Flood Detention Dams
Comprehensive Dam Safety Review

PREPARED FOR HASTINGS DISTRICT COUNCIL | May 2021

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Stantec

Revision Schedule

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
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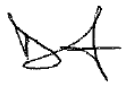
PREPARED BY		
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Executive Summary

Stantec have completed a Comprehensive Dam Safety Review of the flood detention dams in Havelock North, Clifton, and Te Awanga for Hastings District Council. The inspection of the dams was completed over 11 and 12 November 2020.

Overall, the dams were in a satisfactory condition as were the appurtenant structures. The internal condition of the dam pipework could not be inspected either due to their small size, health and safety and the presence of flowing water.

Urgent recommendations in this report relate to the safe management of floods and the condition of the throttle pipework. High Priority recommendations relate to Dam Safety Management including emergency preparedness. Other recommendations relate mainly to land ownership and access issues, surveillance, and maintenance.

All reported recommendations are provided overleaf.

2020 Dam Safety Recommendations

The dam safety recommendations from this review are separated into the following Categories:

A: Physical infrastructure issues.

B: Potential or confirmed dam safety deficiencies.

C: Non-conformances.

Each Category is rated in terms of Priority as either Low Medium or High. Practicable time frames in consideration of both the Category and Priority is provided for programming purposes.

Ref. / Report Ref.	Recommendation	Category	Priority	Time-scale
2020-1 /1.1	It is recommended that the next inspection for a CDSR is on or before 10 November 2025.	-	-	5 yr
2020-2 /2.1	A search through HDC, Hawkes Bay Regional Council, and local library archives is recommended to better understand the history and construction of the dams, especially on the details of the embankment materials.	A	Medium	2 yr
2020-3 /2.2	It is recommended that a factual report on each dam is prepared that includes the most recent topographic survey information and as-built dimensions and key levels, storage information and discharge performance for baseline records on which to base all dam safety management. Any gaps found should be filled by way of additional study and survey. Any gaps found in more complex information (hydraulics) should be filled.	B	High	1 yr
2020-4 /2.3	It is recommended that a Data Book is prepared for the dams.	C	Medium	2 yr
2020-5 /3.1	It is recommended that an assessment is made of the fitness of all the inundation maps on record and confirm what gaps are present and if necessary a new updated set of dam break inundation maps should be prepared to ensure consistency across all of HDCs detention dams.	B	High	1 yr
2020-6 /3.2	Review the historical Havelock North Dam break studies to determine if an update is required to confirm Population at Risk and Potential Loss of Life.	B	High	1 yr
2020-7 /3.3	A PIC study is recommended for the Clifton Dams that should consider Population at Risk and Potential Loss of Life.	B	High	1 yr
2020-8 /3.4	The PIC study for the Upper and Lower Te Awanga Dams is recommended to be updated to consider downstream concurrent flooding, incremental Population at Risk and Potential Loss of Life.	B	High	1.5 yr
2020-9 /3.5	Existing flood studies should be checked and updated with any new hydraulic capacity information from 2.2 if required.	B	High	1.5 yr
2020-10 /3.6	A wind-wave assessment, if not already complete should be carried out for each dam either as a standalone report or as part of any flood study updates to determine the minimum required wave freeboard.	B	High	1.5 yr
2020-11 /3.7	For flood prone structures identified following 2.2, 3.5 and 3.6, carry out high level optioneering for hazard reduction measures.	B	High	2 yr

Ref. / Report Ref.	Recommendation	Category	Priority	Timescale
2020-12 /4.1	Carry out CCTV surveys of all dams' throttle pipework to record gradient, length, and any areas of damage (open joints, cracking etc.), and any such damage repaired. The CCTV survey specification and outputs should be reviewed by a Dam Engineer for comment. Complete future CCTV inspections 5 yearly to be available for review with CDSRs.	B	High	0.5 yr
2020-13 /4.2	A specific Failure Modes and Effects Analysis has not been completed for HDC's dams and this is recommended following flood study updates.	B	Low	3 yr
2020-14 /5.1	Update the contact details of all residents and landowners who own all or parts of the land on which the flood detention structures are located. The responsibilities of HDC and residents in terms of maintenance and operation should be clarified (such as the opening of spillway livestock gates in a flood warning).	-	Medium	2 yr
2020-15 /5.2.1	Karituwhenua - it is recommended that gates or stiles are installed to enable safer crossing for inspection and maintenance purposes. Location to suit landowners and HDC.	A	Medium	3 yr
2020-16 /5.2.2	Karituwhenua - the right-hand side of the dam was very overgrown and needs better maintenance, grass cut (machine or sheep) and small trees completely removed.	B	Medium	2 yr
2020-17 /5.2.3	Karituwhenua - the crest fence was in poor condition and needs replaced. Right hand side was very overgrown and needs improved or more frequent maintenance; grass cut (machine or sheep) and small trees on the dam completely removed.	A&B	Medium	1 yr
2020-18 /5.2.4	Karituwhenua - trees in the vicinity of the dam footprint should be removed.	C	Medium	2 yr
2020-19 /5.2.5	Karituwhenua - Farm management practices should be confirmed (temporary fencing etc) and no obstructions must be allowed across the spillway structure. If a fence or gate is necessary then responsibilities for opening if there is a flood warning should be confirmed.	B	High	1 yr
2020-20 /5.2.6	Karituwhenua - The hydraulic capacity of the overflow should be checked (see also 2.2).	B	High	1 yr
2020-21 /5.2.7	Karituwhenua - Replace end of spillway conduit with a small trap/gully and buried pipe arrangement with an outlet to the downstream channel and reinstate the slope damage. In an extreme flood, significant damage would be expected at this steep drop off at the end of spillway, however it is far enough (80m or so) from the dam to not present significant risk.	A	Low	5 yr
2020-22 /5.2.8	Install a vertical auxiliary inlet pipe to the existing throttle to improve effectiveness of the system and provide greater assurance over blockage risk.	A	Medium	5 yr

Ref. / Report Ref.	Recommendation	Category	Priority	Time-scale
2020-23 /5.3.1	School Stream - It is recommended that gates or stiles are installed to enable safer crossing for inspection and maintenance purposes. Location to suit landowners and HDC.	A	Medium	3 yr
2020-24 /5.3.2	School Stream - the dam needs improved vegetation maintenance, grass cut more frequently (machine or sheep) and bushes on the dam completely removed.	A&B	Medium	2 yr
2020-25 /5.3.3	School Stream - There is a fall hazard at the outlet which could be improved by a new fence.	-	Medium	2 yr
2020-26 /5.3.4	School Stream - Several rotten timbers were noted on the spillway and these should be replaced. The hinged overflow gates across the sill of the emergency overflow were operable but should be checked during routine surveillance visits.	B	Medium	2 yr
2020-27 /5.3.5	School Stream - The need for the spillway gates should be confirmed and it is recommended they should be removed or replaced by a fixed fence set well upstream of the overflow and below the level of the overflow sill.	B	Medium	2 yr
2020-28 /5.3.6	School Stream - The hydraulic capacity of the overflow should be checked (see also 2.2).	B	High	1 yr
2020-29 /5.4.1	Te Kahika - It is recommended that gates or stiles are installed to enable safer access for inspection and maintenance purposes. Location to suit landowners and HDC.	A	Medium	3 yr
2020-30 /5.4.2	Te Kahika - Developing potholes and damage noted on the crest (road surface) should be repaired.	A	Medium	2 yr
2020-31 /5.4.3	Te Kahika - The need for the spillway gate should be confirmed and it is recommended it should be removed or replaced by a fixed fence set well upstream of the overflow and below the level of the overflow sill	B	Medium	2 yr
2020-32 /5.4.4	Te Kahika - The hydraulic capacity of the overflow and stepped timber channel should be confirmed by calculation and if it is shown to be under capacity then the spillway should be considered for improvement (See also 2.2).	B	High	1 yr
2020-33 /5.4.5	Te Kahika - A new bridge deck and parapet system is recommended along with an assessment of structural capacity and appropriate bridge weight limits provided on road signs.	A	Low	5 yr

Ref. / Report Ref.	Recommendation	Category	Priority	Time-scale
2020-34 /5.5.1	Mangarau - It is recommended that gates or stiles are installed to enable safer crossing for inspection and maintenance purposes. Location to suit landowners and HDC.	A	Medium	3 yr
2020-35 /5.5.2	Mangarau - Some bare patches and livestock damage noted at the true dam and the natural dam crest and downstream slope which should be repaired. Grass maintenance needs improved. It is not consistent along the full length of the dam. Trees on the dam must be removed.	A&B	High	1 yr
2020-36 /5.5.3	Mangarau - The make-up of the natural dam is apparently unknown and should be investigated (archive search followed by ground investigation) to confirm its make-up and ability to safely impound water.	B	Medium	3 yr
2020-37 /5.5.4	Mangarau - A large wooden post was lodged vertically at the upstream end of the pipe and this should be removed.	A&B	High	1 yr
2020-38 /5.5.5	Mangarau - It is recommended that the CCTV survey at Mangarau is prioritised over the other dams due to turbulence heard at the outlet suggesting something is disturbing the flows. (See also 4.1)	B	High	0.5 yr
2020-39 /5.5.6	Mangarau - General debris in the downstream channel at the confluence point of the spillway channel should be cleared.	A	Low	5 yr
2020-40 /5.5.7	Mangarau - The hydraulic capacity of the overflow and channel should be confirmed by calculation and if it is shown to be under capacity or to present a risk to the natural dam abutment, then the spillway should be considered for improvement.	B	High	1 yr
2020-41 /5.6.1	Here Here - It is recommended that gates or stiles are installed to enable safer crossing for inspection and maintenance purposes. Location to suit landowners and HDC.	A	Medium	3 yr
2020-42 /5.6.2	Here Here - Grass on the dam was very long and needs improved maintenance, (machine or sheep).	A&B	Medium	2 yr
2020-43 /5.6.3	Here Here - A large bush was growing in front of the trash screen and this should be removed.	A&B	Medium	2 yr
2020-44 /5.6.4	Here Here - The hydraulic capacity of the overflow and channel (including consideration of the closed gate downstream and the fence / vegetation) should be confirmed by calculation and if it is shown to be under capacity or to present a risk to the dam, then the spillway should be considered for improvement. The bend and tapering at the start of the channel should be considered within this calculation to confirm the location of the hydraulic control which may be downstream of the concrete sill. (See also 2.2).	B	High	1 yr

