Marsden Point Refinery: **A Resource Consent Application to Renew 20 Resource Consents from the Northland Regional Council**

Prepared for: **ChanceryGreen on behalf of The New Zealand Refining Company Limited, trading as 'Refining NZ'**

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Refining NZ: Re-consenting Project

ALTERNATIVES ASSESSMENT

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Executive Summary

Refining NZ operates the Marsden Point Oil Refinery under a number of resource consents. Refining NZ is moving to 'reconsent' the Oil Refinery.

This report has been prepared to support Refining NZ's resource consent applications. This report outlines conclusions drawn from an alternatives assessment necessitated as per clause 6 of the Fourth Schedule, and section 105 of the Resource Management Act 1991 ('**RMA**'). Various experts were engaged to perform high level optioneering on possible alternative methods of discharge of emissions (air, sea and land). While not required by the RMA, this report also assesses alternatives in relation to groundwater extraction and coastal structures. Expert reports regarding alternatives are included as appendices to this report. As a result of this analysis it is considered that the applications for the current discharges represent the best practicable option(s).

Discharge to air

Sulphur dioxide (SO_2) is the primary contaminant of interest with respect to Refining NZ's discharges to air. The only feasible means of reducing sulphur dioxide emissions is to reduce the sulphur in fuels burnt on site. This would result in a significant increase in operational costs and/or significant refining margin destruction. Installation of a sulphur dioxide scrubber to treat furnace flue gas is considered prohibitively expensive, at a cost of around US$150 m (+50%/-20%) with a lead time of around 3 years. The environmental effects associated with this discharge do not warrant this level of investment.

Discharge to water

Discharge to water is the preferred method of effluent disposal with a lower material impact on the surrounding environment compared to the alternative, land irrigation. The resource consent application requirements and the new infrastructure required to construct land irrigation on- or off-site mean that discharges to land are not the best practicable options. Both on and off-site options are capital intensive and also may result in negative environmental impacts with implications on the site groundwater behaviour and quality, as well as reduced recovery rates of free phase hydrocarbons from the groundwater table. Again, the projected actual and potential adverse effects of the proposed discharge to water are less than minor, such that investment in alternative discharge locations is not warranted.

Discharge to land

Ongoing maintenance work on the site drain and tankage systems in conjunction with operation of hydrocarbon recovery wells on site has resulted in reduction of the hydrocarbon plume (underneath the site) and improved performance of drains during heavy rain weather events. Refurbishing the entire site's drain systems such that hydrocarbon leaks are completely eliminated is neither possible nor the best practicable option. This is primarily due to some sections running beneath existing plant, requiring plant demolition for safe access to upgrade and repair these lines. Even if all drains on site were to be upgraded and/or repaired, some leakages would still occur. Again, the actual and potential effects of the discharge are expected to be negligible, which makes further investment in enhancements or replacements to the system, beyond those already proposed, unnecessary.

Groundwater Extraction

Various methods to avoid migration of contaminated water and oil over the site boundary to replace Refining NZ's current pumping and treating methodology were investigated. Based on existing performance data of Refining NZ's groundwater extraction system and the resulting groundwater depression, this was determined as the best practicable option for application on site at Refining NZ. No adverse effects are anticipated as a consequence of this abstraction – rather, the pumping results in a net environmental benefit. Costs of installing additional treatment facilities as an add-on to this system outweigh any environmental benefits.

Marine Structures

Operation of the refinery without any jetty facilities is neither realistic nor practicable. Similarly, a reduction in the number of available berths is not practicable as it would place severe constraints on the refinery operation and impact the refinery's viability. The adverse effects associated with continued existence, operation and maintenance of the jetty facilities are generally considered less than minor with the exception of cultural effects. Indeed, their existence provides additional habitat for marine organisms and avifauna, which is thought to represent a beneficial effect. From a cultural perspective these structures were considered to have a moderate to high effect, however removal of the structures is not fiscally practicable and so alternative measures may need to be considered to mitigate/offset these cultural effects.

Contents

List of Tables and Figures

1.0 Introduction

Refining NZ owns and operates an oil refinery at Marsden Point. The Refinery sits on a 119 hectare site that is located at the southern headland of the entrance to the Whangarei Harbour. The plant was commissioned in 1964 and is New Zealand's only oil refinery. It operates 24 hours a day, seven days a week, 365 days a year processing a wide range of crude oil varieties to produce premium and regular petrol, diesel, jet fuel, fuel oil, roading bitumen and sulphur.

The Refinery has a crude oil capacity of 135,000 barrels per day, and is the leading supplier of refined petroleum products to the New Zealand market, producing for our nation around:

- 85% of jet fuel
- 67% of diesel
- 58% of all petrol
- 75% - 85% of bitumen for roading
- 100% of fuel oil for ships

Refining NZ also owns and operates the Refinery to Auckland Pipeline ('**RAP**'), a 170km long high-pressure pipeline running from the Refinery at Marsden Point to the Wiri Oil Terminal in South Auckland. The Refinery Site and the RAP are nationally significant infrastructure resources. They are also identified as Regionally Significant Infrastructure in the Operative Northland Regional Policy Statement. Their uninterrupted and efficient operation is of critical importance nationally. Refining NZ is deemed to be a "lifeline utility" under the Civil Defence Emergency Management Act 2002.

Refining NZ's operations take place on land and in the coastal marine area. The area has important ecological, cultural, and recreational values (among other values). The land at Marsden Point is dominated by industrial and manufacturing land uses, including Northport and the Carter Holt LVL (laminated wood products) facility. The wider surrounding area is predominantly rural. The rural areas around the Refinery are primarily zoned for industrial use.

Refining NZ is a significant contributor to both the local and national economies, employing around 350 staff, with an extended team of approximately 250 local contractors (significantly more during plant maintenance turnarounds). Discharges to air, sea and land as well as operationally flexible jetty arrangements are an essential part of Refining NZ's operations.

Refining NZ is conscious of its responsibility to minimise the impact of its operations on the surrounding environment and is continually aspiring to lift its environmental performance. To achieve this, Refining NZ is ISO 14001 Environmental Management Systems accredited and as such employs both facilities and management processes to minimise the impact of its activities. Refining NZ continues to deliver advances in environmental performance including reductions in sulphur per unit of fuel production as well as the carbon intensity of the refining operation. The Company also continues to invest in improving its environmental performance through projects to prevent hydrocarbons leaving the site. The Company has invested over $24 million over the past four years in order to maintain and improve environmental integrity of the site. The majority of this investment involved major clean-up of the site as well as strengthening of water treatment systems to ensure robust capability in managing heavy rain events and preventing hydrocarbon egress from site to the surrounding environment.

This document considers potential alternatives to the existing discharges to land, water and the air (and alternatives in relation to groundwater extraction and marine structures) and has been prepared in accordance with the requirements of clause 6 to the Fourth Schedule and section 105 of the RMA.

Clause 6(1)(d) of Schedule 4 to the RMA requires that an assessment of effects on the environment must include information on:

> *(d) if the activity includes the discharge of any contaminant, a description of—*
>
> > *(i) the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and*
> >
> > *(ii) any possible alternative methods of discharge, including discharge into any other receiving environment*

The requirement to have regard to alternative methods of discharge is also contained in section 105(1) of the RMA, which requires:

> *(1) If an application is for a discharge permit or coastal permit to do something that would contravene section 15 or section 15B, the consent authority must, in addition to the matters in section 104(1), have regard to—*
>
> > *(a) the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and*
> >
> > *(b) the applicant's reasons for the proposed choice; and*
> >
> > *(c) any possible alternative methods of discharge, including discharge into any other receiving environment.*

Pursuant to the RMA, a wider assessment of alternative locations or methods for undertaking an activity (i.e. for activities other than discharges of contaminants) is only required where it is likely that the activity will result in significant adverse effects on the environment.[1] That is not the case here: Refining NZ's independent experts confirm that none of the adverse effects associated with the proposal will be *significant.* However, for completeness (and while not required under the RMA) this report also considers alternatives relating to non-discharge activities associated with the proposal, including groundwater extraction and marine structures.

Also relevant to this report is section 104(2A) of the RMA, which requires the consent authority must have regard to the value of the investment of the existing consent holder (because the application is affected by section 124).

In accordance with the statutory requirements, Refining NZ's independent expert advisors have undertaken a thorough assessment of the nature of the discharges for which resource consent is sought, and the sensitivity of the receiving environment to adverse effects. The assessments of those various expert advisors have been considered, and where appropriate referenced in this report. Against the context of that expert assessment of the scale and degree of effects, this report:

- provides some background to the current discharges (and groundwater extraction and marine structures), including any upgrades to infrastructure and/or processes and the level of investment in that infrastructure over time,
- explains the reasons for the choice of discharge (and groundwater extraction and marine structures),
- describes any possible alternative methods of discharge, including discharge to any other receiving environment (and possible alternatives to groundwater takes and marine structures).

[1] Clause 6(1) of Schedule 4 to the RMA.

To assist the discussion of possible alternative methods of discharge, guidance is contained in both the operative and proposed regional plans. Those plans provide that when considering resource consent applications for discharges to air[2] and water,[3] consideration of the best practicable option is of relevance. A definition of "best practicable option" is contained in section 2 of the RMA. That provides:

> ***best practicable option****, in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to—*
> *(a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and*
> *(b) the financial implications, and the effects on the environment, of that option when compared with other options; and*
> *(c) the current state of technical knowledge and the likelihood that the option can be successfully applied*

The approach adopted by Refining NZ is therefore to consider for each type of discharge for which resource consent is being sought whether there are adverse effects on the environment which require prevention or minimisation; and if so, what options are available and the effectiveness of each, having specific regard to the level of effects and sensitivity of the receiving environment, financial implications, technical limitations, and likelihood of successful application. Where they exist, suitable alternative technologies that might aid in achieving a reduction or elimination of adverse effects have been identified.

Expert reports regarding alternatives are included as appendices to this report.

Qualifications and Experience

Jane Thomson has a B.E.(Hons) in Chemical and Process Engineering from the University of Canterbury. She has 10 years' experience at Refining NZ in which she has held numerous and diverse roles. Jane therefore has a very extensive, broad and unique knowledge of the Refining NZ business.

Jane began her career at Refining NZ as a Process Engineer in January 2010. In that role for around three and a half years, Jane's responsibilities included:

- Having an intimate knowledge of the Refining NZ operating plant, its component integration and its intricacies. This knowledge was used as a baseline for providing advice and direction around plant optimisation, troubleshooting, and identifying areas for process improvement.
- Planning and providing support during plant turnarounds, specifically for the process units that remove sulphur from kerosene and gasoil to make jet fuel and diesel.
- Acting as the process engineering focal point for the units that scrub and purify ammonia and hydrogen sulphide streams, as well as for the sulphur recovery and offgas treating units that convert hydrogen sulphide (H_2S) into elemental sulphur.
- Validation and maintenance of the sulphur dioxide (SO_2) emissions from site.

Jane then went on to spend two years as the Refining Scheduler within the Strategy and Supply Chain Department. Jane's major responsibility in this role was to plan crude oil rates and diet to optimise plant yield. This required intimate knowledge of different crudes' properties, intimate knowledge of

[2] Proposed Regional Plan for Northland at D.3.1; Operative Regional Air Quality Plan for Northland at 11.1.
[3] Proposed Regional Plan for Northland at D.4.2; Operative Regional Costal Plan for Northland at Policy 19.4.

the crude distillation units as well as secondary downstream units and their technical limitations. As Refining Scheduler, Jane was also responsible for instructions around fuels diet, SO_2 emissions and natural gas rate nominations.

From mid-2015 to 2018, Jane spent around three years in Operations as a Production Controller. The Production Controller role provides leadership and direction for operations staff on shift, presenting an overarching view of the entire production plant, tying together the separate processing units and tank farm. In that role Jane was responsible for ensuring operations are following the processing plan, (or determining why not), for formulation, issuing and releasing finished product tank blends, and for making decisions around furnaces and fuels, and with responsibility to ensure emissions do not exceed consented limits. The Production Controller is the most senior role on site at the refinery after hours, and in the event of an emergency, acts as the Incident Controller until the Incident Control Team is established.

Jane's current role is as a Business Development Manager. In this role, Jane is part of the Corporate Services Unit and provides support to all facets of the business based on her unique and detailed knowledge of plant, processes and component relationships.

2.0 Discharge to Air

2.1 Background/Current situation

Refining NZ is currently consented to discharge contaminants to air from all Refinery site activities (Main discharge to air: AUT.008319.02.02 – discharge to air). This is constituted by the following emissions:

- Furnace flue stack
- Flare stack
- Fugitive (accidental loss of light ends via tank, process losses and drain seals)

Refining NZ also holds a consent to discharge contaminants from spray abrasive blasting and spray painting activities on site, excluding the coastal marine area ('**CMA**') (Land based abrasive blasting discharge to air: AUT.008319.11.01 – discharge to air), as well as a consent to discharge contaminants to air from abrasive blasting of steel dolphins in the CMA (Dolphin abrasive blasting discharge to air: AUT.008319.08.01 – discharge to air). Refining NZ is not seeking to replace this latter consent.

The independent expert air quality assessment undertaken by Tonkin and Taylor in support of Refining NZ's reconsenting proposal[4] concludes that the ongoing discharges to air from the Refinery will have a less than minor effect on the environment with respect to the full range of airborne emissions, including from combustion, fugitive emissions, odour, and dust. The Cultural Effects Assessment (CEA)[5] by Patuharakeke noted that the effects of air discharges from a cultural perspective were considered to be minor due to flaring frequencies and effects. Tonkin and Taylor have taken this into consideration of their findings and associated recommendations. Tonkin and Taylor's report also concludes that the existing level/methods of mitigation associated with combustion discharges is appropriate and that no additional mitigation - beyond what is already implemented by Refining NZ - is required.

