Lecture Notes in Civil Engineering

Sobri Harun
Ilya Khairanis Othman
Mohamad Hidayat Jamal *Editors*

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Current Research in Water Resources, Coastal and Environment

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International Conference on Water Resources (ICWR) – Volume 1

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The 5th International Conference on Water Resources (ICWR2021), held virtually in November 2021, has attracted over 70 abstract submissions and over 100 participants both locally and internationally. We would like to thank all the people involved in organising and sponsoring the conference. Special thanks go to the conference committee and UTM SPACE for their time and efforts in communicating with authors and reviewers. The peer-review processes have narrowed the selected papers to 36, presented in three chapters. Our sincere appreciation goes to more than 30 reviewers for their expertise demonstrated and commitment to reviewing the selected papers. All authors have cooperated in response to reviewers' comments and the editorial needs.

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About the Editors

Dr. Sobri Harun is a professor in water resources engineering at Universiti Teknologi Malaysia (UTM). He received BSc in Civil Engineering from the University of Salford, a Master's degree from Imperial College London, and a PhD from UTM. His lectures concern hydrology, hydraulics, hydraulic structures, water resources, and urban stormwater management for undergraduate and postgraduate. His research and publication mostly related to modelling in hydrology, river engineering, water resources, and climate changes. His research works were published in various indexed journals. He is a panel member of the Malaysian Quality Assurance Agency, visiting professor of Universiti Tun Hussein Onn Malaysia, member of IAHR & IAHS, guest editor to Journal of Water and Climate Change, and editorial board to Malaysian Construction Research Journal. He was chairman of the International Conference on Water Resources, which received support from UNESCO Jakarta and the Department of Drainage and Irrigation Malaysia.

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The Integrated River Basin Management (IRBM) chapter presents papers related to precipitation or rainfall analysis, watershed morphology, water availability under climate change, drought index analysis, stormwater quality, flood modelling and infrastructure, water balance and management issues beneficial to practising engineers and researchers. The hydrometeorological data represent the selected catchment or watershed is utilised. These issues were investigated using multiple types of software and statistical method. The first few papers dealt with design rainfall analysis based on statistical methods. Papers on rainfall analysis in various areas in Malaysia present the trend results, depth-area-duration curves, fitting gamma and normal distribution and probable maximum precipitation. The multivariate analysis of morphometric parameters in the watershed of Peru is also presented. The following paper is the hydrological drought evaluation on streamflow in Thailand's upstream and downstream reservoir areas and the terrestrial research on water availability under climate change in the Amu River basin. The stormwater quality aspect is presented using Bio-Ecological Drainage System (BIOECOD) in JKR Malaysia pilot projects. Papers on the flood issues discuss the uncertainties in the infiltration model and heavy-duty mobile flood wall infrastructure. The last three papers address water balance management and water disputes in Malaysia.

Application of Building Information Modelling (BIM) Technology in Drainage System Using Autodesk InfraWorks 360 Software

King Kuok Kuok, Kia Wee Kingston Tan, Po Chan Chiu, Mei Yun Chin, Md. Rezaur Rahman, and Muhammad Khusairy Bin Bakri

Abstract The increased number of physical drainage drawings at Samarahan district, Sarawak for new development areas is difficult to manage and handle by relevant authorities. Hence, this research is conducted to determine the feasibility of Building Information Technology (BIM) to create a proper drainage inventory system to accurately list and record current drainage information using Autodesk Infraworks 360 software. This inventory system will be employed to examine and validate corresponding drainage parameters based on the recorded information. Taman UniCentral, a residential neighbourhood in Kota Samarahan, has been chosen for this case study. Drainage data, such as drainage size, length, invert level, are entered into GIS-integrated Model Builder in Autodesk InfraWorks 360. Autodesk InfraWorks 360 will conduct a preliminary analysis, including watershed analysis, to delineate the catchment area and drainage performance inspections at rainfall intensities of 2, 5, 10, 20, and 50 years (ARI). Thereafter, the InfraWorks model will be exported into Autodesk Civil3D to conduct a more extensive hydraulic analysis. The results show

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that full integration of these two Autodesk software packages had created a proper inventory system of existing drainage information and simulated its sufficiency in catering surcharge runoff from the new development area at the upper catchment.

Keywords Building Information Modelling (BIM) · Inventory management · system · Autodesk InfraWorks 360 · Autodesk Civil3D Average recurrence interval

1 Introduction

Referring to the 2010 Census (Department of Statistics Malaysia, 2010), the total population of Sarawak has experienced a high population growth of 19.3% since the previous Census conducted in 2000. Based on the data obtained, the Samarahan division holds the highest population growth percentage at 27.1%. The Sibu division follows this at 21.8% and the Kuching division at 21.5% [22].

The high population growth rate of Samarahan can be attributed to the rising position of the division as an education hub with its multitude of higher learning institutions and other educational facilities such as Universiti Malaysia Sarawak (UNIMAS), two campuses of University Teknologi MARA Kota Samarahan Campus (UiTM) and Institute of Teacher Education Tun Abdul Razak Campus. According to [20], with the Samarahan District reaching the criteria to be upgraded as a municipal council with a population of over 250,622 people in 2010 [6], the district is undergoing active property development, which will attract even more investors and therefore will bring an increase in construction works and work opportunities.

The current proposed drainage approval process involves submitting all drainage drawings in physical blueprints to the Department of Irrigation and Drainage (DID) Sarawak. The submission of physical blueprints would mean that submitted drawings may scatter around and are difficult to locate when required. The difficulty in retrieving physical drawings of existing drainage plans would delay the planning and approval process. This would cause great hassle when looking for past drawings as a reference before constructing new drainages discharged into the existing drainage system. Additionally, there is a lack of a proper systematic recording system to store the essential drainage information, including flow direction, drain and culvert size, and catchment areas in a master plan. Moreover, there is no system or software available to check and verify the capacity of the existing drainage system after receiving a surcharge from the nearby drainage system. There is a need to revamp our urban drainage management plans by adopting Autodesk InfraWorks, a Building Information Modelling (BIM) infrastructure software, to create an inventory system to record existing drainage information and integrate Autocad Civil 3D for water level forecasting within the drainage system [1, 2, 4, 14].

Autodesk InfraWorks is preliminary conceptual design software that allows users to visualize and render infrastructure models in real-world and real-time environments. It uses cloud-based 3D modelling technology where data can be obtained from integrated Autodesk sources or manual input [3, 23]. Autodesk InfraWorks provides four main features: generating conceptual design models, contextual modelling, analysis and simulation, and live visualization of models (News [18]. Autodesk InfraWorks can integrate with GIS data for early-stage project planning, and it is interoperability with other BIM-oriented software such as Civil 3D, Navisworks and Revit
[8, 9].

Autodesk InfraWorks was utilized in the SmiSto Hydropower Project, Norway, to combine GIS information of topographical information, areal imagery, and available map web services to create a detailed model [19]. Autodesk InfraWorks was also utilized for the rail track rehabilitation project in Portugal due to its accuracy terrain modelling and geolocation of the study site [16]. Autodesk InfraWorks also provided a brief overview of site conditions for the remodelling of the Ebro River bridge project in Spain [5]. Besides, [21] had utilized Autodesk Infraworks to simulate the stormwater runoff depth of the designed space based on the Low Impact Development (LID) principle in Bangkok, Thailand. However, Autodesk InfraWorks has yet to see practicable use within Malaysia.

In this study, Autodesk InfraWorks will be utilized to create an inventory system to systematically store and organize existing drainage information, including drainage size, invert level, flow direction and catchment area. The interoperability of Autodesk InfraWorks and Civil 3D will be demonstrated by importing the created Autodesk InfraWorks model into Civil 3D to check the adequacy of the existing drainage system to receive runoff from new developments at upper catchments. The selected study region is Taman Uni-Central, a mixed development area located at Kota Samarahan, Samarahan.

2 Study Area

Kota Samarahan is located about 30 km southeast of Kuching city. It is a fast-growing suburb in Sarawak, with an area of approximately 508.1 Km^2 [10, 11]. For decades, the main economic activity in Kota Samarahan has been agriculture with thousands of hectares of coconut, oil palm, and pineapples plantations. However, the Sarawak state government had successfully transformed Kota Samarahan into an educational hub in Sarawak that housed Universiti Malaysia Sarawak, two campuses of Universiti Teknologi MARA Kota Samarahan Campus, Tun Abdul Razak Teacher Training Institute, ILPKS Industrial Training Institute and INTAN Training College [12, 13]. With this transformation, the population in Kota

Samarahan has grown significantly for the past twenty years. Many new mixed developments were built to accommodate the rapidly increasing population.

One rapidly grown mix development is Taman Uni-Central, located at the NorthWestern of the Kuching-Samarahan Expressway (refer to Fig. 1). According to [17], the surrounding Uni-Vista and Uni-Garden have been facing rising flash flood occurrences. Residents have commented that this occurrence was attributed to the existing

Fig. 1 Satellite view of Taman Uni-Central, Kota Samarahan

drainage not being improved despite the rapid development of the areas. Additionally, the increase of impervious surfaces due to rapid urbanization also contributed to flash flooding occurrences in the Uni-Central area [7]. The study further showed that the earth drain is insufficient for discharge capacity, which could not cater to the generated peak discharge flow, thus causing the stormwater overflow. Residents also claimed that the floods were also caused by the undersize of the existing drainage system despite the ongoing rapid development.

