Kinleith Integrated Remediation Project (KIRP)
an integrated approach to dealing with a legacy of historical contamination

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INTRODUCTION

For forty years or so Carter Holt Harvey has utilized a number of sites on land which the Company owns at locations to the south of the Kinleith Industrial Park for the disposal of various wastes associated with the processing and treatment of timber from the local forest resources. These sites include areas where timber treatment, pulp and paper, and agricultural and forestry chemical residues have been placed. Of particular note are two sizeable 'hazardous waste' sites known as Site A (a little over 1 hectare) and Site B (about 5 hectares) and a large stockpile (about 225 000 m^3) of copper-chromium-arsenic and boron treated shavings.

The Kinleith Integrated Remediation Project (KIRP) is a pro-active programme for the rehabilitation of these sites which involves the relocation of the contaminated shavings toa disused quarry (known as the 'Sprinkler Quarry'); the remediation and rehabilitation of Site A by the excavation and relocation of waste material to Site B; significant remediation and engineering works at Site B to ensure its long term integrity; and the construction of a fully engineered containment cell in a location contiguous with Site B to receive various intractable wastes – specifically pentachlorophenol (PCP) contaminated soil.

Construction and design of the containment cell has been planned allow the disposal of PCP-contaminated soils which are both held in storage by Carter Holt Harvey (in a secure facility on the Kinleith Industrial Park) and which exist *in-situ* at a number of former sawmill and timber treatment sites: Kopu, Kinleith, Tokoroa, Whakatane and Brookside (Nelson).

To date, the presence of the PCP has limited disposal options. In order to address this legacy of past practices, and in the absence of a proven commercial technology (despite many years of investigation by Carter Holt Harvey, the timber industry and central government), in 2002 Carter Holt Harvey proposed the development of a containment cell on land in its ownership which would then be sequestered and managed in perpetuity. Since early 2003, Carter Holt Harvey and its collaborators the University of Waikato and a specialist United States based engineering company – EarthFax, have successfully completed fungal bioremediation trials using white rot fungi. A commercial venture was formed to exploit and develop this technology for full scale and commercial application. This developmental field work is being undertaken at the warehouse on the Kinleith Industrial Park which has been used to store Carter Holt Harvey's stockpile of PCP-contaminated soil.

This initiative provides an opportunity to degrade the PCP (and associated dioxin) in these contaminated soils prior to their placement in the proposed containment cell at Site B and thereby reduce potential long-term risk to the Company and the community. Accordingly,

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KIRP is viewed as providing a sustainable solution which provides a 'one-off' opportunity for Carter Holt Harvey to deal with the legacy of these historical residues by consolidating wastes from several sites and locations in a single, secure, repository on Company-owned land.

A projected total of 10 500 m^3 of contaminated soil is to be disposed of in the containment cell.

This paper discusses the extensive site investigations which have been undertaken to date, including environmental (soil and groundwater), geotechnical studies and detailed engineering design, and outlines the programme of works which are anticipated to be carried out over the next year.

SITE INVESTIGATIONS OVERVIEW

Extensive technical investigations have been undertaken by Tonkin & Taylor over the past two years, including environmental, hydrogeological and geotechnical studies, and engineering design. Results of the investigations have been presented in a series of technical reports, which provided the technical support documents for the Assessment of Environmental Effects (AEE) report and resource consent applications.

The purpose of the investigations and subsequent engineering conceptual design work, was to enable Carter Holt Harvey to select the most appropriate long-term management option for the Shavings Stockpile and the former waste disposal Sites A and B.

Previous investigations carried out on and around the waste disposal Sites A and B included an assessment of management options for Site B in 1994, hydrogeological mapping and the installation and sampling of eight monitoring wells/well pairs in 1993-1995, and supplementary hydrogeological investigations comprising the re-sampling of existing wells and a geophysical study to further define the site hydrogeology (Tonkin & Taylor (2002).

