Modelling Urban River Catchment: A Case Study of Berop River, Tanjong Malim, Perak

LEOW CHENG SIANG, *Research Assistant, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia. Email: redac21@eng.usm.my*

ROZI ABDULLAH, *Research Associate, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia. Email: cerozi@eng.usm.my*

NOR AZAZI ZAKARIA, *Director, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia. Email: redac01@eng.usm.my*

AMINUDDIN AB. GHANI, *Deputy Director, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysi.a Email: redac02@eng.usm.my*

CHANG CHUN KIAT, *Science Officer, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia. Email: redac10@eng.usm.my*

ABSTRACT
Over years of development, Berop River that runs through urban area of Tanjong Malim, Perak has become a complicated channel network. Some parts of river are culverted, some channelised with concrete, while other remains as natural stream. The river has also become the receiving water body for the town urban drainage systems and therefore it has become extremely difficult to separate the river from the rest of drainage system. InfoWorks Collection System (CS) is used to model this complex stormwater system and to analyse flood issues haunting the area. The software provides a platform for urban catchment hydrology and hydraulic simulation using one integrated and manageable database. Present study also applied various GIS application made available in InfoWorks CS to aid in data entry, data management and result presentation. The model is calibrated using historical flood event based on flood level. Catchment response towards various storms duration and intensity is also examined. Finally, several flood mitigation proposals and 'what-if' situations were also analysed as part of an effort to propose a flood mitigation plan cum sustainable urban drainage system to the local authority. The study found that within a data scarcity condition, InfoWork CS, which incorporates some advance technologies including GIS and Structured Query Language (SQL), played a significant role in providing a good platform for stormwater system model building as well as creating accurate simulations and analyses for complex combination of river and urban drainage stormwater system.

Keywords: Urban River Catchment, InfoWorks CS, SUDS, Flood, GIS.

1 Introduction

Study of floods requires extensive analysis of the actual world situation. More often than not, flood is associated to river overflowing its banks. While this is an inalienable truth, many overlooked the necessity of studying urban drainage, which is one of the main cause of flash floods in Malaysia, and possibly worldwide. Therefore, in drafting a comprehensive stormwater management and flood mitigation plan for local or national level, it is vital to analyse floods in a broader perspective compared to just modelling rivers. To achieve this, an integrated computer model analysis is needed to consider river and urban drainage, as well as the interaction between these two important water bodies in hydrology and hydraulic aspects (Van Assel, 2003). In this study, it is aimed to create a model to understand how floods and flash floods occur in an urban river catchment. From this understanding, a more thorough stormwater management plan can be drafted to rectify current issue and anticipate potential problems in the future.

2 Study Area

Berop River is a 3.3 km-long tributary of Bernam River, which forms the boundary of Perak and Selangor states in Malaysia. The river flows pass the outskirt of Tanjong Malim town, which made the river a favourite receiving water body for a large portion of the town's urban drains. Tanjong Malim is a small town of relatively long history of urbanization. The town has a complex drainage system, which was modified and altered throughout the course of its development. Up to this stage, the town collection system has evolved into a complicated combination of Berop River, concrete drain, earth drain and culverts (Figure 1). Thus, it is impossible to differentiate between river and drainage system.

The urban catchment of Berop River covers an area of 510.6ha and is dominated by rubber plantation and residential areas. The local authority plans to develop the area into a complete developed area with 96% development with only a mere 4% of green area. Figure 2 shows the land use of current and future condition (based on planning of local authorities) of the catchment. Berop River is facing frequent flash flood, whereby water rises and subsides in matter of hours. Flood might be caused by poor maintenance and ill hydraulic design of existing drainage. Figure 3 shows flood severity while Figure 4 highlights a few conditions of existing river and drainage system.

