

STORMWATER MANAGEMENT AND ROAD TUNNEL (SMART) PROJECT

FLOOD DETECTION SYSTEM (FDS)

BY

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ABSTRACT

The Flood Detection System (FDS) for the Stormwater Management and Road Tunnel (SMART) project comprises mainly of the catchment monitoring system, the warning system, the hydrological and hydraulic modelling component, tunnel / gate monitoring and control system, CCTV monitoring system and the communications system.

The main purpose of the FDS is to provide real time flood prediction and to determine the severity of flood events to enable the safe and efficient dual use of the tunnel system for stormwater diversion from the Central Business District (CBD) and for traffic movement. This paper specifically discusses the various components of the FDS system and how they are structured to work together in a seamless fashion to provide real time flood forecasting for the SMART project.

1.0 INTRODUCTION

The Stormwater Management and Road Tunnel (SMART) was introduced to address two main issues that were plaguing the Kuala Lumpur CBD (see figure 1 for location and alignment of SMART), i.e. major flooding caused by heavy downpour and severe traffic congestion along city streets during peak hours. SMART's primary concern however was to tackle the issue of flash flooding in the CBD and SMART performs this function by diverting a measured amount of flood discharge from the catchments of Klang and Ampang through a bypass tunnel for controlled release downstream of the city center.

The system diverts excess flood water from entering the city into the tunnel for attenuation at a storage pond before being released into Sg Kerayong. The inlet into the tunnel system at the holding pond is an 8-bay offtake structure located on the left bank of the Sg Klang immediately downstream of its confluence with the Sg Ampang. Downstream of this offtake is a 4-bay control structure which would be operated to regulate the flood flows allowed into the city. The excess discharges arising from this regulation would be channelled into the tunnel via the offtake structure.

At its outlet into the Desa Water Park the tunnel is gated by a twin bay structure. These gates would be operated only during flood modes to permit the passage of flood flows into the storage pond. At all other times the gates are kept closed to prevent back flow from the storage pond into the tunnel.

The storage pond is connected to Sg Kerayong via a twin box culvert, approximately 500 meter long. Each culvert is gated at both ends, the structure at the outfall to the Kerayong being a regulating type. At times of flood discharge into the Kerayong, the

downstream gates would be operated to limit the release to within the capacity that the river channel can handle.

The diversion tunnel is a dual purpose tunnel which is also designed for a secondary purpose, i.e. to ease traffic movement between the Sg Besi entrance to the city and the Kampong Pandan round-about. The vehicular tunnel will enter the diversion tunnel system approximately 4.6 kilometres downstream from the holding pond and exit a further three kilometres downstream. The section of the tunnel where the vehicular traffic is included will have three main compartments, namely an upper traffic deck, a lower traffic deck and an under culvert (see figure 2).

During flow conditions at most times of the year however, the tunnel is not required to take in any water because the inflow into the city is within the existing capacity of the river systems. Occasionally though, when the floods exceed a certain magnitude, water would have to be taken into the tunnel for the following conditions:-

- Approximately once a year, the full bore of the tunnel will be required to handle the inflow,
- At other times (about 12 to 15 times a year) part of the tunnel cross section will be required to accommodate the inflow.

On occasions when the tunnel is not being used for flood management, the midsection of the tunnel doubles up as a two-deck motorway to relieve traffic congestion at the main southern gateway into the city center. To fulfill its dual design role, the tunnel operation has been divided into the three following modes (see figure 3):-

MODE I	All stormwater flows through city centre. No diversion of water into the tunnel is required.
MODE II	Stormwater is diverted into the Holding Pond, flowing through the upper barrel of the stormwater tunnel, the lowest drainage chamber provided in the traffic tunnel, the lower barrel in the stormwater tunnel and the Attenuation Pond before discharging into Sg Kerayong. Vehicles within the traffic decks remain uninterrupted. The traffic tunnel will be isolated from the flood tunnel by a set of watertight flood gates. Mode II is expected to operate about twelve to fifteen times a year.
MODE III	The middle barrel (vehicular decks) is evacuated of all traffic. Traffic decks will be sealed to prevent vehicular entry by using various sets of gates. Stormwater is diverted into the Holding Pond, flowing through the upper, middle and lower barrels of the tunnel, and the Attenuation pond before discharging into Sg Kerayong. Mode III is expected to be an annual event.

To enable the safe and efficient dual use of the tunnel system for stormwater diversion from the CBD and for traffic movement, the Flood Detection System (FDS) was set up.

The FDS performs its function by measuring rainfall at ground levels, converting the same to river stages and discharges, and establishing in advanced time whether a mode I, II or III event is to be expected.

2.0 PRINCIPAL OBJECTIVES OF THE FLOOD DETECTION SYSTEM

The FDS performs its function by measuring rainfall at ground levels, converting the same to river stages and discharges, and establishing in advance time whether a mode I, II or III event is to be expected. Apart from that, the FDS is also structured to meet the following objectives among others:-

- To provide advance information on river flow conditions to aid timely operation of the tunnel in the appropriate mode.
- To enable gate operations for the various hydraulic structures.
- To enable gate operations in the tunnel to ensure safe and flood free passage of flood wave through the tunnel.
- To provide information on SMART's operation, in the event of partial failure in the system
- To log and archive events of flood management for future references.