3 Methodology

Figure 2 shows the research project methodology divided into three main stages. The first stage is data collection, which involves procuring data relevant to the drainage system at Taman Uni-Central. The second stage is plotting the drainage system and conducting initial hydraulics analysis using the Autodesk InfraWorks Drainage Design feature. The third stage is importing the model into Autocad Civil 3D for hydrologic and hydraulic analysis.

Stage 1: Data Collection

The initial site investigation was carried out to understand the general layout of Taman Uni Central. The first stage involves data collection of drainage flow direction, catchment areas, drainage layout, and invert levels through site investigation and application of Google Earth Pro. The catchment areas are then suitably delineated into different sub-basin for hydrology and hydraulic analysis. The coefficients of rainfall intensity duration frequency (IDF) curves with different average recurrence interval (ARI) was also obtained from the Urban Storm Water Management Manual (MSMA) published by the Department of Irrigation and Drainage Sarawak [15].

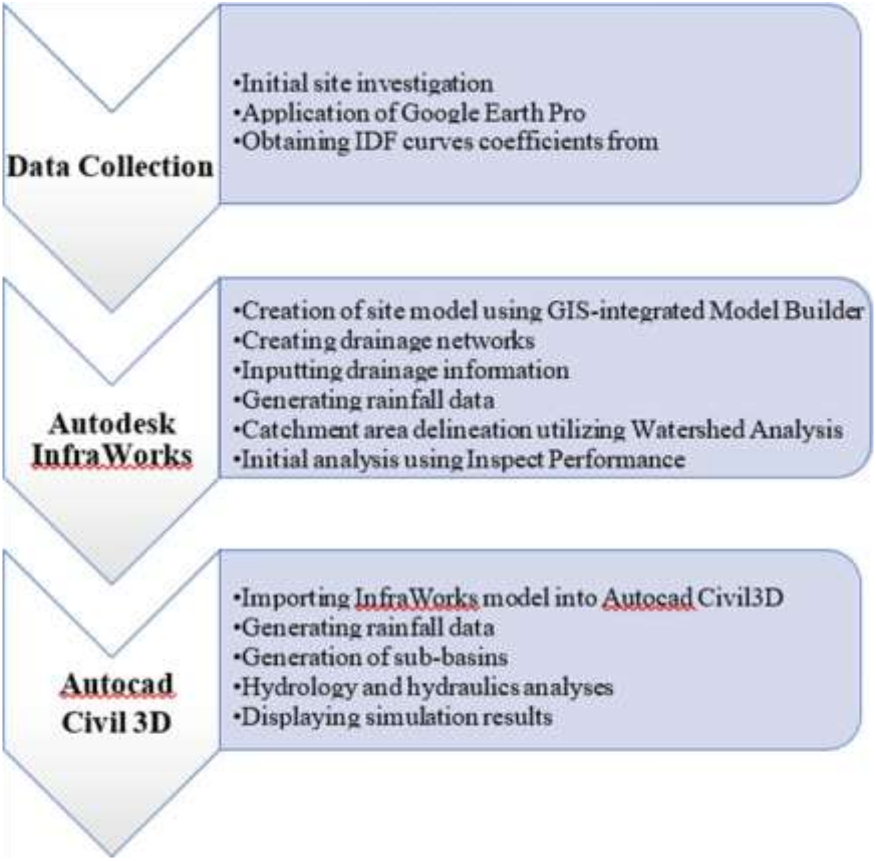

Fig. 2 Overview of research methodology

Stage 2: Autodesk InfraWorks

Autodesk InfraWorks is used to plot the layout of the drainage system of Taman Uni-Central, Kota Samarahan. The modelling procedures of Autodesk InfraWorks are:

a) Determination of Model Extents using Model Builder—The Model Builder feature integrates within InfraWorks is a GIS data source by inputting available data layers from cloud data for model creation. The extent of the model is determined by drawing a rectangle on the model location. Additionally, a coordinate system will be selected to increase the model accuracy. Since Taman Uni-Cental is located within the island of Borneo, the coordinate system with code “BORNEO” for East Malaysia is selected.

b) Creation of Site Model—The site model for Taman Uni-Central can be downloaded from Autodesk Cloud. Figure 3 presents the integrated model builder that already incorporated data layers from OpenStreetMaps and Bing Maps. This integrated Model Builder function is used to obtain the terrain of the site. The red colouration denotes the low areas of the site terrain, whereas the navy-blue colouration denotes the highest areas of the site terrain. The obtained terrain is vital for the delineation of sub-catchments.

c) The input of coefficients of rainfall Intensity Density Frequency (IDF) Curves – The coefficient of rainfall IDF curves obtained from MSMA, as presented in Table 1 are inputted into Autodesk InfraWorks. The polynomial equation for fitted IDF curves for 5, 10, 20, 50 years ARI is presented in Eq. 1.

$$ln(RI\ t) = a + bln(t) + c(ln(t))2 + d(ln(t))3 \quad (1)$$

where ${}^{R}I_t$ is average rainfall intensity (mm/hr) for ARI and duration t, R is average return interval (years) and t is duration in minutes.

d) Plotting of Drainage Layout - The drainage layout can be inputted into the InfraWorks model by inputting the drain sizes, invert levels, bed slope, drainage networks as presented in Fig. 4.

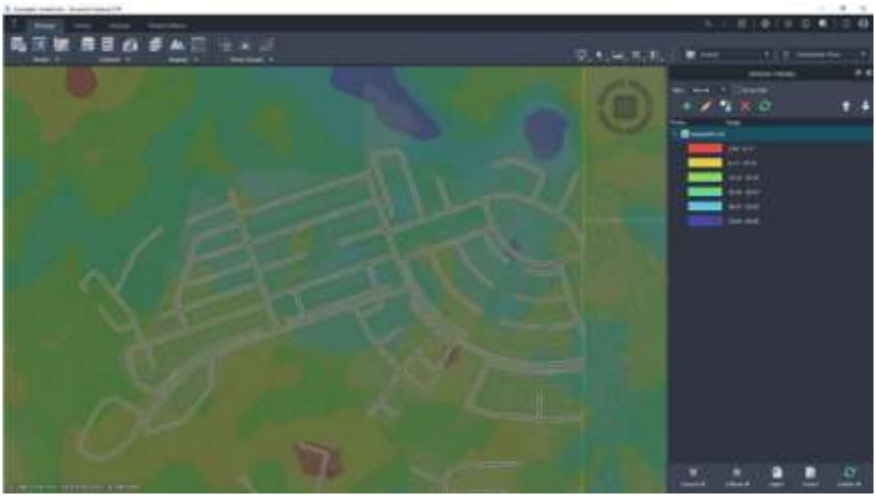

Fig. 3 Terrain theme of Autodesk InfraWorks model

Table 1 IDF polynomial coefficients for different ARI (MSMA, 2000)

Location	ARI parameter (year)	a	b	c	d
Kota Samarahan	2	5.1719	0.1558	0.1093	0.0043
	5	4.8825	0.3871	0.1455	0.0068
	10	5.1635	0.2268	0.1039	0.0039

20	5.2479	0.2107	0.0968	0.0035
50	5.278	0.224	0.0932	

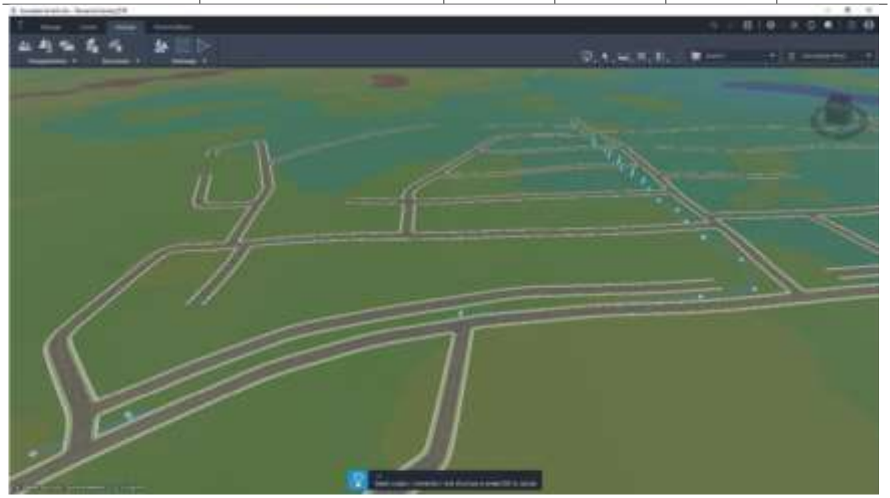

Fig. 4 Plotting of drainage network

e) Watershed Analysis - Autodesk InfraWorks is able to generate the hydraulic and energy grade lines for each drain. Hydraulic grade line (HGL) will help determine probable elevations to which the water would rise under atmospheric pressure occur during a storm event. The energy grade line (EGL) is an imaginary line to measure the total energy including the elevation head, velocity head, and pressure head, along the open channel carrying water.

