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Wellington, New Zealand
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Dear Benjamin,

REVIEW OF MIKE FLOOD MODELLING – PINEHAVEN STREAM PROJECT

In accordance with your request we have reviewed the MIKE FLOOD model developed by Sinclair Knight Merz (SKM) for the purposes of assessing the potential for severe flooding and flood hazard in Pinehaven. This letter summarises our findings at the pre-calibration stage of the model build with brief recommendations where appropriate.

General Overview
The model covers approximately the region between the upper extent of Pinehaven Road and Elmslie Road to Hull Creek. A 5m 2-D MIKE21 bathymetry is used to model the floodplain and a 1-D MIKE11 branch network is used to model sub-grid scale channels and long culverts. There are no model boundaries within the MIKE21 grid and all flow enters and drains from the system via the MIKE11 network and a series of lateral couples. For this review the 10 Year and 100 Year ARI model setups and results were available.

MIKE21 Model

Bathymetry
The selection of a 5m grid size is appropriate considering the scale of features resolved in the MIKE11 model. The modelled area is sufficient as the flood surface does not push up against 'dry land' cells during the largest event simulated (100 Year ARI). Where both left and right lateral couples have been defined for the one branch, cells between the coupled cells have been 'blocked out' with 'dry land' cells to avoid duplication of conveyance in these areas (refer to **Figure 1** in Attachment A). This is considered good modelling practice where the MIKE11 channel exceeds 10m width. No boundaries are specified in the MIKE21 setup file and bathymetry. No obvious interpolation errors or rapidly changing/erroneous bed levels were observed in the grid data.

Timestep & Courant Number
For MIKE FLOOD applications in particular DHI recommends that a Courant number of less than 1 is maintained. With an approximate maximum flood depth of 2m and a timestep of 0.5 seconds the Courant number is approximately 0.5 and within the recommended guideline.

Flood & Drying Depths
A flooding depth of 0.01 m and a drying depth of 0.005 m have been applied. These values are slightly lower than the lowest pair of values generally recommended by DHI for applications where rainfall is not directly applied to the grid as a source. The impact of a very low flooding depth is to artificially increase the speed of the

wetting front across flat areas. We recommend changing the flooding depth to 0.02 m and the drying depth to 0.01 m.

Initial Surface Elevation
The initial surface elevation file specified is appropriate considering the MIKE21 model does not contain inflow or outflow boundaries. No cells are wet at commencement of the simulation, consistent with the relatively steep topography modelled. It may be appropriate to assess any ponded areas at the end of the simulation (areas that do not drain) to determine if these should be filled in the initial condition (only if conservative assessment of lost storage is a project consideration or aids in model calibration).

Eddy Viscosity
A velocity based eddy viscosity value of 1 has been applied globally within the model. This value is within the guidelines recommended by DHI for a grid size of 5 m and timestep of 0.5 seconds. Various empirical relationships exist for estimating appropriate values of eddy viscosity in the absence of observed eddy behaviour. Some of these would yield smaller values of eddy (0.2 to 0.5) based on the relatively shallow flow depths in the model.

Resistance
Four different values of resistance have been defined. These represent road pavement, houses, grass land and forest. Based on visual inspection of aerial photographs the number of regions and the Manning's M values defined for these regions are generally appropriate. However, it should be noted that Manning's M of 6.67 for forest may be found to be too rough during model calibration (refer **Figure 2**).

Results
The MIKE21 model has a one minute save interval and produces a result file of approximately 850mb. Both the save interval and the model result file size are appropriate however a save interval of 30 seconds could be selected and the model result file would still be less than 2GB which is generally targeted as a model result size.

MIKE11 Model

Network
Within the MIKE11 model long pipe sections are represented correctly as cross sections rather than culverts structures. It should be noted that in some cases the closed cross section method for modelling pipes will result in less than adequate head losses as changes in direction and losses at junctions are not properly accounted for. The value for dx Max is currently set at either 20m or 30m depending on the branch in the model, this should be changed to 5m for all branches to suit coupling to the MIKE21 model.

