16.0 Terrain and Soils

16.1 Introduction

This section:

- Describes the geology, geomorphology (landforms and their development processes) soils and land systems, in the Gove Area;
- Identifies and discusses historic, current and potential effects of Alcan Gove operations on these environmental elements; and
- Includes management commitments (controls) to minimise any historic or potential future impacts on these environmental elements as a result of the refinery expansion.

Alcan Gove has a management system that is certified to the ISO 14001 standard. It is designed to continually improve performance in environmental management. This includes a commitment to minimise potential impacts on the land and its soils. These potential impacts include soil contamination, erosion, and sedimentation. The management commitments made in this section of the report are repeated in the commitments listed in Section 25.

16.2 Geology

The geology of the Gove area has been mapped by AGSO (1997) at a map scale of 1:250,000. The geological regimes that occur within the area are shown in Figure 16.2.1. In chronological order (youngest to oldest) they comprise the following:

- Qa Alluvium in active channels, flood plains and swampy areas, comprising mainly gravel, sand and silt.
- Qb Black soil, older coastal alluvial deposits.
- Qc Active tidal and supra-tidal flats comprising sand, silt and clay, often shelly.
- Qr Cheniers and beach ridges – sand, shelly sand.
- Qd Coastal dune fields comprising sand and calcareous sand.
- Cz Undifferentiated Cainozoic deposits - Ferruginous cemented detritus, gravel, sand, silt and clay.
- Czl/Czb Cainozoic laterite, ferricrete / bauxite.
- Pxb Proterozoic, Melville Bay Metamorphics which form part of the Undivided Bradshaw Complex (Px) rock types include mainly greiss, granulite facies, maficgneiss intruded by medium-grained leucogranite.
- Pxd Proterozoic, Drimmie Head Granite mostly white medium to coarse-grained leucogranite and granitic gneiss, with abundant enclaves of granulite facies meta-sedimentary and mafic rocks.

16.3 Geomorphology, Land Systems and Land Units

16.3.1 Geomorphology

The geomorphology and land systems of the Melville Bay – Gove Region have been described by Lynch and Wilson (1998).

The geomorphology of an area characterises the relationship between landforms and the geological regimes and structures on which they have evolved, as a result of land forming processes including climate, changes in sea level, deep weathering processes and erosion.

Lynch and Wilson (1998) sub-divided the geomorphology of Arnhem Land into eight categories based on geology and associated landform, five of which occur within the general project area. These are:

- Coastal dune fields and sand plains;
- Coastal floodplains;
- Alluvial floodplains;
- Plains and rises, and low hills developed on granitic rocks; and
- Plains, rises and plateaux remnants associated with deep weathering.

The terrain types (land systems) that have been identified to occur within these broad geomorphic categories are shown in Table 16.3.1.

Table 16.3.1
Geomorphological Categories and Land Systems

Geomorphological Category	Land System
Coastal dunefields and sandplain	Dune (D), Blue Mud (Bm)
Coastal floodplains	Littoral (L), Pinwinkle (Pw)
Alluvial floodplains	Effington (Ef)
Plains, rises and low hills on granitic rocks	Currency (Cr), Giddy (Gi)
Plains, rises and plateaux remnants – associated with deep weathering	Gove (Go), Klatt (Kl)

16.3.2 Land Systems

The land system concept was originally defined by Christian and Stewart (1953) as an area within which there is a recurring pattern of topography (landforms), soil and vegetation.

The main characteristics of the land systems that occur within the project area are summarised in Table 16.3.2. The extent and distribution of the land systems are shown in Figure 16.3.1. The terrain components that collectively make up the recurring pattern that characterises each land system are termed “land units”. These are discussed in Section 16.3.3.

Table 16.3.2
Summary of Land System Descriptions in the Project Area

Land System	Symbol	Description
Blue Mud	Bm	Beach ridge plains and chenier plains; Orthic Tenosols and Shelly Rudosols; variable:- mid high open woodland (*Acacia auriculiformis, Acacia hemignosta, Melaleuca nervosa* and *Casuarina equisetifolia*)
Currency	Cr	Rolling to steep low hills and undulating rises on granite; Leptic Rudosols, some Red, Yellow and Brown Kandosols; mid high open woodland (*E. tetrodonta, E. tectifica, E. latifolia* and *Erythrophleum chlorostachys*)
Dune	D	Active relict dunes, beach ridges and coastal sand plains; Shelly and Arenic Rudosols; grasslands with smaller areas of *Casuarina equisetifolia* woodland
Effington	Ef	Level to gently undulating alluvial floodplains; Kandosolic, Tenosolic and Chromosolic Redoxic Hydrosols; mid high open woodland of *Melaleuca viridiflora* and *E. polycarpa*
Giddy	Gi	Gently undulating plains (associated with weathered granite); Orthic and Leptic Tenosols; mid high open to tall woodland of *E. tetrodonta* and *E. miniata*
Klatt	Kl	Small plateaux, scarps and some rises on deeply weathered Cretaceous sediments (Mullaman Beds); Leptic Rudosols; mid high to tall open woodland of *E. tetrodonta* with *E. bleeseri* and *E. miniata*
Littoral	L	Tidal mud flats and coastal floodplains with channels and estuaries; Supratidal and Intertidal Hydrosols; mostly bare areas with isolated clumps of *Melaleuca acacioides* and halophytic forbs, mangroves fringe the shoreline and tidal channels
Pinwinkle	Pw	Low swampy coastal floodplains and depressions; Aquic Vertosols; woodland of *Melaleuca nervosa* and *Melaleuca viridiflora.*

16.3.3 Land Units

The terrain within the project area has been assessed in terms of geological regimes, landform attributes and soil types. Terrain mapping has been carried our primarily from interpretation of aerial photographs with reference to existing geological, topographical and land system information together with field investigations and soil sampling, as a basis for characterising “land units”.

A land unit comprises a discrete recurring area of terrain that is considered to have a unique combination of physical attributes in terms of bedrock, surface slope and form, and soil/substrate conditions. Accordingly, engineering and environmental characteristics determined at representative sampling locations may be extrapolated to other occurrences of the same land unit that may occur elsewhere within the project area.

Descriptions of the land units characteristic of the land systems that occur within the project area including their geological, landform and soil characteristics, are given in Appendix F1. These land unit descriptions have been based on field observations and interpretation of the land unit data described by Lynch and Wilson (1998). The distribution of land units within the project area is shown in Figures 16.3.2 and 16.3.3.

16.4 Soils

16.4.1 Objectives

The objectives of the soils investigation were:

- To identify and map the soils of the project area.
- To characterise the soils in terms of:
  - susceptibility to and potential for erosion;
  - permeability and infiltration characteristics of the soils; and
  - physical and chemical characteristics and their potential for use for topsoil resources for rehabilitation purposes.
- To identify any environmental impacts on soils due to the proposed development/construction activities and to recommend appropriate management procedures to mitigate the perceived impacts.

Soil surveys have been undertaken previously in the general area as part of regional land systems and land resources studies and environmental and site investigation studies of refinery and residue disposal area. The main reference documents used in this assessment were Lynch and Wilson (1998) and GHD (1998).

16.4.2 Soil Survey

A soils survey was undertaken over a four day period using a backhoe for sampling in the refinery site area and by hand auger sampling in the residue disposal area and construction accommodation area.

A reconnaissance level survey was carried out to confirm the aerial photograph interpretation and mapping of the land units. There were 15 test pits / hand anger holes completed for soil characterisation purposes. These included:

- Five sites adjacent to the residue disposal area;
- Two sites at the construction accommodation area; and
- Eight sites at the refinery.

Site conditions were assessed for each sampling location and representative soil samples were collected for characterisation and indicative physical and chemical testing. The locations of the sampling sites are shown in Figures 16.4.1 and 16.4.2. Logs of the test pits / hand anger holes are included in Appendix F2.

16.4.3 Soil Types in the Project Area

The soils within the project area have been described and recorded according to the guidelines in the Australian Soil and Land Survey Handbook (McDonald *et al*, 1990). Soils have been classified in terms of Australian Great Soil Groups (Stace *et al*, 1968). They have also been classified in terms of Principal Profile Form (Northcote, 1979) and in accordance with Australian Soil classification (Isbell, 1996).