2.1.1 Main discharge to air

<u>Flue Gas</u>

A key part of various oil refining processes, Refining NZ operates furnaces which burn a combination of fuel gas, fuel oil and asphalt. Emissions from these furnaces are monitored and controlled in line with consented conditions and site imposed requirements. Any flues that could contain flue gas from liquid fuel firing (fuel oil, asphalt) are monitored for opacity (smokiness) in line with existing resource consent conditions, in addition to the total gas fired E Block stack. Continuous opacity metering and routine stack testing are performed on A Block, E Block and Multi-flue stacks (B Block, C Block and Utilities/B2).

Furnace flue gases are discharged to air through their associated stack. Refining NZ's current consent outlines guidelines and limitations on sulphur dioxide (SO_2) emissions reported in tonnes per day, as well as smoke appearance reported as 'opacity'. SO_2 emissions as a result of sulphur in fuels is reported as part of Refining NZ's current consent conditions. The refinery flare is also a source of smoke and/or SO_2 during upset situations.

Due to its very low sulphur content, burning fuel gas produces lower SO_2 emissions than the liquid alternatives of fuel oil and asphalt. Fuel gas is comprised of a mixture of natural gas (imported to site from Taranaki via the First Gas operated multi customer pipeline) and refinery gas (C3/C4 minus

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[4] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).

[5] *Patuharakeke Trust Board, Cultural Effects Assessment Report: Refining NZ Reconsenting*

hydrocarbons contained within the processed crude and small hydrocarbons produced as by-products of the oil refining process).

It is rare that sufficient fuel gas is available to fire 100% of refinery furnaces on fuel gas, therefore flexibility of fuel supply (asphalt, fuel oil and fuel gas) is necessary. Generally, most process furnaces are fired with gas only; with Boilers (F9101A/B/C) and/or Hydrocracker furnaces (F7501/2, F7601/2) being fired with a combination of gas only, dual firing (gas and asphalt) and liquid (asphalt or fuel oil) only. Flexibility of supply is required to combat operational constraints such as furnace bridgewall temperature limitations and is also necessary during winter months to avoid process unit and steam main upsets as a result of fluctuating fuel gas main pressure which can occur during wet weather conditions.

For process and personal safety reasons, a fraction of furnaces on site are only able to be 'started up' (initially lit) using fuel oil. Upgrading these burners and making the required furnace and control system modifications (such as installing flame eye safeguarding systems) requires significant expenditure, as well as introducing operational inflexibility and reduced refinery profitability (lower refining margin). Where it is shown to be practicable however Refining NZ does upgrade furnaces to gas only as evidenced by the 2013 furnace upgrade of F5501 at a capital cost in the order of NZ$ 1.7M.

Any new process units installed on site are generally designed with modern, gas only burners. An example of this was the CCR Platformer unit (Te Mahi Hou) commissioned in 2015.

Where practicable, Refining NZ endeavours to minimise liquid fuel firing and maximise natural gas. In 2017 Refining NZ worked with First Gas to implement additional compression at its Henderson natural gas compressor station, approximately doubling the available capacity of natural gas to Refining NZ. Despite this, availability of natural gas is not assured, and Refining NZ is on occasion exposed to field production outages or high natural gas cost during low production or high demand periods. This has resulted in Refining NZ burning greater quantities of liquid fuel during these periods. Figure A1 in Appendix A displays fuel consumption data from May 2017 until May 2019.

Further emissions to air as part of normal site activities are as follows:

<u>Hydrocarbons and toxic substances</u>

No hydrocarbons or toxic substances are directly vented to atmosphere during normal operation. Some odours may be present in the atmosphere during normal operation.

<u>Fugitive Emissions</u>

Tonkin and Taylor's air quality assessment report[6] discusses fugitive emissions and concludes that fugitive emissions from the refinery site have a less than minor effect at sensitive locations beyond the site boundary. Generally, the bulk of fugitive emissions from refineries is comprised of volatile organic compounds ('**VOC**') emitted from crude and product storage and transfer, as well as the process areas. The high level of control on VOC leaks from the Refinery's process area was noted in a status report by the then Department of Health's Regional Air Pollution Control Officer in 1991. This report commented on the Refinery's "very high degree of containment" of process emissions. It was noted that hydrocarbons, other odour-causing compounds and flame emissions occur only during emergency situations, from minor leaks, or during infrequent catalyst regeneration at certain processing units. Refining NZ has the following controls in place to keep fugitive emissions to a minimum:

- Storage tanks containing material with a vapour pressure (at actual temperature) above 0.1 barg, or which is odorous, are provided with floating roofs or other methods for restricting vapour loss. If above 0.8 barg, vapour recovery systems are required.

[6] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).

- Where practicable, wastewater separators (TPIs) are provided with fixed covers.
- Where practicable, double seals have been installed on pumps where seal leak or failure could lead to large flammable or toxic gas clouds.

Flue Gas effect Off Site

Stack plume SO_2 and other emission modelling has been carried out by Tonkin and Taylor.[7] In terms of combustion effects (including from SO_2 emissions) they conclude:[8]

> *When the predicted cumulative contaminant concentrations are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects of discharges on air quality are considered to be* ***less than minor****, including for the most impacted sensitive locations. This is with the exception of the predicted concentration of nickel (8-hour average) over Reotahi, which is considered further in the report by Environmental Medicine Limited. Based on the review by Environmental Medicine Limited, we consider that the potential adverse effects of nickel are less than minor.*

In addition, Wildlands 'Assessment of Ecological Effects for Air Discharges concluded that:[9]

> *Concentrations and deposition of pollutants in the air discharges are lower than the critical levels and critical loads at which detectable adverse ecological effects on terrestrial fauna and vegetation are predicted to occur within the receiving environment. We therefore do not expect that the air discharges will result in any detectable adverse effects for indigenous terrestrial ecosystems. The air discharge is probably the cause of some adverse effects for lichens within one kilometre of the discharge point at Marsden Point. However, this adverse effect is very localised, and restricted to modified habitats of low ecological value. The level of effect of the air discharge on habitats at Marsden Point is less than minor.*

2.2 Eliminate discharge to air

2.2.1 Sulphur Dioxide

Flue Gas

Firing furnaces is an essential part of the oil refining process. Therefore, eliminating any SO_2 emissions to air is not possible unless the refinery were to cease operating, or make major capital investment in technology such as flue gas scrubbing. Eliminating SO_2 emissions from the majority of furnace stacks is theoretically possible by implementing scrubbing technology. Depending on the technology employed, there are possible by-products which require disposal via means such as water, land or landfill leading to detrimental environmental implications and ongoing operational costs. Table 2.1 below summarises the feasibility of various scrubbing technologies for application on site at Refining NZ: Cansolv, Caustic and unspecified other. Each desulphurisation technology is ranked on a scale of 1 (best) to 3 (worst) in each category. This piece of work was carried out by Worley who have expertise in gas scrubbing at refineries as well as other industrial applications such as power stations and petrochemical plants. The full report containing Worley's comparative analysis and recommendations is available in Appendix A.

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[7] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).
[8] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000) [emphasis added].
[9] *Assessment of Ecological Effects for Air Discharges From the Marsden Point Oil Refinery*, Wildland Consultants Ltd (contract report number 4977a).

Table 2.1 - Feasibility Matrix SO_2 Scrubbing Technology

	Cansolv	Caustic	Other
Suitability of application in an oil refinery	1	1	3
Capex	3	1	2
Opex	1	2	3
Ease of operation	2	1	3
Environmental impact	1	2	3
Byproduct disposal	1	2	3
Reliability	2	1	3
Potential synergy	1	2	3
	12	12	23

Cansolv and Caustic scrubbing technologies are both recommended for application in an existing oil refinery, and - as shown in the above table - are similarly ranked in all categories with the exception of capital expenditure, in relation to which Cansolv is expected to be the more expensive.

Cansolv is a re-generable amine system which absorbs SO_2 from a flue gas stream. The amine is regenerated and the SO_2 rich stream sent to the sulphur recovery units for conversion to elemental sulphur. See Figure 2.1 over for simplified schematic of a Cansolv system for implementation on site.

Cansolv was selected for further investigation due to its re-generable nature and small environmental effect of byproduct disposal; SO_2 recovered by a Cansolv unit would be directed as feed to existing Sulphur Recovery Units ('**SRUs**'), and has the added benefit of debottlenecking SRUs by reducing their air demand. Shell Global Solutions were commissioned to provide a technical proposal for the installation of a Cansolv unit on site, which is included in Appendix A of this report as an addendum to Worley's technology comparison study. A design basis to treat flue gas from Utilities, B Block and C Block stacks was selected. Inclusion of A Block flue gas was not considered necessary as this block rarely fires liquid fuel and it is possible to balance the refinery fuel requirements using Utilities and C Block furnaces.

Estimated capital investment required to design, build and commission a Cansolv scrubber to treat flue gas streams from Refining NZ's B, C and Utilities stacks (multiflue stacks) is US$120m +50%/-20%, with a lead time of around 2.5 to 3.5 years. This level of capital investment in scrubbing technology is not considered justifiable. And as outlined above, Tonkin and Taylor's air quality assessment report concludes that adverse air quality effects from the refinery are less than minor and that the existing level/methods of mitigation associated with combustion discharges is appropriate and that no additional mitigation - beyond what is already implemented by Refining NZ - is required. [10] For all these reasons, significant investment in desulphurisation technology is not considered the best practicable option.

[10] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).

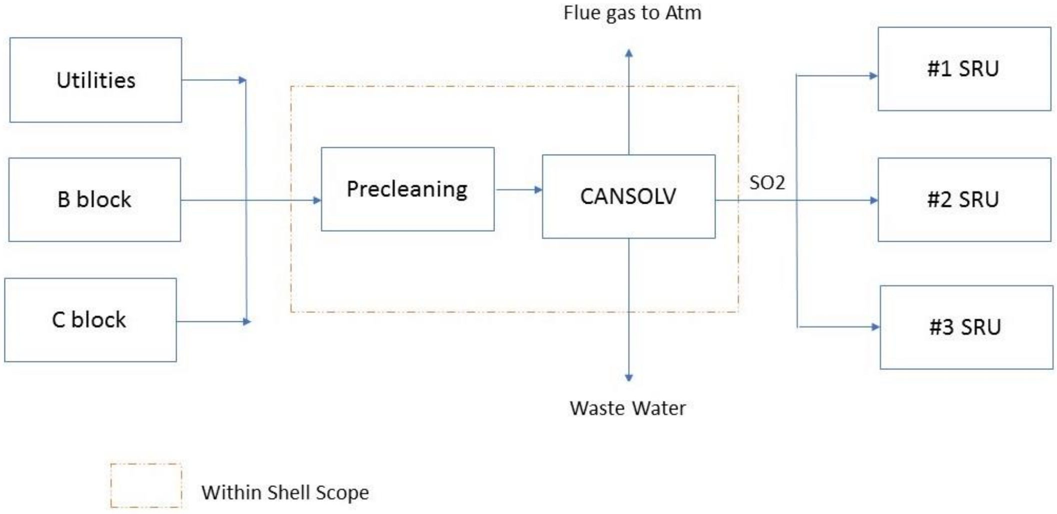

Figure 2.1 – Cansolv simplified schematic

Flare

Eliminating SO_2 emissions from the refinery flare during upset conditions is impossible. The refinery flare system is a vital safety mechanism, which safely combusts hydrocarbons and protects against over pressuring of plant equipment during upset situations. There is no technology available that is a viable alternative to the existing flare arrangement. Notwithstanding, adverse effects associated with flaring are assessed as less than minor.[11]

2.2.2 Fugitive Emissions

Refining NZ currently minimises losses of light hydrocarbons as fugitive emissions via maintenance scheduling, operational and maintenance procedures and site conventions. These steps mean any activities or situations that may lead to fugitive emissions are reduced as far as is practicable.

Process Areas

The majority of Refining NZ's minimal fugitive emissions originate from the process plant area from equipment such as, but not limited to pump seals, valve glands, relief systems and sample points. As noted above, Tonkin and Taylor's air quality assessment report[12] concludes that fugitive emissions from the refinery site are having a less than minor effect at sensitive locations beyond the site boundary. Accordingly, it is not necessary to further consider possible measures to reduce fugitive emissions from these process areas over and above Refining NZ's operational maintenance and upgrade programme.

Tankfarm Areas

Refining NZ's tanks are subject to inspection and repair as part of the tank maintenance schedule. This maintenance ensures tanks remain fit for service, operationally sound and pose minimal environmental or health and safety threats. Repairs made as part of this ongoing maintenance address

[11] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).
[12] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).

any damage/wear to seals on floating roof tanks that could be a source of fugitive emissions, as well as the integrity of tank floor which my lead to groundwater contamination (covered in Section 5).

The feasibility of modifications to tank roofs by the installation of a 'geodesic dome' over top of a floating roof set up has been investigated by Refining NZ, as well as the resulting reduction in fugitive emissions. The indicative cost for installation of such a system on our largest crude tank is $4.5 m; this is considered too capitally intensive to justify based on the less than minor adverse effects resulting from fugitive emissions and the minor reductions in fugitive emissions that would be realised, and is therefore not considered the best practicable option.

