NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance

Ara Tūhono – Pūhoi to Wellsford

This document records technical and factual information used to support the NZTA's Assessment of Environmental Effects for the Pūhoi to Warkworth Project. It has been supplied to the Environmental Protection Authority by the NZTA in response to a section 149(2) Resource Management Act 1991 request. This document did not form part of the NZTA's application for the Project, which was lodged on 30 August 2013.

FURTHER NORTH

Pūhoi to Warkworth

Water Assessment Factual Report 7

Hydrological Data

August 2013

Pūhoi to Warkworth

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Glossary of abbreviations

Abbreviation	Definition
AEE	Assessment of Environmental Effects
ARC	Auckland Regional Council (legacy Council of Auckland Council)
ARI	Average Recurrence Interval
BPO	Best Practicable Option
Ch	Chainage
EPA	Environmental Protection Authority
ha	Hectares
HIRDS	High Intensity Rainfall Design System
HY-8	Federal Highway Administration Culvert Design Software, USA
m	Metres
MfE	Ministry for the Environment
MHWS	Mean High Water Springs
NGTR	Northern Gateway Toll Road
NIWA	National Institute of Water and Atmosphere
NZTA	NZ Transport Agency
OWAR	Operational Water Assessment Report
RMA	Resource Management Act 1991
SHx	State Highway (number)
XP-SWMM	XP Solution Storm Water Management Model (software)
TP108	ARC Technical Publication 108: Guidelines for Stormwater Runoff Modelling in the Auckland Region

Glossary of defined terms

Term	Definition
Alignment	The route or position of a proposed motorway or state highway.
Average Recurrence Interval	The average time period between rainfall or flow events which equal or exceed a given magnitude. Similar to return period.
Culvert	A pipe with an inlet from a watercourse and outlet to a watercourse, designed to convey water under a specific structure (such as a road).
Diversion of stormwater	The turning aside of stormwater from its natural course of flow; causing it to flow by a different route.
Earthworks	The disturbance of land surfaces by blading, contouring, ripping, moving, removing, placing or replacing soil or earth, or by excavation, or by cutting or filling operations.
Fish Passage	The movement of fish between the sea and any river, including up-stream or downstream in that river.
Groundwater	Natural water contained within soil and rock formations below the surface of the ground.
Heading up	Heading up is the term used to denote the condition when the water surface immediately upstream of the culvert rises to an elevation greater than the soffit of the culvert inlet.
Headwater	The water depth from the culvert invert at the inlet, to the water surface of the pool that forms as a result of heading up, is called the headwater.
Indicative Alignment	A route and designation footprint selected after short-list and long-list development to enable consultation with the community. This development involved specialist work assessing environmental, social and engineering inputs.
Intermittent Stream	Any stream or part of a stream that is not a Permanent stream.
Overland Flow Path	The flow path of stormwater over the ground.
Permanent Stream	Downstream of the uppermost reach of a river or stream which meets either of the following criteria: (a) has continual flow; or (b) has natural pools having a depth at their deepest point of not less than 150 millimetres and a total pool surface area that is $10m^2$ or more per 100m of river or stream bed length. The boundary between Permanent and Intermittent river or stream reaches is the uppermost qualifying pool in the uppermost qualifying reach.
Project	Pūhoi to Warkworth section of the Pūhoi to Wellsford Road of National Significance Project
Project area	From Johnstone's Hill portals in south to Kaipara Flats Road in the north.
Reduced Level	Equating levels / elevations to a common datum

Term	Definition
Secondary flow path	The flow path of stormwater or floodwater that activates for larger storm events.
Wetland	Vegetated stormwater treatment device designed to remove a range of contaminants,.

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1. Introduction

This report provides a factual basis for the Operational Water Assessment Report (OWAR) prepared for the New Zealand Transport Agency (NZTA). The OWAR provides an assessment of the environmental effects associated with water, arising from the operational aspects of the Pūhoi to Warkworth section (the Project) of the Pūhoi to Wellsford Road of National Significance Project. The OWAR supports the Assessment of Environmental Effects (AEE), resource consent applications and Notices of Requirement for the Project.

This report documents the methodology, assumptions and process we have used to determine the design rainfall data for the Project. The design rainfall data is required for the hydraulic design of culverts, bridges, stream diversions and overland flow paths (refer to Section 6 of the OWAR). The design rainfall is also used to carry out our hydrological assessment (refer to Section 6.2 of the OWAR).

2. Rainfall analysis

We investigated three different rainfall events from three different sources. The design rainfall events we investigated are a 2 year, 10 year, and 100 year average recurrence interval (ARI). The three data sources we investigated for the design rainfall events are TP108, HIRDS v3 and rainfall gauges.

We adopted a conservative approach to use the data source which yielded the highest estimated rainfall levels i.e. a worst case scenario.

2.1 TP108

TP108 contains figures of daily rainfall depth (mm/24hr) across the Auckland region for several ARIs. Figures 1-3 show the Project catchments and the TP108 rainfall contours for the 2 year ARI, 10 year ARI and 100 year ARI events, respectively.