3.0 FLOOD DETECTION COMPONENTS AND OPERATION

The flood detection system has been made possible through the design and development of a sophisticated system of radio telemetered hydrological data collection network including rainfall, river level, real-time flow and storage pond water level monitoring stations. Data from these stations will be input in real-time to a dynamic hydrological and hydraulic modelling software package for forecasting flood potential and making recommendations for storm water diversion strategies for the SMART system including the regulation of the Sg Klang water flow and the operation of the tunnel system.

In addition to this system, a cable based SCADA system has been designed and developed to monitor and control the various gate systems, water level/pressure sensors and the CCTV system.

In general, the FDS involves the collection, transmission, processing and analysis of hydrological data to forecast the storm characteristics which dictates the operation mode of the SMART system. The FDS can be compartmentalized into the following three main sectors:-

- a. Data Collection system
- b. Information transmission system
- c. Data processing system

3.1 Data Collection System

The data collection system for the FDS can be further divided into two components, namely:

- The hydrological data required to determine the severity of a flood event.
- The supplementary data necessary for the operation of the SMART system once the flood prediction has been made.

3.1.1 Hydrological Data

The hydrological data comprises of rainfall, river level and discharge data which are recorded via the setting up of 28 gauging stations at various locations in the Klang, Ampang, Bunus, Gombak, Batu and Kerayong catchments (see figure 4 for distribution of gauging stations).

The locations of the rainfall stations and the spacing between one station to the other has been carefully determined based on a rain gauge network density analysis, the accessibility of each location and the minimum 2H requirement (the rain gauge must be sited at a location which is two times the horizontal distance of the height difference between the rain gauge and the tallest structure/tree in the vicinity) for positioning rain gauges. The coverage distance for each rain gauge is approximately 2 km and this has been adopted to minimize the risk of missing small storms.

The discharge and water level stations have been sited at locations which will provide the most accurate determinations of the river flow and which are best suited for the purpose of the hydrologic/hydraulic model. The gas purge system is being used to measure water levels (see figure 5) whereas the Doppler Current Meter (DCM) (see figure 6) has been employed for use at discharge measurement locations.

3.1.2 Supplementary Data to Aid the Operation of the SMART System

Once the hydrological data has been analyzed and a storm prediction has been made, the operation of the SMART system will be activated based on a defined set of operation rules. The following data will be utilized to aid the operation of the SMART system:

No.	Type	Location	Purpose
1	Water pressure and flow data within the tunnel using the gas purge system, with a triplicate redundancy provision for critical locations.	At emergency and upper as well as lower deck service gates at NJB and SJB and at Tunnel Outfall gates.	To measure water level and water pressure in the tunnel to ensure that tunnel gates are operating according to the defined operating rules.
2	Storage Pond water level data using the gas purge system.	At Holding Pond and Attenuation Pond.	To monitor the water levels in both the storage ponds.
3	Visual display of river levels and gate positions using the CCTV Surveillance System.	At critical locations at the SMART intake and outlet structures, in the tunnel and in certain rivers in the CBD.	To monitor the operation of stormwater gates, tunnel gates, ponds and to monitor river levels at critical locations.

3.2 Information Transmission System

The information transmission system recovers recorded information from field instruments and transmits them real time to the SCADA system which can be viewed at the display console at the SMART Control Centre (SCC) (see figure 7). The SCC is located in Kg Berembang adjacent to the Holding Pond and functions as the

control center for the stormwater component of the SMART system. A typical display of the operation management of the FDS is shown in figure 8.

The primary system which has been adopted for the hydrological stations and the storage pond water level monitoring stations for SMART is telemetry which uses radio waves to transmit information. VHF radio is the main communication system which is used to transmit data from the hydrological stations to the SCC. Due to the distances covered and the nature of terrain encountered, the hydrological data goes through a repeater station sited in Ulu Kali which then transmits the data to the SCC. A backup communication system has been provided for all hydrological stations to ensure system redundancy.

3.3 Data Processing System

The data processing system comprises mainly of the FDS modeling system, the purpose of which is to predict the operation of the SMART system with the maximum forecast time possible based on the defined operation rules.

The SMART system is made up of a hydrological model, a hydrodynamic model, a database and a scheduler (see figure 9).

Data from the SMART monitoring sites is exported from the SCADA system into the Time Series Manager (TSM) database for archiving. All inputs and outputs for the modeling system are derived directly from the TSM database where all the data are available for viewing and processing. Hydrographs and other data which are the output from the hydrological and hydraulic components of the model are stored directly on this database as the modeling processes are being run in real-time. The hydrological model reads data directly from the TSM database as the processing takes place. Output hydrographs from the hydrologic model runs are then exported from the database into the hydraulic model. Output data from both the hydrological and hydraulic models is stored in the TSM database from which it is exported to the SCADA system for display.