2.2.3 Abrasive blasting and spray painting

Essential maintenance to keep plant and equipment in safe and legal working order can entail blasting and/or spray painting. This maintenance is imperative to keep plant in a condition that ensures safe and leak free operation. While it is possible to fully contain blasting operations by means of specialised habitats and negative pressure ventilation, this comes at a significant cost. The Tonkin and Taylor air quality assessment report concludes that on the basis standard industry practice measures are adopted, potential adverse air quality effects associated with abrasive blasting at the site can be managed, including via imposition of appropriate conditions on the type of abrasive material used, consideration of wind direction and strength, and real-time monitoring in a manner that will ensure that effects are less than minor.[13] Therefore, given the limited effects beyond the Refinery site boundary with current controls, this added expense is not considered the best practicable option.

2.3 Reduce discharge to air

2.3.1 Sulphur Dioxide

A reduction in SO_2 emissions is possible via two strategies

- Reduce sulphur in fuel burnt
- Install flue gas scrubbers

Reduce Sulphur in Fuel Burnt

This can be achieved via two key approaches:

- Reduce or eliminate liquid firing
- Reduce sulphur content in liquid fuel

As outlined in Section 2.1.1 it is operationally impracticable to eliminate liquid firing completely without increasing the probability of operational issues or plant outages resulting from fuel main pressure fluctuations caused by unexpected weather events. In addition it is impracticable and uneconomic to rely totally on natural gas during times of market scarcity.

Sulphur content in liquid fuels is highly dependent on the sulphur in the crude processed. Restricting crude diet to only accept low sulphur expensive 'sweeter' crudes could result in significant refining margin erosion, making Refining NZ less competitive against import alternatives for its oil company customers. To ensure SO_2 emissions remain under consent limitations, Refining NZ's current strategy includes stockpiling volumes of low sulphur fuel oil in tankage during periods of low sulphur diet. This strategy has proven successful and continues to ensure Refining NZ meets the SO_2 emission limits as currently outlined in its current resource consents. And as set out above, Tonkin and Taylor conclude[14] that the ongoing discharges to air from the Refinery will have a less than minor effect on the environment and that no additional mitigation - beyond what is already implemented by Refining NZ - is required.

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[13] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).
[14] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).

2.3.1.2 Install Flue Gas Scrubbing Technology

Refer detail around flue gas scrubbing outlined in Section 2.2.1

2.4 Conclusions

Refining NZ actively seeks to improve its air emissions where it is necessary to prevent or minimise adverse effects on the environment and where it is practicable to do so. The current philosophy around furnace fuel selection and emission monitoring is considered the best practicable option, having regard to the impracticality and high cost of alternatives and when considering the level of effects on the surrounding environment as discussed in section 2.1.1 above. This current philosophy is achieved via the following strategies/activities:

- Minimising liquid fuel firing wherever practicable
- Maximising natural gas supply where economic and available
- Stockpiling fuel oil stocks when processing low sulphur crude diets
- Implementing furnace upgrade programmes e.g.
    - F5501 upgraded 2013, cost NZ$1.74m
    - F251 upgrade project underway, tentative scheduled completion Q1 2021, forecast capital NZ$1.9m

Further reduction in SO_2 emissions from site may be possible however is it not warranted given the very minor (less than minor) adverse effects that arise as a consequence of the discharge. To attempt to further reduce SO_2 emissions would require significant capital investment in SO_2 scrubbing technology, or significantly higher operational costs during times of natural gas scarcity or high low-sulphur crude pricing. Major operational changes to accommodate a change in fuel philosophy to burn lower sulphur fuel is not considered the best practicable option. Tonkin and Taylor confirm[15] that no additional mitigation - beyond what is already implemented by Refining NZ - is required.

[15] *Air Quality Assessment* report, Tonkin & Taylor Ltd, prepared for Refining NZ (Job number 1009695.1000).

3.0 Discharge to water

3.1 Background/Current situation

Refining NZ's site has a water catchment area of around 118.8 ha. Oil interceptors throughout the drain and canal systems assist in removing hydrocarbons (if any) from the storm water. Treated process water and storm water produced and collected on site is held in and discharged from the storm water basin ('**SWB**') located on the Northern site boundary. The discharge enters the harbour via an ocean outfall diffuser located under Jetty 2. In 2015, a spillway was constructed to divert water from the storm water basin to the harbour in the event of an emergency when the storm water basin level cannot be controlled by bypassing the diffuser by utilising an outlet diverter valve under the jetty. When a severe weather warning is in place (generally issued prior to a period of forecast high rate of rainfall) Refining NZ may notify the council and bypass the diffuser using the outlet diverter valve. This is to avoid a situation where the site water accumulation rate exceeds the discharge capacity and there is risk of operating the spillway, which has been utilised twice since its construction.

As stated above, the water from the SWB is discharged into the harbour via an outfall diffuser located at the end of the western arm of Jetty 2. Refining NZ holds a discharge permit which authorises this discharge (AUT.008319.01.04). Figure 3.1 below shows an aerial view of the Jetty area. The location of the diffuser is depicted by a red 'x', the spillway by two parallel red lines.

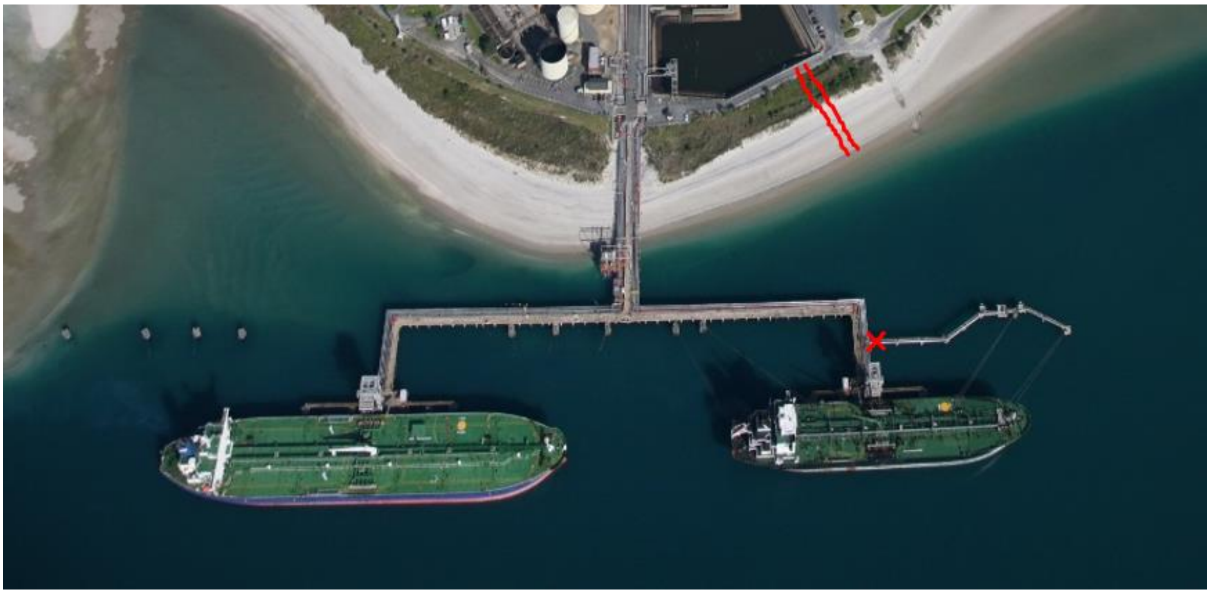

Figure 3.1 – Refining NZ Ocean Outfall Aerial View

The assessment of effects on marine ecological values accompanying the application for the reconsenting proposal[16] concludes that the *level of effect* of all potential adverse effects on marine ecology, including cumulative effects, associated with the Refinery's discharge to water is **very low**, and that avoidance or mitigation is therefore not required. This is based on the receiving environment having high ecological value, but the *magnitude of effect* being negligible in all cases. The Cultural Effects Assessment by Patuharakeke noted that the effects of discharges to water from a cultural perspective were considered to be more than minor primarily due to potential uncertainty and cumulative effects, together with concerns over the health of pipi on Mair and Marsden banks. Boffa Miskell have taken this into consideration of their findings and associated recommendations as discussed within their assessment of effects report.

[16] *Assessment of Effects on Marine Ecological Values – Reconsenting of discharges and structures in the CMA*, Boffa Miskell Ltd, prepared by Dr Sharon De Luca.

Drain Systems

The Refining NZ site has two main drain systems that capture and distribute water from the process and offplot areas on site. The Accidentally Oil Contaminated drain system (‘**AOC**’) and the Constantly Oil Contaminated drain system (‘**COC**’).

AOC drain water mainly consists of rain water, steam condensate that has made its way to grade,[17] and groundwater recovered from on-site recovery wells. This water is collected and routed to the storm water basin via a system of canals. Oil that makes its way into the canal system is recovered before water is discharged to harbour.

Spent process water and any water that has come into contact with oil is disposed of in the COC drain system. Oil and sludge are removed, and this water is treated in the biotreating unit. Treated water from the outlet of the biotreater is discharged to the SWB. Process water comprises contaminated water from various aspects of the refining process with its quality discussed within Streamlined Environmental’s Water quality assessment at Marsden Point oil refinery report.

Stormwater Basin

Water from the SWB is discharged to sea in line with existing consent conditions that outline quality and volume restrictions, as well as mixing and dissipation conditions.

In August 2008, following a 2007 overflow from the SWB, Refining NZ was granted a further discharge permit (CON 2008_08319_13) which authorises the discharge of storm water during intense sustained rainfall events from an outlet diverter valve located on the jetty that bypasses the normal outlet diffuser. The diffuser bypass system is located on the western side of the jetty prior to the fork which leads to the crude and product jetties. This valve is manually operated and is only used when water levels in the SWB are likely to result in the overtopping of the SWB into the spillway (as a result of unusual and sustained rain events). Bypassing the diffuser reduces the pressure drop and allows SWB discharge pumps to move greater volumes from the SWB than could normally be discharged. In the 24 month 2017/2018 period, this outlet diverter has been employed on 12 occasions during high rate rainfall events successfully avoiding use of the spillway.

Biotreater

Since 2014, Refining NZ has invested around $24m on improving environmental performance across its site. As part of that significant investment, $2.8m went towards an upgrade of the biotreater aerator system. This was a two year project, completed in May 2017. This critical piece of plant treats contaminated waste water from the COC drain system. Aerator jets force oxygen through the waste water and work to aerobically break down contaminants. The upgraded bio treater has improved Refining NZ’s capacity to treat waste water particularly during periods such as shutdown when greater volumes of wastewater are generated, as well as strengthened the site’s ability to manage major weather events that place added pressure on treatment capacity.

3.2 Eliminate discharge to water

It is impossible for Refining NZ to eliminate its requirement to dispose of treated process water and stormwater. In that regard, the Refinery will always have process water and stormwater that needs to be discharged. In order to eliminate discharge to the harbour completely, Refining NZ would require another means of water disposal which is expected to require additional resource consent(s). One such option, which Refining NZ has investigated, is land irrigation.

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[17] ‘Grade’ refers to the surface ground level, whether that constitutes soil, concrete or any other pervious/impervious surface. Not all discharges to grade go to ground: as noted here, some is collected and routed to the stormwater basin.

GWS Limited, on behalf of Tonkin and Taylor, investigated the feasibility of alternative disposal of Refining NZ's effluent water via land irrigation. Factors such as the following were taken into consideration:

- Land suitability
- Soil types
- Groundwater depth
- Water quality
- Potential environmental effects

Considerations were made for both high and low discharge rate options. See Tables 3.1 and 3.2 below which outline the disposal rates and land area requirements for each option.

Table 3.1 – High rate land disposal option

Disposal Volume	8000	*m3/d*
Disposal Rate	0.36	*m/d*
Area Required	22,222	*m2*
Blocks Required	5	
Total Area Required	11	*ha*

Table 3.2 – Low rate land disposal option

Volume	8000	*m3/d*
Disposal Rate	0.05	*m/d*
Area per Block	160,000	*m2*
Area per Block	16	*ha*
Blocks	3	
Total Area Required	48	*ha*

Disposal rate in metres per day indicates the recommended rate of application referring to an increase in water table level. GWS concluded that high rate disposal of effluent water on existing land parcels around the periphery of Refining NZ's main site is theoretically possible. Despite this, the majority of the proposed area is currently occupied by catalyst storage sheds, a laydown area and roading which would all require relocation. GWS did not recommend low rate offsite disposal due to unknowns and difficulties around new land use consents, landowner approvals to be able to perform site specific testing that would be necessary, and procurement of a suitable land parcel. The capital costs involved with offsite water disposal, as outlined below, are much greater again, largely due to the magnitude of the infrastructure required (kilometres of piping, road crossings etc.).

Disposal of effluent water via land irrigation is only suitable during periods of dry weather. In the event of any sustained high rainfall event, high rate harbour outfall would still be necessary to avoid flooding on site.

<u>Onsite land irrigation</u>

For onsite land irrigation disposal of 8,000 m^3/day treated wastewater, GWS recommend five irrigation lots with a minimum area of 22,222 m^2 each (11 Ha total area). The cost estimate performed by Tonkin and Taylor determined 7.7 MNZ$ -20%/+50%. Applying factors based on recent projects executed on site (1.4 site factor + 0.2 outside battery limit ('**OSBL**') factor) the estimate is more likely in the region of $12MNZ$ -20%/+50%. This cost is exclusive of any upgrades required on the existing biotreater unit that would enable tighter effluent water specifications to be met. Also, it does not include costs associated with relocation of existing buildings and equipment that currently occupy the majority of the identified location, earthworks for initial site contouring, and other ancillary activities.

