



A composite image for a report cover. The left side features a stylized globe graphic with a grid pattern and glowing blue highlights. The right side shows a close-up photograph of vibrant green fern leaves with prominent veins. A vertical white line separates the two sections.

## Auckland Regional Landfill

**Stormwater pond damming: s92 response**

**Prepared for**

Waste Management NZ Ltd

**Prepared by**

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## 1 Introduction

### 1.1 S92 question

Waste Management NZ Ltd (WMNZ) has applied for resource consents for a new landfill located in the Wayby Valley area north of Auckland, known as Auckland Regional Landfill. Stormwater runoff from the landfill site will be treated in a series of large stormwater ponds constructed at the lower end of the site. The ponds will be formed by the construction of a series of dams across the existing stream below the proposed landfill.

As part of their review of the application, Auckland Council has requested further information in relation to the dams under s92 of the RMA. The wording of the s92 request for further information is:

#### ***Stormwater damming***

*Information and assessment relating to this consent has not been provided.*

- *Please provide an assessment under E7 (e.g. E7.6.1.1, E7.6.1.13 etc.) (of the AUP).*
- *Please provide a report which addresses dam safety aspects and demonstrates that all hazards have been identified and the dam design has addressed these hazards.*

*The report should be in accordance with the New Zealand Society of Large Dams, New Zealand Dam Safety Guidelines (2015) with the amount of detail commensurate with the potential impact classification of the dams.*

*Please note that: Module 1 of the Guidelines provides an outline of typical requirements for a consent application. As a minimum the following aspects should be included;*

- *Potential Impact classification of all dams including cascade effects where relevant (ie upstream dams causing failure of downstream dams). This would identify the consequences of failure downstream.*
- *Geotechnical investigation and assessment specific to each site (ie dam foundations, dam materials and zoning, reservoir and dam batter slope stability, control of seepage and internal erosion).*
- *Flood risks at the dams and how floods are managed during construction and operation.*
- *Outline of proposed construction including proposed designer inspections / quality assurance.*
- *Outline of long term management of dam safety i.e. maintenance / surveillance etc.*

Our response to these questions is provided below. Where required, further information is appended.

### 1.2 General description of dams at the ARL site

Over the life of the landfill five main stormwater ponds are proposed to be used for removal of sediment from stormwater leaving the landfill site. These ponds are labelled Ponds 1 to 5 (Pond 1 being the furthest downstream from the landfill and Pond 4 being the closest, with Pond 5 being upstream of Stages 1 and 2), and their location is shown on Drawing ENG-40.

Pond 1 is a wetland that will be constructed off to the side of the main valley. It will be constructed by cutting a bench at approximately 70.5 mRL and excavating below the bench level to form the wetland. Water depth in the wetland will typically be 300 mm to 600 mm (shallow marsh zone and deep marsh zone) with minor deep areas of 1.5 to 2 m water depth.

Ponds 2 and 3 will be permanent ponds over the life of the landfill and will be formed by damming the stream below the landfill. Pond 3 will initially be kept at a low water level (Pond 3A) to allow for discharge of the flow from the pipe beneath Stage 1 of the landfill. When this is no longer required the water level will be raised (Pond 3B) to increase the storage volume.

Pond 4 will be constructed on the footprint of the future Stage 7 of the landfill and will be constructed by damming the stream with some excavation behind the dam.

Pond 5 is a temporary pond constructed above Stage 1 of the landfill to provide flow attenuation and sediment removal until Stage 3 of the landfill is constructed.

The dams for Ponds 2, 3 and 4 are considered in this report. The dams will be earth embankment dams constructed from locally sourced soils with a 5 m wide crest, a low permeability core, and likely to have 1V:3H side slopes subject to detailed design. The dams will have a filter compatible internal drainage system including chimney drain and drainage under the downstream shoulder. The primary spillway will consist of a drop manhole discharging to an outlet pipe and auxiliary spillway designed for a 1000 year flood event.

Ponds 2 and 3 were proposed to be separate dams to follow the change in elevation along the valley at this location, stepping the level of the ponds to suit the change in elevation. However, as part of this review of the dams, it has been determined that Ponds 2 and 3 could be combined into a single pond with a single dam to provide the same storage volume and hence the same sedimentation function. This option will be considered further during detailed design.

## **2 Potential impact classification (PIC)**

A PIC assessment has been completed in accordance with the New Zealand Society on Large Dam - Dam Safety Guidelines 2015 (DSG 2015). The assessment was an “intermediate assessment” as defined in DSG 2015 as this level of assessment was applicable to the level of detail available.

A PIC assessment is purely a function of the consequences of a hypothetical failure breach or other uncontrolled release of the stored contents of a dam. It is not an assessment of effects and it has no correlation with the probability of the dam failing or experiencing a dam safety incident. In broad terms, the process for classification requires the identification of people, property and the environment that would be impacted by a hypothetical dam failure, or dam safety event, and follows a process defined in DSG 2015.

The PIC assessment has been carried out only for the Ponds 2, 3 and 4 as these are formed by building dams across a valley. As described above, Pond 1 is a relatively shallow wetland, constructed by excavation into a cut slope beside the main stream on the landfill site. The majority of that pond, formed by excavation below the cut platform level, will have a water depth in the order of 0.3 to 0.6 m and an embankment height in the order of 1 m and, as an in-ground pond, is not covered by a PIC assessment.

Pond 5 is a temporary pond only required during operation of Stages 1 and 2 of the landfill and will be removed as construction of the landfill progresses and so has not been considered. Pond 4 is also temporary but will be in place for most of the operating life of the landfill, being decommissioned for the construction of Stage 7.

As Ponds 2, 3 and 4 will be built on the same valley, a cascade failure of all three ponds whereby the failure of an upstream dam could cause overtopping and failure of downstream dams, was considered. Consideration of a potential cascade failure is required by the procedure set out in DSG 2015 for a PIC.

This assessment considered a sunny day failure scenario where the dams fail, for whatever reason, when they are at their normal top water levels. This report has not considered a flood failure

scenario (rainy day failure) as the consequences of a rainy day failure are likely to be significantly less than a sunny day failure, as the PIC only considers incremental damage. Figure 1, included in Appendix B, shows the extent of flooding from the modelled dam-break (sunny day) and the extent of the downstream flood plain from Auckland Council Geomaps. By inspection it is apparent that incremental flooding caused by a dam-break under flood conditions will be extremely small and hence there is unlikely to be any incremental damage i.e. damage caused by a dam-break in addition to the damage already being caused by a flood.