3.3.1 Hydrological Model

The rainfall runoff model covers all of the Sg Klang catchment area upstream of the water level gauge located downstream of the Sg Klang / Kerayong confluence, except for the upper reaches of the Sg Gombak and Batu catchments. Measured flow at each of these gauges is input into the model to account for the catchment area upstream of these gauges. The Australian Water Balance Model (AWBM) is used to calculate the runoff based on rainfall inputs (See figure 10 for schematic of ABWM loss model).

3.3.2 Hydraulic Model

Based on predicted hydrographs from the hydrologic model and measured data (levels, flow and gate positions) from the field, the hydraulic modeling component of the FDS predicts the following:-

- Flood levels within the SMART system and surrounding rivers;
- Flood discharge within the SMART system and surrounding rivers;
- SMART gate and pump operation;
- Override alarms

The hydraulic model has been set up using the MIKE 11 software package.

Both the hydrological and hydraulic models will be calibrated from time to time with data from recorded flood events to further refine the models to suit the catchment conditions.

3.4 Operation of the SMART system

Within the first hour of a storm, data received will be analyzed to predict one of the three modes of operation for the SMART system. If a mode I is predicted, no action by SMART will be required. However, if a mode II or III storm is predicted, based on this prediction and the recorded water levels in Sg Klang, the tunnel and the storage ponds, a set of defined operating rules will be deployed automatically to operate the SMART system. The sequence of operation which involves various sets of gates will be displayed in the video wall display console in the Stormwater Control Centre (SCC) for monitoring and supervision by authorized key personnel.

4.0 CONCLUSION

The Flood Detection System functions as the nucleus for the SMART system. Apart from determining the severity of the flood events, the FDS is also responsible for piecing together the various individual physical components of the project to work as an integrated system for SMART. The main functions of the FDS are as follows:-

- To provide real time measurements and advance information on river flow conditions to aid timely operation of the tunnel in the appropriate mode.
- To enable gate operations for various hydraulic structures.
- To enable gate operations in the tunnel to ensure safe and flood free passage of flood wave through the tunnel.
- To monitor the water pressure and flows within the tunnel.
- To monitor the pond, intake and outlet structures as well as critical locations in the CBD via the CCTV network.
- To provide information on SMART's operation, in the event of partial failure in the system.
- To log and archive events of flood management for future references.

REFERENCES

Ludlow C., Peterson J. and Smith G., "Functional Specification – FDS Modelling System for Stormwater Management and Road Tunnel (SMART) Project".

Sepakat Setia Perunding (Sdn.) Bhd., "Tender Documents for Design, Manufacture, Supply, Install, Testing and Commissioning of Flood Detection System – Volume 2 of 2".

