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Coromandel flood protection scheme service level review

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Disclaimer

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Abstract

Hydrological and hydraulic models of the Coromandel Township and its catchment was developed and used to model the flood levels for Whangarahi Stream, Karaka Stream and the Golf Course Drainage for a range of different return period events, under both current and expected future climate conditions.

The modelled flood levels was then used to assess the performance of the existing stop banks and floodwalls under design storm events. The results was used for the hydrological review, it is concluded that the Coromandel scheme stop banks and floodwalls meet to their design objectives. There could still be a potential risk of flooding in the lower reach of Whangarahi Stream and on the right bank of Karaka Stream near Kapanga Road. This flooding risk is highest when there is a combined high tide level at Coromandel harbour and high overflow from Karaka Stream.

Executive summary

The Coromandel Township Flood protection scheme under review consists of the Whangarahi Stream stop banks at Elizabeth Park, and the Karaka Stream stop bank and floodwall. These streams are located in Coromandel Township (See Figure 2.1). The upper catchments are situated on the western side of the Coromandel Range and are very steep, and the lower parts of the catchments are moderately steep. The total catchment area comprises 1780ha, approximately 60% of the area is in forestry (primarily indigenous forest) and remaining 40% of the area is in pasture (primarily the lower, flatter parts of the catchment).

The Karaka Stream and Golf Course drain enters the lower Whangarahi Stream before it discharges through Coromandel Harbour into the Hauraki Gulf.

There are virtually no records of historical flood discharges within the Whangarahi Stream catchment. The nearest gauging sites with reasonable lengths of historic record are on the Tapu Stream, Opitonui Stream and the Kauaeranga River. Peak flood discharges for the Whangarahi Stream and its tributaries have been assessed by using the historical record for the above three sites. In addition, a hydrological model has been developed to enable flood hydrographs to be derived for both current and future climate conditions. Waikato Regional Council are discussing internally, the plans to install new recorder sites in Coromandel for better assurance and calibration of the Model.

One dimensional hydraulic modelling of water levels in the Whangarahi Stream and its main tributaries has been undertaken using the MIKE11 software package. In addition Mike Flood coupled 1D-2D model has been developed to estimate a real extent of inundation for the 2yr, 5yr, 10yr, 20yr 50yr and 100 year floods.

The modelled flood levels have then been used to assess the performance of the flood protection scheme which includes stop banks and flood walls in the Coromandel Township.

The level of service provided by the Coromandel flood protection scheme is the existing 1 in 100yr ARI event (without climate change) plus 500mm freeboard. The general location of the flood protection assets is shown in Figure 5.1

Based on the above, it is concluded that the Coromandel flood protection scheme stop banks and floodwall meet their design objectives. However, potential risk of flooding can still be expected in the lower reach of Whangarahi Stream and on the right bank of Karaka Stream near Kapanga Road. The flooding risk is due to mainly high tide level at the Coromandel harbour and overflow from the Karaka Stream

All of the Scheme embankment assets reviewed, are above the design flood level, and above 100% of their design freeboard i.e. performance grade 1. The only exception is at Karaka left bank stop bank where the performance is at grade 2.

After a review of the design flood levels (100 year flood event), the section of the Karaka stop banks estimated at performance grade 2 is located upstream of Kapanga Road Bridge. This is due to the severe restriction of flows caused by rock deposit from the upstream section. It is recommended that the rock deposit is to be cleared as soon as possible or during the normal scheduled stream maintenance.

The rock deposit under Kapanga Road is expected to be cleared during the stream maintenance works schedule for summer 2018/2019 (refer doc#13024008 for details)

1 Introduction

1.1 Background

The Coromandel Zone is dominated by the Coromandel Range. The Zone has many short, steep catchments and most of the services are non-asset based, such as soil conservation, river management and pest management. However, five community flood mitigation schemes exist – including Waiomu/Pohue, Te Puru, Tapu, Coromandel including Karaka, and the most recent, Grahams Creek (Tairua). The "Coromandel flood protection scheme" is to be reviewed in this project.

In 2014, Waikato Regional Council released a report (titled "Coromandel Flood Protection Scheme Report") that recommended a review of the scheme every 5 years. This is to be done by assessing any changes in the catchment and undertaking design flood level reviews.

The Karaka Scheme was the only scheme review planned for the 2017/2018 financial year. However, due to the flooding and inundation link between Karaka Stream and the Coromandel Township review, a combined scheme review was agreed when the project brief was being finalised (refer doc#11162115). Efficiencies were expected to be gained by combining the two scheme reviews.

This scheme review has no relationship with the Karaka Stream (Thames) in Waihou Zone.

1.2 Strategic outcomes

A review of the Coromandel flood protection scheme was proposed as part of the requirements from the Coromandel flood protection scheme report (refer Waikato Regional Council Technical Report 2013/45 doc#3059150). The scheme review is a hydrological and hydraulic assessment of streams in Coromandel Township (this includes Karaka Stream, Whangarahi Stream and Golf Course Drainage). It also includes recommendations on the requirements for upgrading any scheme asset to maintain the agreed level of service.

The purpose of this project is to examine the current status of the Coromandel flood protection scheme; to carry out a hydrologic and hydraulic assessment of Karaka and Whangarahi Streams; to establish current performance against performance measures; identify issues in the existing scheme and provide recommendations.

For a more in-depth overview of the Coromandel Zone vision and objectives, refer to the Coromandel Zone Management Plan doc#3310283.

2 Catchment description

The Coromandel Township Flood protection scheme under review consist of Whangarahi Stream stop banks at Elizabeth Park, Karaka Stream stop bank and floodwall. These streams are located in Coromandel Township (See Figure 2.1). The upper catchment is very steep and the lower part of the catchment is moderately steep and is situated on the western side of the Coromandel Range. The catchment area comprises 1780ha, 60% of which is in forest (primarily indigenous forest) and 40% is in pasture (primarily the lower, flatter parts of the catchment).

The Karaka Stream and Golf Course drainage enter the lower Whangarahi Stream, before it discharges through Coromandel Harbour into the Hauraki Gulf.

The catchment has been divided in to 11 distinct sub-catchments for the purpose of hydrological and hydraulic modelling as shown in Figure 2.2 below.

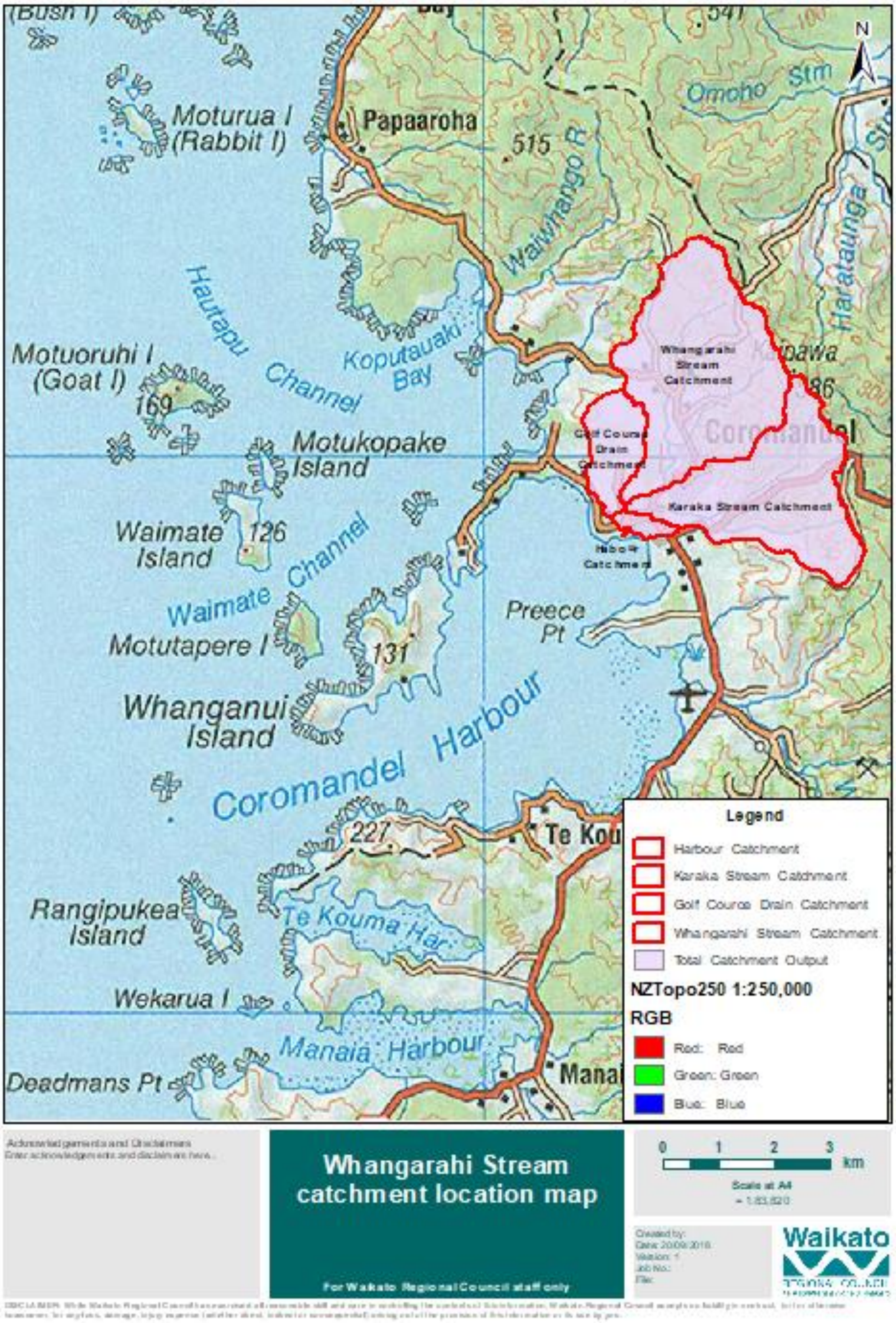

Figure 2.1 Whangarahi Stream catchment location map

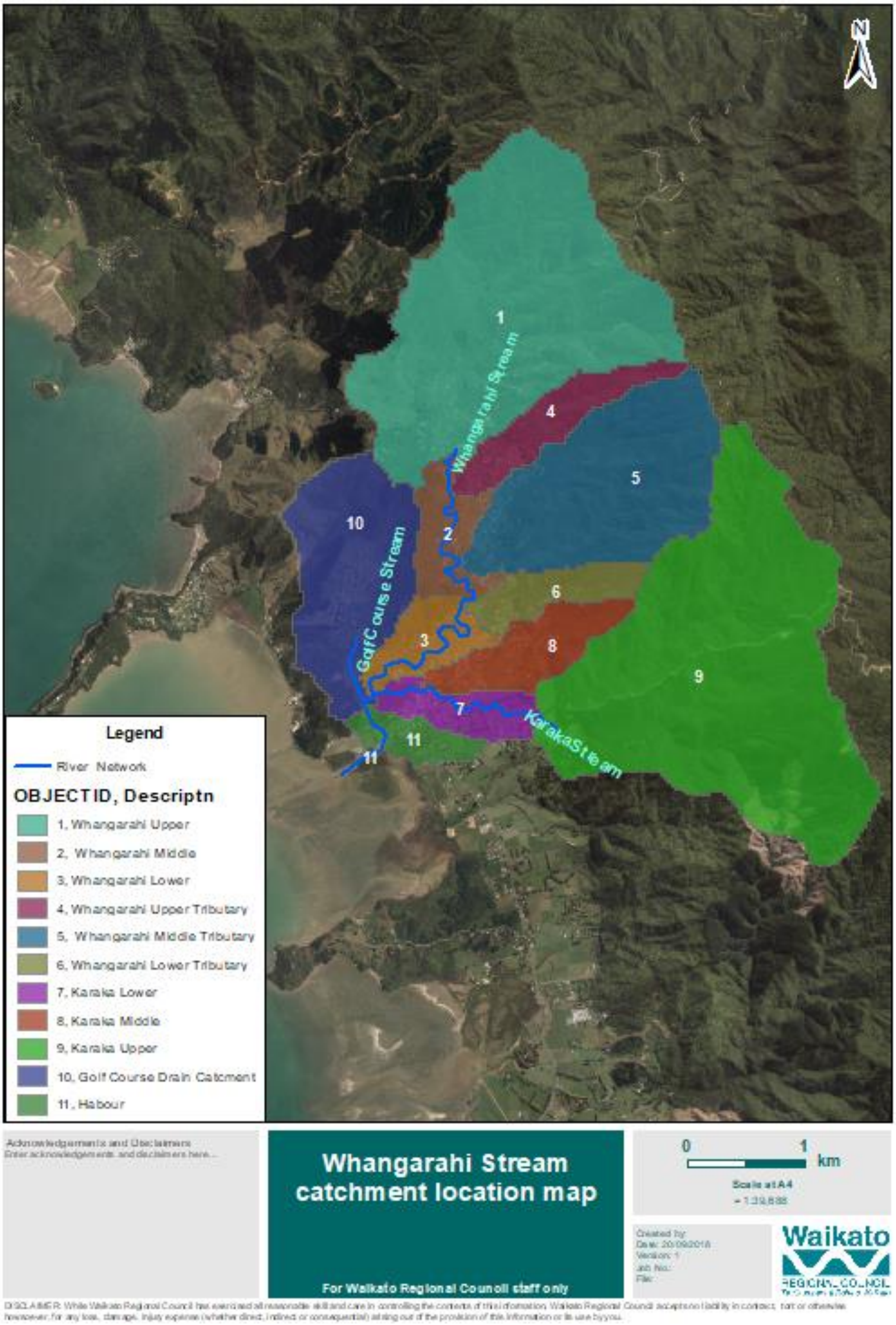

Figure 2.2 **Whangarahi Stream – sub-catchment breakdown (refer table 2.2 for sub-catchment details)**

Catchment	Area (km^2)	Area ratio (%)
Whangarahi	9.05	50.65%
Karaka	6.71	37.59%
Golf Course	1.75	9.85%
Harbour	0.35	1.91%
Total	17.86	100%

Table 2.1 The four main catchments modelled

The four main catchments are to be considered in developing the hydraulic and hydrological model shown in Table 2.1 was further subdivided to give an indication of how flows are accumulating from the various tributaries feeding the Karaka and Whangarahi Stream. These sub-catchment areas were:

ID	Description	Area (hectares)	Area (km^2)	Area ratio (%)
1	Whangarahi Upper	445	4.45	24.93%
2	Whangarahi Middle	55	0.55	3.08%
3	Whangarahi Lower	51	0.51	2.86%
4	Whangarahi Upper Tributary	66	0.66	3.68%
5	Whangarahi Middle Tributary	240	2.40	13.46%
6	Whangarahi Lower Tributary	47	0.47	2.64%
7	Karaka Lower	48	0.48	2.68%
8	Karaka Middle	71	0.71	3.96%
9	Karaka Upper	553	5.53	30.95%
10	Golf Course Drain	176	1.76	9.85%
11	Harbour	34	1.91%	1.91%
	Total	1,786	17.86	100%

Table 2.2 Sub-catchments for Coromandel Scheme

3 Flood hydrology

3.1 Historical records

There are no records of historical flood discharges within the Coromandel Scheme catchment. The nearest gauging sites with reasonable lengths of historic record are on the Opitonui at Downstream Awaroa Confluence (26 years), the Tapu Stream at Tapu-Coroglen Road (26 years) and on the Kauaeranga River at Smiths (48 years). These gauging stations are approximately 10, 25 and 45 kilometres respectively from the Coromandel Scheme asset. Data from these stations gives an indication of flood frequencies in the neighbourhood of Coromandel Township. Opitonui gauging station is located on the eastern side of the Coromandel Range and hence affected by the North-Easterly wind and weather pattern. On the other hand, Kauaeranga River, Tapu River and Whangarahi Stream are all located on the western side of the Coromandel Range and hence affected by the North-westerly wind and weather pattern (refer Figure 3.1 below).

Figure 3.1 River Gauging Stations

Analysis of data from these sites were intended for use in forecasting flood frequencies in the Whangarahi Stream.

Flood frequency analysis has been carried out on the annual maxima series from these gauging sites and the resulting flood flows have then been normalised to catchment size by dividing by catchment area to the power of 0.8 (Table 3.1).

Average recurrence interval (years)	**Kauaeranga at Smiths** (119.5 km^2)		**Tapu** (26.3 km^2)		**Opitonui at Downstream Awaroa Confluence** (28.7 km^2)	
	Total discharge (m^3/s)	**Normalised discharge** (Q/A$^{0.8}$)	**Total discharge** (m^3/s)	**Normalised discharge** (Q/A$^{0.8}$)	**Total discharge** (m^3/s)	**Normalised discharge** (Q/A$^{0.8}$)
2	465	10.13	56	4.13	119	8.11
5	672	14.64	91	6.72	186	12.68
10	808	17.60	114	8.41	231	15.75
20	940	20.48	136	10.04	274	18.68
50	1109	24.16	165	12.18	330	22.50
100	1236	26.92	201	14.83	372	25.37
200	1363	29.68	237	17.48	414	28.22

Table 3.1 Flood frequency analysis of Kauaeranga, Tapu and Opitonui gauging sites and normalisation of discharge to catchment area.

3.2 Data Analysis

Hydrological analysis of the Whangarahi catchments was done using the rainfall runoff component of the MIKE11 application (NAM Model). The results were verified with the normalised flow discharge from Tapu Stream flow record and also compared with a TM61 analysis.

Average recurrence interval (yrs.)	**No climate change** (17.86 km^2)			**With climate change** (17.86 km^2)		
	TM61	**Derived from Tapu Record**		**TM61**	**Derived from Tapu Record**	
	Total discharge (m^3/s)	**Normalised discharge** (Q/A$^{0.8}$)	**Total discharge** (m^3/s)	**Total discharge** (m^3/s)	**Normalised discharge** (Q/A$^{0.8}$)	**Total discharge** (m^3/s)
2	61.30	6.11	41.47	73.10	7.28	49.45
5	80.16	7.99	67.39	96.69	9.64	81.28
10	95.91	9.56	84.42	116.92	11.65	102.91
20	113.74	11.33	100.71	139.83	13.93	123.81
50	141.89	14.14	122.18	175.99	17.54	151.54
100	167.38	16.68	148.84	207.59	20.69	184.60
200	201.08	20.04	175.40	249.36	24.85	217.52

Table 3.2 Flood frequency estimates for the full Whangarahi Stream catchment

The normalised flood discharges for the Tapu Stream is generally much lower than those for the Kauaeranga and Opitonui. The Tapu values have been adopted as the basis for estimating maximum flows in the Whangarahi Stream. This is because the Whangarahi Stream catchment is geographically closer to the Tapu than to the Kauaeranga or Opitonui and is likely similar in terms of slope and rainfall patterns. In the absence of gauging station data in Coromandel Township, this is the most reasonable runoff estimate for Whangarahi Stream.

3.3 Previous analyses

The report “Coromandel Town Flood Protection Scheme Design Report (Waikato Regional Council Technical Report 2013/45 doc#3059150)” provides an estimate of peak flows determined during scheme design. These discharges were derived by correlation with the historical record of flows at the Kauaeranga gauge. These are set out in Table 3.3.

	Peak flows estimates					
Average recurrence interval (yrs.)	2	5	10	20	50	100
Existing peak flow - 2006 (m^3/s)	96	117	155	183	211	253
Future peak flow - 2030 (m^3/s)	105	129	172	202	233	280
Future peak flow - 2080 (m^3/s)	122	150	200	235	272	326

Table 3.3 Whangarahi Stream peak flow estimates

These flows are higher than those obtained in sections 3.1 and 3.2, and reflect the decision to base the Coromandel flow estimates on the recorded data at Tapu.