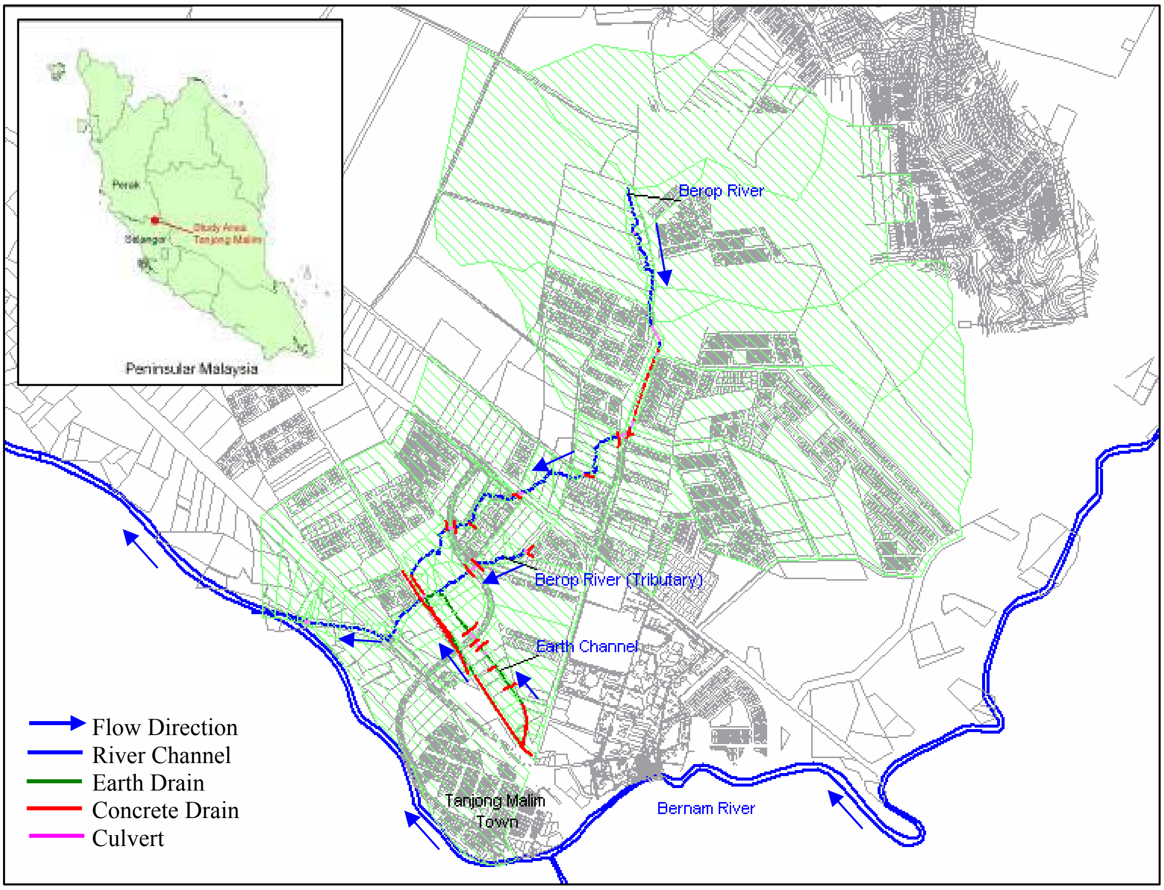
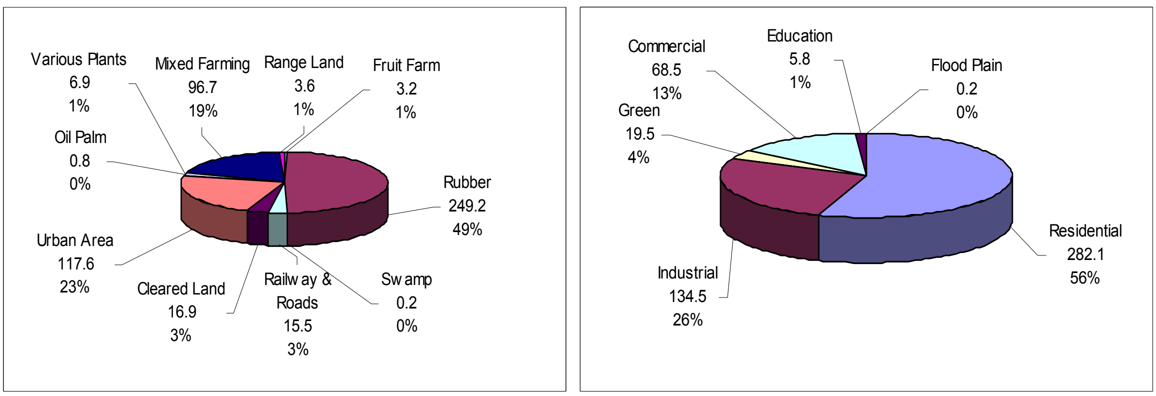