Land irrigation on site for disposal of effluent water is not recommended as the best practicable options for the following reasons:

- As outlined above, the level of adverse marine ecological effects associated with the current/proposed discharge to water has been assessed by Refining NZ's independent ecology expert as being very low, with the magnitude of effect being negligible. As such, there are no adverse effects which are required to be prevented or minimised by implementing an alternative method of discharge.

- Recommended and achievable rates are not practicable for effluent disposal during wet weather.
    - GWS have designed land disposal for average dry weather discharge rates of 8,000 m^3/day, with maximum pumping capacity of 16,000 m^3/day.
    - During periods of rainfall, discharge rates generally exceed 30,000 m^3/day, and on occasion greater than 60,000 m^3/day
    - In the last 24 months (August 15 2017 – August 15 2019), effluent discharge rates in excess of 16,000 m^3/day have occurred 176 times
- Unknown upgrades required on existing biotreater unit to achieve desired effluent water quality
- The Refining NZ land identified for land irrigation is currently in use, occupied by catalyst sheds, roads and laydown areas. It is impracticable/expensive to relocate these
- Groundwater mounding that occurs as a result of land discharge on site may:
    - Raise the level of the water table near the site boundary, resulting in visual groundwater seepages at the adjacent beach
    - Compromise current groundwater containment regime (pump and treat)
    - Increase dissolved phase hydrocarbon in Refining NZ's groundwater, resulting in increased adverse effects
    - Due to a history of land farming contaminated soil, as a result of groundwater mounding, these contaminants may leach and impact groundwater quality

<u>Offsite land irrigation</u>

Many unknowns exist around off-site effluent water disposal such as, but not limited to:

- Availability of suitable land for purchase
- Cost of new land purchase
- New resource consent requirements
- Ground water behaviour – requires modelling

For offsite land irrigation disposal of 8,000 m3/day treated wastewater, GWS recommend three irrigation lots with a minimum area of 16 ha each (48 H ha total area). The cost estimate performed by Tonkin and Taylor determined 20.5 MNZ$ -20%/+50%. Applying factors based on recent projects executed on site (1.4 site factor + 0.2 OSBL factor) the estimate is more likely in the region of 32.8 MNZ$ -20%/+50%. This cost is exclusive of any upgrades required on the existing biotreater unit that would enable tighter effluent water specifications to be met, nor does it include any costs associated with procuring an appropriate parcel(s) of land, nor costs associated with a new resource consent application process.

As outlined above, the level of adverse marine ecological effects associated with the current/proposed discharge to water has been assessed by Refining NZ's independent ecology expert as being very low, with the magnitude of effect being negligible. As such, there are no adverse effects which are required to be prevented or minimised by implementing an alternative method of discharge.

Further to the above, when taking into account the high rates of rainfall experienced at Marsden Point, the limited land parcel sizes available on site and nearby, and the anticipated negative environmental effects of effluent disposal of water to land, the current means of effluent water disposal via ocean outfall is considered the best practicable option.

Please see Appendix B for full report compiled by GWS Limited and Tonkin and Taylor.

3.3 Reduce discharge to water

As discussed above, the current method of discharge to the CMA is deemed to be the best practicable option, when compared against possible land-based disposal. That said, Refining NZ has also considered whether reducing Refining NZ's water discharge volume is possible. The site is fundamentally a large mass balance, see Figure 3.2 below.

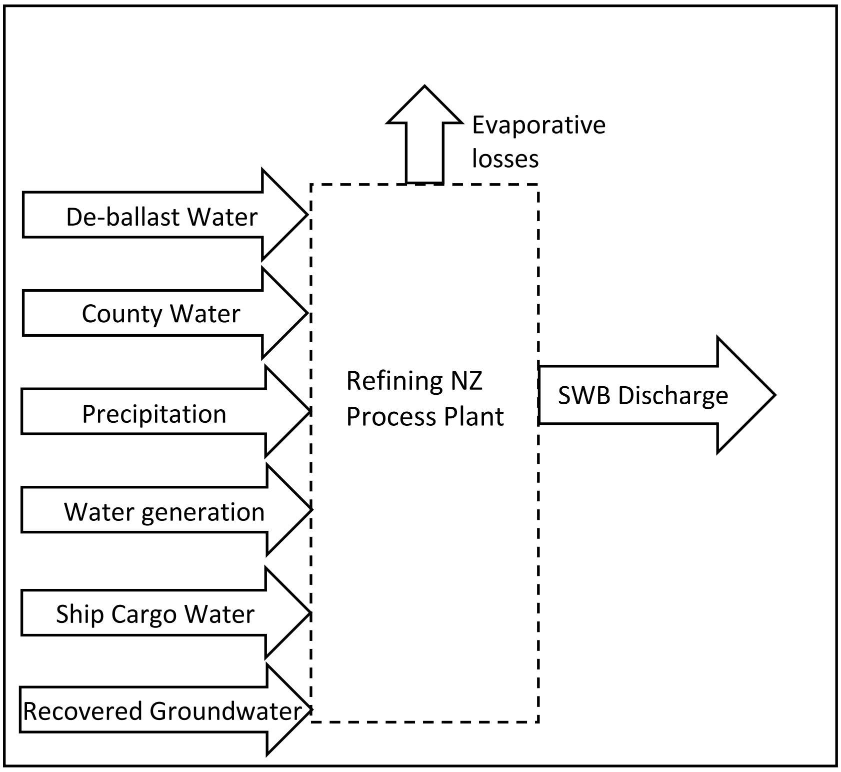

Figure 3.2 – Site Water Balance

Theoretically, water in is equal to water out. By reducing or removing any of the flows in, Refining NZ can reduce flow out. The only flow that can be controlled is the potable water that is supplied by the Whangarei District Council, as all other flows are resultant of processing the plant, jetty operation and site groundwater contamination containment.

To reduce the potable water supply in, Refining NZ would need to reduce its water consumption demand. This is difficult without major capital investment in technology and infrastructure such as reverse osmosis units and associated tankage, pumps and linework. Feasibility work has been carried out in 2019 investigating possible options for installation and operation of Refining NZ's own Reverse Osmosis ('**RO**') water treatment plant. The business case for this proposal is in its infancy however early indications suggest the proposal to be capital intensive with a high level of uncertainty and suggest a poor economic return.

In summary, while reducing potable water demand (and therefore discharge volumes) is a possibility and is something that has been, and is, under investigation, methods to achieve such reductions are not presently considered to be the best practicable option by Refining NZ or its advisors. This is particularly the case in a context where, as noted, the independent expert assessment is that the level of all marine ecological effects associated with Refining NZ's discharge to water are very low and do not require avoidance or mitigation. High capital requirements are also a factor.

In addition, Refining NZ does not consider that moving the diffuser discharge point (for example further offshore) represents the best practicable option. Reasons include: (a) the fact that the *level of effect* of all potential adverse effects on marine ecology associated with the Refinery's discharge to water is very low; (b) considerable capital investment would be required to materially move the discharge point; and (c) other adverse effects, for example effects on benthic ecology, would result from the works required to materially move the discharge point.

3.4 Conclusions

The consenting activities and infrastructure required to construct feasible alternatives to discharging to the marine environment are capital intensive and may result in negative environmental outcomes with implications on the site groundwater behaviour and quality, as well as reduced recovery rates of free phase hydrocarbons on the groundwater table. Based on this, and the assessed level of effects from the discharge being very low, it is concluded that the current treated discharge to water is the best practicable option.

4.0 Discharge to land

4.1 Background/Current situation

Refining NZ is conscious of its responsibility to minimise its impact on the surrounding environment and is continually looking to lift its environmental performance. This is underpinned by a 'no spill' policy across the refinery, and major project investment in cleaning and preventing hydrocarbons leaving the site. Over the past four years, Refining NZ has invested in upgrading of oil traps and boosting the performance of its storm water management capability - cleaning oil traps and holding basins, installing new oil skimmers, clearing canals and installing new bio-treating capability. It has also invested in upgrading hydraulic capacity of COC networks, improving their integrity and efficiency.

Refining NZ's current consent conditions (AUT.008319.04.01) permit the discharge of contaminants to ground as a result of activities associated with the normal operation of the refinery. This includes leaks from drain systems, hydrocarbon egress from tank floors and accidental spills. To ensure no hydrocarbon which has migrated into the water table exits and/or contaminates outside of Refining NZ's perimeter, Refining NZ operates a number of wells around the site designed to recover oil and depress the water table to avoid migration of any hydrocarbons outside of the site boundary. This groundwater pumping and treatment system at Refining NZ is outlined further in Section 5.

Refining NZ is not seeking to renew/replace its existing resource consent for land farming of sludge, a process that was discontinued in the mid-1990s. At present sludges, contaminated soil, and other wastes are disposed of offsite at a suitably authorised facility.

The refinery site at Marsden Point operates an extensive array of tankage and drain systems. Many of these tanks and drains were installed over 50 years ago when the original plant was constructed, with the remaining majority constructed in the mid 1980's. Given the age of this infrastructure, some components are coming to the end of their design life and require 're-lifing' (project work to extend the life of the asset) to ensure ongoing network integrity.

Refining NZ has run a programme entitled 'Project Kleenex' over the past five years costing approximately $25m to date. Part of this programme entails a considered approach to the reparation of leaks from various drain systems across site, as well as upgrading these systems to increase hydraulic capacity. Improved hydraulic capacity give drains the ability to cope with the short bursts of high intensity rainfall the Northland climate is prone to. The stormwater catchment area within the refinery boundary has also increase over the years as the plant expanded. The upgrades to the network are designed to:

- remove leaks to ground from the underground network
- improve hydraulic performance of the network to reduce leaks to grade[18] from surface flooding of the network
- reduce risks associated with surface flooding
- improve the performance of the oil/water separators to increase capacity and output effluent quality
- reduce discharge of oil into the storm water systems

Initially Kleenex targeted the 'white oils' offplots area and focused on the following tasks:

- Replacement of damaged and leaking pipelines and chambers
- upgrading of flexible connections for extended longevity
- modifying the network for increased hydraulic performance
- upgrading the oil/water separator for increased capacity and effluent quality.

[18] Refer footnote 16 above.

For repairs/upgrades made to process areas, the network is running under/between live pieces of equipment. It is therefore very impracticable to isolate these drains for full replacement and to do so would require demolishing of the existing process plant. However, Refining NZ are in the process of making upgrades to the process areas where possible and practicable. These upgrades include activities such as replacement of pipe to chamber connections (link seals), which are the main source of leaks to grade,[19] as well as plans to reline drain pipelines using 'cure in place' technology where suitable.

Once all repairs and upgrades part of Project Kleenex are complete, leaks from the drain systems will be greatly reduced (acknowledging that it is not possible to eliminate them entirely). Recurrent maintenance will be undertaken to ensure that the leaks from the drains are minimised. This maintenance will consist of regular inspection and testing of the network to ensure integrity and implementation of repairs as required.

4.2 Eliminate discharge to land

Completely eliminating any discharge to land is not seen as necessary by Tonkin + Taylor,[20] given the effectiveness of the hydraulic containment system at the site. Further, complete elimination of fugitive discharges not practicable due to, but not limited to, the following reasons:

- Capital requirements
- Lack of access due to existing infrastructure
    - Existing drain network runs underneath process equipment
- Feasibility of isolating certain drain systems to acceptable safety standards
- Components (chamber to pipeline connections) of the network need to be flexible to allow for seasonal ground movement. These flexible components are prone to long term degradation by hydrocarbons in the network and require ongoing inspection and maintenance

To replace/upgrade the entire COC drain system to a level that ensures zero leaks on an ongoing basis, and doing so in a manner that meets site requirements is therefore operationally impracticable. To upgrade the network in process areas would require extensive excavation underneath refining equipment; it is not practicable to excavate and upgrade COC networks beneath process areas due to the infrastructure and process equipment. In addition, the capital cost associated with attempting to achieve such an outcome would be prohibitive.

As noted above, Refining NZ no longer undertakes land farming, and is not seeking to renew/replace that resource consent.

4.3 Reduce discharge to land

Refining NZ is ISO14001 accredited and as such is always looking to improve environmental performance. Ongoing work carried out as part of Project Kleenex is showing benefits in terms of reduced leaks to ground. This, in conjunction with pumping and treating of groundwater on site, has resulted in reduced extent of free phase hydrocarbon over time. Data to corroborate this is displayed in section 5.1, Figures 5.1 – 5.3. With Refining NZ's ongoing maintenance programme (outlined in section 4.1 above) the Company plans to continue to improve environmental performance and reduce discharges to land.

[19] Refer footnote 16 above.

[20] Tonkin + Taylor, 'Marsden Point Refinery: Hydrogeological Conceptual Site Model' (November 2019), at sections 6.5 – 6.6.

4.4 Conclusions

The Refinery is making improvements to the drain network and a maintenance programme which seeks to reduce hydrocarbon egress to ground is in place. For reasons outlined in the above discussions, eliminating discharges to land completely is neither possible nor does it represent the best practicable option in this instance. Continuing to reduce any discharges through focussed operational awareness, continued site maintenance and operation of oil recovery wells is the best practicable option, and these are activities the Company will continue to pursue.

5.0 Groundwater extraction

As outlined above, the RMA does not require consideration of alternatives for non-discharge activities unless any adverse effect associated with such activities is likely to be significant (clause 6(1)(a) of Schedule 4 to the RMA). Because Refining NZ's independent experts have confirmed that are/will be no significant adverse effects associated with the company's groundwater extraction activities (and in fact, that the hydraulic containment provided by the groundwater take is overall a positive effect),[21] it is not necessary to consider alternative locations or methods for undertaking those activities. However, for completeness (and while not required under the RMA) the following section addresses alternatives relating to groundwater extraction.