The Pūhoi and Mahurangi catchments are the main catchments the Project alignment traverses. We then recorded the rainfall contour with the highest rainfall intensity that lay within the Project catchments. These rainfalls are shown in Table 1.

Table 1: TP108 rainfalls for the Project.

ARI	Pūhoi (mm/24hr)	Mahurangi (mm/24hr)
2 year ARI	115	130
10 year ARI	190	210
100 year ARI	280	310

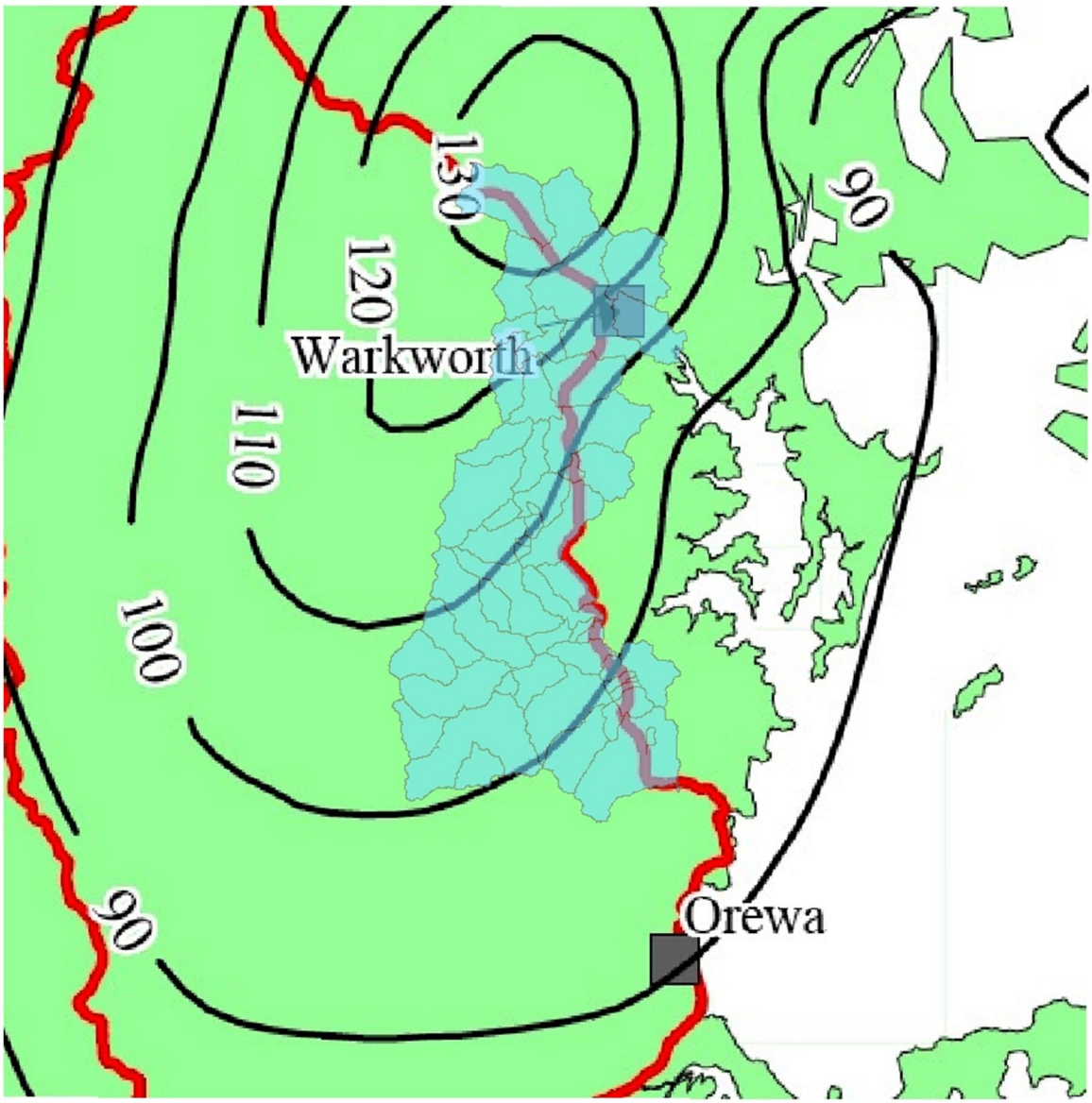


Figure 1: 2 year ARI rainfall contours from TP108.

