Appendix C

Hydraulic Model

C1 Hydraulic Model

C1.1 Conversion of Sobek Model to Tuflow

A Sobek 1D/2D model was originally established as part of the Flood Studies (Cardno Lawson Treloar, 2010). It was calibrated and verified using historical rainfall data. Model setup files and results were provided to Rhelm by Council.

As part of this FRMSP, the supplied Sobek model required conversion into a Tuflow model. Converting the model required the recreation of some model elements in formats which could be input into Tuflow.

The Sobek flood study model had been split into two separate models: one for Davistown and one for Empire Bay. This separation of model sub-areas remains in the Tuflow model.

C1.1.1 Rainfall

Both models utilise the rainfall depths and temporal patterns set out in ARR87. The only difference between the two rainfall input files is that the Sobek model extracts rainfall losses within the rainfall files themselves while the Tuflow model applies losses to each grid cell following rainfall with runoff being produced once the maximum infiltration is reached. A new set of rainfall inputs files were produced for the Tuflow model to account for different methodologies in rainfall losses between the two models. This rainfall data was sourced from the Bureau of Meteorology.

C1.1.2 Model DEM

The Sobek flood study model contains one DEM file for the Davistown area. Grid cell resolution is 3 x 3 metres and covers the entire Davistown study area. This one file is input directly into Tuflow with the same origin coordinates to ensure the Tuflow DEM is the same as the Sobek DEM is most areas. The exceptions to this are locations where 1D elements from the Sobek model have been removed. These include primarily roadside and open space swales where the Tuflow model used the DEM to determine flood behaviour. In other areas where larger swales convey significant discharge of runoff, where the Sobek models conveys these in 1D open channels, the Tuflow model incorporates triangulated surfaces (created using 12d software and based on the same survey information used in the flood study) into the DEM. Specifically, these are the channels conveying flows to the east and west of Davistown Road shown below in **Figure C-1**.