5.1 Background/Current situation

Given its proximity to the Whangarei Harbour and surrounding sensitive sites, Refining NZ is conscious of the impact of its refining operations on the environment, and take responsibility for minimising these by continuing to invest in improving environmental performance. Keeping hydrocarbons on site is crucial to environmental performance.

Refining NZ is currently consented to take ground water for water table depression purposes (AUT008319.05.01). Pump and treat groundwater extraction and oil recovery on site works successfully to recover free phase oil and prevent hydrocarbon contaminated groundwater from leaving the site boundary. Data shows that, over time, the concentration of dissolved phase hydrocarbons has reduced. Figures 5.1 – 5.3 below display the average quarterly Light Non-Aqueous Phase Liquids ('**LNAPL**') thicknesses for 2016 – 2018. The main area of LNAPL concentration is in proximity to and east of the control room. The plots clearly show plumes year to year shrinking in size, with the largest changes observed in the following areas:

- Reduction in LNAPL thickness from monitoring well C1 in C Block from > 1 metre to 0.5 metres,
- Reduction of the plume in the Tank 20's compound, and
- Reduction in the lobe at RWSEQ between 2017 and 2018.

The Surfer plots show light LNAPL thicknesses from 0.1 m in green to more than 1.0 m in red.

[21] Tonkin + Taylor, 'Marsden Point Refinery: Hydrogeological Conceptual Site Model' (November 2019) at sections 8.2.1 - 8.2.9.

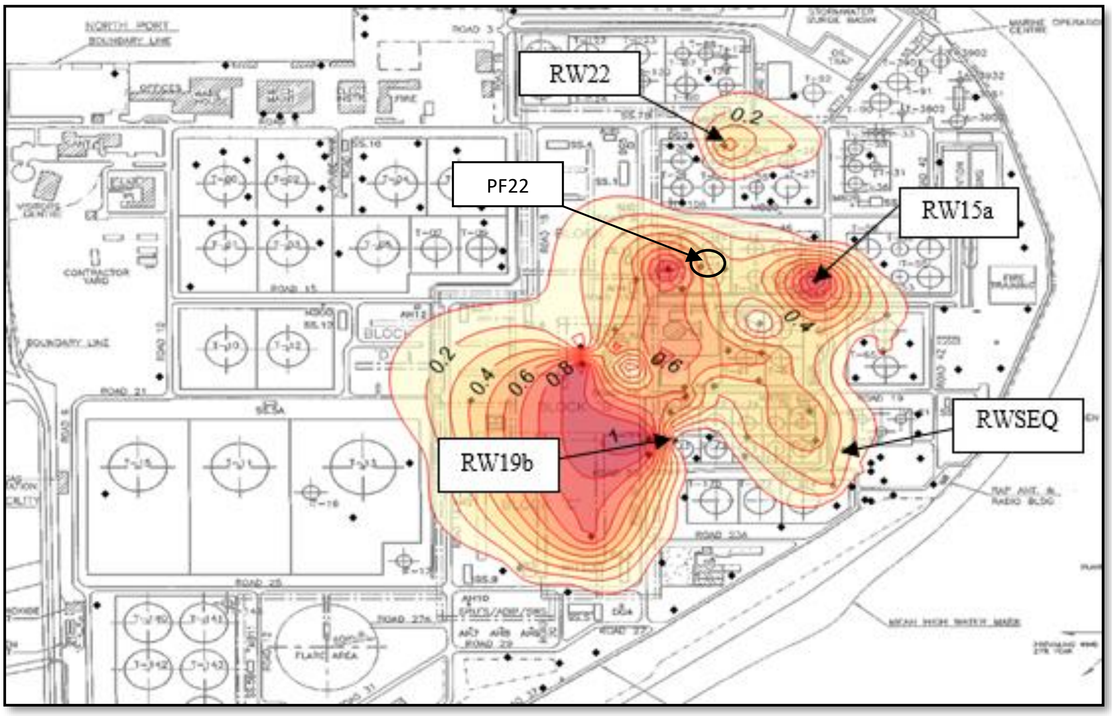

Figure 5.1: 2016 average LNAPL thicknesses

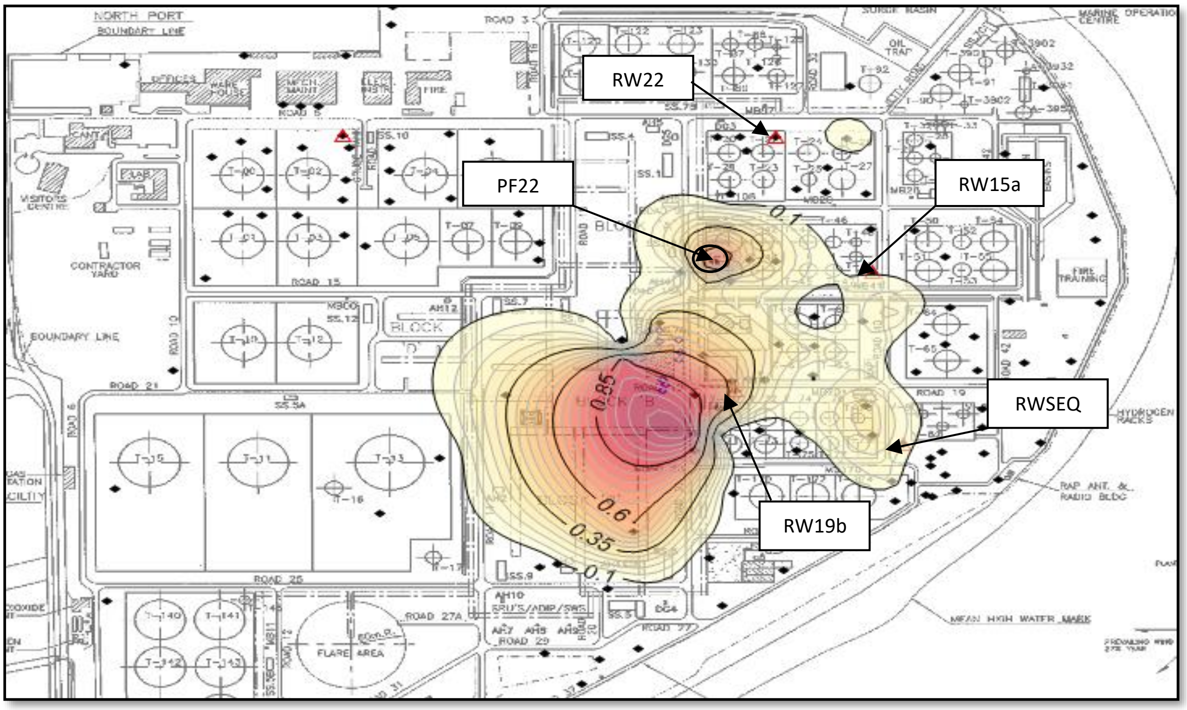

Figure 5.2: 2017 average LNAPL thicknesses

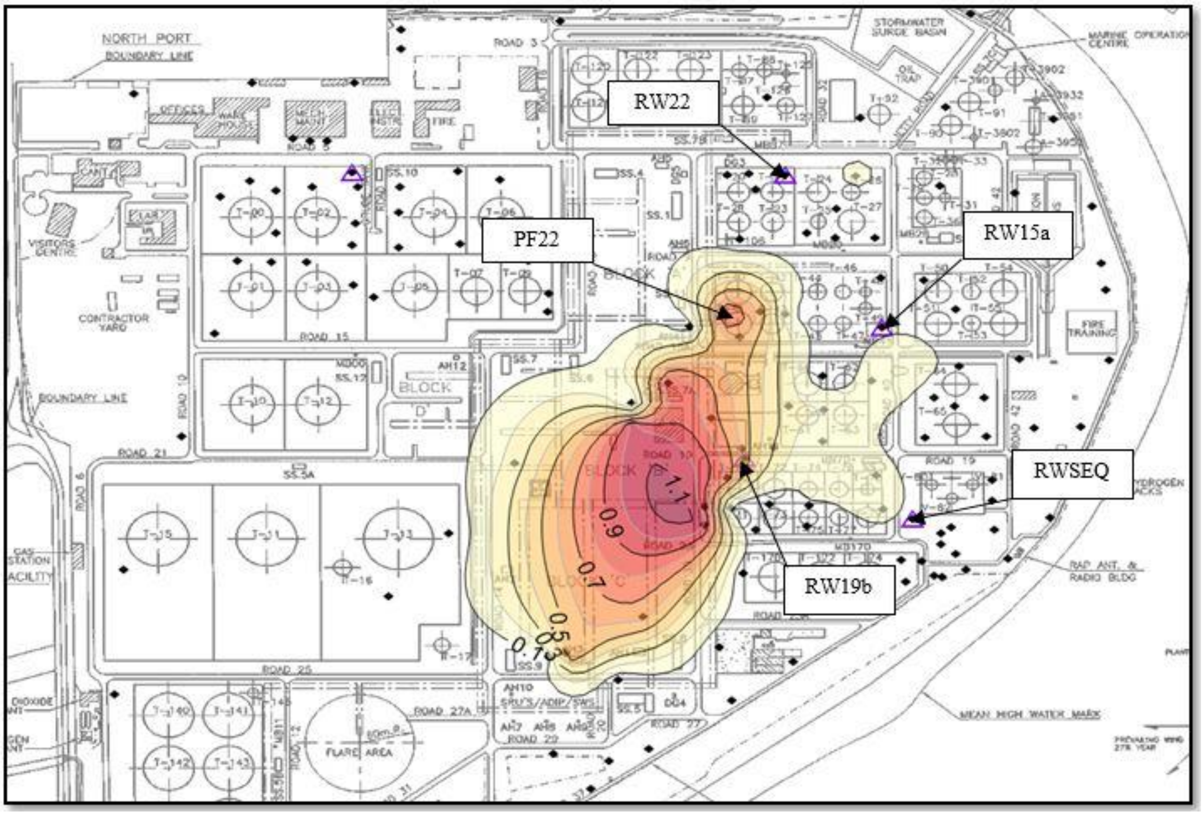

Figure 5.3 - 2018 average LNAPL thicknesses

Tonkin and Taylor were comissioned to review Refining NZ’s current means of site contaminant containment, and make recommendations on alternatives. Their study concluded that the current approach to management of hydrocarbon impacts to control LNAPL and dissolved phase hydrocarbons in ground water, pump and treat, is the most appropriate method. The full report is contained in Appendix C.

5.2 Eliminate Groundwater Extraction

Tonkin and Taylor’s Remediation Options Assessment outlines the practicalities of various alternatives to groundwater extraction on site. The five options investigated were ranked on their technical feasibility and effectiveness for application at Refining NZ, sustainability, environmental effects and financial and time implications. Figure 5.4 below summarises the results of this comparison.

Considerations	Technologies / Approaches				
	Insitu chemical oxidation	Insitu bioremediation	Physical containment	Pump and treat *(current method)*	Hydraulic control by reinjection
Technical feasibility and effectiveness					
Time					
Sustainability					
Protection of the environment					
Financial					

Red –severe constraints for application (such as being unable to treat LNAPL)
Orange –moderate constraints for application
Green –mild constraints for application

Figure 5.4 – Summary: Groundwater pump and treat alternatives

As is apparent in Figure 5.4, the current method of contaminant control on site, pump and treat, is the recommended and most appropriate and practicable method. While other options for site contaminant containment exist, these come with major constraints for application on site. Some relevant reasoning is summarised below:

- In situ chemical oxidation ('**ISCO**') is not suitable for implementation at Refining NZ due to technical constraints such as:
    - Limitations of this methodology's ability to treat LNAPL
    - The extent of the proposed treatment area
    - Infrastructure requirements for treatment of dissolved phase contamination being impracticable and capitally intensive
    - Inability of this method to treat ongoing contamination
- Physical containment is not suitable for implementation at Refining NZ primarily due to the large capital outlay as well as the technical implications of constructing a suitable wall. Even with physical containment, treatment of water and recovery of LNAPL would still be necessary
- In situ bioremediation/sparging is potentially suitable for management of residual/trace hydrocarbons at the site boundary but not for remediation of the main Refinery site.
    - This technology would be an add-on to the current approach and not a replacement.
    - Further assessment is required to establish the relative value in the context of contaminant concentrations that may currently be escaping the existing system.
    - Where the current system can demonstrate sufficient hydraulic control, the cost of adding this technology may outweigh the benefits.
- Hydraulic control by reinjection is feasible at Refining NZ. Additional investigation is required to determine aquifer response to injection and relative effectiveness.
    - This technology would be an add-on to the current approach and not a replacement.
    - Where the current system can demonstrate sufficient hydraulic control, the cost of adding this technology may outweigh the benefits.
- All alternative approaches will require additional resource consents or consent amendments.

Based on the above information and Tonkin and Taylor's Remediation Options Assessment at Appendix A to this report, eliminating groundwater take at Refining NZ is not considered to be the best practicable option. In many instances the reduction in environmental effects from application of a suitable alternative are minimal and the associated costs of implementing a replacement outweigh the improved environmental benefits.