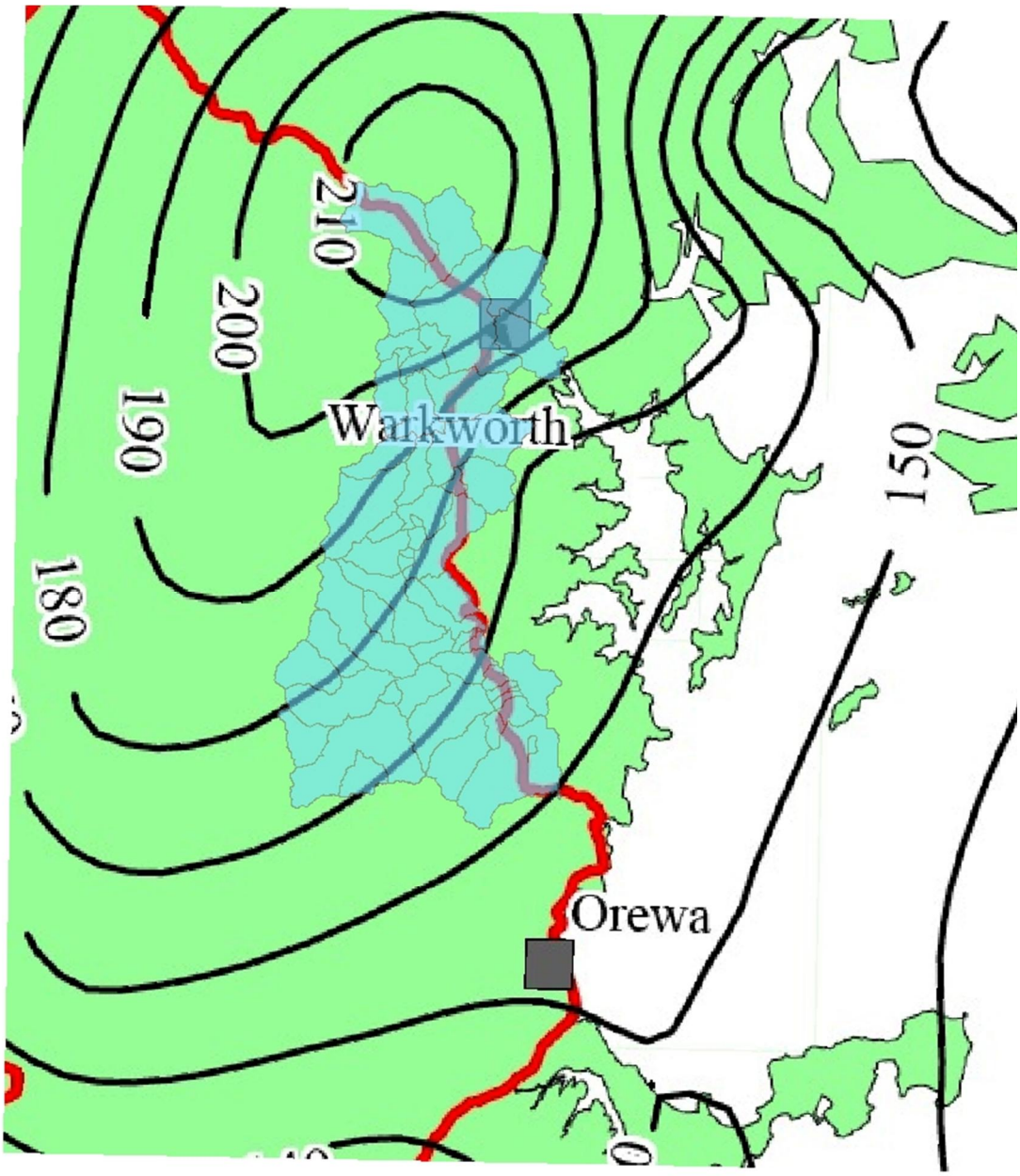


Figure 2: 10 year ARI rainfall contours from TP108.

