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Waimakariri District Council

Silverstream Hydraulic Model Peer Review

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Executive Summary

Model Uncertainty

Flood models provide an indication of what might occur in a flood but they are not definitive. There is uncertainty in the underlying data they used, as well as parameters used to represent hydraulic performance. There is also uncertainty over how the system might actually operate in a flood. Where good records of floods, or flow data are available, the models can be fine-tuned to replicate the observed data as best as is possible. Where observational data is limited, the effect of uncertainty is considered to highlight model sensitivity; this is called 'sensitivity analysis'. Where neither is done, a conservative approach is generally taken, based on the modellers experience and best practice.

Model Changes

The DHI model subject to this peer review follows on from a prior WDC model developed by PDP. Both models are very similar in terms of approach, data sources and hydraulic analysis.

The key differences are:

- Updated flood flows
- Updated topographical information (as-built survey of the Silverstream subdivision)
- Adjusted LiDAR (to reflect differences between the LiDAR and the Silverstream survey)
- Additional waterway cross sections

Key Review Findings

The DHI study is a detailed and comprehensive study. It is thorough and generally follows best practice. Through our review of the documentation we have found no major flaws and the technical review of the model found only minor issues which are not expected to have any bearing on the results.

Our main concerns relate to the following:

- A lack of sensitivity analysis to determine the flood level sensitivity in the Silverstream area. Such an analysis may bolster the results by showing they are not sensitive to various parameters and assumptions made or highlight that the model is sensitive to certain assumptions. This approach is considered best practice where validation / calibration data is limited. This form of analysis would also aid with decisions around appropriate freeboard and risk to existing properties by quantifying model uncertainty to an extent.

- Hydrology - The flood frequency distribution adopted for flow derivation is at the upper bound of valid distributions. Whilst we consider this appropriate for the setting of floor levels and for design purposes it could result in the risk to existing properties being over-stated to some extent. In line with the first point above, consideration of other valid flow rates as part of a sensitivity analysis would provide a better understanding of the risk and uncertainty.

- The report does not appear to answer the central question stated in DHI's mission statement, namely 'to independently ascertain whether or not the previously recommended floor levels are appropriate for the subdivision'.

Assessment of model sensitivity to parameters and assumptions, particularly hydrology could provide an indication of the likely uncertainty range and provide an indication of a lower bound.

The assessment could include:

- ➢ Changing the LiDAR elevation by +/- 100mm to assess the impact on uncertainty over the wider topographical
- ➢ Consider the likely variation in channel and land roughness
- ➢ Consider a wider range of flow rates using different flood frequency distributions
- ➢ Sensitivity to assumptions around Eyre overflow, manual gate positions (i.e. the Cam River gate) and stop bank overtopping

We would recommend the following work is undertaken to assess sensitivity and aid in interpretation of the model results:

- Run the model at high order to assess the impact on results versus low order simulation
- Undertake sensitivity analysis as suggested above
- Calculate the maximum flood elevation for each residential parcel within the subdivision so that an assessment of building freeboard can be undertaken

1 Background

1.1 Scope of peer review

Opus have been asked by Waimakariri District Council (WDC) to undertake an independent peer review of the Silverstream hydraulic model and associated reporting by DHI. This includes a technical review of the model itself, as well as a peer review of the work undertaken.

Opus have also been asked to provide some commentary to accompany the peer review around model uncertainty in general and how the results could be applied.

1.2 Prior history

Opus have previously had involvement with the Silverstream development when WDC asked Opus to peer review an earlier model which was being used by WDC to assess potential effects of proposed earthworks associated with the Northern Arterial. This model had been developed by PDP, initially for the developer, and later used to assist WDC. This model was developed using TUFLOW.

Opus undertook a peer review and technical review of this prior model and found no issue with the model itself or the approach used. However, Opus did raise concerns over the uncertainty associated with key parameter values and hydrology and limited testing of the sensitivity to these to gauge risk.

Opus also undertook a review of the Davis Ogilvie survey for the Silverstream development. Neither the author or the reports reviewer / approver were involved in the survey review.

1.3 Information supplied

Opus have been supplied with the following information for review:

- Peer Review Report Letter LR01.pdf dated 26 June 2017 (GHD reference 51/34455/LR01)
- NZI Silverstream Levels CEAS Claim No. 7567161/IG3696 – Model Build Report, Final Report, June 2017 (pdf format)

2 Software and Approach

The model has been created using DHI Software, namely MIKE FLOOD software which links together MIKE 21 (2D hydraulics), MIKE URBAN (pipe networks) and MIKE 11 (1D open channel) models. This is an industry accepted platform and is directly intended for this type of application.