SCOPE OF INVESTIGATIONS

Proposition One Shavings Stockpile -> Sprinkler Quarry

Shavings Stockpile

The shavings stockpile has been built up over a period of 20 years from trimmings of treated timber. A recent survey indicates approximately 224,000m^3 of shavings occupying a footprint of 2.6 ha. Detailed investigations to characterise the physical and chemical characteristics of the shavings have been undertaken to provide the basis for designing a secure containment facility at the Sprinkler Quarry. Woodwaste samples were analysed for total, TCLP and SPLP concentrations to determine the contaminant mass and leachability of the contaminants prior to disposal in the Sprinkler Quarry, and indicate the presence of boron, arsenic, chromium, copper, pentachlorophenol (PCP) and tetrachlorophenol (TCP). In addition, 400 m^3 of PCP treated timber will be wrapped and sealed, and emplaced in the Sprinker Quarry.

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Sprinkler Quarry
The Sprinkler Quarry is located on Tram Road, about 1.7 km southeast of the stockpile. The floor of the quarry occupies some 1.5 ha, and the volume occupied by the excavation has been estimated at 171,000m^3. Geological and geotechnical investigations were completed and determined that the Whakamaru ignimbrite that underlies the quarry and forms the sidewalls, comprises weakly to moderately welded pumice and crystal rich breccia containing fragments of dark grey glassy rhyolite and rhyolitic obsidian. Vertical cooling joints were recorded in the base and sidewalls of the site.

In addition to geotechnical investigations, groundwater quality beneath and downgradient of the Quarry was also tested, and results indicate very low levels of metals and organic compounds in groundwater. Recorded concentrations were below both drinking water and ANZECC guideline values.

Proposition Two Site B and Containment Cell

Site A Hazardous Waste Facility
Site A is located south of Tram Road and is approximately 1.25 ha in area. Site A operated as a disposal site from the date of construction of the Kinleith Pulp Mill up until 1972. Hazardous wastes placed in the area include chemical (agricultural) residues and associated containers, mercury and hydrocarbon wastes, and a substantial quantity of spent lime. The site is bounded by pine forest or existing roads, and is located in a natural drainage hollow. Surface water drainage is to a pond located in the southern corner of the site.

A total of 32 test pits were excavated across Site A. The geology comprised a layer of fill, overlying soft sediment/peat and/or hard rock. Analysis results indicated predominantly low levels of metals and the presence of some pesticides including chlordane, heptachlor and phenol and PCP. Elevated levels of chlordane and minor 2,4-D were detected in the sediment sample analysed from the base of the pond within Site A. Low levels (below drinking water standards) of the metals boron, arsenic, nickel, lead and zinc were also detected in the pond water samples

Site investigations at Site A indicated that approximately 3,400 m^3 of contaminated soil require removal to Site B. A remediation action plan (RAP) has been prepared for Site A which requires that the former Site A is cleaned up to agricultural standards set out in the Timber Treatment guidelines (MfE/MoH, 1997).

Site B Former Hazardous Waste Facility
Site B is larger than Site A (6.33 ha) and is bounded by local forestry access roads. The site is essentially flat with very low and irregular drainage grades across the surface, and is raised up by about 1-2 m from the surrounding land. A shallow gully slopes into the pine forest that borders the western side of the disposal site. Cleared hilly land surrounds the site to the south and east.

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Hazardous wastes were deposited in Site B from the closure of Site A in 1972 until 1992. The wastes, including forestry chemical residues, asbestos, septic tank cleanings, pulp mill chemicals and waste oil and grease, were segregated into purpose excavated trenches or pits across the site. This disposal method, along with anecdotal information from employees and contractors having knowledge of previous waste disposal activities, was used to guide the test pit layout and sampling strategy. When the site was closed in 1992 the surface was covered in layers of fill comprising of local soils and an ash and clinker mix, and contoured to the present surface.

The disposal pattern on Site B allowed the waste materials to be divided into five areas based on the types of wastes encountered and their disposal configuration, namely Forestry chemicals, asbestos and oil pits (northeast), PAH Waste Pits (northwest), PAH/ Phenol pits (southern-eastern corner); Minor PAH / phenol and general refuse (centre west) and Septic waste pits (south).

Investigations undertaken on Site B comprised a total of 147 test pits and trenches to characterise the waste materials deposited in purpose-excavated trenches and pits. Laboratory analysis was scheduled for a wide range of compounds, including metals, polyaromatic hydrocarbons (PAHs), volatile and semi-volatile organic chemicals, organochlorine, nitrogen and phosphorus pesticides and acid herbicides. The potential for contaminants to leach through the underlying soil profile was determined by site-specific partition coefficients from total soil concentrations, and TCLP, SPLP and lysimeter data.