The dominant soil types that occur within the project area have been mapped on the basis of land systems/land units.

Six soil orders (Isbell, 1996) have been identified within the project area, the morphological characteristics and occurrence of which are given in Table 16.4.1.

Table 16.4.1
Summary Description of Soil Orders and Occurrence

Soil Order	Summary Description	Occurrence in Land Systems / Land Units *
Anthroposols	Man made soils. Soils formed by cut and/or fill operations.	In areas mapped as "DL"
Rudosols	Soils with little if any (rudimentary) pedological organisation; often gravelly with no colour changes apart from a dark organic A1 horizon.	D1-3, Ef3-4, L3, Bm1, Bm3, Cr1, Gi1, Kl1-2, Kl4
Tenosols	Soils with weak pedological development apart from a dark organic A1 horizon and a B2 horizon with <15% clay and no more than a weak grade of structure development.	Gi1-2, Ke1, Ke3 D4, Ef2, Ef5, Bml, Crl-2
Kandosols	Soils with well-developed B horizons which are massive or only weakly structured; B horizon texture exceeds heavy sandy loam.	Ef2, Ef5, Cr1-3, Gi2, Kl1, Kl3
Hydrosols	Soils that are saturated for a period up to several months in most years.	D4, Ef1, L1-2, Pw2, Bm2, Cr4, Gi3, Kl5
Vertosols	Structured clay soils that exhibit strong cracking when dry.	Pw1

**Refer to Figures 16.3.2 and 16.3.3*

The existing RDA is located within the Giddy Land System, primarily within terrain unit Gi1. The undisturbed areas adjacent to the ponds are near flat to very gently sloping lands with ferruginous gravelly sand to loamy soils (ferric orthic or leptic tenosols) underlain by extremely to highly weathered granitic bedrock.

The construction accommodation area also occurs within the Giddy Land System and the soils are similar to those in the undisturbed land at the RDA. They comprise gravelly clayey or loamy sand soils (ferric orthic or leptic tenosols) with up to 50% ferruginous and weathered (granitic) rock gravel underlain by extremely to highly weathered granitic rock. In places due to prior clearing and site leveling/earthworks activities, shallow surficial fill materials occur locally overlying the residual soil profile.

At the refinery extensive clearing and site leveling works including cutting and filling, have previously been carried out. As a result, the soils have been extensively modified and comprise a variable thickness (0.5 to 1.5 m+) of reworked and reconstituted fill material. In some areas, thin surficial layers of (calcined) bauxitic gravelly clay material occur which is both strongly alkaline (with pH levels of 10-12), and locally highly saline with EC levels varying from around 0.5 – 3.0 mS/cm.

These surficial bauxitic clayey fill materials are underlain either by reworked extremely to highly weathered granitic rock fill material which is in turn underlain by ferruginous gravelly and sandy residual soils, or locally by coastal sand deposits overlying the weathered granitic bedrock material. In terms of the Australian Soil Classification these soils are broadly classified as Spolic Anthroposols (man-made soils).

16.4.4 Soil Physical and Chemical Characterisation

Soil physical and chemical properties were assessed primarily to determine the potential erodibility of the soils and the quality and suitability of the soils for site rehabilitation requirements. Soil properties assessed included:

- Soil colour, texture, plasticity, structure and percentage and type of coarse fragments; and

- Soil pH (1:5 H_20), EC (salinity) and soil dispersion characteristics based on a test procedure adapted from Emerson and Seedsman (1981).

The results of the indicative testing are given in Appendix F3.

16.4.4.1 pH

In the RDA and the construction accommodation area, soil pH in general is near neutral to moderately acidic within the range pH 5.6 - 7.0.

At the refinery, a variety of surficial fill materials present have high to very high soil pH in a range pH 8.3 to 12. These surficial fill materials are underlain locally by:

- Coastal sand deposits, with pH ranging from pH 5.7 in highly organic sandy areas, to pH 8.8 - 9.1 in some calcareous sandy areas; or
- Residual soils / EW (granitic) rock with pH in a range of pH 6.0 – 8.8.

16.4.4.2 Electrical Conductivity (Salinity)

Electrical Conductivity (EC) (1:5H_20) determined for the natural in-situ (undisturbed) soil horizons indicated essentially non-saline conditions with EC levels mostly <0.10 mS/cm. Salinity of the reworked surficial fill materials at the refinery are highly variable with EC (1:5 H_20) varying between 0.25 – 2.94 mS/cm which corresponds with moderate to extremely high levels of salinity.

16.4.4.3 Dispersion Class

Based on the indicative dispersion testing carried out, with one exception, all of the samples exhibited only slight dispersion characteristics when remoulded in a saturated condition (Dispersion Classes 3(1), 3(2) or 5) or non-dispersive characteristics (Dispersion Class 6).

In general both the natural (undisturbed) soils and the fill materials exhibit a gravelly and predominantly sandy nature with low levels of dispersion. Given these characteristics, these soils should not be subject to piping and/or gully erosion, provided standard engineering methods are employed to mitigate erosion effects due to wind or from runoff following high intensity wet season rainfall events. However the silt/clayey fines content present in most soils tend to be slightly dispersive and may give rise to turbid runoff following heavy rainfall. Turbidity can be reduced by passing the runoff through settling ponds prior to discharge.

16.4.5 Soil Erosion

16.4.5.1 Erosion Potential

The lands of the northern tropical region are prone to erosion due to high intensity rainfall events during the summer period (wet season) and the inherent erodibility of some of the soil landscapes (land systems/land units). The susceptibility of a land unit to erosion requires an assessment of how the land will respond to disturbance, if it is changed from its natural state as a result of clearing and/or construction activities, whereby the land surface may be exposed more directly to surface water runoff or wind. Table 16.4.2 shows the combined interactions of landform (slope), soil type and susceptibility to runoff (r), flooding (f) and/or wind erosion (w) for the main land units and provides an indication of the existing status and the potential for erosion.

Table 16.4.2
Assessment of Erosion Potential in the Project Area

Land Systems/Land Unit(s)	Dominant Soil Type	Susceptibility to Erosion	Contributing Factors		
			Slope Runoff	Flooding Potential	Soil Characteristics
Bm1-3	TE, RU	M(w)	Undulating rises (2-5%)	Local tidal inundation	Loose sands
L1-2	HY	H(f)	Slopes >2%	Regular tidal inundation	Saline muds
Dune D1-2	RU	M(w)	Undulating rises (2-5%+)	Rarely inundated	Loose sands
Ef1	TE/HY	H(f)	Slopes >2%	Short to medium term	Poor drainage
Kl2-3	RU/TE	H(r)	Moderate to steep slopes >5%	Nil	May contain slightly dispersive fines
Cr1	RU	H(r)	Steep slopes >5%	Nil	Much rock outcrop
Gi1	TE	L-M(r)	Slopes (1-3%)	Rare	May contain slightly dispersive fines
Pw1	VE	H(f)	Slopes >2%	Periodic inundation	Poorly drained
DL	AN	M(w)	Near level slopes >2%	Low	Surface dust from non hard- stand areas

Notes:

Low	*L*	*Nil to low susceptibility to or incidence of erosion.*
Moderate	*M(f)*	*Moderate incidence and/or susceptibility due to flooding.*
	M(r)	*Moderate incidence and/or susceptibility due to slope, soil erodibility (including dispersion potential) and surface water runoff.*
	M(w)	*Moderate incidence and/or susceptibility due to wind action.*
High	*H(f)*	*High incidence and/or susceptibility due to flooding.*
	H(r)	*High incidence and/or susceptibility due to steepness of slopes, soil erodibility (including soil dispersion potential) and surface water runoff.*
	H(w)	*High incidence and/or susceptibility due to wind action.*

In general, the presence of and the potential for erosion at the refinery is low as the majority of the area consists of plant site structures or hard-stand area with very gentle slopes. The north-west corner of the refinery area (around the alumina silos and the calcining area) has the steepest slopes. Although there is no serious erosion in the that area at present, some measures have been taken to minimise erosion around cooling towers to the east of the alumina silos and future use of the area will include assessment of erosion control options.

