4 August 2025

File Ref: OIAPR-1274023063-40407

[redacted]
By email: [redacted]

Tēnā koe [redacted]

Request for information 2025-213

I refer to your request for information dated Monday 7 July 2025, which was received by Greater Wellington Regional Council (Greater Wellington) on Monday 7 July 2025. You have requested the following:

"What reports, investigations, decisions and action has GWRC done or planned since the start of 2018 in regard to reducing the flooding impact (eg image below) from upstream of Harrison Street to the downstream side of SH53 from the Donald Creek Detention Scheme?"

Greater Wellington's response follows:

Under the Regional Water Agreements, Greater Wellington is responsible for managing flood risk from Donalds Creek. This includes (1) flood hazard modelling, (2) flow monitoring and (3) asset management and maintenance.

Wellington office
PO Box 11646
Manners St, Wellington
6142

Upper Hutt
PO Box 40847
1056 Fergusson Drive

Masterton office
PO Box 41
Masterton 5840

0800 496 734
www.gw.govt.nz
info@gw.govt.nz

Since 2018, Greater Wellington has carried out the following actions to reduce the flooding impact from upstream of Harrison Street to the downstream side of SH53 from the Donald Creek Detention Scheme. Noting that these actions are taken for the benefit of the wider community, and not just the property between Harrison Street to the downstream side of SH53.

The following activities are described below with the relevant documentation appended to this response:

- Flood Modelling of Donalds Creek and the Detention Dam
- Regular Maintenance Activities
- Dam Safety Management
- Strategic land purchase for future dam safety improvements.

Flood Modelling of Donalds Creek and the Detention Dam

Greater Wellington is undertaking the development of detailed flood hazard modelling of Donalds Creek in accordance with Greater Wellington's Flood hazard modelling standard. The standard can be accessed on Greater Wellington's website:

https://www.gw.govt.nz/document/16774/flood-hazard-modelling-standard/

The hydraulic modelling and flood hazard assessment process is ongoing. Community engagement for model calibration has been completed. The model has been run for the uncertainties and event scenarios. These scenarios have passed their peer review, and the hazard layer has been supplied to the Combined Wairarapa District Plan Committee. The breach, stopbanks down and dam safety scenarios are currently being modelled. Once these runs are complete the model will undergo its final peer-review and independent audit, which is expected to be complete by July-August.

Further information on the modelling project can be found here: https://www.gw.govt.nz/your-region/emergency-and-hazard-management/flood-protection/our-work/rivers-and-streams/donalds-and-abbots-creeks-flood-hazard-work/

Please see the following attachments which report on the work listed above:

Attachment 1 – Donalds and Abbots_Creek_Hydrological_Assessment Revision_04 Final
Attachment 2 – Donald and Abbots Creek Hydrology Peer Review Final (1)
Attachment 3 – Donalds and Abbots Creek PART A 820.V300278 DRAFT V1.0 (1)
Attachment 4 – Donalds and Abbots Creek Hydraulics Peer Review Preliminary Part B Memo

Regular Maintenance Activities

Greater Wellington does not currently have a scheme agreement for the Donalds Creek area, as a result there are no formalised maintenance plans or agreements. However, Greater Wellington undertakes frequent vegetation control and moving throughout the Donalds Creek stop banked channel. We have removed a number of trees and large bushes that had the potential to reduce the channel capacity and hydraulic efficiency.

Dam Safety Management

In accordance with the dam safety regulations (Building (Dam Safety) Regulations 2022) Greater Wellington managed the detention dam to the north of Harrison Street East. Greater Wellington has determined that this dam is not 'classifiable' under the Regulations; however, we are proceeding with management activities as if it were. This includes:

- Potential impact classification (PIC) – though it is not classifiable, it is being treated as a high impact dam.
- Failure Modes and Effects Analysis for the Donalds Creek Dam, to understand the failure modes of the dam.
- Operational and maintenance plan along with emergency action plan
- Training of Greater Wellington and Emergency Management staff in dam safety which has included the Donalds Creek Detention Dam.
- Installed temporary flow monitoring equipment at the Detention Dam ahead of further investigation and installation of formal telemetry.

Please see attached the reports for this work:

Attachment 5 – DWE-E2417-RPT-Donalds Creek_FMEA_v1 Issue 01.pdf
Attachment 6 – Notification to Regional Authority of change to Dangerous Dam status (13_5_24)
Attachment 7 – Notification to Regional Authority of Dangerous Dam
Attachment 8 – DON Dam Classification
Attachment 9 – Memo DON Dangerous Dam Update April 2024

Strategic land purchase for future dam safety improvements

Greater Wellington has recently acquired a paddock adjacent to the Donalds Creek Detention Dam to support future upgrades to the dam and enhancements to its level of service. This land may also facilitate a more streamlined approach to land designation and help safeguard the spillway discharge flow path from inappropriate use or development. Further investigation into available options will be required to inform any future decisions.

Attachment 10 – Council report – Purchase of land adjacent to Donalds Creek Detention Dam

We note that the Featherston Masterplan & Implementation Plan highlights the area immediately downstream of the detention dam as being prone to flooding. Greater Wellington also urge caution with development in land identified as medium or high-risk Flood Alert Areas in the Proposed Wairarapa Combined District Plan, as highlighted in the following plan:

Planned Work

Greater Wellington does not have planned work to reducing the flooding impact from upstream of Harrison Street to the downstream side of SH53 from the Donald Creek Detention Scheme. However, once the new flood hazard modelling is finalised an assessment will be undertaken to identify if further risk management steps are required.

If you have any concerns with the decision(s) referred to in this letter, you have the right to request an investigation and review by the Ombudsman under section 27(3) of the Local Government Official Information and Meetings Act 1987.

Please note that it is our policy to proactively release our responses to official information requests where appropriate. Our response to your request will be published shortly on Greater Wellington's website with your personal information removed.

Nāku iti noa, nā

Lian Butcher
Kaiwhakahaere Matua Rōpū Taiao | Group Manager Environment

Attachments

The following documents are attached:
Attachment 1 - Donalds_and_Abbots_Creek_Hydrological_Assessment Revision_04 Final
Attachment 2 - Donald and Abbots Creek Hydrology Peer Review_Final (1)
Attachment 3 - Donalds and Abbots Creek PART A 820.V300278 DRAFT V1.0 (1)

Attachment 4 - Donalds and Abbots Creek Hydraulics Peer Review_Preliminary Part B Memo
Attachment 5 - DWE-E2417-RPT-Donalds Creek_FMEA_v1 Issue 01.pdf
Attachment 6 - Notification to Regional Authority of change to Dangerous Dam status (13_5_24)
Attachment 7 - Notification to Regional Authority of Dangerous Dam
Attachment 8 - DON Dam Classification
Attachment 9 - Memo DON Dangerous Dam Update April 2024
Attachment 10 – Council Paper – Purchase of land adjacent to Donalds Creek Detention Dam.

Donalds Creek and Abbots Creek

Hydrological Assessment

10 October 2024

Client: Greater Wellington Regional Council
Report by: Tom Kerr & Matthew Gardner
Land River Sea Consulting Limited
www.landriversea.com

Land River Sea CONSULTING
Greater Wellington Te Pane Matua Taiao

REVISION HISTORY

Author:	Tom Kerr Hydrologist	Matthew Gardner Water Resources Engineer, CMEngNZ, CPEng
Signature:		
Date:	10 October 2024	
Revision:	04	
Authorised by:	Kirsty Duff	
Signature:		
Organisation:	Greater Wellington Regional Council	
Date:	07 October 2024	

Land River Sea Consulting Limited
5/245 St Asaph Street
Christchurch

M: +64 27 318 9527
E: matthew@landriversea.com
W: landriversea.com

TABLE OF CONTENTS

1. INTRODUCTION

The purpose of the hydrological assessment of the Donalds Creek and Abbots Creek catchments is to provide a range of design flow hydrographs and rainfall to be input to a hydraulic model of the Donalds and Abbots Creek floodplain.

There is a lack of flow data in the two catchments and so data from nearby catchments were assessed to identify flow records representative of the Donalds and Abbots creeks. The Pakuratahi and Mangatārere catchments were considered and details of the comparison are included in Section 5.5. The Mangatārere catchment was selected because it a has similar elevation, aspect, and size to the Donalds and Abbots creeks and has a relatively long flow and rainfall record. Pakuratahi and Mangatārere catchment boundaries are shown in Figure 5-3.

A HEC HMS model of the upper Mangātarere catchment was developed and calibrated using nine floods recorded between 2000 and 2014. A HEC HMS model of the Donalds and Abbots Creek basins was then built based on the Mangatārere model parameters.

Design hydrographs for 6 Annual Exceedance Probability (AEP) events and 6 climate scenarios at 15 locations were extracted from the Donalds and Abbots Creek HEC HMS model for input to the Donalds and Abbots Creek hydraulic flood model.

Hydrographs and rainfall for dam breach modelling were also produced.

The scope of works is included in Appendix 1 and in summary is to:

1. Develop a strong understanding of the hydrology within Donalds Creek and Abbots Creek catchments.
2. Highlight possible calibration/validation events.
3. Develop hydrological inputs to the hydraulic model for multiple design events (see FHMS (GWRC, 2021)). These may be rainfall or flow inputs, or both as recommended through this hydrological assessment.
4. Collaborate with the hydraulic modeller, to ensure as much realism as possible within the model.
5. Collaborate with GWRC's appointed peer reviewer.
6. Ensure communication and clarification of findings with interested stakeholders such as South Wairarapa District Council, iwi, and the wider community.

2. CATCHMENT

The combined Donalds Creek and Abbots Creek catchment boundary and the Abbots Creek catchment boundary is shown in Figure 2-1. A summary of Donalds and Abbots Creek catchment statistics is listed in Table 2-1.

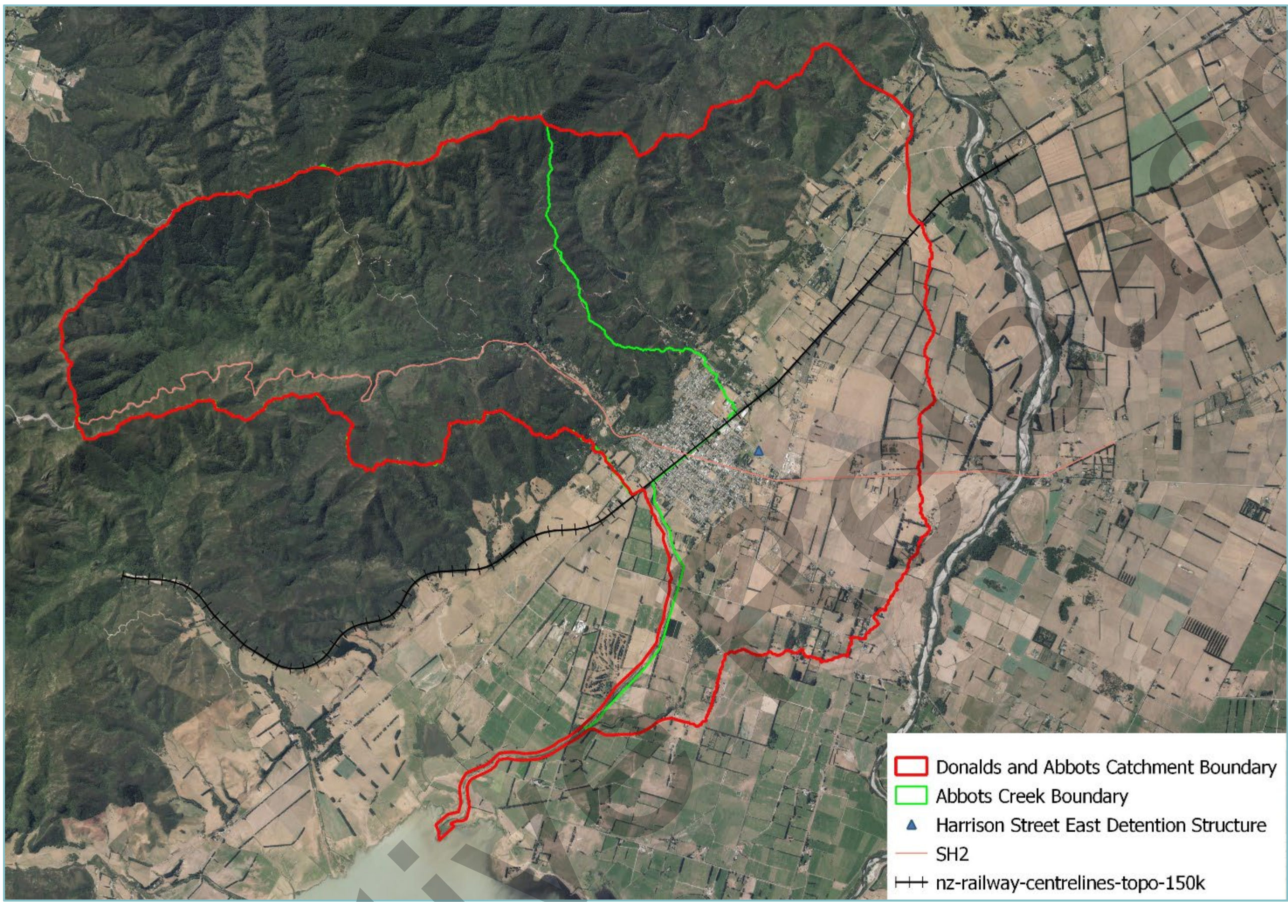

Figure 2-1: Catchment boundary

Table 2-1: Catchment Parameters

Parameter	Unit	Value
Donalds & Abbots creeks catchment area at Lake Wairarapa	km^2	48.7
Abbots Creek catchment area as shown in Figure 2-1	km^2	22.4
Maximum Elevation Donalds Creek	m	608
Maximum Elevation Abbots Creek	m	795

3. SITE VISIT

A site visit was undertaken on 15/05/2023 with Greater Wellington staff to view key parts of the catchment including the Otakura flow gauge, (ref. Figure 5-3), visits to stop banks, creek channels, lower Boar Creek (ref. outlet 4 in Figure 6-11) and the Harrison Street East detention structure shown in Figure 2-1.

4. REPORTS

The following reports, drawings and photos were provided by GWRC.

Table 4-1: Documents received from GWRC

	Document Name	Year
1	Donalds Creek Flood Protection Project Design Report August 1998.pdf	1998
2	Donalds Creek Flood Protection Project As-built Drawings 1998.pdf	1998
3	Donalds Creek Flood Protection Project Assessment of Environmental Effects August 1998.pdf	1998
4	Drawings (x22 TIFF) Various drawings and maps related to Donalds Crk Flood Protection Project	1998
5	Donalds Creek review SH53 to Confluence 19-4-06.doc	2006
6	Donalds Creek Works between SH53 and the confluence with Abbots creek.doc	2006
7	PGWES Hydrological assessment of Donalds Creek 2016.pdf	2016
8	Summary of Wellington Region Surface Water DRAFT (Otakura Stream).pdf	2016
9	Donald's Creek - Memo of site visit recommendations Dec 2017.docx	2017
10	Donalds Creek Detention Facility - Hydrological Analysis July 2018.pdf	2018
11	Donalds Creek Detention Facility - Hydrological Analysis phase 2 Aug 2018.pdf	2018
12	Donalds Creek Detention Facility FMEA memo Sep 2018.pdf	2018
13	Donalds Creek Opus Memo on HIRDS Oct 2018.docx	2018
14	Donalds Creek Post-Event Appraisal (FINAL) Dec 2018.pdf	2018
15	Aerial Photos (x124 JPG) Photos of the 02 December 2018 flood	2018
16	Brookside Developments - Flood-Assessment-Stage-2-3-Report-3-July-2020-1.pdf	2020
17	Draft AMP Contents for Donalds Creek.docx	2022

An assessment of Donalds Creek flood hydrology was included in the 1998 Design Report listed as item 1 above. A Hydrol rainfall runoff model was developed to simulate 1:2 to 1:100 AEP flood inflows at the site of the Harrison Street East detention structure outlet, calculated to have a catchment area of 9.6 km². The regional flood frequency method was also used to estimate peak flows at the outlet. Modelled results are listed in Table 4-2

An updated assessment of flood flows at the Harrison Street East detention structure was made in 2018, (item 10 and 11 in Table 4-1. A HEC HMS rainfall runoff model was developed and calibrated with scaled Mangātarere flow data. Modelled design flood results are listed in

Table 4-2.

Table 4-2: Previous modelled design flood estimates at Harrison Street East

AEP	Hydrol (GWRC) 1998 (m^3/s)	HEC HMS (WSP) 2018 (m^3/s)
1:2	15.2	
1:5	22.3	
1:10	26.9	
1:20	30.7	27.0
1:50	36.6	37.3
1:100	41.1	49.8

Aerial photos taken the day after a major flood on 02 December 2018 were also provided.

A single aerial photo shown in Figure 4-1 was also provided showing ponding behind the Harrison East Street detention structure.

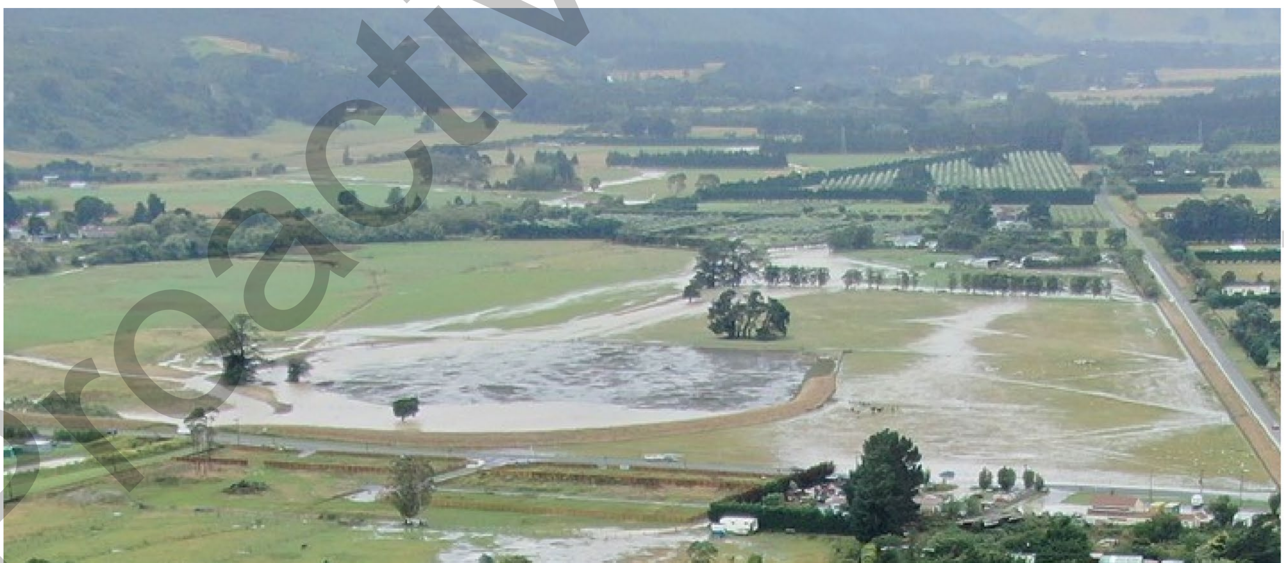

Figure 4-1: Photo looking north to Harrison Street East detention structure (02 Dec 2018)

5. RAIN AND FLOW DATA

Rainfall and flow data were provided by GWRC as xml files.

Graphs of sub daily rainfall and flow sites and the duration of each record are shown below. The vertical lines indicate gaps in the record. The location of selected rainfall and flow sites are plotted in Figure 5-3.

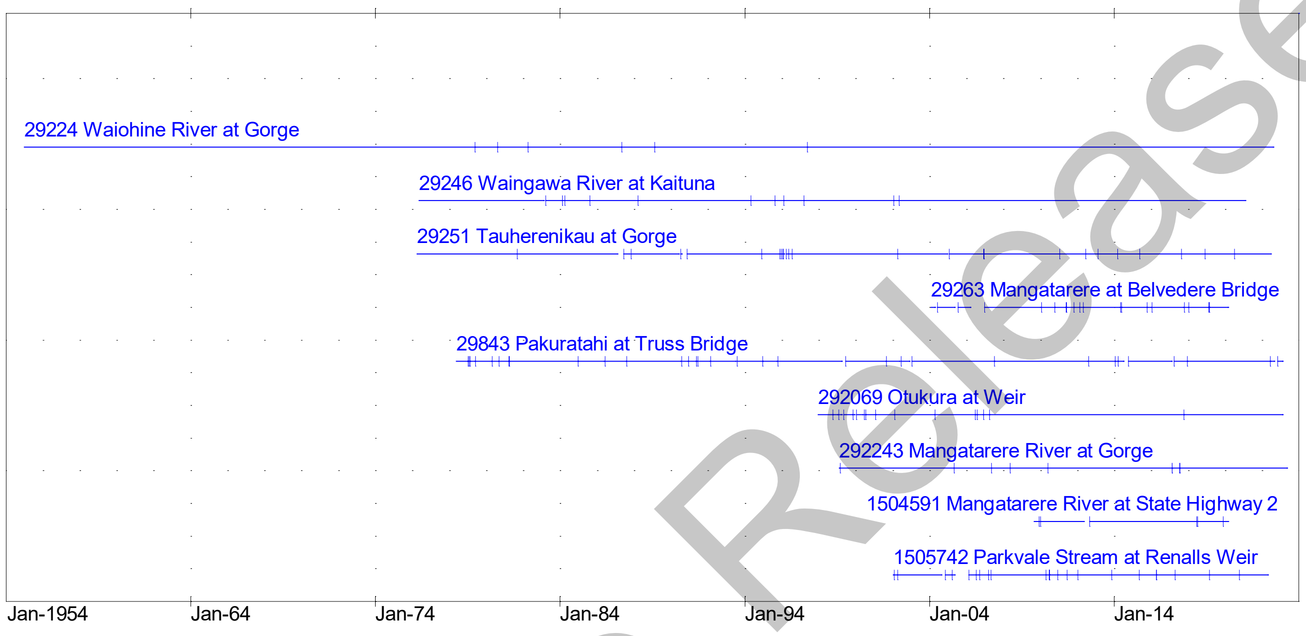

Figure 5-1: Duration of flow records

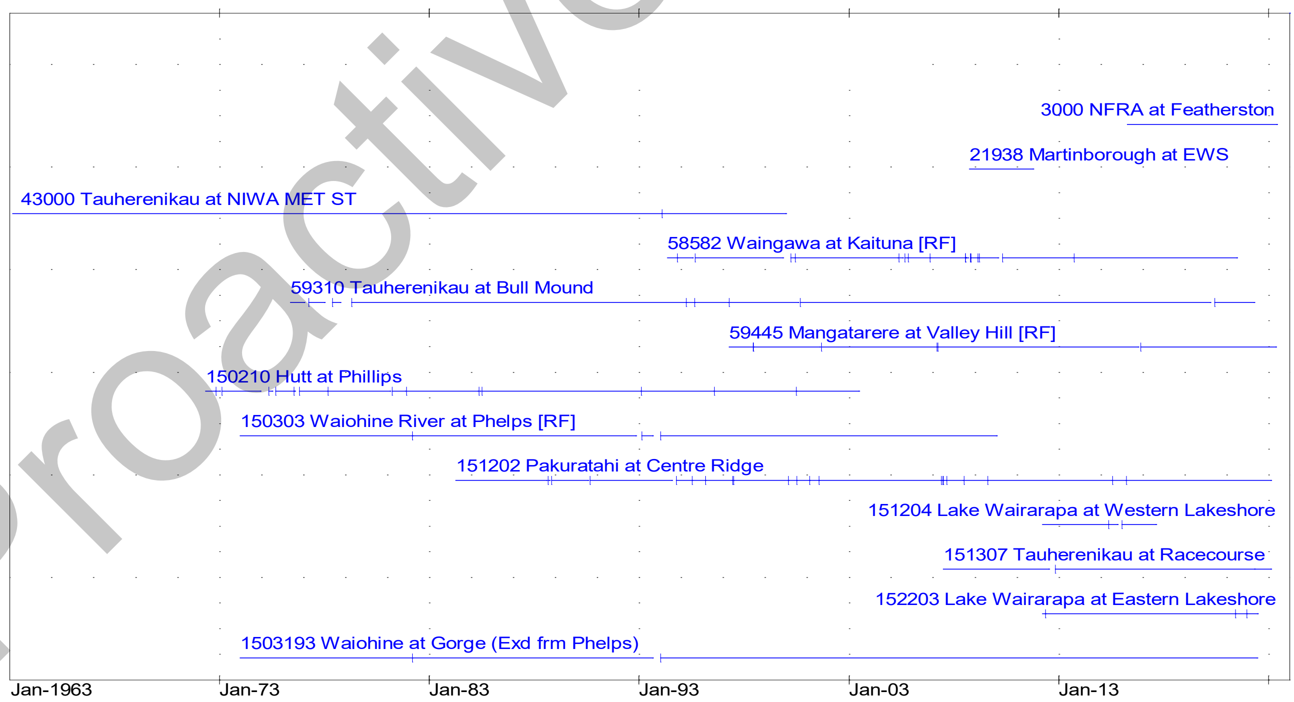

Figure 5-2: Duration of rain records

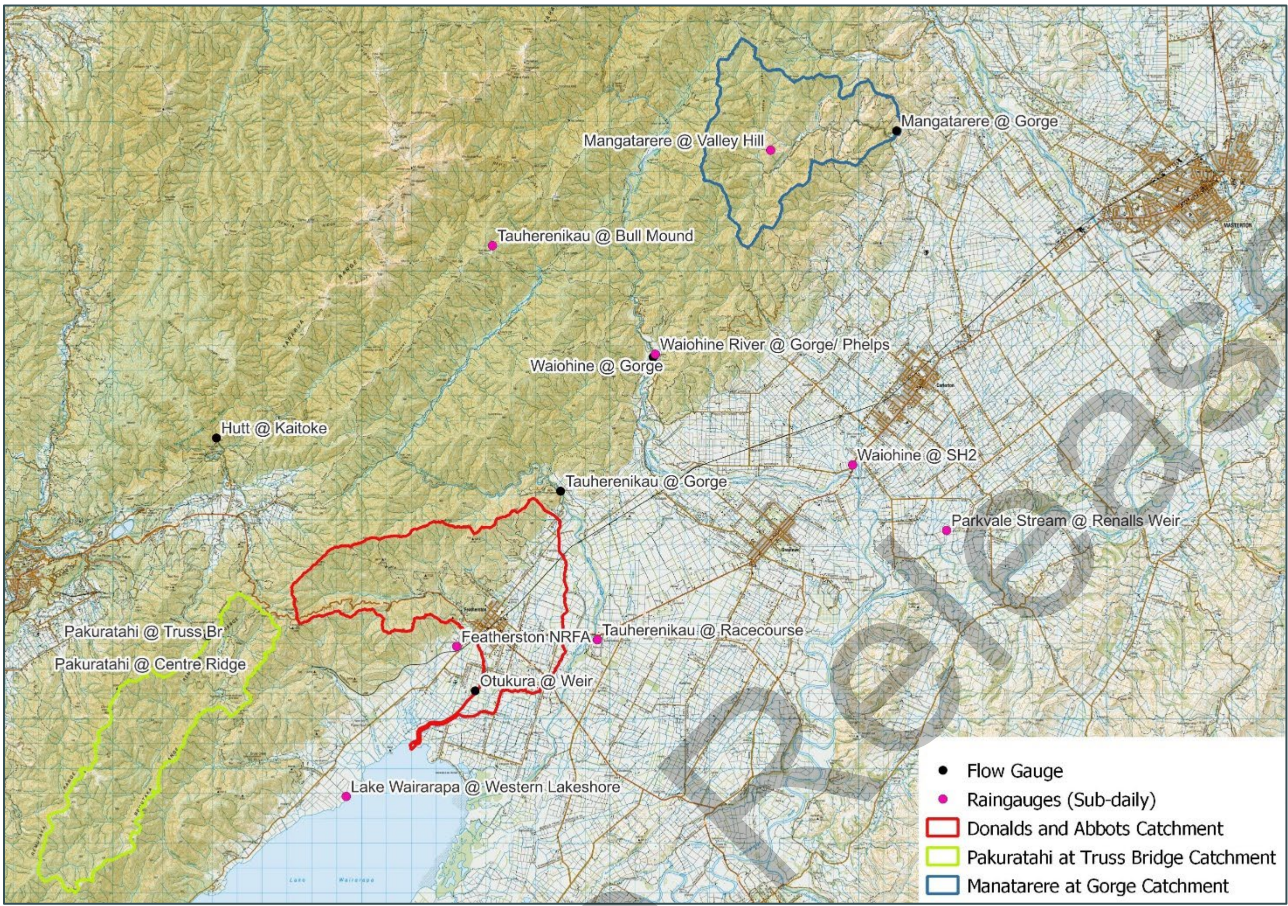

Figure 5-3: Location of flow and rain gauges

5.1. SUB-DAILY RAINFALL

The closest rain gauges to the catchments are the NRFA gauge to the west of Featherston and the Tauherenikau at Racecourse gauge to the east. These gauges are on the floodplain and as discussed in Section 5.2, receive less rain than gauges at higher altitudes.

Cumulative rainfall plots for the gauges used in runoff modelling are shown in Figure 5-4 and confirms that rainfall increases with elevation.

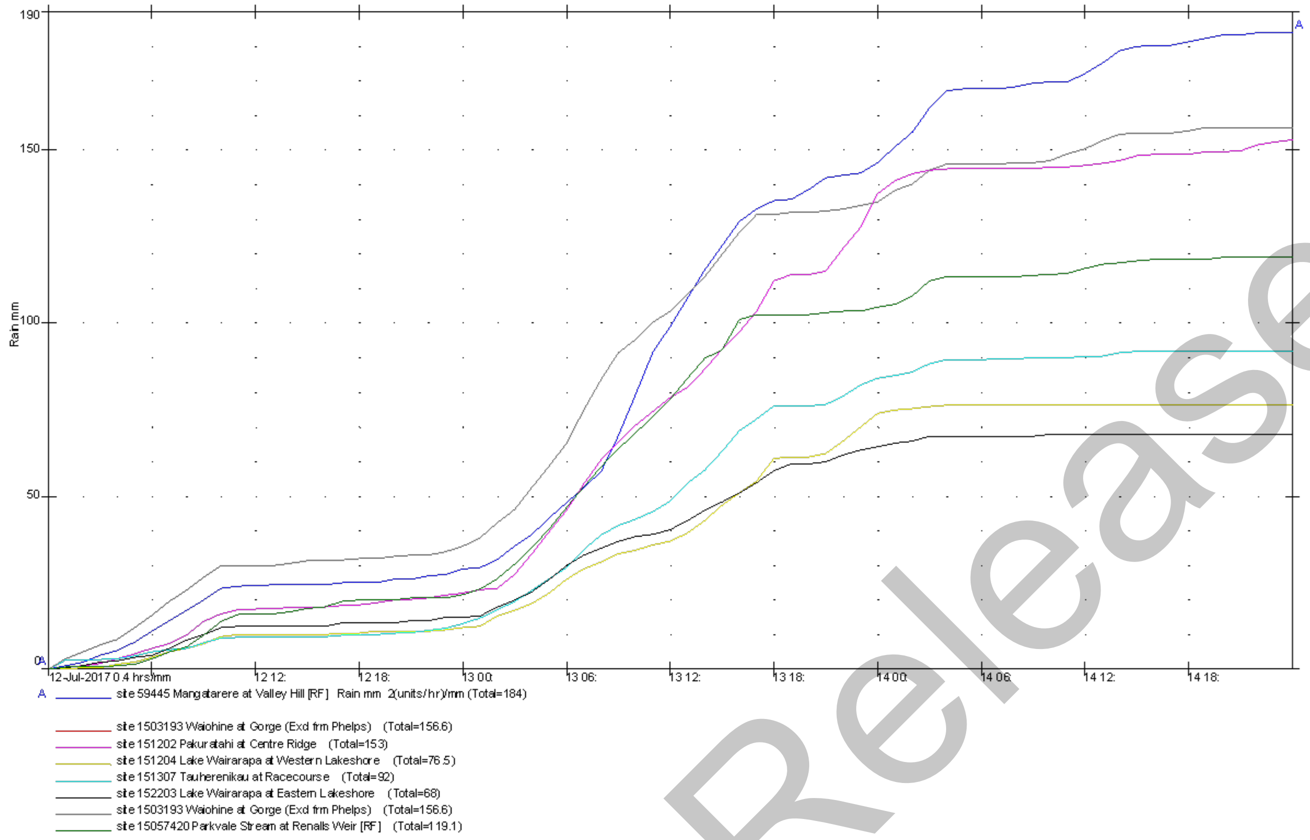

Figure 5-4: Cumulative rainfall

5.2. DAILY RAINFALL

A number of daily rainfall gauges have been operated in and around Featherston dating back to 1884. Daily records are not used in runoff modelling but provide further information on the spatial variation of rainfall with elevation.

Daily data was downloaded from Cliflo (https://cliflo.niwa.co.nz/) and is summarised in Table 5-1. Comparisons of Mean Annual Rainfall (MAR) and elevation are plotted in Figure 5-6 and a similar plot is shown in Figure 5-7 for existing Greater Wellington gauges for the period 2008 to 2021 (complete years only). MAR depths increase with elevation in and adjacent to the catchment.

Table 5-1: Summary of Cliflo daily rain gauge data

Name	Agent Number	Height (m)	Period of Record	MAR (mm)
Rimutaka Summit	2618	561	1962 to 1987	1947
Featherston 2	2620	46	1884 to 1987	1285
Waipoto	2621	27	1940 to 1960	1076
Summit	2617	594	1890 to 1994	2281
Tauherenikau	2623	43	1963 to 1994	1087

Figure 5-5: Daily rain gauge locations

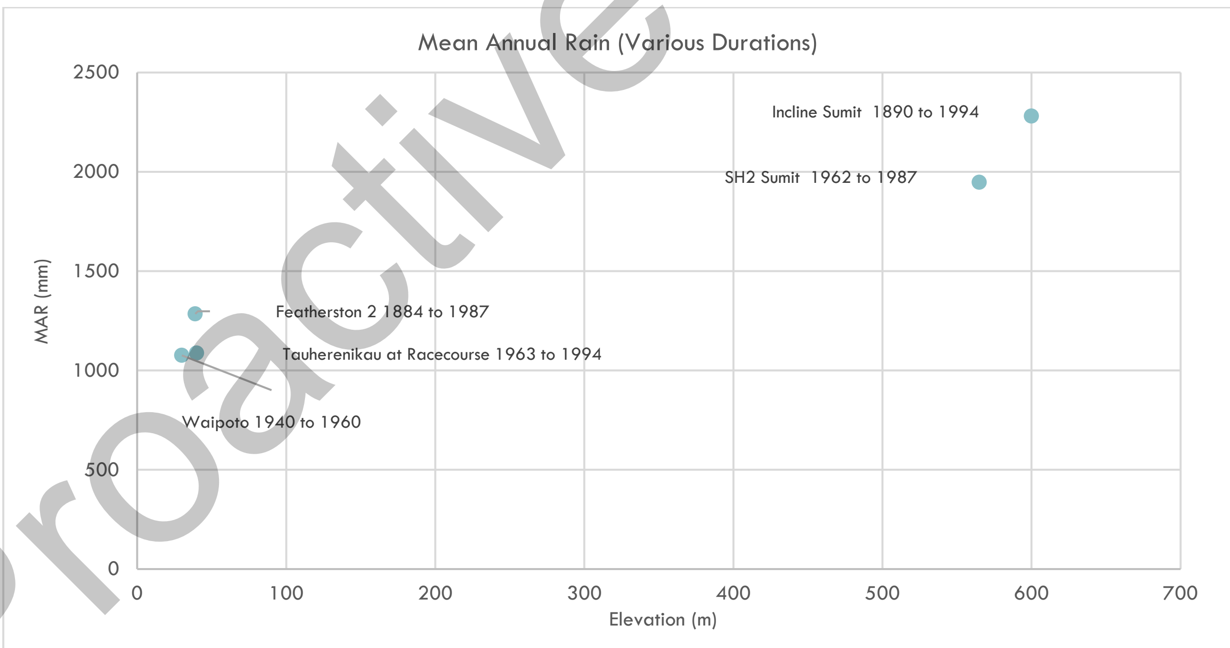

Figure 5-6: Mean Annual Rain vs. Elevation – daily gauges for various time periods.

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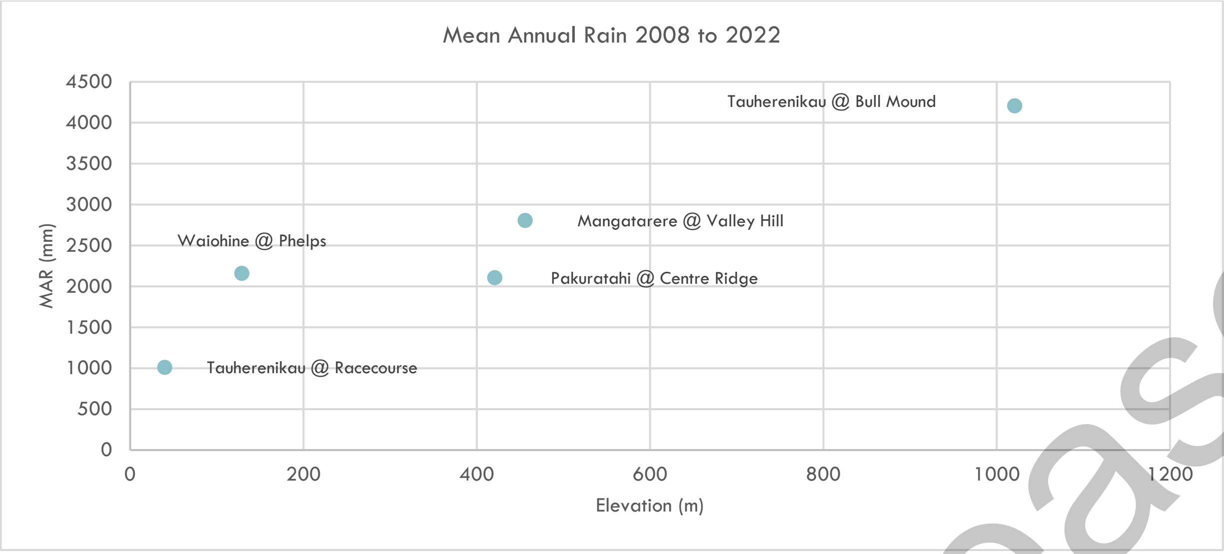


Figure 5-7: Mean Annual Rain vs. Elevation – 2008 to 2021

5.3. DESIGN RAIN

Data from NIWA's High Intensity Design Rainfall System (HIRDS), (Carey-Smith, T, et al, 2018) was compared with recorded rain gauge data.

Figure 5-8 shows HIRDS 1:100 AEP, 6-hour isohyets and an increasing rainfall gradient with elevation, similar to the spatial distribution observed in daily and sub daily recorded data and described in Sections 5.1 and 5.2.

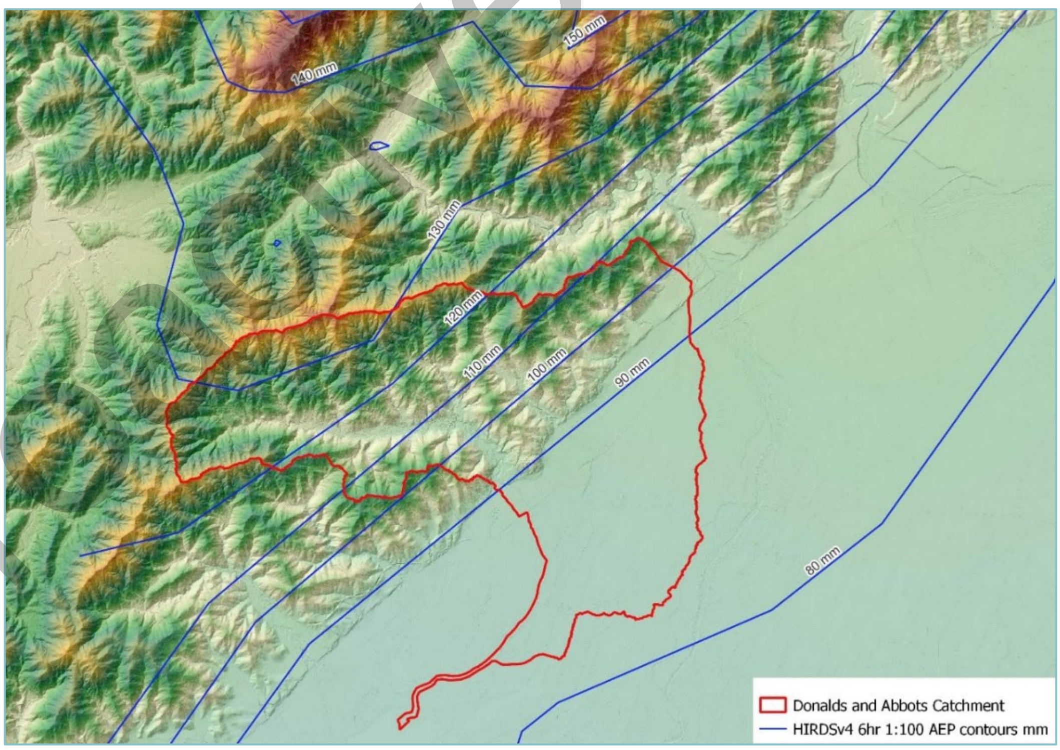


Figure 5-8: HIRDS 1:100 AEP 6-hour contours

Comparisons of HIRDS 4 hour rain depths and results of frequency analysis of recorded rainfall are plotted in Figure 5-9. Rain gauge locations and length of record are given in Figure 5-2 and Figure 5-3. Overall, HIRDS data is generally consistent with frequency analysis of rain gauge data and spatial distribution observed in daily and sub-daily gauges and so was adopted for all design rainfall input to the runoff models.

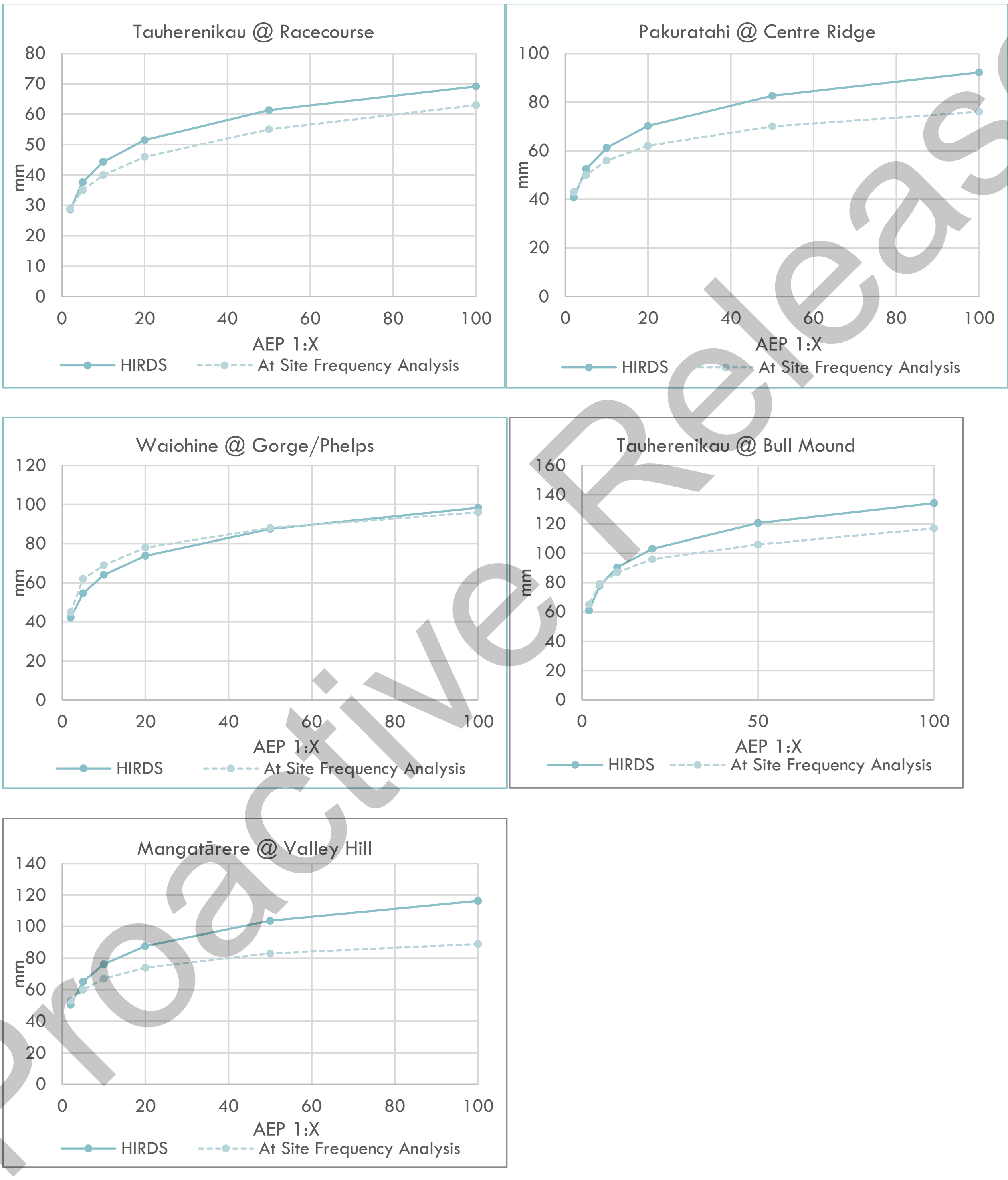


Figure 5-9: HIRDS and at site frequency analysis (4 hr)

5.4. RAIN RADAR

Wellington rain radar data was extracted from the Moata website (Mott-MacDonald, 2023) for a rain event on the 2 December 2018. The event is discussed in more detail in Section 6.4. and a map of radar depths is shown in Figure 6-7.

5.5. RECORDED FLOW

5.5.1. OTUKURA AT WEIR

The only flow data recorded in the Donalds and Abbots creek catchments is at the Otukura at Weir gauging station. The gauge has been in service since 1997 and maximum flow recorded is 17.15 m^3/s. During very high flows the stream overtops its banks upstream of the gauge and so not all flow is captured at the weir site, (Gordon, 2016). The flow record is therefore not suitable for model calibration or flood frequency analysis.

Figure 5-10: Otakura Stream gauging station

5.5.2. TAUHERENIKAU AT GORGE & WAIOHINE AT GORGE

Flow data has been recorded at the Tauherenikau at Gorge recorder since 1976. The gauged catchment is 112 km^2 with headwater elevations of up to 1,049 m. The significant difference in catchment size and average elevation means that recorded discharge from the Taurherenikau catchment is not representative of flows in the Donalds and Abbots catchments.

The same is true of data from the Waiohine at Gorge flow gauge where the gauged catchment is 180 km^2.

5.5.3. MANGĀTARERE AT GORGE

The Mangātarere at Gorge flow gauge is 26 km to the northeast of Featherston within the foothills of the Taurarua Range and records flow from a 33 km^2 catchment. The gauged catchment has an average elevation of 422 m compared to 354 m for the hillslope area of Abbots Creek and 264 m for the hillslope area of Donalds Creek. Its Mean Annual Rainfall from the NZ Environmental Data Stack GIS layer (NZEnvDS), for mean annual rainfall between 1950 and 1980, (Leathwick et al, 2002) is 2517 mm compared with 1811 mm for the hillslope catchments of Donalds and Abbots Creek.

Mangatārere flow data is considered reasonable up to the maximum gauged flow of 71 m³/s. 257 gaugings were carried out at the site between 9-Feb-1999 and 27-Feb-2020. The flow hydrograph is shown in Figure 5-11 and ratings and gaugings for the site in Figure 5-12.

There is uncertainty associated with the largest flood recorded at the site on 17 February 2017. The recorder was damaged by a shipping container carried from upstream during the flood and the peak may have been affected by the breach of an earth dam formed during the 2016 Kaikoura earthquake. An estimated flow of 150 m³/s was adopted for the February 2017 event.

Greater Wellington carried out slope area calculations based on evidence of a peak level at the gauge of 3 m. This gave flows of 125 m³/s and 138 m³/s but these estimates carry a large degree of uncertainty.

Greater Wellington also tested the sensitivity of flood frequency analysis to a range of February 2017 peak values for the period 9-Feb-1999 to 1-Jan-2021. Results are listed in Table 5-2. It shows that a change in value of the selected 2017 peak does not make as big a change to the design floods. For example, a 30 m³/s change in the 2017 peak makes a 9 m³/s difference to the 1:100 AEP flood.

Table 5-2 Summary of FFA sensitivity

AEP	No Feb 2017 Flood (m³/sec)	150 m³/sec Peak (m³/sec)	164 m³/sec Peak (m³/sec)	180 m³/sec Peak (m³/sec)
1:5	76	86	87	89
1:10	92	104	106	109
1:20	107	122	125	128
1:50	126	145	149	153
1:100	140	163	167	172
1:200	154	180	185	191

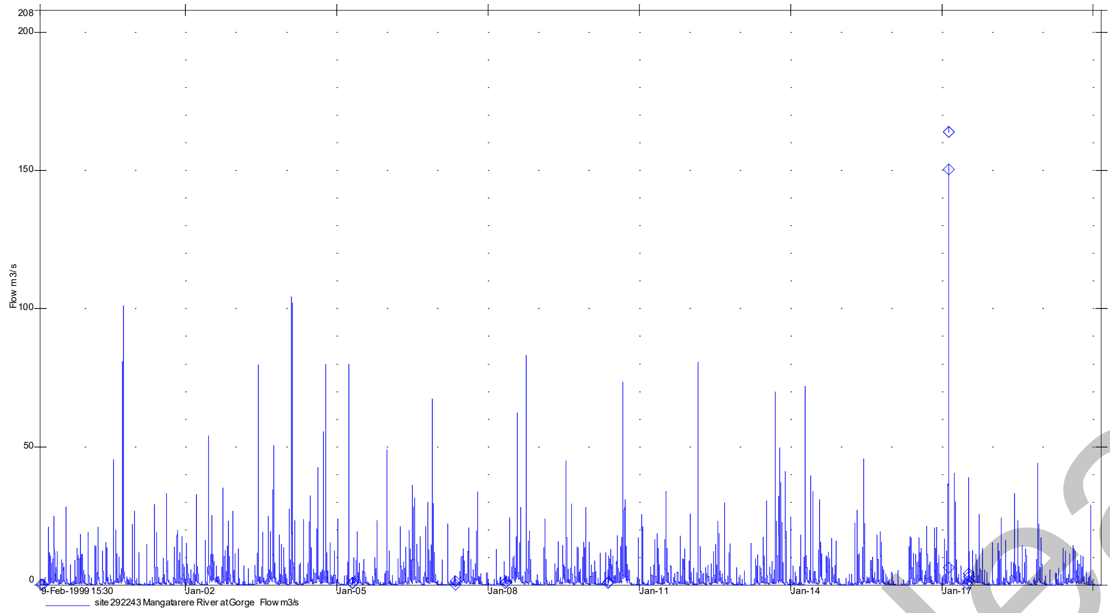


Figure 5-11: Mangatārere at Gorge Flow Hydrograph

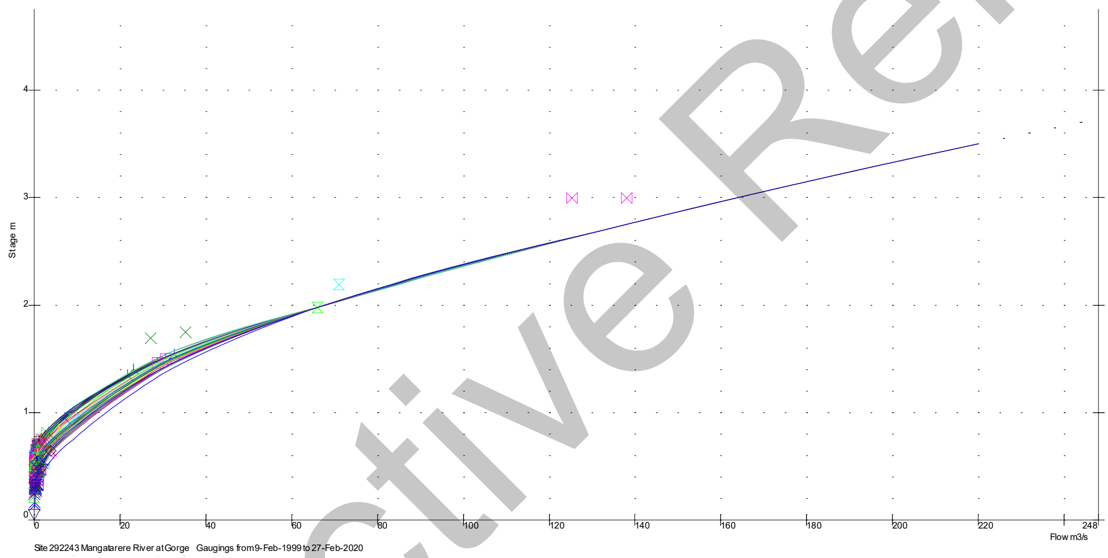


Figure 5-12: Mangatārere Rating and Gaugings

5.5.4. PAKURATAHI AT TRUSS BRIDGE

The Pakuratahi at Truss Bridge gauge is 11 km to the west of Featherston and drains a 37.0 km catchment into the Hutt River. Average catchment elevation is 539 m and MAR[1] is 2244 mm compared with Donalds and Abbots creek's 1811 mm.

5.5.5. DATA REGISTER

A summary of all rainfall and flow data collected and an assessment of the data quality of records used in the assessment is provided in Appendix 2.

[1] Area weighted average from the NZEnvDS mean annual precipitation layer

6. HEC HMS MODELLING

As no recorded flood data are available from within the Donalds and Abbots creek catchments, a HEC HMS model of the upper Mangātarere catchment was developed and calibrated based on data recorded at the Mangātarere at Gorge flow gauge and Mangātarere at Valley Hill rain gauge. Model parameters were then used for a HEC HMS model of the Donalds and Abbots creek catchments. Mangātarere was selected as it has similar elevation, aspect, and size to the Donalds and Abbots creeks and has a relatively long flow and rainfall record.

6.1. MANGATÀRERE HEC HMS MODEL

The Mangatārere model was developed using HEC HMS v4.11.

LiDAR from the Wellington 1 m DEM (2013 to 2014) was imported to HMS and an area parameter of 0.75 km^2 selected for basin delineation. A schematic of the Mangatārere HMS model is shown in Figure 6-1.

Resolution of the 2013/2014 LiDAR data is considered suitable for catchment delineation of both the Mangatārere and Donalds and Abbots Creek models.

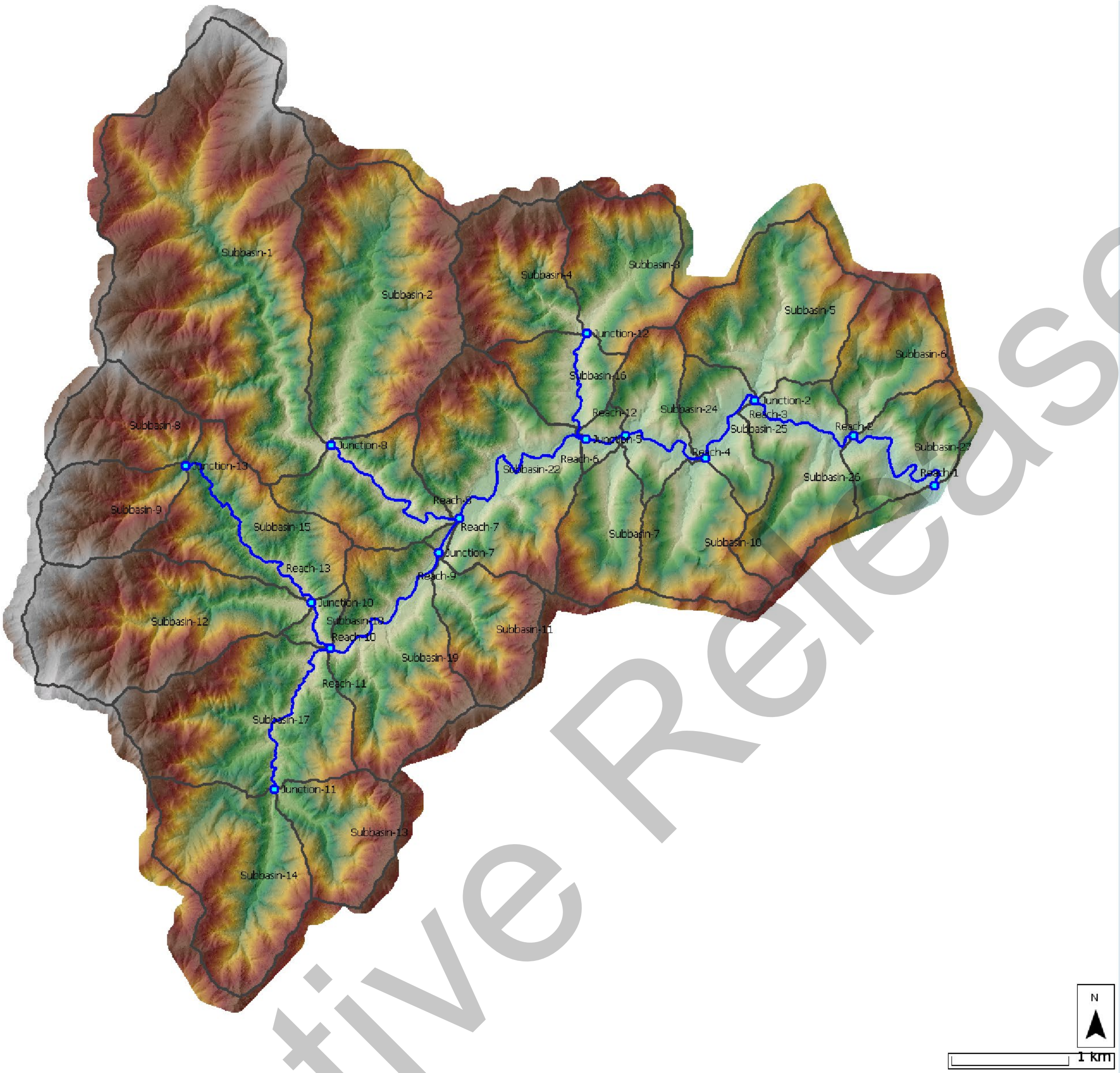


Figure 6-1: Mangatārere HEC HMS Model Schematic

6.1.1. CURVE NUMBER

The Soil Conservation Service (SCS) loss method was used with CN values based on Appendix B of *Reference Guide for Design Storm Hydrology*, (Wellington Water Ltd, 2019) which includes a table of landcover and soil types which are reproduced as Table 6-1 below.

The CN map provided in Appendix B of *Reference Guide for Design Storm Hydrology* does not include Mangatārere or the Donalds and Abbots catchments and so soil and vegetation/ landcover classes were estimated from the Land Cover Database v5.0 (Landcare Research, 2020) and Land Environments of New Zealand (LENZ) Soil Drainage Layer (Ministry for the Environment, 2020).

Table 6-1: Curve Number Table from Table B.1 of *Reference Guide for Design Storm Hydrology*

LAND COVER	A Sand, loamy sand, or sandy loam (low runoff potential)	B Silt loam or loam	C Sandy clay loam	D Clay loam, silty clay loam, sandy clay, silty clay, or clay (high runoff potential)
Alpine tussock/grass	66	77	84	87
Bare	66	77	84	87
Forest	28	46	63	71
Impervious	98	98	98	98
Pasture-Crop	37	59	72	78
Scrub/Flax	33	54	68	75
Urban Open Space	37	59	72	78

The Land Cover Database v5.0 contains 17 vegetative cover elements. To match the 7 landcover classes in Table 6-1, the 17 vegetative cover elements were combined into 7 landcover groups similar to those in Table 6-1 except the Alpine Tussock and Bare categories were combined and a category was included for Exotic Forests. The layer includes data for 5 years, (1996, 2001, 2008, 2012 & 2018). 2008 was selected for estimation of Mangatārere CN values as calibration events are from 2000 to 2014. Table 6-2 lists the adopted landcover categories which are shown for the Mangatārere catchment in Figure 6-2.

Table 6-2 Adopted landcover categories

Class		CN (Soil Type C)
1	Rock/Mine /Lake/ River/Impervious	98
2	Alpine Tussock/ Grass/ Bare	84
3	Urban	72
4	Pasture/ Crop	72
5	Scrub/Flax	68
6	Indigenous Forrest	63
7	Exotic Forrest	60

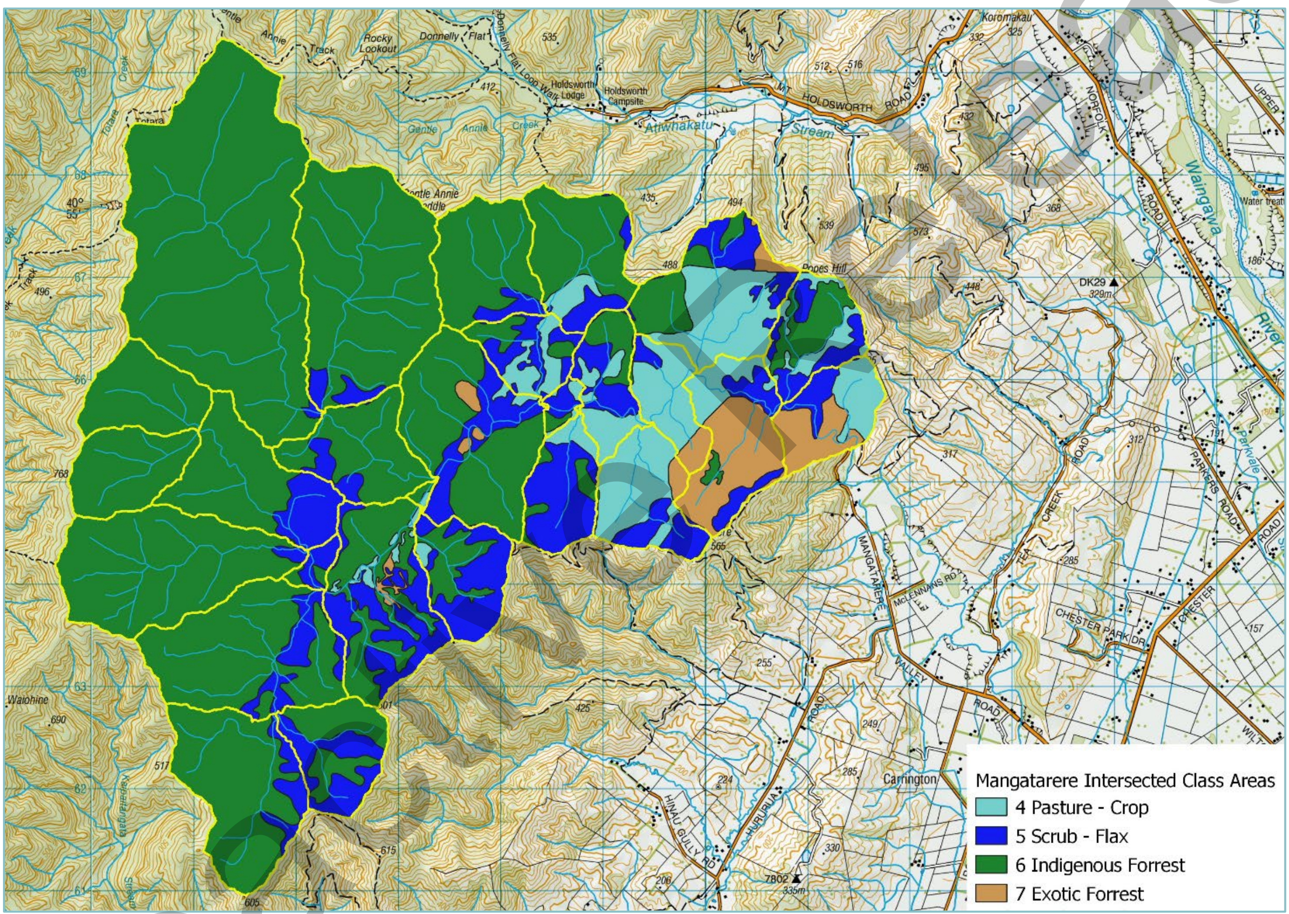


Figure 6-2 Mangatārere landcover areas

The LENZ Soil Drainage Layer has five classes of drainage, from Very Poor (1) through to Good/Well drained (5) and are listed in Table 6-3. This compares with the 4 soil classes in Table 6-1.

Table 6-3 LENZ soil drainage classes

Gridcode	Class
1	Very poor
2	Poor
3	Imperfect
4	Moderate
5	Good (=well)

Only classes 4 and 5 occur in the Mangatārere catchments. Of these, Class 4 makes up 96.9% of the area.

Based on a comparison with the CN map in Appendix B of *Reference Guide for Design Storm Hydrology*, it was determined that Soil Class C is equivalent to Gridcode 4 (moderate drainage class) in Table 6-3. CN values were therefore based on a single soil type, (Soil Class C - Sandy clay/ loam from Table 6-1).

Based in calibration results, CN values were increased by 5% to account for simulated runoff being lower than recorded flows. This amounted to an increase in CN of between 3.2 and 3.5.

6.1.2. INITIAL ABSTRACTION

Initial abstraction (I_a) was calculated from the formula $I_a = 0.05S_t$

Where $S_t = \left(\frac{1000}{CN} - 10\right)25.4$

The units of S_t and I_a are in mm and the constant 0.05 was selected as the recommended 0.1 in *Reference Guide for Design Storm Hydrology* gave relatively high Initial abstraction values.

6.1.3. TRANSFORM PARAMETERS

The Soil Conservation Service Unit Hydrograph Transform Method was used with a Peak Rate Factor of 550 and a Lag parameter of 0.6 x Time of Concentration which was calculated using the Ramser Kirpich formula.

6.1.4. CHANNEL ROUTING

Muskingum-Cunge channel routing for the reach elements shown in Figure 6-1 used channel slope and length information calculated during the basin delineation process and a Mannings *n* of 0.035.

6.2. CALIBRATION

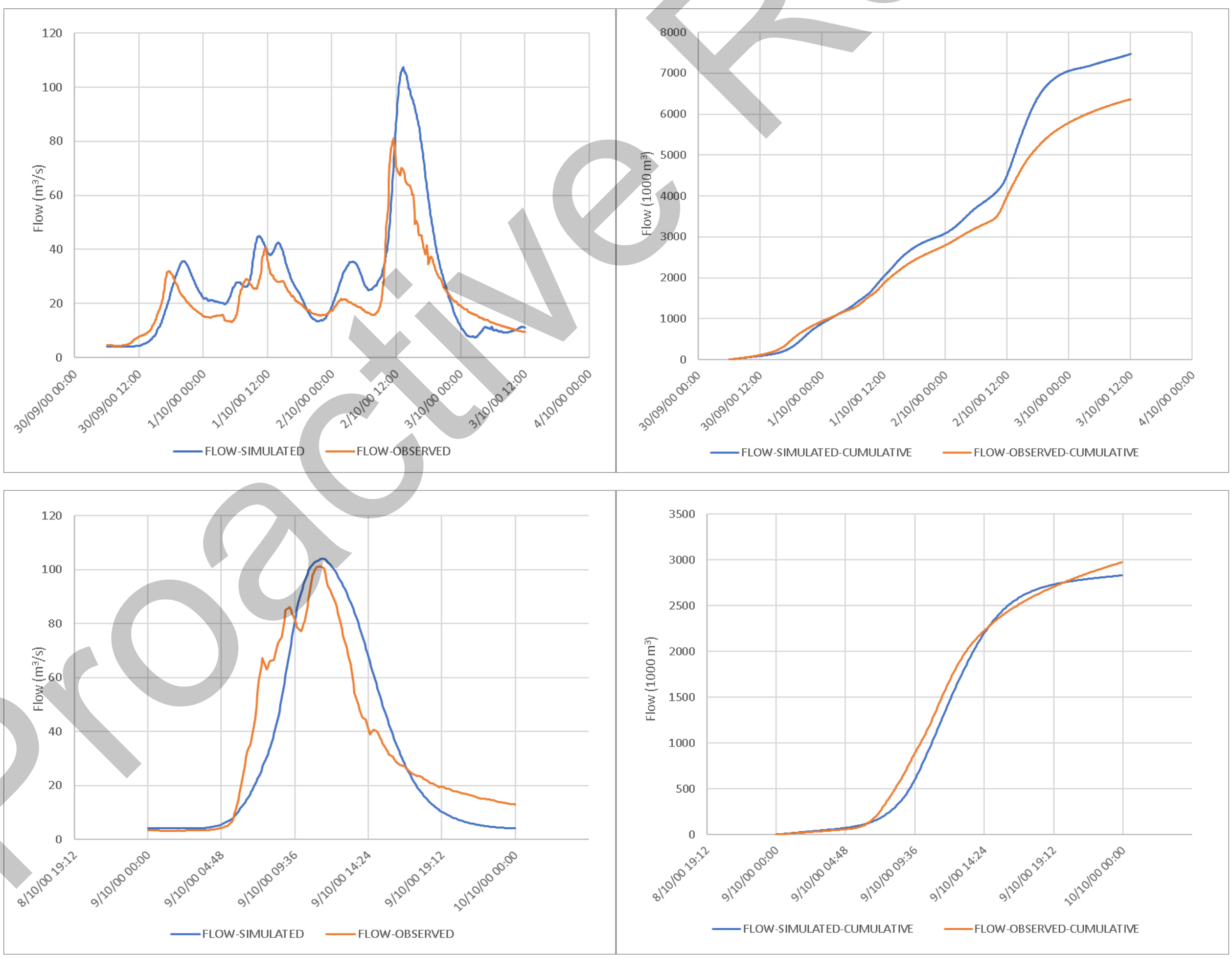
Nine flood events were run with rainfall from the Mangatārere at Valley Hill raingauge. The Valley Hill gauge is located near the centre of the catchment and so the recorded rainfall was input to the model without adjustment for variations in depth or timing across the catchment. A baseflow of 4 m^3/s was added for all events. Results were compared with data from the Mangatārere at Gorge flow gauge.

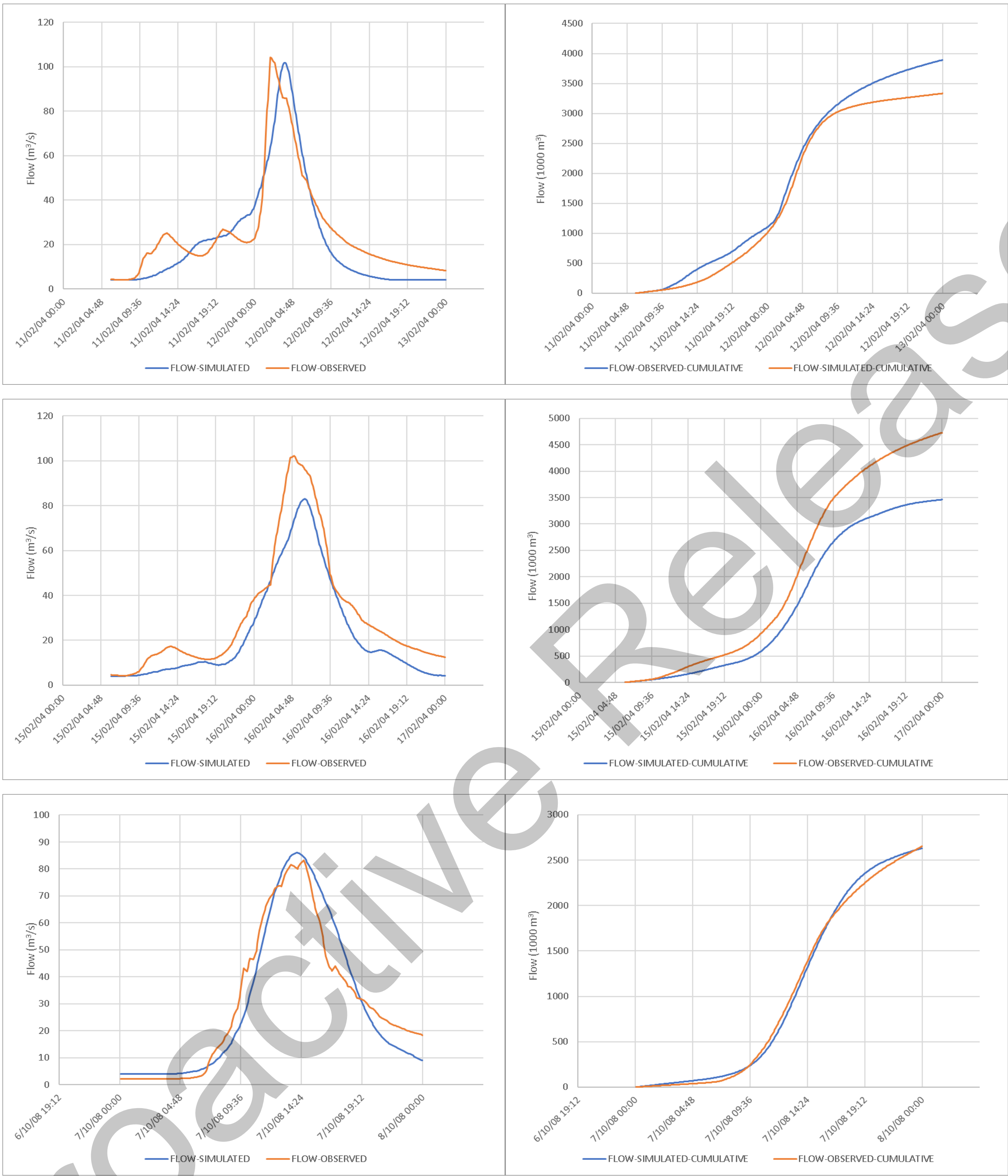
Dates of the calibration events and Nash Sutcliffe Efficiency (NSE) value are listed in Table 6-4 and calibration plots shown in Figure 6-3.

Model parameters were kept the same for all events and are listed in Appendix 2.

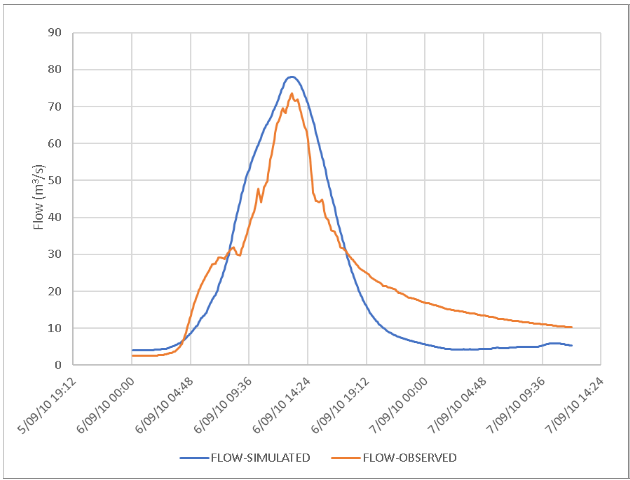
Table 6-4: Calibration flood dates

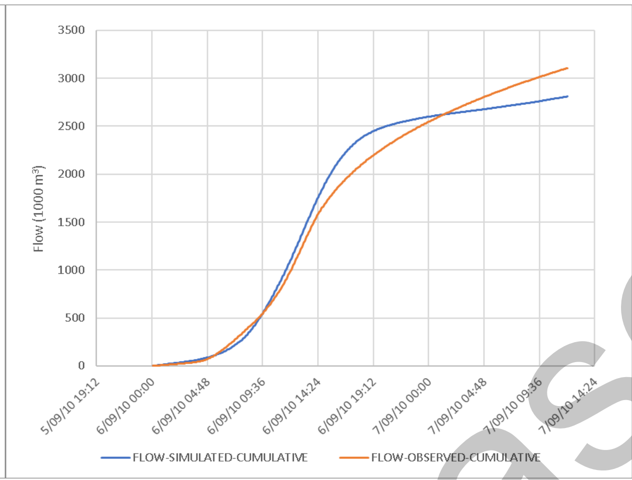
#	Date	Nash Sutcliffe Efficiency
1	Sep-2000	0.332
2	Oct-2000	0.783
3	Feb-2004a	0.798
4	Feb-2004b	0.852
5	Oct-2008	0.917
6	Sep-2010	0.744
7	Mar-2012	0.744
8	Sep-2013	0.521
9	Apr-2014	0.908

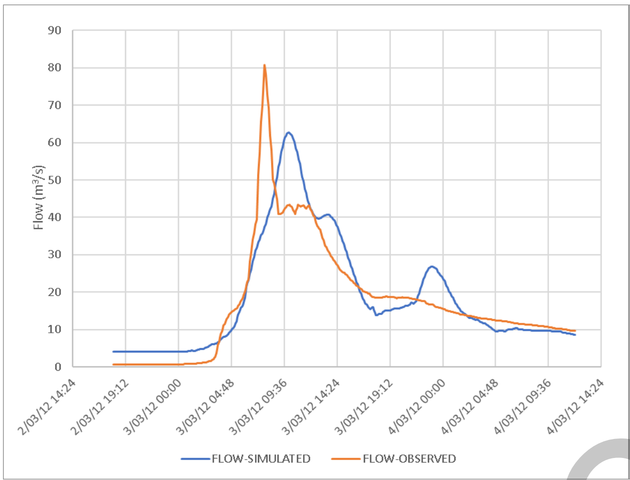


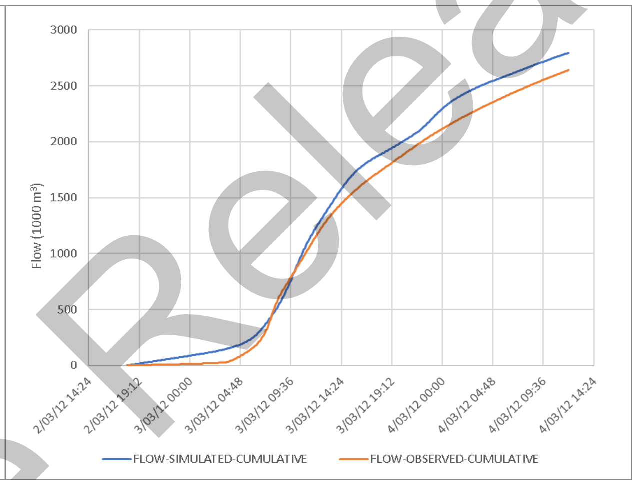


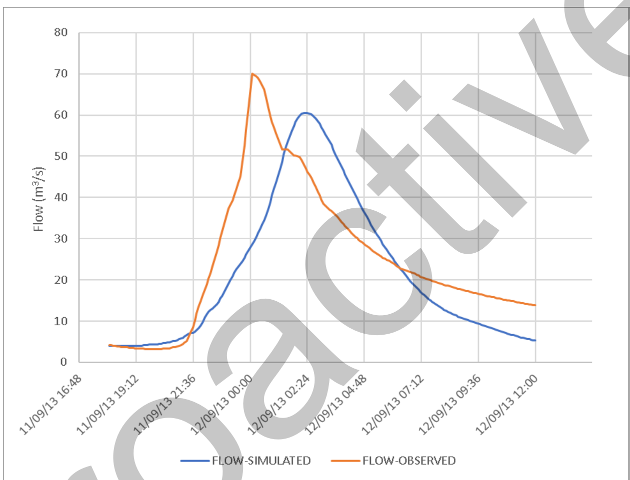
Land River Sea
CONSULTING

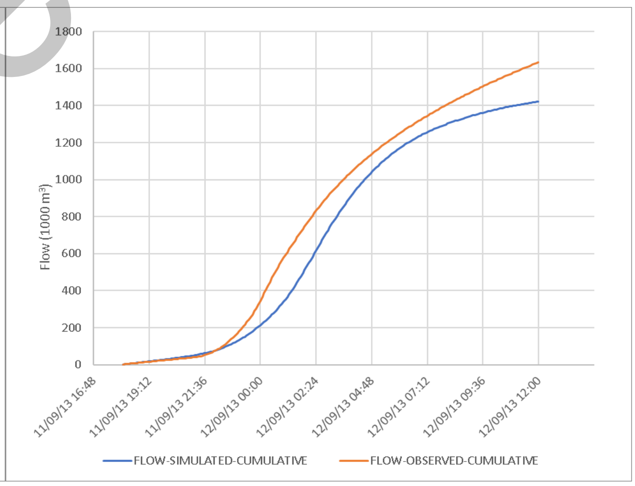

Flow (m³/s)
FLOW-SIMULATED
FLOW-OBSERVED


Flow (1000 m³)
FLOW-SIMULATED-CUMULATIVE
FLOW-OBSERVED-CUMULATIVE


Flow (m³/s)
FLOW-SIMULATED
FLOW-OBSERVED


Flow (1000 m³)
FLOW-SIMULATED-CUMULATIVE
FLOW-OBSERVED-CUMULATIVE


Flow (m³/s)
FLOW-SIMULATED
FLOW-OBSERVED


Flow (1000 m³)
FLOW-SIMULATED-CUMULATIVE
FLOW-OBSERVED-CUMULATIVE

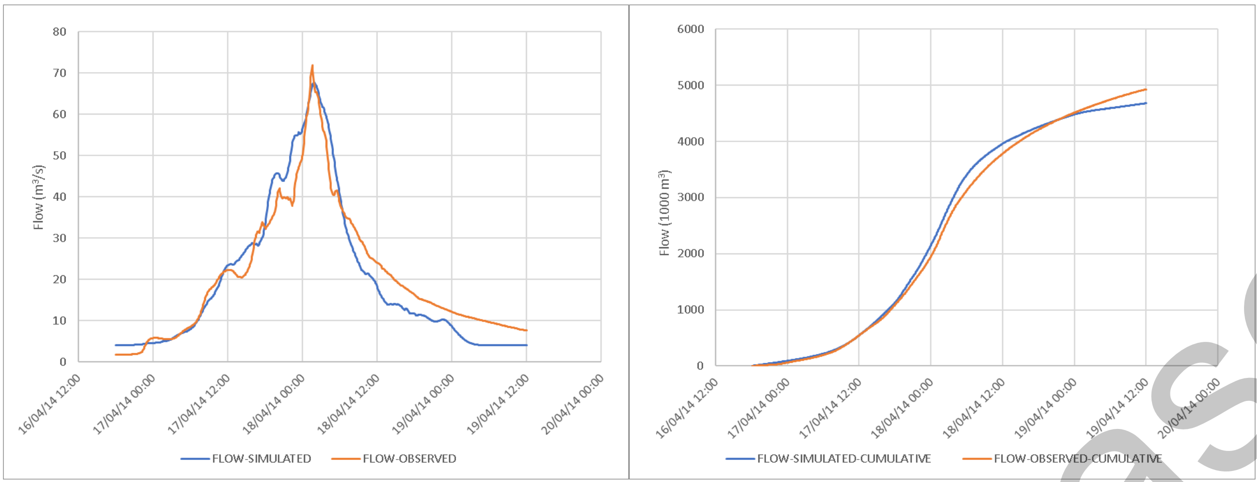


Figure 6-3: Modelled and Observed flow at the Mangatārere at Gorge recorder

6.3. DONALDS AND ABBOTS HEC HMS MODEL

The Donalds and Abbots creek HEC HMS model schematic is shown in Figure 6-4. The model uses the same criteria for selection of basin size, CN, Initial Abstraction, SCS Unit Hydrograph, Lag and Muskingum-Cunge routing parameters as the calibrated Mangatārere model. As with the Mangatārere model, CN values were based on land cover and soil GIS layers. Figure 6-5 shows derived land cover areas for the modelled Donalds and Abbots catchments.