The MIKE FLOOD approach utilising the above models with 1D representation of pipes and open channels with a 2D simulation engine for overland flow / flood plain is also a well-established approach. Combining 1D and 2D simulation in this manner is considered industry best practice for this type of study.

3 Background data

The model has been based on a number of different data sets. Namely:

- LiDAR
- Laser scanned topographical information (from Elliot Sinclair)
- Surveyed cross sections of the watercourse (historic sections supplied by ECan / WDC and new sections procured for the model build)
- As-built information for the development
- Hydrological information (via ECan)

3.1 Hydrology

3.1.1 General

As was previously identified by Opus during the peer review of the Northern Arterial flood modelling, flood flows are a large area of uncertainty for this type of work. Recent flood events have resulted in current estimates of flood flows being higher than those estimated only a few years ago. In the case of this study, the current 2% AEP flow estimate has increased by approximately 10% from the 2012 PDP assessment.

This is particularly an area of uncertainty when the flow record is influenced by long term cyclical patterns in rainfall, such as the El Nino Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO) which exceed the records length. The annual maxima data may not sufficiently capture the full pattern of natural variation, resulting in variation of flow predictions over time when analysed.

As a result, estimation of extreme flood events can be under-estimated (or vice versa). This can often be the largest area of uncertainty in a flood study.

This is however an unavoidable area of uncertainty for flood studies where the historic record is limited in terms of duration. Use of the TM61 method to estimate flow rates, where the use of a gauged donor provides what appear to be high values, is a valid approach in lieu of catchment specific flow data.

3.1.2 Flood Frequency Analysis

The manner in which the flood flow frequency is derived can also be a large area of uncertainty. This relates to the appropriate selection of a flood frequency curve and it's fit with the observed annual maxima data.

The Gumbel distribution used by DHI for example, results in a relatively linear fit. In this application this method is likely to result in higher flows for extreme events than other methods. This could be appropriate for the setting of floor levels or for design, a conservative approach is necessary, but could result in flood risk being over-stated when compared to the historic record.

Best practice would typically involve using a number of established methods and applying judgement as to which provides the best fit. Outliers like linear lines or exponential curves would be discarded, particularly if they result in a poor R^2 value at the upper end of the distribution.

An example below (using a different data set) shows that a GEV or Pearson3 distribution can provide a better fit with the observed data than the Gumbel distribution. Whilst there is precedent that the Gumbel distribution is considered appropriate for Canterbury Rivers, in our view engineering discretion is required for each assessment.