5.3 Reduce Groundwater Extraction

Considering the conclusions of Tonkin and Taylor's Remediation Options Assessment, a reduction in the volume of groundwater consented for extraction is not recommended. They have however, outlined two options that, if used in conjunction, may improve the effectiveness of Refining NZ's current pump and treat approach. Both of these technologies would require additional resource consents as well as substantial capital to design and install:

<u>In situ Bioremediation/ Bio sparging</u>

These are both mature technologies which have been proven in a wide range of remediation applications. In situ bioremediation generally involves adjusting aquifer conditions to increase activity of microbes which break down organic contaminants. This is achieved by the addition of nutrients/food as well as the introduction of oxygen to promote more effective aerobic degradation processes. It is effective in the treatment of Total Petroleum Hydrocarbon ('**TPH**'), BTEX (benzene, toluene, ethylbenzene and xylene) as well as some polyaromatic hydrocarbons ('**PAHs**') and phenols.

Implementing this across the entire site is not practicable due to the network of well sites required for effective introduction of air and nutrients, but it may be possible to introduce this in smaller problem areas to aid effectiveness of the current pump and treat methodology, although capital required to implement such a network (circa $10m) may outweigh the benefits.

<u>Hydraulic Control by Reinjection</u>

This methodology is effectively the inverse of what is currently achieved by pump and treat (groundwater depression). It involves injection of water to create local mounding of groundwater levels, forming a hydraulic divide which prevents migration of LNAPL and can also control dissolved phase flow direction. Potable water is suitable for this purpose, however extracted and treated groundwater is more commonly used. Greater rates of extraction are generally required to implement this technology, although much of this water is returned via reinjection. Capital required to implement this technology is in the realm of $1m, however this does not include additional water treatment facilities or groundwater modelling that would also be required. It is considered the investment required to implement this methodology would outweigh any recognised environmental benefits.

5.4 Conclusions

Groundwater depression in conjunction with groundwater pumping and treating, and oil recovery is working successfully at Refining NZ with tangible reductions in LNAPL as well as in the dissolved phase. The capital required for implementation of any additional technology in tandem with groundwater pumping and treating to enhance performance is likely to outweigh any additional benefits and is not considered best practicable option.

6.0 Marine Structures

As outlined above, the RMA does not require consideration of alternatives for non-discharge activities unless any adverse effect associated with such activities is likely to be significant (clause 6(1)(a) of Schedule 4 to the RMA). Because Refining NZ's independent experts have confirmed that are/will be no significant adverse effects associated with the company's marine structures (see below), it is not necessary to consider alternative locations or methods relating to those structures. However, for completeness (and while not required under the RMA) the following section addresses alternatives relating to marine structures.

6.1 Background/Current situation

Imperative to oil refining operations, Refining NZ owns and operates three jetties and associated equipment adjacent to the Marsden Point site. These jetties are used for importing crude to site for refining, as well as shipping of refined products for dispatch to New Zealand coastal terminals. They are, therefore, key infrastructure. Current consent conditions allow occupation of the coastal marine area with a refinery wharf and associated structures including toilets and sewerage holding tanks, fire pump diesel tanks, slops tanks, breasting and mooring dolphins and a wastewater diffuser outfall structure.

The jetty structures are the only means of importing feedstocks onto site, generally receiving an average of one crude tanker receipt and two product tanker liftings each week.

The three jetties are Jetty 1, Jetty 2 and Jetty 3. Jetty 1 is used primarily for crude receipts, generally receiving one crude tanker cargo per week. It is possible to ship products from Jetty 1, with the exception of Jet A1 which can only be shipped from Jetty 2. Jetty 1 can also be used for ships requiring bunker fuel. It is very rare that product is shipped from Jetty 1.

Jetty 2 is used primarily for loading product on two coastal tankers, Matuku and Kokako, that are responsible for delivery of products from Refining NZ to ports around New Zealand. Depending on destination, these ships generally each visit once or twice a week. Around once per month, the Matuku is used to deliver small condensate crude parcels from the Taranaki region. Jetty 2 is the only jetty that can receive such a parcel.

Jetty 3 was purpose built in 2008 for coastal bunker tanker 'Awanuia' and is covered under its own separate consent 'fuel barge extension' (AUT.008319.12). The Awanuia lifts fuel oil and diesel for bunkering of ships, generally in the Auckland region and visits Refining NZ around once per week. See Table 6.1 below for summary of jetty services.

Table 6.1 – Refining NZ jetty line ups

	Jetty 1	Jetty 2	Jetty 3	Notes
Crude receipt		*		*Only small condensate cargoes (Matuku)
Product receipt				
Product loading	*			*Cannot load Jet A1
Bunker loading			*	*Awanuia only (purpose built)

72% of the time, at least one of the jetties is occupied. 50% of the time, there are multiple ships berthed concurrently, on occasion all three jetties are occupied.

Refining NZ's ability to successfully and feasibly plan and schedule refinery production relies on the ability to berth multiple ships at any one time. The ability to load product and discharge crude concurrently is paramount to maintaining feasible stocks, as well as maintaining steady operation on the process units.

To put this into context:

- a crude cargo generally consists of around 90kt raw crude
  - Equivalent of 5.6 days Refining NZ crude processing
- It takes 24 hours to discharge a crude cargo
- Best practice dictates a crude tank must settle for **at least** 24 hours prior to feeding unit (to allow for sufficient mixing and water draining)
- Refining NZ cannot discharge into and feed from a crude tank at the same time
- One crude cargo will fill 4 small crude tanks, or 1 large + 2 small crude tanks
  - Refining NZ generally requires at least 3 tanks to feed our crude distillers during a crude discharge
  - This leaves only a small margin for late ships
- The refinery cannot be switched on and off as feed is available, it requires steady state operation to produce on grade products.

The assessment of effects on marine ecological values accompanying the application for the reconsenting proposal[22] concludes that the *level of effect* associated with the occupation of the seabed by Refining NZ's structures is **very low (de minimis)**, and that avoidance or mitigation is therefore not required. This is based on the receiving environment having high ecological value, but the *magnitude of effect* being negligible in all cases. The cultural effects assessment (CEA)[23] indicates that the jetty visually bisects the beach resulting in an adverse effect on the cultural landscape. It goes on to conclude that the effect could be moderate to high.

6.2 Eliminate marine structures

Eliminating marine structures completely is not an option for Refining NZ. A report compiled by Poten & Partners as part of the 'Crude Shipping Project',[24] which builds the business case for dredging of the harbour to allow for fully laden larger crude cargo ships, reviewed alternative options to harbour dredging. One such option was single point mooring ('**SPM**'). SPM is a commonly employed alternative to wharf operations, generally used to overcome draught limitations. Hypothetically, if this were to be employed at Refining NZ, the existing jetty(ies) would still be necessary as back up in the event of an SPM outage. Maintaining the refinery jetty would also still be required for product shipping as product parcel sizes and custody transfer procedures do not lend themselves to a SPM system. High level capital estimates for positioning of one SPM berth into the Bream Bay have been performed over the past 20 plus years, the most recent estimate in 2013 indicating an investment of ~ US$150m would be required to build such an arrangement, involving:

- 10 km underwater pipeline
- 3.5 km shore side pipeline
- Additional crude storage at the refinery
- Modifications to existing crude storage at the refinery

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[22] *Assessment of Effects on Marine Ecological Values – Reconsenting of discharges and structures in the CMA*, Boffa Miskell Ltd, prepared by Dr Sharon De Luca.

[23] *Patuharakeke Trust Board, Cultural Effects Assessment Report: Refining NZ Reconsenting*

[24] Poten & Partners, *Crude Shipping Alternatives Marsden Point*, August 2016 (appendix in Tonkin & Taylor *Mid-point Multi-criteria Alternatives Assessment* Report, March 2017).

The Poten & Partners Crude Shipping Alternatives report concluded that retaining the existing jetty infrastructure and dredging was a preferable option than the installation of a SPM system.

While the effects of the current jetty structure on marine ecology are considered to be very low, with the 'hard shore habitat' that is created contributing to beneficial effects, it is noted that the effects of the jetty on the cultural landscape could be moderate to high. As demonstrated above removal of the jetty would not be practicable and, as such, other measures will need to be considered to mitigate or offset these effects to a point they are acceptable.

6.3 Reduce marine structures

Theoretically, it is possible to make changes to the existing jetty arrangement to reduce from three jetties to one. Advisian (part of the Worley group) provided a cost estimate report detailing a high-level analysis of capital requirements to demolish the Jetty 2 and Jetty 3 facilities and relocate all operations to Jetty 1. Advisian performed this analysis with the following in mind:

- Modifications would be needed to enable all products to be shipped from Jetty 1
    - New Jet line
    - New bunker fuel line
- Some recycling of current Jetty 2 infrastructure may be possible e.g. control valves
- There is currently no room for additional linework on Jetty 1 on existing over water pipe racks
- There is room for only one additional hose at Jetty 1 gantry, although hoses may require realigning

Initially it was proposed a new berth ‘Jetty 3.1’ be constructed adjacent to Jetty 1 for Awanuia bunkering. This was however deemed infeasible by Advisian due to draft restrictions in that area brought about by significant shoaling in that vicinity.

Advisian concluded the following:

- Jetty 3.1 is not an option
- The resulting jetty line up is Jetty 1 only with the following modifications:
    - Additional separate berthing dolphins to allow the Awanuia to berth at Jetty 1 as well as modifications to the Jetty itself for loading access
    - Two new product lines constructed on new pipe racks attached to existing structures
- Old product pipelines would be cleaned, cut into lengths and craned away during the demolition process
- Full removal of decommissioned piles is possible, and allowances have been made for this in the cost analysis

Advisian estimate the cost to demolish the Jetty 2 and 3 facilities and re-locate operations to Jetty 1 is approximately NZ$10.5m -30%+50%. (P50).[25] A nominal consideration for non-productive time of NZ$500k is included in this estimate. Applying normal Refining NZ site factors increases the P90 cost estimate to NZ$24m.

These modifications would result in Refining NZ retaining just one operational jetty, severely reducing operational flexibility of the jetty and process plant. As outlined in section 6.1, Refining NZ jetties are currently occupied by more than one ship 50% of the time. With just one operational jetty, operations within the refinery would be severely deoptimized. It is difficult to determine an exact cost of this

[25] P50 cost is the project cost with sufficient contingency to provide 50 per cent likelihood that this cost would not be exceeded. P90 cost is the project cost with sufficient contingency to provide 90 per cent likelihood that this cost would not be exceeded.

deoptimization, however a large reduction in primary intake would likely result, as well as deoptimization of the refined product pool.

Advisian Report, RNZ Resource Consent Renewals– Indicate Estimate for Case 2 Reduction in Marine Structures, is included in Appendix E.

As noted above, the effects of the jetty on the cultural landscape could be moderate to high. Implementation of this option would not serve to mitigate the identified cultural effects; other measures will need to be explored to mitigate the effects to a level that they are considered acceptable.

6.4 Conclusions

Eliminating or reducing Refining NZ jetty and associated structures is not considered the best practicable option given the significant costs and operational constraints that would result, and the very low level of adverse effects associated with the structures. Running the refinery with reduced jetty flexibility would make safe and steady operation of the plant challenging. Removing these structures will also have associated adverse environmental impacts from a marine ecology perspective.

7.0 Conclusions

Conclusions drawn from data and advice of experts as outlined within this report are that Refining NZ's current methods for discharges to air, sea, land, groundwater extraction and marine structures are effective, fit for purpose and considered the best practicable options. Table 7.1 summarises the alternatives assessed and resulting recommendations.

Table 7.1 - Alternative Assessment Summary

Existing Consent	**Current technology/ methodology**	**Alternatives Identified**	**Recommendations**
Discharge to air	SO_2 and stack opacity limits	- Install SO_2 scrubber - Reduce sulphur in fuel burnt -Install habitat around all blasting and painting operations	Maintain existing controls and limits
Discharge to water	Harbour outfall with limitations on volume and contaminant levels	Effluent water disposal to land, on or off site	Maintain existing discharge to harbour
Discharge to land	Allow for minor hydrocarbon egress to ground as a result of oil refinery operations	-Cease running oil refinery -Repair/ replacement of entire drain network	Maintain existing consented conditions + improve systems as the opportunity presents itself + maintenance?
Groundwater extraction	Pump and treat a limited volume of water. Used for groundwater depression purposes so free phase oil may be recovered and oil contaminated water does not leave site boundary	Various alternatives to pump and treat identified. Most capitally prohibitive, some options to use as add-ons to current method	Maintain existing methodology to control groundwater contamination
Occupation of marine area	Three jetties and dolphins	-Single Point Mooring -Demolish Jetty2 and 3 and operate on a single Jetty	Consider alternate measures to mitigate cultural effects as removal of the jetty is not considered practicable.