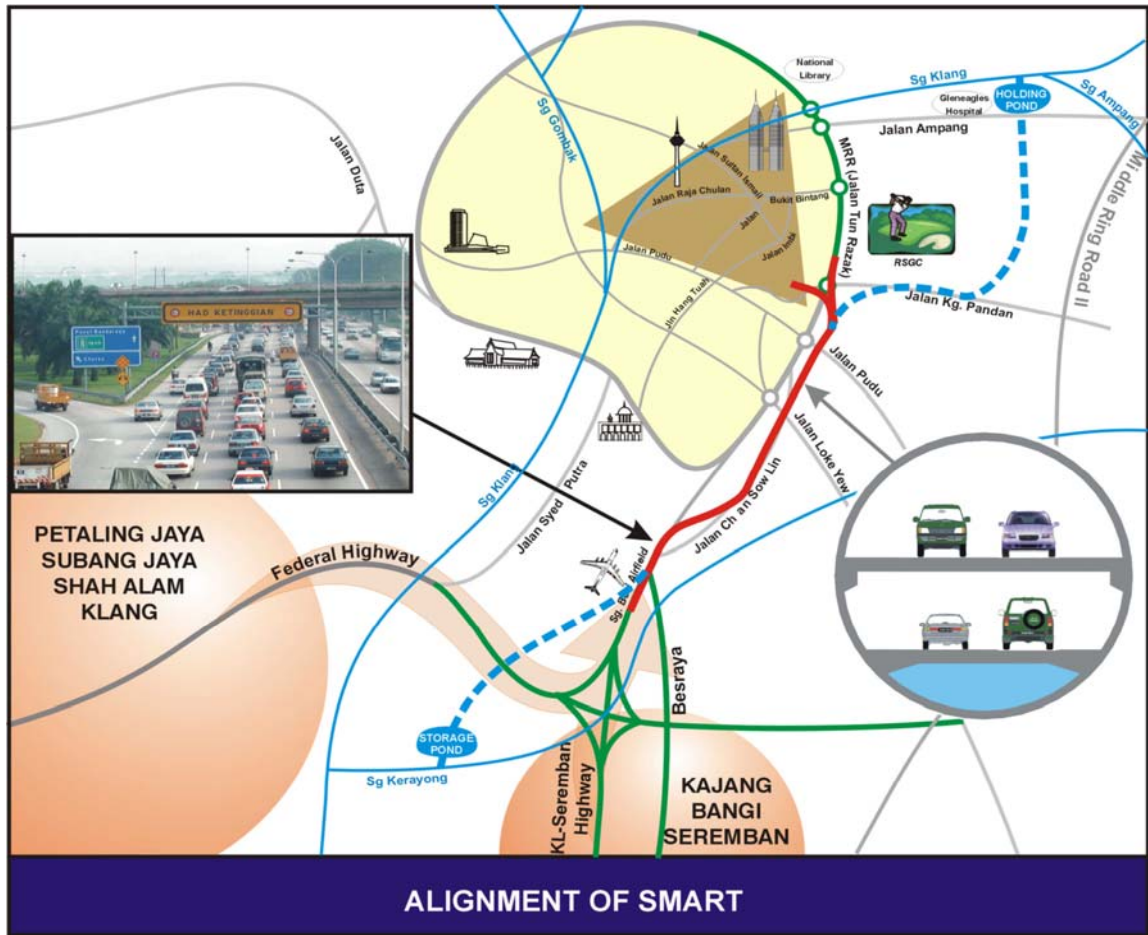


Figure 1: Alignment of SMART

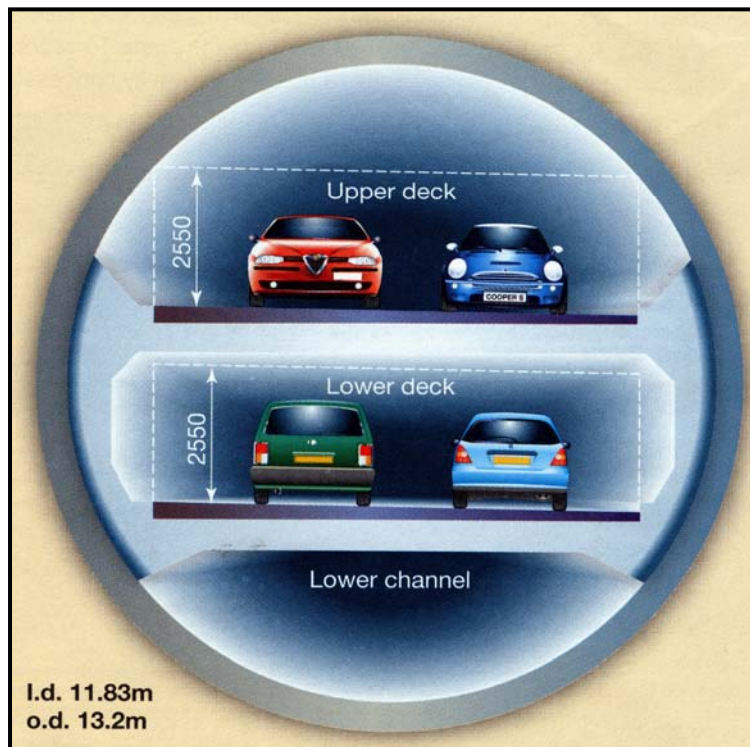


Figure 2: Cross Section of the Vehicular Tunnel

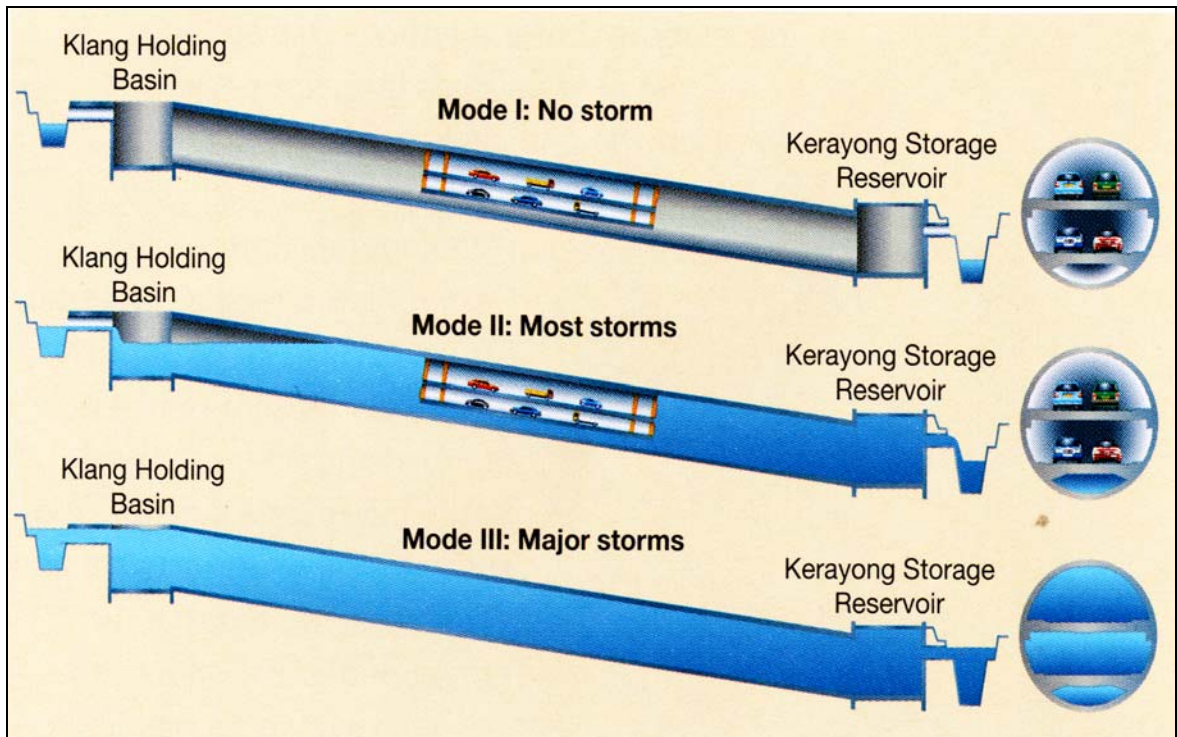


Figure 3: Tunnel Operation Modes