Ref. / Report Ref.	Recommendation	Category	Priority	Time-scale
2020-45 /5.7.1	Clifton - Some improvements are recommended with respect to periodically cutting back vegetation at the sides of the 4x4 vehicle access track over the initial few hundred metres of track.	A&B	Medium	2 yr
2020-46 /5.7.2	Clifton - Cattle damaged areas on the dams should be repaired. It is recommended that cattle are prevented from accessing the dams by installing fencing.	A&B	High	1 yr
2020-47 /5.7.3	Clifton - Small box sized trash screens are recommended to be installed to prevent blockage.	B	Medium	3 yr
2020-48 /5.7.4	Clifton - The outlet channel at the Motor Camp should be continued through the earthworks to the beach.	A	Medium	3 yr
2020-49 /5.7.5	Clifton - A cattle drinking pond perched at the top of the hill above the Western Dam is in a state of gradual failure and this should be monitored for worsening condition and repairs or demolition works carried out as required to reduce the risk to the Western Dam i.e. if the pond fails and materials slip down and inundate and damage the Western Dam.	B	Medium	2 yr
2020-50 /5.7.6	Clifton - The hydraulic capacity of the overflows and channels should be checked. The resilience (erosion resistance) of the Lower Central dam overflow should be appraised. (See also 2.2).	B	High	1 yr
2020-51 /5.7.7	Clifton - A webcam or similar means of remote surveillance is recommended if PIC study shows that the dams present a significant risk to the Clifton Motor Camp.	-	Low	5 yr
2020-52 /5.9.1	Te Awanga Upper - A preferred access route to the dam should be agreed with the landowner and defined accurately on a plan of the area.	A	Medium	3 yr
2020-53 /5.9.2	Te Awanga Upper - The outflow characteristics of the on-catchment lakes to the west of the dam should be investigated and incorporated into hydrological studies as this might affect the outputs of existing flood studies at this dam.	B	High	1 yr
2020-54 /5.9.3	Te Awanga Upper - carry out a CCTV survey of the downstream culvert drop shaft structure. This also requires a portable pump. (See also 4.1). Install a safety screen to the Outlet to Charlton Stream.	A	High	0.5 yr
2020-55 /5.9.4	Te Awanga Upper - The hydraulic capacity of the overflow should be confirmed and if it is shown to be under capacity or to present a risk to the dam (erodibility), then should be considered for improvement.	B	High	1 yr
2020-56 /5.9.5	Te Awanga Upper - Given the remoteness of the site and the current perceived flood risk, a similar water level / rainfall measurement system as used at the Havelock North Dams is recommended. Such a system is not considered to be required for Te Awanga Lower given it is on the same catchment.	A	Medium	2 yr

Ref. / Report Ref.	Recommendation	Category	Priority	Timescale
2020-57 /6.1	Update Surveillance and Monitoring as follows; a) set up trigger warning systems for rainfall (>100m in 24hrs) and water level (>1.5m) b) set up a system to receive earthquake alerts from GeoNet, and a system to trigger an inspection depending on severity of the shaking (MMI 5 and above felt at the dam based on interpolation of felt reports). c) Install permanent settlement monitoring pins on the Havelock North and Te Awanga dams' crests. Carry out a baseline survey, then again after 1 year, then every 5 years after that. d) carry out CCTV surveys at 5 yearly intervals or sooner if there is suspected damage or after an impounding event.	-	n/a	2 yr
2020-58 /6.2	Download all monitoring data (rainfall and water depth) monthly to a spreadsheet and review this data monthly.	-	n/a	1 yr
2020-59 /6.3	Download monthly records from Kopanga rain gauge (HBRC) to compare with HDC data.	-	n/a	2 yr
2020-60 /6.4	It is recommended that all rain gauges are location verified, checked, and calibrated to ensure accurate data capture. Certificates of calibration should then be maintained with the rest of the dam data in the Data Book.	A	Medium	2 yr
2020-61 /7.1	Review the OMS manual for the dams annually and update as required.	-	n/a	1 yr
2020-62 /7.2	It is recommended that an Emergency Action Plans (EAP) should be prepared for each dam.	C	High	1.5 yr

1.0 INTRODUCTION

Stantec New Zealand have completed a Comprehensive Dam Safety Review (CDSR) of eight flood detention dams for Hastings District Council (HDC).

The locations of the dams are described in Table 1. The dams have historically been considered to have the Potential Impact Classifications (PIC) as also shown in Table 1.

Table 1 - HDC Dams

Dam Name	Height	Location	PIC
Karituwhenua Dam	9m	Havelock North, Fulford Rd. 39°40'50.32"S, 176°54'24.27"E	High
School Stream Dam	12m	Havelock North, TeMata Peak Rd. 39°41'4.72"S, 176°53'58.66"E	High
Te Kahika Dam	13m	Havelock North, Tauroa Rd. 39°41'9.89"S, 176°53'43.89"E	High
Mangarau Dam	11m	Havelock North, Keirunga Rd. 39°41'5.89"S, 176°53'15.06"E	High
Here Here Dam	12m	Havelock North, Margaret Ave. 39°41'22.13"S, 176°52'23.84"E	High
Clifton Domain Dams – Western – Upper Central – Lower Central – Eastern	 2m 1.5m 2m 3m	Clifton, hills above Clifton Domain. 39°38'31.74"S, 177° 0'25.73"E 39°38'32.89"S, 177° 0'32.19"E 39°38'31.76"S, 177° 0'31.10"E 39°38'30.56"S, 177° 0'35.81"E	All 4 dams are not Large Dams as defined in the Building Act; however, they have previously been considered Low PIC. A dam break analysis has not been carried out.
Lower Te Awanga Dam	5m	Te Awanga, Clifton Rd. 39°38'16.43"S, 176°58'50.56"E	Medium
Upper Te Awanga Dam	3m	Te Awanga, Cape Estate 39°38'54.27"S, 176°58'36.12"E	Medium

The New Zealand Society on Large Dams (NZSOLD) New Zealand Dam Safety Guidelines (2015) recommends that a CDSR is completed every 5 years for Medium and High PIC dams.

NZSOLD (2015) outlines that a CDSR "is a comprehensive, periodic, independent review of the design, construction, operation and performance of a dam, and all systems and procedures that affect dam and reservoir safety, against current dam safety guidelines, standards and industry practice. The CDSR should identify any dam safety issues and categorise them into physical infrastructure issues, potential or confirmed dam safety deficiencies, and non-conformances."

The most recent CDSR was in 2015 (MWH 2016). That report was reviewed for background information on the dams, and for an understanding of the dam safety issues and recommendations at that time. This report is within 5 years of the previous CDSR and hence is in accordance with the NZSOLD Guidelines. **It is recommended that the next inspection for a CDSR is on or before 10 November 2025.**

This report covers the CDSR Stantec has completed, with the focus on confirming safe dam performance and identifying dam safety issues.

This report covers the following sections:

- A review and summary of relevant background information on the dams.
- A review of the Potential Impact Classifications.
- A review of potential failure modes.
- Observations and photographs (Appendix A-H) taken during the site inspections.
- A review of surveillance data and other salient information.

- A review of the Dam Safety Management System, including operation and maintenance, surveillance, appurtenant structures and gate and valve systems, dam safety reviews, special inspections, and emergency preparedness.
- The identification of any dam safety issues during the inspections and review, including any potential or confirmed dam safety deficiencies.

References to left and right in this report are based on the observer looking in a downstream direction.

2.0 RELEVANT INFORMATION

The following have been reviewed as part of this CDSR.

- Routine inspection sheets / monitoring records (2015 to 2020, HDC).
- 2015 Comprehensive Dam Safety Review (MWH 2016).
- Havelock North Flood Detention Dams - Hydrology and Flood Capacity Review (MWH 2015).
- Latest Intermediate Dam Safety Review (Stantec 2019).
- Clifton Dams Flood Study (Stantec 2020).
- Te Awanga Dams Flood Assessment (Stantec, 2019).
- Te Awanga Dams Dam Break and PIC Assessment (Draft, Stantec 2019).
- Flood Detention Dams - Operation, Maintenance, and Surveillance Manual (Stantec 2020).
- HBRC Flood hazard maps, https://hbmaps.hbrc.govt.nz/hazards/
- Historical drawings and other relevant historical information (HDC).
- Te Kahika and School Stream structural Condition assessment (Stantec 2018).

No CCTV surveys of the dam pipework had been carried out prior to writing this report and no comment can be made on the condition of the pipework.

2.1 THE DAMS AND RESERVOIRS (INCLUDING HISTORY AND CONSTRUCTION)

All eight dams are typically homogeneous embankment flood detention dams with a concrete pipe through the base of the dam to pass normal daily flow and to throttle flood flows. The dams appear to have been designed to throttle back the 1 in 100 annual exceedance probability (AEP) flood and protect the downstream communities of Havelock North, Te Awanga and Clifton. On six of the dams, a vertical stack pipe exists at the upstream end of the culvert as a secondary intake (if the main inlet is blocked). All dams except for the Western Dam at Clifton have an emergency overflow arrangement to safely pass floods that are greater than the intended design capacity. A pressure transducer at the culvert entrance of the Havelock North dams allows reservoir levels to be telemetered to Hastings District Council. Rainfall data is also supplied by telemetry for these dams. The dams at Te Awanga and Clifton have no such monitoring facilities.

The dates of construction are not accurately known, but it is inferred from the dates on historical drawings that the majority would have been designed and constructed between the late 1970's through the early 1980's. Some major repairs were carried out in the 1990's and 2000's. Over the last 20-years the construction of Te Awanga Lower has been undertaken, but little else in terms of major upgrades. Table 2 summarises the history that has been inferred based on the information reviewed.

