14 CATCHMENTS BY ONE ENGINEER

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ABSTRACT

There is a constant trend to require complex hydraulic problems to be solved in more detail, which demands a higher degree of accuracy. Once an important tool which has now become essential for engineering is that of numerical modelling, which (when combined with powerful PCs and GIS tools) enables the engineer to complete complex calculations over large areas, quickly and accurately, providing clear graphics and summarized outputs.

The recent Northland Regional Council (NRC) Flood Risk Management Project is an excellent example of such a complex project, one which incorporates the latest technologies, integrated with hydraulic engineering knowledge and rich experience in the field. These three elements are the key for an efficient and well integrated approach to river catchment modelling.

The NRC Flood Risk Reduction Project included 22 River Catchments across the North land Region. URS was responsible for developing overall project methodology, leading the modelling and delivering 14 catchment Management Plans.

The success of this modelling focused flood risk management has shown the importance of building models by engineers. This paper will share our experience and knowledge gained by using the latest innovative technologies and GIS integration, from commencement through to the completion of developing a reliable product: a meaningful and efficient model.

KEYWORDS

River Modelling, InfoWorks RS, GIS, Northland Region, Hydraulic, URS

PRESENTER PROFILE

Jorge studied 6 years Civil Engineer with a Major in Hydraulics, Sanitary and Environmental Engineering from the University of Chile. His area of expertise is numerical and physical modeling, sediment transport, hydrodynamic, hydraulic, flood assessment and catchment management, among others, adding other 7 years of experience (Chile and New Zealand).

1 INTRODUCTION

It is our view that modelling is about generating knowledge and understanding from the data used. The amount of information and technology available is increasing rapidly. The model build process and methodology needs to develop close with these concepts, based in a constant review of hydraulic and hydrologic knowledge and the objectives to be achieved for each catchment.

The methodology for the numerical modeling of the recent Northland Regional Council (NRC) Flood Risk Reduction Project takes into consideration these basic and fundamental concepts, while an efficient use of the available resources.

The advantage of this methodology is that it uses the latest technologies integrated with hydraulic engineering knowledge and rich field experience. These three elements were the key for an efficient and well integrated approach to river catchment modelling.

This paper will share our experience and knowledge gained by using the latest innovative technologies and GIS integration from project commencement through to the completion of developing a reliable, meaningful and efficient model that serves as a tool for catchment management.

2 BACKGROUND

The NRC Flood Risk Reduction Project included 22 river catchments across the Northland Region. URS was responsible for developing the overall project methodology, leading the modelling GIS analysis, river management plans as well as delivering 14 catchment Management Plans (see Figure 1 of the 22 NRC priority catchments).

The presented methodology was originally developed for any software package. However the subsequent selection to use InfoWorks RS brought several benefits and in our opinion improved our project approach.

InfoWorks RS is a software package originally developed by Wallingford Software that combines hydraulic and hydrological modeling with geographical analysis (GIS).

The critical areas in which we have adopted particular techniques to deal with in depth issues include:

- Application of automated model build routines to complete a large number of project focused models built within a short time period (14 model builds);

- Sub-catchment rainfall runoff modelling and automated connection with river hydraulic models (over 400 sub-catchments, 13400 cross sections in 14 catchments);

- Critical data gaps analysis in various areas and proper application of survey and LiDAR data (more than 400 surveyed cross sections to create DEM of bottom part of rivers in critical areas);

- GIS integration (1 model database with many GIS layers); and,

- Mass result processing for flood hazard and risk mapping.

Figure 1 shows the 22 catchments

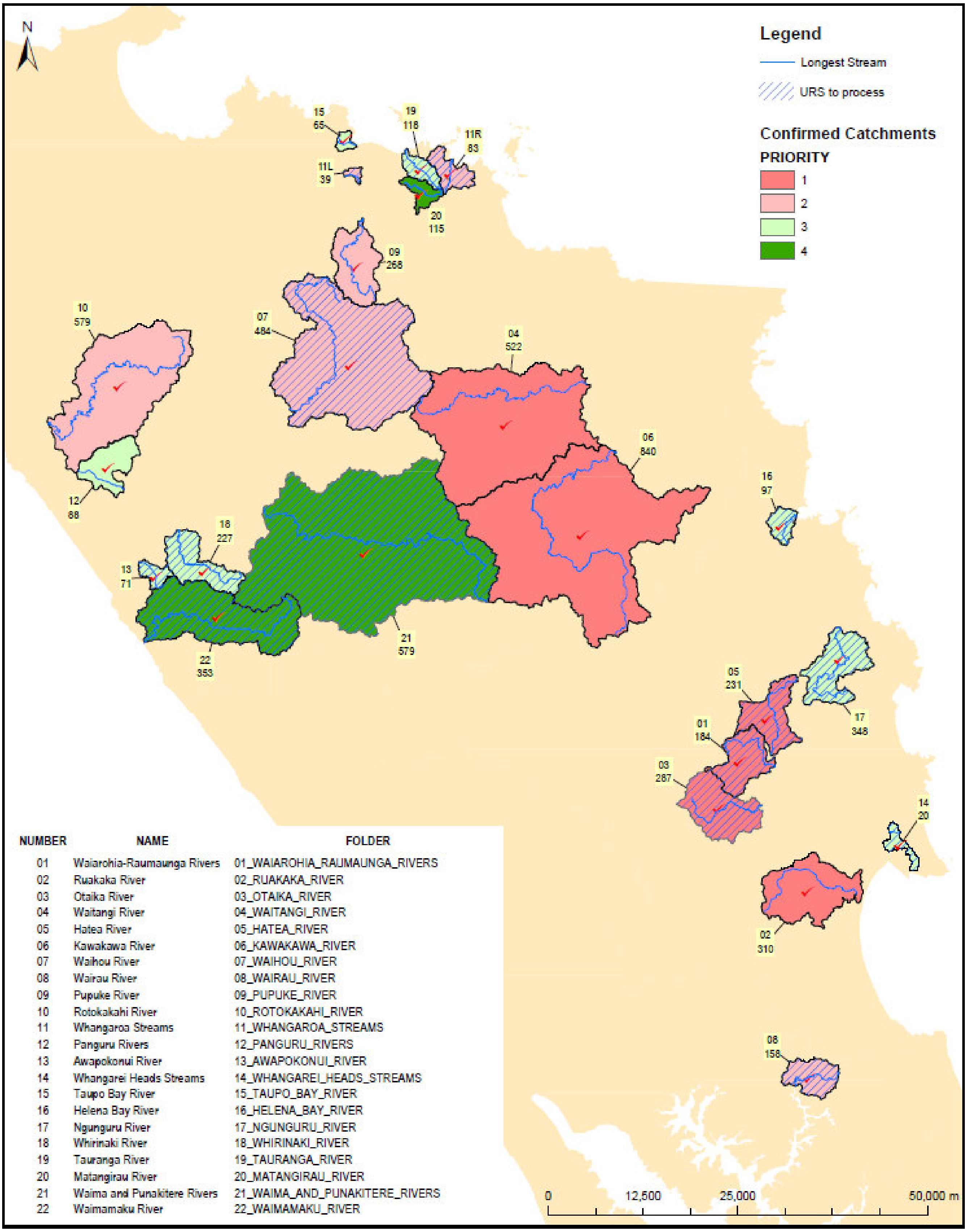

Figure 1: 22 NRC Priority Catchments

3 OBJETIVE OF MODELLING

The 22 river catchments were granted into 4 priorities, where detailed hydraulic flood models were required to be developed for the Priority 1 river systems (RFP issued by NRC).

It was anticipated that these models were to be developed for the use of:

- Flood hazard map production, maps to contain flood extents, depth, velocity and flood hazards (based on velocity and depth), all for a range of specified annual exceedence probabilities (AEP); and.

- Scenario modelling for analysis of flood risk reduction management options.