It was decided not to adopt the above data from the previous scheme review, as their flow data were derived from the normalised Kauaeranga stream record. The Kauaeranga stream catchment is over six times bigger than the Whangarahi Stream catchment. For this scheme review, the normalised Tapu flow records were assumed to be more closely related to flows from Whangarahi Stream catchment as the Whangarahi Stream catchment is geographically closer to the Tapu than to the Kauaeranga. The Tapu flow is more similar in terms of catchment characteristics and rainfall patterns.

3.4 Hydrological modelling

Hydrological modelling has been undertaken using the NAM model which is provided with the MIKE11 hydraulic modelling package. The NAM model is a lumped parameter conceptual rainfall-runoff model for continuous simulation of the land phase of the hydrological cycle. It can also be used for event based simulations provided appropriate initial conditions are provided.

A lumped model considers the catchment to be homogeneous and there is no variation in catchment parameters in space. In practice, a catchment will not be homogeneous so the parameters must be single catchment-wide average value.

The NAM model tracks the soil moisture content and the groundwater level continuously. This is advantageous since infiltration capacity and base flow are dependent to a large degree on these quantities.

NAM requires rainfall and potential evapo-transpiration as input and produces outflow separated into three conceptual outflows, namely;

- Upper zone storage (Quick flow);
- Lower zone storage (Interflow),
- Groundwater storage (Base flow);

3.4.1 Model parameterisation

Because there are no historical records of flows for the Coromandel catchment, direct calibration of the NAM model is not possible. However, the model has been calibrated using the guidelines for calibrating the NAM model (EWDOCS 932615. The model calibration is such that the peak discharge from the model is slightly higher than the normalised flood discharge record for the Tapu Stream. The key parameters of the NAM model are described in Table 3.4.

Parameter	**Parameter description**	**Value**
Umax	Maximum content of the upper storage (mm).	5.0
Lmax	Maximum content of the lower storage (mm).	80.0
CQOF	Maximum volumetric runoff coefficient (varies between 0 and 1)	0.5
CK12	Time response parameter for overland flow and interflow (hr)	varies
CKIF	Time constant for releasing interflow (hr)	varies
CKBF	Time constant for releasing base flow (hr)	varies
TOF	Rootzone threshold for overland flow. (varies from 0 to 1)	0.987
TIF	Rootzone threshold for interflow. (varies from 0 to 1)	0.473
TG	Rootzone threshold for recharge	0.915

Table 3.4 Parameters of the NAM hydrological model

The time based parameters have been scaled for each sub-catchment based on the ratio of the time of concentration.

Catchment		**Parameters**		**NAM parameters**		
ID	**Branch name**	**Catchment area** (km^2)	**Time of conc** (hrs)	**CKIF**	**CK12**	**CKBF**
1	Whangarahi Upper	4.45	0.57	113	1.13	2.00E+06
2	Whangarahi Middle	0.55	0.52	103	1.03	2.00E+06
3	Whangarahi Lower	0.51	0.55	110	1.1	2.00E+06
4	Whangarahi Upper Tributary	0.66	0.30	60	0.6	2.00E+06
5	Whangarahi Middle Tributary	2.4	0.40	80	0.8	2.00E+06
6	Whangarahi Lower Tributary	0.47	0.25	50	0.5	2.00E+06
7	Karaka Lower	0.48	0.58	117	1.17	2.00E+06
8	Karaka Middle	0.71	0.42	83	0.83	2.00E+06
9	Karaka Upper	5.53	0.50	100	1	2.00E+06
10	Golf Course Drain	1.76	0.58	117	1.17	2.00E+06
11	Harbour	0.34	0.35	70	0.7	2.00E+06

Table 3.5 Derivation of NAM time based parameters

3.5 High intensity rainfalls

High intensity rainfalls have been sourced from HIRDS Version 3.0 (National Institute of Water & Atmospheric Research (NIWA), 2018) for Whangarahi, Karaka and Golf Course catchments and they was all found to be very similar in value. Both current climate rainfalls and future climate rainfalls have been obtained. The future climate rainfalls have been derived using the Ministry for the Environment Climate Change Projections for New Zealand (Mullan, 2018, p14) assuming a mean temperature increase of 3.0°C for the year 2090. Also recent publication on ICM Climate Change Guidelines (Waikato Regional Council Policy Series 2017/06) where also taken into consideration.

The data from HIRDS were used as an input into the HEC-HMS frequency storm to derive a nested storms. The nested storms were further process with a spreadsheet to arrive at a design storm for hydrological model. Refer to appendice A2 for design storm chart and table 3.6 for HIRDS 24 hour duration rainfall depth in milimitres.

Average recurrence interval (yrs.)	**Current** **24 hour duration- depth** (mm)	**Future(2090)** **24 hour duration- depth** (mm)
2	149	168
5	191	222
10	225	267
20	263	320
50	323	400
100	376	466
200	438	543
500	535	664

Table 3.6 HIRDS 24 hour duration rainfall depth in milimitres

3.6 Design discharges

Peak discharges have been estimated for a range of recurrence intervals using two different methods in addition to the NAM catchment model. The peak flows scaled from the Tapu flood frequency analysis tend to be on the low side. The peak flows derived from both methods generally agree to within 20%-50% the NAM model result (refer

Average recurrence interval (yrs.)	**Peak discharge** (m3/s)			
	Scaled from Tapu	**TM61 catchment model**	**NAM catchment model**	
			Current climate	**Future (2090) climate**
2	41	61	63	79
5	67	80	85	105
10	84	96	103	129
20	101	114	124	156
50	122	142	156	197
100	149	167	187	232

Table 3.7).

Average recurrence interval (yrs.)	Peak discharge (m³/s)			
	Scaled from Tapu	TM61 catchment model	NAM catchment model	
			Current climate	Future (2090) climate
2	41	61	63	79
5	67	80	85	105
10	84	96	103	129
20	101	114	124	156
50	122	142	156	197
100	149	167	187	232

Table 3.7 Summary of peak flood discharges for the Whangarahi Stream at the outlet to Coromandel Harbour

The NAM model discharges have been adopted for the purposes of hydraulic modelling, because the model provides continuous discharge hydrographs for input into the hydraulic model.

4 Hydraulic modelling

4.1 Boundary conditions

The boundary conditions for the hydraulic model consist of inflow hydrographs for each of the 11 sub catchments at the appropriate locations in the model, and a downstream boundary condition for water levels at the outlet of Whangarahi River to the Coromandel Harbour.

The inflow hydrographs for the tributary catchments are taken directly from the NAM rainfall runoff models developed for these catchments.

The hydraulic model setup is in Coromandel local survey datum. The downstream water level boundary condition for all existing and future model scenarios are set respectively at the present day and future day Mean High Water Spring (MHWS) level for Coromandel Harbour. The MHWS value is represented as the highest 10% of all tides exceeded, also known As MHWS10 (Stephens, S., Robinson, B., & Bell, R. 2015).

The MWHS relative levels (RL) in Moturiki vertical datum (MVD-53) for Coromandel Harbour are 1.58m present day and RL2.58m future projected. A conversion factor of 0.52m were added to the Moturiki vertical datum in Figure 4.1 below in order to convert the datum to the local datum of 2.1 present day and 3.1 future projected. The conversion factor was obtained from the survey information provided by the surveying contractor (Surveying Services). The datum conversion is necessary to compare existing scheme asset survey records which are all in local datum.

Location				Coromandel Harbour
Present Day		MHWS (m)		1.58
		Max Tide (m)		1.86
		Storm Tide Range (Estimate)	Lower (m)	1.88
			Upper (m)	2.67
Future Projected	0.5 m projected Sea Level Rise	MHWS (m)		2.08
		Max Tide (m)		2.36
		Storm Tide Range (Estimate)	Lower (m)	2.38
			Upper (m)	3.17
	1.0 m projected Sea Level Rise	MHWS (m)		2.58
		Max Tide (m)		2.86
		Storm Tide Range (Estimate)	Lower (m)	2.88
			Upper (m)	3.67

Figure 4.1 Coromandel Harbour Tides Level in metres at MVD-53 vertical datum. Reference (Waikato Regional Council. (n.d.))

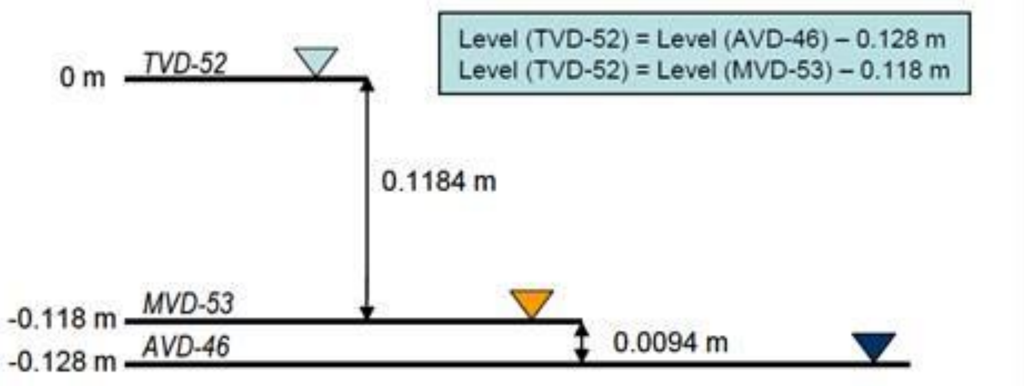

Figure 4.2 Datum difference between Moturiki (MVD-53), Auckland (AVD-46) and Tararu (TVD-52) – Reference (Stephens et al, 2015).

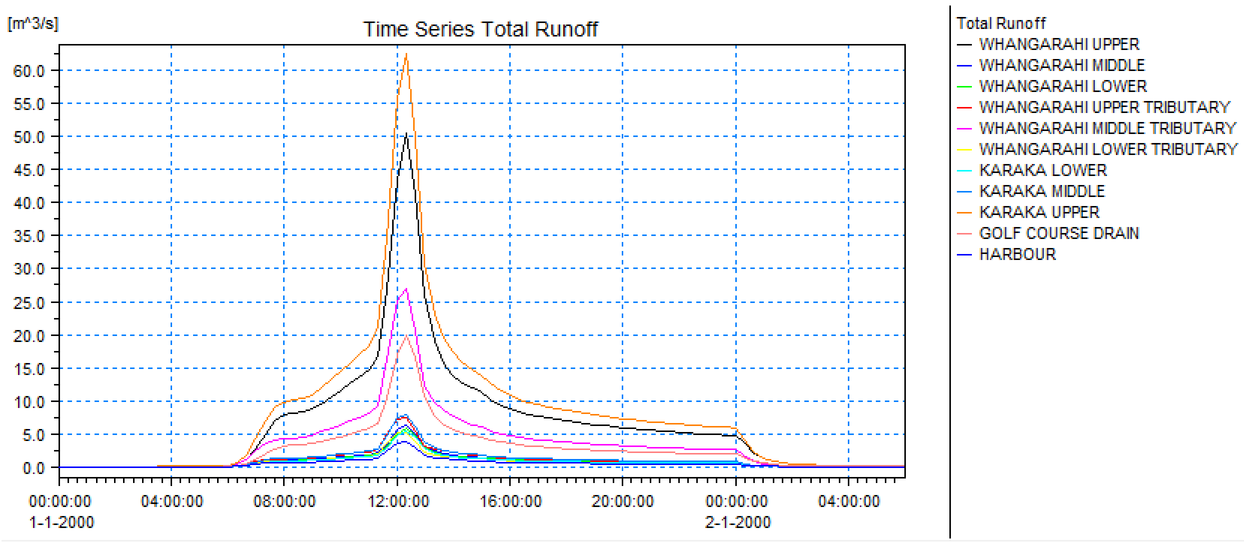

Figure 4.3 100 year ARI NAM catchment discharge hydrographs

4.2 One-dimensional modelling

4.2.1 Channel cross sections and model network

The river channels in the model are defined by surveyed channel cross sections. These cross sections were surveyed in March 2018 by Surveying Services for Waikato Regional Council. The extent of the model and the location of these cross-sections is shown in Figure 4.4. There are nine culvert structures defined in the model, two culverts on the Golf Course stream, a bridge on Karaka Stream, and six bridges along Whangarahi Stream (all bridges were modelled as closed irregular culverts). It is noted that cross section downstream of Kapanga Road Bridge reveals that there are rocky material deposit under Kapanga Road Bridge. The rocky material deposit is restricting flow across the Kapanga Road Bridge opening.

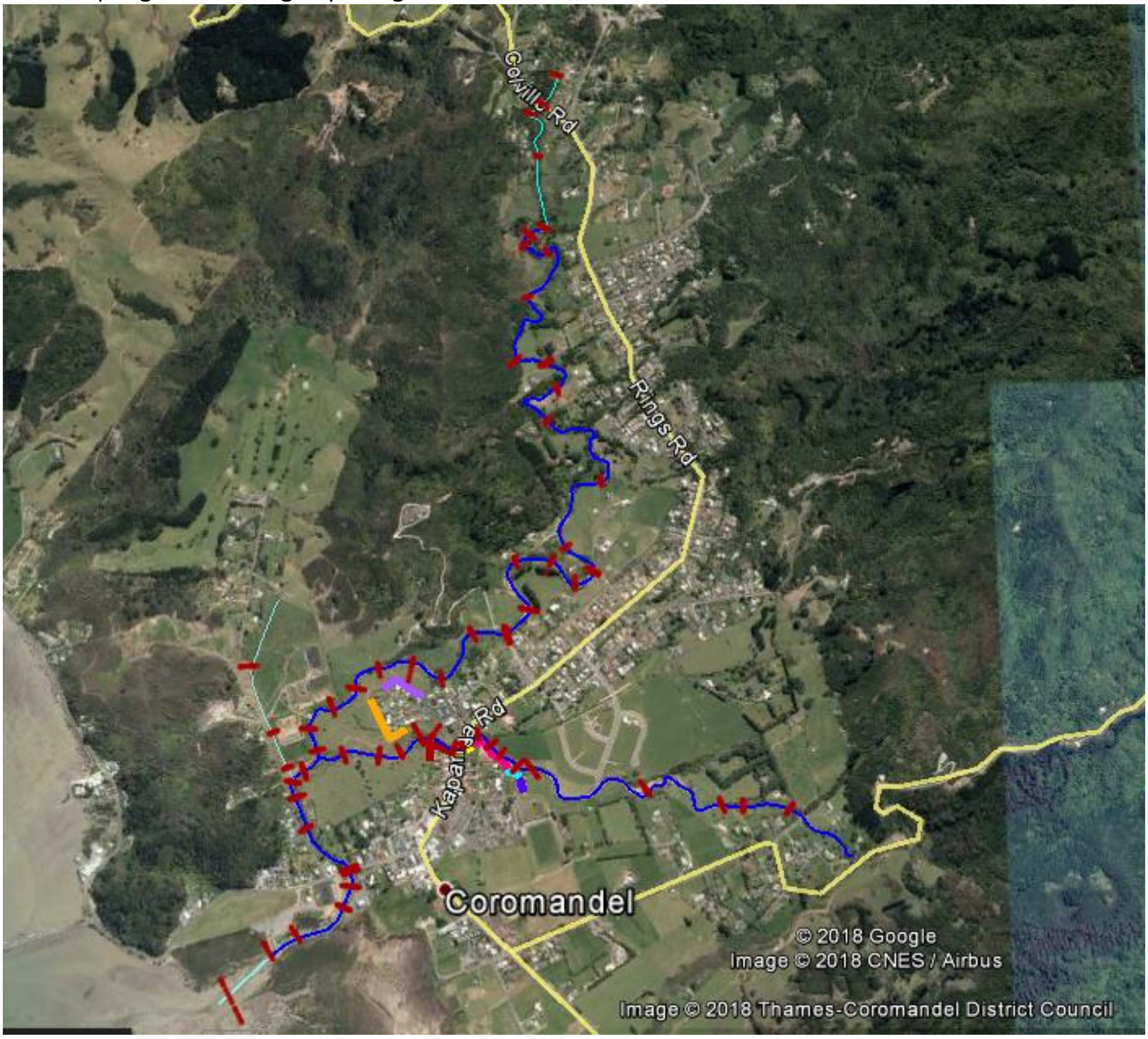

Figure 4.4 Location of MIKE11 model cross sections

4.2.2 Hydraulic parameters

The key hydraulic parameters set in the model (set uniformly across the whole model) are as follows:

Manning's 'n':	Uniform through channel cross section: 0.033
MIKE11 Wave Approximation:	High Order Fully Dynamic

4.2.3 Results

The results for each of the different recurrence interval and climate scenarios are shown in Figure 4.5 through to Figure 4.9 Future climate modelled flood levels for the Karaka Stream