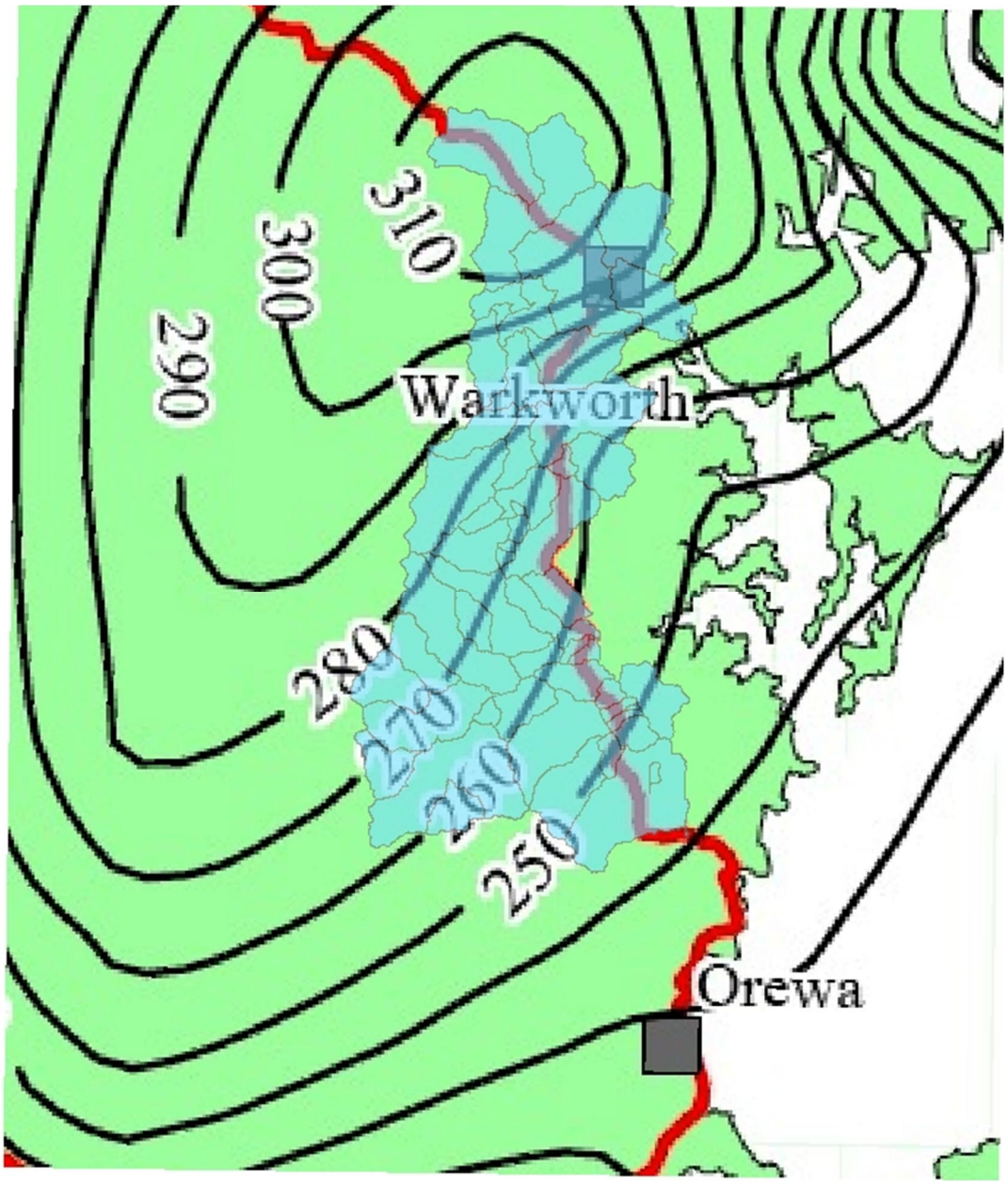


Figure 3: 100 year ARI rainfall contours from TP108

2.2 HIRDS v3

HIRDS v3 (High Intensity Rainfall System, version 3) is a web-based rainfall estimation programme created by NIWA. HIRDS can be accessed at http://hirds.niwa.co.nz. The HIRDS website describes the programme as follows:

"The High Intensity Rainfall Design System is a web-based programme that can estimate rainfall frequency at any point in New Zealand. It can be used to estimate rainfall depths for hydrological design purposes, and to assess the rarity of observed storm events.

NIWA's High Intensity Rainfall Design System (HIRDS) offers planners and engineers more certainty about the frequency of high-intensity rainfalls, enabling them to better design stormwater drainage systems and other structures."

We selected two location points within the Pūhoi and Mahurangi catchments. By entering these locations into the HIRDS v3 programme, we obtained a range of daily rainfall depths (mm/24hr) within the catchments. The four location points we entered into HIRDS v3 were located in the southern and northern extents of the Pūhoi and Mahurangi catchments respectively. This maximised the coverage of the Project area used by HIRDS v3 to derive the design rainfall data. The location points we selected are shown in Figure 4 and the rainfall data for each location point is provided in Tables 2 to 5. The HIRDS results show higher rainfall in the northern parts of each catchment.

From the data obtained from HIRDS v3, we selected the highest rainfall for each catchment (circled in red on Table 2 to Table 5). This daily rainfall depth (mm/24hr) data is summarised in Table 6.

