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Modelling of Pumping Station in Conjunction with Kuching Barrage, Malaysia for Flood Mitigation

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Abstract: Singapore had amazed the engineering communities with the completion of Marina Barrage, particularly its pumping stations claimed to be the largest pumps in the world. This paper is an attempt of benchmarking the Marina Barrage's pumps to be applied in Kuching of Sarawak State, Malaysia. Kuching Barrage was deprived of a pumping station in its design, while Marina Barrage was equipped with seven pumps each with 40 m^3/s in pumping rate, 120 rpm in speed and 3.5 m in head. The modelling efforts had indicated that Kuching Barrage would need five times the number of Marina's pumps to drain out the historical January 2004 major flood volumes to bankful levels. For many years, the local communities cried foul to the authorities on the lacking of a pumping station. This inference had explained the dilemma of situation obviously.

Key words: Barrage, flood, pumping station, river, tides.

Background

Kuching city of Malaysia is located within the Sarawak River basin (see Figure 1). The city is exposed significantly to fluvial and tidal actions (Memon and Murtedza, 1999). In order to protect the city, the Sarawak State Government had established a Sarawak River Regulation Scheme (KTA, 1994) completed in 1998. The Sarawak River flow was modified from a naturally tidal regime to regulated gates system located just downstream of the city. Kuching Barrage (see Figure 2) was the only outlet of the catchment while another two river courses to the sea were blocked. The barrage regulated river and tidal flows. The technical design was deprived of any pumping stations as the internal river storage was confident of its adequacy to reserve a 100-year return period flood (Sharp and Lim, 2000). The post-barrage period of Sarawak River however had seen the occurrence of three extreme flood events, e.g. in February 2003, January 2004 and January 2009. There seemed a pressing need for a pumping station to sustain Kuching Barrage in the local flood mitigation. Due to this, the objective of this paper is to explore the usable possibility of a pumping station in conjunction with Kuching Barrage by means of computer modelling.

Pumping Station for Land Drainage

Pumping stations are facilities including pumps and equipment for pumping fluids from one place to another (Cheremisinoff, 1992). In the case of Sarawak River, flooding occurred from two sources, i.e. high tides and runoff excess from upstream catchments. The barrage gates would close during high tides. Hence, flooding

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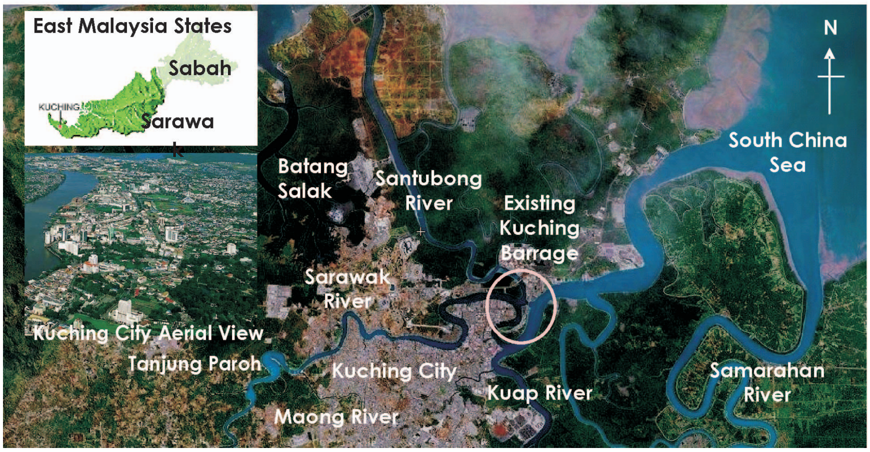


Figure 1: Locality of Kuching City, Malaysia.

Figure 2: Kuching Barrage (taken in 1998).

Figure 3: Marina Barrage, Singapore (Harley and Yap, 2008).

Table 1: Marina Barrage and Kuching Barrage statistics

	Marina Barrage (PUB 2008)	*Kuching Barrage (SRB 2007)*
Catchment Area	100 km^2 (10,000 ha)	1430 km^2
Waterways Upstream	Singapore River, Geylang River and Kallang River	Sarawak River, Sarawak Kanan River and Sarawak Kiri River
Barrage Gates	Nine numbers of 26.8 m wide gates	Five numbers of gates and one shiplock of 25 m wide each
Pumps	Seven number of pumps each with 3.2 m diameter impeller, 120 rpm in speed, 3.5 m in head, 40 m^3/s in pumping rate	None, relied on internal storage

would happen in Sarawak River if concurrently there was a heavy rainfall. The pumps would be set in motion during such conditions. The pumping station would pump out excess water from Sarawak River when Kuching Barrage gates were closed.