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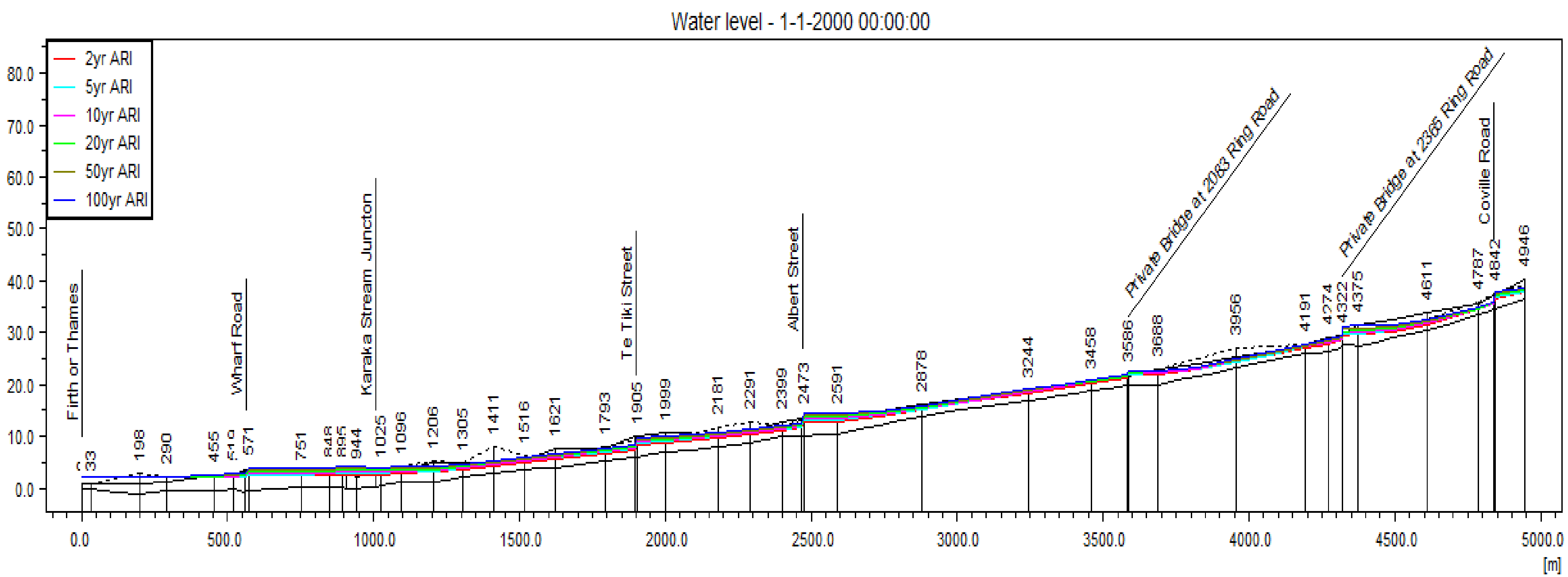
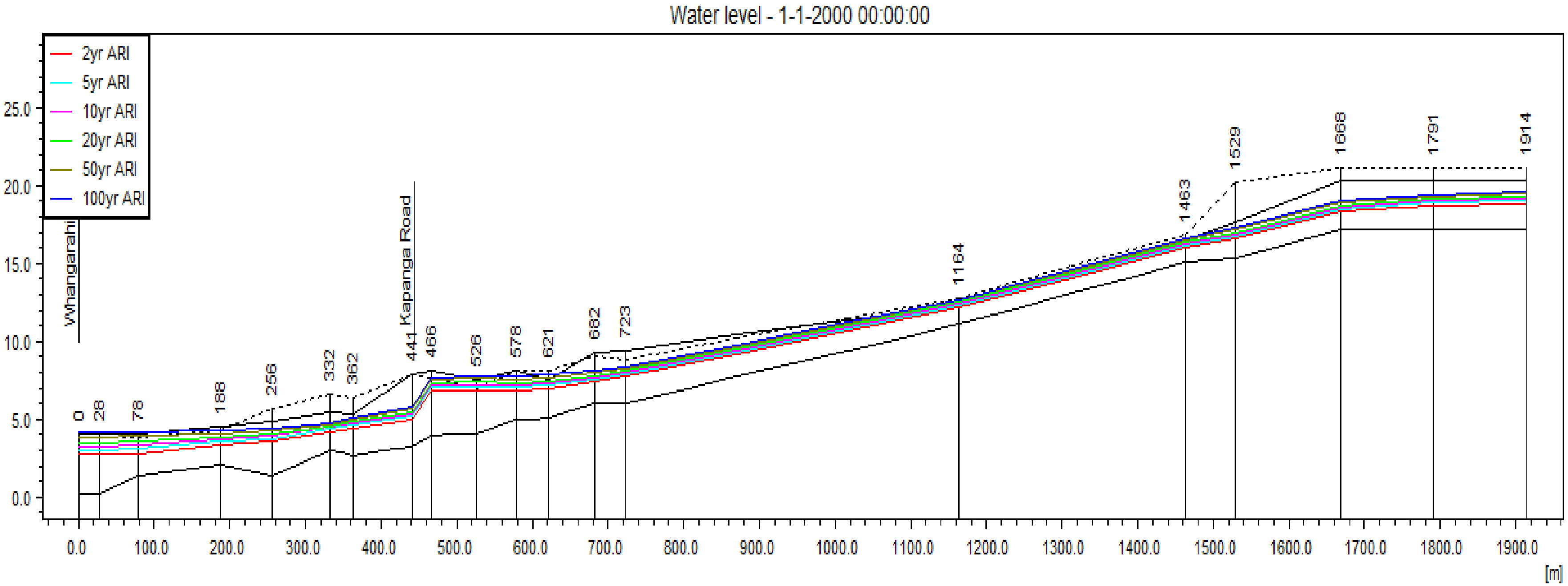


2yr ARI	5yr ARI	10yr ARI	20yr ARI	50yr ARI	100yr ARI
2.100	2.100	2.100	2.100	2.100	2.100
2.118	2.118	2.118	2.121	2.136	2.155
2.106	2.104	2.109	2.124	2.171	2.240
2.180	2.244	2.309	2.407	2.587	2.755
2.212	2.301	2.392	2.518	2.740	2.932
2.494	2.761	3.000	3.250	3.622	3.911
2.582	2.861	3.090	3.322	3.676	3.953
2.710	3.020	3.269	3.527	3.911	4.211
2.721	3.015	3.246	3.488	3.843	4.122
2.825	3.111	3.330	3.566	3.926	4.212
3.107	3.376	3.567	3.774	4.081	4.341
3.679	3.916	4.091	4.275	4.547	4.751
4.335	4.547	4.699	4.855	5.074	5.239
5.093	5.307	5.455	5.594	5.752	5.888
5.738	5.958	6.100	6.222	6.391	6.534
6.786	7.034	7.197	7.351	7.558	7.716
7.449	7.694	7.848	7.998	8.203	8.359
8.694	9.039	9.266	9.455	9.726	9.934
9.630	9.903	10.075	10.239	10.476	10.661
10.360	10.607	10.766	10.920	11.144	11.295
11.175	11.376	11.510	11.640	11.817	11.943
11.635	11.847	11.985	12.123	12.323	12.479
12.839	13.204	13.454	13.726	14.122	14.470
13.828	14.093	14.264	14.442	14.697	14.923
15.106	15.312	15.439	15.564	15.738	15.884
16.693	16.904	17.020	17.134	17.298	17.430
18.267	18.518	18.664	18.803	18.988	19.122
19.267	19.491	19.628	19.760	19.925	20.035
20.274	20.471	20.592	20.706	20.828	20.924
21.220	21.450	21.594	21.732	21.895	22.016
21.916	22.166	22.322	22.468	22.623	22.758
22.817	22.960	23.051	23.162	23.318	23.447
24.286	24.425	24.522	24.627	24.772	24.889
25.685	25.818	25.913	26.012	26.147	26.255
27.110	27.232	27.317	27.409	27.535	27.637
27.861	28.036	28.154	28.281	28.452	28.590
29.622	29.847	30.052	30.325	30.805	31.296
30.229	30.409	30.548	30.719	31.028	31.399
31.598	31.764	31.882	32.014	32.222	32.424
34.383	34.493	34.576	34.669	34.808	34.926
37.756	37.971	38.104	38.232	38.429	38.605

Figure 4.5 Current Climate modelled flood levels for the Whangarahi River



2yr ARI	2.721	2.742	2.794	3.331	3.555	4.208	4.431	5.022	6.806	6.828	6.817	6.909	7.400	7.710	9.154	10.671	12.195	14.079	16.034	16.572	18.305	18.719	18.828
5yr ARI	3.015	3.041	3.082	3.527	3.745	4.363	4.595	5.214	7.045	7.078	7.059	7.152	7.574	7.881	9.334	10.843	12.358	14.217	16.123	16.726	18.462	18.882	19.014
10yr ARI	3.246	3.267	3.298	3.666	3.878	4.456	4.718	5.344	7.178	7.222	7.198	7.300	7.690	8.001	9.448	10.942	12.446	14.308	16.215	16.844	18.583	19.001	19.148
20yr ARI	3.488	3.511	3.537	3.824	4.030	4.544	4.840	5.477	7.318	7.375	7.346	7.454	7.810	8.115	9.545	11.027	12.524	14.402	16.315	16.964	18.706	19.117	19.278
50yr ARI	3.843	3.863	3.884	4.075	4.263	4.682	5.002	5.664	7.527	7.603	7.565	7.677	7.987	8.269	9.664	11.125	12.627	14.521	16.452	17.130	18.879	19.277	19.455
100yr ARI	4.122	4.139	4.158	4.290	4.450	4.801	5.133	5.812	7.691	7.780	7.735	7.848	8.133	8.387	9.745	11.206	12.707	14.610	16.555	17.260	19.016	19.406	19.597

Figure 4.6 Current climate modelled flood levels for the Karaka Stream

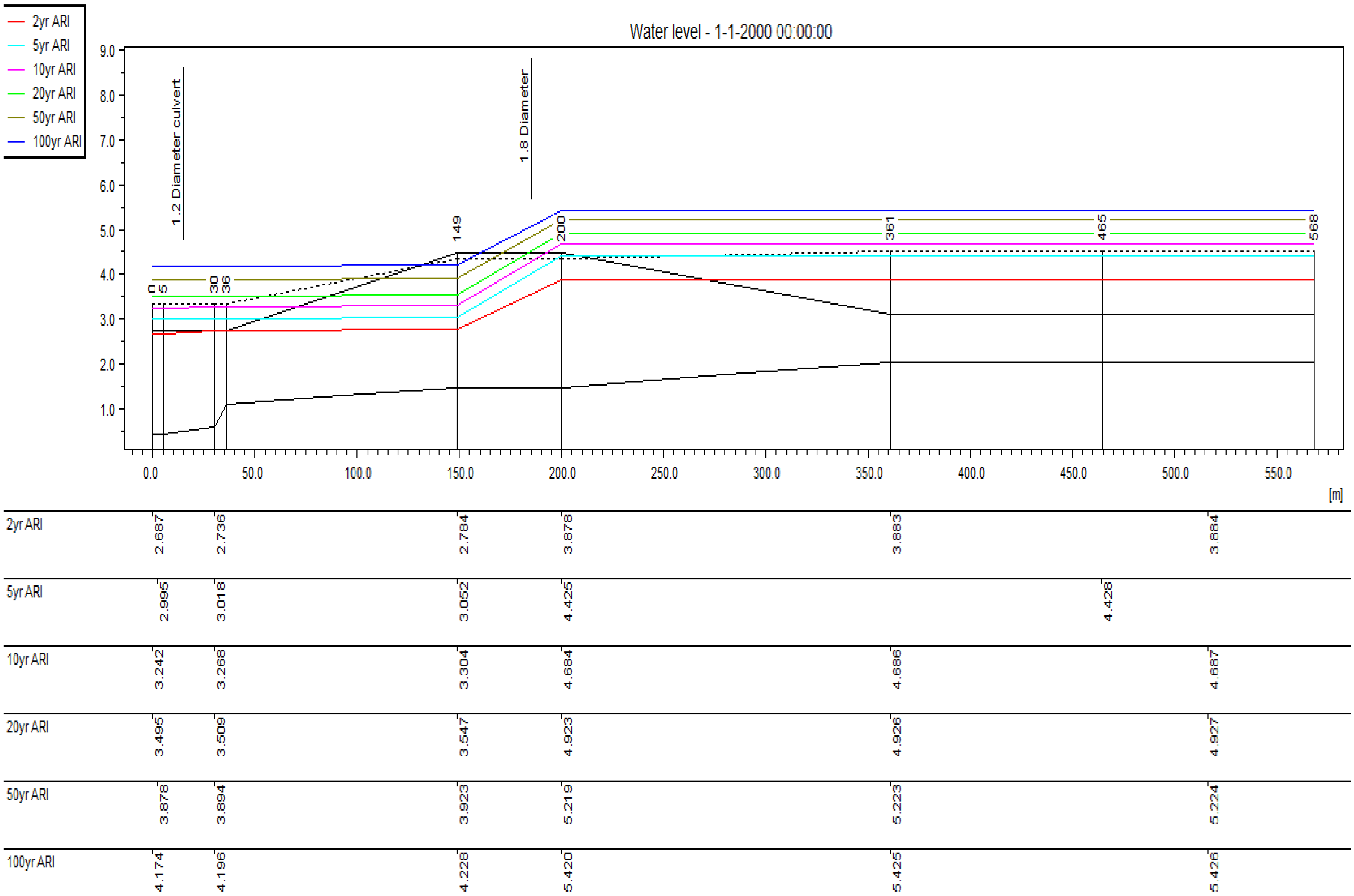
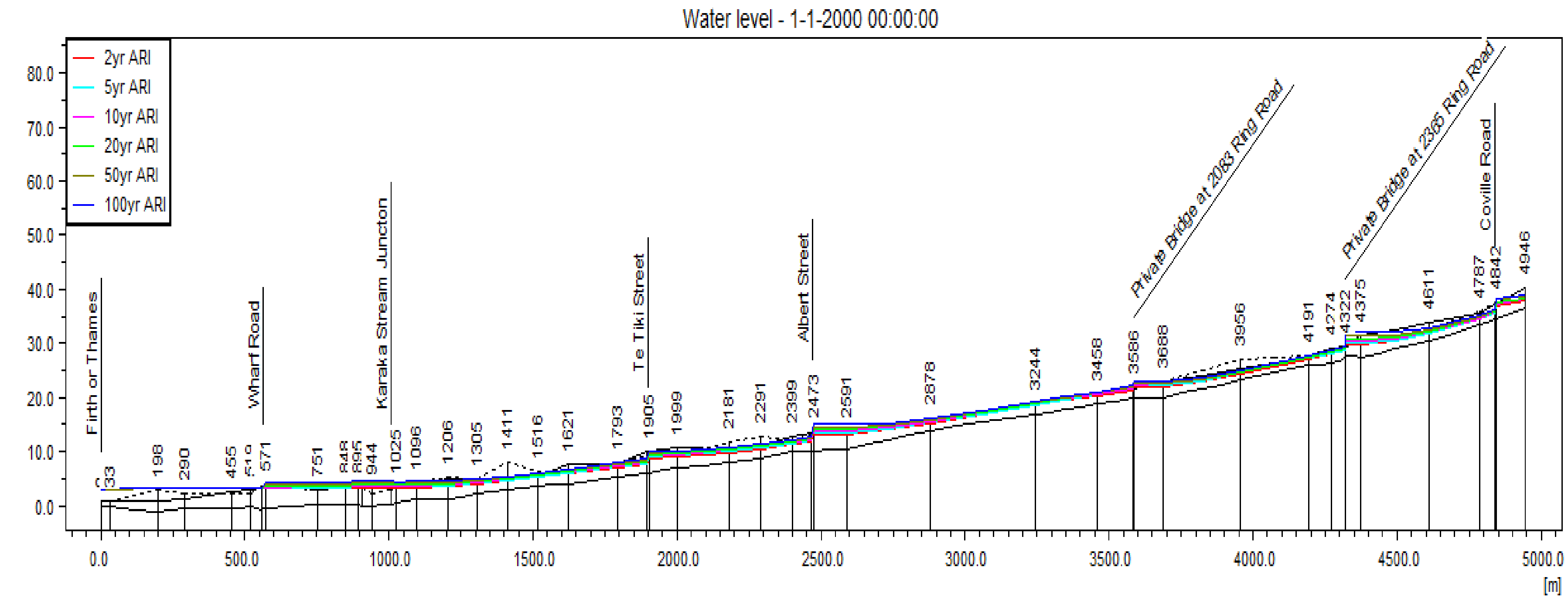


Figure 4.7 Current climate modelled flood levels for the Golf Course Stream

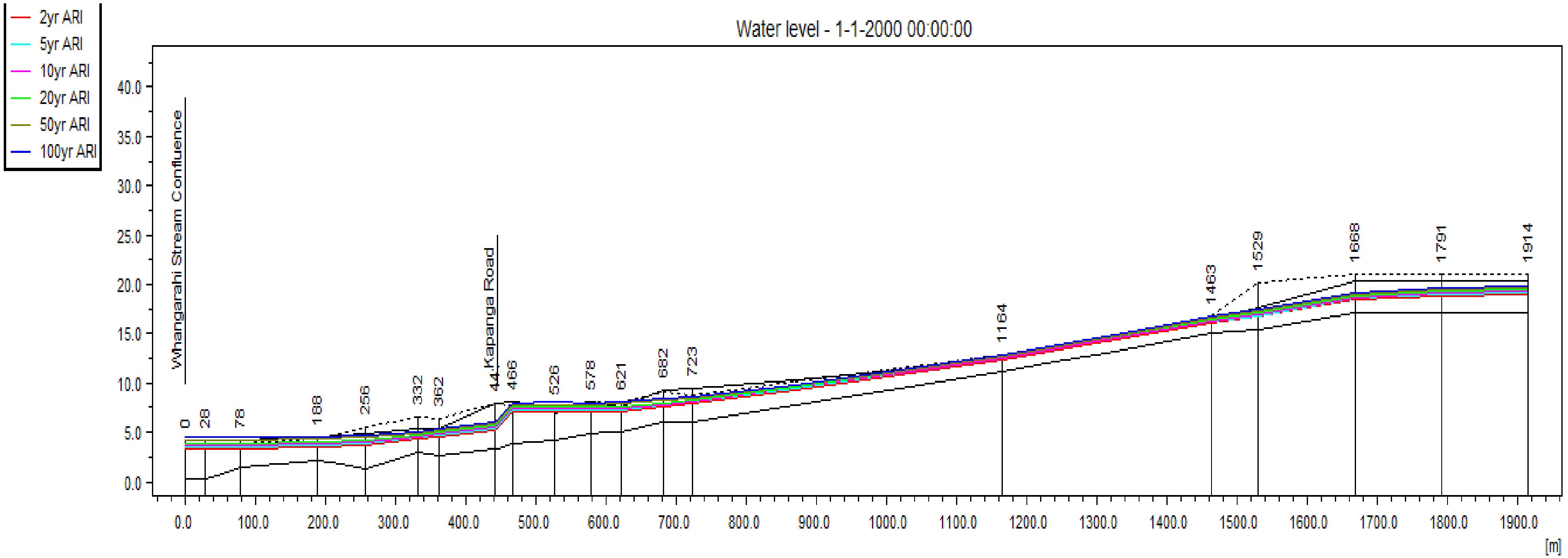


2yr ARI	3.100	3.107	3.113	3.125	3.135	3.222	3.249	3.343	3.314	3.351	3.467	3.897	4.491	5.244
5yr ARI	3.100	3.107	3.113	3.129	3.161	3.325	3.365	3.514	3.473	3.528	3.674	4.128	4.708	5.458
10yr ARI	3.100	3.107	3.113	3.145	3.191	3.451	3.499	3.692	3.639	3.704	3.858	4.324	4.882	5.609
20yr ARI	3.100	3.107	3.113	3.168	3.235	3.632	3.683	3.913	3.845	3.924	4.070	4.529	5.056	5.736
50yr ARI	3.100	3.107	3.113	3.221	3.323	3.987	4.026	4.290	4.197	4.287	4.409	4.803	5.283	5.919
100yr ARI	3.100	3.107	3.113	3.282	3.416	4.278	4.304	4.594	4.480	4.577	4.665	5.006	5.446	6.044

2yr ARI	5.889	6.951	7.611	8.913	9.812	10.528	11.314	11.783	13.096	14.010	15.253	16.843	18.452	19.433
5yr ARI	6.101	7.199	7.850	9.268	10.077	10.768	11.511	11.987	13.458	14.267	15.441	17.022	18.666	19.630
10yr ARI	6.237	7.371	8.018	9.479	10.261	10.941	11.657	12.142	13.762	14.466	15.581	17.149	18.821	19.776
20yr ARI	6.372	7.536	8.182	9.696	10.451	11.122	11.799	12.302	14.078	14.669	15.719	17.280	18.969	19.910
50yr ARI	6.568	7.755	8.397	9.989	10.709	11.337	11.977	12.521	14.566	14.988	15.926	17.465	19.155	20.064
100yr ARI	6.704	7.902	8.544	10.202	10.897	11.505	12.110	12.687	14.994	15.282	16.101	17.603	19.286	20.181

2yr ARI	20.420	21.392	22.093	22.925	24.387	25.780	27.199	27.990	29.783	30.360	31.723	34.464	37.921
5yr ARI	20.593	21.596	22.325	23.052	24.523	25.914	27.318	28.155	30.055	30.549	31.883	34.577	38.105
10yr ARI	20.718	21.748	22.487	23.177	24.640	26.025	27.421	28.296	30.365	30.744	32.032	34.681	38.250
20yr ARI	20.815	21.878	22.605	23.301	24.756	26.132	27.521	28.433	30.748	30.990	32.198	34.792	38.407
50yr ARI	20.949	22.045	22.794	23.481	24.921	26.284	27.664	28.627	31.445	31.519	32.479	34.958	38.658
100yr ARI	21.054	22.160	23.054	23.644	25.048	26.397	27.770	28.769	32.123	32.129	32.729	35.094	38.878