8.0 Appendices

8.1 Appendix A – Discharge to Air

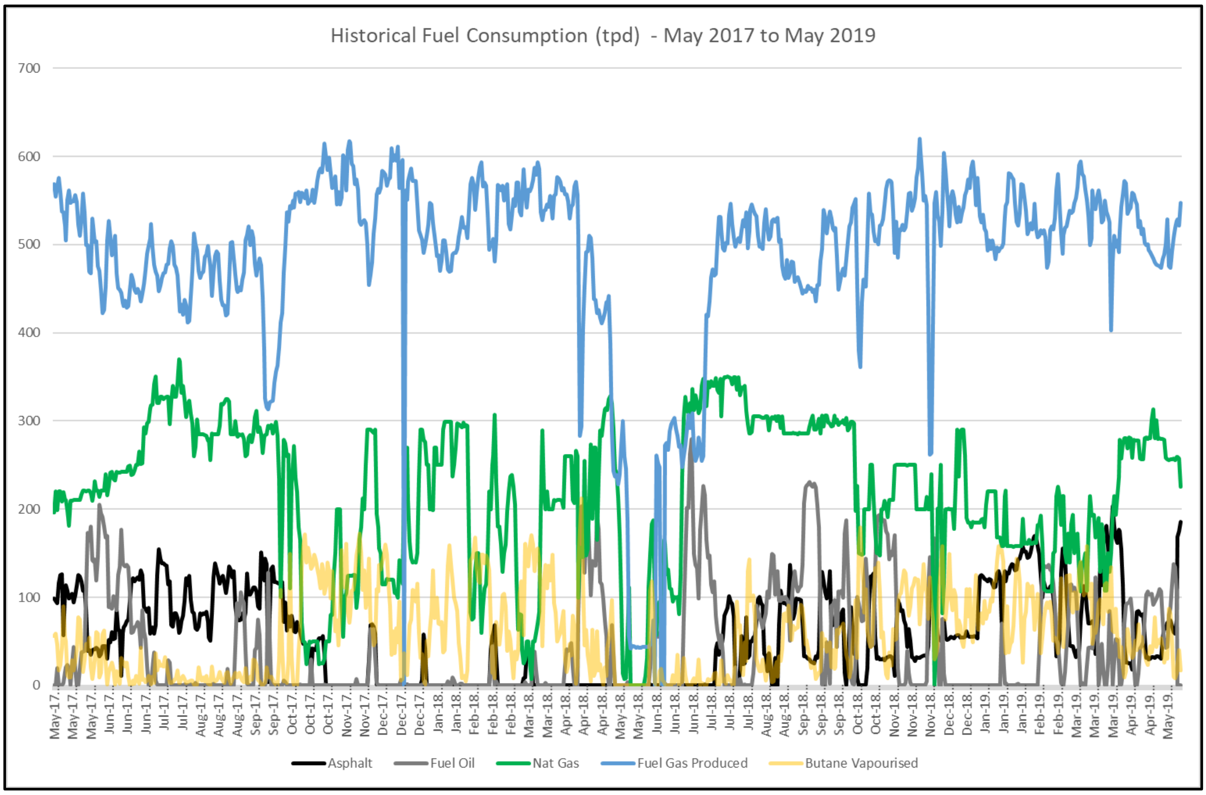

Figure A1 – Historical Fuel Consumption: May 2017 – May 2019

8.1.1 Appendix A1 – Worley/Shell SO2 scrubbing alternatives assessment

REFINING NEW ZEALAND

Comparison of Flue Gas Desulfurization Technologies

26 August 2019

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Synopsis

Worley was asked to provide a high-level feasibility matrix comparing Cansolv/Caustic/Unspecified Other (nonregenerative) flue gas desulfurization technologies, including rankings on a scale of 1 (best) to 3 (worst) in each of the following categories and brief explanations of the basis for the rankings.

Disclaimer

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PROJECT 401010-01563 - Comparison of Flue Gas Desulfurization Technologies -

Rev	Description	Original	Review	Worley Approval	Revision Date	Approval Date
Rev A	Issued for Review	B. DeWees	F. Bela	C. Anderson	23-Aug-19	
Rev B	Revised per RNZ Comments	B. DeWees	F. Bela	C. Anderson	26-Aug-19	
Rev 0	Final Issue	BD B. DeWees	FB F. Bela	CA C. Anderson	02-Sep-19	

Worley energy | chemicals | resources

EcoNomics

Table of Contents

Appendices

List of Tables

Worley
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EcoNomics

1. Executive Summary

A high-level feasibility matrix is provided in Table 1 comparing Cansolv/Caustic/Unspecified Other (nonregenerative) flue gas desulfurization technologies. The processes are ranked on a scale of 1 (best) to 3 (worst) in each category. Process descriptions and brief explanations of the basis for the rankings are provided in subsequent sections.

Table 1 – High-Level Feasibility Matrix

	Cansolv	Caustic	Other
Suitability of application in an oil refinery	1	1	3
Capex	3	1	2
Opex	1	2	3
Ease of operation	2	1	3
Environmental impact	1	2	3
Byproduct disposal	1	2	3
Reliability	2	1	3
Potential synergy	1	2	3
TOTAL	12	12	23

Cansolv and Caustic are similarly ranked in all categories, with the exception of Capex, in which Cansolv is expected to be the more expensive due to stainless steel construction. A more detailed analysis is recommended to choose which is the best fit for Refining New Zealand's specific site requirements.

Other technologies, such as lime, limestone, double-alkali or lime-spray drying are ranked lower than either Cansolv or Caustic in nearly all categories, suggesting they are likely not a good fit.

2. Introduction

Worley was asked to provide a high-level feasibility matrix comparing Cansolv/Caustic/Unspecified Other (nonregenerative) flue gas desulfurization technologies, including rankings on a scale of 1 (best) to 3 (worst) in each of the following categories and brief explanations of the basis for the rankings.

1. Suitability of application in an oil refinery
2. Capex
3. Opex
4. Ease of operation
5. Environmental impact
6. Byproduct disposal
7. Reliability
8. Potential synergy

3. Available Technology Overview

3.1 Cansolv

Cansolv (Shell/Comprimo) is a regenerable wet scrubbing system using an aqueous amine solution to absorb SO_2 from the flue gas stream. Regenerable processes typically absorb the SO_2 from the gas using some type of solvent and then regenerate the solvent, which is returned to absorb more SO_2, and produce a concentrated SO_2 stream which can be converted to elemental sulfur if the facility has a Claus sulfur recovery unit, sulfuric acid or liquid SO_2.

Regenerable processes do not produce a sludge, thereby avoiding problematic disposal. Most regenerable processes also:

- Generally, achieve high SO_2 removal efficiency, usually exceeding 90%
- Utilize the scrubbing reagent more efficiently than non-regenerable processes
- Employ non-fouling scrubbing liquors

The major drawback of these processes is increased complexity, capex and, in some cases, opex.

Other examples of regenerable wet scrubbing systems are Wellman-Lord (Davey Powergas), LABSORB (Dupont/Belco) and ClausMaster (Dupont/MECS).

In the Cansolv process, the flue gas is first water-quenched at around 60°C in a pre-scrubber that also removes SO_3 and some particulates. Next, the gas is contacted with the lean amine solution in a counter-current column where SO_2 is absorbed. The treated gas is discharged to atmosphere through a heated stack. The SO_2-rich amine from the absorber is pumped to the regeneration column via a lean/rich amine heat exchanger for energy recovery. The lean amine solution is regenerated by combined temperature increase and partial pressure reduction resulting from stripping stream generated by indirect heat transfer in the reboiler. Column overhead SO_2 is recovered as a pure, water-saturated product. Lean amine is pumped from the reboiler back to the absorber via the lean/rich amine heat exchanger and subsequent cooler. A slipstream of the amine is purified in the absorbent purification unit (APU), which consists of particulate filtration, activated carbon adsorption of soluble contaminants, and ion exchange to reject Heat Stable Salts (HSS).

The estimated delivery timeline of a fully installed Cansolv unit is between 2.5 and 3.5 years. Installation timing is normally aligned with the next major refinery turnaround.

3.2 Caustic

Caustic scrubbing is a non-regenerable wet scrubbing system employing clear aqueous sodium hydroxide solution. Sodium-based systems are favored over other non-regenerable wet scrubbing technologies (e.g. lime, limestone, and double-alkali) for treating flue gas from industrial boilers for the following reasons:

- Sodium alkali is the most efficient of the commercial reagents for SO_2 removal, and the chemistry is relatively simple.
- They are soluble (as opposed to slurry) systems, resulting in scale-free operation and fewer material-handling components.
- Such systems can handle the wider variations in flue-gas composition resulting from the burning of many different fuels by industry.
- The systems are often smaller, and operating costs are a small percentage of total plant costs.
- In some cases, these plants have a waste caustic stream available for use as the absorbent.

However, these systems have been applied to only a few large utility boilers because:

- The process consumes a premium chemical (NaOH) much more costly than calcium-based reagents.
- The liquid wastes contain highly soluble sodium salts, requiring large evaporation ponds for economic disposal.

SO_2 reacts with caustic to primarily form sodium sulfite (Na_2SO_3) and sodium bisulfite ($NaHSO_3$):

$$2NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$$

$$NaOH + SO_2 \rightarrow NaHSO_3$$

$$Na_2SO_3 + SO_2 + H_2O \rightarrow 2NaHSO_3$$

Potential SO_3 also forms sodium sulfate:

$$2NaOH + SO_3 \rightarrow Na_2SO_4 + H_2O$$

Some sodium sulfite is also subsequently oxidized to sulfate:

$$2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4$$

The spent caustic solution may be routed to the refinery waste water treatment system.

3.3 Other Technologies

Other alkaline non-regenerable wet scrubbing processes generate a product which is either disposed of as waste or sold as a by-product. The three most common processes used on utility boilers in the U. S. are lime, limestone, and double-alkali. Although the double-alkali process regenerates the scrubbing reagent, it still generates a non-saleable solid by-product which must be land-filled.

Lime-spray drying (LSD) is a dry scrubbing process generally used for low-sulfur coal. Flue gas is contacted concurrently in an absorber with atomized lime slurry droplets, simultaneously cooling the gas by partial water evaporation. SO_2 is initially absorbed by virtue of its solubility in water, then reacts with the fine lime particles without forming free acids. The desulfurized flue gas, along with reaction products, unreacted lime and fly ash, passes out of the dry scrubber to a baghouse filter and/or electrostatic precipitator (ESP) prior to atmospheric exhaust.

4. Evaluation Criteria

4.1 Suitability of application in an oil refinery

Cansolv (1)

- Cansolv is used at several refineries.

Table 2 – Examples of Cansolv Oil & Gas (Refinery) Applications

Application	Location	Start-up	Flow rate (m^3/hr)	Feed Gas SO_2	SO_2 emissions (mg/Nm^3)	Notes
Oil & Gas Application						
SAP	USA	2002	40,000	0.35-0.50 %	50	
Sulfur Recovery Unit	USA	2006	20,000	4 %	400	
Fluid Coker	USA	2006	430,000	2,000 ppmv	80	
FCC	USA	2006	740,000	800 ppmv	80	
Fluid Coker and FCC	USA	2011	575,000	1,200 ppmv	30	With combined absorber for FCCU offgas and Coker offgas
Residue Fuel Fired Boiler	India	2012	1,550,000	3,000 ppmv	400	
Residue Fuel Fired Cogen Unit	Iraq	2014	1,050,000	8,400 ppmv	500	
FCC	China	2014	200,000	800ppmv	140	With combined absorber for FCCU offgas and SRU tail gas treatment
Sulfur Recovery Unit	Italy	2015	65,000	200ppmv	50	
Sulfur Recovery Unit	China	2017	7,000	10,500 ppmv	80	
Sulfur Recovery Unit	Oman	2019	100,000	4,500ppmv	50	
Sulfur Recovery Unit	China	2018	72,000	0.79 %	70	With multiple absorbers and combined regenerator
Sulfur Recovery Unit	China	2019	55,000	1.036 %	70	
Sulfur Recovery Unit	China	2019	2,000	0.93 %	100	
Sulfur Recovery Unit	China	2019	50,000	0.36 %	100	
Sulfur Recovery Unit	China	2019	11,500	0.1113 %	100	
Sulfur Recovery Unit	China	2020	62,000	0.805 %	35	
SAP	China	2019	65,000	0.14 %	50	
Resids Boiler	Russia	2020	1,300,000	0.21 %	200	

- Oil refineries typically have Sulfur Recovery Units (SRU) which can accept the regenerated SO_2
- Oil refineries typically have Waste Water Treating facilities that can handle the effluent

Caustic (1)

- Oil refineries typically use caustic for other purposes and may even have a waste partially-spent caustic stream available for use as the absorbent
- Oil refineries typically have Waste Water Treating facilities that can handle the effluent

Other (3)

- Other non-regenerable wet / dry scrubbing processes produce a product which is either disposed of as waste or sold as a by-product. Oil refineries typically do not handle these products, so additional infrastructure may be required.
- Other non-regenerable wet / dry scrubbing processes are typically used for larger utility boilers, not small industrial boilers.

4.2 Capex

Considering the materials and quantity/type of equipment:

- Flue-gas handling – Accomplished with inlet and outlet ductwork, dampers, fans, and stack gas reheaters
- Quench – Accomplished with scrubbers, heat exchangers and circulation pumps
- Absorption – Accomplished with scrubbers and circulation pumps
- Regeneration – Accomplished with columns, heat exchangers and circulation pumps
- Absorbent purification – Accomplished with particulate filtration, adsorption of soluble contaminants via activated carbon, and rejection of soluble contaminants via ion exchange resin
- Chemical storage – Accomplished with tanks
- Lime handling and slurry preparation/storage – Accomplished with lime unloading and storage equipment, lime processing and slurry preparation and storage equipment
- Sludge processing – Accomplished with sludge clarifiers for dewatering, sludge pumps and handling equipment, and sludge solidification equipment

Cansolv (3)

- Highest => US$100m to US$180m
- Flue gas handling, quench, absorption, regeneration and absorbent purification
- Stainless steel

Caustic (1)

- Lowest => US$50m to US$80m
- Least equipment: Flue gas handling, absorption, chemical storage
- Carbon steel or fiber reinforced plastic

Other (2)

- Median $$ => US$80 to US$120m
- Most equipment: Flue gas handling, absorption, lime handling and slurry preparation/storage, sludge processing
- Carbon steel or fiber reinforced plastic

4.3 Opex

Considering chemical and energy consumption as well as maintenance requirements:

Cansolv (1)

- Lowest $
- Low chemical consumption (intermittent makeup only)
- Continuous low-cost LP steam consumed for regeneration

Caustic (2)

- Middle $$

- Continuous chemical consumption

Other (3)

- Highest $$$
- Continuous chemical consumption
- Higher-maintenance sludge handling equipment

4.4 Easy of Operation

Cansolv (2)

- Similar to a typical refinery amine unit

Caustic (1)

- Less equipment than Cansolv

Other (3)

- Sludge handling equipment may be prone to operating / maintenance problems and is not typical in refineries.