Table 2 – Dam Details and Background

Dam	Construction Date	Key Construction Details	Significant Upgrades
Karituwhenua	~1981	Unspecified materials make up the dam, presumably locally won alluvium. Precast jointed concrete throttle pipe with an auxiliary vertical intake. Uncontrolled spillway, trapezoidal grass lined earth channel and controlled section, no concrete overflow sill.	1993 - throttle pipework repairs; cracks and joint repairs, apparently related to settlement of the dam.
School Stream	~1981	Unspecified materials make up the dam, presumably locally won alluvium. Precast jointed concrete throttle pipe with an auxiliary vertical intake. Uncontrolled spillway, concrete trapezoidal control structure, steep timber stepped spillway channel just off the right-hand groin of the dam.	2000 – dam raised; spillway reconstructed.
Te Kahika	~1984	Unspecified materials make up the dam, presumably locally won alluvium. The dam has a vertical cut-off at the upstream end through pumice and limestone strata. There are filter drains extending into the dam body from the downstream toe. Steeply graded precast jointed concrete throttle pipe and auxiliary vertical intake with concrete seepage collars and downstream seepage filter pipework. The throttle pipe is bedded on concrete with an auxiliary vertical intake. Uncontrolled spillway, concrete rectangular channel control structure, steep timber stepped spillway channel in right hand groin of the dam. Vehicular bridge over spillway; unknown weight limit.	2020 – right-hand spillway side wall repaired by installation of new timbers against the original damaged timbers which have been left in-situ.
Mangarau	~1982	Unspecified materials make up the dam, presumably locally won alluvium. The true dam appears to be an add-on at the left abutment of an apparently 'natural' or historical embankment feature which is also of unknown materials. Precast jointed concrete throttle pipe with concrete seepage collars on a steep grade bedded on concrete with auxiliary vertical intake. Uncontrolled spillway off-dam comprising a trapezoidal grass lined channel, and concrete control section within the right abutment of the 'natural' embankment dam feature.	1988 - Some drainage works carried out to transfer flows near and downstream of right abutment to behind the dam. Rock protection added downstream of throttle pipe outlet.

Dam	Construction Date	Key Construction Details	Significant Upgrades
Here Here	~1984	Unspecified materials make up the dam, presumably locally won alluvium. Precast jointed concrete throttle pipe with concrete seepage collars and downstream seepage filter pipework on a shallow grade bedded on concrete with auxiliary vertical intake. Uncontrolled spillway off-dam (left abutment), trapezoidal grass lined earth channel and concrete sill control section.	No known upgrades carried out.
Clifton Domain Dams Western Upper Central Lower Central Eastern	1980's	Unspecified materials make up the 4 dams, presumably locally won alluvium. Small diameter plastic throttle pipes in each. No overflow on Western dam. Uncontrolled overflow off-dam for the upper central and eastern dams. Uncontrolled spillway on-dam crest for the lower central dam. No screens on throttle pipework.	Ad-hoc repairs to embankments due to cattle damage.
Lower Te Awanga	~2010	Unspecified materials make up the dam, presumably locally won alluvium. Precast jointed concrete throttle pipe on a shallow grade with auxiliary vertical intake. Uncontrolled concrete overflow on-dam, downstream trapezoidal grass lined earth channel, with gabion basket check dams downstream.	No known upgrades carried out.
Upper Te Awanga	1980's	Unspecified materials make up the dam, presumably locally won alluvium. Dam is effectively in 3 sections (west, central, and east) that form a single structure. The as-built details do not reflect the historical drawings. Precast jointed concrete throttle pipe on a shallow grade with no auxiliary intake on the central main dam structure. Plastic throttle pipe on the east dam structure. Uncontrolled overflow on-dam (a notch in the crest at the interface between the west and central dams), downstream trapezoidal grass lined earth channels.	No known upgrades carried out.

Given the lack of historical data on the dams (confirmed as-built records, material specifications etc) **a search through HDC, Hawkes Bay Regional Council (HBRC), and local library archives is recommended to better understand the history and construction of the dams, especially on the details of the embankment materials.**

Various topographic surveys have been completed over the last few years at the dams to confirm dam and spillway details for the purposes of carrying out flood and dam break studies. **It is recommended that the most relevant and recent of these surveys are collated and presented in a short factual report for each dam that confirms all as-built dimensions and levels, storage information and discharge performance for baseline records on which to base all dam safety management. Any gaps found in level or dimensional data should be filled by way of additional survey.**

The report on each dam should summarise the following to an appropriate degree of accuracy.

- Outlet pipe details (material / diameter) and invert levels.
- Dam crest levels (minimum and typical range of crest level).
- Spillway levels and channel dimensions and emergency overflow control levels.
- Detention dam depth-storage & surface area curves up to emergency overflow level and dam crest level.

- Catchment area.
- Discharge rating curves that include the flows from both throttle pipes and emergency overflows at a range of reservoir levels up to spillway level and dam crest level.
- Relevant historical drawings.
- Dam construction data.

Discharge from the throttle pipes and emergency overflows will undoubtedly require some additional hydraulic calculations to confirm the rating curves and should take cognisance of downstream effects that might have a backwater effect on the overflows' ability to discharge.

Spillways for School Stream and Te Kahika will undoubtedly require hydraulic capacity checks, since out of channel flow could cause damage to the surrounding land. In the case of Te Kahika this could seriously impact upon dam safety based on its location in the right-hand groin of the dam.

It is understood that most of this information is present across various reports, however it should be collated for all dams and retained in a report for each dam for ease of reference.

It is recommended that a Data Book is prepared for the dams. A data book could be a hard copy or soft copy file system that contains all relevant information for the dams; investigation data and reports, studies, design reports and drawings, as-built drawings, topographic surveys, construction photographs and construction reports, commissioning reports, operation, maintenance and surveillance procedures, surveillance records and relevant operation and maintenance records, event or incident reports and records of any changes to components or operations, and previous inspection and safety review reports. This is recommended to register and store all the historical information, inspection reports and monitoring data. This would be a useful reference for the development and maintenance of the dam safety management system and would be particularly useful for subsequent IDSRs and CDSRs and as a go-to source of documents for preparing Emergency Management Plans.

The data book preparation will also help identify any information gaps and where this information can be looked to be gathered over time e.g. embankment material properties.

As a guide, a folder referencing system might comprise a folder for each dam and common folders for 'all dams' 'Te Awanga Dams' and 'Havelock North Dams' since there are numerous historical reports that bundle together the structures in these groups.

3.0 POTENTIAL IMPACT CLASSIFICATION

The five Havelock North dams have been previously assessed as High Potential Impact Classification (PIC) based on the downstream Population at Risk (PAR). The author agrees with the PIC assessment. As far as it is understood there has been no further study to confirm Potential Loss of Life and hence determine an appropriate inflow design flood AEP. Given the downstream population and previously reported hydraulic deficiencies identified with the structures, **this is recommended** and will help the development of Emergency Action Plans for the dams. However, **it is first recommended that a review of all dam break inundation mapping prepared to date is carried out to determine what further study is required to confirm PAR and Potential Loss of Life and determine an appropriate level of flood protection**. A prudent approach, given the number of houses expected to be destroyed (Table 3), would be to assume the highest level of protection. i.e. to be able to safely pass the PMF at these five dams.

A PIC study has been previously recommended for the Clifton Dams but it is understood that this has not yet been carried out to confirm the classification of the dams as Low, Medium, or High. These dams, by comparison with the others in the area, store only a small volume of water. However, the dams are perched high above and within a few hundred metres of Clifton. Even a small volume of water, uncontrollably released at this location, has the potential to destroy one or two properties in the community (Clifton Motor Camp) below the dams and hence could merit to be treated as High PIC even if the dams were not considered to be Large Dam structures in accordance with the Building Act. Given the infrequent monitoring of the dams, it is entirely possible that one of the small diameter throttle pipes could get blocked by vegetation or debris and the dam fill with water. **A PIC study (PAR and Potential Loss of Life) is therefore recommended for the Clifton Dams** and will help determine the path of the water and which properties would be at risk. The PIC study would help inform the development of Emergency Action Plans, and any requirements for improved monitoring (e.g. a webcam, since a visual assessment might be more appropriate for this site rather than setting up level/rainfall recorders and connecting to the SCADA system).

A preliminary PIC study of the Te-Awanga Upper and Lower dams has recently been carried out which confirms that both dams are considered to be Medium PIC. **This study is recommended to be updated to consider downstream concurrent flooding and Potential Loss of Life.** This is essential to determine an appropriate inflow design flood since the Upper Dam is reportedly a dangerous dam with respect to flooding as it cannot safely pass the 1 in 50 AEP flood. The study will also help inform the development of Emergency Action Plans.

Regardless of the actual PIC of all the dams, HDC carry out monthly surveillance. The dams are inspected (IDSRs and CDSRs) at the recommended frequency for High PIC structures.

HBRC hazard maps (https://hbmaps.hbrc.govt.nz/hazards/) show potential breach inundation zones from a theoretical breach of all the detention dams in the region. It is not understood how these inundation zones have been developed, however they appear to be highly optimistic, and it is anticipated based on experience that dam breaks, especially in Havelock North, would create a much greater zone of inundation than shown in the HBRC hazard maps.

Given that various dam break reports have been prepared over the last 10-15 years, **it is recommended that an assessment is made of the fitness of the inundation maps on record to confirm what gaps are present and if required, a new updated set of dam break inundation maps should be prepared to ensure consistency across all of HDC's detention dams.** Updated mapping using current GIS technology and recent LIDAR will also help capture any new developments in the areas and incorporate improved ground surface mapping. Updated inundation maps combined with the identification of properties at risk will then help the production of an Emergency Action Plan for each of the dams.

A summary of all dam break and PIC studies carried out at the dams is presented in Table 3. A similar table has been prepared for all flood studies carried out to date (Table 4) as this is directly related to PIC in terms of the appropriate flood inflow AEP that is required to be passed safely. It is noted that all these studies generally recommend further work.

