maps surface. The client manages a navigation drawer exposing per-district and per-year layers, handles runtime storage and connectivity permissions, and embeds a media player for CCTV streams.

2. *Application tier*

   A Laravel service mediates all client–database interaction, exposing endpoints for drainage segments, inundation points, CCTV metadata, and reference data. It also serves as the administrative web console used by operators to ingest and maintain records.

3. *Data tier*

   A MySQL database persists both attribute data and geometry, using native spatial column types so that line and point features are stored as first-class geometric objects rather than as serialized text.

4. *External source*

   Since the 2025 release, a scheduled server-side task synchronizes a three-day precipitation forecast from the public Open-Meteo service [32] into the data tier once per day. This is the only external dependency beyond the mapping service and supplies the rainfall values that drive the derived runoff status (Section 3.5).

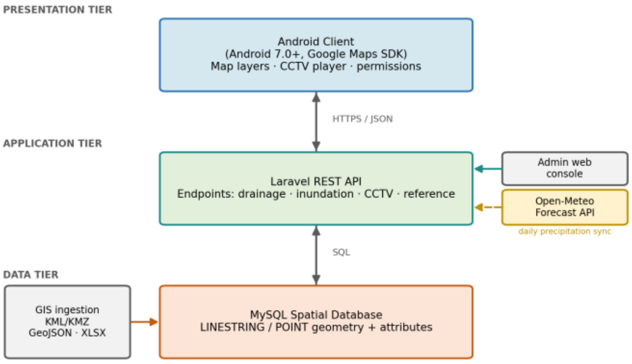


Figure 1. Three-tier architecture: Android client (Google Maps SDK) ⇄ , HTTPS/JSON ⇄ Laravel REST API ⇄ , MySQL spatial database, with the GIS ingestion path and the daily *Open-Meteo precipitation synchronization feeding the data tier.*

3.3 Spatial Data Pipeline

Drainage data originates from field inventory conducted in accordance with the national drainage management regulation (Permen PU No. 12/2014), which prescribes the systematic collection of spatial, hydrological, and hydraulic attributes for each channel segment. The processing chain proceeds as follows: (i) field survey with GPS capture of channel alignment and measurement of cross-sectional dimensions; (ii) compilation into a GIS environment; (iii) export as KML/KMZ and GeoJSON interchange files; (iv) ingestion into MySQL through the administrative console, which also supports bulk XLSX import; and (v) delivery to the Android client as JSON for rendering through the Maps SDK. Channel cross-sections are recorded as one of the standard forms (rectangular or trapezoidal) with the corresponding dimensional parameters required for hydraulic capacity estimation under the rational method (using the 24-hour design rainfall, R24).

Running alongside this survey pipeline is a second, automated data path introduced in 2025. Once per day, the server queries the Open-Meteo forecast endpoint for the city centroid and stores a three-day forecast of daily precipitation sum and maximum precipitation probability. The current-day precipitation sum is then used to evaluate the runoff status of each drainage segment (Section 3.5), which the client renders as line color. The survey pipeline is thus low-frequency and human-curated, whereas the precipitation pipeline is high-frequency and fully automated; the two converge only at the point where the daily rainfall value is compared against each segment's recorded geometry.

Figure 2. Spatial data pipeline from field GPS survey through GIS compilation, interchange-format export, administrative ingestion, and persistence to delivery on the Android map.

3.4 Database Design

The relational schema was derived directly from the entities observable in the application's screens: drainage segments carrying dimensional and documentary detail, filtered by district and survey year; inundation points symbolized as map pins; CCTV streams attached to a subset of those points; and the reference data (district, sub-district, road, physical-condition category, handling category, R24) that the administrative console exposes as master data.

A kecamatan (district) contains many kelurahan (sub-districts); a kelurahan contains many jalan (roads). A drainase segment references one kelurahan, one jalan, one kondisi_fisik (physical-condition) category, and one penanganan (handling) category, and carries a tahun_survei (survey year) discriminator that drives the per-year map layers. Each drainage segment owns many documentation records (geotagged photographs). A titik_genangan (inundation point) may have zero or more CCTV records; the application distinguishes points with an available stream from those without. The users entity holds administrative credentials for the Laravel console. The 2025 release adds a precipitation table holding the daily forecast (precipitation sum and maximum probability per date, with a synchronization timestamp); it has no foreign key to drainage because a single city-centroid forecast is applied to all segments. The runoff status shown per segment is therefore a derived value, computed from the current-day precipitation against each segment's geometry rather than stored as a relationship.

Table 1. SIBAMA database schema.