Stage 3: Autocad Civil 3D (Storm and Sanitary Analysis)

The Autodesk InfraWorks model is imported into Autocad Civil 3D to carry out the Storm Analysis by Storm and Sanitary Analysis (SSA) extension. SSA is typically used to analyze gravity flow-based urban drainage systems. The sub-basins were drawn manually in Autodesk Civil 3D using polylines and converted into parcels after that. The created parcels are then imported into SSA in LandXML files. Figure 5 presents the imported sub-basins into the SSA model.

As SSA focuses primarily on stormwater and urban drainage analysis, all the drainage inventories, including the drainage networks, dimensions, invert levels created in Autodesk InfraWorks, were imported into SSA as Hydroflow Storm Sewers file. The imported drainage networks are imported into SSA is presented in Fig. 6.

The previously created IDF rainfall in Autodesk InfraWorks is also imported into the SSA. The runoff peak is analyzed using the rational method by utilizing the IDF polynomial coefficients for different ARI obtained from the MSMA. The time of concentration (ToC) is determined with the Kirpich method and the flow routing is calculated with the Kinematic Wave method. The analysis options are defined and the analysis is conducted for a duration of one day. Based on the results, the undersized drainage system will then be reanalyzed.

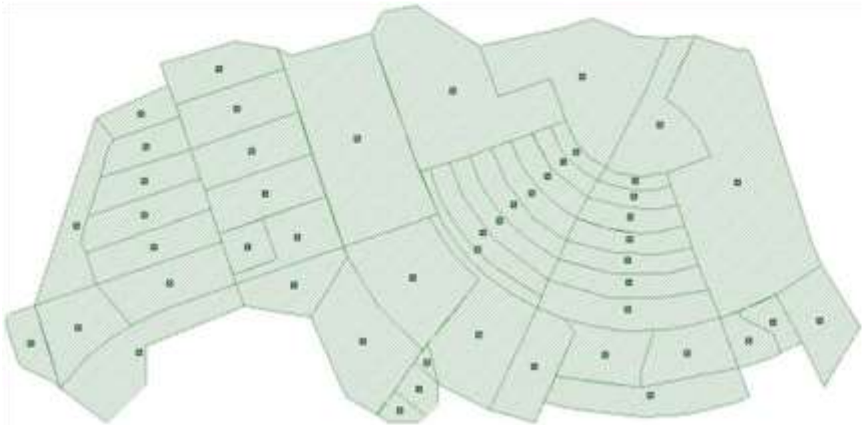

Fig. 5 Imported sub-basin areas into SSA extension

Fig. 6 Import of Autodesk InfraWorks model into SSA

4 Results and Discussion

4.1 Autodesk InfraWorks Analysis

The initial stage of this research project involves modelling the Taman Uni-Central drainage network in Autodesk InfraWorks. Figure 7 shows the successful mapping of the drainage system in Taman Uni-Central. Each drainage network is indicated using different colours and labels systematically according to exact coordinates onsite. Additionally, the existing GIS data sources integrated into Autodesk InfraWorks

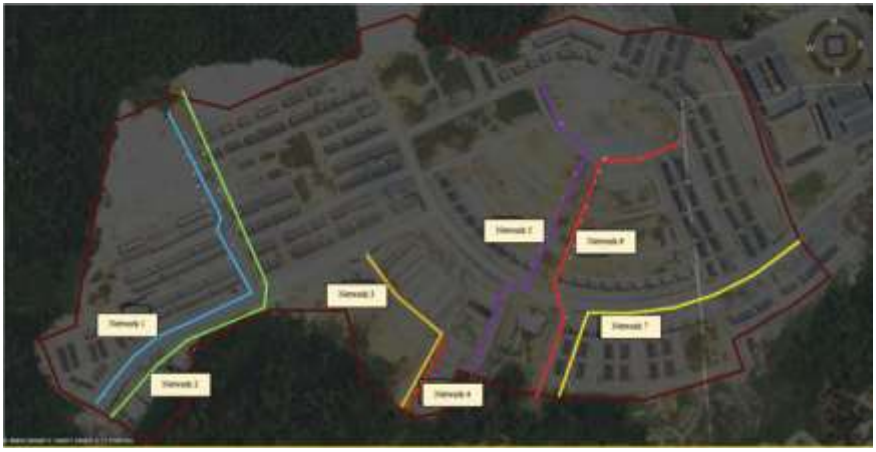

Fig. 7 Completed drainage layout of Taman Uni-Central

are able to provide users with a preliminary base map without carrying the on-site topographic or contour survey. The created model is an inventory system to display, record, and list existing drainage information.

It was found that a thriving watershed was generated for Taman UniCentral. Autodesk InfraWorks is also able to detect and identify the culvert locations if the drain is cutting through the roads. Autodesk InfraWorks also designed the culverts' dimensions after imputing the required hydrology data into the models. As a purely conceptual-based modelling software, the analysis features for drainage design using Autodesk InfraWorks are limited. Thus, hydrology and hydraulic analysis are conducted using SSA extension in Autodesk Civil 3D.

Autocad Civil 3D—Storm and Sanitary Analysis (SSA) Extension

Due to the constraints of Autodesk InfraWorks as a conceptual design software with limited analysis options, Autocad Civil 3D in SSA extension will be used to conduct hydrology and hydraulic analysis of stormwater systems.

The first result obtained from the SSA is in the form of a visual plan view of the overall drainage layout plotted from Autodesk InfraWorks. The flooded drainage area will be highlighted in red colour. The flow direction of the drainage networks will be determined by the drain invert levels provided into the SSA extension. Results show that the map plotted in Autocad Civil 3D is successfully imported from Autodesk InfraWorks for model simulation. The properties of nodes, links, sub-catchments, ground level, drain sizes were successfully imported into Autocad Civil 3D and matched the information inputted in Autodesk InfraWorks. By importing the data of the drainage details directly into Autocad Civil 3D, users will not have to key in the required information one by one. This method is extremely effective and efficient when checking existing drainage capacity after connecting with new development areas. Figures 8, 9, 10, 11, 12 and 13 show the drainage network 1, 2, 3, 5, 6 and 7, respectively, with the extreme rainfall intensity of 30 and 50-year ARI with 30, 60, 120 and 360 min duration.

From the simulation results, drainage network 1, network 2, network 3, network 4, network 5, network 6 and network 7 were found to be sufficient to cater for most of the