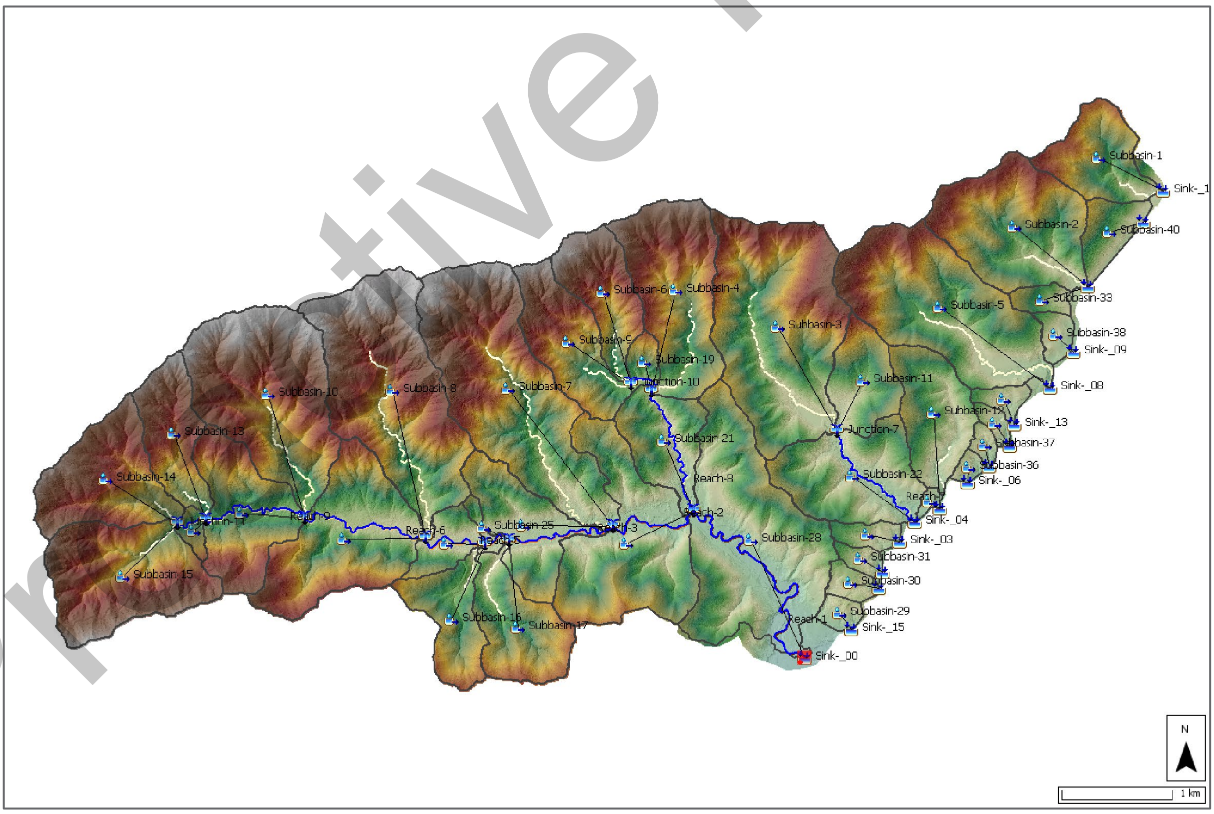


Figure 6-4: Donalds and Abbots HEC HMS Model Schematic

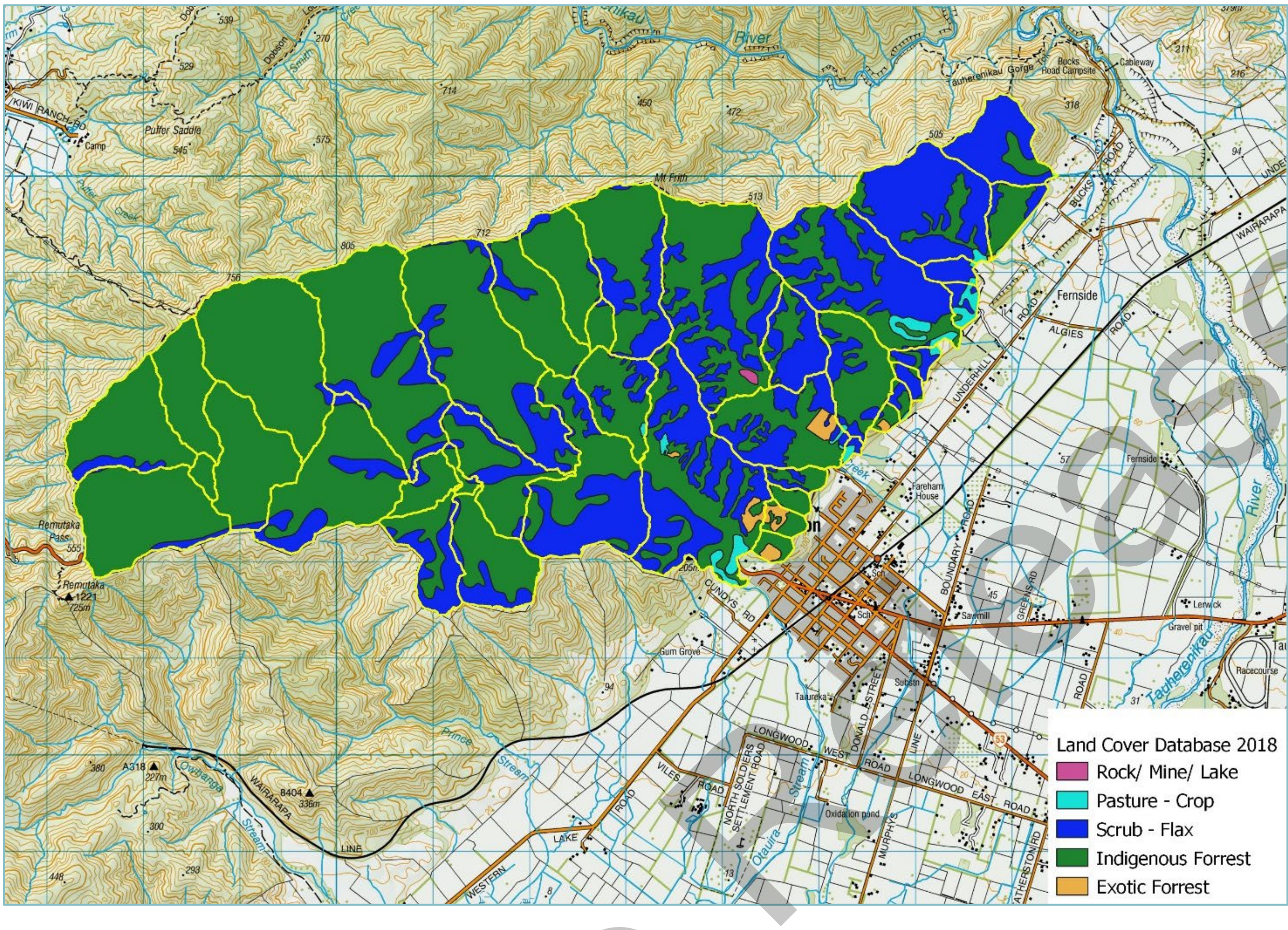


Figure 6-5: Donalds and Abbots creek landcover areas

LENZ Soil Drainage Layer class 3, 4, and 5 occur in the Donalds and Abbots catchments. Of these, Class 3 and 4 make up 94% of the area. CN values were therefore based on a single soil type, (Soil Class C - Sandy clay/ loam from Table 6-1). See Section 6.1.1 for a description of land cover and soil class data.

Based on Mangatārere model calibration results, GIS derived CN values were increased by 5%.

No baseflow was applied to the validation or design simulations. Model parameters were kept the same for the 02 December 2018 validation event and all design simulations.

Manually delineated sub catchments were added to the eastern margin of the model where it intersects the Featherston floodplain. This created a total of 15 outlets from the model which will provide input to the Tuflow hydraulic model boundary.

Model parameters are listed in Appendix 3.

6.4. VALIDATION EVENT 02 DECEMBER 2018

There are no recorded flood flow data within the catchment, but aerial photographs were taken of a flood on 02 December 2018 which shows the extent of flooding near the peak of the event for the area around the Harrison Street East detention structure. A summary of rainfall and estimated flood levels was provided in *Post Event Appraisal Featherston, Wairarapa Flood Event: 2nd December 2018* (GWRC, 2018).

A summary of rainfall depths and AEP for 1, 2 and 3 hour durations recorded during the 2018 event is listed in Table 6-5 and Table 6-6. The 2 and 3-hour totals were the highest on record (1972 to 2023) and have an estimated AEP of 1:85 and 1:54 respectively.

Table 6-5: Waiohine at Gorge/Phelps 02/12/2018 rainfall depths

Duration (hrs)	Recorded Rainfall (mm)	AEP (1:x)
1	41.4	35
2	63.5	85
3	75.1	54

The 2-hour depth at the Featherston NRFA gauge was greater than the Waiohine at Gorge depth and so is estimated to have an AEP of greater than 1:85.

Table 6-6: Featherston at NRFA 02/12/2018 rainfall depths

Duration (hrs)	Recorded Rainfall (mm)
1	46.0
2	63.8
3	67.2

Cumulative rainfall during the event for the six gauges closest to Featherston is plotted in Figure 6-6. It shows rainfall was greatest at the Featherston NRFA gauge and at the Waiohine at Gorge gauge. Rainfall at other gauges was significantly less.

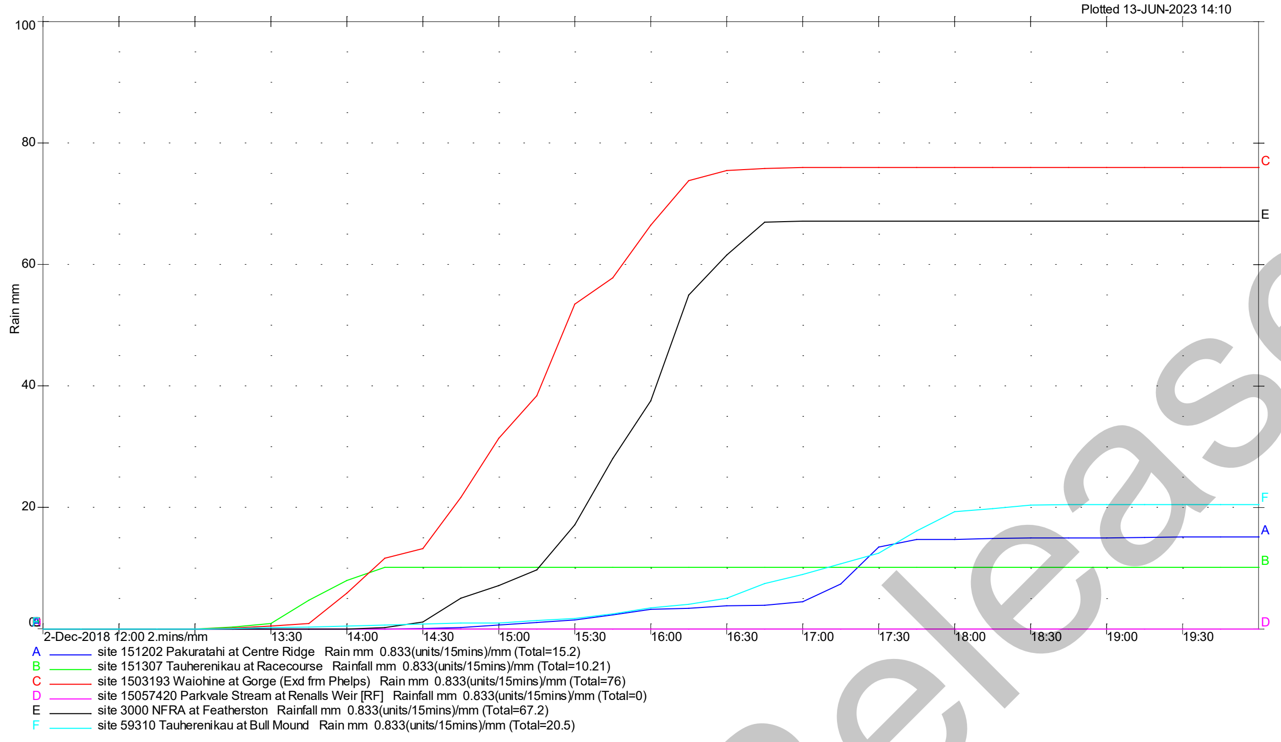


Figure 6-6: Cumulative rainfall

To better understand rainfall spatial distribution during the event, Wellington Rain Radar data was extracted from the Moata website (Mott-MacDonald, 2023) and is shown in Figure 6-7. Total rain radar depths were compared with recorded depths at several gauges and results are listed in Table 6-7.

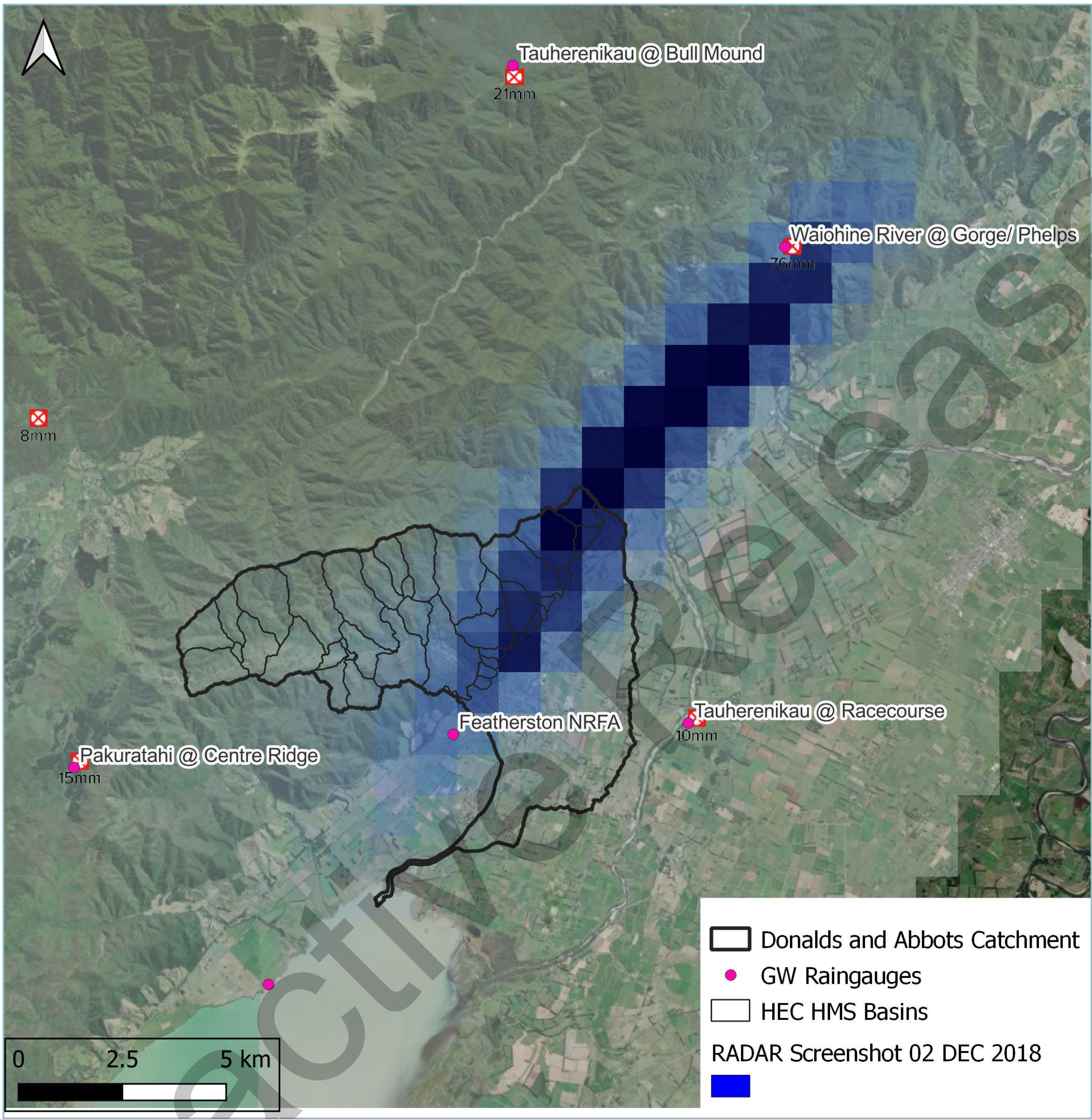


Figure 6-7: 02 December 2018 Wellington rain radar image

Table 6-7: Comparison of gauge and radar depths (02 December 2018)

Gauge	Gauge Depth	Radar Depth (mm)	Difference
Featherston HV AWS	67.2	56.7	-16%
Pakuratahi at Centre Ridge	15.2	14.9	-2%
Tauherenikau at Racecourse	10.2	10.9	7%
Waiohine at Gorge	76.0	80.2	6%
Tauherenikau at Bull Mound	20.5	19.1	-7%
Parkvale Stream at Renalls Weir	0.0	0.1	-

Given the close match of radar and gauge totals and the localised nature of the event it was decided to use radar depths as input to the HEC HMS model to simulate the 2 December 2018 flood.

Radar totals for each 1000m x 1000m grid are shown in Figure 6-8 for the period 14:00 to 18:00 on 02 December 2018. Area weighted depths for each sub catchment were calculated from the gridded radar totals and input to HEC HMS.

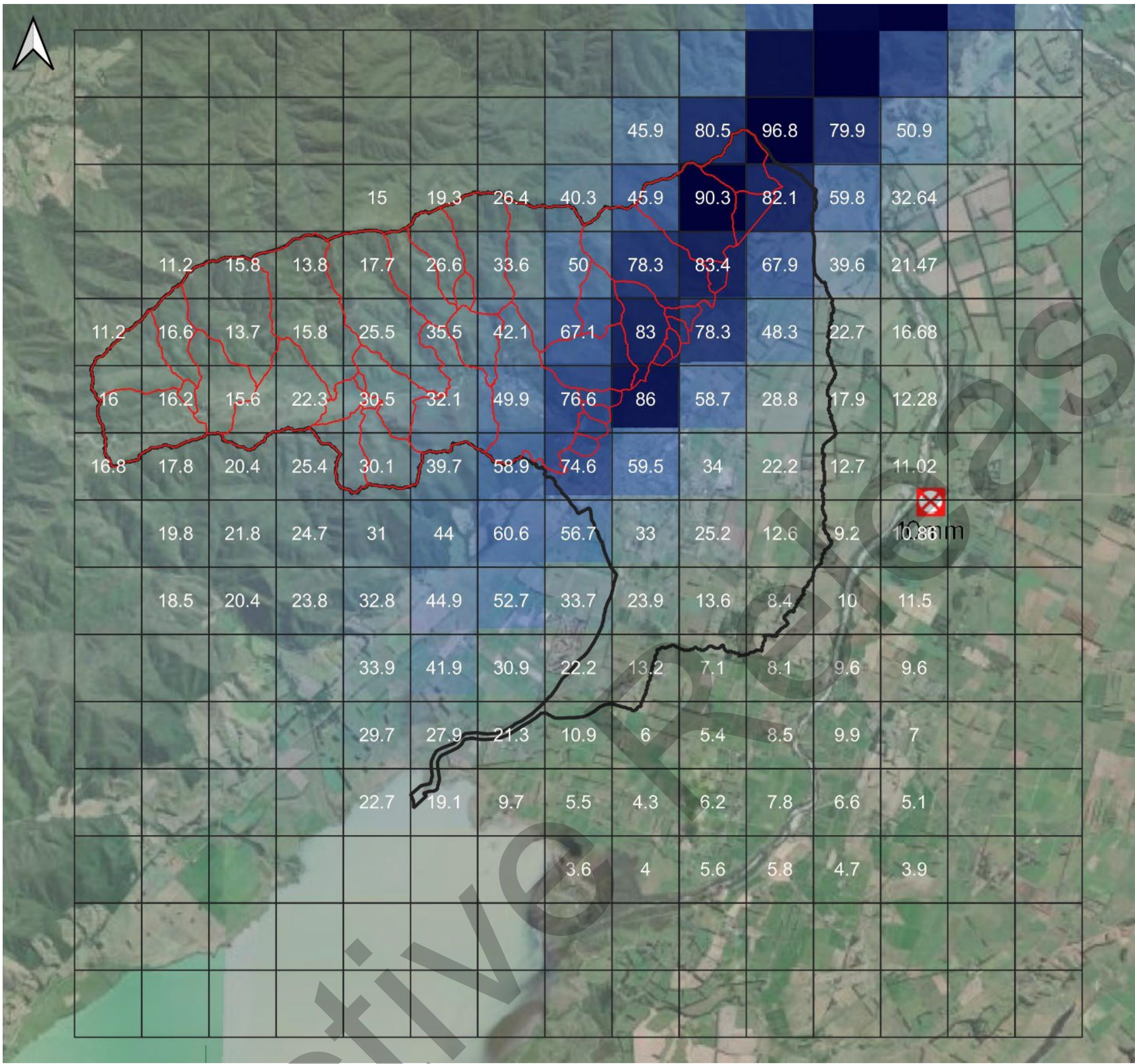


Figure 6-8: 02 Dec 2018 rain radar total depths

Temporal profiles from the Featherston NRFA gauge and the Pakuratahi at Centre Ridge gauge were used for the validation event and are shown in Figure 6-9. They were applied to sub-catchments as indicated in Figure 6-10.

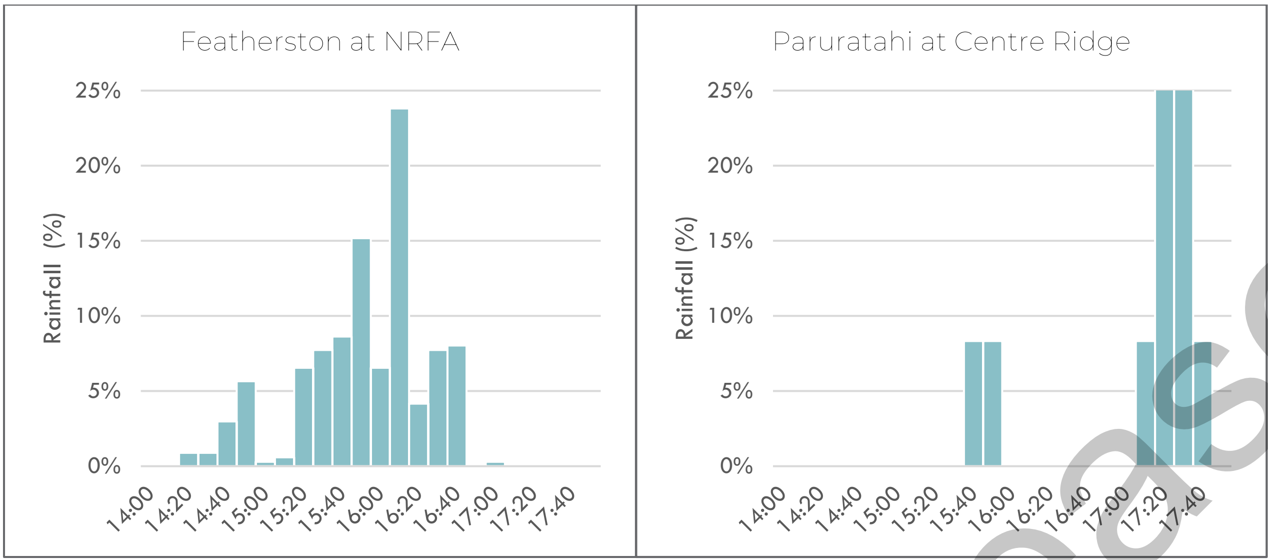


Figure 6-9: 02 Dec 2018 Storm profiles

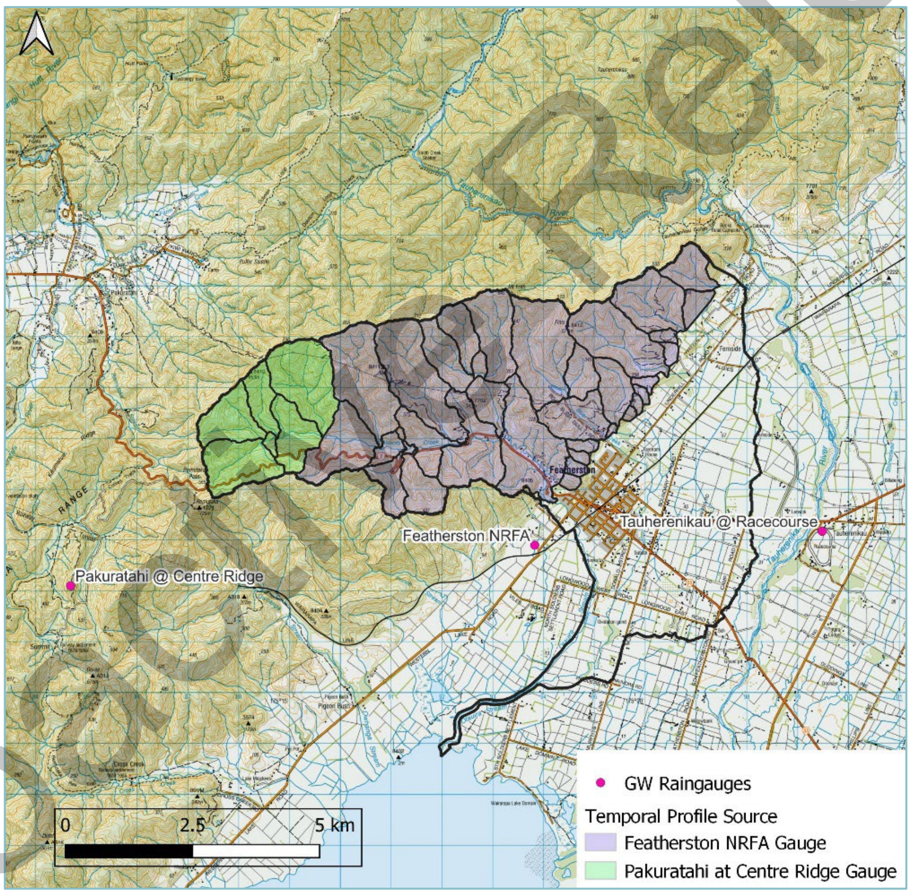


Figure 6-10: 02 December 2018 - assignment of rain gauge temporal profiles to sub-basins

Hydrographs for the 02 December 2018 event simulation were extracted from the HEC HMS model at the 15 locations shown in Figure 6-11 and are plotted in Figure 6-12.

Of the 15 model outlet locations only 5 drain catchments greater than 0.3 km^2. These are Outlets 0, 4, 5, 8, 10 and 12.

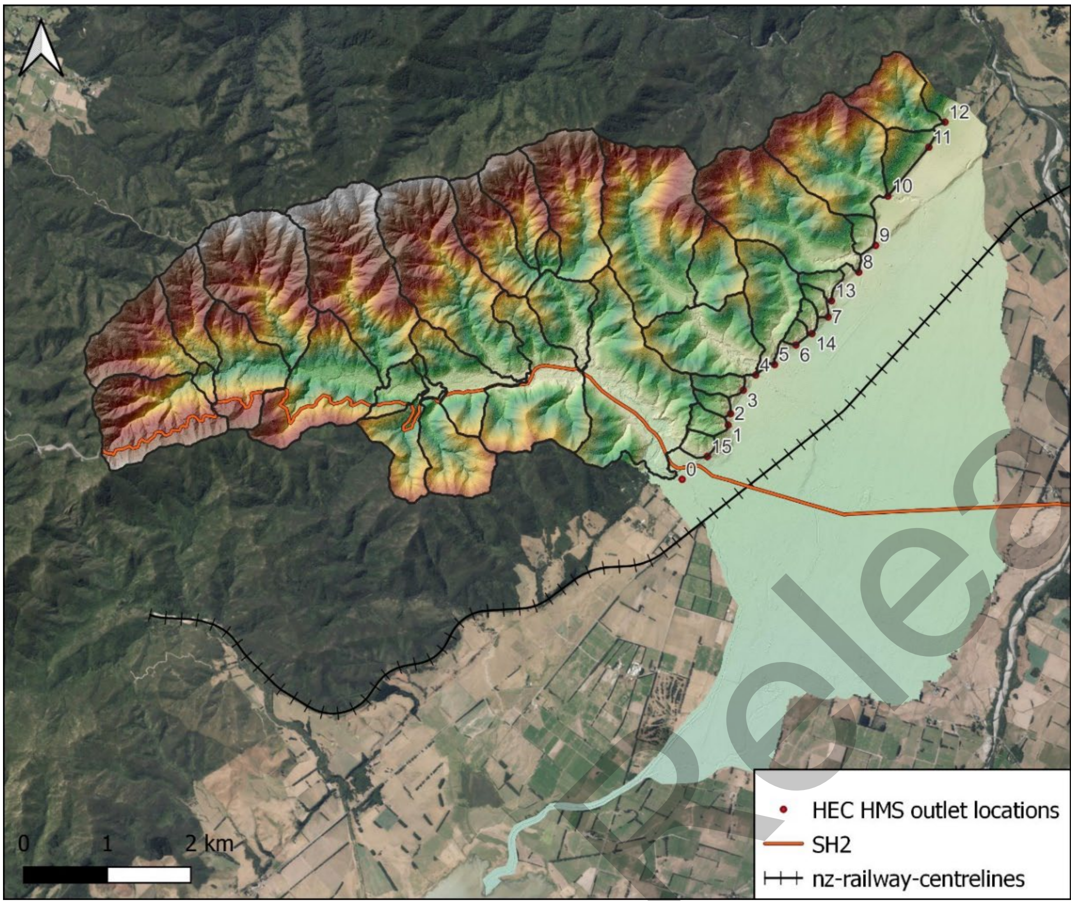


Figure 6-11: HEC HMS outlet locations

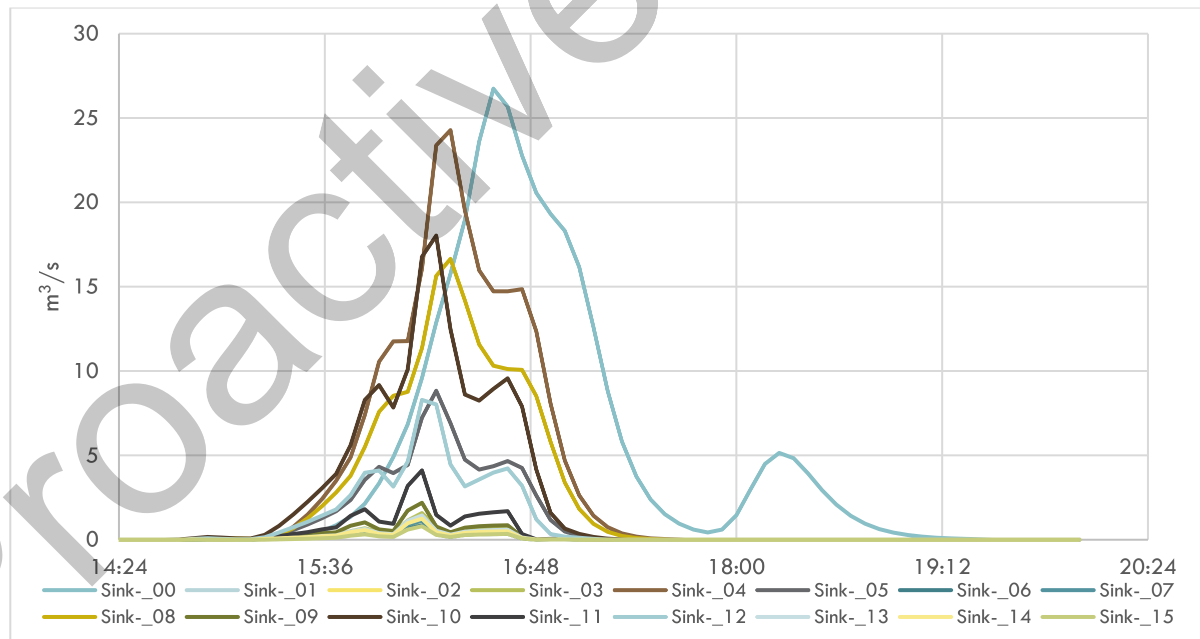


Figure 6-12: 02 December 2018 - modelled hydrographs at 15 outlet locations

HEC HMS modelled hydrographs at the 15 outlet locations were supplied for input to a Tuflow model of the Featherston floodplain. Radar depths shown in Figure 6-8 were also supplied for rain on grid input to the hydraulic model.

6.4.1. HYDRAULIC MODEL VALIDATION

Model results for the December 2018 event were passed to the hydraulic modelling consultant for input to Tuflow. The resulting modelled levels at the Harrison Street East detention structure were compared with photographs of estimated maximum water levels taken after the event. The Tuflow levels were higher than observed levels and so either the HMS model was overpredicting runoff or rainfall depths were overestimated for the 02 December 2018 event. (This assumes Tuflow simulations accurately represent hydraulic flow across the floodplain).

Accordingly, further modelling was undertaken to reduce modelled runoff and so provide a closer match with observed levels at the detention structure.

Reduced CN Values

Donalds and Abbots Creek HEC HMS CN values were reduced by 10% and resulting hydrographs input to the Tuflow hydraulic model. A lower CN value increases losses in the model which reduces runoff. This produced a closer match between modelled levels and observed levels at the Harrison Street East detention structure for the 02 December 2018 event. (See separate report for Tuflow modelling details).

Mangatārere HEC HMS CN values were also reduced by 10% which, as expected, produced modelled hydrographs less than observed flows and an inferior calibration.

Donalds and Abbots Creek HEC HMS design model CN values were reduced by 10% which reduced peak flows by between 28% and 35% at modelled outlets and gave a worse match with peaks estimated from other methods. It also increased design flood critical durations.

It was concluded from these simulations that the CN values adopted for calibration and design are reasonable and a more likely reason for the apparent overestimate of flows at the detention structure is overestimated rain radar data.

Reduced 02 December 2018 Rainfall

Donalds and Abbots HEC HMS modelled rainfall depths for the 02 December 2018 event were reduced by 13% to match results of reducing CN values by 10%. Tuflow simulations based on these outputs gave a closer match to observed levels at the Harrison Street East detention structure.

Conclusion

It was concluded that based on Mangatārere model calibration results and Donalds and Abbots Creek design model results, HEC HMS model parameters give acceptable results and reducing CN values to achieve a closer match with Harrison Street East detention structure levels for the 02 December 2018 event is not justified.

Rainfall based on radar data could be overestimated by around 13%, resulting in higher than observed water levels at the detention structure.

It was therefore decided to retain the calibration parameters described in *Appendix 3: Mangatārere Calibration Model Parameters* and *Appendix 4: Donalds and Abbots Validation & Design Model Parameters* and reduce rain radar vales by 13% for the 02 December 2018 validation event.

7. DESIGN EVENTS

As discussed in Section 5.3, HIRDS design rainfall adequately represents the spatial variation across the Donalds and Abbots catchments. Design rainfall IDF tables were downloaded from NIWA's HIRDS web tool for the centroid of each sub catchment for all design events.

7.1. AREAL REDUCTION

Areal reduction factors were applied based on sub-catchment area and Equation 6 from *High Intensity Rainfall Design System v4*, (Carey-Smith, T, et al, 2018).

Equation 6: $ARF=1-cA^{a}D^{-d}$

Where:

c=0.024
d=0.53
a=0.41

7.2. TEMPORAL PROFILE

Temporal profiles were also from HIRDS v4 using "East of North Island" parameters. An example of the storm profile is shown in Figure 7-1.

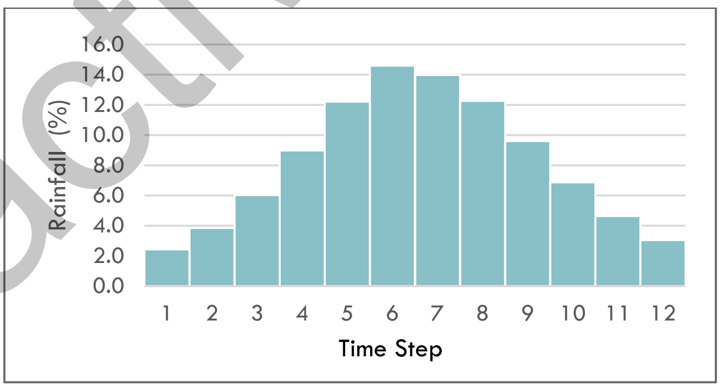


Figure 7-1: HIRDS temporal profile

7.3. DESIGN EVENT SCENARIOS

Design event scenarios are listed in Table 7-1. At least six rainfall durations were run for the current flood scenarios to determine the largest magnitude peak. Critical duration was also tested for climate change scenarios and the 1:1000 AEP flood to determine peak flow.

Table 7-1: Design Flood Scenarios

Current flood frequency	AEP	Climate Change Scenario (RCP)
	39%	n/a
	20%	n/a
	10%	n/a
	5%	n/a
	2%	n/a
	1%	n/a
Future flood frequency (CC)		
	39%	6.0 (2101-2120)
	20%	6.0 (2101-2120)
	10%	6.0 (2101-2120)
	5%	6.0 (2101-2120)
	2%	6.0 (2101-2120)
	1%	6.0 (2101-2120)
Sensitivity		
	1%	2.6 (2101-2120)
	1%	4.5 (2101-2120)
	1%	8.5 (2101-2120)
Dam Breach	0.1%	n/a

7.4. DESIGN FLOOD MODELLING RESULTS

Design flood results are listed in the tables below. The critical rainfall duration for 1:100, 1:50, 1:20 and 1:10 AEP storms was 4 hours for all catchments. The critical duration for 1:2 and 1:5 AEP storms was generally greater than 4 hours. Peak flow and critical duration are listed in Table 7-2 and Table 7-3.

Table 7-2: HEC HMS results - current flood frequency

AEP	Outlet 0 Abbots Crk - (m³/s)	Outlet 4 Boar Creek (m³/s)	Outlet 5 (m³/s)	Outlet 8 (m³/s)	Outlet 10 (m³/s)
39%	26 (7h)	3.9 (6h)	0.6 (6h)	1.9 (6h)	1.7 (6h)
20%	41 (6h)	6.2 (6h)	1.0 (4h)	3.0 (5h)	2.7 (4h)
10%	53 (4h	8.2 (4h)	1.3 (4h)	3.9 (4h)	3.6 (4h)
5%	67 (4h)	10.6 (4h)	1.7 (4h)	5.1 (4h)	4.6 (4h)
2%	90 (4h)	14.1 (4h)	2.3 (4h)	6.8 (4h)	6.1 (4h)
1%	108 (4h)	17.1 (4h)	2.8 (4h)	8.2 (4h)	7.4 (4h)

Table 7-3: HEC HMS results future flood frequency (RCP 6.0)

AEP	Outlet 0 Abbots Crk - (m³/s)	Outlet 4 Boar Creek (m³/s)	Outlet 5 (m³/s)	Outlet 8 (m³/s)	Outlet 10 (m³/s)
39%	36 (6h)	5.3 (5h)	0.8 (4h)	2.6 (4h)	2..3 (4h)
20%	56 (5h)	8.6 (4h)	1.4 (4h)	4.1 (4h)	3.7 (4h)
10%	73 (4h)	11.5 (4h)	1.9 (4h)	5.5 (4h)	5.0 (4h)
5%	93 (4h)	14.6 (4h)	2.4 (4h)	7.0 (4h)	6.3 (4h)
2%	122 (4h)	19.3 (4h)	3.2 (4h)	9.2 (4h)	8.3 (4h)
1%	146 (4h)	23.2 (4h)	3.9 (4h)	11.1 (4h)	9.9 (4h)

7.5. COMPARISON OF MODELLED FLOOD PEAKS WITH OTHER METHODS

Modelled peaks for catchment outlets greater than 0.7 km^2 were compared with results from alternative methods.

Abbots Creek has a catchment area of 21.2 km^2 at Outlet 0 (shown in Figure 6-11). Modelled runoff was compared with results from the method described in *Flood Frequency in New Zealand*, (McKerchar, et al., 1989). Runoff was also compared with results from NIWA's NZ River Flood Statistics web tool (NIWA, 2018) and scaled flood frequency analysis from Mangatārere at Gorge recorded data.

Results of the comparison are listed in Table 7-4 and Figure 7-2. Modelled results fall within the spread of alternative estimates for floods greater than the 1:20 AEP event but are lower than other methods for 1:2, 1:5 and 1:10 AEP floods.

Table 7-4: Peak flow comparison (Outlet 0 - Abbots Creek)

AEP %	HEC HMS Model m³/s	1998 Regional FFA m³/s	2018 Regional FFA m³/s	Scaled from Mangatārere at Gorge m³/s
1%	108	122	85	109
2%	90	110	76	98
5%	67	93	64	82
10%	53	80	55	71
20%	40	66	46	58
39%	24	46	n/a	38

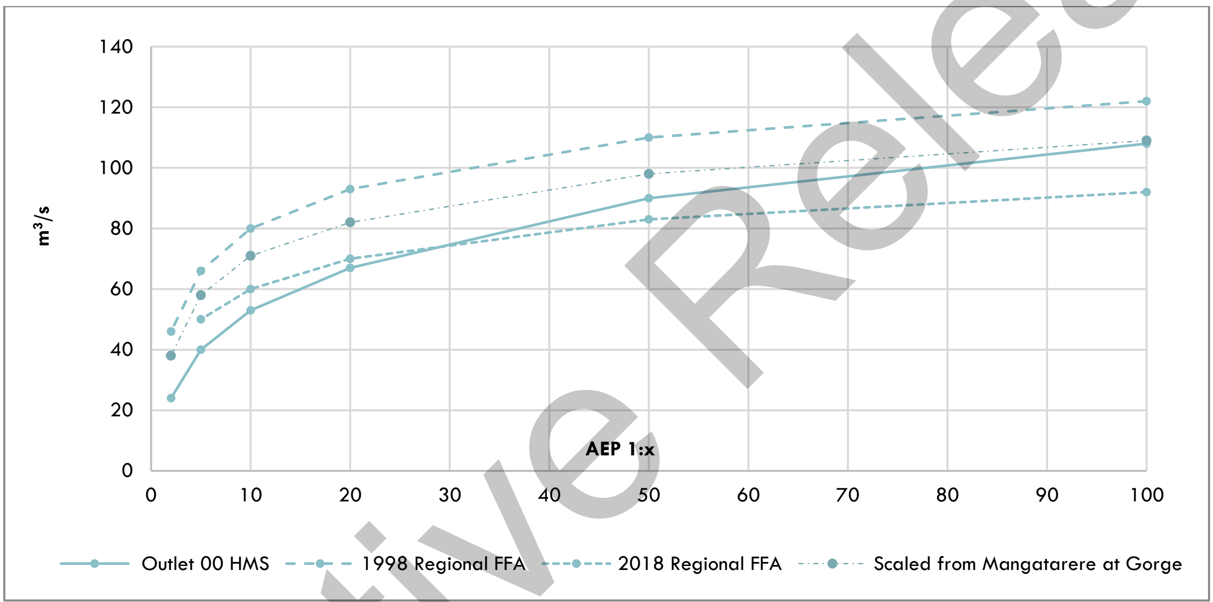


Figure 7-2: HEC HMS results v Regional FFA (Outlet 00 Abbots Crk)

Results for Outlets 4, 5, 8 and 10 were compared with results from the Rational Method and NIWA's NZ River Statistics web tool. The comparison is shown in the tables and figures below. In general, modelled peaks were less than alternate methods for frequent storms and closer to other methods for the 1:100 AEP event. Attempts were made to increase the 1:2, 1:5 and 1:10 AEP modelled flood peaks to align better with other methods, but these parameter adjustments significantly increased more extreme flood peaks such as the 1:00 AEP. It was therefore decided to retain the original Mangatārere calibration parameters which provide results closer to other methods for more extreme floods.

Table 7-5: 1:100 AEP flow comparison (Outlet 04, 05, 08 & 10)

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	2018 Regional FFA m^3/s	Difference HMS v Regional FFA	Rational Method m^3/s	Difference HMS v Rational
4	3.6	17.1	11.1	35%	16.6	3%
5	0.7	2.8	2.1	26%	3.2	-14%
8	1.7	8.2	6.2	25%	8.0	3%
10	1.4	7.4	4.7	37%	6.6	10%

Table 7-6: 1:50 AEP peak flow comparison (Outlet 04, 05, 08 & 10)

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	2018 Regional FFA m^3/s	Difference HMS v Regional FFA	Rational Method m^3/s	Difference HMS v Rational
4	3.6	14.2	9.9	30%	14.8	-4%
5	0.7	2.3	1.9	20%	2.9	-23%
8	1.7	6.8	5.5	19%	7.1	-4%
10	1.4	6.2	4.2	32%	5.9	4%

Table 7-7: 1:20 AEP peak flow comparison (Outlet 04, 05, 08 & 10)

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	2018 Regional FFA m^3/s	Difference HMS v Regional FFA	Rational Method m^3/s	Difference HMS v Rational
4	3.6	10.6	8.4	20%	12.6	-19%
5	0.7	1.7	1.6	7%	2.4	-42%
8	1.7	5.1	4.7	8%	6.0	-19%
10	1.4	4.6	3.6	23%	5.0	-9%

Table 7-8: 1:10 AEP peak flow comparison (Outlet 04, 05, 08 & 10)

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	2018 Regional FFA m^3/s	Difference HMS v Regional FFA	Rational Method m^3/s	Difference HMS v Rational
4	3.6	8.2	7.2	12%	10.9	-33%
5	0.7	1.3	1.4	-4%	2.1	-63%
8	1.7	3.9	4.0	-3%	5.2	-34%
10	1.4	3.6	3.1	15%	4.4	-21%

Table 7-9: 1:5 AEP peak flow comparison (Outlet 04, 05, 08 & 10)

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	2018 Regional FFA m^3/s	Difference HMS v Regional FFA	Rational Method m^3/s	Difference HMS v Rational
4	3.6	6.2	6.0	3%	9.4	-53%
5	0.7	1.0	1.1	-16%	1.8	-88%
8	1.7	3.0	3.3	-13%	4.5	-53%
10	1.4	2.7	2.5	6%	3.8	-39%

Table 7-10: 1:2 AEP peak flow comparison (Outlet 04, 05, 08 & 10)

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	2018 Regional FFA m^3/s	Difference HMS v Regional FFA	Rational Method m^3/s	Difference HMS v Rational
4	3.6	3.9	4.5	-14%	5.5	-42%
5	0.7	0.6	0.8	-39%	1.4	-139%
8	1.7	1.9	2.5	-30%	3.5	-86%
10	1.4	1.7	1.9	-11%	3.2	-86%

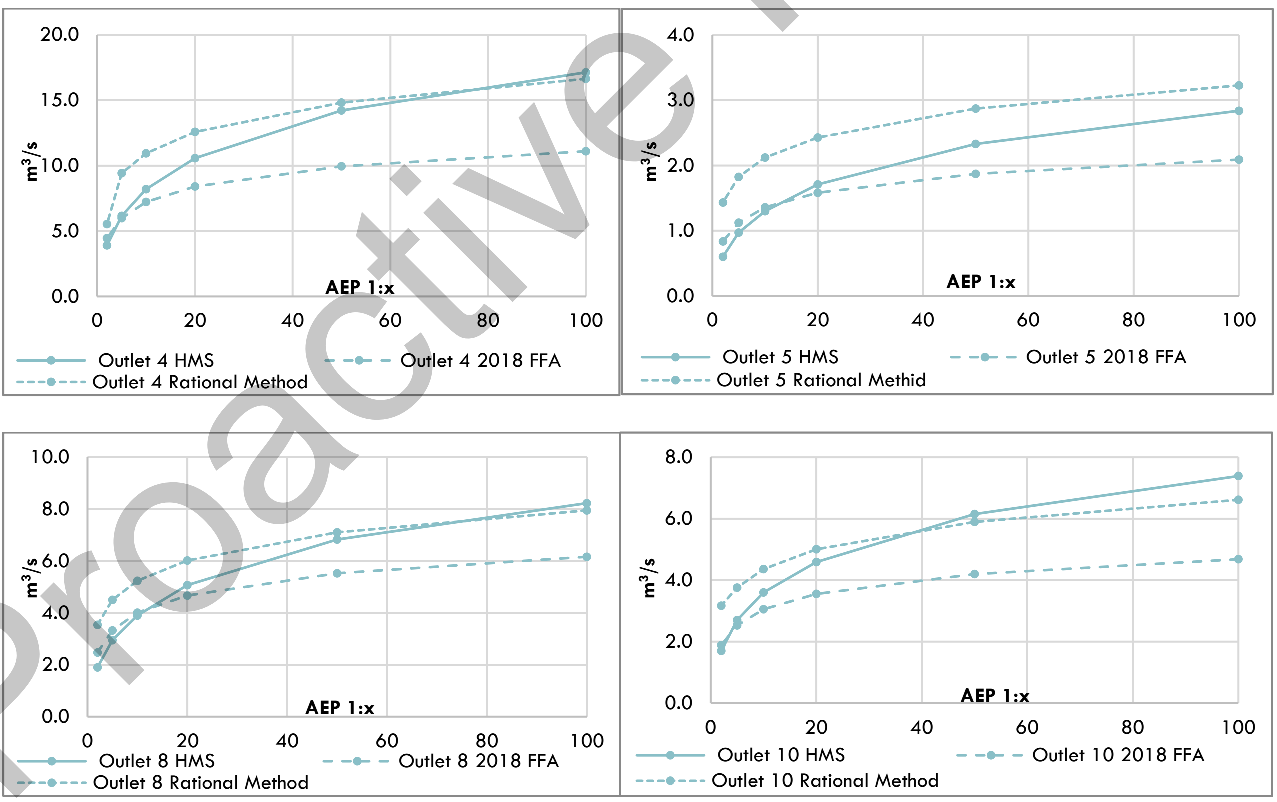


Figure 7-3: Model, 2018 Regional FFA & Rational Method comparison (Outlet 04, 05, 08 & 10)

The HEC HMS model results were close to, or slightly less than NIWA's 2018 FFA tool for more frequent AEP's but significantly higher than the NIWA 2018 tool for more extreme floods. For more extreme events, HEC HMS results were closer to Rational Method results. This is a similar trend to the comparison of results for the much larger Abbots Creek outlet shown in Figure 7-2 where modelled peaks were less than alternate methods for more frequent AEP's. As described above for the comparison of results for Abbots Creek it was decided to retain the model parameters that produced flood peaks that better matched more extreme floods such as the 1:100 AEP event.

7.6. 1:1000 AEP DAM BREACH FLOOD

1:1000 AEP rainfall depths were estimated by two methods. Directly from HIRDS and by interpolating between HIRDS 1:50 and 1:100 AEP depths and the PMP.

Method 1: The frequency equation provided with HIRDS was used to estimate 1:1000 AEP depths. An example of results for catchment 10, for a 4 hour event is shown in Figure 7-4.

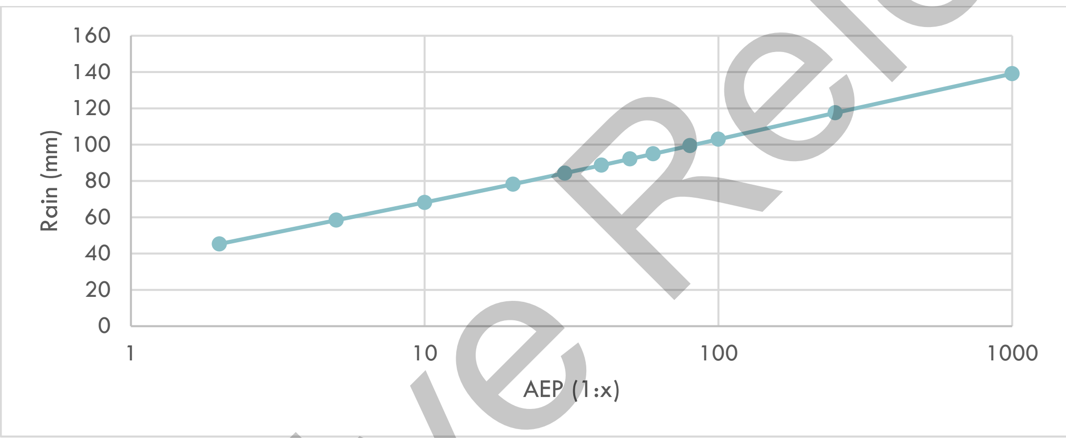


Figure 7-4: HIRDS 4 hour depths for sub-basin 10

Method 2: Table 13.2 of *Australian Rainfall and Runoff* (Pilgrim, 1998) provides an interpolation method and assigns an AEP of the Probable Maximum Event. In this case, 1 in 1,000,000 from Australia's (southern) Zone A.

A PMP of 316 mm (6:1 hour ratio of 2.5) was estimated from methodology described in *Probable Maximum Precipitation in New Zealand for Small Areas and Short Durations* (Tomlinson, et al., 1993). Interpolation results are and plotted in Figure 7-5.

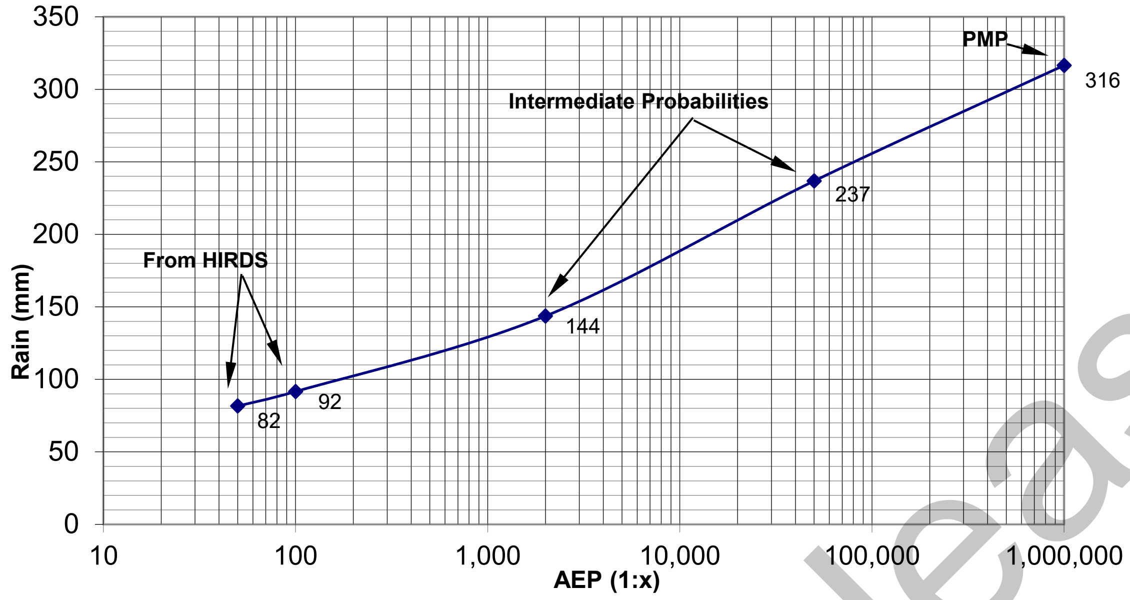


Figure 7-5: Interpolation from 50-yr and 100-yr 4-hour HIRDS depths to the 4-hour PMP

The two methods gave values of 125mm, directly from HIRDS, and 129mm from the interpolation method for the 1:1000 AEP 4 hour rainfall depth for modelled sub- basin 3. The results were sufficiently close to adopt the estimated 1:1000 AEP depths directly from HIRDS for all sub-catchments.

HIRDS 3, 4, 5 and 6 hour 1:1000 AEP rainfall were simulated, with the 4 hour duration creating the highest peak for all model outlets.

HEC HMS runoff for Outlet 0, (Abbots Creek) is shown in Figure 7-1.

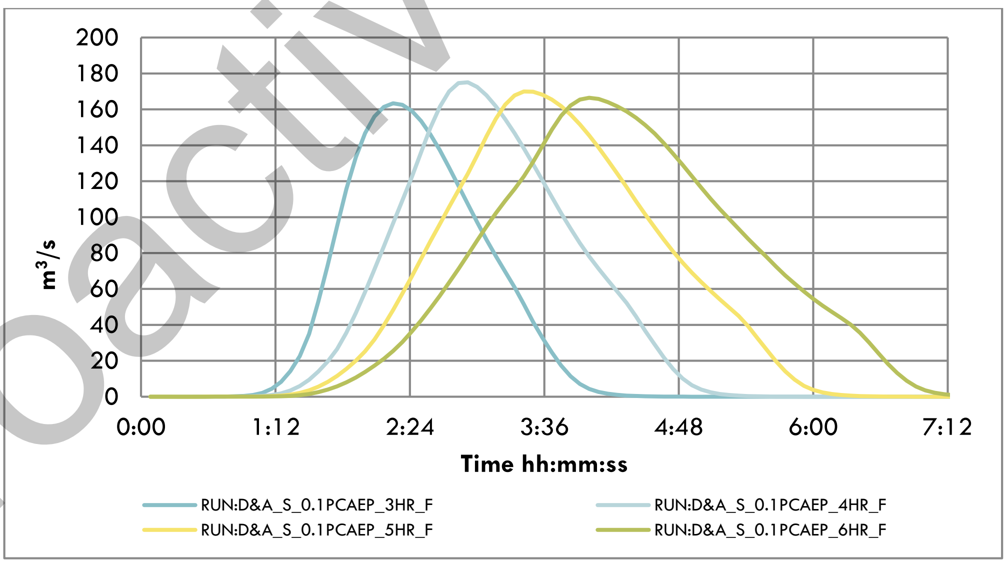


Figure 7-6: 1:1000 AEP modelled hydrographs (Outlet 0)

Table 7-11: 1:1000 AEP dam breach model results

HEC HMS Outlet Location	Area km^2	HEC HMS Model m^3/s	1989 Regional FFA m^3/s	2018 Regional FFA m^3/s	Mangatārere at Gorge Scaled FFA m^3/s
0	21.2	175 (4h)	164	124	147
4	3.6	28 (4h)		15	37
5	0.7	5 (4h)		3	10
8	1.7	14 (4h)		8	20
10	1.4	12 (4h)		6	17

8. SENSITIVITY ANALYSIS

The parameters described in the sections below were varied to test the sensitivity of model results to changes in selected model variables.

Parameters tested are listed in Table 8-1 along with comments on the impact of the changes.

Table 8-1: Summary of Sensitivity Assessment

Model Parameter	Values Tested	Comment
Rainfall Duration	1, 2, 3, 4, 5, 6hr for 1:100 AEP and 1 to 9 hr for 1:2 AEP	Critical rainfall duration was longer for the 1:2 AEP flood compared with the 1:100 AEP flood. After 4 hours, peaks do not change much but of course the hydrograph volume increases. Duration will be a critical variable in hydraulic modelling of the detention structure.
Temporal Profile	HIRDS East of North Island, West of North Island and North of South Island	The West of NI profile produced a lower peak than the adopted ENI profile which produced a similar peak to the NSI profile.
CN	+10% and – 10%	Changes to the CN and associated IA make significant changes to hydrograph peak and volume.
IA	IA of 0 and with a storage coefficient of 0.1.	Adjusting IA on its own does not significantly change hydrograph peak and volume
SCS Unit Hydrograph Peak Rate Factor	PRF of 100, 484 and 500	Dropping the PRF from the adopted 500 to 100 significantly attenuates the hydrograph.
SCS Unit Hydrograph Lag	0.2 x Tc, 0.6 c Tc, 1.0 x Tc	Adjustments to the storage coefficient within the SCS Transform Method did not significantly affect the output hydrograph.
Channel Routing Roughness	*n* of 0.025, 0.035 and 0.10	A small adjustment to the adopted roughness value (0.035 to 0.025) did not significantly affect the output hydrograph. Increasing *n* to 0.1 did produce a noticeable increase in hydrograph lag.

8.1. RAINFALL DURATION

Rainfall duration was varied to determine the duration that caused the highest peak for all outlets. It was found that for an AEP of 1:20 and above the critical duration was 4 hours for all outlets. For AEP's of 1:20 and below the critical duration was often greater than 4 hours. Critical durations for all model results are indicated in Table 7-2, Table 7-3 and Table 7-11.

The figures below show runoff hydrographs for various rainfall durations for the five largest model outlets.

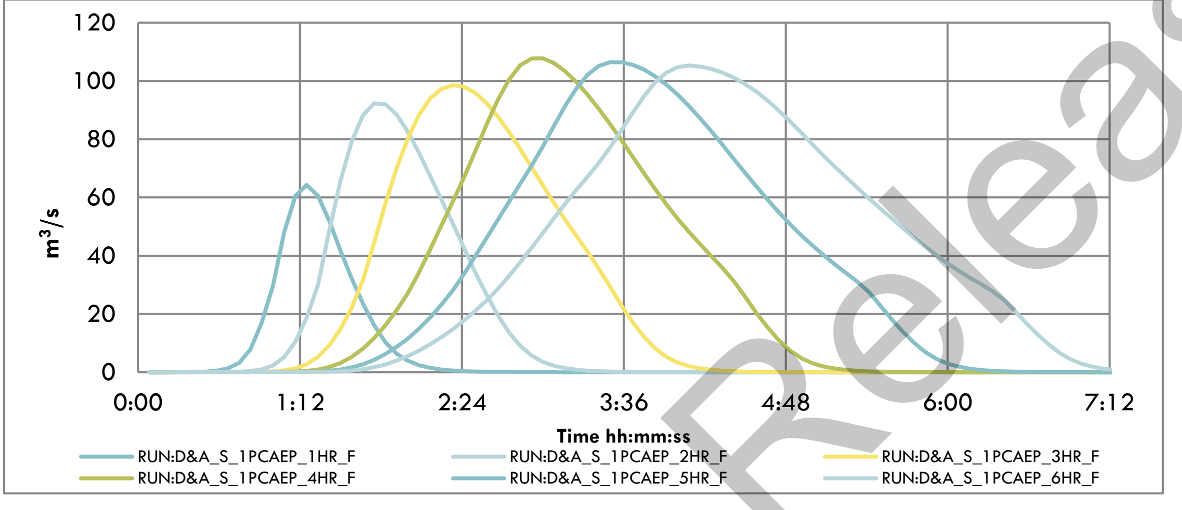


Figure 8-1: Outlet 00 (Abbots Crk) 1:100 AEP

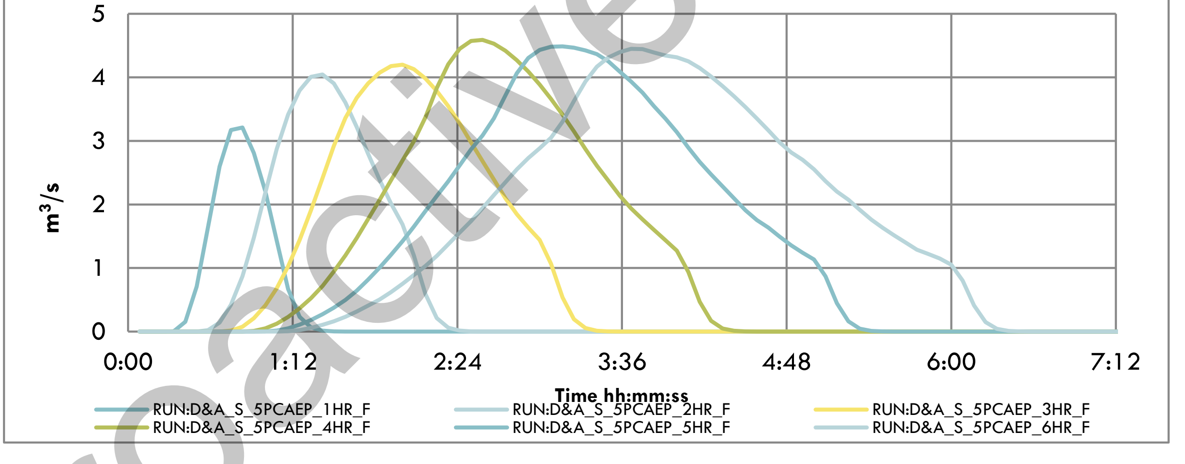


Figure 8-2: Outlet 00 (Abbots Crk) 1:20 AEP

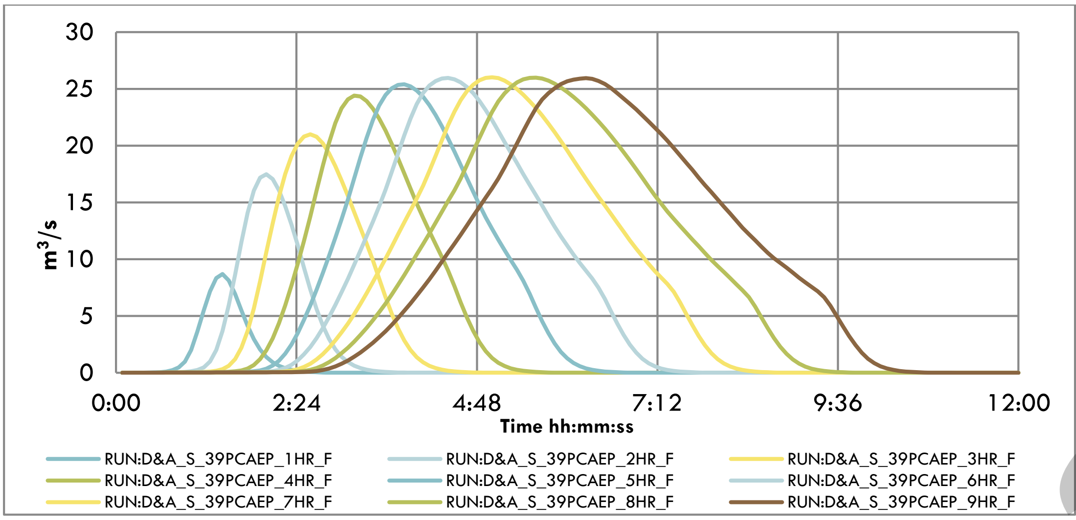


Figure 8-3: Outlet 00 (Abbots Crk) 1:2 AEP

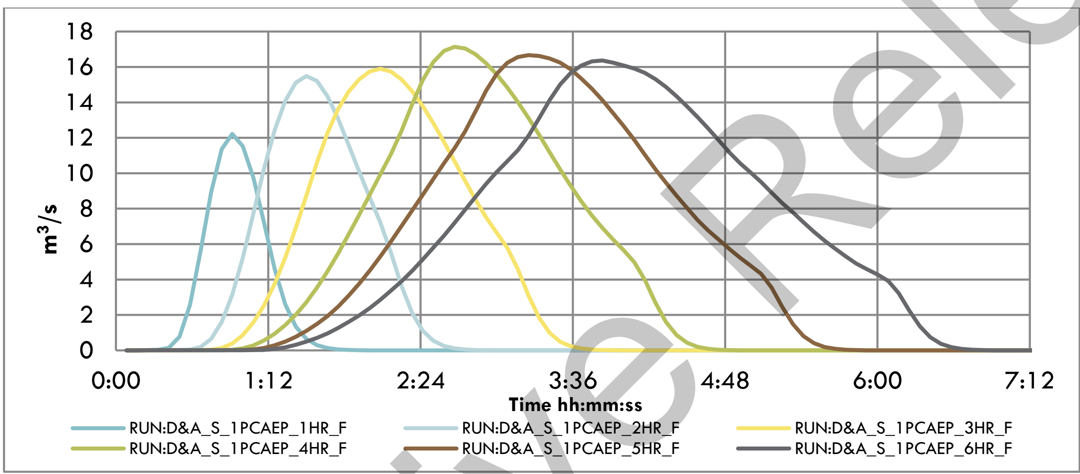


Figure 8-4: Outlet 4 (Boar Creek) 1:100 AEP

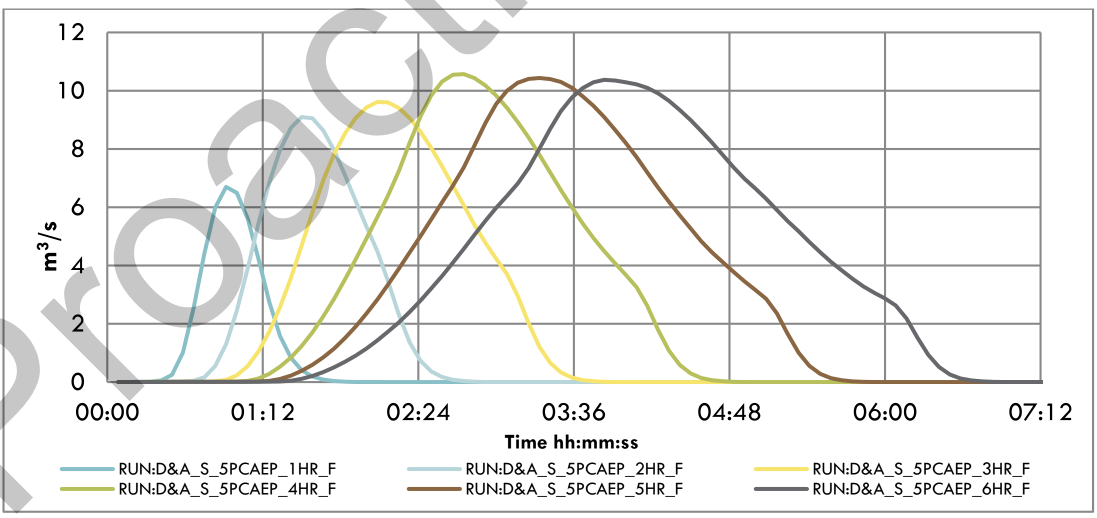


Figure 8-5: Outlet 4 (Boar Creek) 1:20 AEP

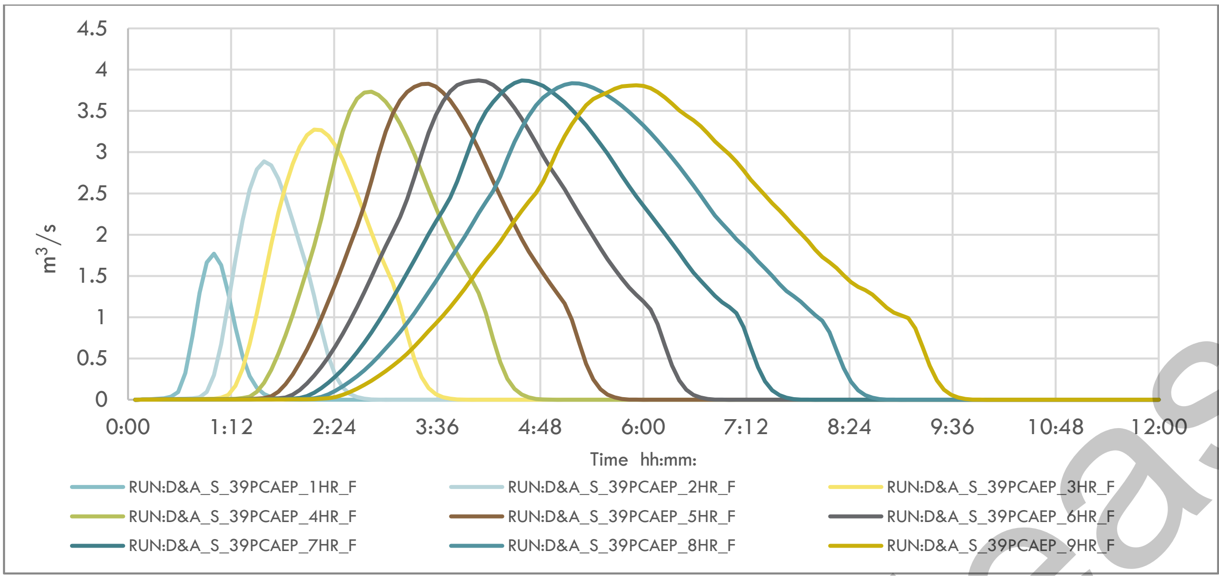


Figure 8-6: Outlet 4 (Boar Creek) 1:2 AEP

8.2. RAINFALL TEMPORAL PROFILE

As described in Section 5.3, the East of North Island temporal profile (Carey-Smith, T, et al, 2018) was used for design flood modelling. To test the sensitivity of results to a different profile, the 1:100 AEP 4 hour event was also run with the West of North Island profile which peaks earlier and the North of the South Island profile which peak later than the adopted storm profile. The three profiles are plotted in Figure 8-7 and model results are shown in Figure 8-8.

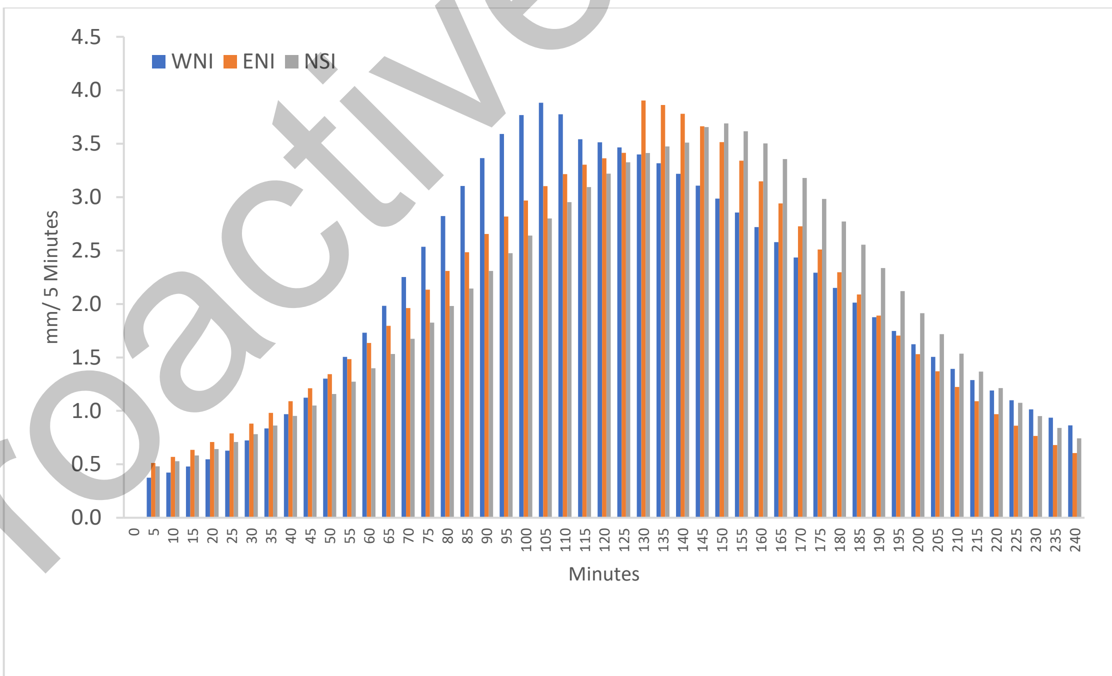


Figure 8-7: Sensitivity test - Temporal profile inputs

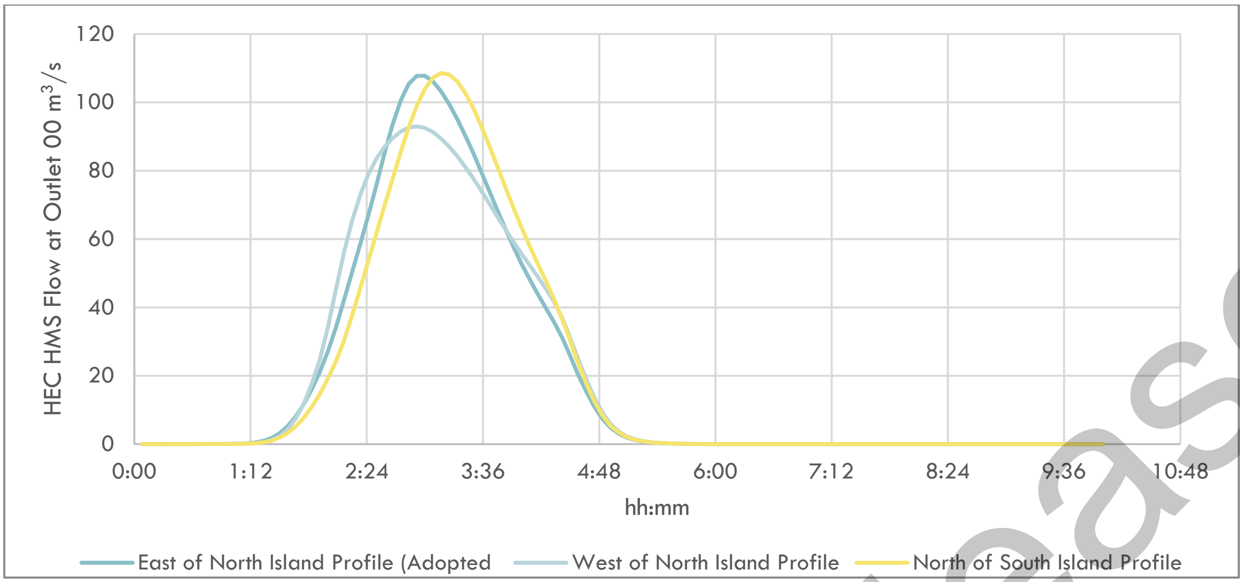


Figure 8-8: Sensitivity test -temporal profile

The West of North Island profile produces lower peak flow than the adopted East of North Island profile. The North of South Island profile gave similar peak flows.

8.3. RAINFALL LOSS – CN

Curve Numbers (CN) were increased and decreased by 10 percent from the adopted values described in 6.1.1.

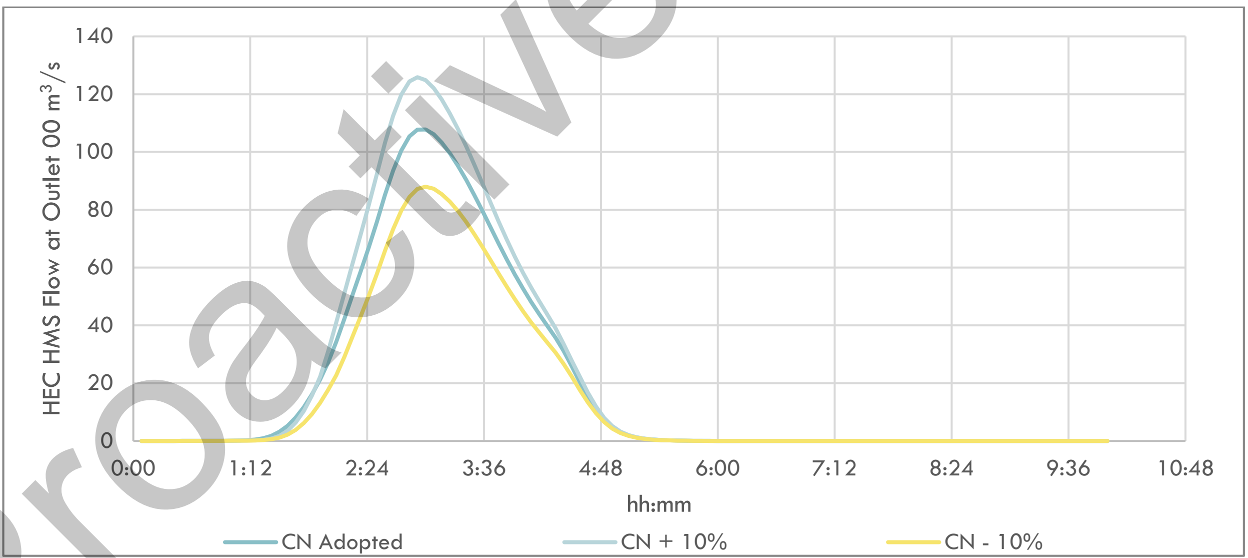


Figure 8-9: Sensitivity test -CN

8.4. RAINFALL LOSS – IA

Initial Abstraction (IA) was reduced to zero and increased by changing the storage coefficient from the adopted 0.05 to 0.1.