Details of the approach taken for the PIC assessment and the result of that assessment are included in **Appendix A**. The potential flood extent associated with the hypothetical instantaneous dam-break is shown on Figure 1 in **Appendix B**.

The assessment finds:

- All of the dwellings identified near the potential dam-break flow path within 5 km downstream of Pond 2 are located well above the estimated flood levels and would not be affected.
- Figure 1 shows the extent of potential flooding, which is significantly less than the Auckland Council flood plain. The flooding is typically maintained within the associated water courses other than the low lying fields on land to the east of Spindler Road, a large proportion of which is within the Waste Management landholding.
- The assessment shows that SH1 bridge crossing the Hōteo River will not be flooded by the dam-break flood.
- Some local roads and private access ways may be affected by the dam-break flood for a relatively short duration.
- No consequences are expected downstream of the SH1 bridge.

The assessment further concludes that Damage Level (a defined term in DSG 2015) is minimal and that the population at risk (PAR) is zero.

Therefore, the overall conclusion is that the Pond 2, 3 and 4 dams are assessed to have a PIC rating of "Low".

### **3 Geotechnical assessment and associated design elements**

#### **3.1 Introduction**

Geotechnical investigations have been carried out to support feasibility level design and consenting of the proposed Auckland Regional Landfill. Investigations were carried out between 26 February 2018 and 7 June 2018, which comprised 14 machine cored boreholes, 21 hand augured boreholes, 10 test pits and geophysics consisting of downhole shear wave velocity and Multi-channel Analysis of Surface Waves (MASW) testing.

Additional geotechnical investigations were also carried out to source clay material for liner and cap construction. The investigations were completed on 13 August 2018 and comprised of 9 hand augers drilled to a maximum depth of 4 m.

Results of the investigations are presented in the Geotechnical Factual Report. Geological and groundwater conditions as well as associated geotechnical model, inferred from the geotechnical investigations, are included in the Geotechnical Interpretive Report.

Geological and geotechnical characteristics, relevant to the proposed stormwater dams, are briefly summarised in this report.

### **3.2 Geotechnical setting**

The proposed landfill site and access alignment is underlain by Pakiri Formation bedrock consisting of interbedded sedimentary sandstone and siltstone with some conglomeritic layers. The bedrock is overlain by a variable thickness of residual, colluvial and landslide soil.

There are no active geological faults mapped in the site area, and no significant fault zones were encountered in the boreholes or MASW testing. Rock mass defects encountered in boreholes included bedding, widely spaced steeply dipping joints and some broken zones. Bedding is gently inclined to the north. It is anticipated that some fault disturbed bedrock may be encountered within the proposed landfill footprint and access road alignments.

### **3.3 Seismic hazard**

A site specific seismic hazard assessment has been prepared for the site and reported in the Probability Seismic Hazard Assessment (PSHA) report. This study concluded that the proposed Auckland Regional Landfill site is in an area of relatively low seismicity compared to the rest of New Zealand. The PSHA also assessed lower levels of shaking than specified in the design standards calculated for the site, such as NZS1170.5 and the Bridge Manual. However, for regions of relatively low seismicity, NZS1170.5 and the Bridge Manual should be used to determine the design peak ground acceleration for the stormwater dams, to take into account unknown fault zones. The dams should be designed to the earthquake events and performance criteria, recommended in the NZSOLD Dam Safety Guidelines, commensurate to the dams' Potential Impact Classification.

### **3.4 Geotechnical implications on dam design**

Extensive geotechnical investigations have been carried out across the proposed landfill site, however not along the proposed dams' alignments. Additional geotechnical investigations will be required as part of detailed design to confirm the geotechnical conditions of the proposed dams' foundations.

Unsuitable materials in the foundation will need to be removed and the foundation properly treated to the satisfaction of the dam designer. A foundation cut off may be required to key the dam into the foundation as well as to mitigate the risk of internal erosion through the dam foundation.

If the proposed dam foundation is rock, any rock defects will need to be cleaned, treated and filled to the satisfaction of the dam designer.

## **4 Dam preliminary design**

### **4.1 Dam and spillway sizing**

A flood routing model was created to size Pond 2, Pond 3B and Pond 4 dams, as well as their primary and auxiliary spillways, using HEC-HMS version 4.3.

Catchment assessment was undertaken based on existing and landfill design contours as well as the drainage plans shown on Figures ENG-41 and ENG-42. The landfill design, at the time of this assessment, is a concept level design and subject to change during detailed design. However, catchment characteristics associated with the ponds are not expected to change significantly. Further analyses are required during detailed design to confirm the dam sizes and levels.

Storage volumes for the ponds were determined based on LiDAR and landfill design contours.

Pond 2, Pond 3B and Pond 4 dams were assessed to have **Low** Potential Impact Classification (PIC) (refer **Section 2** above). As a result, the dams should be designed to pass a hypothetical 1 in 1000 year flood, in accordance with NZSOLD DSG 2015.

Rainfall (depth – duration – frequency) data for the proposed dam location was obtained from HIRDS v4. The data was then extrapolated to estimate rainfall depths for the 1000 year storm event, using the Gumble distribution.

Varying storm durations, ranging from 1 to 48 hours, were run through the flood routing model to find a critical storm duration in terms of peak water level stored behind the dams. The 3 hour storm duration was found to be the critical storm for all three dams.

As a concept, Pond 2, Pond 3B and Pond 4 dams will have a drop manhole and a piped outlet conduit which forms the primary spillway. The level of the drop manhole will be set 300 mm below the respective design top water levels of the ponds. All 3 dams will also have an auxiliary spillway, sized to pass a hypothetical 1000 year flood. The auxiliary spillway channel could be combined with the proposed access road, along the left side of the valley (looking downstream), or at an alternative location. Combining auxiliary spillway with the access road will help minimise the amount of earthworks. However, this is subject to further design and analyses to confirm shapes, levels, and whether erosion protection is required along the spillway channel / access road.

At this preliminary design level the design dam crest level has been set at 900 mm above the respective estimated peak water level (design freeboard). However, during detailed design an appropriate level of freeboard will be provided for wave run-up and, for small dams such as proposed here, a freeboard of approximately 500 mm is considered to be appropriate. The primary spillways for 3 dams comprise 1800 mm drop manholes and 1350 mm outlet conduits. The 3 auxiliary spillways are assumed to be 6 m wide, the same width as the proposed access road.