In the residue disposal area, minor erosion of the external pond embankments has occurred locally and some sheet and gully erosion has occurred adjacent to some unsealed access tracks particularly on the approaches to some intermittent drainage lines. Any significant erosion events on the walls of the disposal area are followed up with the provision of vegetation cover and, if necessary, physical repair and re-contouring.

16.4.5.1 Erosion Management

Erosion control measures outlined below will be adopted to minimise any effects of erosion during the construction phase and to control sediment loss in runoff from disturbed areas following heavy rainfall events. They are based on the NT Government Conservation Commission (Applegate, 1983); Institute of Engineers Australia et al. (IEAust, 1996); and CALM, 1992). Where appropriate, these strategies will be implemented to reduce erosion and sediment loss from disturbed areas during the construction phase and during operation of the expanded refinery.

Infrastructure and Development Areas

Erosion on construction areas cannot be eliminated completely, but measures will be taken to minimise the impact by:

- Limiting the area disturbed, and clearing progressively and immediately prior to construction activities commencing;
- Safeguarding the surface layer by stripping and stockpiling useable topsoil prior to construction (if topsoil is present);
- Using temporary diversion mounds to control runoff within and divert water away from the construction site;
- Minimising the period that bare soil is left exposed to erosive forces;
- Using sediment traps and/or silt fences to minimise off-site effects of erosion;
- Provision of rapid vegetation cover, including, where required, erosion control matting; and
- Use of water and other dust suppression agents where required.

The control of erosion and sediment movement throughout the site will be necessary both during the construction stage and subsequently during the ongoing operations. Where access is required for temporary use only, disturbed areas will be lightly ripped, restored to a stable condition and revegetated as soon as practicable following the completion of construction. Particular attention will be paid to those areas that may contain dispersive soils.

Service Roads and Temporary Access Tracks

- Permanent service roads will be sealed, graded to a crown and provided with efficient surface drainage to prevent runoff eroding adjacent land. For temporary access tracks, low mounds angled across the track will be constructed where necessary to divert runoff (at a non-erosive velocity) into adjacent areas.
- Cut and fill batters associated with service tracks will be formed to a safe slope and stabilised by vegetation where practicable.
- Where table-drains need to be established, they will be constructed to a broad dish shape where practicable, and lined appropriately, to prevent erosion.
- All temporary construction tracks and associated disturbed areas will be ripped and planted when construction is completed. Where suitable topsoil is available, it will be retained for respreading on areas to be vegetated.

Pipelines

- Disturbance of topsoil and vegetation along pipeline easements will be limited to the minimum practicable.
- Where significant disturbance of the ground surface is necessary, topsoil will be removed from the area to be disturbed and stockpiled as work commences. Upon completion of work, the topsoil will be respread over any exposed subsoil areas and the areas of disturbance stabilised with vegetation.

- In areas where diversion channels and culverts are proposed to divert flow and control runoff, the outlets may be prone to erosion and require scour protection. This can be achieved by establishing vegetation growth or rock mulch at these outlets. The outlets will be formed to a broad dish shape to minimise the concentration of run-off. Rock armouring may be required at some outlets to dissipate the force of water and so reduce erosion.

Vegetation Clearing – General

- Disturbance of vegetation in construction areas will be limited to the minimum practicable.
- Wherever practicable, seed/root stock will be left in the ground and surface soil disturbance will be minimised.

16.5 Seismicity

16.5.1 Earthquake History

Several large distant earthquakes have been felt in the Gove area since European settlement, but there have been no large local events. The return period for large earthquakes in this area is much longer than the historical record, but this does not mean that a major local earthquake will not occur in the future.

There have been only a few moderate earthquakes in the Gove area since 1900. The seismicity of the Gove area over the past 38 years is characterised by a series of earthquakes without significant mainshock-aftershock sequences. The strongest earthquake to be felt in the area is about MMI 4 (Modified Mercalli Intensity)[1]. There have been many smaller earthquakes in the area, but there is no reason to suggest that a larger event will not occur in the future.

At Tennant Creek, about 900 km to the south, there was a major sequence of earthquakes in January 1988, but even the main shock was not reported in Gove.

Recent earthquake activity is well distributed throughout the region surrounding Gove. When plotted on a regional scale, earthquake activity appears to be almost randomly distributed. There is an apparent gap in seismicity in the area between Gove and Tennant Creek, but this is likely to be due to limited seismograph coverage.

The low density of seismographs in the area means that most earthquake depths are difficult to determine. Active faults cannot easily be delineated from the earthquake distribution.

16.5.2 Ground Motion Estimates

Estimates of ground motion due to earthquakes at Gove have been computed from the probabilities for earthquakes of all magnitudes up to the maximum credible magnitude and located anywhere in the area at depths from 2 to 20 kilometres (RMIT, 1998). Compared with other locations in Australia, the short-term ground motion ie. for a one- to- ten year return period) is well below average, while the long-term ground motion (ie. for a 1,000 to 10,000 year return period) is only a little below average.

RMIT (1998) has developed a tectonic model for the Gove area. It is a simplified estimation of the future distribution of earthquakes in the area that has been used to compute ground motion recurrence. This has enabled the generation of estimates of peak ground velocity and acceleration for a range of earthquake intensities for use in the design of facilities at Gove.

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[1] MMI zones extend from 1(not felt) to 12 (near total damage). Zone 4 exhibits vibration like a passing heavy truck.

Nearby moderate magnitude events will give high frequency ground motion with high peak accelerations, but with relatively few cycles of strong motion and therefore quite short duration. They are less likely to significantly affect large well-engineered structures with low natural frequencies, but will affect small and more rigid structures with higher natural frequencies.

On the basis of this work, RMIT has concluded the earthquake hazard in the Gove area is below the average for Australia.

16.5.3 Liquefaction

Seismic liquefaction may occur in saturated loose sandy and silty deposits as a result of pore water pressure increases following undrained loading during and after earthquake activity. The development of soil liquefaction in a given soil deposit is closely linked to the intensity and duration of seismic shaking, the relative density of the soil, the soil particle size distribution, and the location of the water table.

The test pits across the site predominantly encountered soil types unlikely to be subject to liquefaction due to their clay, silt or gravel content. However, there were two test pits located toward the eastern end of the refinery that encountered potentially liquefiable discrete soil layers visually classified as loose, poorly graded sand. Groundwater was not encountered in any of the test pits and hence the potential for liquefaction is reduced.

Residue which is stored in the RDA typically includes predominant portions of clay (50% to 60%) and silt (30% to 40%) with a minor sand component (5% to 10%). Most of the residue sand is removed from the red mud and is stored separately prior to deposition within the RDA. Because the vast majority of the stored residue has a fine particle size in the clay/silt range rather than the more coarse sand range, the potential for liquefaction of the stored residue is low.

16.5.4 Design Standard

The seismic design standard for the refinery is Australian Standard AS 1170.4-1993 “Minimum Design Loads on Structures – Part 4: Earthquake Loads”. This Standard requires that the earthquake design for structures incorporates an assessment of all relevant factors including ground acceleration coefficients of the area, site factors, the importance or consequence of failure of the structure, and the structure type. The proposed expansion will comply with this standard.

The seismic acceleration coefficient map of the Northern Territory is used to obtain the ground acceleration factors. Site factors are based on data obtained from on-site geotechnical investigations. The importance of the structure is assessed on the basis of:

- How essential it is to post-earthquake recovery;
- How many people would be at risk if it failed; and
- The environmental consequences of structural failure.

16.6 Soil Contamination

16.6.1 Introduction

Historically, some contamination of soils, groundwater and marine sediments has occurred from Alcan Gove operations.

Alcan Gove is committed to excellence in environmental management through the implementation of EHS First (Alcan's Environment Health and Safety Policy). This implementation process is achieved through improvements in the environmental, health and safety systems, which include capital and operational improvements throughout the operation to address issues of land contamination.

All known areas of contaminated land on the site have been mapped. These include historic waste disposal sites and areas where process wastes has been temporarily stored or liquor has been spilled.

Alcan Gove has prepared a conceptual closure plan for the site as part of its Mining Management Plan that is approved annually by the Department of Business Industry and Resource Development. The closure plan defines closure criteria for all disturbed areas of the site. These criteria are discussed in Section 19.