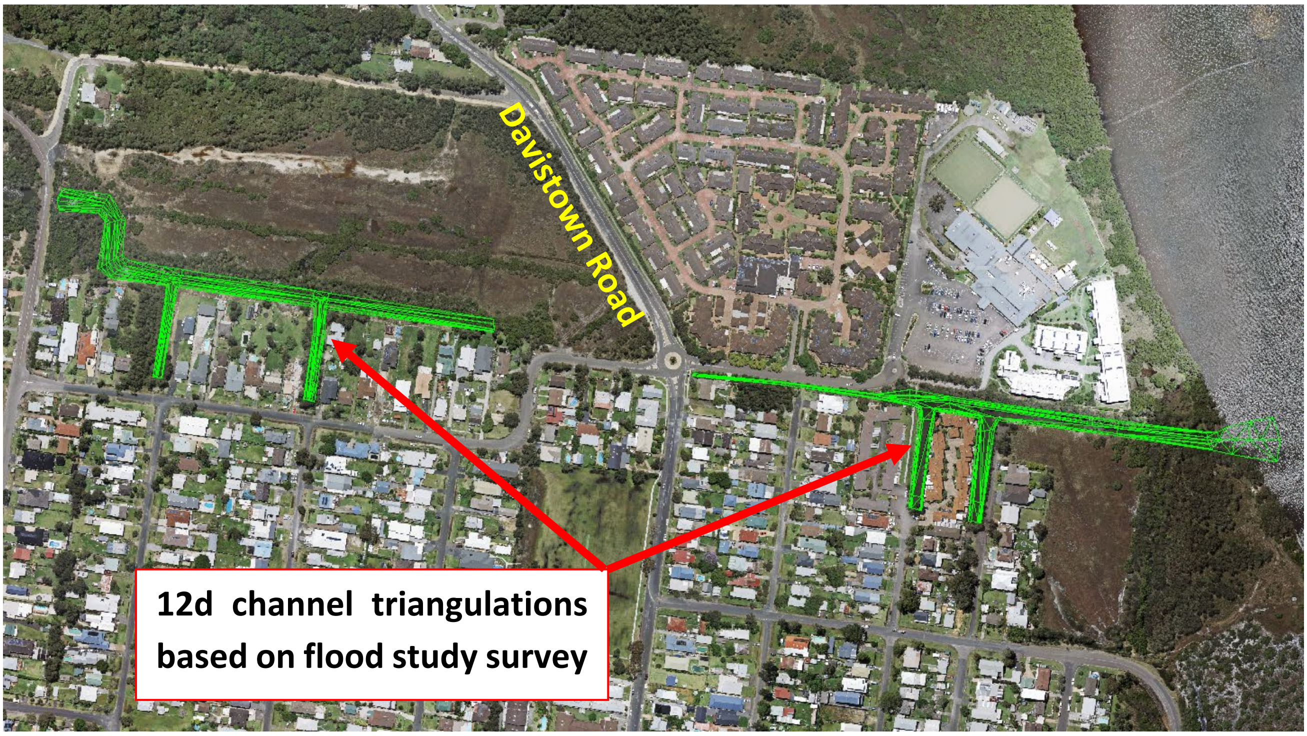

Figure C-11-1 Davistown Channels Surfaces

Moving these channels from the 1D domain to the 2D domain will not have a significant impact on flood behaviour, especially in low lying areas where water levels in Cockle Creek inundate these areas.

The Sobek flood study model contains three DEM files for the Empire Bay area. These include a 9 x 9 metre resolution grid covering the entirely of the study area, and two nested 3 x 3 metre grids covering the urban areas of Empire Bay and Bensville. Similar to Davistown, the DEMs are input directly into the Tuflow model, ensuring original coordinates are matching. The smaller 3 x 3 metre resolution grid files take precedence and overwrites ground levels defined in the 9 x 9 metre resolution grid. Although less prominent in the Empire Bay area compared to Davistown, the 1D swales have been removed and flow behaviour is calculated in the 2D domain. No channels were of significant capacity to warrant the creation of a triangulated surface input into the Tuflow DEM.

Table C-1 gives an overview of the grid cell sizes used in each model.

Table C-11-1 Grid Resolutions

Model	Location	Grid cell size (m)
Sobek	Davistown – all	3
Sobek	Empire Bay – Empire Bay urban	3
Sobek	Empire Bay – Bensville urban	3
Sobek	Empire Bay – rural	9
Tuflow	All	3

The grid cell resolution utilised in the Tuflow model is 3 x 3 m. This allows for the same DEM as the Sobek model in urban areas; however, the surface levels for the rural areas of empire bay do not match as accurately because of the difference in grid resolution. This is more pronounced along steeper gradients. Overall, this DEM change is unlikely to result in differences in overland flow discharge.

C1.1.3 Surface Roughness

The Sobek model files contained raster grid files defining the surface roughness spatial variation across the study area. The different areas for grid resolutions (refer **Table C-1**) also apply to the surface roughness raster files. That is, there is one file defining surface roughness in Davistown and three files in Empire Bay.

To convert this information to a useable file for Tuflow to read the raster files were each converted to polygons. Following this, a materials file was created to define the surface roughness for each area. Again, when input files are read by Tuflow, the rural areas are superseded by the roughness definitions in urban areas. This results in the spatially varying surface roughness being the same for the Sobek and Tuflow models.

C1.1.4 Rainfall Losses

The losses in the Sobek model are split similarly to the grid resolution and surface roughness. The urban areas and rural areas are subject to different initial and continuing loss values. For the Tuflow model, infiltration losses are defined in the materials definition files. Within the materials definition files created to define surface roughness, initial and continuing rainfall losses are added with values depending on location, as shown in **Table C-11-2**.

Table C-11-2 Rainfall Losses

Model	Location	Initial Loss (mm)	Continuing Loss (mm/hr)
Sobek	Davistown – all	5	1
Sobek	Empire Bay – Empire Bay urban	5	1
Sobek	Empire Bay – Bensville urban	5	1
Sobek	Empire Bay – rural	20	2.5

It should be noted that losses are applied in the Sobek model by removing these depths from rainfall applied to the grid at each time step. In the Tuflow model, losses are calculated at the grid cells after applying rainfall. Because of this, the rainfall files found in the Sobek model were not used for direct input into Tuflow. New ARR87 based rainfall files were created for Tuflow.

C1.1.5 Stormwater Network

The basic layout of the pit and pipe network was converted in GIS and inserted into Tuflow formatted layers.

The exact location of pit and pipes are modified to account for the methodology utilised in Sobek. Pit losses and pit inlet rating curves are modelled in the Sobek model with separate links leading into and out of the actual pit. **Figure C-2** illustrates this.