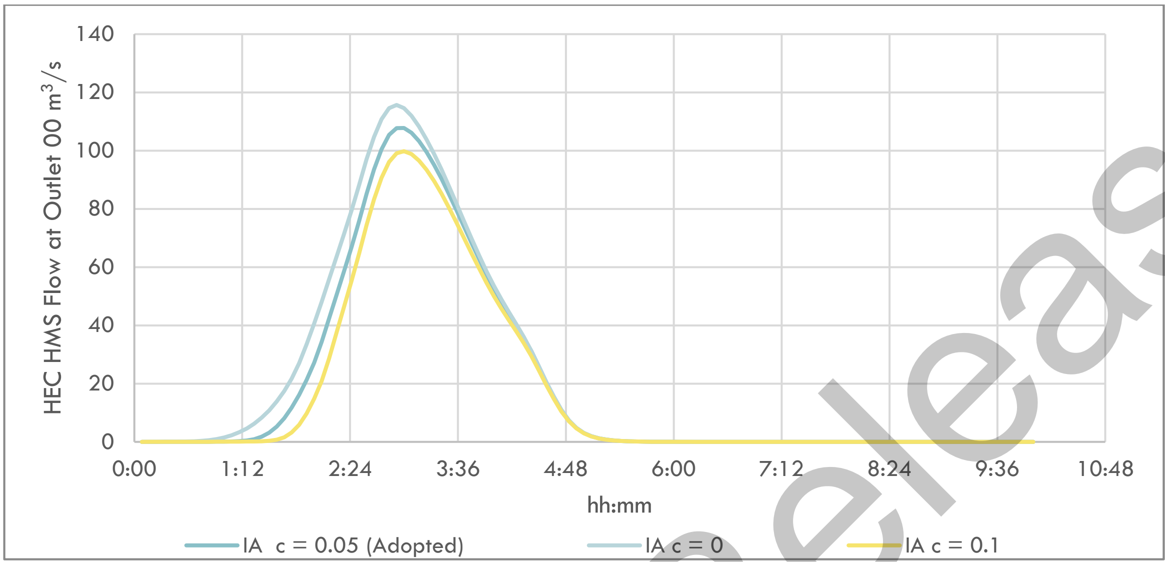


Figure 8-10: Sensitivity test -IA

8.5. SCS UNIT HYDROGRAPH PEAK RATE FACTOR

The SCS Peak Rate Factor, (a variable in the SCS Unit Hydrograph Transform Method) was reduced from the adopted 500 to 100.

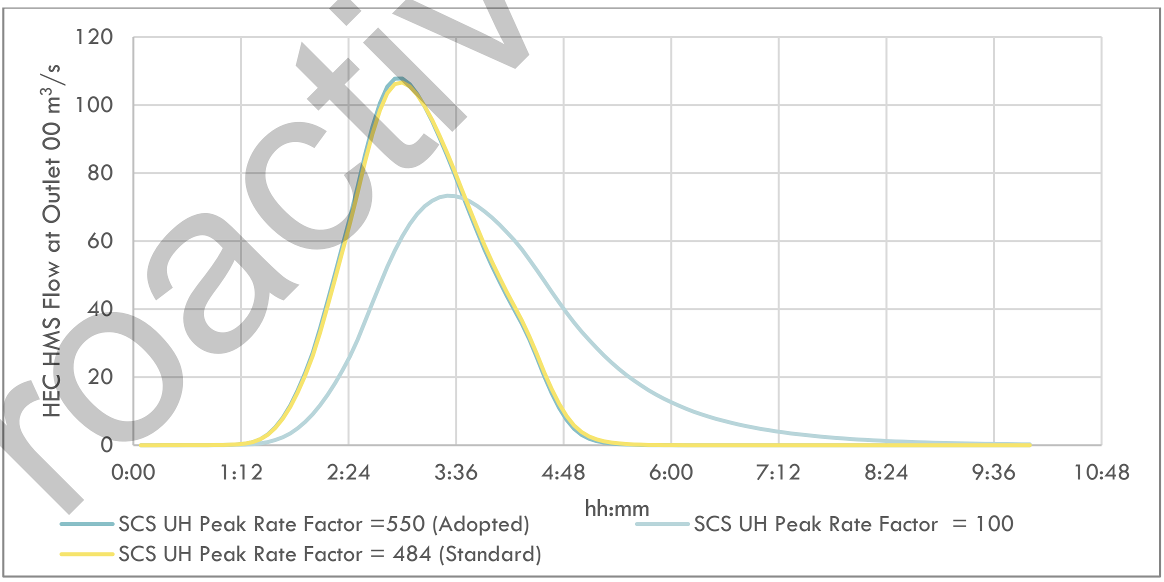


Figure 8-11: Sensitivity Test – SCS Unit Hydrograph Peak Rate Factor

8.6. SCS UNIT HYDROGRAPH – LAG

The SCS Unit Hydrograph Lag parameter was varied either side of the adopted 0.6 x Tc to 0.2 x TC and 1.0 x Tc.

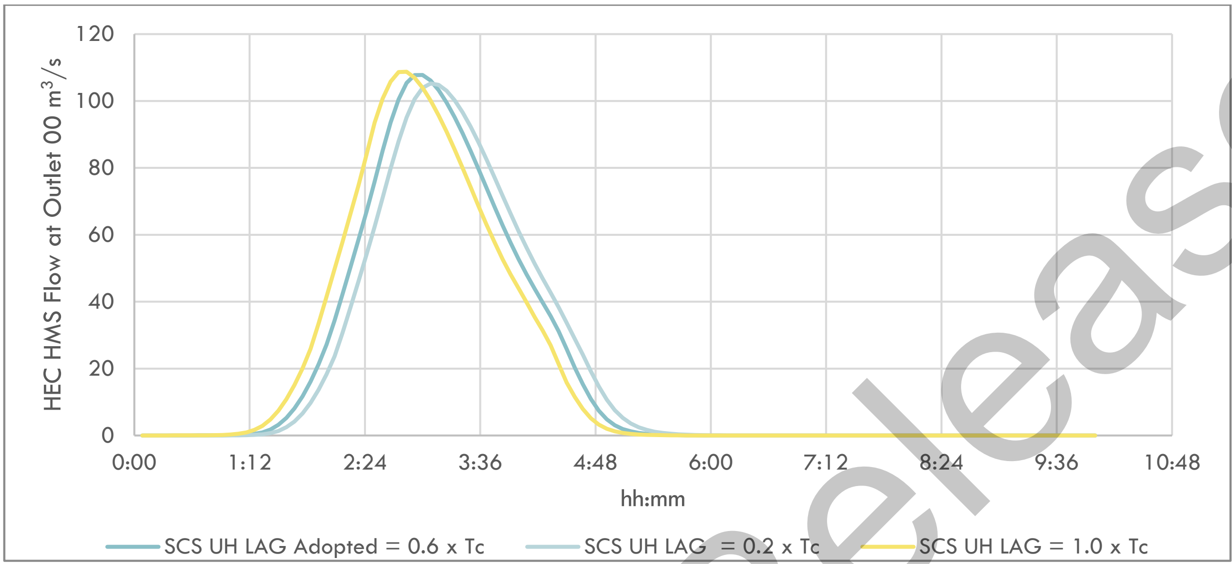


Figure 8-12: Sensitivity Test – SCS Unit Hydrograph Lag

8.7. CHANNEL ROUTING – ROUGHNESS

Mannings *n* roughness was varied within the Muskingum – Cunge channel routing method. The adopted 0.035 *n* value was reduced to 0.025 and increased to 0.1.

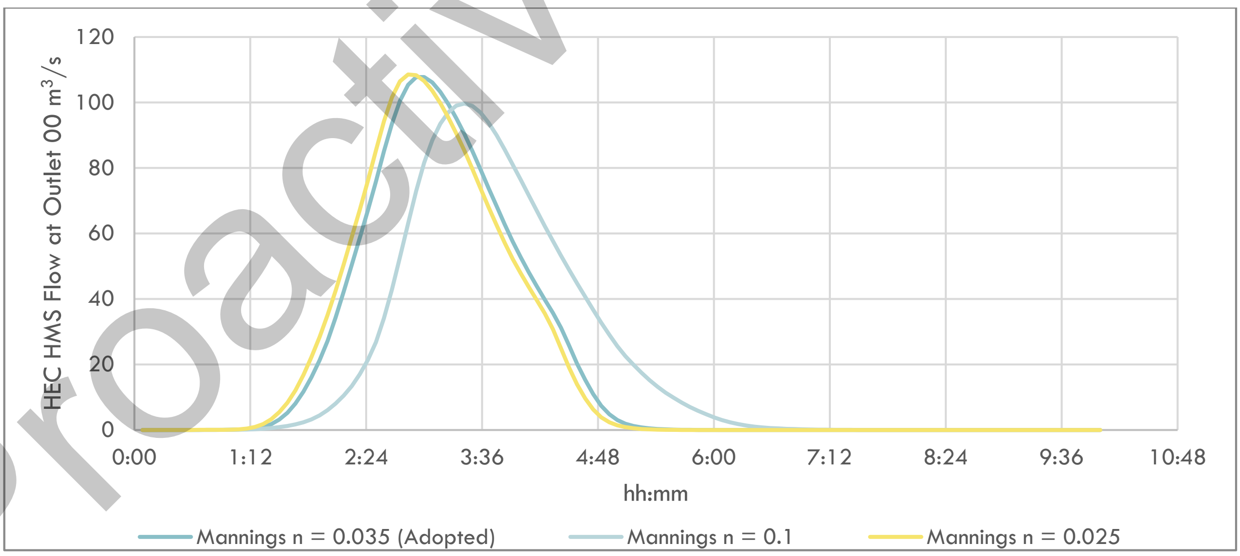


Figure 8-13: Sensitivity Test – Channel routing roughness

9. UNCERTAINTY AND LIMITATIONS

The use of rainfall runoff models to simulate design flood hydrographs for ungauged areas is subject to a range of uncertainty, including the following:

- Uncertainty associated with the recorded flood hydrographs used to calibrate the runoff models. This is estimated to be at least +/- 15% for flood records at a site with relatively stable hydraulic conditions. The Mangatārere flow site has an unstable control and the highest gauged flow is 71 m^3/s, so the level of uncertainty associated with floods above 100 m^3/s is likely to be at least +/- 25%.

- There is considerable variability in the distribution of storm rainfall within the modelled catchments. This is evident from comparison of rainfall in and adjacent to the catchment. This variability is estimated to add +/-15% uncertainty to the rainfall runoff modelling results.

The model is considered appropriate for the estimation of flood hydrographs in the Donalds and Abbots creek catchments taking into account uncertainties associated with input data and the selection of model parameters described above. As the model is calibrated with floods up to an estimated AEP of 1:10, less confidence can be placed in flood results greater than this magnitude with uncertainty increasing with increasing flood magnitude.

The estimation of design rainfall for the 1:1000 AEP event involved extrapolation of frequency analysis based on relatively short periods of record. This along with other model uncertainties should be carefully considered when using simulated hydrographs of this extreme event.

10. REFERENCES

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APPENDIX 1: SCOPE OF WORK

Introduction
This request for proposal is for a hydrological assessment of the Donalds Creek and Abbots Creek catchments to provide a range of design rainfall inputs for subsequent hydraulic modelling.

Background
Donalds Creek is a small stream that flows through the township of Featherston into Lake Wairarapa. It has previously flooded several properties within Featherston; in 1994 an estimated 10% Annual Exceedance Probability (AEP) (10-year) event flooded five properties. It was predicted that another 14 properties would be affected by a 2% AEP (50-year) flood. This prompted the construction of a retention dam along Harrison Street East, as well as channel configuration along with small bunds downstream of the dam. In a recent event in August 2022, the retention dam was out-flanked upstream and new properties that were built in 2016 were flooded.

Both Donalds and Abbots Creek are ungauged catchments and there has been no formal flood hazard mapping for the Donalds or Abbots Creek catchments (Figure 1). Greater Wellington Regional Council (GWRC) wish to undertake hydraulic modelling to create flood hazard maps of these waterways, in line with GWRC Flood Hazard Modelling Standard (FHMS).

There is a lack of hydrological data in the two catchment areas, but there is data available in nearby catchments. Therefore, GRWC requires a qualified hydrologist to examine the available data, including HIRDS, to create hydrologic inputs for the hydraulic modelling process that are robust, defendable, and use industry best standards.

Outcomes
The following outcomes are required sought:

1. A strong understanding of the hydrology within Donalds Creek and Abbots Creek catchments

2. Highlight possible calibration/validation events

3. Hydrological inputs to the hydraulic model for multiple design events (see FHMS). These may be rainfall or flow inputs, or both as recommended through this hydrological assessment.

4. Collaboration with the hydraulic modeller, to ensure as much realism as possible within the model

5. Collaboration with GWRC's appointed peer reviewer

6. Communication and clarification of findings with interested stakeholders such as South Wairarapa District Council, iwi, and the wider community

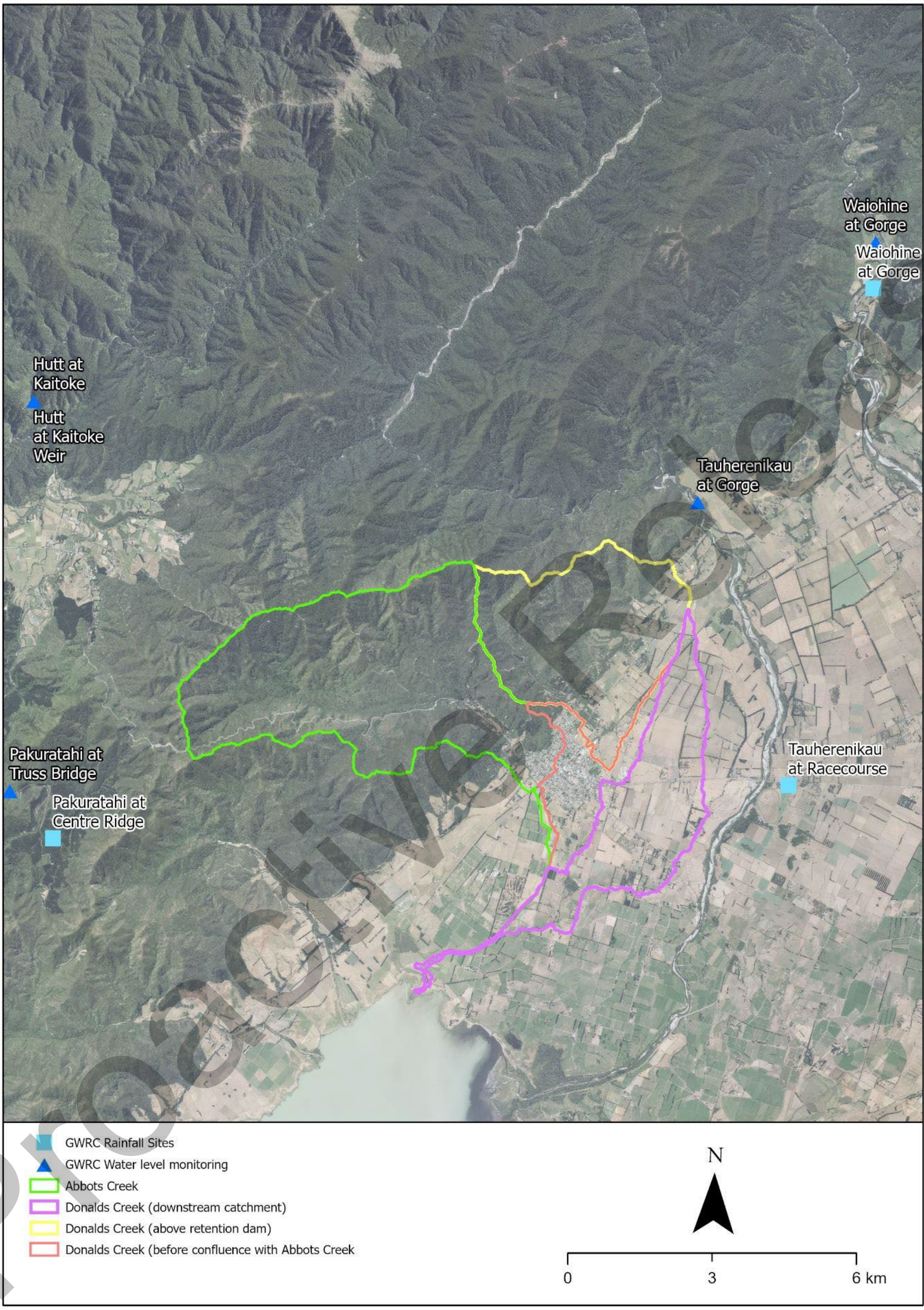

Figure 1: Map of the Donalds Creek and Abbots Creek, with GWRC environmental monitoring sites located

Services /Our requirements

We require a suitably qualified hydrological consultant to undertake:

- A hydrological assessment of Donalds Creek and Abbots Creek
  - Review past hydrological assessments (including those undertaken by other agencies i.e. Wellington Water)
  - Investigate possible calibration and validation events to be used within the subsequent hydraulic model
  - Creation of robust and defendable rainfall or flow inputs (as appropriate) for multiple events (outlined within the FHMS, and the table below) for the hydraulic model

Calibration and validation	As indicated by the hydrological assessment
Current flood risk	• 39% AEP (1 in 2-year ARI) • 20% AEP (1 in 5-year ARI) • 10% AEP (1 in 10-year ARI) • 5% AEP (1 in 20-year ARI) • 2% AEP (1 in 50-year ARI) • 1% AEP (1 in 100-year ARI)
Future flood risk (climate change)	• 39% AEP (1 in 2-year ARI) with allowance for climate change • 20% AEP (1 in 5-year ARI) with allowance for climate change • 10% AEP (1 in 10-year ARI) with allowance for climate change • 5% AEP (1 in 20-year ARI) with allowance for climate change • 2% AEP (1 in 50-year ARI) with allowance for climate change • 1% AEP (1 in 100-year ARI) with allowance for climate change
Dam breach hydrology	• Outlined in the Dam Safety Guidelines (NZSOLD)

Data Description	Data type	Start Date	Finish Date	Source	Limitations or License Terms	Assessment of quality [1]
NFRA at Featherston	Rainfall Record	11-Apr-16	24-May-23	*Provided by GWRC Hydrology team*[2]	*None*	3
Martinborough at EWS	Rainfall Record	1-Oct-08	17-Oct-11	NIWA	*None*	not used
Waiohine River at Gorge	Rainfall Record	27-Dec-54	26-Jun-21	*Provided by GWRC Hydrology team*[2]	*None*	4
Waingawa at Kaituna [RF]	Rainfall Record	9-May-94	2-Jul-21	*Provided by GWRC Hydrology team*[2]	*None*	not used
Tauherenikau at Bull Mound	Rainfall Record	23-May-76	30-Apr-22	*Provided by GWRC Hydrology team*[2]	*None*	4
Mangatarere at Valley Hill [RF]	Rainfall Record	21-Apr-97	12-May-23	*Provided by GWRC Hydrology team*[2]	*None*	4
Hutt at Phillips	Rainfall Record	4-May-72	27-Jun-03	*Provided by GWRC Hydrology team*[2]	*None*	not used
Waiohine River at Phelps [RF]	Rainfall Record	2-Jan-74	14-Jan-10	*Provided by GWRC Hydrology team*[2]	*None*	4
Pakuratahiat Centre Ridge	Rainfall Record	6-Apr-84	13-Feb-23	*Provided by GWRC Hydrology team*[2]	*None*	4
Lake Wairarapa at Western Lakeshore	Rainfall Record	27-Mar-12	24-Aug-17	*Provided by GWRC Hydrology team*[2]	*None*	4
Tauherenikau at Racecourse	Rainfall Record	4-Jul-07	13-Feb-23	*Provided by GWRC Hydrology team*[2]	*None*	4
Lake Wairarapa at Eastern Lakeshore	Rainfall Record	27-Mar-12	28-Jun-22	*Provided by GWRC Hydrology team*[2]	*None*	not used
Waiohine at Gorge (Exdfrm Phelps)	Rainfall Record	2-Jan-74	14-Jun-22	*Provided by GWRC Hydrology team*[2]	*None*	not used
Parkvale Stream at Renalls Weir [RF]	Rainfall Record	8-Jan-08	21-Apr-22	*Provided by GWRC Hydrology team*[2]	*None*	4
Tauherenikau at Alloa	Rainfall Record	18-Aug-99	1-Nov-12	*Provided by GWRC Hydrology team*[2]	*None*	not used
Tauherenikau at NIWA MET Station	Rainfall Record (Daily)	1-Mar-63	1-Jan-00	*Provided by GWRC Hydrology team*[2]	*None*	na
Rimutaka Summit	Rainfall Record (Daily)	1962	1987	*NIWA (Cliflo)*	*None*	3
Featherston 2	Rainfall Record (Daily)	1884	1987	*NIWA (Cliflo)*	*None*	3
Waipoto	Rainfall Record (Daily)	1940	1960	*NIWA (Cliflo)*	*None*	3
Summit	Rainfall Record (Daily)	1890	1994	*NIWA (Cliflo)*	*None*	3
Tauherenikau	Rainfall Record (Daily)	1963	1994	*NIWA (Cliflo)*	*None*	3
Waingawa River at Kaituna	Flow Record	14-May-76	4-Feb-21	*Provided by GWRC Hydrology team*[2]	*None*	not used
Tauherenikau at Gorge	Flow Record	30-Mar-76	23-Jun-22	*Provided by GWRC Hydrology team*[2]	*None*	4
Mangatarereat Belvedere Bridge	Flow Record	26-Jan-04	27-Feb-20	*Provided by GWRC Hydrology team*[2]	*None*	1

Pakuratahiat Truss Bridge	Flow Record	22-May-78	8-Feb-23	*Provided by GWRC Hydrology team[2]*	*None*	4
Otukura at Weir	Flow Record	17-Dec-97	13-Feb-23	*Provided by GWRC Hydrology team[2]*	*None*	1
Mangatarere River at Gorge	Flow Record	9-Feb-99	12-May-23	*Provided by GWRC Hydrology team[2]*	*None*	3
Mangatarere River at State Highway 2	Flow Record	1-Sep-09	27-Feb-20	*Provided by GWRC Hydrology team[2]*	*None*	2
Parkvale Stream at Renalls Weir	Flow Record	15-Jan-02	21-Apr-22	*Provided by GWRC Hydrology team[2]*	*None*	4
LiDAR from the Wgtn 1m DEM (2013 to 2014)	Topographic	na	na	*Provided by GWRC Hydrology team*	*None*	5

[1] 1 = low quality, 5 = high quality
[2] Contact: Mike Harkness

APPENDIX 3: MANGATĀRERE CALIBRATION MODEL PARAMETERS

Mangatārere Model: Mangatārere_Calibration_F.hms

Loss

Subbasin	Initial Abstraction	CN	Impervious %
Subbasin-1	6.5	66	0
Subbasin-10	4.6	74	0
Subbasin-11	5.6	69	0
Subbasin-12	6.5	66	0
Subbasin-13	5.9	68	0
Subbasin-14	6.2	67	0
Subbasin-15	6.2	67	0
Subbasin-16	5.1	71	0
Subbasin-17	6.2	67	0
Subbasin-18	5.6	69	0
Subbasin-19	5.9	68	0
Subbasin-2	6.5	66	0
Subbasin-20	6.2	67	0
Subbasin-21	5.9	68	0
Subbasin-22	6.2	67	0
Subbasin-23	5.1	71	0
Subbasin-24	5.1	71	0
Subbasin-25	4.6	74	0
Subbasin-26	6.2	67	0
Subbasin-27	5.6	69	0
Subbasin-3	5.9	68	0
Subbasin-4	6.2	67	0
Subbasin-5	5.1	71	0
Subbasin-6	5.4	70	0
Subbasin-7	5.1	71	0
Subbasin-8	6.5	66	0
Subbasin-9	6.5	66	0

Transform

Subbasin	Graph Type	Lag Time (min)
Subbasin-1	Peak Rate Factor 550	23.18
Subbasin-10	Peak Rate Factor 550	8.75
Subbasin-11	Peak Rate Factor 550	6.81
Subbasin-12	Peak Rate Factor 550	12.8
Subbasin-13	Peak Rate Factor 550	6.84
Subbasin-14	Peak Rate Factor 550	10.3
Subbasin-15	Peak Rate Factor 550	11.74
Subbasin-16	Peak Rate Factor 550	6.82
Subbasin-17	Peak Rate Factor 550	10.92
Subbasin-18	Peak Rate Factor 550	4.02

Subbasin-19	Peak Rate Factor 550	12.4
Subbasin-2	Peak Rate Factor 550	16.12
Subbasin-20	Peak Rate Factor 550	13.26
Subbasin-21	Peak Rate Factor 550	2.95
Subbasin-22	Peak Rate Factor 550	15.54
Subbasin-23	Peak Rate Factor 550	3.57
Subbasin-24	Peak Rate Factor 550	8.82
Subbasin-25	Peak Rate Factor 550	6.15
Subbasin-26	Peak Rate Factor 550	9.07
Subbasin-27	Peak Rate Factor 550	11.21
Subbasin-3	Peak Rate Factor 550	7.09
Subbasin-4	Peak Rate Factor 550	7.41
Subbasin-5	Peak Rate Factor 550	8.98
Subbasin-6	Peak Rate Factor 550	6.84
Subbasin-7	Peak Rate Factor 550	7.41
Subbasin-8	Peak Rate Factor 550	7.12
Subbasin-9	Peak Rate Factor 550	6.37

Routing

Reach	Length (m)	Slope (m/m)	Mannings n	Index Flow (m3/s)	Shape	Width (m)	Side Slope (xH:1V)
Reach-13	2313.47	0.03899	0.35	20	Trapezoid	5	2
Reach-10	557.19	0.02079	0.35	20	Trapezoid	3	2
Reach-11	1877.87	0.02004	0.35	20	Trapezoid	3	2
Reach-9	1764.74	0.01114	0.35	30	Trapezoid	5	2
Reach-7	393.8	0.00959	0.35	40	Trapezoid	5	2
Reach-8	1847.33	0.01635	0.35	20	Trapezoid	5	2
Reach-6	2201.99	0.00705	0.35	40	Trapezoid	5	2
Reach-12	1291.54	0.02585	0.35	20	Trapezoid	5	2
Reach-5	441.17	0.00729	0.35	50	Trapezoid	7	2
Reach-4	1143.37	0.00629	0.35	50	Trapezoid	7	2
Reach-3	905.53	0.00602	0.35	50	Trapezoid	8	2
Reach-2	1324.04	0.00627	0.35	60	Trapezoid	10	2
Reach-1	1706.51	0.0056	0.35	60	Trapezoid	12	2

APPENDIX 4: DONALDS AND ABBOTS VALIDATION & DESIGN MODEL PARAMETERS

DA_Validation_F.hms & DA_Design.hms

Loss

Subbasin	Initial Abstraction	CN	Impervious %
Subbasin-1	5.3	71	0
Subbasin-10	6.5	66	0
Subbasin-11	5.5	70	0
Subbasin-12	6.1	68	0
Subbasin-13	6.5	66	0
Subbasin-14	6.3	67	0.5
Subbasin-15	6.4	66	0.5
Subbasin-16	5.7	69	0.5
Subbasin-17	6.1	67	0.5
Subbasin-18	6.5	66	0
Subbasin-19	6.4	67	0
Subbasin-2	5.3	71	0
Subbasin-20	6.5	66	0
Subbasin-21	6.1	67	0
Subbasin-22	5.9	68	0.5
Subbasin-23	6.2	67	0.5
Subbasin-24	6.3	67	0.5
Subbasin-25	6.2	67	0.5
Subbasin-26	6	68	0.5
Subbasin-27	5.7	69	0.5
Subbasin-28	5.6	69	0.5
Subbasin-29	6.7	65	0
Subbasin-3	5.8	69	0
Subbasin-30	6.8	65	0
Subbasin-31	6.4	66	0
Subbasin-32	6	68	0
Subbasin-33	5	72	0
Subbasin-35	4.8	73	0
Subbasin-36	6.5	66	0
Subbasin-37	5.7	69	0
Subbasin-38	4.6	74	0
Subbasin-39	5.3	71	0
Subbasin-4	6	68	0
Subbasin-40	6	68	0
Subbasin-41	5.4	70	0
Subbasin-5	5.5	70	0
Subbasin-6	6.4	67	0
Subbasin-7	6.2	67	0
Subbasin-8	6.2	67	0
Subbasin-9	6.3	67	0

Transform

Subbasin-21	Graph Type	Lag Time (min)
Subbasin-1	Peak Rate Factor 550	6.26
Subbasin-10	Peak Rate Factor 550	10.12
Subbasin-11	Peak Rate Factor 550	5.31
Subbasin-12	Peak Rate Factor 550	9.08
Subbasin-13	Peak Rate Factor 550	7.53
Subbasin-14	Peak Rate Factor 550	6.86
Subbasin-15	Peak Rate Factor 550	7.1
Subbasin-16	Peak Rate Factor 550	7.3
Subbasin-17	Peak Rate Factor 550	8.2
Subbasin-18	Peak Rate Factor 550	2.54
Subbasin-19	Peak Rate Factor 550	2.96
Subbasin-2	Peak Rate Factor 550	8.02
Subbasin-20	Peak Rate Factor 550	8.34
Subbasin-21	Peak Rate Factor 550	9.77
Subbasin-22	Peak Rate Factor 550	10.08
Subbasin-23	Peak Rate Factor 550	10.25
Subbasin-24	Peak Rate Factor 550	5.14
Subbasin-25	Peak Rate Factor 550	3.47
Subbasin-26	Peak Rate Factor 550	10.86
Subbasin-27	Peak Rate Factor 550	11.85
Subbasin-28	Peak Rate Factor 550	23.31
Subbasin-29	Peak Rate Factor 550	1.39
Subbasin-3	Peak Rate Factor 550	12.26
Subbasin-30	Peak Rate Factor 550	2.69
Subbasin-31	Peak Rate Factor 550	2.66
Subbasin-32	Peak Rate Factor 550	3.08
Subbasin-33	Peak Rate Factor 550	2.3
Subbasin-35	Peak Rate Factor 550	1.2
Subbasin-36	Peak Rate Factor 550	1.56
Subbasin-37	Peak Rate Factor 550	1.49
Subbasin-38	Peak Rate Factor 550	2.17
Subbasin-39	Peak Rate Factor 550	2.64
Subbasin-4	Peak Rate Factor 550	9.98
Subbasin-40	Peak Rate Factor 550	2.09
Subbasin-41	Peak Rate Factor 550	1.04
Subbasin-5	Peak Rate Factor 550	13.54
Subbasin-6	Peak Rate Factor 550	7.42
Subbasin-7	Peak Rate Factor 550	14
Subbasin-8	Peak Rate Factor 550	13.16
Subbasin-9	Peak Rate Factor 550	7.92

Routing

Reach	Length (m)	Slope (m/m)	Mannings n	Index Flow (m^3/s)	Shape	Width (m)	Side Slope (xH:1V)
Reach-11	370	0.04876	0.035	10	Trapezoid	3	2
Reach-9	1382	0.03439	0.035	10	Trapezoid	3	2
Reach-6	1561	0.02274	0.035	10	Trapezoid	3	2
Reach-5	840	0.017	0.035	20	Trapezoid	5	2
Reach-4	320	0.0175	0.035	30	Trapezoid	10	3
Reach-3	1298	0.01566	0.035	40	Trapezoid	10	3
Reach-2	1150	0.01521	0.035	10	Trapezoid	5	2
Reach-10	371	0.074	0.035	10	Trapezoid	3	2
Reach-8	1590	0.04572	0.035	10	Trapezoid	3	2
Reach-1	3329	0.01126	0.035	50	Trapezoid	10	2
Reach-7	1483	0.02918	0.035	10	Trapezoid	6	2

Donald and Abbots Creek Hydrology

Peer Review

22 December 2023 **Ref: 310104160**

PREPARED FOR:

Greater Wellington Regional Council

PREPARED BY:

Stantec - Petone

Stantec

Revision Schedule

Revision No.	Date	Description	Prepared by	Quality Reviewer	Project Manager Final Approval
0	22/12/2023	Draft for client review	C Hopkirk	W Me	B Parkin

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PREPARED BY
Carrie Hopkirk — 18 / 12 / 2023

REVIEWED BY
Wang Me — 18 / 12 / 2023

APPROVED FOR ISSUE BY
Beth Parkin — 21 / 12 / 2023

Executive summary

Stantec were engaged by Greater Wellington Regional Council (GWRC) to undertake a peer review of the Donald and Abbots Creek hydrological model. The peer review is to determine if the modelling work has fulfilled the requirements of GWRC's Flood Hazard Modelling Standard (FHMS), which was developed to ensure modelling projects follow industry-accepted practice and output results are appropriate for use and robust.

The comments below relate to the Donald and Abbots Creek Hydrological Assessment, dated November 2023 and associated modelling files, and are outcomes of Round 2 of the peer review.

The FHMS requires peer reviewers to categorise the outcome of the review as either "Action Required" or "Suitable to Proceed". The outcome of this review is **Action Required**.

The peer review summary is provided in Table ES 1.

Round 1 review summary

Round 1 was a review of the preliminary draft hydrological modelling report. The report was not complete, and the model was not provided. The purpose of this review was for early engagement with the peer reviewer to agree the approach to modelling, given the limited data available within the catchment.

The outcome of this review was that further information was required to finish the report and model, as expected given the preliminary nature of the work provided for review.

The approach to calibration and validation of the hydrological model was agreed, as outlined below:

- **Calibration:** given the absence of suitable flow data within the catchment, a calibrated model of a donor catchment (Mangatārere River) would be used to provide catchment parameters.
- **Validation:** validation would be undertaken via the hydraulic model using flood photos from the December 2018 event. The hydraulic model was not reviewed as part of this peer review.

Round 2 review summary

The Round 2 review involved a thorough, hands-on review of the completed hydrological modelling report, calibrated Mangatārere River model and the Donald and Abbots Creek model.

This review found that the hydrological assessment is thorough and logical and makes best use of the limited data available in the catchment. No significant flaws in the technical work have been identified.

A small number of items have been flagged as 'major' in the peer review spreadsheet (Appendix A), however these items are primarily requests for further commentary or justification to be provided in the hydrological modelling report.

It is noted that the results of the validation have not been provided as the validation has been undertaken in the hydraulic model. It is requested that the hydrological modelling report is updated to state this.

It is recommended that the validation is discussed with the peer reviewer of the hydraulic model prior to close out of the hydrology peer review.

Table ES 1: Peer review summary

Scope	Round 1 review rating	Comment	Round 2 review rating	Comment
Documentation	Major	Documentation not yet complete or has not been provided.	Minor	Documentation and reporting are thorough. Some further commentary is requested.
Schematisation	Minor	Justification for using the Clark unit hydrograph routing method with the SCS curve number loss method required.	Ok	The model schematisation is appropriate.
Input data review	Major	More information required on the appropriateness of the Mangatarere catchment as source of input parameters. Commentary required on limitations of the data used in the Mangatarere model and how this may impact results.	Major	More information / commentary required on rainfall analysis.
Model inputs	Major	Model not yet provided.	Minor	More information required on curve number selection and application of baseflow.
Rainfall	Minor	Appears acceptable based on the report, however the model has not yet been provided.	Ok	Data used is appropriate and appears to have been applied correctly.
Model Build	Major	Model not yet provided.	Ok	No issues identified.
Run Parameters	Major	Model not yet provided.	Ok	No issues identified.
Calibration	Ok	The Donald and Abbots Creek model is not calibrated due to lack of suitable calibration data. The model parameters are based on the calibrated model of the Mangatārere catchment.	Ok	The Donald and Abbots Creek model is not calibrated due to lack of suitable calibration data. The model parameters are based on the calibrated model of the Mangatārere catchment.
Validation	Major	Model not yet provided. More information required.	Major	Validation will be undertaken in the hydraulic model.
Model Runs	Major	Model not yet provided.	Minor	Please confirm whether the 12- and 24-hour events have been tested for critical duration.
Results	Major	Model not yet provided.	Major	Further commentary required regarding comparison to alternate methods.
Sensitivity Test	Major	Model not yet provided.	Minor	Additional commentary required.
Outputs	Major	Model not yet provided.	Ok	Outputs appear suitable.

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1. Scope of Peer Review

1.1 Purpose

Greater Wellington Regional Council's (GWRC) Flood Hazard Modelling Standard (FHMS) requires all hydrological analysis or modelling to undergo peer review. The peer reviewer's role is to determine whether the work reviewed meets accepted industry practice and is of suitable quality to be used as an input to hydraulic modelling.

Stantec were engaged by GWRC to undertake peer review of the Donald and Abbots Creek hydrological modelling. The peer review has been undertaken in accordance with Procedure 3 of the FHMS.

1.2 Pre-Conditions

We confirm that Stantec meets the required pre-conditions to undertake peer review of the Donald and Abbots Creek model:

- **Independence:** the peer reviewer has not been involved in any aspect of the Donald and Abbots Creek hydrological modelling.
- **Conflict of interest:** Stantec does not have a dependent relationship with the hydrological modeller, including financial or other interests.

1.3 Scope of Works

The scope of this review covers:

- General comments
- Model schematisation
- Input data review
- Model inputs, including rainfall
- Model build
- Run parameters
- Calibration and validation
- Model runs
- Model results
- Sensitivity testing
- Outputs and model documentation

1.4 Files Reviewed

The documents that have been reviewed include:

Table 1 Documents reviewed

Reports	
• Land River Sea Consulting (2023). Donald's Creek and Abbots Creek Hydrological Assessment [Preliminary Draft]. By Tom Kerr. Prepared for Greater Wellington Regional Council. Dated August 2023.	• Land River Sea Consulting (2023). Donalds Creek and Abbots Creek Hydrological Assessment. By Tom Kerr and Matthew Gardner. Prepared for Greater Wellington Regional Council. Dated November 2023.
Spreadsheets	
• Appendix P2-A Donalds and Abbots Model Log	
• HIRDS Master Download & Rational Method 7	
Model Files	
• DA_Design_F.hms	• DA_validation_F.hms

• DA_Sensitivity_F.hms	• Mangatarere_calibration_F.hms

Files that have not been reviewed include:

- **Hydraulic modelling.** The hydraulic model will be peer reviewed separately at a later stage of the FHMS process.
- **Post Event Appraisal Featherston, Wairarapa Flood Event:** 2nd December 2018 (GWRC). This document is referred to in the hydrology report but has not been sighted by the peer reviewer.

1.5 Peer Review Methodology

As indicated in Section 1, this peer review has been undertaken in accordance with Procedure 3 of the FHMS. The peer review has been guided by the Peer Review Spreadsheet template, an appendix of the FHMS. The updated (2023) version of the peer review spreadsheet template was used.

The review has been undertaken based on a 'hands-on' interrogation of the model, and a review of associated model documentation, including the model log and model report.

The hydrology peer review spreadsheet accompanies this report. Stantec have provided review comments against each element and a review rating of ok, minor, major or critical. All review ratings of minor, major and critical require further correspondence with the hydrological consultant to resolve.

Per the requirements of the FHMS, the peer review has been undertaken as an iterative process, involving conversations between the modeller and peer reviewer to resolve review comments. All iterations and review comments are documented in the peer review spreadsheet and this report. Issues have been resolved through provision of further information, additional background information, additional analysis or modifications.

2. Peer Review Comments

The comments below relate to the Donald's Creek and Abbots Creek Hydrological Assessment Report, dated November 2023 and associated modelling files provided for review.

2.1 General Comments

Overall, the models and modelling report represent a thorough and logical assessment of the hydrology of the Donald and Abbots Creek catchments.

It is noted that the assessment is limited by the lack of suitable flow data within the catchment. The approach to modelling used (outlined in Section 2.3) is a sensible approach to estimating flood hydrology in the absence of at-site flow records.

2.2 Documentation

The FHMS requires that key documentation is provided to assist the peer reviewer in undertaking the peer review, and for GWRC's records. The required documentation and a summary of what has been provided is listed in Table 2 below.

Table 2 Model Documentation

Documentation Required	Comment
Hydrological modelling report	A thorough report has been provided. The report outlines the key input parameters, modelling decisions and results. Some additional commentary regarding some modelling choices has been requested in the peer review spreadsheet for clarity and completeness.

Model log	A model log has been provided using the template from the FHMS, modified to be suitable for the software used. The spreadsheet provides a high-level summary of key inputs and the calibration, validation, sensitivity and design runs. Modelling decisions are recorded in the modelling report rather than in the model log.
Hydrometric Feedback Form	Not supplied.

The model naming convention is generally in accordance with the naming convention specified in Procedure 2 of the FHMS.

2.3 Model Schematisation

Two rainfall-runoff models have been developed in order to provide design hydrographs for the Donalds and Abbots Creek catchment due to the absence of suitable gauged flow and rainfall records within the catchment. These models include:

- **Mangatārere River model:** a nearby catchment of similar size and aspect, calibrated against flow records. This model was developed to provide parameters for the ungauged Donalds and Abbots Creek catchments.
- **Donald and Abbots Creek model:** includes the hill sub-catchments of the Donald and Abbots Creek catchment and provides discharge information at 16 outlet locations. The plains of the Donald and Abbots Creek catchment are not included in the model. It has been assumed that the extent of the hydrological model and outlet locations has been discussed and agreed with the hydraulic modeller. The hydrological modeller should confirm that this is the case.

  The model uses the same approach to parameter selection as the Mangatārere River model. The Donald and Abbots Creek model is validated against the preliminary hydraulic model and used to provide design hydrographs.

The models developed are shown schematically in Figure 1 below.

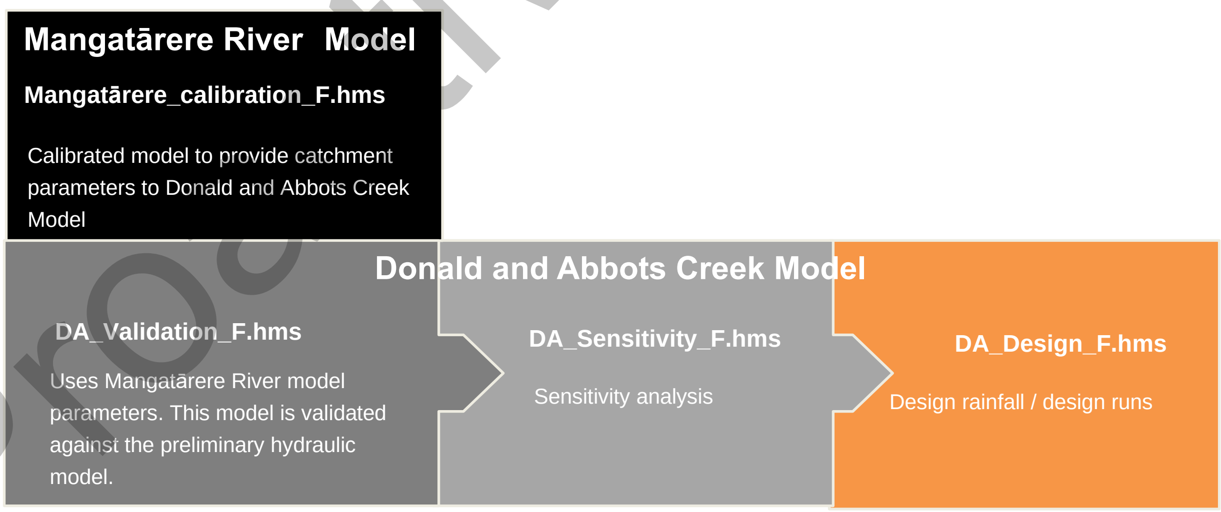

Figure 1 Model Schematisation

The Mangatārere River catchment is relatively close to the Donald and Abbots Creek catchment, has a similar aspect (orientation to weather), elevation and similar catchment attributes, making it a suitable donor catchment in the absence of at-site flow records.

It is noted that uncertainty in the Mangatārere River at Gorge flow record used for calibration of the Mangatārere River model will be a source of uncertainty in the Donald and Abbots Creek model results. This is discussed further in Section 2.4.

2.3.1 Software

The model has been developed in HEC-HMS v4.11. This is a suitable software package and is the most recent version.

2.3.2 Hydrological methods

Modelling has been undertaken using the SCS curve number loss method. The transformation method is the SCS unit hydrograph. These methods are appropriate for event modelling. The Clark unit hydrograph method has also been tested and results were comparable to the SCS unit hydrograph method.

These methods are suitable hydrological methods for event modelling the Wellington/Wairarapa Region.

2.4 Input Data Review

Procedure 1 of the FHMS requires that input data is assessed for quality. The review should identify where input data quality could limit confidence in the model results.

The review of the input data outlined in the hydrological modelling report was detailed, particularly with regard to the hydrometric data. This is summarised in Table 3 below.

Table 3 Input data

Input Data	Comment
Hydrometric data: rainfall	The modeller has reviewed rainfall record lengths and gaps, undertaken an analysis of the spatial variation of rainfall (rainfall gradient across the catchment), and has reviewed HIRDS rainfall data including a spatial analysis and comparison to frequency analysis. It is noted that the HIRDS rainfall depth estimates (except at the Waiohine at Gorge site) are higher than rainfall depths estimated by frequency analysis of gauged rainfalls. The modeller should provide commentary on why this may be, and whether HIRDS rainfall depths may be over-estimated. Data from the rain radar was used for the 2018 validation event. The radar data was validated by comparison to rain gauges in the area.
Hydrometric data: flow	The modeller has reviewed the flow data at the Otukura Stream at Weir site. This site has been deemed unsuitable to use for calibration due to overbank flows during larger events. Other nearby gauges were discarded due to catchment characteristics. A detailed analysis of the Mangatārere at Gorge gauge was undertaken including sensitivity of flood frequency analysis to inclusion of the February 2017 flood that was not well recorded. As noted by the modeller, the Mangatārere at Gorge site has a large number of gaugings (257 between February 1999 and February 2020), however the majority of these gaugings were undertaken outside of high flow conditions. The largest gauged flow (71 m^3/s) equates to less than a 1 in 5-year ARI event. This is a common occurrence at many sites across GWRC's gauging network due to the difficulty of undertaking high flow gaugings. The modeller has identified this as a source of uncertainty in the model results, particularly at higher (less frequent) AEPs.

	It is also noted that the Mangatārere River at Gorge gauging site has an unstable control due to the natural alluvial channel, and as such the rating curve may shift frequently.
Catchment data	Catchment data used in this assessment includes land cover and soil drainage layers. It would be helpful if the report included a sentence relating to the likely appropriateness of these layers.
Historic flood data	The report references flood photos from the 2018 flood event that were taken near the peak of the event.
Topographic	To cover off the FHMS requirement, a comment on whether any errors in the DEM were noticed would be helpful.

2.5 Model Inputs

2.5.1 Curve Number

The SCS method uses a curve number to determine the proportion of rainfall converted to runoff. The modeler has applied the Wellington Water curve number table for the Wellington Region to convert soil drainage and land cover mapping into curve numbers. Curve numbers have then been adjusted during calibration (increased by 5%). This is a reasonable approach.

The adjusted curve numbers are generally reasonable. However, the forest land cover category has been split into two, with an 'indigenous forest' and 'exotic forest' category. The modeller should explain the rationale for the exotic forest having a lower curve number (less runoff) compared to the indigenous forest.

Exotic forest is likely to be planted pine with limited understory, compared to the dense understory generally found in indigenous forests. Please confirm whether a lower curve number may be more appropriate for indigenous forest than for exotic. If not, please justify the higher curve number.

2.5.2 Initial Abstraction

A constant of 0.05 was used in the initial abstraction formula instead of the 0.1 used in the Wellington Water method. The modeller has commented that this is because the 0.1 constant generated relatively high initial abstraction values. Initial abstraction constants were also tested during sensitivity analysis.

2.5.3 Lag

Sub-basin lag and reach lag time was calculated using the time of concentration (Ramsar-Kirpich method) x 0.6 and the Muskingum-Cunge method respectively. This is appropriate.

2.5.4 Peak Rate Factor

A peak rate factor of 550 was used. This is greater than the standard factor of 484. The peak rate factor was adjusted during calibration and tested as part of the sensitivity analysis. Sensitivity analysis indicates that this adjustment results in a small increase in peak discharge.

2.5.5 Baseflow

A baseflow of 4 m^3/s applied in the Mangatārere River model, and no baseflow applied in the Donald and Abbots Creek models. The modeller should provide justification for the baseflow values selected for each model.

2.5.6 Rainfall

The suitability of the rainfall inputs for inclusion in this analysis and data quality are discussed in Section 2.4. This section discusses the application of this rainfall to the model.

Event Rainfall - Calibration

The calibration was undertaken using rainfall inputs from the Mangatārere at Valley Hill rainfall gauge. This is appropriate.

Event Rainfall - Validation

Rain radar was used to provide rainfall inputs for the December 2018 flood event. It was applied to the model as area weighted depths for each sub-catchment based on gridded rain radar totals. Rainfall data is cross checked against gauged data. The data is quite different at the Featherson HV AWS gauge (-16%) but reasonably similar at the other gauges (±7%) included in the analysis. Temporal profiles for the event were based on event rainfall distribution at two rain gauges near to the catchment. Temporal patterns were assigned to sub-catchments, with the majority of the sub-catchments assigned the Featherston at NRFA temporal pattern. The Featherston at NRFA temporal pattern is a more balanced temporal pattern compared to the Parkuratahi at Centre Ridge temporal pattern which is comprised of two discrete bursts of rainfall.

This is a sensible approach given the limited data availability within the catchment. The rationale for selecting which temporal pattern is assigned to which sub-catchment could be expanded upon in the report.

Design Rainfall

Design rainfall has been derived from HIRDS IFD tables for the centroid of each sub-catchment. Areal reduction factors have been applied in line with guidance from NIWA and applied to each sub-catchment. The NIWA HIRDS temporal pattern for East of North Island has been applied. This approach to deriving design rainfall is in line with industry accepted practice.

PMP rainfall

PMP rainfall was derived using the HIRDS equation for the 4-hour duration. This was based on analysis indicating that 4 hours may be the critical duration in the catchment. Comments relating to the critical duration are provided in Section 2.8.

If the critical duration is found to be longer than 4 hours, then this analysis should be revisited.

2.6 Calibration

The Mangatārere River model has been calibrated against nine flood events between 2000 and 2014. This is a reasonably large number of calibration events. The events appear to range in magnitude from approximately 1 in 5-year to 1 in 10-year ARI events based on the flood frequency analysis presented in the modelling report. It is assumed that larger events are not included due to an absence of larger events in the flow record. The modelling report notes that the 2017 event, the largest event on record, is not included due to uncertainty in the recorded data.

Calibration fit is a reasonable representation for most events. There is a mix of over and under-estimation of flood peaks. The hydrograph shape is reasonably well represented. The timing of the peak is slightly early in most of the calibration events, but well represented in some of the events. It would be helpful if the modeller could comment on whether the timing of the peak could be improved.

The approach to parameter selection was then applied to the Donald and Abbots Creek model.

2.7 Validation

The approach to validation is to compare outputs of the hydraulic model to photographs of the 2nd of December 2018 flood event. These photographs were taken near to the peak of the flood.

The Donald and Abbots Creek hydrological model outputs were provided to the hydraulic modeller for input to the hydraulic model for validation. The hydraulic model was not reviewed as part of this peer review. The results of the validation are not discussed in the hydrological modelling report, and as such have not been reviewed. As the outcome of the validation will be influenced by the hydraulic model development, it is recommended that the hydrological model validation is considered as part of the hydraulic model validation during the hydraulic model peer review, or revisited at a later date when the hydraulic modelling has been peer reviewed.

2.8 Design Events

All the design event runs required in the FHMS Procedure 2 (Hydrology) have been run. A range of storm durations have been considered. Results have been provided for the critical duration at each outlet. The modeller should clarify whether any longer durations e.g. 12 hours, 24 hours were tested when selecting the critical duration.

As required under Procedure 2 of the FHMS, the modelling results have been compared to other methods of estimating peak flow, including NIWA's flood statistics tool (referred to as the 2018 regional method), the 1989 regional method (McKerchar *et al.,* 1989), scaled frequency analysis of the Mangatārere at Gorge gauge and the rational method.

A comparison of the percentage difference between peak flows generated by the HEC-HMS model and the alternative methods is provided in Table 4 below. In Table 4, a negative percentage difference indicates that peak flows generated by the HEC-HMS model are lower than the alternative method, a positive value indicates that HEC-HMS model results are higher than the alternative method.

Table 4 Percent difference comparison of peak flow results between methods

Outlet	HEC-HMS outputs compared to:	Results			
		Rare (1% AEP)	Infrequent (5% AEP)	Frequent (20% AEP)	Very frequent (39% AEP)
Abbots Creek (outlet 0)	1989 Regional Method	-13%	-39%	-65%	-92%
	NIWA flood statistics tool (2018 regional method)	+21%	+4%	-15%	Event not included in NIWA analysis
	Scaled flood frequency analysis from Mangatarere at Gorge flow site.	-1%	-22%	-45%	-58%
'Large' sub-catchments (outlets 04, 05, 08 & 10)	NIWA flood statistics tool (2018 regional method)	+25% to +37%	+7% to +23%	-16% to +6%	-11% to – 39%
	Rational method	-14% to +10%	-42% to -9%	-88% to - 39%	-42% to - 139%

This comparison indicates that:

- The 1989 Regional Method (McKerchar, 1989) produces higher peak flows than the HEC-HMS model in all events at outlet 0. This method is not used for comparison at other outlets.
- The NIWA flood statistics tool (2018) produces lower peak flows than HEC-HMS in the 1% and 5% AEP events, and higher peak flows in the 20% and 39% AEP events. The lower peak flows for rare events have been noted in other catchments in New Zealand in other studies. As such, it does not necessarily indicate that the HEC-HMS results may be over-estimated during rare and infrequent events.
- The scaled frequency analysis of the Mangatārere at Gorge gauge produces a very close match for the 1% AEP event, however the HEC-HMS results are lower for more frequent events. The more frequent the event, the bigger the difference in results.
- The peak flows generated using the rational method are reasonably similar for the 1% AEP event, however the HEC-HMS peak flows are lower for all other events. The difference increases with increasing event frequency.

It should be noted peak flows in the HEC-HMS model are consistently lower than the alternative methods for frequent events. The modeller should comment on:

- Any explanation or justification for why alternative methods consistently estimate higher peak flows for the more frequent events.
- Whether there may be a higher level of uncertainty in the results of more frequent flood events.
- The modeller should also test one or two small catchments (i.e. outlets other than outlet 0, 04, 05, 08 and 10) using alternative methods to confirm whether alternative methods estimate higher peak flows in these catchments as well.

2.9 Sensitivity Analysis

Sensitivity analysis has been undertaken to test:

- Rainfall duration
- Rainfall temporal profile
- Rainfall loss (curve number)
- Rainfall loss (initial abstraction)
- SCS unit hydrograph peak rate factor
- SCS unit hydrograph lag
- Channel routing – roughness

This analysis covers all of the key model parameters. There are no concerns with this analysis.

It is requested that the modeller adds a comment in the report under each sensitivity test to explain the significance of the results. For example, are there any parameters that are highly sensitive that should be considered in the uncertainty analysis of the hydraulic model?

2.10 Uncertainty and Limitations

The report covers off the limitations of the modelling in terms of:

- Uncertainty of the recorded flood hydrographs used for calibration in the Mangatārere catchment.
- Variability of spatial distribution of rainfall in the catchment.

As outlined in the section above, the modeller should add comments on the potential under-prediction of frequent events compared to alternative methods. It is noted that the alternative methods are simplistic and not physically based, however some commentary around this would be helpful.

3. Data Gaps/Model Improvements

- Absence of gauged flow data is a limitation to the model. Following a significant flood event, it would be beneficial to survey flood levels to enable calibration or validation of the Donald and Abbots Creek model.
- An alternative flow gauging site could be considered within the Donalds or Abbots Creek catchment. The modeller should fill out the hydrometric feedback form.

4. Summary

Table 5 below summarises the outcomes of this peer review.

The reviewer also noted that validation will be undertaken as part of the hydraulic modelling. As such, there may some iterations / required changes to the hydrological modelling at that time. This item can be signed off later.

The outcome of this review is **Action Required** to provide some further justification and commentary regarding some modelling decisions, significant changes are not expected to be required.

Table 5 Peer Review Summary

Scope	Round 1 review rating	Comment	Round 2 review rating	Comment
Documentation	Major	Documentation not yet complete or has not been provided.	Minor	Documentation and reporting are thorough. Some further commentary is requested.
Schematisation	Minor	Justification for using the Clark unit hydrograph routing method with the SCS curve number loss method required.	Ok	The model schematisation is appropriate.
Input data review	Major	More information required on the appropriateness of the Mangatarere catchment as source of input parameters. Commentary required on limitations of the data used in the Mangatarere model and how this may impact results.	Major	More information / commentary required on rainfall analysis.
Model inputs	Major	Model not yet provided.	Minor	More information required on curve number selection and application of baseflow.
Rainfall	Minor	Appears acceptable based on the report, however the model has not yet been provided.	Ok	Data used is appropriate and appears to have been applied correctly.
Model Build	Major	Model not yet provided.	Ok	No issues identified.
Run Parameters	Major	Model not yet provided.	Ok	No issues identified.
Calibration	Ok	The Donald and Abbots Creek model is not calibrated due to lack of suitable calibration data. The model parameters are based on the calibrated model of the Mangatārere catchment.	Ok	The Donald and Abbots Creek model is not calibrated due to lack of suitable calibration data. The model parameters are based on the calibrated model of the Mangatārere catchment.
Validation	Major	Model not yet provided. More information required.	Major	Validation will be undertaken in the hydraulic model.
Model Runs	Major	Model not yet provided.	Minor	Please confirm whether the 12- and 24-hour events have been tested for critical duration.
Results	Major	Model not yet provided.	Major	Further commentary required regarding comparison to alternate methods.
Sensitivity Test	Major	Model not yet provided.	Minor	Additional commentary required.
Outputs	Major	Model not yet provided.	Ok	Outputs appear suitable.

5. References

Greater Wellington Regional Council, May 2021. Flood Hazard Modelling Standard (FHMS).

Land River Sea Consulting (2023). Donald's Creek and Abbots Creek Hydrological Assessment [Preliminary Draft]. By Tom Kerr. Prepared for Greater Wellington Regional Council. Dated August 2023.

Land River Sea Consulting (2023). Donalds Creek and Abbots Creek Hydrological Assessment. By Tom Kerr and Matthew Gardner. Prepared for Greater Wellington Regional Council. Dated November 2023.

Appendices

Appendix A Peer Review Spreadsheet

Hydrology Peer Review

Element	Review - V1 (Review of preliminary draft - starting point for discussion with reviewer before completion of the modelling and report) (04/09/2023) Reviewers Comments	Review rating	Modellers comments - V1 (13/09/2023) Modellers Comments	Review - V2 (13/12/2023) Reviewers Comments	Review rating
Overall comment	The overall approach to modelling seems reasonable, particularly given the data limitations. The model has not been sighted and the report is only preliminary draft and is not yet complete - in a number of places the review rating is set to 'major' because the information required to complete the review is not yet available. The report would benefit from a section early in the report that explains the approach to modelling given the data limitations (i.e. unable to calibrate, validate with the 2018 event).	N/A	Noted - will provide description of approach in introduction	The overall approach to modelling is reasonable given the data limitations. The modeller should clarify whether the extent of the model and outlet locations are meet the hydrualic modellers needs.	N/A
Documentation					
Model log is complete and up to date	Not yet provided	Major	Noted - to be provided	The model log has been provided, and applies the template from the FHMS, modified to be suitable for the software used.	Ok
All run descriptions are complete	Not yet provided	Major	Noted - to be provided	Runs are described in the model log	Ok
Limitations and assumptions are clearly stated	Assumptions and limitations are documented in the preliminary report, but not complete as report is only an (incomplete) preliminary draft.	Major	Noted - to be provided	The report is throrough and documents major limiations and assumptions. Some further commentary is requested in some of the items below.	Minor
Sufficient information has been provided regarding modelling decisions	Modelling decisions are documented in the preliminary report, but not complete as report is only an (incomplete) preliminary draft.	Major	Noted - to be provided	The report is throrough and documents major modelling decisions. Some further commentary is requested in some of the items in the rows below.	Minor
File naming convention is clear and consistent with requirements of the FHMS (procedure 2)	Model not yet provided	Major	Noted - to be provided	The model naming convention is generally in accordance with the FHMS (depatures due to structure of the model software).	Ok
Schematisation					
The software used is appropriate	The model has been developed in HEC-HMS v 4.11. This is a suitable software package and is the most recent version.	Ok		The model has been developed in HEC-HMS v 4.11. This is a suitable software package and is the most recent version.	Ok
The loss model used is appropriate	The SCS curve number method is used. This is considered appropriate.	Ok		The SCS curve number method is used. This is considered appropriate.	Ok
The transformation method used is appropriate	Please provide justification for using the Clark Unit Hydrograph with the SCS method rather than the SCS unit hydrograph.	Minor	Clark and SCS transform methods have now been compared (give similar results) and will be discussed in report.	Ok	Ok
The routing method used is appropriate	The channel routing method used is the Muskingum-Cunge method. This is considered appropriate.	Ok		The channel routing method used is the Muskingum-Cunge method. This is considered appropriate.	Ok
Input data review					
Review of input data availability and quality (e.g. flow gauge, rainfall data, historic flood information) has been undertaken, and is documented.	**Rainfall:** analysis is appropriate: rainfall records have been reviewed including assessment of spatial variation with respect to elevation. Spatial variation of HIRDS rainfall was also compared. Rain radar also extracted. **Flow**: Otukura at Weir site was reviewed and found not to be suitable. Other sites were reviewed. More information should be provided on the suitability of the selected gauge site. Note that Mangatarere flow gauges are not flood rated. Commentary should be provided on how this may impact confidence in model outputs. **Historical flood data:** reviewed flood photos and rainfall from 2018 event. **Other:** more information on how the catchment compares to Mangatarere may be beneficial since the Mangatarere calibration parameters are used.	Major	Will provide details on catchment comparison and quality and limitations of Mangatarere at Gorge flow gauge.	**Rainfall:** the 4-hour duration was selected for the HIRDS comparison to frequency analysis, presumably because the 4-hour duration is the critical duration for the higher AEPs. Is the data included in the frequency analysis only for 4-hour events or for all durations? All HIRDS estimates except Waiohine at Gorge are higher than the at-site frequency analysis (Figure 5-9). Please provide some commentary on why this might be, and whether the rainfall inputs could be too high. **Flow:** Ok **General:** It would be helpful to have a table in the report to summarise input data quality - this would cover off this requirement of the FHMS.	Major
quality are appropriate	Yes.	Ok		Yes.	Ok
Methods used to assess flow gauge data are appropriate	Yes, but incomplete. Commentary on the gauges used in the Mangatarere model should be provided, and how the limitations associated with data quality may impact the model results.	Major	Will provide details on data quality and implications.	The methods used to assess the data are approriate.	Ok

Topographic data				To cover off the requirement to assess the quality of this data in the FHMS, please add a line to the report on whether the resolution of the data is suitable for this work, and whether any errors in the DEM were noticed.	Minor
Methods used to assess catchment and historical flood data are appropriate	Yes.	Ok		Commentary on when the 2018 photos were taken would be helpful if known. Is there any more detail known, beyond that they were taken near the peak?	Minor
Model inputs					
Is the model referencing the correct input files?	Model not yet provided	Major	Noted - to be provided	Yes. Noted that Gorge and Valley Hill dss files in the Mangatarere mode	Ok
Sensibility check of sub-catchment parameters (e.g., catchment area, slope etc.)	Model not yet provided	Major	Noted - to be provided	Appear sensible	Ok
Antecedent conditions are appropriate	Model not yet provided, Antecedent conditions not mentioned in report.	Major	Discussed briefly with reviewer. Neutral conditions will be used for design.	Ok	Ok
Loss parameters are realistic based on catchment soil drainage properties and land cover	Selection of loss parameters are based on calibrated model for the Mangatarere catchment. This is likely appropriate. The report states that the CN selection uses the same criteria as the Mangatarere model, but these criteria should be spelled out in the report to prevent this report having to be read in conjunction with the Mangatarere report for key model parameters. Report also states that CN values are based on CN maps developed by Wellington Water but these maps don't cover the Wairarapa region. Updated Wellington Water maps provide land cover and soil drainage maps rather than CN maps - please confirm what was used.	Major	Will clarify in report basis for CN selection. 2019 WWL CN maps were used and applied to Donalds and Abbots catchment adjacent to the CN map boundary. (ie inferred) Will compare curently adopted CN values with LENZ Soil Drainage maps and vegetaion cover maps for the catchment.	Why do indigenous forest and exotic forest have different CNs? Would indigenous forest not have a lower curve number than exotic, given likely denser understory than exotic (presumably planted pine?)	Minor
Transform parameters (e.g. time of concentration, storage coefficient etc or equivalent) are appropriate	Model not yet provided	Major	Noted - to be provided	Reasonable	Ok
Other input parameters used are appropriate (if any)	The report notes that the Mangatarere sub-basin transform parameters caused too much attenuation in the model. How was this assessed? Please describe how this was determined and how the revised transform parameter was selected?	Major	Both Clark UH and SCS UH transform calibrated parameters for Mangatarere create too much attenuation for Abbots and Donalds.	Baseflow - 4 m3/s applied in Mangatarere - what is this based on? Just calibration? No baseflow applied in Donald/Abbots - what is this based on? Why do some sub-catchments have 0.5% impervious area?	Minor
Rainfall					
Rainfall data used is appropriate (e.g., selection of gauge, interpolation between gauges, etc.)	Yes.	Ok		Yes.	Ok
Temporal pattern applied is appropriate for the purpose of the modelling	Yes. HIRDS v4 temporal patterns for 'east of north island' parameters were used for modelling of design storms.	Ok		Yes. HIRDS v4 temporal patterns for 'east of north island' parameters were used for modelling of design storms. Temporal pattern for validation based on gauge data from the validation storm.	Ok
Method of generating design rainfalls for frequent, intermediate and rare events is appropriate	Yes.	Ok		Yes.	Ok
Method of extrapolating very rare event (0.1% AEP) rainfalls is appropriate	Yes.	Ok		Yes.	Ok
Areal reduction factors have been applied appropriately	Yes, based on the report. Model not yet sighted.	Minor	Model to be provided.	Ok	Ok
Climate change has been applied to the model correctly	Yes, based on the report. Model not yet sighted.	Minor	Model to be provided.	Ok	Ok
Model Build					
Sub-catchment delineation and sizes are appropriate	Model not yet provided. Sub-catchment delineations look appropriate based on maps in report.	Minor	Model to be provided.	Ok	Ok
Sub-catchments are linked to the appropriate node	Model not yet provided	Major	Model to be provided.	Ok	Ok
Input parameters have been applied to sub-catchments correctly?	Model not yet provided	Major	Model to be provided.	Ok	Ok
Rainfall has been applied to sub-catchments correctly?	Model not yet provided	Major	Model to be provided.	Ok	Ok
Run parameters					

Initial conditions are appropriate	Model not yet provided	Major	Model to be provided.	Ok	Ok
Run parameters are appropriate	Model not yet provided	Major	Clark and SCS transform methods have now be	Ok	Ok
Run times are reasonable and the simulation period is correct	Model not yet provided	Major	Model to be provided.	Ok	Ok
The model timestep is appropriate	Model not yet provided	Major	Model to be provided.	Ok	Ok
Error, warning and check messages have been addressed	Model not yet provided	Major	Warning message for Muskingum-Cunge metho	Ok	Ok
Calibration					
Where a catchment is gauged, the quality of the flow record/ rating curve has been reviewed.	The model is not calibrated due to lack of suitable calibration data. The model parameters are based on the calibrated model of the Mangatarere catchment. The Mangatarere model has been thoroughly peer reviewed, and will not be reviewed again as part of this review.	Ok		The quality of the Mangatarere at Gorge flow data has been assessed. The data from the 2017 flood is questionable due to damage to the gauge site during the event. This event wasn't used for calibration.	Ok
Is the calibration source data appropriate for use?		Ok		The data from this gauge is suitable for calibration, in the absence of anything better. The highest gauged flood is relatively low (~2 x the MAF).	Ok
Is the approach to calibration appropriate?		Ok		Yes. Using a donor catchment to provide parameters for the Donald and Abbots Creek model is a sensible approach.	Ok
Has the approach to calibration been applied to the model correctly?		Ok		Ok	Ok
Does the data used for calibration match the source data?		Ok		Ok	Ok
Has the model been satisfactorily calibrated?		Ok		Ok	Ok
Validation					
Is the approach to validation appropriate?	The approach to validation is reasonable given the limited data available within the catchment.	Ok		The approach to validation is reasonable given the limited data available within the catchment.	Ok
Has the approach to validation been correctly applied to the model?	Model not yet provided	Major	Model to be provided.	Ok	Ok
Is the validation source data appropriate for use?	Yes. There is no suitable gauged flow data within the catchment, as such the validation has been undertaken using 2D HEC-RAS modelling to compare flood extents to photography of the 2018 event. **The hydraulic model has not been reviewed.**	Minor	The intention is that results from the Tuflow model will be used to help with validation of the runoff model for this event. At that point the HEC RAS model will be redundant and will be removed from the report.	How were the temporal patterns from the gauges assigned to the sub-catchments? (please record decision)	Minor
Does the data used for validation match the source data?	Model not yet provided	Major	Model to be provided.	Ok	Ok
Has the model been validated successfully?	More information required - model appears to over-estimate maximum water levels in the detention structure. Commentary on why this might be should be provided. Is it due to the hydrology, or limitations of the HEC-RAS model of the floodplain? Should the validation be re-visited when then Tuflow model is built?	Major	HEC HMS model to be tweaked if necessary when Tuflow results are available for the 02DEC2023 validation event.	The results of the validation are not discussed as the validation will occur in the hydraulic model. Please update the report to explain this and that this will need to be revisited (perhaps iteratively) when the hydraulic model is developed.	Major
Model Runs					
Have the full suite of design runs (see FHMS Procedure 2) been run?	Model not yet provided	Major	Model to be provided.	Yes.	Ok
Have a range of storm durations been considered, and are the durations selected appropriate?	Six durations were run (1,2,3,4,5 and 6 hr). The 4 hour duration produced the largest peaks.	Ok		Six durations were run (1,2,3,4,5 and 6 hr). The 4 hour duration produced the largest peaks at most larger sub-catchment in most AEPs. Have the 12 and 24 hour events been tested?	Minor
Have the correct inputs been applied to the various runs?	Model not yet provided	Major	Model to be provided.	Aereal reduction factors and HIRDS temporal pattern applied.	Ok
Results					
Are peak flows within the expected ranges?	Not yet provided	Major	Noted - to be provided	See Row 68	Major
Are volumes within the expected range?	Not yet provided	Major	Noted - to be provided	Ok	Ok
Sensibility check of hydrograph shape	Not yet provided	Major	Noted - to be provided	Ok	Ok

Results are comparable to alternate methods such as regional flood frequency method and/or frequency analysis, or departures can be justified.	Not yet provided	Major	Noted - to be provided	Results were compared to the regional method, NIWA's river flood statistics tool and scaled flood frequency analysis from the Mangatarere catchment. Results are much lower in the NIWA tool however this has been noted in relation to this tool across other catchments in New Zealand in other studies. Results have a larger departure (predominately potential under-estimation) in smaller (more frequent AEPs). Please provide some justification for this in the report.	Major
Output timeseries are provided in a format appropriate for input into hydraulic models.	Not yet provided	Major	Trial data has been provided for input to Tuflow model. So far OK	Based on modellers comments regarding sucessful trial in Tuflow model.	Ok
Sensitivity Test					
Has sensitivity testing been undertaken?	Not yet provided	Major	Noted - to be provided	Yes	Ok
Are the parameters selected for sensitivity testing (e.g. land use change, antecedent conditions, temporal pattern) appropriate?	Not yet provided	Major	Will provide list of planned sensitivity tests prior to modelling	Yes, key input parameters have been tested.	Ok
Have the changes to the sensitivity parameters been applied to the model correctly?	Not yet provided	Major	Noted - to be provided	Ok	Ok
Are the results of the sensitivity test results in line with expected behaviour?	Not yet provided	Major	Noted - to be provided	Yes, but please provide a sentence or two under each sensitivity test in the report relating to the significance of the results. i.e. are any parameters highly sensitive, should any of these parameters be taken forward to inform sensitivity/uncertainty analysis of the hydraulic model?	Minor
Output timeseries are provided in a format appropriate for input into hydraulic models.	Not yet provided	Major	Noted - to be provided in more detail. A sample output from HEC HMS has been sent to SLR for input to Tuflow.	Marked as 'ok' pending feedback from SLR	Ok
Outputs					
Have output hydrographs been prepared for all runs?	Not yet provided	Major	Noted - to be provided	Yes	Ok
Is the output format likely to be appropriate for input into the hydraulic model?	Not yet provided	Major	Noted - to be provided	Based on modellers comments regarding sucessful trial in Tuflow model.	Ok

Stantec New Zealand
Level 5, 25 Victoria Street, Petone 5011

PO Box 13-052, Armagh, Christchurch 8141
Tel +64 7 839 0241

Donalds and Abbots Creek

Hydraulic modelling

Greater Wellington Regional Council

P O Box 11 646
Manners St
Wellington 6142

Prepared by:

SLR Consulting NZ Ltd

12A Waterloo Quay, Wellington 6011, New Zealand

SLR Project No.: 820.V300278

15 July 2024

Revision: V1.0

Making Sustainability Happen

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
V1.0	15 July 2024	Oliver Anderson	Charlotte Lockyer	Charlotte Lockyer

Basis of Report

This report has been prepared by SLR Consulting NZ Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Greater Wellington Regional Council (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

Executive Summary

A TUFLOW™ computational hydraulic model was built for the floodplain area of the Donalds and Abbots Creek catchments. The model was constructed in accordance with Greater Wellington Regional Council's (GWRC) Flood Hazard Modelling Standard. This report has been developed outline the hydraulic model build to fulfil Part A of Procedure 4. Following peer review, this report will be amended to include details of the model validation, sensitivity analysis, design runs, hazard runs and freeboard.

The model was calibrated to an assumed flood level and flood photos of the 2 December 2018 rainfall event, which was a short and intense localized storm over Featherston. From the Land River Sea Consulting Ltd (LRSC) report, this event resulted in 67.2mm of rainfall recorded at the Featherston at NRFA gauge which is estimated to have an average recurrence interval (ARI) of greater than 85 years. It is estimated that peak flood level at the Harrison Street detention basin for this event had an ARI of approximately 50 years. Only information from one event was available for calibration and there is no flow/water level data within the catchment to support more detailed analyses.

The hydrologic inputs for calibration were provided by LRSC and included:

- Flow hydrographs at sixteen locations along the foothills of the Remutaka Ranges. These were produced using a HEC-HMS hydrologic rainfall runoff model for the December 2018 event and served as inflows to the hydraulic model.
- A 1 km^2 grid of total rainfall depths across the plains area for the December 2018 event and an associated temporal pattern. These were used to generate a time-varying rainfall grid to apply rainfall across the hydraulic model domain.

During the model build process, various parameters such as culvert conveyance, rainfall initial and continuing losses, and the hydrologic inflows were tested for sensitivity. The model was found to be particularly sensitive to hydrologic inflows. Given a degree of uncertainty regarding the rainfall depths applied to both LRSC's hydrologic model and the hydraulic model, a decision was made to decrease rainfall in both models for the December 2018 calibration event by 13% to align with observations. This decision was made in consultation with GWRC and LRSC's hydrologist.

Once all parameters of the model had been finalised, the resulting model generated a peak flood height of 38.56m (NZVD 2016) at the Harrison Street detention basin during the calibration event. This fit well with anecdotal flood evidence provided by GWRC, which indicated a peak flood height of 38.5m +/-0.2m. Model results closely matched flood photography which supports the applied parameters.

Table of Contents

Appendices

1.0 Introduction

Greater Wellington Regional Council (GWRC) have engaged SLR Consulting New Zealand (SLR) to construct a hydraulic flood hazard model for Featherston, a small community in the Wairarapa Valley (**Figure 1**).

On a number of occasions historically, and some more recently, Featherston has suffered from severe and widespread flooding. Flooding has resulted from surface ponding caused by direct rainfall onto sodden ground, and riverine overflow due to high flows in several waterways. The largest of these waterways are Donalds Creek and Abbots Creek.

Donalds Creek in particular is a focus for this flood hazard assessment, as the robustness of existing flood mitigation structures are of interest. These structures include stretches of stopbanks, as well as the detention basin on Harrison Street East.

1.1 Activities and Scope

The Featherston community is at risk of pluvial flooding from direct rainfall, as well as fluvial flooding as a result of overflows from several local waterways. The scope of works for this flood hazard assessment is to:

- Develop a two-dimensional (2D) TUFLOW™ computational hydraulic model of the existing Featherston area. The model will use a 'rain-on-grid' approach to apply rainfall across the floodplain areas, and stream flows will be applied at various 'outlet' points from the Remutaka foothills.
- Calibrate the TUFLOW model using anecdotal data (e.g. observed peak flood levels etc.) from the December 2018 flood event.
- Validate the model by comparing results of inundated areas to post-event (December 2018) photographs to confirm flooding is occurring in expected areas.
- The modelling is developed in accordance with GWRC's Flood Hazard Modelling Standard (FHMS).

1.2 Catchment Overview

The Donalds Creek catchment comprises an area of 52 km^2 and extends from headwaters in the Remutaka Range to the northern end of Lake Wairarapa (**Figure 1**). Featherston is located near the centre of the catchment at the base of the Remutaka foothills.

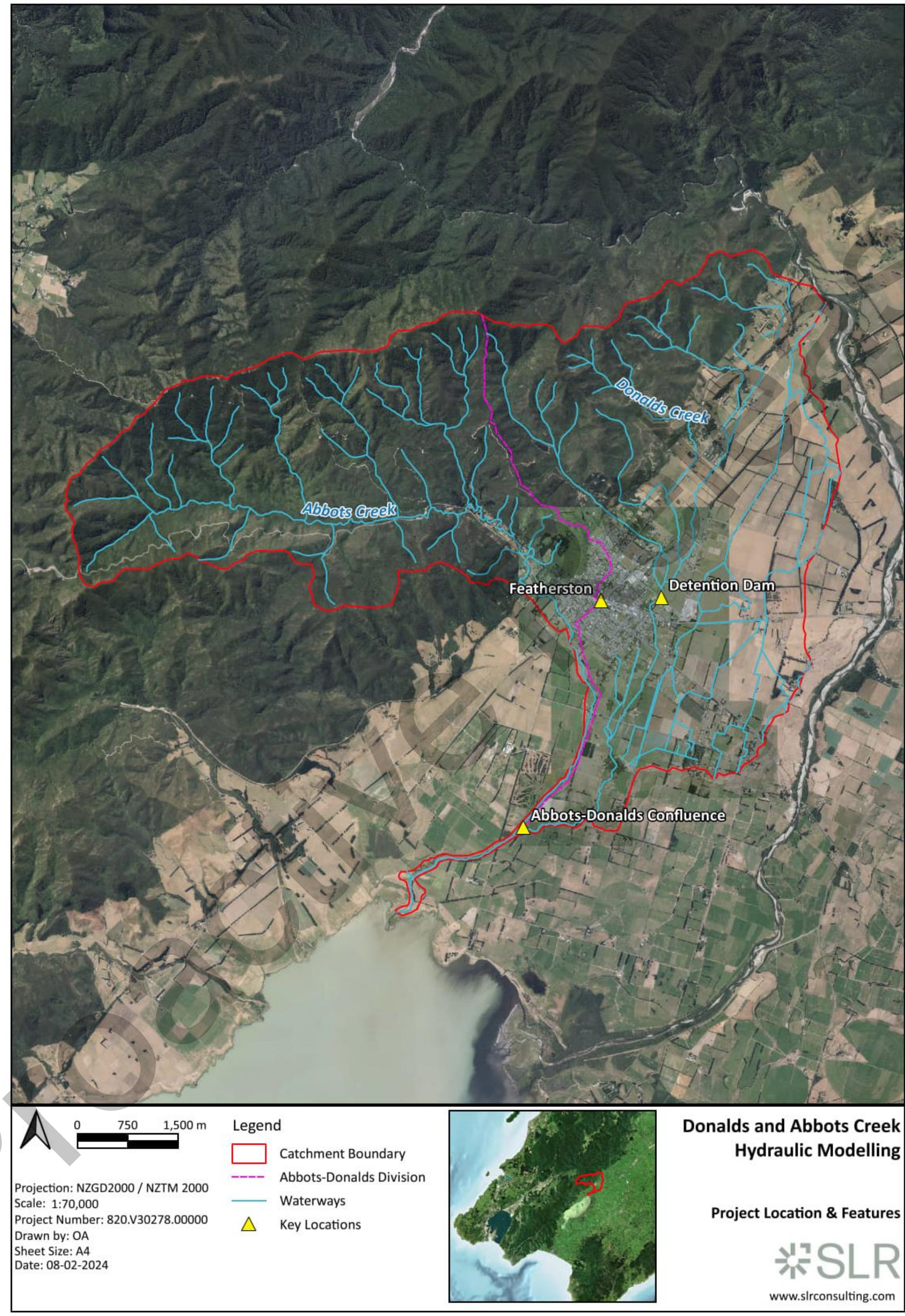

Figure 1 Project location and key features

1.2.1 Hydrology

Donalds Creek and Abbots Creek are the predominant waterways in the catchment and pose a flood risk to the Featherston community. These waterways converge south of Featherston and flow into Lake Wairarapa. The creek confluence location is shown in **Figure 1**, along with a division line indicating the separation of the respective catchments.