Cross Sections
A number of cross sections within the model have non-monotonically increasing conveyance curves. An example of this is Emislie_Rd CH 453 (refer to **Figure 3**). This results from a discontinuity in the hydraulic radius curve, due to a large increase in wetted perimeter with a small increase in area (water level) and typically occurs where the flow transitions from channel to floodplain. The inflection can be corrected in two ways; first by using the left and right banks markers (markers 4 & 5) at the channel banks forcing the conveyance to be calculated in different zones and second by selecting 'Resistance Radius' over 'Total Area Hydraulic Radius' in the Radius Type drop down box within the Cross Section editor for cross sections where this occurs (refer to **Figure 4** for corrected cross section and conveyance curve). Alternatively, bank markers 1 and 3 could be moved in to the channel bank location to reduce the low flow cross section, resulting in flow being transferred to the MIKE21 grid at lower water levels. This should be done in tandem with assessment of the z values in the MIKE21 bathymetry to which these cross sections will be coupled. Selecting the equidistant level selection method in the processed data cross section editor will also assist in smoothing the conveyance curve.

Boundary Conditions
The MIKE11 boundary conditions were examined and found to be appropriate.

Hydrodynamic Parameters
The Delta value on the Default Parameters tab of the HD11 file is used to control the gravity term in the momentum equation. Delta is a weighting factor between upstream and downstream control of flow momentum. The default values is 0.5 which (centred between upstream and downstream) and values greater than default can be used to dissipate the wave front to produce a more stable model. A value of 0.85 was found to have been applied and is too considered high, a value of 0.7 is generally recommended for upland rivers and should be adopted for this application.

A global Manning's n value 0.035 has been applied and pipe and culvert sections have generally been specified as 0.015 and some small open channels have been specified as 0.2. During the calibration process it may be found that 0.015 is too smooth for aged concrete pipe and culvert sections, whilst 0.2 may be too rough for small channels unless dominated by thick vegetation.

MIKE FLOOD model

Where cross sections are open, the MIKE11 channels are coupled to the MIKE21 grid via lateral couples. Standard coupling options have been applied and the number of coupled cells has been trimmed such that the length of each lateral couple is approximately equal to the length of the MIKE11 branch for each open section. This is considered good modelling practice.

For each of the lateral couples the default options have been applied, that is no exponential smoothing (recommended) and HGH structure type for determining the geometry of the internal weir for each lateral link. HGH takes the highest of either the MIKE21 bathymetry level or the MIKE11 bank marker level. This can be interrogated further by using the "MFLateral" diagnostic in to view both these levels in the MIKE11 cross section editor. This is achieved by the following steps:

- Create an empty text file named MFLateral.txt in the same location as the *.sim11 file;
- Run the MIKE FLOOD simulation for at least 1 timestep to populate the file with data;
- Create an empty *.xns11 file; and
- Import mflateral.txt into the empty *.xns11 file.

For each lateral couple the MIKE11 bank marker level, the MIKE21 bathymetry level and the structure level (or internal weir geometry) is visible (Refer to **Figure 5**). The effect of significant difference between MIKE21 and MIKE11 levels is to control the points along the couple where transfer between the two surfaces is possible. A maximum difference of 0.5m is generally recommended and either selection of a different bank marker location or filling of the bathymetry may be used to achieve this.

The MIKE FLOOD model runs in approximately 4hrs on a standard high performance run computer, this is a good outcome as generally 12hr simulation times are targeted. The model results were reviewed and no evidence of instabilities were found either in the MIKE21 result file or the MIKE11 result file.

Summary
Overall the model has generally been built within the guidelines specified by DHI in training material and during provision of software support to software clients. With the following recommendations the model will be suitable to proceed with calibration and assessment of potential for severe flooding and flood hazard within Pinehaven.

Key Recommendations:

- Change the flooding and drying depths to 0.02 m and 0.01 m respectively;
- Remove the culvert structures that precede pipe cross sections;

- Change the Max dx value to 5m for all branches;
- Rectify non-monotonically increasing conveyance curves via cross section settings;
- Change the Delta value in Hydrodynamic Parameter file from 0.85 to 0.7;
- Review resistance values for pipes and culverts with a Manning's n of 0.015 and open channel cross section with a Manning's n of 0.2; and
- Review the mflateral.txt data to identify coupled locations with large differences between the MIKE21 bathymetry and MIKE11 cross section bank markers.

Please do not hesitate to contact me if you require further clarifications.