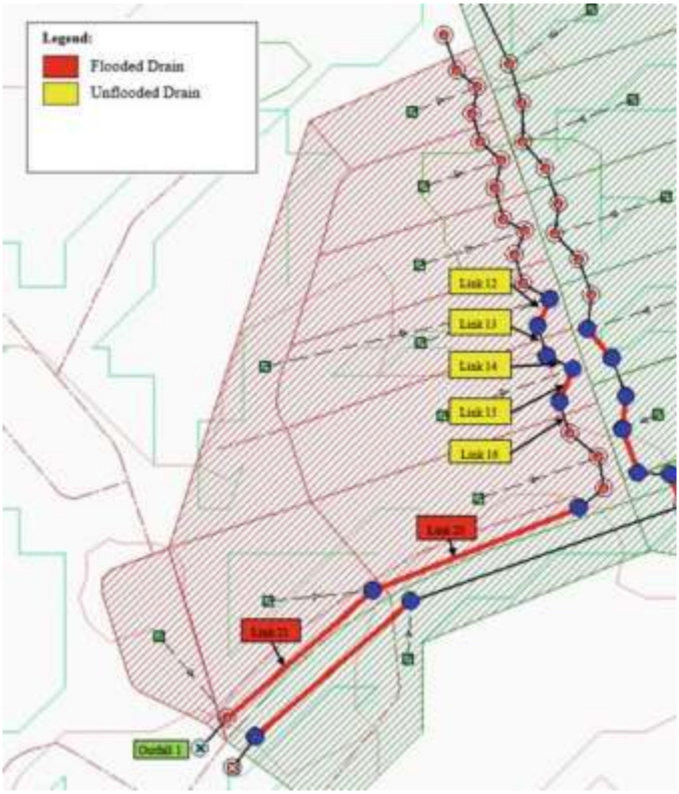

Fig. 8 Locations of highlighted inadequate drainage network 1

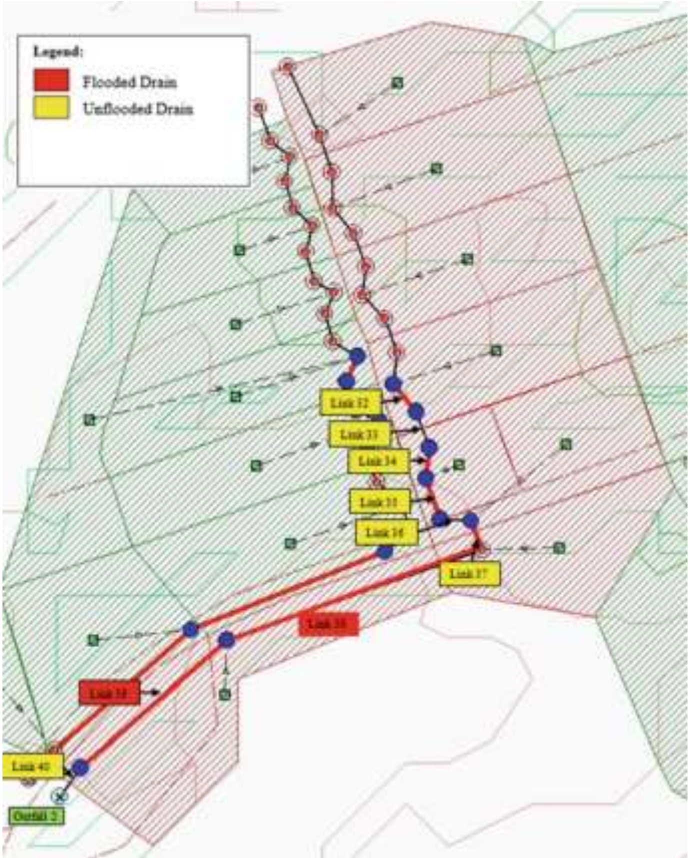

Fig. 9 Locations of highlighted inadequate drainage network 2

rainfall events at different ARIs and durations. However, it was found that drainage network 1 is inadequate to cater for the water flow resulting from the rainfall event of 50 years ARI with 30, 60, 120 and 360 min duration (${}^{50}I_{30mins}$, ${}^{50}I_{60mins}$, ${}^{50}I_{120mins}$, ${}^{50}I_{360mins}$) at links 20 and 21. The water level has also overflown the drainage network 2 at links 38 and 39 for rainfall intensity of 50 years ARI with 60, 120 and 360 min

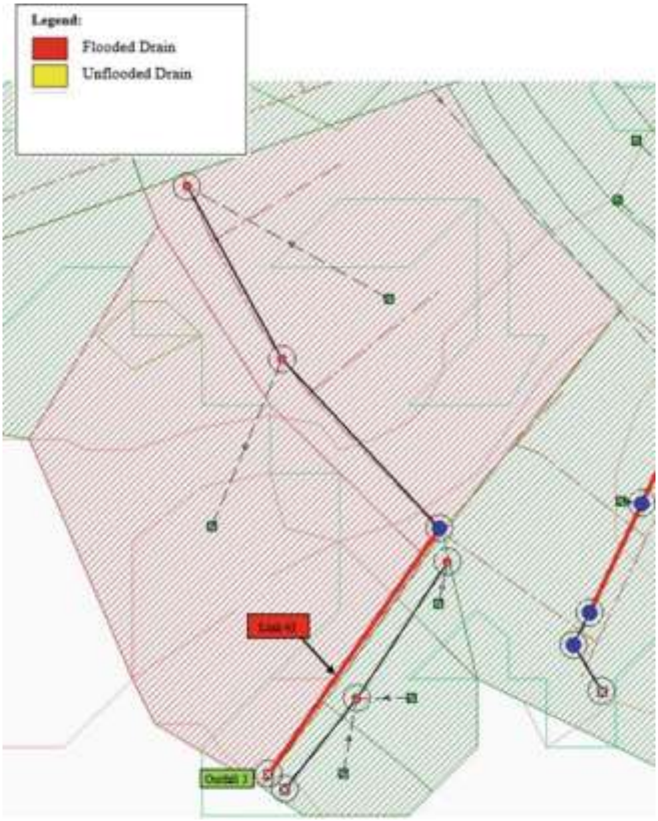

Fig. 10 Locations of highlighted inadequate drainage network 3 duration ($^{50}I_{60mins}$, $^{50}I_{120mins}$, $^{50}I_{360mins}$). Drainage network 3 was flooded as well at link 43 when simulated with rainfall intensity of 50 years ARI with 60 and 120 min duration ($^{50}I_{60mins}$ and $^{50}I_{120mins}$). Drainage network 4 was found to be sufficient to cater to all investigated rainfall intensities at different ARIs and durations. Therefore, no improvement work is required for the Drainage network 4.

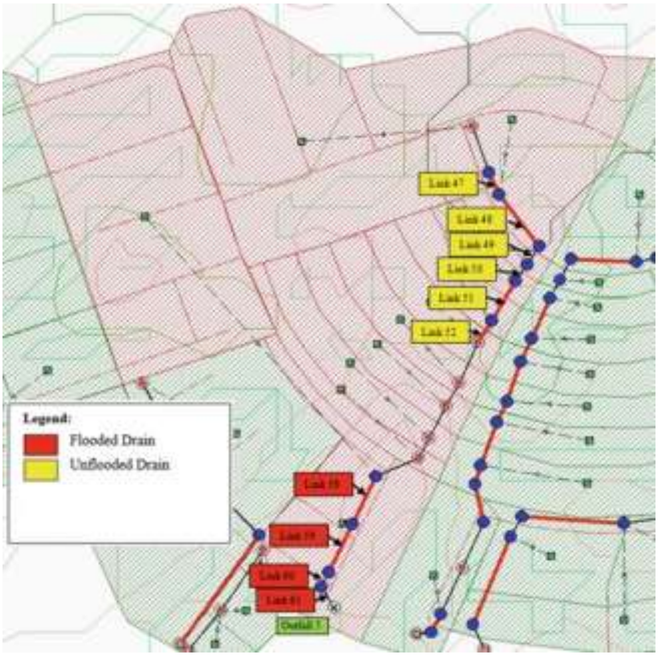

Fig. 11 Locations of highlighted inadequate drainage network 5

The results show that drainage network 5 is able to cater the rainfall intensity at different ARIs and durations except for 50 years ARI at 30, 120, 360 min duration ($50I_{30mins}$, $50I_{60mins}$, $50I_{120mins}$, $50I_{360mins}$) at links 58, 59, 60 and 61. Drainage network 6 is overflowed at links 74, 75, 76 and 77 with the rainfall intensity of 20 and 50 years ARI at 120 and 360 min duration ($20I_{120mins}$, $20I_{360mins}$, $50I_{120mins}$, $50I_{360mins}$). Simulation results also revealed that drainage network 7 is unable to cater for the rainfall intensity of 20 and 50 years ARI with 30, 60, 120 and 360 min duration at links 83, 84, 85 and 86.

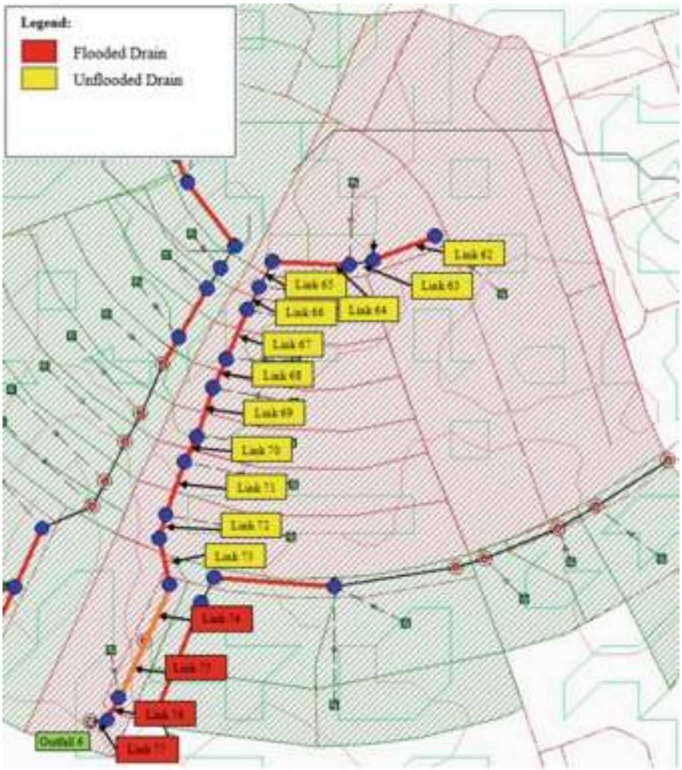

Fig. 12 Locations of highlighted inadequate drainage network 6

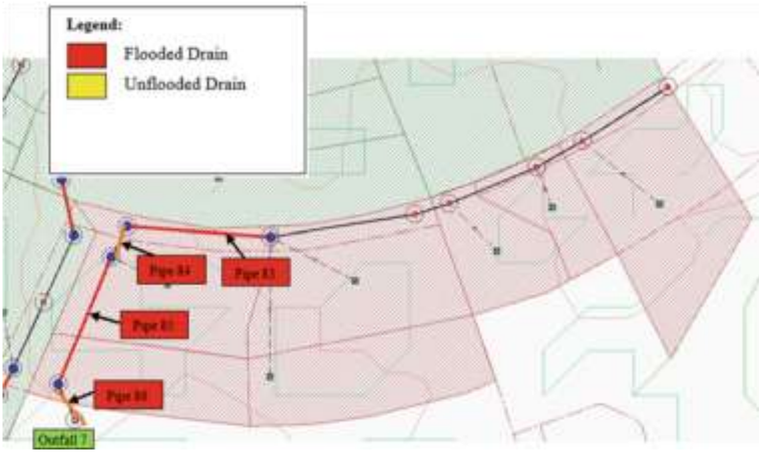

Fig. 13 Locations of highlighted inadequate drainage network 7

5 Conclusion

This research project has shown that the drainage layout of Taman Uni-Central was successfully modelled using Autodesk InfraWorks software, detailing all recorded drainage information. This will help record all the existing drainage neatly and correctly, thus simplifying the process's recording. Whenever drainage from a new development area connects to the existing drainage system, Autodesk InfraWorks will perform as a visual inventory system where all drainage information can be inspected and checked in detail. Autodesk InfraWorks will export the model into Autocad Civil3D under SSA extension to perform hydrology and hydraulics analysis of the drainage networks. This indicates that Autodesk InfraWorks software that performs as BIM for infrastructure works is highly feasible and can be integrated with Autocad Civil3D for performing drainage design processes. Under SSA extension, Autocad Civil3D is able to conduct hydrology and hydraulics analysis with different ARIs and durations to check the adequacy of the existing drainage network in catering the rainfall events.