16.6.2 Current Contaminated Areas

16.6.2.1 Mine

Past and current mine operations have been reviewed to identify those uses that could potentially result in ground contamination (Dames & Moore, 2000). Since that review, many improvements have been made including upgrades of all hydrocarbon and other chemical storage areas around the mine workshop and office area, and installation of a high quality oily water treatment facility incorporating a corrugated plate interceptor and dissolved air flotation unit. In addition, only inert wastes and tyres are now disposed at the mine site.

If any ground contamination is present, it would be associated with:

- Three closed landfills (3.5 ha) that have been soil capped and revegetated.
- One active landfill (1.0 ha). Records of waste streams indicate that disposed wastes currently include only dry inert waste such as scrap steel, timber, conveyor belts and tyres, therefore reducing the potential for ground contamination.

There is no record of groundwater contamination in the vicinity of the mine area or at the groundwater aquifer used for public water supply. However, further investigation of the above closed landfills at the mine will be carried out to determine whether soils outside of the landfill area are contaminated, or could become contaminated in the future. If contamination is identified, remediation measures will be implemented in accordance with the process outlined in Section 16.6.5.2.

16.6.2.2 Refinery

Harbour Tank Farm

The harbour tank farm stores fuel oil and caustic soda. There are nine large above-ground storage tanks, two of which are dedicated to caustic soda storage, with the remainder normally used for fuel oil storage. The above-ground storage tanks are bunded with compacted clay and capable of containing the contents of the largest tank.

There have not been any significant spills from any of the tanks that would have resulted in significant ground contamination outside the bunded area.

A soil investigation in the vicinity of Tank 13 (Dames & Moore, 2000) was undertaken in 1999 to investigate whether a small leak from the tank (prior to the implementation of a new non-destructive testing program) had contaminated the underlying soil. The results showed that some localised caustic soil impact beneath the tank and within about 2 m of the tank had occurred. There was no impact to the groundwater immediately down-gradient of the area.

Groundwater monitoring bores located in the vicinity show no caustic or hydrocarbon groundwater contamination.

Port Office and Hydrate Shed

The port office area contains an above-ground bunded sulfuric acid storage tank which is currently used as an emergency acid storage. The bund is capable of containing the contents of the tank and is lined with high density polyethylene which is covered with limestone-based crushed rock. There have been minor spills associated with transfers to Isotainers at the facility. Lime is used to neutralise and help clean up minor spills. There is no evidence of any long term ground contamination at or near this facility.

Light Fuel Tank Farm

The light fuel tank farm (LFTF) is a fuel storage area that comprises six large above-ground storage tanks and various associated fuel storage and dispensing facilities. Fuel types stored within the LFTF include diesel, petrol, Jet A1 and miscellaneous lubrication and transmission oils.

In 1996, groundwater contamination was detected at the LFTF and was identified to be a result of a diesel leak from a below-ground transfer line (Section 12.1.4.3). A groundwater recovery program was implemented and the site was remediated except for a small quantity of hydrocarbons remaining at the surface of the groundwater. Based on the visual examination of soil cores collected in these areas, there was no evidence that the ground contamination was present beyond 0.5 m depth.

Oily Water Treatment System

An oily water collection system services the main sources of oily waters generated at the refinery. The system comprises drains, sumps, pumps and pipework to convey the effluent to a large retention pond where the oil separates from the water. Oily water is skimmed from the surface of the pond and is treated in a corrugated plate interceptor. The recovered oil is temporarily stored and then filtered and fed into the pipeline carrying fuel oil to calcination where it is burnt.

The retention pond is clay lined. Groundwater monitoring in the vicinity of the pond indicates that hydrocarbon concentrations are below analytical levels and hence any ground contamination in the vicinity would be expected to be minimal.

Process Areas

The main process areas within the refinery where there is potential for ground contamination from spills or leaks are the following:

- Process Areas: Contamination of the ground with process liquors has occurred historically in locations where bunding and operational practices have not been effective in containing spills and cleaning activities. The main source of the contamination is from thickener descaling operations. These practices have recently been significantly reduced by using direct loading of trucks with scale waste in most instances. New technology to be adopted in the expanded refinery will further reduce the risk of soil contamination from the current operational equipment. There are numerous storage tanks for concentrated caustic soda and process liquors. One of these tanks suffered a sudden rupture in June 1999, resulting in the dispersion of concentrated caustic liquor over a significant area of the refinery. Much of the contaminated material was contained and recovered, but areas around the edge of foundations could not be completely cleaned. There is likely to be contaminated material remaining in these locations and possibly contributing to groundwater contamination under the refinery. In response to the tank failure, strict engineering controls have been put in place including upgraded tank inspection programs, modifications to tanks, and targeted emergency response plans.
- Steam Power Station: The steam power station uses fuel oil. Electrical power is also generated using diesel generators. The power station contains diesel and fuel oil in above-ground bunded storage tanks which comply with AS 1940:1993. There has been no oil-contaminated ground detected in this area.

16.6.2.3 Residue Disposal Area

As discussed in Section 3.6, the residue disposal area (RDA) contains the caustic residue from the refinery. The residue is contained within impoundments lined with compacted clay that provide a high level of protection against ground contamination. However, there are locations where some minor seepage has occurred. These areas are closely monitored, and where required, remedial measures are undertaken. Generally, the contamination level in the seepage is low compared to the contained material because the clay lining of the walls and floor of the containment structures adsorb contaminants from the waste water as it passes through. The potential for caustic contamination from the residue is discussed more fully in Section 12.2.

Other areas of potential soil contamination at the RDA are discussed below.

Refinery Wastes

Refinery wastes are currently disposed of within the existing RDA (Pond 4). These wastes include empty drums, scale, and other general industrial and chemical wastes. Hazardous wastes are managed separately to the non-hazardous wastes. Asbestos is buried in a specific disposal site at the RDA. All of these wastes will be encapsulated within the residue and will have minimal potential for ground contamination.

Residue Area Water Treatment Facility

The water treatment facility uses seawater to neutralise waste waters comprised of used process liquor, rainwater and some fresh water used for washing at the refinery. The neutralisation process produces a white precipitate which collects on the floor of the water treatment labyrinth, is removed and dried in an adjacent area. The ground under the water treatment facility and the drying beds for the precipitate have potential to contain contaminants (including metals and nutrients) from the precipitate. Prior to closure of this facility an investigation of contamination in the area will be undertaken and any necessary remediation measures implemented.

Industrial Waste and Scale Dump

Historically, industrial waste from the refinery and caustic scale were disposed at several dump sites located towards the western edge of the current RDA operating area. Some potential soil contaminants are likely to have been included in this waste. This and other historic waste disposal areas have been included in the site closure plan.

For those areas where the potential for off-lease contamination remains low, the areas will continue to be monitored. For areas that may be required for other purposes or that may have some potential for off-lease contamination, further investigation will be undertaken and remediation measures will be carried out if required.

Sewage Ponds

The sewage ponds immediately to the west of the RDA collect sewage from Wallaby Beach, Gunyangara, the Yacht Club and occasional sewage sludge from the refinery. The ground in the vicinity of the sewage ponds has the potential to contain contaminants including nutrients (nitrogen, phosphorus and ammonia products). A nearby groundwater bore indicates only marginally elevated levels of nutrients in the groundwater which suggests that significant ground contamination is not likely to have occurred.

Wallaby Beach Historic Waste Disposal site

The Wallaby Beach waste disposal site was historically used for the disposal of domestic waste and dry waste from the refinery (no caustic was reportedly dumped in this area). Given its relatively small size and the limited nature of wastes it contains, extensive ground contamination from this source is unlikely. However, this area will be evaluated and remediated if required as part of overall closure commitments.

16.6.2.4 Other Potentially Contaminated Areas

Taylor's Pond/ Northern Pond

The Taylor's Pond and Northern Pond area is a former bauxite residue and industrial waste disposal site which operated from the late 1970s through to 1991. The industrial waste deposited at Taylor's Pond includes the full range of industrial wastes generated at the refinery including scales extracted from process equipment. It is therefore likely that this site has potential to contaminate some of the surrounding soil. In addition to further groundwater investigations in this area (Section 12.2.6) the contamination of soils in the surrounding area will also be evaluated and remedial measures taken if required.