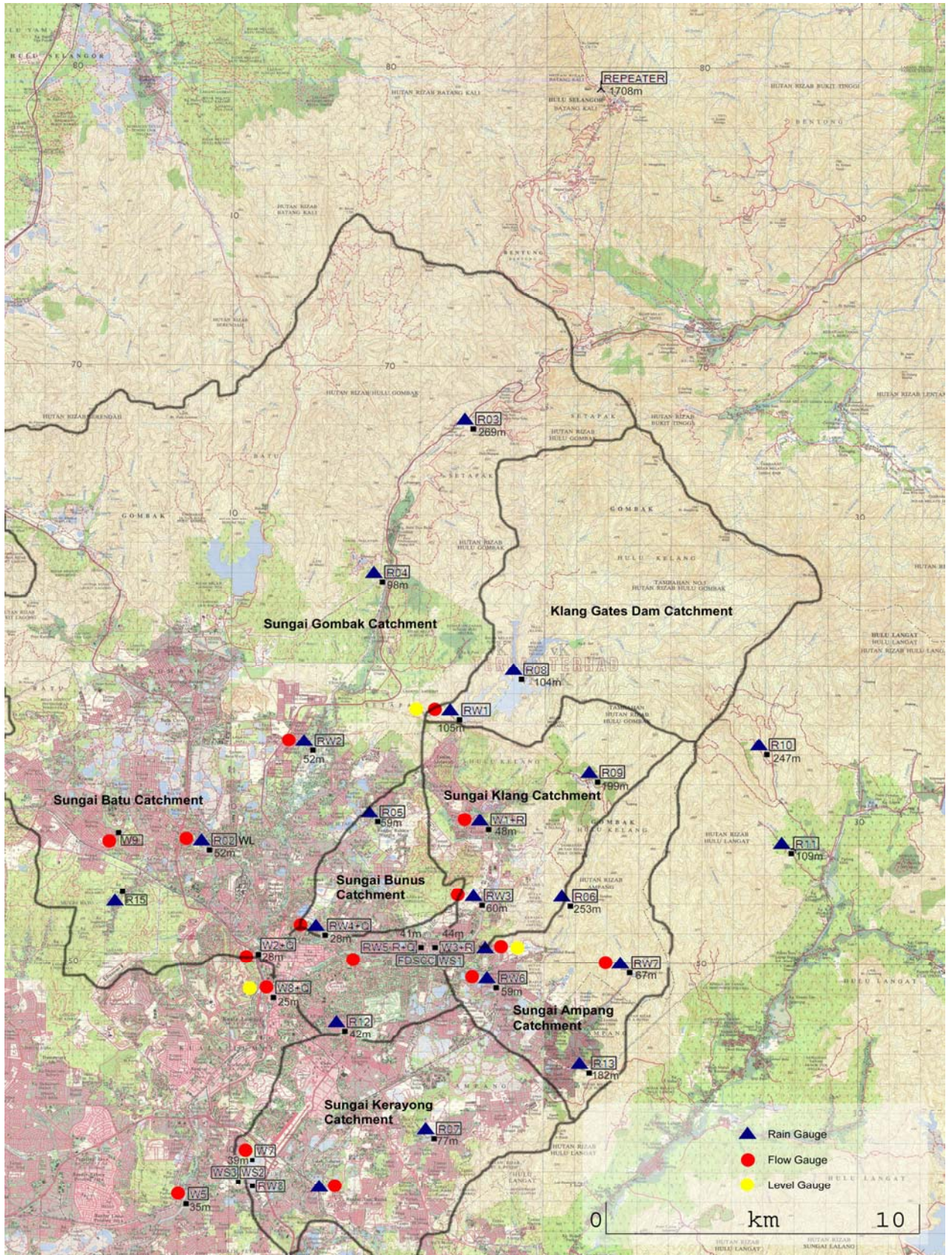


Figure 4: SMART's Flood Detection System's Gauging Station Network

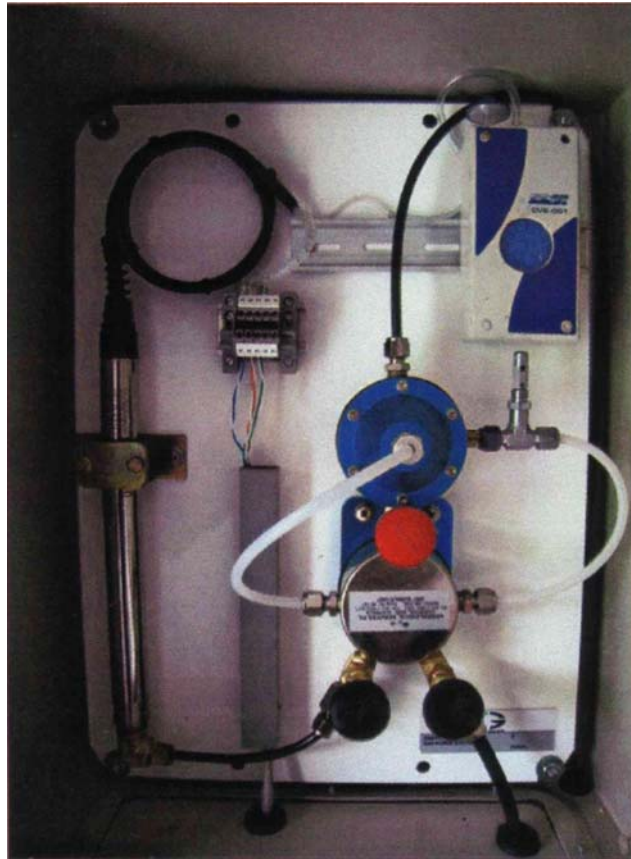


Figure 5: The Gas Purge System which is Used to Measure Water Levels