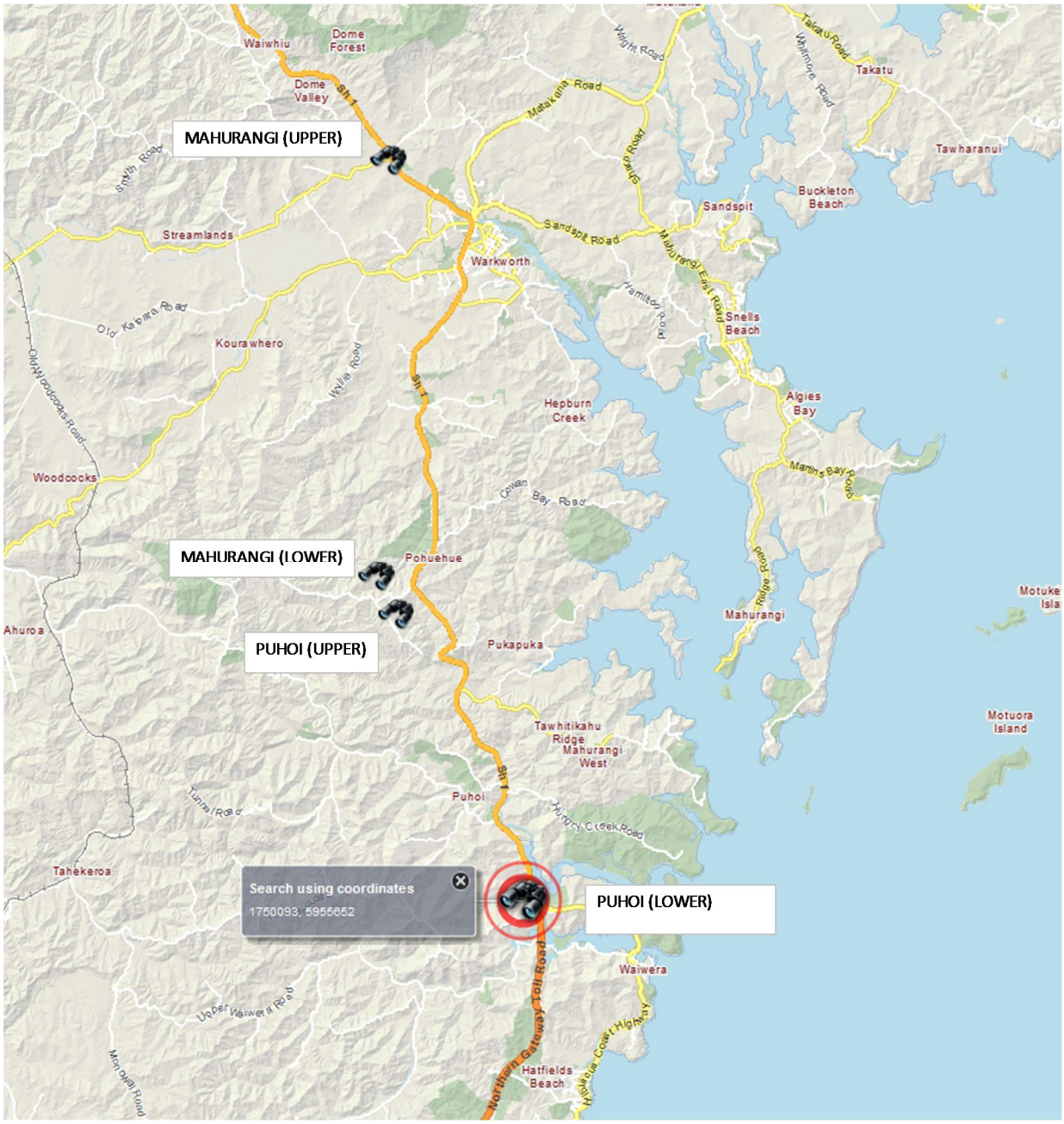


Figure 4: Location points selected and entered into HIRDS v3.

Table 2: Pūhoi (lower) from HIRDS v3.

High Intensity Rainfall System V3

Depth-Duration-Frequency results (produced on Tuesday 5th of March 2013)
Sitename: Puhoi (lower)
Coordinate system: NZMG
Easting: 2660601 1750093
Northing: 6517369 5955652

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	9.4	13.7	17	24.8	32.8	51.1	67.6	89.5	105.8	116.6
2	0.5	10.1	14.7	18.3	26.6	35.3	55.2	73.2	97.1	114.7	126.5
5	0.2	12.5	18.2	22.6	32.9	44	69.7	93.3	124.7	147.3	162.4
10	0.1	14.4	21	26.1	37.9	51	81.5	109.5	147.1	173.9	191.7
20	0.05	16.5	24	29.9	43.4	58.7	94.5	127.7	172.5	203.8	224.7
30	0.033	17.9	26	32.3	47	63.6	103	139.5	189	223.3	246.2
40	0.025	18.9	27.4	34.1	49.6	67.4	109.4	148.5	201.5	238.1	262.5
50	0.02	19.7	28.6	35.6	51.8	70.4	114.6	155.8	211.8	250.3	276
60	0.017	20.4	29.6	36.9	53.6	73	119	162.1	220.6	260.7	287.4
80	0.012	21.5	31.3	39	56.7	77.3	126.4	172.4	235.2	277.9	306.4
100	0.01	22.5	32.7	40.7	59.1	80.7	132.4	180.9	247.1	292	321.9

Table 3: Pūhoi (upper) from HIRDS v3.

High Intensity Rainfall System V3

Depth-Duration-Frequency results (produced on Tuesday 5th of March 2013)
Sitename: Puhoi (upper)
Coordinate system: NZMG
Easting: 2657756 1747234
Northing: 6523742 5962018

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	10.4	14.6	17.8	24.9	33.2	52.4	69.9	93.1	110	121.4
2	0.5	11.1	15.7	19.1	26.8	35.8	56.6	75.6	101	119.3	131.6
5	0.2	13.9	19.6	23.9	33.5	45	71.8	96.5	129.5	153.1	168.8
10	0.1	16.1	22.7	27.7	38.9	52.4	84.1	113.3	152.7	180.5	199.1
20	0.05	18.6	26.1	31.9	44.8	60.6	97.8	132.3	178.9	211.5	233.2
30	0.033	20.1	28.3	34.6	48.6	65.9	106.7	144.6	196	231.6	255.4
40	0.025	21.3	30	36.6	51.5	69.9	113.4	153.9	209	247	272.4
50	0.02	22.3	31.4	38.3	53.8	73.1	118.9	161.6	219.6	259.5	286.2
60	0.017	23.1	32.5	39.7	55.8	75.9	123.6	168.1	228.6	270.3	298
80	0.012	24.5	34.4	42	59.1	80.5	131.4	178.9	243.7	288	317.6
100	0.01	25.6	36	43.9	61.8	84.2	137.7	187.7	256	302.6	333.7

Table 4: Mahurangi (lower) from HIRDS v3.

