TOITŪ TE WHENUA

LAND INFORMATION NEW ZEALAND

Fraser Thomas
ENGINEERS • RESOURCE MANAGERS • SURVEYORS

146 TE MAWHAI ROAD,
FORMER TOKANUI
PSYCHIATRIC HOSPITAL, TE
AWAMUTU

FORMER TOKANUI PSYCHIATRIC HOSPITAL
DEMOLITION AND REMEDIATION
EXISTING DISPOSAL SITES – INTRUSIVE INVESTIGATION REPORT

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FORMER TOKANUI PSYCHIATRIC HOSPITAL DEMOLITION AND REMEDIATION EXISTING DISPOSAL SITES – INTRUSIVE INVESTIGATION REPORT

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Authors	E Bish, T Bohles, S Finnigan		
Reviewer	S Finnigan	Date	26/06/2024

Fraser Thomas Limited
Consulting Engineers, Licensed Surveyors
Planners & Resource Managers
Level 1, 21 El Kobar Drive, East Tamaki, Auckland, 2025
PO Box 204006, Highbrook, Auckland, 2025
Auckland, New Zealand
Tel : +64 9 278-7078
Email: sfinnigan@ftl.co.nz

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EXECUTIVE SUMMARY

E1. Background Information

The closed Tokanui Hospital (the Site) is a former psychiatric hospital approximately 80 hectares (ha) in area located approximately 14km southeast of Te Awamutu, Waikato, with 74 buildings, a decommissioned wastewater treatment plant, swimming pool, eight substations, substantial roading and underground infrastructure and services and a closed landfill (also referred to as the 'existing disposal sites').

The former Tokanui Hospital is managed by LINZ on behalf of the Crown in the Treaty Settlements Landbank. Land held in the Landbank is Crown land which has been declared surplus can be used as cultural or commercial redress in Tiriti o Waitangi Settlement claims. The Tokanui Hospital is a deferred selection property in the Ngāti Maniapoto Deed of Settlement (the Deed) and forms part of the Maniapoto Settlement Claims Act 2022, which gives effect to the Deed. There is no requirement under the Deed to remediate the existing disposal sites, but LINZ is responsible for managing this site in perpetuity, while the ongoing maintenance and monitoring of these sites is covered by a regional resource consent with oversight from Waikato Regional Council.

This intrusive investigation report covers the existing disposal sites portion of the site. This is located off Farm Road (private road), directly east of the Wharekōrino Stream. The investigation area is approximately 7.7ha, of which the existing disposal sites make up approximately 2.1ha in area, including some additional filling areas found during this investigation. This area is currently in pastoral land use (grazing). The existing disposal sites are either referred to as 'existing disposal sites' or landfills in this report, depending on the context.

E2. Intrusive Investigation Findings

The Tokanui Hospital Landfill Closure Assessment of Environmental Effects (AEE) (Worley, 1998) describes the landfill as comprising one fenced off area, within which there are several distinct areas that have been used for different types of refuse disposal. This investigation identified nine areas for intrusive investigation of which all but two were found to contain landfill material. Estimated landfill areas and volumes; closure dates; topsoil, cover and fill characteristics and contamination status are summarised in Table E1. It is important to note that estimated areas and volumes have ±10-30% accuracy, with the higher 30% range allowing for the method and nature of filling in Areas A, H and F (uncontrolled filling).

Overall, the aerial photographs and desktop information show that the portions of the site assessed as part of this investigation were subject to landfilling from at least 1943 through to 1979 and possibly into the 1980s, while information in the 1998 AEE indicates Area A was closed in 1988 and Area C in 1997. Suspected additional filling areas outside of the primary landfilling areas (Areas H & I), east of the existing disposal sites were also assessed, given visual identification of potential filling activities during the historical review and onsite interviews with local Kaumātua.

The geotechnical information available has confirmed the site underlying geology is non-volcanic, and consists largely of alluvial material belonging to the Tauranga Group. Laboratory testing of soil samples confirmed there are high levels of contamination present within the various areas of the existing disposal sites, with exceedances of both the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NESCS) rural residential/lifestyle block- no produce (unpublished) land use criteria and the NESCS commercial/industrial outdoor worker (unpaved) land use criteria. In addition, there were numerous exceedances of the BRANZ asbestos in soil guidelines for both residential and commercial/industrial sites. There were also numerous exceedances of the Class 1 (municipal solid waste) Landfill acceptance criteria in Areas A, C, D & H, which are predominantly located within the areas where disposed material was burnt.

Toxicity Characteristic Leaching Procedure (TCLP) testing was undertaken on the samples exhibiting the highest levels of contamination across the existing disposal sites. Thirteen samples were analysed, with all results indicating the various soil & fill materials across the existing disposal sites would be suitable for disposal off-site, to a Class 1 Landfill.

Given the extent and nature of the fill material found and the contamination identified thus far, it is considered unlikely that the contaminated fill materials could be separated from other materials within Areas A, B, C, D & H.

The areas of the site investigated as part of this Intrusive Investigation have been reinstated in recent months and returned to farming/grazing use. The reinstatement measures consisted of:

1) Additional material compaction where test pits have been backfilled;
2) Track rolling the existing test pit locations;
3) Retopsoiling the depressions that have appeared after backfilling the test pits; and
4) Regrassing the deposited topsoil to reestablish a vegetative cover over the testpit areas.

E3. Critical Assessment of Landfill Construction

The fill material within the landfill would generally be classified as Class 1 landfill material, along with some managed fill and cleanfill materials, as well as some special wastes (i.e., medical wastes, asbestos). A critical assessment of landfill construction identified the following key items of concern:

- Lack of landfill base and side liner and groundwater subsoil drainage allows groundwater to come into direct contact with buried refuse in some locations.
- Refuse burning was common practice over much of the period that the hospital's landfill has been in operation. It was a cheap method of reducing waste volumes (thus maximising landfill lifetime), minimising leachate generation and landfill gas production from the decomposition of combustible organic wastes and providing rudimentary "sterilisation" of some wastes.
- The deposition of boiler ash within landfilling areas, either directly or for use as cover material has likely introduced a significant boron reservoir into the landfill. Boron is relatively soluble and hence likely to leach over a long period, while once boron gets into water it is very difficult and costly to remove. In our opinion, the ash disposed of in Areas A and C of the landfill is the likely source of elevated boron levels in groundwater sampled from the landfill monitoring bores and in the adjacent stream.
- Some areas have non-compliant clay capping (i.e., inadequate thickness and/or permeability) and/or topsoil cover in relation to the approved resource consent for the landfill site.
- There is no leachate collection or landfill gas collection systems, this being consistent with landfilling practice at the time the landfilling areas were constructed.

- The proximity to the Wharekōrino Stream means the site is potentially subject to inundation by flood waters (refer further discussion in section E5).

E4. Landfill Lifecycle Status

The landfill aftercare period refers to the duration of ongoing monitoring for site integrity and environmental effects until the landfill no longer has the potential for adverse environmental effects, effectively defining the landfill "end of life". All landfill areas were assessed to be in the latter stages of the aftercare period, which typically lasts 30-50 years post-closure, as Area C was closed about 26 years ago, Area A 35 years ago and the other areas likely as long as 44 years ago. This is supported by:

- Typical leachate parameters (ammoniacal-nitrogen and chloride) having relatively low concentrations in groundwater and pH being approximately neutral.
- No landfill gas being detected on-site during the 2022 or 2023 intrusive investigations.
- The majority of landfill settlement is inferred to have already occurred.

However, the complicating factor here is the presence of boron in the landfilled materials, which is inferred to derive from coal ash deposition within the landfill. This has resulted in elevated boron levels in the groundwater and stormwater, which are still occurring in 2023. In our opinion, this "potential adverse environmental effect" endpoint has yet to be reached for boron and hence ongoing monitoring should be continued.

E5. Landfill Risk Assessment

The landfill risk assessment found the main issues to be:

- Groundwater contamination from passage through the landfill, with groundwater flowing into the adjacent stream, with boron being the main contaminant of concern, as explained above.
- Culvert 3 (1350dia) pipes the Wharekōrino Stream through Area H of the landfill. This culvert is estimated to be 44-65 years old and could be subject to differential settlement from landfill activity, leading to leaking joints and ultimately possible pipe failure. Attempts have been made to CCTV this culvert but have not been successful to date, due to significant flows through the culvert.
- Flood modelling of the Wharekōrino Stream has shown that the landfill areas A, B, C, G and H are currently likely to be inundated to varying extents during a 1% AEP (annual exceedance probability) storm event, particularly if the two downstream culverts on the stream are blocked or become blocked during the storm, with these effects worsening with predicted climate change. Areas D, E and F have been found unlikely to be affected by flooding. Flooding impacts could potentially be significantly mitigated by the removal of Culvert 2 and the associated embankment, which forms a redundant road crossing over the stream, located below the landfill and above the culvert on Te Mawhai Rd.

Table E1: Landfill Areas/Volumes and Topsoil/Cap/Fill Characteristics (calculation provided as Appendix G; values rounded to nearest 10)

Item	Area								
	A	B	C	D	E	F	G	H	I
Area (m^2)	7,990	2,790	1,180	2,440	660	930	1,310	1,980	1,570
Fill Volume (m^3)	12,960-16,310*	3,420	1,350	3,870	0	3,730	0	910	3,080
Estimated Date for End of Filling	1988	1979	1997	~1979	~ 1979	~ 1979	~1979	~1979	~1974
Topsoil cover – range (average) (mm)	100-300 (145)	100-200 (157)	100-200 (162)	50-200 (139)	100	200	100-200 (151)	0	0-200 (102)
Topsoil contamination	83% > BG but < GL; 9.5% > RR/CI (Asb)	All > BG but < GL	50% > BG but < GL; 50% > RR/CI (Asb)	All > BG < GL	All < BG	All > BG < GL	All > BG < GL	All > BG but < GL; 20% > RR/CL (Asb)	87.5% > BG but < GL; 12.5% > RR/CL (Asb)
Landfill Cap Thickness – range (avg, mm)	100-800 (522)	100-400 (275)	400-600 (476)	0-250 (155)	200 (1 Testpit)	300 (1 Testpit)	0	0	0
Cap permeability (m/s)	$<10^{-7}$ except TP2	$<10^{-7}$	$<10^{-7}$	$<10^{-7}$	$<10^{-7}$	$<10^{-7}$	Not applicable	Not applicable	Not applicable
Fill Description (main content)	Construction & general waste, burnt material, inferred boiler ash, asbestos	Construction/demolition waste, some burnt debris	General & construction waste	Construction waste, including wood, metal, concrete and bricks	None	Medical waste buried in multiple small offal pits	Reworked Material	Construction & general waste, burnt material, tree stumps/wood fragments	Construction & general waste, brick concrete, and plastic bottles
Fill contamination status (% samples)	Landfill (90%), Managed Fill (10%)	Landfill (40%), managed fill (20%), cleanfill (40%)	Landfill (100%)	Landfill (100%)	N/A	Landfill (100%) due to hazardous medical waste	N/A	Landfill (100%)	Landfill (14%), Managed Fill (43%) Cleanfill (43%)

Notes: BG = background, RR = rural residential, C/I = commercial/industrial, GL = guideline, Asb = asbestos, * - range accounts for potential fill volume based on filling method in cells rather than uncontrolled filling.

E6. Recommended Repair/Maintenance Works

The following repair/maintenance works are recommended for consideration by LINZ, as part of a long term management strategy for the landfill:

- Repair (e.g. lining), replacement or removal of Culvert 3. With culvert removal, this would involve transferring buried refuse in this area to another portion of the landfill, outside the floodplain.
- Removal of culvert 2, which will significantly lower flood levels adjacent to the landfill, subject to further investigation, design and an assessment of potential effects on upstream and downstream neighbours.
- Replacement of the landfill cap with a low permeability cap, complying with the consent conditions and/or current best practice. Associated ponding, settlement/subsidence areas would be repaired at the same time.
- Possible installation of a groundwater cut-off trench or similar to divert upgradient groundwater from passing through the landfill, so that it is no longer in contact with buried refuse.

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EXISTING DISPOSAL SITES – INTRUSIVE INVESTIGATION REPORT

1 INTRODUCTION

This report comprises an Intrusive Investigation Report (IIR) for the existing disposal sites at the Former Tokanui Psychiatric Hospital (FTPH). It presents the results of a desktop study, site walkover, intrusive testpit and trench investigations, laboratory sampling and analysis, as well as a landfill construction/risk assessment. The existing disposal sites are either referred to as 'existing disposal sites' or landfills in this report, depending on the context.

The key objectives for this report were:

(a) To summarise previous investigations by others relating to the existing disposal sites area.
(b) To undertake intrusive investigations to provide a more detailed characterisation of the existing disposal sites, including the disposal area extents, type and depth of cover, depth of fill and depth to natural ground; and the extent and severity of soil/fill contamination.
(c) To provide a critical assessment of construction of the existing disposal sites, landfill risk assessment and consent compliance.

This investigation has been managed, reviewed and approved by a Suitably Qualified and Experienced Practitioner (SQEP), as defined in the National Environment Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NESCS) and by suitably qualified and experienced staff with landfill experience.

2 SCOPE

The scope of this investigation is set out below:

(a) Review of all available information and data from the reports provided by LINZ.

(b) Identify any information gaps and request this information from relevant sources (e.g. Council, LINZ).

(c) Receive and review missing information.

(d) Undertake additional intrusive geotechnical and contamination investigations, appraisal and reporting of the disposal site areas, based on the desktop study findings.

(e) Preparation of site plan(s) using ArcGIS or AutoCAD, as appropriate, providing the best understanding of disposal area extents, type and depth of cover, depth of fill and depth to natural ground; and the extent and severity of soil/fill contamination.

(f) Critical assessment of construction of the existing disposal sites, including assessing compliance of the final cover over the landfilled areas with the resource consent requirements.

(g) Landfill risk assessment addressing the risk to the environment from a range of factors.

(h) Estimating where the disposal sites sit in relation to the lifecycle of a closed landfill.

(i) Assessment of consent compliance issues and recommendations for possible repair/maintenance works as part of a long term management strategy for the closed landfill.

(j) Associated reporting including summarising site details, relevant aspects of the existing disposal sites history, including historical aerials review, its environmental context, lab results and presenting a Conceptual Site Model (CSM) and exposure path assessment.

3 INVESTIGATION METHODOLOGY

The methodology used for this investigation is summarised below:

1. Desktop study involving review of existing historical information for the subject site including previous investigations by others, aerial photographs (Appendix A), and interviews with relevant people.
2. Site walkover investigation of the landfill areas within the subject site, with a visual appraisal to identify any disturbed and potentially contaminated areas. Relevant photographs are set out in Appendix B.
3. Intrusive geotechnical (Appendix C) and soil sampling investigation and laboratory analysis (Appendix D).
4. Preparation of an Intrusive Investigation Report (this report) including the results of the desktop study, site walkover survey, laboratory analysis, conclusions and recommendations.
5. Provision of site plans, relevant documentation and representative photographs as appendices to this report.
6. Critical assessment of construction of the existing disposal sites, landfill risk assessment and consent compliance.

Fraser Thomas Limited Health and Safety Management Plan procedures were followed throughout the duration of the investigation. In addition, all individuals involved in the field work were provided with a copy of the Fraser Thomas Limited Job Safety & Environmental Analysis/Safe Work Method titled JSA-01 and the Site-Specific Health & Safety Plan dated 18th October 2022 and subsequent updates of these documents.

4 SITE DETAILS

4.1 LOCATION, ZONING AND LAND USE

The subject site is located at 149 Te Mawhai Road, RD 5 Te Awamutu, 3875 and encompasses an area approximately 79 hectares in size. The legal description of the site is SECS 1 3 SO 44852, SEC 1 SO 59771 BLKS X XI PUNIU SD -TOKANUI HOSP-.

The site is zoned 'Rural Zone' (Waipa District Plan, 2019 – Map 12).

This intrusive investigation report covers the existing disposal sites portion of the site. This is located off Farm Road (private road), directly east of the Wharekōrino Stream. The investigation area is approximately 7.7ha, of which the existing disposal sites make up approximately 2.1ha in area, including some areas of additional filling not shown on the original disposal sites plans. This area is currently in pastoral land use (grazing).

4.2 TOPOGRAPHY, GEOLOGY AND SOILS

The site is located in a predominantly undulating area. A tributary of the Wharekōrino Stream bisects the landfill area east to west and converges with the Wharekōrino Stream near the northern end of the site.

In carrying out the appraisal of the site, reference has been made to the Institute of Geological and Nuclear Sciences geological web map (NZ 1:250,000). The map indicates that the site is predominantly underlain by middle Pleistocene to late Pleistocene River deposits consisting of locally derived pumiceous clays, sandy clays and gravels of the Tauranga Group.

A small portion of the former hospital and existing disposal sites is underlain by early Pleistocene to middle Pleistocene River and igneous deposits consisting of alluvium dominated by primary and reworked, non-welded ignimbrite of the Walton Subgroup, which is part of the Tauranga Group.

As part of this Intrusive Investigation Report, Fraser Thomas Limited has also undertaken a Geotechnical Factual report, which identified the same geological units present across the areas of filling. This is included in Appendix C.

4.3 SURFACE WATER

The landfill is effectively sited between the Wharekōrino Stream and its tributaries, with one tributary entering the stream just upstream of the landfill and another two tributaries converging just south-east of the landfill and entering the Wharekōrino Stream within the landfill paddock downstream of the main landfill areas (refer Figure 2).

The Wharekōrino Stream and its tributaries above the landfill serve a combined approximately 570ha catchment of rural farmland. Hence, the stream upgradient of the landfill can reasonably be expected to contain:

- Suspended solids from any exposed areas of land, atmospheric deposition and land erosion.
- Nutrients such as nitrogen and phosphorus from soil fertilisers, animal faeces, organic debris and atmospheric deposition.
- Faecal coliforms and other bacteria from grazing and other animals/birds.

Just downstream of the landfill, the Wharekōrino Stream passes under Te Mawhai Rd and enters the Pūniu River. The Pūniu River flows south-west, adjacent to Waikeria Road.

4.4 GROUNDWATER

An Environment Waikato database search was done for all groundwater bores within 1km radius of the landfilling area, the results of which are shown on Figure 1, and attached as Appendix F. This search showed there are six groundwater bores within 1km of the site, of which only one is located downgradient (north) of the landfill. This bore (Bore 72, Station 10906) uses water for nursery irrigation. There is one further downgradient bore just outside the 1km limit - Bore 72, Station 4997 – which takes water for household supply and stock watering purposes, according to the Environment Waikato database.

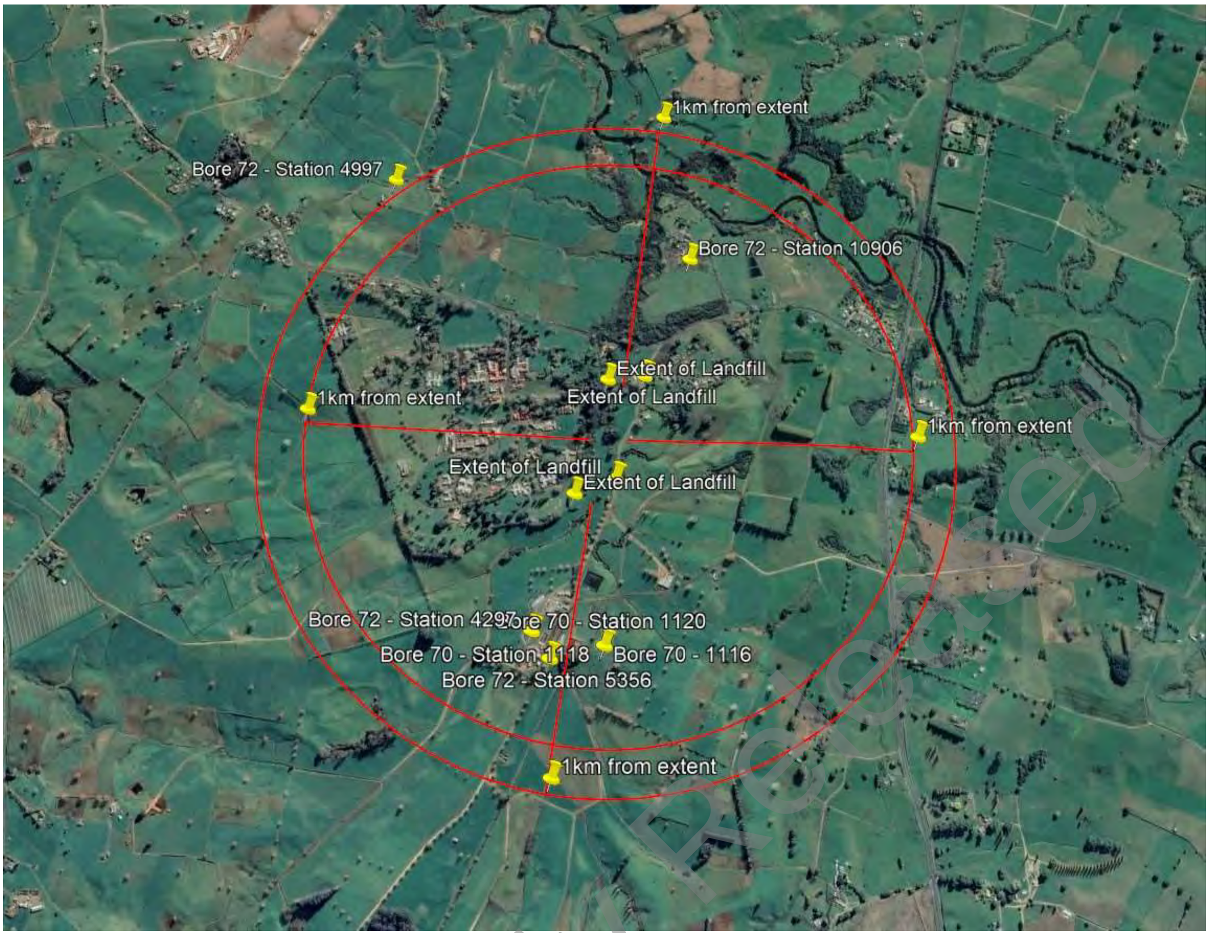


Figure 1: Environment Waikato Groundwater Bore Database Search Results

5 DESKTOP STUDY AND SITE WALKOVER FINDINGS

The results of the desktop study and the site walkover survey are summarised in this section, along with historical aerial photographs (Appendix A), site walkover photographs (included as part of Appendix B) and onsite interviews conducted during the intrusive investigation. Throughout the site walkover survey, a visual assessment was used to classify any foreign materials as particular contaminants, without any formal identification. Hence, reference to a specific contaminant in the survey should essentially be read as "suspected contaminants", unless otherwise stated.

5.1 SITE IDENTIFICATION AND USE

The site details and ownership history are summarised below.

Table 1: Site Details and Ownership History

Registered Owners	His Majesty the King
Street Address	149 Te Mawhai Road, Tokanui
Legal Description	SECS 1-3 SO 44852, SEC 1 SO 59771 BLKS X XI PUNIU SD -TOKANUI HOSP-
Total Area (ha)	~79ha
Zoning	Rural Zone (Waipa District Plan, 2019 – Map 12)

Information provided by LINZ indicates that the Tokanui hospital site was part of a land package taken under the Public Works Act in 1910, which included approximately 93ha for health services. The hospital site has remained under Crown ownership since then and was transferred to the LINZ landbank in July 2016.

5.2 PREVIOUS INVESTIGATIONS

This section covers previous investigations relating specifically to the existing disposal sites. Additional regular monitoring has been undertaken over the years as required by resource consent and these results are discussed separately later in this report.

5.2.1 Tokanui Hospital Landfill Closure AEE (Oct 1998)

The Tokanui Hospital Landfill Closure Assessment of Environmental Effects (AEE, October 1998) describes the landfill as comprising one fenced off area, within which there are several distinct areas that have been used for different types of refuse disposal. These areas are illustrated in Figure 2 below and summarised in Table 2. The AEE refers to Figure 2 as being a "rough sketch", which indicates, from discussions held with people on site and aerial photographs, the approximate locations of where refuse cells may have been constructed – it states that this sketch should be treated as "indicative only".

Table 2: Summary of Landfilling Areas (AEE, Oct 1998)

Area	Description
A	Main landfill area used for general hospital and domestic waste. Closed in 1988 and was operational for at least 40 years. Currently grassed and grazed by stock. Typical operation in this area consisted of long cells dug out of ground ~3m wide and 25-30m long with ~1m between cells. Refuse was placed in cells and then burnt. Cell was covered with ash from hospital boilers when full. Exact number of cells estimated to be in range of 3-5, based on local anecdotal information. At least 1m of material covers these cells based on hand augers, comprising largely a sandy silt with some clay and light topsoil layer, with permeability of ~$2x10^{-4}$m/s (based on 1 permeability test). Refuse estimated to be ~1.8m deep based on 1 piezometer log (P4). Refuse volume was conservatively estimated to be 810m^3 (based on 5 cells x 3m wide x 30m long x 1.8m deep).
B	Used for disposal of old building materials, concrete and pipes (iron and ceramic). Covered in places with soil and grass; edge ~1-1.5m from stream bank in places.
C	Was used until late 1997 for dumping of refuse, comprising coal ash, wastewater sludge, garden waste and general refuse. Stream ponds in swampy area at base of this area. Appendix E of the AEE shows a closure plan for Area C and how it was to be pulled back from the stream edge, placed behind a confined bund, capped with 600mm low permeability clay and 150mm topsoil, with the swampy area backfilled with clean material, (refer Figure 3).
D	Mainly building materials/concrete from demolished site buildings (referred to as cleanfill materials in AEE); fill extends partially into gully area, obstructing stormwater flow path from road, causing some ponding.

E	Site where runoff from road ponds as Area D blocks natural flow path. Remains of old concrete and asphalt also seen scattered around this general area.
F	6 x offal pits; thought to be 4-6m deep. Used to dispose of drugs, needles, etc.
Other (Areas H& I)	Discussions with others indicated that the area directly opposite Wharekōrino Stream from Area A may have been filled at some time earlier than construction of the cells in Area A, with the stream being culverted through this area at the same time. In addition, an area directly south of FTPH buildings 30 & 31 appears to have likely been filled during construction of the southern area of FTPH.