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Application of Building Information Modelling (BIM) Technology in Drainage System Using Autodesk InfraWorks 360 Software

King Kuok Kuok, Kia Wee Kingston Tan, Po Chan Chiu, Mei Yun Chin, Md. Rezaur Rahman, and Muhammad Khusairy Bin Bakri

Abstract The increased number of physical drainage drawings at Samarahan district, Sarawak for new development areas is difficult to manage and handle by relevant authorities. Hence, this research is conducted to determine the feasibility of Building Information Technology (BIM) to create a proper drainage inventory system to accurately list and record current drainage information using Autodesk Infraworks 360 software. This inventory system will be employed to examine and validate corresponding drainage parameters based on the recorded information. Taman Uni-Central, a residential neighbourhood in Kota Samarahan, has been chosen for this case study. Drainage data, such as drainage size, length, invert level, are entered into GIS-integrated Model Builder in Autodesk InfraWorks 360. Autodesk InfraWorks 360 will conduct a preliminary analysis, including watershed analysis, to delineate the catchment area and drainage performance inspections at rainfall intensities of 2, 5, 10, 20, and 50 years (ARI). Thereafter, the InfraWorks model will be exported into Autodesk Civil3D to conduct a more extensive hydraulic analysis. The results show

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that full integration of these two Autodesk software packages had created a proper inventory system of existing drainage information and simulated its sufficiency in catering surcharge runoff from the new development area at the upper catchment.

Keywords Building Information Modelling (BIM) · Inventory management system · Autodesk InfraWorks 360 · Autodesk Civil3D · Average recurrence interval

1 Introduction

Referring to the 2010 Census (Department of Statistics Malaysia, 2010), the total population of Sarawak has experienced a high population growth of 19.3% since the previous Census conducted in 2000. Based on the data obtained, the Samarahan division holds the highest population growth percentage at 27.1%. The Sibu division follows this at 21.8% and the Kuching division at 21.5% [22].

The high population growth rate of Samarahan can be attributed to the rising position of the division as an education hub with its multitude of higher learning institutions and other educational facilities such as Universiti Malaysia Sarawak (UNIMAS), two campuses of University Teknologi MARA Kota Samarahan Campus (UiTM) and Institute of Teacher Education Tun Abdul Razak Campus. According to [20], with the Samarahan District reaching the criteria to be upgraded as a municipal council with a population of over 250,622 people in 2010 [6], the district is undergoing active property development, which will attract even more investors and therefore will bring an increase in construction works and work opportunities.

The current proposed drainage approval process involves submitting all drainage drawings in physical blueprints to the Department of Irrigation and Drainage (DID) Sarawak. The submission of physical blueprints would mean that submitted drawings may scatter around and are difficult to locate when required. The difficulty in retrieving physical drawings of existing drainage plans would delay the planning and approval process. This would cause great hassle when looking for past drawings as a reference before constructing new drainages discharged into the existing drainage system. Additionally, there is a lack of a proper systematic recording system to store the essential drainage information, including flow direction, drain and culvert size, and catchment areas in a master plan. Moreover, there is no system or software available to check and verify the capacity of the existing drainage system after receiving a surcharge from the nearby drainage system. There is a need to revamp our urban drainage management plans by adopting Autodesk InfraWorks, a Building Information Modelling (BIM) infrastructure software, to create an inventory system to record existing drainage information and integrate Autocad Civil 3D for water level forecasting within the drainage system [1, 2, 4, 14].

Autodesk InfraWorks is preliminary conceptual design software that allows users to visualize and render infrastructure models in real-world and real-time environments. It uses cloud-based 3D modelling technology where data can be obtained from integrated Autodesk sources or manual input [3, 23]. Autodesk InfraWorks provides four main features: generating conceptual design models, contextual modelling, analysis and simulation, and live visualization of models (News [18]. Autodesk InfraWorks can integrate with GIS data for early-stage project planning, and it is interoperability with other BIM-oriented software such as Civil 3D, Navisworks and Revit [8, 9].

Autodesk InfraWorks was utilized in the SmiSto Hydropower Project, Norway, to combine GIS information of topographical information, areal imagery, and available map web services to create a detailed model [19]. Autodesk InfraWorks was also utilized for the rail track rehabilitation project in Portugal due to its accuracy terrain modelling and geolocation of the study site [16]. Autodesk InfraWorks also provided a brief overview of site conditions for the remodelling of the Ebro River bridge project in Spain [5]. Besides, [21] had utilized Autodesk Infraworks to simulate the stormwater runoff depth of the designed space based on the Low Impact Development (LID) principle in Bangkok, Thailand. However, Autodesk InfraWorks has yet to see practicable use within Malaysia.

In this study, Autodesk InfraWorks will be utilized to create an inventory system to systematically store and organize existing drainage information, including drainage size, invert level, flow direction and catchment area. The interoperability of Autodesk InfraWorks and Civil 3D will be demonstrated by importing the created Autodesk InfraWorks model into Civil 3D to check the adequacy of the existing drainage system to receive runoff from new developments at upper catchments. The selected study region is Taman Uni-Central, a mixed development area located at Kota Samarahan, Samarahan.

2 Study Area

Kota Samarahan is located about 30 km southeast of Kuching city. It is a fast-growing suburb in Sarawak, with an area of approximately 508.1 Km^2 [10, 11]. For decades, the main economic activity in Kota Samarahan has been agriculture with thousands of hectares of coconut, oil palm, and pineapples plantations. However, the Sarawak state government had successfully transformed Kota Samarahan into an educational hub in Sarawak that housed Universiti Malaysia Sarawak, two campuses of Universiti Teknologi MARA Kota Samarahan Campus, Tun Abdul Razak Teacher Training Institute, ILPKS Industrial Training Institute and INTAN Training College [12, 13]. With this transformation, the population in Kota Samarahan has grown significantly for the past twenty years. Many new mixed developments were built to accommodate the rapidly increasing population.

One rapidly grown mix development is Taman Uni-Central, located at the North-Western of the Kuching-Samarahan Expressway (refer to Fig. 1). According to [17], the surrounding Uni-Vista and Uni-Garden have been facing rising flash flood occurrences. Residents have commented that this occurrence was attributed to the existing

Fig. 1 Satellite view of Taman Uni-Central, Kota Samarahan

drainage not being improved despite the rapid development of the areas. Additionally, the increase of impervious surfaces due to rapid urbanization also contributed to flash flooding occurrences in the Uni-Central area [7]. The study further showed that the earth drain is insufficient for discharge capacity, which could not cater to the generated peak discharge flow, thus causing the stormwater overflow. Residents also claimed that the floods were also caused by the undersize of the existing drainage system despite the ongoing rapid development.

3 Methodology

Figure 2 shows the research project methodology divided into three main stages. The first stage is data collection, which involves procuring data relevant to the drainage system at Taman Uni-Central. The second stage is plotting the drainage system and conducting initial hydraulics analysis using the Autodesk InfraWorks Drainage Design feature. The third stage is importing the model into Autocad Civil 3D for hydrologic and hydraulic analysis.

Stage 1: Data Collection

The initial site investigation was carried out to understand the general layout of Taman Uni Central. The first stage involves data collection of drainage flow direction, catchment areas, drainage layout, and invert levels through site investigation and application of Google Earth Pro. The catchment areas are then suitably delineated into different sub-basin for hydrology and hydraulic analysis. The coefficients of rainfall intensity duration frequency (IDF) curves with different average recurrence interval (ARI) was also obtained from the Urban Storm Water Management Manual (MSMA) published by the Department of Irrigation and Drainage Sarawak [15].