Table	Key columns	Geometry	Purpose
kecamatan	id (PK), nama	-	District reference
kelurahan	id (PK), kecamatan_id (FK), nama	-	Sub-district reference
jalan	id (PK), kelurahan_id (FK), nama	-	Road reference
kondisi_fisik	id (PK), nama, keterangan	-	Physical-condition category
penanganan	id (PK), nama, keterangan	-	Handling category
r24	id (PK), kelurahan_id (FK), tahun, nilai_mm	-	24-hour design rainfall
drainase	id (PK), kelurahan_id (FK), jalan_id (FK), kondisi_fisik_id (FK), penanganan_id (FK), tahun_survei, tanggal_survei, bentuk_penampang, panjang_m, lebar_m, kedalaman_m, kapasitas_m3s	LINESTRING	Drainage segment
dokumentasi	id (PK), drainase_id (FK), url_foto, tanggal, keterangan	-	Field photo documentation
titik_genangan	id (PK), kecamatan_id (FK), nama, sumber_data, keterangan	POINT	Inundation point
cctv	id (PK), titik_genangan_id (FK), url_stream, orientasi, status	-	CCTV stream metadata
presipitasi	id (PK), tanggal, precipitation_sum, precipitation_probability_max, synced_at	-	Daily Open-Meteo forecast (city centroid)
users	id (PK), name, email, password, role	-	Administrative account

Schema definition (MySQL DDL). The core spatial tables are defined as follows: spatial columns use native geometry types so that segment alignment and point location are queryable as geometry rather than reconstructed from text.

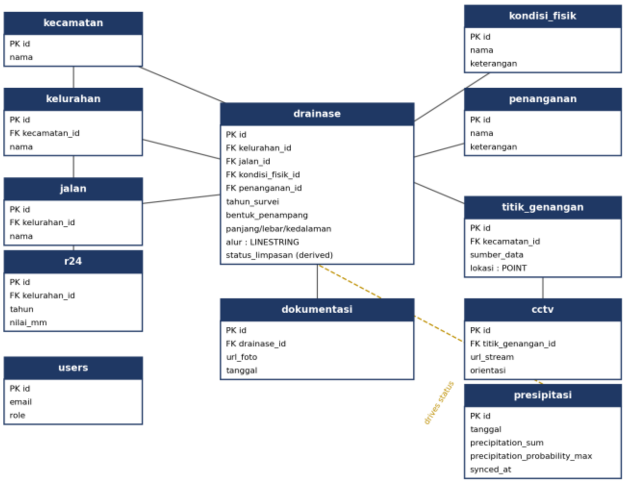


Figure 3. Entity–Relationship Diagram of the SIBAMA database showing primary keys, foreign keys, the spatial LINESTRING/POINT columns, and the standalone presipitasi table whose daily forecast drives the derived per-segment runoff status (dashed link).

Three design choices warrant note. First, the survey year is modeled as an attribute (tahun_survei) on drainase rather than as separate per-year tables; this avoids schema duplication and lets the annual map layers be served by a single indexed query, at the cost of requiring the year filter on every spatial read. Second, the sumber_data field on titik_genangan records provenance (the inundation points derive from the BNPB Malang Drainage Masterplan 2022), preserving an audit trail for data that informs CCTV placement decisions. Third, the runoff status is intentionally not persisted: it is recomputed from the current-day precipitation record whenever segments are served, so that a single daily forecast write propagates to every segment without a per-segment update. The unique constraint on presipitasi.Date makes the daily synchronization idempotent, an upsert keyed on date.

3.5 Forecast-Driven Runoff Status

The 2025 release derives a per-segment runoff status from the daily precipitation forecast. Each day, the system reads the current-day precipitation sum, denoted R24 (mm), from the most recent precipitation record and assigns every drainage segment one of three ordinal classes that the client renders as line color: Normal / Tidak Melimpah (blue), Rawan Genangan (orange), and Genangan Melimpah (red). The maximum precipitation probability is also retrieved and displayed as supporting context, but, per the system documentation, informs the user rather than the status assignment; the status is a function of R24 alone.

The exact decision rule mapping R24 to these three classes is not specified in the available system documentation, which states only that the cross-section overflow illustration and the segment color depend on the daily precipitation forecast. Because the scale is ordinal with three levels, any rule requires two cut points rather than the single threshold a binary scheme would need. Two formulations are consistent with the observed behavior and are reported here as candidates, not as the implemented rule, which must be confirmed against the source code before any operational claim is made.