The four groups of catchments were defined by the NRC to be treated in different levels of detail. Priority 1 catchments were to consist of detailed models considering 2D features for all areas where NRC had defined flood interest areas and LiDAR data was available. For the Priority 2, 3 and 4 rivers, the detail and level of complexity was less demanding. However, similar modelling results needed to be generated to:

- provide a reasonable level of flood maps for the flood risk assessment;

- an evaluation of options to reduce flood risk where needed; and,

- to be further an developed for Early Warning System if needed

4 MODELLING METHODOLOGY

The modeling methodology sought to use the latest innovative technologies and GIS integration in order to develop an efficient model, one with an easy object manipulation via GIS tools which allows the modeler engineer to concentrate in a neat configuration and meaningful results.

The diagram in *Figure 2* shows the processes of the methodology and outlines the benefits of this approach.

Some of the advantages of this methodology are that:

- The modelling software utilized enabled the project team to develop a consistent modelling framework, one which will provide a solid basis for future model updates when needed;

- The 2009 LiDAR and available GIS data have made it possible to build detailed models for all catchments;

- Allows mass data processing in GIS, making fast and efficient the model build.

- The model itself incorporates a GIS structure which enables a strong link with GIS in both direction, to update/ upgrade the model; and to export and post-process result in GIS.

- Delivery of high quality consistently formatted flood maps for the current and future risk assessment, flood mapping and option assessment;

- Delivery higher quality models to client (NRC); and,

• Delivery of sound foundation for future model updates, management of the river systems and the opportunity for the application of future early warning systems.

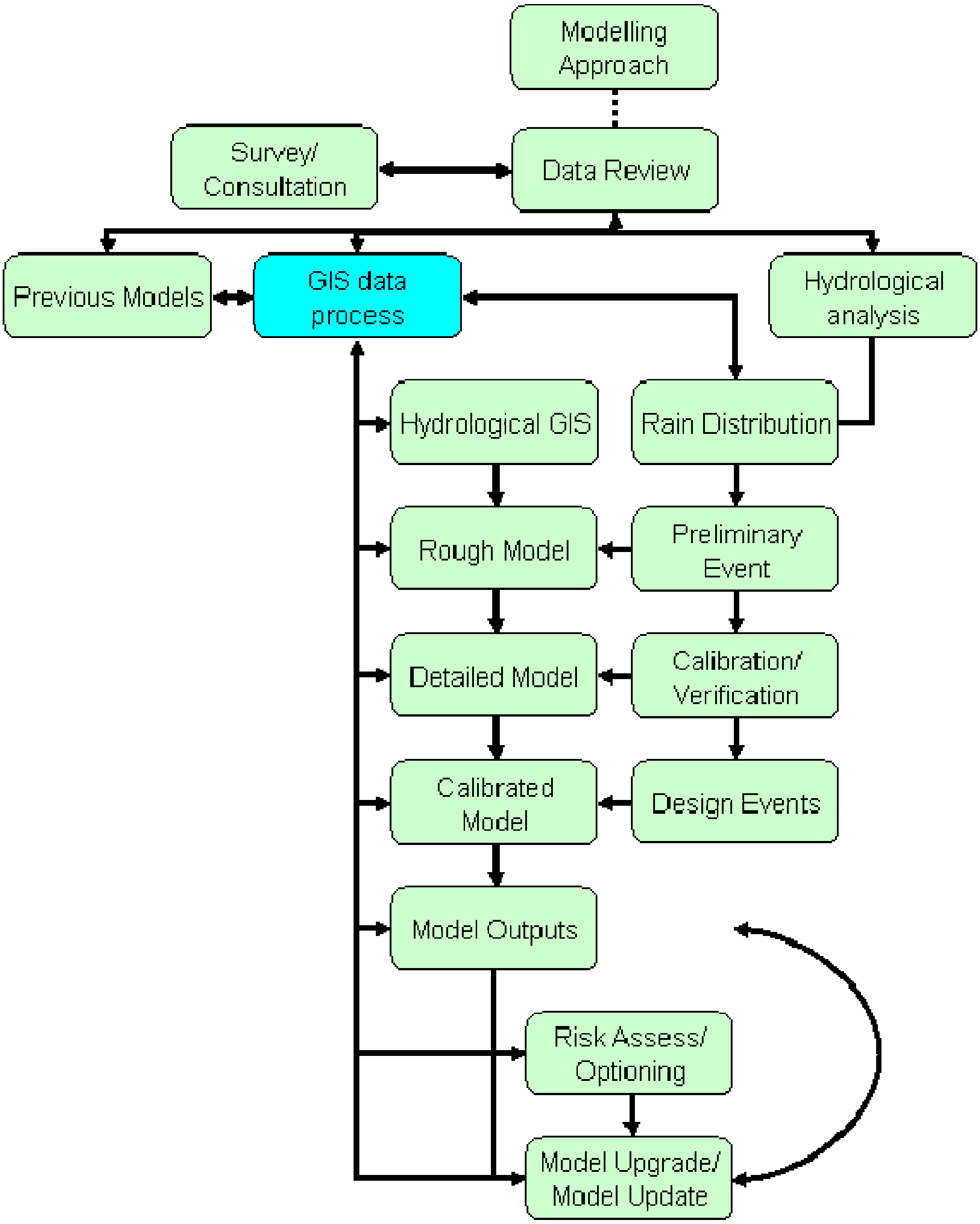

Figure 2: Diagram of Modelling Methodology

The method consisted of mainly of three interconnected branches of processes which have lead to the success of the modeling phase of the project, being: ***GIS data processing***, ***hydrology analysis*** and ***previous models information***, plus a fourth tasks that included the ***survey and consultation data***.

4.1 GIS DATA PROCESSING

Most councils rely on important existing GIS data that can be useful in a flood risk focused modeling project.

Some of the GIS data available for this project is listed below:

- LiDAR, 20m contours;
- Aerial photographs;
- Streams and river catchments boundaries based on 30m grids (NIWA);
- Hydraulic structure locations, bridge locations, dam locations (but no attributes);
- Geology, Soils, Hydrogeology;
- Drinking water Supply sources;
- Landcare septic model;
- Infrastructure, Roads;
- Power Supply;
- Sites of Importance; and many other ground layers.

Even before any modeling commenced, a close analysis of the data revealed much valuable information (land use, ground model features, flood complains, soil cover, aerial photographs, etc)

In general the data was of reasonably good quality for general use with GIS. However, further processing was needed for proper catchment hydrological and hydraulic model build. Some of the most important are listed below:

- The 20 m contours were sufficient to refine catchment boundaries, generate whole catchment ground model, and define sub-catchments boundaries;

- GIS stream lines provided a basis to define sub-catchments. Stream centre lines were improved based on the 15m grid ground model and the 2009 LiDAR. In a traditional 1D model the stream centre lines may not be important hydraulically, but are important when using GIS ground model, LiDAR data for model processing and result presentation;

- 2009 NRC LiDAR was converted into 1m grid. Original sets have a vertical accuracy of 15 cm. This provides a good basis to capture cross-sections profiles.

- 2009 cross-section survey data matched the LiDAR data reasonably well above the water level. Differences were shown below the water describing the channel, as was expected. However, the surveyed cross sections were of greater spacing than typically required in most river modelling projects. The surveyed channel below the water provided valuable information that was used to interpolate a below water level channel for the LiDAR generated cross sections (a DEM for bottom part of river). This process was performed for the Priority 1 main rivers between surveyed cross-sections (see *Figure 3*);

- GIS Land cover and Soil group. These provided ground information for estimating rainfall loss parameters for each sub-catchment; a look-up table was specified to define

CN values for sub-catchments based in these layers (ref example in Table 1). This table can be modified automatically to update sub-catchments in the calibration process.