The Singaporeans adopted the same pumping concept as they built Marina Barrage (see Figure 3) to be part of a flood control scheme to alleviate flooding in low-lying areas of the city (Moh and Su, 2009). It was a major project requiring large capacity pumps, and the organization managed to install seven water pumps that claimed to be the largest low-head pumps (World Pumps, 2008). The pumping station can pump at a rate of 240 m^3/s with one pump in reserve. As the design of pumping station needed to consider the types of pump, pump specific speed and amount of pumps (USACE, 1994); and with the Marina Barrage's pump characteristics available for reference (see Table 1); a modelling of pump system would be possible to be applied on Kuching Barrage though the catchments were more than ten times of Marina's.

River Modelling

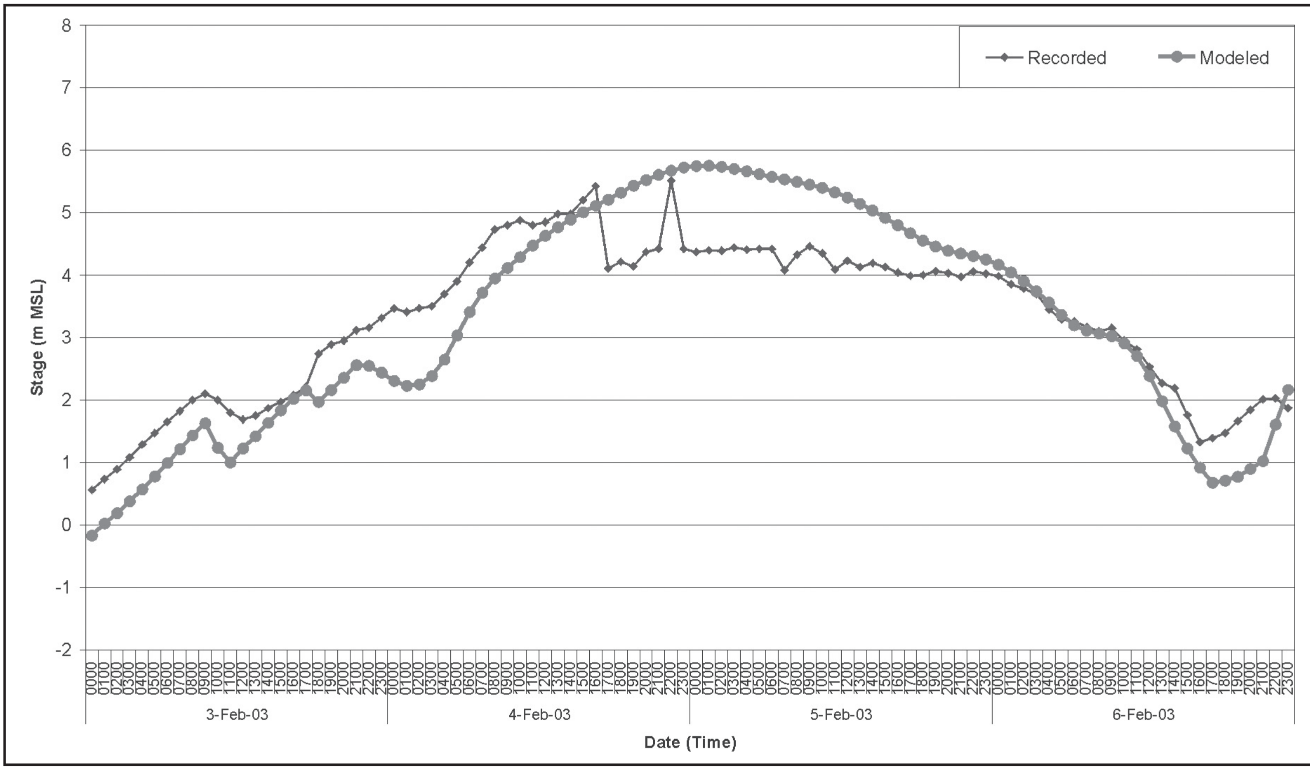
A Wallingford Software model, InfoWorks River Simulation (RS) was utilized for modelling Sarawak River. InfoWorks RS involves tight-coupling of GIS functionality and hydrodynamic flow simulation. Such model relies profoundly on the accuracy of topographical data (Benito et al., 2004). The river basin elevation model was derived from a survey exercise done in year 2000 in conjunction with the Sarawak River Mitigation Options Study (Jurutera Jasa, 2003). In the absence of more advanced earth surface observation datasets, the available topographical data were the best at the moment. These were adequate for one-dimensional (1-D) modelling as previously proven by reports of Jenny et al. (2007) and Salim et al. (2009) in modelling Sarawak River systems.