The first is a global double-threshold on rainfall, with two fixed cut points $\tau_1 < \tau_2$ applied uniformly to all segments:

$$S(seg) = \begin{cases} \text{Normal} & \text{if } R24 < \tau_1 \\ \text{Rawan Genangan} & \text{if } \tau_1 \le R24 < \tau_2 \\ \text{Genangan Melimpah} & \text{if } R24 \ge \tau_2 \end{cases}$$

This is the simplest reading and matches the fact that all segments share one city-centroid forecast; its consequence, however, is that every segment changes class simultaneously, since they all see the same *R24*.

The second is a capacity-relative rule, in which the daily rainfall is converted to a loading ratio $\rho = L(R24) / Q(seg)$, where Q(seg) is the segment's hydraulic capacity estimated from the recorded cross-section (width, depth, form) under the rational method and $L(\cdot)$ is the rainfall-implied load:

$$S(seg) = \begin{cases} \text{Normal} & \text{if } \rho < \rho_1 \\ \text{Rawan Genangan} & \text{if } \rho_1 \le \rho < 1 \\ \text{Genangan Melimpah} & \text{if } \rho \ge 1 \end{cases}$$

Here $\rho = 1$ is the physical overflow point (load meets capacity), and $\rho_1 < 1$ (for example, a fixed fraction of capacity) defines the caution band. This formulation makes the status segment-specific even under a single city-wide rainfall value, and it is more consistent with the animated cross-section, whose fill level rises in proportion to the forecast and reaches the channel top precisely when $\rho \to 1$. Establishing and validating the actual rule, the values of τ_1, τ_2, or of ρ_1 and the capacity model, calibrated against observed inundation events, is a prerequisite for treating the status as a warning rather than as an indicative visualization (Section 4.12).

3.6 Test Design

Functional verification follows black-box testing, which evaluates observed behavior against expected outputs without reference to internal code [9], using equivalence partitioning to bound the input space for each module [18]. The protocol below specifies the test cases, including the modules introduced in 2025; the Result and Status fields are populated during execution. As no execution log was available for this study, these fields are presented as the designed instrument rather than as recorded outcomes.

Table 2. Black-box test design (equivalence partitioning).

No.	Module	Test case	Expected output
1	Splash screen	Launch with an active connection	Logo shown; permissions requested; auto-dismiss after 3.5 s to home
2	Splash screen	Launch with no connection	Connectivity warning surfaced
3	Navigation drawer	Select a district layer	Corresponding district drainage rendered
4	Year filter	Select Data 2020–2023	Only the selected year's segments rendered
5	Segment detail	Tap a drainage polyline	Detail with dimensions and documentation photo
6	Inundation point	Tap a pin without CCTV	“CCTV not available” notice
7	Inundation point	Tap a pin with CCTV	Navigation to live stream page
8	CCTV view	Rotate device; pinch to zoom	Portrait/landscape layout adapts; stream zooms in/out
9	Precipitation panel	Open R24 / probability panel; sync	Three-day sum and max probability listed; last-sync time updated
10	Runoff status	Render segments under low vs high R24	line color reflects one of three classes (Normal / Rawan Genangan / Genangan Melimpah) per legend.
11	Dynamic cross-section	Open segment detail under varying R24	Overflow illustration fills proportionally to the forecast
12	SAMBAT link	Tap the SAMBAT shortcut	Opens the SAMBAT complaint page/app download
13	About	Open Info App	Application identity information is shown

User acceptance testing uses a structured questionnaire administered to target users (residents and sub-district officials), scored on a five-point Likert scale across functionality, usability, and information clarity, with the acceptance index computed as the ratio of obtained to maximum attainable score [10]. The instrument design and respondent profile are reported in Section 4.

IV. RESULT AND ANALYSIS

4.1 Implementation Environment

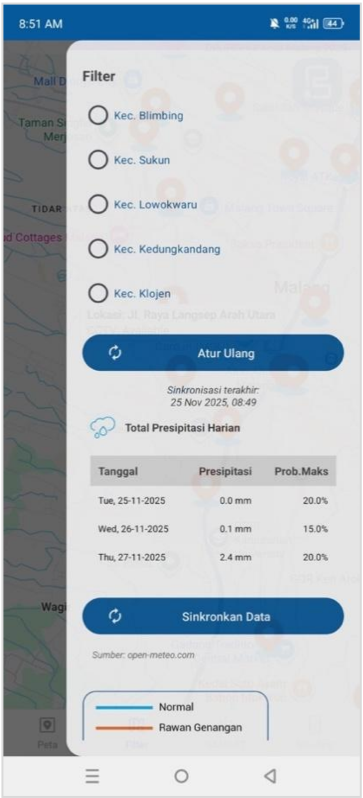
The current client (2025 release) was implemented in Kotlin in Android Studio Otter 2025.2.1 against the Google Maps SDK; earlier releases used Android Studio Electric Eel (2022.1.1). The recommended configuration is Android 10 with 4 GB RAM and roughly 30 MB of storage, over Wi-Fi or cellular. The server side comprises a Laravel application exposing a REST API over a MySQL datastore, with the administrative console hosted as a companion web platform and a scheduled task performing the daily Open-Meteo synchronization. The choice of Laravel as the API layer is consistent with comparative evaluations reporting a workable performance-to-productivity balance for REST services backing mobile clients [15], [16]. The client communicates over HTTPS, exchanging JSON, and requires a network connection for all map and data operations; the application is distributed through Google Play. Drainage coverage now spans all five districts of Malang (Blimbing, Lowokwaru, Klojen, Sukun, Kedungkandang).