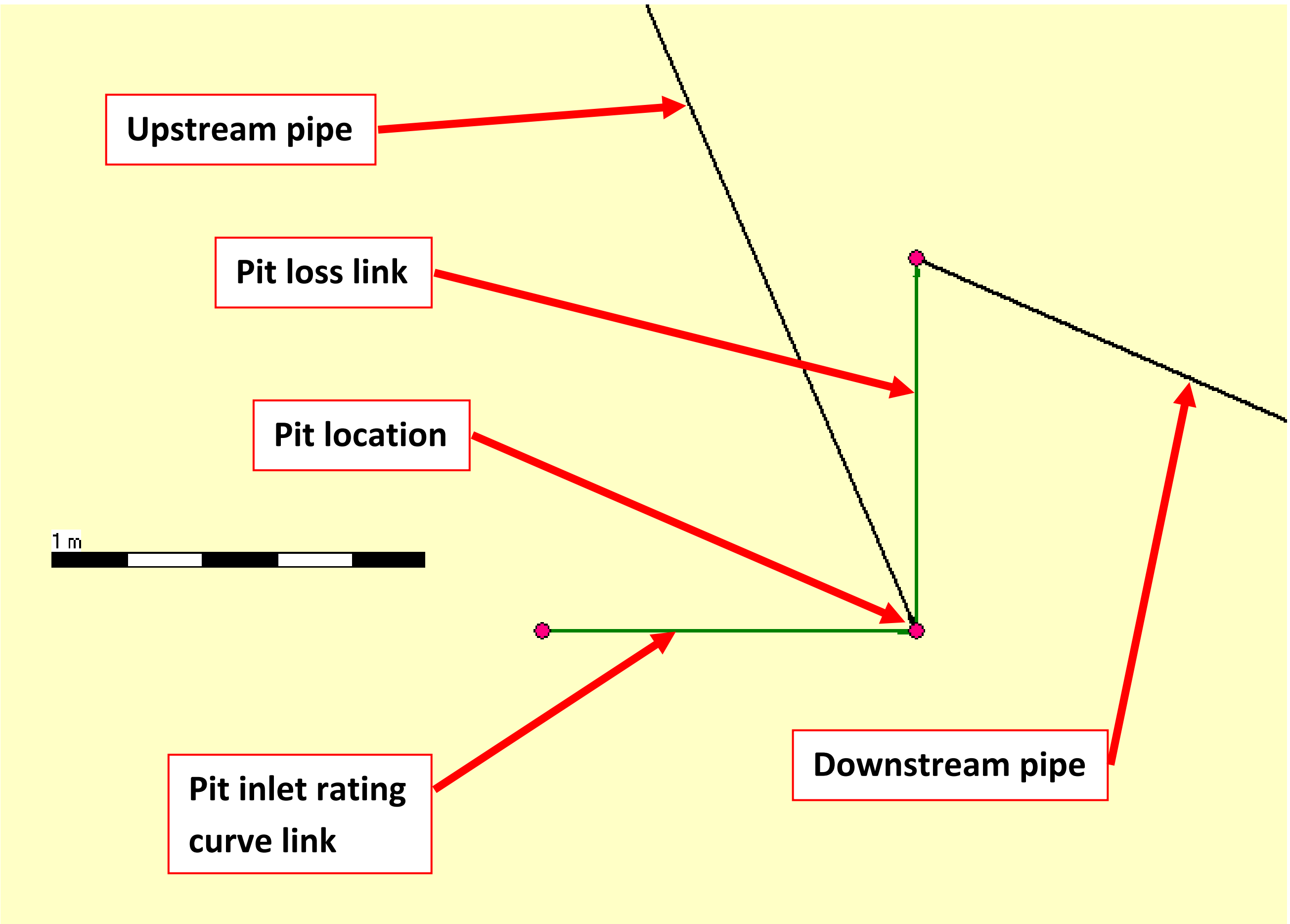

Figure C-11-2 Sobek Model Pit Schematisation

The pit loss and inlet rating curve links are represented in Sobek as rectangular orifices.