Figure 1 Location of Study Area and Berop River Catchment



(a) Land Use of Existing Condition (2002) (Source: Land Use Map 2002; Department of Agriculture)

(b) Land Use of Future Development (2010) (Source: Tanjong Malim- Slim River Local Plan, 1998-2010; Majlis Daerah Tanjong Malim)

Figure 2 Landuse of Berop River Catchment

Figure 3 Flash Flood Severity in Berop River Catchment

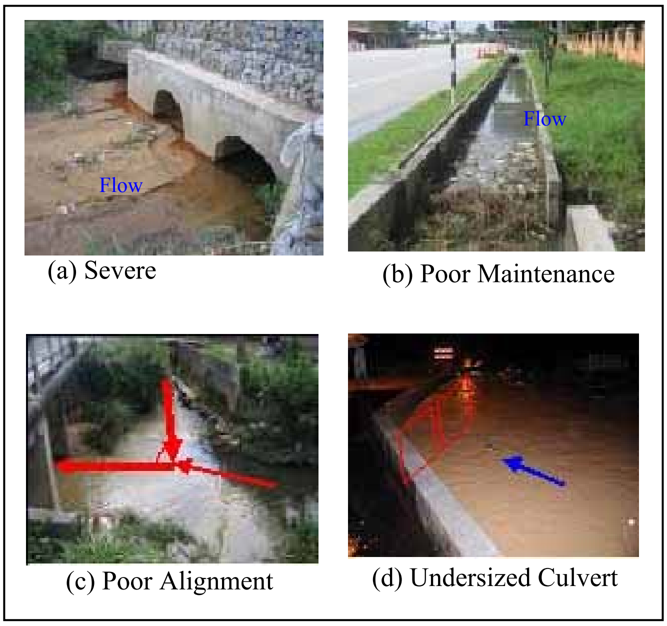


Figure 4 Current Conditions of Existing Berop River and Contributing Drainage System

3 InfoWorks CS Model Build-up

InfoWorks CS version 7.5 (Wallingford, 2006a) was used in this study. The model is a hydrology and hydraulic model, which is capable to include both river sections and urban drainage components (Wallingford, 2006b). In addition to this, the model is also capable to simulate the effect of hydraulic structures such as pumps and outlet structures. Sustainable Drainage System (SUDS) components were also included in the model, which gave the model extra advantage in aiding the preparation of conceptual design of stormwater management plan.

First and foremost, the physical layout of the river and its related drainage system was built in InfoWorks CS based on survey data and inventory work findings. The subcatchment for each component of river and drain were delineated based on available contour lines and inventory data. Land use properties were assigned to each subcatchment using “area take-off” method, which is a GIS-based tool developed using ESRI MapObjects 2.2 and incorporated in InfoWorks CS. The tool enables direct access of data and information in ESRI shapefile format to determine the area of each land use type in subcatchments (Wallingford, 2006a).

The SCS Curve Number method (SCS, 1986) was chosen as the rainfall-runoff method used in the model. Curve Number assignment was based on more general landuse type compared to runoff surfaces. The research adopts calibrated Curve Number in previous study carried out in Malaysia condition (Hassan, 2006; Yip, 2002). Table 1 gives the final CN value for each landuse type after calibration on this model. SWMM routing model which applies non-linear reservoir routing method was chosen for the model.