Donalds Creek flows southwards, through the eastern edge of Featherston from headwaters to the north. This creek has a total catchment area of 22.5 km^2 upstream of its confluence with Abbots Creek.

Abbots Creek initially flows east from headwaters in the Remutaka Range west of Featherston. Towards the foothills, Abbots Creek begins to turn southwards and exits onto the floodplains at the eastern edge of Featherston. Along the floodplain, Abbots Creek continues to curve around and adopts a southwest flow path. The total catchment area upstream of the confluence with Donalds Creek is 23 km^2.

Boar Creek is a relatively large tributary to Donalds Creek with a catchment area of 4.2 km^2. The creeks converge immediately upstream of the Harrison Street detention basin. Along with Boar Creek, there are numerous unnamed tributaries that convey flow into Donalds Creek and Abbots Creek.

1.2.2 Topography

The catchment is divided into two very distinct topographical zones, these being the mountains and the floodplain. **Figure 2** shows a LiDAR derived digital elevation model (DEM) for the catchment. This DEM combines 2013 LiDAR for the entire catchment with 2023 LiDAR for the Featherston and downstream Donalds Creek and Abbots Creek areas.

The mountains of the Remutaka Range, northwest of Featherston, are formed by tectonic activity of the Wairarapa Fault and rise to almost 800 metres above sea level (m asl) within the catchment. This upper catchment area is characterised by steep sided river valleys interspersed by long ridgelines.

From the base of the Remutaka foothills, the topography of the catchment is generally flat, with small, low-lying topographic highs, active stream channels and abandoned paleochannels. This is typical of the extensive Wairarapa Valley floodplains.

Because of the tectonic nature of the landscape, the transition from steep mountainous terrain to flat floodplains is remarkably rapid.

While the topography is largely the result of natural processes, anthropogenic activity has also impacted the landscape. Manmade topographic features of the catchment include flood mitigation assets such as stopbanks and the detention dam, opencut drains and transport infrastructure including the local roads and the railway, which in places are elevated above the natural floodplain.

1.2.3 Climate

Climate in the Donalds Creek catchment is influenced by the surrounding topography, principally the Remutaka Range. The peaks of the Remutaka Range, when interacting with the prevailing westerly winds, induce orographic forcing. This results in high rainfalls in the west and over the range and comparably drier conditions across the eastern plains. This means that the upper catchment, northwest of Featherston, is susceptible to extremely high amounts of rainfall, while moving east total rainfall decreases.

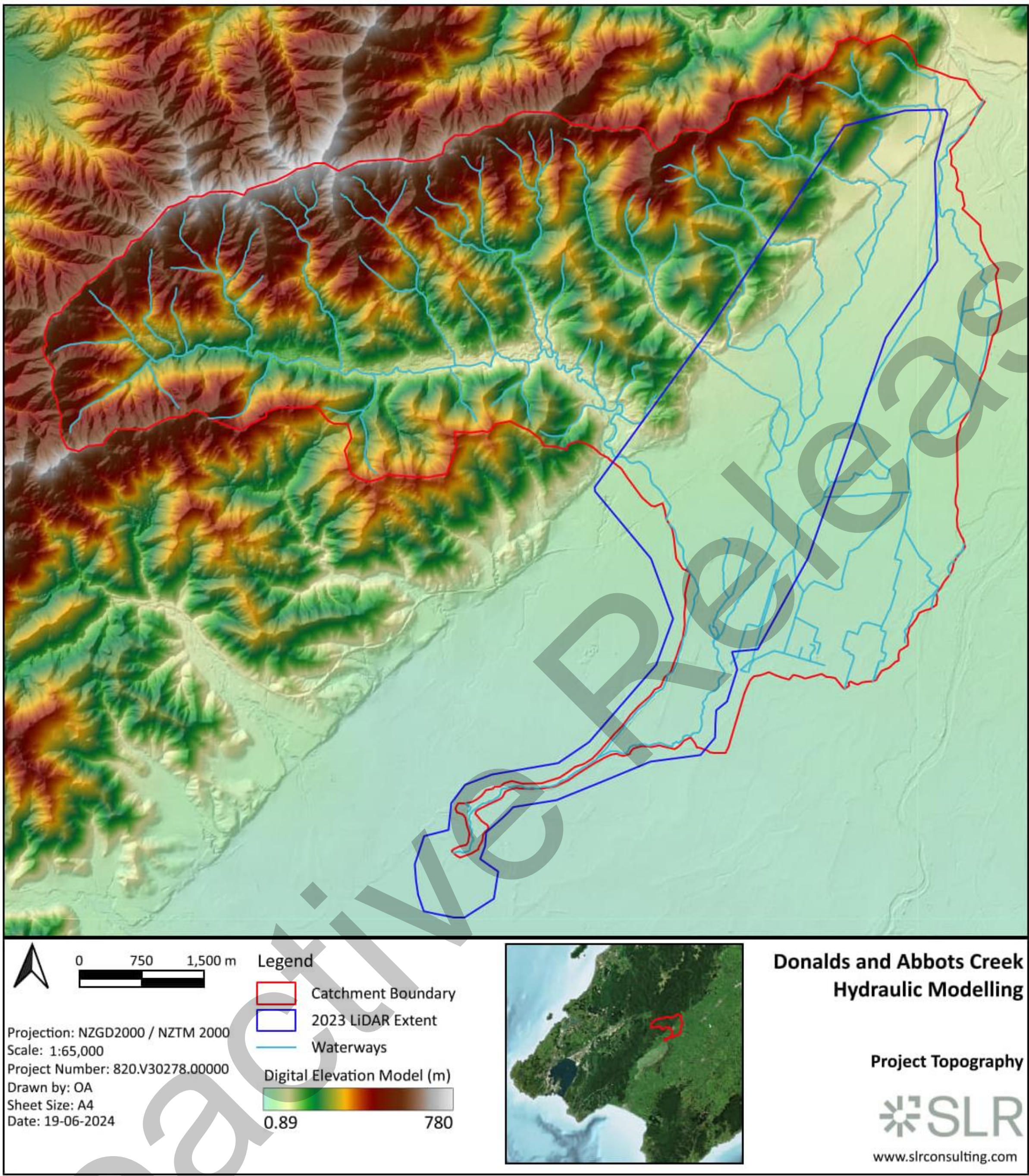

Figure 2 Local topography

1.2.4 Land Use

The mountains and foothills of the Remutaka Range consist predominantly of dense native forest and scrub. Few small areas of pasture are present in the valley alongside the lower reaches of Abbots Creek prior to it opening up into the floodplain. Transport infrastructure in the form of State Highway 2 traverses the southern hillside of the Abbots Creek upper catchment.

Land use across the floodplain is more variable, though primarily consists of pasture used for dairy, and non-dairy stock grazing and cropland. Patches of forest and scrub are scattered around the floodplain, typically near the numerous watercourses that exit the mountains. The Featherston township represents urban land use in the catchment and comprises an area of approximately two square kilometres. The transport infrastructure network spreads across the floodplain, and consists of sealed and gravel roads, and the railway line.

1.2.5 Soil Type

The soil type classification for the majority of the catchment is orthic brown (Manaaki Whenua Landcare Research, 2023b). Brown soils are the most common soil type in New Zealand, accounting for 43% of the country's soil, and orthic brown is typical of the lower North Island. Along the Abbots Creek valley floor, upstream of Featherston, allophanic brown soils are prevalent. Allophanic brown soils are also present in the foothills towards the northeast corner of the catchment.

Recent fluvial soils are present on the floodplain northeast of Featherston and in vicinity of Donalds Creek. These are soils that have been deposited by flowing water and are typical of alluvial floodplains such as this. Recent fluvial soils also dominate the catchment south of Featherston along Donalds and Abbots Creeks.

While the physical properties of the three soil types present within the catchment vary, they have similar hydraulic properties, including 'moderate' porosity.

1.2.6 Geomorphology

The presence of fault-lines and the formation of the lower catchment landscape on alluvium mean that geomorphic change in the catchment can occur over relatively short time scales. Changes in the topography can be caused by seismic activity and the gradual erosion and migration of streams may affect the size, location and direction of channels.

2.0 Available Information

2.1 Previous Work

Greater Wellington Regional Council provided SLR with a number of existing documents pertaining to Donalds Creek. These are listed below in **Table 1**. Further detail pertaining to these reports are included in the Data Register spreadsheet.

WSP Opus (2018A) provided a level-storage curve and level-discharge information, as well as peak flood heights and flows at the detention basin structure for a range of design events. These peaks were generated by routing rainfall through a HEC-HMS hydrologic model.

Table 1 Previous study documents provided by GWRC.

	Document	Year
1	Donalds Creek Flood Protection Project Design Report August 1998.pdf	1998
2	Donalds Creek Flood Protection Project As-built Drawings 1998.pdf	1998
3	Donalds Creek Flood Protection Project Assessment of Environmental Effects August 1998.pdf	1998
4	Donalds Creek review SH53 to Confluence 19-4-06.docx	2006
5	Donalds Creek Works between SH53 and the confluence with Abbots creek.docx	2006
6	PGWES Hydrological assessment of Donalds Creek 2016.pdf	2016

	Document	Year
7	Donald's Creek – Memo of site visit recommendations Dec 2017.docx	2017
8	Donalds Creek Detention Facility – Hydrological Analysis July 2018.pdf	2018
9	Donalds Creek Detention Facility – Hydrological Analysis Phase 2 Aug 2018.pdf	2018
10	Donalds Creek Detention Facility FMEA memo Sep 2018.pdf	2018
11	Donalds Creek Opus Memo on HIRDS Oct 2018.pdf	2018
12	Donalds Creek Post-Event Appraisal (FINAL) Dec 2018.docx	2018
13	Brookside Developments – Flood-Assessment-Stage-2-3-Report-3-July-2020-1.pdf	2020
14	Draft AMP Contents for Donalds Creek.docx	2022

The Wellington Regional Council (1998) (Document 1 in **Table 1**) provides an assessment of Donalds Creek flood hydrology. This assessment included the construction of a rainfall runoff model to simulate various design inflows at the Harrison Street detention structure. Peak water levels at the detention structure were also estimated using the regional flood frequency method.

WSP Opus (2018) (Document 9 in **Table 1**) provides an updated assessment of flood hydrology for Donalds Creek which included development of a calibrated HEC-HMS rainfall runoff model. This hydrologic model also provided estimates for peak water levels at the Harrison Street detention structure.

The estimated peak flood water levels provided in the two documents above are outlined in **Table 2**.

Table 2 Estimated peak flood levels at the Harrison Street detention basin (Wellington Regional Council, 1998; & WSP Opus, 2018).

AEP	Peak Flood Level – Detention Basin at Culvert (m)	
	WRC (1998)	WSP Opus (2018)
0.05 (50%)	-	37.87
0.02 (2%)	38.78	38.36
0.01 (1%)	39.00	38.67

2.2 Hydrologic Data

Hydrologic data is required as input to the computational hydraulic model. GWRC engaged LRSC to undertake the hydrological analysis to generate inflow data for the TUFLOW™ model.

As a result of the hydrological analysis, SLR was provided with the following hydrologic data:

- Flow hydrographs, generated by a HEC-HMS rainfall runoff model, for the 2 December 2018 event at 16 outlet locations along the foothills. Only one event was available for model calibration;
- Flow hydrographs, generated by a HEC-HMS rainfall runoff model, for 0.1%, 1%, 2%, 5%, 10%, 20% and 39% AEP design events, as well as RCP 6.0 climate scenarios for the same seven design events.

- 1 km^2 grid rainfall totals, obtained from RADAR, for the December 2018 event; and
- A temporal distribution for the December 2018 and design events, derived for the floodplain using data from the NFRA Featherston rain gauge.

Design rainfall depths for across the floodplain are yet to be provided.

These data, and the methodologies implemented in their generation and acquisition, have been peer reviewed. As such, SLR is confident that the data provided is reasonable, to industry standard, and suitable for use in the hydraulic model.

2.3 Historic Flood Data

Greater Wellington Regional Council provided photographs and videos of flooding following two rainfall events. These were the 2 December 2018 and 12-13 July 2022 storms. Photographs from the December 2018 event were not timestamped, so it is unclear whether peak flood conditions have been captured. Flood photos from the July 2022 event are intending to be used to validate model parameters during the Part B phase, following peer review. No further information was available or deemed suitable for model calibration or validation.

2.4 Topographic Data

The 2013 DEM was collected via the Land Information New Zealand (LINZ) Data Portal, while 2023 DEM was provided by GWRC. Both have a one metre resolution and were developed from LiDAR, flown for the Wellington Region and processed to New Zealand Vertical Datum 2016. The 2023 LiDAR provided a more up-to-date representation of the local topography, and had been more effectively post-processed, meaning more vegetation had been burnt out of the DEM to more accurately represent the hydraulic connectivity.

The quality of the two DEM's have been reviewed by comparing topographic structures to evidence of their existence based on aerial imagery dated 31/06/2021. For the majority of the relevant area, the DEM accurately represented the terrain. In some isolated areas, tree cover has not been filtered from the DEM's. This is a quality issue as it results in untrue and unrealistic landforms which can alter flow paths. This has been addressed in the model by modifying the topography using gully lines (further details in section **3.2.5**).

2.5 Structures and asset information

Structures and asset information was available through several sources as outlined below:

- Greater Wellington Regional Council
  - South Wairarapa District Council stormwater asset shapefile including culvert locations, lengths, diameters, materials and shapes. Data was assumed correct and not independently verified.
  - Surveyed information of the detention dam structure, culverts, flood protection assets and stream channel. Surveying was undertaken in 1993 and drawings/plans are contained with Document 2 of **Table 1**, and 22 'TIF' files.
  - Surveyed culvert details including lengths, widths, heights and inverts. Surveying was undertaken in December 2023 for the following culverts:
    - Donalds Creek at Underhill Road;
    - Donalds Creek at Harrison Street;

- Donalds Creek at Fitzherbert Road;
- Donalds Creek at Revans Street;
- Boar Creek at Underhill Road; and
- Abbots Creek at Western Lake Road.

– Surveyed bridge details for one location downstream of the Harrison Street culvert, including soffit and deck heights, and railing specifications. Surveying was undertaken in December 2023.

- Waka Kotahi, New Zealand Transport Agency
  – Stormwater drainage assets spreadsheet including culvert locations, lengths, diameters, materials and shapes. Information had typically been updated between 2009-2021. Asset information was not suitable for use because asset locations were in the form of point coordinates, with no information regarding entry or exit points. 116 out of the 155 listed stormwater drainage assets had no coordinates at all.
- Kiwi Rail
  – Wairarapa line bridge 47 drawings and photographs. Latest bridge inspection and detailed report occurred in 2019.
  – Wairarapa line culvert information including diameters and materials. Latest culvert inspections occurred in 2020. Asset information for Wairarapa line culverts could not be applied to the model due to the absence of information regarding entry and exit points.

3.0 Model Build

3.1 Model Build Overview

The two-dimensional (2D) computational hydraulic model was constructed using TUFLOW™ (build 2020-10-AD), which is an industry standard hydrodynamic modelling software.

TUFLOW™ is also strongly compatible with QGIS, the geographic information system (GIS) that was implemented in the model build process. The QGIS TUFLOW plugin allowed for the initial model setup to be completed in QGIS. This setup included creation of template folders for organizing model files, creation of TUFLOW 'empty' files for model input layers and defining the coordinate reference system for the model, inputs, and results. The New Zealand Transverse Mercator 2000 coordinate reference system was selected.

A grid cell size of two metres was used in the hydraulic model. This cell size was chosen as the modelling area is relatively large, and a one metre cell size for the entire area would have impaired model performance by drastically increasing computation run times. Instead, a TUFLOW quadtree mesh was applied over the detention basin area to increase model resolution to 1m. This enabled critical structures to be captured with greater accuracy. Any further increase to cell size across the floodplain risked losing definition of the network of smaller channels and overland flowpaths.

The sub-grid sampling (SGS) feature of TUFLOW perfectly suited the modelling requirements by providing increased definition of the model terrain and flow conveyance in critical areas. This enables model resolution to be improved without significant increases in computational run times.

3.2 Model Inputs

3.2.1 Hydrological Inputs

3.2.1.1 Rainfall

LRSC provided a 1 km^2 grid of total rainfall depths for the December 2018 event. This grid was obtained using RADAR. It should be noted that the accuracy of the RADAR data is limited due to the rain shadow cast by the Remutaka Ranges. In the absence of catchment rain gauge data, the RADAR data is considered appropriate, though there is degree of uncertainty.

Centre points of 40 of the grid cells have then been extracted to be used as 'point' rainfalls. Rainfall triangles were then digitized, connecting points to their neighbours. The rainfall points and triangles are used in combination by the hydraulic model to generate a triangulated irregular network (TIN) interpolation of the rainfall (i.e. a rainfall grid). A 100 m^2 grid cell size has been applied for rainfall.

SLR was also provided with a temporal distribution for the December 2018 event, based on rainfall at the NFRA Featherston rain gauge. This distribution was applied to the rainfall totals for each of the 40 points.

This process resulted in the model generating rainfall grids for each timestep of the December 2018 event, allowing for the variability of rainfall depth across the model domain to be captured.

3.2.1.2 Flow

Flow hydrographs were provided by LRSC for 16 locations. These were outlet points where flows transitioned from the foothills to the floodplains. The hydrographs were applied as inflows to the model using upstream boundary conditions at the locations provided.

3.2.2 Initial Conditions

There was a relatively significant period of wet weather six days prior to the calibration event, with 69.8mm falling at the Tauherenikau at Racecourse gauge from 25 November to 27 November, 2018. In the four days immediately prior to the calibration event, 4mm of rainfall was recorded at the Tauherenikau at Racecourse gauge.

Given the lack of rain in the four days leading up to the calibration event, and because of moderately well-drained soils across the floodplain, the model has been set up to begin dry prior to the simulation beginning. No initial water levels or baseflows are applied.

Initial conditions may be applied to design runs during the sensitivity stage of modelling to determine the impact of varying antecedent conditions on flood hazard.

3.2.3 Model Domain

The model boundary was created using topography (DEM and contours) and aerial imagery and is shown in **Figure 3**. Topography is essential for delineating catchments when using a rain-on-grid modelling approach, as rainfall is applied across every cell of the model domain. This means that 'glass-walling' can occur where water trying to leave the model is blocked by the model boundary. The results of glass-walling are model instability, and potentially incorrect flood depths/extents. Topography was used to ensure that the boundary was created along ridgelines so that all rainfall would flow inwards. Aerial imagery was used for cross-referencing to verify the model boundary during construction.

The upstream extent of the hydraulic model was defined by the locations of foothill outlets as provided by LRSC. The model domain encompassed all overland flow paths within the catchment downstream of the outlet points.

The downstream extent of the model was determined from the flow paths where water is conveyed away from the site. It was ensured that the model extended far enough downstream to capture the entire area of interest without risking inaccuracies in flood extents resulting from the choice of tailwater level.

3.2.4 Boundary conditions

3.2.4.1 Upstream boundaries

The locations of the upstream boundaries to the 2D model, along the Remutaka Range foothills are shown in **Figure 3**. Following discussion with GWRC, the upstream boundary across Abbots Creek was moved slightly upstream from the location specified by LRSC. This was done to allow for the model boundary to be extended upstream to capture a potential area of interest where there were concerns that Abbots Creek may breach its banks.

3.2.4.2 Downstream boundaries

Two types of downstream boundaries were applied to the model (**Figure 3**). Hydraulic outlet boundaries were applied where water leaves the model, generally characterised by stream channels. These downstream boundary conditions were based on the hydraulic gradient of each channel, allowing uninterrupted flow, to minimise any potential for tailwater effects to extend into the model domain.

A lake level boundary was applied at the southern end of the model domain, where the creeks flow into Lake Wairarapa. No time series for Lake Wairarapa was available. A constant level of 0.562 metres above sea level was therefore applied as recommended by GWRC.

3.2.5 Topography

The two LiDAR datasets were merged using a feathering approach. This allowed for the recent 2023 LiDAR derived DEM being used for the areas it covered, and the 2013-14 DEM adopted for the wider floodplain. Feathering was necessary to ensure a smooth connection between the two DEMs was achieved to allow flow to pass smoothly from one DEM to the other.

Channel cross-sections were provided by GWRC. These were not included in the model due to uncertainties regarding the cross-section locations, date of the survey, and whether the cross-sections reflected current bathymetry. The 2023 DEM represented the channel well, so inclusion of the channel cross-sections would be negligible.

As previously mentioned, the model adopted a two-metre grid cell size. However, the finer resolution of the DEM allowed for the use of one metre sub-grid sampling across the model domain.

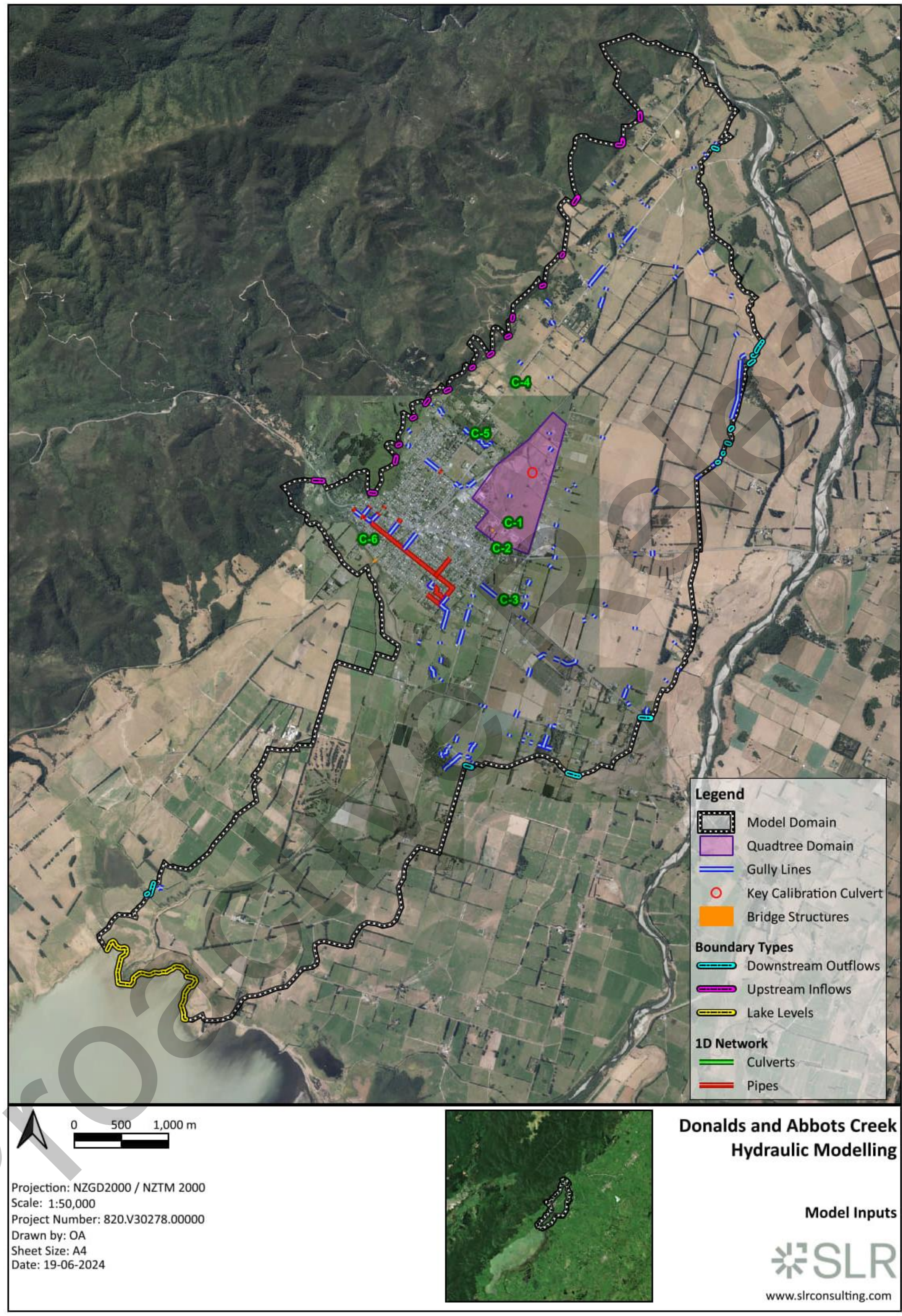

Figure 3 Key hydraulic model inputs.

3.2.5.1 Topographic modifications

Hydraulic Connections

Gully lines were created across the model domain to ensure hydraulic connectivity (**Figure 3**). Gully lines were used in place of culverts where it was assumed that a culvert exists, where no surveyed measurements/data were readily available and where absolute accuracy would not be critical to resulting flood extents. It is important that gully lines are only used for culverts that are not critical as the lack of specifications may over or underestimate flow. At one location, indicated by the red circle labelled ‘Key Calibration Culvert’ in **Figure 3**, simulations were completed with the culvert included as a burnt in gully line, and with it excluded. The final calibration run excluded the gully line because GWRC indicated that this culvert became blocked in the December 2018 event.

Road Embankments

At several locations, the creek channels had been burnt into the original DEM, cutting through roads. Where culvert information was available at these locations, the topography was modified to set the roads to surveyed heights so that culverts could be created for the flow constriction to be properly represented. This was done by digitizing polygons over the DEM gaps and setting the ‘Z’ value to the appropriate elevation.

3.2.6 Hydraulic Roughness and Losses

The hydraulic roughness values, which affects flow across the ground surface, were based on a combination of Manaaki Whenua Landcare Research’s Land Cover Database (LCDB) for 2018 (Manaaki Whenua Landcare Research, 2023a), shapefile layers from the Land Information New Zealand (LINZ) data service, analysis of 0.3 metre aerial imagery for 2021, and ground truthing during a site visit.

Using the available information, a ‘materials’ layer was created. For each ‘material’, a Manning’s roughness coefficient, *n*, (Manning’s *n*) value was assigned. The values assigned are consistent with those outlined in the FHMS for minor streams and floodplains.

Initial and continuing losses were applied to the model through the Materials Definition file. This method allowed for initial loss depths and continuing loss rates, which varied depending on land cover type, to be removed from the rainfall before it was applied as surface runoff to the 2D grid cells.

Loss values were initially set based on a predominantly silt/loam soil and increased slightly depending on land cover to represent losses from other means such as interception. The initial infiltration values were acquired from an investigation conducted by CLIMsystems, which took loss values for different soil classes from various literature to provide lower bounds, medians and upper bounds for both initial and continuing losses (CLIMsystems, 2024). It should be noted that all sources used in their investigation are specific to the northern North Island of New Zealand. Due to the lack of information for the lower North Island, these values were applied to the initial model setup and adjusted during calibration.

Sensitivity testing was conducted on these parameters during the calibration process. The final Manning’s *n* roughness, initial rainfall loss and continuing rainfall loss values are presented in **Section 4.0, Table 3**.

3.2.7 Structures

3.2.7.1 Culverts and pipes

Surveyed measurements exist for numerous culverts and pipes in and around Featherston. Twenty-eight have been represented in the hydraulic model (**Figure 3**). Twenty-two are South Wairarapa District Council SWDC pipes. These are typically small, circular pipes which help to drain the urban area. The remaining six are larger culverts, four along Donalds Creek, one along Boar Creek and one along Abbots Creek. The culverts on Donalds Creek include the Harrison Street culvert (i.e. the detention dam release point), the Underhill Road culvert upstream, and the Fitzherbert and Revans Street culverts downstream of Harrison Street. The Boar Creek culvert is also through Underhill Road, and the Abbots Creek culvert is beneath Western Lake Road.

Survey of Donalds Creek at the Underhill Road culvert, as well as a brief discussion with a member of the Featherston community during a site visit, indicated that this culvert is susceptible to blockage, and oftentimes a large portion of the barrels are filled with gravels. This information was adopted in the calibration model by setting the blockage attribute to 75%. Various degrees of blockage will be considered during the model sensitivity stage.

Culverts/pipes are represented in the model by a one-dimensional (1-D) network line with dimensions (specified by survey), an invert level (determined by the upstream and downstream DEM elevations), and various other specifications including roughness, form loss, and shape. The 1-D network is linked to the two-dimensional (2-D) model domain using 2-D boundary condition lines.

All culverts/pipes included in the hydraulic model were made of concrete. A Manning's *n* value of 0.012 was assigned to all culvert/pipe structures. Observations during the site visit led to the decision to set blockage percentages for the culverts labelled C-4 and C-6 in **Figure 3**. Typical entry and exit form loss coefficients were used to model culverts, however, no precise calculations have been used. Culvert roughness, blockage and form loss coefficients may be tested for sensitivity in the next phase of modelling.

The piped stormwater network has not been explicitly modelled, only pipes that are conveying flow between defined open channels are represented. This results in the majority of the piped stormwater network being modelled, excluding a very small portion of the network on the southern side of Brandon Street. Inflow into the stormwater network via sumps has not been modelled.

3.2.7.2 Bridges

Two bridge structures were included in the hydraulic model (**Figure 3**). These were a small bridge on Donalds Creek, located just downstream of the detention dam, and Kiwirail Bridge 47, which is the railway bridge over Abbots Creek southwest of Featherston. These bridges are represented in a 2-D layered flow constriction shapefile, which uses soffit height and bridge deck depth in conjunction with blockage percentages and form loss for each layer to determine flow conveyance. The actual soffit/deck height of KiwiRail Bridge 47 was unknown, so it was set to the level of the railway track either side of Abbots Creek, as per the DEM. It was assumed that this estimation would have no major implications as the deck depth was known, and the DEM levels selected are likely very close representations of the actual deck height.

Both bridges had piers which were represented in the layered shapefiles by setting appropriate blockage percentages and form loss coefficients for the layer beneath the bridge soffit. These parameters were estimated based on the size and number of piers compared to the below soffit area but were not calculated precisely. Bridge pier blockage and form loss coefficient values may be tested for sensitivity in the next phase of modelling.

3.2.7.3 Detention Basin, Spillway and Stopbanks

The detention basin and spillway structures, as well as stopbanks along Donalds Creek and Abbots Creek, were appropriately represented in the DEM.

3.2.7.4 Headwall and Wingwalls

At the detention basin outlet, on the upstream side of Harrison Street, the impervious concrete headwall and wingwalls were included as breaklines. These were necessary to include in the model as the DEM along did not accurately represent them.

3.2.7.5 Buildings

Buildings were added to the model using a layer obtained from the LINZ Data Service. The imported buildings layer was given a high Manning's *n* value (0.5) to the area of each building. This means that buildings have a high frictional resistance to flow, so while floodwater can flow through the buildings, this occurs at a low velocity representative of significant obstruction. Such an approach is considered appropriate.

3.3 Model Limitations and Assumptions

In developing the rain-on-grid model, several assumptions were necessary which may affect the results. These include:

- Hydrological inputs as provided by LRSC are the best representation of the December 2018 event. However, the accuracy of RADAR data used to apply rainfall over the floodplain is questionable given the rain shadow effects caused by the Remutaka Ranges.
- Where culvert information was not available, hydraulic connections were added to the model by burning channels into the DEM. The burned channels may therefore allow either too much or too little flow to pass. Furthermore, there are likely some hydraulic connections that were missed because of uncertainty regarding their existence. As such, flow paths and areas of ponding may not accurately represent the existing conditions. Care has been taken to minimise this occurrence through undertaking a site visit, talking with stakeholders, comparison to aerial imagery, and model results verified through calibration and validation.
- Blockage percentages have been applied to some culverts based on anecdotal evidence. The effects of various degrees of blockage on design runs will be investigated during the sensitivity stage of modelling.
- Roughness values were derived from a combination of the Land Cover Database (LCDB) for 2018, Land Information New Zealand (LINZ) data, analysis of 0.3 metre aerial imagery for 2021, and ground truthing during a site visit. This method follows industry best practice, though small inaccuracies may occur.
- Vegetation has been imperfectly filtered in the creation of the 2013 DEM, therefore where forests exist the terrain is often being read as the top of the trees, rather than the ground that lies below. This causes unrealistic flow paths, basins and blockages. The 2023 DEM is filtered better, however there are still some outstanding areas. This is unlikely to have a significant impact on results as gully lines have been digitized for hydraulic connectivity, and because the 2023 DEM covers the urban area while the 2013 DEM is most representative of the terrain over pasture land use.
- The LiDAR data used in the model is a combination of datasets captured in 2013 and 2023. The feathering approach used to merge the DEM's is not seamless, so there are

likely to be some minor inaccuracies, particularly where the edges of the 2023 LiDAR were merged.

- The LiDAR that underpins the topography of the wider floodplain, in particular the area east of Donalds Creek, was captured in 2013. Since then, it is possible that the landscape has changed because of channel migration and other geomorphic processes, as well as land and urban development.
- Channel cross-sections were not used in the model. However, the 2023 DEM covers the key reaches of Donalds Creek and Abbots Creek and represent the channel to an acceptable standard.

4.0 Model Calibration

The model has been calibrated to the 2 December 2018 storm event. This was a short, intense rainfall event concentrated over the Featherston area. From the LRSC report, this event resulted in 67.2mm of rainfall recorded at the Featherston at NRFA gauge which is estimated to have an average recurrence interval (ARI) of greater than 85 years. It is estimated that peak flood level at the Harrison Street detention basin for this event had an ARI of approximately 50 years.

There is limited quantitative information available to calibrate the hydraulic model to. The most valuable information was two images of the water level at the Harrison Street detention basin during the event (**Figure 4** and **Figure 5**). The images are open to a degree of interpretation given that:

- They do not provide definitive peak flood level values, so this can only be estimated. It is difficult to determine exactly how far, vertically, the GWRC staff member is positioned from the top of the detention dam in **Figure 4**.
- While the surveyed information for the Harrison Street culvert is useful for determining the water level pictured in **Figure 5**, there is no clarification regarding what time this photograph was taken. Therefore, it cannot be stated with confidence that this photograph shows the peak flood level.

Interpreting the below two images (**Figure 4** and **Figure 5**) and considering surveyed heights for the Harrison Street culvert (obvert at 37.6m and top of head wall at 38.9m), it is estimated that the peak flood level at the detention basin was 38.5m, +/-0.2m, during the 2 December 2018 event.

Based on the WSP Opus (2018) hydrological analysis report for the Harrison Street detention structure, the 2 December 2018 calibration event appears to have been approximately a 50-year ARI storm at the detention basin. Given the 3-hour duration of rainfall, this indicates a peak flood height of ~38.36m. There is uncertainty with this peak flood estimate, however it does help to verify and give confidence to the above interpretation of flood photographs.

Figure 4 Photograph of the Harrison Street detention structure following the 2 December 2018 event. The position of the GWRC staff member pictured indicates the peak flood water level.

Figure 5 Photograph of the Harrison Street culvert taken on 2 December 2018.

4.1 Parameter Modifications

An initial calibration run generated a peak flood height of 38.9m (NZVD 2016) at the detention basin i.e., water level at top of the culvert headwall. Based on the anecdotal evidence, it was understood that the model was producing a peak flood height that was too high. As such, various model parameters were investigated and modified to achieve a better fit to calibration data. The following sections outline the key modifications.

Rainfall Initial and Continuing Losses

Values within the range of soil group B (CLIMSystems, 2024) were applied to the model. Modifications to rainfall losses indicated that the model was sensitive to extreme changes (i.e. values at the lower and upper bounds), however, such loss values would be unrealistic for the catchment. Small changes to loss values resulted in little to no changes in peak flood depths, velocities or extents.

Hydraulic Connectivity

GWRC indicated that during the 2018 storm event, one of the culverts north of the detention basin became blocked, thereby diverting water around the side of the basin. As part of the parameter modifications, this culvert (which was being represented by a 2D gully line as no specific measurements were available) was removed. This caused a minor decrease in modelled peak flood height, though it was not a significant enough reduction to fit the calibration estimate. Blocking the waterway diverted water to the east of the detention basin, as occurred during this event.

Hydrologic Inputs

Due to the necessity to lower peak flood height at the detention basin by a significant amount, it was determined that this could not be achieved solely through modification of hydraulic model parameters without setting these to unrealistic values. The use of unrealistic values would compromise design event runs by underestimating flooding. As such, attention was turned back to the hydrologic inflows from the upper catchment.

Hydrologic inputs were modified and results assessed for three scenarios:

- Decreasing the hydrologic model CN values by 5%;
- Decreasing the hydrologic model CN values by 10%; and
- Decreasing the hydrologic model rainfall inputs, and the hydraulic model rain-on-grid inputs, by 13%.

All methods had significant effects on peak flood heights at the detention basin. However, changing the CN values caused major changes in the design flow outputs and was therefore deemed inappropriate. Alternatively, the method of modifying rainfall inputs was considered to be more appropriate because it did not significantly alter the hydrologic models design flow outputs. There was some uncertainty regarding the accuracy and reliability of the RADAR rainfall inputs, which further justifies modifications.

4.2 Final Calibration

The final calibration run used the parameters displayed in **Table 3**. The resulting modelled peak flood height of 38.56m (NZVD 2016) at the detention basin was within the acceptable range based on anecdotal flood evidence from the 2 December 2018 event. It is understood that no significant changes to the catchment have occurred since the 2018 event that might alter the peak flood heights.

The models mass balance is acceptable (<+/-5%), with a model continuity error of 0.01%.

Table 3 Final calibration model setup.

Miscellaneous			
Parameter	**Notes**		
Grid cell size	2m grid cell size, with 1m sub-grid sampling. Quadtree area (0.5m grid cell size) around detention basin.		
Materials Layer Paramaters			
Land cover	**Manning's n value**	**Initial rainfall losses (mm)**	**Continuing rainfall losses (mm/hr)**
Pasture	0.03, 0.04, 0.10, 0.03	32	12
Brush (light brush and trees)	0.035	35	12
Trees (stage below branches)	0.08	35	12
Brush (medium to dense)	0.05	35	12
Trees (stage above branches)	0.10	35	12
Pavement	0.01	0	0
Backyards	0.08	18	5
Gravel and dirt	0.025	3	1
Buildings	0.03, 0.02, 0.10, 0.50	0	0
Channels	0.10, 0.04, 0.30, 0.02	0	0
Roads	0.01	2	0
Railway	0.04	3	1
Channel banks	0.1, 0.05, 0.30, 0.035	18	5
*	Depth-varying Manning's n applied (d, n, d, n). Manning's n values are interpolated between the two specified depths.		
Hydraulic Connections			
Connection	**Blockage**	**Notes**	
1-D Network (ID's: P-1 – P-22, C-1, C-2, C-3, C-5)	0%	No evidence of significant blockage on site visit, nor any mention of blockage by GWRC.	

1-D Network (ID: C4)	75%	Substantial amount of sediment in and upstream of culvert.
1-D Network (ID: C6)	15%	Culvert not perfectly rectangular – blockage represents protruding walls.
Culvert north of basin	100%	Initially represented as a gully line – removed for final calibration run.
Gully Lines	0%	Typically where vegetation was not filtered out of the DEM and generally given widths of 4m to ensure conveyance through the 2m grid.
Layered Flow Constrictions (Bridges)		
Bridge	**Layer 1 Blockage**	**Pier Form Loss**
D/S Detention Basin Bridge	5	0.2
KiwiRail Bridge 47	8	0.3
Boundary Conditions		
Type	**Data**	**Notes**
Downstream Boundaries	Slope	Values based on hydraulic gradient (range from 0.001 – 0.012).
Upstream Boundaries	Flood hydrographs	Values as generated by hydrologic model with a 13% reduction in rainfall (model *DA_V20181202_F_v3*)
Tidal Boundaries	Water Level	Boundary at Lake Wairarapa edge set to water level of 0.562m (NZVD 2016).
Rain-on-Grid		
Model Input		**Notes**
Time-varying rainfall grids (HIRDS East of North Island distribution)		13% reduction in total rainfall depth from the source 1km^2 RADAR grid data applied.

4.3 Calibration to Photographs

The location and extent of modelled inundation from the calibrated model was compared to flood photographs provided by GWRC. **Figure 6** shows flooding from upstream of the detention basin to just north of State Highway 53. GWRC indicate that this photograph was possibly taken after the December 2018 event, though this is not confirmed. The photograph is also not timestamped, so it is unknown whether it captures peak flood conditions.

The numbered areas in **Figure 6** have been compared to the corresponding model results (**Figure 7**). At each of the four locations the areas, extents and patterns shown in **Figure 6** are well reciprocated in **Figure 7**. An overview of the comparisons is provided in **Table 4**.

Figure 6 Photograph of flooding following the December 2018 event. Circles indicate key comparison areas.

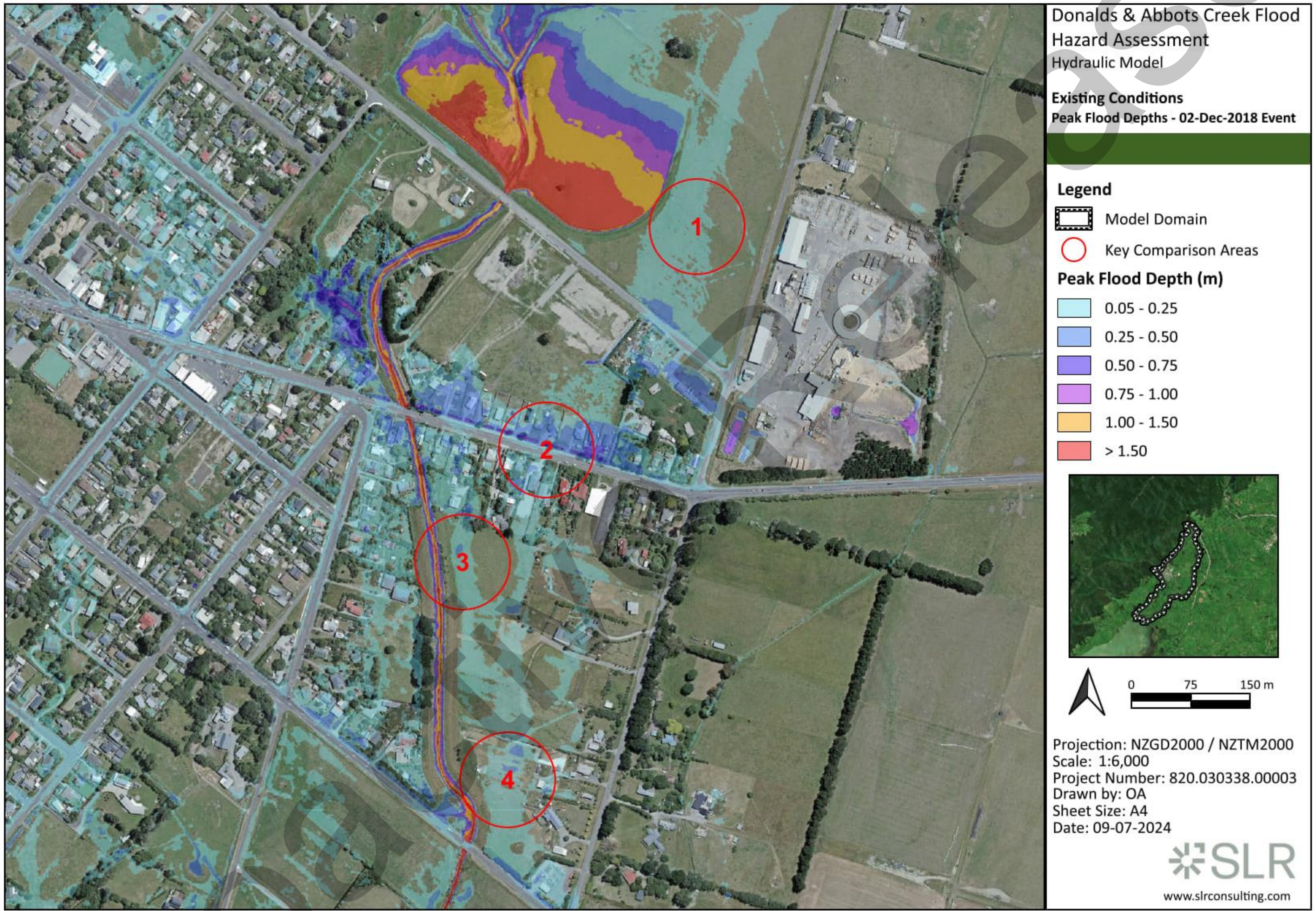

Figure 7 Model results between the detention basin and SH53 for the 2-Dec-2018 event. Circles indicate key comparison areas

Table 4 Comparison of flooding at four locations between a flood photograph (Figure 6) and model results (Figure 7) during the 2 December 2018 event.

Location	Comparison
1	Model results show flooding of the area east of the Harrison Street detention structure. The main flowpath into this area, which as indicated by GRWC was a result of blockage of the culvert north of the detention basin, is visible in both **Figure 6** and **Figure 7**. The 'zig-zag' flowpaths shown in the photograph are also visible in the model results. The deepest water is evident on the upgradient side of Harrison Street in both figures. Flood extents compare well, with a slightly larger flood extent shown in the model results likely due to shallow depths (<10mm) not being captured in the photograph.
2	The flowpath resulting from Harrison Street overflow from Location 1 is evident in both **Figure 6** and **Figure 7**. The model results show the deeper inundation surrounding the houses immediately upgradient of State Highway 2 (SH2), as visible in the photograph.
3	The photograph and model results (**Figure 6** and **Figure 7**) both show another flowpath into the area between SH2 and SH53. Model results capture the extent of this flowpath well. Additional inundation in the model results is likely a result of shallow depths not captured in the photograph.
4	Areas of deeper ponding at this location are clearly shown in **Figure 6** and **Figure 7**. Where there appears to be little to no flooding across this area in the photograph, the model results show either very shallow or no inundation.

5.0 Summary

5.1 Modelling Outcome

A TUFLOW^{TM} computational hydraulic model was built for the floodplain area of the Donalds and Abbots Creek catchments. The model was constructed in accordance with GWRC's FHMS. The model was calibrated to the 2 December 2018 rainfall event, which was a short and intense localized storm over Featherston.

The hydrologic inputs for calibration were provided by Land River Sea Consulting Ltd. (LRSC) and included:

- Flow hydrographs at sixteen locations along the foothills. These were produced using a HEC-HMS hydrologic rainfall runoff model for the December 2018 event and served as inflows to the hydraulic model.
- A 1 km^2 grid of total rainfall depths for the December 2018 event and an associated temporal pattern. These were used to generate a time-varying rainfall grid to apply rainfall across the hydraulic model domain.

During the model build process, various parameters such as culvert conveyance, rainfall initial and continuing losses, and the hydrologic inflows were tested for sensitivity. The model was found to be particularly sensitive to hydrologic inflows. Given a degree of uncertainty regarding the rainfall depths applied to both LRSC's hydrologic model and the hydraulic model, a decision was made to decrease rainfall in both models by 13%.

Once all parameters of the model had been finalised, the resulting model generated a peak flood height of 38.56m (NZVD 2016) at the Harrison Street detention basin. This fit well with anecdotal flood evidence provided by GWRC, which indicated a peak flood height of 38.5m

+/-0.2m. Model results closely matched flood photography which supports the applied parameters.

5.2 Recommendations

The hydraulic model has been developed with little information to calibrate or validate modelled results to. To improve the confidence in model results, it is recommended that further hydrometric data is recorded within the catchment, and/or following a significant flood event within the catchment, that time and location stamped photographs be taken, and peak flood levels be surveyed.

6.0 References

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Greater Wellington Regional Council, 2021. Flood Hazard Modelling Standard. May 2021.

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Manaaki Whenua Landcare Research, 2023b. Fundamental Soils Layer. https://lris.scinfo.org.nz/data/?q=FSL

Wellington Regional Council, 1998. Donalds Creek Flood Protection Project Design Report. August 1998.

WSP Opus, 2018. Addendum A Donalds Creek Detention Facility Hydrological Analysis Phase II. August 2018.

Appendix A Data Register

Donalds and Abbots Creek

Hydraulic modelling

Greater Wellington Regional Council

SLR Project No.: 820.V300278

15 July 2024

Table A - 1 Data Register.

Data Description	Data type	Date data collected	Source	Limitations or License terms	Assessment of quality
Wellington LiDAR 1m DEM (2013-2014)	*Elevation data*	*27-04-2023*	*LINZ Data Service (https://data.linz.govt.nz/layer/53621-wellington-lidar-1m-dem-2013-2014/)*	*LiDAR flown 10 years ago*	*Covers relevant area, high resolution, collected using industry best practice.*
Wellington LiDAR 1m DEM (2022-23)	*Elevation data*	*03-06-2023*	*Provided by GWRC*	*LiDAR does not cover the entire model domain*	*Provides up to date LiDAR for both streams and some of the wider model area. High resolution and collected using industry best practice.*
South Waikato District Council Stormwater GIS Layers	*Stormwater culvert, pipe and channel information*	*23-05-2023*	*GWRC Open Data Portal*	*Not all information categories contain data for all features*	*Accurate pipe network lines and measurements.*
Tomlinson and Carruthers survey	*Stream culvert and bridge cross-sections and asbuilt data*	*02-11-2023*	*Tomlinson and Carruthers survey data*	*Limited by the available attributes of TUFLOW culvert and bridge layers*	*Provides up to date and accurate culvert and bridge dimensions.*
Land Cover Database v50 (2018)	*Land cover class polygons shapefile*	*28-04-2023*	*LRIS Portal (https://lris.scinfo.org.nz/)*	*Based on 2018 land cover.*	*National-scale assessment so lacking accuracy in areas. Required modification to be suitable for use.*
NZ Building Outlines	*Buildings polygons shapefile*	*28-04-2023*	*LINZ Data Service (https://data.linz.govt.nz/layer/101290-nz-building-outlines/)*	*Does not include some of the newest buildings. These were added manually.*	*Accurate and frequently updated. Required modification to fix geometries to make suitable for use.*
NZ Primary Road Parcels	*Road parcel polygons shapefile*	*10-05-2023*	*LINZ Data Service (https://data.linz.govt.nz/layer/50772-nz-primary-parcels/)*	N/A	*Accurate and frequently updated roading across the model area.*
NZ Property Titles	*Property title polygons shapefile*	*10-05-2023*	*LINZ Data Service (https://data.linz.govt.nz/layer/50804-nz-property-titles/)*	N/A	*Accurate and frequently updated outlines for backyard with Featherston township.*

NZ Railway Centrelines	*Railway centreline shapefile*	*10-05-2023*	*LINZ Data Service (https://data.linz.govt.nz/layer/50781-nz-railway-centre-lines/)*	N/a	*Accurate railway line delineation. Required modification to create buffer to include in material layer.*
NZ River Centrelines	*River centreline shapefile*	*27-04-2023*	*LINZ Data Service (https://data.linz.govt.nz/layer/103632-nz-river-name-lines-pilot/)*	*Does not include all waterways/drains. Some added manually.*	*Inaccuracies in stream delineation. Manually modified using LiDAR and aerial imagery to improve fit. Buffered to generate channel and channel banks layers.*
Calibration rainfall grid points	*Point (shapefile) rainfall depths for 02-12-2023 event in grid formation*	*Initial: 08-06-2023* *Reduced by 13% following Revision 3 of the hydrology.*	*Provided by Land River Sea Consulting Limited*	*1km2 grid - large space to interpolate between*	*High quality. Rainfall depths generated using radar data from 02-12-2023. Hydrology has been peer reviewed.* *More accurate than a global floodplain rainfall.*
Design rainfall grid points	*Point (shapefile) rainfall depths for various design events and durations in grid formation*	---	*Yet to be provided by Land River Sea Consulting Limited*	---	---
Temporal profiles	*Temproral profiles for rainfall depths to be distributed against.*	*Initial: 08-06-2023* *Revised: Unchanged*	*Provided by Land River Sea Consulting Limited*	N/A	*High Quality. Uses HIRDSv4 East of North Island profile, suitable for the Project area.*
Flow outlet points	*Point (shapefile) outlets from the upper catchment*	*Initial: 08-06-2023* *Revised: 07-02-2024*	*Provided by Land River Sea Consulting Limited*	N/A	*Outlets at the bases of contributing upper catchments, prior to entry onto the floodplain.*
Calibration flow hydrographs	*Hydrographs for outlet points from the upper catchment for the 02-12-2023 event.*	*Initial: 08-06-2023* *Revision 1: 22-02-2024* *Revision 2: 22-04-2024* *Revision 3: 04-06-2024*	*Provided by Land River Sea Consulting Limited*	N/A	*High quality. Flow hydrographs generated using HEC HMS modelling software. Hydrology has been peer reviewed.*

Table A - 2 Document Register.

Data Description	Data type	Date data collected	Source	Limitations or License terms	Summary of findings
Donalds Creek Flood Protection Project Design Report August 1998.pdf	*Technical Report - previous flood study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Flood hazard information including estimates of flows and water levels at the detention structure.*
Donalds Creek Flood Protection Project As-built Drawings 1998.pdf	*Design plans*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*As-built designs with information and measurements for flood protection structures.*
Donalds Creek Flood Protection Project Assessment of Environmental Effects August 1998.pdf	*Technical Report - previous flood study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Antecedent flood information from community engagement.*
Donalds Creek review SH53 to Confluence 19-4-06.docx	*Technical Report - previous flood study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Assessment of flood risk for the lower section of Donalds Creek, including estimated flood flows.*
Donalds Creek Works between SH53 and the confluence with Abbots creek.docx	*Brief Report - scope of works*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Proposed works to upgrade the flood protection assets on Donalds Creek between the detention basin and Abbots confluence.*
PGWES Hydrological assessment of Donalds Creek 2016.pdf	*Technical Report - previous hydrological study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Synthetic flow series for Donalds Creek and estimated design flows*
Donald's Creek – Memo of site visit recommendations Dec 2017.docx	*Brief memo - previous flood study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Detention structure images and flood protection scheme information.*
Donalds Creek Detention Facility – Hydrological Analysis July 2018.pdf	*Technical Report - previous hydrological study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Flood hazard information including estimates of flows and water levels at the detention structure.*
Donalds Creek Detention Facility – Hydrological Analysis Phase 2 Aug 2018.pdf	*Technical Report - previous hydrological study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Flood hazard information including estimates of flows and water levels at the detention structure.*
Donalds Creek Detention Facility FMEA memo Sep 2018.pdf	*Technical Memo - previous dam breach assessment*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Assessment of the possible dam breach scenarios and where the likely effects will be.*

Donalds Creek Opus Memo on HIRDS Oct 2018.pdf	*Technical Memo - previous hydrological study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Design rainfall frequency analysis.*
Donalds Creek Post-Event Appraisal (FINAL) Dec 2018.docx	*Brief memo - previous flood study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Calibration event overview and information.*
Brookside Developments – Flood-Assessment-Stage-2-3-Report-3-July-2020-1.pdf	*Technical Report - previous flood study*	*01-05-2023*	*Provided by GWRC. Contact: Kirsty Duff*	*None*	*Previous local hydraulic model build information.*

Appendix B   Model Log

Donalds and Abbots Creek

Hydraulic modelling

Greater Wellington Regional Council

SLR Project No.: 820.V300278

15 July 2024

Table B - 1 Hydraulic model inputs and key parameters.

Hydraulic Model Component	Input data / source	Method	Key assumptions
Hydraulic Roughness *Initial Rainfall Losses* *Continuing Rainfall Losses*	*Site visit and photographs of sections of river channels and bed including observation of bed material, vegetation type and density.* *Aerial imagery and LRIS land cover shapefile for land use types in floodplain and catchment.*	*Roughness values assigned to land cover classes and aligned with GWRC FHMS.* *Initial and continuing rainfall losses assigned depending on land cover.*	*Manning's n roughness values are generally mid to low range of those presented in the GWRC Flood Hazard Modelling Standard.* *Roughness is higher on the banks than the main channel.* *Roughness is higher in and around properties due to buildings, garden vegetation and fences.* *Initial loss is high densely vegetated area due to rainfall interception by trees*
Digital elevation model	*LiDAR (1m resolution) flown for Wellington Region in 2013-14* *LiDAR (1m resolution) flown for Featherston are in 2022-23* *Aerial imagery dated 31/06/2021*	*Quality of DEMs reviewed. Review concluded the DEM has been mostly filtered of vegetation and buildings, with exceptions in some areas. A feathering approach was used to merge the DEM's.* *Aerial imagery used to identify linear features that may not have been captured, or have been disrupted by unfiltered vegetation, such as small drains and railway.* *A number of small drains in the around the catchment were disrupted by vegetation and have been burnt into DEM using 'gully' points and lines based on drain invert levels.*	*Any drains that have not been burnt in are far enough away from interest areas, that disruption of the flow will not impact relevant flood depths.*
Culverts (Circular)	*South Wairarapa District Council Stormwater GIS Layers* *Retrieved from GWRC Open Data Portal on 23/05/2023*	*Downloaded layer provided culvert diameters, lengths and material for most features. Upstream and downstream inverts determined using DEM elevations or culvert line nodes. Culverts added as a 1d Network and linked to the 2d domain using boundary conditions.*	*Form losses typical/standard for circular culverts are applicable.* *There are no blockages in the culverts.*
Culverts (Rectangular)	*Culvert cross-sections & as-built survey information for seven sites* *Survey undertaken by Tomlinson & Carruthers Surveyors on 02/11/2023*	*Upstream and downstream inverts determined using DEM elevations on culvert line nodes. Culverts added as a 1d Network and linked to the 2d domain using boundary conditions.*	*Form losses typical/standard for rectangular culverts are applicable.* *Assumed partial blockage for some culverts where structures protrude into the otherwise rectangular culvert.*
Model domain	*Aerial imagery and LiDAR*	*Cross-checking with aerial imagery, LiDAR layers with three different symbology's (singleband psuedocolour, hillshade and contour lines) were used to delineate the model domain.*	*No direct rainfall outside of the model domain will contribute to flood depths in areas of interest.* *Inflows at foothill outlet points will account for all flow contributions from the upper catchment.*

Upstream boundaries	*Aerial imagery, LiDAR and coordinate references for foothill outlets where inflows would be provided*	*At foothill outlets, aerial imagery and LiDAR was used to draw upstream boundary lines that encapsulated the entire relevant channel for which flows were being provided. Boundary lines are referenced to the inflow histograms.*	*All catchment area above the upstream boundaries is represented in the applied flows.*
Downstream boundaries	*Aerial imagery and LiDAR*	*Identifying locations where flow is likely to exit the model domain. Slopes applied to downstream boundary lines using the elevation profile tool on the DEM for inside key channels.* *Lake water level boundary set where model flows into Lake Wairarapa.*	*Lake water level is constant throughout the event.*
Rainfall grid	*Point rainfall distributions*	*Rainfall points linked to associated rainfall histograms are read and interpolated between to create rainfall grids.*	*Assume Triangular Irregular Network (TIN) Interpolation is appropriate*
Buildings	*2d Z Shape Buildings Polygons retrieved from LINZ Data Service*	*Buildings elevated by 1m above DEM*	*Elevating buildings by 1m is sufficient for diverting flood waters around the structures, and no flood water will overtop them.*
Road embankments	*2d Z Shape Polygons drawn with guidance from the DEM and aerial imagery*	*Road embankments were cut through at three key locations along Donalds Creek. Elevating the roads to the match topography either side of the cut-through was necessary for culverts to be added beneath the roads.*	*Elevates the road vertically - No slope up to top of embankment where modifications have occurred. May cause flow form loss.*
Breaklines	*2d Z Shape Line drawn with guidance from aerial imagery*	*The wall above the detention basin culvert is solid concrete and was not registered by the DEM. The breakline artificially adds this wall in to ensure the dam functions correctly has to right spillway level.*	*As-built surveyed level is correct. May change following new surveying.*
Bridges	*2d Layered Constriction Shape polygon drawn with guidance from aerial imagery*	*Polygons spanning the void extent where bridges exist (where information was available), with layers for soffit, deck and railing. Applied blockage and form loss to layers as appropriate*	*KiwiRail Bridge 47 - no information regarding bridge deck height, but known depth. Assumed LiDAR either side of bridge appropriate for use as top of bridge deck height.*

Table B - 2 Model version log.

Model version	Version description	Date run	Outputs from this version	Comments
DONALDSCREEK_W_~s1~_~s 2~_~e1~_~e2~_~e3~_001	*Working run using initial Dec 2018 storm event data*	*07-07-2023*	*DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_001_TMax_h.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_001_h_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_001_V_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_001_d_Max.flt*	*Initial working version, run to troubleshoot model setup/inputs.*
DONALDSCREEK_W_~s1~_~s 2~_~e1~_~e2~_~e3~_002	*Working run using initial Dec 2018 storm event data*	*28-07-2023*	*DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_002_TMax_h.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_002_h_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_002_V_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_002_d_Max.flt*	*Initial working version, run to troubleshoot model setup/inputs - with revised model boundary to check for risk of stream bank overflow northwest of Featherston, and to include greater downstream area*
DONALDSCREEK_W_~s1~_~s 2~_~e1~_~e2~_~e3~_003	*Working run using initial Dec 2018 storm event data*	*05-10-2023*	*DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_003_TMax_h.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_003_h_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_003_V_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_003_d_Max.flt*	*Initial working version, run to troubleshoot model setup/inputs - model boundary revised again to cover larger downstream area, and initial rainfall losses applied.*
DONALDSCREEK_W_~s1~_~s 2~_~e1~_~e2~_~e3~_004	*Working run using initial Dec 2018 storm event data*	*11-12-2023*	*DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_004_TMax_h.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_004_h_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_004_V_Max.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_004_d_Max.flt*	*Initial working version, run to troubleshoot model setup/inputs - model boundary revised to follow lake coastline, additional gullies added, additional road Z shapes added, additional culverts added, and existing ones updated per survey data.*
DONALDSCREEK_W_~s1~_~s 2~_~e1~_~e2~_~e3~_005	*Working run using initial Dec 2018 storm event data*	*13-02-2024*	*DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_005_TMax_h.flt DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_005_h_Max.flt*	*Post first internal review working version - modifications to culvert*

			DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_005_V_Max.flt *DONALDSCREEK_W_2m_SGS1m_NA_12HR_tp01_005_d_Max.flt*	*conditions and buildings materials layer*
DONALDSCREEK_W_~s1~_~s 2~_~e1~_~e2~_~e3~_006	*Working run using revised Dec 2018 storm event data (Rainfall reduced by 13% in hydrologic model)*	*14-06-2024*	*DONALDSCREEK_W_2m_SGS1m_20181202-RF-13_12HR_HIRDS _006_h_Max.flt* *DONALDSCREEK_W_2m_SGS1m_20181202-RF-13_12HR_HIRDS _006_V_Max.flt* *DONALDSCREEK_W_2m_SGS1m_20181202-RF-13_12HR_HIRDS _006_d_Max.flt*	*Working model version - modifications to model domain, addition of extra outflow boundaries and inclusion of KiwiRail Bridge 47 structure.*

Table B - 3 Calibration log.

Model Version	Rainfall Event Name	Result Run Name	Conclusion
DONALDSCREEK_C_~s1~_~s2~_~e1~_~e2~_~e3~_001	*Featherston 02 Dec 2018*	*DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_001_TMax_h.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_001_h_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_001_V_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_001_d_Max.flt*	*Peak water level at detention basin ~39.1m, which is approximately 500-800mm higher than event photography indicates. Inundated areas match those identified in event photography but are too extreme in extent.*
DONALDSCREEK_C_~s1~_~s2~_~e1~_~e2~_~e3~_002	*Featherston 02 Dec 2018*	*DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_002_TMax_h.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_002_h_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_002_V_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_002_d_Max.flt*	*Increased rainfall initial and continuing losses. Peak water level at detention basin between ~38.9-39.0m (~100mm closer to calibration value). Inundated areas match those identified in event photography but are too extreme in extent.*
DONALDSCREEK_C_~s1~_~s2~_~e1~_~e2~_~e3~_003	*Featherston 02 Dec 2018*	*DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_003_TMax_h.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_003_h_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_003_V_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_003_d_Max.flt*	*Blocked culvert north of detention basin. Peak water level at detention basin ~38.9m (did not have a significant impact on results). Inundated areas match those identified in event photography but are too extreme in extent.*
DONALDSCREEK_C_~s1~_~s2~_~e1~_~e2~_~e3~_004	*Featherston 02 Dec 2018*	*DONALDSCREEK_C_2m_SGS1m_20181202-5CN_12HR_HIRDS_004_h_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202-5CN_12HR_HIRDS_004_V_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202-5CN_12HR_HIRDS_004_d_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202-10CN_12HR_HIRDS_004_h_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202-10CN_12HR_HIRDS_004_V_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202-10CN_12HR_HIRDS_004_d_Max.flt*	*Applied inflows as generated by hydrologic model with 5% and 10% decreases to CN values. Peak water level at detention basin for 10% CN decrease ~38.4-38.5m (good match to calibration estimate). Inundated areas match those identified in event photography well. Applied reasonable rainfall losses, however, SLR was informed that the CN reduction was causing substantial changes to the design inflows and therefore was not appropriate.*
DONALDSCREEK_C_~s1~_~s2~_~e1~_~e2~_~e3~_005	*Featherston 02 Dec 2018*	*DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_005_h_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_005_V_Max.flt DONALDSCREEK_C_2m_SGS1m_20181202_12HR_HIRDS_005_d_Max.flt*	*Applied inflows as generated by hydrologic model with 13% decrease to rainfall values. Rainfall across floodplain also reduced by 13% for consistency. Peak water level at detention basin ~38.45m (good match to calibration estimate). Inundated areas match those identified in event photography well. Applied reasonable rainfall losses without having an effect on design estimates.*

Appendix C Calibration Outputs

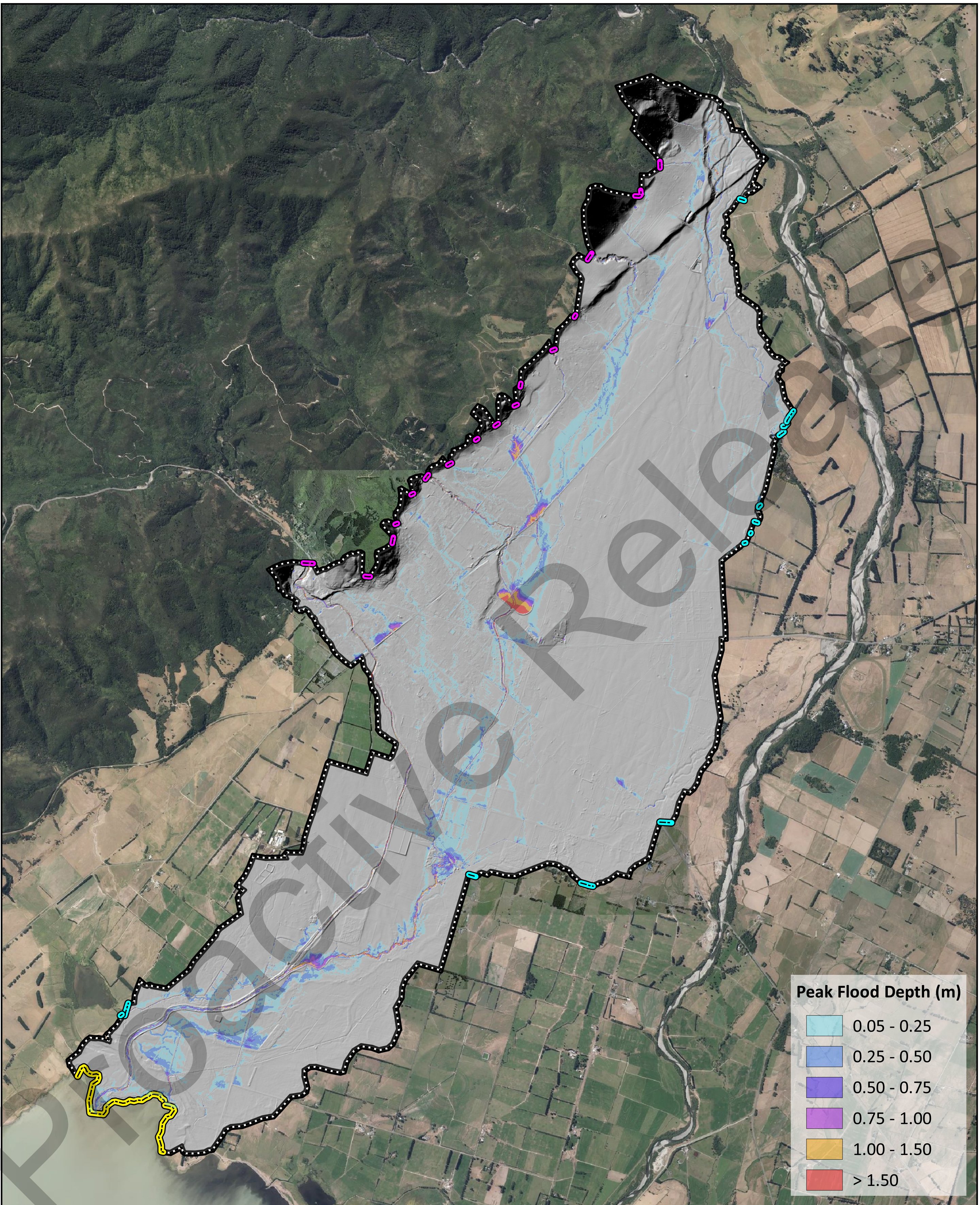
Donalds and Abbots Creek

Hydraulic modelling

Greater Wellington Regional Council

SLR Project No.: 820.V300278

15 July 2024



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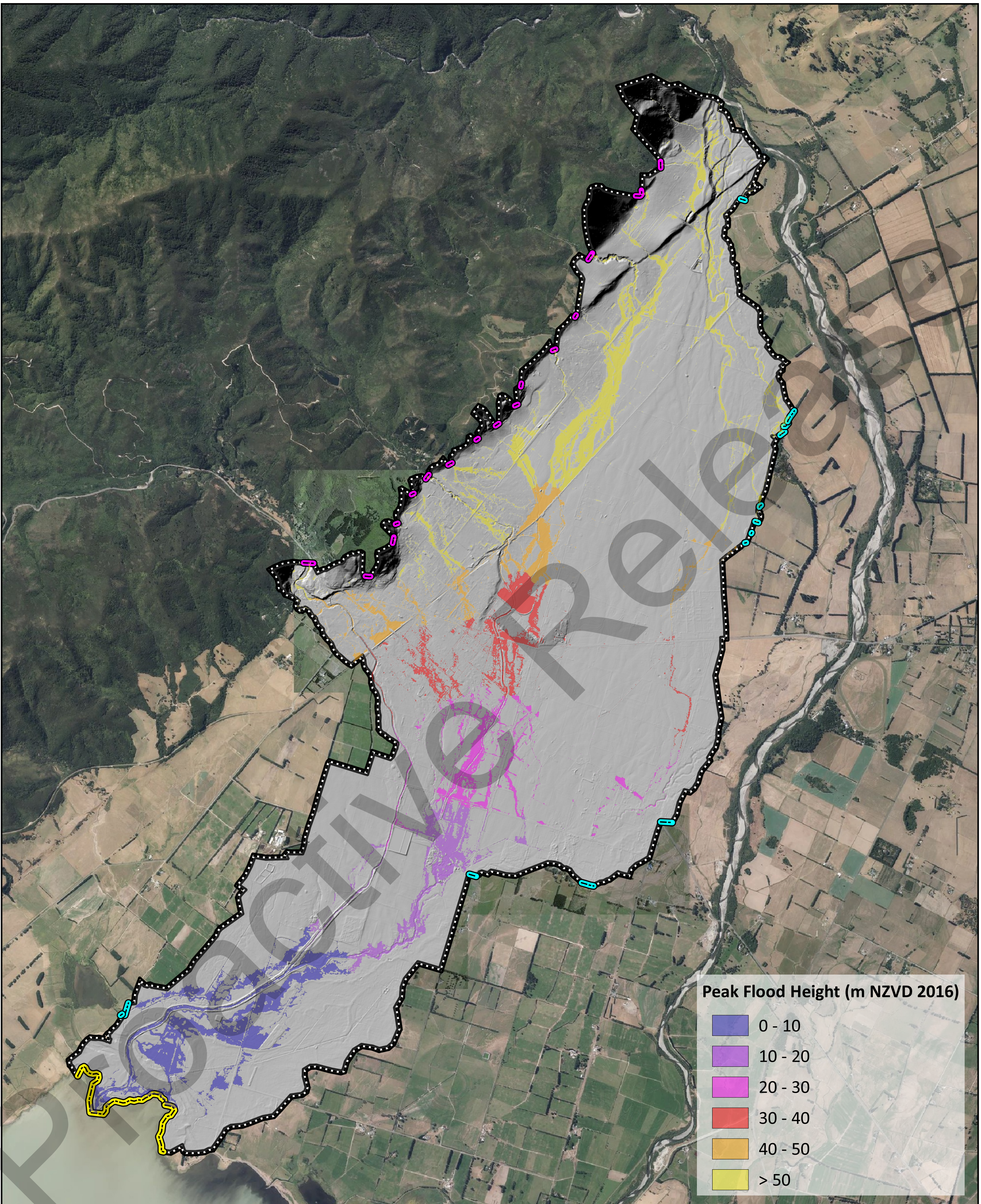
Projection: NZGD2000 / NZTM 2000
Scale: 1:50,000
Project Number: 820.V30278.00000
Drawn by: OA
Sheet Size: A4
Date: 09-07-2024

Legend
Model Domain
Boundary Conditions
Outflows (HQ)
Inflows (QT)
Water Level (HT)

Donalds and Abbots Creek Hydraulic Modelling

Peak Flood Depths
02-Dec-2018 Event

SLR
www.slrconsulting.com



0 500 1,000 m

Legend

Model Domain

Boundary Conditions

Outflows (HQ)

Inflows (QT)

Water Level (HT)

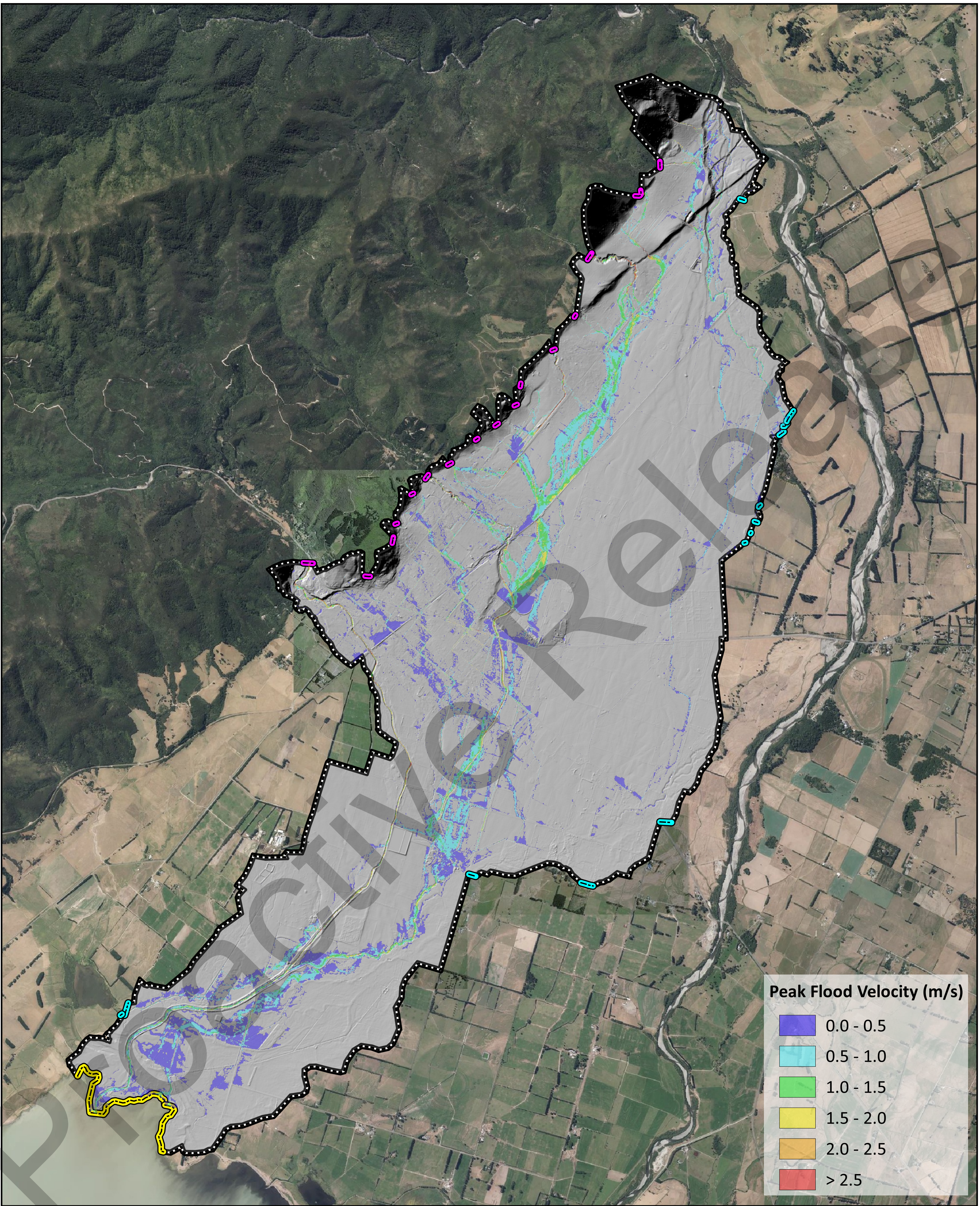
Projection: NZGD2000 / NZTM 2000
Scale: 1:50,000
Project Number: 820.V30278.00000
Drawn by: OA
Sheet Size: A4
Date: 09-07-2024

Donalds and Abbots Creek Hydraulic Modelling

Peak Flood Heights 02-Dec-2018 Event

SLR

www.slrconsulting.com



0 500 1,000 m

Projection: NZGD2000 / NZTM 2000
Scale: 1:50,000
Project Number: 820.V30278.00000
Drawn by: OA
Sheet Size: A4
Date: 09-07-2024

Legend

Model Domain

Boundary Conditions

Outflows (HQ)

Inflows (QT)

Water Level (HT)

Donalds and Abbots Creek Hydraulic Modelling

Peak Flood Velocities 02-Dec-2018 Event

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Making Sustainability Happen

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Memo

To:	**Greater Wellington Regional Council**	From:	Kate Bozek Mail to: PO Box 13052, Christchurch 8140 NEW ZEALAND
Project/File:	**Donalds and Abbots Creek Hydraulics – Peer Review**	Date:	20 May 2025

Reference: 310104160 - Peer Review Part B

Stantec were engaged by Greater Wellington Regional Council (GWRC) to undertake a peer review of the Donald and Abbots Creek hydraulic model. The peer review is to determine whether the modelling work has fulfilled the requirements of GWRC's Flood Hazard Modelling Standard (FHMS), which was developed to ensure modelling projects follow industry-accepted practice and output results are appropriate for use and robust.

Part A of the hydraulic model review involved a thorough, hands-on technical review of the Donalds and Abbots Creek hydraulic model build and calibration, including review of the modelling report. This review found that the hydraulic modelling approach is in line with the GWRC modelling specifications and makes best use of the limited data available in the catchment. A small number of items were flagged for model updates and suggested improvements.

Following the Part A review, the hydraulic model has been updated to address comments raised and to make further improvements. The updated model has been used to simulate a suite of current and future climate design runs for a series of annual exceedance probability (AEP) events, sensitivity tests and residual hazard assessment. The updated model and results were submitted for peer review Part B.

Stantec undertook a preliminary Part B review of the updated model and results in accordance with Procedure 3 of the FHMS. The review found that the previously raised comments have been satisfactorily addressed. There are outstanding review tasks to be completed to confirm compliance of all outputs with the FHMS. These include detailed checks of the analysis of model results from uncertainty assessment, such as blockage, changes to roughness, debris loading, boundary conditions, hydrological inputs. Furthermore, review of all required outputs and updated modelling report in line with FHMS will be undertaken, once these are completed.

The additional outputs and report would not change the already supplied model results for the design simulations and sensitivity assessment. We understand that these results will be used for District Planning purposes. We have not identified any unresolved issues or concerns with the modelling that would suggest that it is not appropriate to use these results for District Planning.

We expect that the outstanding outputs and report will be provided when completed to allow finalisation of the Part B peer review.

Reference: 310104160

Yours sincerely

Stantec New Zealand

Kate Bozek

Senior Hydraulic Modeller
Phone: +64 9 580 7602
kate.bozek@stantec.com

Donalds Creek Detention Dam

Donalds Creek Detention Dam, Failure Modes & Effects Analysis

10/06/2024

Prepared for
Greater Wellington Regional Council

E2417

Issue 1

P +64 4 381 1300 F +64 4 381 1301
A Level 3, 88 The Terrace, PO Box 1549, Wellington 6140, New Zealand

DAMWATCH ENGINEERING
www.damwatch.co.nz

Damwatch Engineering Ltd
PO Box 1549
Wellington 6140
New Zealand
Telephone: +64 4 381 1300
https://damwatch.co.nz/
info@damwatch.co.nz

Project name	Donalds Creek Detention Dam
Document title	Donalds Creek Detention Dam, Failure Modes & Effects Analysis
Client name	Greater Wellington Regional Council
Client contact	Rolayo Olukunle
Damwatch project no. and task	E2417

Document history and status

Issue no.	Issue date	Description	Prepared by	Reviewed by	Approved by
1	2024-06-10	Issue 1	MA	KD/DMA	SMI

Current document approval

Prepared by	Margela Andrews		
Reviewed by	Karina Dahl/David Menendez Aran		
Approved for issue	Steve McInerney	Signature:	

Executive Summary

A Failure Modes and Effect Analysis (FMEA) was carried out for the Donalds Creek Detention Dam in accordance with the 2023 NZ Dam Safety Guidelines (NZDSG). The purpose of a FMEA is to define and assess the Potential Failure Modes (PFMs) associated with a dam with respect to current understanding and potential hazards.