Table 3 – PIC and Dam Break Studies

Dam	Dam break and PIC Study Date	Summary of Conclusions
Karituwhenua Dam.	2005 & 2011	High PIC dam. 2 houses destroyed. Population at Risk (PAR) of 11. Community recovery time is likely to be years. The overall damage level is assessed to be major. Critical and major Infrastructure (schools, roads, farmland) is impacted.
School Stream Dam.	2005 & 2011	High PIC dam. 4 houses destroyed. Population at Risk (PAR) of 13. Community recovery time is likely to be years. The overall damage level is assessed to be major. Critical and major Infrastructure (schools, roads, farmland) is impacted.
Te Kahika Dam.	2005 & 2011	High PIC dam. 19 houses destroyed. Population at Risk (PAR) of 89. Community recovery time is likely to be years. The overall damage level is assessed to be major. Critical and major infrastructure (roads, farmland) is impacted.
Mangarau Dam.	2005 & 2011	High PIC dam. 10 houses destroyed. Population at Risk (PAR) of 364. Community recovery time is likely to be years. The overall damage level is assessed to be major. Critical and major Infrastructure (bridges, roads, farmland) is impacted.
Here Here Dam.	2005 & 2011	High PIC dam. 40 houses destroyed. Population at Risk (PAR) of 121. Community recovery time is likely to be years. The overall damage level is assessed to be major. Critical and major Infrastructure (schools, roads, farmland) is impacted.
Clifton Domain Dams – Western, – Upper Central, – Lower Central, – Eastern.	n/a	A dam break and Potential Impact Classification assessment is required for the Clifton Dams.
Lower Te Awanga Dam.	2020	Medium PIC dam. Population at Risk (PAR) of 20. It was determined that it is not “highly likely that a life will be lost”.
Upper Te Awanga Dam.	2020	Medium PIC dam. Population at Risk (PAR) of 40. It was determined that it is not “highly likely that a life will be lost”.

Table 4 - Flood Studies Carried Out to Date

Dam	Flood Study Date	Summary of Conclusions and Recommendations in these reports
Karituwhenua Dam.	2015	High PIC dam fails to safely pass minimum inflow design flood of 1 in 10,000 AEP. Carry out high level assessment of improvements required to overflows / dam to safely pass floods.
School Stream Dam.	2015	High PIC dam reportedly can just pass the maximum inflow design flood (PMF), but there is no residual freeboard for waves.
Te Kahika Dam.	2015	High PIC dam reportedly can pass the minimum inflow design flood of 1 in 10,000 AEP but not PMF.
Mangarau Dam.	2015	High PIC dam fails to safely pass minimum inflow design flood 1 in 10,000 AEP. Carry out high level assessment of improvements required to overflows / dam to safely pass design flood.
Here Here Dam.	2015	High PIC dam fails to safely pass minimum inflow design flood of 1 in 10,000 AEP. Carry out high level assessment of improvements required to overflows / dam to safely pass an appropriate design flood.
Clifton Domain Dams – Western, – Upper Central, – Lower Central, – Eastern.	2020	The Western Dam can just contain the 10,000 AEP flood, but not the PMF. The Western Dam has no emergency spillway. All other dams can just contain the PMF.
Lower Te Awanga Dam.	2020	Medium PIC dam fails to safely pass minimum inflow design flood of 1 in 1,000 AEP. Carry out high level assessment of improvements required to overflows / dam / downstream area to safely pass the appropriate design flood (probably 1 in 10,000 AEP).
Upper Te Awanga Dam.	2020	Medium PIC dam fails to safely pass minimum inflow design flood of 1 in 1,000 AEP. Carry out high level assessment of improvements required to overflows / dam / downstream area to safely pass the appropriate design flood (probably 1 in 10,000 AEP). Note this is a current Stantec project. Investigate the outlet and consider the effects of the large waterbodies in the catchment and their ability to attenuate the flood inflows and hence reduce the effects of flooding at the detention dams.

In summary, based on a review of all the studies carried out to date, all the dams except for Clifton Domain and School Stream appear to be under-capacity with respect to emergency discharge capabilities (design flood capacity, or performance criteria, based on the dams' PIC). The most onerous of these are Mangarau, Karituwhenua, and Here Here. These 3 dams have populations downstream and failure of any one of these could lead to widespread inundation, destruction of property and more than likely cause fatalities. The five Havelock North dams' catchments are directly adjacent to each other therefore it is likely that all could experience the same extreme flood at the same time putting a very high, cumulative population of greater than 500 people at risk. Therefore, it is likely following analysis that the Havelock North dams will have to be capable of safely passing the Probable Maximum Flood however this can be confirmed by an assessment of Potential Loss of Life. It is noted that some of the dams possess overflows which are likely, based on their individual geometries and characteristics, to have capacities less than currently assessed. An example is Te Kahika, where the 6.5m wide bridged overflow tapers to ~4m wide with little drop in level to otherwise compensate for the channel narrowing. Flow then cascades down a steep wooden stepped spillway in the right-hand groin of the dam.

The following vulnerabilities to Te Kahika's hydraulic capacity are anticipated based on a detailed review of the site and the spillway geometry from historical drawings.

- Substantial steel bridge beams that may constrict flows.
- Channel narrowing over a flat graded section that may cause a choke and alter the location of the hydraulic control.

- Presence of a livestock gate across the spillway which, if not opened in an extreme flood, will exacerbate flood rise and increase the risk of dam overtopping (waves), overflowing (still water flood rise), and failure.
- Steep, stepped timber spillway that will encourage significant turbulence and out-of-channel flow that might put the dam in danger during an event less than the PIC based inflow design flood event.

The latest flood study (MWH 2015) estimated the Te Kahika dam crest emergency spillway flood capacity to be in the order of 35m^3/s based on zero residual freeboard and a basic 1-D computer model of the surveyed overflow width. However, the capacity is expected to be ~20% less, hence a detailed hydraulic review of the emergency overflow capacity as part of an earlier recommendation in this report is crucial to understanding behaviour during extreme flood. The emergency overflow capacity for all dams is to be determined by way of producing a stage discharge curve for each structure that considers the overflow and spillway geometry and any other factors that are likely to limit the capacity such as bridges, fences, closed gates or vegetation. These rating curves should be compared against the existing flood study information to determine if the flood capacity is less than currently assessed. Flood studies should then be updated to include this information and update the likely dam crest flood return period as well as reviewing wave freeboard. It is suggested that the dams are sorted into a high-level priority order and flood studies completed as separate reports, rather than grouped together.

Wave freeboard is a key consideration for embankment dams and including flood detention structures. Concurrent high winds during a flood is entirely plausible. The NZSOLD Guidelines recommend a minimum freeboard of 900mm should be allowed for wave run up, however this is a very general recommendation, and for small area reservoirs such as these, with very limited fetch, the wind generated waves will be quite small. **A wind-wave assessment should be carried out and should consider wave overtopping in accordance with current guidance[1] taking cognisance of downstream slope erosion resistance to determine the minimum acceptable freeboard required for waves.**

Once this exercise is complete, it is recommended to take, in order of priority, the highest hazard dams and prepare outline options to reduce the current level of hazard. This might include dam crest (or spillway crest level) lowering or raising, downstream face erosion protection, enlargement of throttle pipes and enlargement of spillways (or full replacement or supplementary spillways).

The highest priority recommendations in this report centre around collating as-built dam records, understanding hydraulic capacity, flooding, and PIC, and EAPs.

It is therefore suggested, given the current risk to the downstream population that the highest risk dams; Mangarau and Here Here, are selected first in order to;

1. Gather the pertinent as-built information and topographic surveys,
2. Review the hydraulic capacity of the overflows and prepare stage-discharge curves up to and beyond the dam crest, then,
3. Carry out wind-wave assessments at reservoir full conditions, then,
4. Update flood studies if required and model appropriate flood routing scenarios, e.g. 1 in 100, 1,000, 10,000 AEP and PMF, then
5. Carry out additional dam break modelling in consideration of appropriate downstream concurrent flooding scenarios[2] to determine the worst-case incremental PAR and Potential Loss of Life then
6. Explore high level options to improve upon the current situation, if required.

On the basis that most of this information appears to be present in some form, it should not be a complicated task to complete tasks 1-5 for all the dams in order of apparent hazard and flood prone priority, e.g. tentatively

1. Mangarau.
2. Here Here.
3. Te Kahika.
4. Karituwhenua.
5. School Stream.
6. Te Awanga Upper (largely complete already and underway with options assessment).
7. Te Awanga Lower.
8. Clifton Domain Dams.

[1] http://www.overtopping-manual.com/
[2] Most likely to be a constant downstream channel flow equal to the maximum outflows from the dam at the point of failure, with an appropriate allowance for flooding from the downstream, i.e. populated, portion of the catchment itself, e.g. during a smaller flood of 1 in 100 AEP and then at the dam crest flood.

4.0 POTENTIAL FAILURE MODES

The main hazards for dams are generally associated with natural phenomena; floods, earthquakes, landslides, and wind generated waves. There are also human threats including design flaws/issues or routine operations, which can be controlled to an extent by good management and following good practice. Other threats such as vandalism or terrorism cannot easily be controlled but can be mitigated, to an extent, by regular surveillance and appropriate security.

The primary potential failure modes (PFMs) for the HDC flood detention embankment dams are outlined in Table 5.

The PFMs are mechanisms or circumstances that could result in the uncontrolled release of the reservoir. Avoidance, or mitigation, of PFMs is a fundamental part of dam design and safety assessments. A Failure Modes and Effects Analysis (FMEA) is part of on-going dam safety (e.g. these can be completed with or for or recommended by Comprehensive Dam Safety Reviews). **A specific FMEA has not been completed for HDC's dams and is recommended.**

Table 5 Primary Potential Failure Modes (PFM) with specific reference to HDC Dams

PFM & Common Causes	Dams at risk	Risk Reduction Measures / Intervention
Breach due to dam crest overtopping during flood. Insufficient freeboard to accommodate floods and waves.	All Dams	Regular hydrological assessment. Wave assessment. Ensuring adequate emergency overflow capacity. Regular surveillance of inlets and pipes for blockage and upgrading of inlet screens. Livestock gate removal / management. Ensuring crest is regulated and the downstream slope has good grass cover to provide erosion protection.
Breach due to internal erosion during flood. Seepage occurring along defects / interfaces within dam body, throttle pipe, and foundation during impoundment.	All Dams	Surveillance to identify defects such as settlement, shrinkage cracking and earthquake related damage. The dams are all largely untested as they do not impound unless during flood.
Breach due to failure of the throttle pipework during flood. Pipework fails at a weak or damaged area in combination with high pressure/high velocity flow.	All Dams	CCTV surveys to identify internal issues (evidence of misalignment, leakage into/out of pipework, damage). Checking structural capacity of pipework based on hydraulic and ground pressures / flow velocities / material interfaces. Carry out joint and cementitious repairs or larger scale repairs or improvements by cast-in-place (CIP) lining or slip-lining.
Breach due to spillway failure (floods, structural and hydraulic capacity). Insufficient hydraulic and/or structural capacity of the spillway channel to accommodate flood flows. Channel fails and causes erosion of dam, instability loss of freeboard and failure.	Te Kahika, Mangarau, Te Awanga upper Te Awanga lower Clifton Western and Lower central Dams	Improving spillway hydraulic and structural capacity e.g. replacing Te Kahika wooden spillway with a concrete spillway. Relocating spillways to safer locations remote to the dam. The spillways for the dams are all untested as they have not knowingly operated to date.