When converting the pit locations in Tuflow, the downstream pipe's upstream inverts is moved to the pit location and the pit loss and inlet rating curves links are deleted. In Tuflow, inlet rating curves are modelled at the pit node while pit losses are calculated within the pipe links. For each different size of 'orifice' found in the Sobek model inlet rating curve links, a different curve was established in the Tuflow boundary control database. For pit losses, the default pipe entry and exit losses coefficients (0.5 for entry loss, 1.0 for exit loss) are adopted. It is not possible to exactly match in Tuflow the pit losses modelled in the Sobek flood study model.

Pipe properties (roughness, inverts, types, and sizes) are converted directly in GIS from Sobek to Tuflow input files.

Pit surface levels are not defined in the Sobek model directly. The Tuflow model reads the inlet pit surface level directly from the DEM, while pit inverts are determined by the lowest outgoing pipe invert.

C1.1.6 Bridges

There is one bridge in the flood study model. It is located along Morton Crescent in Davistown. The Sobek model represents this element as a link with cross-sections defined from the flood study survey.

The Tuflow model modifies the DEM (which shows the road surface) with shape files defining the upstream and downstream cross-sections and interpolating between to define the channel surface. The bridge deck is defined with layered flow constriction shapes. This allows for the bridge deck and guardrails to be modelled with different blockage and losses. The bridge guardrails were assumed, from site inspections, to be 0.5 m high with 50% blockage applied.

C1.1.7 Boundary Conditions

Boundary conditions for both models remain the same. The 1% PoE level of 0.64 m AHD in Cockle Channel is constant throughout each modelling rainfall event.

In the Tuflow model, this level is also applied as an initial water level.

C1.1.8 Results

To compare the two model results, the updated Tuflow model was run for the 1% and 20% AEP and the following storm durations: 15, 30, 60, 90, 120 and 180 minutes. This corresponds to the storm durations reported in both the Davistown Catchment Flood Study (Cardno Lawson Treloar, 2010a) and Empire Bay Catchment Flood Study (Cardno Lawson Treloar, 2010b).

Refer to **maps G110 to G113** displaying the following information:

- 1% AEP - Tuflow peak depth less Sobek peak depth for Davistown;
- 20% AEP - Tuflow peak depth less Sobek peak depth for Davistown;
- 1% AEP - Tuflow peak depth less Sobek peak depth for Empire Bay;
- 20% AEP - Tuflow peak depth less Sobek peak depth for Empire Bay;

Differences in flood depths are calculated by taking the difference between the depth rasters for each model then filtering out the results external to the cut-off depth of 100 mm, as defined by the flood study Sobek model.

In general, peak flood depths matched reasonably well throughout both study areas. Maximum differences in depths were less than 100 mm in the majority of areas; however, there are a few exceptions.

In Davistown, where the open channels are location in the Sobek 1D domain and in the Tuflow 2D domain (refer **Figure C-1)**, the Tuflow model reports significantly larger flood depths. This is due to the Sobek model reporting depths only above the 1D domain (i.e. above the channel top of banks) while the Tuflow model reports full depths to the channel invert. A check of the modelled water elevations in this area revealed that differences are minor and approximately a maximum of 50 mm. **Figure C-3** displays the depth differences in these areas.

Figure C-11-3 Open Channel Depth Differences - 1% AEP

These two large channels are the primary examples of the effect of moving 1D domain channel to the 2D model domain. Similar occurrences appear at the southern end of Davis Street and Elinya Lane, although to a lesser extent and magnitude.

Along the western extent of the Davistown study area the Tuflow model produced maximum flood depths approximately 200 mm less than the Sobek model. This was caused by a change in the Davistown model's boundary condition. At this location, the 2D boundary condition transitions from water (HT boundary of 0.64 m AHD in Cockle Creek) to land (HQ boundary with assumed 3% gradient). The Sobek model has a downstream boundary condition schematisation which produced a greater water depth at the location shown in **Figure C-4.**