Figure 4.8 Future climate modelled flood levels for the Whangarahi River



2yr ARI	3.314	3.327	3.339	3.572	3.727	4.332	4.554	5.168	6.995	7.023	7.007	7.098	7.533	7.840	9.292	10.803	12.322	14.186	16.094	16.692	18.424	18.839	18.965
5yr ARI	3.473	3.490	3.506	3.741	3.908	4.460	4.721	5.347	7.180	7.224	7.200	7.302	7.691	8.002	9.450	10.943	12.447	14.309	16.216	16.845	18.584	19.002	19.149
10yr ARI	3.639	3.658	3.677	3.895	4.077	4.559	4.856	5.495	7.338	7.397	7.367	7.476	7.827	8.130	9.557	11.037	12.533	14.414	16.328	16.980	18.722	19.132	19.294
20yr ARI	3.845	3.864	3.885	4.068	4.251	4.669	4.986	5.644	7.504	7.578	7.541	7.653	7.967	8.253	9.652	11.115	12.616	14.509	16.437	17.113	18.860	19.260	19.436
50yr ARI	4.197	4.212	4.230	4.347	4.500	4.835	5.170	5.853	7.735	7.828	7.781	7.894	8.174	8.420	9.769	11.228	12.728	14.633	16.581	17.294	19.052	19.440	19.635
100yr ARI	4.480	4.493	4.505	4.584	4.713	4.984	5.322	6.019	7.920	8.025	7.971	8.080	8.349	8.561	9.866	11.315	12.810	14.721	16.683	17.428	19.190	19.576	19.786

Figure 4.9 Future climate modelled flood levels for the Karaka Stream

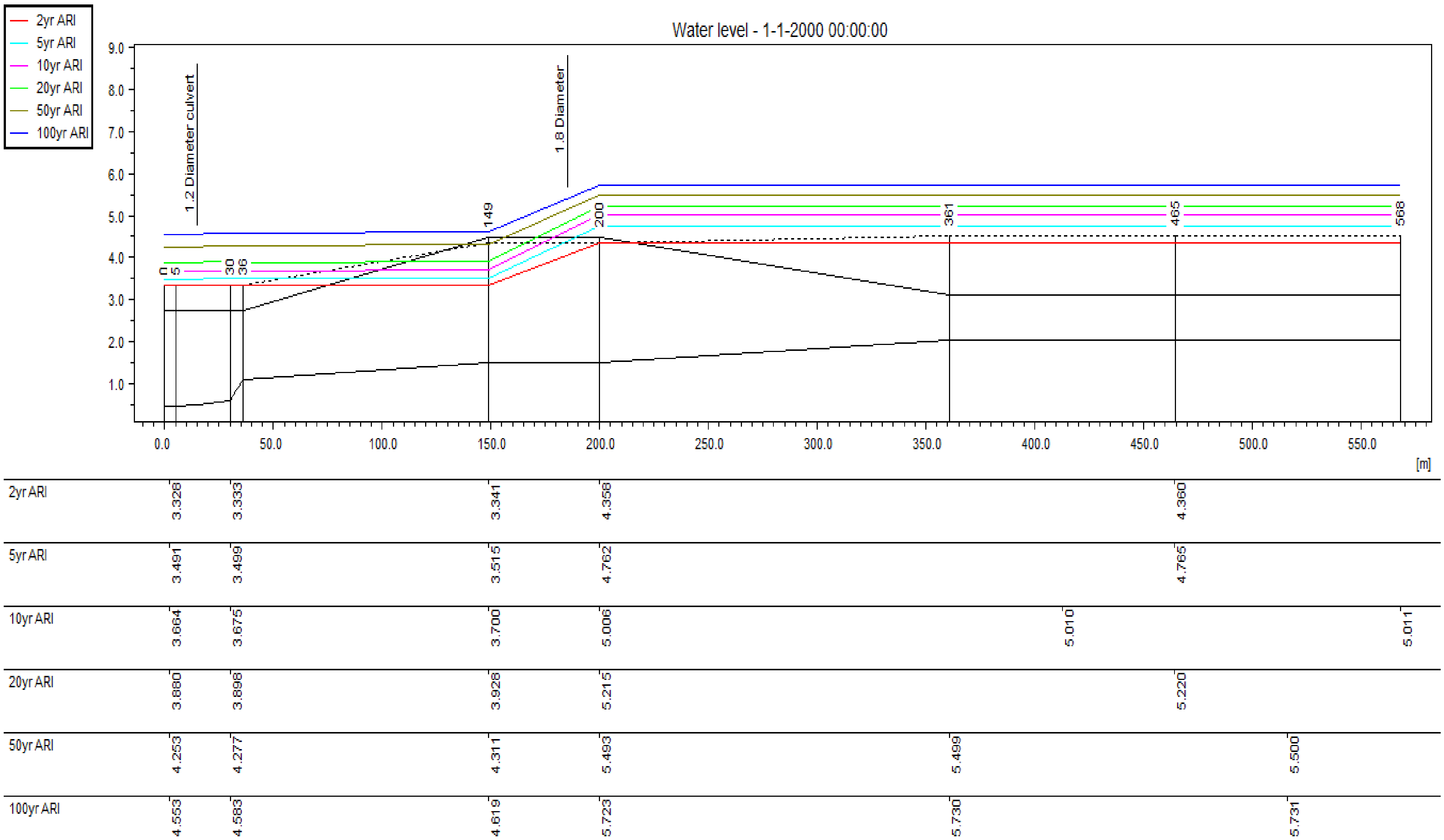


Figure 4.10 Future climate modelled water level profiles for the Golf Course Stream

4.3 Coupled One/Two-dimensional modelling

4.3.1 Digital elevation data

In 2012/2013, Waikato Regional Council carried out a Light Detection and Ranging (LiDAR) survey to provide detailed topographic data for the Coromandel Peninsula and harbours. The LiDAR and digital imagery was acquired between 1 January and 12 March 2013 using NZAM's Optech 3100EA LiDAR system (05SEN178) and Trimble AIC medium format digital camera. The data set contains both the ASCII point data and the ESRI Grid data which are all within 0.15m Root-Mean-Square (RMS) error at 68% confidence, relative to Auckland 1946 or Tararu 1952 (depending on area) or NZVD datum in each case.

The above data was converted to the local vertical datum by applying a blanket shift of 0.53m off set using DHI Mike Zero Tool Box. This was done so that the modelling results would be in the same datum as the as-built records for the scheme asset. The conversion of LiDAR data from standard datum to local datum may have introduce some conversion errors into the modelling process. Hence it is recommended that for all future scheme review, the Hydraulic modelling be carried out in the standard vertical datum or the same datum as the LiDAR data. This will usually be in using Moturiki Vertical Datum or New Zealand Vertical Datum.

The extent of coverage of the above data for this project includes only the lower Whangarahi Stream catchment. This LiDAR data forms the base topographical data for the two dimensional modelling and is shown in
Figure 4.11

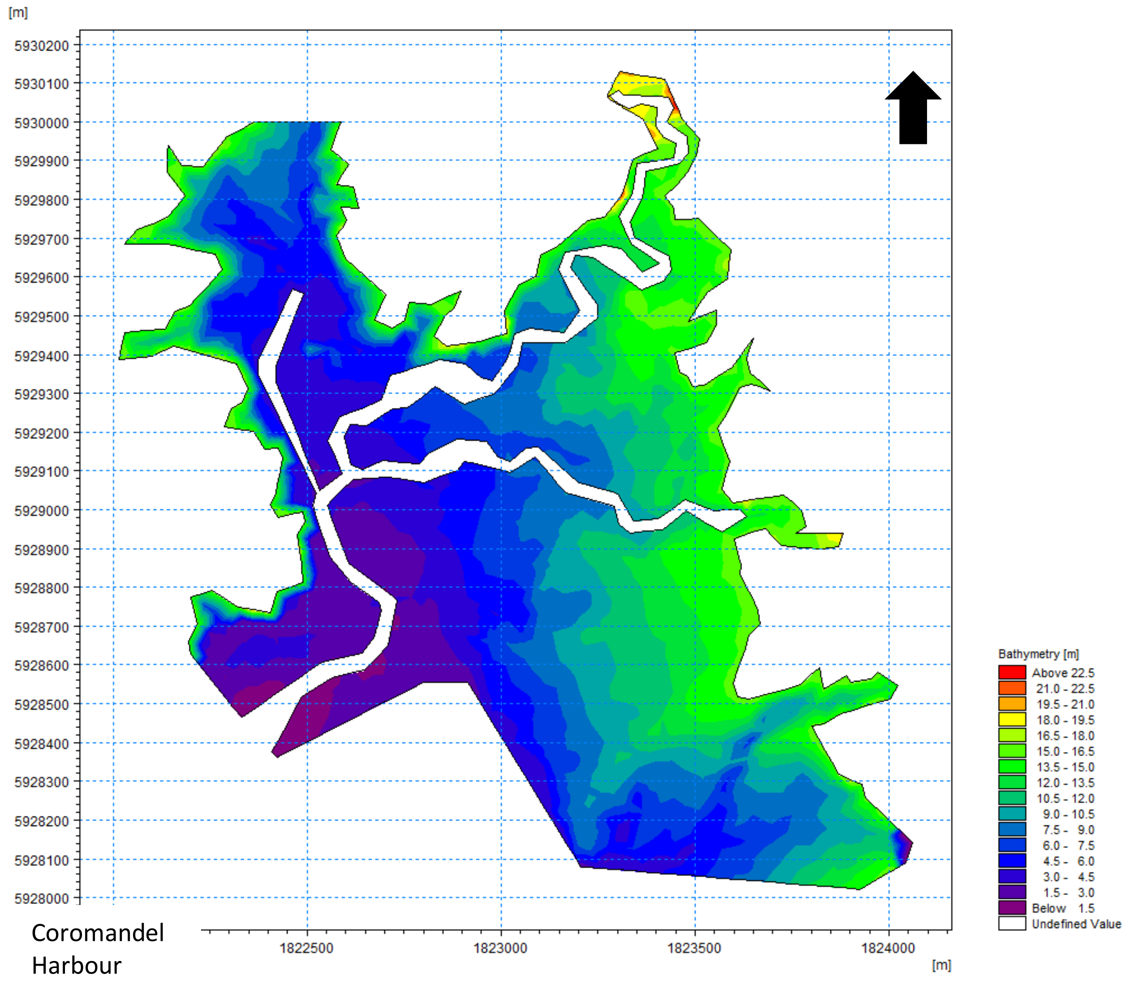


Figure 4.11 Mike 21 model extent and bathymetry

The coupled one/two-dimensional modelling was carried out by first developing two separate models in Mike 11 (one dimensional model) and Mike 21 flow model FM. MIKE 21 Flow Model FM is a two dimensional modelling system based on a flexible mesh approach. The two models was then merged together using Mike Flood. The Rainfall Runoff Module and the Hydrodynamic Module were enabled in the one dimensional model while only the Hydrodynamic Module was enabled in the two dimensional model

The one and two dimensional model was linked into Mike Flood, using user defined links to represent the left and right side embankment. Karaka left bank embankment and Coromandel Retirement Village stop bank (section 2) were added to the coupled model as external lateral link structures with known elevations. Section 1 of Coromandel Retirement Village stop bank that is not directly related to the main channels were added to the two dimensional model as a dike structure.

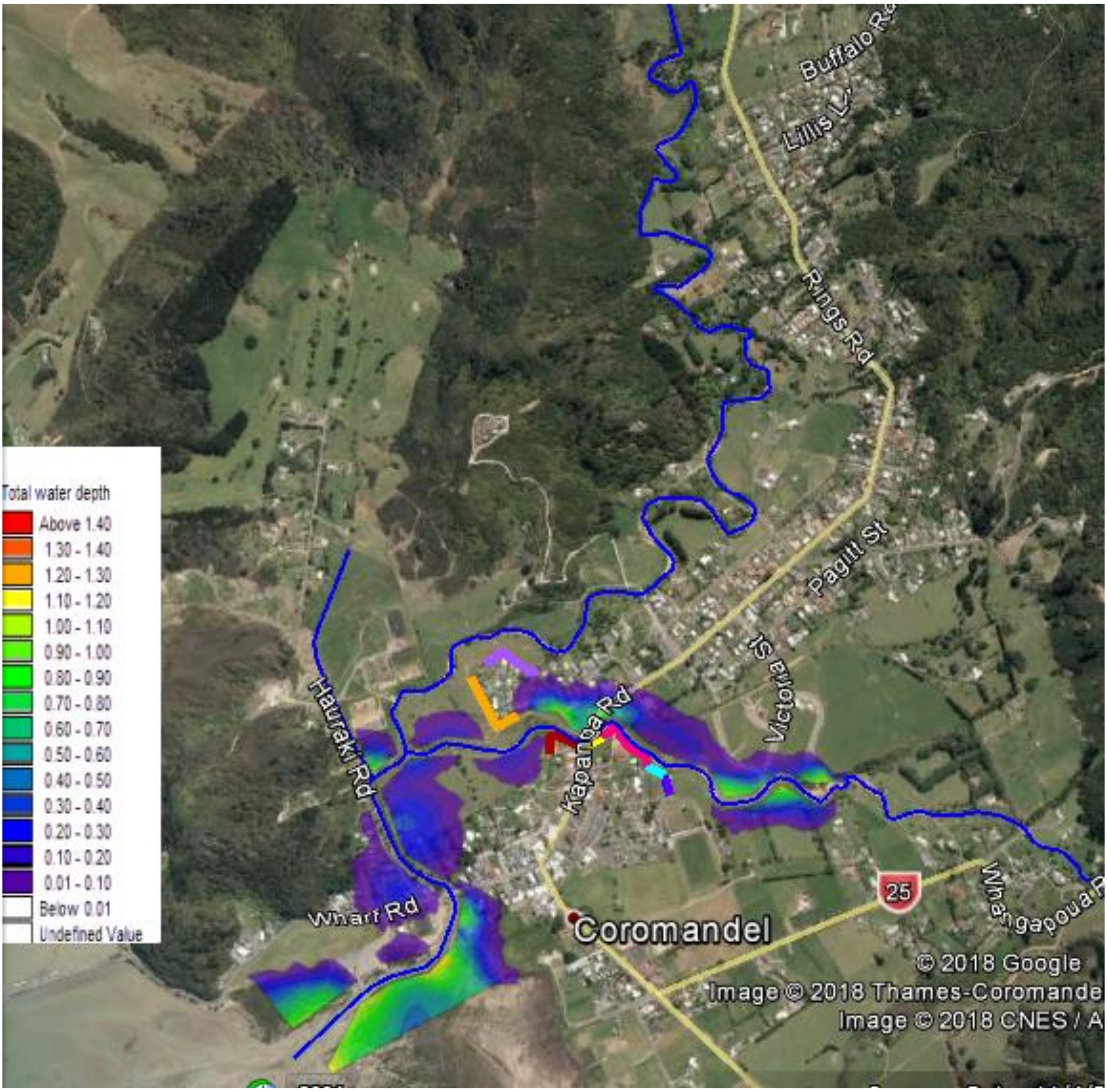
4.3.2 Hydraulic parameters

The roughness parameters for the model have been set at the same value as for the 1 dimensional model. In addition the eddy viscosity parameter has been set to 0.3.

4.3.3 Results

Six different scenarios have been modelled. They are the 20, 50, 100 year ARI current climate inflows with the present day MWHS; the 100 year future climate inflows with projected 1m sea level rise MWHS (future climate); and the 2 and 10 year flood with projected 1m sea level rise for the storm tide upper range estimate(refer Figure 4.1).

Peak water depths for these six scenarios are shown mapped in



Total water depth
Above 1.40
1.30 - 1.40
1.20 - 1.30
1.10 - 1.20
1.00 - 1.10
0.90 - 1.00
0.80 - 0.90
0.70 - 0.80
0.60 - 0.70
0.50 - 0.60
0.40 - 0.50
0.30 - 0.40
0.20 - 0.30
0.10 - 0.20
0.01 - 0.10
Below 0.01
Undefined Value
Buffalo Rd
Lillis La
Rings Rd
Pagitt St
Victoria St
Kapanga Rd
Hauraki Rd
Wharf Rd
Coromandel
25
© 2018 Google
Image © 2018 Thames-Coromande
Image © 2018 CNES / A

Figure 4.12 to

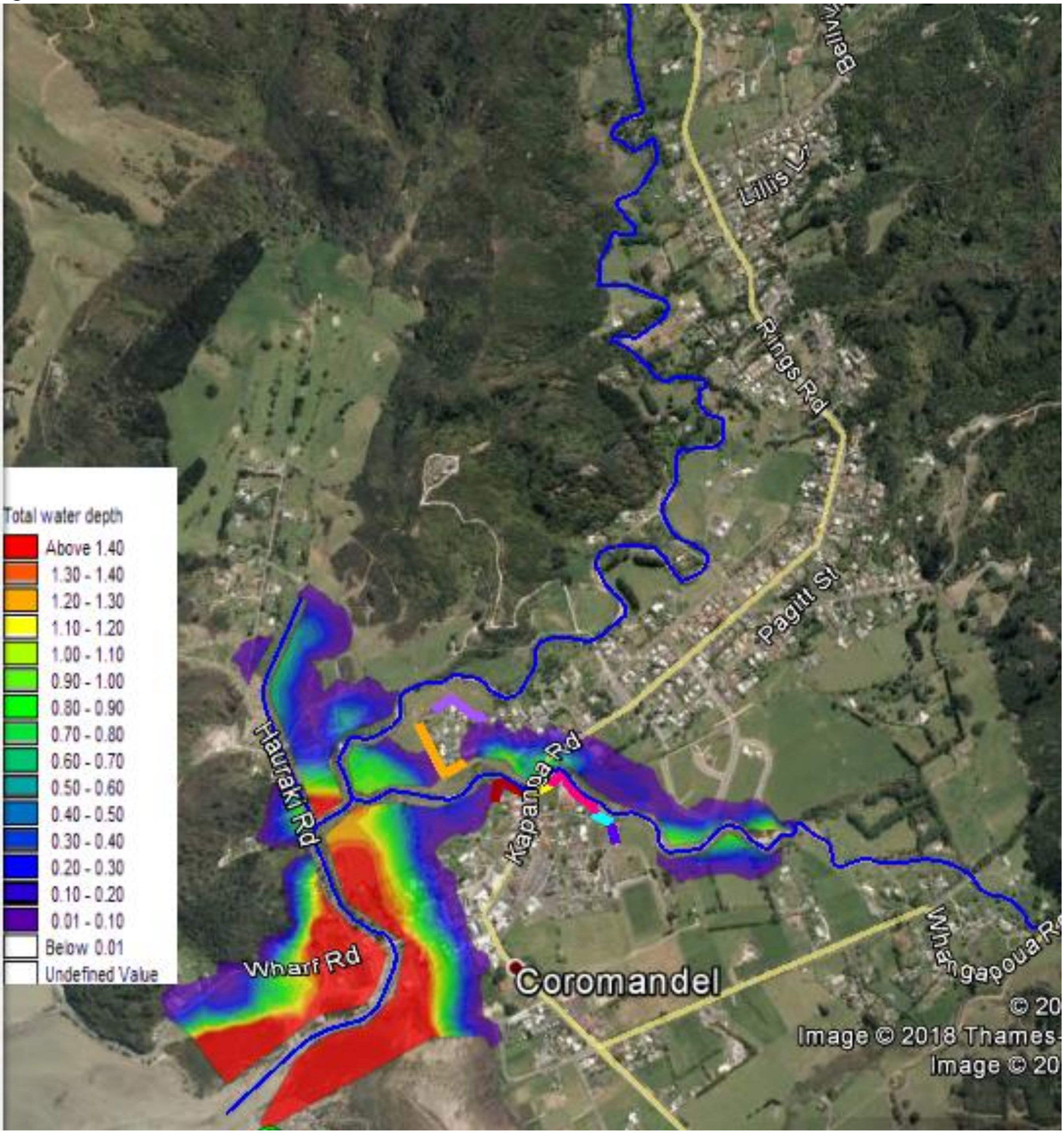


Figure 4.17.