Other considerations include loss of freeboard and shoulder instability because of earthquake shaking or because of inherent instability based on design or construction flaws. This would be extremely unlikely to cause a catastrophic dam breach (i.e. combined probability of simultaneous extreme flood and earthquake). However, such activity could change or weaken the structure such that when it does impound at some point in the future, it fails catastrophically. Special Inspections are required following seismic activity. Loss of freeboard can be

visually assessed immediately following such events and if suspected confirmed by topographic survey following the event.

Due to the complex nature of ground motions it is difficult to ascertain the level of shaking at sites for a given earthquake (known magnitude, depth, and distance from site). For this reason, we typically recommend post-earthquake inspections are undertaken following a set Modified Mercalli Intensity (MMI) value event. This is a qualitative measure of the level of shaking experienced at a site. A simplified version of the New Zealand MMI available on the GeoNet website.

Another useful qualitative tool for understanding the level of shaking is the GeoNet Shaking Map available on their website. This collates reports from people in different locations who felt the earthquake and maps this using a scale ranging from weak to extreme. This could be used for initial assessments of whether special inspections (following an earthquake) are required. The information is updated relatively quickly.

With a tool like this there is some scatter in the level of shaking reported. Therefore, judgement is required to identify outliers from the general shaking level in the area.

Embankment stability was previously reviewed in the 2007 CDSR and that report stated that the dams had adequate general stability.

5.0 SITE INSPECTION OBSERVATIONS

5.1 GENERAL

The site inspection was undertaken on Wednesday the 10th and Thursday 11th November 2020 by Dougie Armour (Principal Dam Engineer) with Phelia Klopper (Civil Engineer) of Stantec and Emile Klopper (Project Manager) of HDC in attendance. Weather conditions were showery and wet on 10/11/2020 and warm sunny and dry on 11/11/2020. The preceding weather had been exceptionally wet. Napier CBD reported 229mm of rain on 9th November, whereas only a few kilometres south at Havelock North where most of the detention dams are located, only 65mm was recorded (Kopanga rain gauge, https://www.hbrc.govt.nz/environment/rainfall/). None of the dams were impounding flood water at the time of the inspection.

HDC retain a contact list of residents and landowners who are stakeholders at the detention dams. **This is recommended to be fully updated with current contact details (emails and contact phone numbers).** This would assist with making contact in advance of inspections, surveillance visits, investigations (e.g. CCTV etc) and any works to be carried out. It would also be worthwhile to discuss dam safety with all affected residents and landowners, perhaps in a factsheet by letter drop. Based on discussions with some residents at the detention dams, it was apparent that their understanding of the structures was limited. For example, some believed there was an alarm/siren system in place to evacuate the downstream area. **Discussions should also clarify, in writing, the responsibilities of all stakeholders**. This should include areas of maintenance that are not Council responsibilities.

5.2 KARITUWHENUA DAM

Item	Description / condition
Location	Havelock North
Access	The dam was accessed via Fulford Rd. off Te Mata Rd. then along private access tracks. The inspection team parked the car at a house at the end of the access road (at 39°40'43"S, 176°54'26"E). No residents were present. The team walked up through two gates and followed an access track cut into the hillside through a small wood and down to the dam where some fences had to be crossed. Some goats were in neighbouring fields, but no animals present on the dam. Access is reasonable for small-medium sized plant 1-13t. The dam is split into ~3 landowner sections by fences and gates. **It is recommended that stiles are installed to enable safer crossing for inspection and maintenance purposes.**
Upstream Face / Toe	Generally good on the west side but t**he east side was very overgrown and needs better maintenance, grass cut (machine or sheep) and small trees completely removed.**
Crest	**Crest fence in poor condition and needs replacement**. **Trees at the right abutment should be removed. Right hand side was very overgrown and needs improved or more frequent maintenance; grass cut (machine or sheep) and small trees completely removed.**
Downstream Face / Toe	**Trees in the vicinity of the dam footprint should be removed.**
Reservoir Area	Not inspected, however based on aerial mapping there would be medium to significant debris picked up in an extreme flood.
Trash Screen	Clear, but some flattened weeds in the approach. Bars are very wide spacing presumably to allow small debris to pass through and trap large debris.
Throttle Pipework	The pipework could not be inspected. The inlet and outlet headwall structures were in satisfactory condition. **A CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, cracking etc.), and any such damage repaired.** **Like the other Havelock North dams, install a vertical auxiliary inlet pipe to the existing throttle to improve effectiveness of the system and provide assurance over blockage risk.**
Pipework Headwalls	No issues, satisfactory condition.
Downstream Channel	No issues, flattened grass suggestive of recent high flows. No damage was noted.
Emergency Spillway	The spillway is off the dam on the left abutment. There was evidence of a temporary gate / fence being installed from time to time across the spillway. **No obstructions must be allowed across the spillway structure. The hydraulic capacity of the overflow should be checked.** There was a small, undermined (i.e. failed), corrugated low flow half-pipe conduit near the end of the spillway which is quite steep. This is presumably to reduce the effects of erosion from smaller flows running down the face. **It is suggested, to improve this; replace with a small trap/gully and buried pipe arrangement with an outlet to the downstream channel and the slope damage reinstated. In an extreme flood, significant damage would be expected at this steep drop off at the end of spillway, however it is far enough (80m or so) from the dam to not present significant risk.**
Instrumentation / Telemetry / Scada	Water level recorder and rain gauge on the pole on the dam crest appeared in satisfactory condition.
Bridges	None present.

5.3 SCHOOL STREAM DAM

Item	Description / condition
Location	Havelock North
Access	The dam was accessed via Te Mata Peak Rd, parking at the side of the road at 39°41'3"S 176°53'54.67"E then walking down an original access track to the dam crest (left abutment). No residents were present. Some fences had to be crossed. No animals present on the dam. Access is reasonable for small-medium sized plant 1-13t. Would benefit from stiles to enable simpler crossing for inspection purposes. Some fall hazards with respect to channels and outlets that have no edge protection. **It is recommended that stiles are installed to enable safer crossing for inspection and maintenance purposes.**
Upstream Face / toe	Generally good but **needs better maintenance, grass cut (machine or sheep). Large bushes on the upstream face should be removed.**
Crest	Generally good but **needs better maintenance, grass cut (machine or sheep).**
Downstream face / toe	Generally good but **needs better maintenance, grass cut (machine or sheep).**
Reservoir Area	Not inspected, however based on aerial mapping there would be small to medium debris picked up in an extreme flood.
Trash Screens	Clear, but some flattened weeds in the approach. Bars are very wide spacing presumably to allow small debris to pass through and trap large debris.
Throttle Pipework	The pipework could not be inspected. The inlet and outlet headwall structures were in satisfactory condition. **A CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, cracking etc.), and any such damage repaired.**
Pipework Headwalls	No issues, satisfactory condition.
Downstream Channel	No issues, flattened grass suggestive of recent high flows. No damage was noted. **There is a fall hazard at the outlet which could be improved by a new fence.**
Emergency Spillway	The spillway is slightly off the dam near the left abutment. **Several rotten timbers were noted and these should be replaced. The hinged overflow gates across the sill of the emergency overflow were operable but should be checked during routine surveillance visits.** **The need for the gates should be confirmed and if possible, they should be removed or replaced by a fixed fence set well upstream of the overflow and below the level of the overflow sill.** **The hydraulic capacity of the overflow should be checked.**
Instrumentation / Telemetry / Scada	Water level recorder and rain gauge appeared in satisfactory condition.
Bridges	None present.

5.4 TE KAHIKA DAM

Item	Description / condition
Location	Havelock North
Access	The dam was accessed via Tauroa Rd, then driving along the dam crest (access road for private houses) and parking at the driveway of a resident at 39°41'14.10"S 176°53'44.08"E. The inspection team walked back to the overflow and rest of dam. One resident accompanied on part of the inspection. Some fences had to be crossed on site. Sheep were present on the upstream face of the dam. Access is reasonable for small-medium sized plant 1-13t. **It is recommended that stiles are installed to enable safer crossing for inspection and maintenance purposes.**
Upstream Face / toe	Satisfactory.
Crest	Satisfactory, **some developing potholes and damage noted which should be repaired.**
Downstream face / toe	Satisfactory.
Reservoir Area	Not inspected, however based on aerial mapping there would be medium to significant debris picked up in an extreme flood.
Trash Screens	The upstream screen was completely blinded with weed and was cleared by HDC following the inspection. Bars are very wide spacing presumably intended to allow small debris to pass through and trap large debris.
Throttle Pipework	The pipework could not be inspected (not safe to enter – health and safety). The inlet and outlet headwall structures were in satisfactory condition. **A CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, cracking etc.), and any such damage repaired.**
Pipework Headwalls	No issues, satisfactory condition.
Downstream Channel	No issues, flattened grass suggestive of recent high flows. Heavy vegetation had recently been cleared by a resident; however, this would likely be washed away in an extreme flood. No damage was noted.
Emergency Spillway	The spillway is at the right abutment of the dam and flows down the right groin. The spillway had recently been repaired by the addition of timbers at the downstream end. Several warped timbers were noted but none appeared to be broken. The livestock gate across the spillway is not preferred as this will significantly reduce flow capacity if not opened and becomes blinded during an extreme flood. **A preferred solution would be a new fence set upstream and below the level of the overflow.** **The location of the overflow is such that it presents a risk to the dam if it were to be damaged or flows come out of bank. The hydraulic capacity of the overflow and channel should be confirmed by calculation and if it is shown to be under capacity then the spillway should be considered for improvement.**
Instrumentation / Telemetry / Scada	Water level recorder and rain gauge appeared in satisfactory condition. Piezometers were noted at the downstream toe however these do not appear to be monitored.
Bridges	**The bridge parapets (fences) were in very poor condition and this is a general health and safety hazard. These should be replaced with a better edge protection system**. The bridge beams need painting but were in satisfactory condition and are probably sufficient for most large plant. Bridge deck planks were in satisfactory condition however are unstable and are free to move laterally. **A new deck and parapet system are recommended along with an assessment of structural capacity and appropriate weight limits provided on road signs.**

