Red Bluff Creek Flood Mapping

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Waterways and Land Investigations

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Executive Summary

The report was developed to summaries the results of the Red Bluff Creek Flood Mapping Project completed 2014. The project area covered Red Bluff Creek (DR 2500), unnamed Creek (DR 2504) and tributary.

The aim of the project was to investigate the flood behaviour of the 100 year ARI flooding from Melbourne Water drain. The project was set as a flood mapping project for the area to generate the flood information.

The main catchment for the model area is Red Bluff Creek catchments. RORB model were developed for this catchment to generate hydrographs for the hydraulic model. The results from the RORB model were input into the HEC RAS and TUFLOW model for a 100 year Annual Recurrence Interval (ARI) flood event.

The hydraulic modelling was completed using HEC RAS and TUFLOW. The TUFLOW model extends from Westernport Bay to 5km upstream and continuous combined with HEC RAS model to 3km upstream.

As part of the final submission, the 100 year flood levels, flood extent, flood contours, water depths, velocities and V x D (site and access safety) were generated from the modelling and to be uploaded to Melbourne Water GIS system.

Table of Contents

Introduction

The project is currently unmapped waterways within the area of Melbourne Water drainage responsibility. There was existing mapping for Red Bluff Creek (DR 2500), unnamed Creek (DR 2504) and tributary which is covered by the sea level rises mapping from Westernport Bay. Given that, the Waterways & Land Investigations would take this opportunity to update the new flood mapping that including all the waterways and tributary.

The project was setup using the Melbourne Water MGA 94 Projection.

Scope of Works

The scope of the mapping project included the following:

- Mapping of the Red Bluff Creek (DR 2500), unnamed Creek (DR 2504), including tributary designated as of Melbourne Water drainage responsibility so that flood levels, flood extent, flood contours, water depths, velocities and V x D (site and access safety) can be added to the GIS data.

- Develop a RORB model that represents the existing conditions for Red Bluff Creek (DR 2500), unnamed Creek (DR 2504) and tributary.

- Develop the hydraulic model (HEC RAS and TUFLOW) to access the flood behavior of the area for the 100 year Annual Recurrence Interval storm event.

- Provide relevant information (final deliverables) to the Waterways & Land Flood Mapping & Mitigation to allow the update all the flood information.

Catchment & Drainage System

Summary of Data Sources

The following data was used in this study:

- Elevation and drainage alignment information from Melbourne Water GIS.
- Lidar survey information (Westernport, AAMHatch, 2007 and Bass/Neerim, AAMHatch, 2006)

LIDAR data and DTM

The available LIDAR was exported as a points file to be used in the different applications. Digital Elevation Models (DEM) or a Triangulated Irregular Networks (TIN) was developed to define the existing surface level and modelling purposes.

A DEM was developed, with a resolution of 1m, by the special analysis software Engage 3d to be used as the basis for defining the model surface for TUFLOW.

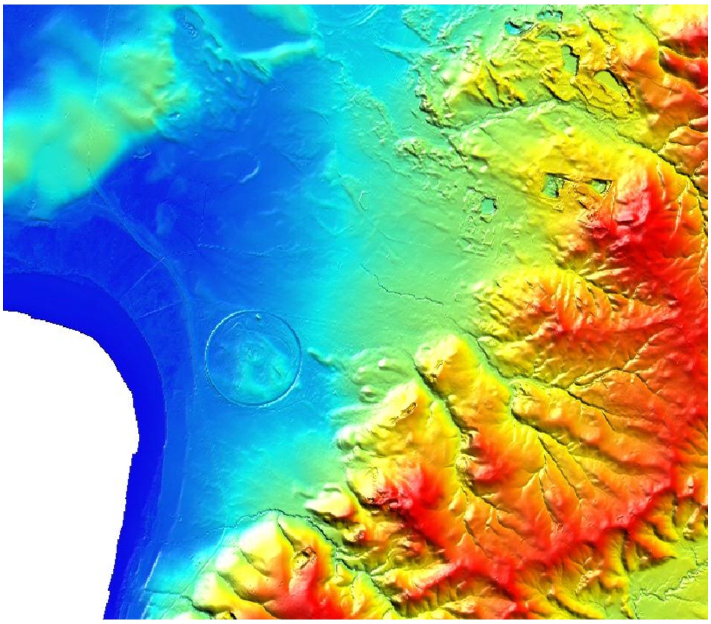


Figure 1 – LIDAR surface DEM

Hydrology Modelling

Introduction

The RORB hydrological model version 6.15 was used for this study. RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It works by subtracting losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce flood hydrographs and storm rainfall hyetographs and can be used for modelling natural, part urban and completely urban catchments. RORB is an industry standard mode that is widely used in studies undertaken by Melbourne Water.

The RORB model was developed for this project, included Red Bluff Creek (DR 2500), unnamed Creek (DR 2504) and tributary.

Catchment & Sub-catchment Definition

The subcatchments were drawn primarily using GIS contours. For most of the model these contour were sufficient. However, at certain places the contours were not detailed enough to determine the catchment boundary and Lidar based DTMs were used to determine the catchment boundary.

The catchments and subcatchment are shown in the Appendix:

Figure 2 - RORB Model Schematic

RORB model Parameters

The loss model used for this project was the Initial Loss – Runoff Coefficient model.

Calibration

The following model parameters were used to calibrate the model:

- Catchment area: 44.70 km^2
- Initial Loss (IL)
- Kc value
- Runoff Coefficient (ROC)

IL of 15mm was used, and Kc value was calculated using the 1.19 x $A^{0.56}$ formula

For the design Annual Recurrence Interval storm event, rainfall information was obtained using the IFD charts for Lang Lang.

Table 1 – Kc values

Model	Kc
Red Bluff Creek, Unnamed Creek and tributary	10.03

Table 2 – RORB ROC values

ARI (years)	ROC
100	0.60
50	0.55
20	0.45
10	0.35
5	0.25

Table 3 – 100 year ARI RORB Flow Information

Sub-catchment	Peak flow (m^3/s)	Critical Duration (hr)
A	7.1	9
B	21.5	2
C	28.3	9
D	29.9	9
E	4.27	9
F	7.1	9
G	4.6	9
H	8.4	4.5
I	11.3	9
J	44.5	9
K	46.4	9
L	10.9	2
M	9.0	2
N	20.6	4.5
O	14.3	2

P	9.3	2
Q	24.2	2
R	42.2	6
S	40.8	9
T	41.0	6
U	9.4	2
V	17.2	2
W	51.0	9
X	54.2	2
Y	6.8	2
Z	7.9	2
AA	20.8	2
AB	17.6	6
AC	19.4	9
AD	2.4	2
AE	5.3	4.5
AF	11.6	2
AG	75.4	9

Most of the flow into the hydraulic model and as the different in the peak flow between the 2 hour and 9 hour events for Red Bluff Creek, unnamed Creek and tributary, the 9 hour event was selected as the key event to be modelled in TUFLOW and HEC RAS for 100 year ARI storm.

Hydraulic Modelling

The results from the hydrologic modelling in RORB were used as inputs into the hydraulic model. The HEC RAS & TUFLOW modelling were used for the purposes of this study.