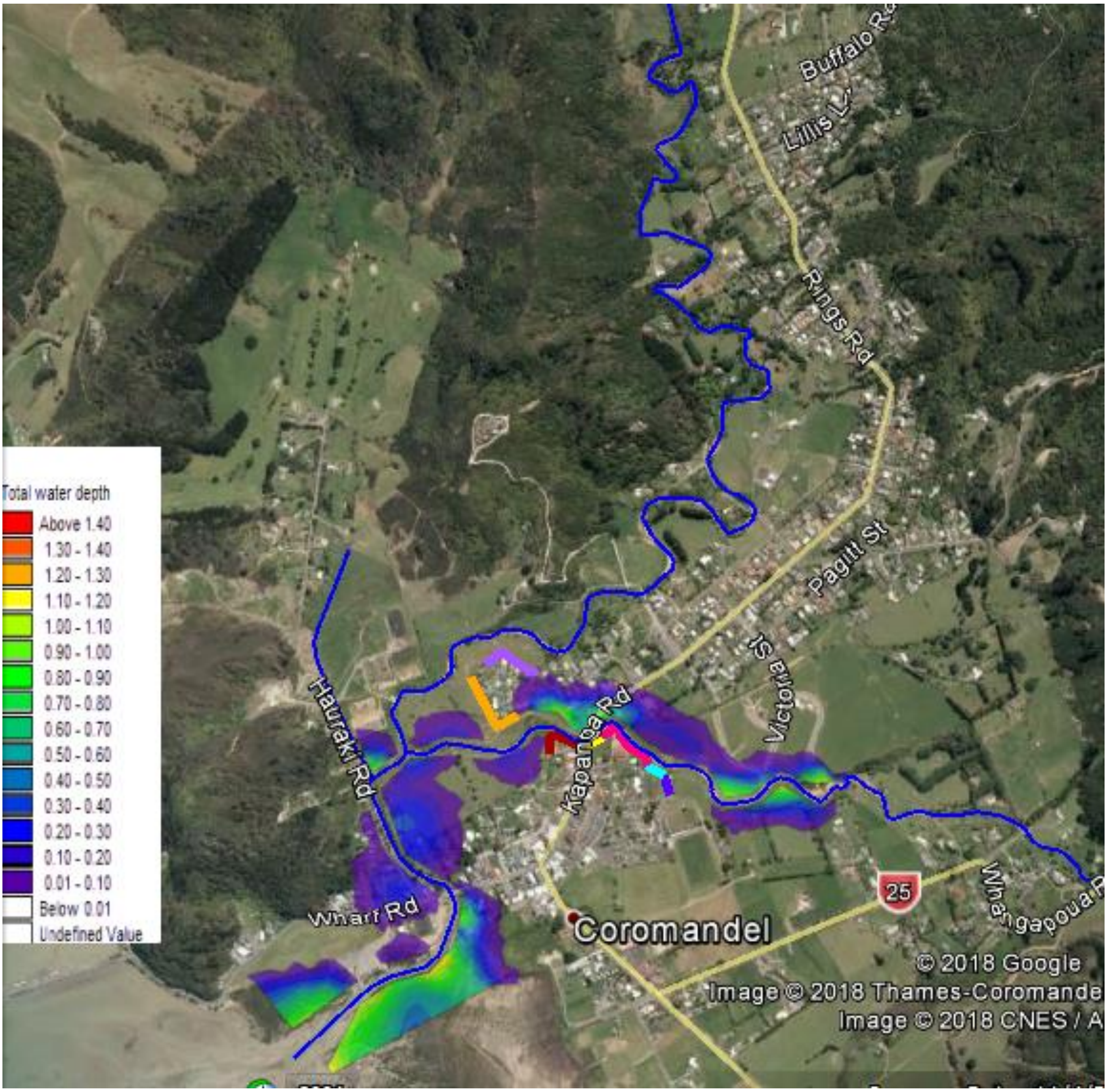


Figure 4.12 Two-dimensional model results for the 20 year flood (current climate)

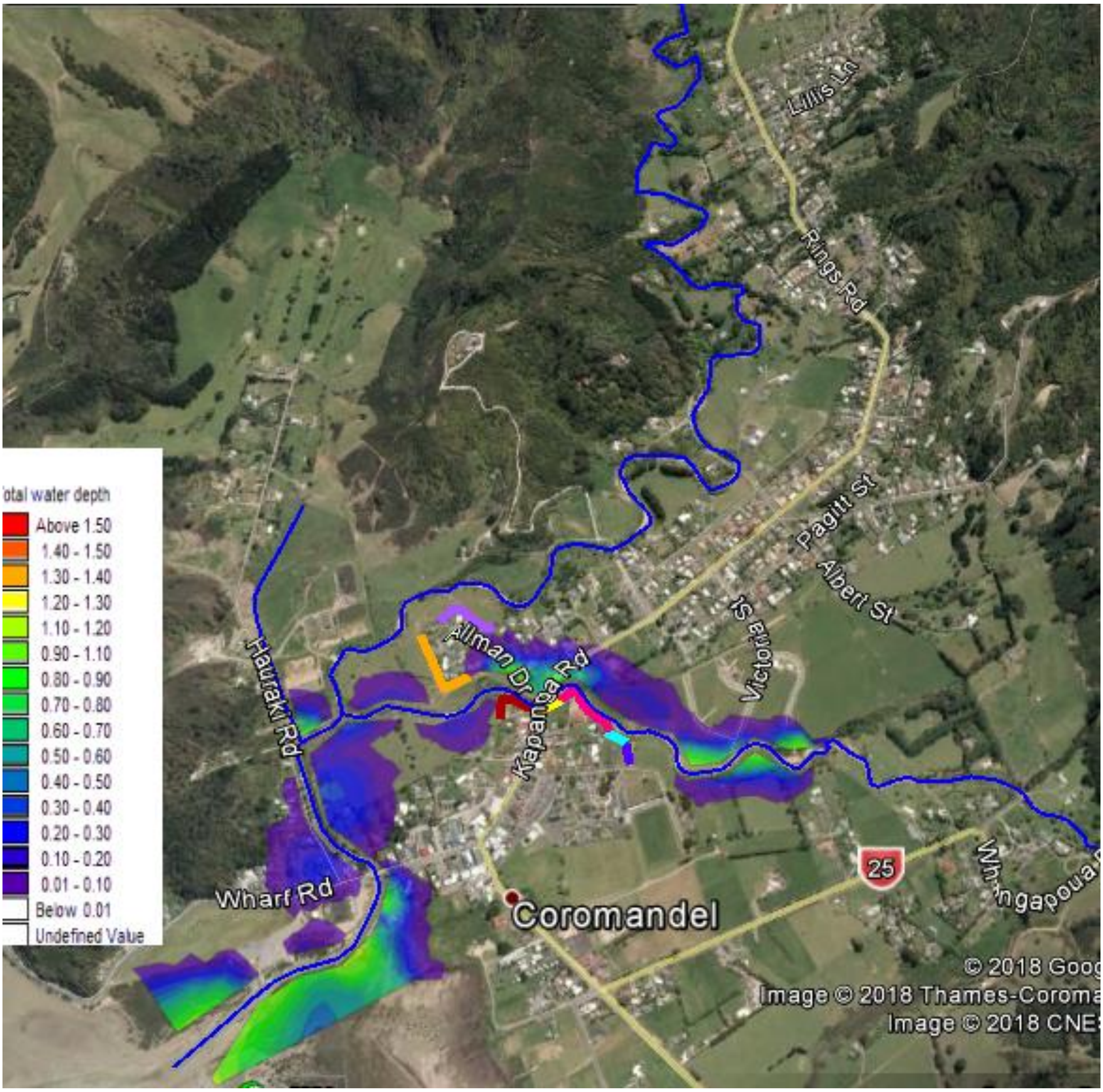


Figure 4.13 Two-dimensional model results for the 50 year flood (current climate)

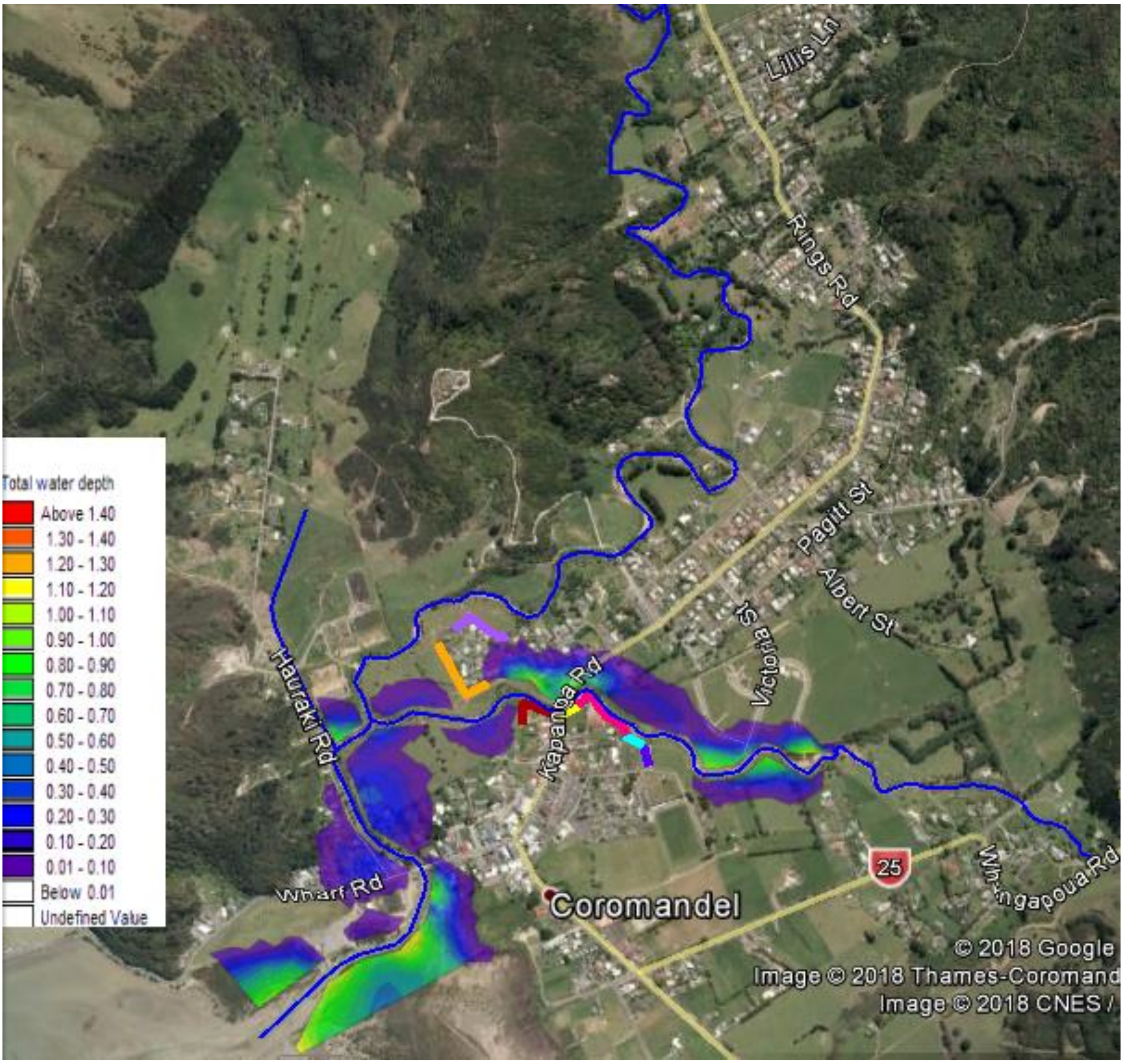


Figure 4.14 Two-dimensional model results for the 100 year flood (current climate)

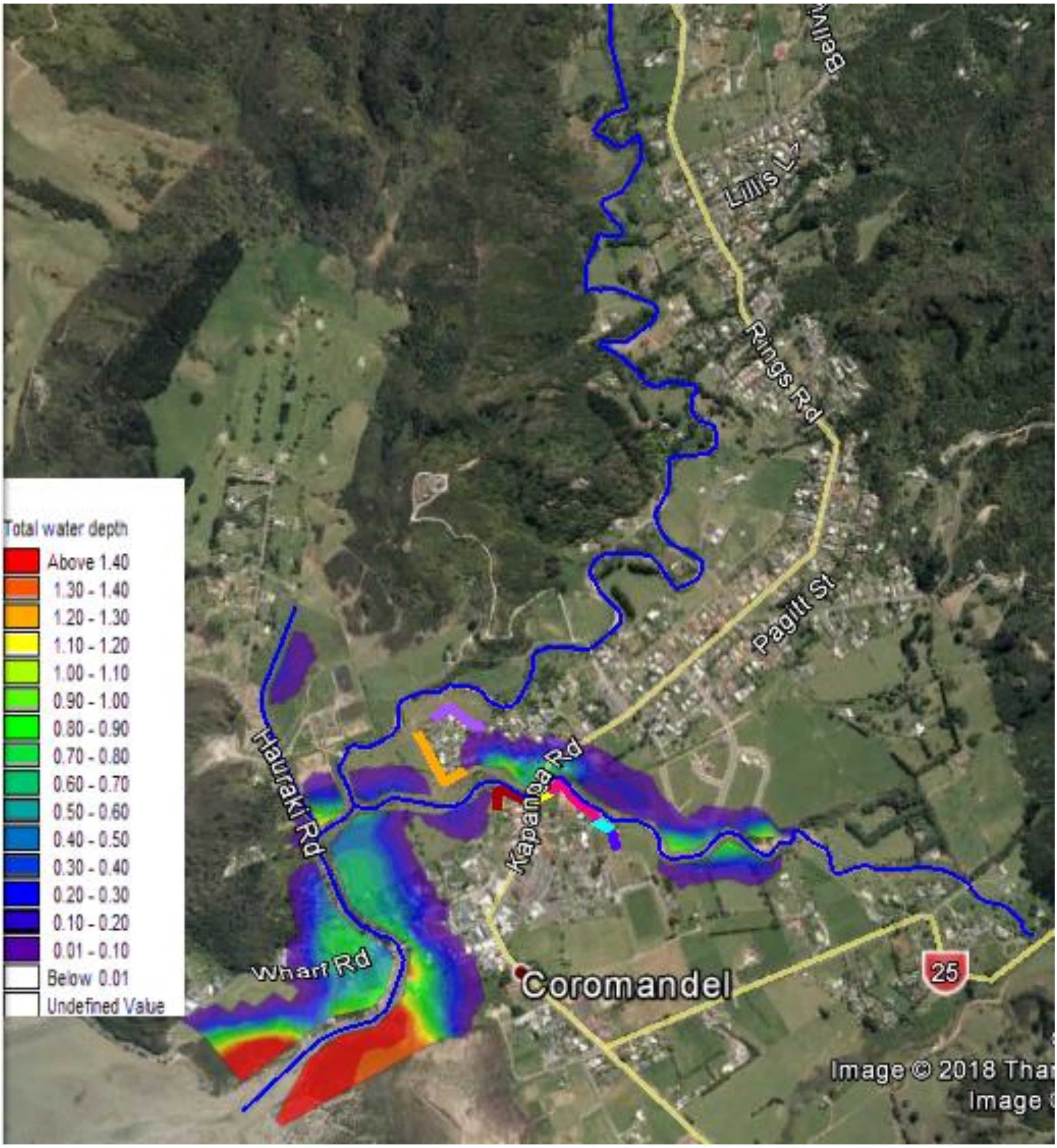


Figure 4.15 Two-dimensional model results for the 100 year flood (Future climate)

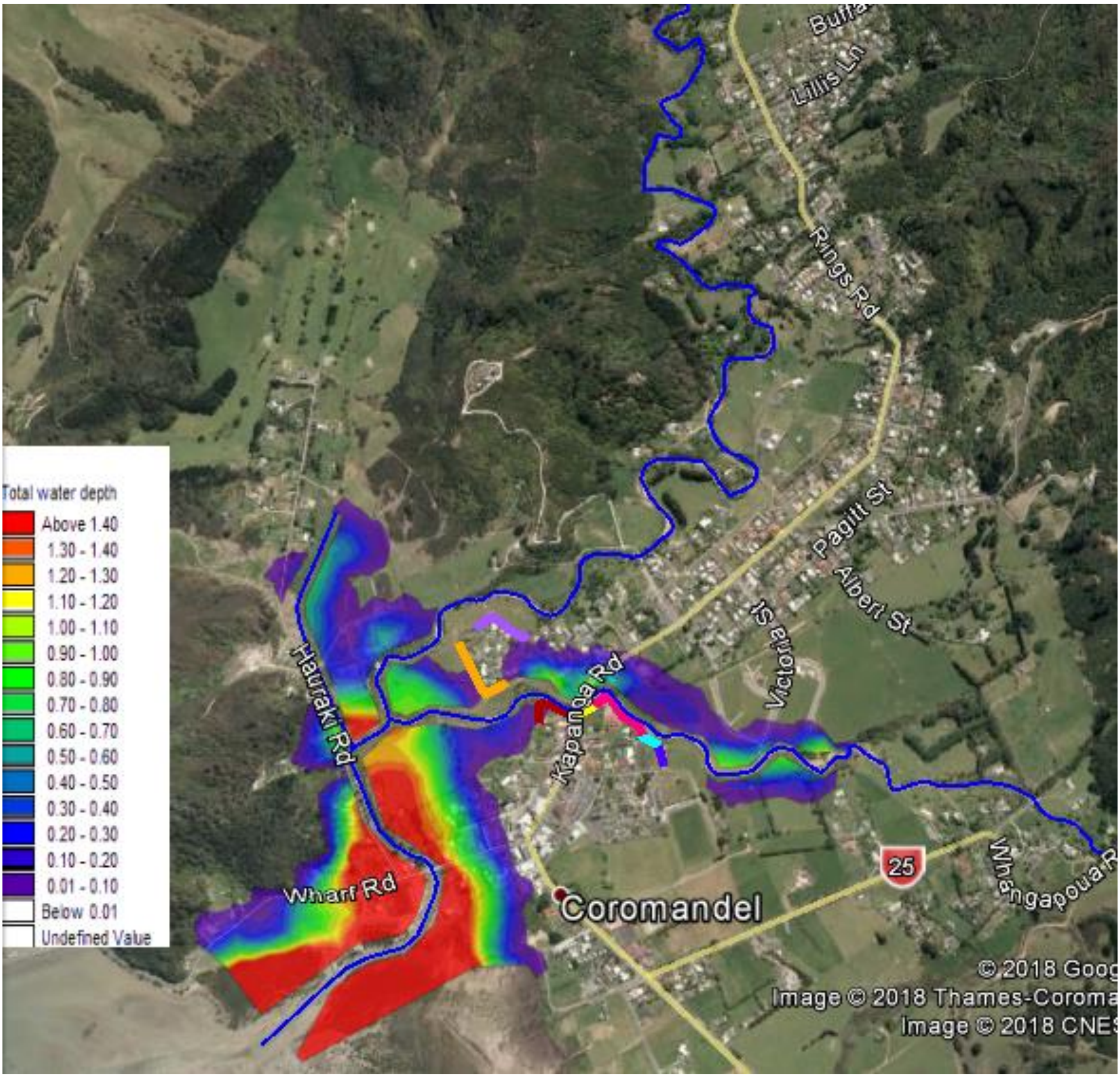


Figure 4.16 Two-dimensional model results for the 2 year flood with projected 1m sea level rise (Future climate)