Donalds Creek Detention Dam is not classifiable under the 2022 Building (Dam Safety) Regulations but has potential consequences due to downstream development after construction. Greater Wellington Regional Council (GWRC) has proactively chosen to better understand the dam's PFMs. GWRC engaged Damwatch Engineering Ltd. (Damwatch) to perform a screening level FMEA of Donalds Creek Detention Dam.

FMEA scope and methodology

The FMEA included an inspection of the dam and an FMEA Workshop. The primary participants of the FMEA Workshop were GWRC and Damwatch team members.

The approach of the FMEA Workshop followed the Canadian Dam Association's systematic procedures to develop a picture of the dam system, its components, and their interactions. This framework was used to analyse how component failure could lead to system failure.

Damwatch developed a simplified Hazard and Failure Mode Matrix (HFMM) to systematically screen and analyse the PFMs. The HFMM presents conceivable combinations of hazards and basic functional failure characteristics related to the dam and its components.

The two basic failure modes in the HFMM by which a dam structure can fail are collapse by:

- overtopping, and
- loss of strength.

Hazards applicable to Donalds Creek Detention Dam in the HFMM are:

- Flood
- Seismic

This FMEA established the first formal list of PFMs for the dam. A total of 10 failure modes were identified and assessed in the FMEA Workshop. The PFMs were categorised into the following four groups:

- Category I: Credible – Highlighted
- Category II: Credible – Not Highlighted
- Category III: Not Enough Information
- Category IV: Not Credible – Ruled Out

FMEA results

The FMEA Workshop participants assessed each of the PFMs in the HFMM and categorised them as follows:

- Four (4) of the PFMs as Category I: Credible – Highlighted.
- Five (5) of the PFMs as Category II: Credible – Not Highlighted.
- One (1) PFM as Category IV: Not Credible – Ruled Out.

Table ES1 lists the 10 PFMs identified during the FMEA and their likelihood of failure.

Table ES1: Donalds Creek Detention Dam PFMs

No.	Potential Failure Mode	PFM ID	Loading Condition	Failure Likelihood
Category I: Credible – Highlighted				
1	Overtopping: Dam overtopping due to insufficient spillway capacity	PFM01-F	Flood	Very High
2	Overtopping: Dam overtopping due to culvert blockage	PFM02-F	Flood	Very High
3	Loss of Strength: Internal erosion along culvert	PFM05-F	Flood	High
4	Loss of Strength: Spillway discharges erode left embankment	PFM06-F	Flood	Very High
Category II: Credible – Not Highlighted				
1	Loss of Strength: Internal erosion through embankment	PFM03-F	Flood	Moderate
2	Loss of Strength: Internal erosion through the foundation	PFM04-F	Flood	Moderate
3	Loss of Strength: Culvert undermined due to scour	PFM07-F	Flood	Low
4	Overtopping: Damage of culvert due to seismic event blocks culvert	PFM08-SF	Seismic-Flood	Low
5	Loss of Strength: Instability of downstream or upstream slopes of embankment dams during seismic event	PFM10-SF	Seismic-Flood	Low-Moderate
Category IV: Not Credible – Ruled Out				
1	Loss of Strength: Liquefaction of foundation during seismic event	PFM09-SF	Flood	NA

At the end of the FMEA workshop, the participants had an informal discussion about:

- The implications of a dam that is not classifiable per the Dam Safety Regulations and New Zealand Dam Safety Guidelines but has downstream consequences.
- Whether the dam is still classified as rural or if it should be classified as urban based on the downstream residential development.

Key performance indicators

Key performance indicators were identified for the PFMs during the screening and analysis. PFM tables in Appendix D list the KPIs for each PFM.

Information gaps

The FMEA Workshop participants identified information gaps associated with the PFMs.

Information gaps relating to the PFMs include:

- Geometry, construction and composition of embankment and foundation including:
  - whether seepage cutoff trench was constructed as designed, and

  - whether riprap has been installed at downstream end of culvert.
- Foundation geology and liquefaction potential.
- Structural performance of culvert under seismic load.
- Embankment seismic performance.
- Downstream stopbank capacity relative to the higher culvert discharge capacity than estimated in design.
- Incremental effect of the dam break relative to flood event.
- Embankment overtopping resistance.
- Confirm classification of Donalds Creek Detention Dam per GWRC Floodplain Management Planning Principles to know the level of flood protection to be provided.

Risk reduction measures

Tasks to provide risk reduction measures for the PFMs include:

- Monitor the water level sensor during periods of high water to inform:
  - potential need for emergency action, and
  - observation of flood trends.
- Perform dam break assessment, including the effect of blockage of the culvert, to provide information on discharge through the spillway, depth of overtopping, and flow velocities.
- Assess consequences of dam break assessment.
- Obtain as-constructed drawings of the original culvert, prior to flood protection project upgrades.
- Assess the level of flood protection provided by Donalds Creek Flood Protection Project given as-built varies for the original design assumptions.
- Coordinate with the owner of the culvert on it’s operation and maintenance, and appreciation that it is an appurtenant dam safety structure.
  - Include removal of tree planting on road adjacent to culvert
- Consider engaging with the area community on the flood protection provided by Donalds Creek Detention Dam, expected spillway overland flood discharges and potential dam break flood hazards.
- Consider limiting development within known inundation areas immediately downstream of the dam.
- Monitor deposition and the type of material deposited within the reservoir pond area following each flood event.
- Maintain grass/weeds along embankments for effective surveillance visual inspections.

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List of abbreviations

Abbreviation	Meaning
AEP	Annual Exceedance Probability
CDA	Canadian Dam Association
CDSRs	Comprehensive Dam Safety Review
Damwatch	Damwatch Engineering Ltd.
FERC	Federal Energy Regulatory Commission
FMEA	Failure Modes and Effects Assessment
GWRC	Greater Wellington Regional Council
HFMM	Hazard and Failure Mode Matrix
IDF	Inflow Design Flood
KPI	Key Performance Indicator
masl	meters above sea level
MBIE	Ministry of Business, Innovation & Employment
NSHM	National Seismic Hazard Model
NZDSG	New Zealand Dam Safety Guidelines
NZSOLD	New Zealand Society on Large Dams
OBE	Operating Basis Earthquake
PAR	Population at Risk
PGA	Peak Ground Acceleration
PFM	Potential Failure Mode
PIC	Potential Impact Classification
PLL	Potential Loss of Life
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RL	Reduced Level
Regulations	2022 Building Dam Safety Regulations
SEE	Safety Evaluation Earthquake
SH2	State Highway 2
USBR	United States Bureau of Reclamation

1 Introduction

1.1 Background

Donalds Creek Detention Dam is a flood detention dam owned and operated by Greater Wellington Regional Council (GWRC). It was constructed in 1998/99 as part of the larger Donalds Creek Flood Protection Project. Donalds Creek Detention Dam is located on Donalds Creek in the northeastern edge Featherson town centre in the South Wairarapa District of the Wellington Region.

Since the dam construction, residential properties have been constructed within the ponding area of the spillway flows and dam breach inundation area. This change of land use would result in increase in potential consequences if a dam failure were to occur.

1.1.1 Dam classification and Dam Safety Regulations

In March 2024, GWRC performed an initial desktop assessment (Polvere, 2024a; Polvere, 2024b) of the Potential Impact Classification (PIC) of Donalds Creek Detention Dam. At that time, the dam height and estimated stored volume met the 2022 Building Dam Safety Regulations (Regulations) (MBIE, 2022) for a classifiable dam. GWRC assessed the dam to be a High PIC dam per methods in the New Zealand Dam Safety Guidelines (NZDSG) (NZSOLD, 2023).

In April 2024, the classifiable dam definition in the Regulations was revised. A dam is classable if it has a dam height of 4 m or more and stores 20,000 m^3 or more water. The Regulations came into effect on 13th May 2024.

Donalds Creek Detention Dam with a dam height of 3.5m is not a classifiable dam under the Regulations. It is also not a ‘Large Dam’ per NZDSG, which has the same criteria as the Regulations.

1.2 Purpose of FMEA

GWRC has chosen to take a proactive approach in the dam safety management of Donalds Creek Detention Dam even though it is not a classifiable dam. As an initial step, GWRC engaged Damwatch Engineering Ltd. (Damwatch) to perform a screening level Failure Modes and Effects Assessment (FMEA) for Donalds Creek Detention Dam. A screening level FMEA is meant to enhance the understanding of the dam’s PFMs.

No PFMs have previously been developed or assessed for Donalds Creek Detention Dam.

The purpose of this FMEA is to:

- Identify and develop the Potential Failure Modes (PFMs),
- Use best practice to undertake the FMEA and assess each PFM,
- Identify Key Performance Indicators (KPIs) to incorporate into the surveillance programme for early detection of the PFMs development, and
- Identify information gaps in understanding the PFMs.

This report documents the Donalds Creek Detention Dam FMEA.

2 FMEA scope and methodology

2.1 FMEA scope of work

The scope of work for the FMEA included:

- Collate and review available documentation on the dam,
- Site inspection of the dam,
- Develop draft PFMs,
- One-day FMEA Workshop to:
  - Screen and assess the PFMs,
  - identify KPIs, and
  - document information gaps
- Document the FMEA discussion and findings in this report.

2.2 FMEA methodology

The FMEA methodology followed the Canadian Dam Association's (CDA's) systematic procedures to develop a picture of the dam system, its components and their interactions. This framework was used to analyse how component failure could lead to system failure. Fundamental to the approach is an understanding of the dam safety functions of each component.

The dam components were divided into elements that:

- contain,
- convey and
- control the reservoir contents.

The FMEA is based on the current understanding of the dam and its potential hazards.

2.2.1 Hazards and Failure Modes Matrix

The Hazards and Failure Modes Matrix (HFMM) is a CDA tool to ensure a systematic and structured approach to screening and identifying dam safety hazards and PFMs. The HFMM comprises a series of rows and columns to consider combinations of the basic functional failure (rows) and hazards (columns).

Damwatch developed a simplified HFMM for Donalds Creek Detention Dam for screening and analyses of the PFMs. Appendix B provides the HFMM developed for Donalds Creek Detention Dam.

There are two basic functional failure modes in the HFMM by which a dam structure can fail:

- Collapse by overtopping – water level too high
- Collapse by loss of strength – crest level too low

Failure of management systems (i.e., operations, maintenance and surveillance) crosses over these two basic functional failure modes.

There are two external hazards:

- Flood.
- Seismic

Columns of the HFMM for internal hazards (i.e., normal static) were removed from the simplified HFMM since the flood detention dam normally does not store water. Internal hazards of infrastructure and plans were covered by the management system functional failure rows.

2.3 PFM load conditions for the external hazards

The PFM Workshop considered the following definitions for the external hazards:

- Flood (F): A flood event resulting in the detention of water against the embankment and operation the spillway.
- Seismic (S): An earthquake of sufficient magnitude to cause damage followed by a moderate flood.

2.4 PFM categories

PFMs were categorised into one of four categories based on screening and analysis of each PFM.

Table 2.1 lists the PFM categories.

Table 2.1: PFM categories

Category	Classification	Description
I	Credible – Highlighted	Highlighted Potential Failure Modes – Those potential failures modes of greatest significance considering need for awareness, potential for occurrence, magnitude of consequence and likelihood of adverse response (physical possibility is evident, fundamental flaw or weakness is identified and conditions and events leading to failure seemed reasonable and credible) are highlighted.
II	Credible – Not Highlighted	Potential Failure Modes Considered but not Highlighted – These are judged to be of lesser significance and likelihood. Note that even though these potential failure modes are considered less significant that Category I they are all also described and included with reasons for and against the occurrence of the potential failure mode. The reason for the lesser significance is noted and summarized in the documentation reports or notes.
III	Not Enough Information	More Information or Analyses are needed in order to classify these potential failure modes to some degree lacked information to allow a confident judgement of significance and thus a dam safety investigative action or analyses can be recommended. Because action is required before resolution the need for this action may also be highlighted.
IV	Not Credible – Ruled Out	Potential Failure Mode Ruled Out Potential failure modes may be ruled out because the physical possibility does not exist, information came to light which eliminated the concern that had generated the development of the potential failure mode, or the potential failure mode is clearly so remote a possibility as to be non-credible or not reasonable to postulate.

Source: Engineering Guidelines for the Evaluation of Hydropower Projects (FERC, 2017)

2.4.1 Failure to function

In the scenario where a dam component fails to function but does not result in dam failure, the FMEA participants assigned a separate category, Failure to Function. This scenario may involve significant repair costs or reputational damage for GWRC.

2.5 Likelihood of failure PFMs

After categorising the PFMs, the workshop participants assessed the failure likelihood of the credible PFMs using the semi-quantitative methodology by the United States Bureau of Reclamation (USBR, 2019).

Table 2.2 below lists failure likelihood categorises and their descriptions.

Table 2.2: Failure likelihood categories and descriptions

Failure Likelihood Category	Description
Very High	There is direct evidence to suggest it is certain to nearly certain that failure is imminent or extremely likely in the next few years.
High	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward “more likely” than “less likely.”
Moderate	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward “less likely” than “more likely.”
Low	The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to initiation.
Remote	Several events must occur concurrently or in series to cause failure, and most, if not all, have negligible likelihood such that the failure likelihood is negligible.

Source: Best Practices in Dam and Levee Safety Risk Analysis (USBR, 2019)

3 FMEA reference material

3.1 Reports and studies

Available documentation on the dam and considered in the FMEA include:

- Donalds Creek Flood Protection Project Design Report (WRC, 1998).
- Donalds Creek Flood Protection Project Assessment of Environmental Effects (WRC, 1998).
- Donalds Creek Flood Protection Recommendations Memorandum (Bowman, 2017).
- Donalds Creek Detention Facility – FMEA Memorandum (WSP Opus, 2018c).
- Post-Event Appraisal Report (GWRC, 2018).
- Donald’s Creek Detention Dam Confirmed Dam Safety Deficiencies Memorandum (Polvere, Dam Safety Issues: Donalds Creek Detention Dam Confirmed Dam Safety Deficiencies Memorandum, 2024a).
- Donald's Creek Dam Potential Impact Classification Desktop Assessment Memorandum (Polvere, Donald's Creek Dam Potential Impact Classification Desktop Assessment Memorandum, 2024b).

Key flood studies include:

- Hydrological Assessment of Donalds Creek (PGWES, 2016).
- Donalds Creek Detention Facility: Hydrological Analysis (WSP Opus, 2018a).
- Donalds Creek Detention Facility: Hydrological Analysis Phase II (WSP Opus, 2018b).
- Additional information on flood hazard modelling for new development at Harrison Street East, Featherston (Tonkin & Taylor, 2020).

Supplemental documentation considered in the FMEA include:

- NZ topographic maps,
- LiDAR data,
- Regional geology mapping,
- Liquefaction hazard mapping, and
- National Seismic Hazard Model 2022 (NSHM22).

3.2 Key drawings

Appendix A provides key drawings that are available on Donalds Creek Detention Dam.

3.3 Workshop supplemental information

During the workshop, GWRC provided the following pertinent supplemental information:

- GIS model of overland flow in the Donalds Creek area,
- GWRC Floodplain management planning principles,
- 1943 aerial photograph of the project site, and
- Aerial photograph of a flood, probably taken in 2021.

Appendix E provides this supplemental information.

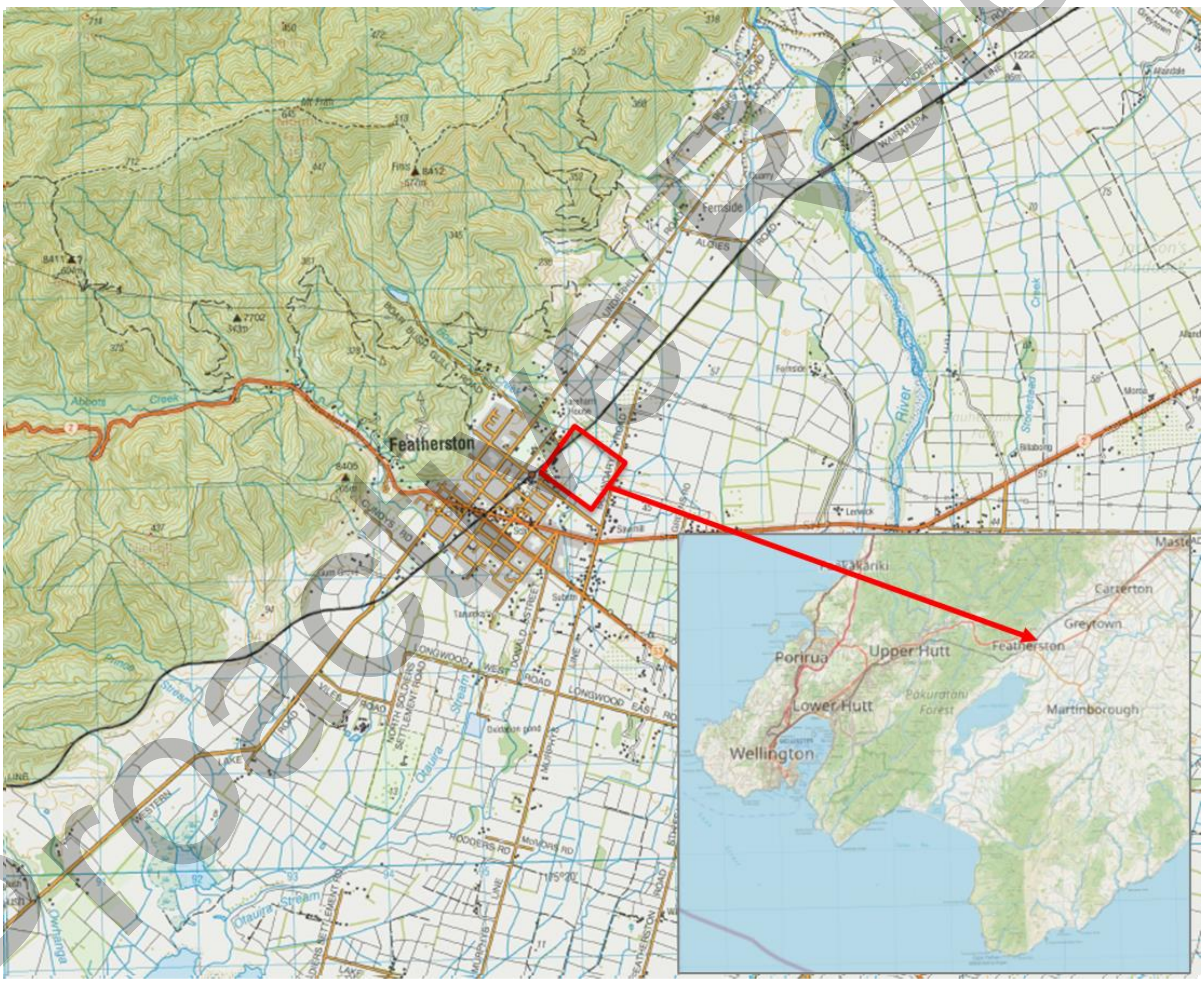
4 Dam Information

The Donalds Creek Detention Dam is located at the upstream end of the Donalds Creek Flood Protection Project. The project includes stop banks, floodgates and culvert enlargements downstream of the dam. It was designed by Wellington Regional Council, Wairarapa Division, and constructed in 1998/1999. There are no construction records available on the dam.

4.1 Dam location

Donalds Creek Detention Dam is a 2.5 to 3.5 m high horseshoe shaped embankment at the northeastern edge of the Featherston town centre. The dam is located just east of the Tararua mountains with Boundary Road at the east and Harrison Street at the south.

Figure 4.1 shows the location of Donalds Creek Detention Dam.



Source: www.topomap.co.nz

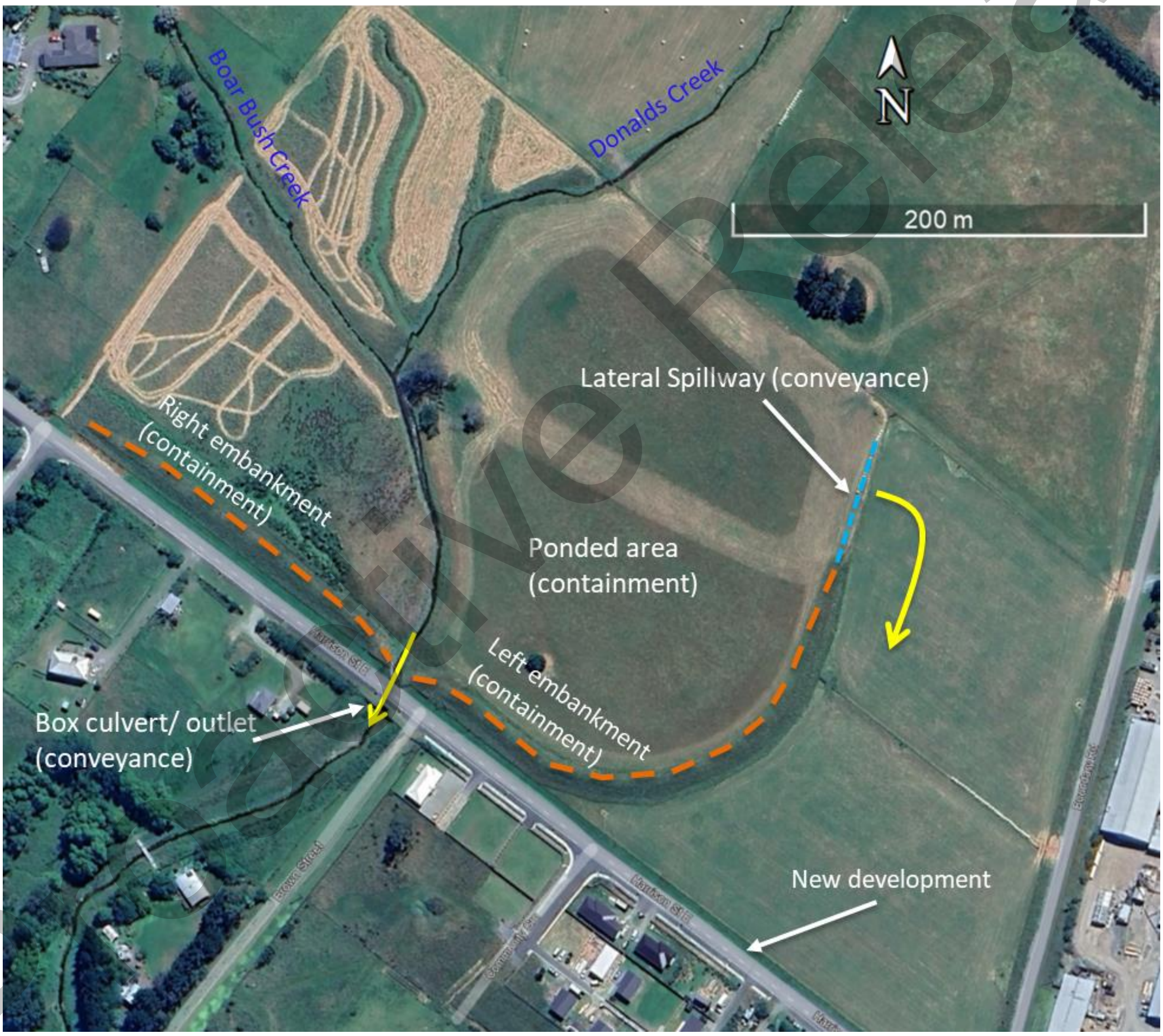
Figure 4.1: Location of Donalds Creek Detention Dam

4.2 Dam components, system definitions and safety functions

The dam components comprise:

- The left and right earthfill embankments.
- A box culvert with two (ungated) openings under Harrison Street. Modified with extended wingwalls and cutoffs as part of the dam construction.
- A lateral spillway at the end of the left embankment.
- Flood detention pond area.

Figure 4.2 is a photograph showing the layout of Donalds Creek Detention Dam and dam safety components.



Source: Google Earth Pro

Figure 4.2: Donalds Creek Detention Dam components and dam safety functions

4.2.1 Dam system definitions

Components of Donalds Creek Detention Dam were defined into system elements per the CDA approach.

Table 4.1 lists system definition for each component of the dam.

Table 4.1: Donalds Creek Detention Dam structures and components

Water Barrier	Hydraulic Structures
Right embankment	Lateral spillway
Left embankment	Culvert
	Spillway flow path
	Culvert outlet dissipation area

Damwatch identified and categorised the dam safety function of each component of Donalds Creek Detention Dam as either containment, conveyance and/or control.

4.2.2 Dam safety functions

Table 4.2 lists the dam safety function of each component.

Figure 4.2 shows each dam component and their dam safety functions.

Table 4.2: Dam safety functional components of Donalds Creek Detention Dam

Component	Dam Safety Function
Ponded area	Containment
Right embankment	Containment
Left embankment	Containment
Lateral spillway	Conveyance
Culvert	Conveyance
Spillway flow path	Conveyance

4.3 Key parameters of the dam

Table 4.3 lists the key parameters and flood detention (reservoir) levels of Donalds Creek Detention Dam.

Table 4.3: Key Parameters and Levels of Donalds Creek Detention Dam

Parameter	Value
Construction	1998/99
Location of dam	Across Donalds Creek on the northeastern edge of Featherston
Purpose of dam	Flood mitigation for downstream community. The dam only impounds water during floods.
Type of dam	Earth embankment – gravel core with upstream inclined silt layer
Height of dam	2.5 m (above ground level) to 3.5 m (above lowest foundation)
Reservoir maximum capacity	80,000 m^3 (design) 105,000 m^3 (at 39 masl)
Total pond area	5.6 ha
Left Dam Crest RL Right Dam Crest RL Spillway Crest RL	39.3 m (design); 38.6 (surveyed low point, WSP Opus 13/7/2018) 39.3 m (design); 38.9 (surveyed low point, WSP Opus 13/7/2018) 38.9 m (design); 38.4 (surveyed low point, WSP Opus 13/7/2018)
Dam crest width	3 m
Dam crest length	552.5 m
Slopes	2H:1V (design) 1H:1V (site visit estimate, 8/5/2024) 1.5H:1V to 2H:1V (upstream slope, 2014 LiDAR) 2H:1V to 2.5H:1V (downstream slope, 2014 LiDAR)
Outlet	Culvert with two 2.1 m wide x 2.1 m high openings with upstream invert at RL 36 m (design); 35.6 m (surveyed)
Type of spillway	Lateral
Spillway Crest length	76 m
Maximum spillway capacity	25 m^3/s

Source: Donalds Creek Flood Protection Project Assessment of Environmental Effects (WRC, 1998); Donalds Creek Flood Protection Project Design Report (WRC, 1998); Hydrological Analysis & Hydrological Analysis Phase II (WSP Opus, 2018a)

4.4 Dam site inspection

The Damwatch and GWRC personnel inspected the Donalds Creek Detention Dam on 8th May 2024.

Key observations from the site inspection are:

- Grass cover – The team observed significant grass/weed growth along the full length of both embankments which prohibited inspection of the slope.
- Embankment slopes – Both the upstream and downstream slopes appeared steeper (~1H:1V) than the design (2H:1V) in places. A review of the 2014 LiDAR Data indicates slopes that are similar to the designed slopes but may have been influenced by the grass/weed cover.
- Embankment crest width – In some areas, the width of the crest appeared to be narrower than the design (3 m).

- Wetlands planting – An area at the upstream toe of the right embankment (right of the culvert) is fenced and planted with native vegetation. The planting is in line with a drain that runs along the embankment toe.
- Culvert:
  - Sediment accumulation – Approximately 7 cm of sediment has accumulated at the downstream end of the left culvert. The right culvert did not have significant sediment accumulation.
  - Downstream condition – The team noted offset and tilting in the downstream left and right wingwall extensions.
  - Concrete deterioration – The concrete has deteriorated at base of right wall of the left culvert.
  - Hanging fences – Fences are in place at the downstream end of the culvert to prevent livestock entry. These fences connected from the top of the culvert (allow to swing outward) and can be raised from the road.
  - Inlet slope - The slope of the riprap at the inlet channel between the concrete weirs is not as steep as shown in the design drawings.
- Spillway outlet channel – The topography of the spillway overland flow area has a steeper slope (~3%) than typical spillway channel.

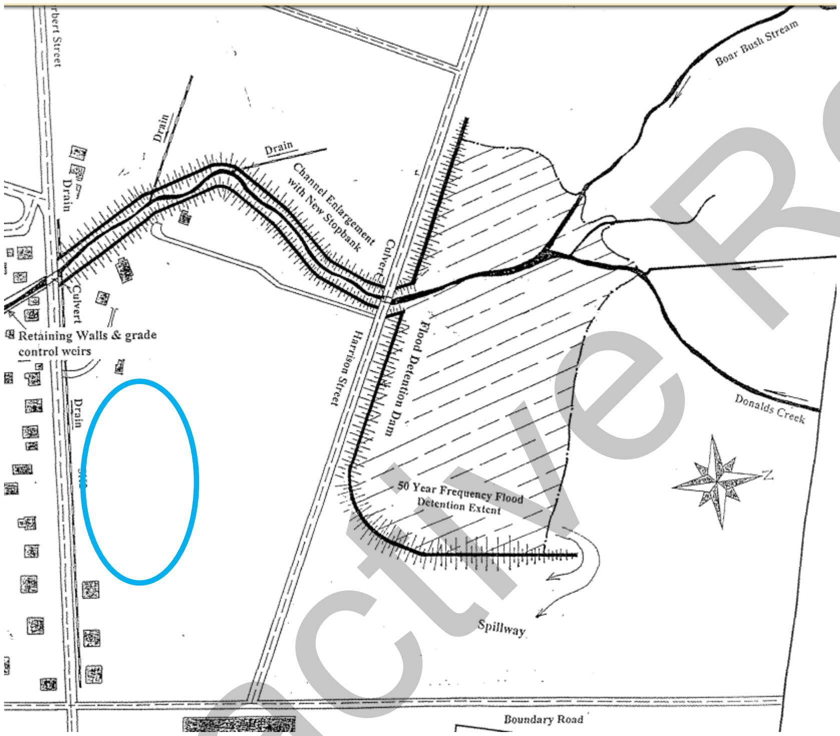
5 Flood and Seismic Hazards

5.1 Flood Hazard

5.1.1 Dam flood design and ponding areas

The Donalds Creek Detention Dam was designed to pass the 1 in 50 AEP flood. The spillway discharge flows travel overland adjacent to the downstream toe of the left embankment. For floods exceeding the design flood, a provision was made for spillway flows and possible embankment overtopping flows to pond downstream. The ponding area is between Boundary Road, State Highway 2 (SH2), and the left stopbank downstream of the Harrison Street culvert (WRC, 1998).

Figure 5.1 shows the design flood detention area, spillway flood flows and indicative ponding area.



Source: Donalds Creek Flood Detention Project, Design Report (1998)

Figure 5.1: Donalds Creek Detention Dam design spillway flood flows and ponding area

The flood ponding area is also where residential structures have been constructed after the construction of the flood protection system.

Figure 5.2 shows the increase in downstream development that has taken place since dam construction.

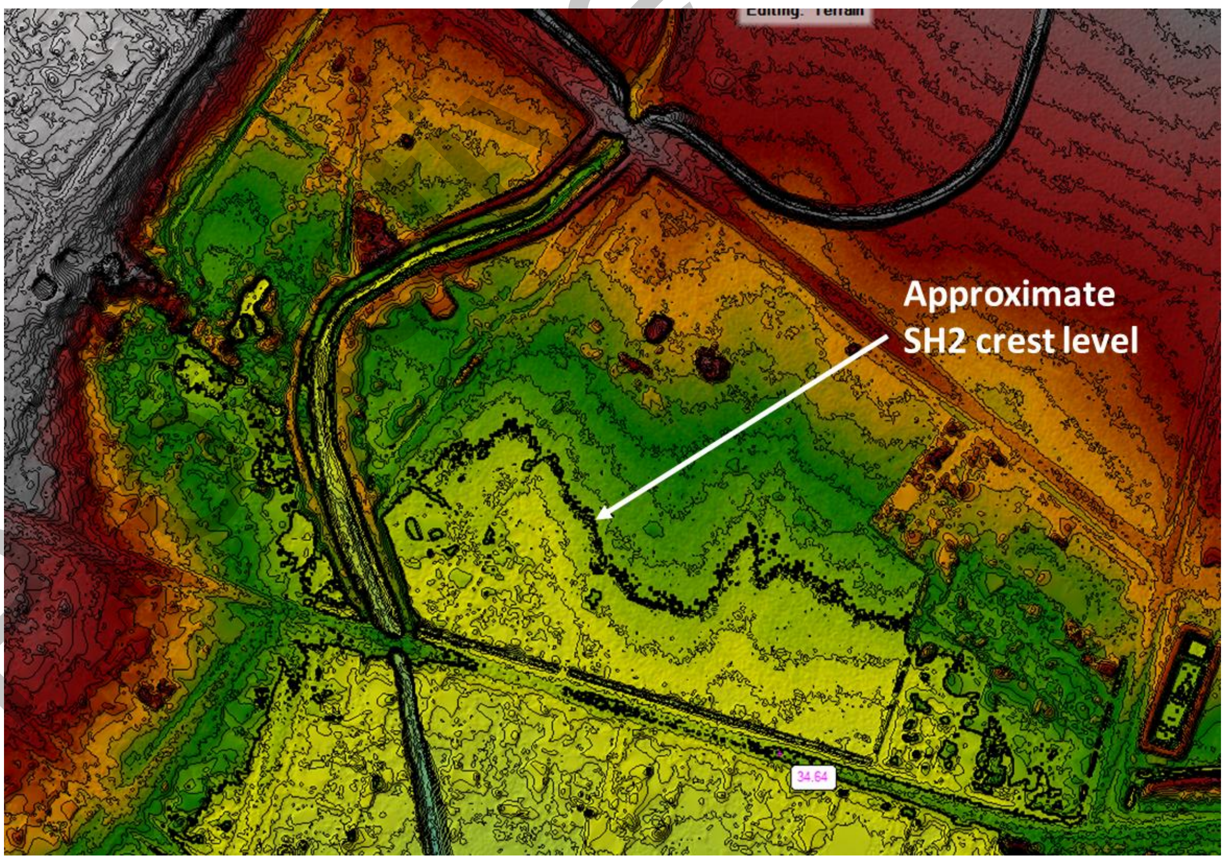
April 2002 December 2023

Source: Google Earth Pro

Figure 5.2: Post-construction development downstream of Donalds Creek Detention Dam

Figure 5.3 shows 2014 LiDAR data from the Land Information website (Wellington LiDAR 1m DEM (2013-2014) | LINZ Data Service).

The figure indicates that the topography generally slopes downstream in a southwest direction. The lowest ground surface elevation lies within the indicated contour, which is approximately the same elevation of SH2 at its southern extreme. This suggests that any flood flows will pool in this area and residences located within this area have the greatest flood risk.



Source: https://data.linz.govt.nz/layer/53621-wellington-lidar-1m-dem-2013-2014/

Figure 5.3: Donalds Creek Detention Dam and surrounding area topography

5.1.2 Design flood routing parameters

Based on Damwatch's review of the key flood documents, the embankment overtops for a:

- 1:50 AEP event considering the effects of climate change, and
- 1:100 AEP event under current climate conditions.

Table 5.1 shows the peak inflows, outflows and elevations per the dam design.

Table 5.1: Design flood routing details

Annual Exceedance Probability	**Peak inflows** (m^3/s)	**Peak outflows** (m^3/s)	**Peak elevation** (RL m)
1:2	15.2	13.8	
1:5	22.3	19.2	
1:10	26.9	22.4	
1:20	30.7	25.1	
1:50	36.6	29.4	38.79
1:100	41.1	32.6	39.00

Source: Donalds Creek Flood Protection Project Assessment of Environmental Effects (WRC, 1998)

Table 5.2 shows this data per the 2018 WSP Opus Hydrological Analysis Phase II (WSP Opus, 2018b). The red text indicates that at those flood levels, the embankment is overtopping.

Table 5.3 shows the effects of culvert blockage as assessed by the 2018 WSP Opus assessment.

We note that once the detention pond level gets higher than the lowest points along the embankments, the dam is no longer operating normally according to its design. Overtopping of the embankment is an emergency scenario and could lead to the dam breaching. The capacity of embankment dams to safely pass low overtopping flows without failing is not usually considered when reviewing the safe passage of the inflow design flood.

Table 5.2: Flood routing results as simulated by WSP Opus

Annual Exceedance Probability	Peak inflows (m^3/s)	Peak outflows (m^3/s)	Peak elevation (RL m)
1:20 (Present)	27	22.4	37.86
1:20 (Climate Change)	34.2	27.2	38.25
1:50 (Present)	36.6	28.7	38.36
1:50 (Climate Change)	52.3	48.9	38.71
1:100 (Present)	49.3	45.3	38.67
1:100 (Climate Change)	67.4	65.9	38.84
PMF	300 - 320		

Source: Hydrological Analysis Phase II (WSP Opus, 2018b)

Table 5.3: Flood routing results as simulated by WSP Opus

Annual Exceedance Probability	Blockage	Case	Peak inflows (m^3/s)	Peak outflows (m^3/s)	Peak elevation (RL m)
1:100	0%	Present	49.3	45.3	38.67
		Climate Change	67.4	65.9	38.84
	20%	Present	49.3	46.6	38.74
		Climate Change	67.4	66.5	38.89
	50%	Present	49.3	49.3	38.83
		Climate Change	67.4	68.2	38.96

Source: Hydrological Analysis Phase II (WSP Opus, 2018b)

Table 5.4 shows the results of the flood hazard assessment conducted by Tonkin & Taylor prior to the development of the downstream residential area just south of Harrison Street and left of Donalds Creek.

Table 5.4: Flood routing results as simulated by Tonkin & Taylor

Annual Exceedance Probability	Method	Peak flood inflows (m^3/s)	Peak outflows (m^3/s)
1:100	NIWA (Regional)	24.5	
	NIWA (Rational)	23 – 45	
	SCS (HEC-HMS model)	23 - 30	~29
1:100 (RCP 6.0 2100)	SCS (HEC-HMS model)	~48	~43

Source: Additional information on flood hazard modelling for new development at Harrison Street East, Featherston (Tonkin & Taylor, 2020)

5.1.3 Standards for safe flood passage

The current safe flood passage capacity of the dam (i.e., without overtopping of the embankment) is in line with GWRC Floodplain Management Planning Standards for rural areas. The standard requires no flooding in rural area under the 1 in 20 AEP event. However, the recent downstream development may lead to the area being reclassified as urban. This potential reclassification could require meeting a higher standard of 1 in 100 AEP (Berghan, 2017).

A review of Donalds Creek Detention Dam classification per the Floodplain Management Planning Standards is needed to confirm if it has changed given the downstream development.

Donalds Creek Detention Dam is not a classifiable dam per the Regulations and NZDSG. However, there are potential consequences from the flood loading and dam break flood.

The NZDSG provides guidance on the AEP for the Inflow Design Flood (IDF) to consider for engineering assessment based on the PIC:

- Low PIC dam: between the 1 in 100 and the 1 in 1,000 AEP flood event.
- Medium PIC dam: between the 1 in 1,000 and the 1 in 10,000 AEP, and
- High PIC dam: between the 1 in 10,000 AEP and the Probable Maximum Flood (PMF).

5.1.4 2018 flood event

GWRC personnel were able to observe the performance of the dam during a flood event in 2018 (GWRC, 2018). The 2018 flood event was estimated at 1 in 50 AEP. Significant overland flow was reported during the 2018 event.

Figure 5.4 shows the estimated flood area observed during the 2018 flood event.

Source: Post-event appraisal (GWRC, 2018)

Figure 5.4: Estimated flood areas around Donalds Creek Detention Dam during the 2018 flood event

Based on visual observations, a culvert upstream of the dam restricted and diverted flows to the left of the detention pond area (reservoir), around the left embankment and over Harrison Street. Spillway discharges also occurred by Donalds Creek Detention Dam.

Flooding downstream of the dam could be attributed to the combination of overland flows and small discharge from the dam's spillway.

There are limited records on the performance of the dam during other flood events.

5.2 Seismic hazard

Seismic hazards to dams and reservoirs include ground motions, fault displacements and liquefaction. The South Wairarapa District is a high seismic area.

5.2.1 Area active faults

Active faults mapped relative to the Donalds Creek Detention Dam include the Wairarapa Fault, which is located approximately 1 km to the west of the dam (https://data.gns.cri.nz/af/). The Wairarapa Fault is a reverse fault with a recurrence interval of < 2,000 years and capable of a earthquake magnitude of 8.2 (Stirling, et al., 2012). The fault dips to the northwest and has a very high slip rate of > 10 mm/year. Fault traces may be closer to the dam as inferred by planning maps (refer to Appendix E liquefaction map)

The Design Report (WRC, 1998) does not discuss seismic loads or corresponding performance criteria for Donalds Creek Detention Dam embankments and culvert.

5.2.2 Estimated ground motions

Damwatch used GNS' 2022 National Seismic Hazard Model (NSHM22) online tool to develop seismic loads for the dam (GNS Science, 2024). The site Pliocene soil deposit and relatively near bedrock depth was assigned an estimated shear wave velocity of 300 m/s.

Table 5.5 lists the Peak Ground Acceleration (PGA) for Donalds Creek Detention Dam per the NSHM22.

Table 5.5: Seismic loads per the NZ NSHM22 at Donalds Creek Detention Dam

AEP	PGA (g)
150	0.53
500	0.96
1,000	1.26
2,500	1.72

Source: National Seismic Hazard Model 2022 (NZGS, 2022)

5.2.3 Liquefaction potential

Liquefaction can occur when loose, poorly consolidated, saturated and primarily granular sands and gravels are subjected to significant dynamic earthquake shaking. Dynamic loading may lead to increased pore pressures within these materials causing a sufficient loss in shear strength. Liquefaction of loose foundation materials or inadequately compacted embankment fill may result in deformations from slope instability, which if significant, may lead to dam failure.

No liquefaction assessment has been performed for Donalds Creek Detention Dam. The PFM Workshop participants considered the potential for liquefaction triggering at a high level based on available information.

The foundation materials of Donalds Creek Detention Dam were considered unlikely to liquefy under the 1 in 150 AEP ground motions. This judgement was based on:

- Foundation soils being Pleistocene in age (> 11,700 years old), which are more resistant to liquefaction than Holocene age deposits (< 11,700 years old).
- Regional liquefaction triggering mapping of the site has low hazard (Wairarapa District Councils, 2024)
  - Appendix E provides the liquefaction potential map.

The embankment fill consists of silts, sands and gravels which could be susceptible to liquefaction. There are no available construction records to understand the degree of compaction and density of the embankment fill. This is an identified information gap.

6 Loading conditions

Flood and seismic loads considered in the FMEA Workshop are provided in this section.

6.1 Flood loads

Flood loading corresponds to an event that results in the detention of water against the embankment and operation of the spillway. Overtopping of the embankment was considered for some of the PFMs. The flood level considered ranged from 1 in 50 AEP with and without climate change up to the 1in 100 AEP.

6.2 Seismic loads

Seismic loads corresponds to an event with sufficient ground shaking to result in regional and localised damage followed by a moderate flood (to pool water).

The seismic loads are high in the region and ground motions at the 1 in 150 AEP with a PGA of 0.53 g were considered. The 1 in 150 AEP corresponds to the Operating Basis Earthquake (OBE) in the NZDSG.

The subsequent flood loading is at a frequency expected to occur within the timeframe before dam repairs are completed.

7 FMEA Workshop

The FMEA was performed for Donalds Creek Detention Dam through a one-day workshop. It was held on the 15th May 2024 at Damwatch's office in Wellington.

Damwatch provided an informational package to the participants prior to the workshop consisting of the agenda and preliminary list of PFMs.

Appendix C provides the FMEA Workshop package (agenda and preliminary list of PFMs for screening) and the workshop presentation.

Appendix D provides the PFM tables and assessment.

Appendix E provides the Workshop whiteboard notes and supplemental information.

7.1 FMEA workshop participants

Table 7.1 lists the FMEA Workshop participants.

Table 7.1: FMEA Workshop Attendees

Participant	Role & Representation
George Bowman	Team Leader Flood Operations Planning, GWRC
George Balfour	Engineering Officer, GWRC
Rolayo Olukunle	Project Engineer, GWRC
Rebecca Polvere	Dam Safety Technical Advisor, GWRC
Tim Lewis	Area Engineer, GWRC
Margela Andrews	FMEA Recorder & Associate Principal Geotechnical Engineer, Damwatch
Karina Dahl	FMEA Facilitator & Principal Geotechnical Engineer, Damwatch
David Menéndez Arán	Associate Principal Hydraulics Engineer, Damwatch

7.2 PFM screening methodology

The FMEA Workshop comprised the following steps:

1. Review key information on Donalds Creek Detention Dam and appurtenant structures.
2. Provide overview of the HFMM and dam component system definitions and dam safety functions.
3. Review of draft PFM in context of the HFMM and identify any new PFMs.
4. Screen and assess the PFMs.
5. Identify key performance indicators (KPIs),
6. Identify information gaps or limitation to understanding for the PFMs.

8 FMEA Results

A total of 10 PFMs were identified, screened and analysed in the FMEA workshop. The PFMs were aligned with the basic functional failure mode and hazards of the HFMM in Appendix B.

The workshop participants assessed the credibility category of each PFMs as follows:

- Four Category I: Credible – Highlighted
- Five Category II: Credible – Not Highlighted
- None as Category III: More Information Needed
- One Category IV: Not Credible – Ruled Out

Credible PFMs were assigned a likelihood of failure per Table 2.2.

8.1 Category I: Credible - Highlighted

Table 8.1 lists the four PFMs identified as Credible – Highlighted and their likelihood of failure.

Table 8.1: Category I: Credible – Highlighted PFMs

PFM ID	Load	Potential Failure Mode	Likelihood
PFM01-F	Flood	Overtopping: Dam overtopping due to insufficient spillway capacity	Very High
PFM02-F	Flood	Overtopping: Dam overtopping due to culvert blockage	Very High
PFM05-F	Flood	Loss of Strength: Internal erosion along culvert	High
PFM06-F	Flood	Loss of Strength: Spillway discharges erode left embankment	Very High

8.2 Category II: Credible - Not Highlighted

Table 8.2 lists the five PFMs identified as Credible – Not Highlighted and their likelihood of failure.

Table 8.2: Category II: Credible – Not Highlighted PFMs

PFM ID	Loading Condition	Potential Failure Mode	Likelihood
PFM03-F	Flood	Loss of Strength: Internal erosion through embankment	Moderate
PFM04-F	Flood	Loss of Strength: Internal erosion through the foundation	Moderate
PFM07-F	Flood	Loss of Strength: Culvert undermined due to scour	Low
PFM08-S	Seismic	Overtopping: Damage of culvert due to seismic event blocks culvert	Low
PFM10-S	Seismic	Loss of Strength: Instability of downstream or upstream slopes of embankment dams during seismic event	Low-Moderate

8.3 Category III: More Information Needed

No PFMs were classified as Category III – More Information Needed.

8.4 Category IV: Not Credible - Ruled Out

Table 8.3 lists the one PFM identified as Not Credible, Ruled Out.

Table 8.3: Category IV: Not Credible – Ruled Out

PFM ID	Loading Condition	Potential Failure Mode	Likelihood
PFM09-SF	Flood	Loss of Strength: Liquefaction of foundation during seismic event	NA

8.5 Failure to Function

No PFMs were classified as a failure to function during the workshop.

8.6 Key performance indicators and information gaps

Key performance indicators (KPIs) and information gaps were identified as part of the PFM screening and analysis. Appendix D PFM tables lists the identified KPIs and information gaps by each PFM.

8.7 Dam safety challenges

At the end of the FMEA workshop, the participants had an informal discussion regarding:

- The implications of a dam that is not classifiable per the Dam Safety Regulations and New Zealand Dam Safety Guidelines but has downstream consequences.
- Whether the dam is still classified as rural or if it should be classified as urban based on the downstream residential development.

Key points from this discussion are summarised in Section 9 and Appendix E.

9 Summary of FMEA

The screening-level Failure Modes and Effect Analysis (FMEA) was carried out for Donalds Creek Detention Dam in accordance with the NZDSG (NZSOLD, 2023).

The FMEA comprised of:

- Developing PFMs for the dam,
- Site inspection, and
- FMEA Workshop.

9.1 FMEA approach

The FMEA Workshop approach followed the Canadian Dam Association's systematic procedures to develop a picture of the dam system, its components and their interactions.

Damwatch developed a simplified Hazard and Failure Mode Matrix (HFMM) to systematically screen and analyse the PFMs. The HFMM presents conceivable combinations of hazards and basic functional failure characteristics related to the dam and its components. The basic failure modes are divided into 'collapse by overtopping' and 'loss of strength'. Flood and seismic hazards were considered.

9.2 FMEA Workshop results

The FMEA Workshop participants assessed each of the PFMs in the HFMM and categorised them as follows:

- Four (4) of the PFMs as Category I: Credible – Highlighted with very high to high likelihood of failure.
- Five (5) of the PFMs as Category II: Credible – Not Highlighted with moderate to low likelihood of failure.
- One (1) PFM as Category IV: Not Credible – Ruled Out.

Table 8.1 to Table 8.3 give a summary of the PFMs, their category and likelihood of credible PFMs.

9.2.1 Key FMEA Workshop findings

The following are summary of key findings from the FMEA workshop.

- Spillway discharge channel is at a relatively steep gradient (~3%) than typical.
- The spillway is undersized.
- Some features of the existing dam are not as indicated in the original design.
- Dam slopes need to be confirmed to assess stability.
- Grass/weed cover on the embankment slope prohibits identification of potential seepage or defects during visual inspections.
- The 2014 LiDAR suggests that the right embankment may have low spots. GWRC has more recent LiDAR data (December 2023) however the high grass/weed growth could have affected the accuracy of the data.
- The capacity of the culvert is greater than what was estimated in the design and greater than what is typical for a flood detention dam. This capacity allows for self-cleaning.

9.3 Information gaps

Identified information gaps relating to the PFMs are:

- Geometry, construction and composition of embankment and foundation including:
  - whether seepage cutoff trench was constructed as designed,
  - compaction of the embankment fill, and
  - whether riprap has been installed at the downstream end of the culvert.
- Foundation geology and liquefaction potential.
- Structural performance of culvert under seismic load.
- Embankment seismic performance.
- Downstream stopbank capacity relative to the higher culvert discharge capacity than estimated in design.
- Incremental effect of the dam break relative to flood event.
- Embankment overtopping resistance.
- Confirm classification of Donalds Creek Detention Dam per GWRC Floodplain Management Planning Principles to know the level of flood protection to be provided.

9.4 Risk reduction measures

The FMEA Workshop participants identified the following risk reduction measures to help reduce uncertainties regarding some of the PFMs:

- Monitor the water level sensor during periods of high water to inform:
  - potential need for emergency action, and
  - observation of flood trends.
- Perform dam break assessment, including the effect of blockage of the culvert, to provide information on discharge through the spillway, depth of overtopping, and flow velocities.
- Assess consequences of dam break assessment.
- Obtain as-constructed drawings of the original culvert, prior to flood protection project upgrades to understand the structural performance.
- Assess the level of flood protection provided by Donalds Creek Flood Protection Project given as-built varies for the original design assumptions.
- Coordinate with the owner of the culvert on it's operation and maintenance, and appreciation that it is an appurtenant dam safety structure.
  - Include removal of tree planting on road adjacent to culvert
- Consider engaging with the area community on the flood protection provided by Donalds Creek Detention Dam, expected spillway overland flood discharges and potential dam break flood hazards.
- Consider limiting development within known inundation areas immediately downstream of the dam.
- Monitor deposition and the type of material within the pond area (reservoir) following each flood event.
- Maintain grass/weeds along embankments for effective surveillance visual inspections.

10 References

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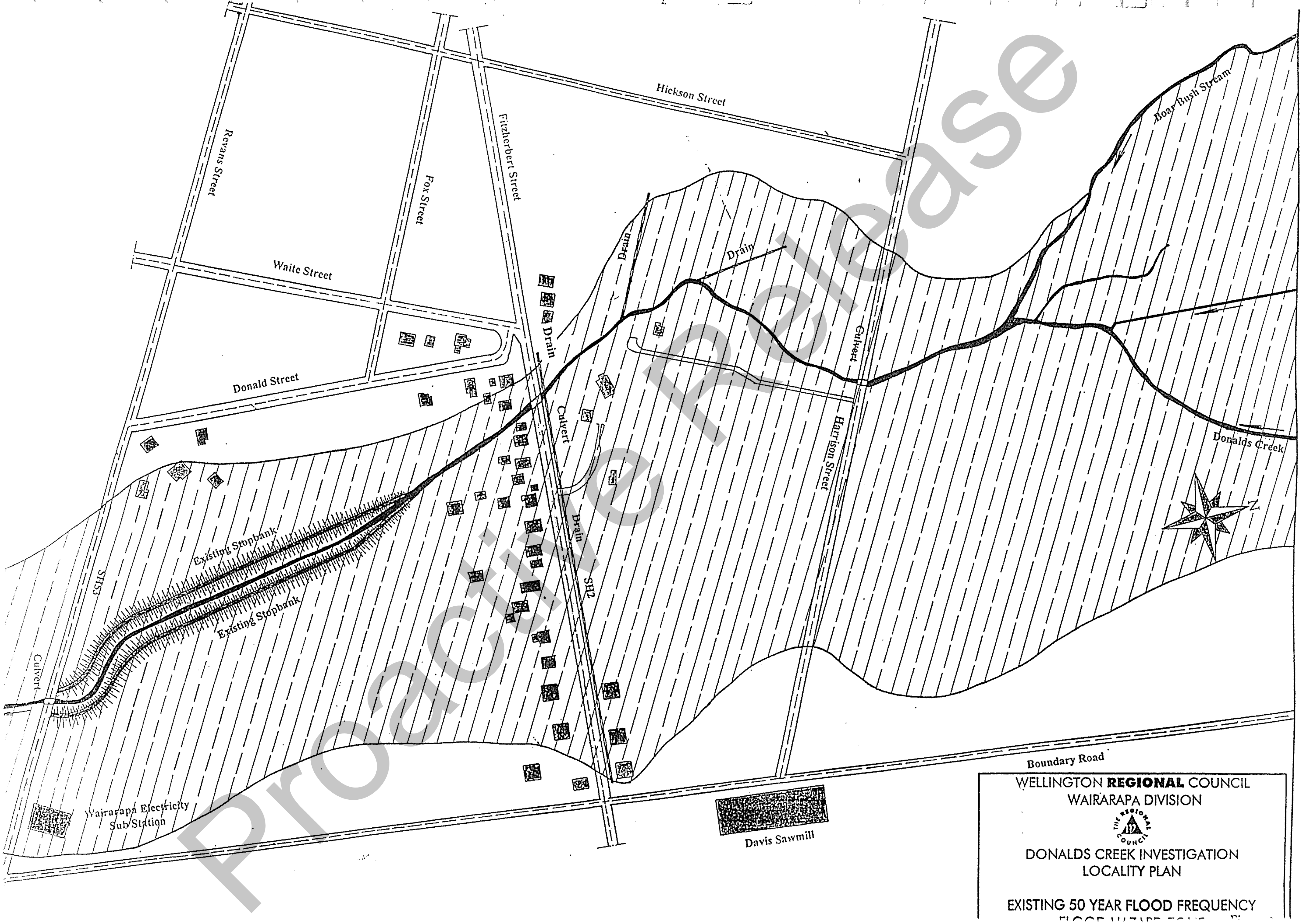
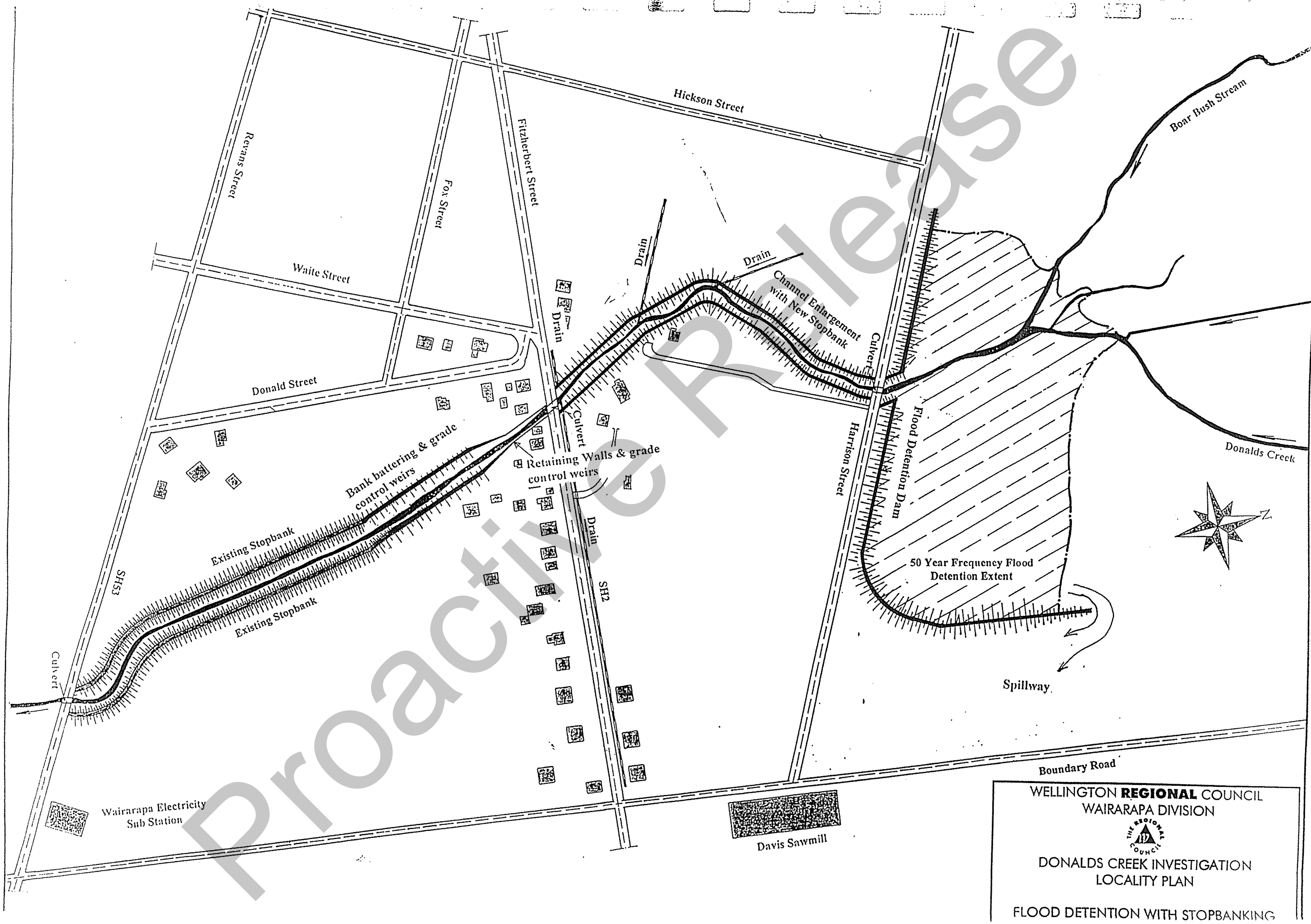
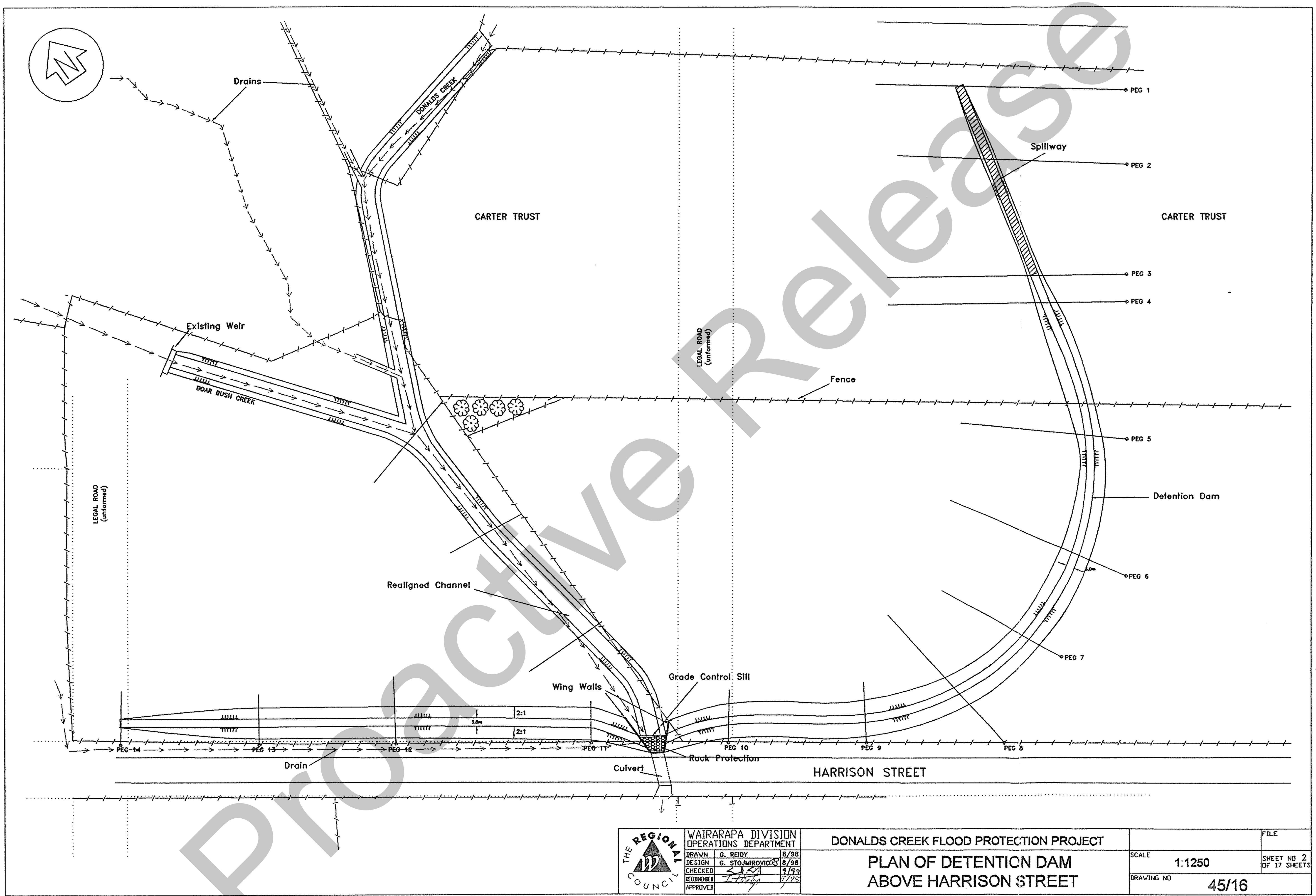
WSP Opus. (2018b). *Donalds Creek Detention Dam: Hydrological Analysis Phase II.* WSP Opus.

WSP Opus. (2018c). *Donalds Creek Detention Facility - FMEA Memorandum.*

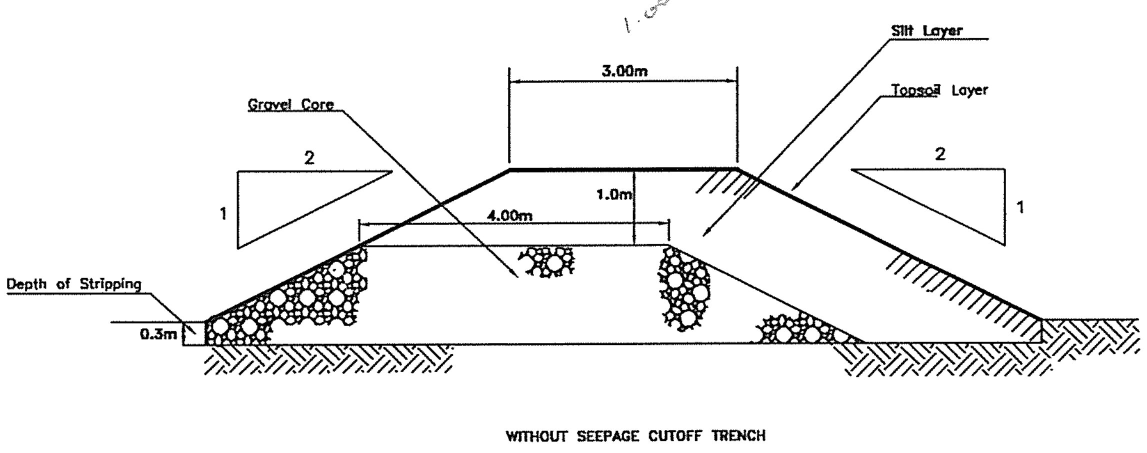
Appendix A Key Drawings

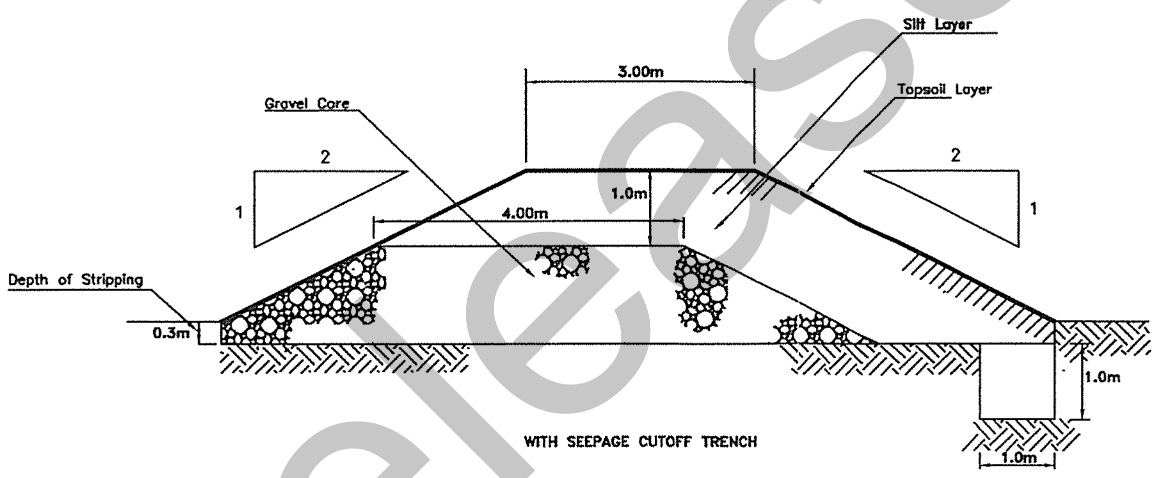

Hickson Street
Revans Street
Fox Street
Fitzherbert Street
Waite Street
Donald Street
Drain
Drain
Drain
Culvert
Culvert
Culvert
Drain
SH2
SH3
Harrison Street
Boar Bush Stream
Donalds Creek
Existing Stopbank
Existing Stopbank
Boundary Road
Wairarapa Electricity
Sub Station
Davis Sawmill
WELLINGTON REGIONAL COUNCIL
WAIRARAPA DIVISION
THE REGIONAL COUNCIL
DONALDS CREEK INVESTIGATION
LOCALITY PLAN
EXISTING 50 YEAR FLOOD FREQUENCY


Hickson Street
Boar Bush Stream
Revans Street
Fox Street
Fitzherbert Street
Waite Street
Donald Street
Drain
Drain
Channel Enlargement with New Stopbank
Culvert
Culvert
Drain
Bank battering & grade control weirs
Retaining Walls & grade control weirs
Existing Stopbank
Existing Stopbank
SH53
SH2
Harrison Street
Flood Detention Dam
Donalds Creek
N
50 Year Frequency Flood Detention Extent
Spillway
Culvert
Boundary Road
Wairarapa Electricity Sub Station
Davis Sawmill
WELLINGTON REGIONAL COUNCIL
WAIRARAPA DIVISION
DONALDS CREEK INVESTIGATION
LOCALITY PLAN
FLOOD DETENTION WITH STOPBANKING

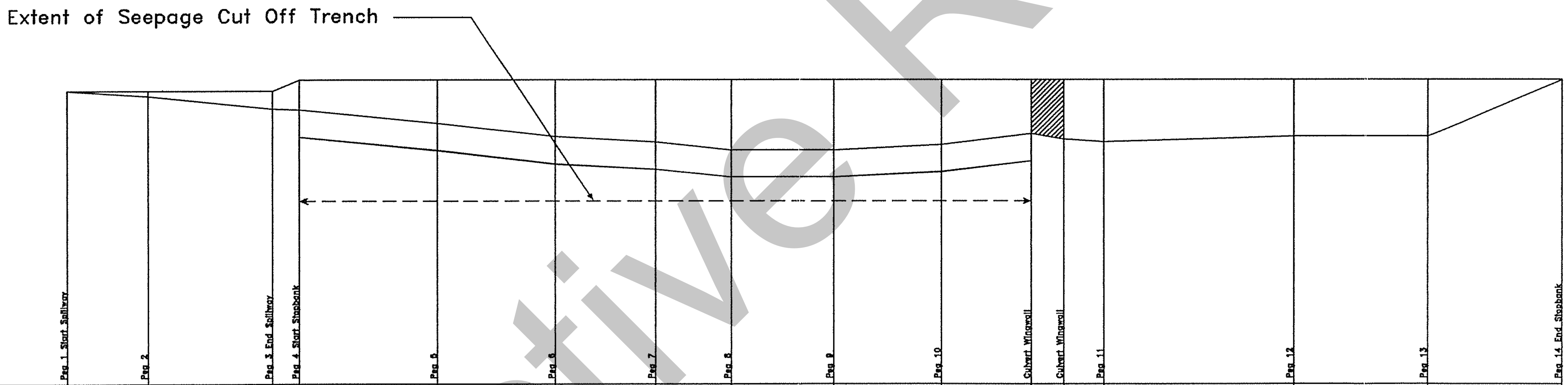


N
Drains
DONALDS CREEK
CARTER TRUST
CARTER TRUST
PEG 1
PEG 2
Spillway
PEG 3
PEG 4
Existing Weir
BOAR BUSH CREEK
LEGAL ROAD (unformed)
LEGAL ROAD (unformed)
Fence
PEG 5
Detention Dam
PEG 6
PEG 7
Realigned Channel
Grade Control Sill
Wing Walls
2:1
2:1
PEG 14
PEG 13
PEG 12
PEG 11
PEG 10
PEG 9
PEG 8
Drain
Rock Protection
Culvert
HARRISON STREET
THE REGIONAL COUNCIL
WAIRARAPA DIVISION
OPERATIONS DEPARTMENT
DRAWN G. REIDY 8/98
DESIGN G. STOJMIROVIC 8/98
CHECKED
RECOMMENDED
APPROVED
DONALDS CREEK FLOOD PROTECTION PROJECT
PLAN OF DETENTION DAM
ABOVE HARRISON STREET
SCALE 1:1250
DRAWING NO 45/16
FILE
SHEET NO 2 OF 17 SHEETS





TYPICAL CROSS SECTIONS OF DETENTION DAM
Scale = 1:100



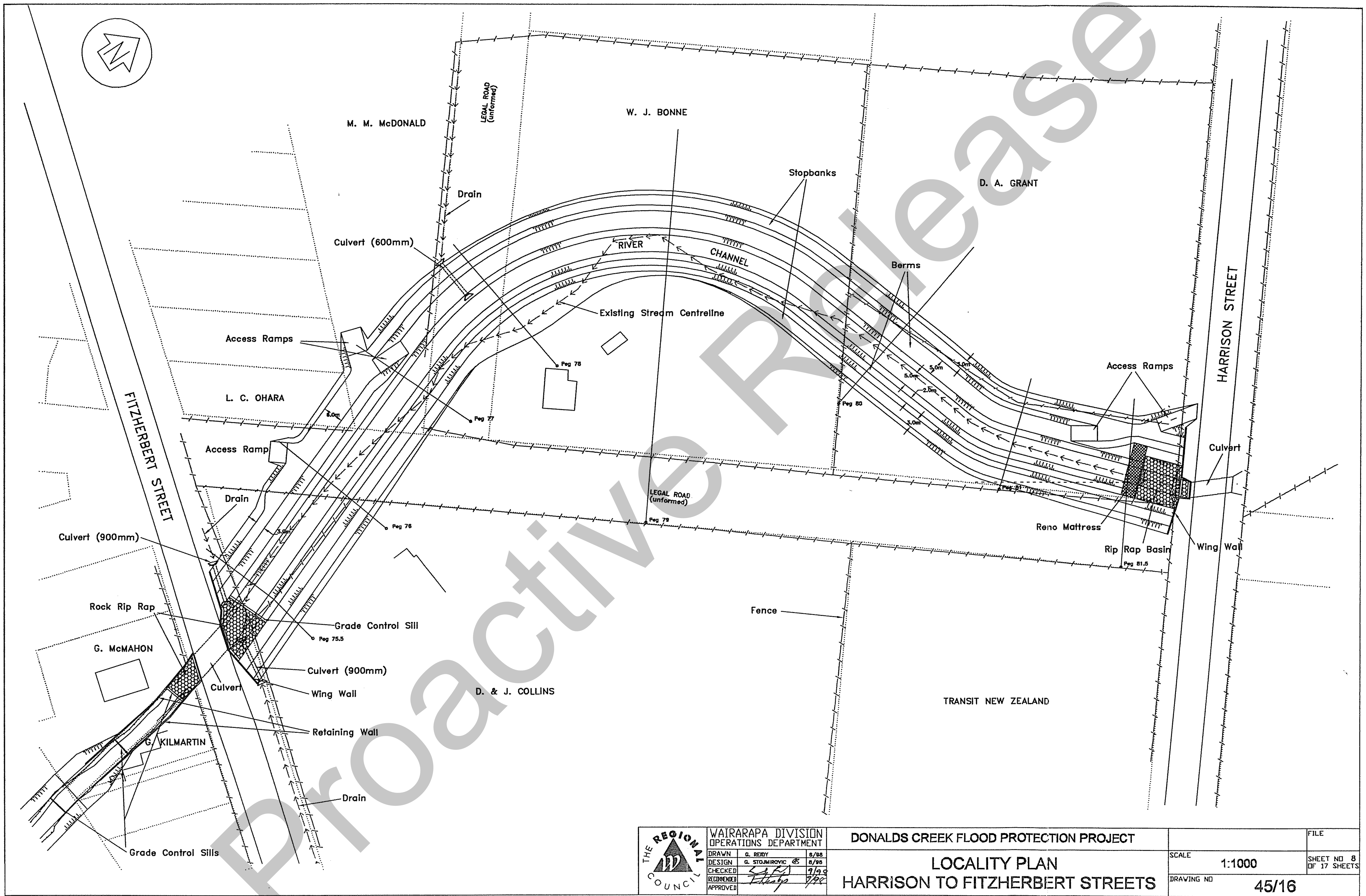
H.A.D. 28.0 m

	Peg 1 Start Spillway	Peg 2	Peg 3 End Spillway	Peg 4 Start Stopbank	Peg 5	Peg 6	Peg 7	Peg 8	Peg 9	Peg 10	Culvert Wingwall	Culvert Wingwall	Peg 11	Peg 12	Peg 13	Peg 14 End Stopbank
Distance (m)	0.00	30.00	78.00	85.00	137.00	180.50	217.00	245.00	282.50	322.50	355.50	387.50	382.50	452.50	502.50	552.50
Peg Level	38.89	38.67	38.26	38.15	37.62	37.09	36.99	36.52	36.70	36.87	36.93	36.93	37.09	37.10	37.30	39.03
Ground Level	38.89	38.70	38.24	38.20	37.70	37.20	37.00	36.70	36.70	36.90	37.30	37.10	37.00	37.20	37.20	39.29
Design Level	38.90	38.90	38.90	39.30	39.30	39.30	39.30	39.30	39.30	39.30	39.30	39.30	39.30	39.30	39.30	39.30

DETENTION DAM LONGSECTION

Scale H=1:2000
V=1:200

THE REGIONAL COUNCIL	WAIRARAPA DIVISION OPERATIONS DEPARTMENT	DONALDS CREEK FLOOD PROTECTION PROJECT	FILE
	DRAWN G. REIDY 8/98	DETENTION DAM LONG SECTION & TYPICAL CROSS SECTIONS	SCALE AS SHOWN
	DESIGN G. STOJMIROVIC 8/98		SHEET NO 3 OF 17 SHEETS
	CHECKED 9/98		DRAWING NO 45/16
	RECOMMENDED 9/98		
	APPROVED		



THE REGIONAL COUNCIL

WAIRARAPA DIVISION
OPERATIONS DEPARTMENT

DRAWN	G. REIDY	8/98
DESIGN	G. STOJMIROVIC	8/98
CHECKED	[signature]	9/98
RECOMMENDED	[signature]	9/98
APPROVED		

DONALDS CREEK FLOOD PROTECTION PROJECT

LOCALITY PLAN
HARRISON TO FITZHERBERT STREETS

SCALE 1:1000
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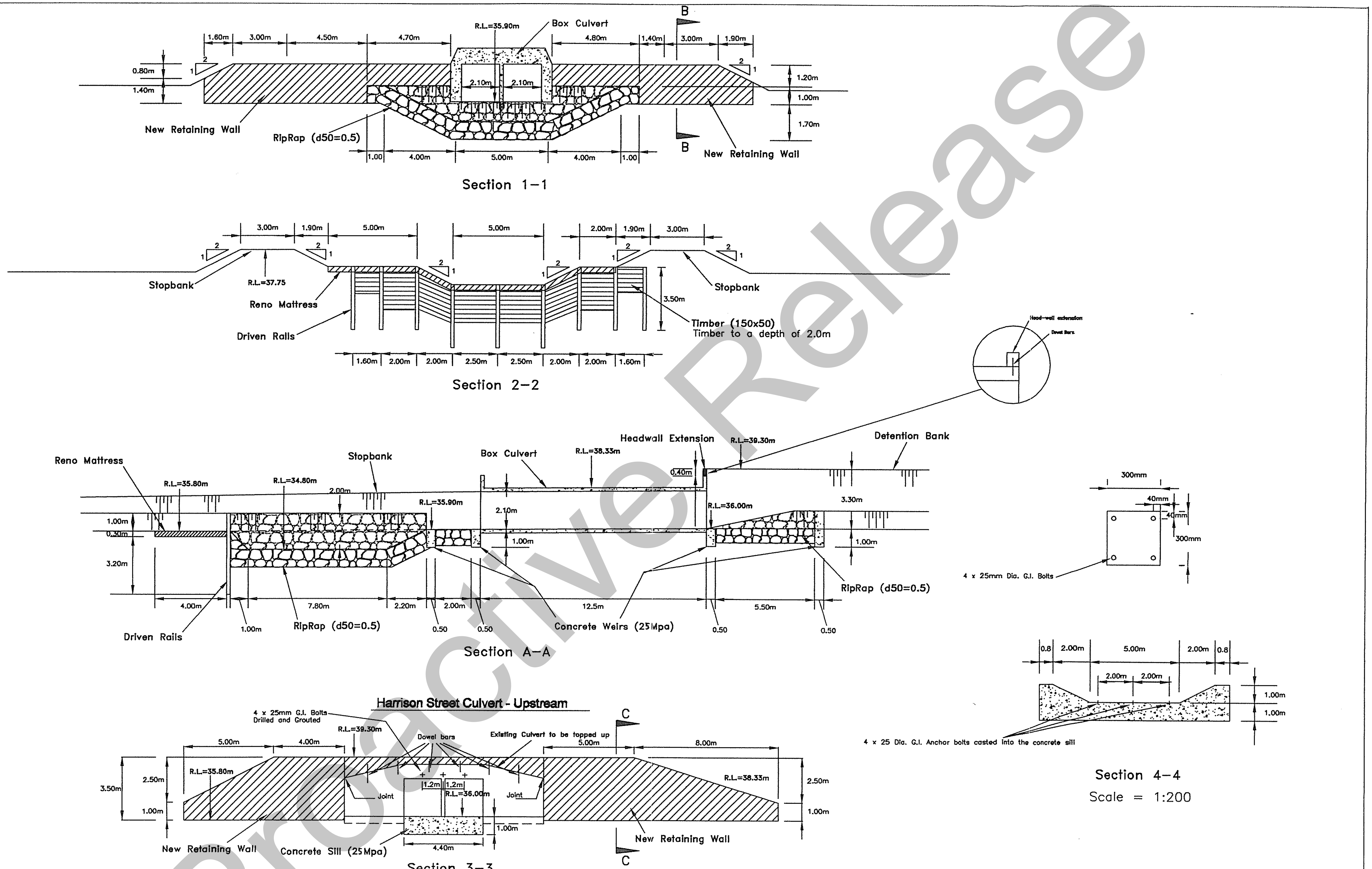
SHEET NO 8 OF 17 SHEETS