Main source: Tokanui Hospital Landfill Closure AEE (Oct 1998)

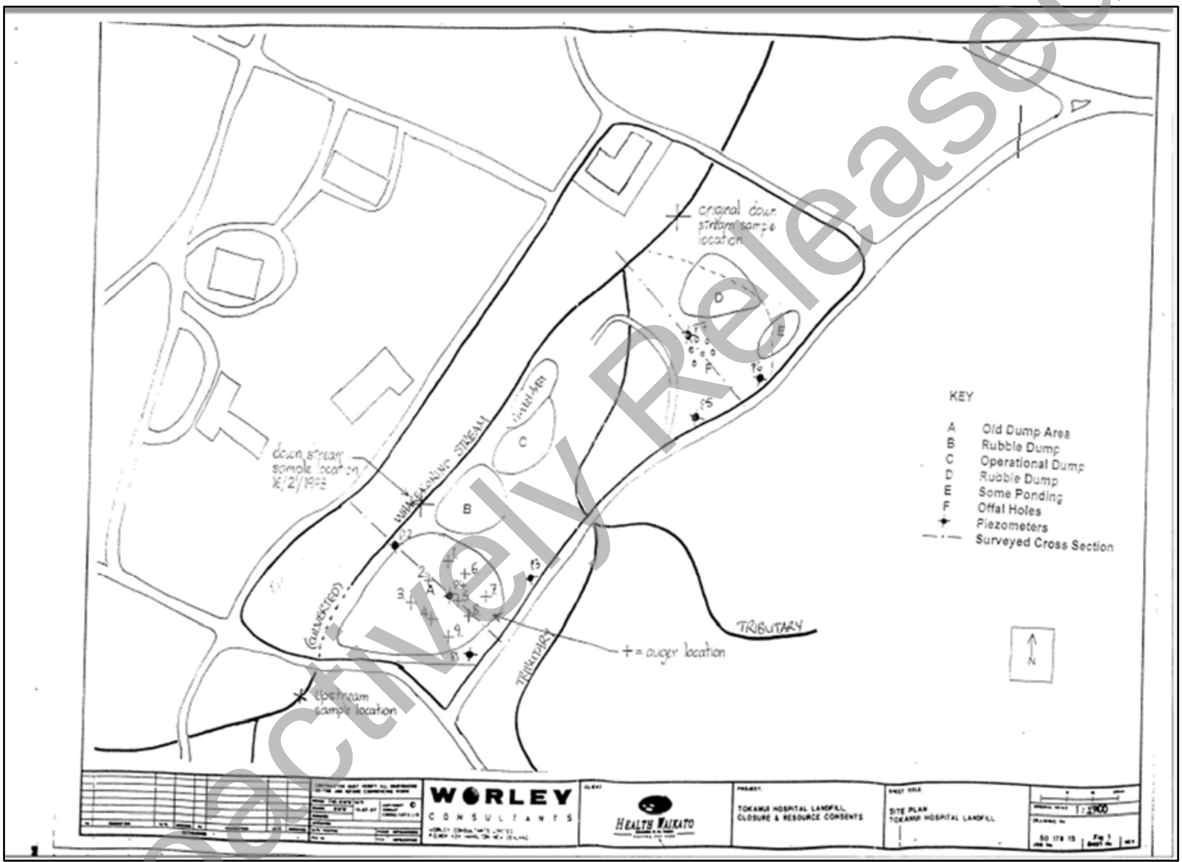


Figure 2: Closed Landfill Site Plan ex Worley

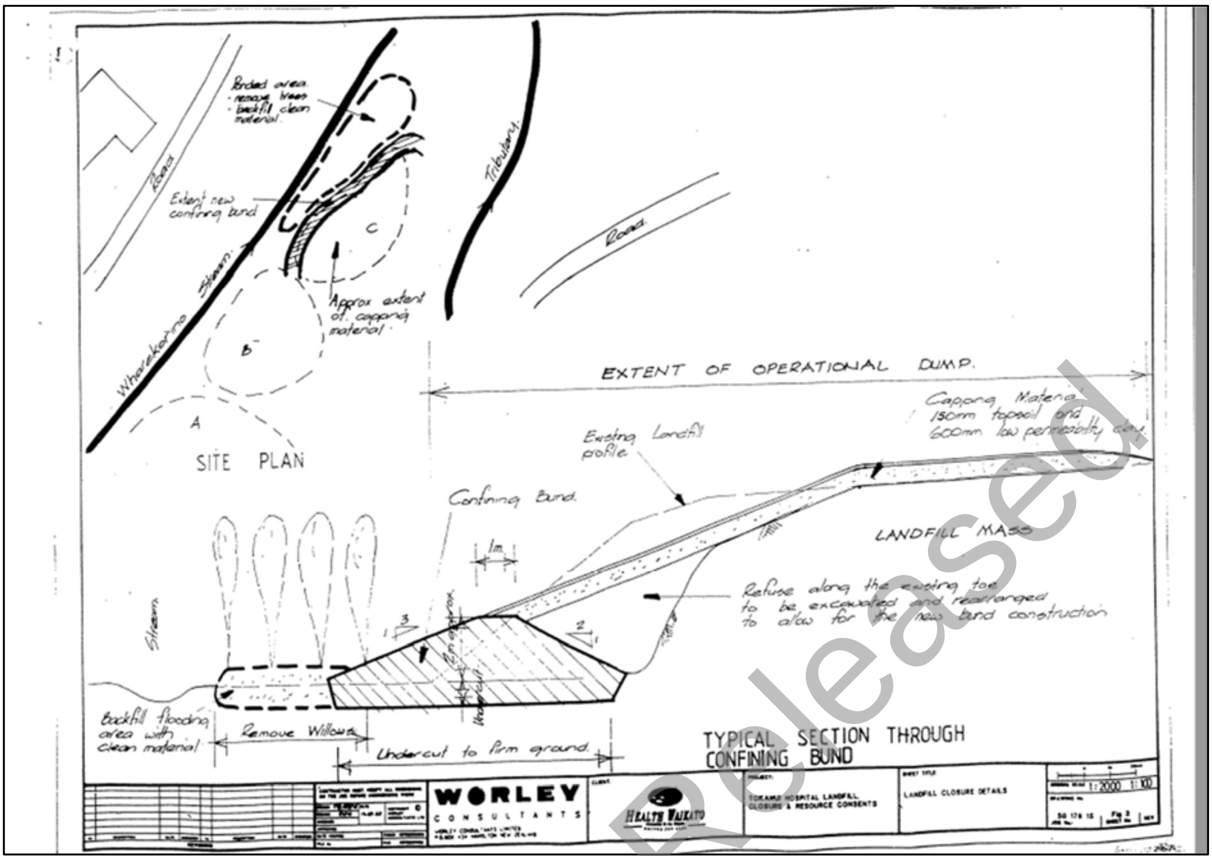


Figure 3: Closed Landfill – Closure Details for Area C (ex Worley)

5.2.2 Meritec Developed Site Plan (Oct 2000)

The Meritec "Developed Site Plan" (Oct 00) (Figure 4) has modified the area and extent of some of the landfill areas A-F from the Worley AEE (Figure 2) and shows five cross-sections through Areas A, B, C, D (part) and E, none of which were included in the CWR documentation. This plan also shows:

- Two piezometers. P2 and P7, which were to remain and be upgraded, for ongoing monitoring use, while the rest of the piezometers were to be decommissioned by grouting.
- Area C is shown as having an existing bund between it and the stream, and there is reference to a new imported clay bund, indicating that at least some of the closure works referred to in Figure 3 were completed for this area.
- Two additional areas (directly north of Area C and west of Area D were labelled as being part of a borrow area to be used initially to store and consolidate sludge and dirty water from existing ponds, with the borrow area to be later graded to fall, topsoiled and grassed.
- It also refers to the final cover comprising:
    - Areas A, C and F: 100mm topsoil on 100mm subsoil layer on low permeability clay layer. Thickness to be determined by permeability testing as per specification; minimum 450mm.
    - Areas B, D and E: 100mm topsoil on 200mm thick low permeability clay layer.
    - Subsoil layer: sand or free draining material from the site.
    - Compaction: compacted clay shall be compacted in layers or no more than 150mm thickness to ensure even compaction and maximum cap effectiveness.

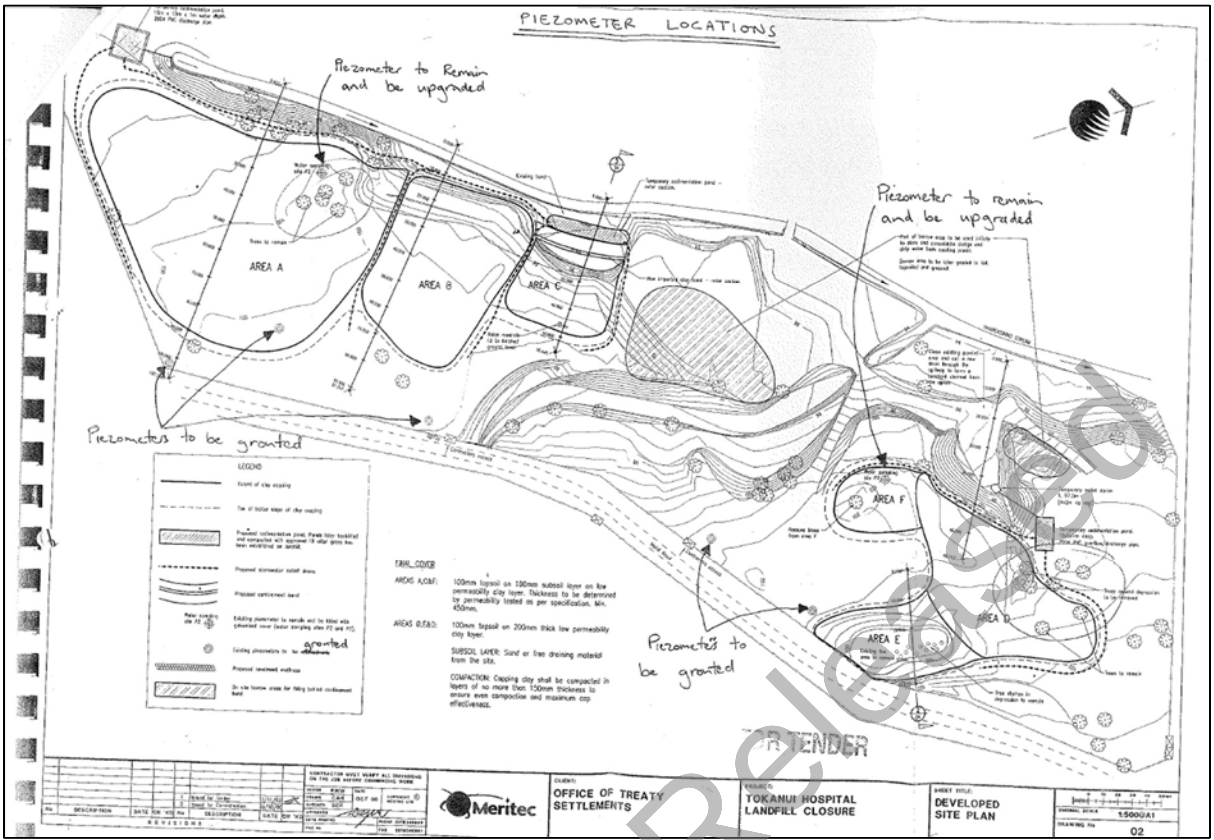


Figure 4: Meritec Developed Site Plan (October 2000)

5.2.3 Data Gaps

From the desktop review of relevant reports provided by LINZ and others, the following key data gaps were identified. These were discussed with LINZ with the outcome also recorded below.

Table 3: Identified Data Gaps and Outcome

Data Gap	Outcome
Lack of historical topographical survey data showing landfilling contours, ideally in CAD format.	Best historical contour information is a pdf copy of the Meritec 2000 Developed Site Plan (Figure 4 above). No other topo information found.
Worley closed landfill site plan (Figure 2) shows the locations of some hand augers (9 in Area A) and piezometers (P1-P7).	Hand auger borehole logs and piezometer P1-P7 logs were requested but have not been found.
Meritec 2000 drawing (Figure 4) includes a number of cross-sections.	Cross-sections requested but not found.
Any additional landfill cover composition, thickness and permeability data.	None found

Meritec 2000 drawing (Figure 4) is stamped for tender and would be part of a much larger tender package.	No other tender drawings or corresponding technical specification or any supporting technical report have been found. Similarly, no construction observation or certification documentation has been found.

5.3 AERIAL PHOTOGRAPHS

Historical aerial photographs dating from 1943 through to 1979, and 1995 through to 2021 have been reviewed as part of this desktop aerial photograph review. It should be noted that no historical aerial photographs of the FTPH were found during the 1980s.

5.3.1 Area A

The area of filling shifts east and north east from as early as 1957, filling the area, marked as Area A in the 1998 AEE (Figure 2). Early aerials show some buildings/dwellings in this area, but the majority of these were removed between 1966-1974. It was not possible to verify the closing year of the landfill (1988 from Table 2) due to the lack of any historical aerials covering the 1980s.

5.3.2 Area B

Multiple structures appear in this area from as early as 1943, that look to be dwellings. These structures remain in place until approximately 1974, where they are all removed. It is not clear where the building materials have been removed to; however, there are clear signs of soil disturbance visible, and infilling of depressions in this area of the site. The 1961 aerial shows two depressions adjacent to the stream path and the two most southern dwellings. The depression located to the south may relate to waste filling in Area B. Based on this, it is inferred that building demolition materials were dumped in this area. The 1979 aerial then shows the area as grassed over with some vegetation growing. From 1979 to present no further signs of ground disturbance are apparent.

5.3.3 Area C

Land depressions are visible in this area from 1943, and the area appears to be disturbed until 1979. Due to vegetation growth, it is difficult to delineate extents of filling from the historical aerials. There appears to be some soil disturbance through the centre of this area in the 1995 aerial photograph, which appears as vehicle tracks, indicating this was potentially one of the last filled areas, or that some capping materials were possibly sourced from this area.

5.3.4 Area D and E

A noticeable change in topography occurs between 1966 to 1974. It is during this period that the buildings and structures (4-5) in the area were demolished and cleared. Based on this, it is assumed that construction debris was disposed in these areas. The 1974 aerial appears to show a reasonably uniform settlement zone, gully or pit for filling; however, it is unclear which of these this feature is. In the 1979 aerial, this area appears to have been filled. By 1995, the area appears fully vegetated with no signs of soil disturbance visible.

5.3.5 Area F

There are clear signs of soil disturbance visible in the historical aerials from 1943 through 1979 in this area, with some small, possibly circular holes visible directly east of the Wharekōrino Stream, which may be offal pits. There is also possible construction debris from removal of nearby structures that has been deposited within the gully/settlement zone in the southern portion of this area. By 1995, the area appears fully vegetated with no signs of soil disturbance visible.

5.3.6 Other Areas

The 1943/44 aerials show a depressed area west of Area A with the Wharekōrino Stream flowing through it. This is likely to be part of the stream floodplain. From 1957 until the late 1960s, aerials show the ground in this area as disturbed, and being filled in with the stream channel no longer visible by 1979. This is consistent with the information included under "other" in Table 2. This area has been labelled Area H and added to the intrusive investigation.

The 1943-44 aerials also clearly show a low-lying area west of Area H, on the other side of an access road that bisects Area H and this low-lying area (Area I). The 1974-79 aerial shows some indications of soil disturbance activities in this area, while more recent aerials and the LiDAR survey data for the site suggest this area may have been filled at least in part.

An additional area, termed 'Area G' has been identified directly north of Area C, where the potential for building demolition debris is considered likely. This is based on historical aerials for the area showing structures (likely residential buildings) directly east of the stream in the 1940s-1960s From the 1970s onwards, these structures are no longer visible. This area has been added to the intrusive investigation.

5.4 SITE INTERVIEWS

Given the time period of active filling at the site, very few people were able to be interviewed as part of the desktop study. One individual, a local Kaumātua, made himself available to discuss the history of the site.

During various discussions onsite with this person, it was made clear that the extent of fill in Area A was more extensive than first understood, potentially capturing Areas B & C as well. The contents of the landfill were also discussed, with Area A being identified as the original dumping area, and there being little discretion on the type of material deposited in this portion of the landfill.

It was revealed that the interviewee knew the member of staff who managed the landfill while it was operational, and this past staff member came to site the following day and was also interviewed. This past staff member stated that the landfill cells and contents were set on fire and left for multiple days, and that all material deposited within the cells was burnt, including building materials. In addition, the interviewee stated that no fill was deposited within Area G, nor was any fill deposited north of Areas D & E.

Furthermore, the interviewee revealed that when the FTPH proposed closure was made public knowledge, there was an increase in materials that were deposited within the landfilling areas, understood to be materials from the FTPH buildings.

5.5 SITE WALKOVER RESULTS

A walkover of the portion of the site assessed as part of this investigation was undertaken by FTL Environmental Scientist, Elliot Bish, on 1st November 2022 and 17th April 2023. The hospital existing disposal sites is located within a paddock currently leased to AgResearch, which is usually grazed but sometimes mown for silage.

Across the existing disposal sites, there were various areas showing minor localised patchiness/die off. Some kanuka trees adjacent to the landfill (western side of existing disposal sites) also showed signs of dieback. There were various instances of individual refuse pieces protruding through the cap at the extents of the landfill. In addition, there was one area which showed small localised damage to the cap of the landfill.

There appears to be minor to moderate settlement and ponding in some areas, which has appeared largely unchanged from previous investigations. Area C has continued to show frequent ponding conditions.

Some subsidence was observed around the site, forming an uneven ground profile. No erosion was observed. There was no obvious evidence of contaminant leaching at any of the landfill sites. Wharekōrino Stream had an overall clear and slightly cloudy appearance, with debris build-up at the fence line and ponding in the paddock indicative of stream bank overtopping during periods of high stream flows.

An in-depth site walkover discussion, and associated photos are provided in the FTL report titled *"Tokanui Closed Landfill, Te Awamutu, Wharekōrino Stream & Bore Water Sampling, Water Quality Annual Report 2022"*, dated December 2022.

As part of the additional investigation, which was undertaken on the western side of the Wharekōrino stream, and below FTPH buildings 30 & 31, another site walkover was completed on 17th April 2023. This area of the site, referred to as Area I, appeared undeveloped, and likely used for grazing purposes. There was a farm access track observed running north-south along the eastern boundary of Area I. The area adjacent to the farm track was observed partially swampy underfoot, with moderate to steep slopes observed west and north of the swampy area. It should be noted the 'swampy' conditions may have been due to severe rainfall recently experienced. No areas of stunted grass growth or discolouration were observed. A single area of subsidence was observed, adjacent to the west of an established tree, directly south of FTPH buildings 30 & 31.

6 INTRUSIVE SAMPLING

6.1 INTRODUCTION

The intrusive sampling investigation of the former hospital existing disposal sites was completed between the 1st-11th November 2022 and 17th-20th April 2023. The April 2023 investigation focussed on delineating Area A, and investigating suspected additional filling areas. Due to relatively limited information obtained from the desktop study, an extensive investigation was undertaken to confirm the horizontal landfill extent, cap/refuse depths, coal ash distribution (if possible) and underlying soils. Permeability testing of selected samples from Areas A, C and F was also undertaken to check the permeability of the landfill cap. During the course of the investigation, a total of 56 machine excavated test pits, 40 machine excavated trenches and 11 hand augered boreholes were put down across the existing disposal sites, suspected additional filling areas and the Wharekōrino stream bank.

6.2 RATIONALE

Targeted intrusive soil sampling was conducted across the existing disposal sites and suspected additional filling areas based on the findings of the desktop study and information gathered from onsite interviews to:

(a) Check the nature of the soil and fill materials (visual observation, soil sampling) underneath the site.
(b) Determine the nature and severity of contamination (if any) in the soil and fill materials.
(c) Determine whether the soil/fill can be retained on-site or where it can be disposed to off-site (cleanfill, managed fill or landfill); and
(d) Determine whether the existing disposal sites and suspected additional filling areas are a potential risk to human and/or environmental health.
(e) Check the permeability of the landfill cap.

The intrusive investigation focused on the potential presence of Heavy Metals, Boron, Polycyclic-Aromatic Hydrocarbons (PAHs) and Semi-Quantitative Asbestos in soil.

6.3 DATA QUALITY OBJECTIVES & CONCEPTUAL SITE MODEL

In accordance with MfE Contaminated Land Management Guidelines (CLMG) No.5, the Data Quality Objectives (DQOs) and Conceptual Site Model (CSM) for this investigation are summarized below in Table 4.

Table 4: DQOs and CSM

Item	Description	
Purpose of investigation	To assist with developing a long term management strategy for the site, consistent with consenting requirements, best practice and to manage and/or mitigate potential human health and environmental effects.	
Date quality objectives	To determine the contamination status of the soil & fill materials contained within the existing disposal sites & suspected additional filling areas, and assess the human and environmental health risks posed by the existing disposal sites and suspected additional filling areas	
Define boundaries	Investigation focused on the extent of the existing disposal sites and suspected additional filling areas determined from the desktop study.	
Develop Conceptual Site Model	Known/possible HAIL land use	Landfill Sites HAIL category: G3 Asbestos products manufacture or disposal including sites with buildings containing asbestos products known to be in a deteriorated condition: E1 Any other land that has been subject to the intentional or accidental release of a hazardous substance in sufficient quantity that it could be a risk to human health or the environment: I

	Contaminants of concern	Heavy Metals (Arsenic, Cadmium, Chromium, Copper, Lead, Nickel & Zinc), Boron, Polycyclic-Aromatic Hydrocarbons (PAHs) and Semi-Quantitative Asbestos in Soil
	Distribution of contaminants	Lateral – across the existing disposal sites and suspected additional filling areas Vertical – depending on the soil type & depth of filling
	Receptors	Site users (long term) and construction/maintenance workers (short term)
	Potential pathways	Dermal contact, ingestion and inhalation.
	Applicable land use scenario	NESCS Rural Residential/Lifestyle Block – no produce (unpublished) NESCS Commercial/Industrial outdoor worker (unpaved)
Additional information required (Sampling and Analysis Plan)	144 soil samples collected from 56 test pits, 40 trenches & 11 hand augers at varying depths (Surface (0.0m) – 4.80m) below ground level (BGL) 135 soil samples analysed for Heavy Metals, PAHs & Semi Quantitative Asbestos. 11 Duplicate samples analysed for Heavy Metals for quality assurance/quality control purposes.	

6.4 EVALUATION BASIS

The sampling results have been compared with the NESCS Soil Contaminant Standards (SCS) for Rural Residential/Lifestyle Block – No Produce (unpublished) and Commercial/Industrial Outdoor Worker (Unpaved) land uses. In addition, an assessment against the adopted Waikato Regional Council cleanfill criteria, Envirofill South managed fill and Hampton Downs landfill acceptance criteria has been undertaken.

6.5 METHODOLOGY

Between the 1st-11th of November 2022, a total of 118 soil samples were collected from varying depths at 42 locations across 8 potential filling areas within the identified existing disposal sites and suspected additional filling areas. In addition, across the 8 potential filling areas, 16 permeability samples were collected for geotechnical analysis to assess the permeability of the existing landfill cap, while an additional 40 trenches were excavated to confirm the horizontal fill extent in the different landfill areas.

Between the 17th – 20th April 2023, a total of 37 soil samples were collecting from varying depths at 21 locations across 2 known filling areas (A & H) and 1 potential filling area (I) within the identified existing disposal sites and suspected additional filling areas.

Throughout the intrusive investigations, landfill gas was measured using a GA5000 Landfill Gas Analyser.

The sampling locations and results are shown on FTL Drawings 33097/003 – 33097/006 appended to this report and in the attached Appendix D. Test Pit logs are provided as part of the geotechnical factual report in Appendix C. Test pits TP41 – TP45 were not logged, as they were landfill cap sampling locations only. The numbers 1 to 6 below relate to the soil/fill matrix each sample was collected from.

All test pits and trenches were temporarily reinstated by placing excavated materials back into the pits/trenches in the same order as the material was removed, with the soil/fill being compacted using the excavator bucket. Hand auger locations were reinstated and compacted with the auger head.

Table 5: Soil Sample Information

ID	Depth (mm)	Soil/Fill Matrix	Test
TP1 – TP33, TP35, TP37 – TP39, TP46 – TP52, TP54 – TP56 SUR	0-150	Rootlets, Topsoil (1)	Heavy Metals (As, Cd, Cr, Cu, Pb, Ni, Zn), B, PAHs & SQ Asbestos
TP1, TP11 0.6m	550-650	Landfill Cap (2)	
TP8 1.0m	950-1050		
TR9 0.2m	150-250		
TR10 0.5m	450-550		
TR11, TR27 0.3m	250-350		
TR16 0.4m	350-450		
TP38 0.3m	250-350		
TP39 0.5m	450-550		
TP40 0.6m	550-650		
TP41 0.2m	150-250		
TP42 0.2m	150-250		
TP42 1.0m	950-1050		
TP43 0.3m	250-350		
TP43 0.7m	650-750		
TP44 0.4m	350-450		
TP45 0.2m	150-250		
TP3, TP17 0.7m	650-750	Interface of Landfill Cap and Mixed Fill (3)	
TP4 1.0m	950-1050		
TP10 0.8m	750-850		
TP15 0.5m	450-550		
TP44 1.0m	950-1050		
TP1, TP3, TP5, TP8, TP10, TP38 2.0m	1950-2050	Mixed Fill (4)	
TP2, TP7 1.8m	1750-1850		
TP2, TP5, TP6 3.0m	2950-3050		
TP6, TP9, TP30, TP26, TP57 1.5m	1450-1550		
TP9, TP35 2.5m	2450-2550		
TP12 1.2m	1150-1250		
TP13, TP27, TP35, TR22, TP40 1.0m	950-1050		

ID	Depth (mm)	Soil/Fill Matrix	Test
TP14, TP15, TP26, TP57 0.8m	750-850		Heavy Metals (As, Cd, Cr, Cu, Pb, Ni, Zn), B, PAHs & SQ Asbestos
TP16, TP46, TP50 0.3m	250-350		
TP17 3.7m	3650-3750		
TP32, TP50 0.5m	450-550		
TP34 SUR	0-150		
TP51 0.25m	200-300		
HA1	200-600		
TP4 4.0m	3950-4050	Interface of Mixed Fill and Natural Ground (5)	
TP7 3.0m	2950-3050		
TP12 2.7m	2650-2750		
TP13 3.2m	3150-3250		
TP14, TP18 1.2m	1150-1250		
TP16 0.5m	450-550		
TP21 1.0m	950-1050		
TP30 3.5m	3450-3550		
TP56 2.3m	2250-2350		
TP11, TP32 1.5m	1450-1550	Natural Ground (6)	
TP19 0.8m	750-850		
TP20, TP24 1.5m	1450-1550		
TP23 1.2m	1150-1250		
TP25 2.0m	1950-2050		
TP27 1.7m	1650-1750		
TR27 4.8m	4750-4850		
TP28, TP33, TP34 0.5m	450-550		
TP29 0.3m	250-350		
TR29 2.9m	2850-2950		
TP31, TP22 1.0m	950-1050		
TP40 2.1m	2050-2150		
HA2 – HA7, HA9, HA10	0-1000		Not Sampled
HA8	0-2000		
HA11	0-1500		

7 INTRUSIVE INVESTIGATION RESULTS AND DISCUSSION

7.1 SOIL/FILL PHYSICAL OBSERVATIONS

The geotechnical factual report in Appendix C includes all testpit & hand auger logs from the intrusive investigations. Test pit logs of the shallow trenches are not appended to this report as these trenches were used to determine the extent of fill. Key physical observations from this investigation are summarised below:

(a) The areas where landfill material was encountered were generally observed to comprise grassed, flat lying farm paddocks. Evidence of shallow soil creep, including terracettes and hummocky topography, were observed in areas where the site topography sloped at, or was steeper than, 14° to the horizontal (1V:4H), as shown on the appended Fraser Thomas Ltd drawing 65547/101.

(b) A 'tomo', or area of subsidence, up to approximately 1 m^2 in plan area and up to 0.6 m deep, was noted in the northern part of the site, within close proximity to TP36, where construction debris were encountered from 0.2 m to 1.8 m depth below the ground surface.

(c) Area A: Landfill material was confirmed to be present in Area A at variable depths (refer TP1-TP12, TP35 and TP38-TP45) comprising a mixture of construction debris, general refuse, burnt material, tree stumps/wood fragments inferred boiler ash and some sharps and asbestos. This was overlain by a silt capping/cover layer and topsoil. The cap appeared to be continuous across Area A. Evidence of trenches where fill was deposited and burnt was identified across Area A; however, it was not possible to confirm trench dimensions due to frequent trench collapse during excavations.

(d) Area B: Landfill material was confirmed to be present in Area B (TPs 13-16) at variable depths comprising a mixture of mainly construction/demolition waste and some burnt debris and sharps. This was overlain by a silt capping/cover layer and topsoil.

(e) Area C: Landfill material was confirmed to be present in Area C (TPs 17-18) at variable depths comprising a mixture of general and construction waste, including some potential ACM (asbestos containing materials), barbed wire and sharps. This was overlain by a silt capping/cover layer and topsoil.

(f) Area G: Landfill material was not found in Area G (refer TPs 19-24 and TR 21 and 22), although some non-engineered fill (reworked natural) was present at three test pits in this location (possibly from capping of adjacent area or from reworking of natural ground in this area as part of post-landfilling works).

(g) Area E: Landfill material was not found in Area E (TP25 and TR37-40).

(h) Area F: Medical waste (needles, razors, blood bags and bottles; no soil matrix) was found in Area F at TP26, where 7 x 600mm diameter bored offal pits were encountered within the test pit and surrounding area. Inferred boiler ash was also noted in one of the offal pits. Table 2 refers to there being a total of 6 offal pits used for medical waste in this area. No other offal pits were found in the three trenches excavated in this area. Low density construction and demolition debris as well as non-engineered fill (likely reworked natural ground) was also identified in this area.

(i) Area D: Landfill material was confirmed in this area (TPs 27, 30, 36) mainly comprising construction waste, including wood, metal, concrete, bricks and some sharps. No landfill material was found in the other test pits (TPs 28, 29, 31) and trenches excavated in this area.

(j) Area H: Landfill material was confirmed to be present in Area H at variable depths (refer TP32, TP33, TP34, TP54 & TP55) comprising a mixture of construction debris, general refuse, burnt material and sharps. It was partially overlain by a silt capping/cover layer and topsoil, with some areas having no capping layer and just being covered with topsoil.

(k) Area I: Landfill material was confirmed in this area (TP50, TP56 & TP57) at variable depths mainly comprising construction debris, general refuse and large quantities of buried topsoil.

The waste materials found in Areas A-F are generally consistent with the waste descriptions from the 1998 AEE in Table 3 of this report.

The test pitting work was relatively difficult for a number of reasons, including:

- Excavating into historic landfill areas.
- In some locations, test pit side wall collapse meant the test pits were terminated before natural ground was reached.
- It was sometimes difficult to determine the fill/natural ground interface due to the depth of the test pits and groundwater infiltration.

7.2 SHEAR VANE RESULTS

In situ undrained shear strength measurements were carried out in the sides and base of the test pits using hand held field shear vane equipment in accordance with the NZ Geotechnical Society 'Test Method for Determining the Vane Shear Strength of a Cohesive Soil using a Hand-Held Shear Vane, August 2001'. These tests were carried out in the walls and floor of the test pits at 0.5 m depth intervals, where possible, enabling a strength profile of cohesive soils to be obtained from the test pits.

It is noted that in situ undrained shear strength measurements were not generally undertaken in the granular material i.e., landfill refuse.

It is also noted that due to instability of the area surrounding the test pits, dynamic cone (Scala) penetrometer (DCP) tests were not undertaken in the landfill refuse.

In situ undrained shear strength values measured in the landfill capping material were generally greater than 100 kPa, corresponding to a very stiff to hard consistency.

In situ undrained shear strength values measured in the Hamilton Ash and Tauranga Group alluvial sediments ranged between 31 kPa and greater than 200 kPa, corresponding to a firm to hard consistency.

7.3 GENERAL COMMENTS

Throughout the investigation, no putrescible waste (i.e., odorous or decaying waste) was observed within the refuse. In addition, there were no organics observed within the fill apart from some wood.

ACM were not easily identifiable within the fill, given the wide range of refuse observed within the fill and poor condition of much of the fill contents. However, some test pits contained stacked asbestos roof tiles (super six cement) and other ACM such as pipe lagging.