Figure 6: The Doppler Current Meter Provided with a Protective Housing

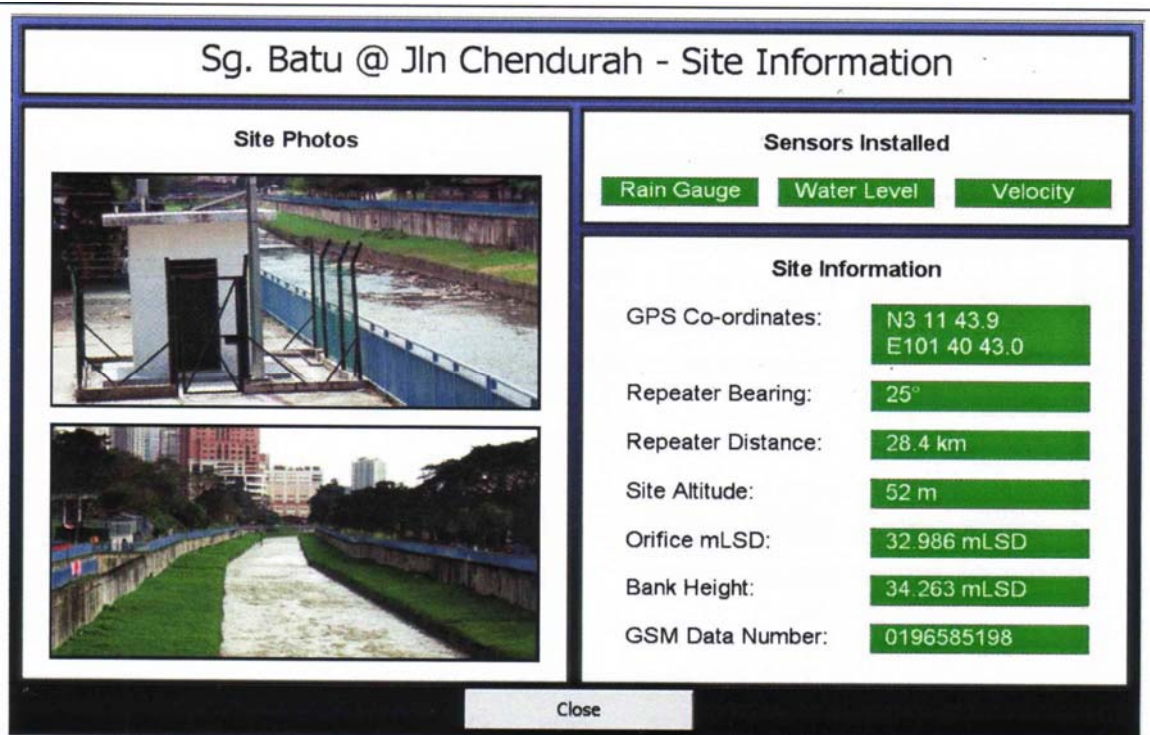


Figure 7: The Display Console at SCC Showing Information Received from One of SMART's Gauging Stations