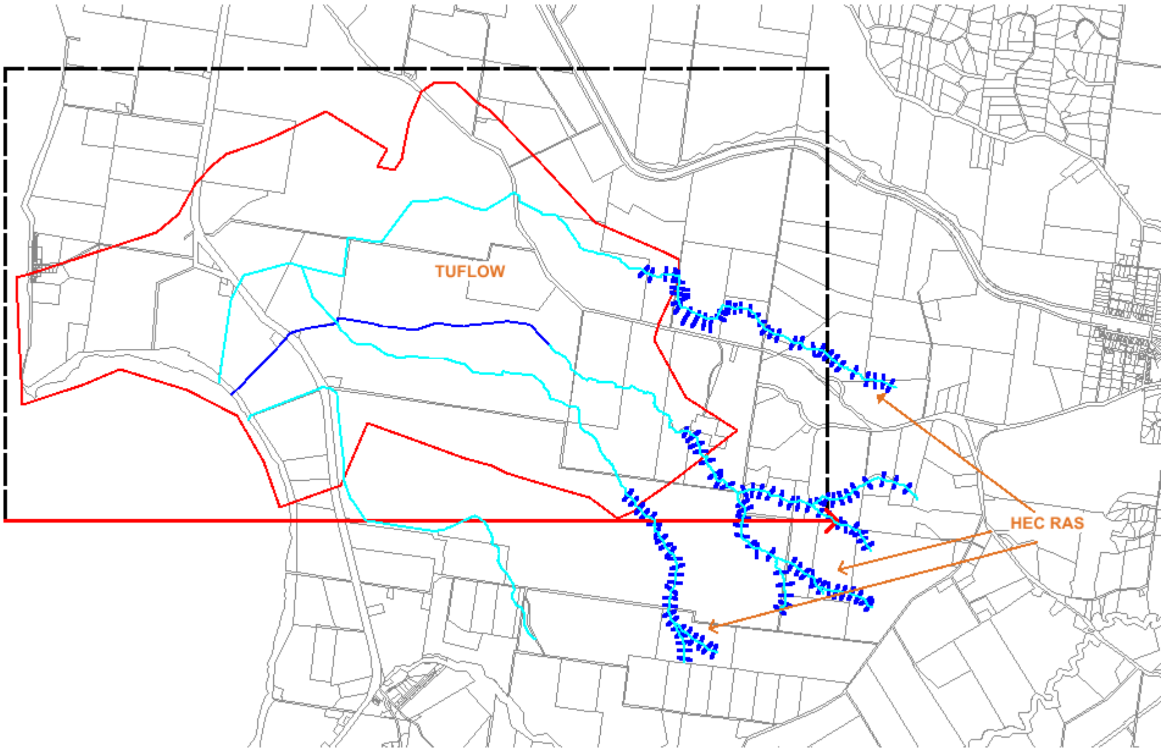


Figure 3 – TUFLOW & HEC RAS Project Area

HEC RAS

Introduction

The Hydrologic Engineering Centre River Analysis System (HEC RAS) is a one dimensional backwater calculation program that can be run in either steady or unsteady status.

Hydraulic Model Establishment

The establishment of the hydraulic model consists of two main components:

- Development of the HEC RAS model in 12D using the River Interface.
- Adjustment of the model within the HEC RAS interface

These components are discussed in the following two sections:

Development of the HEC RAS model using 12D

The HEC RAS project was developed using the River Interface within the 12D model. 12D is a terrain modelling, surveying and civil engineering software package that allows for the production of a number of projects in a variety of modelling areas. The 12D Model's Rivers module offer river engineers and mappers a new level of power and productivity in reducing modelling setup time for river, floodplain and open channel studies. Within the River module, option is provided to allow for a HEC RAS project to be created using a TIN. Using the LIDAR, the HEC RAS project was created. The River module places dummy values into the HEC RAS model for parameters such as flows and Manning's n – this is be addressed in the next section.

Final adjustment of the HEC-RAS model within the HEC-RAS interface

Once created using the Rivers module in 12D, the project was opened using the HEC-RAS interface where the tail water level, flow information (see Table 3) and Manning's n values were corrected from the dummy values input by the 12D Rivers module. There were two reaches in the HEC RAS model - the upper reach and two lower reaches. The tail water parameter was set from the upstream result of the TUFLOW model, the sections of Manning's n value was set at 0.045 for the waterways and 0.05 – 0.07 for the floodplain Note two culverts are included in the upper reach. The culverts are located at The Bass Gas access road on the west side of the quarry – assume box culvert 1200W x 600H and to the east side of the quarry – steel pipe 900mm diameter). No bridges or culverts are included in the lower reach. For any improved result, the model can be upgraded with relevant obstruction included.

Hydraulic Model Results

The hydraulic model was run using the peak flows from the 100 year Annual Recurrence Interval events for the existing conditions along the waterway. It should be noted that the flood shape produced is only a representation of the actual flooding conditions of the catchment, being based on the DEM developed for the project.

The flood shape was produce using 12d HEC-RAS Read feature and Tin Interpolation tool, and then uses the other tool to smooth the flood shape. The flood boundary is defined as the intersection line of the water surface and the ground surface.

Aware Locations – Upper Reach

In December 2012, the temporary drain diversion through the quarry on 5815 South Gippsland Highway assumes an open waterway trapezoidal shape 1.5m base width and 2:1 side batters.

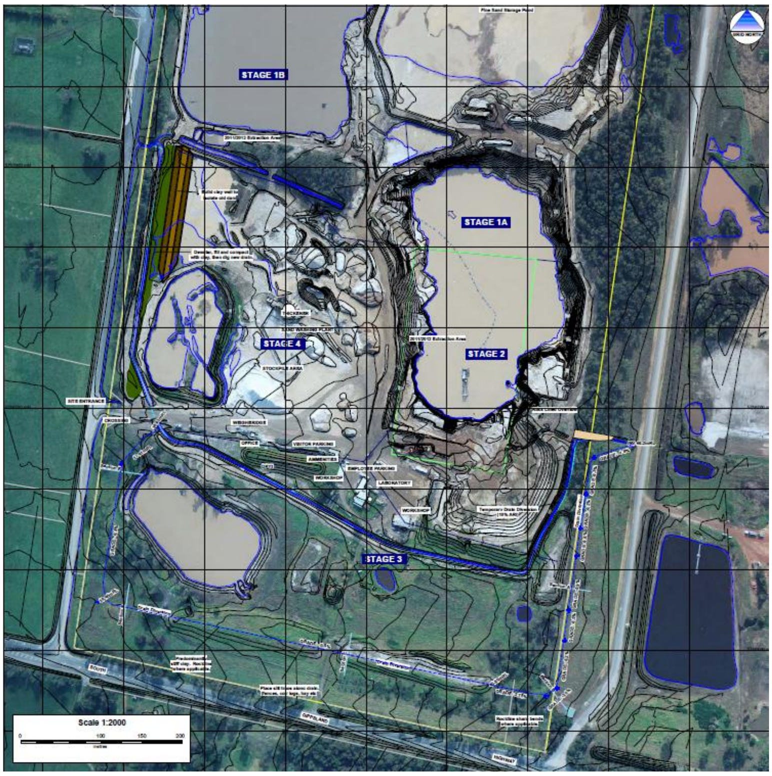


Figure 4 – Diversion Flow at Quarry on 5815 South Gippsland Highway (ESMAP 824 I7)

There are some inverts shown on the following map:

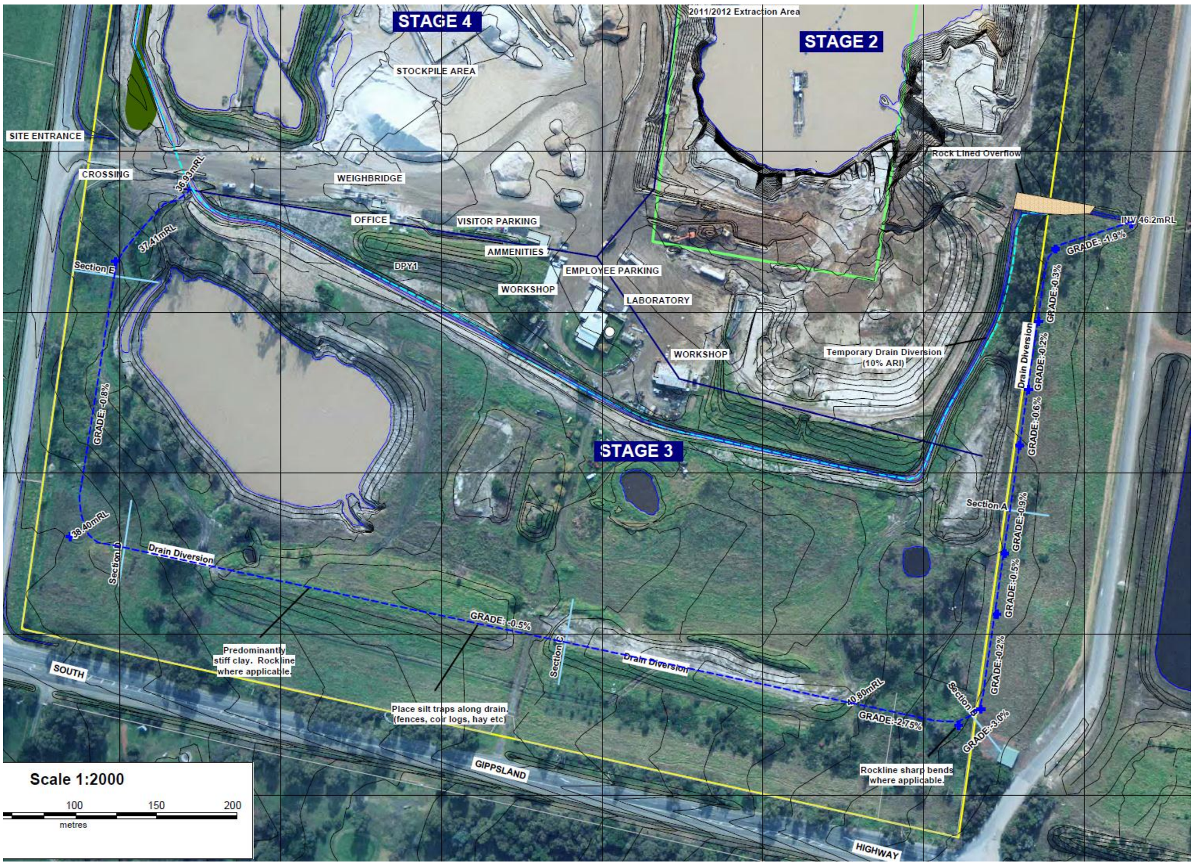


Figure 5 – Temporary drain diversion

TUFLOW

Introduction

The two-dimensional Unsteady Flow (TUFLOW) modelling system was used for the purposes of this study. TUFLOW is a two dimensional hydraulic modelling tools, which models unsteady flow by solving continuity and momentum equations for a 2d grid over the storm duration. TUFLOW also allows the use of 1d modelling within the 2d domain for 1D flow such as pipes, culverts and channels.

Hydraulic Model Establishment

- Setup of an empty model
- Defining the 2d surface
    - Elevations
    - Bed Resistance
- Defining 1d sections
    - Cross section
    - 1d to 2d boundaries
- Establishing boundary condition
    - Inflow into the model area
    - Outflow from the model area
    - Rainfall/Rain on grid onto the model area
- Define special features
    - Lakes / Pond
    - Pipelines
    - Culverts / Bridges
    - Weirs
- Select output methods
    - Digitise Print Output (PO) lines where necessary
    - Digitise WLL lines to view 1d results
- Decide on modelling duration and time step

Model Setup

The model was setup using the Melbourne Water MGA 94 Projection.

Table 4 - Model Bounds

Bounds	Min	Max
Easting	370,046.05	380,045.06
Northing	5,759,547.77	5,759,547.96

- Model Area – 10,000m by 5,500m
- Resolution – 3m cell size

2d Surface Elevations

The LIDAR DEM was used to define the surface elevation within the model area. TUFLOW Zpts were then populated using this DEM.

Bed Resistance

The project area was classified using 13 different resistance factors. Bed resistance can be set using Manning's n values.

Table 5 - Materials Table

Material Code	Type	Manning's n value
1	Natural Waterway	0.050
2	Grassed Channel / Floodway	0.035
3	Constructed Channel	0.020
4	Residential Block	0.150
5	Recently Constructed Residential Block	0.200
6	Vegetation (very heavy veg)	0.080
7	Vegetation (pasture grass)	0.045
8	Building, Footprints only	3.000
9	Un-vegetated Ovals, Reserves and Park	0.035
10	Vegetated Parks, Reserves	0.060
11	Road / Road Reserve	0.025
12	Commercial Buildings	0.060
13	Greenfield	0.050

Note: This materials table covers the entire model area. Some of the areas mentioned above might not be involved in active modelling.

1d culverts

There are 4 culverts in the active model area and these were modelled using the 1d engine.

Table 6 – Culverts Information

Crossings	Coordination (Easting & Northing)	Culverts Dimension
South Gippsland Highway #1	X:377,092.77 Y:5,756,642.71	3 x 1.25m x 0.7m
South Gippsland Highway #2	X:376,244.55 Y:5,758,025.45	1 x 2.4m x 1.8m
Bass Highway #1	X:373,509.74 Y:5,756,327.85	2 x 1.2m x 0.9m
Bass Highway #1	X:373,515.30 Y:5,756,323.91	6 x 0.9m
Bass Highway #1	X:373,470.31 Y:5,756,285.41	3 x 1.8m x 1.8m
Bass Highway #2	X:372,887.55 Y:5,756,928.12	5 x 1.6m
Bass Highway #2	X:372,868.99 Y:5,756,890.08	5 x 1.6m

Entrance loss of 0.5 and exit loss of 1 was used for all these culverts and a Manning's value of 0.013 was used.

Inflows

Flows obtained from the RORB model were used as inflows into the model area. There have 6 flows input into the model.

Flows from the Unnamed Creek (DR 2504) were entered at 3 input locations, flow from unnamed Creek main catchment, other two flows from breakaway of unnamed Creek.

Flows from Red Bluff Creek (DR 2500) were entered at 2 input locations, flow from Red Bluff Creek main catchment, flows from upstream breakaway of unnamed Creek.

Flows from Unnamed Creek Tributary (DR 2505) main catchment.