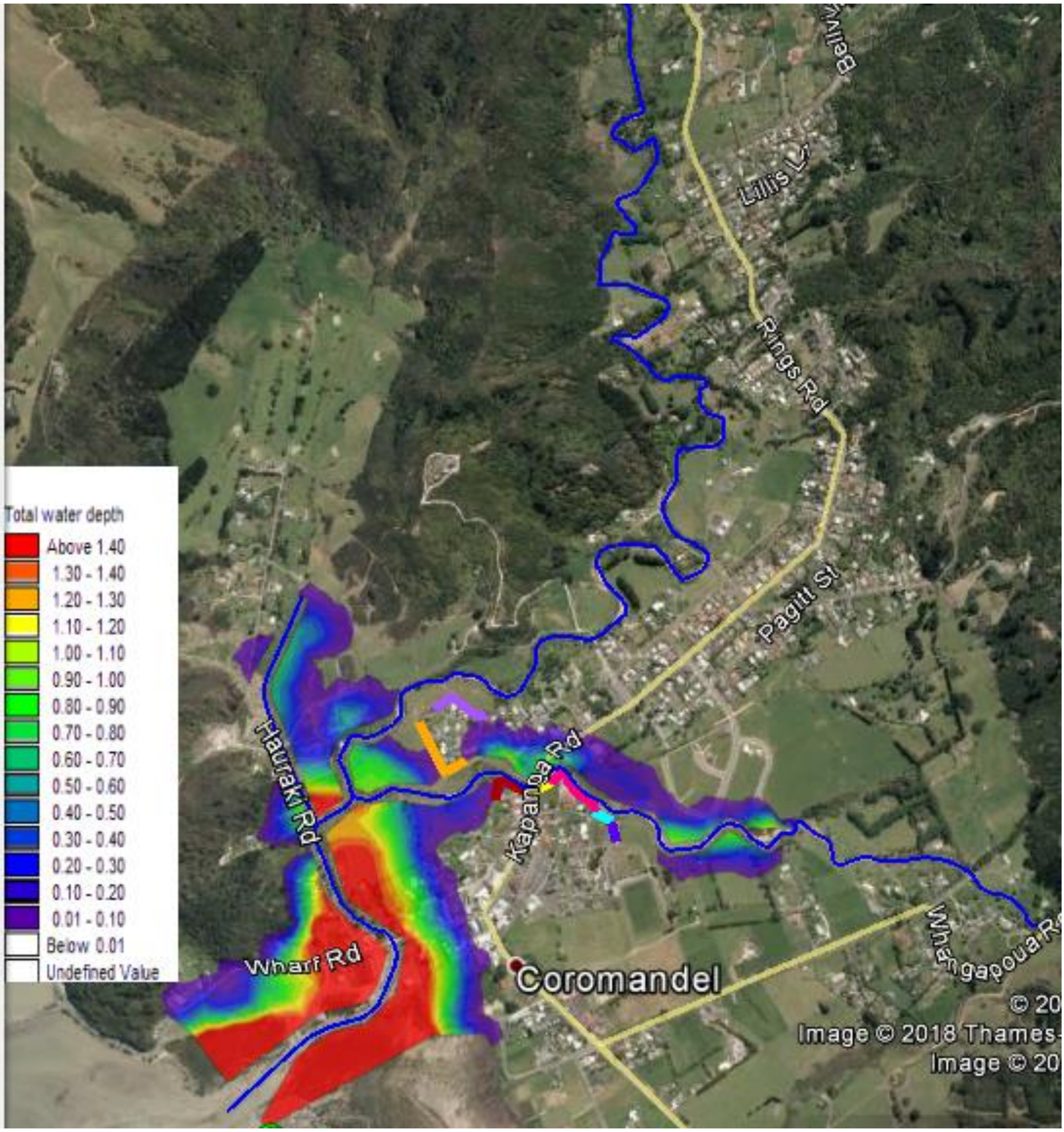


Figure 4.17 Two-dimensional model results for the 10 year flood with projected 1m sea level rise (Future climate

5 Service level assessment

5.1 Introduction

This section presents a review of service levels for the stop bank at Elizabeth Park (Coromandel Retirement Village) and the Karaka Stream left bank stop bank and floodwalls.

Levels of Service (LOS) for a particular amenity is defined by the quality of delivery against which service performance can be measured. The level of service provided by the scheme at Elizabeth Park Retirement Village and on Karaka Stream in the vicinity of the Kapanga Road Bridge is the existing 1 in 100yr ARI event (without climate change) plus 500mm freeboard. The general location of the flood protection assets is shown in Figure 5.1 below

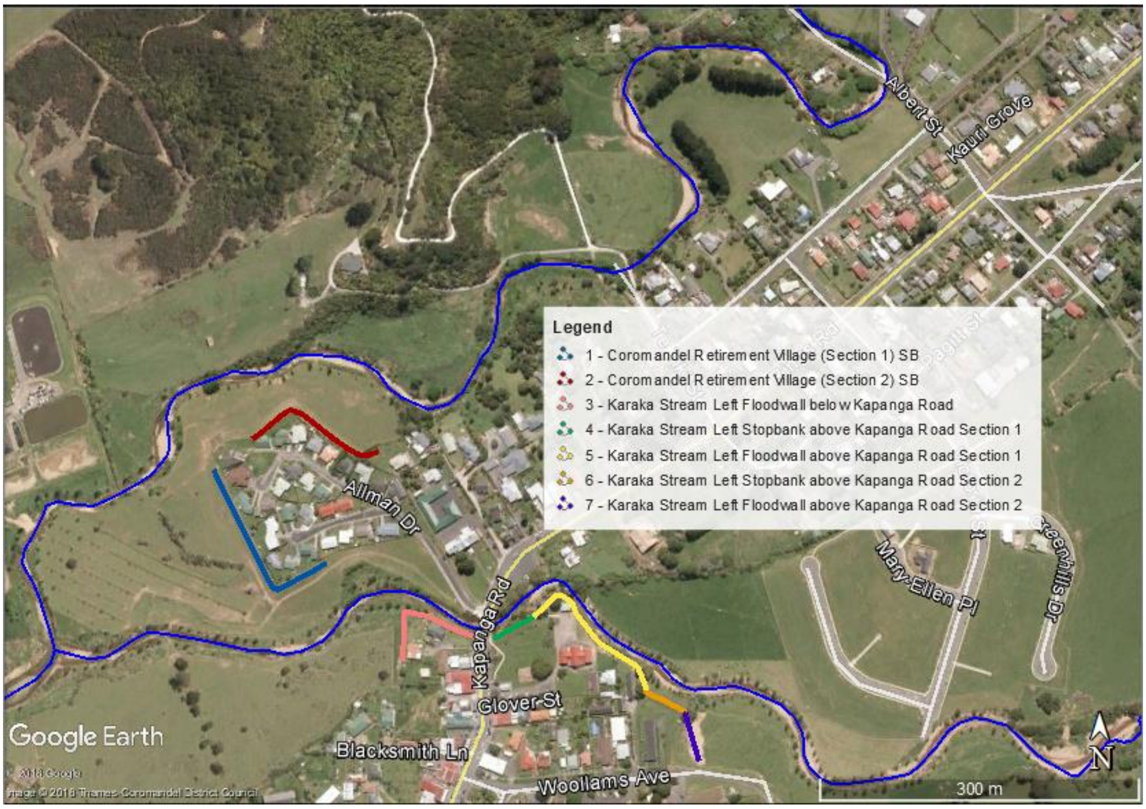


Figure 5.1 The general location of the flood protection assets

Associated with each service level are one or more performance measures which enable measurement of service level performance. Appendix 3 of the Coromandel Zone Management Plan gives the capacity and performance for scheme asset as shown in Table 5.1 below (refer doc#3310283 for further details).

Table 5.1

Table 5.1 Capacity and performance of scheme assets

Notes:

1 in 100yr (future) flood level is the forecasted flood level that takes into account climate change predictions by the end of the century (using MFE guidance (2008))

The performance measures for the scheme indicate that a percentage of stop banks may not meet the design flood standard at any point in time. The current performance standard requires that 100% of stop banks be above design flood level at any time (refer doc#3310283 p.81).

The performance measures for stop banks are normally set in terms of the Design Flood Standard which the scheme stop banks are designed to provide protection against and the Design Freeboard. Design Flood Standard is normally expressed as an Average Recurrence Interval (ARI) or Annual Exceedance Probability (AEP) of the design event. Design Flood Levels for stop banks are then determined based on this. Design Freeboard provides for a safety allowance (over and above the design flood level) when constructing and maintaining stop banks. Freeboard is a safety margin to allow for variations including:

- Uncertainty in hydrological modeling
- Uncertainty in hydraulic modeling
- Wind and wave set-up on the water surface
- Super-elevation on the water surface at bends
- Settlement of stop banks over time
- Aggradation of river bed levels over time
- Construction tolerance.

The original objective of the Coromandel flood protection works was to protect the floodplain of the Whangarahi Stream and its adjoining tributaries from 1 in 100yr flood event (i.e. 1 % AEP) refer appendix 3 of doc#3310283 for further details.

The assets considered in this review consist of approximately over 0.7km of stop banks and floodwall. Design flood levels have been adopted as the modelled 1 in 100yr design flood profile.

5.2 Performance grade

To enable measurement of performance against target, stop banks (and spillways) are graded on a one to five scale. The performance grade is based on the available freeboard relative to the design freeboard (where the available freeboard is the difference between the surveyed actual stop bank crest level and the design flood level). The five performance grades for both stop banks and spillways are set out in Table 5.2. The Coromandel Zone Management Plan states that service levels will be achieved by maintaining stop banks to achieve performance grade 3 or better (refer doc#3310283 p.81).

Performance grade	Stop banks	Spillways
	P= (actual freeboard/design freeboard) x 100%	**A = Actual freeboard**
1	P ≥ 100%	|A| <= 0.025 m
2	100% > P ≥ 50%	0.025 m < |A| <= 0.050 m
3	50% > P ≥ 25%	0.050 m < |A| <= 0.075 m
4	25% > P ≥ 0%	0.075 m < |A| <= 0.100 m
5	P < 0%	0.100 m < |A|

Table 5.2 Stop bank and spillway performance grades

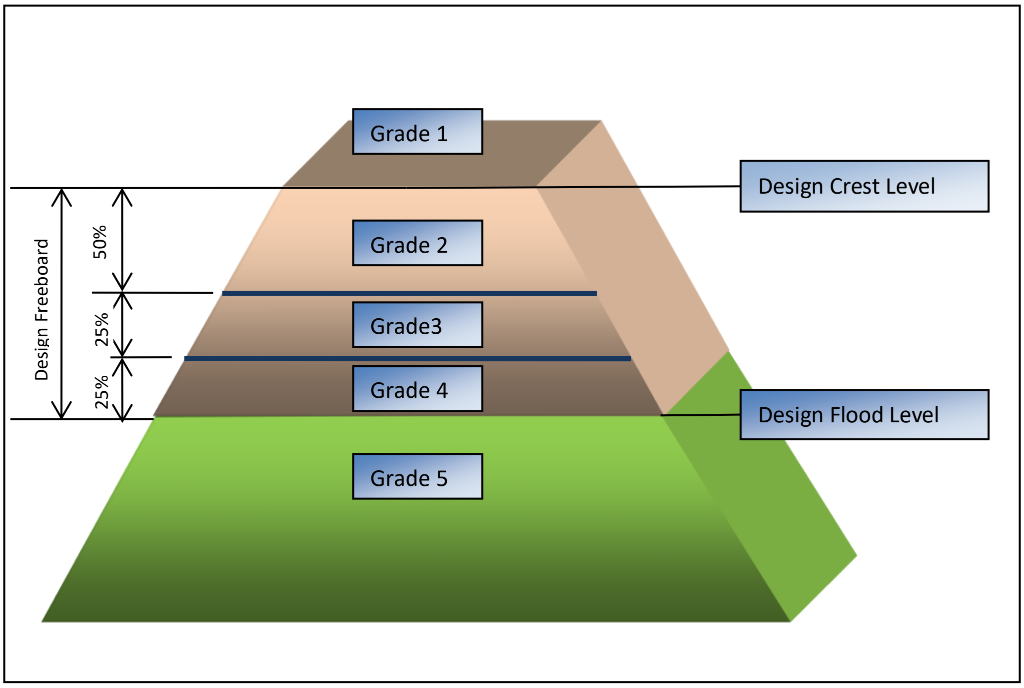


Figure 5.2 Diagrammatic representation of stop bank performance grades

Current performance has been assessed against the design performance standard based on most recent stop bank crest level survey data.

5.3 Results

The results of the service level review are set out in Figure 5.3 and Figure 5.4 as follows:

- Figure 5.3 Longitudinal section: Coromandel River left bank stop bank- design flood levels, design crest levels and actual crest levels.
- Figure 5.4 Longitudinal section: Coromandel River right bank stop bank- design flood levels, design crest levels and actual crest levels

The results of the service level review shows that the stop banks are currently predominantly categorised as either Grade 1 or Grade 2 performance grade. The stop banks therefore are largely satisfactory in terms of current performance.

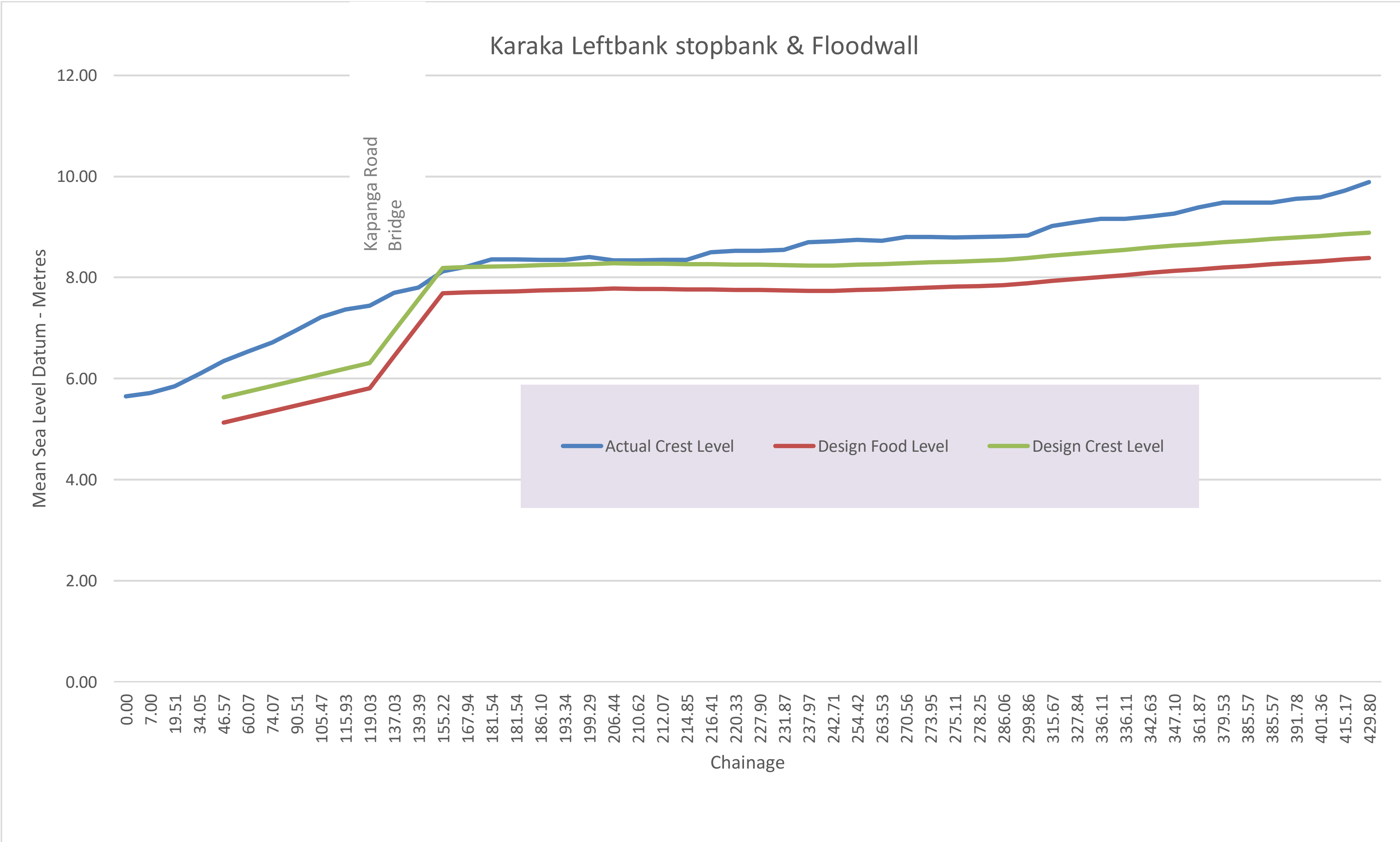


Figure 5.3 Longitudinal section: Karaka Stream left bank stop bank- design flood levels, design crest levels and actual crest levels

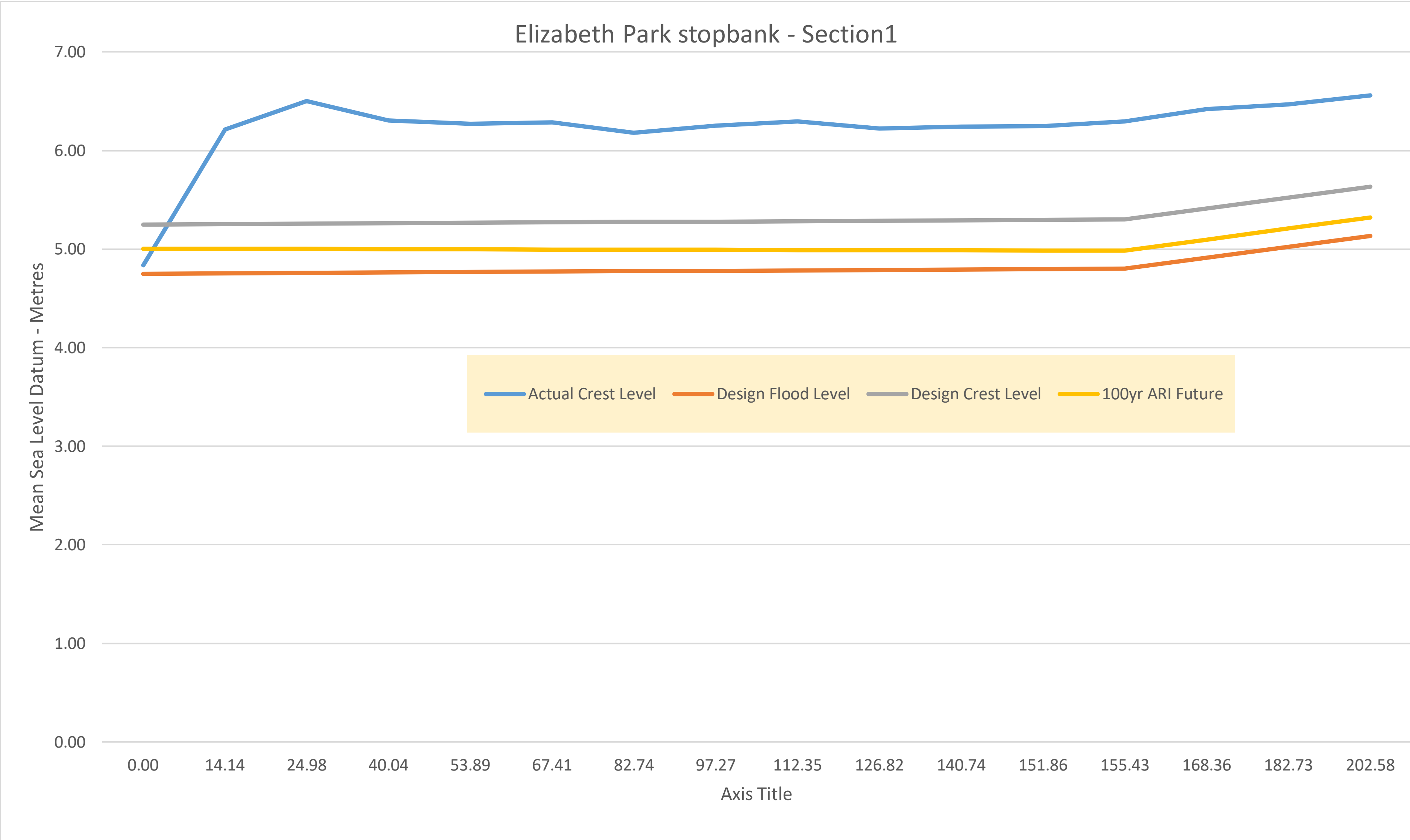


Figure 5.4 Longitudinal section: Elizabeth Park stop bank - Section1 stop bank- design flood levels, design crest levels and actual crest levels