There are 24 hydrological stations along Sarawak River to record rainfall and water level data hourly. However, there is no direct measurement of flow data. Rating curves are available for two upstream non-tidal stations of Buan Bidi and Kpg Git that have been calibrated from time to time (Mah et al., 2007). With these hydrological data, a base river model simulating the existing conditions of Sarawak River was able to be calibrated. As demonstrated in Figure 4, the matching of the recorded and modelled hydrographs during February 2003 flood event is acceptable, with a correlation coefficient of over 0.80. The calibrated model had been able to mimic the real river behaviours by 80% of confidence before a pumping station was added to the network for investigation.

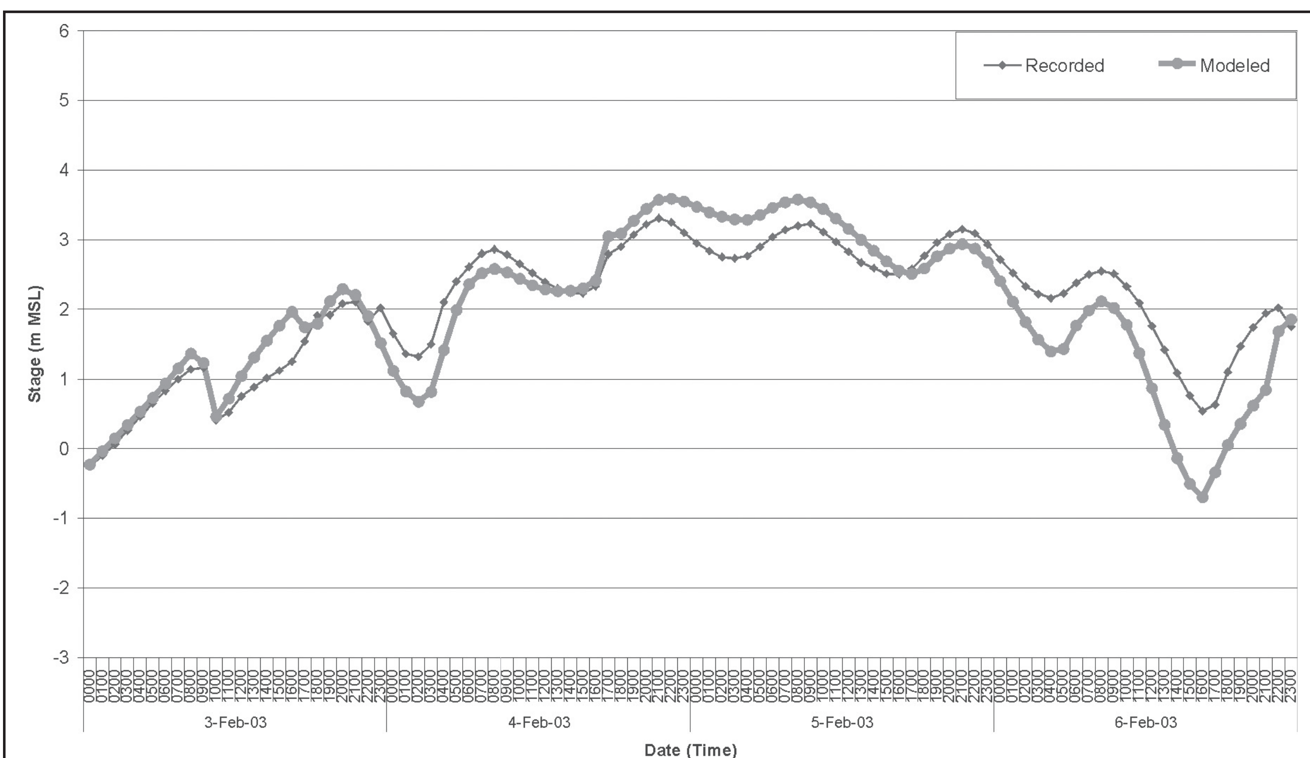
The upstream-ends at Buan Bidi and Kpg Git were treated as Flow-Time Boundaries. The Kuching Barrage was modelled as radial gates. The gauges at the barrage had recorded tidal fluctuations that were fed to Muara Tebas end (downstream of Kuching Barrage) as tidal Stage-Time Boundaries. A pumping station was attached to the network beside the barrage (Wallingford, 2008).