The systematic approach to test pitting adopted is considered to be the most appropriate and representative method for capturing typical refuse composition and contaminant concentrations within the various landfill areas, while the number of test pits and trenches put down is also considered to be appropriate based on the investigation objectives. However, the observed heterogenity of the fill material in many locations and small volume of the samples collected for testing from each test pit means that the sampling results could potentially miss localised contamination hotspots. Furthermore, the presence of hazardous materials within various landfill areas is important in determining the overall human health risk. These hazardous materials are generally present in small quantities dispersed throughout the waste mass, apart from the "offal pits" in Area F that contain mainly medical waste.

7.4 SOIL/FILL ANALYTICAL RESULTS

All soil/fill results are provided in tabulated form as Appendix D.

7.4.1 Area A

A. Topsoil (15 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 15 topsoil samples within Area A. Concentrations of boron detected in samples TP1 SUR, TP2 SUR, TP3 SUR, TP5 SUR, TP7 SUR, TP10 SUR,TP12 SUR, TP35 SUR, TP38 SUR & TP39 SUR exceeded the Waikato Regional Council cleanfill acceptance criteria (noting that the lab detection limit for boron (20mg/kg) is greater than the cleanfill criteria, but not including these samples). Concentrations of boron detected in samples TP2 SUR, TP5 SUR & TP12 SUR exceeded the managed fill acceptance criteria. Furthermore, concentrations of boron detected in sample TP12 SUR also exceeded the Class 1 landfill acceptance criteria, but were below the relevant NESCS guidelines.
- PAHs were elevated above the analytical limit of detection in 14 of 15 topsoil samples within Area A. The concentrations of BaP Eq. in sample TP12 SUR were also elevated above the Class 1 Landfill acceptance criteria, but were below the relevant NESCS guidelines.
- Asbestos (AF/FA portion) was detected in 5 (TP5 SUR, TP12 SUR, TP35 SUR & TP38 SUR) of the 15 topsoil samples within Area A. Concentrations of free fibres in samples TP5 SUR & TP12 SUR exceeded the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

B. Landfill Cap (17 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in 14 of the 17 landfill cap samples within Area A. Concentrations of boron detected in sample TP1 0.6m, TR11 0.3m, TP38 0.3m, TP39 0.5m, TP40 0.6m & TP43 0.7m exceeded the Waikato Regional Council cleanfill acceptance criteria; however, there were no exceedances of the managed fill or Class 1 landfill acceptance criteria, nor the relevant NESCS guidelines.
- Residual concentrations of PAHs were detected in 5 of the 17 landfill cap samples within Area A, while a further 5 landfill cap samples had concentrations of PAHs elevated above background concentrations for the site. There were no exceedances of the NESCS or any waste acceptance criteria noted for PAHs.
- Residual concentrations of Asbestos fibres were detected in 2 of the 17 landfill cap samples; however, no exceedances of the NESCS or waste acceptance criteria was noted for Asbestos.

C. Mixed Fill (21 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 21 mixed fill samples within Area A. Concentrations of arsenic detected in samples TP1 2.0m, TP3 2.0m, TP5 2.0m, TP9 2.5m,TP10 2.0m, TP35 2.5m & TP38 2.0m also exceeded the NESCS rural residential/lifestyle block- no produce (unpublished) land use criteria, and sample TP38 2.0m also exceeded the NESCS commercial/industrial outdoor worker (unpaved) land use criteria. Concentrations of lead detected in mixed fill samples TP2 1.8m, TP2 3.0m, TP3 2.0m, TP5 2.0m, TP5 3.0m, TP8 2.0m, TP9 2.5m, TP10 2.5m, TP35 1.0m, TP35 2.5m & TP38 2.0m exceeded the NESCS rural residential/lifestyle block - no produce (unpublished) land use criteria, but did not exceed the NESCS commercial/industrial outdoor worker (unpaved) land use criteria. Concentrations of boron, copper, lead and zinc all exceeded the Class 1 landfill acceptance criteria in samples between 0.9m-3.0m depth, indicating the mixed fill materials within this layer exhibit the highest levels of contamination within Area A.

- Residual concentrations of PAHs were detected in 7 of 21 samples, while PAHs were elevated above the analytical limit of detection in a further 13 of 21 mixed fill samples within Area A. The concentrations of BaP Eq. in sample TP12 1.2m was also elevated above the Class 1 Landfill acceptance criteria, but were below the relevant NESCS guidelines.
- Asbestos (AF/FA Portion) was detected in 16 of the 21 mixed fill samples within Area A. Six of the 21 samples (TP1 2.0m, TP3 2.0m, TP10 2.0m, TP12 1.2m, TP3 2.5m & TP40 1.0m) had concentrations of free fibres that exceed the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites. Sample TP3 2.0m also had concentrations of asbestos containing materials (%ACM portion) that exceeded both BRANZ residential and commercial/industrial sites guidelines.

D. Natural Ground (5 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in 4 of the 5 natural ground samples within Area A. Boron was also elevated above the WRC Cleanfill criteria in samples TP4 4.0m, TP7 3.0m & TP40 2.1m and was elevated above the Class 1 landfill acceptance criteria in sample TP12 2.7m.
- PAHs were not detected in any of the natural ground samples within Area A.
- Asbestos (AF/FA & %ACM portions) was not detected in any of the natural ground samples within Area A.

7.4.2 Area B

A. Topsoil (4 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 4 topsoil samples within Area B. Boron was also elevated above the WRC Cleanfill criteria in sample TP14 SUR.
- PAHs were elevated above the analytical level of detection in all 4 topsoil samples within Area B. The concentration of BaP Eq. in sample TP14 SUR was also elevated above the Class 1 landfill acceptance criteria, but was below the relevant NESCS guidelines.
- Asbestos (AF/FA & %ACM Portions) was not detected in any of the topsoil samples within Area B.

B. Mixed Fill (5 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 5 mixed fill samples within Area B. The concentration of lead detected in sample TP13 1.0m exceeded the NESCS rural residential/lifestyle block- no produce (unpublished) land use criteria, but did not exceed the NESCS commercial/industrial outdoor worker (unpaved) land use criteria.

- PAHs were elevated above the analytical level of detection in 3 of the 5 mixed fill samples within Area B. There were no exceedances of the NESCS or any waste acceptance criteria noted for PAHs.
- Residual concentrations of asbestos (AF/FA & %ACM Portions) were detected in 1 (TP16 0.3m) of the 5 mixed fill samples within Area B, exceeding the WRC Cleanfill acceptance criteria. However, no exceedance of the BRANZ Asbestos in Soil guidelines was noted.
- It is considered likely that samples TP15 0.5m & TP15 0.8m have been collected from the interface of landfill cap and fill (TP15 0.5m), and interface of fill and underlying natural ground (TP15 0.8m), which could explain the relatively low contaminant concentrations within these samples.

C. Natural Ground (3 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 3 of the natural ground samples within Area B. Boron, lead and zinc were also elevated above the WRC Cleanfill criteria in samples TP 13 3.2m (boron, lead, zinc), TP14 1.2m (boron) and TP16 0.5m (lead). No exceedances of the relevant NESCS guidelines were noted.
- PAHs were elevated above the analytical level of detection in 2 (TP13 3.2m, TP16 0.5m) of the 3 natural ground samples within Area B. There were no exceedances of the NESCS or any waste acceptance criteria noted for PAHs.
- Residual Asbestos (AF/FA Portions) was detected in 2 (TP13 3.2m & TP16 0.5m) of the natural ground samples within Area B, exceeding the WRC Cleanfill criteria. However, no exceedance of the BRANZ Asbestos in Soil guidelines was noted.

7.4.3 Area C

A. Topsoil (2 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in 1 of the 2 topsoil samples within Area C. Boron was also elevated above the WRC Cleanfill criteria in sample TP18 SUR. No exceedances of the relevant NESCS guidelines were noted.
- PAHs were elevated above the analytical level of detection in both topsoil samples within Area C, but was below the relevant waste acceptance criteria and NESCS guidelines.
- Asbestos (AF/FA portion) was detected in 1 (TP18 SUR) of the topsoil samples within Area B. The sample results identified concentrations of free fibres that exceed the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

B. Landfill Cap (1 sample)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in the single (TR16 0.4m) landfill cap sample within Area C. No exceedances of the relevant waste acceptance criteria or NESCS guidelines were noted.

- Residual concentrations of PAHs were detected above the analytical level of detection in the single landfill cap sample within Area C, but were below the relevant waste acceptance criteria and NESCS guidelines.
- Asbestos (AF/FA & %ACM portions) was not detected within the single landfill cap sample from Area C.

C. Mixed Fill (2 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in both (TP17 0.7m & TP17 3.7m) mixed fill samples within Area C (latter sample from interface of mixed fill and natural ground and included here, based on results). Lead was detected at levels that exceed the Class 1 Landfill acceptance criteria in both samples, was equal to the NESCS rural residential/lifestyle block – no produce (unpublished) guidelines in sample TP17 0.7m and, along with arsenic, exceeded the NESCS rural residential/lifestyle block – no produce (unpublished) guidelines in sample TP17 3.7m. Zinc was also detected in sample TP17 3.7m at levels that exceed the Class 1 Landfill acceptance criteria.
- PAHs were detected above the analytical level of detection in the 2 mixed fill samples within Area C, but were below the relevant waste acceptance criteria and NESCS guidelines.
- Asbestos (AF/FA portion) was detected within mixed fill sample TP17 3.7m. The sample result identified concentrations of free fibres that exceed the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

D. Natural Ground (1 sample)

- One heavy metal (lead) was elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in the single natural ground sample within Area C. No exceedances of the relevant waste acceptance criteria or NESCS guidelines were noted.
- PAHs were not detected in the single natural ground sample within Area C.
- Asbestos (AF/FA & %ACM Portions) was not detected in the single natural ground sample within Area C.

7.4.4 Area D

A. Topsoil (5 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in 4 of the 5 topsoil samples within Area D. Boron was also elevated above the WRC Cleanfill criteria in sample TP31 SUR. No exceedances of the relevant NESCS guidelines were noted.
- PAHs were elevated above the analytical level of detection in 4 of the 5 topsoil samples within Area D, but were below the relevant waste acceptance criteria and NESCS guidelines.
- Asbestos (AF/FA & %ACM portions) was not detected in any of the topsoil samples from Area D.

B. Mixed Fill (2 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in both (TP27 1.0m & TP30 1.5m) mixed fill samples within Area D. The concentrations of lead detected in sample TP30 1.5m exceeds the NESCS rural residential/lifestyle block – no produce (unpublished) guidelines, and the concentrations of lead detected in both samples exceed the Class 1 landfill acceptance criteria.
- PAHs were detected above the analytical level of detection in both mixed fill samples within Area D, but were below the relevant waste acceptance criteria and NESCS guidelines.
- Asbestos (AF/FA portion) was detected in sample TP27 1.0m from Area D. The sample result identified concentrations of free fibres that exceed the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

C. Natural Ground (6 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in 3 of the 6 natural ground samples within Area D. The concentrations of lead detected in sample TP30 3.5m exceed the NESCS rural residential/lifestyle block – no produce (unpublished) guidelines and the Class 1 landfill acceptance criteria.
- PAHs were not detected in the natural ground samples within Area D.
- Asbestos (AF/FA & %ACM Portions) was not detected in the natural ground samples within Area D.

7.4.5 Area E

A. Topsoil (1 sample)

- Heavy metals were detected in the single topsoil sample collected from Area E; however, all heavy metal concentrations were below the upper limit background concentrations for selected elements in soil from the Waikato Region.
- PAHs were not detected in the single topsoil sample from Area E.
- Asbestos (AF/FA & %ACM Portions) was not detected in the single topsoil sample within Area E.

B. Natural Ground (1 sample)

- Heavy metals were detected in the single natural ground sample collected from Area E; however, all heavy metal concentrations were below the upper limit background concentrations for selected elements in soil from the Waikato Region.
- PAHs were not detected in the single natural ground sample from Area E.
- Asbestos (AF/FA & %ACM Portions) was not detected in the single natural ground sample within Area E.

7.4.6 Area F

A. Topsoil (1 sample)

- One heavy metal (zinc) was elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in the single topsoil sample collected from

Area F. There were no exceedances noted for the relevant waste acceptance criteria or the NESCS guidelines.

- PAHs were not detected in the single topsoil sample within Area F.
- Asbestos (AF/FA & %ACM Portions) was not detected in the natural ground samples within Area F.

B. Landfill Cap (1 sample)

- Two heavy metals (nickel & zinc) were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in the single landfill cap sample collected from Area F. There were no exceedances noted for the relevant waste acceptance criteria or the NESCS guidelines.
- Residual concentrations of PAHs were detected in the single landfill cap sample collected from Area F. No exceedances of the relevant waste acceptance criteria or NESCS guidelines were noted.
- Asbestos (AF/FA & %ACM Portions) was not detected in the landfill cap sample within Area F.

C. Mixed Fill (2 samples)

- Two heavy metals (lead & zinc) were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in 1 of 2 mixed fill samples collected from Area F. There were no exceedances noted for the relevant waste acceptance criteria or the NESCS guidelines.
- PAHs were not detected in either mixed fill sample collected from Area F.
- Asbestos (AF/FA & %ACM Portions) was not detected in either mixed fill sample within Area F.
- It should be noted, Area F mixed fill samples were collected from materials in contact with medical waste containers (containing syringes & medicine bottles); therefore, a biohazard risk should be noted.

D. Natural Ground

- Heavy metals were detected in the single natural ground sample collected from Area F; however, all heavy metal concentrations were below the upper limit background concentrations for selected elements in soil from the Waikato Region.
- PAHs were not detected in the single natural ground sample from Area F.
- Asbestos (AF/FA & %ACM portions) was not detected in the single natural ground sample within Area F.

7.4.7 Area G

A. Topsoil (6 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 6 topsoil samples collected from Area G. The concentrations of boron detected in samples TP19 SUR, TP20 SUR, TP22 SUR & TP23 SUR exceed the WRC Cleanfill criteria; however, no exceedances were noted for Class 1 landfill criteria or the NESCS rural residential/lifestyle block – no produce (unpublished) guidelines.

- PAHs were detected above the analytical level of detection in 5 of the 6 mixed fill samples within Area G, but were below the relevant waste acceptance criteria and NESCS guidelines.
- Residual concentrations of asbestos (AF/FA Portion) were detected in sample TP19 SUR, exceeding the WRC Cleanfill criteria. However, no exceedance of the BRANZ Asbestos in Soil guidelines was noted.

B. Mixed Fill (reworked natural material) (1 sample)

- Two heavy metals (lead & zinc) were marginally elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in the single mixed fill sample collected from Area G (and are considered to essentially be at background levels). No exceedances were noted for Class 1 landfill criteria or the NESCS rural residential/lifestyle block – no produce (unpublished) guidelines.
- Residual PAHs were detected above the analytical level of detection in the single mixed fill sample within Area G, however the concentrations were below the relevant waste acceptance criteria and NESCS guidelines and BAP(eq) was less than the lab detection limit – i.e., essentially at background levels.
- Asbestos (AF/FA & %ACM Portions) were not detected in the single mixed fill sample.
- In our opinion, the material termed 'Fill' at this location is likely to be reworked natural ground, likely disturbed during the removal of historical buildings in this area.

C. Natural Ground (6 samples)

- Heavy metals (lead & zinc) were detected in 1 (TP21 1.0m) of the 6 natural ground samples collected from Area G at levels elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region. The concentration of zinc detected in sample TP21 1.0m was also elevated above the WRC cleanfill acceptance criteria. The remaining 5 samples (TP19 0.8m, TP20 1.5m, TP22 1.0m, TP23 1.2m & TP24 1.5m) did not have any concentrations of heavy metals elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region.
- PAHs were not detected in any of the natural ground samples from Area G.
- Asbestos (AF/FA & %ACM Portions) was not detected in any of the natural ground samples within Area G.

7.4.8 Area H

A. Topsoil (5 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 5 topsoil samples within Area H. There were no exceedances of the Waikato Regional Council cleanfill acceptance criteria, Class 1 landfill acceptance criteria or the relevant NESCS guidelines noted for heavy metals.

- PAHs were elevated above the analytical limit of detection in 3 of the 5 topsoil samples within Area H. The concentrations detected were below both the Waikato Regional Council cleanfill acceptance criteria, the Class 1 Landfill acceptance criteria and the relevant NESCS guidelines.
- Asbestos (AF/FA Portion) was detected in 1 (TP35 SUR) of the 3 topsoil samples within Area H. The concentrations of free fibres detected were below the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

B. Mixed Fill (2 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in both mixed fill samples within Area H. Concentrations of arsenic detected in samples TP32 0.5m and both exceed the NESCS rural residential/lifestyle block- no produce (unpublished) land use criteria. Furthermore, the arsenic concentrations detected in sample TP32 0.5m also exceeds the NESCS commercial/industrial outdoor worker (unpaved) land use criteria. Concentrations of lead detected in all Area H mixed fill samples (TP32 0.5m, TP34 SUR, TP35 1.0m & TP35 2.5m) exceeded the NESCS rural residential/lifestyle block - no produce (unpublished) land use criteria, but did not exceed the NESCS commercial/industrial outdoor worker (unpaved) land use criteria. Concentrations of arsenic, boron, copper, lead & zinc all exceeded the Class 1 landfill acceptance criteria in samples between 0.0m-2.5m depth, indicating the mixed fill materials within this layer exhibit the highest levels of contamination within Area H. As this area is adjacent to Area A, it is considered this area of the landfill contains the highest levels of contamination.
- PAHs were elevated above the analytical limit of detection in 3 of the 4 mixed fill samples within Area H. The concentrations detected were below both the Class 1 Landfill acceptance criteria and the relevant NESCS guidelines.
- Asbestos (AF/FA Portion) was detected in all 4 mixed fill samples within Area H. The sample results identified concentrations of free fibres in samples TP34 SUR & TP35 2.5m that exceed the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

C. *Natural Ground (3 samples)*

- One heavy metal (lead) was detected in 1 (TP32 1.5m) of the 3 natural ground samples collected from Area H at levels marginally elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region. No other elevated concentrations of heavy metals were detected in the natural ground samples collected from Area H.
- PAHs were not detected in any of the natural ground samples from Area H.
- Asbestos (AF/FA & %ACM Portions) was not detected in any of the natural ground samples within Area H.

7.4.9 Area I

A. Topsoil (8 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 8 topsoil samples within Area I. There were no exceedances of the Waikato Regional Council cleanfill acceptance criteria, Class 1 landfill acceptance criteria or the relevant NESCS guidelines noted for heavy metals in Area I.

- PAHs were elevated above the analytical limit of detection in 3 of the 8 topsoil samples within Area I. In addition, residual concentrations of PAHs were detected in 3 of the 8 samples. The concentrations detected were below both the Waikato Regional Council cleanfill acceptance criteria, the Class 1 Landfill acceptance criteria and the relevant NESCS guidelines in all samples in Area I.

- Asbestos (AF/FA Portion) was detected in 1 (TP56 SUR) of the 8 topsoil samples within Area I. The concentrations of free fibres detected were in exceedance of the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites.

B. Mixed Fill (7 samples)

- One or more heavy metals were elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region in all 7 mixed fill samples within Area I. Concentrations of arsenic detected in sample HA01 0.2-0.6m, boron detected in sample TP50 0.5m and copper detected in sample TP57 0.8m all exceeded the WRC cleanfill criteria. Furthermore, the concentrations of copper detected in sample TP57 0.8m also exceed the Envirofill managed fill criteria. There were no exceedances of the Class 1 landfill acceptance criteria or the relevant NESCS guidelines noted for heavy metals in Area I.

- PAHs were elevated above the analytical limit of detection in 5 of the 7 mixed fill samples within Area I. The concentrations detected were below the WRC Cleanfill criteria, Class 1 Landfill acceptance criteria and the relevant NESCS guidelines.

- Residual concentrations of Asbestos (AF/FA Portion) were detected in 2 of the 7 mixed fill samples within Area I, exceeding the WRC Cleanfill criteria. However, the concentrations detected were below the relevant BRANZ Asbestos in Soil guidelines for both residential (proxy for maintenance workers exposure) and commercial/industrial sites, and the Class 1 Landfill acceptance criteria.

C. *Natural Ground (1 sample)*

- One or more heavy metals were detected in the single natural ground sample collected from Area I at levels elevated above the upper limit background concentrations for selected elements in soil from the Waikato Region. No other elevated concentrations of heavy metals were detected in the natural ground samples collected from Area I.

- PAHs were not detected in any of the natural ground samples from Area H.

- Asbestos (AF/FA & %ACM Portions) was not detected in any of the natural ground samples within Area H.

7.4.10 Summary

This section provides a summary of these results in terms of:

(a) Potential risks to human health;
(b) Potential risk to the environment; and,
(c) Disposal classification requirements.

These are summarised on a "layer by layer" basis in relation to topsoil, capping layer (where present), mixed fill and the underlying natural ground.

A. Human Health Risks

The topsoil quality is at or below background levels in Area E only. It is within adopted NESCS guidelines in Areas B, D, F, G and H and 50-83% of Area A and C samples. It exceeds the NESCS rural residential standards in 17% of Area A samples and exceeds both the NESCS rural residential and commercial/industrial guidelines in 50% of Area C, both due to asbestos contamination.

The landfill cap quality is within background levels in 33% of Area A samples and within adopted NESCS guideline levels in the rest of Area A and in Areas C, and F.

The mixed fill generally exceeded one or both of the adopted NESCS guidelines in Areas A, C, D and H for over half the samples collected. Area B, F and G samples were 80-100% within the adopted guidelines. No mixed fill was found in Area E. The Area G fill is considered to be reworked natural ground, with the contamination detected being marginal and essentially at background levels.

The natural ground was generally less than background in 25% of samples in Area A, 50% in Area D, 67% in Area H, 83% in Area G and 100% in Areas C, E and F. Natural ground sample was 100% within guidelines in Area B. It only exceeded NESCS rural residential guidelines in 17% of Area D samples.

All the commercial/industrial guideline exceedances relate to asbestos.

These results are summarised in tabular form below and by colour coding in the results tables and figures.

Table 6: Results Summary relative to human health risk

Area	Topsoil	Landfill Cap	Mixed Fill	Natural Ground
A	83% within GL, 9.5% > RR & C/I (Asb)	82% > background, 100% within GL	100% > background, 67% > RR < C/I, 33% > RR & C/I	80% > BG, 100% < GL
B	100% > background, 100% within GL	Not applicable	80% within GL, 20% > RR	100% within GL
C	50% within GL, 50% > RR & C/I (Asb)	Within GL	50% within GL, 50% > RR & C/I (Asb)	100% < GL
D	100% within GL	Not applicable	50% > RR < C/I, 50% > RR & C/I (Asb)	50% < BG, 17 > GL, 17% > RR
E	100% < BG	Not applicable	Not applicable	100% < BG
F	100% < GL	100% < GL	100% < GL (but medical waste)	100% < BG

G	100% within GL	Not applicable	100% within GL	83% < BG, 17% < GL
H	40% < GL, 20% > RR & C/I (Asb)	Not applicable	100% > RR < C/I, 50% > C/I (Asb)	67% < BG, 33% > BG, 100% < GL
I	87.5% < GL, 12.5% > RR & C/I (Asb)	Not applicable	100% within GL, but residual Asb.	100% within GL

Notes: RR = rural residential, GL = guideline, C/I =commercial/industrial, BG = background

B. Environmental Risk

Waikato Regional Council (WRC) does not have an environmental protection guideline for soil according to the best of our knowledge. Environment Canterbury use one based on the Interim Sediment Quality Guidelines (ISQGs) with three times dilution, which we have applied before on other projects in a number of regions around New Zealand. In this case, the main pathway for environmental effects is via groundwater to the adjacent stream – hence, the routine water quality sampling data from the groundwater and stream itself has been used to assess the environmental risk of the historical landfills.

Long term monitoring data appears to show that boron is leaching from the landfill into the stream, being consistently present at elevated levels in the groundwater in one monitoring bore (refer Figure 5). All stream samples have recorded boron levels below the ANZECC freshwater guidelines for protection of 95% aquatic species, but the monitoring data shows that boron levels are consistently higher downstream of the landfill, with some data indicating boron leaching may primarily be coming from landfill areas A, B or C (refer Figure 6).

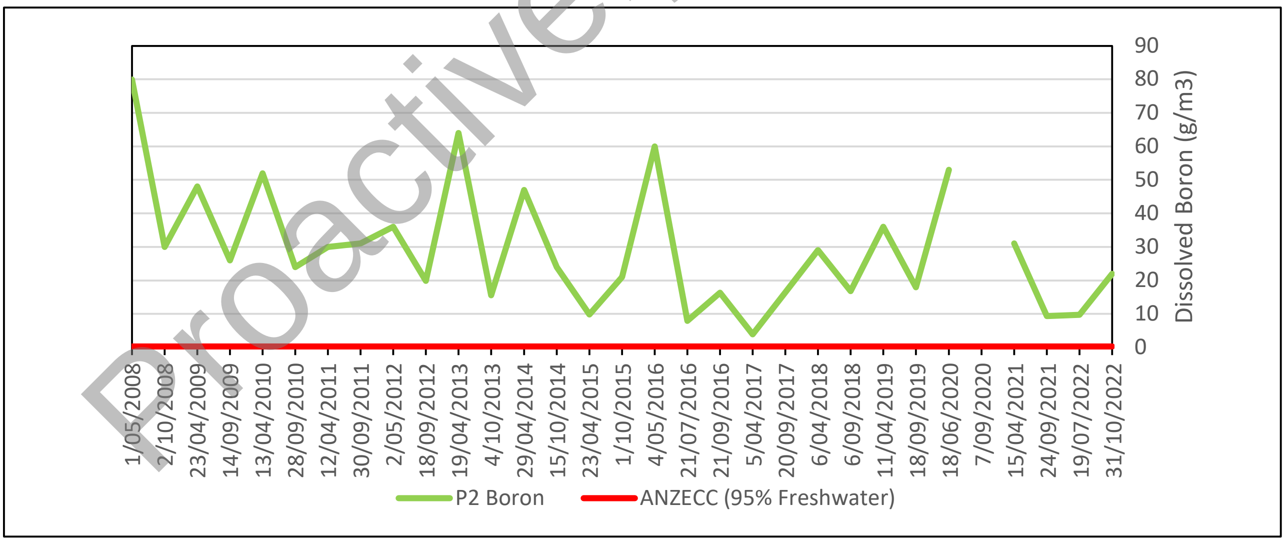


Figure 5: Long term dissolved boron levels (g/m^3) in shallow groundwater from monitoring well P2

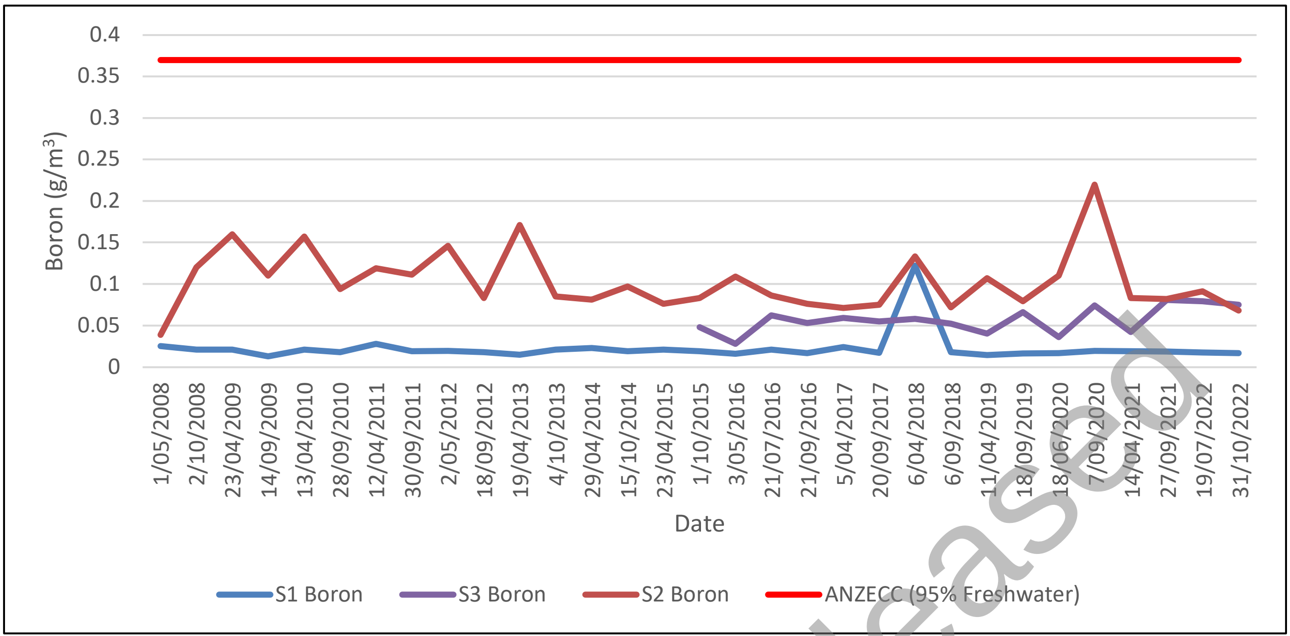


Figure 6: Long term boron levels (g/m³) upstream (S1), midstream (S3), and downstream (S2) of the landfill in comparison to ANZECC 95% protection trigger value for aquatic species. See Figure 7 for sampling locations

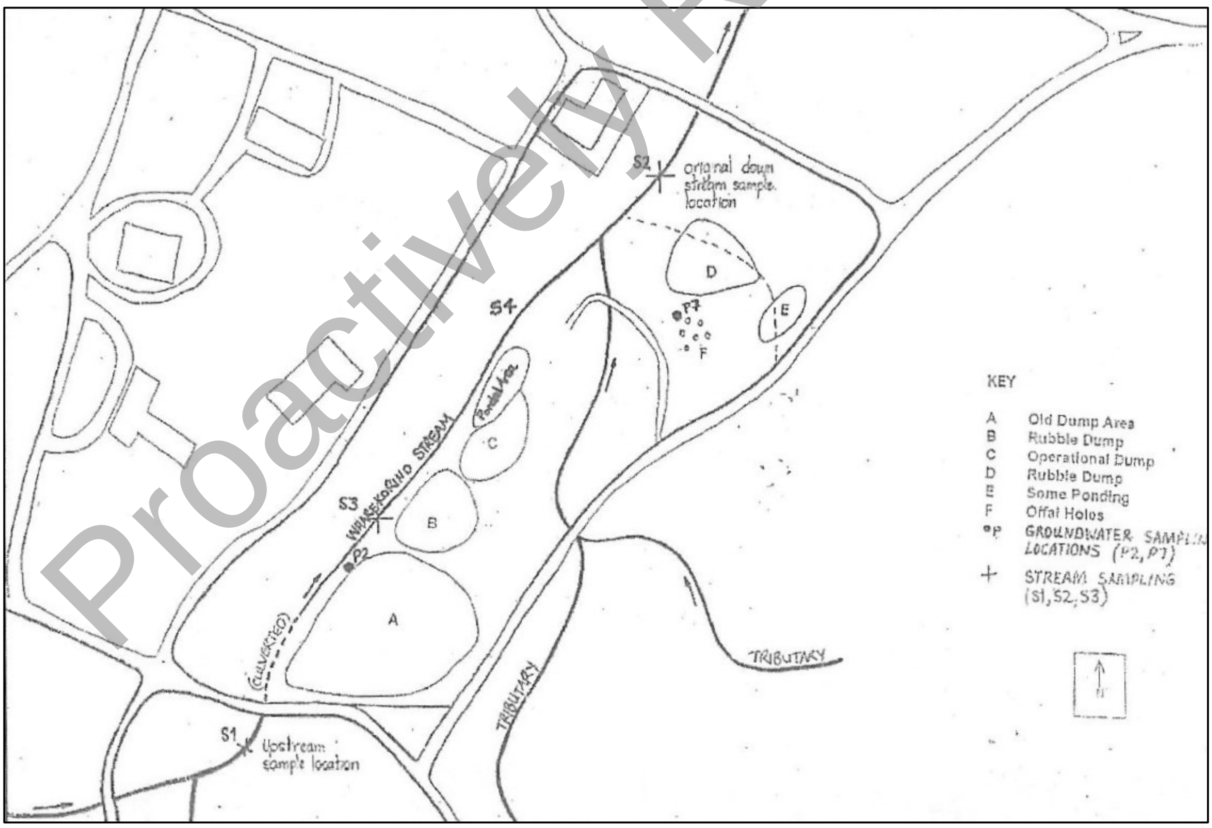


Figure 7: Location of stream and bore (groundwater) sampling sites relative to landfill areas

The likely source is coal ash, which is understood to have been used as a cover material in some landfilling areas.