Table 7 – Inflows

Creek	Type	Input Name
Unnamed Creek (DR 2504)	2d input line	Subarea B
	2d input line	Subarea E
	2d input line	Subarea H
	2d sa polygon	Subarea C
	2d sa polygon	Subarea D
	2d sa polygon	Subarea F
	2d sa polygon	Subarea I
Red Bluff Creek (DR 2500)	2d input line	Subarea V
	2d input line	Subarea R
	2d sa polygon	Subarea S
	2d sa polygon	Subarea T
	2d sa polygon	Subarea W
	2d sa polygon	Subarea X
	2d sa polygon	Subarea J
	2d sa polygon	Subarea K
Unnamed Creek Tributary (DR 2505)	2d input line	Subarea AA
	2d sa polygon	Subarea AB
	2d sa polygon	Subarea AC
	2d sa polygon	Subarea AD
	2d sa polygon	Subarea AE
	2d sa polygon	Subarea AF
	2d sa polygon	Subarea AG

Outflows

A tail water level of 1m AHD was used as the downstream boundary condition for 100 year ARI.

Initial Water Levels

An initial water level was set for Westernport Bay to correctly simulate the model in a storm event. For 100 year, a 1m AHD (10 year water level) was adopted.

TUFLOW Model Runs Summary

There is determined a 100 year run as part of the final submission of this project.

Table 8 – Run Summary

ARI	Run ID
100 year	RBC_009

The following layers were used in the final 100 year TUFLOW model:

Table 9 – TUFLOW Layers

Used For	Used In	Layer Type	Layer Name	Comments
2d Topography	tgc	2d_loc	2d_loc_RBC_002	The origin and orientation of the model
		2d_zpt	2d_zpt_stab_3m_RBC_009	Surface elevation points
		2d_mat	2d_mat_RBC_009	Roughness values
		2d_code	2d_code_RBC_009	2d cell activation boundary
1d Topography	ecf	1d_nwk	1d_nwk_RBC_009	Centerline of Culverts
Boundary Condition	tbc	2d_bc	2d_bc_Ext_RBC_009	2d inputs into the model and outflow boundary
		2d_bc	2d_bc_Culvert_RBC_009	Connections between culverts and the 2d surface
		2d_sa	2d_sa_RBC_009	2d distributed flow input polygons
Results	tcf	2d_po	2d_po_RBC_009	2d print output lines

Hydraulic Model Results

The maximum water surface elevation, depth, velocities and V x D data from TUFLOW was imported into MapInfo.

These results were then filtered using the following criteria.

- Depth must be equal or greater than 50mm
- V x D must be equal or greater than 0.008 m^2/s

The filtered results were used to create water surface DEMs of maximum flooding using Engage 3d. Using manipulation method, the flood extents and floor contours were generated for the 100 year ARI flood.

Recommendation

In the future remapping of this area, the following improvements should be considered.

- Creek survey for all of Red Bluff Creek, unnamed Creek and tributary.
- Culverts field survey along South Gippsland Highway and Bass Highway.

Final Combined Hydraulic Model Result Map

Figure 6 shows the maximum flood extent for the existing condition from HEC RAS & TUFLOW for the 100 year Annual Recurrence Interval flood event.

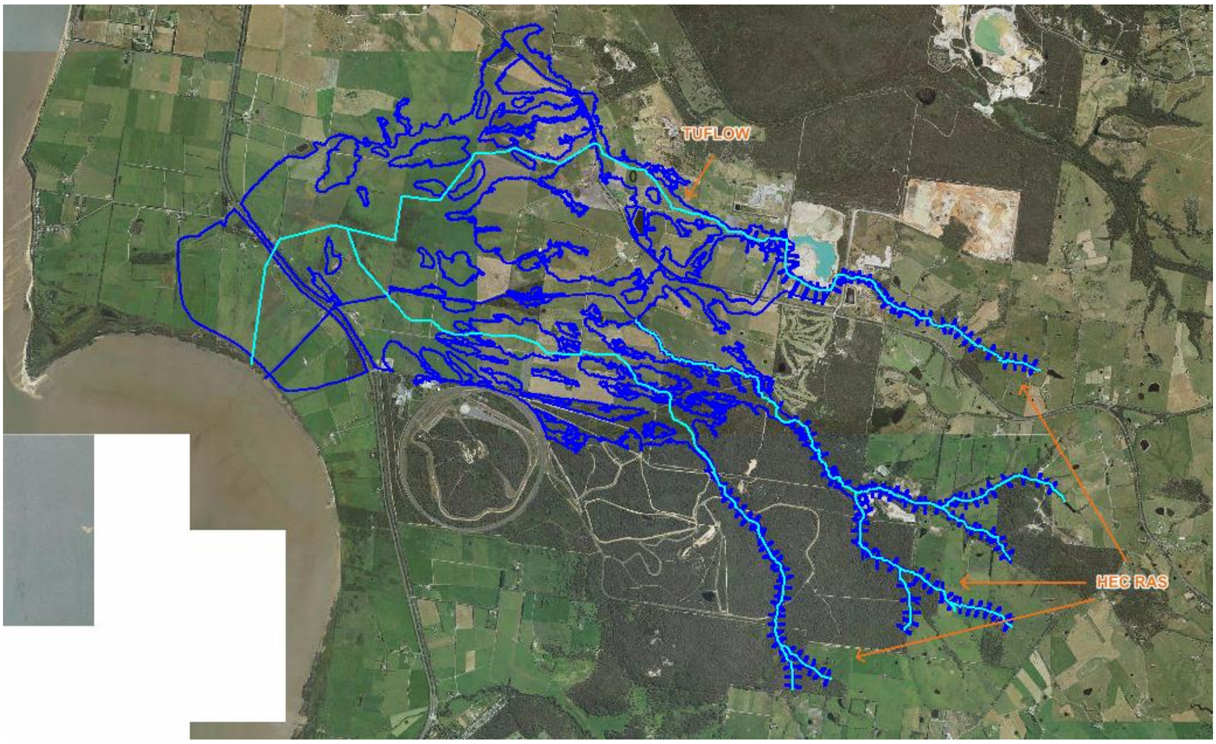
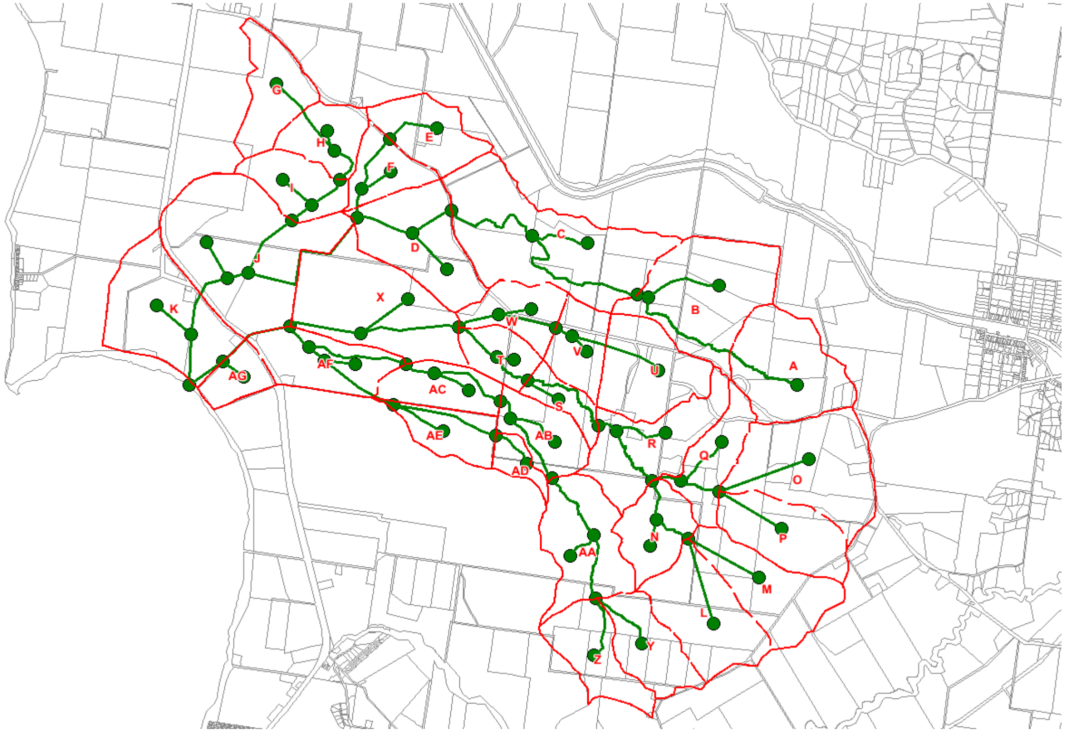