5.5 MANGARAU DAM

Item	Description / condition
Location	Havelock North
Access	The dam was accessed via Keirunga Rd, parking at 39°40'54.17"S 176°53'14.89"E. The inspection team walked up the access track to the overflow and the dam. No residents were present. Numerous fences and gates had to be crossed on site. No animals were present on the dam but there was evidence of sheep. Access is reasonable for small-medium sized plant 1-13t. **It is recommended that stiles are installed to enable safer crossing for inspection and maintenance purposes.** Reference to the 'true' dam in this section refers to the section of the structure at the throttle pipe. Reference to the 'natural' dam refers to the longer section of embankment to the right of the true dam which may be a natural or historical man-made structure (internal make-up is unknown).
Upstream Face / toe	Highly variable condition across the true dam and the natural dam, but generally satisfactory.
Crest	**Some bare patches and livestock damage noted at the true dam and the natural dam which should be repaired.** **The make-up of the natural dam is largely unknown and should be investigated (archive search followed by ground investigation) to confirm its make-up and ability to safely impound water.**
Downstream face / toe	**Some bare patches and livestock damage noted at the true dam and the natural dam which should be repaired. Trees on the dam must be removed.**
Reservoir Area	Not inspected, however based on aerial mapping there would be medium to significant debris picked up in an extreme flood.
Trash Screens	The upstream screen was clear. Bars are very wide spacing presumably intended to allow small debris to pass through and trap large debris. **A large wooden post was lodged vertically at the upstream end of the pipe and this should be removed ~~unless this has a screening function~~.**
Throttle Pipework	The pipework could not be inspected. The inlet and outlet headwall structures were in satisfactory condition. **A CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, cracking etc.), and any such damage repaired.** Turbulence could be heard at the downstream end of the pipework, suggestive of something within the pipe causing a flow disruption such as damage or debris. **It is recommended that the CCTV survey at Mangarau is prioritised over the other dams.**
Pipework Headwalls	No issues, satisfactory condition.
Downstream Channel	No issues, flattened grass suggestive of recent high flows. No damage was noted. **General debris in the downstream channel at the confluence point of the spillway channel should be cleared.**
Emergency Spillway	The spillway is at the right abutment of the natural dam. It doubles as the access road over the first section before turning left and meeting the downstream channel. The spillway has a concrete overflow sill which was in satisfactory condition. Extreme flood flows will flow across the grass covering to the abutment of the natural dam. **The hydraulic capacity of the overflow and channel should be confirmed by calculation and if it is shown to be under capacity or to present a risk to the natural dam abutment, then the spillway should be considered for improvement.**
Instrumentation / Telemetry / Scada	Water level recorder and rain gauge appeared in satisfactory condition.
Bridges	None.

5.6 HERE HERE DAM

Item	Description / condition
Location	Havelock North
Access	The dam was accessed via Margaret Ave. parking at 39°41'22"S 176°52'26.32"E. Numerous fences and gates had to be crossed on site. No animals were present on the dam. Access is reasonable for small-medium sized plant 1-13t. **It is recommended that stiles are installed to enable safer crossing for inspection and maintenance purposes at a location to suit HDC and landowners.**
Upstream Face / toe	Generally good but grass was **very long and needs improved maintenance, (machine or sheep).**
Crest	Generally good but grass was **very long and needs improved maintenance, (machine or sheep).**
Downstream face / toe	Generally good but grass was **very long and needs improved maintenance, (machine or sheep).**
Reservoir Area	Not inspected, however based on aerial mapping there would be medium to significant debris picked up in an extreme flood.
Trash Screens	The upstream screen was clear. Bars are very wide spacing presumably intended to allow small debris to pass through and trap large debris. **A large bush was growing in front of the screen and this should be removed.**
Throttle Pipework	The pipework could not be inspected. The inlet and outlet headwall structures were in satisfactory condition. **A CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, cracking etc.), and any such damage repaired.**
Pipework Headwalls	No issues, satisfactory condition.
Downstream Channel	No issues, flattened grass suggestive of recent high flows. No damage was noted.
Emergency Spillway	The spillway is off the dam near the left abutment. The grass lined trapezoidal spillway has a concrete overflow sill which was in satisfactory condition. The livestock gate near the end of the spillway is not preferred as this will significantly reduce flow capacity if not opened and becomes blinded during an extreme flood. Similarly, the fence, trees and woody vegetation on the left-hand side will retard flows and generally reduce the capacity of the channel. **The hydraulic capacity of the overflow and channel (including consideration of the closed gate downstream and the fence / vegetation) should be confirmed by calculation and if it is shown to be under capacity or to present a risk to the dam, then the spillway should be considered for improvement. The bend and tapering at the start of the channel should be considered within this calculation to confirm the location of the hydraulic control which may be downstream of the concrete sill.**
Instrumentation / Telemetry / Scada	Water level recorder and rain gauge appeared in satisfactory condition.
Bridges	None.

5.7 CLIFTON DOMAIN DAMS

Item	Description / condition
Location	Clifton
Access	The dams were accessed by 4x4 vehicle via Clifton Rd, and a steep and narrow access track which starts at 39°38'29.19"S 176°59'37.93"E. Numerous unlocked gates had to be crossed on site. No animals were present on the dams however there were cattle on the ridge above the dams and evidence of cattle on the dams. Access is reasonable for small-medium sized tracked plant 1-13t. Access is reportedly difficult in wet weather; however, the dams were accessed with little difficulty on this occasion (dry but preceding days had been wet). **Some improvements are recommended with respect to periodically cutting back vegetation at the sides of the access track over the first few hundred metres.**
Upstream Faces / Toes	Generally satisfactory.
Crests	**Cattle damaged areas on the larger dams should be repaired. It is recommended that cattle are prevented from accessing the dams by installing fencing.**
Downstream Faces / Toes	Generally satisfactory.
Reservoir Area	Clear, no debris. **A cattle drinking pond perched at the top of the hill above the Western Dam was in a state of gradual failure and this should be monitored for worsening condition and repairs or demolition works carried out as required to reduce the risk to the Western Dam i.e. if the pond fails and materials slip down and inundate the Western Dam.**
Trash Screens	None. **Small box sized trash screens are recommended to be installed.**
Throttle Pipework	The pipework could not be inspected (very small diameter). **A push rod CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, collapse etc.), and any such damage repaired.**
Pipework Headwalls	None.
Downstream Channels	No issues, some flattened grass suggestive of recent flows. No damage was noted. At the Clifton Motor Camp downstream of the dams, the main outlet channel (which only carries flow from the Lower Central and Western Dams) was dry and blocked at the downstream end by new earthworks to restore/protect the eroded coastline. **This channel should be continued through the earthworks to the beach.** The section of the channel upstream of the Motor Camp was badly damaged with landslides and vegetation and there seems little point in attempting to repair this aside from cleaning out and maintaining a clear path for water to pass. It may also be of benefit to route flows away from this channel at the upstream end.
Emergency Spillways	The Western Dam has no spillway (aside from the dam crest). The Eastern & Upper Central Dam (joint) spillway (to the east/sea) was clear. The Lower Central Dam spillway was clear. **The hydraulic capacity of the overflows and channels should be checked.**
Instrumentation / Telemetry / Scada	None. **A webcam or similar means of remote surveillance is recommended if PIC study shows that the dams present a significant risk to the Clifton Motor Camp.**
Bridges	None.

5.8 TE AWANGA LOWER

Item	Description / condition
Location	Te Awanga
Access	The dam was accessed on foot via Clifton Rd, and parking in a field adjacent to the dam at 39°38'18.46"S 176°58'53.97"E. A high barbed wire fence had to be crossed on site. No animals were present on the dam. Access is reasonable for small-medium sized plant 1-13t.
Upstream Face / toe	Generally satisfactory.
Crest	Generally satisfactory.
Downstream faces / toes	Generally satisfactory.
Reservoir Area	Generally clear, no obvious debris.
Trash Screens	Clear.
Throttle Pipework	The pipework could not be inspected. **A CCTV survey of the pipework is recommended to record gradient, length, and any areas of damage (open joints, collapse etc.), and any such damage repaired.**
Pipework Headwalls	Satisfactory.
Downstream Channels	No issues. There are gabion check dams at 20m intervals downstream of the dam. These were in satisfactory condition. Previous recommendations have suggested cutting slots in the gabions however this is not warranted as they are designed to create a set of hydraulic jumps and operate as an energy dissipation system.
Emergency Spillways	The spillway was clear.
Instrumentation / Telemetry / Scada	None.
Bridges	None.

5.9 TE AWANGA UPPER

Item	Description / condition
Location	Te Awanga
Access	The dam was accessed by 4x4 via Cape Estate Country House then parking in a field near the dam at 39°38'40.28"S 176°58'39.96"E. The dam was then accessed on foot. Several fences had to be crossed on site, but there is understood to be a route with gates. No animals were present on the dam though there were sheep present nearby. Access is reasonable for small-medium sized tracked plant 1-13t. **A preferred access route to the dam should be agreed with the landowner and defined accurately on a plan of the area.**
Upstream Face / toe	Generally satisfactory.
Crest	Generally satisfactory.
Downstream face / toe	Generally satisfactory.
Reservoir Area	Generally clear, no obvious debris. The Western end of the dam had impounded recently based on tide mark evidence. **The outflow characteristics of the on-catchment lakes to the west of the dam should be investigated and incorporated into hydrological studies as this might significantly affect the outputs of existing flood studies at this dam.**
Trash Screens	Clear, though the fine mesh trash screen at the western end will be prone to blockage and should be reviewed and improved with a screen with greater spacing appropriate to the size of the pipework.
Throttle Pipework	The pipework could not be inspected. **A CCTV survey of the main pipework is recommended to record gradient, length, and any areas of damage (open joints, collapse etc.), and any such damage repaired. A push rod CCTV survey of the smaller pipework at the eastern and western ends is recommended.**
Pipework Headwalls	Satisfactory.
Downstream Channels	No issues. The channel meets a drop shaft which transfers a large majority of flow through a culvert to the adjacent river, the inlet and outlet structures appeared in reasonable condition. **The culvert is recommended to be CCTV surveyed along with the dam's pipework but as it is a drop shaft structure it will be full of water and need to be pumped out with a portable pump.**
Emergency Spillways	The spillway was clear. **The hydraulic capacity of the overflow should be confirmed and if it is shown to be under capacity or to present a risk to the dam (erodibility), then should be considered for improvement.**
Instrumentation / Telemetry / Scada	None. **Given the remoteness of the site and the current perceived flood risk, a solar powered water level / rainfall measurement system as used at the Havelock North Dams is recommended. Such a system is not considered to be required for Te Awanga Lower given it is on the same catchment.**
Bridges	None.