Key design parameters for the Pond 2, Pond 3B and Pond 4 dams, based on the flood routing assessment results, are summarised in Table 4.1. Estimated storage volumes are provided in **Table 4.2**.

**Table 4.1: Summary of flood routing assessment results**

1 in 1000 year ARI 3 hour duration storm	Est. peak inflow (m <sup>3</sup> /s)	Est. peak discharge (m <sup>3</sup> /s)	Primary spillway level (RL m)	Auxiliary spillway level (RL m)	Est. peak water level (RL m)	Design dam crest level (RL m)	Approx. dam height (m)
Pond 2 dam	19.4	19.1	78.2	78.5	79.7	80.6	13
Pond 3B dam	19.9	19.0	84.4	84.7	85.9	86.8	9
Pond 4 dam	17.9	15.7	85.2	85.5	86.5	87.4	6
Note: Estimated peak discharge is the combined discharge through the primary and auxiliary spillways							

**Table 4.2: Estimated storage volumes**

	Auxiliary spillway level (RL m)	Est. storage volume (m <sup>3</sup> )	Est. peak water level (RL m)	Est. storage volume (m <sup>3</sup> )	Design dam crest level (RL m)	Est. storage volume (m <sup>3</sup> )
Pond 2 dam	78.5	15,500	79.7	20,400	80.6	24,100
Pond 3B dam	84.7	20,300	85.9	27,100	86.8	32,700
Pond 4 dam	85.5	40,500	86.5	51,700	87.4	61,700

## 4.2 Embankment design

The three dam embankments are proposed to have:

- 5 m crest width for access.
- 1V:3H batter slopes both upstream and downstream for stability and maintenance (e.g. mowing). However, the actual slope will be determined as part of detailed design to suit the materials used and the specific geotechnical design. In particular, both faces of the dam for Pond 3 will be submerged and gentle slopes are not required for maintenance. Steeper slopes would provide additional pond storage.
- A foundation cut off to mitigate against internal erosion through the foundation: level and detail of the foundation cut off to be confirmed during detailed design once additional geotechnical investigation is carried out, or when the foundation is exposed during construction.
- A central or upstream low permeability core: material sources for the low permeability core to be determined during detailed design.
- A chimney filter drain along the downstream side of the low permeability core and a drainage blanket at the dam foundation downstream of the chimney drain to mitigate against internal erosion, control seepage and increase the factor of safety against stability. The outlets from the drains will be positioned so that they can be monitored.

Typical sections showing the construction of the dams are shown on drawings included in **Appendix C**.

## 4.3 Preliminary assessment of potential failure modes and proposed mitigation

Preliminary assessment of potential failure modes associated with Pond 2, Pond 3B and Pond 4 dams is shown in Table 4.3. Table 4.3 also outlines the proposed measures that will be considered during the design process to mitigate the risk of dam failure.

**Table 4.3: Preliminary assessment of potential failure modes and proposed mitigation measures**

Potential failure mode	Load cases	Proposed mitigation measures	Likelihood of failure post mitigation
Overtopping of the dam embankment during a large flood due to insufficient spillway capacity and freeboard	• Flood	• Carry out hydrology assessment and flood routing to size the spillways and determine dam crest level to ensure there is sufficient freeboard	Very unlikely
Internal erosion / piping failure through the dam embankment	• Normal • Flood • Earthquake	• Prepare technical specifications to specify suitable materials for the dam embankments during detailed design • Filter design and drainage requirements to be determined during detailed design	Very unlikely
Internal erosion of embankment materials into foundation materials	• Normal • Flood • Earthquake	• Carry out additional geotechnical investigation during detailed design	Very unlikely

Potential failure mode	Load cases	Proposed mitigation measures	Likelihood of failure post mitigation
		<ul style="list-style-type: none"> <li>• Prepare technical specification to specify suitable foundation treatment during detailed design</li> <li>• Filter design along dam / foundation interface and cut off requirements to be determined during detailed design</li> </ul>	
Internal erosion / piping failure along the outlet conduit	<ul style="list-style-type: none"> <li>• Normal</li> <li>• Flood</li> <li>• Earthquake</li> </ul>	<ul style="list-style-type: none"> <li>• Seepage control, filter design and drainage requirements around outlet conduit to be determined during detailed design</li> <li>• Prepare technical specification to specify suitable materials and compaction standard along conduit during detailed design</li> </ul>	Very unlikely
Instability of upstream and downstream shoulder	<ul style="list-style-type: none"> <li>• Normal</li> <li>• Flood</li> <li>• Earthquake</li> <li>• Rapid drawdown</li> </ul>	<ul style="list-style-type: none"> <li>• Adopt 1V:3H batter slopes for the upstream and downstream faces of the dam embankments</li> <li>• Carry out stability assessment during detailed design to ensure adequate factor of safety</li> </ul>	Very unlikely
Internal erosion of foundation materials	<ul style="list-style-type: none"> <li>• Normal</li> <li>• Flood</li> <li>• Earthquake</li> </ul>	<ul style="list-style-type: none"> <li>• Filter design, drainage and cut off requirements in the foundation to be determined during detailed design</li> </ul>	Very unlikely
Overtopping failure due to embankment deformation / settlement / liquefaction of the embankment / foundation under seismic loading causing loss of freeboard	<ul style="list-style-type: none"> <li>• Earthquake</li> </ul>	<ul style="list-style-type: none"> <li>• Carry out liquefaction, stability, and settlement assessments during detailed design to ensure the amount of settlement under various load cases is acceptable</li> </ul>	Very unlikely

## 5 Outline of proposed construction

The following measures are suggested to mitigate the risk of dam failure during and following construction. This is not an exhaustive list. Additional control measures may be developed during the detailed design process.

- The dams should be constructed during the dry summer months to mitigate the risk of flooding during construction.
- A contractor who has experience in the construction and commissioning of similar dams should be engaged.
- A suitable flood diversion method should be developed which is capable of passing a flood event that can be reasonably expected during construction.
- An experienced dam engineer should be involved at the commencement of construction, at critical times during construction and whenever observed conditions are different from those assumed in the design. Ideally this should be the dam designer who is familiar with the design.
- A surveillance plan and a contingency plan should be prepared, as a minimum, during the construction period. A surveillance plan will increase the likelihood of any potential dam

safety issues being identified in a timely manner. A contingency plan will ensure there are appropriate systems, processes and resources in place to deal with any dam safety emergencies, if they occurred.