- Rain gauge and flow gauge data was available, however the availability varied between catchments;

- Rain depth and areal reduction factor for design events, for each catchment, plus a rain distribution factor for each sub-catchment (refers to 4.2 Hydrological Analysis); and,

- Various reports describing historical flood events with photos. Flood level surveys were also available for some of the catchments. Some of this information is also linked to the model (Hyperlinks).

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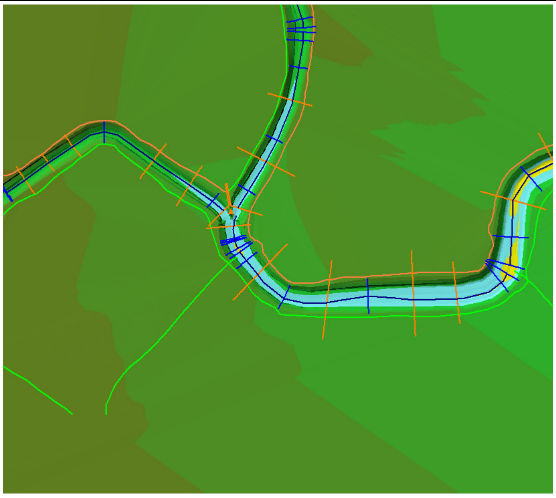
<td></td>
</tr>
<tr>
<td>1m Ground Model from LiDAR.
To be used for XS out of bank lines or where survey is not available</td>
<td>Ground model from survey.
To be used for bottom part of XS between bank lines.</td>
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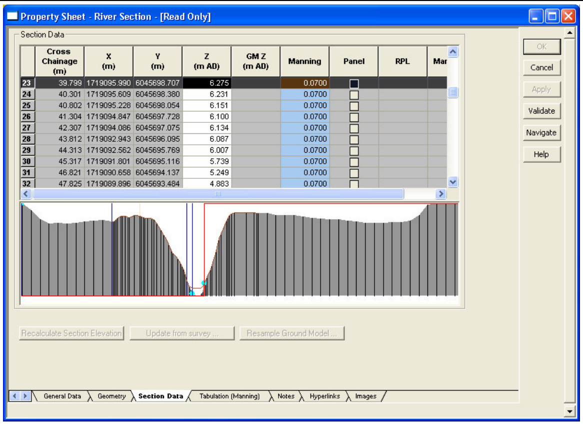
<td>
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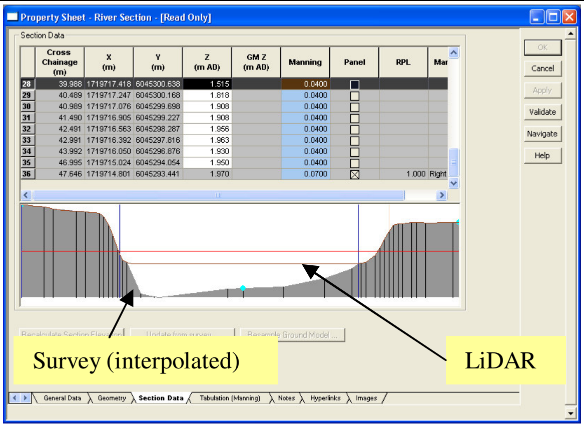
<td>
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<tr>
<td>Example of LiDAR XS and XS from ground mode from survey</td>
<td>Example of LiDAR XS and XS from ground mode from survey</td>
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</table>

Figure 3: Ground model for cross sections (LiDAR and survey)

Based on the previous information, the following shape files were derived using GIS by a hydrologist in preparation for the model build:

- Sub-catchment boundaries, including main channel length, slope, Tc & Tp (TP108 formulations); based on 20m contours;

- Stream centre lines (new and corrected based in 20m contours and LiDAR);
- Stream left and right bank lines, or digitalized from LiDAR where needed;
- Land use/cover map, soil map;
- Asset layers; such as properties, roads, farms, etc;
- River structures, bridges locations, etc;
- Image layers (for example, aerial photographs);
- Process of 2009 surveyed cross-sections;
- Previous model objects geo-referenced;
- Rain distribution factor for the design events for all sub-catchments, with areal reduction factor incorporated, and many others.

In addition, all non geo-referenced related information (i.e. photos, reports, etc) were organized in a specific folder structure that allowed the creation of an automated hyperlink between this information (example: survey photographs) and the respective object in the model (example: surveyed 3D line).

From this point of the process all information will be managed in GIS. *Figure 4* describes some examples of the GIS data processing and derivation.

Table 1: CN values for land cover available in GIS (sample)

ID	**Description**	**Average % Impervious**	**Curve Number by Hydrologic Soil Group**				**Typical Land Uses**
			A	**B**	**C**	**D**	
2	Residential (Med. Density)	30.00	57	72	81	86	Single-Family, Lot Size ¼ to 1 acre
4	Commercial	85.00	89	92	94	95	Strip Commercial, Shopping Ctrs, Convenience Stores
7	Agricultural	5.00	67	77	83	87	Cultivated Land, Row crops, Broadcast Legumes
8	Open Land – Good	5.00	39	61	74	80	Parks, Golf Courses, Greenways, Grazed Pasture
10	Woods	5.00	30	55	70	77	Forest Litter and Brush adequately cover soil
12	Impervious	95.00	98	98	98	98	Paved Areas, Shopping Malls, Roadways

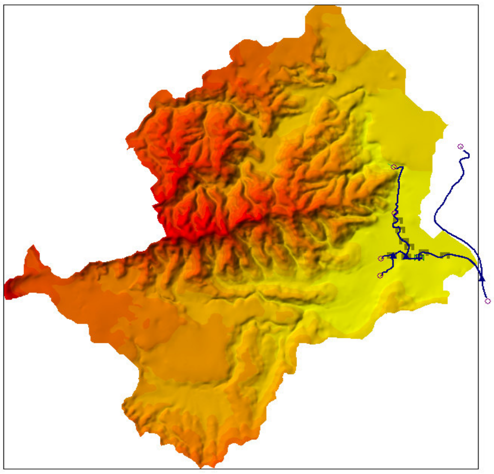
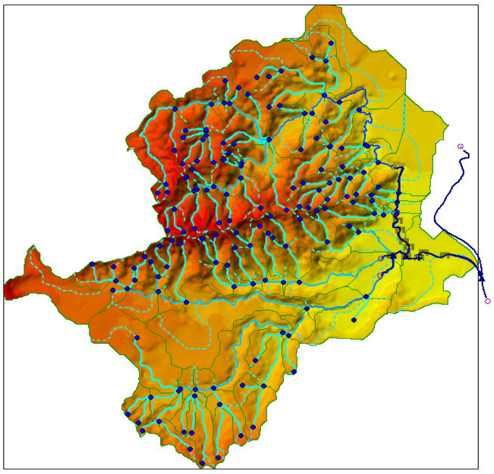
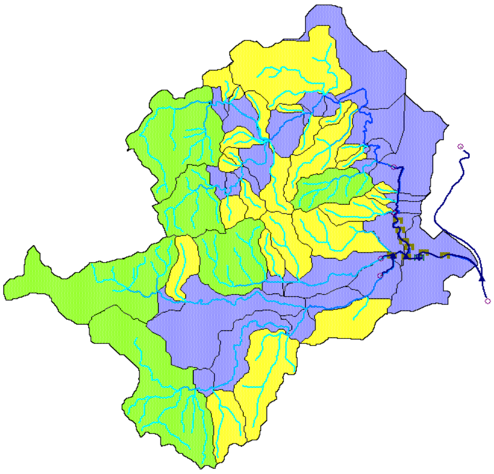
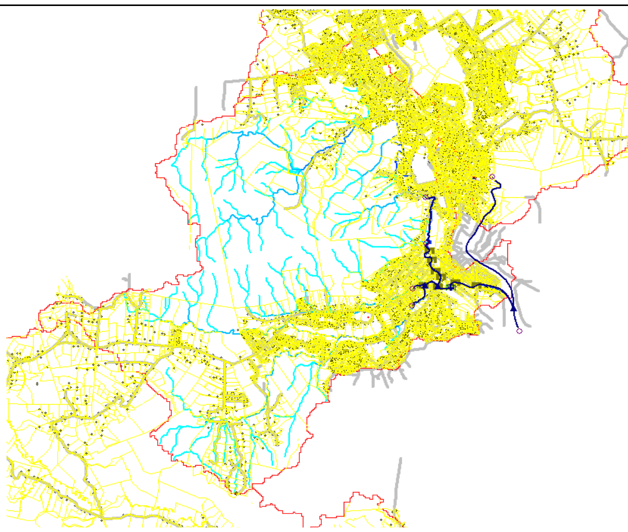
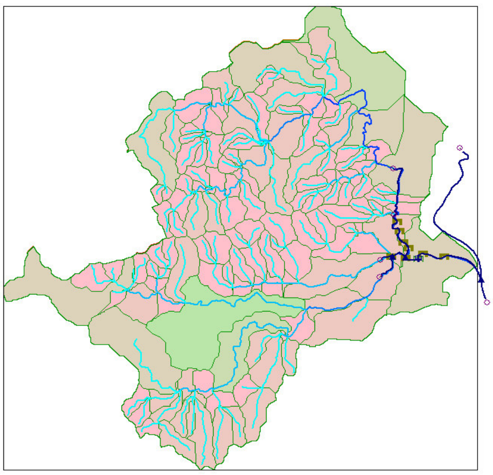
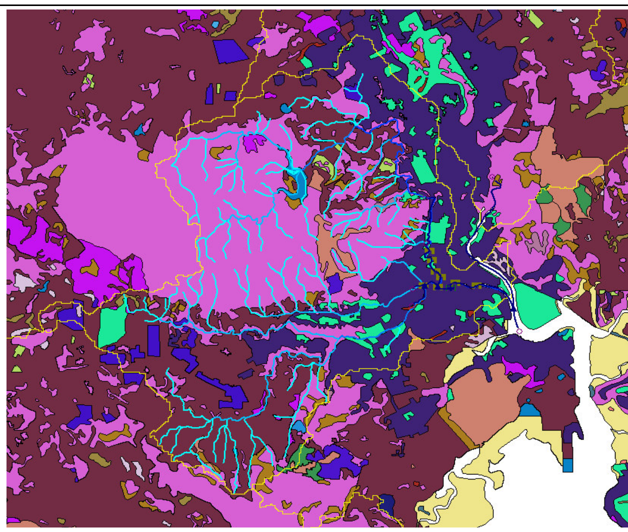
	