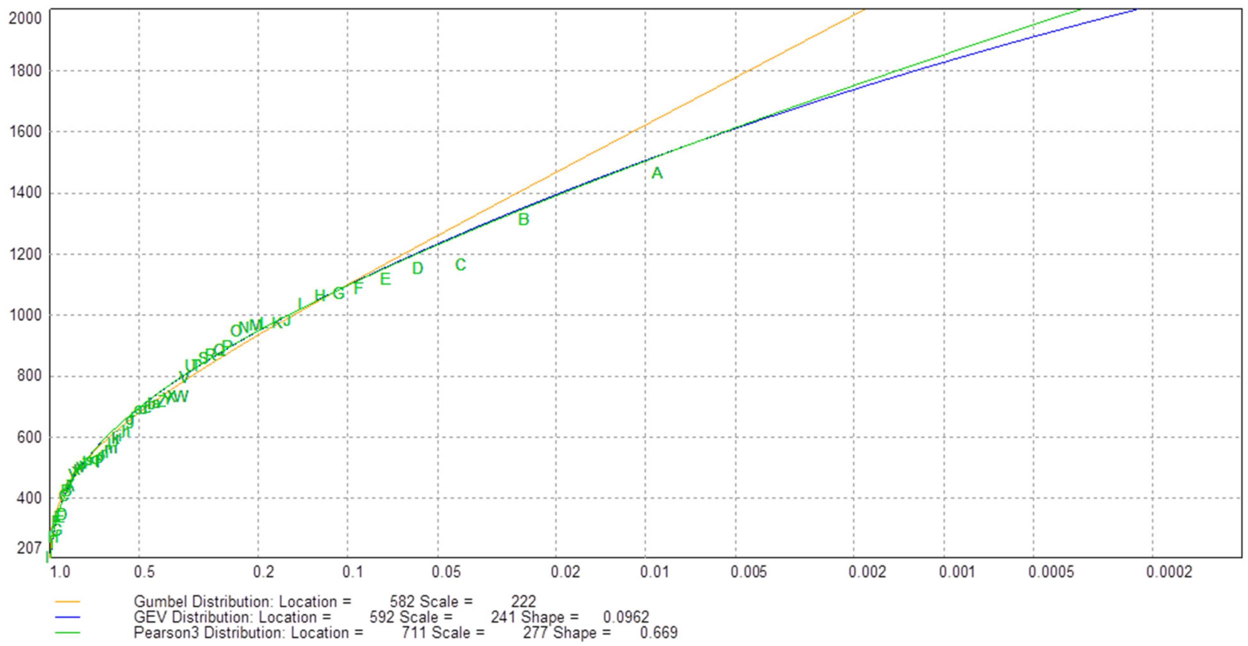


Figure 1 – example of different flood frequency distributions overlaid on observed annual maxima data

Our view is that use of the Gumbel distribution could over state flood risk compared to other valid distributions. The DHI assessment has selected the upper range values rather than assessing a range of values (sensitivity analysis) to reflect uncertainty over the hydrology.

3.2 Digital level information

It appears that Elliot Sinclair have provided both site level data, cross section data and guidance on LiDAR adjustment to DHI. This should ensure consistent data in terms of survey control. It also appears that the adjustment to LiDAR has been applied globally which would appear the best approach. However, the discrepancies between the LiDAR and survey information does highlight another area of uncertainty common to studies of this nature.

4 Technical model review

A technical review of the model files supplied by DHI has been undertaken. The results of the review are appended. Whilst the review did highlight some model instabilities and odd interpolation of Stormwater pipes within the Silverstream development, none of these are expected have a notable effect on the model results in the area of interest.

It may however be worth running the model at High Order (a software setting) and reviewing the results to quantify the impact of running the model at Low Order.

5 Differences from the prior model

Whilst the new DHI Silverstream model uses a different software platform, both use the same data and equations to undertake the hydraulic analysis and should provide very similar results.

The key differences are:

- Increased flood flows (due to updated analysis of the flow record)
- Modified LiDAR levels (based on comparison of the LiDAR with recent survey information)
- Additional cross sections have been added to the model in the vicinity of the subdivision
- Inclusion of overland flow from a WDC regional 2D flood model
- Inclusion of as-built level data within the Silverstream subdivision

Otherwise both models are very similar in their approach to simulation and the data sources used.

6 Uncertainty and risk

As discussed above there are several areas of uncertainty and risk associated with any model of this nature. Subject to the hydraulic flow regime, the uncertainty in terms of flood level can be minor, but in some case more significant.

It is our view that model outputs should consider such uncertainty where there is limited observed flow data, limited validation information and assumptions have been made in order to quantify the uncertainty. This is particularly relevant when assessing flood risk to existing properties where the outcomes of the model affect an existing community directly. However, we also note the need to err on the conservative side to ensure nothing is overlooked or underestimated.

Sensitivity analysis is conventionally done by running ‘sensitivity scenario’s to provide an approximation of the uncertainty through changes in assumptions, parameters and flows. This then provides information on the sensitivity of the results with upper and lower bounds to aid decisions around freeboard and risk.

Key areas of uncertainty in general and specific to the Silverstream model are as follows:

- Hydrology – the flow derived from annual maxima data has already changed by 10% and should be considered to be +/- 15% or higher. Where the hydrology has been inferenced from other locations or estimated using TM61 the uncertainty could be even larger.

- LiDAR / survey information – LiDAR and survey information have an inherent error margin. For LiDAR this can at times be significant. For the Silverstream subdivision this was found to be 130mm (on average) which is not unusual.

- Assumptions around the behaviour of secondary flow – this relates to assumptions around the Cust Main Drain / Kaiapoi River stop banks not overtopping, break-out flow from the Ashley, and flow from rural land to the west including the Eyre River. These all represent unknowns that result in uncertainty. DHI have made reasonable assumptions to try and accommodate these within the model, but have not considered a range of potential scenarios to understand the impact of them.

- Burning a 500mm deep channel into the LiDAR – whilst it is reasonable to lower the channel to allow for the LiDAR hitting the water surface, the manner in which it is done can affect results. Is it dropped 500mm at the Thalweg only and graded to the banks; is the whole channel width dropped; and which approach corresponds best with the nature of the river? The effect of such assumptions has not been tested.