- Geotechnical testing should be undertaken throughout the construction period in accordance with the technical specification and results properly documented. This is to ensure the dams will be built as designed and specified by the dam designer. Testing may include but not limited to particle size distribution, Atterberg limits, moisture content, permeability, soil density and compaction of the dam embankment and foundation materials.
- A completion report and as built drawings will be required as part of the Building Consent Process. These should be developed throughout the construction period and issued to the dam owner after commissioning.

## **6 Long term management of dam safety**

Dam safety management is required, not only during construction but also during the dam life cycle. It is critical that sufficient systems, processes and resources are put in place to ensure potential dam safety issues are picked up in a timely manner and any dam safety emergencies are managed effectively, as and when they occur.

It is a good practice that a Dam Safety Management System (DSMS) is developed that covers relevant dam safety components. Key elements of a DSMS are:

- Operation, maintenance and surveillance.
- Emergency preparedness.
- Intermediate and comprehensive safety reviews.
- Identifying and managing dam safety issues.

It is recommended that these procedures are established during detailed design of the dams.

## **7 Regulatory compliance and quality assurance**

The Building Act 2004 requires that all large dams need a building consent before they can be constructed. Large dams are defined as “a dam that has a height of 4 or more metres, and holds 20,000 or more cubic metres volume, of water or other fluid”. Under this definition, Ponds 2, 3B and 4 dams meet the definition of large dams.

If a building consent is required, detailed design of the dam along with a building consent application needs to be submitted to the relevant Building Consent Authority for dam works. This process ensures that the dam has been designed to current standards and practices and all potential failure modes have been considered and mitigated, as far as reasonably practical.

Quality assurance testing and engineer inspections will likely be required by the building consent, if it is granted. This process provides another level of quality assurance oversight to the design and construction of large dams.

It is envisaged that the types and frequency of quality assurance testing and inspections will be determined as part of detailed design.

## 8      Applicability

This report has been prepared for the exclusive use of our client Waste Management NZ Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for resource consent and that Auckland Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

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## **Appendix A: Potential Impact Classification assessment**

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## A1 Introduction

### A1.1 Background

This report assesses the downstream impact of dam failure of ponds proposed to be constructed as part of the Auckland Regional Landfill development and documents the Potential Impact Classification (PIC) assessment of the proposed dams. The assessment was carried out in accordance with the New Zealand Society on Large Dam - Dam Safety Guidelines 2015 (DSG 2015).

DSG 2015 states: *A dam's PIC is purely a function of the consequences of a hypothetical failure breach or other uncontrolled release of the stored contents. It has no correlation with the probability of the dam failing or experiencing a dam safety incident. In broad terms, the process for classification requires the identification of people, property and the environment that would be impacted by a hypothetical dam failure, or dam safety event.*

Consequence assessment and dam classification are essential to ensure that appropriate performance criteria are used in the design and safety evaluation of a dam.

### A1.2 Scope of the assessment

The PIC assessment was carried out only for the ponds that are formed by building dams across a valley. It does not cover in ground ponds (i.e. ponds that are constructed by excavation into the ground) which do not pose a threat to downstream environments if they fail.

Of the proposed ponds on site, four ponds were identified as having a dam component, namely Pond 2, Pond 3, Pond 4 and Pond 5. Pond 5 is a temporary pond only required during operation of Stages 1 and 2 of the landfill and will be removed as construction of the landfill progresses. Pond 4 is also temporary but will be in place for most of the operating life of the landfill, being decommissioned for the construction of Stage 7. Pond 1 is a relatively shallow wetland, constructed by excavation into a cut slope beside the main stream on the landfill site. The majority of Pond 1, formed by excavation below the cut platform level, will have a water depth in the order of 0.5 m and an embankment height in the order of 1 m.

Therefore, this assessment looks at the potential impact of Ponds 2, 3 and 4 as they will be formed by dams across the valley and will remain on site on a more permanent basis.

As Ponds 2, 3 and 4 will be built on the same valley, a cascade failure of all three ponds whereby the failure of an upstream dam could cause failure of downstream dams, was considered. This is considered to be an appropriate scenario as the volume of Pond 4 is greater than Pond 3 which in turn is greater than Pond 2 so it is possible that the downstream ponds could not attenuate or store the flow from a failed upstream dam.

The PIC assessment was carried out at an intermediate level as defined by DSG 2015.

This assessment considered a sunny day failure scenario, such as could be caused by a large earthquake, where the dams fail when they are at their normal top water levels. This report has not considered a flood failure scenario (rainy day failure) as the consequences of a rainy day failure are likely to be significantly less than a sunny day failure, as the PIC only considers incremental damage. Figure 1, included in Appendix B, shows the extent of flooding from the modelled dam-break (sunny day) and the extent of the downstream flood plain from Auckland Council Geomaps. By inspection it is apparent that incremental flooding caused by a dam-break under flood conditions will be extremely small and hence there is unlikely to be any incremental damage i.e. damage caused by a dam-break in addition to the damage already being caused by a flood.

Figure Eng-40 shows the schematic layout of these ponds. It is noted that the ponds are subject to further stages of design which may impact the final design water levels, storage volumes and dam

heights. As these are parameters that affect dam breach flows the dam breach assessment should be revisited to confirm that any change in these parameters does not change the outcome of the PIC assessment.

## A2 Potential impact classification assessment

### A2.1 Overview of the process

In accordance with DSG 2015<sup>1</sup>, the process to assess the PIC for a dam involves three main steps:

- The first step involves a dam-break flood hazard assessment. There are three levels of dam-break assessment that could be undertaken: initial, intermediate and comprehensive. Therefore, a decision must be made at the outset as to what level of assessment will be adopted. This decision is dependent on the amount of data available and the overall objective of the assessment. The process requires that the decision regarding the level of assessment be reviewed once the PIC has been determined. For this study we have completed an intermediate assessment.
- The second step involves the determination of a damage level that a dam failure event is expected to cause to private properties, critical or major infrastructure, or the natural environment as well as taking into account the anticipated recovery time following the failure incident. This second step also assesses the population at risk (PAR) that will likely be exposed to the flooding caused by a hypothetical dam failure incident.
- In the third and final step, the PIC of the dam is assigned based on the assessed damage level and the PAR in step 2.

The overall process is summarised in **Figure 8.1**. Each step is outlined in more detail in the following sections.