Stream water samples typically have neutral to slightly acidic pH, low suspended solids and electrical conductivity, low boron and low chloride levels. Heavy metal concentrations are typically considerably lower than all ANZECC criteria assessed.

Iron concentrations are sometimes in exceedance of the ANZECC long term Irrigation (100 years), and the Drinking water standards for Aesthetics (2005-2008). These exceedances in Iron levels are only considered cause for concern in situations where the water is used for continuous long-term irrigation (100 years +). As noted in the 2021 WSP monitoring report, The Report to Hearings Committee (2000) states that due to the low flows in the vicinity of the site, the Wharekōrino Stream is highly unlikely to be used for irrigation purposes; therefore, these elevated iron levels are not a cause for concern.

Nitrate levels in the Wharekōrino stream have fluctuated from <0.10 to 3.3 g/m^3. These levels tend to be lower during low water levels (first half of the year) and higher during high water levels (second half of the year). The elevated levels are considered more likely to derive from upstream agricultural inputs (e.g., fertiliser) rather than the result of leaching from the landfill.

A single round of sediment sampling was undertaken by FTL in April 2023 from the four sampling locations S1-S4 shown in Figure 7. Cadmium and zinc were higher than the upstream sample (S1) in the downstream samples (S3, S4 and S2), while boron was only detected in one sample (S3) closed to landfill area A. The elevated concentrations were well within the ISQG-Low trigger values with three times dilution (and even without allowing for any dilution). GHD also did some stream sediment sampling but further downstream by the Wastewater Treatment Plant and found slightly elevated cadmium and zinc levels (relative to background) in some samples but did not detect any boron. As boron is relatively soluble, this is not unexpected.

Overall, the water quality results indicate in our opinion that the historic landfilling activity is not affecting the surface water quality in the stream, other than for boron, with the boron results in the stream being well within ANZECC protection criteria for 95% of freshwater species.

C. Disposal Requirements

The following outlines the disposal requirements for each component of the existing disposal sites, should there be any works in the future that would necessitate offsite disposal of material, such as during repair or maintenance works, although the need for this is considered unlikely.

The topsoil quality complies with Waikato region cleanfill waste acceptance criteria in Areas E and F and portions of Areas A, B, C, D, G, H & I. Topsoil quality exceeds managed fill waste acceptance criteria in 17-50% of Areas A, B, C, G and H & 12.5% of Area I.

The landfill cap quality complies with Waikato region cleanfill waste acceptance criteria in Areas C and F and 65% of Area A samples, with 100% of Area A cap samples complying with managed fill waste acceptance.

The mixed fill from Areas A, B, C, D, F, H & I would require disposal to an appropriate engineered landfill , as TCLP results have confirmed the material is suitable for disposal to a Class 1 Landfill. Area F has been included in this category due to the presence of medical waste in the waste offal pits found in this area. Area G fill can be classified as cleanfill. No mixed fill was found in Area E. Mixed fill from

Area I would require disposal to a Managed fill, licensed to accept low-level asbestos in soil. Removal of the landfill is not within the scope of the demolition and remediation project.

The majority of the natural ground samples comply with cleanfill waste acceptance criteria, particularly in Areas C to F and I. Portions of the natural ground in Areas A, B, D and G appears to be impacted by the overlying fill material.

These results are summarised in tabular form below and by colour coding in the results tables and figures.

Table 7: Results Summary relative to disposal requirements

Area	Topsoil	Landfill Cap	Mixed Fill	Natural Ground
A	33% cleanfill, 47% managed fill, 20% landfill*	65% Cleanfill/ 35% managed fill	Mainly landfill (90%)*, 10% managed fill	20% cleanfill, 60% managed fill, 20% landfill*
B	75% cleanfill, 25% managed fill	Not applicable	40% cleanfill, 20% managed fill, 40% landfill*	100% managed fill
C	50% cleanfill, 50% landfill	Cleanfill	Landfill*	Cleanfill
D	80% cleanfill, 20% managed fill	Not applicable	Landfill*	83% cleanfill, 17% landfill*
E	Cleanfill	Not applicable	Not applicable	Cleanfill
F	Cleanfill	Cleanfill	Landfill (due to medical waste)	Cleanfill
G	33% cleanfill, 67% managed fill	Not applicable	Cleanfill	83% cleanfill, 17% managed fill
H	80% cleanfill, 20% landfill	Not applicable	Landfill*	Cleanfill
I	87.5% cleanfill, 12.5% landfill	Not applicable	43% cleanfill, 43% managed fill, 14% landfill	Cleanfill

Notes: RR = rural residential, GL = guideline, C/I = commercial/industrial, BG = background.

* Landfill acceptability subject to TCLP test results

7.4.11 RPD RESULTS

As part of the quality control procedures followed during this investigation, relative percentage difference between the laboratory analysed samples was calculated, based on sample duplicate analysis. The highest RPD % results are provided in Table 8 below, and full RPD calculation are appended to this report as Appendix E.

Table 8: RPD Analysis

Parameter	Sample ID	Duplicate No	RPD %
Arsenic	TP27 1.0m	DUP04	*33.33*
Cadmium	TP6 SUR	DUP08	*43.48*
Chromium	TP4 SUR	DUP07	26.09
Copper	TP6 SUR	DUP08	*42.62*
Lead	TP27 1.0m	DUP04	20.41
Nickel	TP4 SUR	DUP07	*44.44*
Zinc	TP6 SUR	DUP08	*79.85*

Note: Results in *Italics* exceed 30% RPD. Results in red exceed 50% RPD.

With exception to the RPD % results for zinc, the remaining RPD results are elevated, but acceptable, and likely due to the relatively low concentrations of the parameters detected within the respective samples and poor homogeneity of the soils. The high RPD % result for zinc is likely due to the non-homogeneity of the material in this sample. Throughout the intrusive investigation, industry standard decontamination procedures were followed, and samples were collected from individual stockpiles, based on the strata defined in each test pit. Based on this, it is considered that the data gathered from this investigation is accurate, reliable, and repeatable.

7.5 LANDFILL GAS

Throughout the investigation, a GA5000 Landfill Gas Analyser device was utilised to identify and understand whether landfill gas was a potential risk at the site. The GA5000 was held adjacent to the areas of soil disturbance while test pits were being excavated. Where any suspect material was identified, a portion of this material was collected in a zip lock bag, and the GA5000 detector tube was inserted into the zip lock bag. Throughout the course of the investigation, no landfill gas was identified at any of the locations.

7.6 GROUNDWATER

Groundwater strikes were encountered in 15 test pits at depths ranging from 1.4 – 5.5m bgl. Standing groundwater was measured at depths ranging from 1.4 – 5.3m bgl. Groundwater generally appeared to be part of the groundwater table rather than perched groundwater, and was observed in direct contact with refuse. Small groundwater strikes were also noted in between compacted layers of clay and cap (likely perched groundwater).

Furthermore, based on cross-sections completed for the EDS, groundwater at monitoring location P2 is in direct contact with refuse, while groundwater at monitoring location P7 is just below the refuse, which is consistent with groundwater monitoring rounds completed to date, where P7 has consistently been dry.

It should also be noted that the groundwater levels used in the cross-sections were taken from the October/November monitoring round, which was undertaken following a wet spring.

8 CRITICAL ASSESSMENT OF LANDFILL CONSTRUCTION

8.1 INTRODUCTION

The landfill areas were constructed and used from at least the 1940s through to the late 1990s. Over this time period, landfilling in New Zealand and internationally evolved as a progression in the following order:

- **open dumping:** dumping waste on the ground without any protection measures, often as a means of reclaiming land;
- **controlled tipping:** dumping of waste under controlled conditions with some protection measures taken – e.g., daily soil cover, minimise filling area, odour/pest control, ban on fires, vehicle trip recording system, vehicle access road, litter fence; and
- **sanitary landfilling:** disposal of waste under highly controlled conditions to an engineered landfill where multiple protection measures are taken – e.g., base liner, leachate collection and treatment, landfill gas capture and use for generating electricity.

These changes have been prompted by:

- more stringent regulations (e.g., RMA) and consenting requirements;
- developments in landfilling practice and design and across the world. In New Zealand, the Centre for Advanced Engineering published their "Landfill Guidelines" in 2000 and the Ministry for the Environment published a "A Guide to the Management of Cleanfills" in 2002, which have recently been superseded by the WasteMINZ "Technical Guidelines for Disposal to Land" (Rev 3, Oct 2022);
- increasing environmental awareness and public expectations.

The fill material within the landfill would generally be classified as Class 1 landfill material, along with some managed fill and cleanfill materials, as well as some special wastes (i.e., medical wastes, asbestos). This section provides a critical assessment of landfill construction in relation to the following key items:

- Groundwater subsoil drainage.
- Landfill base and side liner (below refuse).
- Waste compaction.
- Waste burning and covering with boiler ash.
- Clay capping (thickness, permeability and compaction) and topsoil cover.
- Final surface grading.
- Leachate collection.
- Landfill gas collection.
- Proximity to Wharekōrino Stream

8.2 GROUNDWATER SUBSOIL DRAINAGE

It is expected that groundwater subsoil drainage would have been installed under different landfill areas as a means of keeping the groundwater table below the deposited refuse, so as to avoid direct contact of groundwater with refuse, due to elevated groundwater levels. However, none of the information reviewed as part of this investigation refers to the landfill having any groundwater subsoil drainage.

The Worley AEE (1998) refers to the results of groundwater monitoring undertaken by them which indicates that the groundwater flow direction is towards the Wharekōrino Stream, the groundwater is above the invert of the stream and at a depth where it is likely to come into contact with refuse in both the areas investigated (Areas A and F). Refer to Section 4.2.2 of the Worley report.

Based on FTL cross-sections completed for the site, and as mentioned above, groundwater at monitoring location P2 is in direct contact with refuse, forming a pathway for contaminants to leach into the nearby Wharekōrino stream, while groundwater at monitoring location P7 is just below the refuse, which is consistent with groundwater monitoring rounds completed to date, where P7 has consistently been dry. Furthermore, cross-section analysis has confirmed the groundwater flow direction generally tracks east to west, towards the Wharekōrino stream.

The above findings and the lack of groundwater subsoil drainage results in a complete migration pathway for contaminants from the deposited fill material to be taken up by groundwater and flow into the Wharekōrino Stream.

8.3 LANDFILL BASE/SIDE LINER

None of the information reviewed as part of this investigation refers to the landfill having any base or side liners. Such liners are important to minimise seepage through the base of the landfill into the underlying groundwater and to capture any leachate generated from the landfill for conveyance to a leachate treatment/disposal system. However, the lack of a landfill liner is consistent with the era in which the landfill areas were constructed.

8.4 WASTE COMPACTION

Insitu refuse materials appeared relatively well consolidated, however when removed, the materials exhibited a lack of cohesion and stability. All material within the different areas of landfilling appeared to have been directly tipped into the disposal areas, with combustible materials typically being burnt, and is likely to have been compacted by tamping with an excavator bucket, if at all.

8.5 REFUSE BURNING AND COVERING WITH BOILER ASH

Refuse burning was common practice over much of the period that the hospital's closed landfills have been in operation. It was a cheap method of reducing waste volumes (thus maximising landfill lifetime), minimising leachate generation and landfill gas production from the decomposition of combustible organic wastes and providing rudimentary "sterilisation" of some wastes.

The Worley AEE refers to ash from the hospital boilers having been used as a cover layer in Area A and also having been disposed of in Area C. These boilers were used to generate steam which was piped around the hospital to provide heating inside buildings and hence it is expected that a reasonable volume of ash would have been produced over the hospital's lifetime. It is likely that coal was used to power these boilers and that this coal came from the Waikato area, where coal has been mined from the 1870s. Other work done by FTL relating to the disposal of Huntly coal ash to the North Waikato Regional landfill found that this ash has a very high boron content and that deposition of this coal ash within the landfill would create a significant boron reservoir. Boron is relatively soluble and hence likely to leach over a long period, while once boron gets into water it is very difficult and costly to remove. In our opinion, the ash disposed of in Areas A and C of the landfill is the likely source of elevated boron levels in groundwater sampled from the landfill monitoring bores.

8.6 CLAY CAPPING AND TOPSOIL COVER

Resource consent condition 3 refers to the final cover over areas A, C and F comprising 600mm of earth cover with insitu impermeability of $1x10^{-7}$m/s overlain by 150mm minimum thickness of topsoil or topsoil/compost mix, or 500mm of $1x10^{-7}$m/s earth cover, overlain by 100mm subsoil layer, overlain by 100mm topsoil or topsoil/compost/mix or alternative cover approved by WRC in writing (Type A cover).

Resource consent condition 4 required the final cover over the filled areas B, D and E to consist of at least 300mm of clay/soil material and regrassing (Type B cover).

8.6.1 Clay Cap and Topsoil Thickness

Table 9 summarises the depths of topsoil and clay cap determined from the FTL field investigations and compares them with the resource consent requirements. This shows:

- Areas A and C have non-compliant topsoil and cap depths, and Area F has a non-compliant cap depth.
- Areas B and D have non-compliant combined cover depths in part.
- Area H is not covered by the resource consent, but would be expected to have similar cap and topsoil requirements to Area A. On this basis, the cap and cover in Area H are also non-compliant. Furthermore, Area H only had a small isolated portion of cover, which could be an extension of the cover from Area A.
- Area I is not covered by the resource consent, however given the localised area of filling identified in this area, this portion of Area I would be expected to have similar cap and topsoil requirements to Area A. on this basis, cap and cover in Area I is non-compliant.
- Area G also had landfill cap cover - however the fill identified here was found under to be reworked natural ground.

Table 9: Cap/Topsoil Assessment

Area	RC cover requirement		Actual Thickness - Range (average) (mm)		Fill
	Topsoil	Cap	Topsoil	Cap	
A	150	600	100 – 300(145)	100 800 (522)	Mixed
B	300 combined		100 – 200(157)	100 – 400(275)	Mixed
C	150	600	100 – 200(162)	400 – 600(476)	Mixed
D	300 combined		50 – 200(139)	0 – 250(155)	Mixed
E	300 combined		100 (1 Testpit)	200 (1 Testpit)	None
F	150	600	200 (1 Testpit)	300 (1 Testpit)	Mixed (in offal pits)
G	Not required – reworked natural ground		100 – 200(151)	0	None

H	Not stated – 150 expected	Not stated – 600 expected	0	0	Mixed
I	Not stated – 150 expected	Not stated – 600 expected	0 – 200 (102)	0	Mixed (in localised area)

Note: Red shading = non-compliance

8.6.2 Clay Cap Permeability

The only historical permeability test result found was from the 1998 AEE for the Area A landfill cover, which describes the cover sample as gravelly silty sand with a permeability of ~$2x10^{-4}$m/s, which is significantly more permeable than the consent requirement. The AEE does refer to Areas A, C and F having a higher level of capping in accordance with the consent conditions but with no supporting information included.

Fraser Thomas collected 16 cap samples and tested these for permeability, using the constant head permeability test. These results are summarised in Table 10. The permeability test results generally complied with the consent requirement, except in Area A (TP02).

Table 10: Permeability Results Summary

Area	Sample Number	Depth (m)	Coefficient of Permeability (m/s)	Consent Requirement
A	TP02	0.3 - 0.4	>8.6×10^{-6}**	$1x10^{-7}$m/s
	TP04	0.3 - 0.4	5.1×10^{-8}	
	TP07	0.2 - 0.3	1.6×10^{-8}	
	TP10	0.2 - 0.3	6.6×10^{-8}	
	TP12	0.2 - 0.3	3.8×10^{-9}	
	TR09	0.2 - 0.3	4.4×10^{-8}	
B	TP13	0.2 - 0.3	2.1×10^{-8}	Not specified
C	TP17	0.2 - 0.3	4.4×10^{-8}	$1x10^{-7}$m/s
	TP18	0.2 - 0.3	2.1×10^{-8}	
	TR16	0.2 - 0.3	1.1×10^{-8}	
	TR18	0.2 - 0.3	1.4×10^{-8}	
D	TP30	0.2 - 0.3	8.0×10^{-7}	Not specified
	TR34	0.2 - 0.3	1.0×10^{-7}	
E	TP25	0.2 - 0.3	>4.2×10^{-6}**	Not specified
F	TP26	0.2 - 0.3	2.0×10^{-8}	$1x10^{-7}$m/s
	TR27	0.2 - 0.3	5.7×10^{-8}	

Permeability Tests: BS EN ISO 17892-11:2019: Part 11

**This determined value is approximately equal to the measured permeability of the test equipment; therefore, the permeability of the sample should be regarded as being greater than this value.

8.7 FINAL SURFACE GRADING

It would be expected that the final surface of each landfill area would have been graded so as to shed runoff from the landfill areas, rather than allow for runoff to travel slowly over the landfill areas or pond, increasing potential infiltration into the landfill and thus leachate generation. Landfill settlement will occur over time as a result of refuse consolidation and decomposition, which can create ponding areas depending on the nature of the surface grading and particularly if differential settlement occurs. Refuse burning would have reduced the amount of settlement expected through waste decomposition.

The annual site walkovers for 2022 and 2023 observed ponding in multiple locations across the site and referred to ponding in Area C having been consistently observed since the 2017 WSP field visit. This does not comply with good practice.

8.8 LEACHATE COLLECTION

The landfill areas do not have any leachate collection system, which is consistent with them not having any base and side liner system. This is consistent with the time the landfills were constructed but not with current best landfill practice.

8.9 LANDFILL GAS COLLECTION

The landfill areas do not have any landfill gas system, which is consistent with the time they were constructed but not with current best landfill practice.

8.10 PROXIMITY TO WHAREKŌRINO STREAM

The Wharekōrino Stream total catchment area at the upgradient end of the landfill is approximately 570ha catchment, representing a moderate sized catchment. The landfill areas are located within close proximity of the Wharekōrino Stream, while Area H bridges the stream with a culvert piping the stream through it. It appears no consideration was given to the landfill’s proximity to this stream during siting and design and the potential for a large flood event to encroach on the landfill potentially causing slips/erosion/scouring. Climate change considerations further exacerbate this risk. This risk is assessed further in Section 10 of this report.

8.11 SUMMARY

This critical assessment of landfill construction is summarised below.

Table 11: Summary – Critical Assessment of Landfill Construction

Criteria	Status	Impact	Significance
Groundwater subsoil drainage	None	Allows groundwater to come into direct contact with refuse and creates pathway for contaminants to leach to Wharekōrino Stream.	High
Landfill base and side liner	None	No containment of any leachate generated in the landfill.	Medium
Waste compaction	None	All waste appears to have been direct tipped into filling areas, with combustible materials burnt and with little or no compaction.	Medium
Waste burning and covering with boiler ash	Common operational practice at landfill	Boiler ash likely source of boron in waste which is present at elevated concentrations in groundwater.	High
Clay capping	Areas A, C and F capped to high standard, although cap is "skinnier" than consent in Areas A and C; areas B, D and E have lower specification cap. Newly found Areas H & I have no cap.	Reduces rainfall infiltration into landfill, thus reducing leachate generation.	High (Area H) Medium (other areas)
Topsoil cover	Average topsoil cover across the areas of landfilling ranges from 100mm-200mm	Helps maintain healthy vegetation cover on landfill surface and provides first barrier to rainfall infiltration.	Medium
Final surface grading	Landfill surface is prone to ponding, particularly in Area C	Potential increased infiltration through landfill, increasing risk of contaminant leaching	Medium
Leachate collection	None	Any leachate generated from refuse likely to enter groundwater	High
Landfill gas collection	No system installed, but no landfill gas detected during 2022 intrusive investigation.	Landfill gas can present explosion (methane) and asphyxiation (carbon dioxide) hazards at certain concentrations	Low
Proximity to Wharekōrino Stream	Landfill areas are located relatively close to stream	Potential flood hazard, causing slips, scour and erosion and possible remobilisation of buried refuse (extreme event).	High

9 LANDFILL RISK ASSESSMENT

This landfill risk assessment addresses the following issues:

- Topsoil contamination
- Cover/cap integrity
- Contact with contaminated materials/refuse
- Settlement, subsidence and erosion
- Stability
- Surface water runoff contamination
- Groundwater contamination
- Landfill gas
- Culvert failure
- Flooding

This risk assessment has been undertaken from an engineering perspective. The risk assessment findings have been used in assessing the status of the landfill in relation to its life cycle and a hazard risk matrix is presented at the end of this section.

An exposure pathway assessment, based on a contaminated land source – receptor – pathway assessment follows in section 11 of this report. There is some duplication of material between the two assessments.

9.1 TOPSOIL CONTAMINATION

Topsoil testing undertaken as part of this investigation has found that topsoil quality is at or below background levels in Area E only. It is within adopted NESCS guidelines in Areas B, D, F and G and 20-83% of Area A, C & H samples. It exceeds the NESCS rural residential standards in 9.5% of Area A samples, 20% of Area H samples, and exceeds both the NESCS rural residential and commercial/industrial guidelines in 50% of Area C and 12.5% of Area I samples (due to asbestos contamination in both cases). Hence, topsoil quality does pose a human health risk in relation to asbestos in parts of Areas A, C, H & I.

9.2 COVER/CAP INTEGRITY

The landfill areas generally comprise grassed, relatively flat farm paddocks, that are routinely grazed.

During the 2022 annual walkover survey (refer separate report for details and Appendix B for grid walkover findings), it was found that there were various instances of individual refuse items (e.g., wooden posts, planks, cement blocks) protruding through the landfill surface, consistently around the edges of the landfill areas (refer Figure 8, below). There was one area which showed small localised damage to the landfill cap of the landfill (refer Figure 9, below). These observations mainly apply to Areas A and D. They mean that the landfill cap has been breached in a number of locations. The protruding objects should be removed and the landfill cap reinstated.

Figure 8: Refuse protrusion across the site (ceramic pipe (B3), wooden post (E4), brick (D4, concrete (D4)) – for grid references, refer Appendix B for grid locations**

Figure 9: Evidence of damage to landfill cap in Area E and at extent of Area A (Left N7, Right A3)

9.3 CONTACT WITH CONTAMINATED MATERIALS/REFUSE

Contact with refuse is directly related to the integrity of the landfill cap. If refuse is exposed through breaching of the landfill cap as a result of site disturbance works or natural hazards (e.g., extreme flood event causing slip), the nature of the fill material present in the landfilled areas presents a significant hazard to people, including:

(a) Potential physical injury through contact with sharp objects;
(b) Potential injury through contact with medical waste (Area F only);
(c) Possible contact with fill containing elevated contaminant levels;
(d) Possible contact with asbestos containing materials.

This risk can be mitigated by ensuring that appropriate cap and topsoil cover is maintained over the landfill area, with this being inspected regularly, as is currently done.

9.4 SETTLEMENT, SUBSIDENCE AND EROSION

Historical landfill area contour data was limited to the contours shown on the Meritec developed site plan from 2000, which was only available in pdf format. Comparison of this contour data with recent LiDAR survey data for the site suggests very little settlement has occurred over the intervening 22-year period. However, it is not clear if the contours shown on the Meritec plans are pre- or post-capping contours, reducing the reliability of this comparison.

Hence, more reliance has been placed on visual observations in assessing settlement, subsidence and erosion. These observations from the 2022 annual walkover and from review of previous WSP annual reports support that no significant erosion has occurred in recent years. Minor subsidence was observed around the site, resulting in an uneven profile across the landfill areas. It is unclear whether this is naturally occurring or influenced by the landfill. There have been no new instances since the previous inspection, based on comparison with photos in the WSP 2021 report.

There are localised ponding areas, which seem more related to final surface grading or lack of it, and to landfilling areas being a number of discrete, small individual areas, tying in with existing topography. Observations for different landfilling areas are summarised below:

- In Area A, ponding was observed at Grid D7, surrounding a permanent water trough. Subsidence was visible at grid A3 at the fence line boundary.
- Area C was observed as having large portions of ponding and some visible settlement and subsidence. Significant ponding was observed at H4 and minor ponding at K5, both located between the extent of area C and the Wharekōrino stream. Ponding at both locations has been noted in previous years, and high stream flow is likely a large contributor. Localized settlement is observable at I5 at the extent of area near the fen cline. Subsidence was noted at K6 at the north-eastern extent of area C.
- Area D was observed as having very uneven topography including patches of settlement. Significant subsidence was observed at grid N7.
- Area E was primarily in good condition. The only feature of note was general sloping settlement of the land. Previous visits have noted ponding filling this settled area, but none was observed during 2022.

Figure 10: Instances of subsidence visible on site at areas E and A respectively (Left N7, Right E4)

As stated earlier, landfill settlement will occur over time as a result of refuse consolidation and decomposition, which can create ponding areas depending on the nature of the surface grading and particularly if differential settlement occurs. Refuse burning would have reduced the amount of settlement expected through waste decomposition. As the last landfilling areas was closed over 20 years ago, it is expected that most settlement would have occurred by now.

Figure 11: Areas of ponding observed across the landfill site (Top Left H4, Top right D7, Bottom Left K4, Bottom Right I7)

9.5 LANDFILL STABILITY

The geotechnical factual report noted some evidence of shallow soil creep, including terracettes and hummocky topography, were observed in areas where the site topography sloped at, or was steeper than, 14° to the horizontal (1V:4H). Areas with gradients exceeding 1V:4H have been plotted using site LiDAR data on Fraser Thomas Ltd drawing 65547/101. These steeper areas are almost entirely located along or adjacent to the western extremities of the landfill areas. This suggests that landfill instability is low risk. A site-specific stability assessment would be required to confirm this, but this is outside the scope of this investigation.

9.6 SURFACE WATER RUNOFF CONTAMINATION

Contamination of surface water runoff is considered a low risk, as surface water will only come into contact with the landfill surface soils – i.e., topsoil of which only a small portion (9.5% Area A, 50% Area C, 20% Area H & 12.5% Area I) represents a human health risk as explained earlier. The contaminants found in the topsoil are expected to generally be well bound to the soil matrix and hence would primarily be lost to runoff as particulate material, associated with soil scour/erosion. There is relatively low evidence of this occurring.

9.7 GROUNDWATER CONTAMINATION

As explained earlier, the 1998 AEE refers to the results of groundwater monitoring undertaken by them which indicates that the groundwater flow direction is towards the Wharekōrino Stream, the groundwater is above the invert of the stream and at a depth where it is likely to come into contact with refuse in both the areas investigated (Areas A and F).