6.0 DAM SAFETY DATA REVIEW

Monthly routine inspections by HDC comprises going through a checklist of key areas around the dam where vulnerabilities may lie, such as blockage of the screens, damage by livestock etc. These checklists sheets are stored electronically and used to raise work orders to complete maintenance tasks.

The five Havelock North dams have 10-minute rainfall measurement and hourly water level measurement which is downloaded and stored on a spreadsheet-based system. No physical monitoring is undertaken. The Te Awanga and Clifton Domain Dams have no such monitoring systems. **It is recommended that the physical parameters in Table 6 are monitored going forward.**

Table 6 – Recommended Surveillance Parameters

Parameter	Details	Minimum Recommended Frequency
Rainfall	A rain gauge is installed on the 5 Havelock North Dams only. Rainfall collection data should also be taken from the nearby HBRC rain gauge network at https://www.hbrc.govt.nz/environment/rainfall/. **A gauge is also recommended at Te Awanga Upper.** **A trigger warning system should be set up to notify HDC when the rainfall > 100mm in any 24-hour period.**	Hourly and Daily.
Water Level	A water level gauge is installed on the 5 Havelock North Dams **and is recommended at Te Awanga Upper**. **A trigger warning system should be set up to notify HDC when the dams impound, e.g. depth rises to > 1.5m.**	10 minutes.
Seismic Activity	**A system should be set up to receive alerts** (e.g. using GNS science's Geonet) and trigger further investigations upon deciding if this is warranted (See Section 4).	A monitoring frequency is not appropriate as this is a warning system.
Embankment Survey	**Permanent crest monitoring stations (steel pins set in concrete blocks) are recommended to be installed at ~20m intervals on all the Havelock North and Te Awanga dams crests**, referencing the overflow level, which for the purposes of regular surveys shall be considered a permanent marker on which to base future surveys, then a baseline survey taken, then survey in one year and then in 5 yearly intervals or more frequently if a visual change suggests that deformation has occurred (or post a significant earthquake). Repeat crest surveys shall always be based on the same datum to ensure change in level, and especially dam freeboard can be evaluated.	Baseline, then 1 year, then every 5 years after that.
Pipework condition	**Regular CCTV surveys of the pipework should be carried out to monitor condition.**	5 yearly, or sooner if there is suspected damage, or there has been an impounding event where the pipework has become. pressurised.

As well as setting up a trigger warning system, rainfall and water level records should be downloaded monthly by HDC into a monitoring spreadsheet that presents the data graphically and will allow the observation tracking of historical data with ease. This will also help with the detection of faults in the system.

Rainfall records from the nearest HBRC gauge (Kopanga gauge) should also be taken for comparison purposes.

Based on the last 12 months of data and the complete data record going back to around 2007, several unusual observations were made.

The five Havelock North dams have automatic rain gauges at each of them. The outputs from each are surprisingly different given the proximity to each other. Very heavy rain occurred on 9th November 2020, a day before the inspection, but Te Kahika and Here Here recorded zero rainfall. Karituwhenua, Mangarau and School Stream recorded 106.5 mm, 43.75 mm, and 36.75 mm, respectively. The nearest HBRC gauge captured around 63.5 mm on this day. **It is recommended that all gauges are checked and calibrated to ensure accurate data capture.**

Water level data appeared to be in-keeping with site observations. It was visually clear that the Havelock North dams did not impound during the recent heavy rain and the depths of water seen in the channel were consistent with the water level depths recorded.

Such equipment is crucial for monitoring and it should be calibrated at a frequency as recommended by the manufacturers. Certificates of calibration should then be maintained with the rest of the dam data in the Data Book.

In the absence of real-time monitoring at Te Awanga, it is recommended that a similar setup to Havelock North (water level and rainfall) is set up at Te Awanga Upper dam.

7.0 DAM SAFETY MANAGEMENT SYSTEM

7.1 OPERATION AND MAINTENANCE

An Operation, Maintenance and Surveillance (OMS) Manual was recently developed for all HDC dams (Stantec 2020). This sets out the framework for how the dams should be managed. **It is a live document and it is recommended to be reviewed annually and updated as appropriate**.

The dams have been designed to self-operate, in low flows, water passes through the culverts under each dam. In high flows the capacity of the culverts is exceeded and water level rises as the dams start to impound. As a flood subsides, the water level drops again and the dams return to the low flow condition. In an extreme flood, an emergency overflow passes excess flood flow that is over and above the design flood.

Generally, maintenance is being carried out to a fair level. Maintenance of grass is routinely needed for the dam embankment crests, and downstream embankment slopes and the spillways where appropriate. Maintenance of vegetation is also required in and around spillway channels, inlet approaches and outlets.

The grassed crest and downstream face of the flood detention dams is very important as it provides erosion protection. The grass should therefore be kept at a short length not exceeding 150mm, and therefore may require several cuts per year. It is acceptable to have sheep on dams to help control vegetation, but not cattle which can severely damage embankment slopes because of ponding water within hoof prints.

7.2 SURVEILLANCE

Surveillance enables the effective management of dam safety and operational risks and includes:

- Routine visual inspections.
- Instrument monitoring.
- Data review and evaluation.
- Reporting.

Surveillance is carried out monthly by HDC's maintenance contractor visiting the dams and using a dam safety check sheet to record observations and request any minor repairs. The routine inspection forms contained within the OMS manual should be used going forward. Surveillance must be carried out by competent and trained HDC personnel or contractors who understand the following.

- Dam safety and surveillance principles including visual recognition of the onset of potential failure modes and dam safety deficiencies.
- Potential failure modes.
- Emergency response procedures including escalation process for alerting others.
- Safe operation of gates and valves (if appropriate).

The current recommended frequency for surveillance walkovers for these dams is monthly. This is more than would normally be recommended for flood detention dams (annually) because of the flood safety deficiencies at the structures and the downstream hazards. A routine surveillance walkover should also be carried out by HDC immediately before[3], during and after a flood event. The Clifton Dams are difficult to access and a webcam system may be of benefit to regular surveillance depending on the level of hazard the structures present.

7.3 APPURTENANT STRUCTURES AND GATE AND VALVE SYSTEMS

The outlet structures and spillways are discussed in Section 5. It is recommended that an inspection and maintenance plan is developed for these. The highest priority items are the spillways (i.e. maintaining the grass,

[3] if a regional flood warning has been issued the dams must be inspected for blockages, closed spillway gates, and damage that might otherwise reduce the effectiveness of the structures.

maintaining the spillway clear of vegetation and opening livestock gates) and the screened inlet pipework (debris and damage, observed by doing CCTV surveys).

There are no penstock gates or valves at these dams.

7.4 DAM SAFETY REVIEWS

The current HDC dam safety review programme for the detention dams is that Intermediate Dam Safety Reviews are completed annually, and Comprehensive Dam Safety Reviews are completed every 5 years. This aligns with the recommended frequency of reviews in the NZSOLD Dam Safety Guidelines, for a Medium or High PIC dam.

7.5 SPECIAL INSPECTIONS

According to GeoNet, no significant earthquakes have been noted in the last 5 years. Smaller earthquakes of intensities ~3.0 have been recorded closer to the dams over the last couple of years, however these have not been of an intensity that warranted a Special Inspection of the dams and key elements. Only ~5 large earthquakes >5.0 MMI have occurred within proximity to the dams in the last 40 years, i.e. within the dams' lifetime.

No significant rainfall events have been recorded in the last 5 years that warranted a Special Inspection.

For the purposes of HDC's dams Special Inspections should be carried out after an earthquake has been felt or there is a Modified Mercalli Intensity of 5 (V) or greater, or after greater than 100mm rainfall in a 24-hour period.

Specific areas of the dams to inspect include;

- Earthquake
  - Dam Crest (Settlement? / Cracking?)
  - Dam Slopes (Cracking? / Instability?)
  - Emergency spillway (Damage?)
  - Pipework (Damage e.g. open joints or collapsed pipe?)

- Flood
  - Emergency spillway (Damage?)
  - Culvert inlet & outlet (Blockage / Damage / Evidence of seepage around pipe outlet?)
  - Downstream face (Evidence of seepage?)

It is suggested that a folder for Special Inspections is set up within a Data Book as recommended earlier in this report.

7.6 EMERGENCY PREPAREDNESS

NZSOLD Dam Safety Guidelines outline that an Emergency Action Plan (EAP) should be prepared for all Medium and High PIC dams. An EAP has not been prepared for the detention dams. **It is recommended that an EAP is prepared for each dam since each dam has a different downstream population**. This is extremely important since the dams have identified flood deficiencies . The EAPs should be rolled out in the order of hazard and flood risk as stated previously.

1. Mangarau.
2. Here Here.
3. Te Kahika.
4. Karituwhenua.
5. School Stream.
6. Te Awanga Upper.
7. Te Awanga Lower.
8. Clifton Domain Dams.

In preparation for emergencies, key aspects of the EAPs should be trialled to enable testing of systems in real time to gauge their effectiveness and to make improvements.