High Intensity Rainfall System V3

Depth-Duration-Frequency results (produced on Tuesday 5th of March 2013)
Sitename: Mahurangi (lower)
Coordinate system: NZMG
Easting: 2657310 1746786
Northing: 6524593 5962868

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	10.5	14.7	17.9	25.1	33.6	53.2	71.2	95.3	112.8	124.6
2	0.5	11.3	15.8	19.3	27	36.2	57.5	77.1	103.3	122.3	135.1
5	0.2	14.1	19.8	24.1	33.8	45.5	73	98.3	132.4	156.9	173.2
10	0.1	16.4	23	28	39.2	53	85.4	115.5	156.1	185	204.2
20	0.05	18.9	26.5	32.3	45.2	61.3	99.4	134.8	182.9	216.6	239.2
30	0.033	20.5	28.7	35	49.1	66.7	108.4	147.3	200.2	237.2	262
40	0.025	21.7	30.5	37.1	52	70.7	115.3	156.9	213.5	252.9	279.3
50	0.02	22.7	31.8	38.8	54.3	74	120.9	164.7	224.3	265.8	293.5
60	0.017	23.6	33	40.2	56.4	76.9	125.6	171.3	233.6	276.7	305.6
80	0.012	25	35	42.6	59.7	81.5	133.5	182.3	248.9	294.9	325.6
100	0.01	26.1	36.6	44.5	62.4	85.3	140	191.3	261.5	309.8	342.1

Table 5: Mahurangi (upper) from HIRDS v3.

High Intensity Rainfall System V3

Depth-Duration-Frequency results (produced on Tuesday 5th of March 2013)
Sitename: Mahurangi (upper)
Coordinate system: NZMG
Easting: 2657611 1747067
Northing: 6533801 5972075

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	10.5	14.8	18	25.3	34.5	56.2	76.6	104.3	126	140.7
2	0.5	11.4	15.9	19.4	27.3	37.2	60.7	82.8	112.8	136.3	152.3
5	0.2	14.3	20	24.4	34.3	46.8	76.9	105.2	143.8	173.8	194.1
10	0.1	16.6	23.3	28.4	39.9	54.6	90	123.3	168.9	204	227.9
20	0.05	19.2	26.9	32.8	46.1	63.3	104.5	143.5	197	238	265.9
30	0.033	20.9	29.3	35.7	50.1	68.9	114	156.6	215.3	260.1	290.5
40	0.025	22.1	31.1	37.9	53.1	73.1	121.1	166.6	229.2	276.9	309.3
50	0.02	23.2	32.5	39.6	55.6	76.5	127	174.8	240.5	290.6	324.6
60	0.017	24	33.7	41.1	57.7	79.5	131.9	181.7	250.2	302.3	337.6
80	0.012	25.5	35.8	43.6	61.2	84.3	140.2	193.2	266.2	321.6	359.2
100	0.01	26.7	37.4	45.6	64	88.3	146.9	202.5	279.3	337.4	376.9

Table 6: HIRDS v3 highest rainfalls for each catchment.

ARI	Pūhoi (mm/24hr)	Mahurangi (mm/24hr)
2 year ARI	101	113
10 year ARI	153	169
100 year ARI	256	279

2.3 Rainfall gauges

We sourced rainfall gauge data from Auckland Council Environmental Monitoring. Three gauges are relevant to the Project based on their locations and period of recording. Information about each rain gauge is provided in Table 7.

Mahurangi at Satellite and Warkworth Composite gauges are within the Mahurangi catchment. There are no rainfall gauges in the Pūhoi catchment. The Orewa at Treatment Plant rain gauge is the nearest gauge to the southern extent of the Pūhoi catchment.

Regression analysis results and Intensity Frequency Duration analysis were provided by Auckland Council Environmental Monitoring (refer to Table 8 to 10). From this data, we recorded the highest rainfalls for specified design rainfall events at each rain gauge (circled in red on Table 8 to 10). Table 11 is a summary of the highest rainfalls for the Mahurangi catchment based on Mahurangi at Satellite and Warkworth Composite gauges, and for the Pūhoi catchment based on Orewa at Treatment Plant gauge.

Table 7: Rainfall gauge information.

Rain gauge (ref no.)	Catchment	Period of recording	Type of recording
Mahurangi at Satellite (644616)	Mahurangi	06/12/1994 – present (>18 years)	Record is intensity event based rainfall measured to 0.5 mm depths.
Warkworth Composite (644626C)	Mahurangi	03/07/1921 – present (>91 years)	This site is a combination of earlier manual daily read stored rainfall and more recent intensity event based rainfall measured to 0.5 mm depths. The site combines the following records: Warkworth Post Office, Warkworth, Warkworth EWS and Warkworth Mahurangi Sewage Plant.
Orewa at Treatment Plant (646619)	Close to Pūhoi	17/10/1995 – present (>17 years)	Record is intensity event based rainfall measured to 0.5 mm depths.