Ground Model (GM) from 20m Contours	Catchments and streams from GM
	
Hydrological Model (inflow type)	Road, services, parcels (Information GIS layers)
	
Hydrological Model (time of concentration)	Land cover for CN values estimation

Figure 4: GIS data processing and derivation

4.2 HYDROLOGICAL ANALYSIS

The hydrological data is usually dense and fragmented hence demands careful treatment. However it is processed, hence can be separated into two tasks, being: calibration events and design events. Each requires rain depths, rain profile and rain distribution. All three of them become quite complex for big catchments when storms are moving and changing constantly over the catchment area. Additionally, pre-storm-conditions are also important to establish a proper relationship between rainfall and runoff.

4.2.1 CALIBRATION/ VERIFICATION EVENTS

Rainfall runoff model results ware calibrated with available flow data for a range of events. The calibration results were then used as reference for catchments with insufficient flow data for verification.

Calibration and verification storms were selected from available information taking into account the spatial and temporal distribution using all rain gauges with sufficient data. Rain was distributed over the sub-catchments using Thiessen polygons in GIS.

4.2.2 DESIGN EVENTS

Design rainfall data was verified with consideration being given to elevation and area factors by rainfall records within the whole Northland region.

A design rain profile was developed for a third party and storm durations were defined in accordance with NRC.

All design parameters (i.e. rain depth, rain distribution factor, areal factor, storm duration) were imported to InfoWorks through GIS tools. This information was processed with the rain profile into a routine to create all design events for all 22 catchments for 2, 10, 50, 100 and 200 years (100 years plus climate change) AEP, and then exported directly into InfoWorks RS.

4.3 PREVIOUS MODELS, SURVEY AND CONSULTATION

Traditional 1D models don’t require to be geo-reference as the 1D engine only required a schematic representation of the river system. However, the modeling approach for this particular project was Geographic Information System (GIS) based and hence information was maintained as geo-referenced.

For that reason, cross section, river centre lines, structure location and any useful information related to previous models, was all required to be geo-referenced and manipulated in a GIS structure.

Similarly other project inputs, such as surveys and consultation information, were also treated in a similar fashion as they were considered to be processed in a GIS structure.

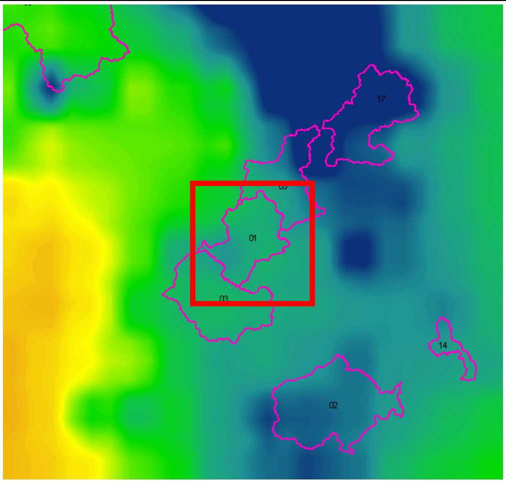
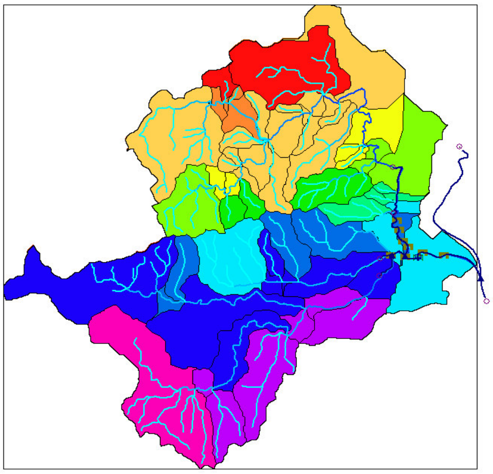
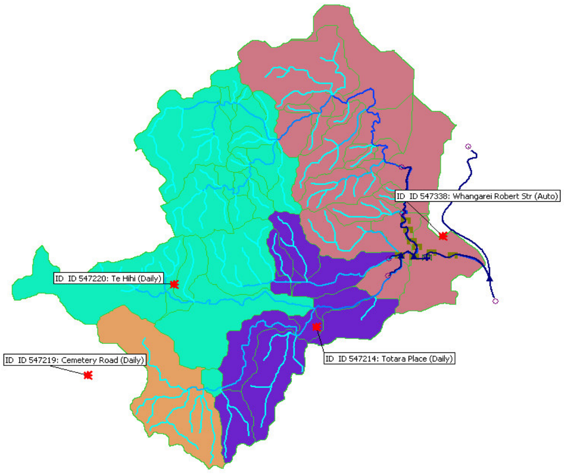
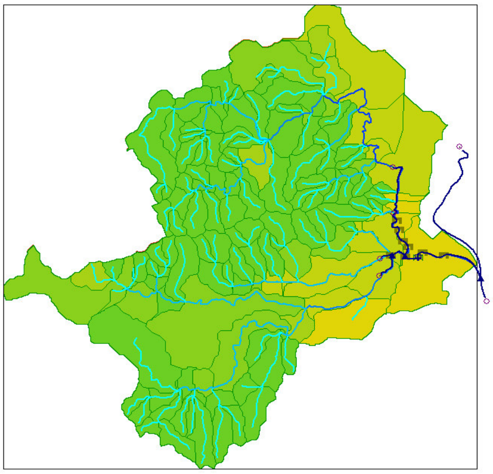
	
Rain distribution for 100yrs event (NIWA)	Rain distribution from 100yrs rain distribution (NIWA)
	
Rain gauge for each sub-catchment (Thiessen Polygons)	CN values (from land cover)

Figure 5: Hydrological GIS data derived

5 MODEL BUILD

Within InfoWorks RS, the components that make up a model of a river network are divided into three separate but closely related database items.