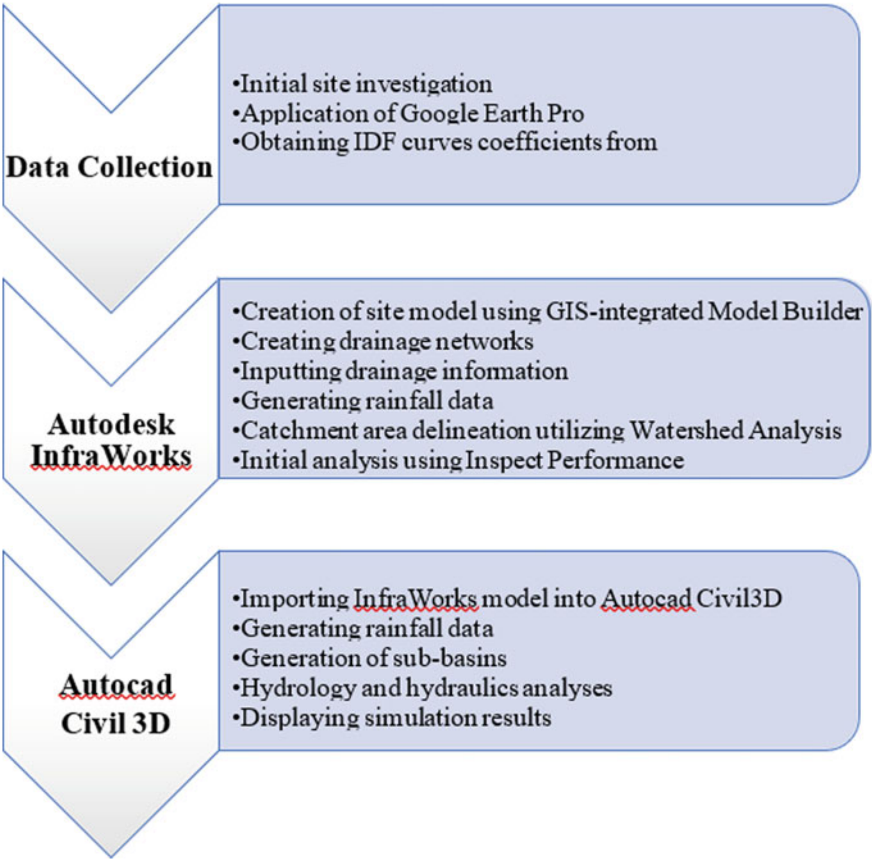

Fig. 2 Overview of research methodology

Stage 2: Autodesk InfraWorks

Autodesk InfraWorks is used to plot the layout of the drainage system of Taman Uni-Central, Kota Samarahan. The modelling procedures of Autodesk InfraWorks are:

a) Determination of Model Extents using Model Builder—The Model Builder feature integrates within InfraWorks is a GIS data source by inputting available data layers from cloud data for model creation. The extent of the model is determined by drawing a rectangle on the model location. Additionally, a coordinate system will be selected to increase the model accuracy. Since Taman Uni-Cental is located within the island of Borneo, the coordinate system with code “BORNEO” for East Malaysia is selected.
b) Creation of Site Model—The site model for Taman Uni-Central can be downloaded from Autodesk Cloud. Figure 3 presents the integrated model builder that already incorporated data layers from OpenStreetMaps and Bing Maps. This

integrated Model Builder function is used to obtain the terrain of the site. The red colouration denotes the low areas of the site terrain, whereas the navy-blue colouration denotes the highest areas of the site terrain. The obtained terrain is vital for the delineation of sub-catchments.

c) The input of coefficients of rainfall Intensity Density Frequency (IDF) Curves – The coefficient of rainfall IDF curves obtained from MSMA, as presented in Table 1 are inputted into Autodesk InfraWorks. The polynomial equation for fitted IDF curves for 5, 10, 20, 50 years ARI is presented in Eq. 1.

$$ln(RIt) = a + bln(t) + c(ln(t))2 + d(ln(t))3 \tag{1}$$

where ${}^{R}I_t$ is average rainfall intensity (mm/hr) for ARI and duration t, R is average return interval (years) and t is duration in minutes.

d) Plotting of Drainage Layout - The drainage layout can be inputted into the InfraWorks model by inputting the drain sizes, invert levels, bed slope, drainage networks as presented in Fig. 4.

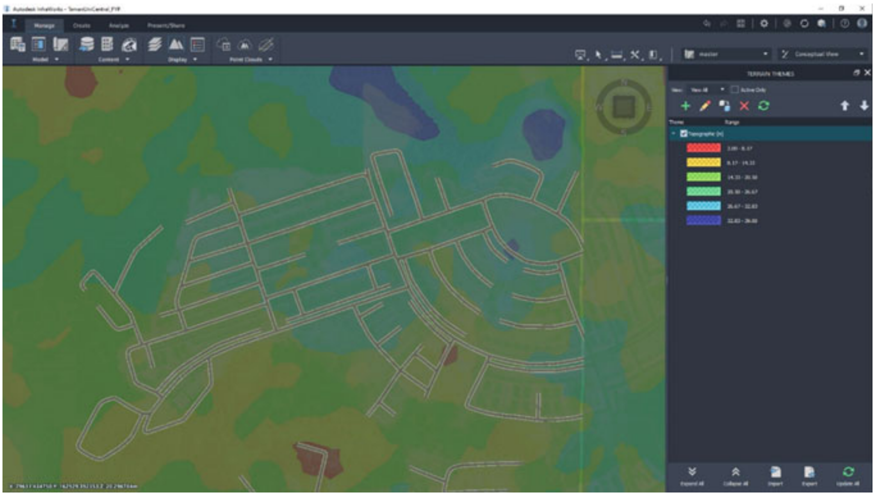

Fig. 3 Terrain theme of Autodesk InfraWorks model

Table 1 IDF polynomial coefficients for different ARI (MSMA, 2000)

Location	ARI parameter (year)	a	b	c	d
Kota Samarahan	2	5.1719	0.1558	0.1093	0.0043
	5	4.8825	0.3871	0.1455	0.0068
	10	5.1635	0.2268	0.1039	0.0039
	20	5.2479	0.2107	0.0968	0.0035
	50	5.278	0.224	0.0932	

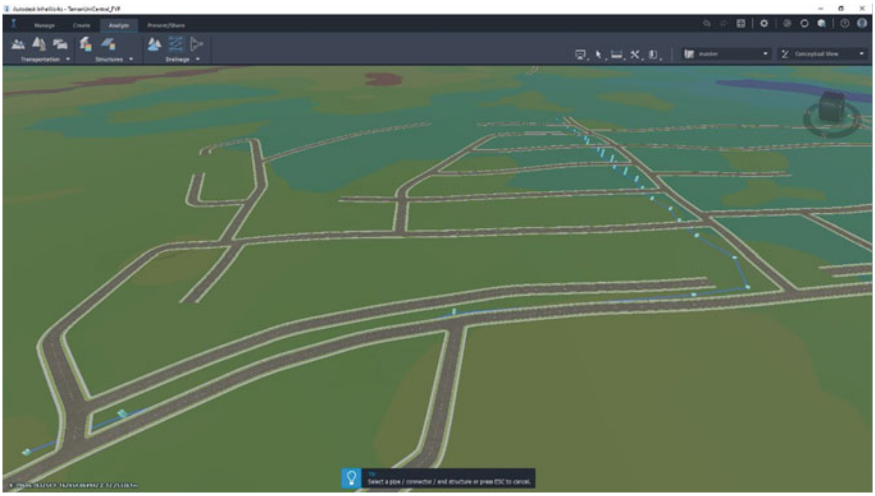

Fig. 4 Plotting of drainage network

e) Watershed Analysis - Autodesk InfraWorks is able to generate the hydraulic and energy grade lines for each drain. Hydraulic grade line (HGL) will help determine probable elevations to which the water would rise under atmospheric pressure occur during a storm event. The energy grade line (EGL) is an imaginary line to measure the total energy including the elevation head, velocity head, and pressure head, along the open channel carrying water.

Stage 3: Autocad Civil 3D (Storm and Sanitary Analysis)

The Autodesk InfraWorks model is imported into Autocad Civil 3D to carry out the Storm Analysis by Storm and Sanitary Analysis (SSA) extension. SSA is typically used to analyze gravity flow-based urban drainage systems. The sub-basins were drawn manually in Autodesk Civil 3D using polylines and converted into parcels after that. The created parcels are then imported into SSA in LandXML files. Figure 5 presents the imported sub-basins into the SSA model.

As SSA focuses primarily on stormwater and urban drainage analysis, all the drainage inventories, including the drainage networks, dimensions, invert levels created in Autodesk InfraWorks, were imported into SSA as Hydroflow Storm Sewers file. The imported drainage networks are imported into SSA is presented in Fig. 6.

The previously created IDF rainfall in Autodesk InfraWorks is also imported into the SSA. The runoff peak is analyzed using the rational method by utilizing the IDF polynomial coefficients for different ARI obtained from the MSMA. The time of concentration (ToC) is determined with the Kirpich method and the flow routing is calculated with the Kinematic Wave method. The analysis options are defined and the analysis is conducted for a duration of one day. Based on the results, the undersized drainage system will then be reanalyzed.