Groundwater was encountered in multiple test pits during the FTL intrusive investigation, while two cross-sections plotted across the landfill indicate there is a direct connection of the groundwater with refuse and a direct pathway to the stream at groundwater monitoring location P2.

This means there is a complete migration pathway for contaminants from the deposited fill material to be taken up by groundwater and flow into the Wharekōrino Stream. The main contaminant of concern identified from regular groundwater and surface water monitoring is boron. This is believed to be associated with the presence of coal ash in the existing disposal sites, with the historical documentation reviewed referring to it having been used as a cover layer in Area A and also for it to have been disposed of in Area C. Other work done by FTL relating to the disposal of Huntly coal ash to the Hampton Downs landfill found that the ash has a very high boron content with high leaching potential. Boron is relatively soluble and hence likely to leach over a long period, while once boron gets into water it is very difficult and costly to remove.

The monitoring undertaken to date has confirmed elevated boron levels in the groundwater and within the stream, but the stream levels are much lower than in groundwater and within the ANZECC guidelines for the protection of 95% of freshwater species. This means there is significant attenuation and mixing within the stream, so that any contaminants present would not pose an unacceptable risk to ecological receptors.

9.8 LANDFILL GAS

The landfill gas (LFG) risk is considered low for the following reasons:

- The extent of LFG emissions is typically controlled by the integrity of the landfill containment systems, the nature of the landfill, the landfill materials and landfill age.
- The fill material observed in landfill areas contains very little, if any, decomposable material that is necessary to generate landfill gas.
- It has been over 34 years since Area A was reportedly closed to landfilling (1998) and 25 years since Area C was closed to landfilling, while other areas may have been closed as long as 44 years ago, meaning that landfill gas generation from any decomposable material present in the waste material would be tapering off by now and expected to be at low levels, if any.
- No landfill gases were detected by gas monitoring during the FTL 2022 intrusive investigation.
- The landfill has no passive or active LFG extraction system and there are no known services trenches, drains or penetrations within the landfill areas that could provide a preferential pathway for LFG migration, other than likely some shallow water reticulation to the animal water troughs, which would likely be buried in the ground with no drainage media around it and thus not providing a preferential pathway for LFG migration.
- The landfill areas can be classified as a "shallow" landfill, with LFG able to escape from it relatively easily through the landfill cap or laterally. The LFG will seek to escape from the landfill by the easiest pathway. The main components of LFG are methane, which can pose an explosion hazard, and carbon dioxide which can pose an asphyxiation hazard, while odour nuisance can also be a concern. Methane and carbon dioxide are both greenhouse gases. Lighter gases such as methane will tend to want to migrate upwards and where avenues exist, laterally. Hence, methane emissions in this case are most likely to occur through the landfill surface (e.g., cracks or through the cap itself) to the atmosphere. Heavier gases such as carbon dioxide tend to sink and can accumulate in depressions/cavities, of which only one structure was observed on-site in Area H, as shown below (Figure 12). This appears to be a redundant manhole chamber.

B1 – cement block/piping debris

B1 – manhole

Figure 12: Obsolete MH chamber in Area H

9.9 CULVERT 3 LEAKS/FAILURE

Culvert 3 comprises a 1350mm diameter pipe that pipes the Wharekōrino Stream through Area H of the landfill (refer Figure 14 for its location). Its condition is unknown, although it appears to not be subject to any significant blockage. Aerial photographs indicate this area was infilled over the period from at least 1957 to 1979, meaning that Culvert 3 is likely to be somewhere in the range of 44-65 years old, compared with a typical design life in the range of 50-100 years, depending on manufacturing standards at the time of culvert installation. This pipe could be subject to differential settlement associated with the landfilling activity. If its joints were to leak or the pipe to fail, this would result in significant stream flows being piped through the Area H landfill, which would likely lead to landfill washout and collapse.

CCTV survey has been attempted of this culvert, but was unsuccessful, due to high water flows through the culvert.

If a significant risk is confirmed, damaged culvert sections should be replaced, or the culvert lined, or the stream reinstated through this area, which would involve significant removal of Area H fill.

9.10 FLOODING

Flooding of the Wharekōrino Stream is considered to potentially be the most significant landfill risk, as it was to encroach on the landfill, it may cause slips, erosion and/or scouring.

HEC-RAS modelling has been undertaken to assess this risk. This modelling has shown that the landfill areas A, B, C, G, H are currently likely to be inundated to varying extents during a 1% AEP storm event, particularly if the two downstream culverts on the stream are blocked or become blocked during the storm, with these effects worsening with predicted climate change. Areas D, E and F have been found unlikely to be affected by flooding. These results are shown in Figure 13, below.

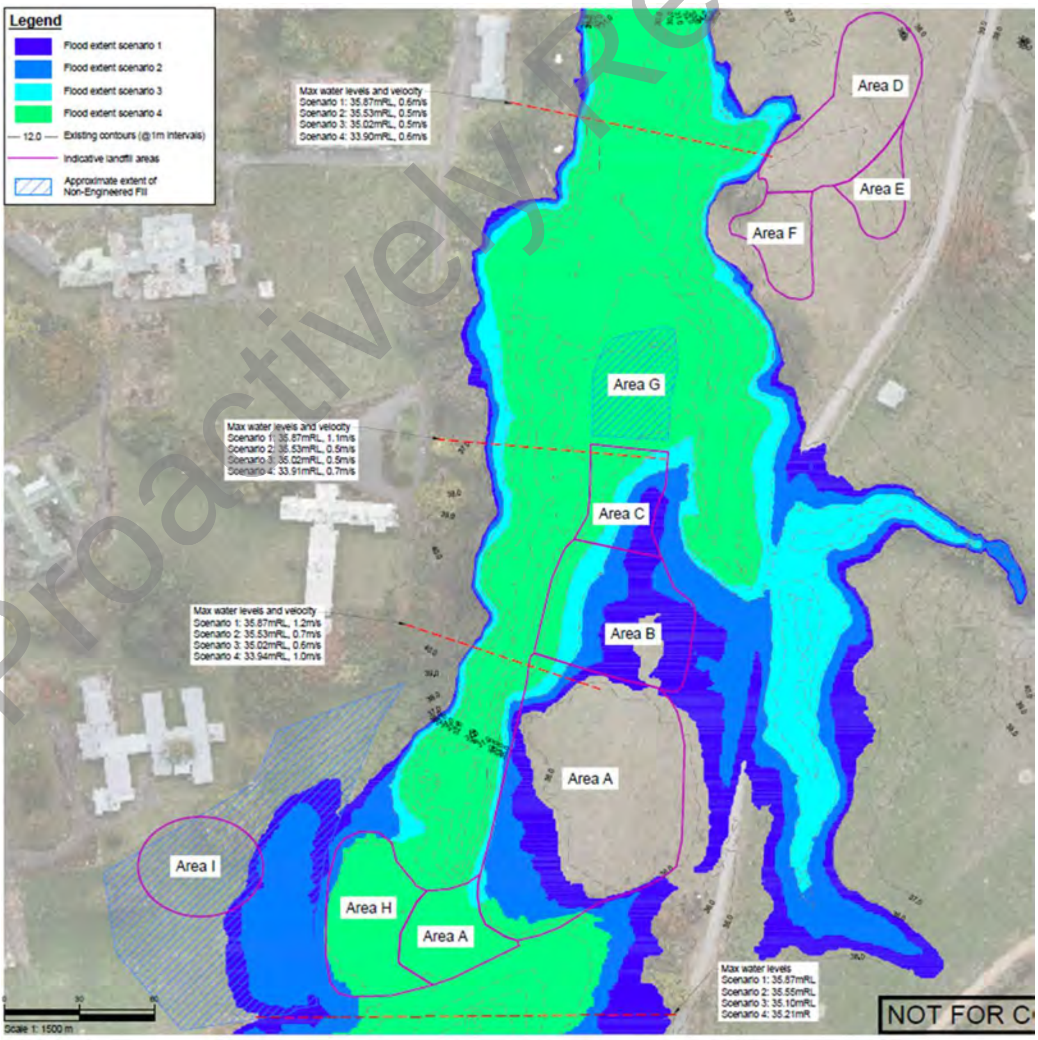


Figure 13: Flood Modelling Results:

- Scenario 3 = 1% AEP storm event, all culverts operational (light blue)
- Scenario 2 = 1% AEP + climate change event, all culverts operational (medium blue)
- Scenario 1 = 1% AEP + climate change event, all culverts blocked (dark blue)
- Scenario 4 = 1% AEP + climate change event with culvert 2 and associated embankment removed (green)

Site inspections of the culverts (refer Figure 14) found that culverts 3 and 4 appear to be fully operational while both culverts 1 and 2 could not be located – some ponding does occur upstream of both of these culverts, suggesting that they are partially blocked to a reasonable extent. Hence, the most realistic scenarios, representing the actual current situation, allowing for climate change, are considered to be somewhere between Scenarios 1 and 2.

Scenario 4 was included as a possible mitigation option. The culvert 2 embankment comprises a former road crossing of the stream into the hospital site, which is now redundant, and is at approximately 36.3m RL. The culvert 2 embankment level is approximately 34.6m RL, while the Te Mawhai Road embankment (over Culvert 1) is approximately 33m RL. Preliminary flood modelling showed flood levels are largely controlled by these embankments. Modelling of this scenario found that removal of Culvert 2 and associated embankment would result in a significant reduction in flood levels due to the elevation difference of the two embankments.

This would prevent the inundation of the majority of the landfill areas during a 1% AEP storm. However, it should be noted that this access road acts to detain water within the catchment, and removing it may result in higher peak flows downstream. Downstream discharges were calculated as $2.5m^3/s$ for the completely blocked scenario 1, $10.7m^3/s$ for the unblocked scenario 2, and $33m^3/s$ for scenario 4 which allowed for the culvert 2 embankment being removed. Overall, this shows that the bund performs a good detention function for the overall catchment.

Below Culvert 1, the stream flows approximately 700m before entering the considerably larger Pūniu River. Mangatoatoa Marae is located on the eastern side of the stream before the confluence with the Pūniu River. There are no other buildings along this section of the stream. Downstream effects of culvert 2 removal are considered likely to be less than minor, as the Marae is approximately 9m above the level of the stream, and as such should not be affected by an increase in the stream flows. This can be checked as part of further design work for removal of this culvert.

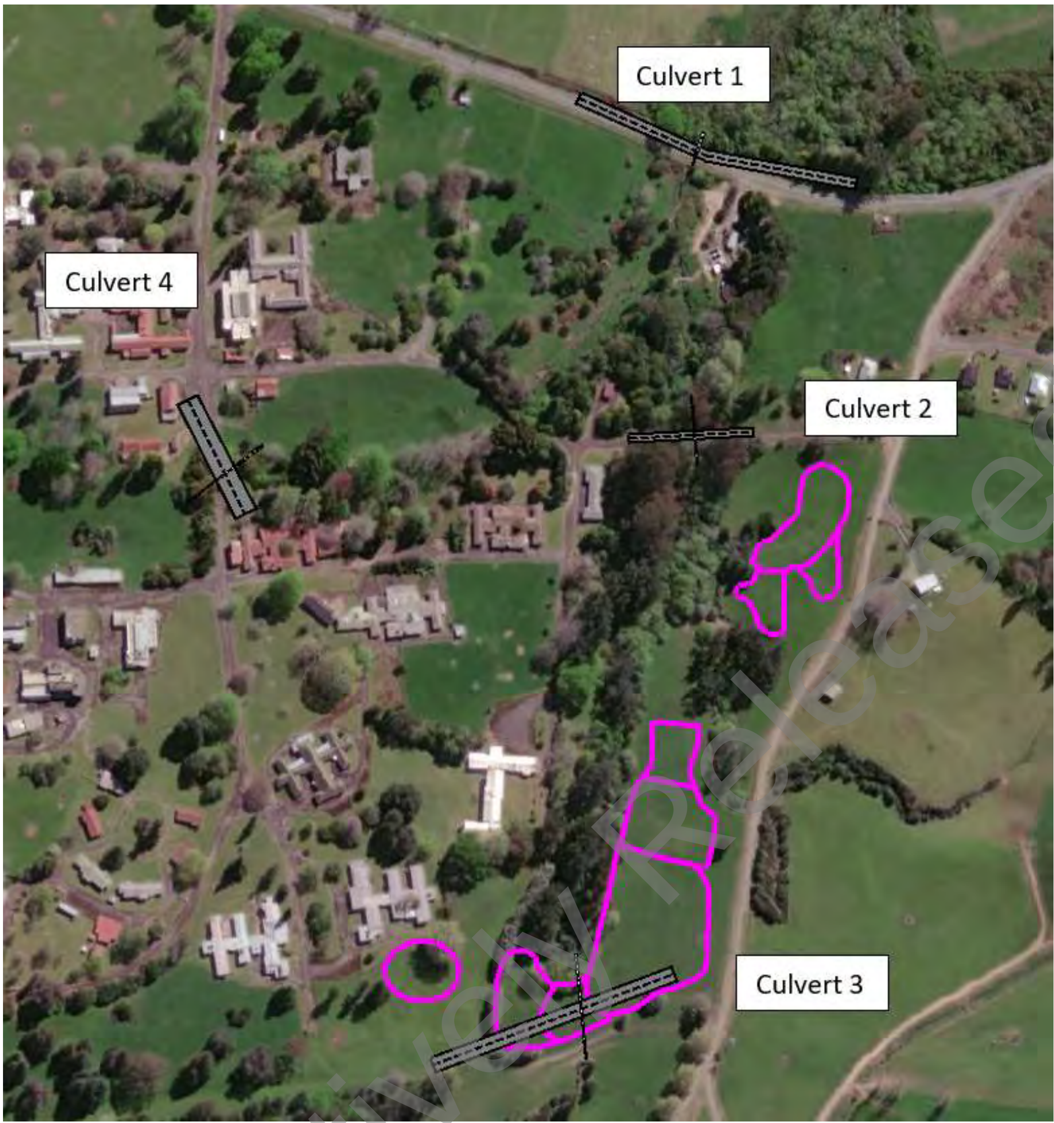


Figure 14: Culvert locations relative to the landfill areas

Landfill area A effectively dams the stream, with culvert 1 passing under it. Modelling has shown this area to be inundated during a 1% AEP event, with the culvert being overtopped and flood waters flowing overland through Areas A & H. Velocities over the bunded area where the culvert passes may be quite high. This could result in localised scour/erosion along the overland flow path, potentially exposing the underlying landfill materials, and in the worst case, uplifting some of these materials and carrying them into the stream. This effect has not been quantified as part of the modelling done to date.

9.11 HAZARD RISK MATRIX

A hazard risk matrix addressing the above issues and possible control/management methods is included in Figure 15, with the legend shown below.

			Impact						
			1	2	3	4	5		Risk Level
Probability (Likelihood)			Insignificant	Minor	Moderate	Major	Extreme		1-4 Low
	1	Rare	1	2	3	4	5		5-14 Medium
	2	Unlikely	2	4	6	8	10		15-25 High
	3	Moderate	3	6	9	12	15		
	4	Likely	4	8	12	16	20		
	5	Very likely	5	10	15	20	25		

Figure 15: Hazard Risk Matrix

Hazard	Description	Consequences and Effects	Risk assessment: Likelihood (1-5)	Risk assessment: Impact (1-5)	Risk assessment: Risk Level (RAG)	Control/Management Method	Risk assessment (post-control): Likelihood (1-5)	Risk assessment (post-control): Impact (1-5)	Risk assessment (post-control): Risk Level (RAG)
Topsoil contamination	Topsoil in 9.5% Area A, 50% Area C, 20% Area H & 12.5% Area I exceeds NESCS rural residential and commercial/industrial standards (asbestos)	Potential human health risk	3	2	6	Human contact with topsoil in these areas will be intermittent and short duration and hence unlikely to pose a significant health risk, except if this area was to be remediated or redeveloped in the future. Affected topsoil could be replaced with clean topsoil to mitigate risk.	1	2	2
Landfill cover/cap integrity	Breach of landfill cap/cover may result in sharp objects protruding from landfill surface	Potential injury to humans/animals	2	3	6	Remove protruding objects and reinstate landfill cap in these areas	1	1	1
Contaminated materials/ refuse	Exposure to contaminated material/refuse, including sharp objects, medical waste, contaminated fill material and asbestos	Potential injury/health impacts	2	3	6	Main risk applies to contractors during soil disturbance or in other areas with inadequate cap. Intrusive investigations undertaken to delineate this risk, with areas where contaminated soils and/or refuse may be encountered shown on Fraser Thomas drawings and explained in the intrusive investigation report. Any contractors undertaking soil disturbance work are to review this information to fully understand requirements relating to contaminated soil/refuse management during works and address them in their Construction Management Plan. Work areas will be cordoned off from public access.	2	2	4
Settlement, subsidence, erosion	Changes in ground level may create uneven, unsafe surface, will erosion may expose landfill material	Potential injury/health impacts	2	3	6	Regular monitoring is undertaken to check settlement, subsidence and erosion. Affected areas should be remediated as required.	1	2	2

Landfill stability	Soil creep and instability issues affecting landfill long term integrity for refuse containment, particularly along western side close to stream	Landfill batter failure, exposing refuse	2	4	8	Check by regular monitoring (current system). Undertake slope stability analysis of any critical slopes and implement any remedial works identified as necessary from this analysis.	1	4	4
Surface water runoff contamination	Contamination of surface water runoff from overland flow across landfill areas	Stream contamination - adverse effects on aquatic life	2	3	6	Remediate contaminated topsoil areas	1	2	2
Groundwater contamination	Contamination of groundwater from passage through landfill, with groundwater flowing into adjacent stream (main contaminant is boron)	Potential human health/environmental effects on any groundwater and surface water users	5	2	10	Continue ongoing monitoring to quantify risk and long-term trends. Current monitoring confirms elevated boron levels in stream are within acceptable levels for the protection of 95% of freshwater species. No remedial works necessary at this stage.	5	2	10
Landfill gas	Landfill gas escaping through landfill surface	Injury or death	1	5	5	Landfill gas considered low risk, based on nature of landfill, landfill materials, age and containment systems. No action required.	1	5	5
Culvert 3 leaks/failure	Culvert 3 pipes the Wharekōrino Stream through Area A of the landfill. This culvert is estimated to be 44-65 years old and could be subject to differential settlement from landfill activity, leading to leaking joints and ultimately possible pipe failure	Landfill washout and collapse, with refuse being washed down the stream	2	5	10	Likelihood of leaks/failure estimated but needs confirming through further investigation, if possible. If a significant risk is confirmed, damaged culvert sections should be replaced, or the culvert lined or the stream reinstated through this area, which would involve significant removal of Area A fill.	2	5	10
Flooding	Flooding of Wharekōrino Stream inundating landfill and threatening integrity of steeper slopes along western side	Ponding, increased infiltration into landfill, scour/erosion, slips	2	5	10	Potentially reinforce steeper slopes on western side of landfill and/or remove culvert and redundant road crossing on stream below landfill (culvert 2 crossing)	1	3	3

9.12 LANDFILL LIFECYCLE STATUS

Landfills have a life cycle, that is typically divided into site development, operation and aftercare phases. The development phase relates to construction of landfilling facilities pre-waste deposition. The operation phase relates to the period over which waste materials are deposited in the landfill until it is closed. The aftercare period relates to the post-closure period, where the landfill must continue to be actively monitored for site integrity and environmental effects until the landfill no longer has the potential for adverse environmental effects.

The duration of the operational period depends on the size of the landfill and how quickly it is filled up, while the aftercare period for a Class 1 (municipal solid waste) landfill is likely to be at least 30-50 years according to the WasteMINZ Land Disposal Guidelines.

The physical, chemical and biological breakdown of waste within a Class 1 or Class 2 (construction and demolition) landfill produces leachate and landfill gas, which typically will continue to be produced for many years post-closure.

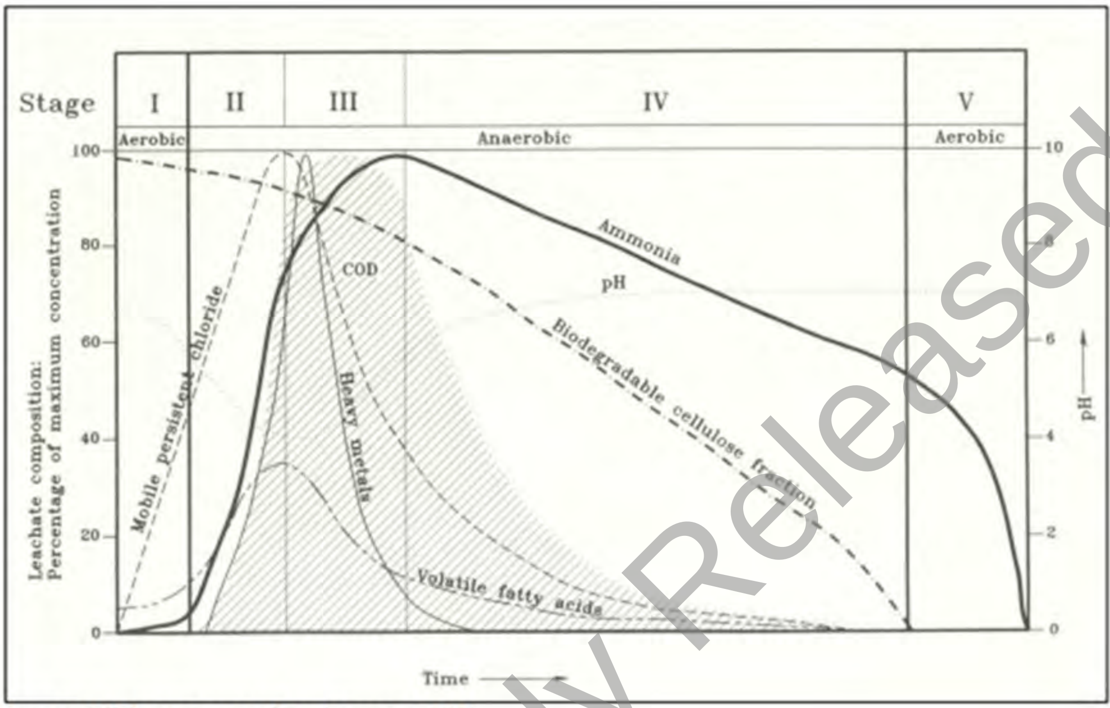
Monitoring of groundwater, surface water and landfill gas needs to be continued during the aftercare period of the landfill, until the strength of any discharges has reduced to a level at which they are unlikely to have any adverse effects on the environment. Settlement monitoring is also important to check when the landfill has reached its final or near final ground level.

Leachate is produced primarily form rainfall infiltration into a landfill leaching contaminants from the deposited waste. Landfill gas is a by-product of the decomposition of waste within the landfill (Class 1 and Class 2). Different reactions occur at different times in the process of waste decomposition. See Figure 16-17. The waste decomposition process is generally acknowledged to occur in five phases:

- During Phase 1, the decomposable organic components of the waste undergo aerobic decomposition, resulting in the production of simpler organic compounds, carbon dioxide and water. Heat is generated, and the aerobic organisms multiply. Phase 1 commences just after the placement of the waste and lasts for a number of months.
- Phase 2 commences due to the depletion of available oxygen and marks the commencement of the anaerobic stage. Aerobic organisms, which thrived when oxygen was available, then die-off. The degradation process is then taken over by facultative organisms that can thrive in either the presence or absence of oxygen. These organisms continue to break down the organic material present into simpler compounds such as hydrogen, ammonia, water, carbon dioxide and organic acids. During this stage carbon dioxide concentration can reach a maximum of 90 percent, although concentrations of about 50 percent are more usual. Phase 2 can last a number of months.
- Phase 3 is marked by the transformation of complex materials such as cellulose, fats, proteins and carbohydrates into simple organic materials such as fulvic and acetic acids. Phase 3 can last from a number of months to a number of years.
- Phase 4 represents the consumption of the acids developed in Phase 3 by specialised anaerobic methanogenic bacteria that convert them into methane and carbon dioxide: the principal components of landfill gas. Ammonia concentrations in leachate drop over this period, while the pH increases and stabilises. This phase usually lasts a significant number of years.

- Phase 5 signals the decline of landfill gas production because most of the nutrients required to sustain the methanogenic bacterial population have been depleted during previous phases. This stage typically lasts a number of years.

These phases are illustrated in Figures 16 and 17 for leachate and landfill gas respectively. In an actual landfill, different areas may be in different stages of the landfill cycle at the same time.



Source: UK Department of Environment 1991

Figure 16: Changes in Leachate Composition over Time (from WasteMINZ Land Disposal Guidelines, Figure 5-3)

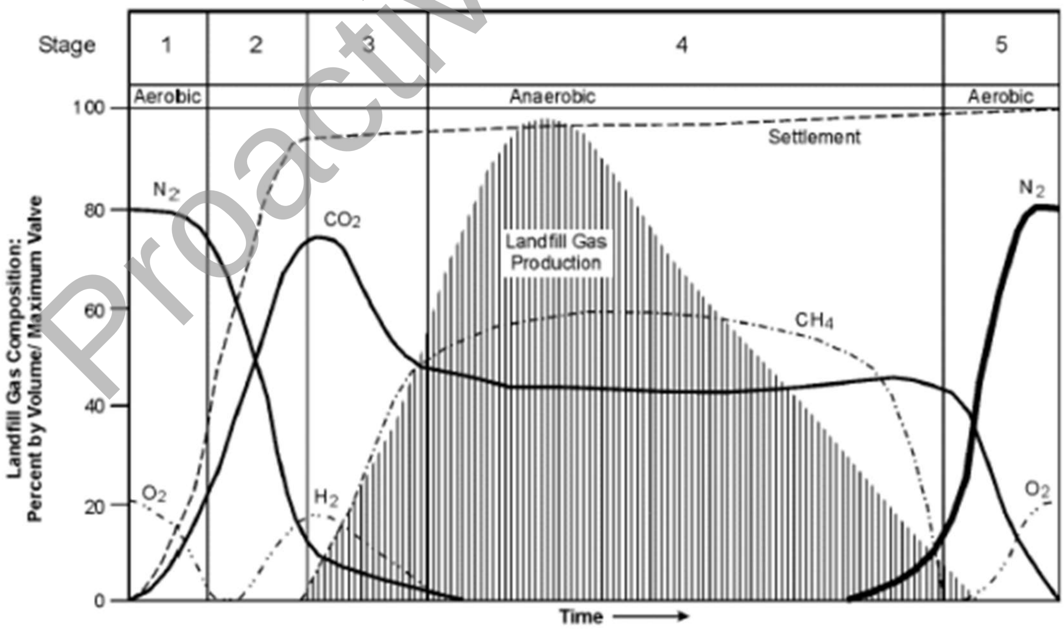


Figure 17: Changes in Landfill Gas Composition over Time (from WasteMINZ Land Disposal Guidelines, Figure 5-7)

Table 12 provides estimated landfill area closing dates, based on the information presented in this report. This shows that Area C was closed about 26 years ago, Area A 35 years ago and the other areas likely as long as 44 years ago. Hence, all landfill areas are assessed to be in the latter stages of the aftercare period.

Table 12: Estimated Landfill Area Closure Dates and Predominant Type of Landfill

Area	Closure Date	Source	Landfill Type
A	1988	1998 AEE	Landfill
B	1979	Aerials	Landfill
C	1997	1998 AEE	Mainly C&D
D	Likely 1979, well grassed in 1995	Aerials	Mainly C&D
E	Likely 1979, well grassed in 1995	Aerials	Not applicable
F	Likely 1979	Aerials	Medical waste
G	Likely 1979	Aerials	Non-Engineered Fill
H	Likely 1979	Aerials	Landfill
I	Likely 1974 or earlier	Aerials	Mainly C&D

This is supported by:

- Typical leachate parameters (ammoniacal-nitrogen and chloride) having relatively low concentrations in groundwater and pH being approximately neutral.
- No landfill gas being detected on-site during the 2022 intrusive investigation.
- The majority of landfill settlement is inferred to have already occurred.

However, the complicating factor here is the presence of boron in the landfilled materials, which is inferred to derive from coal ash deposition within the landfill. As discussed earlier, such practice is likely to have created a significant boron reservoir, with boron being soluble and likely to leach out slowly over a long period, resulting in elevated boron levels in the groundwater and stormwater, which are still occurring in 2022. Inspection of Figure 5 suggests that boron levels in the groundwater at monitoring bore P2 have decreased from around 40-50g/m^3 in 2008 to around 10-20g/m^3 in 2022 but there is no corresponding clear downward trend in the stream water quality results (Figure 6).

The aftercare period refers to ongoing monitoring for site integrity and environmental effects until the landfill no longer has the potential for adverse environmental effects. In our opinion, this endpoint has yet to be reached for boron and hence ongoing monitoring should be continued. Further analysis may be required of this issue.

10 EXPOSURE PATH ASSESSMENT

This section provides an exposure path assessment for the landfill areas. Table 13 provides a summary of relevant baseline data used in the assessment, while Table 14 provides the exposure path assessment.