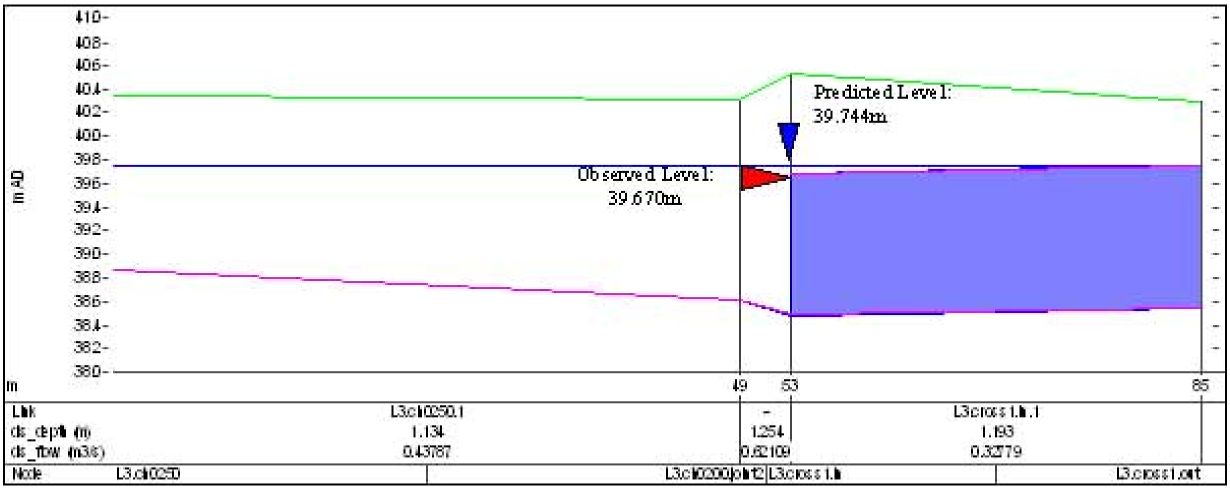
Model was then calibrated against flood level of a selected historical flood event on 16th February 2006. The SQL-based tool of search and query is especially useful in modifying massive amount of data in one go. The selected parameters of certain network component can be adjusted by percentage to view the effect of changes on the model. The calibration method was due to the lack of flood records and gauging station. The flood levels were determined from site observation and information from flood victims as well as local authorities. Among parameters calibrated to obtain better model performance were SCS Curve Number, catchment slope, and catchment width. Figure 5 shows the water level calibration result at one of the observed culvert.

Table 1 SCS Curve Number for Various Landuse Type and Hydrological Soil Group

Land Use	Given Land Use ID	Hydrological Soil Class			
		A	B	C	D
Existing Land Use					
Fruit Farm	1	61	70	77	80
Rubber	2	64	73	88	90
Mangrove Swamp	3	77	80	83	86
Road & Railways	4	90	90	90	90
Cleared Land	5	70	80	85	87
Urban Land	6	83	90	93	96
Oil Palm	7	50	66	80	87
Various Plants	8	62	70	78	81
Mix Farming	9	67	72	81	86
Rangeland	10	66	77	88	94
Shrubland	11	55	66	80	87
Pasture	12	61	77	85	91
Future Land Use					
Commercial	1	89	92	94	95
Educational	2	57	72	81	86
Flood Plain	3	39	61	74	80
Green Area	4	39	61	74	80
Industrial	5	81	88	91	93
Residential	6	77	85	90	92

(a) Calibration Point (During Flood Event) (Node: L3.cross.in)

(b) Calibration Point (During normal flow) (Node: L3.cross.in)



(c) Predicted and Observed water level during flood of 16th February 2006 (Long Section) (Node: L3.cross.in)