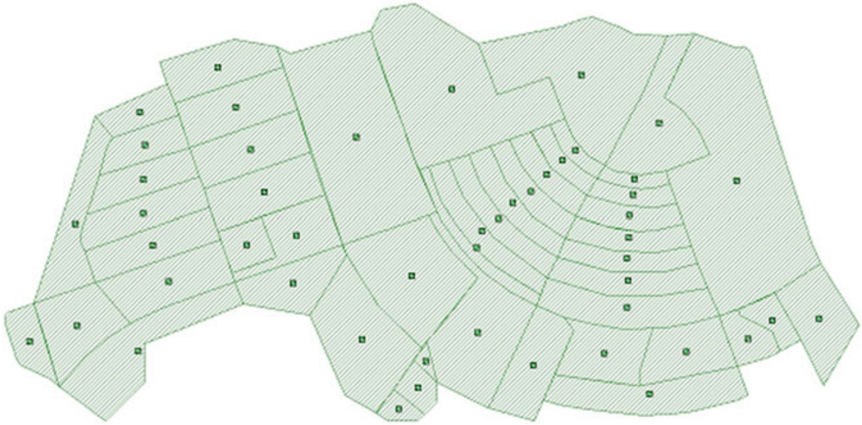

Fig. 5 Imported sub-basin areas into SSA extension

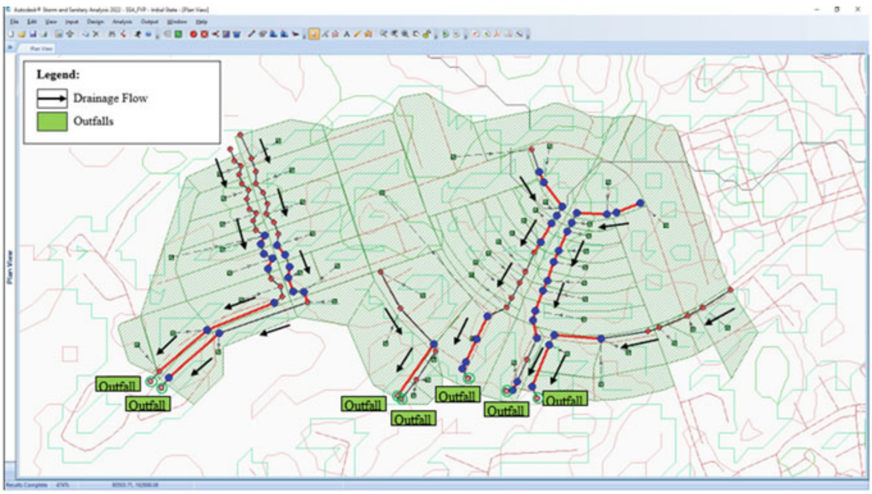

Fig. 6 Import of Autodesk InfraWorks model into SSA

4 Results and Discussion

4.1 Autodesk InfraWorks Analysis

The initial stage of this research project involves modelling the Taman Uni-Central drainage network in Autodesk InfraWorks. Figure 7 shows the successful mapping of the drainage system in Taman Uni-Central. Each drainage network is indicated using different colours and labels systematically according to exact coordinates on-site. Additionally, the existing GIS data sources integrated into Autodesk InfraWorks

Fig. 7 Completed drainage layout of Taman Uni-Central

are able to provide users with a preliminary base map without carrying the on-site topographic or contour survey. The created model is an inventory system to display, record, and list existing drainage information.

It was found that a thriving watershed was generated for Taman UniCentral. Autodesk InfraWorks is also able to detect and identify the culvert locations if the drain is cutting through the roads. Autodesk InfraWorks also designed the culverts' dimensions after imputing the required hydrology data into the models. As a purely conceptual-based modelling software, the analysis features for drainage design using Autodesk InfraWorks are limited. Thus, hydrology and hydraulic analysis are conducted using SSA extension in Autodesk Civil 3D.

Autocad Civil 3D—Storm and Sanitary Analysis (SSA) Extension

Due to the constraints of Autodesk InfraWorks as a conceptual design software with limited analysis options, Autocad Civil 3D in SSA extension will be used to conduct hydrology and hydraulic analysis of stormwater systems.

The first result obtained from the SSA is in the form of a visual plan view of the overall drainage layout plotted from Autodesk InfraWorks. The flooded drainage area will be highlighted in red colour. The flow direction of the drainage networks will be determined by the drain invert levels provided into the SSA extension. Results show that the map plotted in Autocad Civil 3D is successfully imported from Autodesk InfraWorks for model simulation. The properties of nodes, links, sub-catchments, ground level, drain sizes were successfully imported into Autocad Civil 3D and matched the information inputted in Autodesk InfraWorks. By importing the data of the drainage details directly into Autocad Civil 3D, users will not have to key in the required information one by one. This method is extremely effective and efficient when checking existing drainage capacity after connecting with new development areas. Figures 8, 9, 10, 11, 12 and 13 show the drainage network 1, 2, 3, 5, 6 and 7, respectively, with the extreme rainfall intensity of 30 and 50-year ARI with 30, 60, 120 and 360 min duration.

From the simulation results, drainage network 1, network 2, network 3, network 4, network 5, network 6 and network 7 were found to be sufficient to cater for most of the

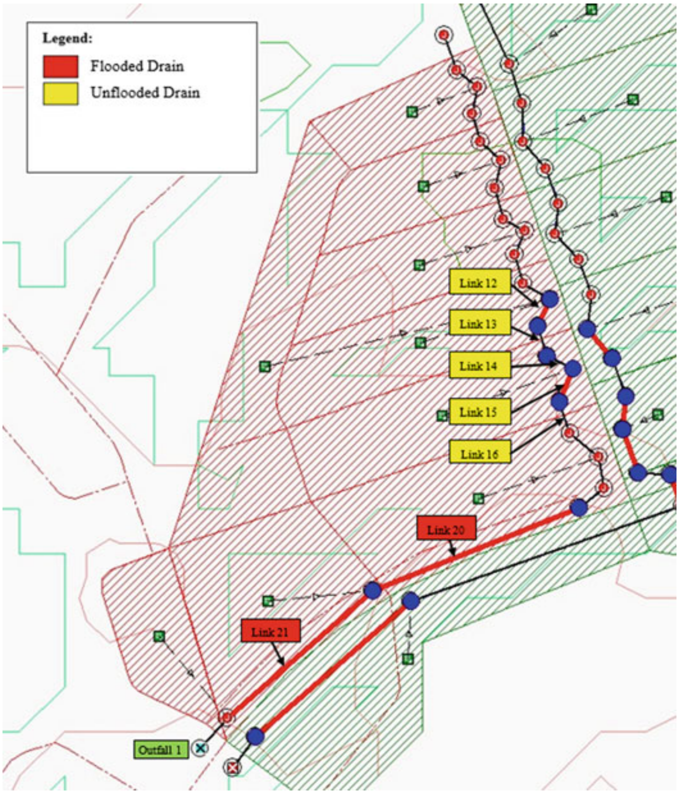

Fig. 8 Locations of highlighted inadequate drainage network 1

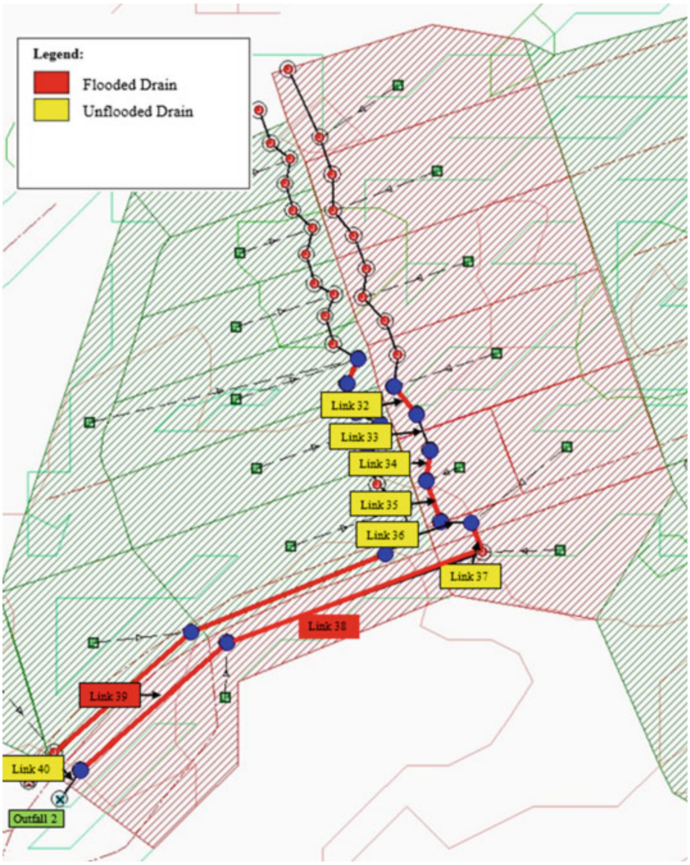

Fig. 9 Locations of highlighted inadequate drainage network 2

rainfall events at different ARIs and durations. However, it was found that drainage network 1 is inadequate to cater for the water flow resulting from the rainfall event of 50 years ARI with 30, 60, 120 and 360 min duration ($^{50}I_{30mins}$, $^{50}I_{60mins}$, $^{50}I_{120mins}$, $^{50}I_{360mins}$) at links 20 and 21. The water level has also overflown the drainage network 2 at links 38 and 39 for rainfall intensity of 50 years ARI with 60, 120 and 360 min