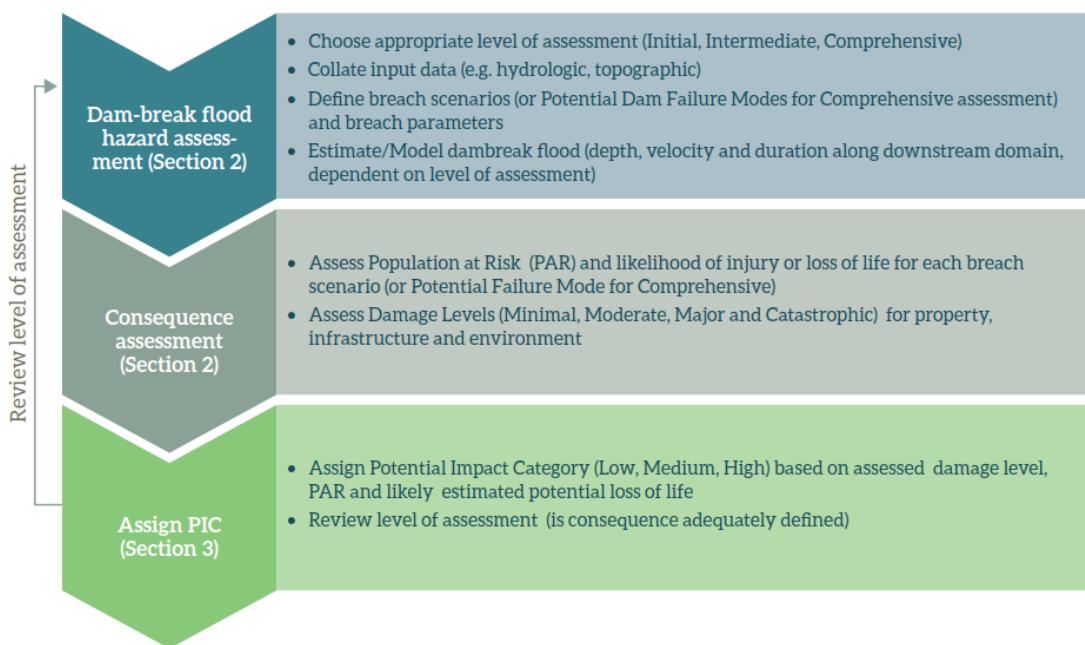


Figure 8.1: Overview of the dam classification process (extracted from NZSOLD's DSG 2015)

<sup>1</sup>New Zealand Society on Large Dams. Dam Safety Guidelines. May 2015

## A2.2 Dam-break hazard flood assessment

### A2.2.1 Methodology

An intermediate level of dam-break flood assessment was carried out for Pond 2, Pond 3 and Pond 4 dams.

HEC-HMS version 4.3 was used to simulate a cascade dam failure scenario, i.e. the ‘domino’ effect of the failure of an upstream dam causing consequential failure of downstream dams. Breach parameters used in the model for each dam were estimated using Froehlich (2008) method. Breach parameters are used in the model to simulate the failure process associated with the dam. Breach parameters include factors such as the final breach shape and the time it takes to reach the final breach shape. Froehlich (2008) method, like many other methods, uses empirical formula developed from historical dam failure cases.

It was assumed in the model:

- Pond 4 dam, the most upstream, will fail when pond water level is at primary spillway level of 85.2 mRL. Dam-break outflow from Pond 4 will then discharge into Pond 3 raising Pond 3 water level.
- Pond 3 dam will fail when water level reaches its auxiliary spillway level of 84.7 mRL. Dam-break outflow from Pond 3 will then discharge into Pond 2, the most downstream, raising Pond 2 water level.
- Pond 2 dam will fail when water level reaches its auxiliary spillway level of 78.5 mRL. Combined dam-break outflow from Pond 2 will then discharge into the downstream environment.

The combined dam-break hydrograph out of Pond 2, obtained from the HEC-HMS model was then routed through a 2 dimensional (2D) flood model to estimate the downstream dam-break flood impact. Maximum combined dam-break discharge coming out of Pond 2 was estimated at approximately 200 m<sup>3</sup>/s. The dam-break hydrograph coming out of Pond 2 is shown in Figure 8.2 below.

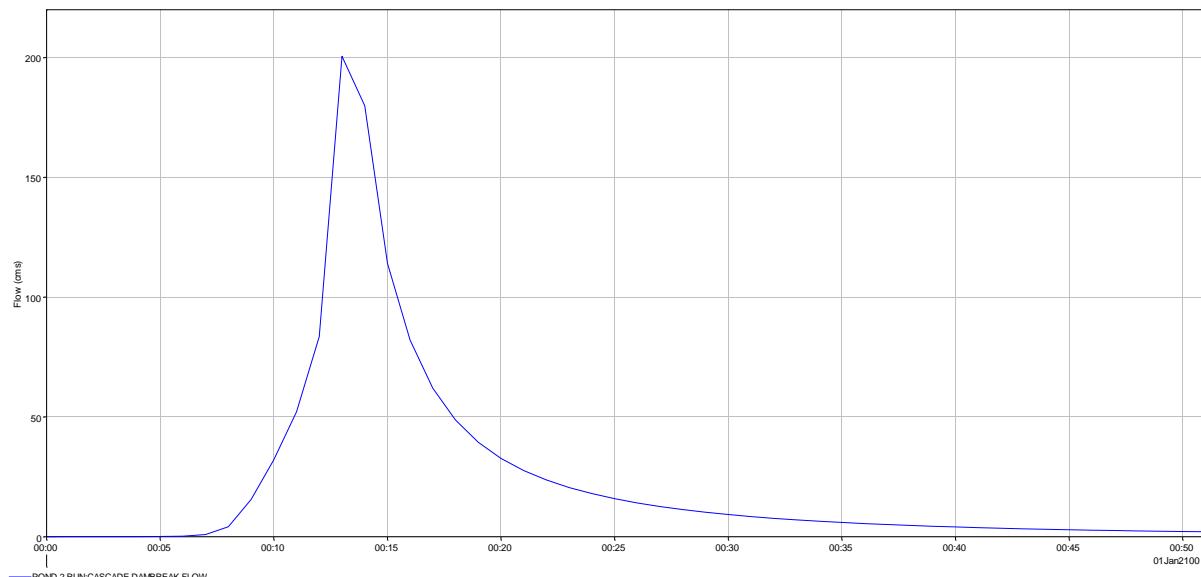


Figure 8.2: Combined dam-break flood hydrograph coming out of Pond 2 (horizontal axis showing time in minutes)

Dam breach parameters adopted for each dam are shown in **Table 8.1**.