All river models are subject to such areas of uncertainty. Hence freeboard is included when setting floor levels using model results. The freeboard typically accounts for several factors:

- Model uncertainty – accounts for error margins and limitations in data / knowledge

- Operational uncertainty – accounts for other factors such as changes in channel vegetation, bed level, blockage at culvert inlets or obstructions at bridges, changes in land use and land form

- Wave action / wind chop / bow waves – variation in the flood level due to localised factors

- Climatic variation over time, whether natural or anthropogenic in origin

These are typically accommodated by the building codes requirement for a minimum freeboard.

7 Interpretation and use of results

Common approaches to setting property floor levels are based on the land parcel area. This approach provides a property specific value and avoids the need to interpret levels from a map.

The maximum flood level is calculated for each residential parcel and converted to a minimum floor level with a freeboard allowance added.

This approach will cover all potential property locations within the parcel. The analysis can be done using GIS information quickly, so long as an appropriate output from the model is available.

The model outputs from the DHI Silverstream model could be analysed in this way to provide property specific values. If the same analysis is done for the prior PDP flood modelling, then the variation in flood elevation between each study could also be quantified at a property level and mapped spatially.

If as-built finished floor levels are also available, this could also be used to calculate property specific freeboards and highlight where any existing properties are subject to flood risk or reduced freeboard within the Silverstream development.

8 Conclusions and Recommendations

The Silverstream model follows industry best practice using appropriate software and methodology. The study is thorough and we found no areas of major significance within the model.

Our main comment would be that no sensitivity analysis has been undertaken when there is limited calibration / validation information and that the report does not clearly state the change in flood level and the impact on building freeboard as was outlined in DHI's mission statement.

The results presented are valid, but sit within a range of potentially valid results. Without sensitivity analysis it is hard to understand the model uncertainty in terms of flood elevation and interpret those results in terms of property freeboard.

Our recommendations would be:

- To run the model at High Order to assess the impact on flood elevation.
- Undertake sensitivity analysis to provide a better understanding of how robust the predicted flood levels are and the level of uncertainty.
- Calculate the maximum flood elevation for each residential parcel within the subdivision so that an assessment of building freeboard can be undertaken

Appendix A– Appended Information

MIKE FLOOD Flexible Mesh Verification

Project	3-C656.00 Silverstream Mike Flood Model Review		
Model:	"P:\EnvProj\WaimakaririDC\Delivery_20170927\Design\Silverstream_Design_Q200CC EyreOverflow Cam.couple"		
Modeller(s):	DHI		
Verifier:	Franciscus Maas	**Date:**	9 October 2017

Item	**Value**	**Comment**
Mike Flood		
Linked models	Mike 11, Mike Urban & Mike 21 FM	OK
Link definitions	227 Urban links 43 Lateral links 10 River/Urban links 1 Side Structure link **TOTAL: 256 links**	OK, more Urban and River/Urban links presumably to reflect the design scenario modelled
Lateral link options • Type • Source • Depth tolerance • Weir coefficient • Roughness (Manning's n) • Exponential smoothing	 Weir 1 most M21, some HGH 0.1m 1.838 0.05 1	OK
Urban link options • Type • MaxFlow (m^3/s) • Inlet area • Discharge coefficient • QdH • Exponential smoothing	 6 outlets, 221 inlets 10 0.1215 to 0.243m^2 0.67 0.3 1	OK
River/urban link options • Exponential smoothing	 1	OK, two additional links
Side structure link options • Depth adjustment • Exponential smoothing	 No 1	OK
Mike 11		
Mike11.ini		
Provided?	Yes	OK
Changes:	Default values used except for: • File_Flush_Freq = 1	OK, no impact on results
SIM11		
Models	Hydrodynamic only	OK
Simulation mode	Unsteady	OK
Simulation duration	73hr	OK

Item	Value	Comment
Simulation timestep	30s	OK
Initial conditions • HD	Parameter file	OK
NWK11		
Points	474	OK
Branches • dxmax	17 20 to 10000, most 20m	OK
Structures	5 culverts 5 bridges 4 pumps	OK
XNS11		
Raw data • Section type • Radius type • Resistance type • Transveral distribution	Open Total Area, Hydraulic Radius Relative Uniform	OK
Processed data	Hydraulic radius is not monotonically increasing in a large number of cross-sections examined. This could lead to model instabilities.	
BND11		
Water level	1 (defined by a time series)	OK, time series changed to reflect that it is a design event. One additional time series to represent the Eyre Overflow.
Flow	6 (1 constant no flow, remainder all defined by a time series)	
Closed	4	
RR11		
Number of catchments	None included	
Rainfall runoff model		
HD11		
Initial	Global water depth=0m Global discharge=0m³/s	OK
Bed resistance	Global value of n=0.035 plus specific points with values ranging from 0.02 to 0.05	OK
Wave approximation	High Order Fully Dynamic	OK
Default values	Default values used except for: • Delta=0.85	OK, increase in delta smooths out instabilities especially at structures and enforces an alternative way of dealing with supercritical flow.
Quasi steady	Default values used	OK
Additional output	Selected velocity at Q&H points, Resistance, Volume at H/Q points and total as well as lateral inflows at H/Q points.	OK, though could also have selected Froude Number to give an overview of the flow regime