4.2 Splash Screen and Runtime Permissions

Figure 4. 2025 splash screen with connectivity check and storage-permission request.

On launch, the application presents a splash screen that displays the SIBAMA identity (logo, name, the tagline “Wadah Pengendalian Genangan”, owner, and year) while performing two initialization tasks: a network-connectivity check and a request for the runtime permissions needed to access device storage. The 2025 release restyles the background color relative to 2024 but keeps the behavior: the screen dismisses automatically after 3.5 seconds and transitions to the main view. This placement is functional rather than cosmetic because every downstream feature depends on network access and the Maps SDK. Resolving connectivity and permissions before the map is constructed prevents the partially-initialized states that otherwise produce blank-tile failures. Deferring the connectivity verdict to the splash phase is the correct placement, although a fixed 3.5-second timeout couples the dismissal to a timer rather than to the completion of the checks themselves, which is a design weakness on slow networks (Section 4.12).

4.3 Navigation Drawer and Main Menu



Sinkronisasi terakhir:
25 Nov 2025, 08:49

Tanggal	Presipitasi	Prob.Maks
Tue, 25-11-2025	0.0 mm	20.0%
Wed, 26-11-2025	0.1 mm	15.0%
Thu, 27-11-2025	2.4 mm	20.0%

Sumber: open-meteo.com

Figure 5. 2025 navigation and filter panel with the new shortcut bar.

Navigation is organized through a drawer/filter panel that exposes the principal functions: the inundation-point map, per-district drainage filters for the five districts of Malang, the daily precipitation panel reporting the precipitation sum (R24) and maximum probability, and a legend mapping line color to runoff status. The 2025 release adds a persistent bottom shortcut bar (Peta, Filter, SAMBAT, Info App) that promotes the most frequent actions out of the drawer. The drawer pattern remains appropriate for a catalog of mutually exclusive map layers, since only one layer is meaningfully displayed at a time, while the shortcut bar addresses the drawers by surfacing the map, filter, complaint channel, and information pages at one tap. Each layer selection resolves to a filtered query against the drainase or titik_genangan tables defined in Section 3.4, with district and year as predicates.

4.4 Per-District Drainage Layers

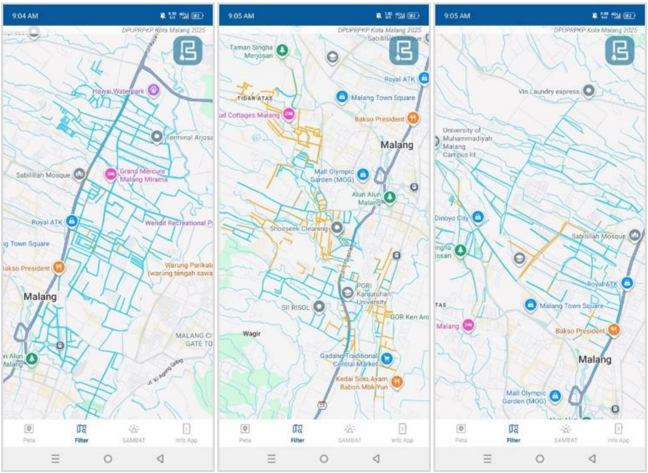


Figure 6. Per-district drainage networks rendered as interactive map polylines.

Selecting a district renders its surveyed drainage network as polylines over the base map. The geometry corresponds to the “alur” LINESTRING column of the drainage table, ingested from KML/KMZ and GeoJSON exports produced by the survey and GIS team. Rendering channel alignments as native map polylines, rather than as static raster overlays, preserves interactivity at the segment level and is the established approach for serving server-side spatial features to a mobile map client [1], [9]. The same map-centric presentation of flood- and drainage-related spatial data has been adopted in comparable Indonesian systems for flood-prone-area mapping and disaster information delivery [11], [12], [13].