**Table 8.1: Estimated dam breach parameters for Ponds 2, 3 and 4 dams**

Description	Pond 2	Pond 3	Pond 4
Adopted failure mode	Piping	Piping	Piping
Trigger level at time of breach (mRL)	78.5	84.7	85.2
Average breach width (m)	7.5	7	8
Breach development time (hours)	0.1	0.12	0.24
Breach side slope (1V:xH)	0.7	0.7	0.7

Figures obtained from the 2D flood model, showing estimated flood depth, velocity and flood arrival time, are provided in Appendix B.

### **A2.2.2 Findings**

Figures 1 in Appendix B shows that the dam-break flood wave, once released from Pond 2, will travel along the gully in the north, north-west direction towards the Hōteo River and flood low-lying lands nearby.

All of the dwellings identified near the potential dam-break flow path within 5 km downstream of Pond 2 are located well above the estimated flood levels and would not be affected.

The structure with the highest potential to be affected by the dam-break flood is the Springhill Airport runway. Figure 1 in Appendix B shows that low lying fields on the eastern side of the runway may be flooded; however the runway itself is unlikely to be affected.

SH1 bridge crossing the Hōteo River is unlikely to be affected by the dam-break flood. Dam-break flow is likely to be contained inside the deeply incised channel of the Hōteo River at the bridge location.

Some local roads and private access ways may be affected by the dam-break flood and the exposure of risk to traffic is considered in the assessment.

Downstream of the SH1 bridge, it is expected that the dam-break flood would have attenuated further due to depression storages on the existing ground surface, with no downstream consequences.

### **A2.3 Damage level assessment**

Table 8.2, extracted from the DSG 2015, shows the recommended damage levels in four categories, namely minimal, moderate, major and catastrophic and the assessment criteria for each category.

Once the likely flow paths had been determined from the dam-break assessment, the damage level was assessed qualitatively based on the framework outlined in Table 8.2. Population at risk (PAR) was also determined based on the estimated peak discharge and the areas of impact obtained from the dam-break assessment.

**Table 8.2: Determination of damage level (extracted from DSG 2015)**

Damage level	Specified categories				
	Residential houses <sup>1</sup>	Critical or major infrastructure <sup>2</sup>		Natural environment	Community recovery time
		Damage	Time to restore to operation <sup>3</sup>		
Catastrophic	More than 50 houses destroyed	Extensive and widespread destruction of and damage to several major infrastructure components	More than 1 year	Extensive and widespread damage	Many years
Major	4 to 49 houses destroyed and a number of houses damaged	Extensive destruction of and damage to more than 1 major infrastructure component	Up to 12 months	Heavy damage and costly restoration	Years
Moderate	1 to 3 houses destroyed and some damaged	Significant damage to at least 1 major infrastructure component	Up to 3 months	Significant but recoverable damage	Months
Minimal	Minor damage	Minor damage to major infrastructure components	Up to 1 week	Short-term damage	Days to weeks

Notes:

- 1 In relation to residential houses, destroyed means rendered uninhabitable.
- 2 Includes:
  - Lifelines (power supply, water supply, gas supply, transportations systems, wastewater treatment, telecommunications (network mains and nodes rather than local connections)).
  - Emergency facilities (hospitals, police, fire services).
  - Large industrial, commercial, or community facilities, the loss of which would have a significant impact on the community.
  - The dam, if the service the dam provides is critical to the community and that service cannot be provided by alternative means.
- 3 The estimated time required to repair the damage sufficiently to return the critical or major infrastructure to normal operation.

Based on the findings of the dam-break assessment, the damage level under a cascade failure scenario of Ponds 2, 3 and 4 is considered minimal.

No permanent PAR were identified from the dam-break assessment. Temporary PAR (e.g. people on walking tracks, farmers working on the field etc.) is expected to have a very small probability of coincidence. As a result, overall population at risk is estimated to be 0 for the purposes of this analysis.

## A2.4 Assignment of potential impact classification

Table 8.3, extracted from the DSG 2015, shows the recommended potential impact classification for various different combinations of damage level and PAR. PIC is assessed in three categories, namely Low, Medium and High.

Assignment of potential impact classification for each pond was carried out in accordance with the framework outlined in Table 8.3, using the damage level and PAR determined in Section A2.3.

**Table 8.3: Determination of dam classification (extracted from NZSOLD's DSG 2015)**

Assessed damage level	Population at risk (PAR)			
	0	1 to 10	11 to 100	More than 100
Catastrophic	High potential impact	High	High	High
Major	Medium potential impact	Medium/High (see note 4)	High	High
Moderate	Low potential impact	Low/Medium/High (see notes 3 and 4)	Medium/High (see note 4)	Medium/High (see notes 2 and 4)
Minimal	Low potential impact	Low/Medium/High (see notes 1, 3, and 4)	Low/Medium/High (see notes 1, 3, and 4)	Low/Medium/High (see notes 1, 3, and 4)

Notes:

- 1 With a PAR of five or more people, it is unlikely that the potential impact will be low.
- 2 With a PAR of more than 100 people, it is unlikely that the potential impact will be medium.
- 3 Use a medium classification if it is highly likely that a life will be lost.
- 4 Use a high classification if it is highly likely that two or more lives will be lost.

Given an assessed damage level of Minimal and a PAR of 0, Ponds 2, 3 and 4 dams are expected to have a PIC rating of **Low**.