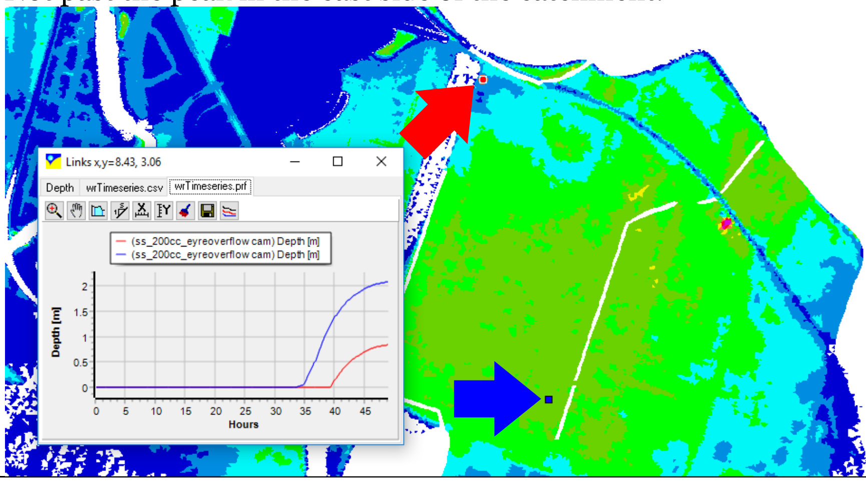
Mike 21 FM

Domain	SS_mesh_structure_8.mesh	OK

Item	Value	Comment
Simulation duration	49hr	OK
Simulation timestep	0.5s	OK
Module selection	Inland Flooding selected	OK
Hydrodynamic Module • Solution Technique	 Low Order in time and space	 Select High Order
• Depth	Not used	OK

• Flood and Dry
  ○ Drying depth
  ○ Flooding depth
  ○ Wetting depth
	Advanced flood and dry
	0.004m
	0.007m
	0.01m
		OK

• Eddy Viscosity	Smagorinsky formulation • Constant format (0.28) • Eddy viscosity limited to 1.8x10-6 and 2,147,483,647m2/s	OK, though could mask instabilities and will increase model run time.
• Bed Resistance	Manning's M number map	OK, different land use map than for calibration
• Precipitation	Time varying dfs0 map	OK, used a dfs2 in calibration model
• Infiltration	Time varying dfs2 map	OK, different than for calibration, large (766Mb)
• Sources	8 inflow point sources defined by time series	OK, added in point source for "Burgess2 EyreOverflow"
• Structures	7 dikes	OK
• Initial Conditions	0m @ 0m/s	OK
• Boundary Conditions	Land boundary round the mesh area	OK
MIKE URBAN		
dhiapp.ini		
Provided?	No	OK
Model		
Model network		Layout OK
Node losses		OK
Pipe roughness • Concrete (normal) • Concrete (smooth) • Plastic	 M=75 (n=0.013) M=85 (n=0.0117) M=80 (n=0.0125)	OK, though concrete may be slightly too smooth
Long section	Sampled long sections generally ok, though there is a jump in Stage2_MH_T3	OK, look at pipe inverts at Stage2_MH_T3
Boundaries	None	OK
Simulation duration	31 days	OK
Simulation timestep	31 days	OK, controlled by MikeFlood

Item	Value	Comment
MIKE 11 Results		
Stability		Slight instability in the following branches • Cust • Parnhams
Simulation length		Simulation possibly not past peak in • Adderly • Dudley
MIKE 21 Results		
Stability		OK
Simulation length	Not past the peak in the east side of the catchment: 	
MIKE URBAN Results		
CRF		
Stability	N/A – Rain on Grid simulation in Mike 21	
General shape of plots		
PRF		
Stability		OK
Simulation length		Simulation not past the peak in some nodes, e.g.: • Existing_Sump_19 • Existing_Sump_370 • Existing_Sump_408 • Existing_M21_outlet_1 • Existing_M21_outlet_49

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