THE REGIONAL COUNCIL	WAIRARAPA DIVISION OPERATIONS DEPARTMENT	DONALDS CREEK FLOOD PROTECTION PROJECT
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	DESIGN G. STOJMIROVIC 8/98	SCALE 1:200
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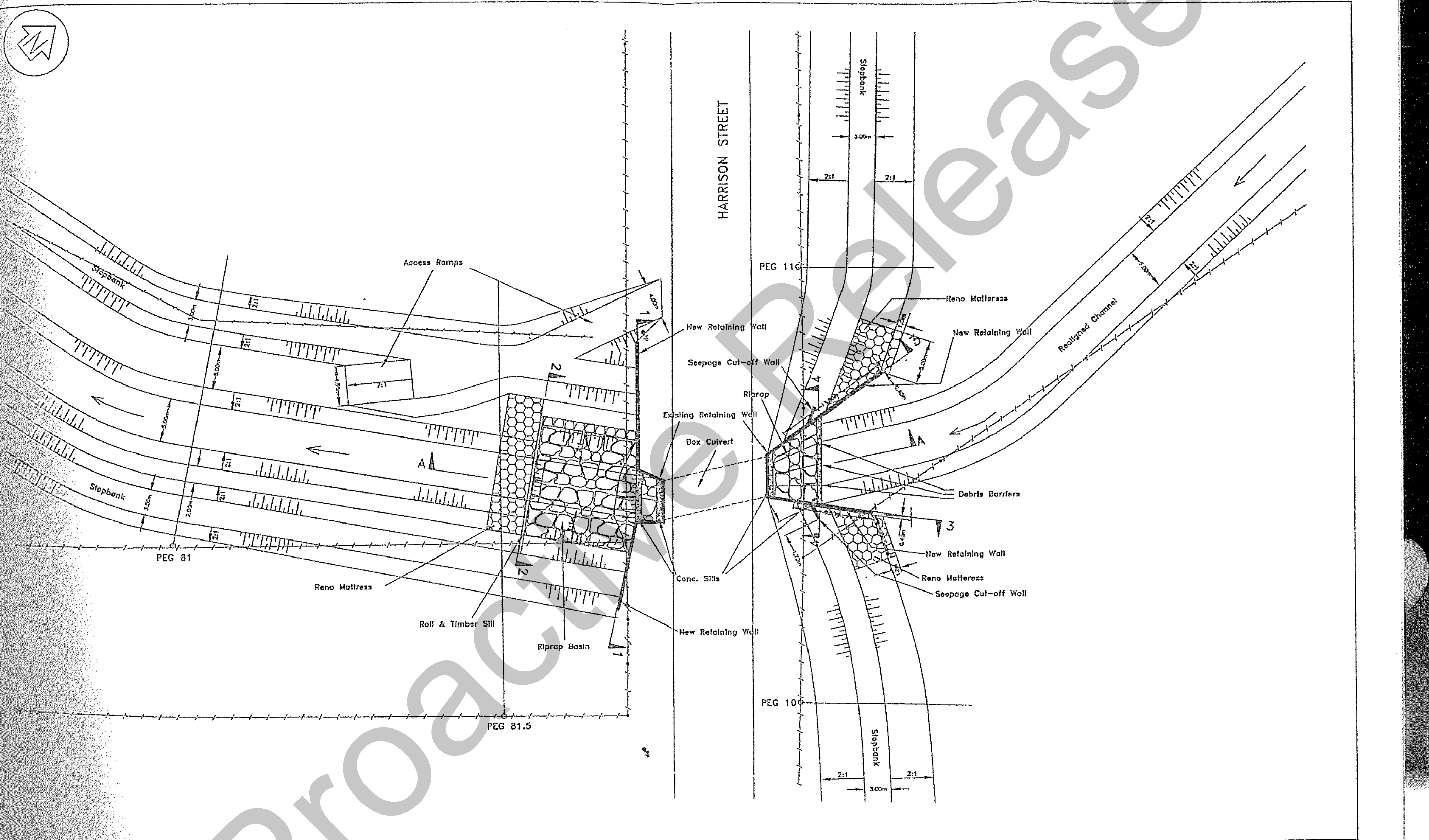
	APPROVED	FILE



THE REGIONAL COUNCIL

WAIRARAPA DIVISION
OPERATIONS DEPARTMENT

DRAWN	G. REIDY	8/98
DESIGN	G. STOJMIROVIC	8/98
CHECKED		
RECOMMENDED		
APPROVED		

DONALDS CREEK FLOOD PROTECTION PROJECT

HARRISON STREET CULVERT CONSTRUCTION PLAN

SCALE 1:400

DRAWING NO 45/16

FILE

SHEET NO 11 OF 17 SHEETS

LEGEND

- Development Area
- Flow direction

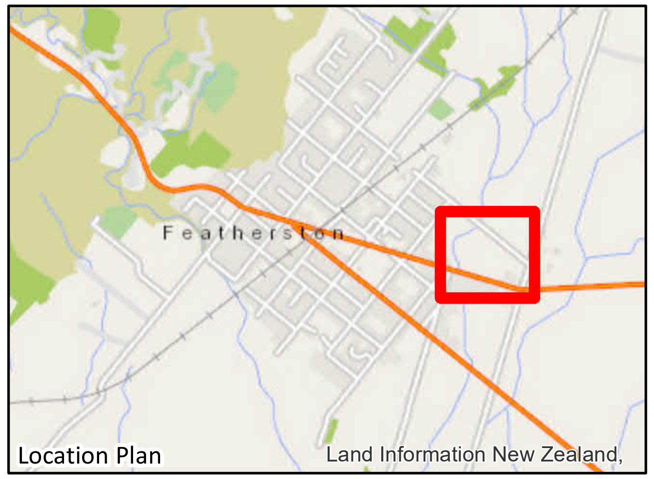
Post-Development Modelled Flood Depth (m)

- < 0.05
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 0.75
- > 0.75

A3 SCALE: 1:1,750

0 10 20 30 40 50 Meters

N



Notes:
Property boundaries sourced from GWRC WebGIS
Lot layout as per Tomlinson & Carrruthers Surveyors Ltd
Drawing: T18/051 S 4A

DRAWN	AAJE	Jul.20
CHECKED	DNV	Jul.20
APPROVED	DNV	Jul.20

ARCFILE 1008135-F1.mxd

SCALE (AT A3 SIZE) 1:1,750

PROJECT No. 1008135

Tonkin+Taylor
Lucas House, 51 Halifax Street, Nelson
www.tonkintaylor.co.nz

BROOKSIDE DEVELOPMENTS - FEATHERSTON LTD
DONALD STREAM, FEATHERSTON
POST DEVELOPMENT
MODELLED FLOOD DEPTH

1008135-F1

LEGEND

Development Area

Difference in Modelled Flood Depth (mm)

- < -100
- -100 - -10
- 10 - 100
- > 100

A3 SCALE: 1:1,750

0 10 20 30 40 50 Meters

N

Notes:
Property boundaries sourced from GWRC WebGIS
Lot layout as per Tomlinson & Carruthers Surveyors Ltd
Drawing: T18/051 S 4A

DRAWN	AAJE	Jul.20
CHECKED	DNV	Jul.20
APPROVED	DNV	Jul.20

ARCFILE
1008135-F2.mxd

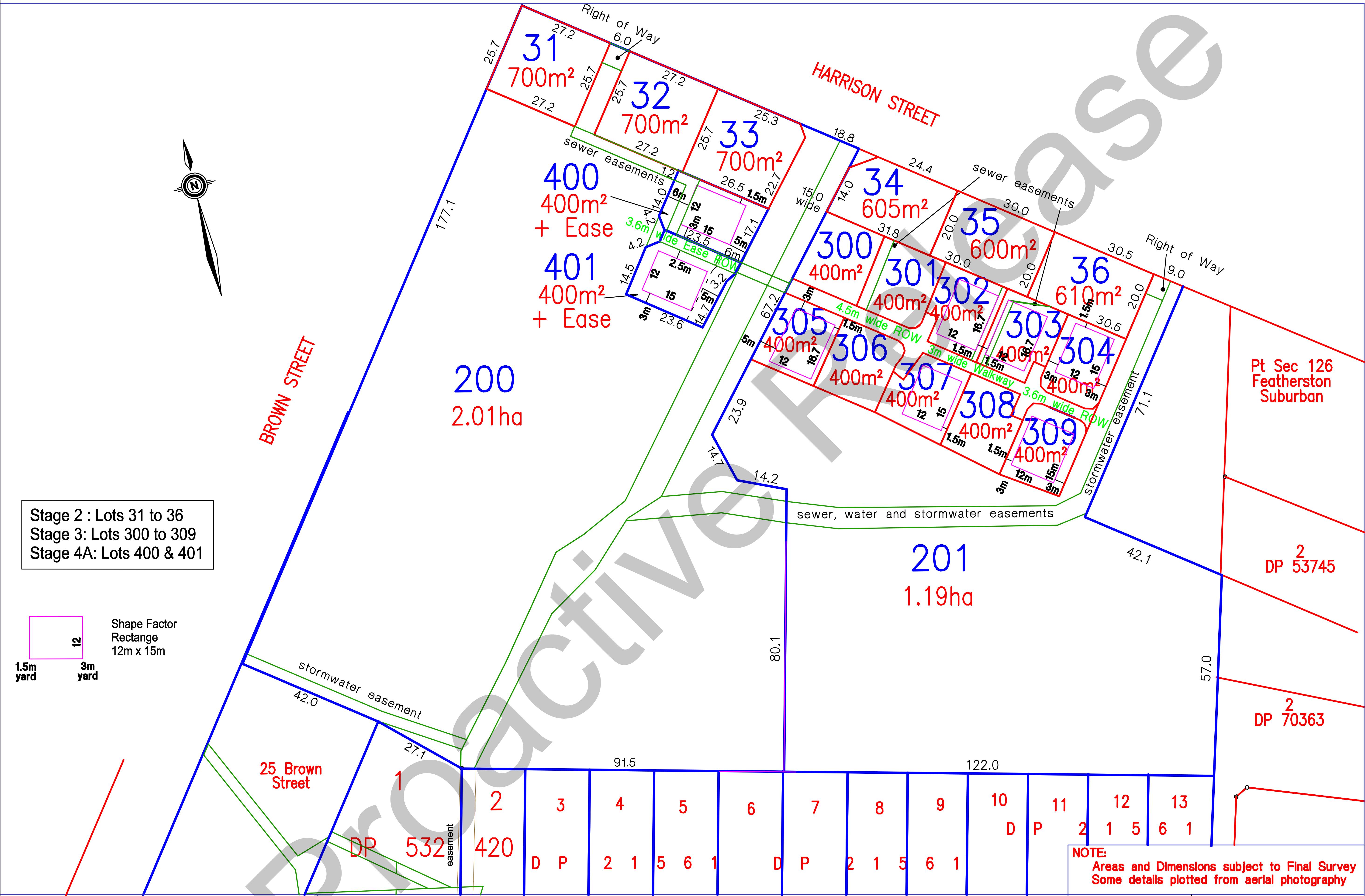
SCALE (AT A3 SIZE)
1:1,750

PROJECT No.
1008135

Tonkin+Taylor
Lucas House, 51 Halifax Street, Nelson
www.tonkintaylor.co.nz

BROOKSIDE DEVELOPMENTS - FEATHERSTON LTD
DONALD STREAM, FEATHERSTON
DIFFERENCE IN
MODELLED FLOOD DEPTH

1008135-F2

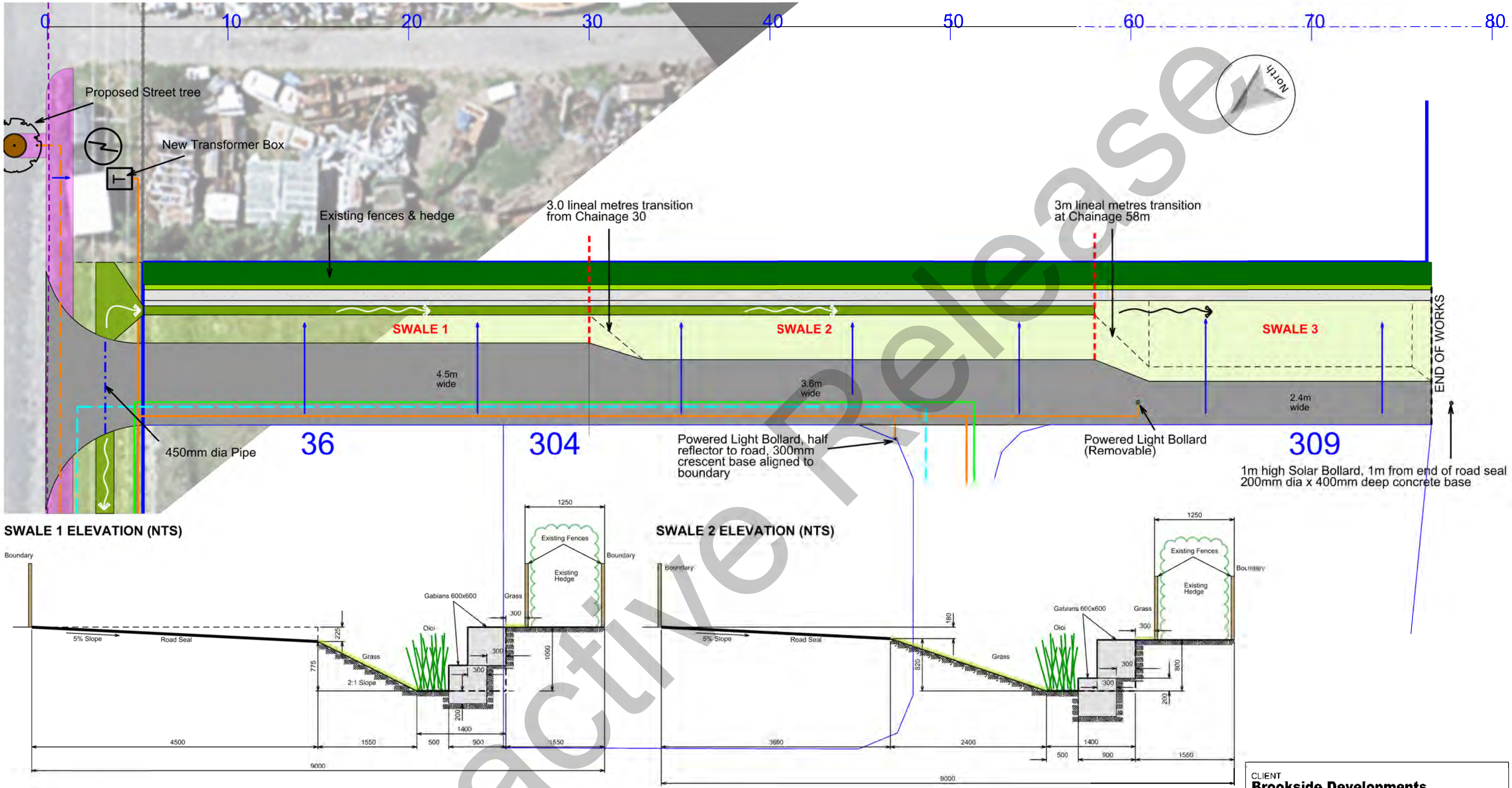


Tomlinson & Carruthers Surveyors Ltd

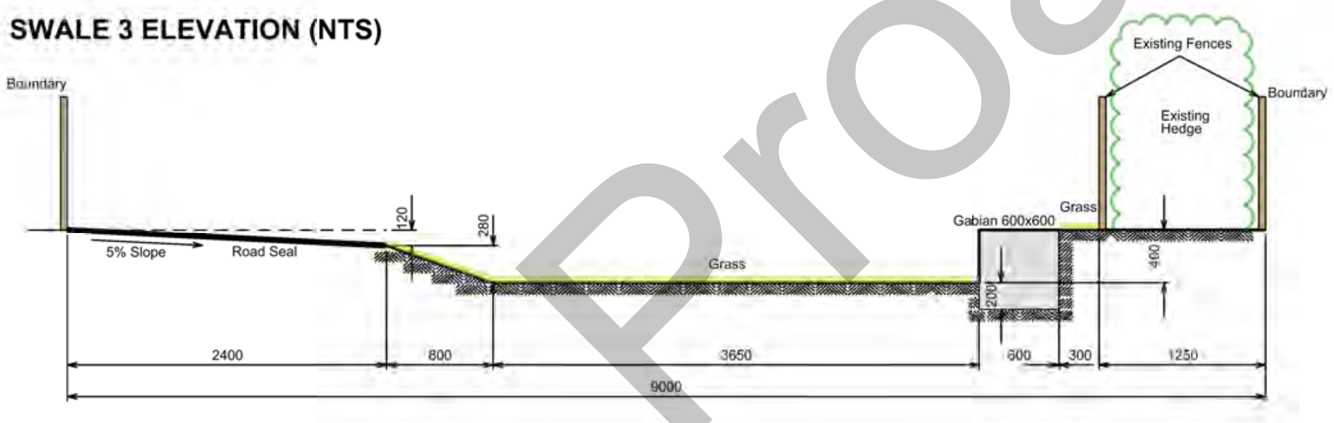
16 Perry Street, P.O. Box 246, Masterton
Ph (06) 370-0800 Email: eric@tcsurvey.co.nz

STAGES 2, 3 & 4A PROPOSED SCHEME
LOT 3 DP 532420
HARRISON STREET, FEATHERSTON

Prepared for:	Brookside Developments
Drawn Date:	29 June 2020 w Shapes
Compiled in:	RT 871419
Territorial Authority:	South Wairarapa District
Scale: 1:1000 @ A3	Ref #: T18/051 S 4A



SWALE 3 ELEVATION (NTS)



KEY

Water (Existing)	Power Pole
Water (New) - refer to Water Plan	Lot Boundary & Number (New)
Stormwater	Property Boundary (Existing)
Stormwater crossfall direction	Light Bollards (Black, Powered, Yellow, Solar)
Power (Proposed, East of bridge)	Chainage
Power (Proposed, Bollard Circuit)	Vegetation
Chorus Duct (New)	Planted Swale Base + Flow Direction
Edge of Road Seal (Existing)	Grass
Bitumen	Swale Berm & Slope
Porous Concrete	
Gabion	

CLIENT
Brookside Developments (Featherston) Ltd

PROJECT
Brookside Subdivision

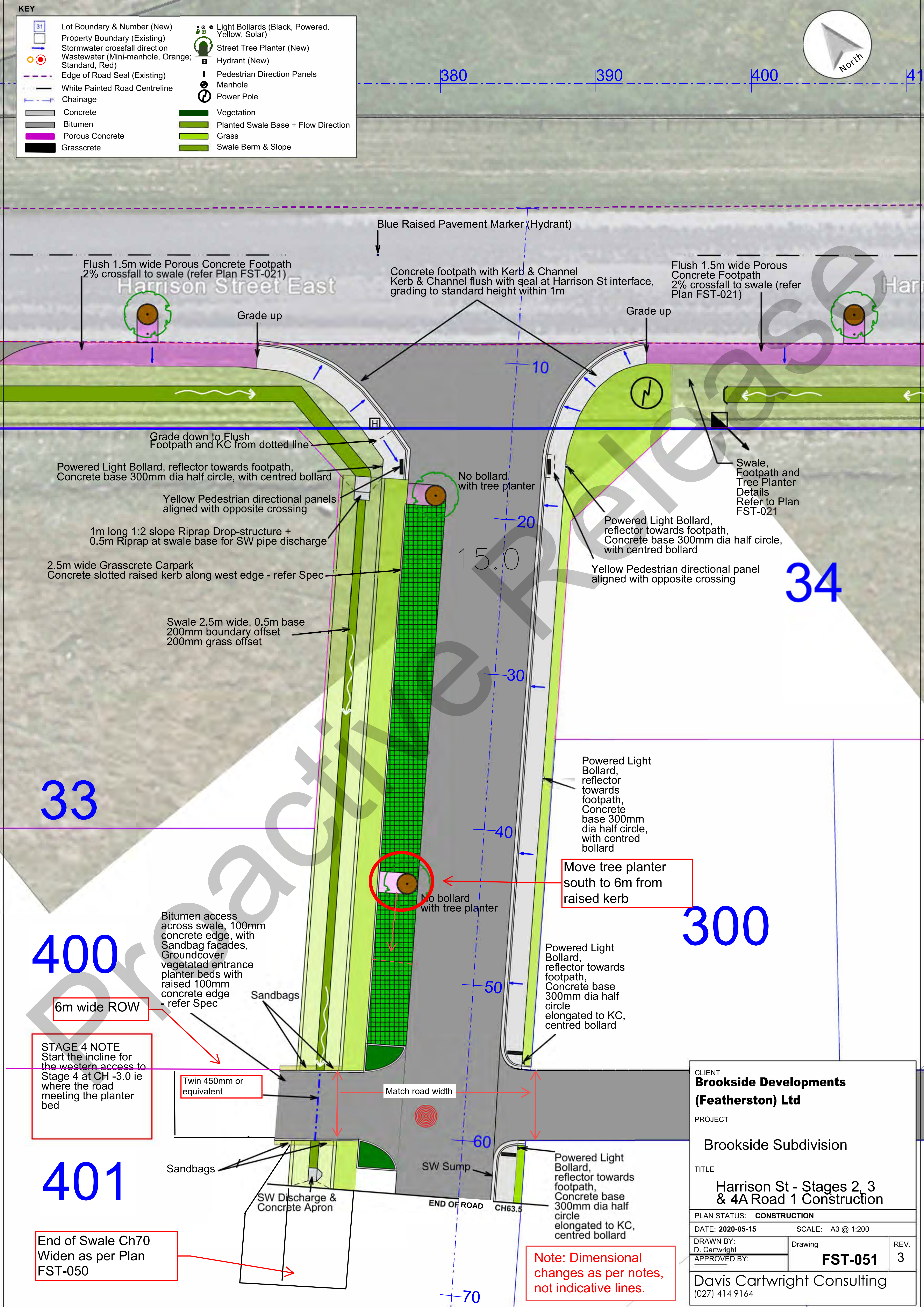
TITLE
Harrison St - Stages 2 & 3
East Swale & Elevations

PLAN STATUS: **DRAFT**

DATE: **2020-03-11** SCALE: A3 @ 1:200

DRAWN BY: D. Cartwright
APPROVED BY:
Drawing **FST-050**
REV. **(0)**

Davis Cartwright Consulting
(027) 414 9164


KEY
Lot Boundary & Number (New)
Property Boundary (Existing)
Stormwater crossfall direction
Wastewater (Mini-manhole, Orange; Standard, Red)
Edge of Road Seal (Existing)
White Painted Road Centreline
Chainage
Concrete
Bitumen
Porous Concrete
Grasscrete
Light Bollards (Black, Powered, Yellow, Solar)
Street Tree Planter (New)
Hydrant (New)
Pedestrian Direction Panels
Manhole
Power Pole
Vegetation
Planted Swale Base + Flow Direction
Grass
Swale Berm & Slope
380
390
400
North
Blue Raised Pavement Marker (Hydrant)
Flush 1.5m wide Porous Concrete Footpath
2% crossfall to swale (refer Plan FST-021)
Harrison Street East
Concrete footpath with Kerb & Channel
Kerb & Channel flush with seal at Harrison St interface,
grading to standard height within 1m
Flush 1.5m wide Porous Concrete Footpath
2% crossfall to swale (refer Plan FST-021)
Grade up
Grade up
10
Grade down to Flush Footpath and KC from dotted line
Powered Light Bollard, reflector towards footpath,
Concrete base 300mm dia half circle, with centred bollard
Yellow Pedestrian directional panels
aligned with opposite crossing
1m long 1:2 slope Riprap Drop-structure +
0.5m Riprap at swale base for SW pipe discharge
2.5m wide Grasscrete Carpark
Concrete slotted raised kerb along west edge - refer Spec
Swale 2.5m wide, 0.5m base
200mm boundary offset
200mm grass offset
No bollard
with tree planter
Swale, Footpath and Tree Planter Details
Refer to Plan FST-021
Powered Light Bollard,
reflector towards footpath,
Concrete base 300mm dia half circle,
with centred bollard
Yellow Pedestrian directional panel
aligned with opposite crossing
20
15.0
34
30
33
Powered Light Bollard, reflector towards footpath, Concrete base 300mm dia half circle, with centred bollard
40
Move tree planter south to 6m from raised kerb
No bollard
with tree planter
300
400
Bitumen access across swale, 100mm concrete edge, with Sandbag facades, Groundcover vegetated entrance planter beds with raised 100mm concrete edge - refer Spec
Sandbags
Powered Light Bollard, reflector towards footpath, Concrete base 300mm dia half circle elongated to KC, centred bollard
50
6m wide ROW
STAGE 4 NOTE
Start the incline for the western access to Stage 4 at CH -3.0 ie where the road meeting the planter bed
Twin 450mm or equivalent
Match road width
60
401
Sandbags
SW Sump
SW Discharge & Concrete Apron
END OF ROAD
CH63.5
Powered Light Bollard, reflector towards footpath, Concrete base 300mm dia half circle elongated to KC, centred bollard
End of Swale Ch70
Widen as per Plan FST-050
Note: Dimensional changes as per notes, not indicative lines.
70
Proactive Release
CLIENT
Brookside Developments (Featherston) Ltd
PROJECT
Brookside Subdivision
TITLE
Harrison St - Stages 2, 3 & 4A Road 1 Construction
PLAN STATUS: CONSTRUCTION
DATE: 2020-05-15
SCALE: A3 @ 1:200
DRAWN BY: D. Cartwright
APPROVED BY:
Drawing FST-051
REV. 3
Davis Cartwright Consulting
(027) 414 9164

Appendix B Hazard and Failure Mode Matrix

GLOBAL FAILURE MODES		ELEMENT AND/OR ELEMENT FUNCTION	MOST BASIC FUNCTIONAL FAILURE CHARACTERISTICS	External Hazards	
				Flood	Seismic
DAM COLLAPSE BY OVERTOPPING (erosion or overturning)	Water elevation too high	Inadequate installed discharge capacity	Meteorological inflow > buffer + outflow capacity	1. Inflows greater than spillway outflow capacity, leading to dam overtopping at low spots along left and right embankments	
		Inadequate available discharge capacity	Inadequate reservoir operation (rules not followed)		
			Random functional failure on demand		
			Discharge capability not maintained or retained	2. Blockage of culvert inlet, inlet trashrack or outlet reduces discharge capacity, leading to dam overtopping at low spots along left and right embankments.	8. Damage of culvert due to seismic event blocks outlet. Minor flood occurs before the culvert can be repaired, leading to dam overtopping at low spots along left and right embankments or internal erosion along culvert/embankment interface.
		Inadequate freeboard	Excessive elevation due to landslide or U/S dam		
			Wind-wave dissipation inadequate		
	Management System Failure	Safeguards fail to provide timely detection and correction	Operation, maintenance and surveillance fail to detect/prevent hydraulic adequacy		
DAM COLLAPSE BY LOSS OF STRENGTH (External orinternal structural failure and weakening)			Operation, maintenance and surveillance fail to detect poor dam performance		
	Crest elevation too low	Stability under applied loads	Mass movement (external stability:- displacement, tilting, seismic resistance)	6. Spillway discharges erode downstream toe of left embankment, causing slope instability of downstream face and significantly increasing outflows as erosion progresses.	10. Seismic event causes instability and failure of upstream or downstream slope of dam, effectively reducing the embankment thickness and potentially the dam crest level. Moderate flood occurs before the embankment dam can be repaired, leading to overtopping or internal erosion failure at the location of the slope failure.
			Loss of support (foundation or abutment failure)	7. Culvert outlet is undermined due to scour at the energy dissipator. Culvert fails, leading to a collapse or cracking of the embankment. Breach occurs due to internal erosion along cracks or overtopping.	
		Watertightness	Seepage around interfaces (abutments, foundation, water stops)		
			Through dam seepage control failure (filters, drains, pumps)		
		Durability/cracking	Structural weakening (internal erosion, AAR, crushing, gradual strength loss)	3. Internal erosion through embankment during a flood, leading to increased seepage, retrograde progression of erosion towards reservoir, gross enlargement or formation of sinkholes and breach of the left or right embankment dams. 4. Internal erosion through the foundation during a flood, leading to increased seepage, retrograde progression of erosion towards reservoir, gross enlargement or formation of sinkholes on embankment dams and breach. 5. Internal erosion along culvert due to concentrated leakage along its interface with the embankment, leading to increase leakage, gross enlargement and breach.	
			Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking)		9. Seismic event causes liquefaction of foundation, leading to slope failure of the embankment dams and/or damage to the culvert outlet. Moderate flood occurs before the dam can be repaired, leading to overtopping at low spots along left and right embankments.

Appendix C Workshop Agenda and Presentation

Meeting Agenda

Type of Meeting: Donalds Creek Detention Dam Failure Modes & Effects Analysis Workshop

Date: 15 May 2024

Location: Damwatch Wellington Office

Note Taker: Margela Andrews

Attendees:

GWRC:

George Bowman (Team Leader Flood Operations Planning),

George Balfour (Engineering Officer),

Dhiya Guler (Engineering Officer),

Rolayo Olukunle (Project Engineer),

Rebecca Polvere (Technical Adviser),

Andy Brown (Team Leader Knowledge Water),

Hamish Fenwick (Team Leader Flood Operations)

Tim Lewis (Area Engineer),

Damwatch:

Karina Dahl (Principal Geotechnical Engineer),

David Menendez Aran (Associate Principal Hydraulics Engineer),

Margela Andrews (Associate Principal Geotechnical Engineer).

Donalds Creek Detention Dam – Failure Modes & Effects Analysis Workshop

Time:	Issues / Questions	Presenter	Comments
15th May (Wednesday)			
08:30 – 10:00	Introduction & Workshop Objectives	KD	
	Donalds Creek Detention Dam General - Background Information	MA/DMA/KD	Including a brief summary of: • Design & as-built • Dam key parameters • Changes in downstream development • Flood & seismic hazards • Assessments & studies findings
10:30 – 10:15	Morning Tea/Break		
10:15 – 11:00	Review of background information	MA GWRC input	Discussion • Current surveillance • Site inspection

P +64 4 381 1300 F +64 4 381 1301
A Level 8, 80 The Terrace, PO Box 1549, Wellington 6140, New Zealand

DAMWATCH ENGINEERING
www.damwatch.co.nz

Time:	Issues / Questions	Presenter	Comments
15th May (Wednesday)			
11:00 – 12:00	CDA System Approach & Internal Erosion		• CDA Approach to FMEA - System components & function - Hazard & Failure Modes Matrix • Internal erosion process • Review draft PFMs
	Screening of Potential Failure Modes (PFMs)	All	• KD as facilitator with inputs from all attendees • Assess PFMs
12:00 – 12:30	Lunch		*Bring your own lunch*
12:30 – 14:30	Screening PFMs (cont'd)	All	
	Afternoon Tea/Break (if needed)		
14:30 – 15:00	Challenges – non-classifiable PIC dam	All	
	Workshop Summary & Wrap Up	All	

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Donalds Creek Detention Dam Failure Modes & Effects Analysis

15th May 2024

Damwatch Wellington Office

Agenda

Time:	Issues / Questions	Comments
08:30 – 09:00	Introduction & Workshop Objectives	
09:00 – 10:00	General Key Information	Including a brief summary of: • Design & construction • Dam key parameters • Changes in downstream development • Seismic & flood hazards • Assessments & studies findings
10:00 – 10:15	Morning Tea/Break	
10:15 – 11:00	Review of background information	Discussion • Current surveillance • Site inspection
11:00 – 12:00	CDA System Approach	CDA Approach to FMEA • System components & function • Hazard and Failure Modes Matrix • Intro to internal erosions
	Screening of Potential Failure Modes (PFMs)	• Assess draft PFMs and any newly identified
12:00 – 12:30	Lunch	
12:30 – 14:30	Screening of PFMs (cont'd)	
	Afternoon Tea/Break (if needed)	
14:30 – 15:00	Challenges – non-classifiable PIC dam	
	Workshop Summary and Wrap up	

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FMEA Workshop Objectives

FMEA

- Develop PFMs
- Assess credibility
- Assess qualitatively likelihoods & highlight key PFMs
- Identify key performance indicators (KPIs)
- Identify knowledge gaps - improved PFMs understanding

Synergise of understanding

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ENGINEERING BEYOND THE SURFACE

Workshop Participants

Participant	Role & Representation
George Bowman	Team Leader Flood Operations Planning, GWRC
George Balfour	Engineering Officer, GWRC
Rolayo Olukunle	Project Engineer, GWRC
Rebecca Polvere	Technical Advisor, GWRC
Tim Lewis	Area Engineer, GWRC
Margela Andrews	Associate Principal Geotechnical Engineer, Damwatch; Note Taker
Karina Dahl	Principal Geotechnical Engineer, Damwatch; Facilitator
David Menéndez Arán	Associate Principal Hydraulics Engineer, Damwatch

Workshop Format

- Informal collaborative work session (*not a presentation*)
- No silly questions

  ASK!

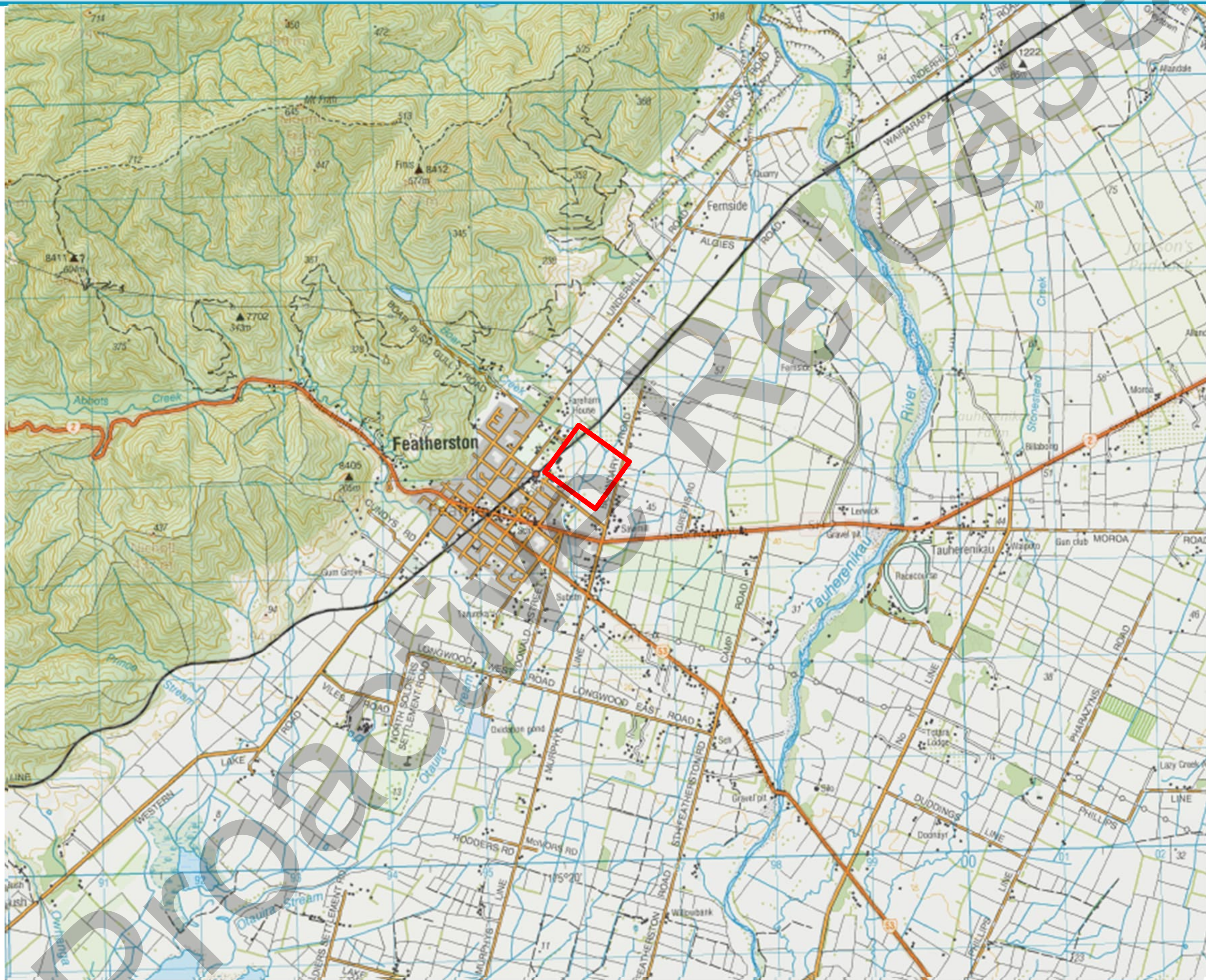
- Different perspectives REQUIRED to meet FMEA objectives

  CONTRIBUTE

- Get up to stretch, go to toilet or use phone outside anytime
- *STAY FOCUSED*

General Description & Dam Key Parameters

Donalds Creek Detention Dam Location



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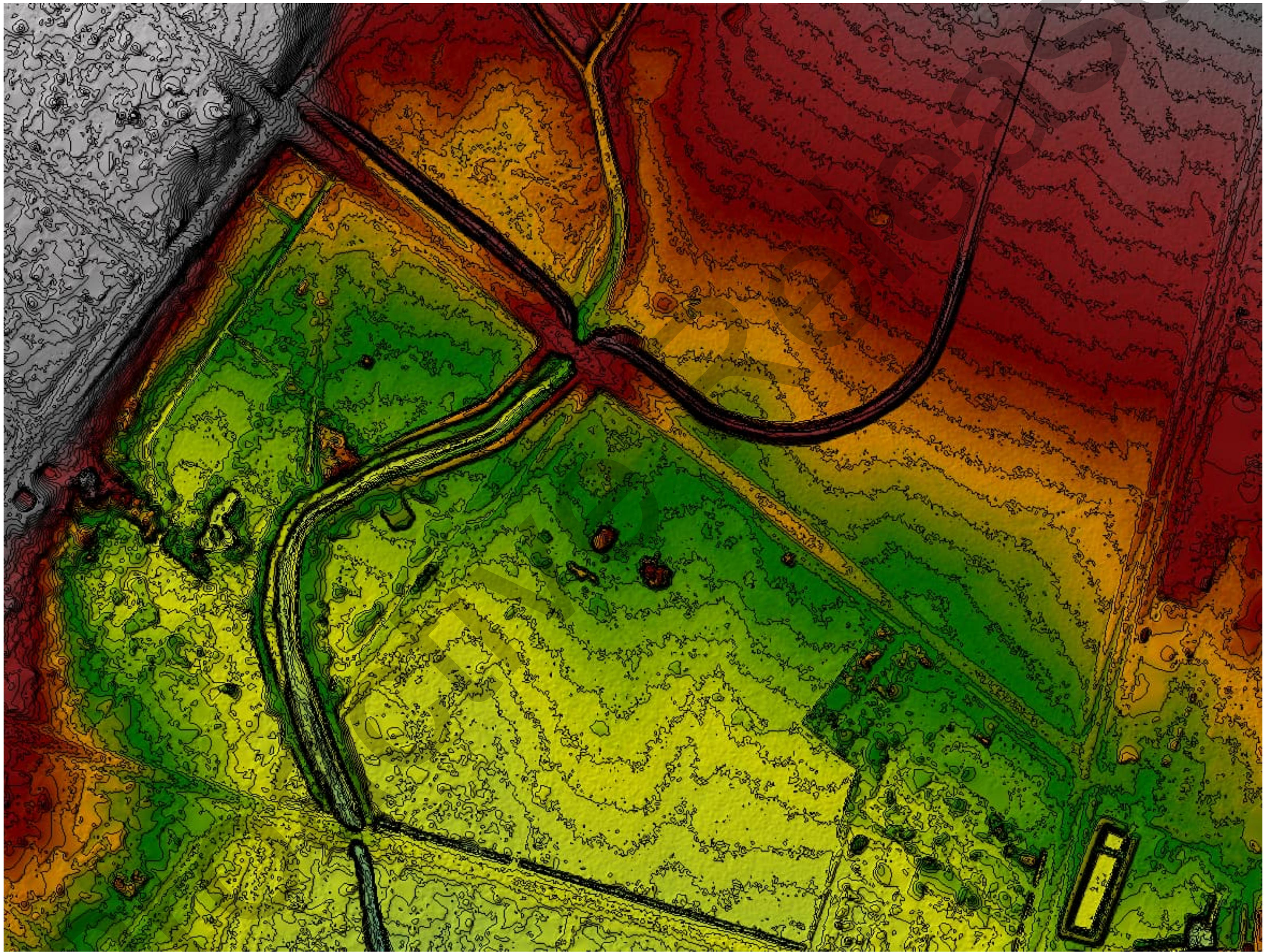
Donalds Creek Detention Dam Layout

Photos of Dam Site – General Layout

Donalds Creek Detention Dam – Key Parameters

Date of construction	1998/99
Location of dam	Located across Donalds Creek on the northeastern outskirts of Featherston
Purpose of dam	Flood mitigation for downstream community. The dam only impounds water during floods
Type of dam	Earth embankment – gravel core with upstream inclined silt layer
Height of dam (m)	2.5m (above ground level) to 3.5m (above lowest foundation)
Reservoir maximum capacity (m^3)	80,000 (design) 105,000 (at 39 masl)
Total pond area (ha)	5.6
Left Dam Crest RL (m) Right Dam Crest RL (m) Spillway Crest RL (m)	39.3 (design); 38.6 (surveyed low point) 39.3 (design); 38.9 (surveyed low point) 38.9 (design); 38.4 (surveyed low point, WSP Opus survey on 13/7/2018)
Dam crest width (m)	3
Dam crest length (m)	552.5
Slopes	2H:1V (design); 1:1 (site visit estimate, 8/5/2024) LiDAR: US slope – 1.5H:1V to 2H:1V, DS slope – 2H:1V to 2.5H:1V
Outlet	Box Culvert with two 2.1m wide x 2.1m high openings with upstream invert at RL 36m (design); 35.6m (surveyed)
Type of spillway	Lateral
Spillway crest length (m)	76
Maximum spillway capacity (m^3/s)	25
No details on construction or as-built drawings; no known changes in design since construction	

LiDAR Topography



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Downstream Development – before construction

Google Earth Imagery (April 2002)

Downstream Development – current

Google Earth Imagery (December 2023)

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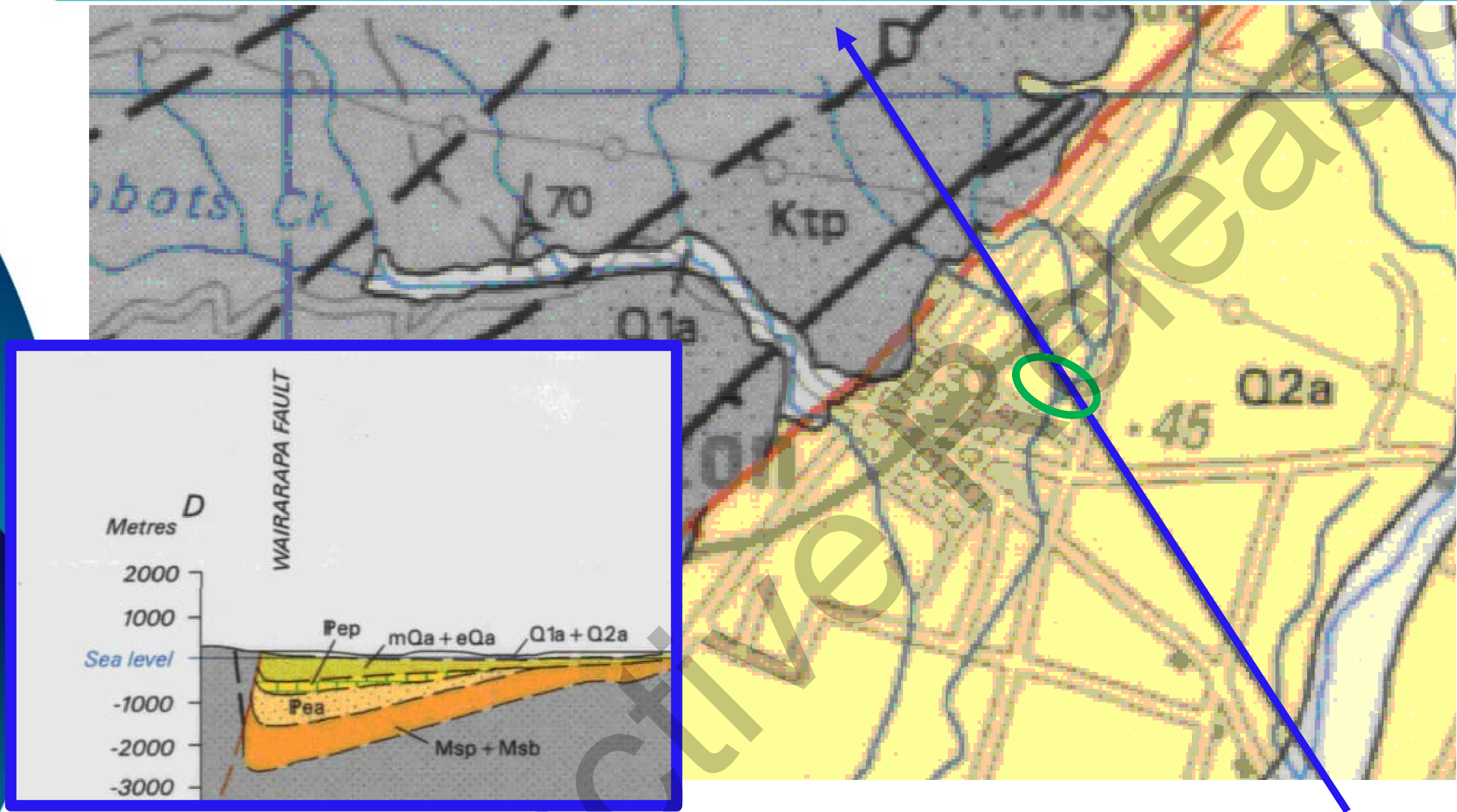
Regional Geology & Foundation



- Q2a – Gravels w/ minor sands or silts, Pleistocene
- Below mudstone, siltstone, limestone

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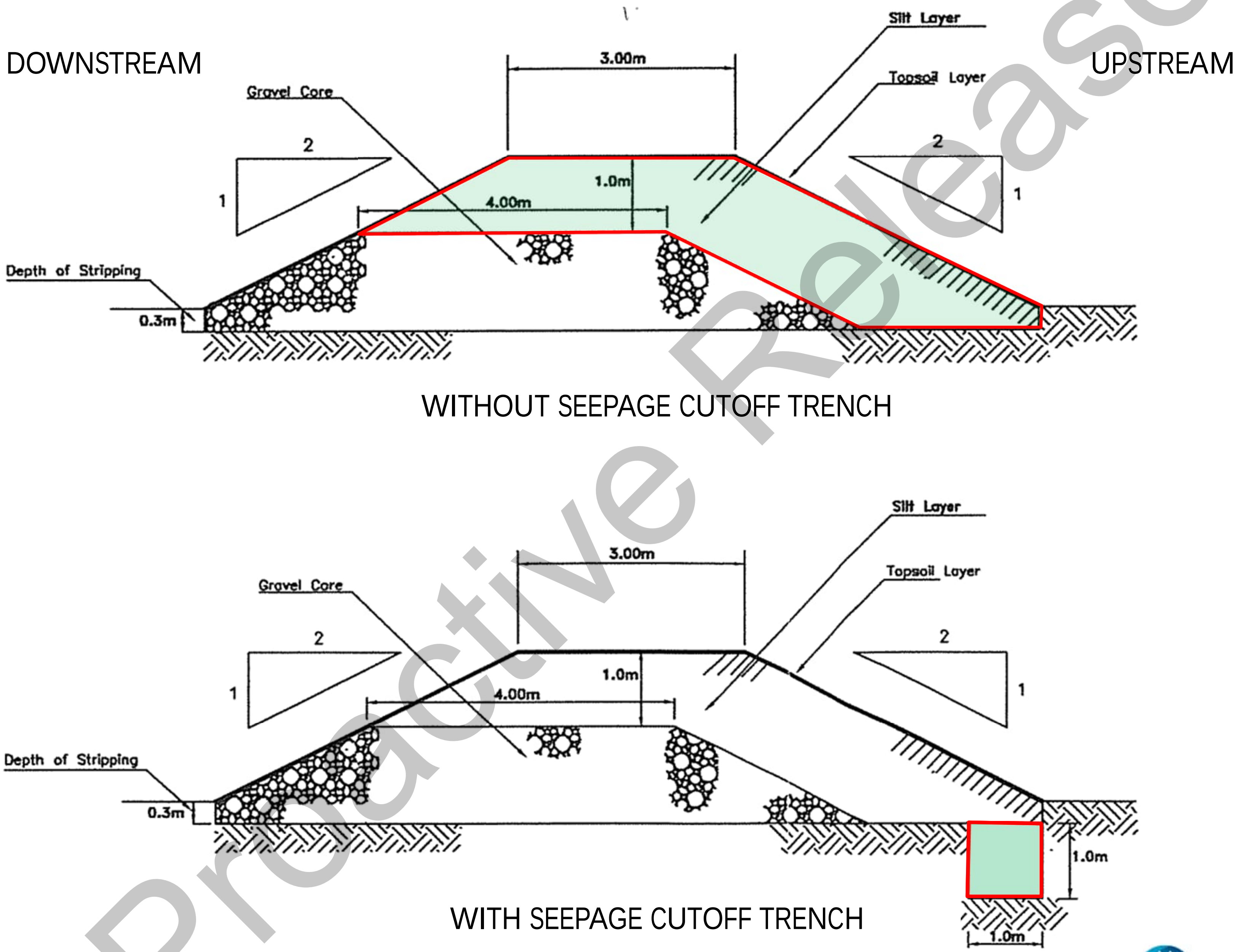
Embankment Dam

Embankment Cross Sections



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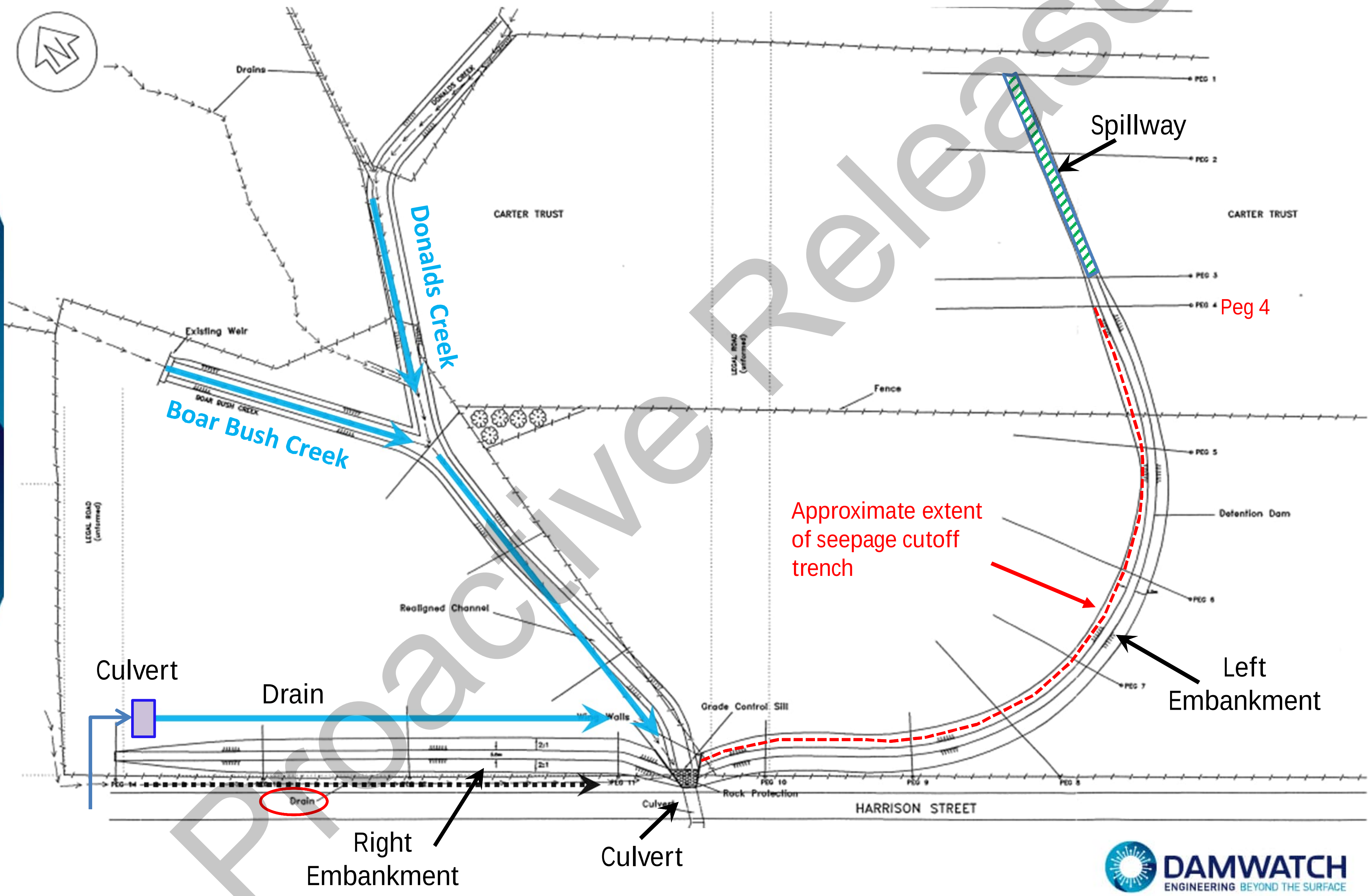
Embankments – Plan



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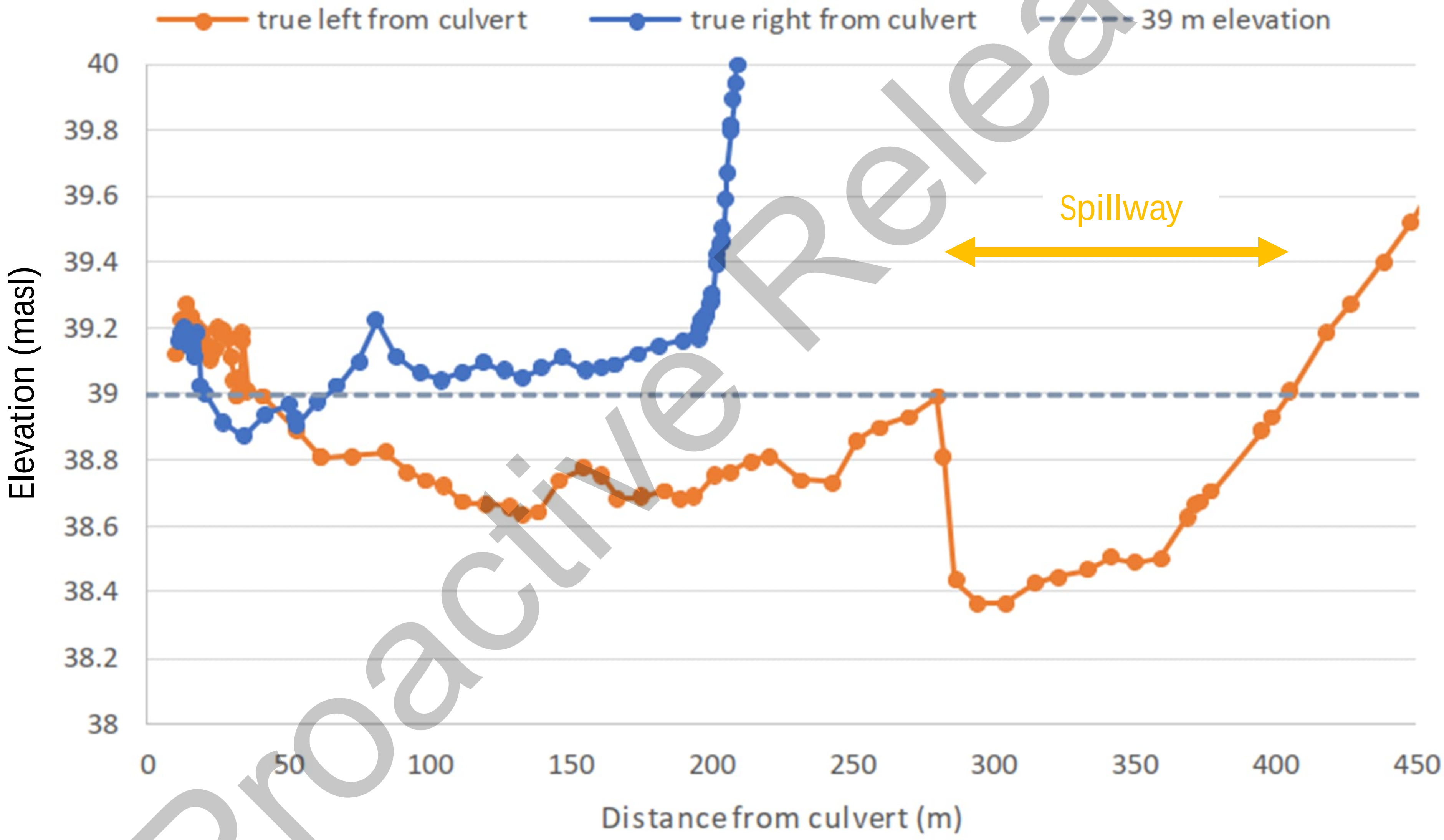
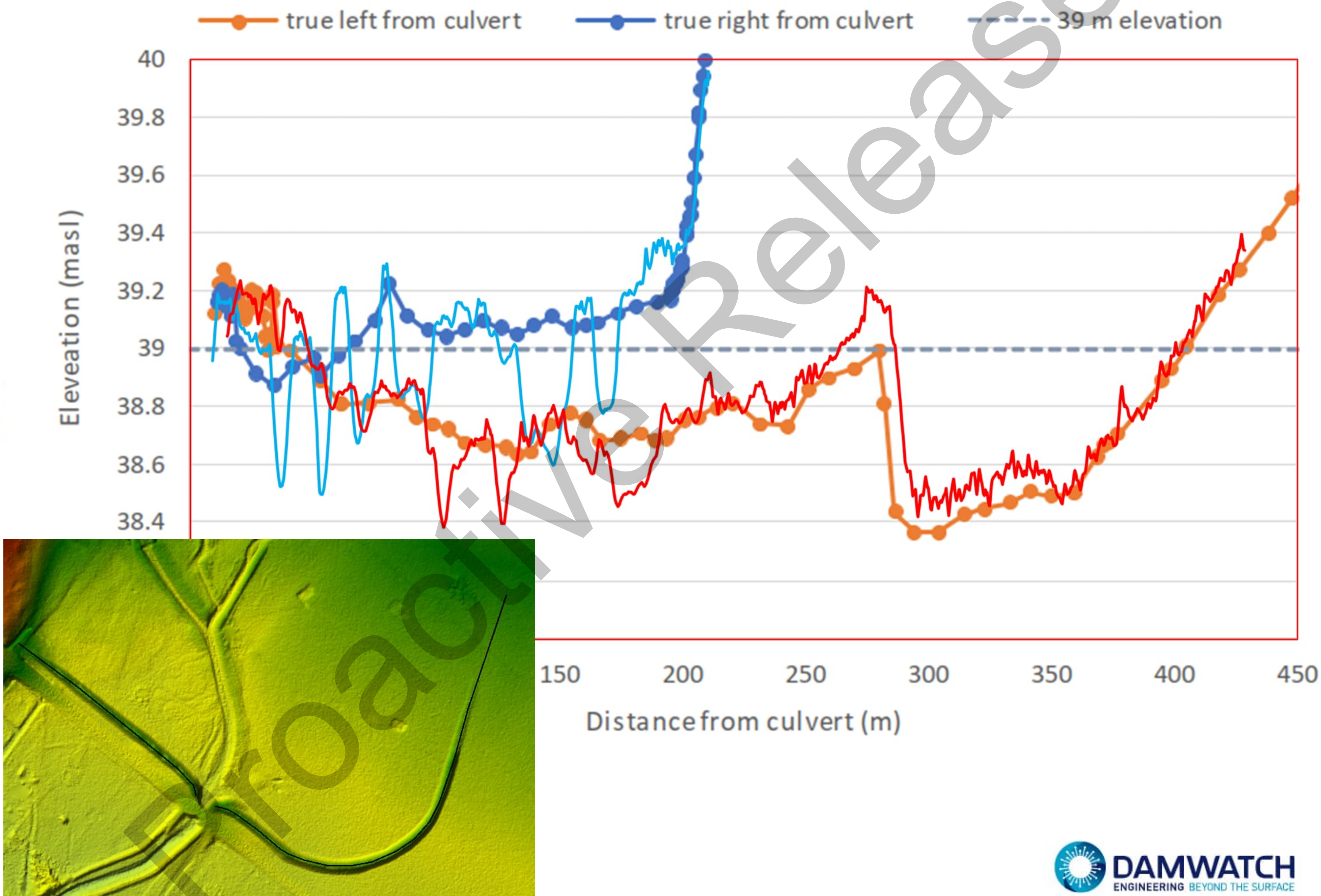
Surveyed Embankment Crest Levels

Left Dam Crest RL (m)	39.3 (design); 38.6 (surveyed low point)
Right Dam Crest RL (m)	39.3 (design); 38.9 (surveyed low point)
Spillway Crest RL (m)	38.9 (design); 38.4 (surveyed low point, WSP Opus survey on 13/7/2018)



DAMWATCH ENGINEERING BEYOND THE SURFACE

Comparison with LiDAR data



Spillway

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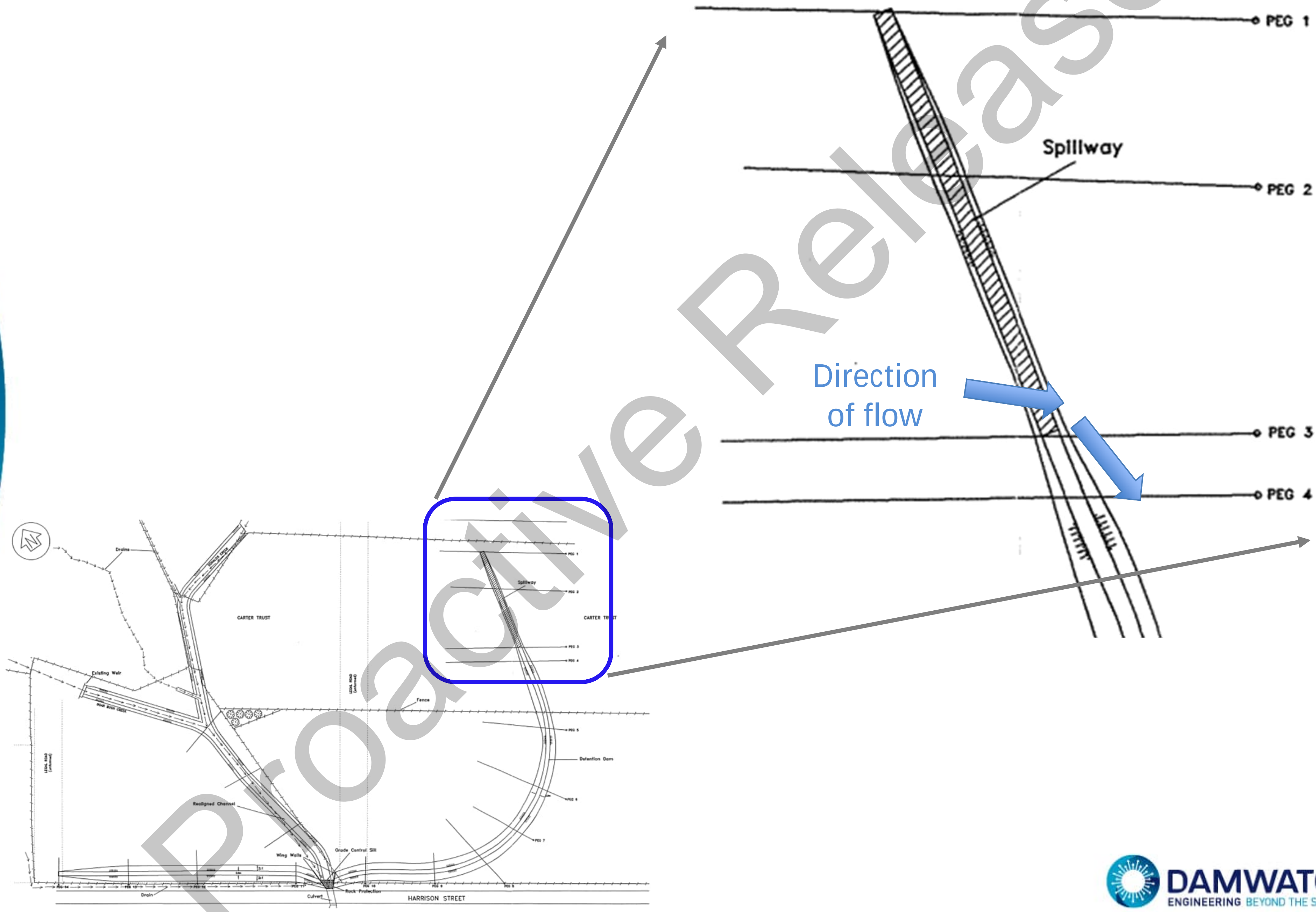
Lateral Spillway



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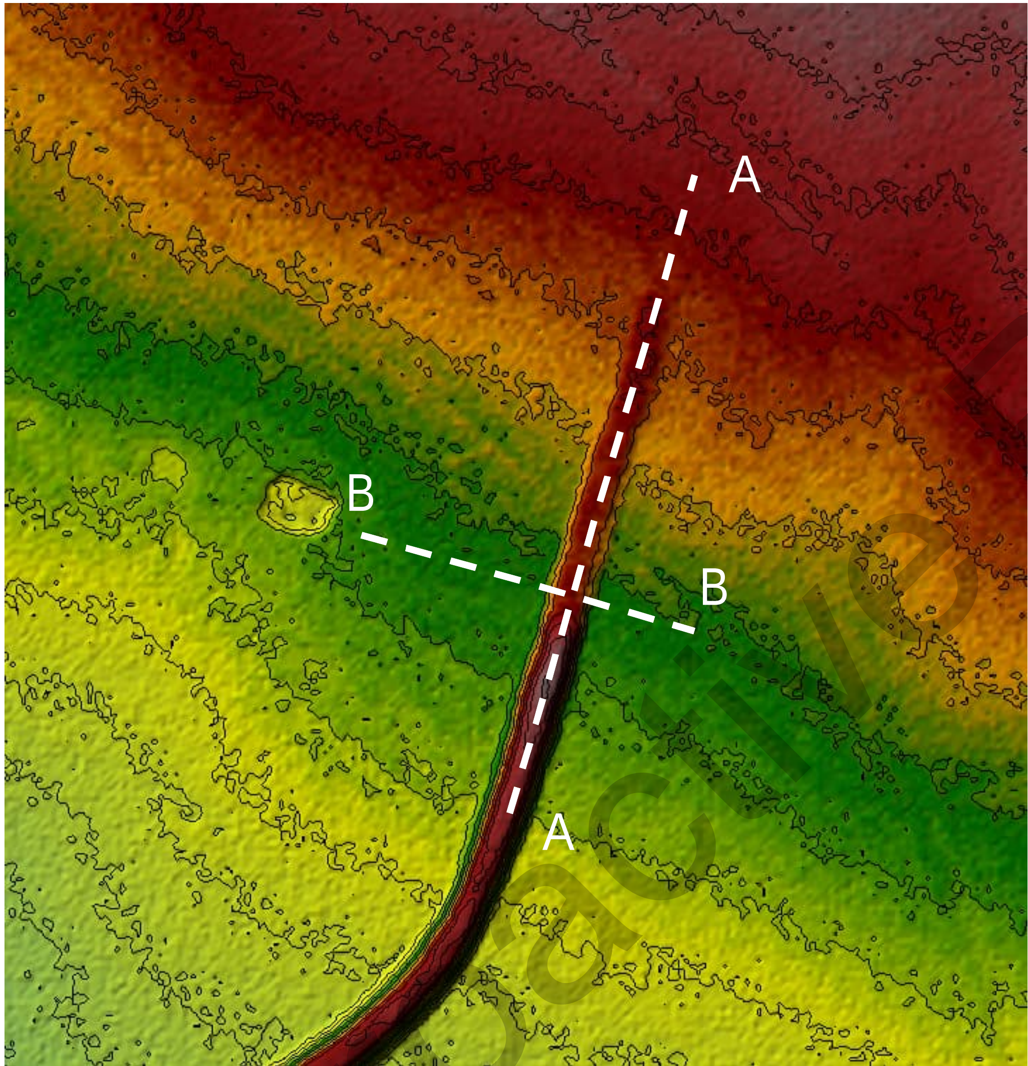
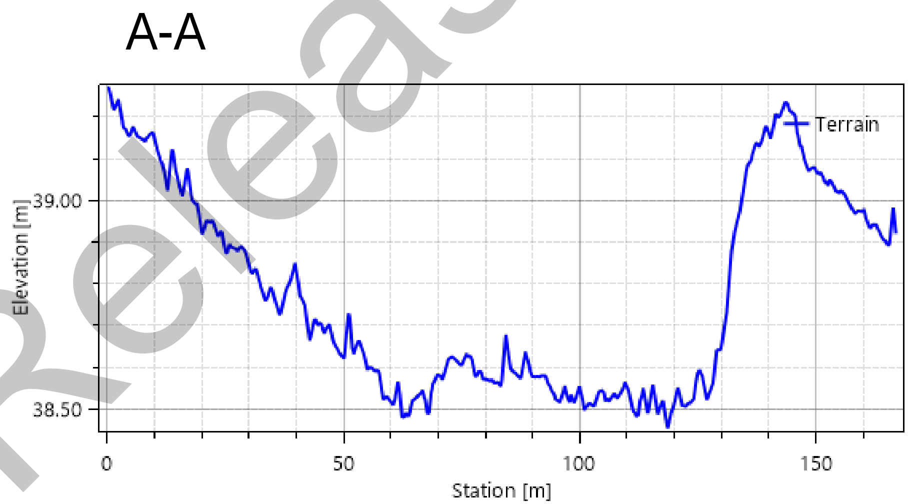
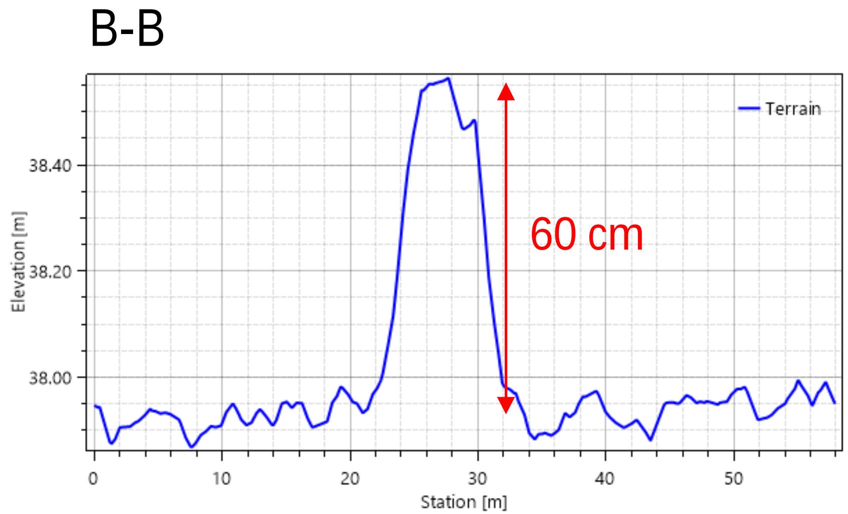
Lateral Spillway







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Lateral Spillway – Photos (8/5/2024)

Photo along upstream toe of left embankment, facing northeast toward end of embankment and spillway

Photo from spillway facing left embankment (south) showing flow path of spillway discharge

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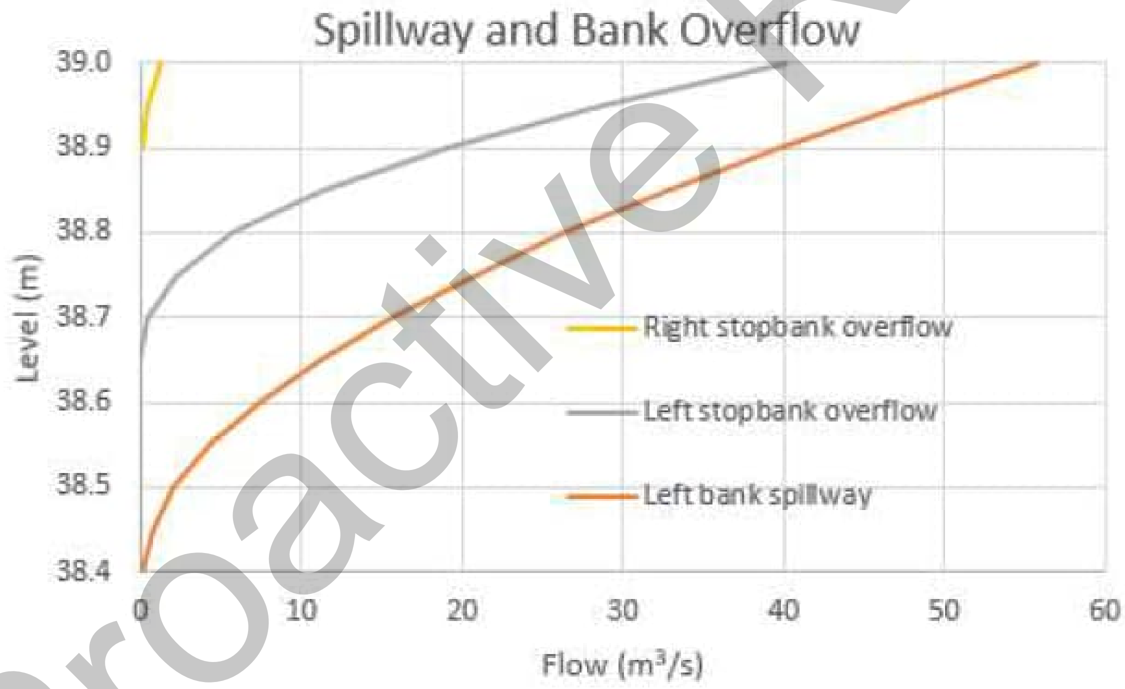
Spillway – Discharge Capacity

- 2018 Donalds Creek Hydrological Analysis (WSP):
  - Crest level ~ RL 38.4 to 38.5 m.
  - Capacity at lowest point of left embankment (RL 38.4 m to RL 38.64 m) of 0 to ~ 9 m^3/s.
  - Capacity of ~ 56 m^3/s at nominal dam crest (RL 39 m).



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Box Culvert

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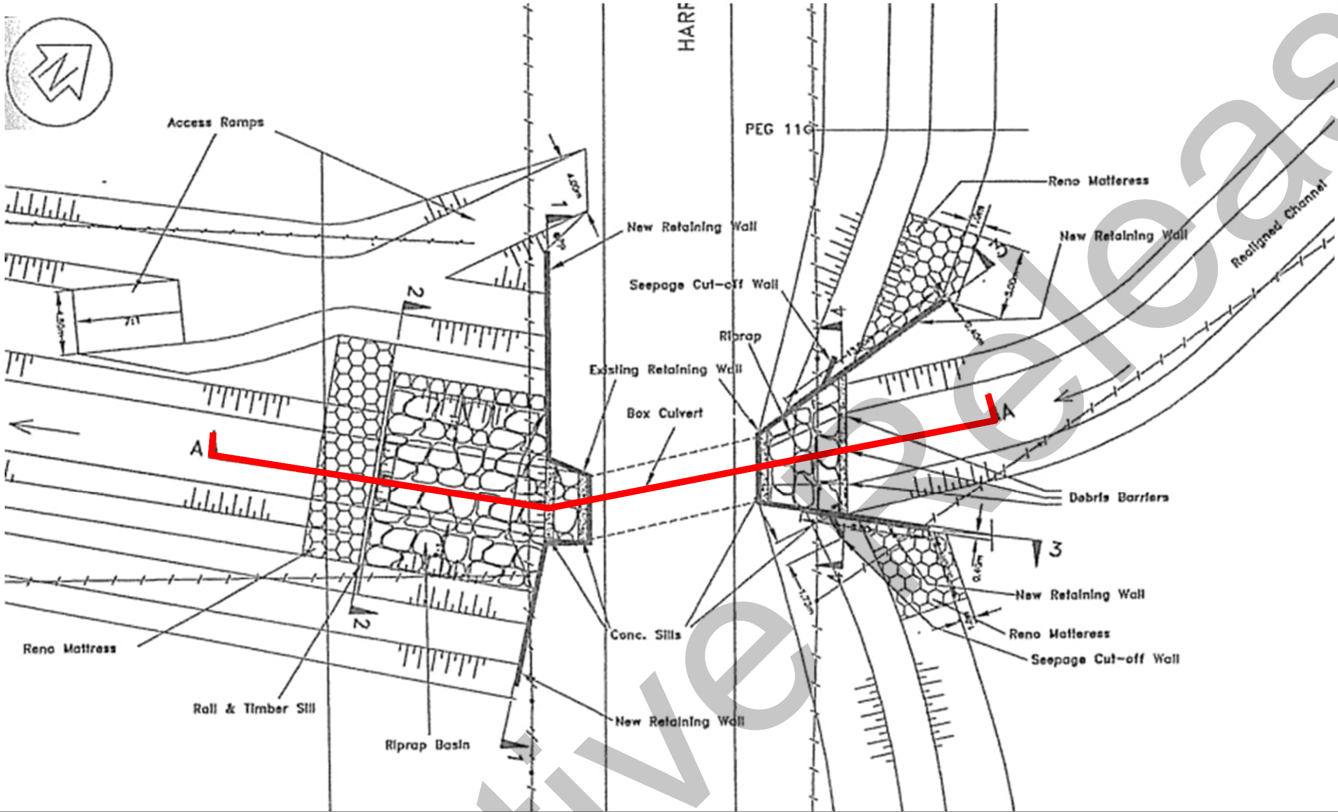
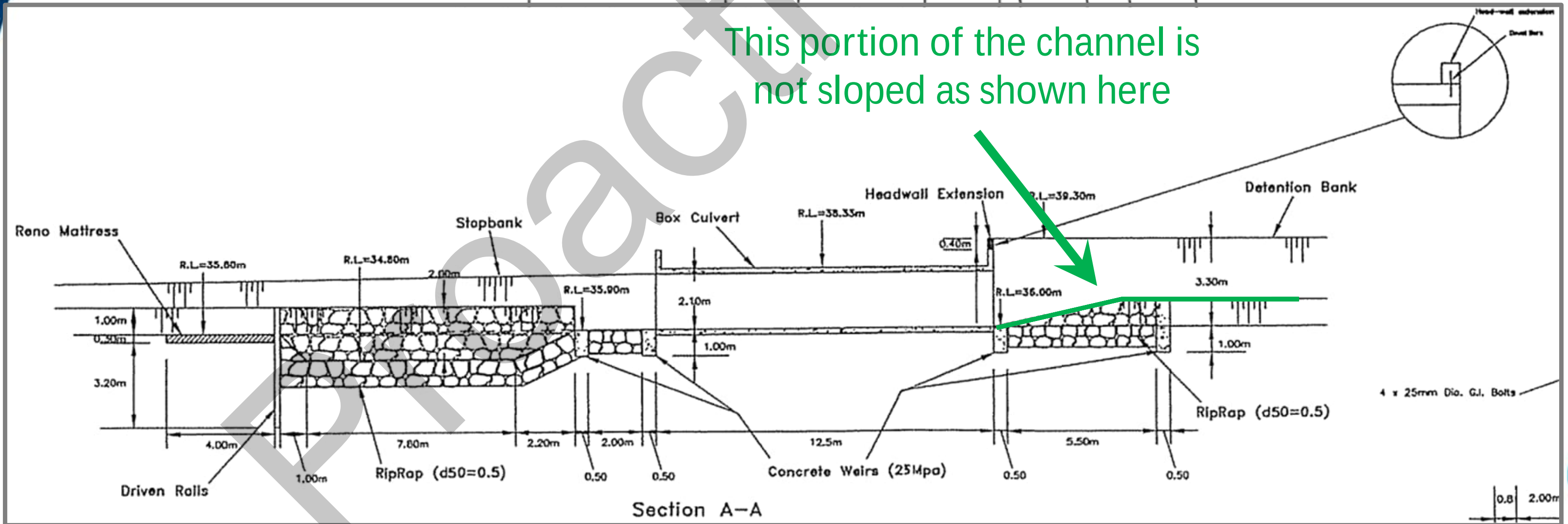
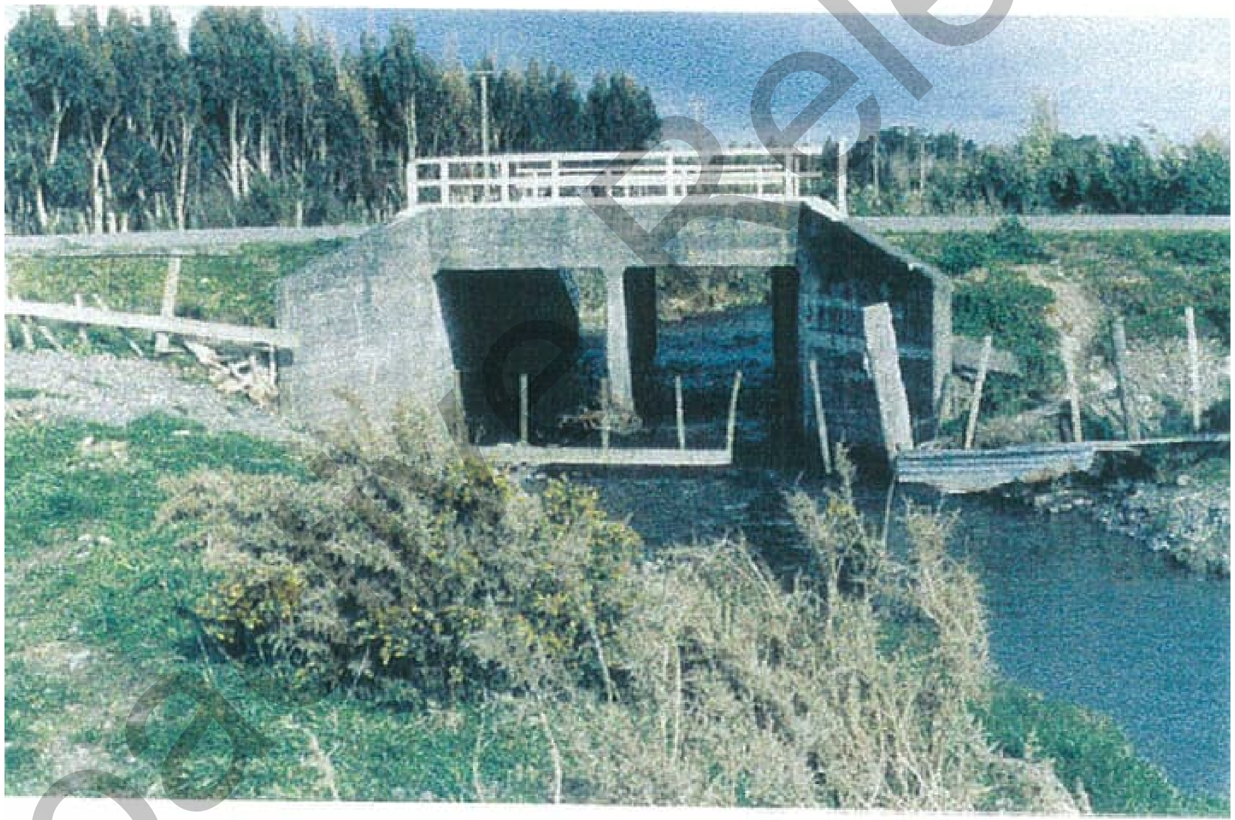
Culvert – Plan view and profile





Culvert

- Donalds Creek, “Assessment of Environmental Effects” (1998):
  – Original culvert inlet:



Harrison St Culverts, looking downstream

Culvert

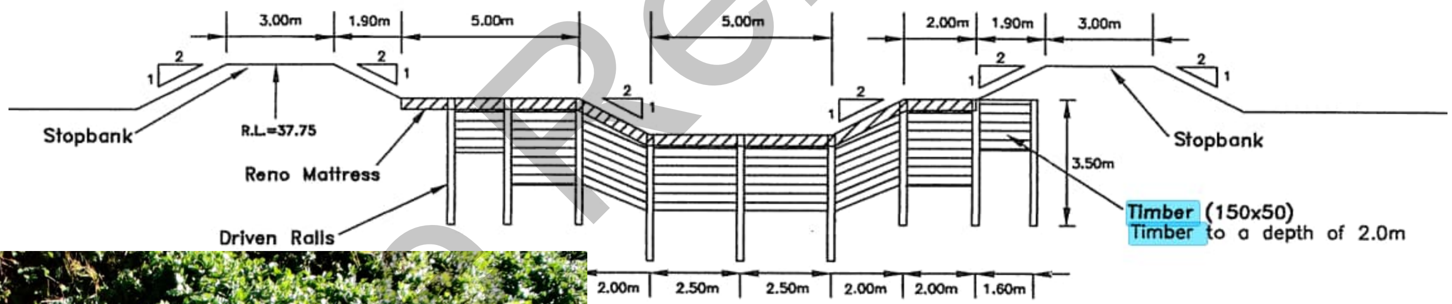
- Inlet:

Culvert

- Outlet:

Culvert

- Timber weir downstream:
  - Placed during construction to prevent further degradation of the stream.
  - 6 timber control structures built from SH2 to just downstream of SH53. Other structures between Harrison St. and SH2?