4.5 Multi-Temporal Data and Segment Detail

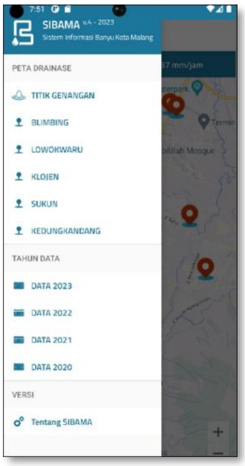
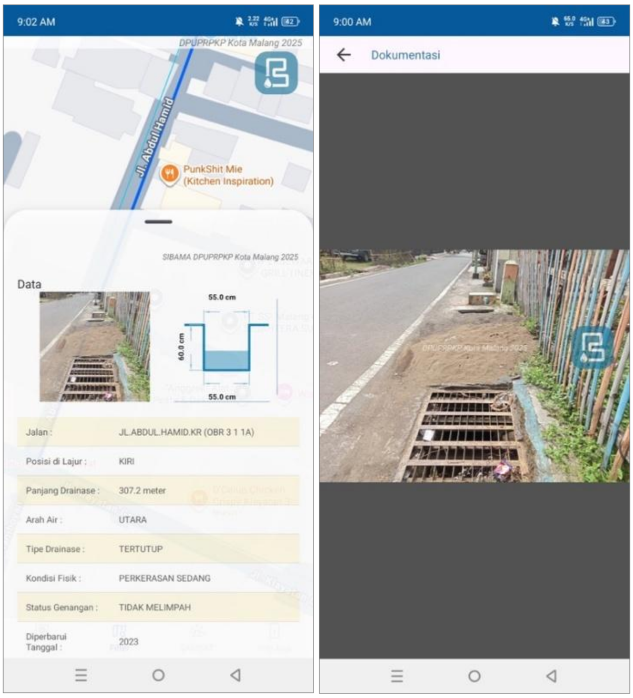


Figure 7. The annual survey layer is selected from the navigation drawer.



Jalan : JL.ABDUL.HAMID.KR (OBR 3 1 1A)
Posisi di Lajur : KIRI
Panjang Drainase : 307.2 meter
Arah Air : UTARA
Tipe Drainase : TERTUTUP
Kondisi Fisik : PERKERASAN SEDANG
Status Genangan : TIDAK MELIMPAH
Diperbarui Tanggal : 2023

Figure 8. Segment-level detail with dimensions and dated field documentation.

The annual layers (Data 2020 through Data 2023) expose the multi-temporal dimension that distinguishes SIBAMA from single-state monitoring systems. Each layer is the result of filtering drainage on tahun_survei, so the four views share one schema and one rendering path rather than four parallel structures. Tapping a polyline retrieves the associated attributes, cross-sectional form (rectangular or trapezoidal), length, width, depth, and the linked documentation photographs from the documentation table, and presents them in a detail panel. This segment-level disclosure is the core of the system's public-information function: it converts an archived engineering inventory into a record a resident can inspect for a specific channel near them. The capacity to compare a channel's documented condition across successive survey years is precisely the persistent, navigable record that sensor-centric early-warning platforms do not provide [2], [4], [6], and it aligns with the broader argument that returning situational information to the community is a precondition for participatory maintenance [3], [21].

4.6 Inundation Points and Live CCTV

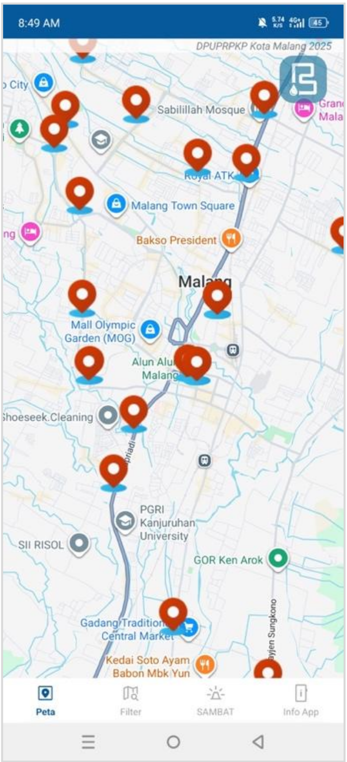


Figure 9. Inundation-point pins with conditional CCTV availability.