Table 13: Summary – Baseline Data

Item	Area								
	A	B	C	D	E	F	G	H	I
Area (m^2)	7,990	2,790	1,180	2,440	660	930	1,310	1,980	1,570
Fill Volume (m^3)	12,960-16,310*	3,420	1,350	3,870	0	3,730	0	910	3,080
Topsoil cover – range (average) (mm)	100-300 (145)	100-200 (157)	100-200 (162)	50-200 (139)	100	200	100-200 (151)	0	0-200 (102)
Topsoil contamination	83% > BG but < GL; 9.5% > RR/CI (Asb)	All > BG but < GL	50% > BG but < GL; 50% > RR/CI (Asb)	All > BG < GL	All < BG	All > BG < GL	All > BG < GL	All > BG but < GL; 20% > RR/CL (Asb)	87.5% > BG but < GL; 12.5% > RR/CL (Asb)
Landfill Cap Thickness – range (average mm)	100-800 (522)	100-400 (275)	400-600 (476)	0-250 (155)	200 (1 Testpit)	300 (1 Testpit)	0	0	0
Cap perm-eability (m/s)	$<10^{-7}$ except TP2	$<10^{-7}$	$<10^{-7}$	$<10^{-7}$	$<10^{-7}$	$<10^{-7}$	Not tested	Not tested	Not tested
Fill Description (main content)	Construction & general waste, burnt material, inferred boiler ash, asbestos	Construction/demolition waste, some burnt debris	General & construction waste	Construction waste, including wood, metal, concrete and bricks	None	Medical waste buried in multiple small offal pits	Non-engineered (reworked natural)	Construction and general waste, burnt material, tree stumps/wood fragments	Construction and general waste, brick concrete, and plastic bottles
Fill contamination status (% samples)	Landfill (90%), Managed Fill (10%)	Landfill (40%), managed fill (20%), cleanfill (40%)	Landfill (100%)	Landfill (100%)	N/A	Landfill (100%) due to hazardous medical waste	N/A	Landfill (100%)	Landfill (14%), Managed Fill (43%) Cleanfill (43%)

Notes: BG = background, RR = rural residential, C/I = commercial/industrial, GL =guideline, Asb = asbestos, * - range accounts for potential fill volume based on filling method in cells rather than uncontrolled filling.

Table 14: Exposure Pathway Assessment (note source = fill material in landfilled areas)

Potential Pathways	Potential Receptors	Likelihood of linkage	Likely Consequence of linkage	Risk Pathway Status	Comments
Ingestion and dermal contact of contaminated materials	Site users	Low	High	Complete (Parts of Areas A, C, H & I only – asbestos); Incomplete – other areas	Current use = pastoral farming (animal grazing) and animal food crops (e.g., maize). Surficial soil (topsoil) contains some minor elevated contaminant levels, including some asbestos contamination >0.001% in Areas A, C, H & I, while depth to fill varies within and across different landfilled areas. Areas D, H & I have no landfill cap in some areas. The landfill area is subject to intermittent access by site users and more frequent but still intermittent animal grazing. It is considered unlikely there would be an unacceptable risk of contaminant exposure to humans associated with ongoing direct soil contact, except in the portions of Areas A, C, G, H & I with asbestos contamination. This risk can be further mitigated through providing relevant H&S advice to site users and through appropriate management controls.
	Maintenance and excavation workers	High	High	Complete	Surficial soil (topsoil) contains some asbestos contamination >0.001% in Areas A C, H & I representing risk to outdoor workers, while fill also contains elevated asbestos > C/I levels in Areas A, C, D and H as well as medical waste in Area F. Depth to fill varies within and across different landfilled areas, with Areas D and H having no clay cap in some locations. Hence, fill materials exceeding human health protection criteria for maintenance/excavation workers and waste materials are present within the fill profile. If soil disturbance activities (e.g., repair or replacement of farm water pipe network feeding troughs in landfill areas) are to be undertaken then specific contaminated land management controls would

					need to be implemented to manage potential risks.
Inhalation of contaminated soils (dust)	Site Users Neighbouring site users	Low	High	Potentially complete	**Inhalation of contaminated dusts and asbestos fibres generated during any disturbance of soils within the site presents a risk to site users, maintenance/excavation workers, and neighbouring site users. The risk is considered low for existing site users and neighbours and can be mitigated through specific land management controls during any such works.**
	Maintenance and excavation workers	High	High	Complete	
Inhalation landfill gas	Site users Maintenance and excavation workers Neighbouring site users	Low	Low	Incomplete	**Potential for landfill gases to be generated within the fill profile due to disposal of putrescible materials, including green waste, is considered low, based on the landfill areas having been closed for at least 25 years, the nature of the fill observed from FTL test pits and no landfill gases being detected during the FTL intrusive investigation. Any landfill gas that was generated would likely be vented through the surface of the fill material to atmosphere. Main possible risk relates to accumulation of landfill gas within confined spaces (e.g., manholes or pump chambers, etc.) of which only one was found within or close to the fill area**
Overland transport of contaminants within surface water and sediments	Downgradient receiving environments	Low	Low	Potentially complete	**The landfill area generally has good grass cover, except for the FTL testpit/trench investigation areas, where grass is slowly reestablishing. There are also some areas of exposed soils and some ponding areas around the landfill areas. Hence, there is potential for surficial silt/sediment from topsoil across the fill area containing above background but within guideline levels of heavy metals and PAHs and some asbestos fibres to be transported in surface runoff to the Wharekōrino Stream.** **Six monthly monitoring of Wharekōrino Stream water quality samples both upstream and downstream of the site has found heavy metal concentrations to be lower than the adopted ANZECC guidelines, but iron concentrations often exceed ANZECC long term irrigation and**

					aesthetics drinking water standards. The Wharekōrino Stream in the vicinity of the site is typically subject to low flows and is considered unlikely to be used for water consumption or long-term irrigation. Furthermore, the Wharekōrino Stream merges with the much larger Pūniu River approximately 670m downstream of the landfill site, where it is considered unlikely, that after attenuation and mixing, contaminants would be recorded in concentrations that would pose an unacceptable risk to ecological receptors. If uncontrolled soil disturbance (e.g., ploughing of landfill area) is undertaken, then potential exists for contaminant release to the downgradient receiving environment via soil erosion and stormwater runoff. This is considered unlikely based on existing use of the landfill paddocks.
Leaching of contaminants to groundwater	Downgradient groundwater users Downgradient receiving environments	High	Low	Complete	A complete pathway exists for contaminants to leach from fill materials to shallow groundwater beneath the site and discharge to the Wharekōrino Stream. Long term groundwater and stream water quality monitoring has shown elevated boron levels within the groundwater and corresponding elevated groundwater levels mid-stream and downstream of the site in excess of upstream boron levels, but with all results complying with ANZECC 95% freshwater protection level standards. As there is only one groundwater abstraction bore within 1km downstream of the site where water is used for nursery irrigation, it is considered unlikely that any potential contaminant migration via groundwater would pose an unacceptable risk to human health. Furthermore, it has been confirmed that there is a direct pathway for shallow groundwater under the landfill to flow in to the Wharekōrino Stream and hence be subject to attenuation and mixing, so that any contaminants present would not pose an unacceptable risk to ecological receptors.

11 CONSENT COMPLIANCE AND RECOMMENDED REPAIR/MAINTENANCE WORKS

Resource consents for the closed landfill are summarised in Table 15. These consents allow for the discharge of leachate to land, discharge of stormwater into the Wharekōrino Stream and discharge of contaminants to air. They all expire in March 2035.

Table 15: Existing Closed Landfill Consents

Resource Consent	Status	Description	Commenced	Expiry
AUTH102269.01.01 (269)	Current	Discharge leachate into land in circumstances that may result in contaminants entering groundwater	17/04/2000	10/03/2035
AUTH102270.01.01 (270)	Current	Divert & discharge stormwater into the Wharekōrino Stream	17/04/2000	10/03/2035
AUTH102271.01.01 (271)	Current	Discharge contaminants to air	17/04/2000	10/03/2035
AUTH102272.01.01 (272)	Current	Undertake earthworks within 5 metres of the Wharekōrino Stream	17/04/2000	10/03/2035

Compliance has been assessed against these consent conditions, and is summarised below:

(a) The landfill cap does not comply in some areas with consent requirements for cap thickness and/or permeability and for topsoil thickness (consent 269, conditions 3 and 4). Refer sections 8.6.1 and 8.6.2 of this report for further details.

(b) Some ponding and settlement/subsidence has been observed at localised locations within the landfill area. Consent 269 requires any such defects noticed during site inspections to be remedied immediately (condition 5).

(c) Consent 269, condition 9, refers to a monitoring report being provided to Env-Waikato within three years of granting the consent, that shall include proposals for additional remediation works or monitoring requirements that the consent holder considers necessary in light of the monitoring results. Whilst it is now over 20 years since this consent was granted, ongoing monitoring data, as required under consent 269, condition 7, confirms leachate is entering groundwater and the Wharekōrino Stream, with boron being the main contaminant of concern, and that some remedial works would be beneficial to reduce leachate discharges to ground and groundwater.

(d) Consent 269, condition 10 requires the consent holder to develop, implement and maintain a riparian margin along both banks of the Wharekorino Stream. A Riparian Planting Plan was required under this condition and this was provided in Attachment 2 of the Aftercare Plan for the existing disposal sites, which is understood to have been prepared around the same time as the Meritec capping works (2000). According to WRC compliance records (2012), the plan was approved and implemented, and this condition has been met. Ongoing stock exclusion and regular removal of nuisance plant species is required. It is considered that a critical review of this plan would be required if the existing riparian planting is proposed to be altered by any proposed remedial works, and that this would be more appropriately addressed by the project ecologists.

Furthermore, whilst not consent compliance issues, the following risks are considered to need addressing:

(a) Potential leakage/failure of Culvert 3 due to its age and unknown condition.
(b) Identified flood risk, particularly given recent severe flooding events in New Zealand and the increased awareness of climate change issues and associated predicted increases in rainfall, compared with when these consents were granted in 2000.

For these reasons the following repair/maintenance works are recommended for consideration by LINZ, as part of a long term management strategy for the landfill:

(a) Repair (e.g. lining), replacement or removal of Culvert 3. With culvert removal, this would involve transferring buried refuse in this area to another portion of the landfill, outside the floodplain.
(b) Removal of culvert 2, which will significantly lower flood levels adjacent to the landfill, subject to further investigation, design and an assessment of potential effects on upstream and downstream neighbours.
(c) Replacement of the landfill cap with a low permeability cap, complying with the consent conditions and/or current best practice. Associated ponding, settlement/subsidence areas would be repaired at the same time.
(d) Possible installation of a groundwater cut-off trench or similar to divert upgradient groundwater from passing through the landfill, so that it is no longer in contact with buried refuse.

12 CONCLUSIONS & RECOMMENDATIONS

The 1998 AEE describes the landfill as comprising one fenced off area, within which there are several distinct areas that have been used for different types of refuse disposal. This investigation identified nine areas for intrusive investigation of which all but two were found to contain landfill material. Estimated landfill areas and volumes; closure dates; topsoil, cover and fill characteristics and contamination status are summarised in Table E1. It is important to note that estimated areas and volumes have ±10-30% accuracy, with the higher 30% range allowing for the method and nature of filling in Areas A, H and F (uncontrolled filling).

Overall, the aerial photographs and desktop information show that the portions of the site assessed as part of this investigation were subject to landfilling from at least 1943 through to 1979 and possibly into the 1980s, while information in the Worley AEE indicates Area A was closed in 1988 and Area C in 1997. Suspected additional filling areas outside of the primary landfilling areas (Areas H & I), east of the existing disposal sites were also assessed, given visual identification of potential filling activities during the historical review and onsite interviews with local Kaumātua.

The geotechnical information available has confirmed the site underlying geology is non-volcanic, and consists largely of alluvial material belonging to the Tauranga Group. Laboratory testing of soil samples confirmed there are high levels of contamination present within the various areas of the existing disposal sites and suspected additional filling areas, with exceedances of both the NESCS rural residential/lifestyle block- no produce (unpublished) land use criteria and the NESCS commercial/industrial outdoor worker (unpaved) land use criteria. In addition, there were numerous exceedances of the BRANZ asbestos in soil guidelines for both residential and commercial/industrial sites. There were also numerous exceedances of the Class 1 Landfill acceptance criteria in Areas A, C, D & H, which are predominantly located within the 'old landfill' areas where disposed material was burnt.

Toxicity Characteristic Leaching Procedure (TCLP) testing was undertaken on the samples exhibiting the highest levels of contamination across the existing disposal sites and suspected additional filling areas. Thirteen samples were analysed, with all results indicating the various soil & fill materials across the existing disposal sites and suspected additional fill areas would be suitable for disposal off-site, to a Class 1 Landfill.

Given the extent and nature of the fill material found and the contamination identified thus far, it is considered unlikely that the contaminated fill materials could be separated from other materials within Areas A, B, C, D & H.

The areas of the site investigated as part of this Intrusive Investigation have been reinstated in recent months and returned to farming/grazing use. The reinstatement measures consisted of:

1) Additional material compaction where test pits have been backfilled;
2) Track rolling the existing test pit locations;
3) Retopsoiling the depressions that have appeared after backfilling the test pits; and
4) Regrassing the deposited topsoil to reestablish a vegetative cover over the testpit areas.

The fill material within the landfill would generally be classified as Class 1 landfill material, along with some managed fill and cleanfill materials, as well as some special wastes (i.e., medical wastes, asbestos). A critical assessment of landfill construction identified the following key items of concern:

- Lack of landfill base and side liner and groundwater subsoil drainage allows groundwater to come into direct contact with buried refuse.
- Refuse burning was common practice over much of the period that the hospital's closed landfills have been in operation. It was a cheap method of reducing waste volumes (thus maximising landfill lifetime), minimising leachate generation and landfill gas production from the decomposition of combustible organic wastes and providing rudimentary "sterilisation" of some wastes.
- The deposition of boiler ash within landfilling areas, either directly or for use as cover material has likely introduced a significant boron reservoir into the landfill. Boron is relatively soluble and hence likely to leach over a long period, while once boron gets into water it is very difficult and costly to remove. In our opinion, the ash disposed of in Areas A and C of the landfill is the likely source of elevated boron levels in groundwater sampled from the landfill monitoring bores and in the adjacent stream. However, ongoing monitoring has confirmed that boron levels in the adjacent stream comply with ANZECC criteria for the protection of 95% of freshwater species.
- Some areas have non-compliant clay capping (i.e., inadequate thickness and/or permeability) and/or topsoil cover in relation to the approved resource consent for the landfill site.

- There is no leachate collection or landfill gas collection systems, this being consistent with landfilling practice at the time the landfilling areas were constructed.
- The proximity to the Wharekōrino Stream means the site is potentially subject to inundation by flood waters.

The landfill aftercare period refers to the duration of ongoing monitoring for site integrity and environmental effects until the landfill no longer has the potential for adverse environmental effects, effectively defining the landfill "end of life". All landfill areas were assessed to be in the latter stages of the aftercare period, which typically lasts 30-50 years post-closure, as Area C was closed about 26 years ago, Area A 35 years ago and the other areas likely as long as 44 years ago. This is supported by:

- Typical leachate parameters (ammoniacal-nitrogen and chloride) having relatively low concentrations in groundwater and pH being approximately neutral.
- No landfill gas being detected on-site during the 2022 or 2023 intrusive investigations.
- The majority of landfill settlement is inferred to have already occurred.

However, the complicating factor here is the presence of boron in the landfilled materials, which is inferred to derive from coal ash deposition within the landfill. Such practice is likely to have created a significant boron reservoir, with boron being soluble and likely to leach out slowly over a long period, resulting in elevated boron levels in the groundwater and stormwater, which are still occurring in 2023, although boron levels in the stream have always complied with ANZECC 95% freshwater species protection levels. In our opinion, this "potential adverse environmental effect" endpoint has yet to be reached for boron and hence ongoing monitoring should be continued.

The landfill risk assessment found the main issues to be:

- Groundwater contamination from passage through the landfill, with groundwater flowing into the adjacent stream, with boron being the main contaminant of concern, as explained above.
- Culvert 3 (1350dia) pipes the Wharekōrino Stream through Area H of the landfill. This culvert is estimated to be 44-65 years old and could be subject to differential settlement from landfill activity, leading to leaking joints and ultimately possible pipe failure. Attempts have been made to CCTV this culvert but have not been successful to date, due to significant flows through the culvert.
- Flood modelling of the Wharekōrino Stream has shown that the landfill areas A, B, C, G and H are currently likely to be inundated to varying extents during a 1% AEP storm event, particularly if the two downstream culverts on the stream are blocked or become blocked during the storm, with these effects worsening with predicted climate change. Areas D, E and F have been found unlikely to be affected by flooding. Flooding impacts could potentially be significantly mitigated by the removal of Culvert 2 and the associated embankment, which forms a redundant road crossing over the stream, located below the landfill and above the culvert on Te Mawhai Rd.

The following repair/maintenance works are recommended for consideration by LINZ, as part of a long term management strategy for the landfill:

- Repair (e.g. lining), replacement or removal of Culvert 3. With culvert removal, this would involve transferring buried refuse in this area to another portion of the landfill, outside the floodplain.

- Removal of culvert 2, which will significantly lower flood levels adjacent to the landfill, subject to further investigation, design and an assessment of potential effects on upstream and downstream neighbours.
- Replacement of the landfill cap with a low permeability cap, complying with the consent conditions and/or current best practice. Associated ponding, settlement/subsidence areas would be repaired at the same time.
- Possible installation of a groundwater cut-off trench or similar to divert upgradient groundwater from passing through the landfill, so that it is no longer in contact with buried refuse.

13 LIMITATIONS

The professional opinion expressed herein has been prepared solely for, and is furnished to our client, Toitū Te Whenua – Land Information New Zealand, on the express condition that it will only be used for the purpose for which it is intended.

No liability is accepted by this firm or by any Principal, or Director, or any servant or agent of this firm, in respect of its use by any other person, and any other person who relies upon any matter contained in this report does so entirely at its own risk. This disclaimer shall apply notwithstanding that this report may be made available to any person by any person in connection with any application for permission or approval, or pursuant to any requirement of law.

We do not assume any liability for misrepresentation or items not visible, accessible or present at the subject site during the time of the site inspection; or for the validity or accuracy of any information provided by our client or third parties that have been utilised in the preparation of this report.

Figures

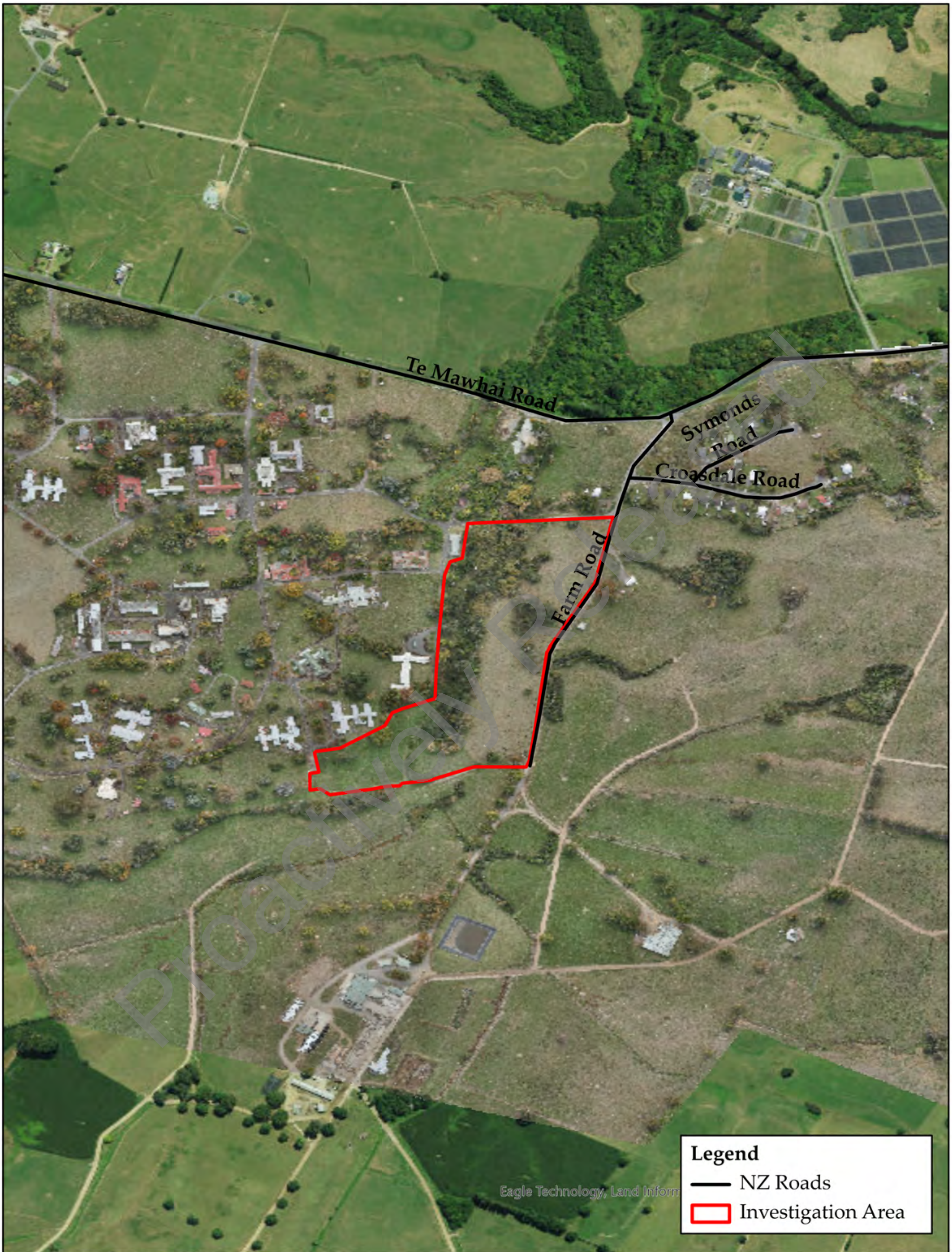


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Figure 1: Site Location Plan

Toitū Te Whenua Land Information New Zealand
Intrusive Investigation
Former Tokanui Hospital Demolition and Remediation Project
Tokanui
Te Awamutu

Date:	19/06/2023
Figure Reference:	33097/001
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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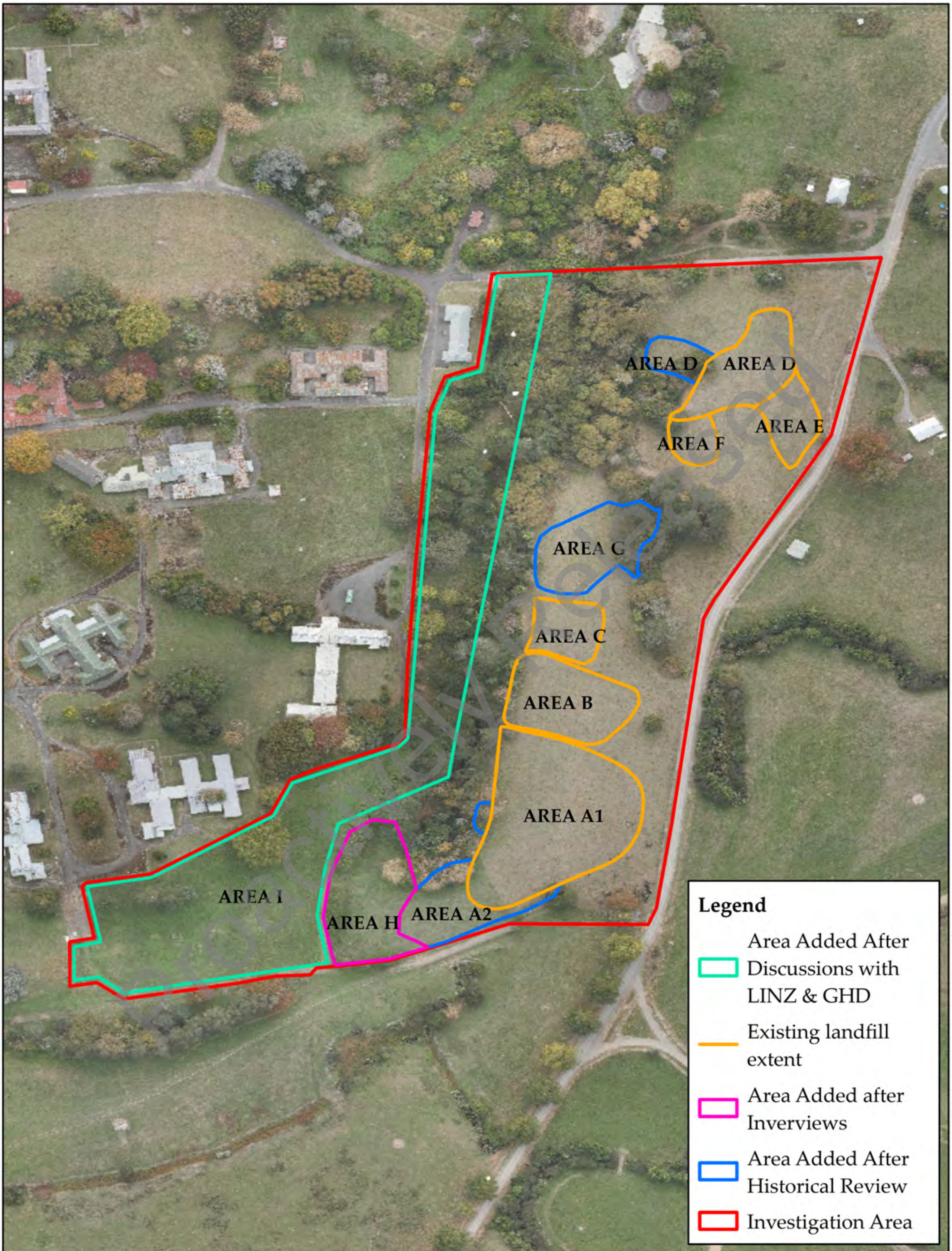

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Figure 2: Landfill Location Plan

Toitū Te Whenua Land Information New Zealand
Intrusive Investigation
Former Tokanui Hospital Demolition and Remediation Project
Tokanui
Te Awamutu

Date:	24/11/2023
Figure Reference:	33097/002
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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Meters

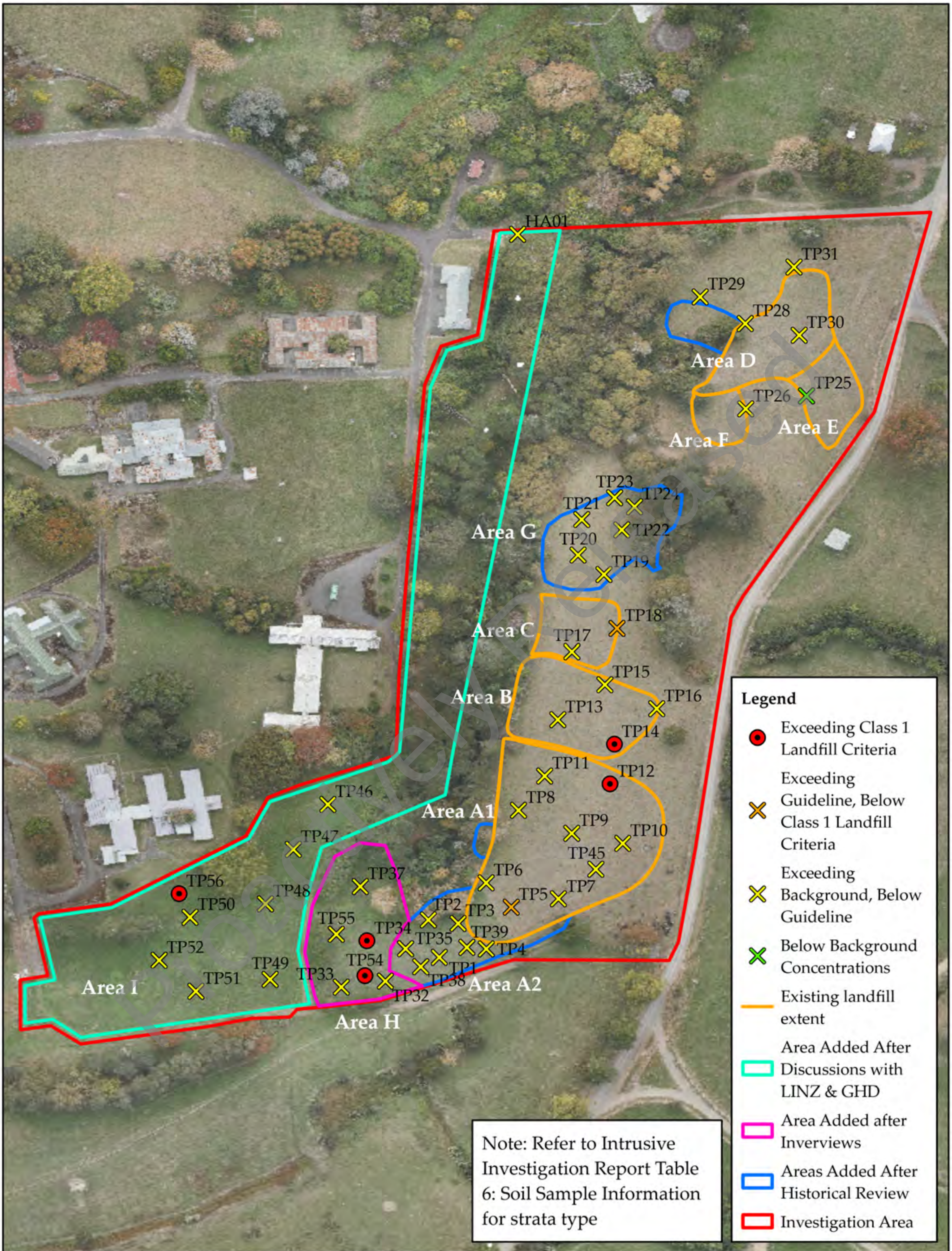

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Figure 3: Topsoil Contamination Plan