In summary, forestry chemical containers, asbestos or waste oil was recorded in the northeastern corner of Site B, with White Veldpar (hexazinone) containers being the most common. Old containers of Roundup (glycophos), atrazine, and drums formerly containing 2,4-D and Chlordane 80 were also recorded on site. Elevated concentrations of chlordane, atrazine, 2,4,5-T, 2,4-D, clopyralid and PCP were detected, along with total petroleum hydrocarbon (TPH), PAH and copper chromium arsenate (CCA).

Other wastes recorded on Site B include oil pits and a broad area of buried asbestos predominantly in a white fibre form located within the northeastern portion of Site B. Phenolic waste pits are present in the southeast of the site are generally covered by 1-2 m of fill comprising a 0.5 m layer of ash and clinker overlying locally derived sands and silty sands. Waste thickness ranges from 1-2.5 m and the base of the pits at 2-4.5 m depth predominantly rest on a layer of natural soils overlying hard ignimbrite. A number of the deeper waste pits (mainly in the southern part of the area) sit directly on rock. High concentrations of CCA sludge were also encountered in the northwestern sector of the site. Septic wastes and minor PAHs were identified along the southwestern boundary of the site.

The nature and extent of contamination was comprehensively evaluated in each waste area, providing the basis for evaluating potential effects on the environment and development of the proposed capping option described below.

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GEOLOGY AND HYDROGEOLOGY

Geological and hydrogeological investigations comprised a review of previous investigations in the area, and the drilling, installation and sampling of 23 groundwater monitoring wells within the Marshall and, if present, the Whakamaru Ignimbrite aquifers in the area of Sites A and B. Seven wells, or well pairs (if the Whakamaru Ignimbrite was present), were drilled around the margins of Site B. A single well was drilled at Site A. Based on petrography and drill holes by IGNS 1993 and 1995, and subsequent investigations, the following is a summary of the stratigraphy of geological units encountered at Site B. These are, in order of increasing geological age and depth:

1. Ash, pumice and tephra deposits, including the Rotoehu and Oruanui ashes
2. Whakamaru Ignimbrite;
3. Marshall Ignimbrite; and
4. Uncorrelated pumice lapilli.

A series of staged investigations to characterise the Whakamaru ignimbrite surface in the area of the proposed landfill cell was undertaken to assess the underlying rock conditions in the area of the proposed containment cell, the Marshall ignimbrite on the western side of Site B, and exposure and mapping of the Whakamaru / Marshall contact. The investigations involved detailed collation of fracture patterns and conditions of the rock surface, and exposed rock surfaces were logged, with fracture strike, density, continuity and aperture measured.

Permeability testing in the Marshall Ignimbrite unit was undertaken and indicated that hydraulic conductivity values in the range 8.7 x 10^{-9}m/sec to 6.5 x 10^{-7}m/sec. This preliminary testing was followed by a constant rate-pumping test completed in the southern part of Site B. The constant discharge test was carried out at a rate of 300m^3/day for 5 days, followed by a recovery phase of 1 day in duration. Selected monitoring wells drilled by Tonkin & Taylor during investigation of Site B were used as observation bores, and results of the pumping test indicated a hydraulic conductivity of up to 1.5 x 10^{-4} m/sec for the Marshall Ignimbrite. A low permeability layer of pumice silt provides significant hydraulic separation between the Whakamaru Ignimbrite and the underlying Marshall aquifer.

A series of piezometric surveys indicate flow of groundwater away from Site B to the north, northwest and south. A north/south aligned depression in the Whakamaru piezometric surface extends from the eastern side of Site B towards the Sprinkler Quarry. This feature is associated with the depression in the upper surface of the underlying Marshall Ignimbrite. Groundwater hydraulic gradients of 0.04m/m in the Whakamaru aquifer slope towards the Sprinkler Quarry from Site B whereas gradients of 0.02m/m extend from the southern area of the site in south and southwesterly directions. Storage coefficient values indicate that the Marshall Ignimbrite aquifer ranges from confined, where there is a thick cover of Whakamaru Ignimbrite, to unconfined where the Marshall is exposed close to the surface. A site average storage coefficient of 0.003 was considered typical of most of Site B and the surrounding areas where Whakamaru Ignimbrite overlies the Marshall Ignimbrite.