Section 2–2

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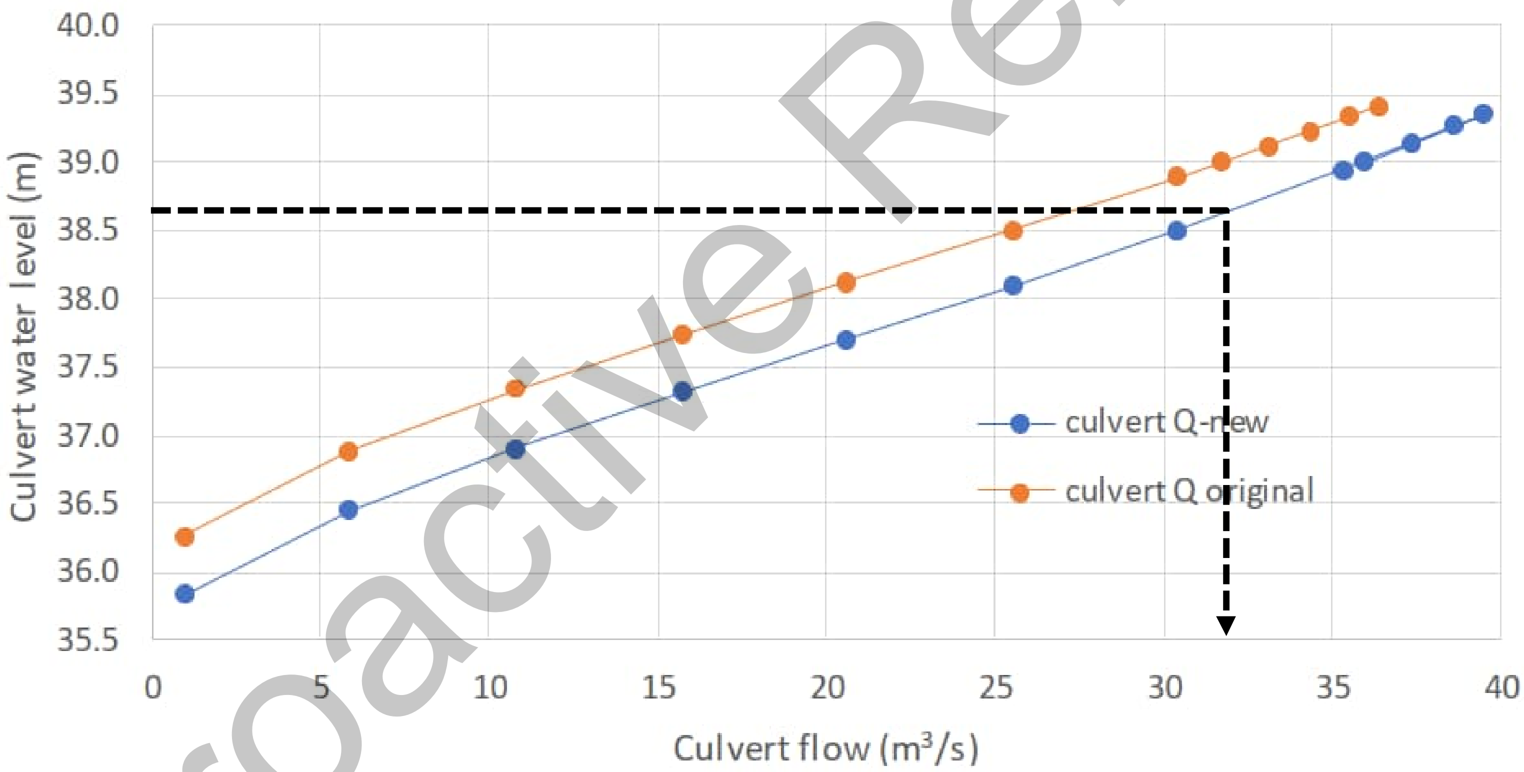
Culvert – Discharge Capacity

- 2018 Donalds Creek Hydrological Analysis (WSP):
  - Capacity of ~32 m^3/s at lowest points of the left embankment dam crest.
  - Capacity of ~36 m^3/s at nominal dam crest (RL 39 m) (+5 m^3/s with respect to design capacity).



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Flood Hazard & Seismic Hazard

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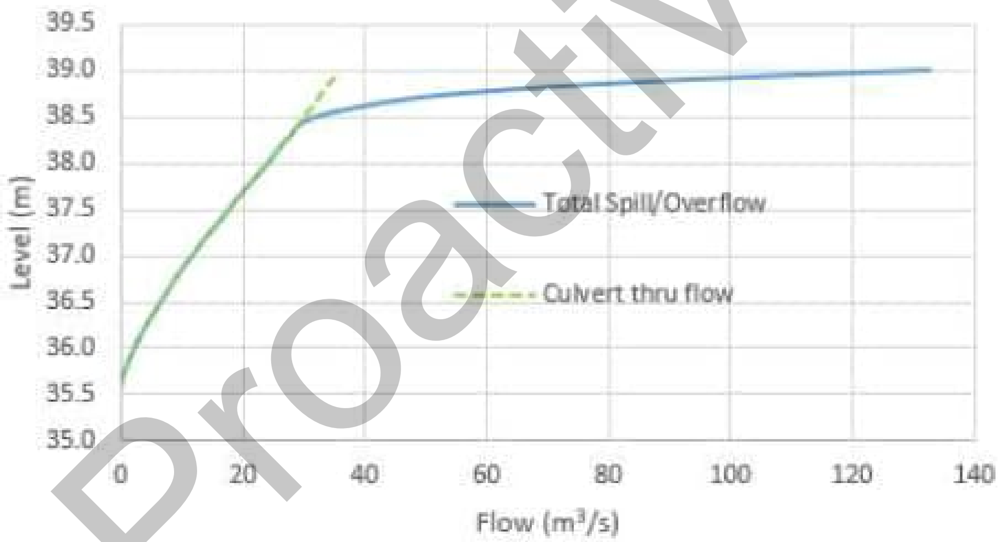
Total discharge capacity

- 2018 Donalds Creek Hydrological Analysis Phase II (WSP):

POND LEVEL (m)	CULVERT FLOW (m^3/s)	LEFT BANK SPILLWAY (m^3/s)	LEFT STOPBANK OVERFLOW (m^3/s)	RIGHT STOPBANK OVERFLOW (m^3/s)	TOTAL POND OUTFLOW (m^3/s)
35.56	0	0	0	0	0
37.0	11.7	0	0	0	12
38.0	24.1	0	0	0	24
38.5	30.2	2.0	0	0	32
39.0	35.7	55.7	40.1	1.2	133



Significant capacity after overtopping of left embankment dam if considered to be a weir

Hydrology

- Donalds Creek Flood Protection Project, "Assessment of Environmental Effects" (1998):

Annual Exceedance Probability	Peak inflows [m³/s]	Peak outflows [m³/s]	Peak elevation [RL m]
1:2	15.2	13.8	
1:5	22.3	19.2	
1:10	26.9	22.4	
1:20	30.7	25.1	
1:50	36.6	29.4	38.79
1:100	41.1	32.6	39.00

Hydrology

- 2018 Donalds Creek Hydrological Analysis Phase II (WSP):
  - GWRC allowance for climate change (HIRDS v4 + 20%).
  - Dam can pass design events up to the 1:100 AEP flood, including climate change (allowing for up to 20 cm overtopping for up to 1 hour and 43 min).

Annual Exceedance Probability	Case	Peak flood inflows [m^3/s]	Peak outflows [m^3/s]	Peak elevation [RL m]
1:20	Present	27	22.4	37.86
	CC (2090)	34.2	27.2	38.25
1:50	Present	36.6	28.7	38.36
	CC (2090)	52.3	48.9	38.71
1:100	Present	49.3	45.3	38.67
	CC (2090)	67.4	65.9	38.84
PMF	-	300 - 320		

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Hydrology

- 2018 Donalds Creek Hydrological Analysis Phase II (WSP):
  - Effect of blockage:

Annual Exceedance Probability	Blockage	Case	Peak flood inflows [m^3/s]	Peak outflows [m^3/s]	Peak elevation [RL m]
1:100	0%	Present	49.3	45.3	38.67
		CC (2090)	67.4	65.9	38.84
	20%	Present	49.3	46.6	38.74
		CC (2090)	67.4	66.5	38.89
	50%	Present	49.3	49.3	38.83
		CC (2090)	67.4	68.2	38.96

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Hydrology

- 2020 Flood Hazard assessment for new developments on Harrison St. (T&T):
  - Donalds Creek Dam expected to overtop.
  - Downstream “stopbank breach” is mentioned.

Annual Exceedance Probability	Method	Peak flood inflows [m^3/s]	Peak outflows [m^3/s]
1:100	NIWA (Regional)	24.5	
	NIWA (Rational)	23 – 45	
	SCS (HEC-HMS model)	23 - 30	~29
1:100 (RCP 6.0 2100)	SCS (HEC-HMS model)	~48	~43

Hydrology

- 2020 Flood Hazard assessment for new developments on Harrison St. (T&T):

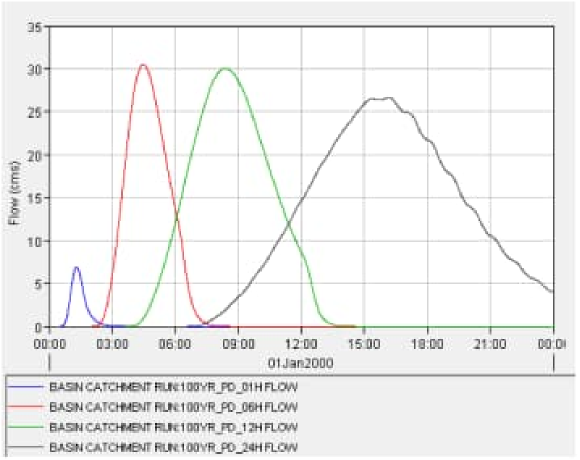

Figure 2-1. HEC-HMS present day pond inflow hydrographs

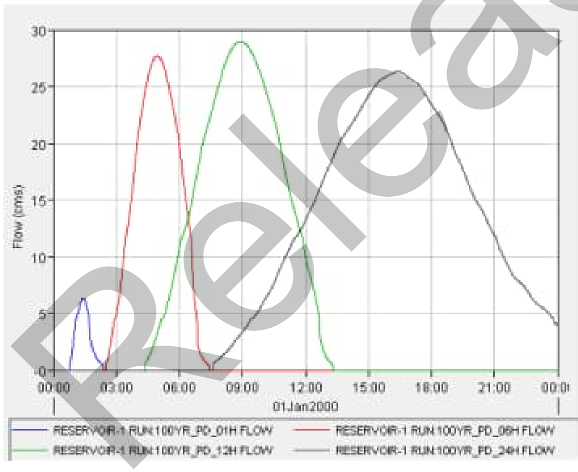

Figure 2-2. HEC_HMS present day pond outflow hydrographs

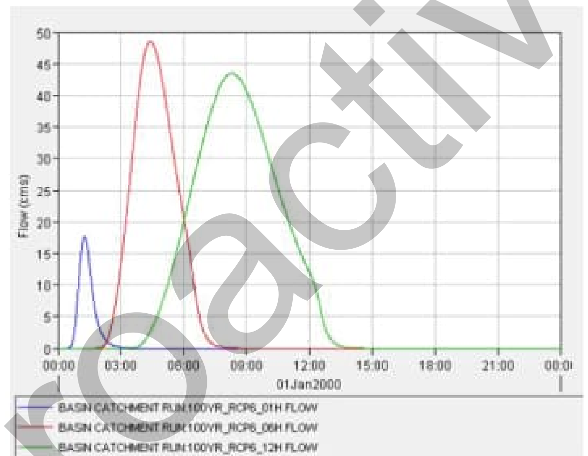

Figure 2-3. HEC-HMS RCP6.0 pond inflow hydrographs

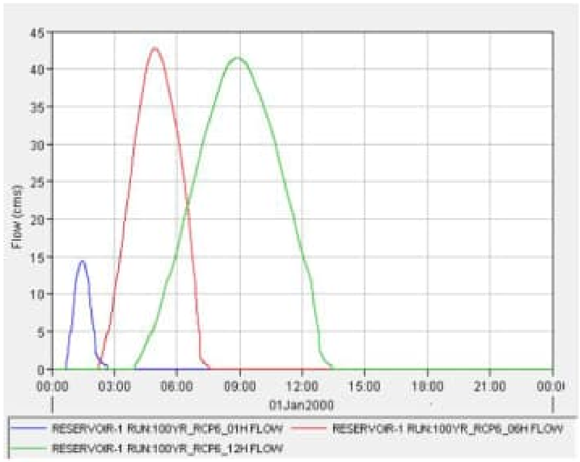

Figure 2-4. HEC-HMS RCP6.0 pond outflow hydrographs

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Flood Hazard

- Donalds Creek Flood Protection Project, “Assessment of Environmental Effects” (1998):
  - “Donalds Creek channel above SH2 has a tendency to aggrade, with excess gravel having been removed over the years, typically at a 2 year cycle.”
  - 50-year return design event. Peak inflow of 37 m^3/s. Peak outflow 29 m^3/s.
  - For over-design floods, provision “for overflows to spill around the north-[eastern] end of the embankment, and pond in the existing ponding area between Boundary Road, SH2, and the stream channel stopbank”.

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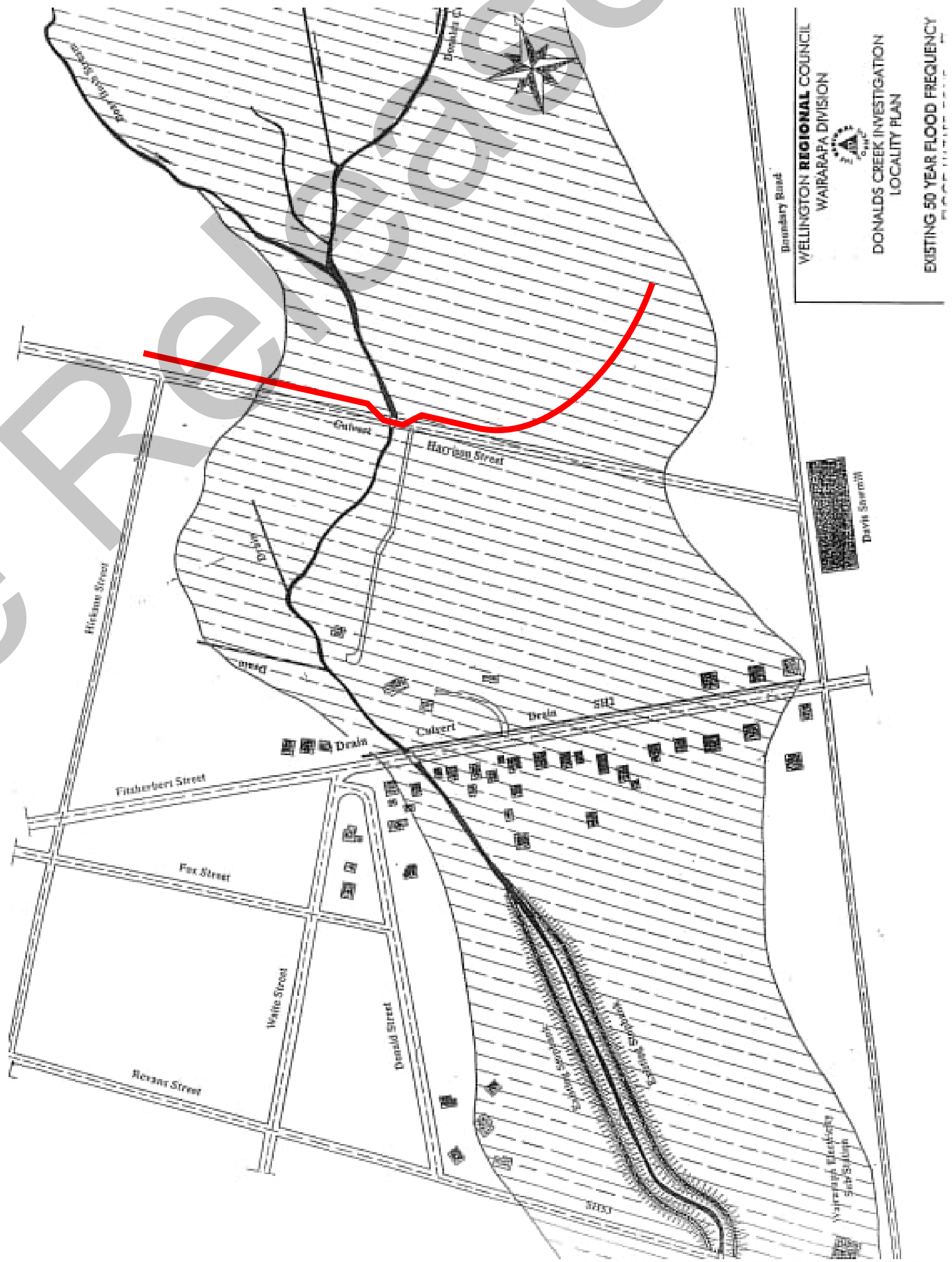
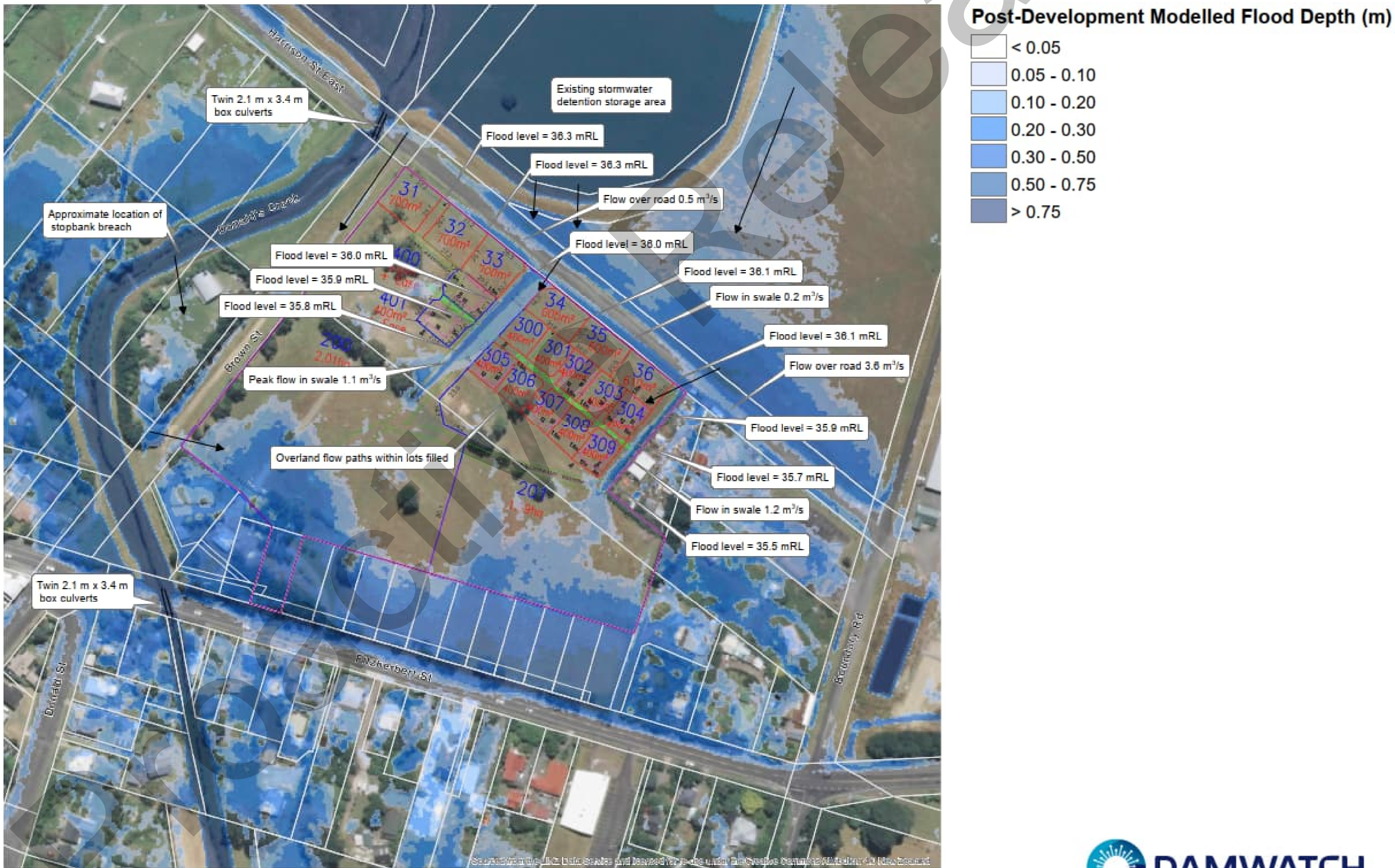
Flood Hazard

- Donalds Creek Flood Protection Project, “Assessment of Environmental Effects” (1998):
  - 1:50 AEP flood inundation extents prior to construction of dam:



Flood Hazard – Base scenario (no dam failure)

- 2020 Flood Hazard assessment for new developments on Harrison St. (T&T):



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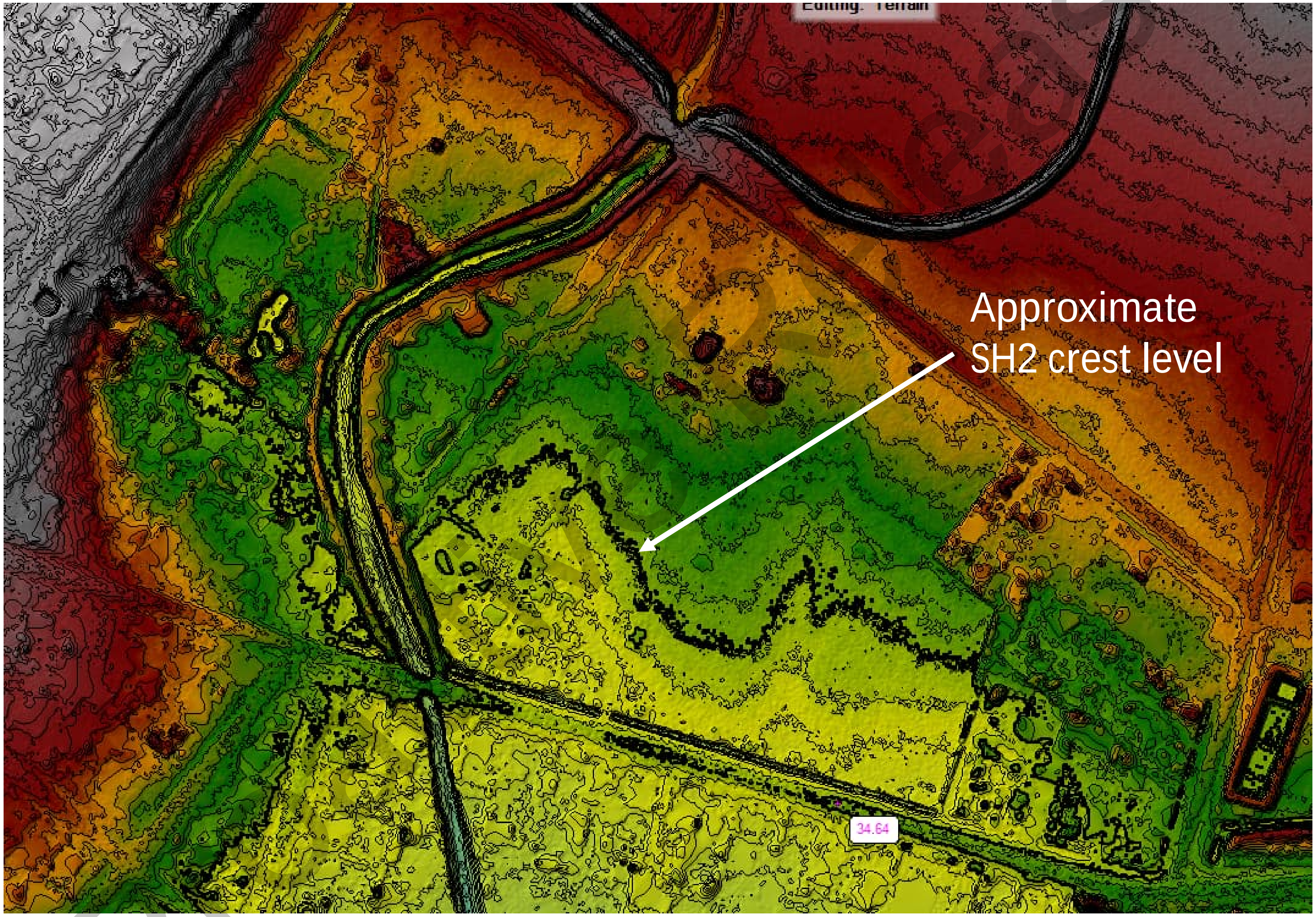
Flood Hazard – LiDAR survey



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Flood Hazard – LiDAR survey

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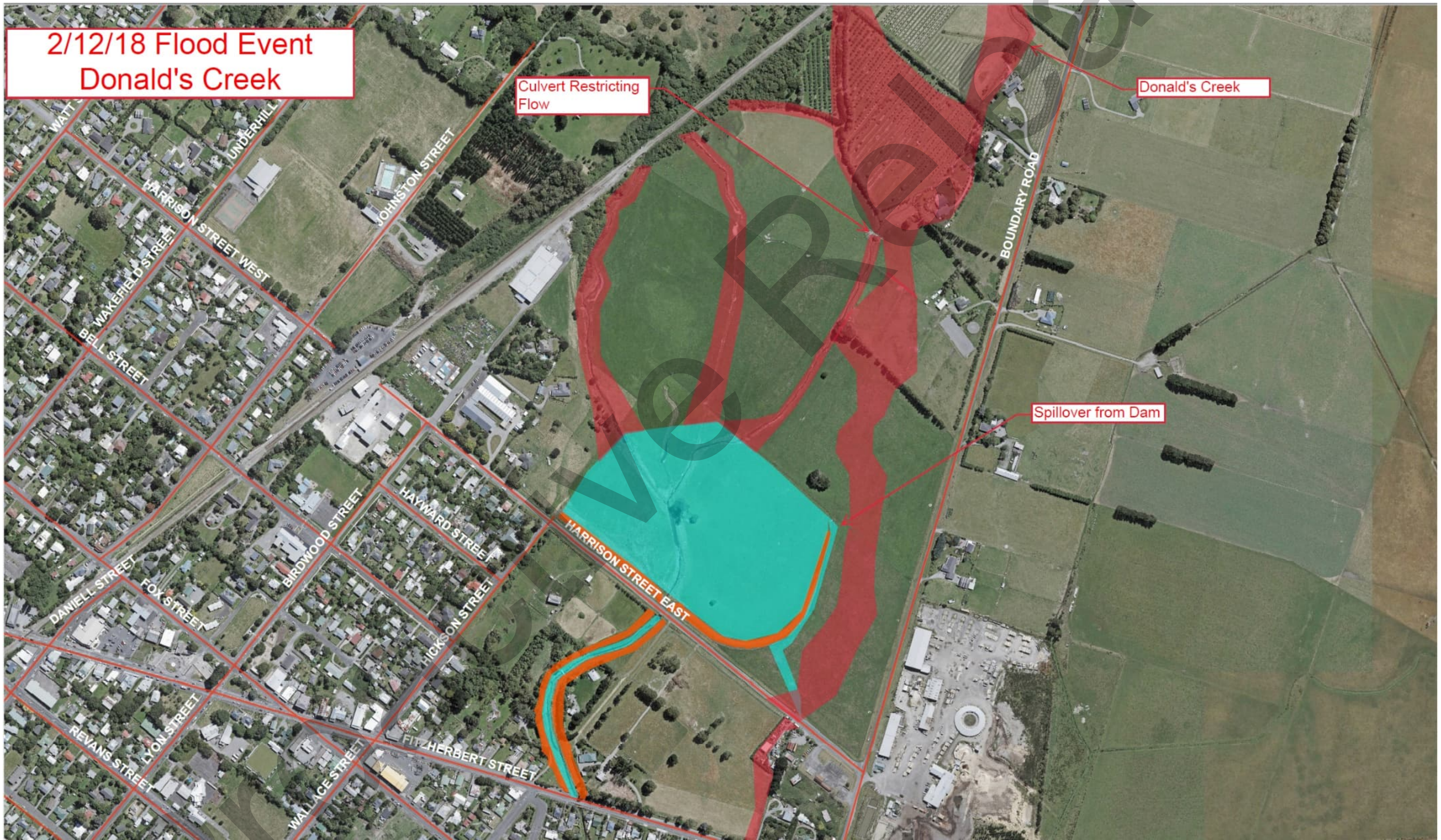
Flood Hazard

- Floods in 2003 and 2005, estimated to have a 1:10 AEP.
- Most recent flood on 2 December 2018:
  - Spillway discharge estimated to be ~ 2 m^3/s at RL 38.37 m.
  - Estimated by GWRC to have been a 1:50 AEP event including effects of climate change based on WSP study. (How?)

  - A culvert upstream of the dam restricted flow and diverted the flow away from the reservoir.

Flood Hazard – Dec 2018 Flood

- GW 2018 post-event appraisal:



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Flood Hazard – Dec 2018 Flood

- Peak level:

Flood Hazard – Dec 2018 Flood

- Flow crossing Harrison Street East (December 2018):

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Flood Hazard – Dec 2018 Flood

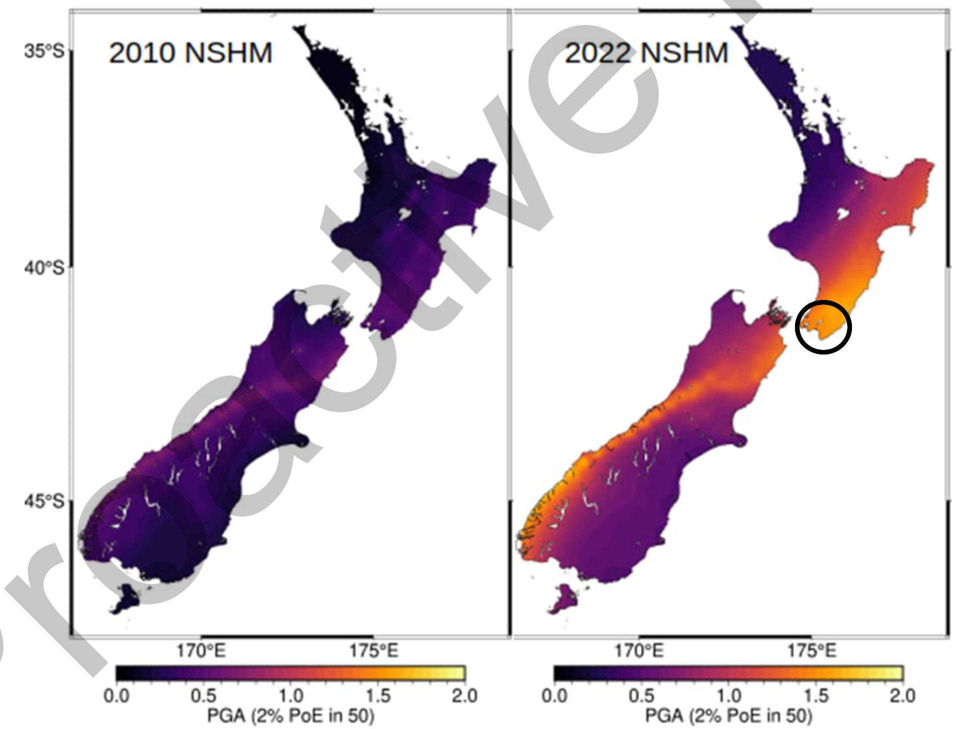
- Channel between SH53 and SH2:

Seismic Loads NSHM22

Sa (g)			
150 AEP	500 AEP	1,000 AEP	2,500 AEP
0.53	0.96	1.26	1.72

Comparison of 2010 and 2022 PGA *Hazard* Maps

PGA: 2% Probability of Exceedance in 50 years: lower risk tolerance



Liquefaction Hazard

4 conditions needed for liquefaction to occur:

- Earthquake
- Cohesionless sands, silts, gravels
- Saturated material
- Loose material

Foundation:

- Pleistocene age >11,700 yr old
  - *more resistant than recent river deposits*

Embankment silts, sands & gravels:

- Degree of compaction (??)

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Surveillance & Site Inspection

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Surveillance

- Monthly inspections
  - Started in April 2024
- Water level sensor
  - Right wingwall of box culvert
  - High water levels only
  - Telemetry 15-min frequency

Embankment Slopes Steeper than Design

- U/S & D/S slopes
  - ~1H:1V in places
    - Compared with LiDAR – estimated 2H:1V downstream and 1.5H:1V upstream
  - Sheep tracks
  - Vegetation height

Upstream slope of right embankment

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Site Inspection – 8th May 2024


Sediment at base of left culvert (~7cm thick near downstream end)

Upstream view of culvert


Site Inspection – 8th May 2024


Right culvert, facing downstream

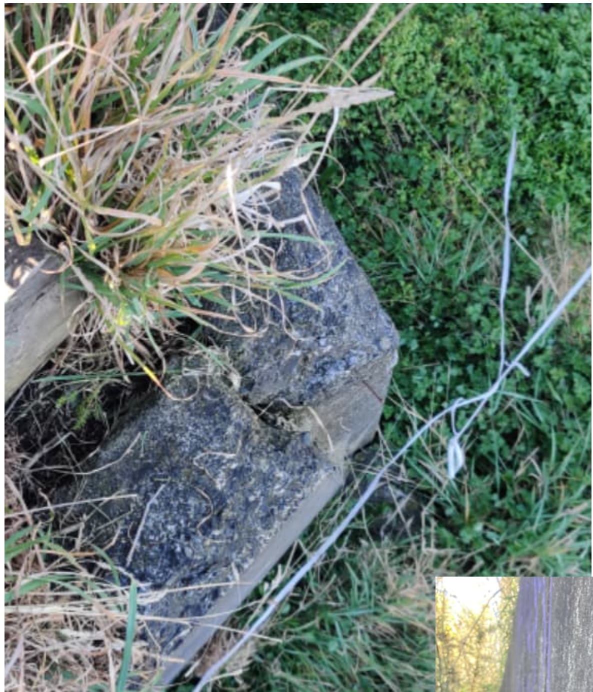
Site Inspection – 8th May 2024

Hanging fences at downstream end of culvert

Signs of deterioration at base of right wall of left culvert

Site Inspection – 8th May 2024

Displacement along joint at corner of downstream right wingwall



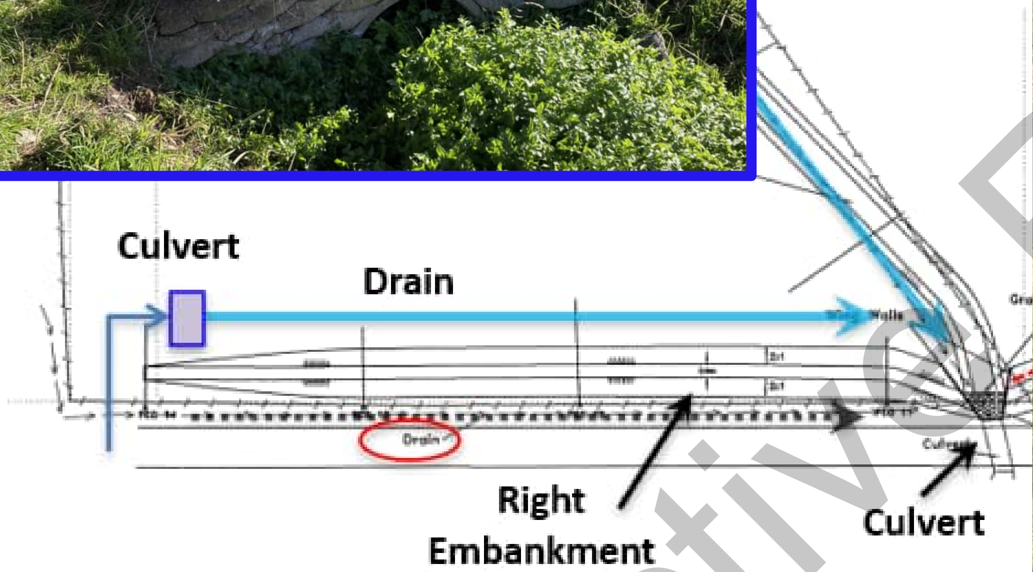
Site Inspection – 8th May 2024

Displacement at corner along joint of downstream left wingwall

Site Inspection – 8th May 2024

Drain along upstream toe of right embankment

Embankments – Plan view



Drain along upstream toe of right embankment

CDA System Approach for FMEA

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FMEA – New Zealand Dam Safety Guidelines (2023)

- Identify the system into components & functions
  - Containment, Conveyance & Control
- Purpose is to understand the components:
  - interdependencies,
  - designed function
  - failure modes

Use function diagrams & hazard matrix

Donalds Creek Detention Dam Layout

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Hazard & Failure Modes Matrix (HFMM) – High Level Screening

GLOBAL FAILURE MODES		ELEMENT AND/OR ELEMENT FUNCTION	MOST BASIC FUNCTIONAL FAILURE CHARACTERISTICS	External Hazards			Internal Hazards (Design, Construction, Maintenance, Operation)			
				Meteorological	Seismic	Reservoir Environment	Water barrier	Hydraulic struct.	Mech/elec	Infrastructure & Plans
DAM COLLAPSE BY OVERTOPPING (erosion or overturning)	Water elevation too high	Inadequate available discharge capacity	Inadequate reservoir operation (rules not followed)							
			Random functional failure on demand							
			Discharge capability not maintained or retained							
		Inadequate freeboard	Excessive elevation due to landslide or U/S dam							
			Wind-wave dissipation inadequate							
	Management System Failure	Safeguards fail to provide timely detection and correction	Operation, maintenance and surveillance fail to detect/prevent hydraulic adequacy							
DAM COLLAPSE BY LOSS OF STRENGTH (External orinternal structural failure and weakening)			Operation, maintenance and surveillance fail to detect poor dam performance							
	Crest elevation too low	Stability under applied loads	Mass movement (external stability:- displacement, tilting, seismic resistance)							
			Loss of support (foundation or abutment failure)							
		Watertightness	Seepage around interfaces (abutments, foundation, water stops)							
			Through dam seepage control failure (filters, drains, pumps)							
		Durability/cracking	Structural weakening (internal erosion, AAR, crushing, gradual strength loss)							
			Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking)							

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Hazard & Failure Modes Matrix – Failure Modes

GLOBAL FAILURE MODES		ELEMENT AND/OR ELEMENT FUNCTION	MOST BASIC FUNCTIONAL FAILURE CHARACTERISTICS	Meteorologica
DAM COLLAPSE BY OVERTOPPING (erosion or overturning)	Water elevation too high	Inadequate available discharge capacity	Inadequate reservoir operation (rules not followed)	
			Random functional failure on demand	
			Discharge capability not maintained or retained	
		Inadequate freeboard	Excessive elevation due to landslide or U/S dam	
			Wind-wave dissipation inadequate	
	Management System Failure	Safeguards fail to provide timely detection and correction	Operation, maintenance and surveillance fail to detect/prevent hydraulic adequacy	
			Operation, maintenance and surveillance fail to detect poor dam performance	
DAM COLLAPSE BY LOSS OF STRENGTH (External orinternal structural failure and weakening)	Crest elevation too low	Stability under applied loads	Mass movement (external stability:- displacement, tilting, seismic resistance)	
			Loss of support (foundation or abutment failure)	
		Watertightness	Seepage around interfaces (abutments, foundation, water stops)	
			Through dam seepage control failure (filters, drains, pumps)	
		Durability/cracking	Structural weakening (internal erosion, AAR, crushing, gradual strength loss)	
			Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking)	

Courtesy of BC Hydro

Hazard & Failure Modes Matrix – Hazards

NAL TICS	External Hazards			Internal Hazards (Design, Construction, Maintenance, Operation)			
	Meteorological	Seismic	Reservoir Environment	Water barrier	Hydraulic struct.	Mech/elec	Infrastructure & Plans
tion							

- External
  - Flood (meteorological)
  - Seismic
- ~~Internal~~
  - ~~Design, Construction, O&M~~
  - ~~Water barrier, hydraulic structures, mech/electrical, infrastructure & plans~~

Hazard & Failure Modes Matrix

- Questions assigned to each box to be answered
- Workshop review of initial HFMM screening
- Identify key failure modes to analyse

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Failure Modes and Effects Analysis

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NZ Dam Safety Guidelines (2023) Module

- Dam Safety Principles and Objectives

  Principle 2: All natural hazards, loading conditions, potential failure modes and other threats to the safe design, construction, commissioning, operations and rehabilitation of a dam should be identified.

- What is a Potential Failure Mode?

"A mechanism or set of circumstances that could result in uncontrolled release of all or part of the reservoir content."

- Each PFM assessed by load condition:

  - ~~Normal (N)~~
  - Flood (F)
  - Earthquake (S) *followed by minor flood*

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Categories of PFMs

- Category I – Credible, Highlighted
  - *PFM of greatest significant considering need for awareness, potential for occurrence, magnitude of consequence & likelihood of adverse response (physical possibility is evident, fundamental flaw or weakness is identified & conditions & events leading to failure seemed reasonable & credible) are highlighted*
- Category II – Credible, Not Highlighted
- Category III – More Information Needed
- Category IV – Not Credible, Ruled Out
  - *Physical possibility does not exist or clearly so remote a possibility as to be non-credible*

Failure Likelihood Categories for Dams

Failure Likelihood Category	Description	
Very High	There is direct evidence or substantial indirect evidence to suggest it has initiated or is likely to occur in future.	Category 1
High	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward "more likely" than "less likely."	Category 1
Moderate	The fundamental condition or defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward "less likely" than "more likely."	Category 2
Low	The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to initiation.	Category 2
Remote	Several events must occur concurrently or in series to cause failure, and most, if not all, have negligible likelihood such that the failure likelihood is negligible.	Category 4

Based on USBR (2019), Best Practice in Dams and Levee Safety Risk Analysis.

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Internal Erosion

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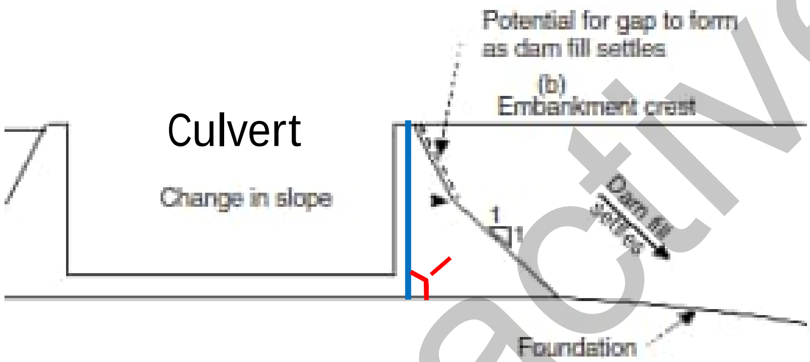
Internal Erosion Process

INITIATION → CONTINUATION → PROGRESSION → BREACH

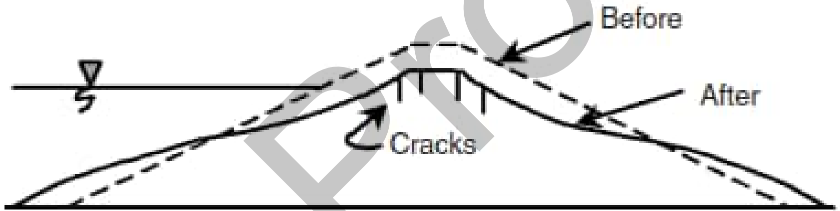
INITIATION	CONTINUATION	PROGRESSION	BREACH
Concentrated leak forms, erosion initiates along walls of crack	Continuation of erosion	Enlargement of concentrated leak	Breach mechanism forms

(a) Internal erosion in the embankment initiated by erosion in a concentrated leak



Hard to compact against vertical wall

- differential settlement
- low stress zone promoting cracking



Post-earthquake cracking

- embankment has steeper slopes

Backward Erosion Piping

Need:
1. Seepage flow,
2. Erodible material,
3. Unfiltered exit,
4. Pipe formation

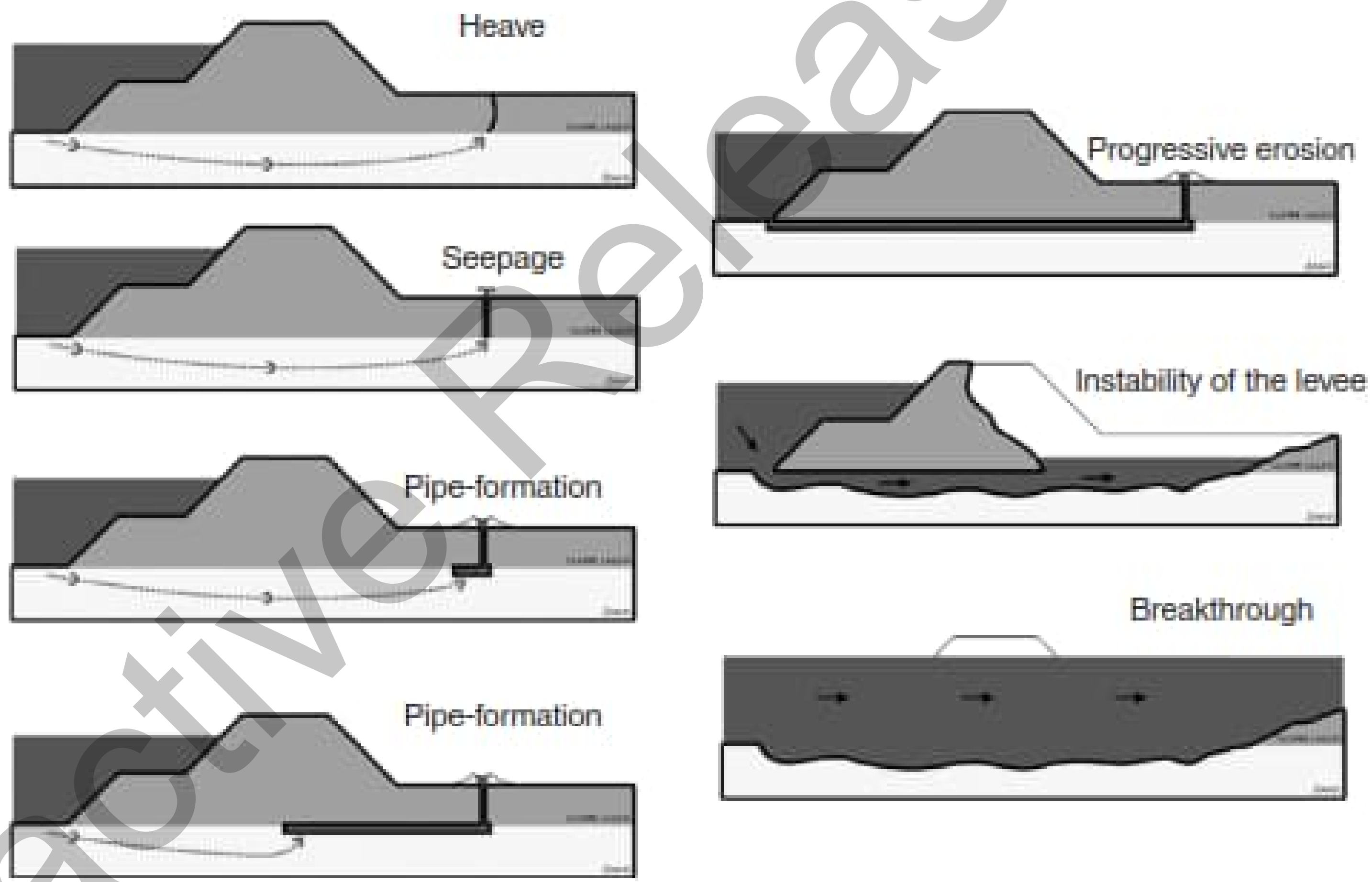
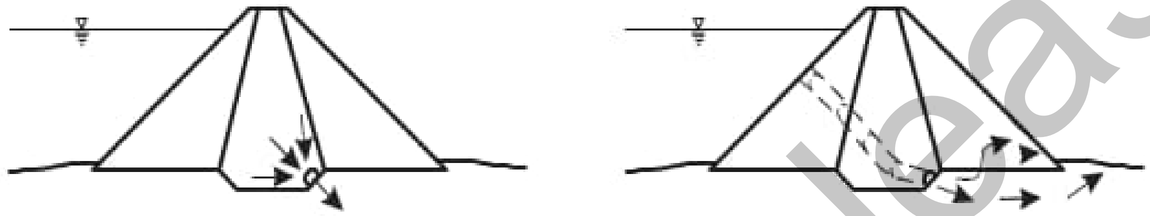


Figure 8.34 Backward erosion piping model (Sellmeijer et al., 2011).

Internal Erosion Process

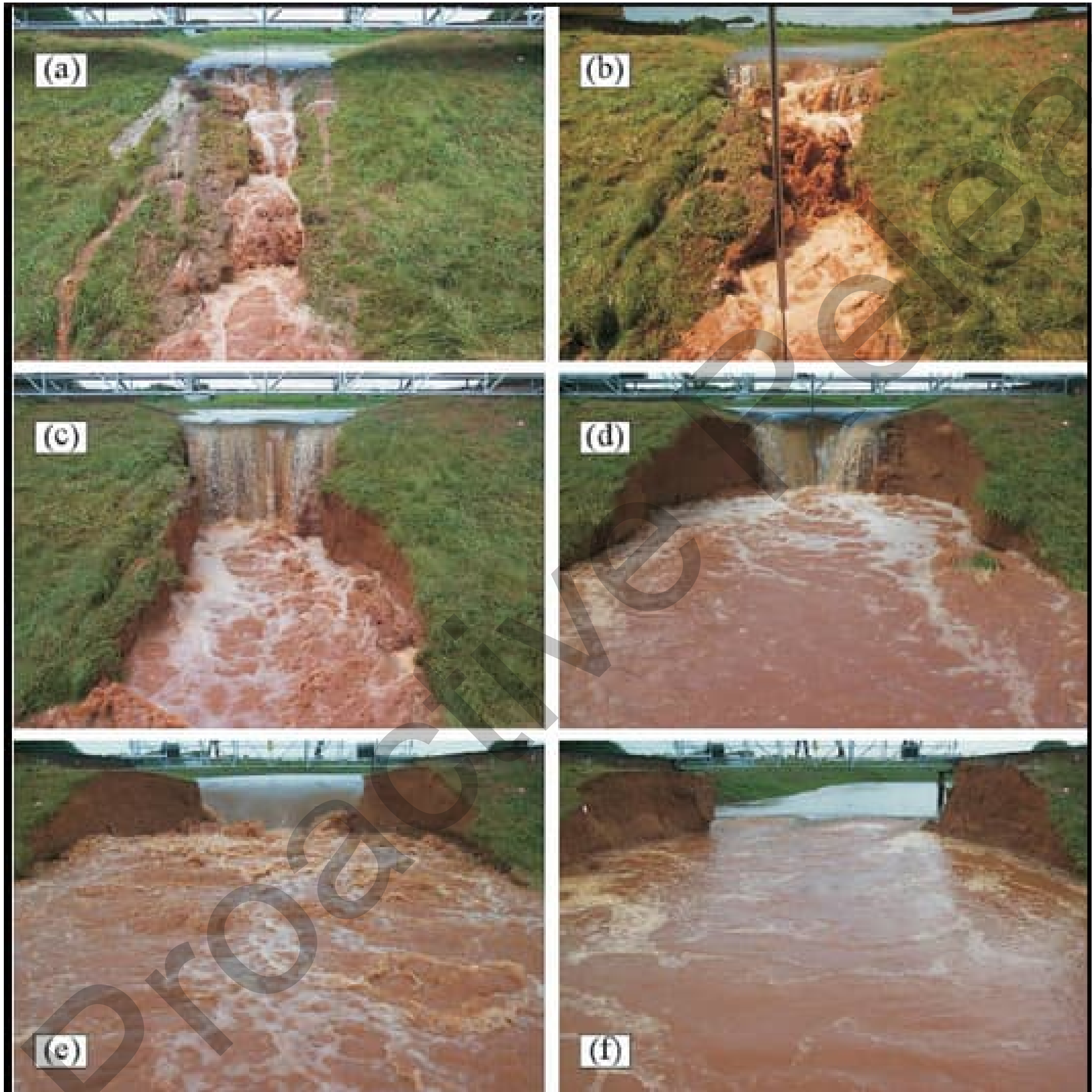


INITIATION → CONTINUATION → PROGRESSION → BREACH

INITIATION	CONTINUATION	PROGRESSION	BREACH
Leakage exits the core into the foundation and backward erosion initiates as core erodes into the foundation	Continuation of erosion	Backward erosion progresses to form a pipe. Eroded soil is transported in the foundation	Breach mechanism forms

(c) Internal erosion from embankment to foundation initiated by backward erosion piping

Overtopping Process



Internal erosion processes :

1. Initiation of erosion *(flaw or triggering event)*,
   2. Continuation of erosion *(unfiltered exit)*,
      3. Progression (pipe forms & u/s zone fails to limit flow),
         4. Intervention / Breach.

Breach Mechanism

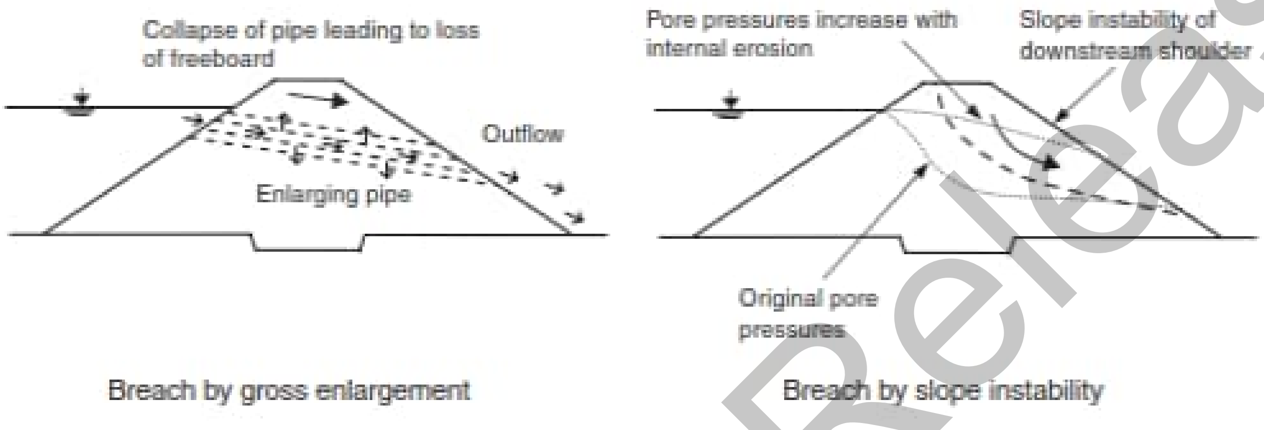


Figure 8.64a Potential breach (failure) phenomena-pipe enlargement and slope instability.

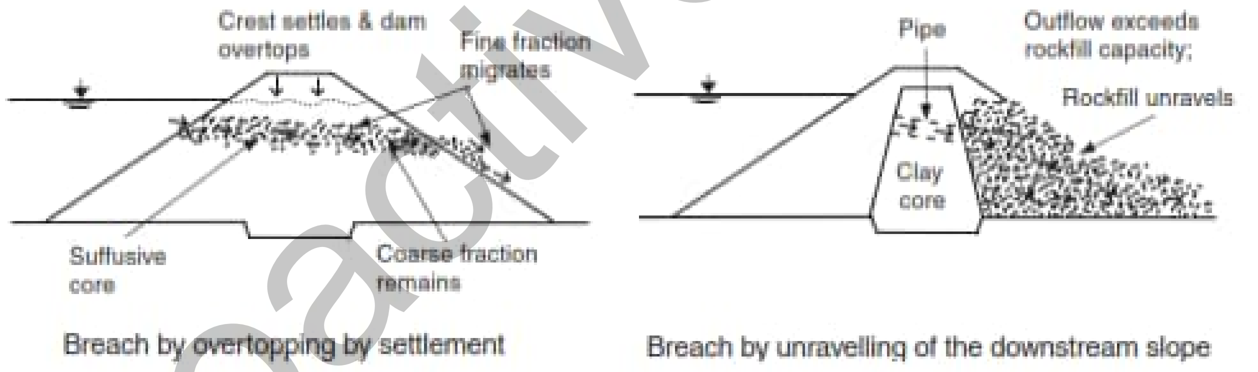
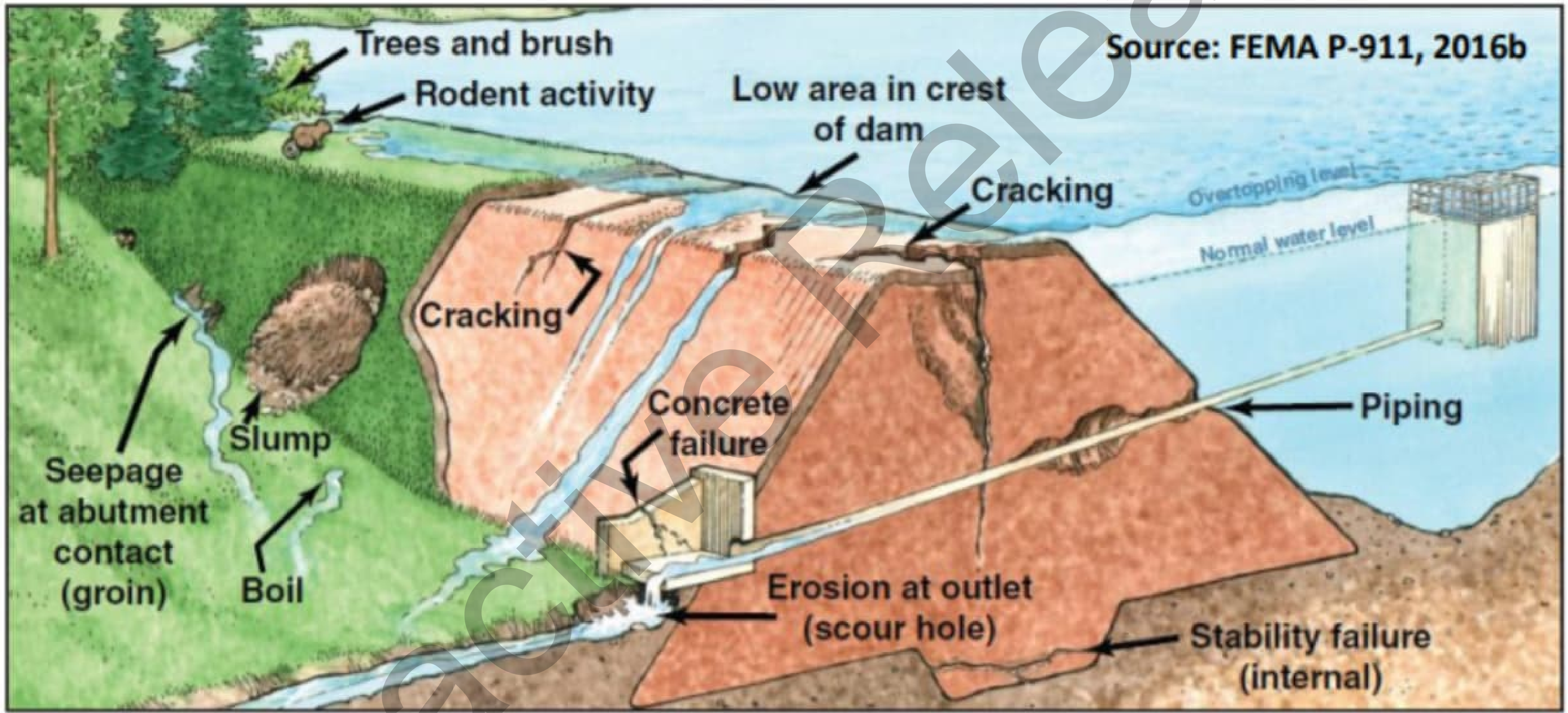


Figure 8.64b Potential breach (failure) phenomena-overtopping by settlement and unravelling of the downstream face (Fell and Fry, 2007).

Internal Erosion of Earth Structures

- Embankment PFMs & Key Performance Indicators (KPIs)



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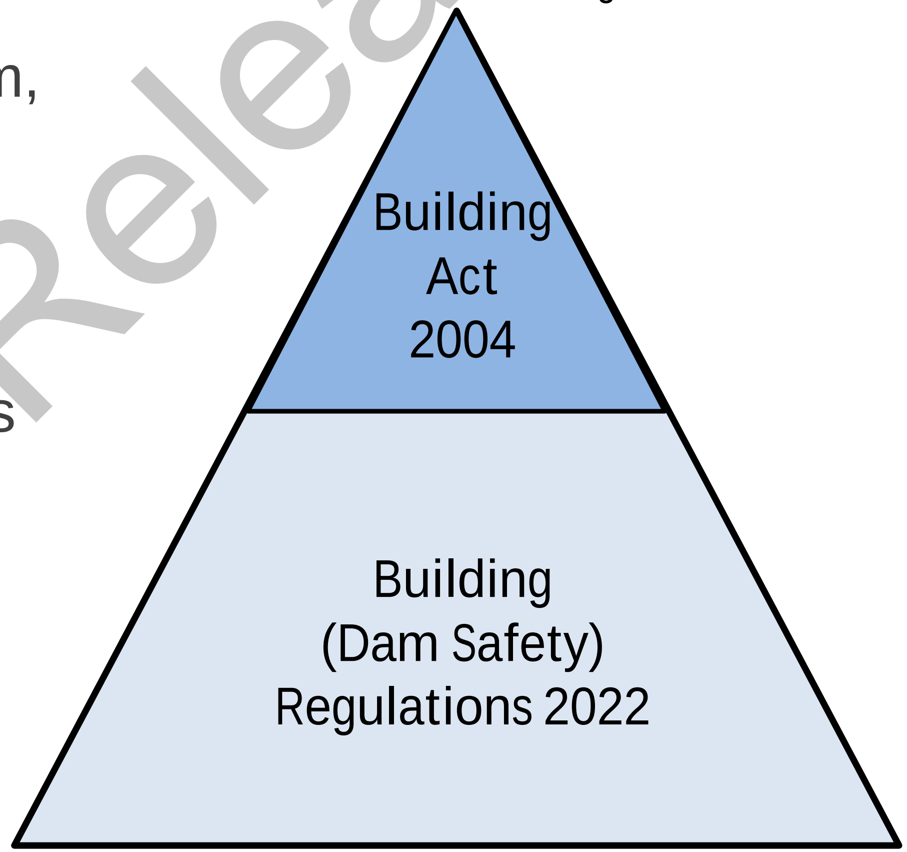
Dam Potential Impact Classification & Challenges

Building (Dam Safety) Regulations 2022

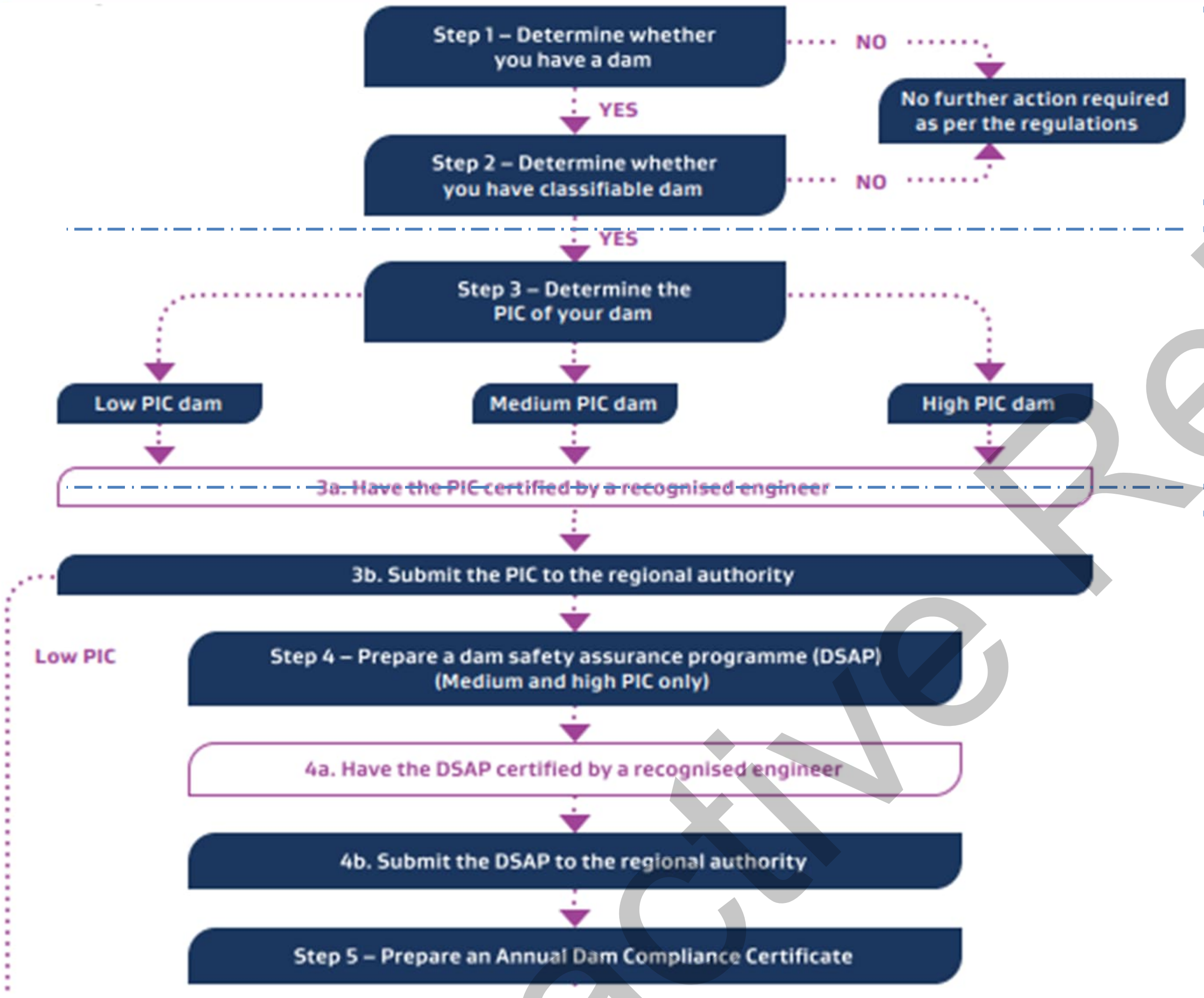
- 13 May 2024, the **Building (Dam Safety) Regulations** in force.
- The Regulations provide a minimum, consistent risk-based regulatory framework for dam safety.
- Dam owners are responsible for complying with the new Regulations and for ensuring their dams are managed appropriately.

Controls and guides safe design and construction for new dams and for rehabilitation of existing dams



Controls and guides ongoing dam safety management of existing dams

Building (Dam Safety) Regulations - Overview



Only relevant to dams that meet classifiable thresholds
≥ 4m high and 20,000m3, or
~~**>1m high and 40,000m3**~~
NB: This threshold removed by MBIE, April 2024

Potential Impact Classification (PIC)

Dam Safety Assurance Programme (DSAP)
(for Medium and High PIC dams only)

Large Dam: ≥ 4m & 20,000m³ (NZ Dam Safety Guidelines 2023)

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Timeline

Date	Event
1998/99	Donalds Creek Dam constructed
September 27, 2018	WSP Opus report recommending no FMEA
2020	Brookside Developments constructed within flooded area downstream of dam • Increases consequences of dam failure
September 21, 2023	Building Regulations updated Classifiable dam: • > 1m high & stores > 40,000 m^3; or • > 4m high & stores > 20,000 m^3
March 25, 2024	Donalds Creek Dam classified as High PIC (desktop assessment) • Impacted requirements for dam, including increase in design flood
March 25, 2024	Confirmed dam safety deficiencies based on High PIC (desktop assessment) identified • Dam will overtop during 100-yr flood • Insufficient freeboard for flood events >20-year flood event • Impounded area is not well defined • Dam cannot safety convey flows > 100-year event
March 28, 2024	Building Regulations updated Classifiable dam: • > 4m & > 20,000 m^3 • Donalds Creek dam no longer classifiable but downstream consequences of dam failure remain

Challenges

- Ownership of culvert
- Develop a DSAP
  - O&M procedures
    - Embankment veg. cover
    - Culvert structural condition
  - Surveillance record keeping & review
  - Emergency planning & response

- Post-event (flood/earthquake) inspection
  - Embankment cracking &
  - Structural capacity of culvert
- Perceptions dam vs. stopbank
- Development pressures

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Thank you &

your thoughts

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- Extra

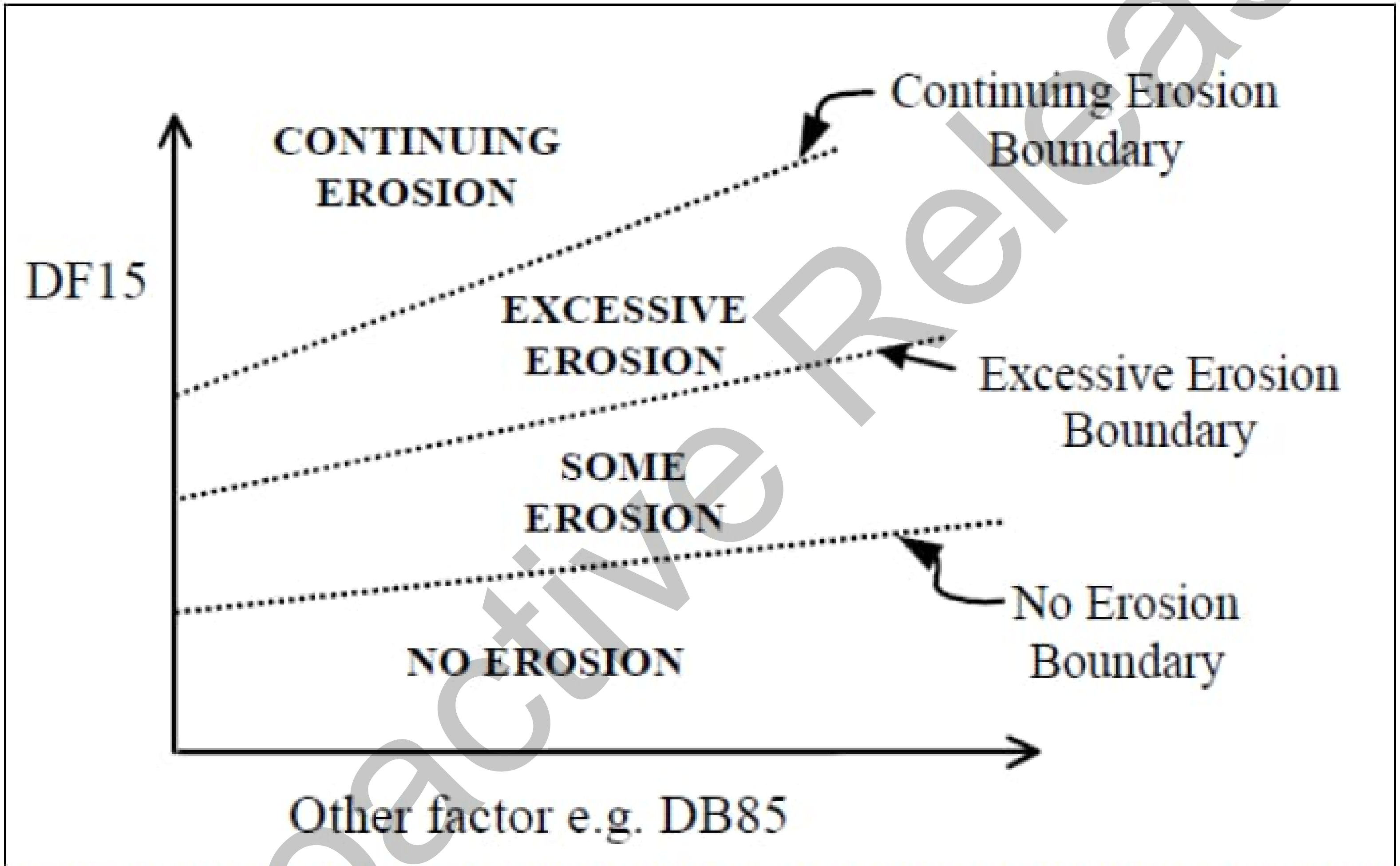


Figure 13 – Conceptual erosion boundaries of filter test behaviour (Foster & Fell, 2001)

Erosion Mechanisms

Initiation and progression of internal erosion may occur by:

- Concentrated leak.
- Backward erosion.
- Suffusion.
- Contact erosion.

The nature of the soil in the dam or foundation determines its mechanism of internal erosion:

- Non plastic soils such as silts, sands, silty sands, and silt, sand, gravel mixtures are subject to backward erosion, contact erosion or suffusion depending on their particle size distribution.
- Plastic soils, such as clays, clayey sands, and clayey sandy gravels are subject to concentrated leak erosion and contact erosion. Backward erosion and suffusion cannot occur in these soils under the gradients normally experienced in dams and their foundations but may occur if local gradients are very high.