Figure 6 - 100 year ARI Flood Extent

Appendix

RORB Model Schematic



Red Bluff Creek RORB Model Schematic

RORB Model Coding

C Red Bluff Creek Catchment DR2500
C Catchment File Written by Joe Pang 21 Oct 2013
C Total Catchment Area = 45 square km2
C IFD Parameter = Lang Lang
C Kc = 10.03 Kc = 1.19 x A^0.56 (A in km2), m = 0.8
C IL = 15mm (Rural), ROC = 0.6(100y), 0.55(50yr), 0.45(20yr), 0.35(10yr), 0.25(5yr), 0.15(2yr), 0.10(1yr)

0	
1,2,2.654,1.631,-99	Reach 1 - 2, SubArea A
7	
U/S of Reach 1 - 2	
3	Store at Junction 2
1,2,1.038,2.781,-99	Reach 3 - 2, SubArea B
4	Add to value stored at Junction 2
7	
U/S of Reach 2 - 4	
5,2,0.156,1.357,-99	Reach 2 - 4
7	
U/S of Reach 4 - 5	
5,2,2.249,0.883,-99	Reach 4 - 5
7	
D/S of Reach 4 - 5	
3	Store at Junction 5
1,2,0.788,1.499,-99	Reach 6 - 5, SubArea C
7	
D/S of Reach 6 - 5	
4	Add to value stored at Junction 5
7	
U/S of Reach 5 - 7	
5,2,1.498,0.600,-99	Reach 5 - 7
5,2,0.612,1.298,-99	Reach 7 - 8
3	Store at Junction 8
11,2,0.674,0.934,-99	Reach 9 - 8, SubArea D
4	Add to value stored at Junction 8
7	
U/S of Reach 8 - 10	
5,2,0.784,0.594,-99	Reach 8 - 10
3	Store at Junction 10

1,2,0.731,0.001,-99	Reach 11 - 12, SubArea E
7	
U/S of Reach 12 - 13	
5,2,0.816,0.943,-99	Reach 12 - 13
3	Store at Junction 13
11,2,0.459,0.399,-99	Reach 14 - 13, SubArea F
4	Add to value stored at Junction 13
7	
U/S of Reach 13 - 10	
5,2,0.397,0.441,-99	Reach 13 - 10
4	Add to value stored at Junction 10
7	
U/S of Reach 10 - 15	
5,2,2.143,0.073,-99	Reach 10 - 15
3	Store at Junction 15
1,2,1.206,0.270,-99	Reach 16 - 17, SubArea G
7	
U/S of Reach 16 - 17	
3	Store at Junction 17
1,2,0.289,2.448,-99	Reach 18 - 17, SubArea H
4	Add to value stored at Junction 17
5,2,0.597,0.385,-99	Reach 17 - 19
7	
U/S of Reach 19 - 20	
5,2,0.531,0.224,-99	Reach 19 - 20
3	Store at Junction 20
11,2,0.517,1.209,-99	Reach 21 - 20, SubArea I
4	Add to value stored at Junction 20
7	
U/S of Reach 20 - 22	
5,2,0.338,0.044,-99	Reach 20 - 22
5,2,0.946,0.144,-99	Reach 22 - 15
4	Add to value stored at Junction 15
7	
U/S of Reach 15 - 23	
5,2,0.297,0.074,-99	Reach 15 - 23
3	Store at Junction 23
11,2,0.563,0.144,-99	Reach 24 - 23, SubArea J
4	Add to value stored at Junction 23
7	
U/S of Reach 23 - 25	
5,2,1.013,0.014,-99	Reach 23 - 25

3	Store at Junction 25
11,2,0.599,0.094,-99	Reach 26 - 25, SubArea K
4	Add to value stored at Junction 25
7	
U/S of Reach 25 - 27	
5,2,0.686,0.016,-99	Reach 25 - 27
3	Store at Junction 27
1,2,1.199,4.157,-99	Reach 28 - 29, SubArea L
7	
U/S Reach 28 - 29	
3	Store at Junction 29
1,2,1.075,2.084,-99	Reach 30 - 29, SubArea M
7	
U/S Reach 30 - 29	
4	Add to value stored at Junction 29
7	
U/S of Reach 29 - 31	
5,2,0.550,0.669,-99	Reach 29 - 31
3	Store at Junction 31
1,2,0.356,7.134,-99	Reach 32 - 31, SubArea N
4	Add to value stored at Junction 31
7	
U/S of Reach 31 - 33	
5,2,0.574,1.127,-99	Reach 31 - 33
3	Store at Junction 33
1,2,1.283,2.944,-99	Reach 34 - 35, SubArea O
7	
subarea O	
3	Store at Junction 35
1,2,0.984,2.955,-99	Reach 36 - 35, SubArea P
7	
subarea P	
4	Add to value stored at Junction 35
7	
U/S of Reach 35 - 37	
5,2,0.550,1.013,-99	Reach 35 - 37
3	Store at Junction 37
1,2,0.793,5.228,-99	Reach 38 - 37, SubArea Q
4	Add to value stored at Junction 37
7	
U/S of Reach 37 - 33	
5,2,0.407,1.471,-99	Reach 37 - 33

4	Add to value stored at Junction 33
7	
U/S of Reach 33 - 39	
5,2,1.022,1.078,-99	Reach 33 - 39
3	Store at Junction 39
1,2,0.709,3.902,-99	Reach 40 - 39, SubArea R
4	Add to value stored at Junction 39
7	
U/S of Reach 39 - 41	
5,2,0.301,0.559,-99	Reach 39 - 41
5,2,1.420,1.121,-99	Reach 41 - 42
3	Store at Junction 42
11,2,0.485,2.099,-99	Reach 43 - 42, SubArea S
4	Add to value stored at Junction 42
7	
U/S of Reach 42 - 44	
5,2,0.589,0.969,-99	Reach 42 - 44
3	Store at Junction 44
11,2,0.236,2.389,-99	Reach 45 - 44, SubArea T
4	Add to value stored at Junction 44
7	
U/S of Reach 44 - 46	
5,2,0.669,0.666,-99	Reach 44 - 46
3	Store at Junction 46
1,2,1.265,3.318,-99	Reach 47 - 48, SubArea U
7	
U/S Reach 47 - 48	
3	Store at Junction 48
1,2,0.279,1.211,-99	Reach 49 - 48, SubArea V
4	Add to value stored at Junction 48
7	
U/S of Reach 48 - 50	
5,2,0.252,0.719,-99	Reach 48 - 50
5,2,0.788,0.749,-99	Reach 50 - 51
3	Store at Junction 51
11,2,0.450,0.426,-99	Reach 52 - 51, SubArea W
4	Add to value stored at Junction 51
7	
U/S of Reach 51 - 46	
5,2,0.569,1.040,-99	Reach 51 - 46
4	Add to value stored at Junction 46
7	