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Geotechnical investigations at Site B comprised an assessment of the subsoil compressibility and the permeability of the linear surface geology. The nature of the contaminated material within the waste trenches precluded a conventional engineering assessment to evaluate consolidation characteristics, however the design approach takes account of the variable stiffness and weak nature of these materials. Boreholes were advanced around the site perimeter to sample the upper materials for the assessment of near-surface seepage characteristics. Results for laboratory permeability tests were in the range 1.4×10^{-6} m/s to 6.9×10^{-9} m/s, reflecting variability in these materials.

GROUNDWATER QUALITY

Groundwater Analysis Results

Four groundwater sampling rounds were completed in June, August and November 2002, and in July 2003 to characterise existing groundwater quality beneath and adjacent to Site B, and to assess whether adverse effects on groundwater quality had occurred as a result of the presence of the waste materials disposed at Site B. Laboratory analysis for a wide range of organic and inorganic compounds (including metals, cyanide, major cations and anions, VOCs, SVOCs, acidic herbicides, OCP and ONP and OPP were completed.

Results of these investigations indicated that in general, recorded contaminant levels in groundwater at Site B are either below the limit of detection or less than New Zealand Drinking water standards (NZDWS,2000) or ANZECC guideline values. Manganese, arsenic (GEB05 deep only) and chlordane (GEB02 shallow and deep, GEB05 shallow and deep, and GEB06) were the only chemicals found to exceed NZDWS guideline values at Site B. Other organic compounds detected at very low levels (but not exceeding relevant criteria) included hexazinone, and atrazine (GEB04 deep), clopyralid, picloram and minor VOCs. The low levels of these compounds generally reflect relative proximity to the forestry chemical disposal pits.

Groundwater sampling of the regional investigation bores indicated low or non-detect levels of contaminants, and samples from the shallow Whakamaru Ignimbrite aquifer showed very little contamination.

Lysimeter Sampling and Analysis Results

A lysimeter network comprising 11 lysimeters was installed on Site B to allow the collection and analysis of pore water samples at varying depths within the vadose zone.
Lysimeter sampling rounds completed in August and November 2002 indicate generally very low or non-detect concentrations of most contaminants reflecting the significant attenuation occurring in the soils underlying the waste materials. Compounds showing elevated concentrations have a similar profile to those detected in groundwater.

Lysimeter analysis results were also used to generate site-specific soil water distribution coefficient (K_d) values to represent contaminant leaching from the soil profile, and these values used in the subsequent contaminant fate and transport modelling (described below).

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CONTAMINANT MODELLING

Contaminant Fate and Transport

A conceptual hydrogeologic model was developed for Site B, based on detailed geological and hydrogeological investigations completed in the vicinity of Sites A and B. Fate and transport modelling was then undertaken using the RBCA risk assessment software to assess the potential for contaminant migration from Site B to down-gradient groundwater and surface water receptors. A Domenico 3-D groundwater solute transport model was used to calculate concentrations through time under steady state and transient groundwater flow conditions. The modelling was also undertaken to evaluate the cumulative effect of Sites A and B, the containment cell, and the Sprinkler Quarry.

Predicted contaminant concentrations in groundwater down gradient from Site B were evaluated in terms of a hypothetical abstraction well (point of exposure or POE well) located on the northern boundary of the CHH site, some 1,000 m north of Site B. The predicted contaminant levels in groundwater were compared to NZDWS (2000), and ANZECC aquatic ecosystem standards, and indicate that the emplacement of a low permeability capping over Site B should result in very low concentrations of the key contaminants observed in Site B soils leaching to underlying groundwater, and concentrations will reduce to very low levels down-gradient of Site B.

Containment Cell Failure Analysis

Risk assessment of potential cell failure scenarios releasing contaminants to the underlying groundwater system have been evaluated using a fault tree analysis, followed by implementation of the fate and transport model configured for the site. The potential leachate migration pathway in the event of a cell failure is likely to follow the northwest dipping surface of the Whakamaru Ignimbrite to the Whakamaru/Marshall contact. Leakage rates evaluated ranged from 0.078 m^3/day/ha to 2.21 m^3/day/ha.