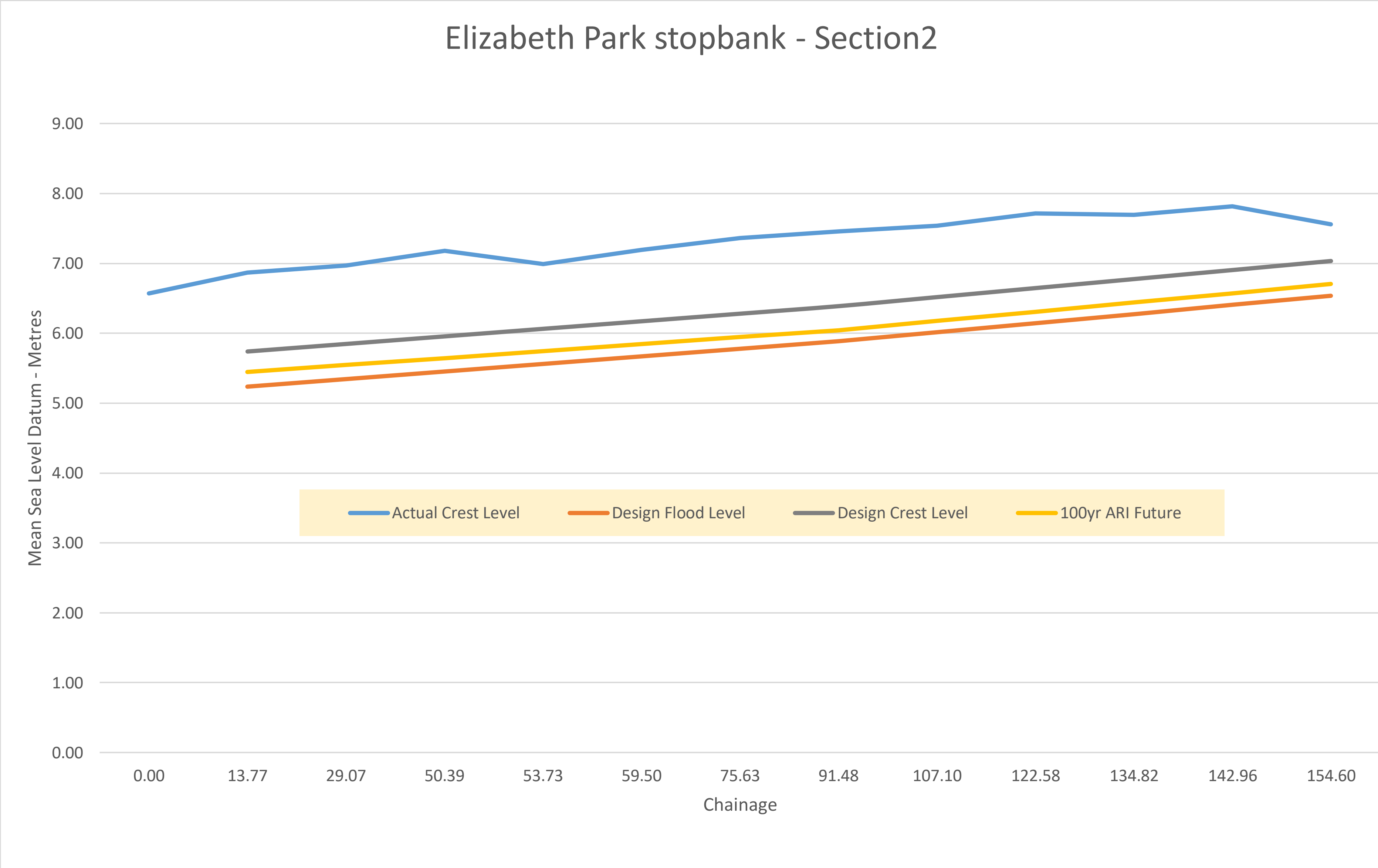


Figure 5.5 Longitudinal section: Elizabeth Park stop bank – Section2 stop bank- design flood levels, design crest levels and actual crest levels

6 Conclusion

Modelled flood levels have been used to assess the performance of the existing stop banks along the Whangarahi Stream and its tributaries. The scheme embankment assets reviewed are above the design flood level, and above 100% of their design freeboard (i.e. performance grade 1). The only exception is at Kapanga Road whereby the performance is at grade 2.

The primary difference between the previously existing hydraulic model and the newly developed hydraulic model, is the source of the hydrological data. The previous hydraulic model data were obtained from the normalised discharge for Kauaeranga Stream at Smiths gauging station. The newly developed hydraulic model is based on the Mike 11 rainfall runoff model (NAM Model) which was then calibrated from normalised discharge data from Tapu stream catchment at Tapu-Coroglen Road. A conservative runoff estimate was allowed for in these hydraulic model to account for the unknown variations between runoff from Tapu and Whangarahi Catchment.

Based on the above, it is concluded that the Coromandel scheme stop banks and floodwall meet their design objectives. However, potential risk of flooding can still be expected in the lower reach of Whangarahi Stream and on the right bank of Karaka Stream near Kapanga Road. This flooding risk is mainly due to high tide level at Coromandel harbour and overflow from Karaka Stream.

It is recommended that the rocky material deposit under Kapanga Road Bridge, downstream of Karaka River be cleared as soon possible. The rocky material deposit is restricting flow across the Kapanga Road Bridge opening and is a potential source of flooding risk.

It is also recommended that a gauging station be installed in the Coromandel flood protection scheme catchment. The ideal location for gauging stations in this catchment are at the Kapanga Road Bridge on Karaka Stream and Te Tiki Street Bridge on Whangarahi Stream

7 Recommendations

It is recommendation that:

- This report is accepted,
- The new design flood levels and crest levels are adopted.

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Appendices

Appendix 1: Scheme Review Process Schematic

Appendix 2: Nested Design Storm Data

Appendix 3: Water Levels at different ARI

Appendix 1: Scheme Review Process Schematic

High level process followed to do a review of stop bank and spillway service levels

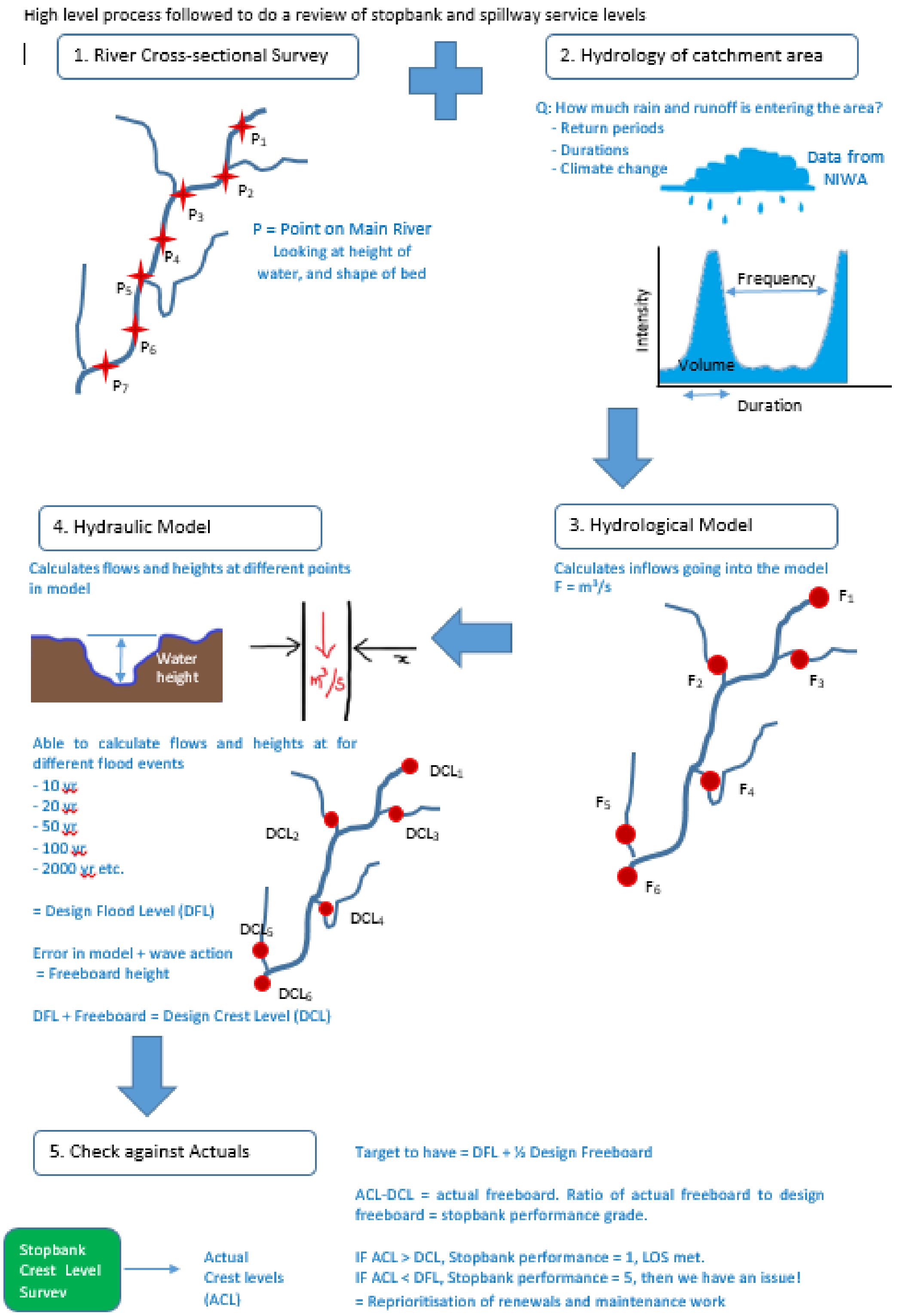

Figure A 1 Scheme Review Process Schematic

Appendix 2: Nested Design Storm Data

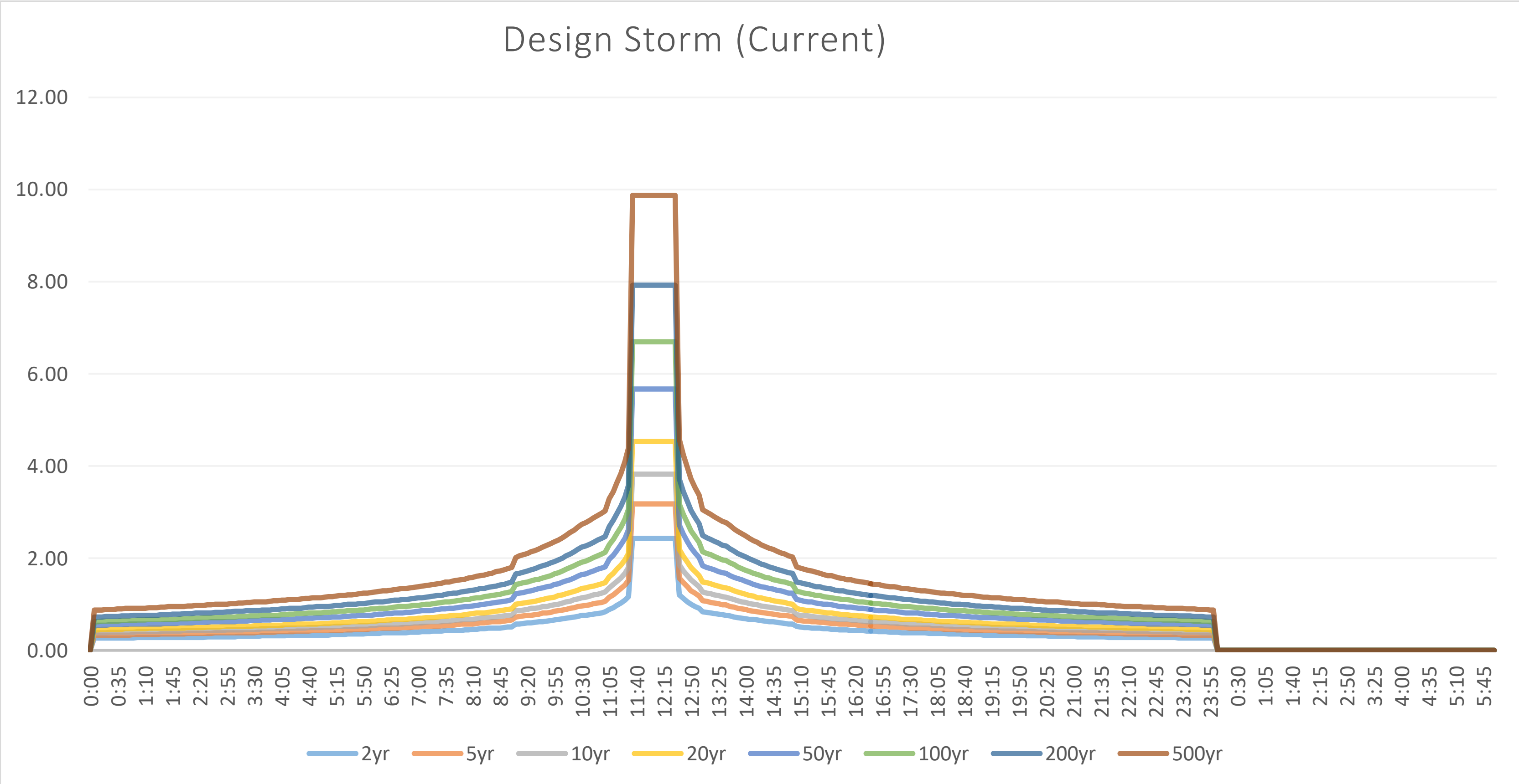

Figure A 2.1 **Nested design storm (current scenario) for hydrological model**

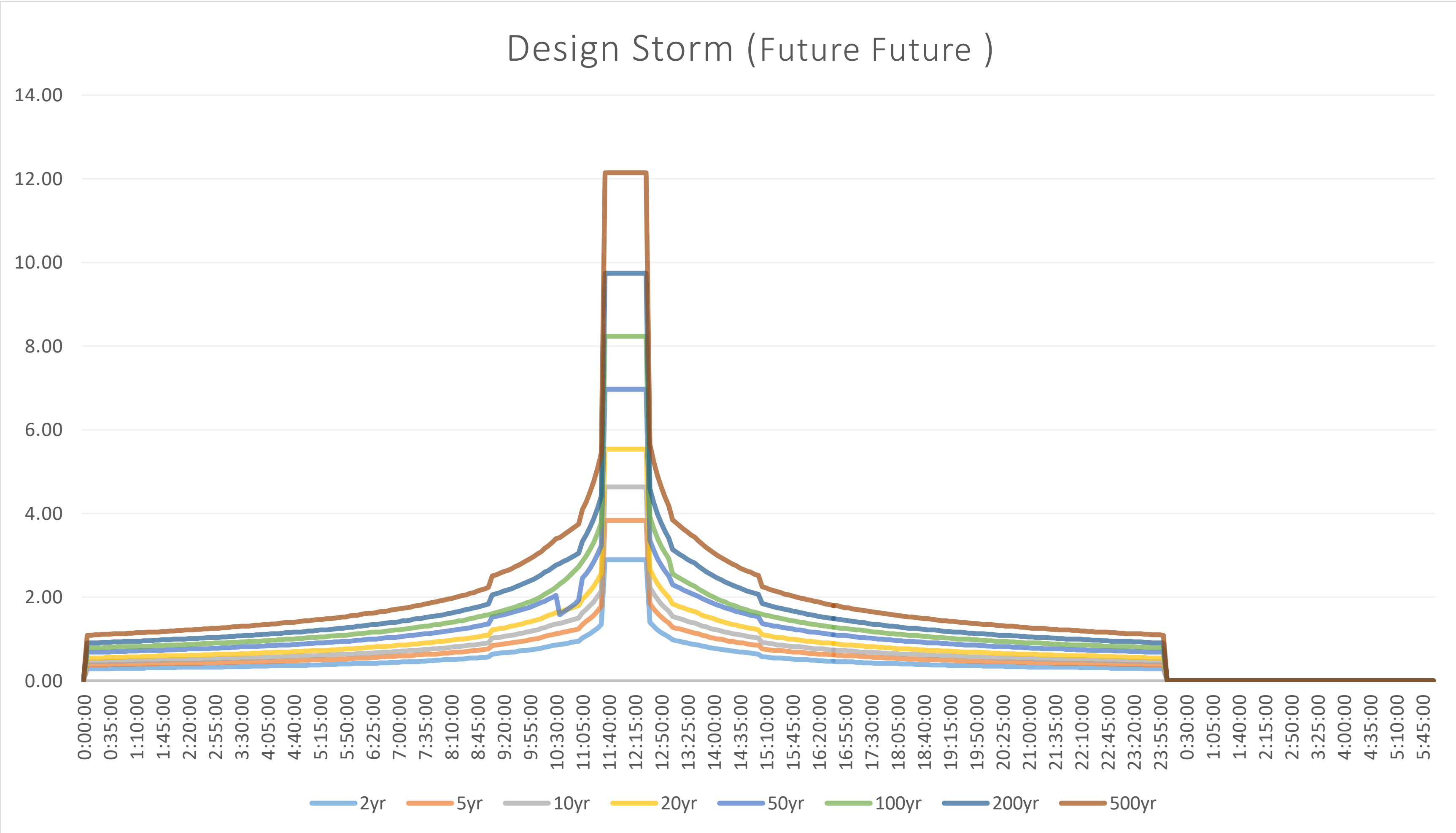

Figure A 2.2 Nested design storm (Future scenario) for hydrological model

Appendix 3: Water Levels at different ARI

Table A 3.1 Water level estimate from hydraulic model (Current Scenario)