U/S of Reach 46 - 53	
5,2,1.344,0.697,-99	Reach 46 - 53
3	Store at Junction 53
11,2,0.783,0.586,-99	Reach 54 - 53, SubArea X
4	Add to value stored at Junction 53
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U/S of Reach 53 - 55	
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3	Store at Junction 55
1,2,0.942,2.327,-99	Reach 56 - 57, SubArea Y
7	
U/S Reach 56 - 57	
3	Store at Junction 57
1,2,0.868,3.533,-99	Reach 58 - 57, SubArea Z
7	
U/S Reach 58 - 57	
4	Add to value stored at Junction 57
7	
U/S of Reach 57 - 59	
5,2,0.918,1.406,-99	Reach 57 - 59
3	Store at Junction 59
1,2,0.462,5.378,-99	Reach 60 - 59, SubArea AA
4	Add to value stored at Junction 59
7	
U/S of Reach 59 - 61	
5,2,1.013,1.429,-99	Reach 59 - 61
7	
U/S of Reach 61 - 62	
5,2,1.034,1.564,-99	Reach 61 - 62
3	Store at Junction 62
11,2,0.730,1.939,-99	Reach 63 - 62, SubArea AB
4	Add to value stored at Junction 62
7	
U/S of Reach 62 - 64	
5,2,0.329,1.083,-99	Reach 62 - 64
5,2,1.061,1.043,-99	Reach 64 - 65
3	Store at Junction 65
11,2,0.525,1.095,-99	Reach 66 - 65, SubArea AC
4	Add to value stored at Junction 65
7	
U/S of Reach 65 - 67	
5,2,0.422,0.808,-99	Reach 65 - 67