Figure 5 Calibration Results for Berop River Catchment

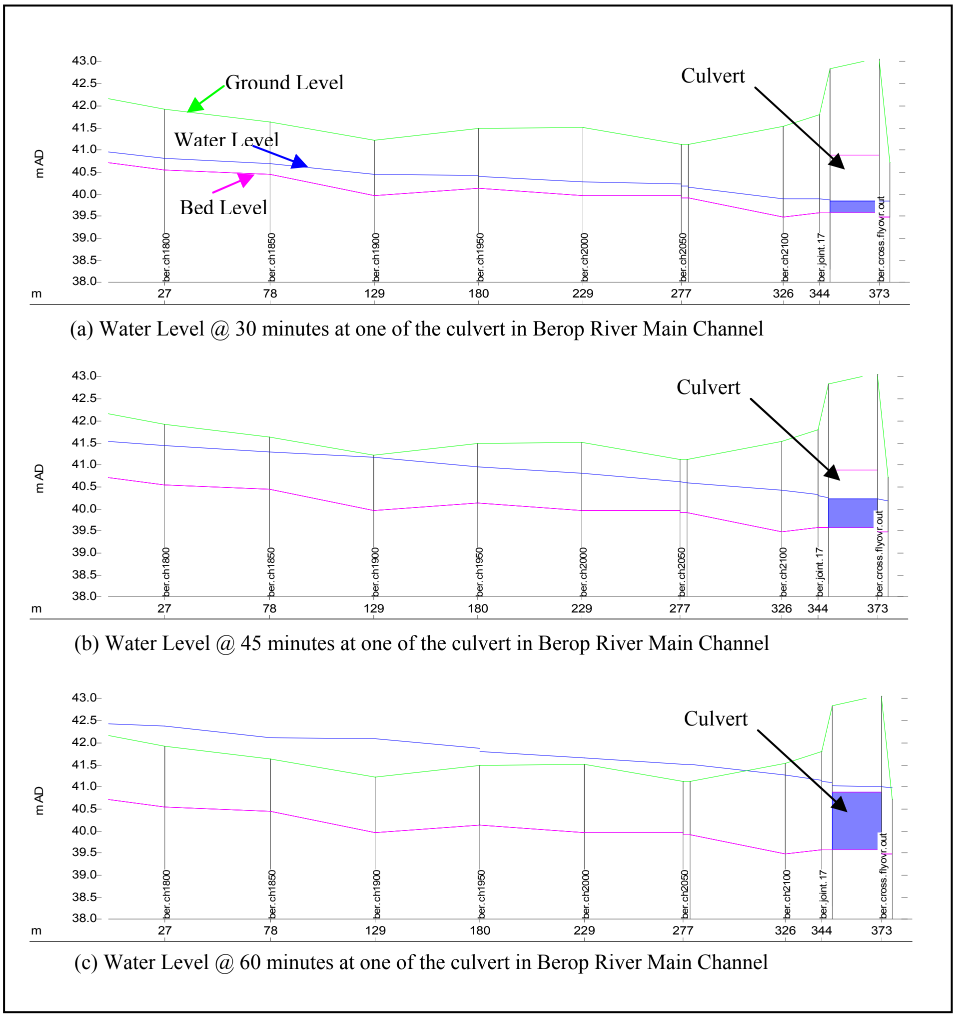
4 Hydrology and Hydraulic Analyses

The model was examined for different rainfall condition. 10, 50 and 100 years Average Recurrence Interval (ARI) (DID, 2000) rainfall of 30, 60, 120 and 180 minutes duration were induced to the model to study Berop River response. Results showed that for the catchment, rainfall of 120 minutes was critical as it generated the highest peak discharge for all three tested ARI rainfall events. From the model, it was also found that the current collection system is not able to handle the amount of stormwater generated from its catchments, even for 10 years ARI event. Culvert choking was proved to be one of the major causes of flash floods in low-laying areas of the catchment, especially at the middle span of Berop River. The low capacity of culvert caused backwater effect as water collects at the inlet and to a certain point, overflowed bank and caused flood. Example of culvert choking was shown in Figure 6.

Future development (according to plan) will see a rise in average Curve Number of the Berop River catchment from 75 (existing) to about 84 (2010). The increase in runoff generation, coupled with the lack of stormwater management planning could spell serious flood problems in the area come 2010. Table 2 shows the predicted flood level at two critical points along Berop River. Figure 7 shows maximum flood effect for Berop River under future development under 100 years ARI event. Almost all observation points indicated occurrence of flood. Unfortunately, no detail ground information was available for Berop River and thus, the actual extent of flood could not be mapped.