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Intrusive Investigation
Former Tokanui Hospital Demolition and Remediation Project
Tokanui
Te Awamutu

Date:	23/11/2023
Figure Reference:	33097/003
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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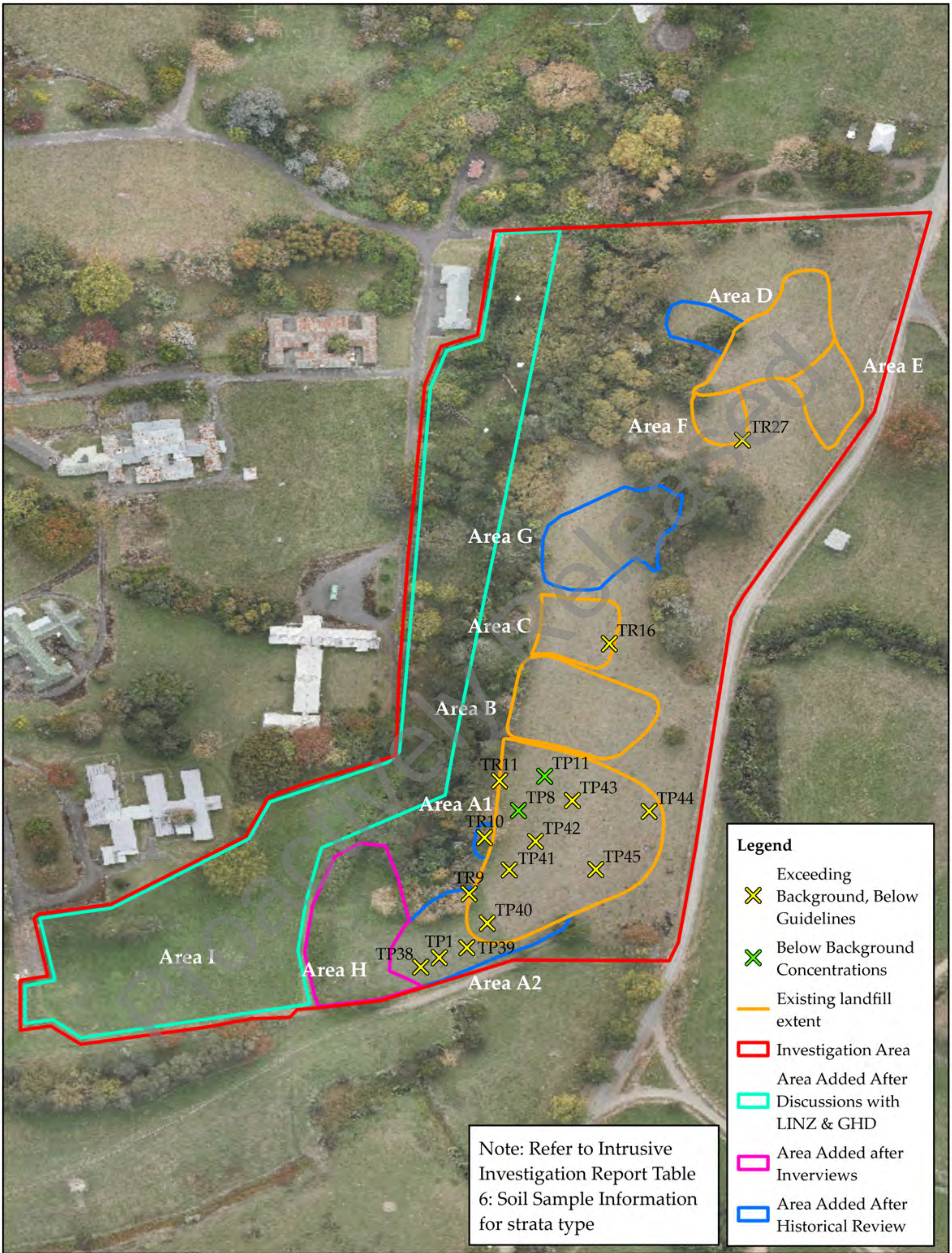

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Figure 4: Landfill Cap Contamination Plan

Toitū Te Whenua Land Information New Zealand
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Te Awamutu

Date:	23/11/2023
Figure Reference:	33097/004
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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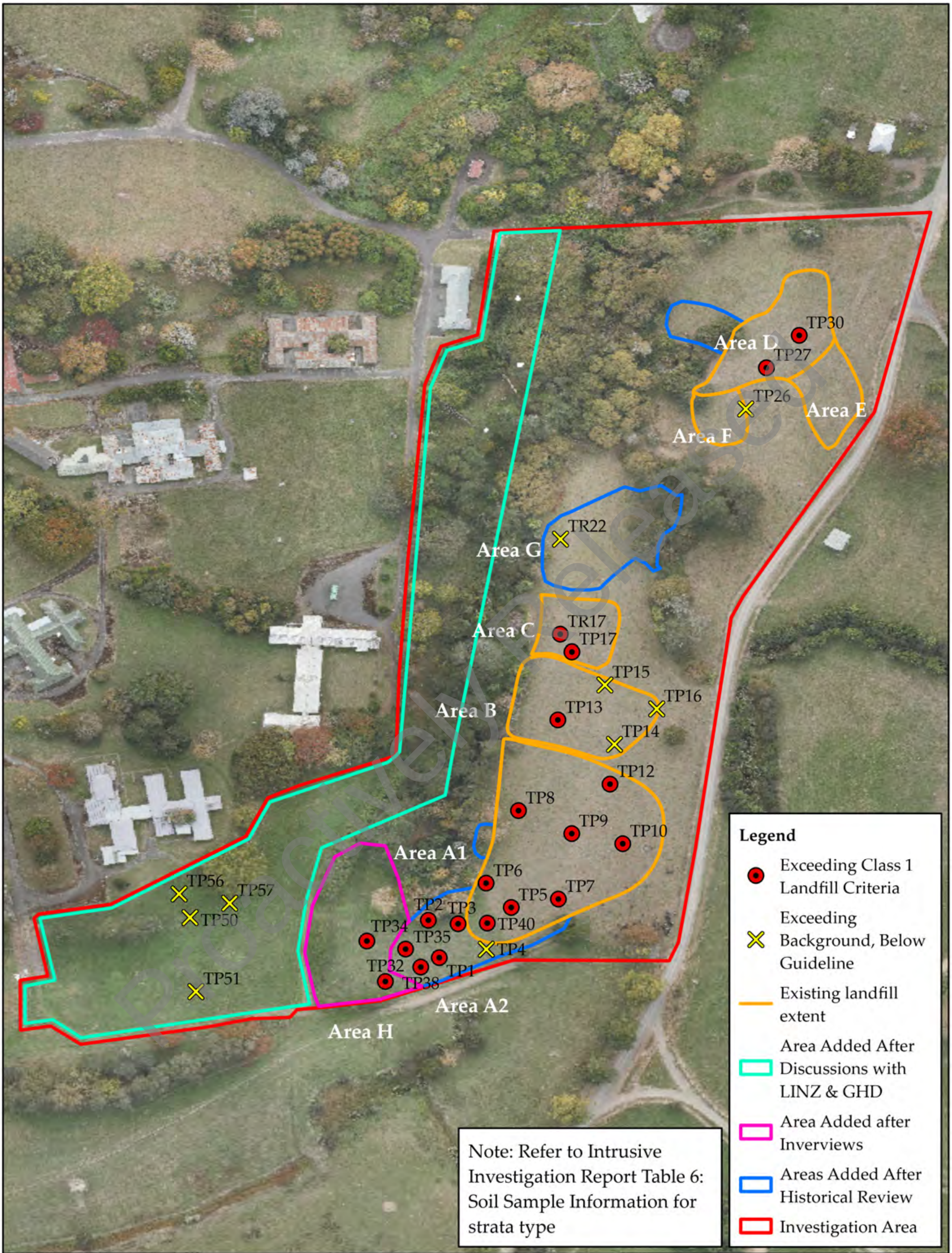

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Figure 5: Fill Contamination Plan

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Te Awamutu

Date:	23/11/2023
Figure Reference:	33097/005
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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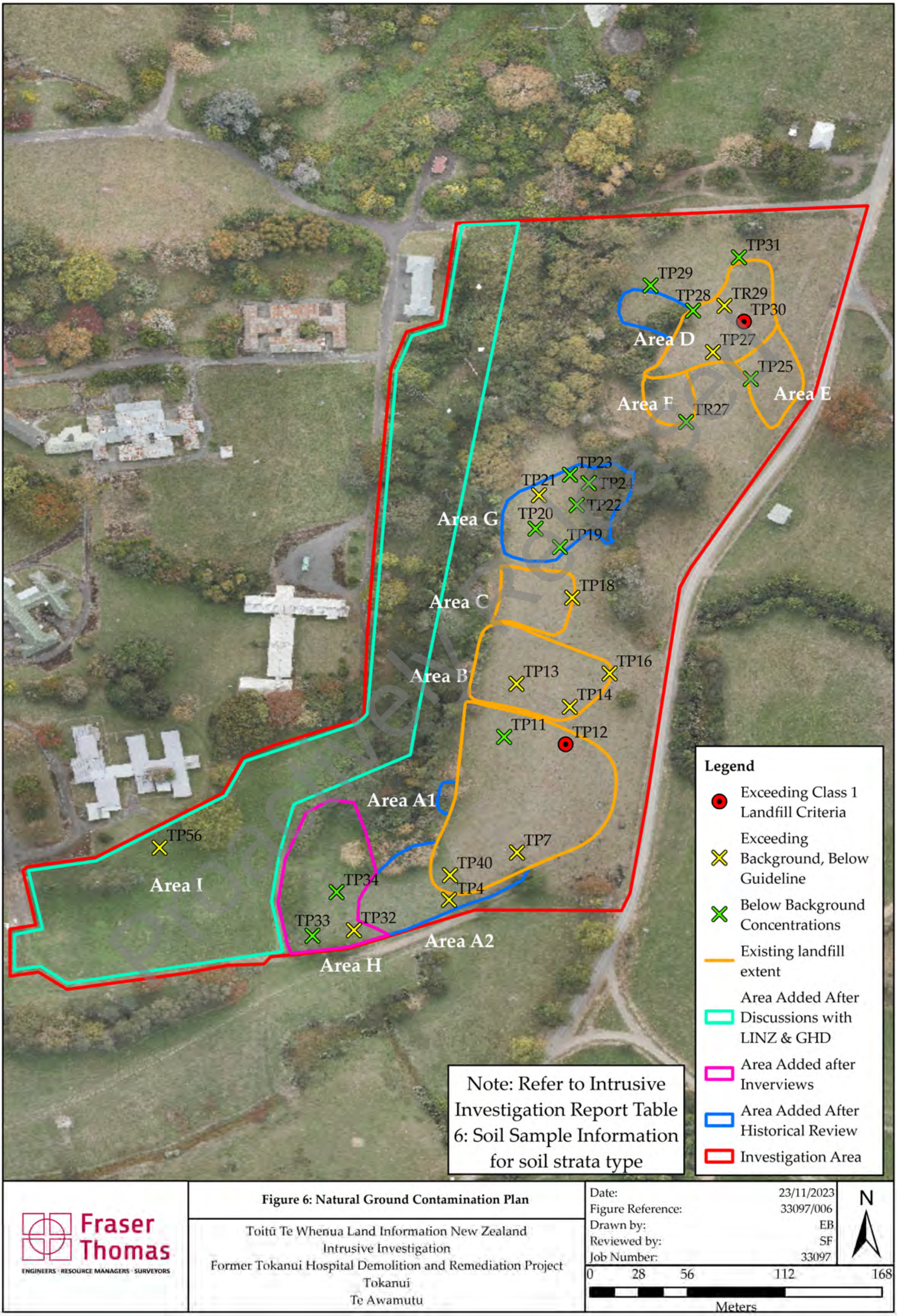

Figure 6: Natural Ground Contamination Plan

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Date:	23/11/2023
Figure Reference:	33097/006
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

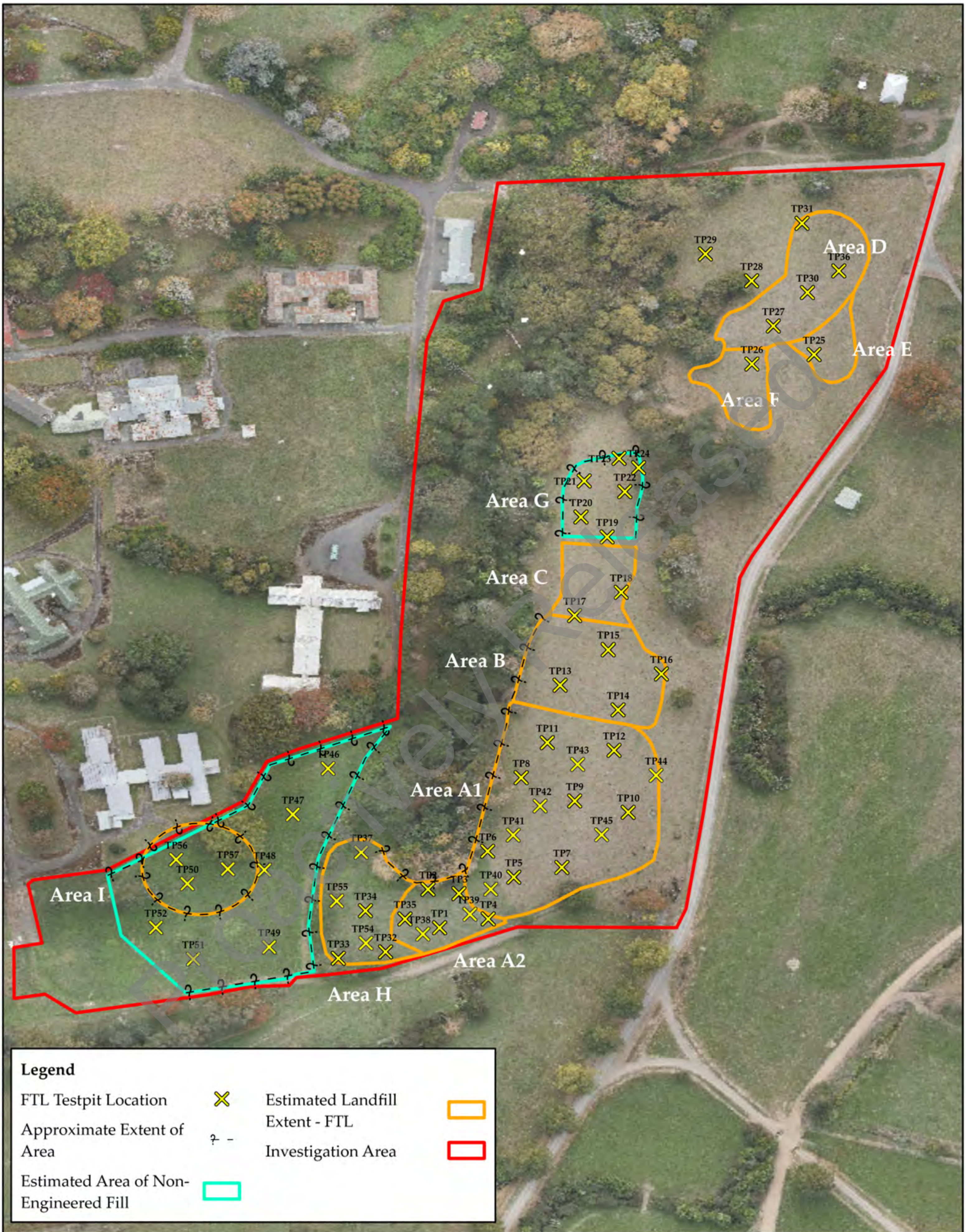

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Figure 7: Test Pit Location Plan

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Date:	24/11/2023
Figure Reference:	33097/007
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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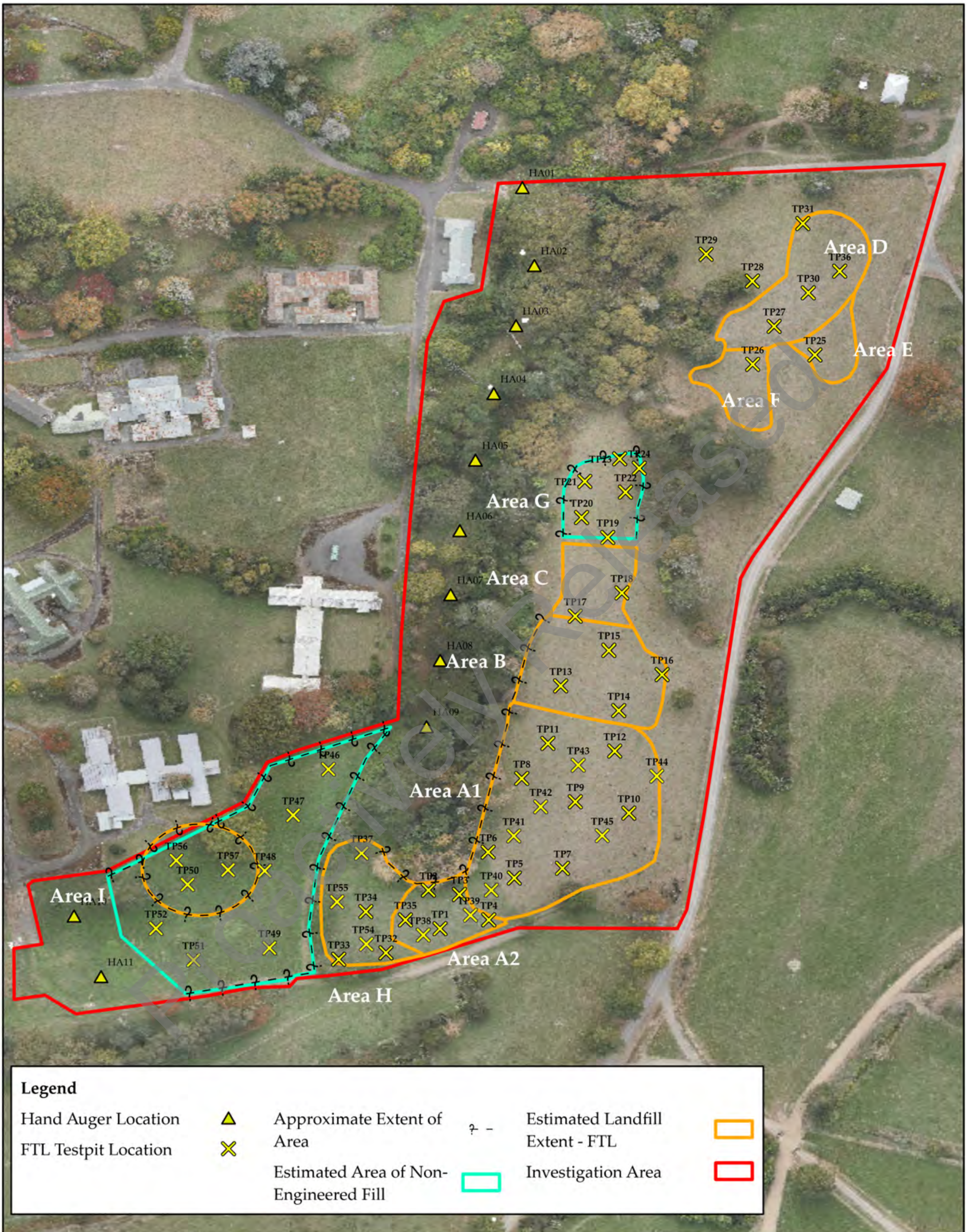

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Figure 8: Trench & Hand Auger Location Plan

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Te Awamutu

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Figure Reference:	33097/008
Drawn by:	EB
Reviewed by:	SF
Job Number:	33097

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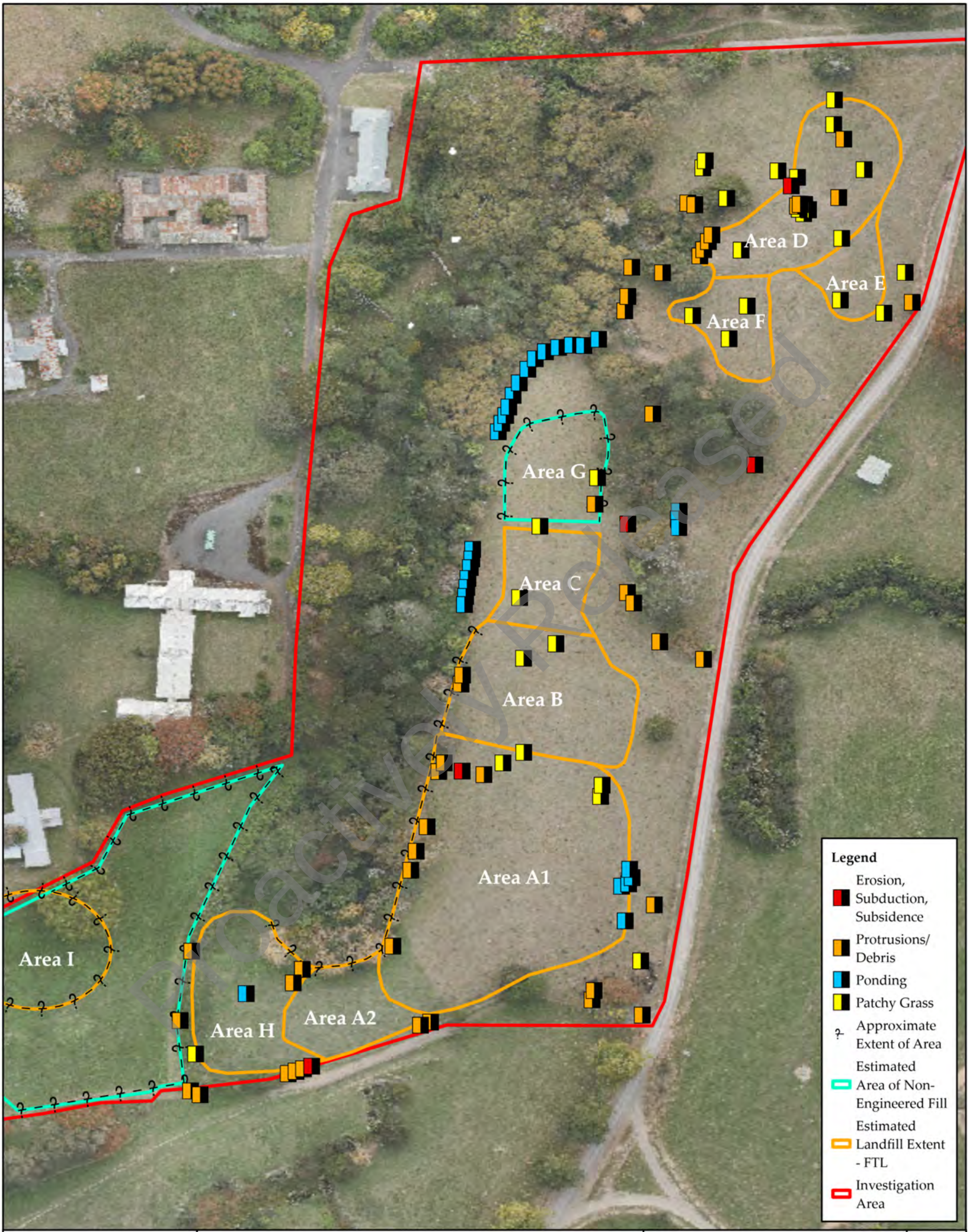

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Figure 9: Landfill Cover Condition Plan

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Figure Reference:	33097/009
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Reviewed by:	SF
Job Number:	33097

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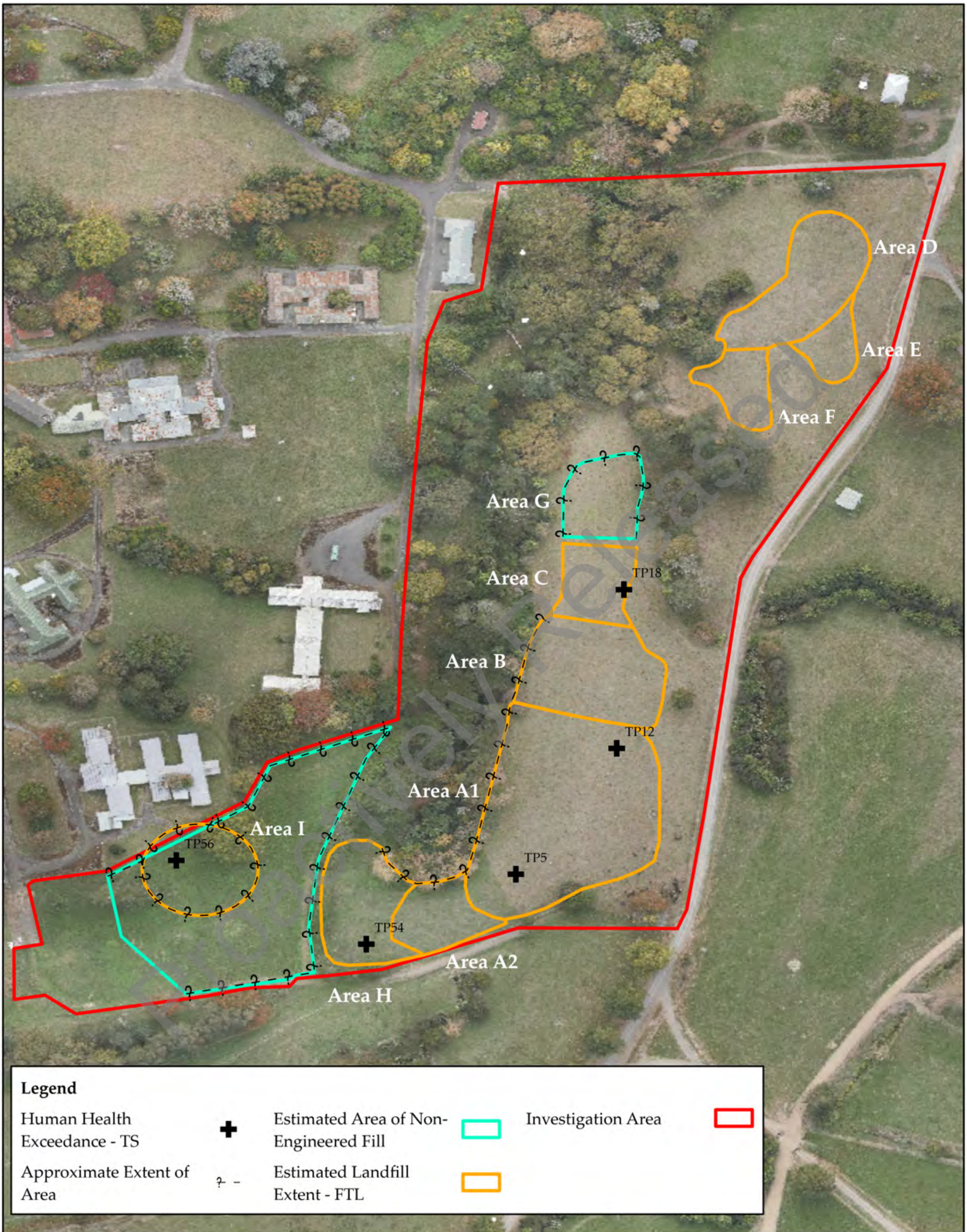

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Figure 10: Human Health Exceedance Plan - Surface

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Date:	24/11/2023
Figure Reference:	33097/010
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Job Number:	33097

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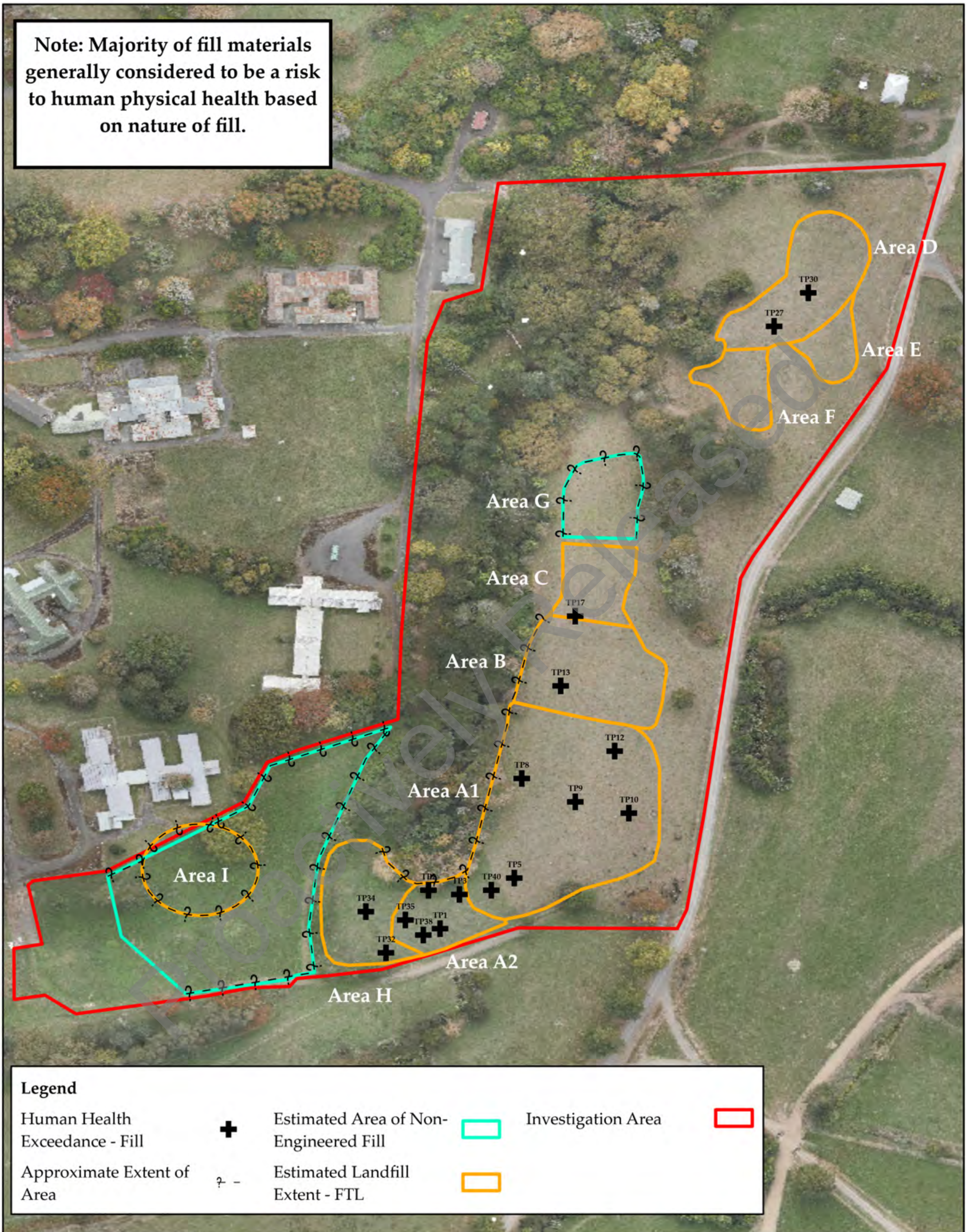