Stream Branch and Chain age	Cross section name	5yr	2yr	10yr	20yr	50yr	100yr
GOLF COURSE STREAM 0		2.687	2.995	3.242	3.495	3.878	**4.174**
GOLF COURSE STREAM 5	DUMMY_G1	2.688	2.995	3.243	3.496	3.878	**4.175**
GOLF COURSE STREAM 30	DUMMY_G2	2.736	3.018	3.268	3.509	3.894	**4.196**
GOLF COURSE STREAM 36	NW-04	2.732	3.015	3.264	3.504	3.89	**4.192**
GOLF COURSE STREAM 149	NW-05	2.784	3.052	3.304	3.547	3.923	**4.228**
GOLF COURSE STREAM 200	DUMMY_G3	3.878	4.425	4.684	4.923	5.219	**5.42**
GOLF COURSE STREAM 361	NW-23	3.883	4.428	4.686	4.926	5.223	**5.425**
GOLF COURSE STREAM 464.5		3.884	4.428	4.687	4.927	5.224	**5.426**
GOLF COURSE STREAM 568		3.884	4.428	4.687	4.927	5.224	**5.426**
KARAKA STREAM 0	DUMMY_K1	2.721	3.015	3.246	3.488	3.843	**4.122**
KARAKA STREAM 28	DUMMY_K1	2.742	3.041	3.267	3.511	3.863	**4.139**
KARAKA STREAM 78	EX-09	2.794	3.082	3.298	3.537	3.884	**4.158**
KARAKA STREAM 188	EX-11	3.331	3.527	3.666	3.824	4.075	**4.29**
KARAKA STREAM 256	EX-14	3.555	3.745	3.878	4.03	4.263	**4.45**
KARAKA STREAM 332	EX-15	4.208	4.363	4.456	4.544	4.682	**4.801**
KARAKA STREAM 362	EX-16	4.431	4.595	4.718	4.84	5.002	**5.133**
KARAKA STREAM 441	EX-18	5.022	5.214	5.344	5.477	5.664	**5.812**
KARAKA STREAM 466	NW-24	6.806	7.045	7.178	7.318	7.527	**7.691**
KARAKA STREAM 526	EX-20	6.828	7.078	7.222	7.375	7.603	**7.78**
KARAKA STREAM 578	EX-21	6.817	7.059	7.198	7.346	7.565	**7.735**
KARAKA STREAM 621	EX-22	6.909	7.152	7.3	7.454	7.677	**7.848**
KARAKA STREAM 682	EX-23	7.4	7.574	7.69	7.81	7.987	**8.133**

KARAKA STREAM 723	EX-25	7.71	7.881	8.001	8.115	8.269	**8.387**
KARAKA STREAM 870	EX-25	9.154	9.334	9.448	9.545	9.664	**9.745**
KARAKA STREAM 1017	EX-25	10.671	10.843	10.942	11.027	11.125	**11.206**
KARAKA STREAM 1164	NW-19	12.195	12.358	12.446	12.524	12.627	**12.707**
KARAKA STREAM 1313.5	NW-19	14.079	14.217	14.308	14.402	14.521	**14.61**
KARAKA STREAM 1463	NW-20	16.034	16.123	16.215	16.315	16.452	**16.555**
KARAKA STREAM 1529	NW-21	16.572	16.726	16.844	16.964	17.13	**17.26**
KARAKA STREAM 1668	NW-22	18.305	18.462	18.583	18.706	18.879	**19.016**
KARAKA STREAM 1791	NW-22	18.719	18.882	19.001	19.117	19.277	**19.406**
KARAKA STREAM 1914	NW-22	18.828	19.014	19.148	19.278	19.455	**19.597**
WHANGARAHI STREAM 0		2.1	2.1	2.1	2.1	2.1	**2.1**
WHANGARAHI STREAM 33	NW-01	2.102	2.103	2.105	2.107	2.112	**2.117**
WHANGARAHI STREAM 198	EX-01	2.118	2.118	2.118	2.121	2.136	**2.155**
WHANGARAHI STREAM 290	EX-02	2.106	2.104	2.109	2.124	2.171	**2.24**
WHANGARAHI STREAM 455	EX-05	2.18	2.244	2.309	2.407	2.587	**2.755**
WHANGARAHI STREAM 519	EX-06	2.212	2.301	2.392	2.518	2.74	**2.932**
WHANGARAHI STREAM 559	NW-02	2.241	2.343	2.44	2.567	2.777	**2.951**
WHANGARAHI STREAM 571	EX-07	2.427	2.679	2.909	3.154	3.511	**3.789**
WHANGARAHI STREAM 751	EX-04	2.494	2.761	3	3.25	3.622	**3.911**
WHANGARAHI STREAM 848	EX-03	2.582	2.861	3.09	3.322	3.676	**3.953**
WHANGARAHI STREAM 895	NW-03	2.681	2.986	3.233	3.485	3.866	**4.16**
WHANGARAHI STREAM 907.171	Golf Course Junction	2.687	2.995	3.242	3.495	3.878	**4.174**
WHANGARAHI STREAM 907.171	Golf Course Junction	2.687	2.995	3.242	3.495	3.878	**4.174**
WHANGARAHI STREAM 944	EX-08	2.71	3.02	3.269	3.527	3.911	**4.211**
WHANGARAHI STREAM 1007.8	Karaka Stream Junction	2.721	3.015	3.246	3.488	3.843	**4.122**
WHANGARAHI STREAM 1007.8	Karaka Stream Junction	2.721	3.015	3.246	3.488	3.843	**4.122**
WHANGARAHI STREAM 1025	NW-06	2.71	2.995	3.22	3.461	3.809	**4.082**

WHANGARAHI STREAM 1096	NW-07	2.825	3.111	3.33	3.566	3.926	**4.212**
WHANGARAHI STREAM 1206	EX-10	3.107	3.376	3.567	3.774	4.081	**4.341**
WHANGARAHI STREAM 1305	EX-12	3.679	3.916	4.091	4.275	4.547	**4.751**
WHANGARAHI STREAM 1411	EX-13	4.335	4.547	4.699	4.855	5.074	**5.239**
WHANGARAHI STREAM 1516	EX-17	5.093	5.307	5.455	5.594	5.752	**5.888**
WHANGARAHI STREAM 1621	EX-19	5.738	5.958	6.1	6.222	6.391	**6.534**
WHANGARAHI STREAM 1793	NW-08	6.786	7.034	7.197	7.351	7.558	**7.716**
WHANGARAHI STREAM 1896	EX-24	7.449	7.694	7.848	7.998	8.203	**8.359**
WHANGARAHI STREAM 1905	NW-09	8.491	8.862	9.082	9.263	9.524	**9.722**
WHANGARAHI STREAM 1999	EX-27	8.694	9.039	9.266	9.455	9.726	**9.934**
WHANGARAHI STREAM 2181	EX-26	9.63	9.903	10.075	10.239	10.476	**10.661**
WHANGARAHI STREAM 2291	EX-28	10.36	10.607	10.766	10.92	11.144	**11.295**
WHANGARAHI STREAM 2399	EX-29	11.175	11.376	11.51	11.64	11.817	**11.943**
WHANGARAHI STREAM 2468	NW-10	11.635	11.847	11.985	12.123	12.323	**12.479**
WHANGARAHI STREAM 2473	EX-31	12.695	13.076	13.347	13.657	14.124	**14.51**
WHANGARAHI STREAM 2591	EX-30	12.839	13.204	13.454	13.726	14.122	**14.47**
WHANGARAHI STREAM 2734.5		13.828	14.093	14.264	14.442	14.697	**14.923**
WHANGARAHI STREAM 2878	EX-32	15.106	15.312	15.439	15.564	15.738	**15.884**
WHANGARAHI STREAM 3061		16.7	16.9	17.0	17.1	17.3	**17.43**
WHANGARAHI STREAM 3244	EX-33	18.267	18.518	18.664	18.803	18.988	**19.122**
WHANGARAHI STREAM 3351		19.267	19.491	19.628	19.76	19.925	**20.035**
WHANGARAHI STREAM 3458	NW-30	20.274	20.471	20.592	20.706	20.828	**20.924**
WHANGARAHI STREAM 3582	NW-11	21.22	21.45	21.594	21.732	21.895	**22.016**
WHANGARAHI STREAM 3586	NW-12	21.819	22.108	22.277	22.43	22.584	**22.718**
WHANGARAHI STREAM 3688	NW-29	21.916	22.166	22.322	22.468	22.623	**22.758**
WHANGARAHI STREAM 3822		22.817	22.96	23.051	23.162	23.318	**23.447**
WHANGARAHI STREAM 3956	EX-34	24.286	24.425	24.522	24.627	24.772	**24.889**

WHANGARAHI STREAM 4073.5		25.685	25.818	25.913	26.012	26.147	**26.255**
WHANGARAHI STREAM 4191	NW-13	27.11	27.232	27.317	27.409	27.535	**27.637**
WHANGARAHI STREAM 4274	NW-28	27.861	28.036	28.154	28.281	28.452	**28.59**
WHANGARAHI STREAM 4320	NW-26	28.583	28.739	28.847	28.965	29.128	**29.261**
WHANGARAHI STREAM 4322	NW-25	29.562	29.787	29.998	30.269	30.75	**31.244**
WHANGARAHI STREAM 4375	NW-27	29.622	29.847	30.052	30.325	30.805	**31.296**
WHANGARAHI STREAM 4493		30.229	30.409	30.548	30.719	31.028	**31.399**
WHANGARAHI STREAM 4611	NW-14	31.598	31.764	31.882	32.014	32.222	**32.424**
WHANGARAHI STREAM 4787	NW-15	34.383	34.493	34.576	34.669	34.808	**34.926**
WHANGARAHI STREAM 4837	NW-16	35.634	35.634	35.661	35.763	35.912	**36.035**
WHANGARAHI STREAM 4842	NW-17	36.638	36.922	37.119	37.36	37.745	**38.025**
WHANGARAHI STREAM 4946	NW-18	37.756	37.971	38.104	38.232	38.429	**38.605**

Table A 3.2 Water level estimate from hydraulic model (Future Scenario)

Stream Branch and Chain age	Cross section name	2yr CC	5yr CC		10yr CC	20yr CC	50yr CC	100yr CC	200yr CC
GOLF COURSE STREAM 0		3.328	3.491		3.664	3.88	4.253	4.553	4.851
GOLF COURSE STREAM 5	DUMMY_G1	3.328	3.491		3.664	3.88	4.253	4.553	4.859
GOLF COURSE STREAM 30	DUMMY_G2	3.333	3.499		3.675	3.898	4.277	4.583	4.884
GOLF COURSE STREAM 36	NW-04	3.332	3.497		3.672	3.893	4.273	4.578	4.888
GOLF COURSE STREAM 149	NW-05	3.341	3.515		3.7	3.928	4.311	4.619	4.93
GOLF COURSE STREAM 200	DUMMY_G3	4.358	4.762		5.006	5.215	5.493	5.723	5.961
GOLF COURSE STREAM 361	NW-23	4.36	4.765		5.01	5.22	5.499	5.73	5.969
GOLF COURSE STREAM 464.5		4.36	4.765		5.01	5.22	5.5	5.731	5.97
GOLF COURSE STREAM 568		4.36	4.765		5.011	5.22	5.5	5.731	5.971
KARAKA STREAM 0	DUMMY_K1	3.314	3.473		3.639	3.845	4.197	4.48	4.763
KARAKA STREAM 28	DUMMY_K1	3.327	3.49		3.658	3.864	4.212	4.493	4.774
KARAKA STREAM 78	EX-09	3.339	3.506		3.677	3.885	4.23	4.505	4.785
KARAKA STREAM 188	EX-11	3.572	3.741		3.895	4.068	4.347	4.584	4.837
KARAKA STREAM 256	EX-14	3.727	3.908		4.077	4.251	4.5	4.713	4.926
KARAKA STREAM 332	EX-15	4.332	4.46		4.559	4.669	4.835	4.984	5.153
KARAKA STREAM 362	EX-16	4.554	4.721		4.856	4.986	5.17	5.322	5.484
KARAKA STREAM 441	EX-18	5.168	5.347		5.495	5.644	5.853	6.019	6.197
KARAKA STREAM 466	NW-24	6.995	7.18		7.338	7.504	7.735	7.92	8.134
KARAKA STREAM 526	EX-20	7.023	7.224		7.397	7.578	7.828	8.025	8.253
KARAKA STREAM 578	EX-21	7.007	7.2		7.367	7.541	7.781	7.971	8.189
KARAKA STREAM 621	EX-22	7.098	7.302		7.476	7.653	7.894	8.08	8.312
KARAKA STREAM 682	EX-23	7.533	7.691		7.827	7.967	8.174	8.349	8.55
KARAKA STREAM 723	EX-25	7.84	8.002		8.13	8.253	8.42	8.561	8.736
KARAKA STREAM 870	EX-25	9.292	9.45		9.557	9.652	9.769	9.866	9.974

KARAKA STREAM 1017	EX-25	10.803	10.943		11.037	11.115	11.228	11.315	11.412
KARAKA STREAM 1164	NW-19	12.322	12.447		12.533	12.616	12.728	12.81	12.886
KARAKA STREAM 1313.5	NW-19	14.186	14.309		14.414	14.509	14.633	14.721	14.811
KARAKA STREAM 1463	NW-20	16.094	16.216		16.328	16.437	16.581	16.683	16.789
KARAKA STREAM 1529	NW-21	16.692	16.845		16.98	17.113	17.294	17.428	17.565
KARAKA STREAM 1668	NW-22	18.424	18.584		18.722	18.86	19.052	19.19	19.331
KARAKA STREAM 1791	NW-22	18.839	19.002		19.132	19.26	19.44	19.576	19.715
KARAKA STREAM 1914	NW-22	18.965	19.149		19.294	19.436	19.635	19.786	19.946
WHANGARAHI STREAM 0		3.1	3.1		3.1	3.1	3.1	3.1	3.1
WHANGARAHI STREAM 33	NW-01	3.101	3.101		3.102	3.103	3.104	3.106	3.108
WHANGARAHI STREAM 198	EX-01	3.107	3.107		3.107	3.107	3.107	3.107	3.107
WHANGARAHI STREAM 290	EX-02	3.113	3.113		3.113	3.113	3.113	3.113	3.113
WHANGARAHI STREAM 455	EX-05	3.125	3.129		3.145	3.168	3.221	3.282	3.373
WHANGARAHI STREAM 519	EX-06	3.135	3.161		3.191	3.235	3.323	3.416	3.539
WHANGARAHI STREAM 559	NW-02	3.134	3.158		3.188	3.231	3.318	3.411	3.538
WHANGARAHI STREAM 571	EX-07	3.185	3.263		3.365	3.524	3.864	4.157	4.44
WHANGARAHI STREAM 751	EX-04	3.222	3.325		3.451	3.632	3.987	4.278	4.561
WHANGARAHI STREAM 848	EX-03	3.249	3.365		3.499	3.683	4.026	4.304	4.577
WHANGARAHI STREAM 895	NW-03	3.323	3.484		3.654	3.868	4.239	4.536	4.833
WHANGARAHI STREAM 907.171	Golf Course Junction	3.328	3.491		3.664	3.88	4.253	4.553	4.851
WHANGARAHI STREAM 907.171	Golf Course Junction	3.328	3.491		3.664	3.88	4.253	4.553	4.851
WHANGARAHI STREAM 944	EX-08	3.343	3.514		3.692	3.913	4.29	4.594	4.899
WHANGARAHI STREAM 1007.8	Karaka Stream Junction	3.314	3.473		3.639	3.845	4.197	4.48	4.763
WHANGARAHI STREAM 1007.8	Karaka Stream Junction	3.314	3.473		3.639	3.845	4.197	4.48	4.763
WHANGARAHI STREAM 1025	NW-06	3.301	3.452		3.613	3.812	4.155	4.432	4.707
WHANGARAHI STREAM 1096	NW-07	3.351	3.528		3.704	3.924	4.287	4.577	4.867
WHANGARAHI STREAM 1206	EX-10	3.467	3.674		3.858	4.07	4.409	4.665	4.929

WHANGARAHI STREAM 1305	EX-12	3.897	4.128		4.324	4.529	4.803	5.006	5.212
WHANGARAHI STREAM 1411	EX-13	4.491	4.708		4.882	5.056	5.283	5.446	5.606
WHANGARAHI STREAM 1516	EX-17	5.244	5.458		5.609	5.736	5.919	6.044	6.178
WHANGARAHI STREAM 1621	EX-19	5.889	6.101		6.237	6.372	6.568	6.704	6.847
WHANGARAHI STREAM 1793	NW-08	6.951	7.199		7.371	7.536	7.755	7.902	8.049
WHANGARAHI STREAM 1896	EX-24	7.611	7.85		8.018	8.182	8.397	8.544	8.695
WHANGARAHI STREAM 1905	NW-09	8.728	9.084		9.285	9.495	9.775	9.978	10.18
WHANGARAHI STREAM 1999	EX-27	8.913	9.268		9.479	9.696	9.989	10.202	10.417
WHANGARAHI STREAM 2181	EX-26	9.812	10.077		10.261	10.451	10.709	10.897	11.094
WHANGARAHI STREAM 2291	EX-28	10.528	10.768		10.941	11.122	11.337	11.505	11.677
WHANGARAHI STREAM 2399	EX-29	11.314	11.511		11.657	11.799	11.977	12.11	12.246
WHANGARAHI STREAM 2468	NW-10	11.783	11.987		12.142	12.302	12.521	12.687	12.854
WHANGARAHI STREAM 2473	EX-31	12.963	13.351		13.701	14.075	14.614	15.069	15.668
WHANGARAHI STREAM 2591	EX-30	13.096	13.458		13.762	14.078	14.566	14.994	15.574
WHANGARAHI STREAM 2734.5		14.01	14.267		14.466	14.669	14.988	15.282	15.736
WHANGARAHI STREAM 2878	EX-32	15.253	15.441		15.581	15.719	15.926	16.101	16.346
WHANGARAHI STREAM 3061		16.8	17.0		17.1	17.3	17.5	17.603	17.767
WHANGARAHI STREAM 3244	EX-33	18.452	18.666		18.821	18.969	19.155	19.286	19.433
WHANGARAHI STREAM 3351		19.433	19.63		19.776	19.91	20.064	20.181	20.311
WHANGARAHI STREAM 3458	NW-30	20.42	20.593		20.718	20.815	20.949	21.054	21.168
WHANGARAHI STREAM 3582	NW-11	21.392	21.596		21.748	21.878	22.045	22.16	22.285
WHANGARAHI STREAM 3586	NW-12	22.025	22.279		22.45	22.567	22.753	23.019	23.519
WHANGARAHI STREAM 3688	NW-29	22.093	22.325		22.487	22.605	22.794	23.054	23.535
WHANGARAHI STREAM 3822		22.925	23.052		23.177	23.301	23.481	23.644	23.896
WHANGARAHI STREAM 3956	EX-34	24.387	24.523		24.64	24.756	24.921	25.048	25.202
WHANGARAHI STREAM 4073.5		25.78	25.914		26.025	26.132	26.284	26.397	26.513
WHANGARAHI STREAM 4191	NW-13	27.199	27.318		27.421	27.521	27.664	27.77	27.882

WHANGARAHI STREAM 4274	NW-28	27.99	28.155		28.296	28.433	28.627	28.769	28.921
WHANGARAHI STREAM 4320	NW-26	28.698	28.848		28.98	29.11	29.297	29.436	29.584
WHANGARAHI STREAM 4322	NW-25	29.722	30.001		30.308	30.693	31.393	32.075	32.996
WHANGARAHI STREAM 4375	NW-27	29.783	30.055		30.365	30.748	31.445	32.123	33.038
WHANGARAHI STREAM 4493		30.36	30.549		30.744	30.99	31.519	32.129	33.025
WHANGARAHI STREAM 4611	NW-14	31.723	31.883		32.032	32.198	32.479	32.729	33.196
WHANGARAHI STREAM 4787	NW-15	34.464	34.577		34.681	34.792	34.958	35.094	35.262
WHANGARAHI STREAM 4837	NW-16	35.634	35.662		35.777	35.895	36.069	36.206	36.362
WHANGARAHI STREAM 4842	NW-17	36.853	37.122		37.399	37.705	38.103	38.389	38.743
WHANGARAHI STREAM 4946	NW-18	37.921	38.105		38.25	38.407	38.658	38.878	39.164