Results of the cell failure analysis and contaminant fate and transport modelling indicate that the potential for adverse environmental effects on down-gradient groundwater and surface water resulting from the failure scenarios evaluated is likely to be very low or negligible. The model predictions are considered conservative and realistic due to the selection of the site-specific parameters and chemical factors.

An extensive network of monitoring wells and lysimeters will be maintained and a detailed monitoring programme is to be implemented to confirm that the potential for adverse effects on human health and the environment remains very low.

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ENGINEERING DESIGN AND SOLUTIONS

Shavings Stockpile -> Sprinkler Quarry

This stockpile of old shavings of treated timber has been part of the Kinleith landscape for 20-30 years. The shavings were initially stockpiled because they had been derived from treated timber and were thus considered unsuitable for burning in the boiler. Chemical analysis of samples of the shavings showed the following timber treatment chemicals:

Total Recoverable Treatment Chemicals in Shavings (mg/kg)

	Boron	Arsenic	Chromium	Copper	PCP
Mean	16.7	149	296	415	31.3
95% UCL	25.8	231	356	496	54.8

TCLP Concentrations of Treatment Chemicals in Shavings (g/m^3)

	Boron	Arsenic	Chromium	Copper	PCP
Mean	0.17	0.29	0.04	0.85	0.0032
95% UCL	0.26	0.49	0.05	1.24	0.0047

The total volume of shavings, as surveyed, is 224,000 m^3. An old ignimbrite quarry, known as the Sprinkler Quarry, located approximately 2 km from the stockpile was identified as a potential permanent repository for the shavings, the airspace volume of the quarry closely matching the volume of shavings. The base of the quarry covers an area of approximately 1.6 ha and it has a depth below the rim of about 10 metres. The quarry was being used as a log storage area.

Investigations showed that the quarry had been excavated into jointed Whakamaru ignimbrite, and that numerous cooling joints were exposed on the floor and walls. Joint widths up to 170 mm were observed with a typical opening of 40 mm, and some joints provided a direct connection to the underlying groundwater. Because if this jointing, and the direction of flow of the underlying groundwater, it was decided that a high quality liner system should be provided if the quarry was to be used for containing the shavings, even though the leachability of contaminants from the shavings was low.

The overall philosophy for containment of the shavings was thus:

- Mound the top of the fill and provide a low permeability cap to restrict the ingress of water to the shavings fill.
- Provide a low permeability liner to restrict the flow of leachate through the base of the quarry.
- Provide a leachate collection system, and discharge the collected leachate to the Kinleith wastewater treatment plant.

The soils in the general area of the site are ash soils, described as silt or sandy silt. A borrow site was identified on elevated ground adjacent to both the quarry and Site B.

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Construction trials of the ash soils from this site indicated that permeabilities of between 1 x 10^{-7} m/s and 1 x 10^{-8} m/s could be achieved. Laboratory testing showed that the permeability could be improved by 1 to 2 orders of magnitude by mixing the ash soils with bentonite powder, however very little improvement in permeability was achieved in field trials using bentonite enrichment.

A number of liner options were considered with various combinations of compacted ash, geosynthetic clay liner (GCL) and HDPE liner in association with different leachate drainage options. The liner option that ultimately met the objectives of providing a suitable level of containment at an acceptable cost comprised from bottom to top:

- 600 mm compacted ash with a permeability not exceeding 1 x 10^{-7} m/s.
- 1.5 mm HDPE liner
- 200 mm pea gravel liner protection layer and leachate collection layer.

Bridging over the joints in the ignimbrite will be achieved by ripping the rock surface and placing a geotextile beneath the ash liner. An ash liner will be constructed against the walls of the quarry. Because the walls are nearly vertical, analysis shows that there will be virtually no leakage through the side walls. A gravity pipeline will be provided to convey leachate to the main drain leading to the treatment plant. This will be drilled through the rock around the quarry.

Resource consents have now been obtained for this solution and construction commenced during October 2003.

Site B

Site B is a flat site with poor surface drainage to the extent that water ponds on areas of the site and around the site. There is poor vegetation cover over the site. Under these conditions there is practically no direct run-off of rain water from the site.

As described, the extensive investigation programme had defined the extent and characteristics of the wastes previously disposed of on the site. On the basis of this work, and due to potential health, safety and environmental risks, it was considered inappropriate to excavate this material for removal and/or treatment. The option of capping the site to reduce infiltration and thus control any future discharges of contaminants to groundwater was thus selected as the preferred management option.