Results and Discussion

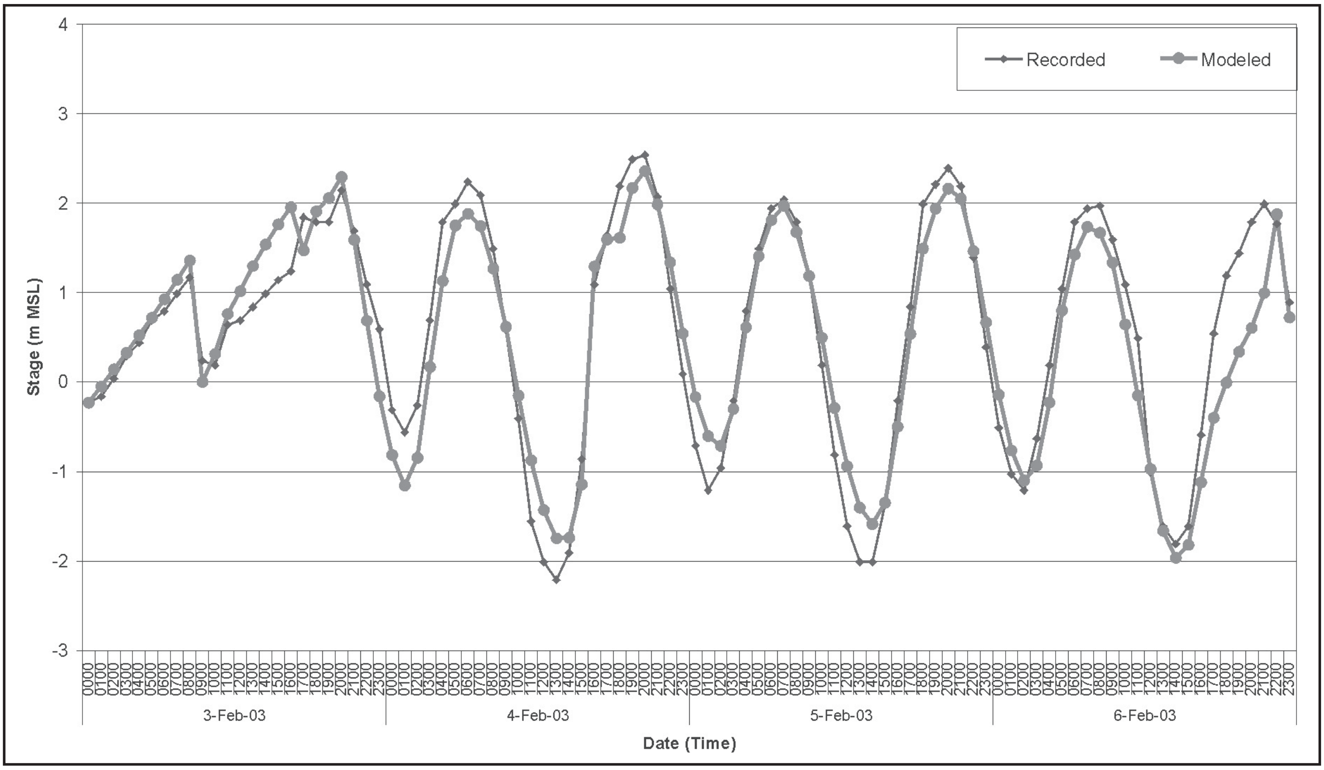
The January 2004 event, generally quoted as a 100-year flood (DID, 2004), was run through the model to explore the pumping system under study. The modelling approach adopted was that the barrage gates were fully closed. Due to that, the water level of Kuala Maong, one of the lowest locations in the city rose to a high level. By borrowing those Marina Barrage's pump capacities, first seven pumps were inserted to the pumping station, and later the number of pumps were increased until the flood level reduction achieved in Kuala Maong close to bankful level of +2 m. The results in Table 2 have indicated that a number of 35 pumps would be needed for Kuching Barrage, which is five times in pump number with reference to Marina Barrage.



(a) Batu Kawa Bridge



(b) Satok Bridge



(c) Ship Lock

Figure 4: Model Calibration of February 2003 Flood Event at locations (a) Batu Kawa Bridge, (b) Satok Bridge and (c) Ship Lock (at Kuching Barrage).