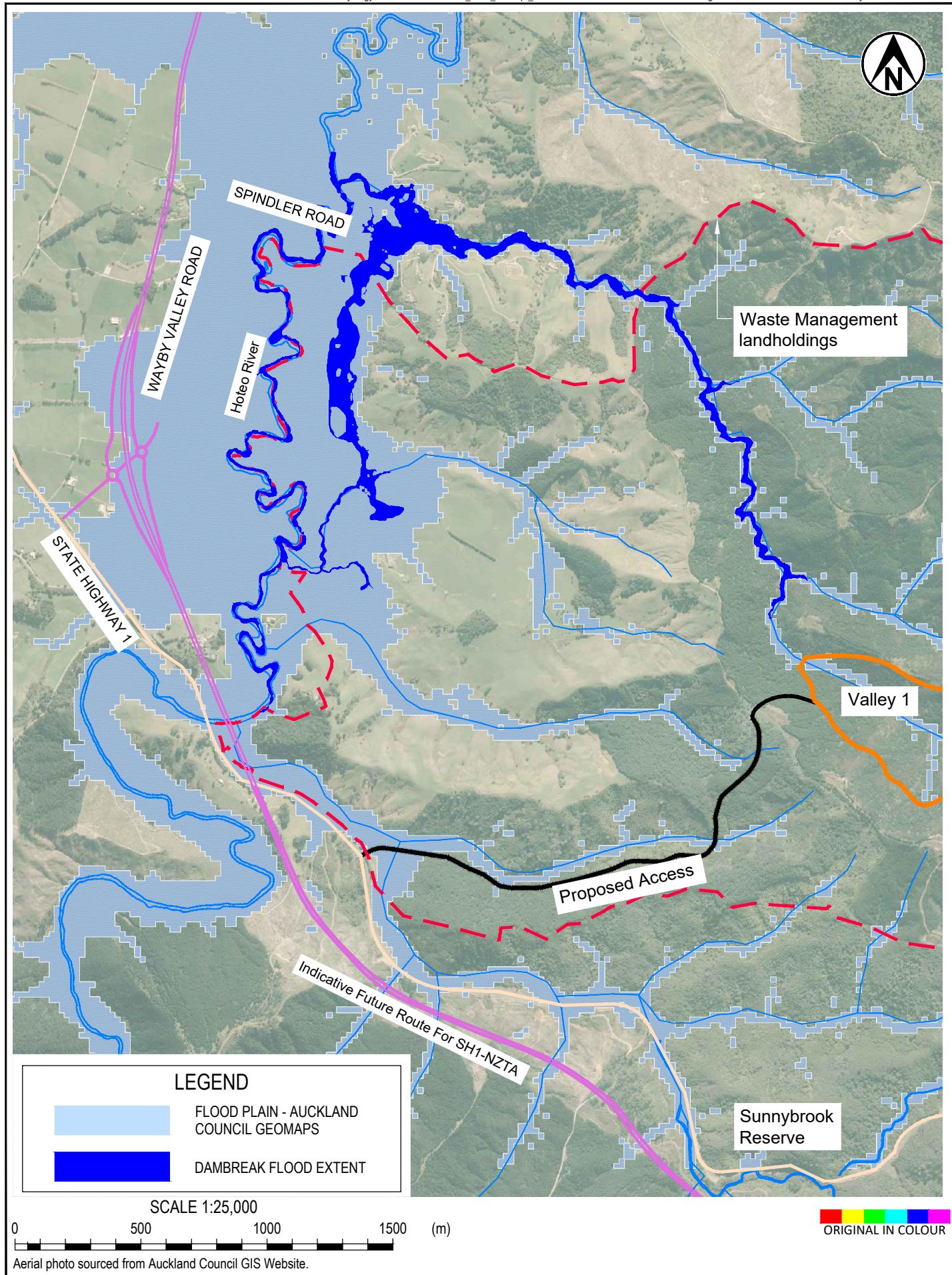
### A3 Conclusion

This report has considered a cascade (sequential) failure of Ponds 2, 3 and 4 dams during sunny day conditions. The report assesses the potential dam-break impact downstream of the dams, using conservative assumptions in accordance with an intermediate level of assessment outlined in NZSOLD DSG 2015.

Pond 2, 3 and 4 dams were assessed to have a PIC rating of **Low**.

## **Appendix B: Figure from dam-break assessment**

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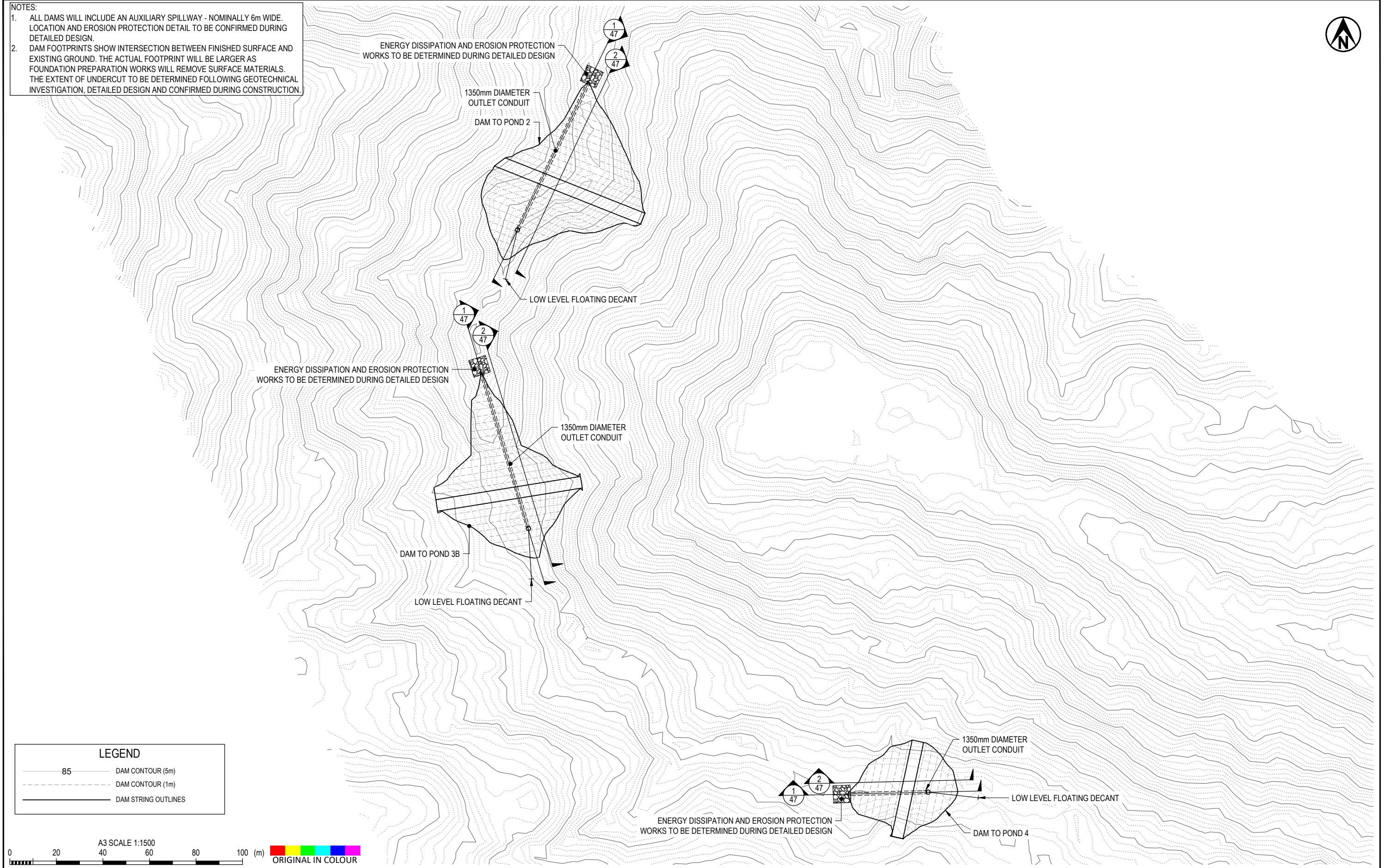
## **Appendix C: Drawing**