Figure 6 shows a basic InfoWorks RS model structure. The items are:

- The Network Database item: defines all the physical aspects of the network that do not change over the time frame of a simulation, such as the parameters of a bridge, or a channel cross section, etc. Changes to the network are made by creating different versions of the network.

- The Event Data item: defines aspects of the network that vary with time during the simulation (i.e. rain profile, tide levels, discharge curves, inflows, etc), and information about the initial state of the network at the start of the simulation.

- The Logical Control Data item: contains rules used to control the more complex operations of some network structures. The Logical Control Data is only required if there are structures in the model that use complex control rules (i.e. pumps, valves, etc.). This NRC Priority Rivers did not require this type of controls.

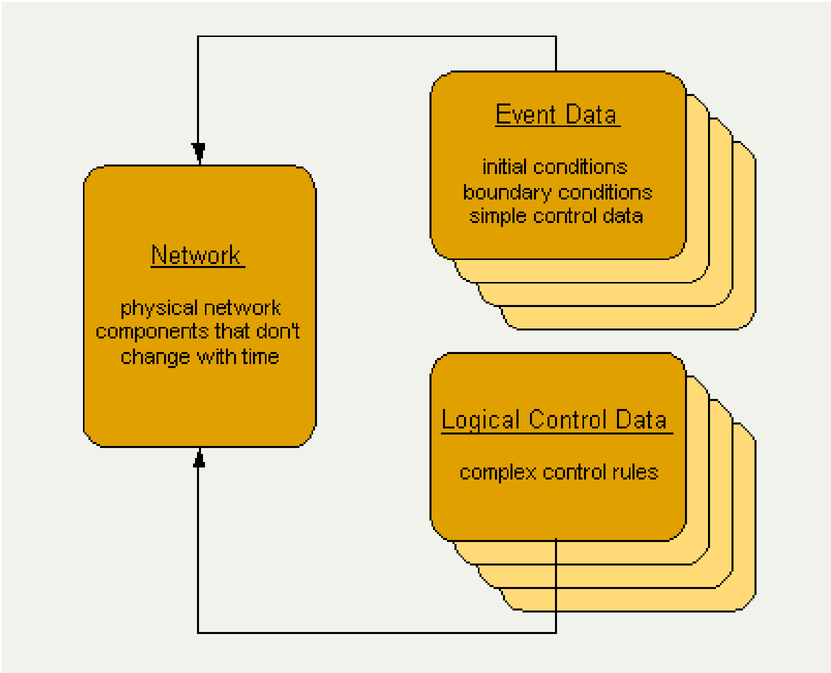


Figure 6: Basic InfoWorks Model Structure

The Figure 7 shows a diagram of the basic structure of a river network InfoWorks RS model.

Critical objects are:

- Sub-catchments: We defined three types: Type 1 for lateral point inflows, Type 2 for upstream point inflows and, Type 3 for lateral distributed inflows.

- Cross sections: These can be created from survey lines or LiDAR.

- Links: connections between different objects require different type of links (connectivity, river link, lateral flows, bridges, etc). They can be created using river centre lines or automatic routines.

- LiDAR: It has an important role in cross section levels, storages volumes and flood mapping, amongst other objects and variables.

- Boundary Nodes: They contain the boundary model to be applied over the hydraulic model. It can be set for different hydrological models, inflows, levels, infiltration, etc. It is directly linked to time dependant parameters held in the Event Data.

- Others objects such as orifices, weirs, bridges, culverts, spill ways, pond, and storage areas etc are also added to the model and connected by links, connectivity links, junctions and spill links, depending on each situation.

A River Network object can be addressed to different Event objects or Logical Control rules.

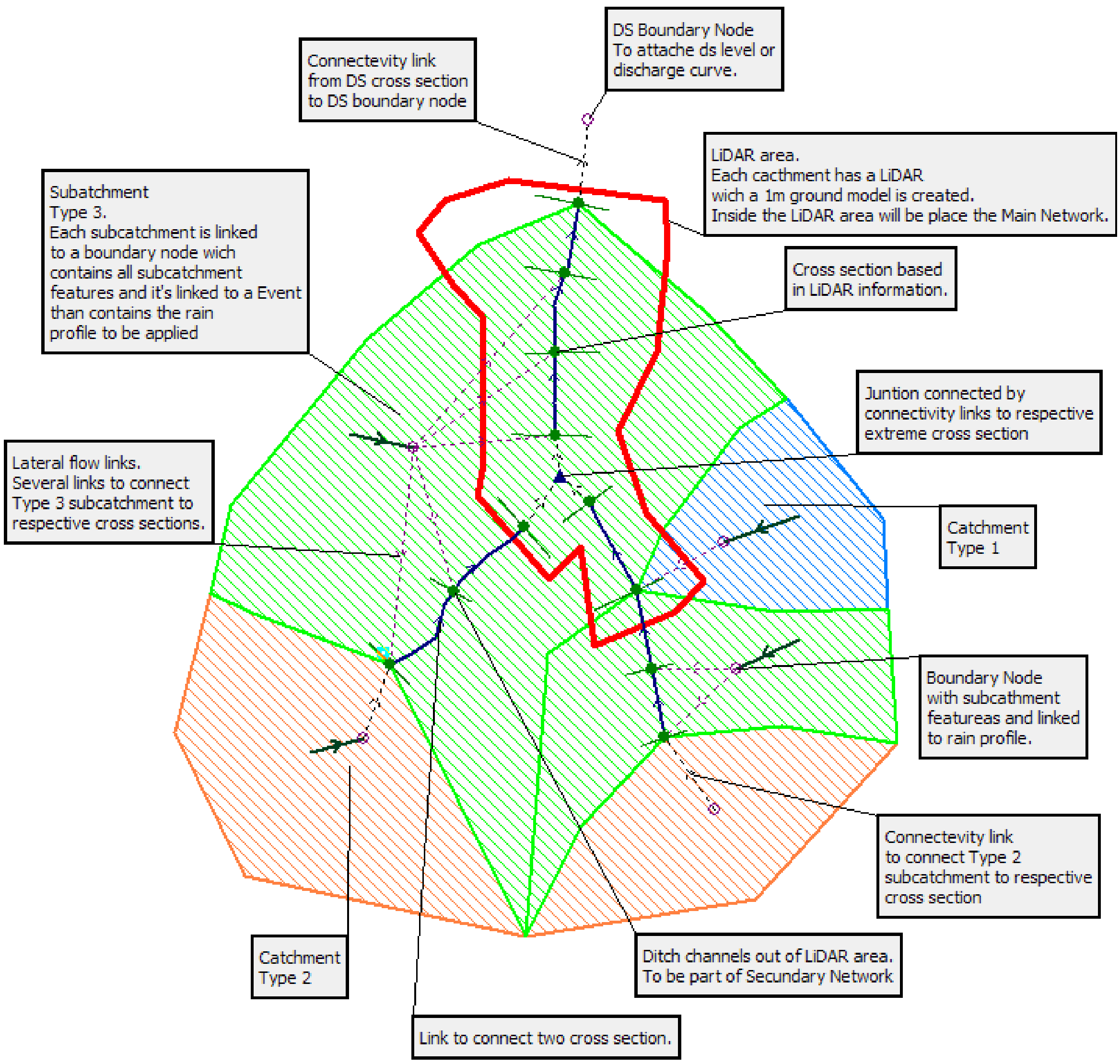


Figure 7: Basic structure of river network in InfoWorks RS

5.1 HYDROLOGICAL MODEL

In InfoWorks RS, the US SCS Method Hydrological Boundary is a hydrological model for determining runoff from rainfall for a sub-catchment using the United States Soil Conservation Service (US SCS) unit hydrograph method. It is used as an upstream boundary condition producing output equivalent to a Flow Time Boundary.