Historic Scale Disposal Areas

Two historical scale disposal sites (3 ha) are located on the southern side of Melville Bay Road to the east of the decommissioned Taylor's and Northern Ponds. Caustic contamination of the surrounding soil is likely. These areas will also be further investigated and any necessary remedial measures taken in a timeframe to be determined by the outcome of the investigations.

16.6.3 Site Contamination Standards

The Northern Territory Department of Infrastructure, Planning and Environment regulates site contamination in accordance with the *Waste Management and Pollution Control Act, 1998*. Pursuant to Section 19 of this Act, a draft document titled *A Northern Territory Proposal for the Preparation of a Draft Environment Protection (Site Contamination) Objective (EPO)* has been published for public comment and outlines procedures for the management of site contamination including:

- Identification and preliminary risk assessment - to identify contaminated sites;
- Site assessment guidelines – consistent with the NEPC (1999) *National Environment Protection (Assessment of Site Contamination) Measure (NEPM)*. The *NEPM* sets out the recommended process as a staged approach

and includes guidelines for the assessment of site contamination and directions about where and when each should be applied;

- Audit/verification – if the land could be a threat to human health or the environment due to possible contamination, the requirement for the land to be audited by an independent auditor whose expertise and competence have been confirmed by their appointment under a NT Government recognised Environmental (Contaminated Land) Auditors' scheme;
- Remediation or other forms of management of site contamination – guidelines for managing site contamination to eliminate the threat to human health or the environment for its current or intended land use.

Until the EPO has been finalised, the Northern Territory Department of Infrastructure, Planning and Environment uses the NEPM guidelines and relevant investigation levels. Requirements for remediation and site cleanup levels are determined on a site-specific basis.

16.6.4 Proposed Expansion and Potential Contamination Impacts

16.6.4.1 Mine

While the current mining rate will increase with the refinery expansion, no significant change in the mine plan is required to extract the increased tonnage. The existing mine procedures will continue and all mining will take place in accordance with existing approvals and within the existing mine lease. Some changes will be made to the crushing and screening area including system upgrades and modifications.

The mine infrastructure and landfill will support the expansion in their current form. No new wastes will be introduced and all existing waste management and disposal procedures will continue. Consequently no soil contamination impacts are envisaged at the mine as a result of the expansion.

As discussed in Section 16.6.2.1, Alcan Gove has committed to rectifying any ground contamination at the closed landfills at the mine site as well as developing management strategies for waste tyres.

16.6.4.2 Refinery

The main components of the refinery expansion and the associated projects that have the potential to influence ground contamination are discussed below.

Ferrosilt Area

As discussed in Section 4.3.4, new high-rate decanters will be used for residue separation in the expanded refinery. As part of the expansion project, the existing multi-stage thickeners that are currently used for residue separation will be converted to become additional washers. This will eliminate thickener de-scaling in the area occupied by the existing thickeners. In this way the risk of ground contamination will be substantially reduced.

Fuel Usage

The existing bunded fuel storage facilites will continue to be used and no additional storage is required for the expansion. While the refinery remains oil-fired, throughput will increase. Once gas supply is secured, fuel oil consumption and the risk of potential soil contamination will reduce significantly.

Containment and Bunding

As discussed in Section 11.3.1.3, the refinery will install effective bunding and containment for the expansion component and will progressively improve the bunding and containment for existing facilities. In this way any spilt material will remain on an impervious surface and ground contamination will be avoided.

16.6.4.3 Construction Activities

The refinery areas to be affected by new plant and equipment are shown on Figure 4.4.1. They will require ground excavation as part of the construction activities. Some of these areas have been identified as potentially contaminated, and will require appropriate management strategies to minimise environmental impact associated with their disposal.

Prior to construction commencing, these areas will be subject to a site contamination assessment as outlined in Section 16.6.5 and appropriate remediation strategies will be implemented.

16.6.4.4 Residue Disposal Area

The expansion project covered by this EIS does not require any new equipment to be installed at the RDA to manage residue disposal. No additional ground contamination impacts at the RDA are likely to occur as a direct consequence of the expansion. The proposed small infill area between Ponds 5 and 6 will be addressed when required as part of the Mining Management Plan reporting process. This area will be covered with residue and will eventually be revegetated in the same way as the rest of the existing residue disposal ponds.

Most of the other areas of potential ground contamination in the vicinity of the RDA are from historical activities and will not be affected by the expansion. Alcan Gove has committed to investigating and remediating any ground contamination in these areas as discussed in Section 16.6.5.2.

16.6.5 Contamination Management

16.6.5.1 Construction Activities

Investigations of the extent of contaminated soils in the areas to be excavated for the construction of new plant at the refinery will be carried out prior to completion of detailed engineering design. Excavated ground that is identified by these investigations to be contaminated will be managed in a manner that does not pose an unacceptable risk to human health or the environment. Alcan Gove will remediate ground contamination wherever practicable in the short term and commits to total clean-up at eventual closure.

Potentially contaminated ground exposed during excavation will be handled so as to minimse the environmental risk. Where appropriate during excavations, bunding will be used to minimise any potentially contaminated runoff that may be generated during the wet season.

All works will be conducted in general accordance with NEPC (1999) Schedule B (9) *Guideline on Protection of Health and the Environment During the Assessment of Site Contamination* which includes the preparation and implementation of a site specific plan having the following general components:

- Scope of work;
- Relevant legislation, guidelines and standards;
- Key personnel, their roles and responsibilities;

- Site security, classification and personal protective equipment;
- Physical and chemical hazards and environmental risks;
- Earthworks (including location of site services or utilities);
- Risks associated with each operation;
- Training requirements before commencement of work;
- Manual handling;
- Management of plant and equipment on the site, including traffic management;
- Replacement requirements for mandatory use and replacement of personal protective equipment;
- Calibration of monitoring equipment;
- Any site-specific exposure monitoring or medical surveillance required;
- Heat stress monitoring, where applicable;
- Actions to be taken to mitigate existing hazards;
- Decontamination procedures;
- Waste disposal procedures;
- Relevant standard operating procedures;
- Location of nearest wash station and medical centre;
- A contingency plan for emergencies; and
- Emergency evacuation procedures.

16.6.5.2 Expanded Operation

Numerous preventative measures are in place to minimise the risk of land and groundwater contamination occurring. These measures have been progressively implemented and improved over recent years as part of the operation's environmental health and management systems. These measures will be implemented and improved for the expanded operation.

These risk reduction measures currently in place have several layers of protection to prevent contamination of the surrounding environment. They have an emphasis on incident prevention, bunding, and emergency procedures and include the following:

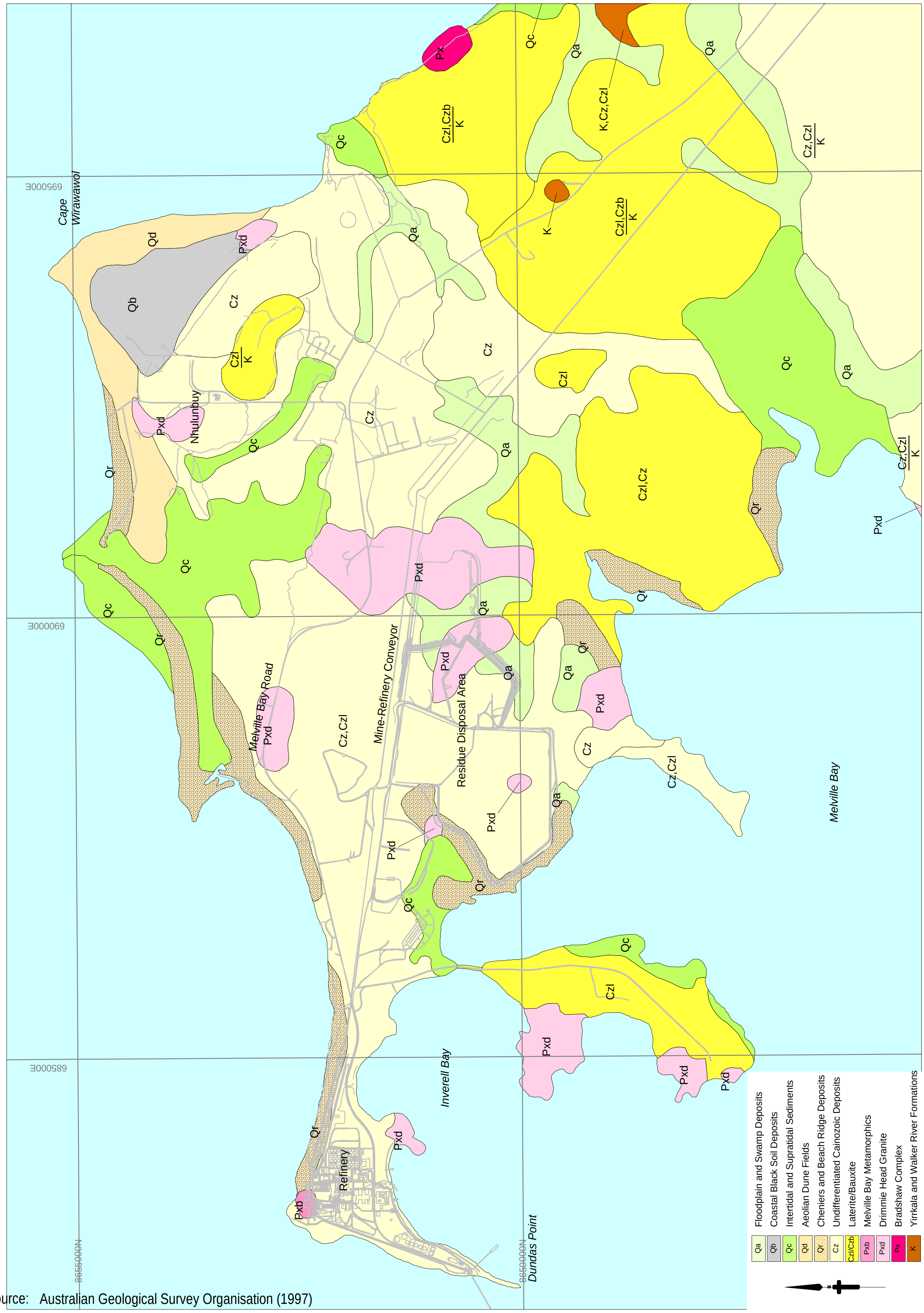
- Tank design to best practice engineering standards;
- HAZOP and CHAZOP design review process;
- Process controls;
- Critical alarms, operator supervision and manual process shutdown;
- Automatic emergency shutdown (plant trips);
- Regular non-destructive testing and inspections;
- Compliance with Australian Standards for the storage and handling of corrosive liquids and flammable and combustible liquids;

- Slab design;
- Emergency response.

In accordance with Alcan Gove policy on soil contamination, where there is reasonable belief that an area may present a risk to the environment, a phased assessment will be undertaken. The general approach to this work would include the following activities as appropriate:

- Phase I – Contamination Audit. A records search, site reconnaissance, and risk appraisal to determine the relative characteristics of the area and the potential likelihood and consequence of ground contamination.
- Phase II - Ground Investigation and Risk Assessment. If the Phase 1 audit determines intrusive investigations are required, then this phase of work would include drilling and/or sampling to define the nature and the vertical/lateral extent of the contamination. Following the definition of the ground contamination, an assessment of the likely impacts/risks to human health and the environment would be undertaken to determine the requirements for remediation.
- Phase III – Remediation. If the Phase II investigation determines ground remediation is required, then applicable ground remediation measures would be employed to ensure that there is no unacceptable risk to human health or the environment.

Other areas of potential ground contamination that are still being used for operational purposes will be investigated and, if necessary, remediated at site closure.



Source: Australian Geological Survey Organisation (1997)

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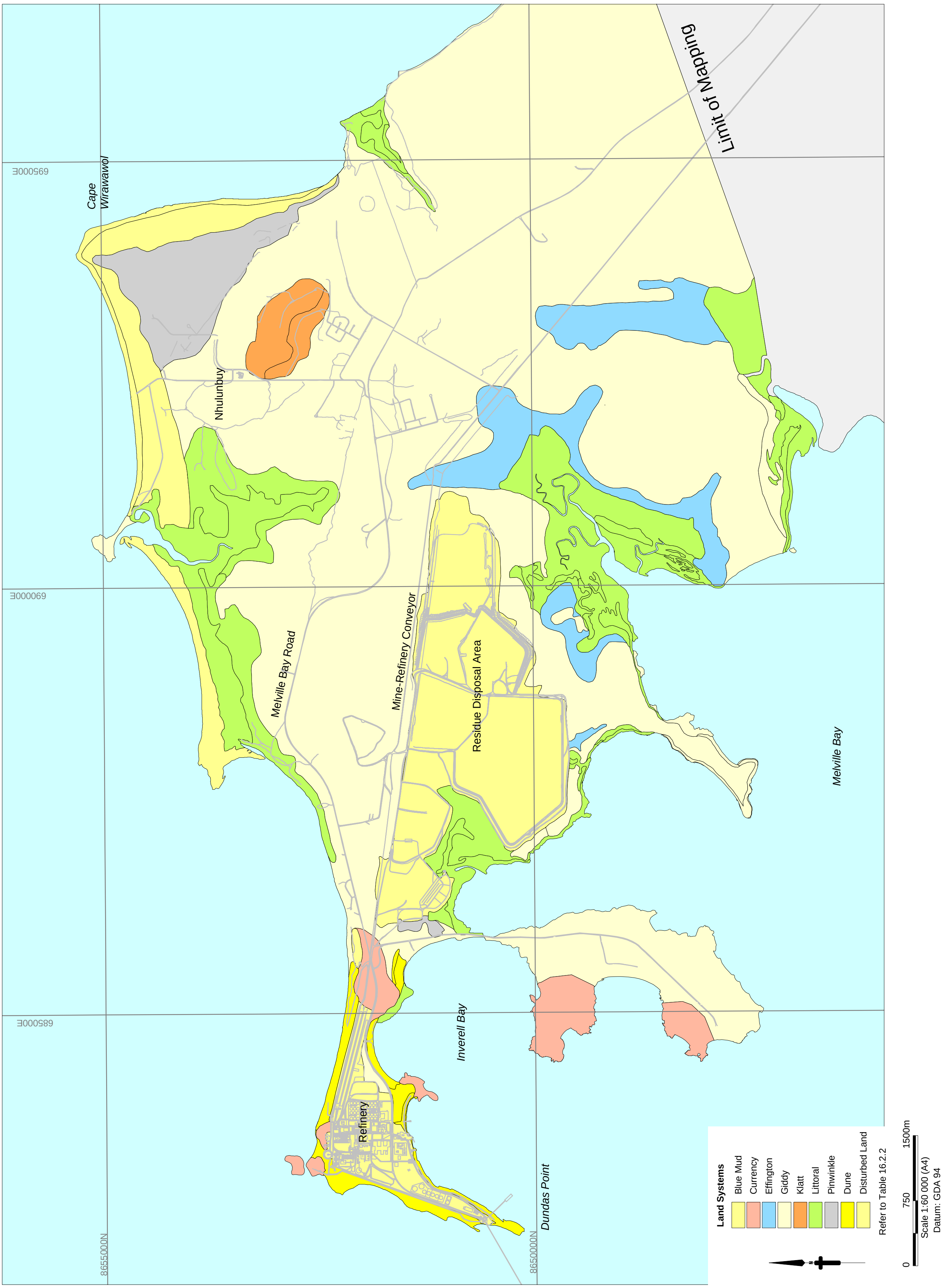
REGIONAL GEOLOGY

Project No.	12373-021-559	Date :	29-01-04
MapInfo File No.	12373-021-g-030d.wor	Revision: D	A4