Yours sincerely,
DHI Water and Environment Pty Ltd

Mark Britton
MIKE FLOOD Trainer – Australia

Attachment A

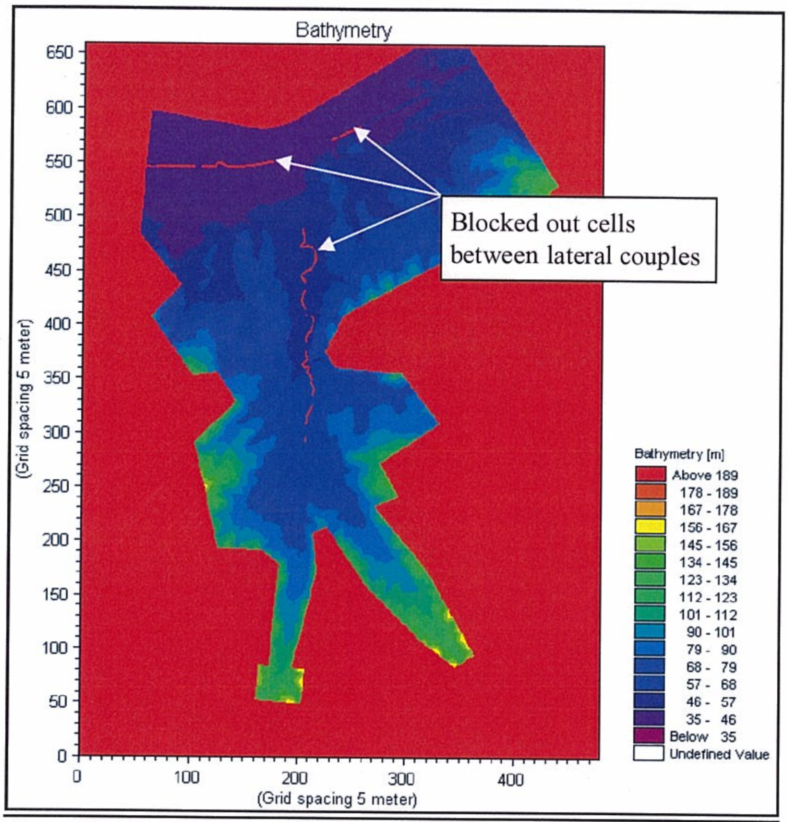

Figure 1 – MIKE21 Bathymetry

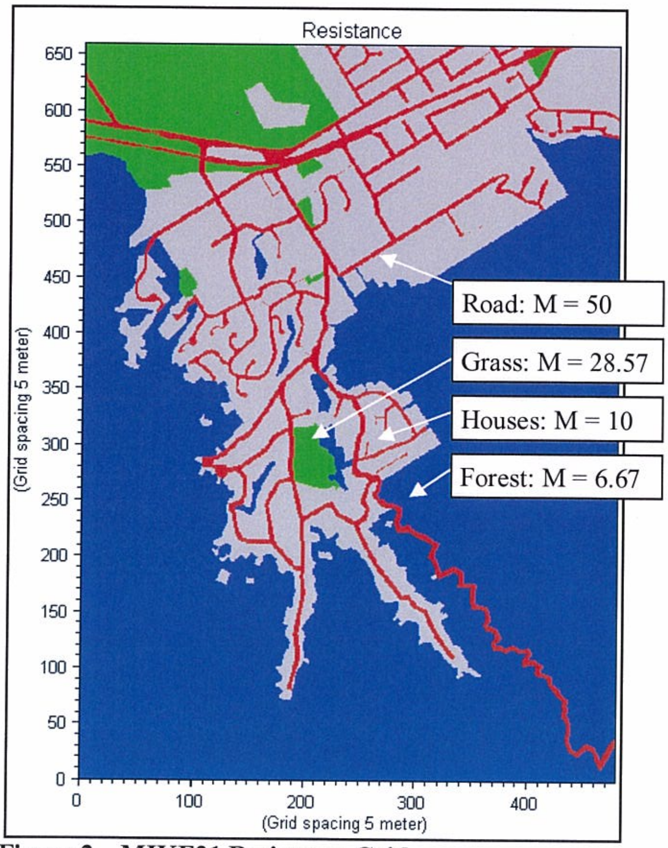