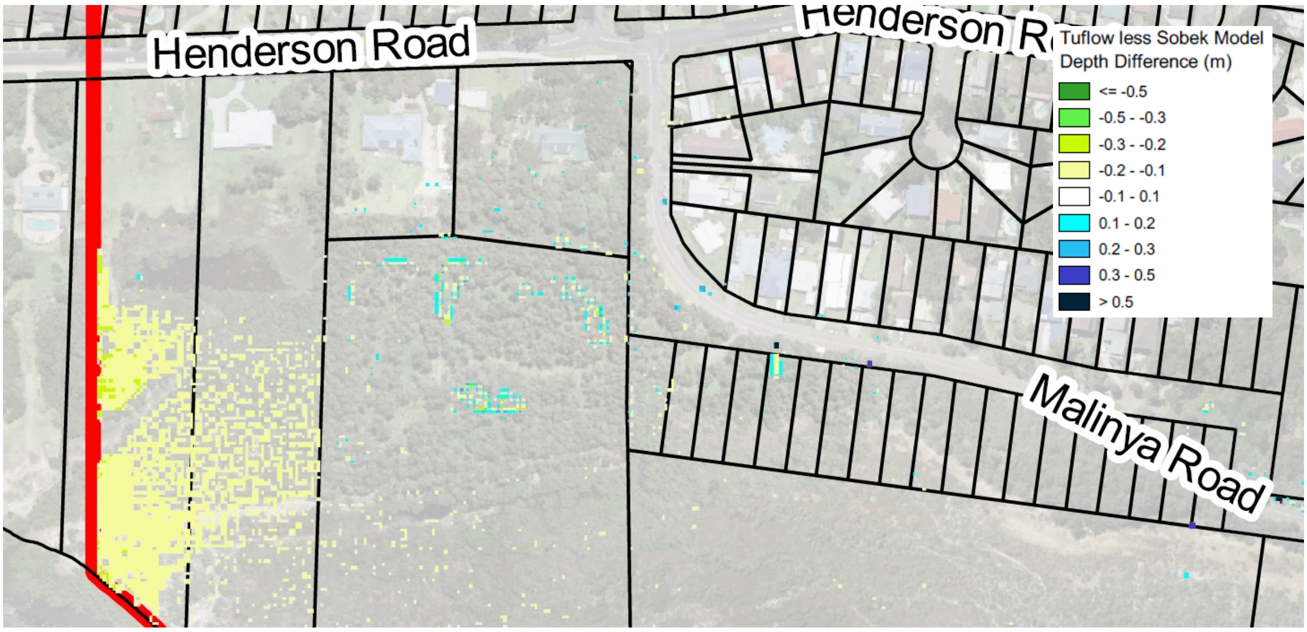

Figure C-11-4 Boundary Conditions Resulting in Depth Differences - 1% AEP

Depths produced in the Tuflow model are in the magnitude of approximately 200 mm less than the Sobek model. This is acceptable given the location of these results do not impact any structures within the study.

The flow west of Malinya Road and beneath the Morton Crescent bridge display varying depth differences primarily around channel banks. These variations are positive and negative even for adjacent grid cells and can be best explained by the differences in the cell gridding and/or computational processes with Tuflow and Sobek. Refer to **Figure C-5** for an illustration.

Figure C-11-5 Depths Differences West of Malinya Road - 1% AEP

Although the models depths do not match, an inspection of the 1D element upstream, the twin 1200 mm diameter culverts, reveal similar peak flows discharging to this area – 1.09 m^3/s and 1.08 m^3/s for the Sobek and Tuflow models, respectively in the 1% AEP event. Neither model displayed any overtopping of Malinya Road in the 1% AEP event.

In the Empire Bay rural areas, large differences in peak flood depths are observed where slopes are the steepest. This includes along the banks of drainage lines and at roadway embankments. Other variations are seen sporadically in the downstream area of the model within and surrounding the wetland southeast of the Empire Bay urban area. These differences are caused by the grid cell resolution not being the same in this area of both models. The Sobek 9 x 9 m grid cells will have a constant elevation across them, while the Tuflow 3 x 3 m grid cells vary in elevation in the same area. Refer to **Figure C-6** showing this area.