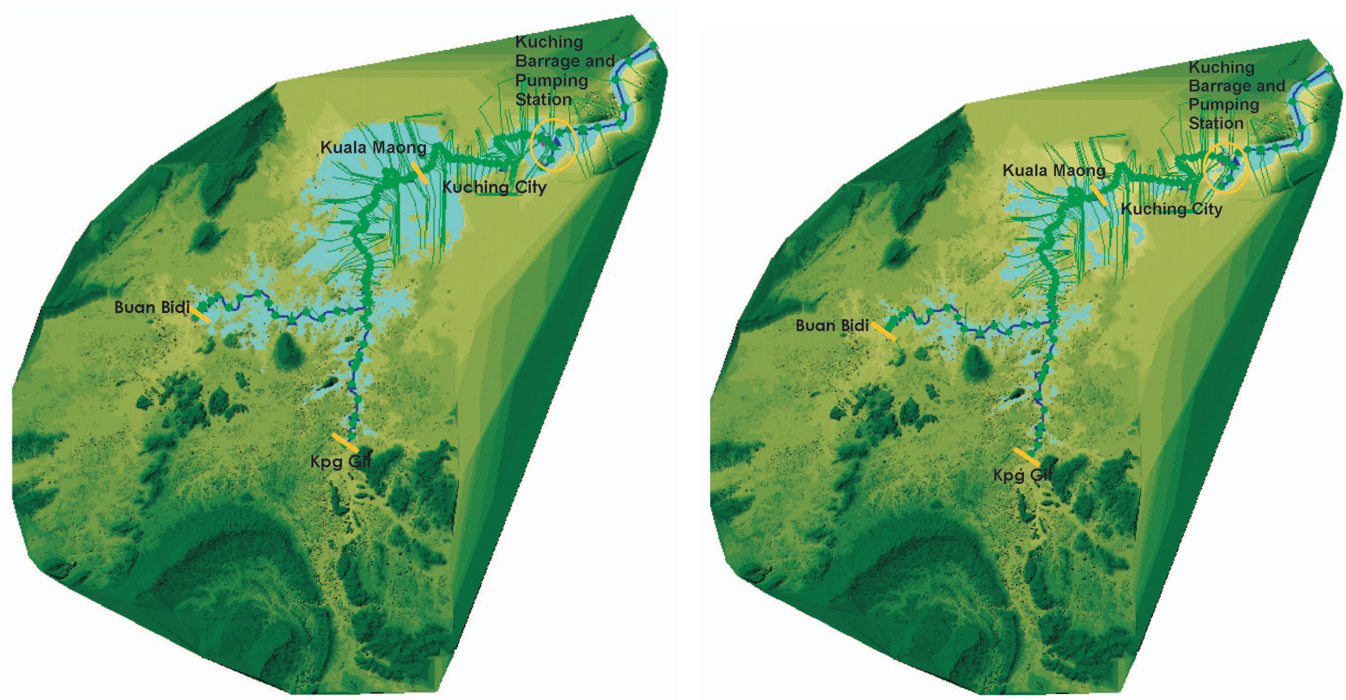
Table 2: Modelling of pumping system for Kuching Barrage

Pump (Nos)	*Pump capacities*	*Flood water level at Kuala Maong (m)*		
		Without pump	*With pump*	*Remarks*
7	Each pump with	10.754	8.723	– 2.031
14	40 m^3/s in pumping rate,		6.520	– 4.234
21	120 rpm in speed,		5.186	– 5.568
28	3.5 m in head.		3.359	– 7.395
35			1.929	– 8.825

The resulting flood maps are shown in Figure 5. Modelling of 35 pumps had been able to reduce flood extent of January 2004 event. Figure 5(b) is a result of pumping floodwater to bankful level referring to Kuala Maong. However, noticeable inundations would still remain in the upstream of Kuala Maong.

Conclusions

Repeated floods in Kuching in recent years had spurted anger among the public. Many blames had been forwarded, and it was not easy to convince them on the deficiency of a pumping station. The modelling output had presented a figure easy to understand for any layman. Having 35 pumps the height of a two-storey house is hardly a wise move. A pumping station with the modelled pump numbers and sizes would not be a feasible option. The flooding problem in Kuching would therefore require another approach.



(a) Without pumping **(b) With pumping (using 35 pumps)**

Figure 5: Flood Maps of Sarawak River Basin: (a) without pumping, (b) with pumping (using 35 pumps).

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