Figure: **16.2.1**



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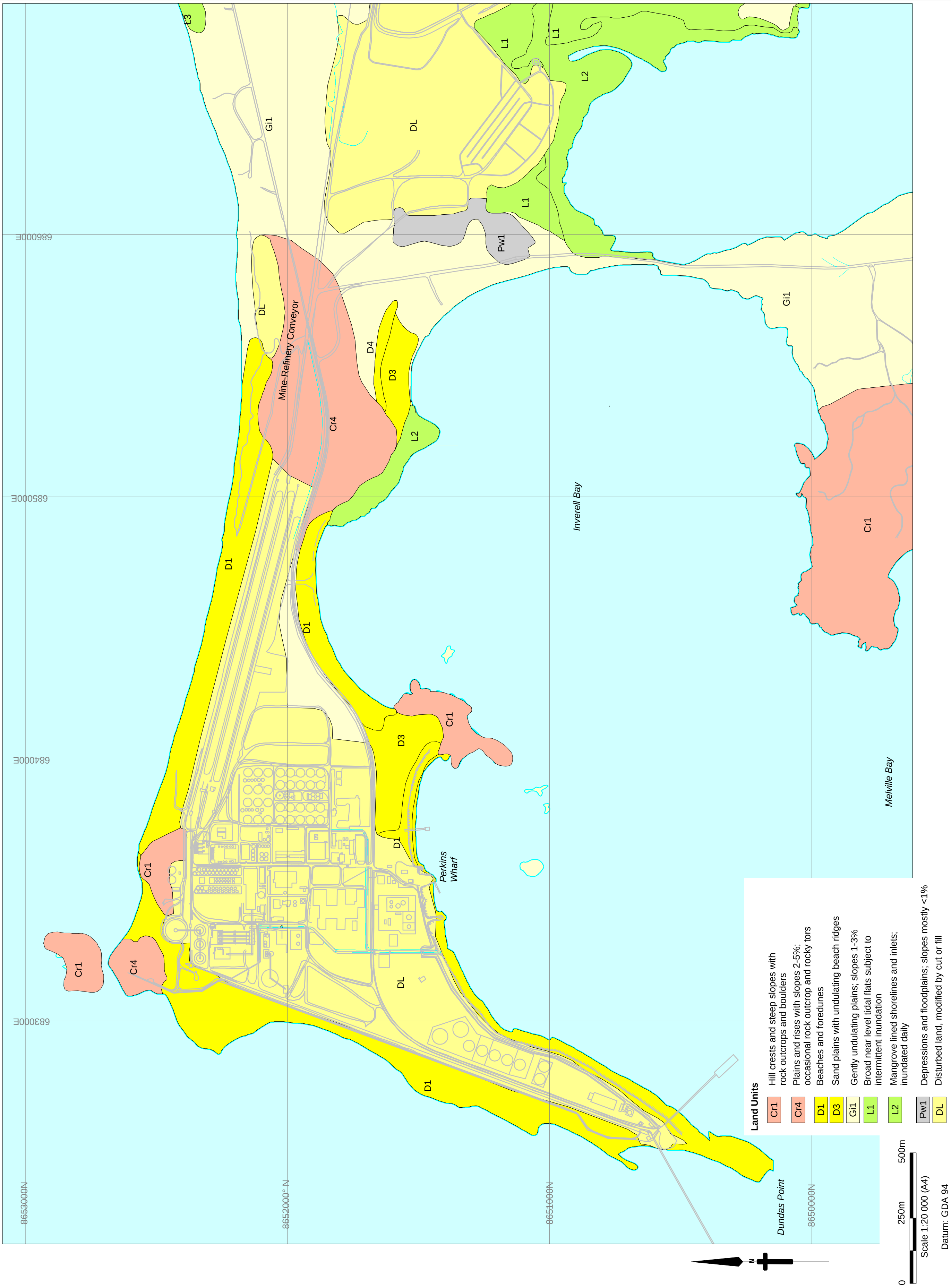
ENVIRONMENTAL IMAPCT STUDY

LAND SYSTEMS

Project No.	12373-021-559	Date :	29-01-04
MapInfo File No.	12373-021-g-029d.wor	Revision: D	A4

Figure: **16.3.1**



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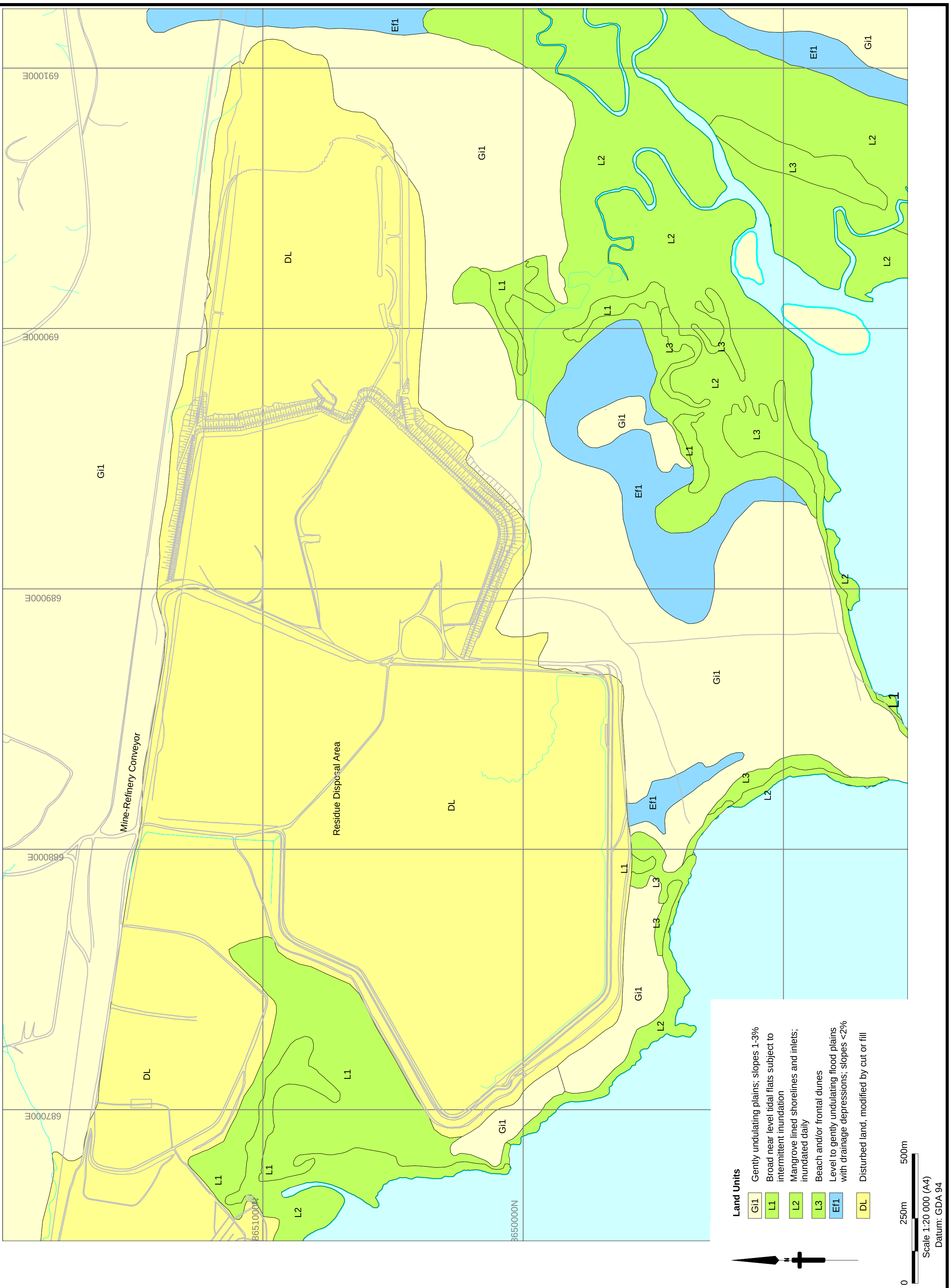
ALCAN GOVE REFINERY EXPANSION
ENVIRONMENTAL IMAPCT STUDY

LAND UNITS
REFINERY

Project No.	12373-021-559	Date :	15-12-03	
MapInfo File No.	12373-021-g-028d.wor	Revision:	C	A4