Table 2 Maximum Flood Depth for Berop River under Various Design Rainfalls

Design ARI	Existing Condition			Future Development		
	10-year	50-year	100-year	10-year	50-year	100-year
Max. Flood Depth @ Taman Sri Tanjong	1.841 m	2.344 m	2.381 m	2.516 m	2.751 m	2.872 m
Max. Flood Depth @ Kampong Berop	1.562 m	1.818 m	1.858 m	1.952 m	2.056 m	2.119 m



(a) Water Level @ 30 minutes at one of the culvert in Berop River Main Channel

(b) Water Level @ 45 minutes at one of the culvert in Berop River Main Channel

(c) Water Level @ 60 minutes at one of the culvert in Berop River Main Channel

Figure 6 Choking at One of the Culvert in Berop River Main Channel

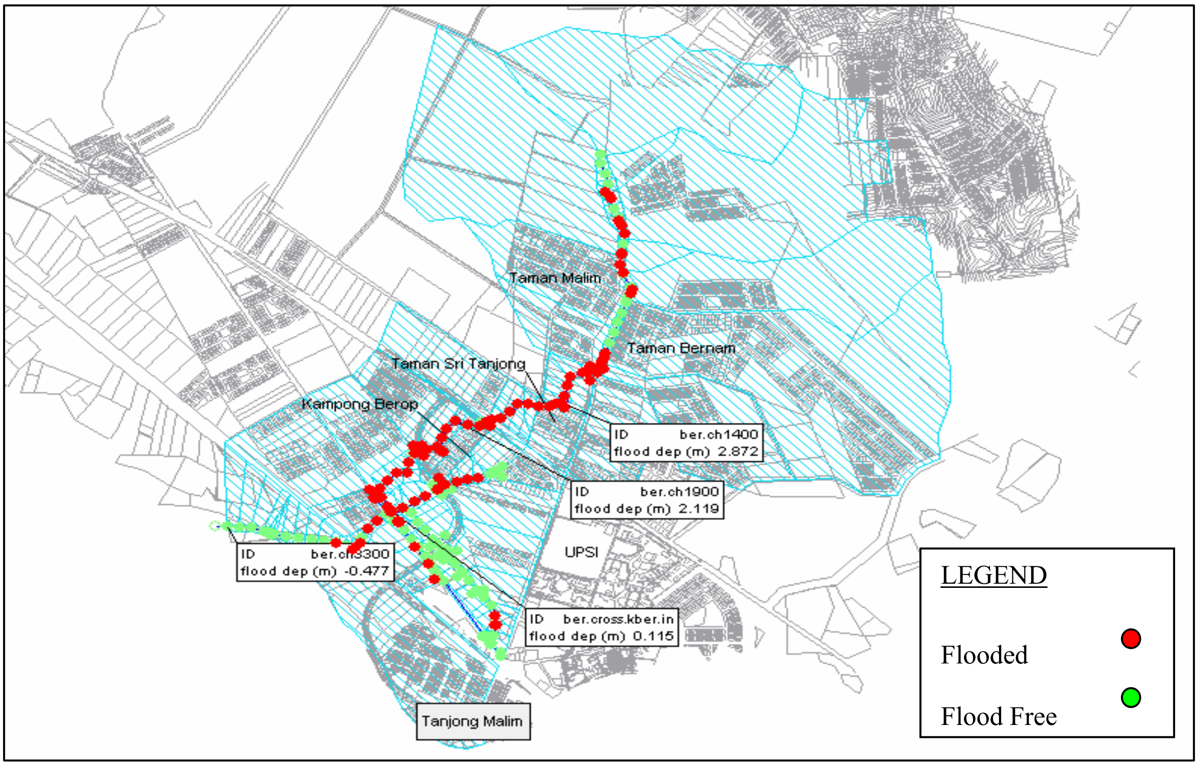


Figure 7 Flood Indication for Berop River Catchment in 2010 under 100-Years ARI Event