The hydrograph produced by the US SCS Boundary can be viewed prior to use as a table of values or a graph on the Calculated Hydrograph Page or the Calculated Hydrograph Plot Page of the Boundary Node Property Sheet. InfoWorks carries out a limited Boundary Mode simulation to generate the hydrograph.

To achieve a well defined hydrological boundary node, all parameters were derived in GIS using the data available (CN values, distribution and areal factor, time of concentration, etc), and exported directly into InfoWorks RS using GIS tools for all 14 catchments.

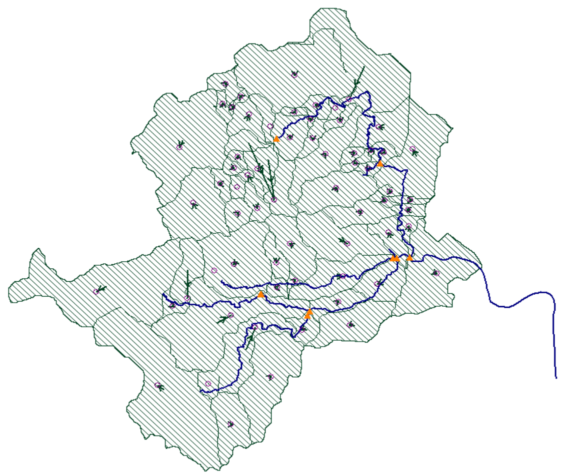
5.2 ROUGH MODEL BUILD

Based on the GIS information previously processed and derived, the rough model build responds to a well defined structure which can be obtained with logical routines that can be programmed and applied on mass for all catchments. Data is flagged to indicate the different sources of information improving source data analysis of results.

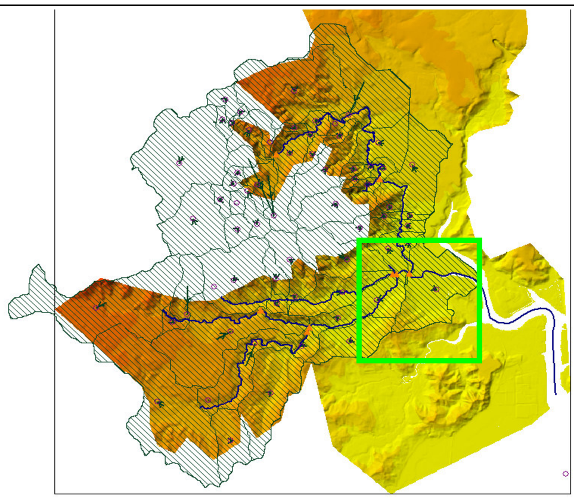
Figure 8 shows part of the sequence of a rough model built.

Rough models were anticipated to provide a good review of the available data and help identify critical data gaps for modelling.

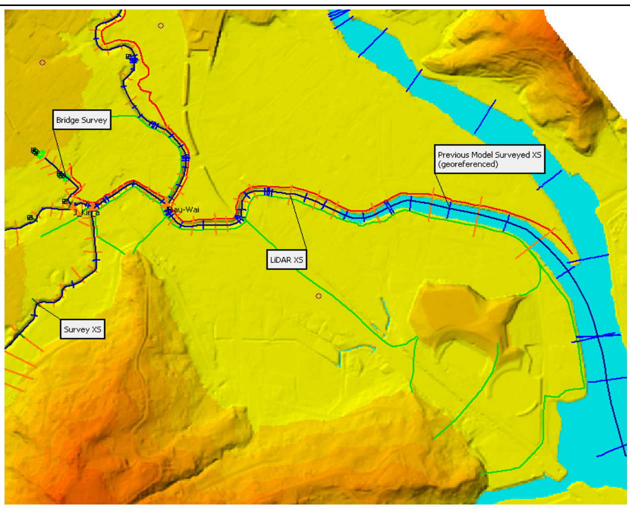
Rough models produced flood maps. These initial maps were used by NRC staff in order to check for issues from staff and input community local knowledge. Comments were sought on identified areas for further model improvement during the detailed model stage.



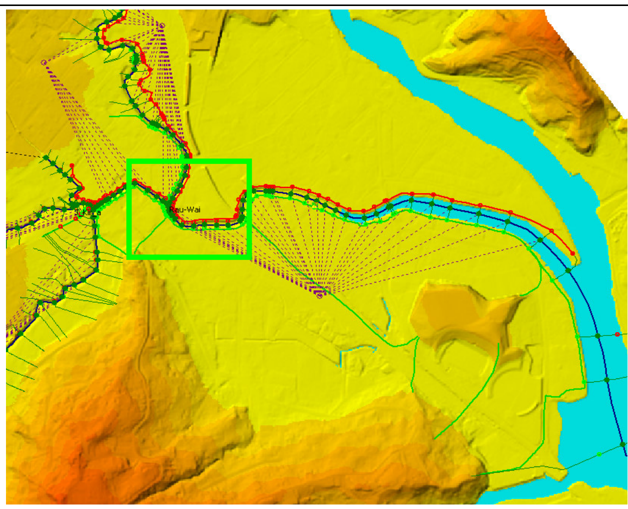
River centre lines, junctions, boundary nodes & sub-catchments from GIS



LiDAR added for detail modeling (detail frame from next image)



Surveyed XS, XS from LiDAR and left/right bank lines from LiDAR



XS for modeling. Automated linking (detail frame for *Figure 9*)

Figure 8: Model built from GIS

5.3 DETAIL MODEL

In addition to the integration of GIS features to the modeling construction, there are some other aspects of interest in the detailed model build process. The assumption and simplification of the general hydraulic equation are important for any 1D model. It is important to not make the potential error of hiding modeling capabilities behind the impressive graphics outputs.

The base of any hydraulic model is the hydraulic equations, which primarily include:

1. Mass equation; and
2. Momentum equation.

The assumptions for most hydraulic 1D numerical models are:

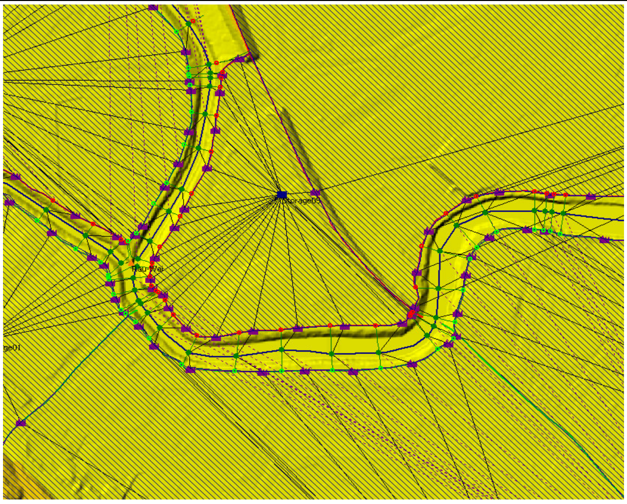
- Gravity acceleration is constant and equal to *g*. hile this may be obvious for most situations, there are other situations which may not be consistent with this assumption (research purposes).
- Water is compressible and homogeneous.
- 1D problem. The flow level and speed are constant along the cross section.
- The bed slope is small and $\cos(\delta) \approx 1$, where δ is slope in long profiles (not applicable for hydraulic jet ski)
- The length of dynamic waves are big compared with water depth, allowing to negligee vertical speeds and assuming hydrostatic water pressure (not applicable for dam break).
- Lateral inflows are not important in the momentum equation

Simplifications for most hydraulic numerical models include:

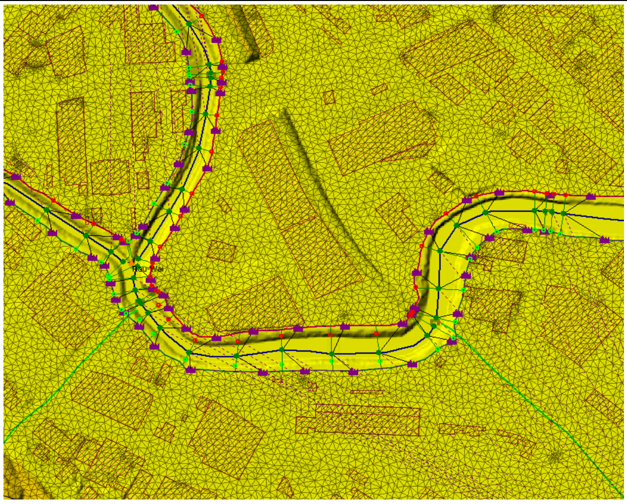
- Water flows from sub-catchments to river and from river to flood plains.
- Most models have simplified hydraulic equations to solve only subcritical flows (i.e. real supercritical flow can not be solved).
- 1D models requires a good representation of cross sections to allow accuracy in effective flows v/s wet areas, volumes between cross sections, main channels and flood plains. 1D models remain in the concept of parallel flow.
- Most numerical models consider that changes of width along rivers are smooth, so contractions and expansions are not well represented unless a coefficient is specified. Head losses for contractions, expansion or severe bends need special treat.
- Numerical simplifications. The model can not solve hydraulic equations. Instead it solves an approximation of it; and many others.

GIS tools are still useful for the detail model build, as the data processing is only limited by GIS capabilities. This scheme of work allows the hydraulic engineer to focus on the modeling features for a superior configuration and meaningful results.

Figure 9 shows and example of detail model build. Table 2 shows some information of the 14 catchments detail models processed all together under this scheme.



Spills and storages areas from left/right bank lines. Automated linking



2D zones from Storages areas, and more…

Figure 9: Detail Model

Table 2: 14 catchments and some modeling features

Catchment		Catch. Area (ha)	No of Sub-catch.	Max Sub-Catch. Area (ha)	No of X-Secs	Surveyed X-Secs
01_WAIAROHIA_RAUMAUNGA_RIVERS		4337	63	369	792	160
03_OTAIKA_RIVER		6215	150	484	947	99
05_HATEA_RIVER		4296	117	403	1486	92
07_WAIHOU_RIVER		27899	314	2225	3512	16
08_WAIRAU_RIVER		2700	56	185	984	12
11_WHANGAROA_STREAMS	Wahinepua	560	13	107	293	0
11_WHANGAROA_STREAMS	Wainui	688	23	136	308	0
11_WHANGAROA_STREAMS	Te Ngaire	587	21	79	246	0
13_AWAPOKONUI_RIVER		1000	42	132	257	0
14_WHANGAREI_HEADS_STREAMS		962	31	52	Full 2D	0
16_HELENA_BAY_RIVER		1272	62	95	850	0
17_NGUNGURU_RIVER		5384	174	286	1526	6
18_WHIRINAKI_RIVER		4290	155	209	1594	6
19_TAURANGA_RIVER		1371	41	151	666	0
21_WAIMA_AND_PUNAKITERE_RIVERS		51691	235	2784	Full 2D	13
22_WAIMAMAKU_RIVER		13261	150	1029	897	0

6 SIMUATIONS

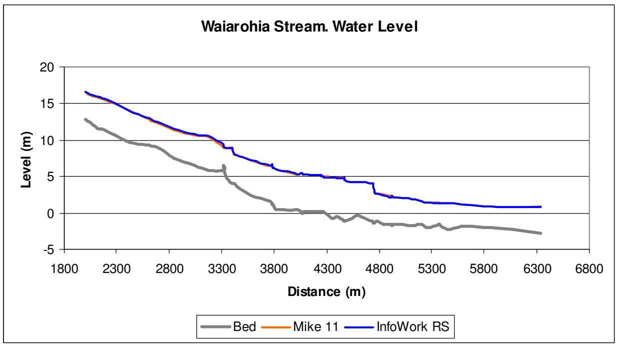
6.1 CALIBRATION/ VERIFICATION

Hydrologic and hydraulic models were calibrated based on available data records. The main parameters to calibrate were:

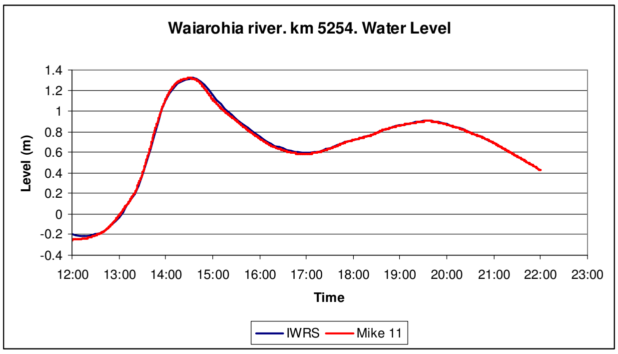
- CN values (for a US SCS hydrologic model);
- River roughness (manning);
- Structures (operation or singular losses); and,
- Time of concentration to be reviewed if found to be critical.

Model calibration and verification for Priority 2, 3 and 4 catchments were simplified dependant upon the available data in a particular catchment. For theses catchments, calibration parameters were estimated based on the gained experience of the calibrated catchments processed with similar features.

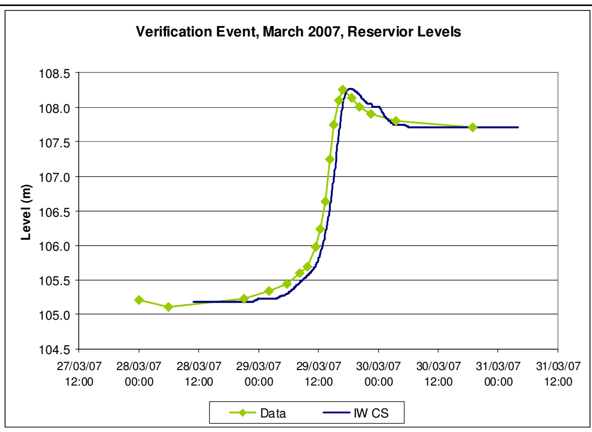
For those catchments that had a previous model, flow series, level series and long profiles were also used to calibrate early stages of the model build, where InfoWorks RS had the same features as the previous model.



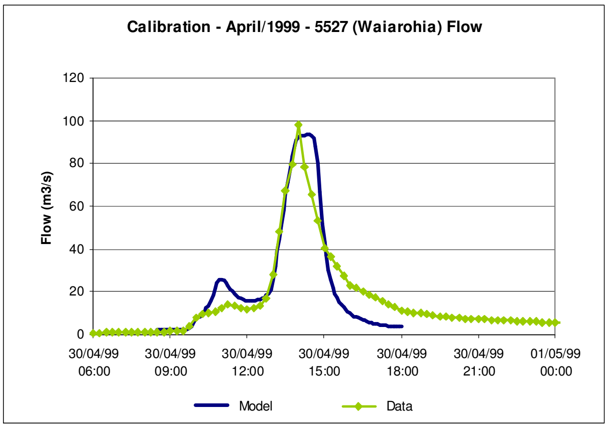
Long profile. Previous model v/s InfoWorks RS model



Water Level series. Previous model v/s InfoWorks RS model



Reservoir level. Recorded levels v/s InfoWorks RS results



Flow station. Recorded flows v/s InfoWorks RS results

Figure 10: Calibration/ Validation

6.2 DESIGN EVENTS

2, 10, 50, 100 and 100 years ARI's with climate change was run for all Priority 1 catchments. For all the rest, just 10 years and 100 years ARI's with climate change were modelled.