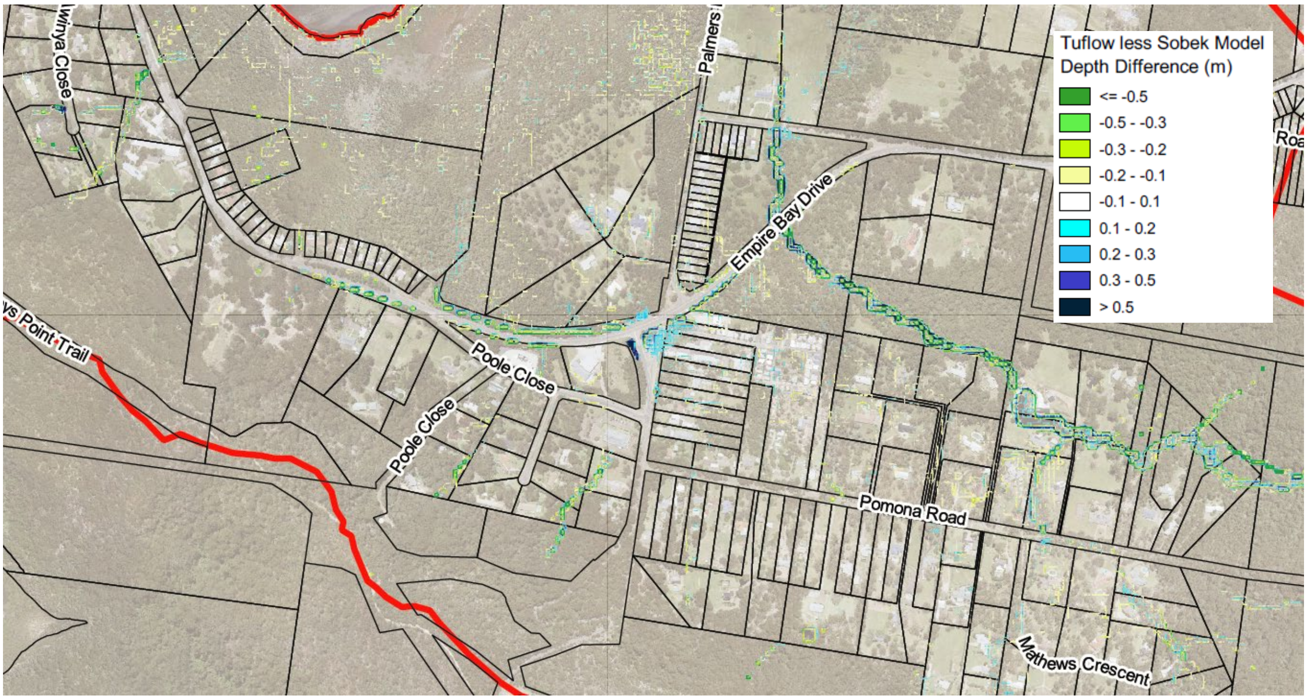

Figure C-11-6 Empire Bay Depth Differences - 1% AEP

Generally, the differences are located in areas where no buildings are located. The exemption to this is area north of Pomona Road where semi-rural areas are subject to different levels between the two models. The Tuflow model produces flood depths up to a maximum of approximately +/- 200 mm in the 1% AEP event.

In the urban areas of Empire Bay and Bensville, differences in the modelled flood depths were insignificant.

For all areas, the results of the 20% AEP event comparison between the Tuflow model and Sobek model were similar to the 1% AEP event; however, the extent and magnitude of the differences in flood depth were less.

Overall, the model conversion has resulted in a Tuflow model which reasonably replicates results of the Sobek model and is suitable for use in this FRMS.

C2 Model Results

The flood model developed for the Flood Studies (Cardno Lawson Treloar, 2010) has effectively been maintained through its conversion to Tuflow. As demonstrated in **Section C1**, the Tuflow model provides consistent results with the Sobek model. As such, the flood mapping and other results presented in the Flood Studies (Cardno Lawson Treloar, 2010) should be referred to for floodplain management purposes.

C3 Sensitivity Analysis

A comprehensive sensitivity analysis was undertaken of the flood models as part of the Flood Studies (Cardno Lawson Treloar, 2010) and as such, no additional sensitivity of model parameters is being undertaken as part of this FRMS.

Sensitivity analysis has been undertaken for the application of Australian Rainfall and Runoff hydrological methods, as discussed below.

C3.1 Australian Rainfall and Runoff 2019

Since the Flood Studies (Cardno Lawson Treloar, 2010) were completed, the Australian Rainfall and Runoff 2019 (ARR2019) has been published. The new ARR2019 has a number of changes to the hydrological methods that have been traditionally employed, including those in the 2010 Flood Studies. This includes updated design rainfall intensities, new ensemble storms and other catchment parameters such as losses.