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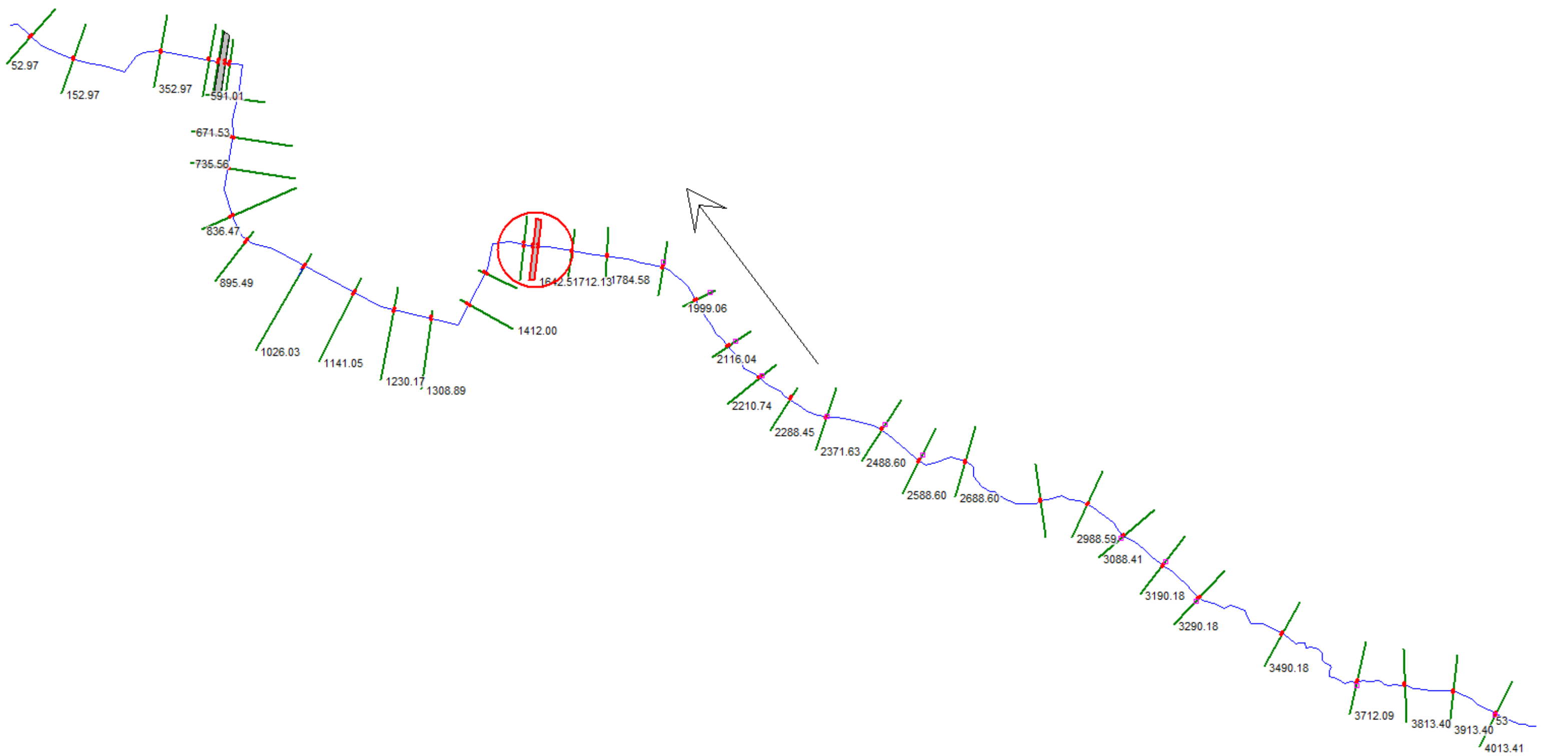
5,2,1.372,0.660,-99        Reach 67 - 68
3                          Store at Junction 68
1,2,0.607,3.458,-99        Reach 69 - 70, SubArea AD
7
U/S of Reach 69 - 70
5,2,1.453,1.095,-99        Reach 70 - 71
3                          Store at Junction 71
11,2,0.759,0.915,-99       Reach 72 - 71, SubArea AE
4                          Add to value stored at Junction 71
7
U/S of Reach 71 - 73
5,2,1.113,0.637,-99        Reach 71 - 73
3                          Store at Junction 73
11,2,0.417,0.594,-99       Reach 74 - 73, SubArea AF
4                          Add to value stored at Junction 73
7
U/S of Reach 73 - 68
5,2,0.275,0.349,-99        Reach 73 - 68
4                          Add to value stored at Junction 68
7
U/S of Reach 68 - 55
5,2,0.377,0.188,-99        Reach 68 - 55
4                          Add to value stored at Junction 55
7
U/S of Reach 55 - 75
5,2,1.065,0.037,-99        Reach 55 - 75
3                          Store at Junction 75
11,2,0.345,0.229,-99       Reach 76 - 75, SubArea AG
4                          Add to value stored at Junction 75
7
U/S of Reach 75 - 27
5,2,0.548,0.038,-99        Reach 75 - 27
4                          Add to value stored at Junction 27
7
Outlet
0
C  A     B     C     D     E     F     G
C  H     I     J     K     L     M     N
C  O     P     Q     R     S     T     U
C  V     W     X     Y     Z     AA    AB
C  AC    AD    AE    AF    AG
1.857,  2.316,  3.253,  1.753,  1.030,  0.721,  1.114,
```

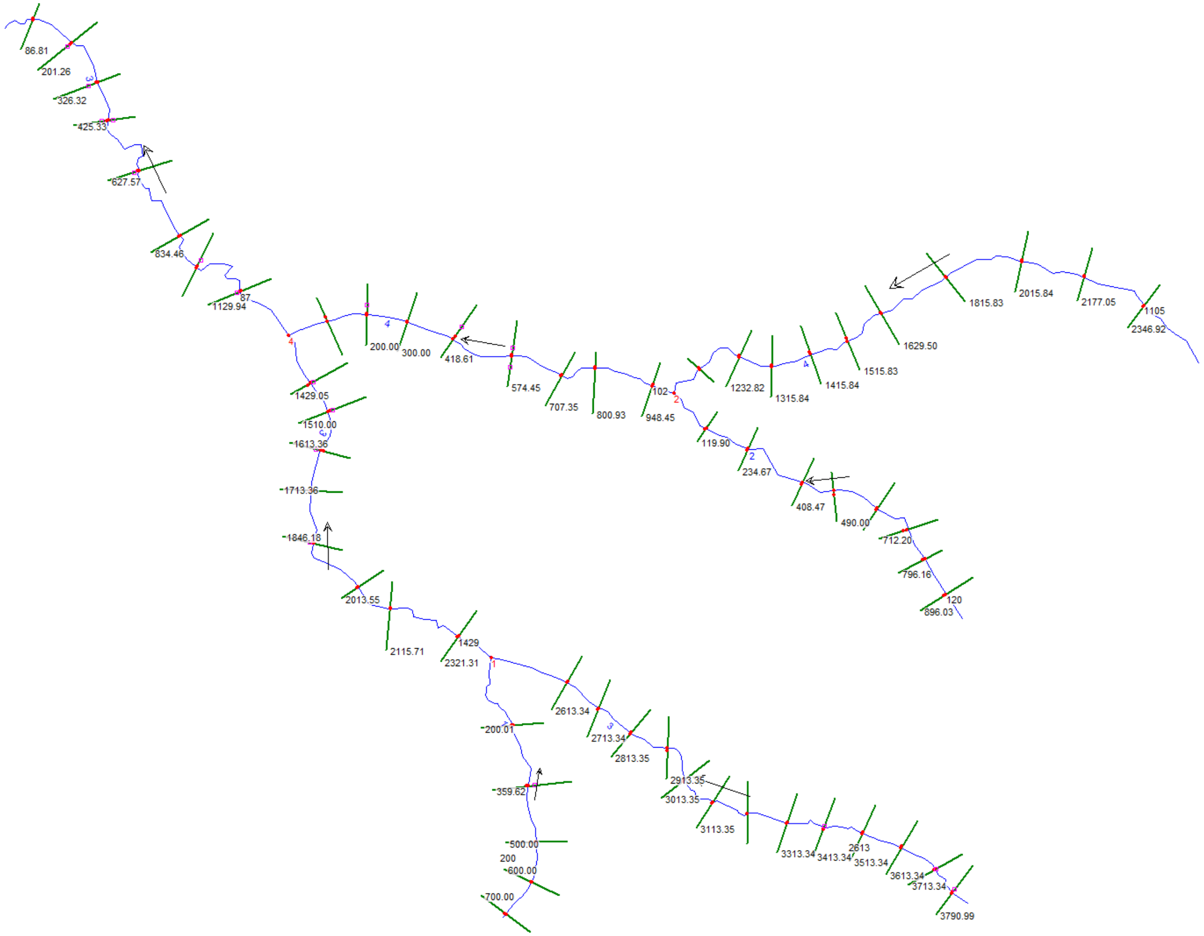
0.840, 0.908, 3.252, 2.109, 1.685, 1.481, 0.968,
2.249, 1.375, 0.949, 1.633, 0.465, 0.645, 1.545,
0.804, 0.849, 2.489, 1.061, 1.082, 1.618, 0.902,
0.888, 0.313, 0.786, 1.230, 0.516,
-99
1,
0.084, 0.060, 0.056, 0.066, 0.065, 0.079, 0.073,
0.063, 0.050, 0.078, 0.066, 0.050, 0.050, 0.093,
0.084, 0.050, 0.157, 0.038, 0.044, 0.050, 0.069,
0.058, 0.084, 0.058, 0.050, 0.050, 0.050, 0.047,
0.050, 0.050, 0.050, 0.077, 0.080,
-99

HEC RAS reach schematic

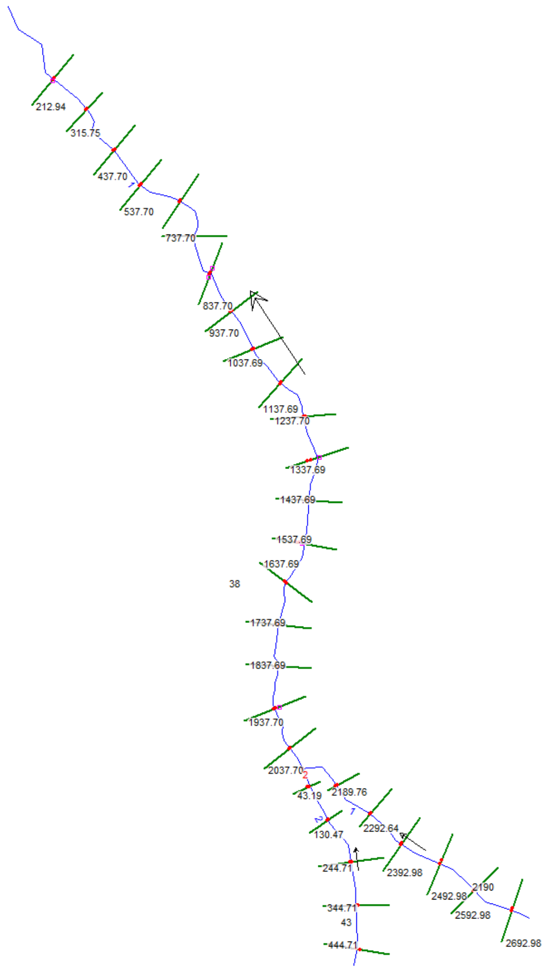
Upper reach:



Lower reach (1):



Lower reach (2):



HEC RAS results:

HEC RAS results – upper reach

River	Reach	River Station	Q Total (m3/s)	W.S. Elevation (m)	Velocity Channel (m/s)
Upper	53	4013.41	7.1	89.86	1.90
Upper	53	3913.40	7.1	86.77	1.14
Upper	53	3813.40	7.1	85.57	2.33
Upper	53	3712.09	7.1	82.14	2.30
Upper	53	3490.18	7.1	77.31	2.53
Upper	53	3290.18	7.1	73.03	1.96
Upper	53	3190.18	7.1	71.90	1.82
Upper	53	3088.41	7.1	70.46	2.09
Upper	53	2988.59	7.1	68.97	2.03
Upper	53	2888.59	7.1	67.23	2.03
Upper	53	2688.60	7.1	65.16	1.50
Upper	53	2588.60	7.1	63.59	1.78
Upper	53	2488.60	7.1	61.84	1.05
Upper	53	2371.63	7.1	60.00	1.72
Upper	53	2288.45	7.1	58.40	1.61
Upper	53	2210.74	7.1	57.37	2.09
Upper	53	2116.04	7.1	55.19	1.27
Upper	53	1999.06	7.1	53.06	0.64
Upper	53	1901.22	7.1	52.00	1.54
Upper	53	1784.58	7.1	50.06	1.61
Upper	53	1712.13	21.5	48.83	2.11
Upper	53	1642.50	21.5	48.03	1.40
Upper	53	1642.00	Culvert		
Upper	53	1632.60	21.5	47.81	1.89
Upper	53	1612.72	21.5	47.55	1.86
Upper	53	1485.34	21.5	46.08	2.45
Upper	53	1412.00	21.5	45.18	2.42
Upper	53	1308.89	21.5	43.03	2.14
Upper	53	1230.17	21.5	40.81	
Upper	53	1141.05	21.5	38.60	
Upper	53	1026.03	21.5	37.02	
Upper	53	895.49	21.5	37.01	

Upper	53	836.47	21.5	36.97	0.29
Upper	53	735.56	21.5	36.84	0.55
Upper	53	671.53	21.5	36.76	0.57
Upper	53	591.01	21.5	36.64	0.79
Upper	53	496.11	21.5	36.25	1.87
Upper	53	486.50	21.5	36.22	1.45
Upper	53	486.40	Culvert		
Upper	53	472.20	21.5	35.98	1.96