5 Proposed Solutions and 'What-if' Scenarios

The concept of the proposed stormwater management plan was in-lined with the Urban Stormwater Management Manual for Malaysia, better known as MSMA (DID, 2000). The idea is to limit post development peak dischargee to that of pre-development. Any excess in volume of runoff shall be stored or detent to avoid over burden to receiving water body. Thus, it was proposed that the current Berop River channels and urban drains to be enlarged. The proposed solution also includes the introduction of a 10ha regional pond to divert water away from flood prone area and release the excess water gradually into Bernam River. Outlet structures were proposed to control flow traffic especially at meeting points of urban drains and Berop River. All these proposals were applied to the model and the changes of catchment response was examined. It was found that the methods were successful in controlling floods up to 100 years ARI events. Figure 8 shows the plan view of water level at observation points after introduction of flood mitigation facilities and upgrades.

After evaluation of preliminary design, numerous 'what-if' situations were examined. InfoWorks CS provides good platform to simulate all these possible scenarios. These scenarios were created to fine-tune the design parameters, to study the feasibility of new concepts, and to examine worst-case scenarios such as extreme floods and breakdown or malfunction of hydraulic structures. Findings from these scenarios helped planners in drafting a better stormwater management plan, which is more cost-effective and comprehensive. The final product of this research was a detail design of river and urban drainage upgrade as part of stormwater management plan.

6 Further Improvement

This study had covered the hydrology and hydraulic part of Berop River catchment. As the study is still in progress, the team is currently collecting on site data of flow, water quality, and water level to validate model results. The model is also in the process of modification to accommodate water quality simulation, with special interest in sedimentation in conduits and river channels. Current model did not include Digital Terrain Model (DTM), which is essential in determining flood compartments and storage areas. The team is currently obtaining this data by Remote Sensing technique.

These improvements will allow the research team to examine the complex collection system closer and better. The end product of this research shall be a comprehensive stormwater management plan that covers hydrology, hydraulic and water quality aspect of Berop River urban catchment and its contributing drainage system. The plan will be able to solve current flood issue as well as providing guide for future development of the area.