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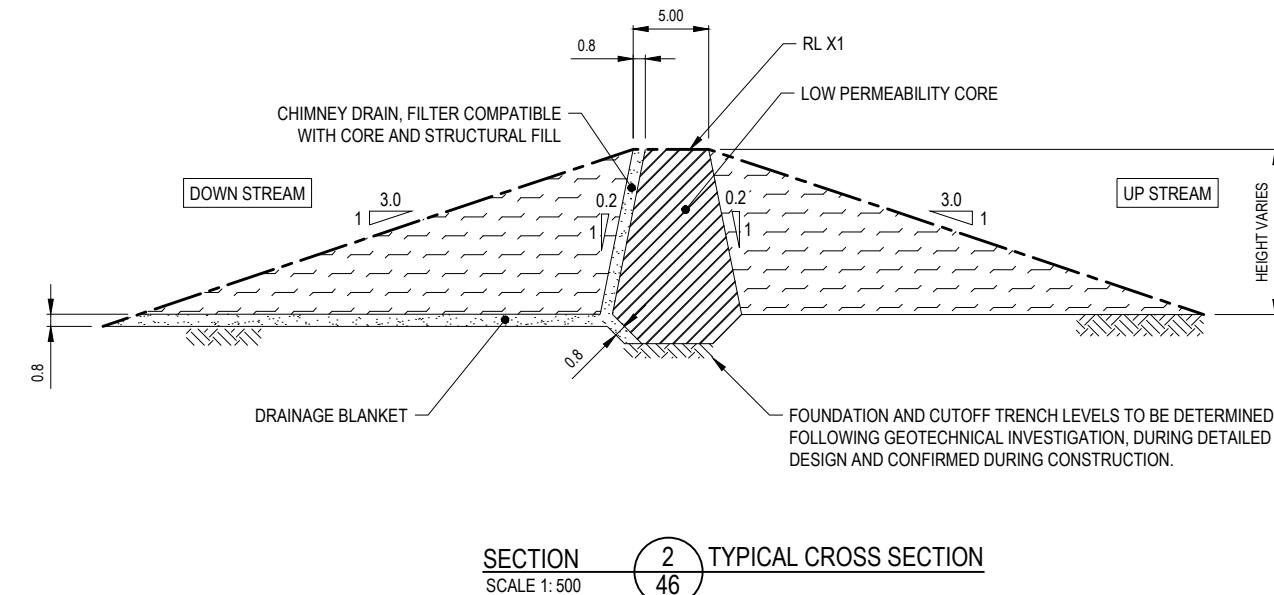
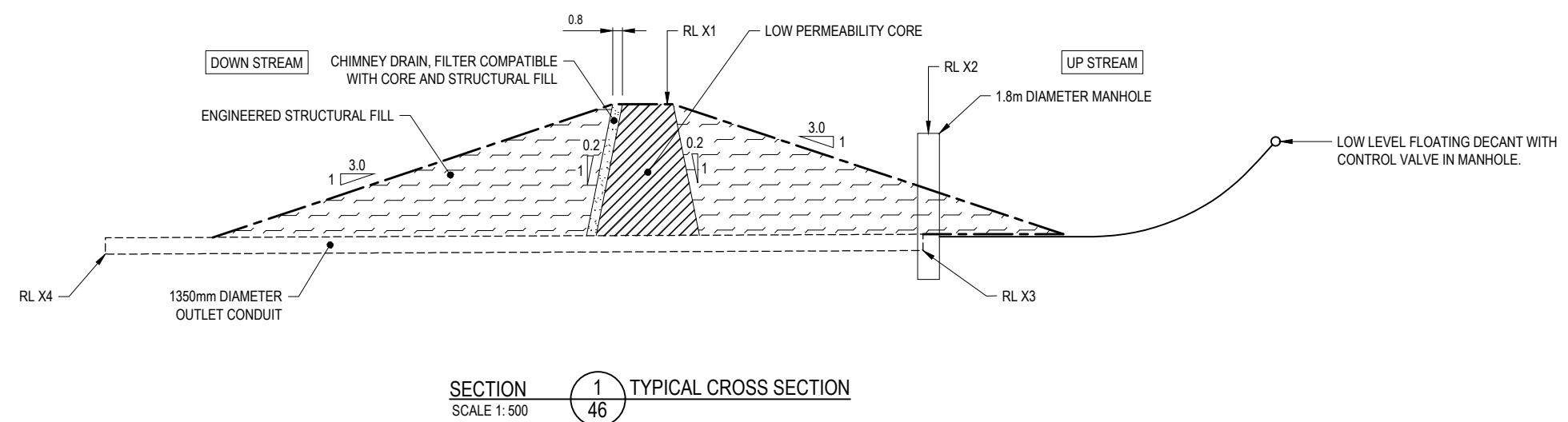


## NOTES:

- ALL DAMS WILL INCLUDE AN AUXILIARY SPILLWAY - NOMINALLY 6m WIDE. LOCATION AND EROSION PROTECTION DETAIL TO BE CONFIRMED DURING DETAILED DESIGN.
- DAM FOOTPRINTS SHOW INTERSECTION BETWEEN FINISHED SURFACE AND EXISTING GROUND. THE ACTUAL FOOTPRINT WILL BE LARGER AS FOUNDATION PREPARATION WORKS WILL REMOVE SURFACE MATERIALS. THE EXTENT OF UNDERCUT TO BE DETERMINED FOLLOWING GEOTECHNICAL INVESTIGATION, DETAILED DESIGN AND CONFIRMED DURING CONSTRUCTION.



	POND 2	POND 3B	POND 4
RL X1	80.6m	86.8m	87.4m
RL X2	78.2m	84.4m	85.2m
RL X3	68.5m	78.5m	81.5m
RL X4	68.2m	78.2m	81.2m



ORIGINAL IN COLOUR

A3 SCALE 1:500  
0 5 10 15 20 25 (m)

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