Upper	53	452.97	21.5	35.75	2.08
Upper	53	352.97	21.5	34.79	1.14
Upper	53	152.97	21.5	32.27	1.51
Upper	53	52.97	21.5	30.75	1.08

HEC RAS results – Lower reach (1)

River	Reach	River Station	Q Total	W.S. Elevation	Velocity Channel
			(m3/s)	(m)	(m/s)
Lower 1	1105	2346.92	14.3	92.33	0.37
Lower 1	1105	2177.05	14.3	87.80	0.81
Lower 1	1105	2015.84	14.3	84.47	0.22
Lower 1	1105	1815.83	14.3	81.84	0.31
Lower 1	1105	1629.50	14.3	78.36	0.29
Lower 1	1105	1515.83	14.3	76.30	0.44
Lower 1	1105	1415.84	14.3	72.90	0.81
Lower 1	1105	1315.84	14.3	71.54	0.26
Lower 1	1105	1232.82	14.3	70.11	0.39
Lower 1	1105	1104.55	14.3	68.54	0.23
Lower 1	102	948.45	23.6	65.64	0.89
Lower 1	102	800.93	23.6	64.06	0.14
Lower 1	102	707.35	23.6	63.34	0.17
Lower 1	102	574.45	23.6	61.62	0.20
Lower 1	102	418.61	23.6	60.23	0.22
Lower 1	102	300.00	23.6	58.31	0.12
Lower 1	102	200.00	23.6	57.06	0.18
Lower 1	102	101.56	23.6	55.83	0.45
Lower 1	2613	3790.99	9.0	87.21	2.18
Lower 1	2613	3713.34	9.0	85.91	2.38
Lower 1	2613	3613.34	9.0	83.37	2.60
Lower 1	2613	3513.34	9.0	81.66	2.50

Lower 1	2613	3413.34	9.0	79.75	2.86
Lower 1	2613	3313.34	9.0	78.05	2.42
Lower 1	2613	3213.34	9.0	75.59	2.83
Lower 1	2613	3113.35	9.0	73.69	2.83
Lower 1	2613	3013.35	9.0	71.89	2.03
Lower 1	2613	2913.35	9.0	71.04	2.28
Lower 1	2613	2813.35	9.0	69.74	2.40
Lower 1	2613	2713.34	9.0	68.53	2.28
Lower 1	2613	2613.34	9.0	67.82	1.89
Lower 1	1429	2321.31	20.0	64.45	2.81
Lower 1	1429	2115.71	20.0	62.20	2.52
Lower 1	1429	2013.55	20.0	61.90	1.35
Lower 1	1429	1846.18	20.0	60.50	3.09
Lower 1	1429	1713.36	20.0	59.15	1.14
Lower 1	1429	1613.36	20.0	58.49	2.20
Lower 1	1429	1510.00	20.0	57.71	1.25
Lower 1	1429	1429.05	20.0	57.41	1.75
Lower 1	87	1129.94	45.0	52.50	4.27
Lower 1	87	936.07	45.0	51.22	2.33
Lower 1	87	834.46	45.0	50.12	3.73
Lower 1	87	627.57	45.0	48.25	3.05
Lower 1	87	425.33	45.0	46.74	3.15
Lower 1	87	326.32	45.0	46.41	2.25
Lower 1	87	201.26	45.0	45.41	3.17
Lower 1	87	86.81	45.0	45.00	2.29
Lower 1	120	896.03	9.3	87.21	0.30
Lower 1	120	796.16	9.3	85.29	0.39
Lower 1	120	712.20	9.3	83.68	0.33
Lower 1	120	608.99	9.3	82.26	0.25
Lower 1	120	490.00	9.3	78.79	0.56
Lower 1	120	408.47	9.3	77.40	0.30
Lower 1	120	234.67	9.3	72.18	2.67
Lower 1	120	119.90	9.3	69.26	0.16
Lower 1	200	700.00	10.9	79.16	2.04
Lower 1	200	600.00	10.9	76.62	2.76
Lower 1	200	500.00	10.9	74.10	2.41
Lower 1	200	359.62	10.9	71.69	2.55
Lower 1	200	200.01	10.9	68.29	2.57

HEC RAS results – Lower reach (2)

River	Reach	River Station	Q Total (m3/s)	W.S. Elevation (m)	Velocity Channel (m/s)
Lower 2	43	444.71	7.9	83.43	1.94
Lower 2	43	344.71	7.9	81.31	2.28
Lower 2	43	244.71	7.9	78.93	2.43
Lower 2	43	130.47	7.9	76.06	2.17
Lower 2	43	43.19	7.9	73.77	2.19
Lower 2	2190	2692.98	6.9	84.10	2.13
Lower 2	2190	2592.98	6.9	81.59	1.95
Lower 2	2190	2492.98	6.9	79.81	1.90
Lower 2	2190	2392.98	6.9	78.23	1.13
Lower 2	2190	2292.64	6.9	76.74	2.24
Lower 2	2190	2189.76	6.9	74.58	1.37
Lower 2	38	2037.70	14.8	72.66	2.48
Lower 2	38	1937.70	14.8	71.23	1.79
Lower 2	38	1837.69	14.8	69.75	2.58
Lower 2	38	1737.69	14.8	68.80	2.19
Lower 2	38	1637.69	14.8	67.61	2.40
Lower 2	38	1537.69	14.8	65.91	2.05
Lower 2	38	1437.69	14.8	64.19	2.27
Lower 2	38	1337.69	14.8	62.57	1.69
Lower 2	38	1237.70	14.8	61.41	1.67
Lower 2	38	1137.69	14.8	60.04	1.46
Lower 2	38	1037.69	14.8	58.67	1.33
Lower 2	38	937.70	14.8	57.37	2.08
Lower 2	38	837.70	14.8	55.96	1.42
Lower 2	38	737.70	14.8	54.72	1.58
Lower 2	38	637.70	14.8	53.13	1.89
Lower 2	38	537.70	14.8	51.25	1.67
Lower 2	38	437.70	14.8	49.70	2.15
Lower 2	38	315.75	14.8	48.43	1.75
Lower 2	38	212.94	14.8	46.96	1.90