Appendix D PFM Tables

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	**Loading Condition**	**Workshop Comments**
1	Inflows greater than spillway outflow capacity, leading to dam overtopping at low spots along left and right embankments.	Flood	**CREDIBLE – HIGHLIGHTED** **Likelihood: Category 1 Very High** **Factors**: Positive GW has a good forecasting system – tied to meteorological system Telemetry water level sensor at culvert Grass embankment has overtopping resistance Relatively short duration of overtopping (1-2 hours) Limited depth of overtopping Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events There are known low points along the left and right embankments. The LiDAR data for 2014 shows that there may also be lower points than indicated during the WSP Opus 2018 survey for the right embankment We know that overtopping occurs for the 1:100 year flood Geometry of embankment is likely to have steeper slope and narrower crest (than design) Uneven surface on the crest likely to concentrate flow Embankment materials are unlikely to be cohesive (i.e. more susceptible to erosion) Blockages (fences) could reduce capacity (contributing factor) Observed large debris Downstream fences reduce outlet capacity and may collect debris **KPIs**: Monitor water level sensor for rise Discharge through spillway Debris within reservoir and culvert Telemetry of flood detention level

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	**Loading Condition**	**Workshop Comments**
			Information gaps: Actual geometry, construction and composition of the embankment There is no inflow data The consequence of dam break assessment Actual depth of overtopping Effect of blockage on floods less (more frequent) than 1:100
2	Blockage of culvert inlet, inlet trashrack or outlet reduces discharge capacity, leading to dam overtopping at low spots along left and right embankments.	Flood	**CREDIBLE – HIGHLIGHTED** **Likelihood: Category 1 Very High** **Factors**: Positive GW has a good forecasting system – tied to meteorological system Telemetry water level sensor at culvert Grass embankment has overtopping resistance Relatively short duration of overtopping (1-2 hours) Limited depth of overtopping Trash rack is widely spaced and well designed so large debris is unlikely to block flow through the culvert Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events There are known low points along the left and right embankments. The LiDAR data for 2014 shows that there may also be lower points than indicated during the WSP Opus 2018 survey for the right embankment We know that overtopping occurs for the 1:100 year flood Geometry of embankment is likely to have steeper slope and narrower crest (than design) Uneven surface on the crest likely to concentrate flow Embankment materials are unlikely to be cohesive (i.e. more susceptible to erosion) Blockages (fences) could reduce capacity (contributing factor) Observed large debris Downstream fences reduce outlet capacity and may collect debris

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	**Loading Condition**	**Workshop Comments**
			KPIs: Telemetry of flood detention level Monitor water level sensor for rise Discharge through spillway Debris within reservoir and culvert **Information gaps**: Actual geometry, construction and composition of the embankment There is no inflow data The consequence of dam break assessment Actual depth of overtopping Effect of blockage on floods less than 1:100 (more frequent)
3	Internal erosion through embankment during a flood, leading to increased seepage, retrograde progression of erosion towards reservoir, gross enlargement or formation of sinkholes and breach of the left or right embankment dams.	Flood	**CREDIBLE – NOT HIGHLIGHTED** **Likelihood: Category 2 Moderate based on lack of embankment filter** **Factors**: Positive Relatively short duration of floods (~2-6 hours) No history of rodent activity observed Rare ponding events for erosion to continue & progress Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events Lack of QA construction records Relatively short path Long grass obstructs observation of defects in embankments Lack of monitoring during event or identified seepage observation points There is no designed filter The embankment is long – greater opportunity for flaw to exist

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	Loading Condition	Workshop Comments
			KPIs: Seepage on downstream face Depressions in the crest or slope Rodent holes Telemetry of flood detention level **Information gaps**: Lack of QA construction records
4	Internal erosion through the foundation during a flood, leading to increased seepage, retrograde progression of erosion towards reservoir, gross enlargement or formation of sinkholes on embankment dams and breach.	Flood	**CREDIBLE – NOT HIGHLIGHTED** **Likelihood: Category 2 Moderate** **Factors**: (similar comments from PFM 3 apply) Positive Seepage cutoff trench (left embankment) Relatively long seepage path (right embankment) Regional stop banks have performed well under flood conditions with no signs of erosion No deep rooted vegetation Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events No seepage cutoff trench (right embankment) Upstream wetland area **KPIs**: Seepage or sand boil along or beyond downstream toe, downstream side of Harrison St Potholes/depressions in road or embankment Telemetry of flood detention level

<table>
<tr><th rowspan="2">PFM ID</th><th colspan="3">Donalds Creek Detention Dam Draft Potential Failure Modes</th></tr>
<tr><th>Description</th><th>Loading Condition</th><th>Workshop Comments</th></tr>
<tr><td></td><td></td><td></td><td>Information gaps:
Was seepage cutoff trench constructed as designed
Foundation geology</td></tr>
<tr><td>5</td><td>Internal erosion along culvert due to concentrated leakage along its interface with the embankment, leading to increase leakage, gross enlargement and breach.</td><td>Flood</td><td>CREDIBLE – HIGHLIGHTED
Likelihood: Category 1 High

Factors:
Positive
Relatively long seepage path from upstream to downstream (under road)

Adverse
There is no EAP, DSAP, DSMS – Lack of intervention plans
Intervention is unlikely due to access being limited during flood events
Very difficult to compact around seepage cutoff walls and vertical wall
Upstream to downstream connection along culvert
No filter along culvert
Downstream planters on either side of the culvert on the road
New retaining walls are offset from original culvert – this shortens the path
Roadway embankment is typically constructed to a lesser standard

KPIs:
Downstream Seepage through downstream wingwall joints or at end of wingwalls
Deposition of material
Condition of the downstream wingwalls
Depressions along the top and adjacent to the wall, in the road (aligned with culvert)
Telemetry of flood detention level

Information gaps:
Drawings of the original culvert</td></tr>
</table>

<table>
<tr><th rowspan="2">PFM ID</th><th colspan="3">Donalds Creek Detention Dam Draft Potential Failure Modes</th></tr>
<tr><th>Description</th><th>Loading Condition</th><th>Workshop Comments</th></tr>
<tr><td>6</td><td>Spillway discharges erode downstream toe of left embankment, causing slope instability of downstream face and significantly increasing outflows as erosion progresses.</td><td>Flood</td><td>CREDIBLE – HIGHLIGHTED
Likelihood: Category 1 Very High

Factors:
<u>Positive</u>
Grass provides resistance to erosion
Spillway is only engaged for floods greater than the 1:50 event
Overland flows have not historically caused gullying or erosion

<u>Adverse</u>
There is no EAP, DSAP, DSMS – Lack of intervention plans
Intervention is unlikely due to access being limited during flood events
Spillway and overland Flow appears to collect along the downstream toe of the left embankment
Spillway crest is an embankment which is likely to erode while operating, increasing discharge flows
Downstream toe is erodible
Spillway Flow path has a steep grade (~3%)
Overland flows occur for less than 1:50 events
PFM could initiate at a lower flood if there is blockage at the culvert

KPIs:
Spillway discharge
Erosion at spillway crest
Erosion of left embankment, downstream toe
Gullying of discharge flows along toe
Bare patches or exposed soil at downstream toe and slope
Embankment slumping
Telemetry of flood detention level

Information gaps:
Flow velocities and depths
How much erosion can occur per event</td></tr>
</table>

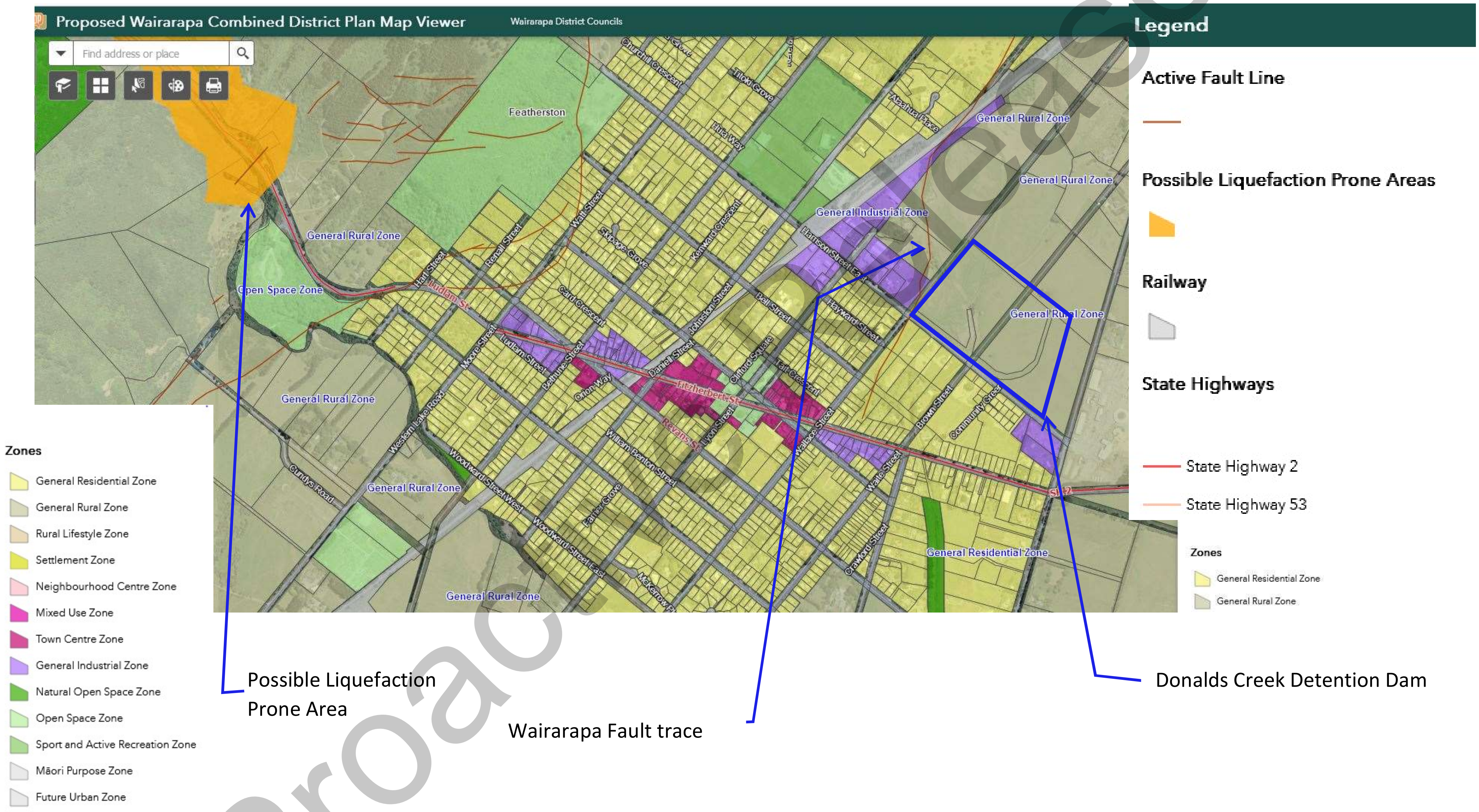
PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	**Loading Condition**	**Workshop Comments**
			(understand consequences between PFM 1 – overtopping – and this PFM)
7	Culvert outlet is undermined due to scour at the energy dissipator. Culvert fails, leading to a collapse or cracking of the embankment. Breach occurs due to internal erosion along cracks or overtopping.	Flood	**CREDIBLE – NOT HIGHLIGHTED** **Likelihood: Category 2 Low** **Factors**: Positive Timber control weir will help to maintain channel level No scour observed after flood events (2018, 2021) Culvert is long – significant undermining required Culvert is downstream of embankment Upstream and downstream concrete cutoff Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events High discharge Likely no hydraulic design of riprap **KPIs**: Scour on the downstream end of the outlet Abnormal flow patterns (eddying, etc) Roadway cracking or slumping Telemetry of flood detention level **Information gaps**: Has riprap been installed (as designed) No hydraulic design of culvert
8	Damage of culvert due to seismic event blocks outlet. Minor flood occurs before	Seismic – Flood	**CREDIBLE – NOT HIGHLIGHTED**

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	**Loading Condition**	**Workshop Comments**
	the culvert can be repaired, leading to dam overtopping at low spots along left and right embankments or internal erosion along culvert/embankment interface.		**Likelihood: Category 2 Low given that the exposure time (between seismic event and repair) will be long** **Factors**: Positive Low amount of fill above culvert Reinforced concrete Unlikely to fully block Cast in place Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events Culvert is likely to be damaged during a 0.5g PGA seismic event, looks like cast in place, is reinforced, no joints Wing walls likely to collapse Invert of culvert difficult to observe during flood Health and safety issues to inspect Resources likely to be taxed due to regional damage **KPIs**: Cracking, spalling, deformation of culvert and wingwalls Cracking in roadway Telemetry of flood detention level **Information gaps**: Structural performance of culvert under seismic load Comments: PGA of 0.5g Concern is how safe is it for the culvert to operate in a post-earthquake condition Regional damage to infrastructure

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	Loading Condition	Workshop Comments
			Community engagement and awareness; camera; capture of performance
9	Seismic event causes liquefaction of foundation, leading to slope failure of the embankment dams and/or damage to the culvert outlet. Moderate flood occurs before the dam can be repaired, leading to overtopping at low spots along left and right embankments.	Seismic - Flood	**NOT CREDIBLE, RULED OUT** **Likelihood: Remote** **Factors**: Positive Liquefaction might be localised (extensive liquefaction not likely based on general Wairarapa liquefaction risk map; 0.3 to 0.6g) Embankment is likely to be dry during earthquake Repair time will be relatively fast Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans Intervention is unlikely due to access being limited during flood events **KPIs**: Telemetry of flood detention level **Information gaps**: No foundation information
10	Seismic event causes instability and failure of upstream or downstream slope of dam, effectively reducing the embankment thickness and potentially the dam crest level. Moderate flood occurs before the embankment dam can be repaired, leading to overtopping or internal erosion failure at the location of the slope failure.	Seismic - Flood	**CREDIBLE – NOT HIGHLIGHTED** **Likelihood: Category 2 Low/Moderate – Donalds Creek is likely lower priority for the region and the exposure time could be long** **Factors**: Positive After a seismic event, repairs are easier to make and would be faster GW has a post-earthquake inspection guide Adverse There is no EAP, DSAP, DSMS – Lack of intervention plans

PFM ID	Donalds Creek Detention Dam Draft Potential Failure Modes		
	Description	**Loading Condition**	**Workshop Comments**
			Intervention is unlikely due to access being limited during flood events Crest likely to have deformation Steep slopes – likely to have some deformation If significant crest loss occurs subsequent dam failure flood would be less severe **KPIs**: Sand boils Slumps, depressions Cracking Telemetry of flood detention level **Information gaps**: Comments: Relatively low strength material with high loads Won't need multiple floods to fail the embankment Needs to be a flood sufficient to pool Not an extreme earthquake (1:150)

Appendix E Workshop Notes


Proposed Wairarapa Combined District Plan Map Viewer
Wairarapa District Councils
Find address or place
Legend
Active Fault Line
Possible Liquefaction Prone Areas
Railway
State Highways
State Highway 2
State Highway 53
Zones
General Residential Zone
General Rural Zone
Rural Lifestyle Zone
Settlement Zone
Neighbourhood Centre Zone
Mixed Use Zone
Town Centre Zone
General Industrial Zone
Natural Open Space Zone
Open Space Zone
Sport and Active Recreation Zone
Māori Purpose Zone
Future Urban Zone
Featherston
General Rural Zone
Open Space Zone
General Industrial Zone
General Residential Zone
Fitzherbert St
SH 2
Possible Liquefaction Prone Area
Wairarapa Fault trace
Donalds Creek Detention Dam


98824
F8½
Martinborough
161 – 162
13-2-43
98823
F8½
Martinborough
161 – 162
13-2-43
250/5

Legend ×

Regional Exposure Assessment 1% AEP RCP8.5 2101-2120

Regional_Exposure_Assessment_1__AEP_RCP8_5_2101_2120_WTL1

Regional Exposure Assessment 1% AEP RCP8.5 2101-2120

tile_4_2.flt

Value

- 0.01 - 0.5
- 0.5 - 2
- >2

tile_3_5.flt

Value

- 0.01 - 0.5
- 0.5 - 2
- >2

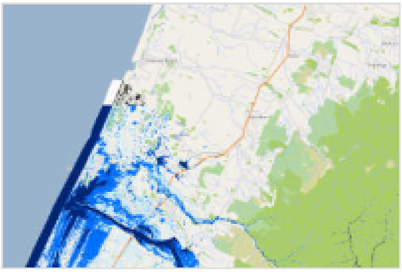
tile_3_4.flt

ment 1% AEP RCP8.5 2101-2120

Overview

Open in Map Viewer

Open in ArcGIS D



This flood hazard layer comes from the rain-on-grid modelling undertaken within the Regional Exposure Assessment. This extent is relevent to the 1% AEP with RCP 8.5 climate change predictions to 2101 - 2120.

Web Map by Kirsty.Duff_GWRC

Item created: 25 Jul 2022
Item updated: 25 Jul 2022
View count: 731

Description

An in-depth description of the item is not available.

Layers

Regional Exposure Assessment 1% AEP RCP8.5 2101-2120
Group layer

Regional_Exposure_Assessment_1__AEP_RCP8_5_2101_2120_WTL1
Tile layer

New Zealand Imagery (ArcGISOnline)
Tile layer

Tables

Basemap

newzealand
Basemap

newzealand

Details

Size: 1.565 KB
ID: 58181cc76856479aacb

Share

Owner

Kirsty.Duff_GWRC

Tags

Flood, flood hazard, Regional Exposure Assessment

Tile layer

Terms of Use

No special restrictions or limitations on using the item's content have been provided.

Comments (0)

Sign in to add a comment.

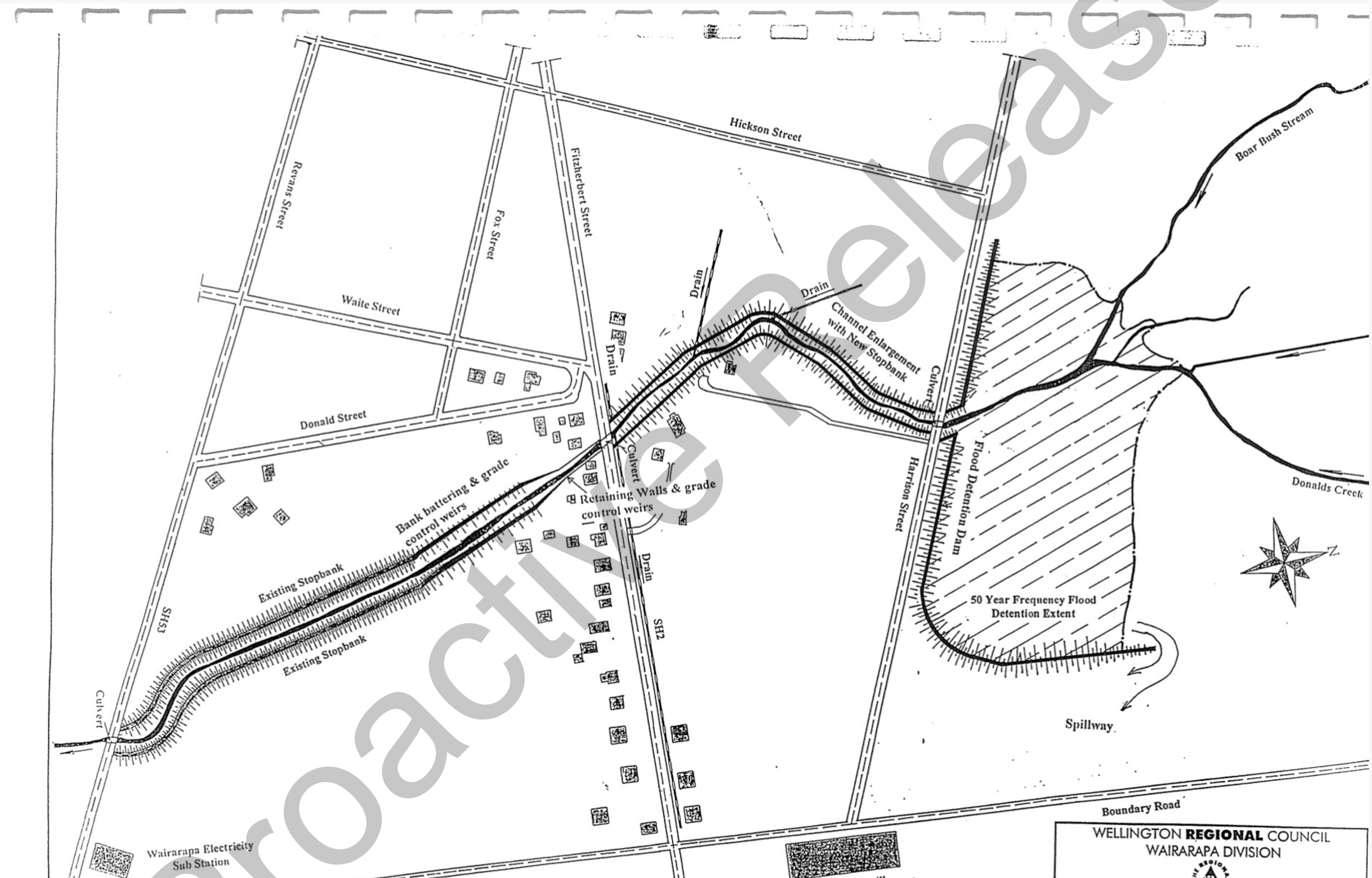
Credits (Attribution)

No acknowledgements.

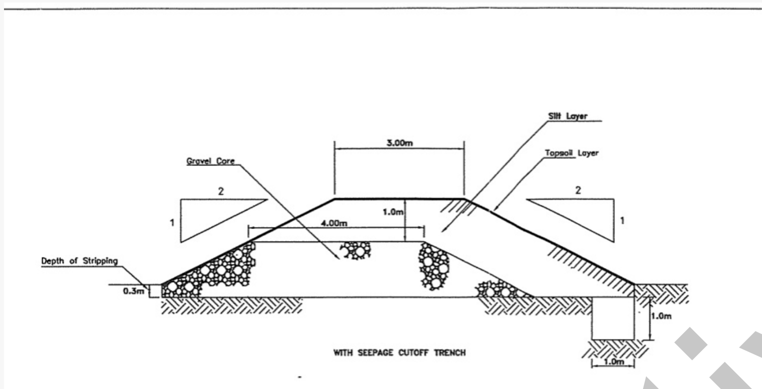
Help

Web maps

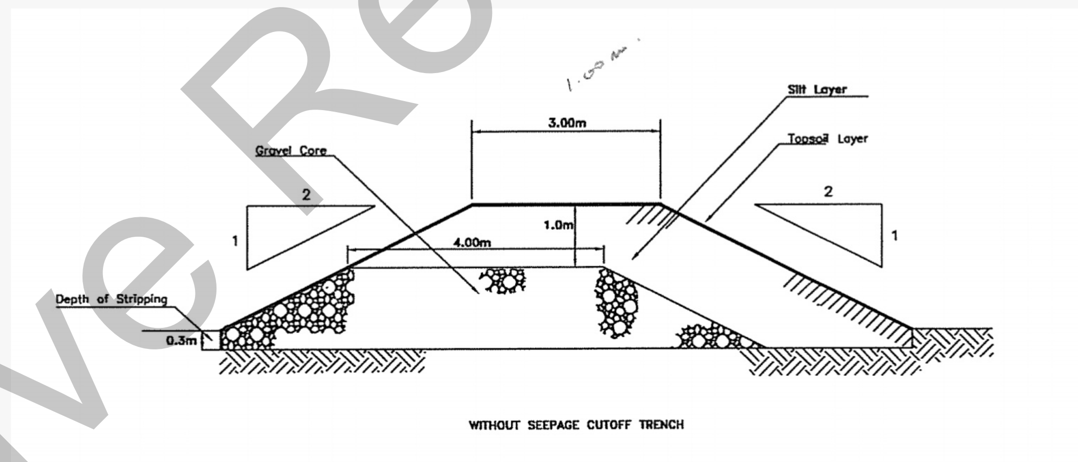
Web maps (developer)

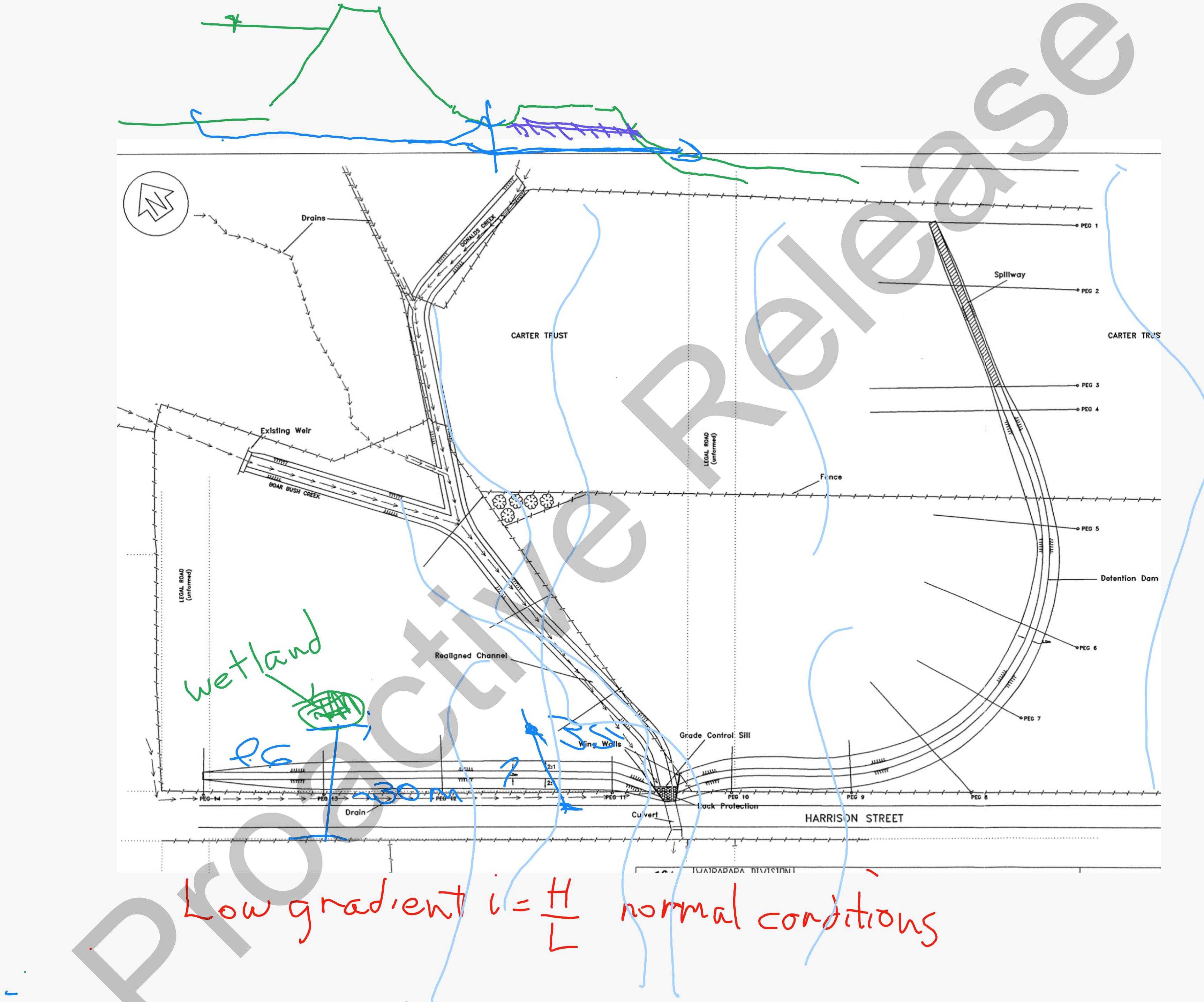


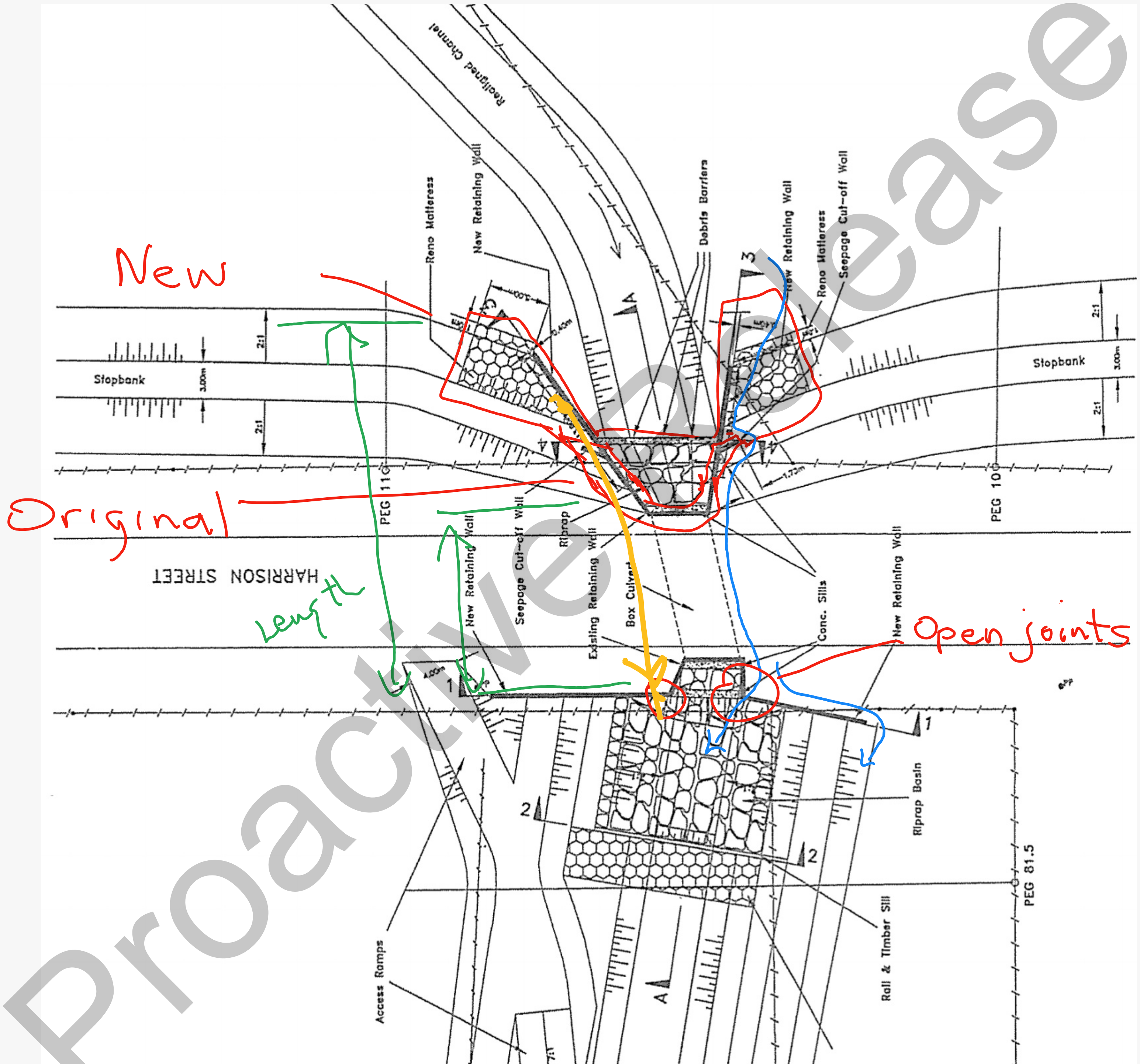
Hickson Street
Revans Street
Fox Street
Fitzherbert Street
Waite Street
Donald Street
Drain
Channel Enlargement with New Stopbank
Culvert
Boar Bush Stream
Donalds Creek
Flood Detention Dam
Harrison Street
Bank battering & grade control weirs
Retaining Walls & grade control weirs
Existing Stopbank
Existing Stopbank
SH53
SH2
50 Year Frequency Flood Detention Extent
Spillway
Boundary Road
Wairarapa Electricity Sub Station
WELLINGTON REGIONAL COUNCIL
WAIRARAPA DIVISION



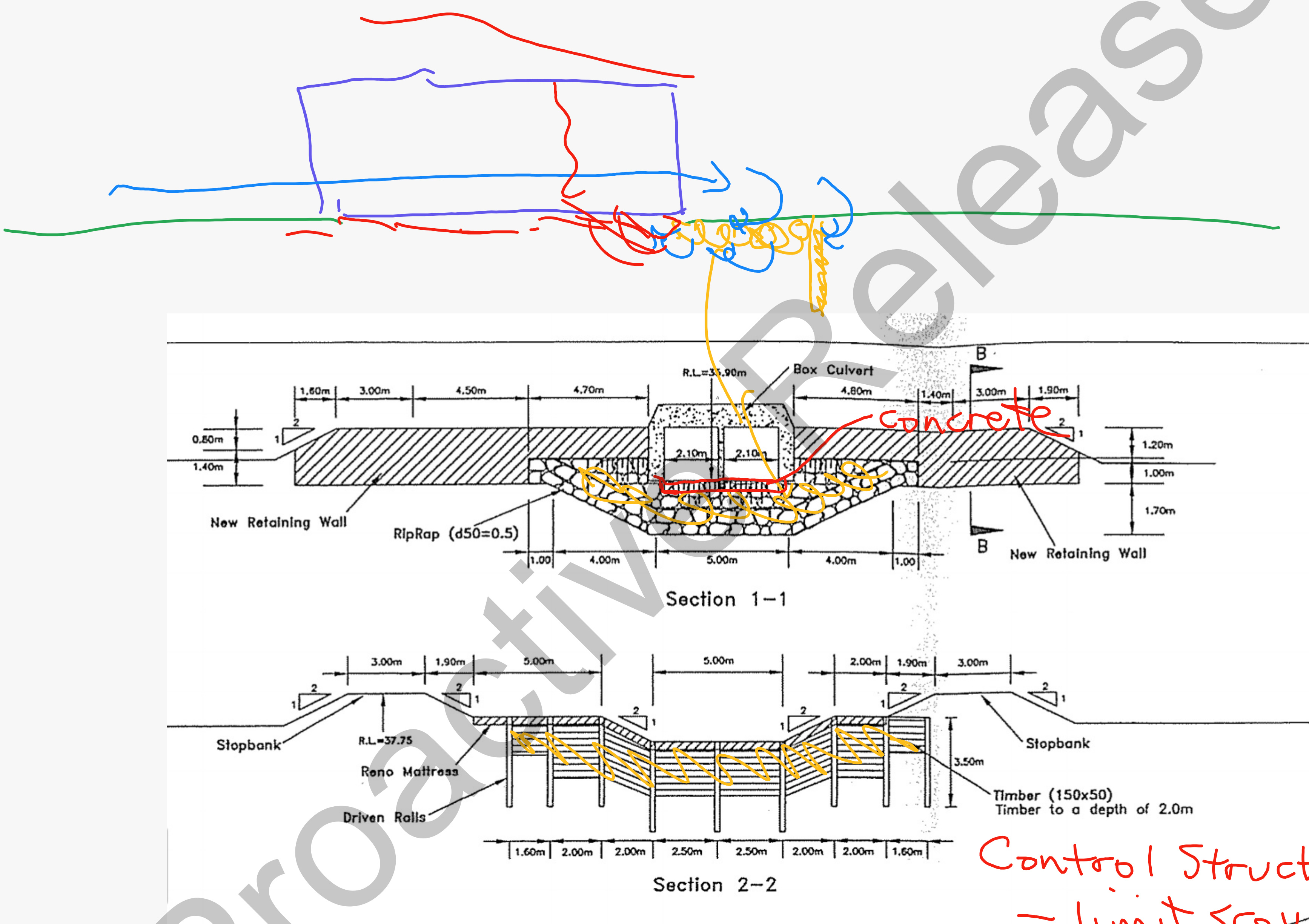
NS OF DETENTION DAM
1:100




Drains
DONALDS CREEK
CARTER TRUST
Existing Weir
BOAR BUSH CREEK
LEGAL ROAD (unformed)
Spillway
PEG 1
PEG 2
PEG 3
PEG 4
Fence
PEG 5
Detention Dam
PEG 6
PEG 7
Realigned Channel
Wing Walls
Grade Control Sill
2:1
PEG 14
PEG 13
PEG 12
PEG 11
PEG 10
PEG 9
PEG 8
Rock Protection
Drain
Culvert
HARRISON STREET
WAIRARAPA DIVISION
wetland
~30m
35
Low gradient i = H/L normal conditions

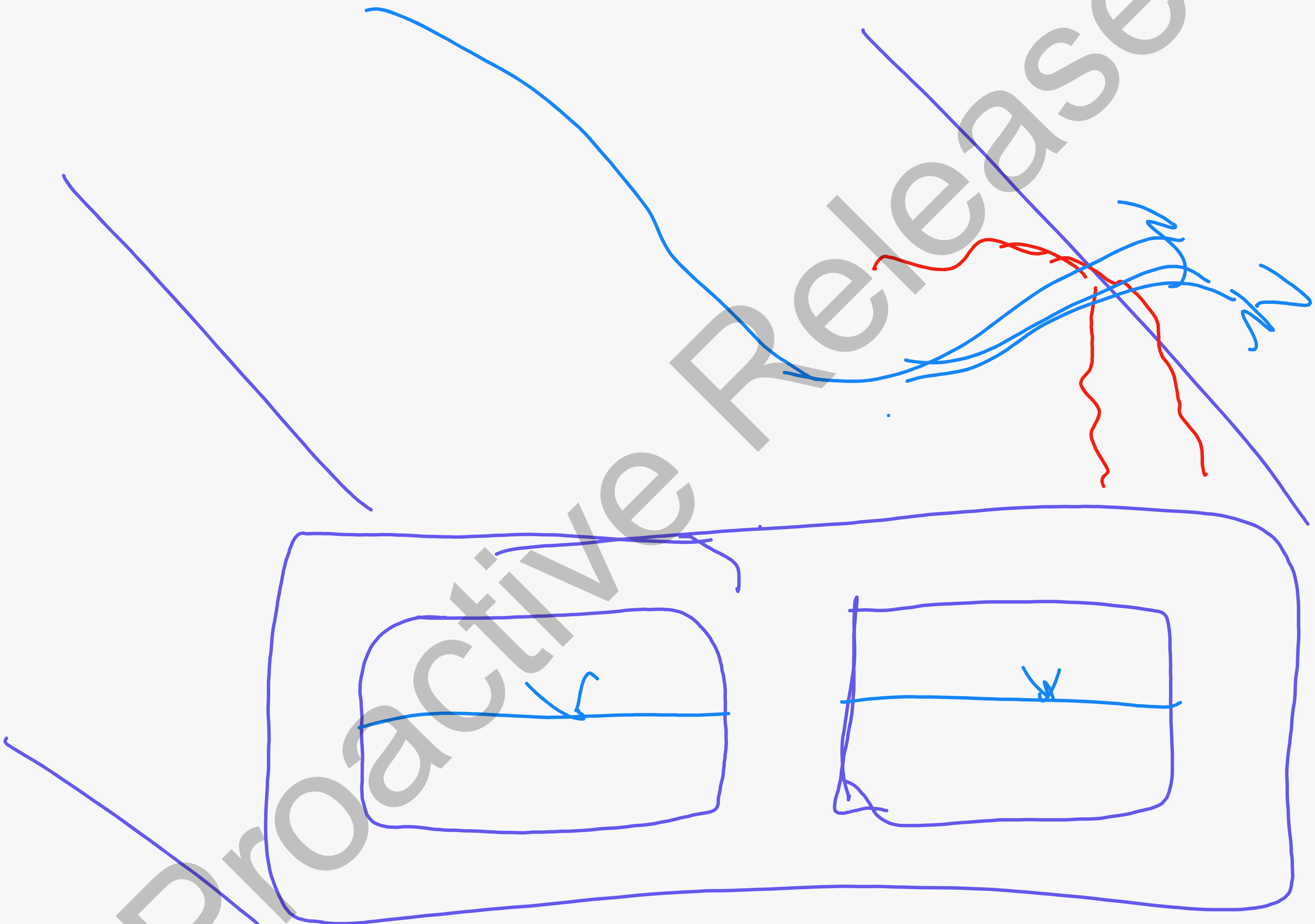


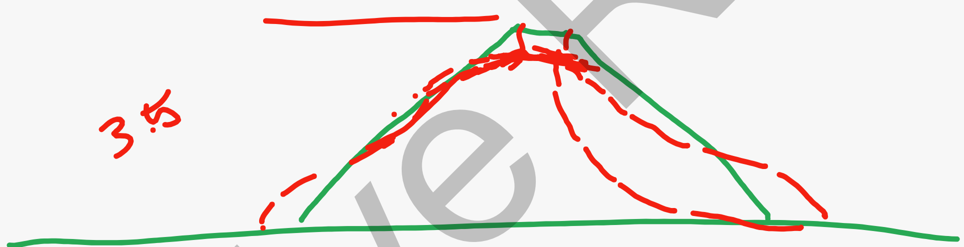
Realigned Channel
Reno Mattress
New Retaining Wall
Debris Barriers
New Retaining Wall
Reno Mattress
Seepage Cut-off Wall
Stopbank
3.00m
2:1
Stopbank
3.00m
2:1
4.00m
1.73m
PEG 110
PEG 100
HARRISON STREET
New Retaining Wall
Seepage Cut-off Wall
Riprap
Existing Retaining Wall
Box Culvert
Conc. Sills
New Retaining Wall
Riprap Basin
Rail & Timber Sill
PEG 81.5
Access Ramps
A
1
2
3
4
New
Original
Length
Open joints



Control Structure
– limit scour

Figure 3333. Map of major flow paths (red) during the Donald's Creek flood event 2/12/2018. The areas shaded blue represent the water contained and attenuated in the Donald's Creek Dam Facility and the minor overflow adjacent.




3.5

Report	17.494
Date	22 November 2017
File	CCAB-10-447
Committee	Environment Committee
Author	Tracy Berghan, Principal Planning Advisor

Floodplain management planning – principles update

1. Purpose

To update the Committee on the floodplain management planning principles that were approved by the Council in 2015 (Report 15.99).

2. Background

At a workshop on the 28 October 2014, the Strategy and Policy Committee discussed the report *Floodplain Management Planning – Principles* which is included as **Attachment 1** to this report. The workshop covered:

- The four principles that underlie GWRCs approach to floodplain management in the Region;
- The rationale behind the introduction and application of these principles; and
- Examples of relevant national and international research, guidance and policy directives that support their application.

In 2015, Council agreed that the four principles discussed at the workshop and detailed in section 2.1 below were representative of Greater Wellington Regional Council's current practice in its delivery of floodplain management planning in the region and approved the continued application of these principles in future floodplain management planning in the region.

3. Principles

Principle 1: Avoid building in areas at high risk of flood hazard

Avoiding the construction of residential and other buildings vulnerable to flooding in undeveloped urban and rural areas (i.e. a 'greenfields' situation) exposed to a high level of flood hazard is the most effective way of managing flood risk in these locations in the long-term. In areas subject to a lesser degree of flood hazard, activities and development should be appropriate to the circumstances and should not exacerbate flood risk.

Principle 2: Only consider new flood protection infrastructure where existing development is at risk

Where existing urban or rural land use and/or development (e.g. dwellings, irrigation infrastructure, dairy sheds) is subject to an unacceptable degree of flood risk the construction of new structural protection measures (e.g. stopbanks, elevating existing buildings) will be considered.[1]

Principle 3: Establish standards of flood protection relative to the degree of risk

In developing and implementing structural and non-structural measures within areas subject to flood risk, the following standards are to be applied by GWRC and, where relevant, city/district councils:

- Protection of all habitable buildings and urban areas
  - A minimum 1 in 100 year flood standard to floor levels for habitable buildings and new development within existing urban areas, along with provision of safe access.
- Stopbank protection
  - Where required to protect existing urban areas and associated land use, stopbanks will be constructed to achieve a minimum 1 in 100 year flood standard.
  - Where required to protect rural areas and associated land use, stopbanks are generally constructed up to a 1 in 20 year flood standard to alleviate frequent or nuisance flood events.

Principle 4: Plan for climate change in assessing the degree of flood hazard risk and in determining an appropriate response

GWRC will use the following allowances for climate change predicted to occur over the next 100 years in the design criteria for its flood hazard investigations.

The current allowances are:

- Increase in rainfall intensity 20%
- Sea Level Rise 0.8m

4. Comment

The floodplain management planning approach adopted by GWRC continues to represent an effective response to managing flood risk, and is premised on the core principles outlined above and also reflects the following:

- The evolving nature of GWRC's practice in preparing and implementing FMPs throughout the region and the corresponding lessons learnt; and

[1] The presence of property or infrastructure in an area subject to a 1 in 100 year flooding does not necessary justify intervention. Such intervention is only appropriate where there is an "unacceptable level of risk."

- The political and economic realities associated with any prospective change to GWRC's current approach to managing flood hazard risk (e.g. managed retreat vs building or upgrading flood protection structures).

The principles contained in this report reflect current practice and have been developed over time as part of the outcomes of the FMPs completed to date. These principles are not the final word on these issues, but they continue to represent a baseline that would not be compromised in an individual FMP without re-examining the principles as a whole. How the principles are applied in detail will vary within each FMP.

The principles also reinforce and complement the objectives and policies in the Regional Policy Statement (RPS) for the Wellington Region and GWRC's operational floodplain management guidelines.

5. Communication

The principles have been discussed as part of the FMP processes undertaken by GWRC and are referenced in various discussions between GWRC and TA council officers. Principles 1 and 3 are communicated through the RPS. RPS Policy 29 is a directive policy to avoid inappropriate subdivision development in areas at high risk from natural hazards and Policy 51 is a consideration policy which requires the minimisation of the risks and consequences of natural hazards, including the need to locate habitable floor areas and access routes above the 1 in 100 year flood level.

6. Consideration of Climate Change

The matter/s addressed in this report have been considered by officers in accordance with the process set out in the GWRC Climate Change Consideration Guide.

6.1 Mitigation assessment

Mitigation assessments are concerned with the effect of the matter on the climate (i.e. the greenhouse gas emissions generated or removed from the atmosphere as a consequence of the matter) and the actions taken to reduce, neutralise or enhance that effect.

The effect of the proposed principles on the climate are not considered significant, and will be addressed through GWRCs procurement process which is undergoing review in 2017 and will encourage suppliers and contractors to minimise emissions.

6.2 Adaptation assessment

Adaptation assessments relate to the impacts of climate change (e.g. sea level rise or an increase in extreme weather events), and the actions taken to address or avoid those impacts.

GWRC plans for climate change in assessing the degree of future flood hazard and in determining an appropriate response. There are only specific, limited situations in which climate change is not relevant (for example, planning for present-day emergency management).

In terms of the wider, long term work of the Department which these principles support, assessing flood hazard and determining appropriate structural and/or non-structural responses in areas subject to flood risk, GWRC applies the following allowances for climate change predicted to occur over the next 100 years in the design criteria for flood hazard investigations which is the same as the principles above:

- Increases in rainfall intensity – 20%
- Sea level rise – 0.8m.

7. The decision-making process and significance

Officers recognise that the matters referenced in this report may have a high degree of importance to affected or interested parties.

The matter requiring decision in this report has been considered by officers against the requirements of Part 6 of the Local Government Act 2002 (the Act). Part 6 sets out the obligations of local authorities in relation to the making of decisions.

7.1 Significance of the decision

Part 6 requires Greater Wellington Regional Council to consider the significance of the decision. The term 'significance' has a statutory definition set out in the Act.

Officers have considered the significance of the matter, taking the Council's significance and engagement policy and decision-making guidelines into account. Officers recommend that the matter be considered to have low significance.

The decision is of low significance as the Committee, by approving this paper, is confirming the Greater Wellington Regional Council's current practice for the delivery of its flood protection responsibilities.

Officers do not consider that a formal record outlining consideration of the decision-making process is required in this instance.

7.2 Engagement

In accordance with the significance and engagement policy, no engagement on the matters for decision is required

8. Recommendations

That the Committee:

1. ***Receives*** *the report.*
2. ***Notes*** *the contents of the report.*

3. ***Endorses** the four principles that underlie GWRCs approach to floodplain management in the Region.*

Report prepared by:	Report approved by:	Report Approved by:
Tracy Berghan Principal Planner Advisor	Graeme Campbell Manager Flood Protection	Wayne O'Donnell Group Manager, Catchment Management

Attachment 1: Floodplain management planning – Principles (Background Paper)

Workshop Notes

Wednesday, 15 May 2024 8:30 am

Presentation:

LiDAR data is from 2014 so downstream development is not included

When conditions are wet - seepage comes through drain

Downstream toe of right embankment - gradual swale

There is December 2023 LiDAR data but the level of the grass could have affected it

Slope of spillway flow path is 1:35 (~3%) which is very steep for a discharge channel

Capacity is greater than what was estimated in the design

Reno mattress present, downstream of timber?

Blockage at downstream fences could reduce the capacity of the outlet

Downstream wire is better than fences - this will just break under high floods

During flooding - barriers just break away/disconnect

WSP study:

- Spillway gets activated at 38.5
- 1:50 event can pass without overtopping
- 1:100 - conclusion is that you can have blockage of the culvert and still pass the flows (with overtopping occurring). However, overtopping occurring could result in failure

T&T:

- 100 year event - overtopping for about 1.5 to 2 hours

Normal flood detention dam does not have a culvert with a huge capacity
Donalds Creek culvert has significant capacity for the type of detention embankment

Flow along downstream left toe widens - which is good - less erosion

Dam break model could be useful in determining the flood wave which could be higher than whatever the overtopping depth is

There is significant over land flow that could affect the flow during a flood

- [ ] Need to look at two scenarios for events when conducting hydrologic/hydraulic analyses (dam break?)
    - Localized event
    - Area effects

    Typically start large scale then move to smaller scale

Need to consider the effects of the whole Donalds Creek Flood Protection System

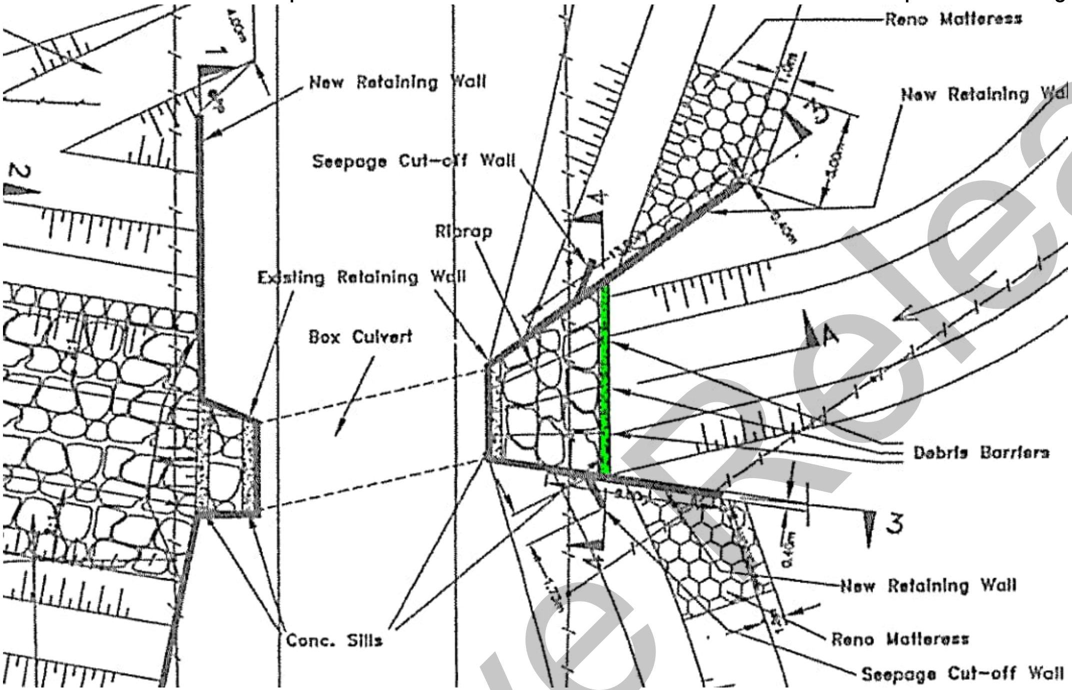
Slope estimated:

Areas in right embankment estimated at 1.5H:1V

From LiDAR, estimated 2H:1V

How is the information recorded?
- Gets saved in data system
  - What is the response?
- Telemetry gets saved in a separate system
- Only two inspections have been conducted so far

Debris barrier shown in plan and are the little blocks that extend from the upstream wingwalls:



Annual inspections - complete FPS
Monthly inspections - detention dam

GW has a policy for the design of their stop banks
- 1:100 flow event - urban; 1:20 - rural
- From Flood Plain Management Principles

- There is a change with the downstream development
  - Is this area considered rural or urban?
  - Stop banks were originally designed for the 1:20 (rural)
- Stop banks are granular material
- Therefore needs to be designed so that spillway does not discharge during the 1:100 flow event
- Incremental effect of the dam failing is unknown

Culvert has self-cleaning capacity

Biggest problem is the spillway - undersized


1943 imagery

Recommendations

Wednesday, 15 May 2024 10:36 am

Assess the effect of the flood protection system:

Including stop banks, etc.

Need to record that there is a flooding risk in the "ponding area"

Post-event - check for signs of deposition and the type of material deposited

Parking Lot

Wednesday, 15 May 2024 10:38 am

- Is this area considered urban or rural?

Information gaps

Wednesday, 15 May 2024 10:44 am

- Stop bank capacity relative to the Harrison St culvert capacity
- Incremental effect of the dam failing

Challenges

Wednesday, 15 May 2024 3:32 pm

See slides for regulation information

Steps were taken to see if dam was Classifiable, it was classified as a High PIC dam

Consequences will occur even during normal operation (non-failure). However, you only have to account for the incremental effect of the presence of the dam.

Problem with the non classifiable dams is that under the regulations, you do not have to do anything.

Positives:
- GWRC is open about the level of protection provided
- The level of protection at time of construction was higher than required by their policy (for a rural area)
- Development occurred AFTER construction
- Overland flows are significant so incremental flows may not be a lot

If GW adheres to flood plain classification of the area now being an urban area
    Under the 1:100 flood (adhering to flood protection principles), overland flows and outflanking of the dam

Not protecting downstream population at flows below spillway elevation

Typically localise failure to minimise consequences

Housing along SH 2 have been constructed in ~2016 and have been flooded twice

South Wairarapa is the owner of the culvert
    They have some responsibility

GW will progress as if it were a Classifiable dam due to the consequences

An additional challenge
    Community
        There are plans in place to move forward with this

TO	Greater Wellington Regional Council (GWRC)
COPIED TO	Nigel Corry, Chief Executive, GWRC Lian Butcher, General Manager Environment Group, GWRC Shaun Andrewartha, Manager Environmental Regulation, GWRC Jack Mace, Director, Delivery, GWRC Jacky Cox, Manager Logistics & Resourcing, GWRC Rebecca Polvere, Recognised Engineer
FROM	George Bowman, Team Leader Flood Operations Planning, GWRC
DATE	13/4/2024

FOR YOUR ACTION

Urgent: Notification to Regional Authority of change in status of Dangerous Dam

To Whom it Concerns at Greater Wellington Regional Council

I am writing on behalf of Greater Wellington Regional Council (GWRC) to formally notify you that following further investigations, we have identified that the Donald's Creek Detention Dam in Featherston, Wairarapa, as no longer meeting the criteria for a "Dangerous Dam" as defined under *Subpart 7 – Safety of Dams* of the Building Act (2004).

A recent press release from the Ministry of Business, Innovation, and Employment (MBIE) dated 28 March 2024, indicated changes in the definition of a 'classifiable dam'. According to the release, the Building (Dam Safety) Regulations 2022 [Regulations] will no longer apply to dams that are less than 4 metres in height, regardless of their storage volume. Given that Donald's Creek Detention Dam falls below this height threshold, this dam is no longer be classified under the Regulations. The Regulations came into effect 13 May 2024.

Further, Section 133A of the Building Act (2004) [Act], states:

"133A Dams to which subpart 7 provisions apply

(1) Sections 133B and 157 to 159 apply to all dams.

(2) The other provisions in this subpart apply only to classifiable and referable dams."

Section 133B relates to the Measurement of dams and applies to all dams.

Sections 157-159 relates to measures to avoid immediate danger and applies to all dams.

It is important to reiterate that there is currently no immediate danger to the safety of persons, property, or the environment associated with Donald's Creek Detention Dam.

Further,

Section 153 *Meaning of a dangerous dam* states:

A dam is dangerous for the purposes of this Act if the dam—

(a) is a high potential impact dam or a medium potential impact dam; and

(b) is likely to fail—

(i) in the ordinary course of events; or

(ii) in a moderate earthquake (as defined in the regulations); or

(iii) in a moderate flood (as defined in the regulations).

Section 153A *Meaning of earthquake-prone dam and flood-prone dam* states:

(1) A dam is an earthquake-prone dam for the purposes of this Act if the dam—

(a) is a high potential impact dam or a medium potential impact dam; and

(b) is likely to fail in an earthquake threshold event (as defined in the regulations).

(2) A dam is a flood-prone dam for the purposes of this Act if the dam—

(a) is a high potential impact dam or a medium potential impact dam; and

(b) is likely to fail in a flood threshold event (as defined in the regulations).

While Donald's Creek Detention Dam has been assigned a High PIC by a Recognised Engineer, the above provisions only apply to classifiable or referable dams (as per Section 133A above). Therefore, we believe that Donald's Creek Detention Dam does not meet the definition of a dangerous dam, earthquake-prone dam, or flood-prone dam.

As responsible dam owners, we will continue to manage any safety risks associated with the dam, including but not limited to, the following key actions:

- Engaging Damwatch Engineering to undertake a Failure Modes and Effects Assessment. Site visit completed 8 May 2024, workshop due 15 May 2024, report due 30 May 2024.

- Develop a Dam Safety Management System in alignment with the NZ Dam Safety Guidelines, for dams owned and managed by GWRC. This will include establishing a dam safety policy.

- Develop and implement a Dam Safety Assurance Programme commensurate with the size and consequences of the dam. This will include an Emergency Action Plan. These will be finalised in 24/25.

- Flood hazard modelling for Donald's Creek flood protection system, including dam break consequence assessment, due 24/25.

Sincerely,

George Bowman
Team Leader Flood Operations Planning
Logistics and Resourcing, Delivery
DD: 021370128
George.Bowman@gw.govt.nz

TO	Greater Wellington Regional Council (GWRC)
COPIED TO	Nigel Corry, Chief Executive, GWRC Lian Butcher, General Manager Environment Group, GWRC Shaun Andrewartha, Manager Environmental Regulation, GWRC Jack Mace, Director, Delivery, GWRC Jacky Cox, Manager Logistics & Resourcing, GWRC Rebecca Polvere, Recognised Engineer
FROM	George Bowman, Team Leader Flood Operations Planning, GWRC
DATE	28/3/2024

FOR YOUR ACTION

Urgent: Notification of Dangerous Dam to Regional Authority

To Whom it Concerns at Greater Wellington Regional Council

I am writing on behalf of Greater Wellington Regional Council (GWRC) to formally notify you that we have identified the Donald's Creek Detention Dam in Featherston, Wairarapa, as potentially meeting the criteria for a "Dangerous Dam" as defined under Section 135B of the Building Act (2004). Based on our preliminary assessments, we have reasonable grounds to believe that the dam poses a risk under specific conditions.

It is important to clarify that there is currently no immediate danger to the safety of persons, property, or the environment associated with this dam. However, our initial assessments indicate that it could be classified as dangerous under certain flood or seismic events.

Note: a recent press release from the Ministry of Business, Innovation, and Employment (MBIE) dated today (28 March 2024), indicated changes in the definition of a 'classifiable dam'. According to the release, the Dam Safety Regulations will no longer apply to dams that are less than 4 metres in height, regardless of their storage volume. Given that Donald's Creek Detention Dam falls below this height threshold, it suggests that the dam would no longer be classified under the current Regulations, and removes the classification of 'dangerous dam'.

Given the timing of this press release and its implications for the status of Donald's Creek Detention Dam, we seek your guidance and clarification on the correct course of action. Specifically, we need to confirm whether the updated Regulations take immediate effect and if this reclassification removes the 'dangerous' status of the dam. This clarification will significantly impact our next steps in managing the dam's safety assurance processes, and timing thereof.

We are prepared to take all necessary actions required by the regional authority to ensure compliance with the law and to safeguard the community. Your prompt response and guidance on this matter would be greatly appreciated to ensure that we proceed correctly under the new regulatory landscape.

Please find attached within the email the MBIE press release for your reference. We look forward to your guidance and clarification on how to proceed under the updated Regulations.

Sincerely,

George Bowman
Team Leader Flood Operations Planning
Logistics and Resourcing, Delivery
DD: 021370128
George.Bowman@gw.govt.nz

MEMO

TO	Jack Mace, Director Delivery
COPIED TO	Jacky Cox, Manager Resources and Logistics Delivery, George Bowman Team Lead Flood Operations Planning
FROM	Rebecca Polvere CPEng, Recognised Engineer – DSAP and PIC (Reg# 257826)
DATE	25/03/2025
FILE NUMBER	DON Dam Classification.docx

FOR YOUR INFORMATION

Donald's Creek Dam Potential Impact Classification Desktop Assessment

As a Recognised Engineer (DSAP and PIC) I will be submitting the Dam Classification Certification Certificate (as per Building (Dam Safety Act 2022) based upon the detail provided in this Memo.

Dam Name	Donald's Creek Detention Dam
Name of Owner	Greater Wellington Regional Council
Chief executive of owner	Nigel Corry
Location of Dam	Located on the outskirts of Featherston, retaining flow and engulfing Donald's Creek when flows in the creek exceed the capacity of the culvert under State Hwy 2.
Date of construction	1998/99
Building Consent number or identification	Consent File Number : WAR98019101
Purpose of Dam	Built for flood mitigation for the Donald's Creek. The dam allows detention of flood flows to protect downstream people, property and the environment. The dam only impedes water during floods.
Type of dam	Earth embankment
Height of Dam	2.5 m to 3.5 m (Regional Council Design Report 1998)
Dam's stored volume	105,000 m^3 at 39 masl crest level (WSP 2018 Hydrological Analysis Phase 2)
Relevant regional authority	Greater Wellington Regional Council
Potential Impact Classification (PIC)	High

Potential Impact Classification Assessment

Based on an initial desktop assessment, Donald's Creek is assigned a Potential Impact Classification (PIC) of High. The PIC for the dam has not been previously assessed. This assessment only includes for the direct tangible community damage level based on an assumed inundation resulting from a potential dam breach.

The dam height and estimated stored volume meet the regulation definition for a classifiable dam and a PIC assessment is required.

The following documents this initial assessment to assign the PIC for Donald's Creek Dam to meet the regulations. This desktop assessment uses conservative assumptions to inform the PIC due to the limited available detail for the dam.

A detailed dam break and consequence assessment is scheduled for later this year, the results are currently programmed to be received after the regulations require the PIC to be submitted to the regional authority. This may result in a reduction in the PIC at which time the Dam Safety Assurance Programme (DSAP) can be adjusted, and the PIC resubmitted to the regional authority.

The detention dam forms part of the flood protection system on Donald's Creek which includes stopbanks along the banks of the river, downstream of the dam. The appurtenant structures have not been identified.

The direction of flow from any dam breach has been previously identified by WSP in 2018 to be constrained by the local topography (see Figure 1 attached). No further dam-break flood hazard study has been undertaken. A dam-break flood hazard study (planned for later this year) will confirm the extent of inundation based upon ground topography and provide flow depths and velocity to understand the significance of the hazard.

Based on the 2018 dam breach flow path the inundation area is assumed to be the area downstream of the dam, bounded by Hickson Street to the west and no obvious physical boundary to the east (besides the ground topography). To the south, State Highway 2 (SH2) is raised above the surrounding ground level and will likely provide containment of the flow unless there is sufficient flow depth to continue beyond SH2. SH2 is assumed to be the southern boundary where flows will likely be directed to the culvert under SH2 and re-enter Donalds Creek. To the north, it is assumed that the natural ground profiles prevent water discharging beyond or around the horseshoe shaped dam structure. Without a dam-break flood hazard assessment to confirm otherwise, this has been taken as the dam-break flood hazard area. Aerial photography following 2018 flood indicates that the assumed inundation area is a reasonable assumption for defining the impacts of a potential dam break.

Within this assumed inundation area, the direct physical community impacts consist of at least 40 residential buildings and potentially at least 10 industrial buildings (to the east) as assessed using google maps satellite imagery. With at least one to two people per residential property the population at risk is likely to be between 11 to 100 persons at risk. Once the likely dam-break inundation area is identified a visual inspection of the area is required to confirm the potential tangible and intangible impacts (for more information see the NZ Dam Safety Guidelines, DSG). The detailed PIC assessment should be undertaken and completed with full consideration of Schedule 2 of Building Act 2022 to properly define the impacts to ensure the Emergency Action Plan adequately protects the downstream people, property and the environment.

There has been no determination of the damage level besides a high-level assessment of the tangible physical community impacts in the immediate (assumed) inundation area. Further assessment of the damage level to all the specified categories (see Schedule 2 Table 1 and DSG Table 2.2) is required.

This assessment also assumes that the flow depth and velocity is sufficient to be considered a hazard, causing damage and the potential to lead to loss of life.

The Donalds Creek Detention Dam impounds water episodically and generally for short duration, high flow events. Should a dam-break occur the proximity of the houses will likely encounter water and debris laden flow. Similar small dam failures have resulted in large mudslides that continue to collect debris as the slide progresses downstream (e.g. Oliver Dam failure in British Columbia Canada). There are at least 10 residential buildings within 20 to 50 m of the dam, the remainder are further away towards SH2 (in the order of 100+ m away). It is unlikely that properties within 20 to 50m of the dam will experience no to minimal damage following a potential dam break due to their proximity to a dam breach. Without a Failure Modes and Effects Analysis (FMEA) to understand the potential failure mechanisms and the dam-break study to understand the hazard it is considered that the damage level is Moderate to Major.

This desktop study identified less than 50 houses and less than 20 commercial or industrial buildings in the inundation zone. As a result, the Catastrophic damage level does not get triggered as defined by Schedule 2 Table 1 determination of assessed damage level.

Note residential development has occurred in the dam breach flow path and inundation area since the WSP assessment in 2018 (comparing Figure 1 attached to google satellite imagery). An FMEA should now be undertaken to enhance the understanding of the key vulnerabilities of the dam (which will assist the dam break study) and surveillance requirements to provide early warning of the development of the potential failure modes.

Based upon this simplified conservative assessment of building impacts, the Population at Risk is greater than 10, damage level Moderate or higher and the proximity of the buildings to the dam, the PIC is assessed to be High as defined by the Schedule 2 Table 2 of Building Act 2022 (and Dam Safety Guidelines Table 2.6).

Until a more comprehensive PIC assessment is completed the Dam Safety Assurance Programme for Donald's Creek Dam should be commensurate with a High PIC classification. This is the highest classification defined by the Dam Safety Regulations.

References:

- WSP, Memo Donalds Creek Detention Facility – FMEA, September 2018
- WSP Addendum A Donalds Creek Detention Facility Hydrological Analysis Phase 2, Draft, August 2018
- Building Act 2004, Version as at 23 December 2023
- Building (Dam Safety) Regulations 2022, Version as at 21 September 2023
- NZSOLD, New Zealand Dam Safety Guidelines 2023

Rebecca Polvere
CMEngNZ, CPEng, Recognised Engineer - Dam Safety Assurance Programme and Potential Impact Classification (Registration Number 257826)

Attachments

Figure 1: The direction of flow from any dam breach identified by WSP 2018

MEMO

TO	Jack Mace, Director Delivery
COPIED TO	Jacky Cox, Manager Resources and Logistics Delivery, George Bowman Team Lead Flood Operations Planning
FROM	Rebecca Polvere CPEng, RecEng DSAP and PIC (Reg# 257826)
DATE	24/04/2025
FILE NUMBER	Memo DON Dangerous Dam Update April 2024.docx

FOR YOUR INFORMATION

Donald's Creek Detention Dam Update to Dangerous Dam Status

Donald's Creek Detention Dam (DON) will no longer meet the threshold for classifiable dam and will no longer be required to meet the performance thresholds defined within the Building (Dam Safety) Regulations 2022 (Regulation), Section 19. Therefore, Donald's Creek Detention Dam is no longer a dangerous dam (as per the Building Act 2004 and Regulation).

In Mar 2024 DON was identified as a dangerous dam as per Building Act 2004 and the Regional Authority notified 27 Mar 2024. Memo 1 (DON Confirmed Dam Safety Deficiencies.docx) outlined the justification for notifying DON as a dangerous dam.

The Government announced on 27 Mar 2024 that the threshold requirement for dams impacted by the Building (Dam Safety) Regulations 2022 is a height of 4 or more metres and stores 20,000 or more cubic metres volume of water, or other fluid (Resources | Building Performance). DON is 3.5m high. Therefore, DON will no longer be a classifiable dam and will no longer be required to meet the performance thresholds defined within the Regulation.

As such DON will no longer be notified as a dangerous dam. There is now an action with the Regional Authority to confirm how to rescind this notification.

Memo 1 documented four confirmed dam safety deficiencies. Now that the Regulation does not set the performance thresholds for DON, the performance criteria for DON is considered to be set by what the original design performance criteria was for the dam. On this basis the confirmed dam safety deficiencies are updated to align with the original design performance criteria and the updates are provided in Table 1 below. This updates Memo 1.

Table 1: Update to the Confirmed Dam Safety Deficiencies

#	March 2024	Update
1	Donald's Creek Detention Dam will overtop during the 100-year flood event	Close – this performance threshold defined by the Regulation is no longer applicable.
2	There is insufficient freeboard for flood events greater than 20-year flood event	No change
3	The impounded area is not well defined and therefore the actual stored volume (105,000 m^3 at 39 masl crest level) is significantly larger than the design of 80,000 m^3.	No change
4	The dam cannot safely convey flows above 100-year event. The flood threshold event as defined by the Dam Safety Regulations is 1 in 500 AEP for high PIC and 1 in 250 for medium PIC	Update: The dam is unable to safely convey flows via the free overflow spillway if the culverts become blocked.

Prior to the Government announcement an indicative Potential Impact Classification (PIC) assessment was completed for DON to assign the PIC. This assessment was documented in Memo 2 (DON Dam Classification.docx). The assessment was undertaken on the basis that at the time DON was a classifiable dam. DON is no longer classifiable, and the dam does not legally require to be assigned PIC. However, Memo 2 provides a summary of the potential consequences of a potential dam breach. The assessment identified the potential for life safety and major assets (State Highway 2) at risk during a flood event and a dam breach.

Despite DON not being classifiable, DON still functions as a dam. With the downstream area increasing in urban development the life safety risk is also increasing. Without any other guidance, the dam is recommended to be managed in alignment with the NZ Dam Safety Guidelines (DSG). The DSG provide a validated industry practice in the management of dam safety for the protection of people, property and the environment. Therefore, it is recommended that the following is adopted at a minimum from the Dam Safety Management System:

1. Emergency Action
2. Appropriate Surveillance monitoring

3. Identifying and managing dam safety issues

Adopting these key elements ensure the dam safety deficiencies are appropriately managed including the defining the roles and responsibilities. In addition, adopting these key elements also ensures the dam safety deficiencies are understood and prioritised in the context of GWRC dam portfolio.

With Government announcement to change the Regulation, there is no precedent for expectations for performance for dams which would have been classified as high or medium PIC but do not meet the classifiable threshold. In addition, GWRC do not have a dam safety policy which would also provide a framework and expectation for how dam safety is to be managed (GW as the dam owner). Without any other guidance or industry precedent, the performance expectation is being considered to be set by the original design performance. It is recommended that GW develop a Dam Safety Policy, Statement or Standard (refer DSG) to provide expectations for dam safety performance and management.

This Memo updates the Memo 1 DON Confirmed Dam Safety Deficiencies.docx and Memo 2 DON Dam Classification.docx.

Recommendations:

1. Work with the Regional Authority to rescind the dangerous dam notification.

2. Manage the dam in alignment with the NZ Dam Safety Guidelines, adopting key elements of a Dam Safety Management System to undertake the management of the risk to life safety.

3. Develop a Dam Safety Policy, Statement or Standard (refer DSG) to provide expectations for dam safety performance and management for both classifiable and non-classifiable dams.

Council
26 September 2024
Report PE24.416

For Decision

PURCHASE OF LAND IN FEATHERSTON

Te take mō te pūrongo
Purpose

1. To seek approval to enter negotiations for the purchase of Lot 6 DP 397203 within Record of Title 387606 adjacent to Donald's Creek Detention Dam in Featherston.

2. To delegate authority to enter into any necessary agreements to complete the purchase of the land to the Chief Executive of Greater Wellington Regional Council (Greater Wellington).

He tūtohu
Recommendations

That Council:

1 **Approves** Greater Wellington entering into negotiations for the purchase of Lot 6 DP 397203 within Record of Title 387606 adjacent to Donald's Creek Detention Dam in Featherston.

2 **Authorises** the Chief Executive to enter into any agreements necessary to complete the proposed land purchase, and provided the Chief Executive is satisfied the terms and conditions negotiated represent a fair and reasonable outcome for Greater Wellington.

Te aukati atu i te marea
Exclusion of the public

3. Grounds for exclusion of the public under section 48(1) of the Local Government Official Information and Meetings Act 1987 are:

    The information contained in this report relates to a proposed land purchase upon terms and conditions that are yet to be negotiated and agreed. Having this part of the meeting open to the public would disadvantage Greater Wellington Regional Council in its negotiations as it would reveal Greater Wellington Regional Council's negotiation strategy.

    Greater Wellington Regional Council has not been able to identify a public interest favouring disclosure of this information in public proceedings of the meeting that would override the need to withhold the information.

Te tāhū kōrero/Te horopaki
Background/Context

4. Donald's Creek Detention Dam (the Dam) in Featherston was constructed in 1998 following flooding events (**Attachment 1**: Design Report). The purpose of the Dam is to retain excess water in high flow storm events to ensure that the flow in Donald's Creek does not exceed the capacity of the downstream culverts under SH2. The Dam was constructed to a nominal 1 in 50-year flow (as at 1998).

5. The Dam features a free overflow spillway on the eastern embankment such that once the Dam has reached full capacity water discharges over the eastern side to prevent the Dam from being overtopped. Overtopping of the Dam could lead to the uncontrolled release of the reservoir through eroding and breaching the Dam. The spillway is an appurtenant structure and is an integral part to ensuring the safe performance of the Dam.

6. Currently the spillway discharges onto land not owned by Greater Wellington, and the land is also neither demarcated nor protected by a designation. Greater Wellington has no protections in place to safeguard the spillway discharge flow path against development or other works that could impact its performance. The Dam and relevant features are noted below in figure 1.

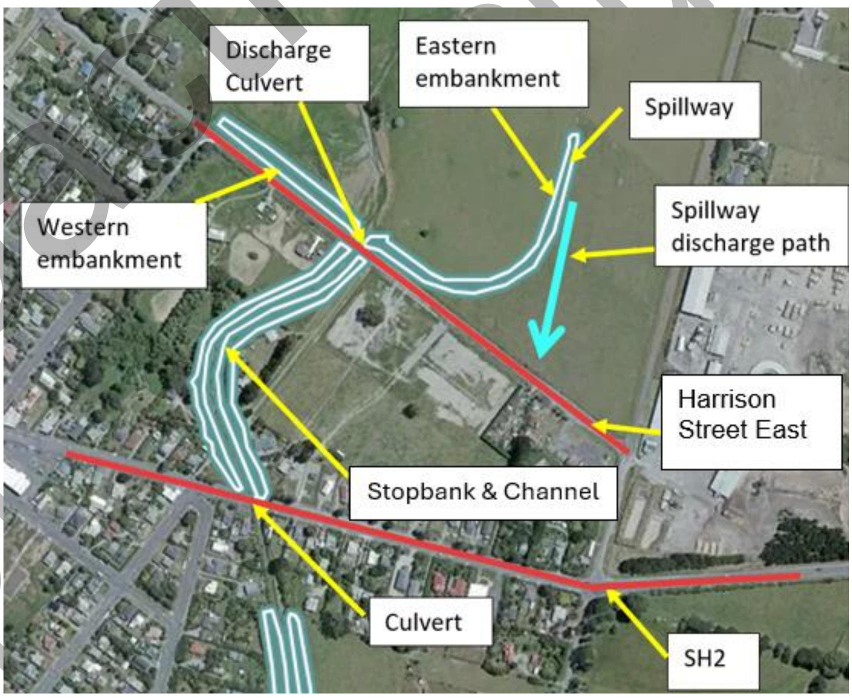


Figure 1: Donald's Creek Detention Dam

7. The Dam is not required to comply with the new Dam Safety Regulations due to the height of the dam being less than 4 metres. However, the regulations and New Zealand Dam Safety Guidelines provide the industry with principles and recommended practices for dams where the consequences of failure are expected to be unacceptable to the public. While not all recommended practices are applicable to the safe management of the Dam, the expectation is that as a responsible dam owner, Greater Wellington undertake actions to protect people,

property and the environment from the adverse effects resulting from dam operation, or in the event of a potential dam breach.

8. The spillway adjacent to the Dam, legally described as Lot 6 DP 397203 under Record of Title 387606, is being offered for public sale. This subject land (the Land) comprises 3.8521 hectares and holds a Fee Simple title. It is zoned as General Rural under the Proposed Wairarapa Combined District Plan. Lot 6, as shown in Figure 2 below, is the focus of this report.

Figure 2: Lot 6 adjacent to Donald's Creek Detention Dam

9. The property purchase is not included in Greater Wellington's Long Term Plan (LTP). However, there is sufficient LTP capex budget for the Land acquisition due to anticipated Crown funding for the Before the Deluge resilience programme. A decision to purchase the land is subject to ensuring funding can be appropriately allocated.

Te tātaritanga
Analysis

10. The Land to the east of the Dam is currently advertised for sale as an "opportunity for those seeking a bare land block to develop". Flood hazard maps in the proposed Wairarapa Combined District Plan show the flooding risk to this land as noted in Figure 3 below.

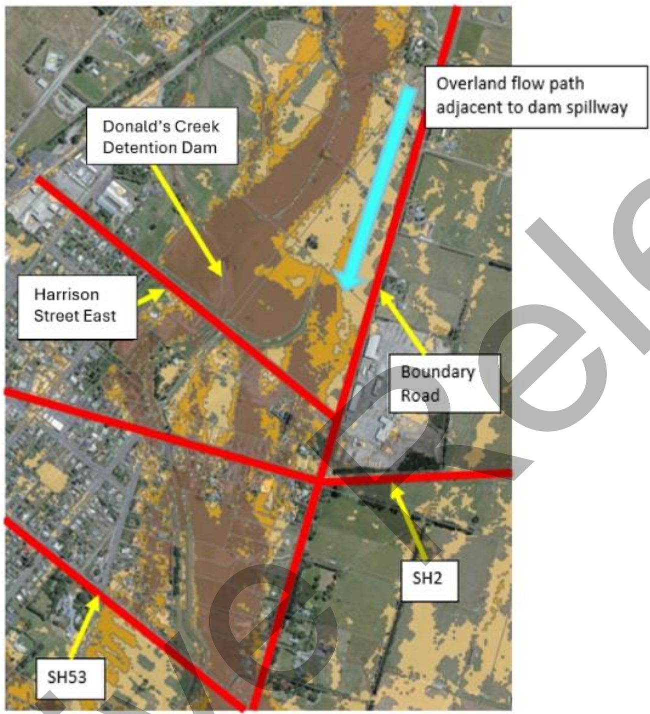


Figure 3: Flood hazard map

11. Greater Wellington has a duty of care for the protection of people, property and the environment during the usual operation of a dam. In a flood event the spillway is required to operate to maintain the integrity of the Dam; and this may result in damage to the Land, any improvements on the Land and any people on the Land at the time.

12. The purchase of the Land represents an opportunity to:

- Bring the spillway discharge flow path into Greater Wellington ownership and protect it from inappropriate use or development.
- Provide a clearer pathway for designation of the Land.
- Increase the level of service of the Dam in the future should Greater Wellington and the community choose to.

13. If we do nothing, the Land may be sold to a private owner and there is the potential for further development of infrastructure and the increase in the permanent presence of the public. This will increase Greater Wellington's risk exposure, becoming more difficult, time consuming and costly to remedy.

Nga kōwhiringa
Options

14. Table 1 below presents an analysis of three potential options regarding the acquisition of the Land. It outlines the benefits and drawbacks associated with each option: doing nothing, purchasing the Land now, and purchasing the Land later.

Table 1: Analysis of Benefits, and Drawbacks for Purchasing Land Adjacent to the Dam

Option	Benefits	Drawbacks
Do Nothing	• Avoids the time and effort involved in negotiations, legal processes, and land management. • Allows Greater Wellington to focus on other pressing issues without diverting attention and resources to land acquisition. • Greater Wellington avoids the responsibility and costs associated with maintaining the Land.	• Greater Wellington will be unable to fulfil its obligations to the community. • The Land could be purchased by a private owner who may not maintain it appropriately, potentially compromising the spillway's effectiveness and increasing flood risks. • Greater Wellington would have no authority over future developments on the Land, which could negatively impact dam safety. • If the Land becomes more valuable or developed, it might cost significantly more to purchase or require expensive mitigation measures.
Purchase the Land now	• Greater Wellington will be able to fulfil its obligations to the community. • Immediate control over the Land ensures that it can be managed properly to maintain the spillway's function, safeguarding dam safety. • Locking in the current price could be cheaper than waiting, especially if property values increase. • Greater Wellington can ensure that the Land is used in a manner that is safe and beneficial to the region, potentially even improving or enhancing the spillway.	• Lack of engagement with all relevant stakeholders. • The public or stakeholders may question why Greater Wellington is choosing to purchase this piece of land over other areas with similar safety or strategic concerns.

Option	Benefits	Drawbacks
Purchase the Land later	• Greater Wellington will be able to fulfil its obligations to the community. • Greater Wellington can delay the expenditure, potentially allowing for better financial planning. • Allows time to explore alternative solutions, gather more data, or secure additional funding.	• Exposed to potential liability for a longer period. • Land prices may increase over time, leading to higher costs in the future. • If the Land is sold to another party before Greater Wellington can act, it may be developed in a way that compromises the spillway and safety. • Delaying the purchase means the Greater Wellington does not have control over the Land, which could increase the risk of unsafe conditions arising.

Ngā hua ahumoni
Financial implications

15. The cost of the Land is estimated to be approximately $500,000. There is sufficient LTP capex budget for the acquisition due to anticipated Crown funding for the Before the Deluge resilience programme. A decision to purchase the land is subject to ensuring funding can be appropriately allocated.

16. The ownership and maintenance responsibility is proposed to fall under the Lower Wairarapa Valley Development Scheme, with day-to-day maintenance managed by the Southern Wairarapa Area Engineer, Flood Operations Delivery.

17. There will be a small increase in annual costs to cover the rates for the Land. For 2024/25 these are assessed at $2,203.98. However, this could be offset through revenue obtained from a grazing licence.

18. The cost of purchasing now, when the vendor is willing to sell, is estimated to be less than a future purchase under the Public Works Act due to the possible increase in Capital Value of the Land and any additional costs associated with the sale under the Public Works Act.

Ngā Take e hāngai ana te iwi Māori
Implications for Māori

19. Purchase of the Land will not lead to any additional benefits or disbenefits to Māori than the rest of the community.

Te huritao ki te huringa o te āhuarangi
Consideration of climate change

20. Officers have assessed that the recommended land purchase will provide an improvement to the way we can adapt to climate change, by allowing for future options to increase the level of service of the flood detention dam should Greater Wellington and the community choose to.

21. Grazing is considered the most effective and low carbon method to maintain the Land when compared to the alternative of mowing.

Ngā tikanga whakatau
Decision-making process

22. The matters requiring decision in this report were considered by officers against the decision-making requirements of Part 6 of the Local Government Act 2001.

Te hiranga
Significance

23. Officers' assessment of this proposal against Greater Wellington's Significance and Engagement Policy is that the matter be considered to have low significance.

Te whakatūtakitaki
Engagement

24. Officers' assessment of this proposal against Greater Wellington's Significance and Engagement Policy is that no engagement on the matters for decision is required.

Ngā tūāoma e whai ake nei
Next steps

25. Provided that the purchase is approved in principle then the next steps would be:

- Engage Jigsaw Property Consultancy Ltd to obtain current land valuation and enter into negotiation with the vendor.
- Authorise the Chief Executive to confirm purchase agreement if they are satisfied that the terms and conditions negotiated represent a fair and reasonable outcome for Greater Wellington.
- Once the Land is in Greater Wellington ownership, commence the process to designate the Land.

Ngā āpitihanga
Attachment

Number	Title
1	Donalds Creek Flood Protection Project Design Report

Ngā kaiwaitohu
Signatories

Writers	Tim Lewis, Area Engineer Southern Wairarapa, Flood Operations Rolayo Olukunle, Project Engineer, Assets and Performance Rebecca Polvere, RiverLink Owner Engineer, RiverLink George Bowman, Team Leader Assets and Performance
Approvers	Jacky Cox, Manager, Infrastructure, Assets and Support Jack Mace, Director Delivery Lian Butcher, Group Manager, Environment Group Nigel Corry, Chief Executive

He whakarāpopoto i ngā huritaonga
Summary of considerations

Fit with Council's roles or with Committee's terms of reference

Purchase of the Land to bring the Dam spillway in Greater Wellington ownership meets our community outcome of a resilient future by providing for modern robust infrastructure.

Contribution to Annual Plan / Long Term Plan / Other key strategies and policies

The project is currently not signalled within the 2024-34 LTP but there is sufficient LTP capex budget for the acquisition due to anticipated Crown funding for the Before the Deluge resilience programme. A decision to purchase the land is subject to ensuring funding can be appropriately allocated.

Internal consultation

Representatives within the organisation from the Environment and Corporate Services Groups were consulted including from flood operations delivery, finance, legal, climate change and risk.

Risks and impacts - legal / health and safety etc.

Risks of not purchasing:

- The Dam spillway asset is not under Greater Wellington ownership and not protected from inappropriate use or development.
- Obtaining the Land in the future would require more time, resource and cost under the Public Works Act 1981.

Risks of purchasing now:

- An increase in maintenance costs of managing the additional land. This is expected to be minor, especially as maintenance and inspection works are already being undertaken on the adjacent land and can be accommodated within the existing scheme finances or offset through grazing.
- Public expectation is raised that Greater Wellington will purchase floodable land that will not easily sell on the open market. It must be clear that this purchase is solely to protect the spillway asset.

Risks of purchasing later:

- As above.
- Delaying the purchase means that the Greater Wellington does not have control over the land designated for flood protection, leaving Greater Wellington Regional Council exposed to potential liability for an extended period. This lack of control could result in increased risks if the land is developed or managed in a way that compromises its intended dam safety function.