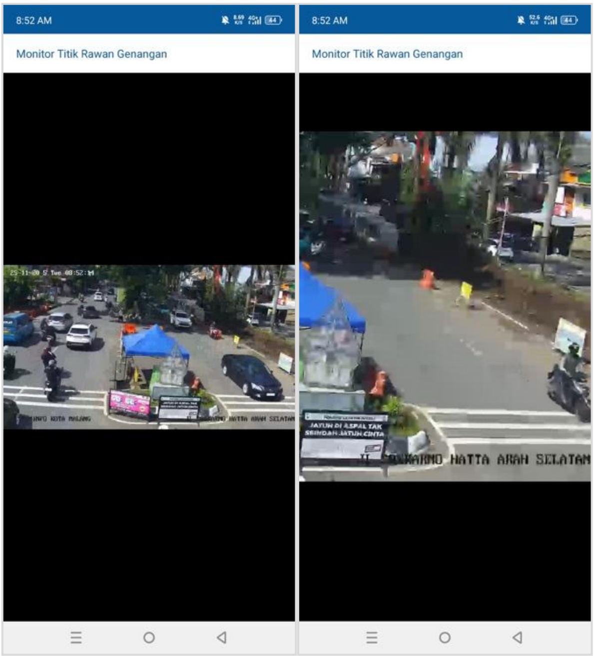
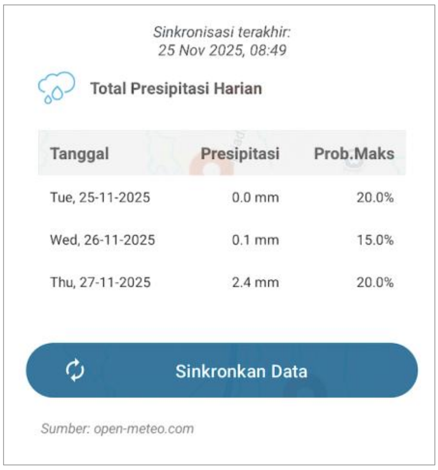


Figure 10. Orientation-adaptive live CCTV stream with 2025 zoom support.

Inundation points are symbolized as Pin Point markers drawn from the titik_genangan table, whose sumber_data field records that the points derive from the BNPB Malang Drainage

Masterplan 2022; the 2025 release adds further points and cameras. Tapping a pin branches on the presence of a linked record in the CCTV table: where no camera faces the point, the application surfaces a "CCTV not available" notice; where a stream exists, it transitions to a live video view that adapts between portrait and landscape orientation and, in 2025, supports pinch zoom for closer inspection of the water level at the scene. Coupling a static risk-point inventory with on-demand live visual confirmation is a pragmatic substitute for a dense in-channel sensor network, situating SIBAMA between archival GIS tools and instrumented IoT early-warning systems [2], [6]. The provenance field also preserves the audit trail linking observed inundation history to camera placement, consistent with evidence that traceable data underpins trust in municipal smart-government services [20], [22].

4.7 Precipitation Forecast Panel and Daily Synchronization



Sinkronisasi terakhir:
25 Nov 2025, 08:49

Total Presipitasi Harian

Tanggal	Presipitasi	Prob.Maks
Tue, 25-11-2025	0.0 mm	20.0%
Wed, 26-11-2025	0.1 mm	15.0%
Thu, 27-11-2025	2.4 mm	20.0%

Sumber: open-meteo.com

Figure 11. Three-day precipitation panel and synchronization control.

The 2025 release adds a precipitation panel that lists, for the current and two following days, the daily precipitation sum (R24, mm) and the maximum precipitation probability (%), with a manual synchronization control and a last-sync timestamp. The data are retrieved from the Open-Meteo forecast endpoint for the city centroid [32]; the 2025 request adds the precipitation_probability_max field to the precipitation_sum used in 2024. A representative response is shown below; the current-day precipitation_sum is the value subsequently used to evaluate runoff status (Section 3.5).

```
{
  "daily_units": { "time": "iso8601",
                   "precipitation_sum": "mm",

"precipitation_probability_max": "%" },
  "daily": {
    "time": ["2025-11-25", "2025-11-26",
"2025-11-27"],
    "precipitation_sum": [0.00, 0.10, 2.40],
    "precipitation_probability_max": [20, 15,
34]
  }
}
```

Storing only a three-day window keeps the precipitation table small and the daily upsert idempotent on date, but it also means the system retains no precipitation history of its own; any retrospective comparison of forecast against observed inundation would require an external archive. This is acceptable for a display-oriented indicator but is a constraint on using the data for calibration (Section 4.12).