The floodplain management industry is currently in a transitional phase between ARR87 and the new ARR2019. Generally, it is recommended to continue with the use of ARR87 where studies are in progress or there is a minor update or design scenario to be assessed within an existing model that was established. Where a completely new model is established, ARR2019 represents the best and most up to date information and would be recommended. This is in line with guidance from DPIE.

Sensitivity analysis has been undertaken of the 2010 flood studies with the revised IFD and temporal patterns associated with ARR2019 using an XP-RAFTS model, to understand the likely sensitivity of the flows. This analysis has been undertaken for the Davistown model only, for 10 temporal patters for the 2 hour 1% AEP event. The difference in flood levels between the Flood Study (ARR87) and the ARR2019 sensitivity runs is shown in **Map G114**. Overall, there were minor increases in flood depths up to approximately 30mm in some areas and a decrease in other areas up to 50mm.

It was agreed by Council and DPIE to continue modelling for the FRMS using ARR87.

C3.2 Arial Survey

A comparison of the Flood Studies (Cardno Lawson Treloar, 2010) model DEMs to the LiDAR received from NSW Spatial Services (dated 2013) was undertaken. Throughout Davistown, the 2013 LiDAR data is generally at the same elevation with isolated areas where the LiDAR elevation data is greater than 0.3 m different than the DEM. For the lower elevation areas of Empire Bay, the same is true; however, there are greater discrepancies at higher elevations and where tree coverage is dense. The sporadic nature of the comparison in some areas is caused by comparing the 1 m gridded LiDAR data to the 3 m and 9 m DEM data.

The Empire Bay model was updated with the 2013 LiDAR and 1 hour 1% AEP event was run for comparison of flood depths. The comparison of the flood depths is shown in **Map G115.**

The differences are generally sporadic throughout the study area. Major differences are noticed in rural / semi-urban areas, especially where gradients are steeper (i.e. along drainage paths). This is expected as it is where the ground elevations differed between the two surfaces because of the 3m vs 9m grid sizes. Urban areas of Empire Bay show isolated pockets of depth differences greater than 200mm (positive and negative), possibly due to lot level development between data acquisition dates or better acquisition of real ground levels around vegetation and/or structures.

Overall, the depth differences are generally less than 0.2m with some larger differences within the creeks. This is not likely to impact on Council's flood planning and associated controls and provides confidence in continuing to use the existing Flood Study (2010) results for Council's planning purposes.

C3.3 Pomona Road Structure Analysis (Option 1)

There is an unapproved wall structure downstream of Pomona Road. This structure was not included in the Flood Study (2010). Council understands that this structure has the potential to impact flood behaviour.

Survey of the wall, along with the surrounding ground surface and watercourse to the immediate north up to Empire Bay Drive, was undertaken by CBH Intrax and received by Rhelm on 9 August 2019. The survey extent modified DEM levels for areas north of Pomona Road and south of Empire Bay Drive.

In addition, data was also received providing greater detail on culverts crossings at the upstream extent of the survey (crossing under Pomona Road) and downstream extent of the survey (crossing under Empire Bay Drive). For the top of the wall, located along the eastern boundary of the caravan park, the surveyed heights were set into the model DEM as a separate elevation shape to ensure proper representation.

Map G116 shows the impact this survey information has on the modelled flow depths compared to the Flood Study (2010) modelling. The map highlights that, as expected, the flood wall diverts a proportion of flow to the north where in the original case they would flow through the caravan park. This results in lesser flood depths to the west and greater flood depths to the east and north of the wall.

The flood depth impacts of the surveyed levels and flood wall are restricted to the local vicinity between Pomona Road and Empire Bay Drive. Where flood depth differences are most significant (i.e. greater than 0.5m), this is primarily limited to 9 Pomona Road and areas where there are no existing buildings. Impacts to flood flows overtopping Empire Bay Drive are isolated to the immediate extent of the surveyed area. This is due to the survey being significantly different to the DEM from the original Sobek model. However, this does not impact the peak flows downstream of Empire Bay Road.

In the context of the overall FRMSP for Empire Bay, the survey information received will not have an impact on the selection of mitigation options or results and recommendations. For this reason, it is not proposed to incorporate the wall into the Tuflow model as a modification to the base case scenario.