6.3 RESULT ANALYSIS AND RISK ASSESSS

Flood maps can be directly created in InfoWorks RS (i.e. flood depth, flood extent, flood levels) and exported to GIS for further touch up if required. Flood risk assessment and mapping can also be carried out in GIS.

In GIS, post processing can include an unlimited combination of GIS layers to query flood depths in parcels, hospitals or other key infrastructure; maximum levels in a property parcel; level in rivers; risk in urban areas, etc.

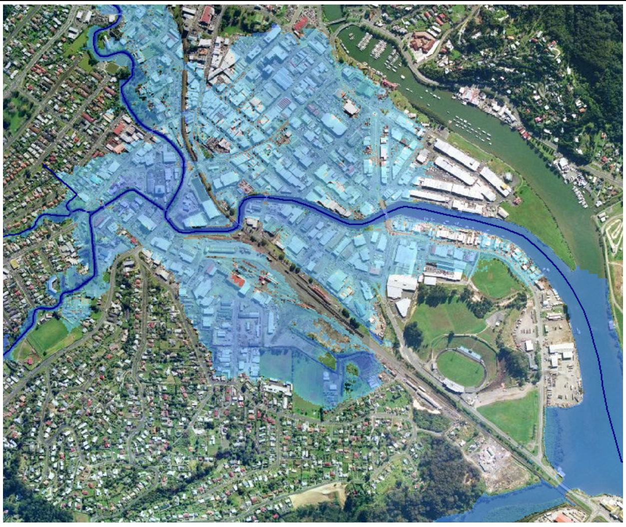
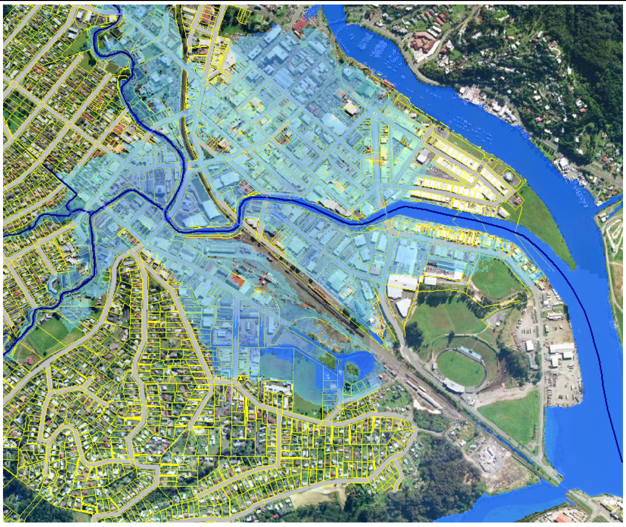
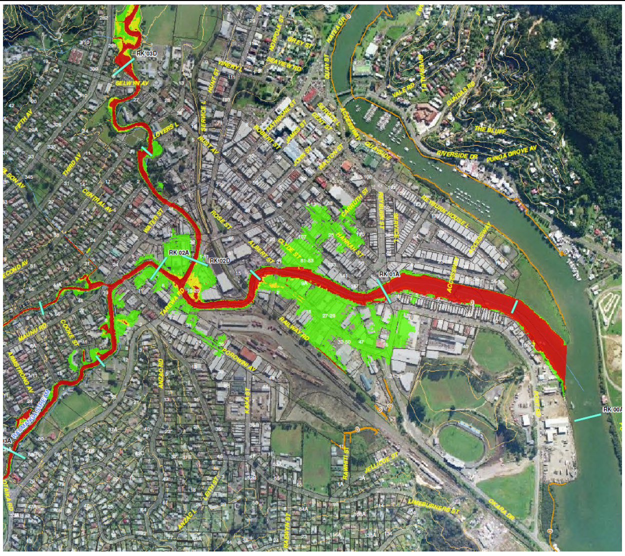
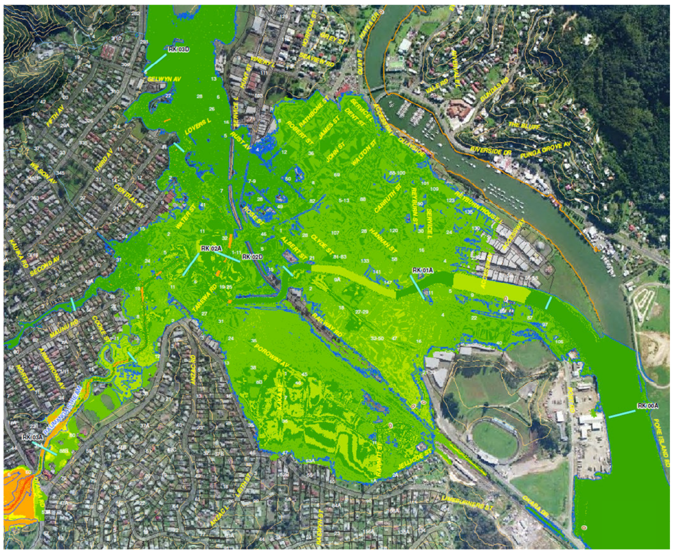
	
Flood map. Depths.	Flood depth and property parcels.
	
Risk function.	Option comparison. Grade of influence.

Figure 11: Result analysis in InfoWorks RS and GIS.

7 CONCLUSIONS

The project methodology that we have presented here was originally developed for non specific modeling software package. However the subsequent selection of InfoWorks RS enriched the benefits of the project outputs and made modeling tasks easier, allowing the hydraulic engineer to focus in more meaningful outputs.

GIS centralized most information going to, and coming from, the InfoWorks RS models. This provided not only a high degree of accuracy, but also the ability to constantly update or upgrade the models.

Model builds were focused in order to achieve a good representation of hydraulic features and elemental equations. Using the GIS interface of data with modelling, the model build became: much easier and systematic; avoided typing errors and long manual data inputs, plus placed emphasis on an easy object manipulation, which allowed the engineer to concentrate on a tidy configuration and accurate results.

The post processing of the results in GIS allowed the engineer to perform unlimited analysis and to manage results for different purposes. Flood maps, flood depths, flood risk (based in velocity and depths), property parcel with flood levels, and risk assessment in GIS format that could be used for survey or consultation, were some benefits of this approach described.

The model features will not expire and can be only updated based in new survey, GIS layer, consultation, flood complaints, etc. The models can therefore be constantly upgraded and evolve with the technologies as they become available and growing databases.

The InfoWorks RS software package integrated GIS tools in order to manage geo-reference information in all within one package, in a user friendly environment with multiples features.

The fact that all project information was managed in GIS for a hydrologist and the modeling completed for a hydraulic engineer meant that the process of model build, calibration and results analysis, was efficient, accurate and quick.

Through this methodology, 14 detailed models for 4 priorities were built in InfoWorks RS, calibrated, run for design events and processed in GIS in only 9 months, being left only review and particular issues derived of data gaps.

"14 Catchments by One Engineer" is considered as an apt description of the technical skills and technology, coupled with engineering knowledge and field experience. In summary, the exposed methodology described proved to be efficient and quick, taking the best use of available information, in combination with knowledge and experience to produce accurate and meaningful modeling results.

Currently, the level of information available in most councils and technical organisms is capable to support this GIS based methodology.

In the near future, we can expect to count with databases able to provide, for example, statistic of rain depth in a good temporal and spatial resolution; those will allow us to improve hydrological data analysis, calibration/verification processes and evaluate more realistic scenarios, etc.

The effort to develop better and efficient resources management should be put into improving the way we manage data (from councils to consultants and all involved organisms) in all areas of information (gauges, survey, terrain, property data, services, complaints), and all areas of knowledge (meteorology, hydrology, hydraulic, demography, water quality, air contaminants, etc) to achieve a level of analysis according with the actual and increasing demand levels of precision and efficiency.

Never the less it is important and critical to count with well trained professional and technicians able to move forward with current technologies and knowledge; and be able to couple information, technology and knowledge to achieve the required targets.

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