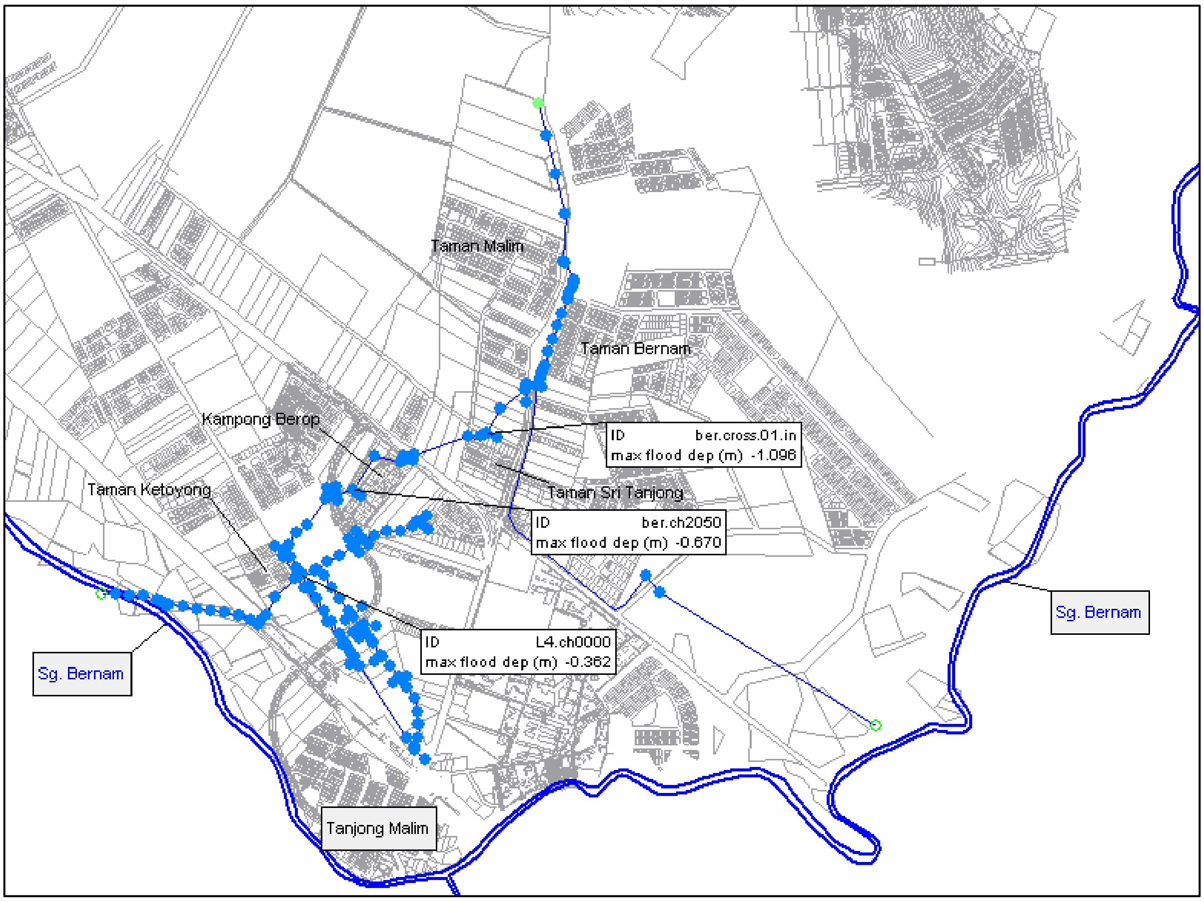


Figure 8 Simulation Results of Proposed River and Drainage Improvements and Upgrades

7 Conclusion

Rivers are not the only contributing factor to the occurrence of flood. With the availability of technologies, study on flood shall extend to a broader perspective and takes into counts urban drainage system and its interaction with natural river system. In this century, many river catchments have been invaded by aggressive human developments. It is almost impossible to analyse flood in these urban catchment without relating it to river and urban drainage systems since both are part of the stormwater collection system. Current study showcased an effort to model an urban catchment with InfoWorks CS. The created model allowed better simulation of flood and interaction between river and urban drainage. The effort benefited the researchers as river and urban drainage can be analysed at the same time. Findings of this model were considered during the draught of stormwater management plan to solve flood issue in Berop River catchment.

Acknowledgements

This study is funded by Distrcit Council of Tanjong Malim, Perak. The authors would like to thank Department of Irrigation and Drainage Malaysia, and Department of Agricultural Malaysia for providing data, as well as staff of REDAC, Universiti Sains Malaysia, for their involvement in the research work.

References

1. DID, (2000). *Urban Stormwater Management Manual for Malaysia*. Department of Irrigation and Drainage, Malaysia.
2. Hassan, A.J. (2006). River and Floodplain Modelling for the Development of Flood Risk Map: A Case Study of Sg. Selangor. *Msc. Thesis*, Penang: Universiti Sains Malaysia.
3. SCS, (1986). *Technical Release 55: Urban Hydrology for Small Watershed*. NRCS-USDA, 1986.
4. Van Assel, J. (2003). Modeling Hydraulic Interaction between Rivers and Sewers in Flanders, Belgium- Past and Future approaches. *Wallingford Software's 2003 International User Conference.*
5. Wallingford. (2006a). *InfoWorks CS Technical Review*. Wallingford Software, United Kingdom.
6. Wallingford. (2006b). InfoWorks CS Solves Urban River Challenge in El Salvador. [online]. Wallingford Software. Available from: http://www.wallingfordsoftware.com/casestudies/fullarticle.asp?ID=585&prt=1 [cited 19 December 2006].
7. Yip, H.W. (2002). Flood Runoff Estimation of Ungauged River Catchments Using Soil Conservation Service Method. *MSc. Thesis*, Penang: Universiti Sains Malaysia.