The site covers an area of over 6 hectares, measuring approximately 200 m by 300 m. Significant earthworks would be required to form reasonable drainage grades to readily shed stormwater from the site. Given the characteristics of the locally available ash soils, it was not considered that sufficient improvement in the infiltration characteristics of the site could be readily achieved with a soil cap alone. Therefore, other options were sought to provide a more effective cap.

The investigation revealed that the worst of the contamination occurred along the north-eastern and south-eastern boundaries of the site, covering about 50 percent of the total site area. The option was put forward and eventually adopted that the more contaminated portion of the site would be capped with a membrane layer, and the balance of the site

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where there was either no waste, or relatively benign or sparse waste would be capped with a low permeability soil layer. Prior to placing the cap, the site would be contoured, using imported soils from the adjacent area, so that water would freely drain from the site. The membrane selected for the cap was 0.75 mm Linear Low Density Polyethylene (LLDPE) as meeting all the technical requirements for a cap on this site at a suitable cost. The design of the cap includes drainage layers and subsoil and topsoil layers placed over the membrane. In order to provide suitable drainage away from the site, the re-contouring work needs to extend well beyond the site boundary.

Due to the surface of the underlying ignimbrite sloping towards the site and the presence of higher permeability layers above the ignimbrite, there is concern that surface groundwater may flow beneath the capping layer and transport contaminants to the groundwater below. It is proposed that a cut-off wall be constructed around part of the site to mitigate against this.

Hazardous Waste Containment Cell

As well as the existing contamination of Site B, Carter Holt Harvey was responsible for a number of other contaminated materials for which a permanent solution was required. These included PCP contaminated soils and debris from various sawmills around the country, most of which was already held in store at Kinleith, and the material to be excavated from Site A. This material comprises a total volume of 10,400 m^3.

The project objective of addressing this legacy of historical contamination in one overall management solution led to consideration of how best these materials could be managed in association with the remediation of Site B. In parallel with this work, Carter Holt Harvey was also investigating other options for treating and disposing of some of these contaminated materials. However, initially at least, proposals were developed on the basis that all of these materials would need to be disposed of at their current level of contamination.

A proposal was developed to construct an appropriately engineered hazardous waste containment cell on Site B to effectively contain this material. An internationally recognised standard for hazardous waste containment is embodied in the requirements of USEPA Resource Conservation and Recovery Act (RCRA) Subtitle C legislation. The objective for the construction of a cell to Subtitle C requirements is to provide a robust, conservative containment cell design to effectively isolate the waste from the environment and to provide back-up and monitoring systems to deal with any potential leakage. The cell would comprise from bottom to top:

- A secondary composite liner comprising HDPE and a 900 mm compacted clay layer.
- A secondary leachate collection/detection system comprising a geonet.
- A primary liner comprising HDPE.
- A primary leachate collection system
- The contained waste.
- A capping layer incorporating a geomembrane.
- Passive gas venting through constructed vents at the surface.

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Due to the inability to compact the local ash soils to achieve a permeability as low as 1 x 10^{-9} m/s normally required for the compacted clay liner, it is currently proposed that this be replaced with a combination of GCL and soils compacted to 1 x 10^{-8} m/s.

It is proposed that the site beneath the cell be excavated down to the underlying ignimbrite surface (typically at about 2.5 metres depth), any jointing in the ignimbrite sealed with "dental" concrete and the cell liner constructed immediately on top of the rock surface. A clay cut-off wall would be constructed around the cell to minimise the potential for horizontal migration of any leakage from the cell. The proposed cell footprint covers approximately 4 500 m^2.

The location of the cell on the site was selected to meet the following criteria:

- Area to be free of historical contamination.
- Site to be located above the Whakamaru ignimbrite remote from the interface with the Marshall ignimbrite and the open jointing present at this location.
- If possible, the site to be clear of perched groundwater observed above the Whakamaru ignimbrite on the south-western boundary of Site B.
- Site to be located to the south of the underlying groundwater divide.

This led to the proposal to locate the cell just outside the fenceline of Site B at the southern corner of the site.

Resource consents have been sought for the elements of Site B and the containment cell.

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