Figure 5: Rainfall gauge locations.

Table 8: Orewa – treatment ponds rainfall gauge – Puhoi catchment.

Orewa at Treatment Ponds					Site # 646619					
Intensity Frequency Duration Analysis Rainfall Totals (mm)										
Return Period	10 Minute	20 Minute	30 Minute	1 Hour	2 Hour	6 Hour	12 Hour	24 Hour	48 Hour	72 Hour
1 Year	8.6	13	16.3	21.6	29.2	42.7	55	70.6	79.8	91.2
2 Year	10.7	16.1	20.1	26.7	35.9	52.8	69.4	88.6	101	113.2
5 Year	12.8	19.1	23.6	31.1	41.5	63.1	86.3	109.6	125.5	136.3
10 Year	14	20.8	25.7	34.1	45	68.9	97	122.1	141.5	149.7
20 Year	15.1	22.3	27.5	36.9	48.3	73.9	107.1	133.3	156.8	161.4
50 Year	16.4	24.1	29.8	40.5	52.3	79.8	119.8	147.1	176.5	175.4
100 Year	17.4	25.4	31.4	43.3	55.2	83.8	129.3	156.8	191.4	185.1

Table 9: Mahurangi – satellite rainfall gauge – Mahurangi catchment.

Mahurangi at Satellite					Site # 644616					
Intensity Frequency Duration Analysis Rainfall Totals (mm)										
Return Period	10 Minute	20 Minute	30 Minute	1 Hour	2 Hour	6 Hour	12 Hour	24 Hour	48 Hour	72 Hour
1 Year	8.6	12.2	15	22.2	30.9	52.6	74.2	94.4	108.9	117.2
2 Year	11.3	16.4	20.1	29.1	40.4	67.8	94.8	118.4	136.8	147.5
5 Year	15.2	23.2	28.4	39.5	55.1	89.4	122.7	149.4	169.2	184
10 Year	17.8	28.4	34.7	46.9	64.9	103.4	139.9	166.1	188.9	205.8
20 Year	20.4	33.9	41.5	54.3	74.3	116.7	155.6	179.8	206.8	225.3
50 Year	23.9	41.8	51.2	64.3	86.6	133.7	175.2	195.3	229	249.1
100 Year	26.6	48.3	59.4	72.3	95.8	146.5	189.4	205.4	244.9	265.9

Table 10: Warkworth composite rainfall gauge – Mahurangi catchment.

Warkworth Composite					Site # 644626C					
Intensity Frequency Duration Analysis Rainfall Totals (mm)										
Return Period	10 Minute	20 Minute	30 Minute	1 Hour	2 Hour	6 Hour	12 Hour	24 Hour	48 Hour	72 Hour
1 Year	8.3	11.7	14.8	20.1	24.8	42.5	64.4	70.9	95.3	105.6
2 Year	10.8	15.4	19	25.2	32.3	57.2	85	93.3	123.3	136.6
5 Year	14.3	20.4	24.6	31	42.7	78.3	115.1	128.4	164.7	181.9
10 Year	16.7	24.3	28.5	34.6	50.3	96.3	137.6	153	191.3	211.4
20 Year	19.1	28.5	32.3	38	58.2	117.2	161.7	177.5	216.3	239.4
50 Year	22.3	34.4	37.6	42.1	69.2	148.9	195.5	210.5	248.2	275.5
100 Year	24.8	39.5	41.7	45.2	78.2	177.8	223.9	236.7	271.9	302.6

Table 11: Highest rainfall recorded by rain gauge for each catchment.

ARI	Pūhoi (mm/24hr)	Mahurangi (mm/24hr)
2 year ARI	89	118
10 year ARI	122	166
100 year ARI	157	237

2.4 Rainfall comparison

From the three sources of rainfall data discussed above, the TP108 design rainfall data consistently provided the highest 24 hour rainfall depths. A comparison of the design rainfall data from each source is provided Table 12.

To be conservative, we selected the TP108 design rainfall data to use for the Project.

Table 12: Summary of rainfall data from each source.

	Pūhoi (mm/24hr)			Mahurangi (mm/24hr)		
ARI	**TP108**	**HIRDS v3**	**Rainfall Gauge**	**TP108**	**HIRDS v3**	**Rainfall Gauge**
2 year ARI	**115**	101	89	**130**	113	118
10 year ARI	**190**	153	122	**210**	169	116
100 year ARI	**280**	256	157	**310**	279	237

3. Climate change

We included an increase to design rainfall depths for the Project to allow for predicted climate change effects. This is necessary as these climate change effects are predicted to occur over the life of the Project's stormwater infrastructure, assuming a 100 year design life from an assumed 2020 construction completion.