4.8 Forecast-Driven Runoff Status and Legend

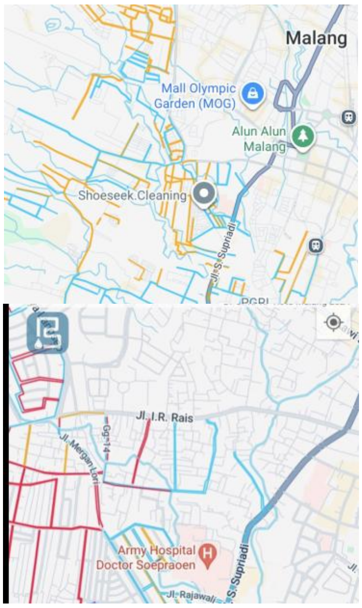
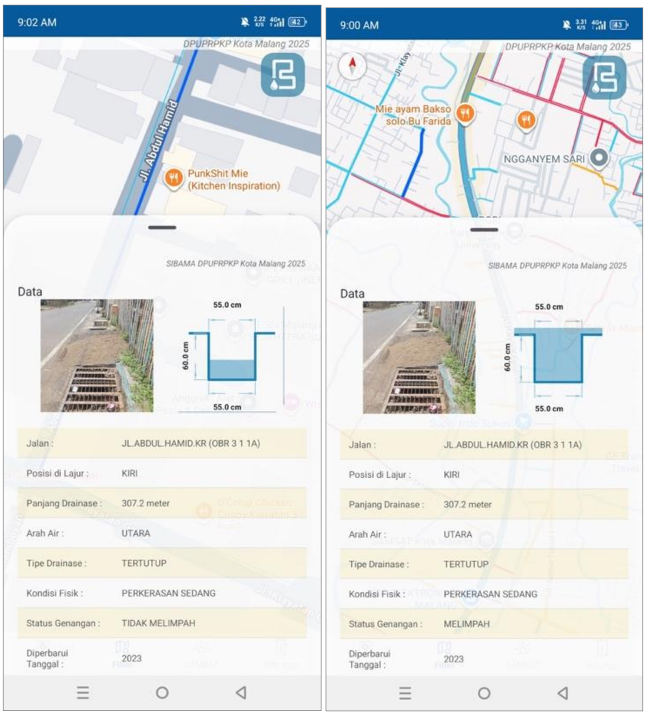


Figure 12. Per-segment runoff status rendered as line color with legend.

The most consequential 2025 addition recolors each drainage segment by the runoff status derived from the current-day R24 (Section 3.5). Rather than a binary safe/unsafe flag, the legend defines a three-level ordinal scale: Normal (Tidak Melimpah), Rawan Genangan (at risk of overflow), and Genangan Melimpah (overflowing), rendered respectively in blue, orange, and red. The intermediate Rawan Genangan tier is the informative one: it separates channels that are merely conveying the forecast load from those predicted to exceed capacity, giving the user an early-caution band between the clearly-safe and clearly-overflowing extremes. Functionally, this converts SIBAMA from a record of past survey condition into a forward-looking daily indicator, and it does so without any in-channel instrumentation. The approach belongs to the family of rainfall-threshold inundation indicators, which are valued precisely for avoiding dense sensing and complex hydrodynamic modeling [31]; a three-level scheme implies two decision thresholds on R24 (or two capacity ratios) rather than the single threshold a binary scheme would use, which sharpens the need to specify and calibrate those cut points (Section 3.5). The design is well matched to a resource-constrained municipality. Its principal weakness is spatial: because a single city-centroid forecast drives every segment in all five districts, even a three-level status cannot reflect local differences in catchment, elevation, or sub-basin response, so two channels with very different exposure but identical geometry receive the same rainfall driver and therefore the same class (Section 4.12).

4.9 Dynamic Cross-Section Illustration



Jalan : JL.ABDUL.HAMID.KR (OBR 3 1 1A)
Posisi di Lajur : KIRI
Panjang Drainase : 307.2 meter
Arah Air : UTARA
Tipe Drainase : TERTUTUP
Kondisi Fisik : PERKERASAN SEDANG
Status Genangan : TIDAK MELIMPAH
Diperbarui Tanggal : 2023

Jalan : JL.ABDUL.HAMID.KR (OBR 3 1 1A)
Posisi di Lajur : KIRI
Panjang Drainase : 307.2 meter
Arah Air : UTARA
Tipe Drainase : TERTUTUP
Kondisi Fisik : PERKERASAN SEDANG
Status Genangan : MELIMPAH
Diperbarui Tanggal : 2023

Figure 13. Dynamic cross-section overflow illustration tied to the daily forecast.

Segment detail retains the recorded attributes (road, lane position, length, flow direction, drainage type, physical condition, and update date) and the field photograph, and in 2025 renders the cross-section with a water-fill illustration that varies with the forecast, accompanied by a status field reading not-overflowing or overflowing. Tying the illustration to the same daily R24 that drives line color gives the user a consistent signal at two levels of detail: aggregate color on the map and an explicit fill at the segment. The visual is effective for communication, but the fill level should be read as indicative rather than as a calibrated hydraulic water level, since the underlying rule is not documented (Section 3.5).