Figure: **16.3.2**



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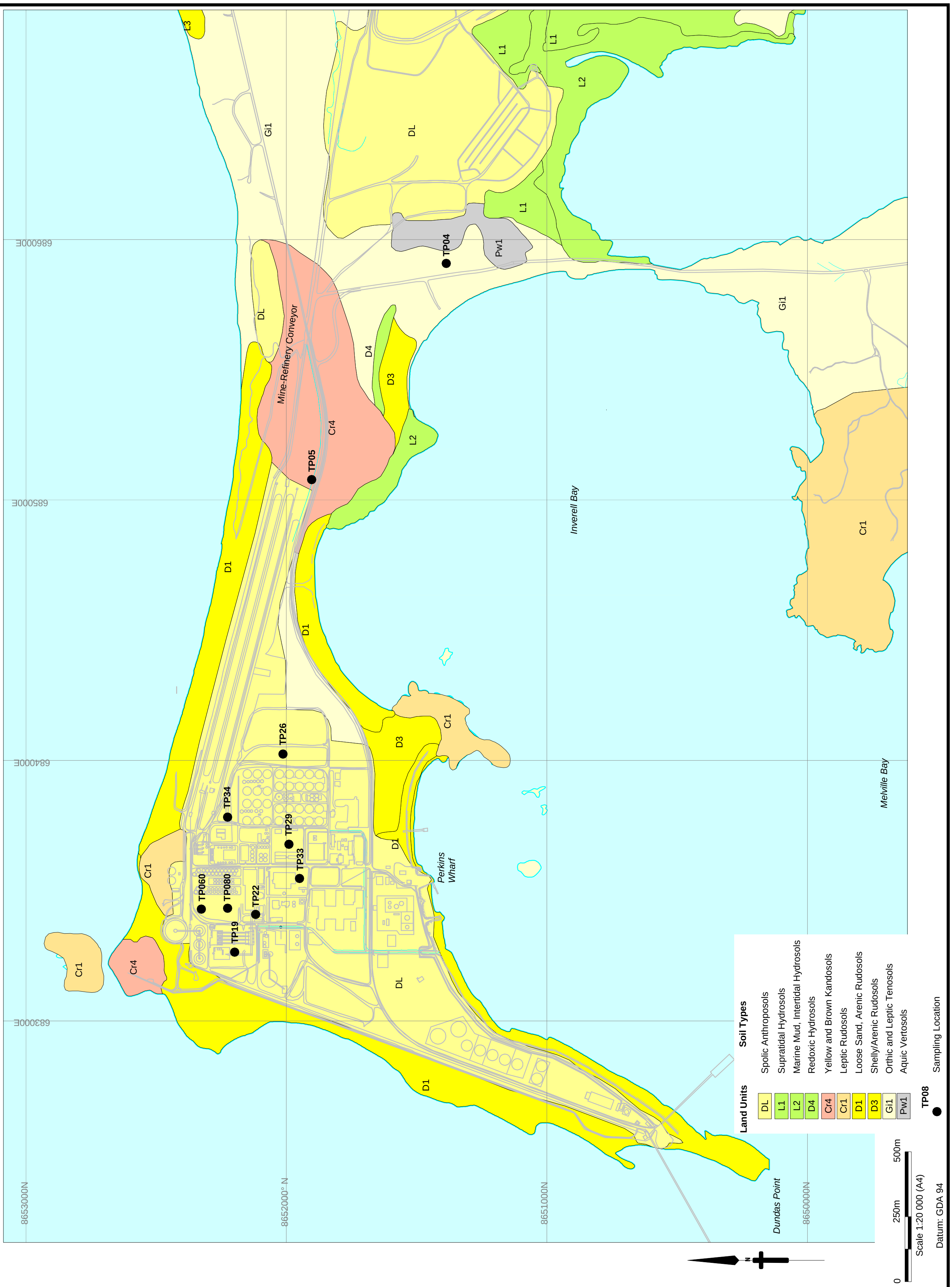
ALCAN GOVE REFINERY EXPANSION
ENVIRONMENTAL IMAPCT STUDY

LAND UNITS
RESIDUE DISPOSAL AREA

Project No.	12373-021-559	Date : 29-01-04		
MapInfo File No.	12373-021-g-028d.wor	Revision: D	A4	

Figure: **16.3.3**



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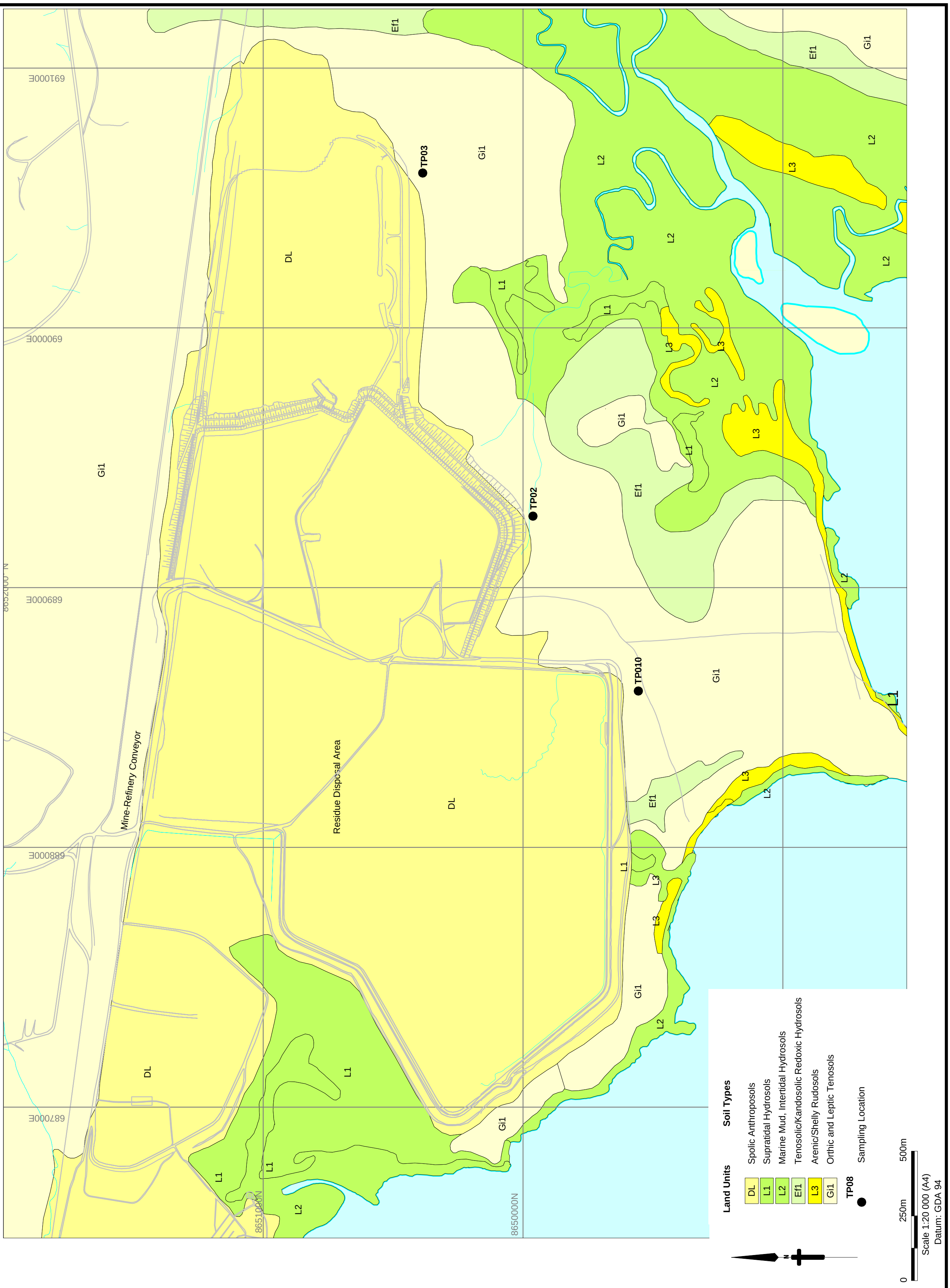
SOIL TYPES REFINERY

Project No.	12373-021-559	Date : 19-11-03	
MapInfo File No.	12373-021-g-038b.wor	Revision: B	A4

Figure: **16.4.1**



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ENVIRONMENTAL IMAPCT STUDY

SOIL TYPES
RESIDUE DISPOSAL AREA

Project No.	12373-021-559	Date : 29-01-04		
MapInfo File No.	12373-021-g-038c.wor	Revision: C	A4	

Figure: **16.4.2**