The TP108 rainfall data in Table 1 was multiplied by a factor recommended in "Preparing for climate change. A guide for local government in New Zealand" (Ministry for the Environment (MfE), 2008). Extreme rainfall events relative to 1990 are increased based on a mean predicted temperature rise for the Auckland region of 0.9°C in 2040 and 2.1°C to 2090. We applied linear interpolation of the 2040 and 2090 values in order to estimate the projected 2120 rainfall data.

The methodology we used to estimate the 2120 rainfall data is as follows:

Step 1. Obtain the mid-range projected change in annual mean temperature;

Projected changes in annual mean temperature in degrees C relative to 1990

		Degrees C Increase		
Region	**Year**	**Mid**	**Low**	**High**
Auckland	**2040**	0.9	0.2	2.5
Auckland	**2090**	2.1	0.6	5.8

Step 2. Obtain multiplying factor per °C increase in temperature;

Factors for use in deriving extreme rainfall information for preliminary assessment scenarios (per degree C)

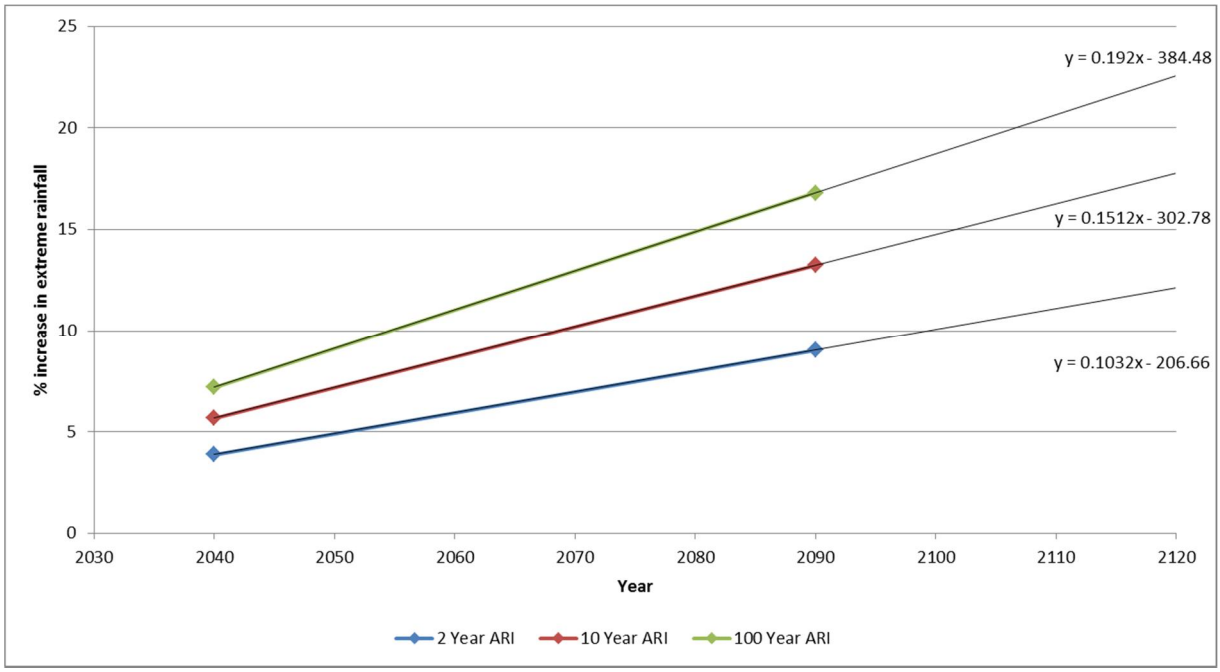
	ARI						
Duration	**2**	**5**	**10**	**20**	**30**	**50**	**100**
24 hour	4.3	5.4	6.3	7.2	8	8	8

Step 3. Multiply the mid-range projected change in annual mean temperature by the multiplying factor;

Percentage increase in extreme rainfall relative to 1990

		ARI		
Duration	**Year**	**2**	**10**	**100**
24 hour	**2040**	3.9	5.7	7.2
	2090	9.0	13.2	16.8

Step 4. Extrapolate out to 2120 to determine percentage increase in rainfall in 2120.



Linear extrapolation to determine % increase in extreme rainfall in 2120
Percentage increase in extreme rainfall relative to 1990

		ARI		
Duration	**Year**	**2**	**10**	**100**
24 hour	**2120**	12.1	17.8	22.6

The percentage increase in 24 hour rainfall depth for the 2 year, 10 year and 100 year ARI storm events in 2120 compared to 1990 is 12.1%, 17.8% and 22.6% respectively. We applied these percentage increases to estimate the projected 2120 rainfall for the Pūhoi and Mahurangi catchments, provided in Table 13.

4. Design rainfall

The design rainfall is based on the TP108 rainfall depths with climate change allowance for 2120. These are the design 24 hour rainfall depths we have used for our hydraulic design and hydrological assessments for the Project, which are shown in Table 13.

Table 13: Design 24 hour rainfall depths for 2120.

ARI	Pūhoi (mm/24hr)	Mahurangi (mm/24hr)
2 year ARI	129	146
10 year ARI	224	247
100 year ARI	343	380

Rainfall depths should be reassessed for detailed design stage of the Project.