Figure 11: Human Health Exceedance Plan - Fill

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Reviewed by:	SF
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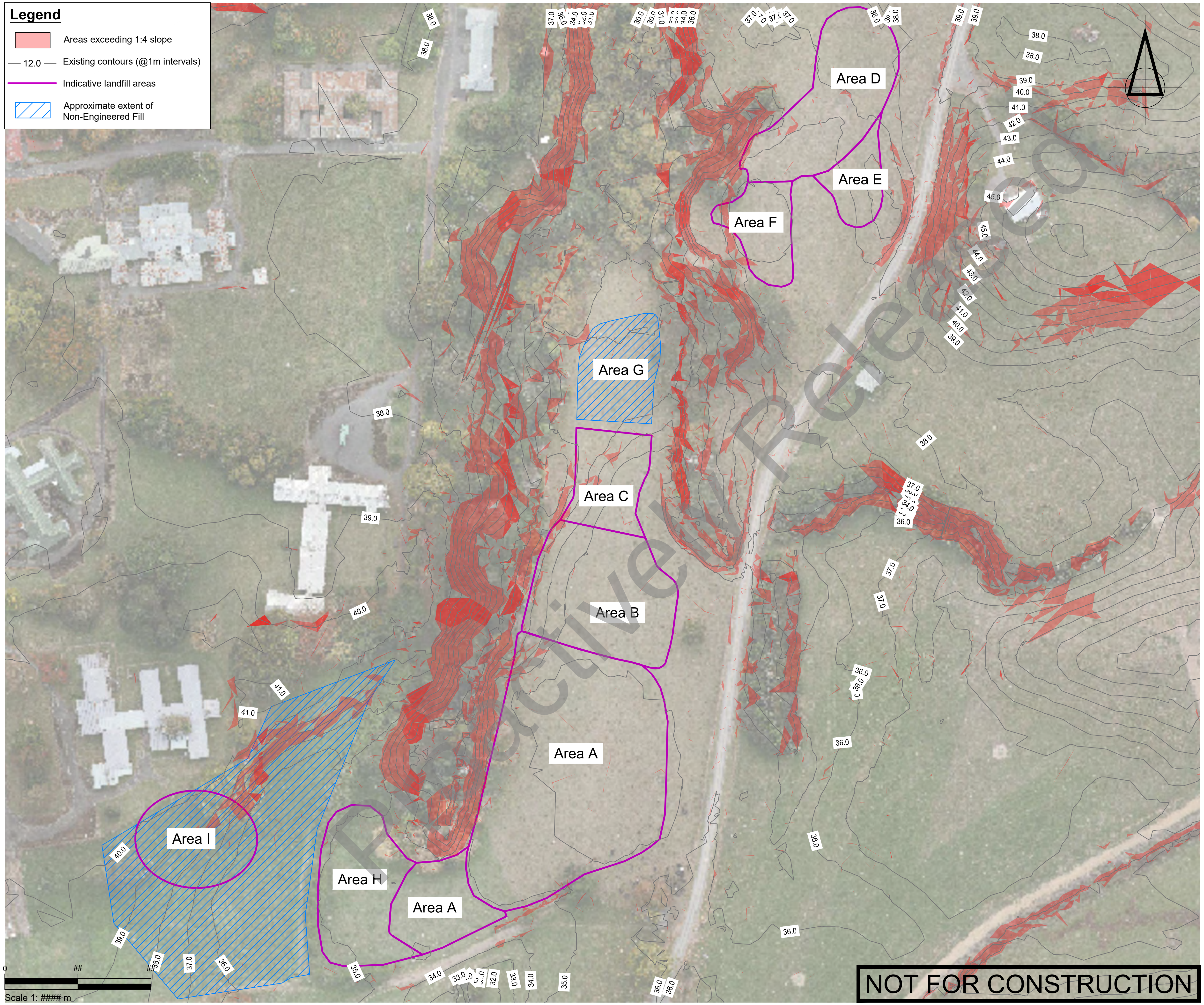
Drawings



Proactive Release

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SURVEYED			APPROVED	DATE
DESIGNED				
DRAWN	TB	02/02/23		
CHECKED				

REVISION	CHANGES	CHECKED	DATE

NOTES

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LAND INFORMATION NEW ZEALAND

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FORMER TOKANUI HOSPITAL
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STATUS
FOR INFORMATION
Construction works shall commence only on receipt of and in accordance with the Council or Council organisation stamped approved drawings, unless otherwise indicated.

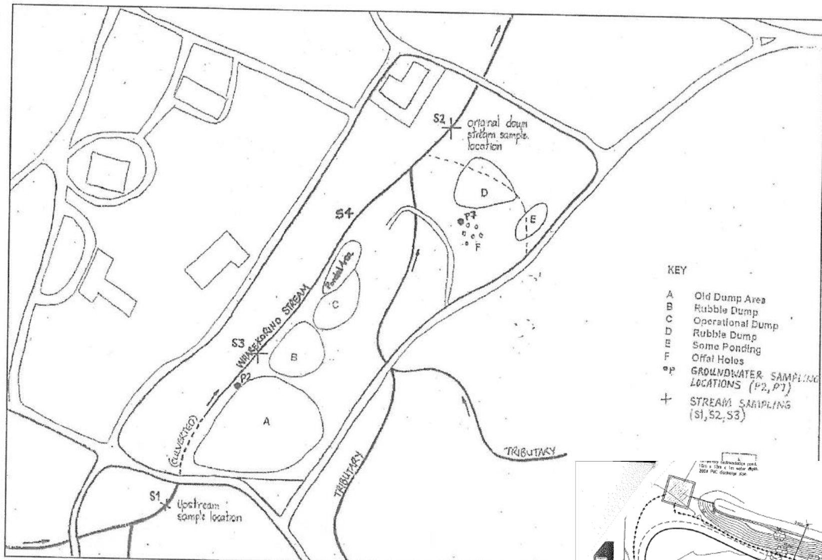
SCALE 1:1500 (A3)

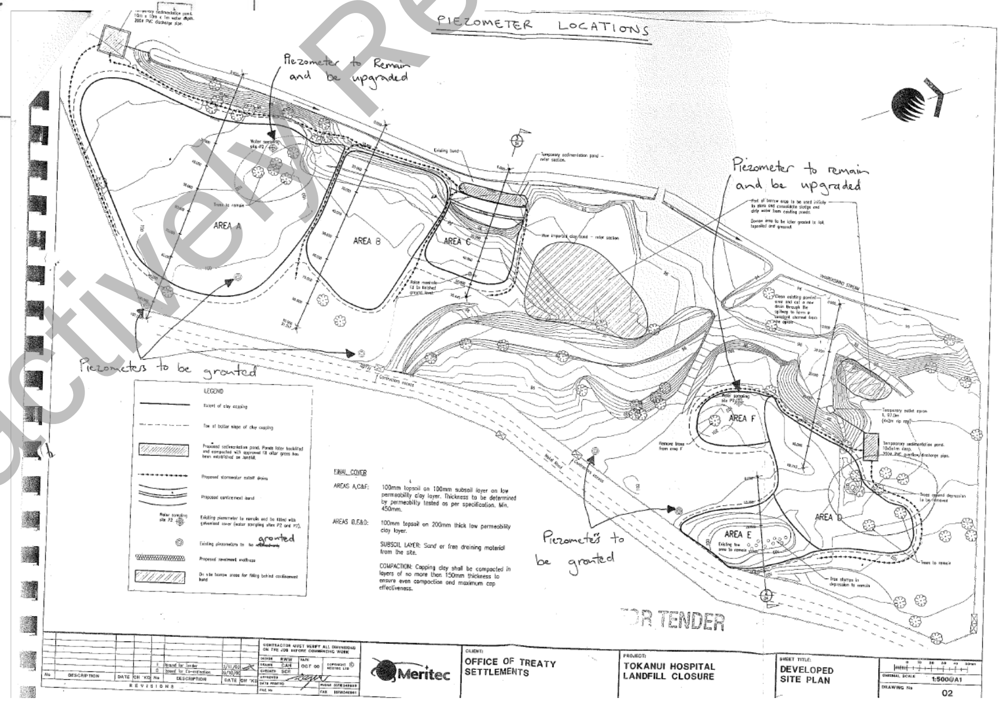
DRAWING No 65547/101 REVISION -

Appendix A

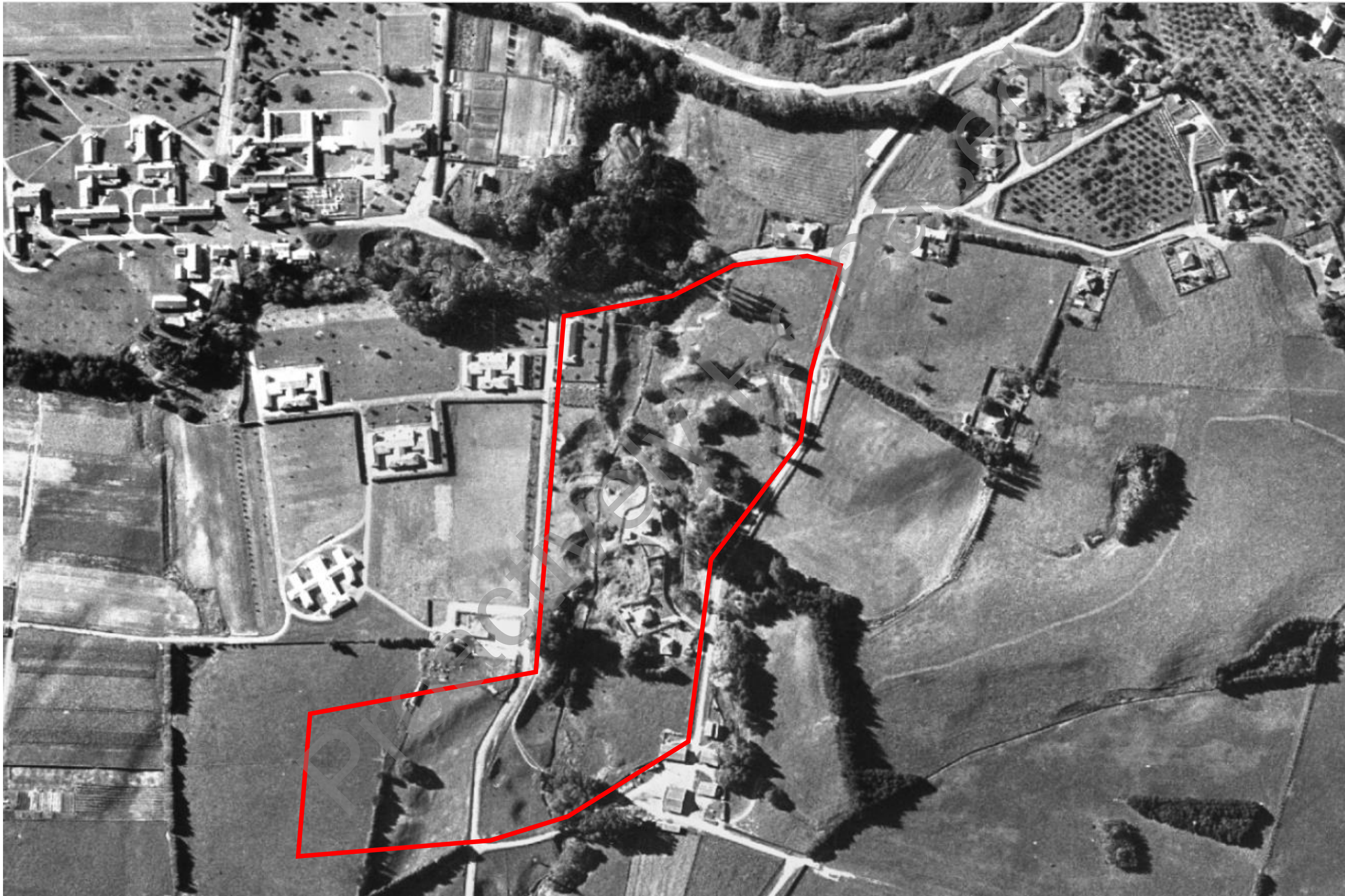
Historical Aerial Photographs

Figure 2: Location of groundwater and surface water quality monitoring sites



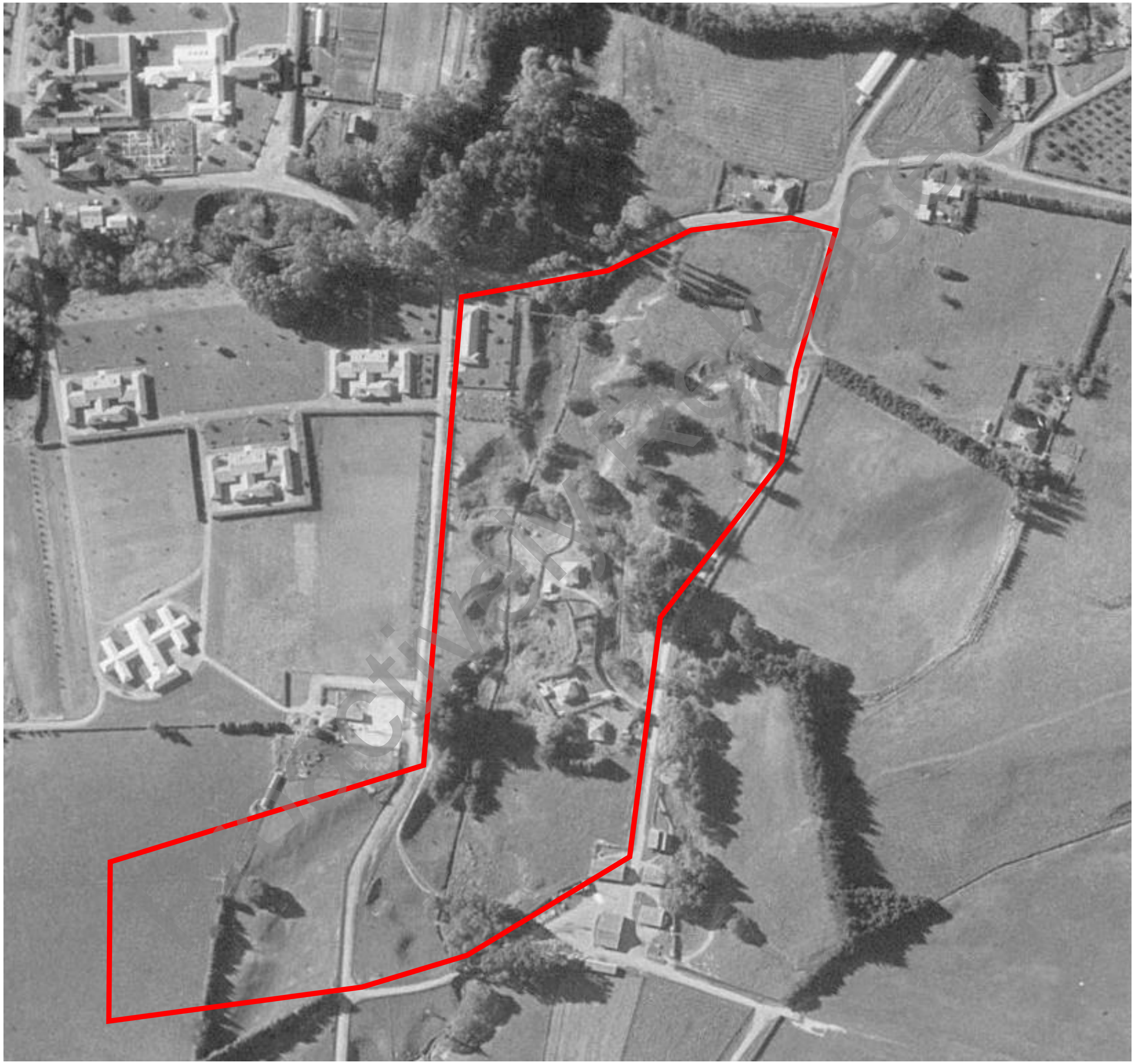


1943



Source: Waikato Regional Council

1944

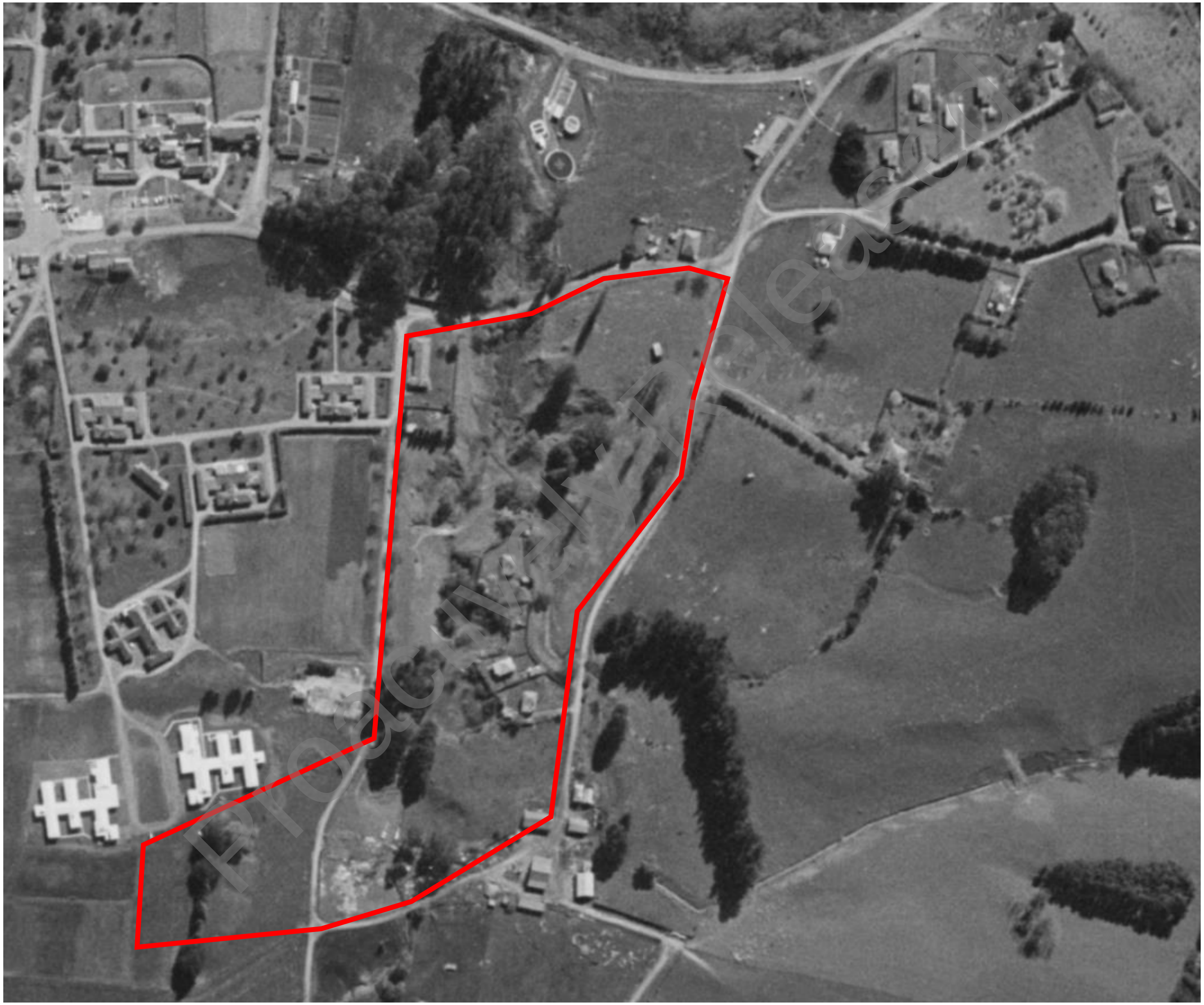


Source: NZ Aerial Imagery: retrolens.co.nz

1951

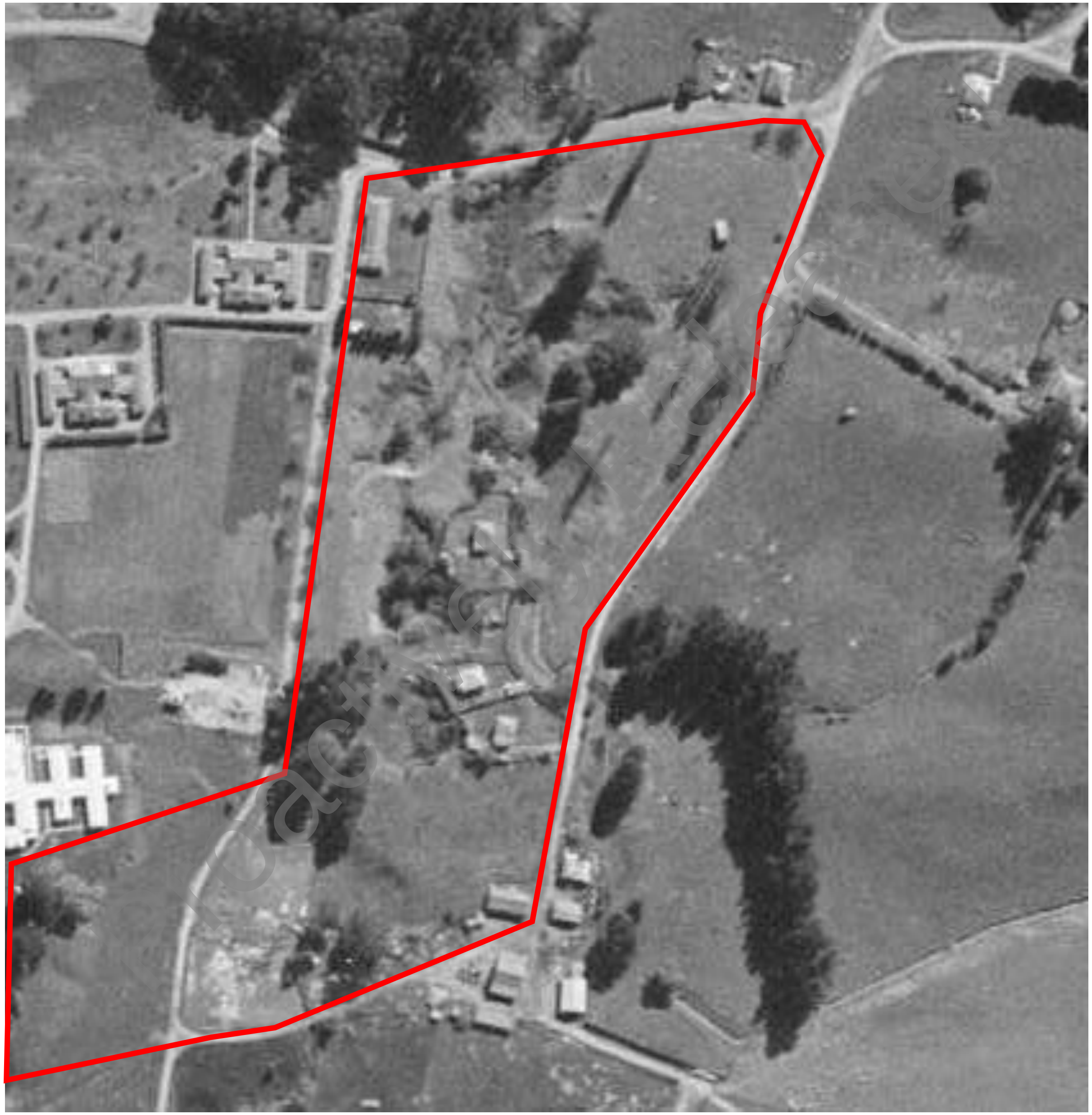
Source: Alexander Turnbill library https://natlib.govt.nz/

1957



Source: Waikato Regional Council

1961



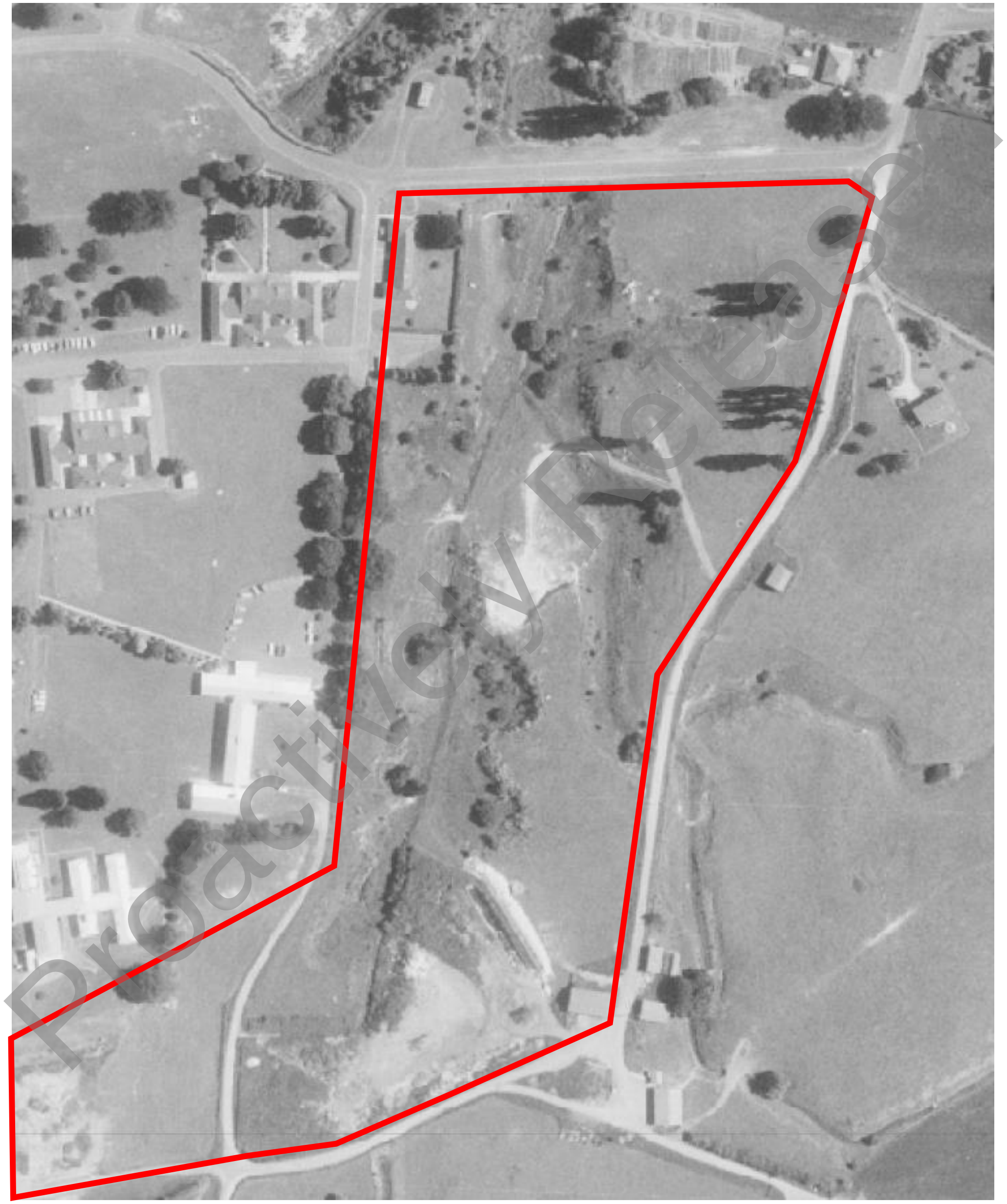
Source: NZ Aerial Imagery: retrolens.co.nz

1966 – East Portion

1974

Source: NZ Aerial Imagery: retrolens.co.nz

1979



Source: Waikato Regional Council: retrolens.co.nz

1995

Source: NZ Aerial Imagery: retrolens.co.nz