8.0 PREVIOUS CDSR RECOMMENDATIONS

Table 6 – 2015 CDSR Recommendations and Status

Reference	Recommendation	Status
2015.1	Develop a dam safety management plan and procedures for the flood detention dams.	Largely complete with the preparation of the OMS manual.
2015.2	Develop an Emergency Action Plan for the flood detention dams and procedures for training and testing.	Incomplete.
2015.3	Use As-Built survey data to confirm the spillway discharge capacity and rerun hydraulic models to confirm the dam crest flood capacity and improvement options.	Complete. But some spillways warrant more detailed hydraulic analysis.
2015.4	Undertake a condition survey of the timber spillway chutes for the appropriate dams.	Completed.
2015.5	Evaluate options to repair the cracked section of culvert through School Stream Dam. Repeat CCTV examination after any very large flood or before next CDSR.	Not completed.

9.0 CURRENT CDSR RECOMMENDATIONS

The complete table of prioritised dam safety recommendations is provided at the start of this report (Executive Summary) for ease of reference and prevention of repetition in this section.

10.0 CONCLUSIONS

Overall, the dams are in a satisfactory visual condition. Vegetation management is fair to poor, and some of the dams would benefit from more frequent grass cutting, perhaps using sheep as opposed to machinery.

There are some unknowns with respect to the history and modifications to the structures, however this could be gleaned through archive research.

The Havelock North and Te Awanga dams generally fall below their extreme flood carrying capacity with respect to current dam safety guidance (NZSOLD Guidelines). This must be investigated without delay and, if necessary, works carried out to address any issues.

Recent studies on the dams include flood and dam break studies, however the information is becoming quite fragmented and some work is recommended to gather all data, ensure consistency, and carry out updates to studies as required.

CCTV surveys of the dam pipework are urgently required. When completed, these should be reviewed by a Dam Engineer. HDC's specification for the CCTV survey should be reviewed by a Dam Engineer prior to the survey to ensure the information obtained will be useful.

A data book should be prepared to store all the dam data in a safe and secure manner.

The parapet walls (fences) of the bridge at Te Kahika are inappropriate and constitute a safety hazard and the bridge deck would benefit from an upgrade to prevent lateral movement.

A more effective landowner notification system should be set-up to carry out routine visits, IDSRs and CDSRs, small-scale repairs, and general maintenance. This might involve a letter or email drop and courtesy telephone call in advance of a visit.

An Emergency Action Plan needs to be prepared for each dam.

An OMS manual has recently been prepared. The routine inspection checklists from this OMS should be used in the monthly walkovers of the dams by competent and trained HDC personnel or contractors who understand the following.

- Dam safety and surveillance principles including visual recognition of the onset of potential failure modes and dam safety deficiencies.
- Potential failure modes.
- Emergency response procedures including escalation process for alerting others.
- Safe operation of gates and valves (if appropriate).

Minor items of maintenance and improvement are required at all the dams.

11.0 REFERENCES

1. New Zealand Society on Large Dams (2015), New Zealand Dam Safety Guidelines.
2. Seismicity and Dam Design (1983), ICOLD Bulletin 46.
3. Historical Reference Documents as listed in Section 2.

Appendices

We design with community in mind

Appendix A KARITUWHENUA DAM

Figure 1: Downstream face

Figure 2: Dam crest with weak fence

Figure 3: Screened inlet headwall with side inlet

Figure 4: Outlet headwall and downstream face

Figure 5: Outlet channel

Figure 6: Spillway (low flow channel at end of spillway)

Figure 7: Spillway channel

Figure 8: Upstream face

Appendix B SCHOOL STREAM DAM

Figure 9: Catchment and reservoir area

Figure 10: Dam crest

Figure 11: Downstream slope

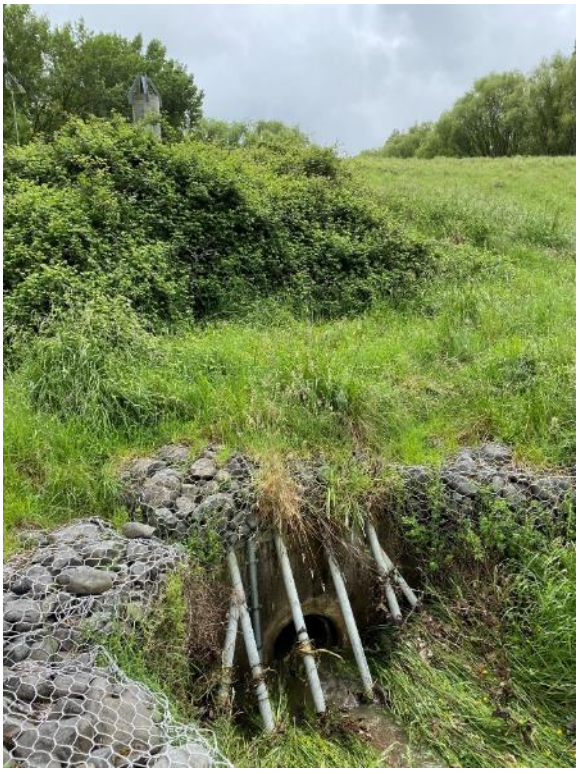

Figure 12: Screened inlet headwall structure

Figure 13: Outlet headwall structure

Figure 14: Livestock gate across spillway

Figure 15: Spillway (showing tree roots probably lifting slab)

Figure 16: Missing timber on spillway

Figure 17: Spillway looking upstream (very long vegetation)

Figure 18: Outlet channel

Figure 19: Spillway looking downstream

Appendix C TE KAHIKA DAM

Figure 20: Reservoir area and with auxiliary inlet upstand

Figure 21: Upstream slope and spillway approach / overbridge and gate (under bridge)

Figure 22: Dam crest

Figure 23: Downstream slope

Figure 24: Inlet structure (blocked, subsequently cleared)

Figure 25: Outlet structure

Figure 26: Recent spillway repair at downstream end of channel

Figure 27: Buckling cross timbers in spillway

Figure 28: Narrowing of upper spillway channel

Figure 29: Timber spillway channel looking upstream (repair is lighter wood)

Appendix D MANGARAU DAM

Figure 30: Upstream slope

Figure 31: Natural Dam crest

Figure 32: Damage on downstream slope

Figure 33: Auxiliary intake and inlet structure (blocked with log)

Figure 34: Outlet structure (turbulence heard)

Figure 35: Spillway and recent repair to right hand side

Figure 36: Spillway channel

Figure 37: Spillway sill and 'natural' dam crest / right abutment

Figure 38: General debris at spillway discharge to downstream channel

Appendix E HERE HERE DAM

Figure 39: Reservoir area and auxiliary inlet

Figure 40: Dam crest

Figure 41: Downstream slope

Figure 42: Inlet structure (bush to be removed)

Figure 43: Culvert crossing upstream of inlet

Figure 44: Culvert outlet with flap gate

Figure 45: Spillway control sill

Figure 46: Spillway (undesirable fence / vegetation on the left-hand side and closed gate at the end of the channel)

Appendix F UPPER TE AWANGA DAM

Figure 47: Reservoir Area

Figure 48: Central dam (highlighted)

Figure 49: Inlet structure on central dam, noting slight settlement in the vicinity of the pipe.

Figure 50: Outlet structure

Figure 51: Evidence of recent ponding at east dam inlet pipe

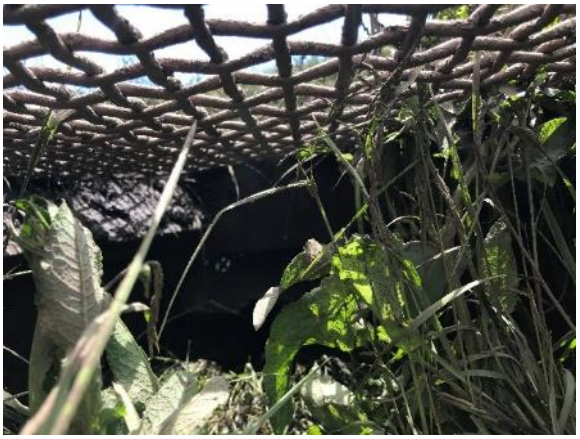

Figure 52: East dam inlet pipe and screen

Figure 53: Downstream drop structure to Charlton Stream

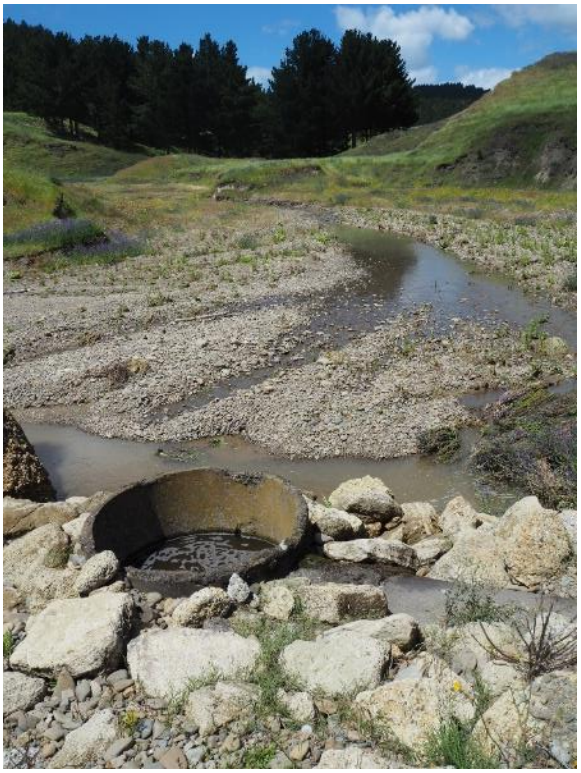

Figure 54: Outlet to Charlton Stream. Screen Required,

Appendix G LOWER TE AWANGA DAM

Figure 55: Reservoir area

Figure 56: Upstream slope, spillway, and intake structure with auxiliary intake

Figure 57: Downstream slope and spillway

Figure 58: Screen at intake structure

Figure 59: Auxiliary inlet structure

Figure 60: Spillway and gabion check dams

Appendix H CLIFTON DOMAIN DAMS

Figure 61: Upstream edge of failing pond (for cattle drinking water) above Western Dam

Figure 62: Downstream edge of failing pond (for cattle drinking water) above Western Dam

Figure 63: Western Dam (upstream side)

Figure 64: Lower Central Dam (upstream side) spillway notch visible at treeline

Figure 65: Upper Central Dam crest and upstream face looking to right abutment

Figure 66: Upper Central Dam crest

Figure 67: Eastern Dam crest

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