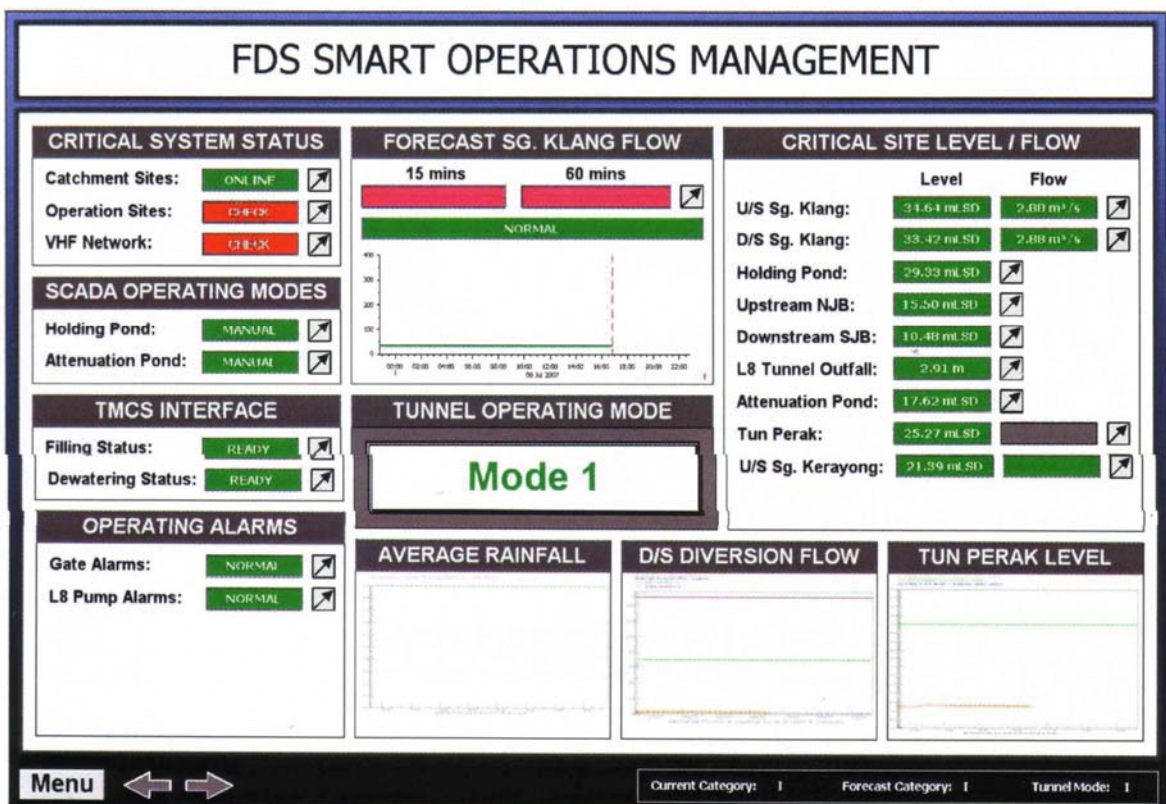


Figure 8: A Typical Display of the FDS Operation Management at the SCC

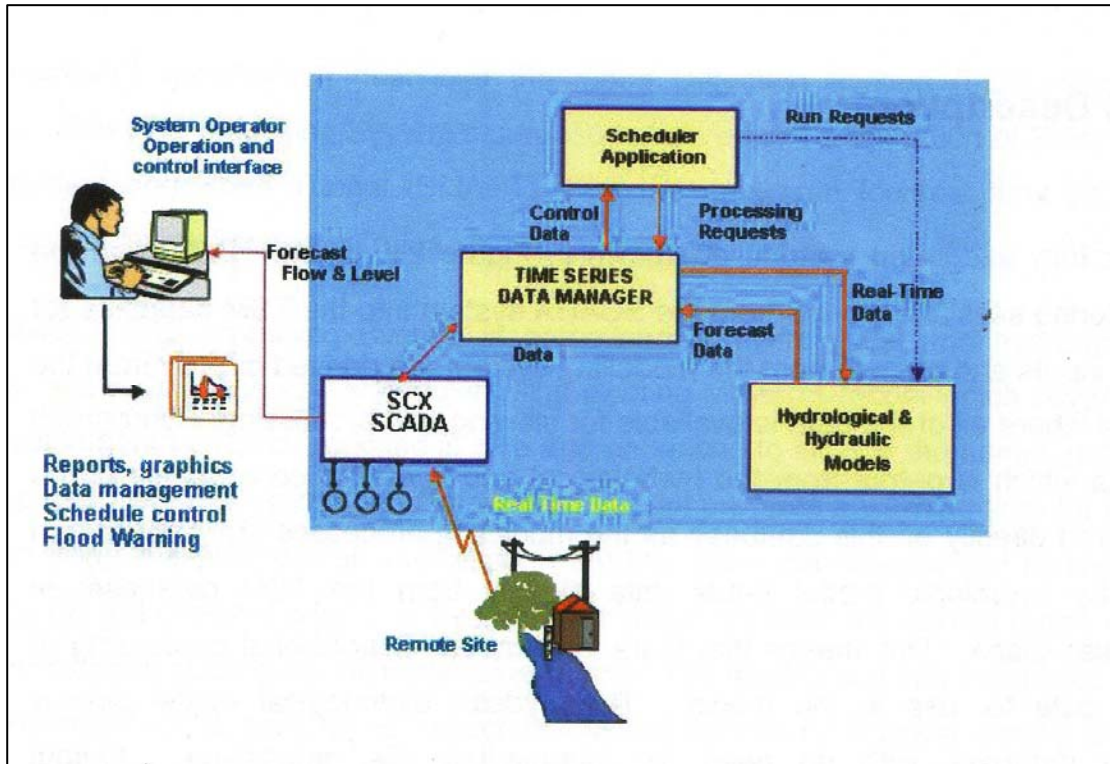