4.10 SAMBAT Integration and Information

Warga menginput pengaduan SAMBAT dengan login, klik buat tiket.

Figure 14. SAMBAT complaint-channel integration and Info App page.

The 2025 release links SIBAMA to SAMBAT, the Malang municipal complaint platform, via a shortcut that directs the user to the SAMBAT channel where a drainage issue can be reported. This closes a loop left open in the earlier design: a resident who observes an inundation-prone segment or a live CCTV scene can move directly from information consumption to a formal report, operationalizing the participatory-governance rationale that motivated the system [20], [21]. The Info App page mirrors the Play Store profile, providing application identity and a summary of features.

4.11 Technical Specification

The deployed 2025 configuration uses Google Maps as the mapping service, Open-Meteo as the precipitation source, and MySQL as the datastore; it is written in Kotlin, mandates a network connection, and is distributed through Google Play. The recommended device profile is Android 10 with 4 GB RAM and about 30 MB of storage. Reported completion of the contracted 2025 scope is full.

4.12 Discussion: Contributions, Comparison, and Limitations

Mapped against the database design, the implemented screens exercise the full schema: the per-district and per-year layers consume drainase filtered on kelurahan/kecamatan and tahun_survei; the segment detail joins dokumentasi, kondisi_fisik, and penanganan; the inundation workflow traverses titik_genangan to cctv; and the runoff layer reads the current-day presipitasi record. The single-schema, attribute-filtered design (Section 3.4) is validated in use, since all annual layers and all five district layers are served without schema duplication, and a single daily forecast write propagates to every segment as a derived value.

Relative to prior work, SIBAMA occupies an underserved position. Engineering-grade drainage GIS, including a drainage-network evaluation in the same city, Malang [14], targets analysts rather than the public [1], [10]. Indonesian flood-information applications more commonly deliver hazard zonation or emergency response [11], [12], [13], [26], and rainfall-threshold methods supply a forecast signal without a public map-based delivery vehicle [31]. SIBAMA's contribution is the fusion of three layers that are usually found separately: a multi-temporal segment-level survey record, live CCTV confirmation, and a forecast-driven per-segment runoff status, delivered on a deliberately low-infrastructure stack whose only external dependencies are a mapping service and a free weather API.

Four limitations bear directly on validity and are stated plainly. First, the functional verification reported here is a designed black-box and UAT protocol (Section 3.6); no execution log or acceptance scores were available, so no claim of measured pass rates or satisfaction indices is made, and any deployment should populate those instruments before asserting reliability or usability. Second, the forecast forcing is spatially uniform: a single city-centroid query drives the runoff status of every segment across all five districts, ignoring local catchment, elevation, and sub-basin response, which is the most significant scientific weakness of the 2025 design. Third, the runoff decision rule is undocumented (Section 3.5); until the threshold or capacity model is specified and calibrated against observed inundation, the status must be presented as an indicative visualization rather than a warning. Fourth, the system is network-dependent with no offline cache, so during the connectivity disruption of a flood event, when the inundation, CCTV, and status features are most needed, it has a material single point of failure, compounded by the timer-based splash dismissal (Section 4.2). The forecast coupling thus advances the system beyond the static archive of earlier releases, but its present form is an indicative aid, not a calibrated early-warning system.

V. CONCLUSION AND FUTURE WORK

This study reported the design, incremental development, and test design of SIBAMA, an Android application with a Laravel REST backend and a MySQL spatial datastore that disseminates municipal drainage information to the public in Malang City. Across releases, the system grew from a multi-temporal, segment-level survey archive with live CCTV into a forecast-coupled tool whose 2025 release derives a daily per-segment runoff status from an Open-Meteo precipitation forecast, animates the cross-section overflow, integrates the SAMBAT complaint channel, and covers all five districts in Kotlin. Its contribution is the fusion of survey record, live confirmation, and forecast-driven status on a stack whose only external dependencies are a mapping service and a free weather API, with the relational schema in Section 3.4 offered as a replicable artifact for comparable municipalities.

Future work follows from the limitations in Section 4.12. Most importantly, the spatially uniform forecast should be replaced by sub-basin or per-district precipitation queries so that runoff status reflects local exposure, and the decision rule should be specified and calibrated against observed inundation before the status is presented as a warning. The designed black-box and UAT instruments should then be executed on real devices and users, reporting measured functional coverage and an acceptance index. An offline-first cache would remove the network single point of failure during flood events, and building on the new SAMBAT link, a structured in-app reporting channel could feed resident observations back as a data source for calibrating the runoff rule, advancing the participatory-governance objective the system was commissioned to serve [20], [21], [31].

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