Figure 2 – MIKE21 Resistance Grid

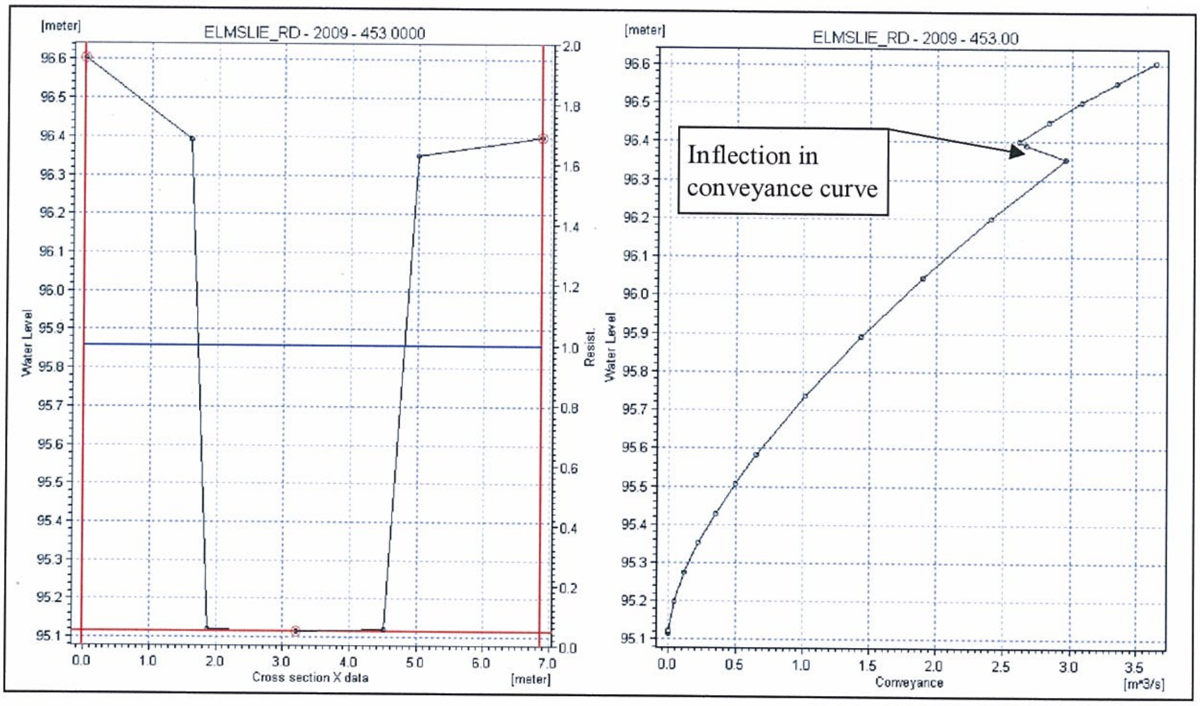

Figure 3 – Elmslie_RD CH 453 – Non Monotomically Increasing Conveyance Curve

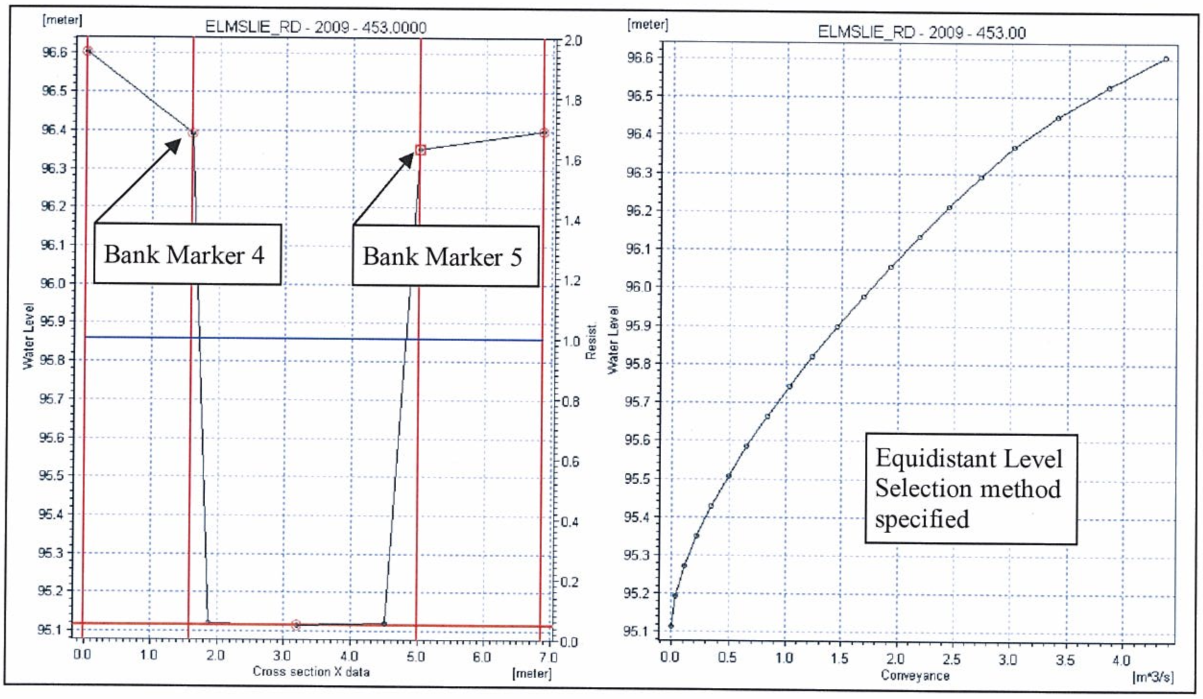