Figure 9: FDS Modelling System Set Up

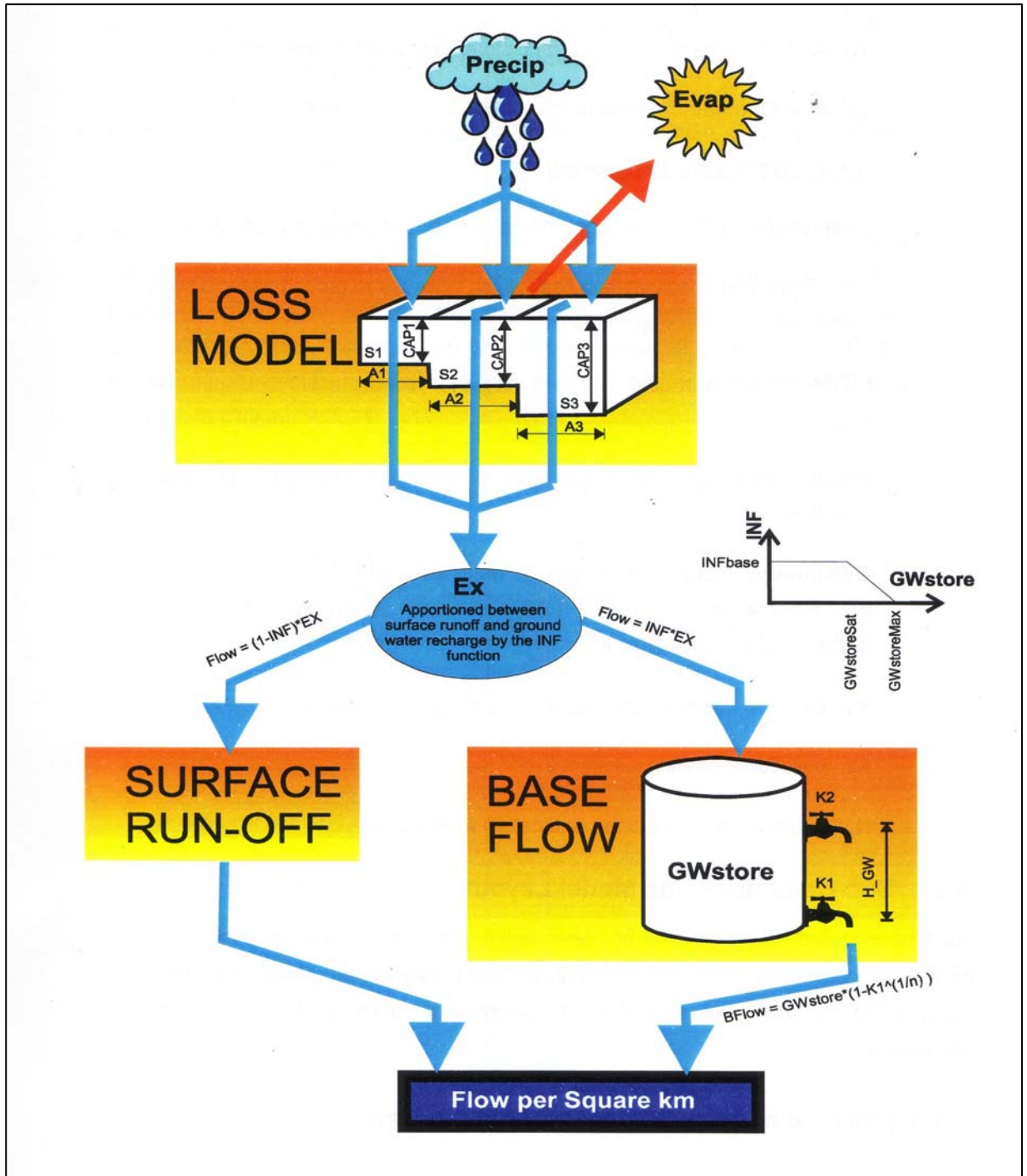


Figure 10: Schematic of AWBM Loss Model