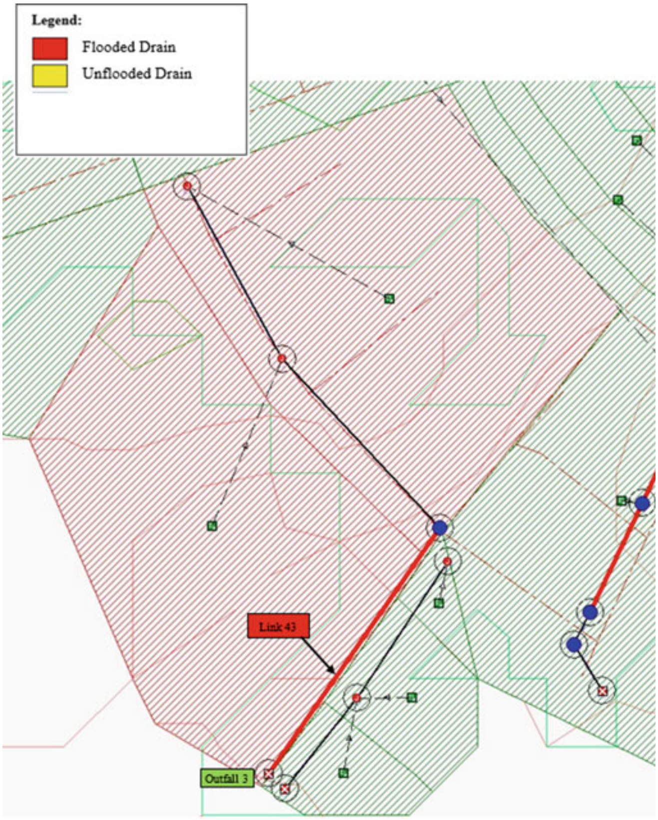

Fig. 10 Locations of highlighted inadequate drainage network 3

duration ($^{50}I_{60mins}$, $^{50}I_{120mins}$, $^{50}I_{360mins}$). Drainage network 3 was flooded as well at link 43 when simulated with rainfall intensity of 50 years ARI with 60 and 120 min duration ($^{50}I_{60mins}$ and $^{50}I_{120mins}$). Drainage network 4 was found to be sufficient to cater to all investigated rainfall intensities at different ARIs and durations. Therefore, no improvement work is required for the Drainage network 4.

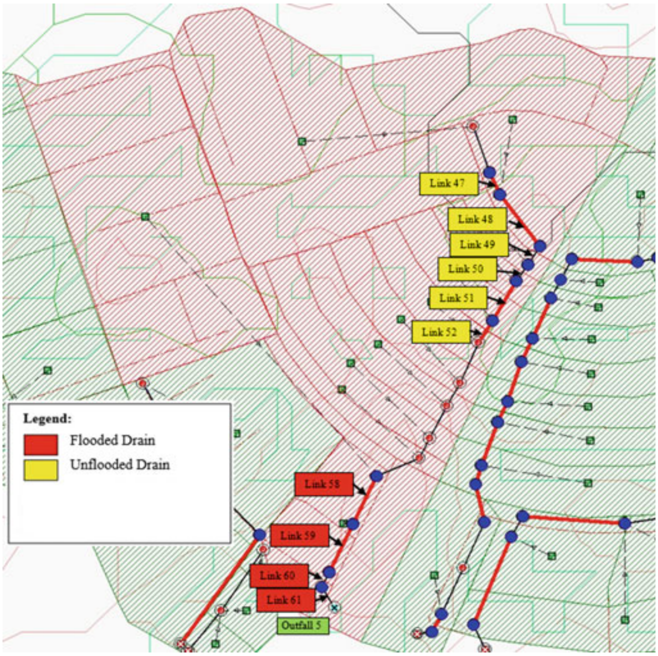

Fig. 11 Locations of highlighted inadequate drainage network 5

The results show that drainage network 5 is able to cater the rainfall intensity at different ARIs and durations except for 50 years ARI at 30, 120, 360 min duration (${}^{50}I_{30mins}$, ${}^{50}I_{60mins}$, ${}^{50}I_{120mins}$, ${}^{50}I_{360mins}$) at links 58, 59, 60 and 61. Drainage network 6 is overflowed at links 74, 75, 76 and 77 with the rainfall intensity of 20 and 50 years ARI at 120 and 360 min duration (${}^{20}I_{120mins}$, ${}^{20}I_{360mins}$, ${}^{50}I_{120mins}$, ${}^{50}I_{360mins}$). Simulation results also revealed that drainage network 7 is unable to cater for the rainfall intensity of 20 and 50 years ARI with 30, 60, 120 and 360 min duration at links 83, 84, 85 and 86.

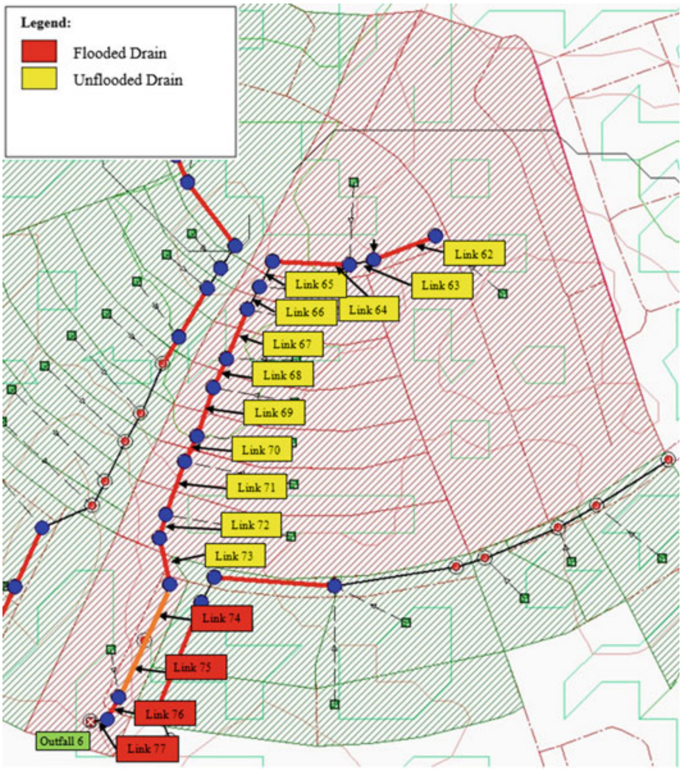

Fig. 12 Locations of highlighted inadequate drainage network 6

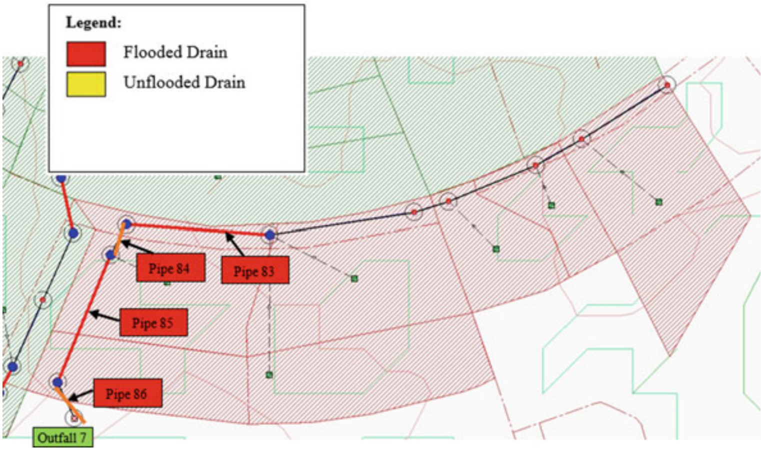

Fig. 13 Locations of highlighted inadequate drainage network 7

5 Conclusion

This research project has shown that the drainage layout of Taman Uni-Central was successfully modelled using Autodesk InfraWorks software, detailing all recorded drainage information. This will help record all the existing drainage neatly and correctly, thus simplifying the process's recording. Whenever drainage from a new development area connects to the existing drainage system, Autodesk InfraWorks will perform as a visual inventory system where all drainage information can be inspected and checked in detail. Autodesk InfraWorks will export the model into Autocad Civil3D under SSA extension to perform hydrology and hydraulics analysis of the drainage networks. This indicates that Autodesk InfraWorks software that performs as BIM for infrastructure works is highly feasible and can be integrated with Autocad Civil3D for performing drainage design processes. Under SSA extension, Autocad Civil3D is able to conduct hydrology and hydraulics analysis with different ARIs and durations to check the adequacy of the existing drainage network in catering the rainfall events.

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