Figure 4 – Elmslie _Rd CH 453 – Rectified Cross Section and Conveyance Curve

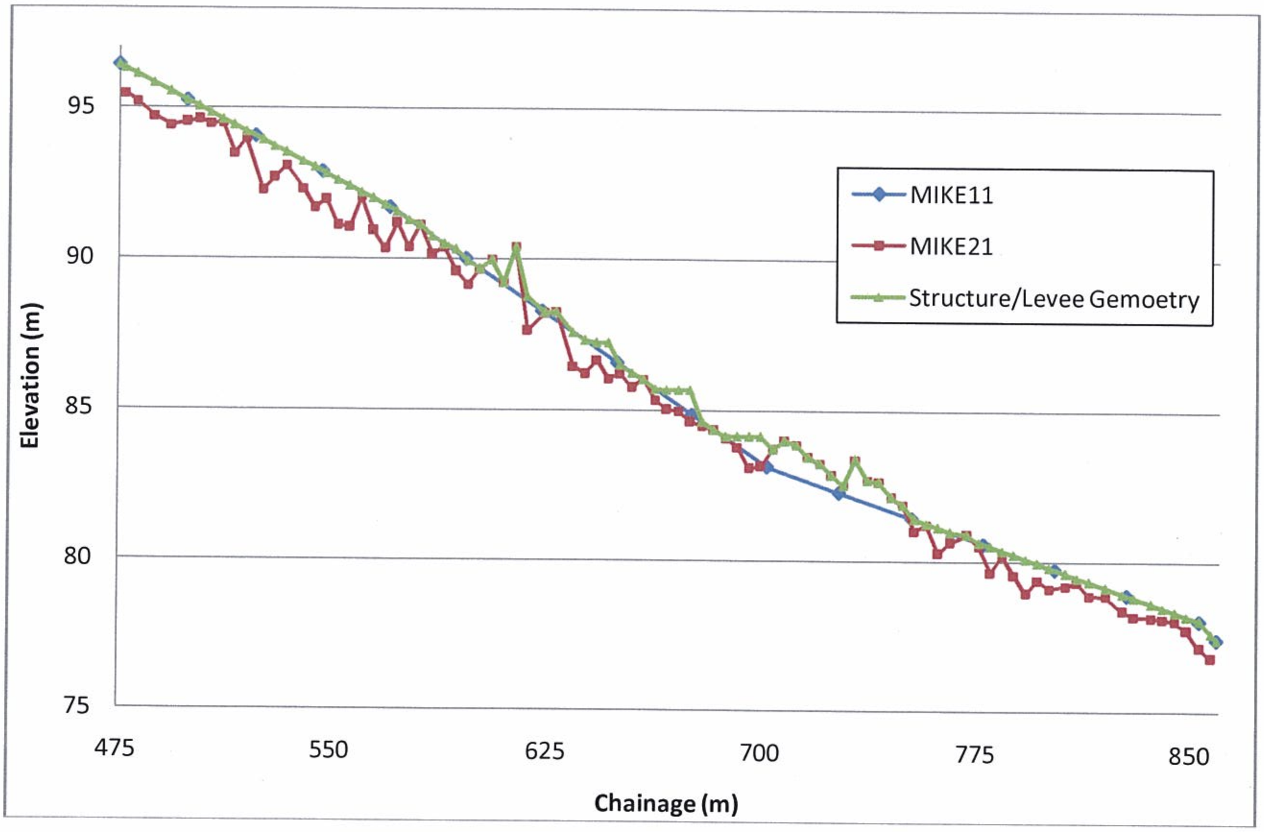

Figure 5 – Chart of Selected Structure/Levee Level verus MIKE11 and MIKE21 model levels for Elmslie_Rd 475 m.