4.5 Environmental Impact

Considering feed chemical and by-product inventory and transportation requirements (potential for spills):

Cansolv (1)

- Low chemical inventory

Caustic (2)

- Large chemical inventory
- Frequent chemical delivery

Other (3)

- Large chemical inventory
- Frequent chemical delivery
- By-product transportation and disposal

4.6 By-product Disposal

Cansolv (1)

- Aqueous solution of sulfur dioxide (sulfurous acid) from Pre-Scrubber/Quench Tower and Regenerator reflux purge may be routed to the refinery waste water treatment system following neutralization.

- Aqueous solution of sodium sulfate, sodium sulfite, sodium hydroxide and amine from amine Purification Unit (APU) may be routed to the refinery waste water treatment system. Relatively small flow.
- Spent resin, carbon and filters replaced approximately every six months may be disposed of in a landfill.

Caustic (2)

- The spent caustic solution (aqueous solution of sodium sulfate and sodium hydroxide) may be routed to the refinery waste water treatment system. Relatively large flow.

Other (3)

- A small blowdown from the process filtrate is required to remove chloride from the process, which may be routed to the refinery waste water treatment system or disposed of in a landfill or onsite pond.
- The dewatered gypsum ($CaSO4{\cdot}2H2O$) product is transported to an offsite user or landfill.

4.7 Potential Synergy

Cansolv (1)

- Regenerated SO2 can be routed to the existing SRU, increasing sulfur recovery capacity / efficiency by reducing air demand.
- Same Cansolv solution can also recover SO_2 from incinerated SRU tail gas for 99.99% overall sulfur recovery.

Caustic (2)

- Oil refineries typically use caustic for other purposes and may even have a waste caustic stream available for use as the absorbent.

Other (3)

- None

5. Conclusions/Discussion

A summary of the above rankings is provided in Table 3.

Table 3 – High-Level Feasibility Matrix

	Cansolv	Caustic	Other
Suitability of application in an oil refinery	1	1	3
Capex	3	1	2
Opex	1	2	3
Ease of operation	2	1	3
Environmental impact	1	2	3
Byproduct disposal	1	2	3
Reliability	2	1	3
Potential synergy	1	2	3
TOTAL	12	12	23

Cansolv and Caustic are similarly ranked in all categories, with the exception of Capex, in which Cansolv is expected to be the more expensive due to stainless steel construction. A more detailed analysis is recommended to choose which is the best fit for Refining New Zealand's specific site requirements.

Other technologies, such as lime, limestone, double-alkali or lime-spray drying are ranked lower than either Cansolv or Caustic in nearly all categories, suggesting they are likely not a good fit.

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Appendix A. Cansolv Non-Confidential Proposal

Shell Catalysts & Technologies

CANSOLV SO_2 Post Combustion Unit

Technical Proposal

Refining New Zealand

NON-CONFIDENTIAL

DATE: 23 AUG 2019

DOCUMENT NO.: **RNZ_NCP_DS**

DEPT/SECT.: GAS PROCESSING

VERSION CONTROL

0	23 Aug 19	Version sent to client	LW/KT	WB	IC
B	22 Aug 19	Updated after internal review	LW/KT	WB	
A	20 Aug 19	Draft for internal review	LW/KT	WB	
REV.	**DATE**	**DESCRIPTION**	**PREPARED**	**CHECKED**	**APPROVED**

Shell Catalysts & Technologies

CONTENTS

Disclaimer

This Technical Proposal is based on the assumptions that Shell's standard terms and conditions would apply to the scope of supply presented herein. The Proposal does not constitute an "offer" and is subject to mutual agreement. Until the time that a final contract is signed, either party may close discussions for any reason with no liability to the other.

1 INTRODUCTION

This non-confidential technical proposal is provided for the purpose of evaluating the option to pursue further the application of Shell Catalysts & Technologies' (Shell C&T) CANSOLV SO_2 Technology for Refining New Zealand's (RNZ) facilities in Whangarei.

This proposal is based on the Request for Technical Proposal received from Worley (c/o Advisian) on 26th July 2019.

This non-confidential proposal contains the following technical information:

- ✓ Project Premises (including any assumptions made at this stage)
- ✓ General Process Description
- ✓ Typical PFDs
- ✓ Major Equipment Summary Sheet for selected equipment & estimated plot plan
- ✓ Utility & Chemical Consumption Estimates
- ✓ Reference List (indicating where similar line-ups have been implemented)

Once RNZ has evaluated and accepted the feasibility of the proposed application, Shell and RNZ (and its contractors) will be required to execute a Non-Disclosure Agreement (NDA) to allow:

- ✓ Shell to gather other required details to proceed with a Basic Design Package for the next engineering phase. The scope of this is outlined in Section 5.
- ✓ RNZ to receive confidential technical information regarding the technology and additional details of the proposed design.

Shell would provide a Basic Design Package (BDP) which also includes Mandatory Services and Activities up to the Performance Test Run of the unit. As Shell has an existing Technical Services Agreement (TSA) with RNZ, the scope of services will be discussed separately.

2 PROJECT PREMISES

The following information was taken from the "Refining New Zealand Request for Technical Proposal" document, dated 25th July 2019, received by Shell on 26th July 2019 and any subsequent information received in emails and/or verbal discussions.

2.1 DESIGN BASIS

2.1.1 UNIT CONFIGURATION

As requested by RNZ, Shell had evaluated the preferred configuration (Option 1) of having a single CANSOLV Flue Gas Treatment unit for the combined flue gases streams.

Based on the gas compositions provided, Shell confirms that it is feasible to have a combined CANSOLV flue gas treatment unit as this provides simplicity in configuration and optimization of the overall cost.

For such a configuration, it is critical to have the flue gas ducting and induced draught (ID) fans between the various sources and the CANSOLV unit to be designed properly using the shortest possible length.

Based on the Site Plot Plant provided, the proposed CANSOLV Absorber location is ~200m away in from the multi-stack location in the Block A location.

The location of the Stripper/Regenerator is not specified in the provided plot plan but is recommended to be as close as possible to the SRU units where the recovered SO_2 is intended to be utilized.

The relative location of the various equipment can be discussed further during next stage of the project. A simplified block flow diagram is shown below

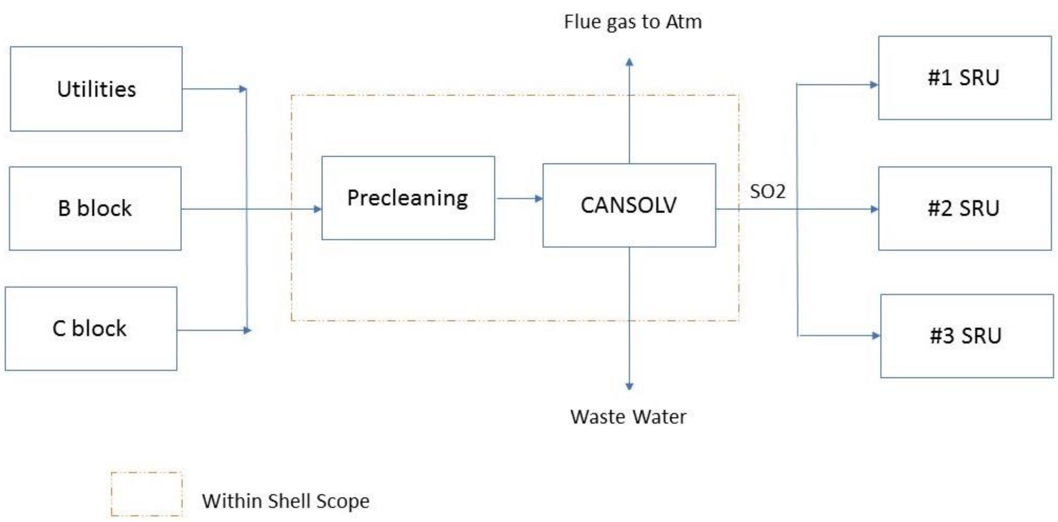


Figure 1: Flue gas treatment Block Flow Diagram

2.1.2 FEED GAS

The conditions and composition for the combined flue gas is provided as below:

Table 1: Flue Gas Specification (1)

	Unit	Combined Case
Temperature	℃	213.8
Pressure	kPag	~7(2)
Flowrate	kmol/hr	20507.243
Gas Composition		
H_2	kmol/hr	12.021
N_2	kmol/hr	15462.613

O_2	kmol/hr	1400.528
CO_2	kmol/hr	1576.396
H_2O	kmol/hr	2022.658
SO_2	kmol/hr	23.300
NO_2	kmol/hr	2.596
Ar	kmol/hr	7.131
Dust	mg/Nm3	15
SO_3	ppmv	< 25

Notes:

(1) The design basis needs to be confirmed at the next stage of the project.

(2) Minimum pressure requirement at the CANSOLV battery limit, this will be finalized during the design development.

2.1.3 SO_2 SPECIFICATIONS

The CANSOLV SO_2 Scrubbing System will be designed to meet the required SO_2 emission specification of less than 0.5 ton/day (98.6% SO_2 removal), no further allowance for tightening of this specification in the future is included as confirmed by Worley.

Shell is prepared to offer this as a process guarantee.

2.1.4 UTILITIES

The following utility conditions are used in the estimates

Table 2: Utilities Conditions

		Unit
Cooling water inlet/outlet Temperature	26/40	℃
Demin Water(1)	atm	℃
Saturated LP Steam Pressure	350	kPag

Notes:

(1) Equivalent water quality from the site to be confirmed in the next phase.

2.2 ASSUMPTIONS USED

2.2.1 ENVIRONMENTAL SPECIFICATIONS

Table 3: Environmental Conditions

		Unit
Location	New Zealand	
Ambient Pressure	101.325	kPa

2.2.2 CONTAMINANTS IN THE FLUE GAS

The following has been assumed for contaminants at CANSOLV System:

- Chlorides and fluorides concentrations are NIL. The actual Cl/F concentration should be validated at the next stage of engineering as this may result in a higher metallurgy requirement for the CANSOLV process.
- NO_2 concentration is assumed to be 10% of actual NOx concentration in line with experience in other CANSOLV units. The actual NO_2 concentration should be validated at the next stage of engineering as this may have an incremental impact on the APU size and related consumables.
- Assume residual sulphur species (H_2S, COS, CS_2) are NIL due to proper combustion. The actual concentration of residual sulphur species (H_2S, COS, CS_2) should be validated at the next stage of engineering as this may have an incremental impact on the APU size, related consumables and liquid waste generation.
- Organic compounds in the flue gases are assumed to be NIL.
- The component “Dust” in Table 1 represent particulate matter. As clarified by Worley in correspondence

  “[Existing flue gas] pre-treatments unknown, but stack samples when firing fuel gas (not liquid fuel) indicate PM2.5 about 5 mg/Nm3 (dry) and TSP about 10-15 mg/Nm3.”
- As most of the various furnaces can process different fuel sources, the composition provided above represents the worst flue gas quality that can be simultaneously emitted by the various furnaces.

2.2.3 MANAGEMENT OF EFFLUENTS

All effluents are assumed to be managed by existing treatment facilities on site.

2.2.4 USE OF COOLING WATER

For the purpose of this proposal, cooling water is used as the preferred medium due to:

- Plot plan constraints
- Minimize absorbent circulation rates

The current estimated plot area for the entire CANSOLV unit is around 1800 m2, assuming all equipment are co-located.

Further optimization options include combining the Pre-scrubber and CANSOLV Absorber in one shell, as done in some of the reference locations.

Heat exchanger duties are provided to allow Worley/RNZ to make estimates for the use of air cooling as an option.

3 GENERAL PROCEES DESCRIPTION

The CANSOLV SO_2 Flue Gas Treating Unit mainly consists of:

- a gas pre-cleaning section;
- an absorption section;

- a regeneration section, and;
- an Absorbent Purification Unit (APU)

3.1 PRE-CLEANING

The combined flue gas is first sent to pre-cleaning tower before contacting with the CANSOLV Absorbent. The flue gas is contacted with recycled water and quenched to saturation conditions (approximately 60°C) in a scrubber that also removes part of dust and SO_3. The pre-scrubber re-circulating water stream is partially purged to remove the captured dust and SO_3.

The pressure drop of the pre-cleaning system is typically 4.0 kPa. The pressure drop across the CANSOLV SO_2 Absorber is about 3.0 kPa under the design condition. Hence, the total pressure drop of the CANSOLV SO_2 Scrubbing System will be approximately 7.0 kPa.

Depending on the duct routing and the stack strategy, the discharge pressure of the ID fans will be confirmed during next stage.

3.2 SO_2 ABSORPTION

The gas leaving the pre-cleaning tower will enter the CANSOLV absorber. In this absorber, it will be contacted counter-currently with the CANSOLV absorbent, which will absorb the SO_2 contained in the gas.

In the absorber, SO_2 will be absorbed from the feed gas by contacting with the CANSOLV absorbent. As the CANSOLV Absorbent reacts reversibly with SO_2, multi-stage counter current contacting is used to achieve maximum SO_2 loading of the rich absorbent. Lean cool absorbent will be fed to the top of the absorber and absorb SO_2 as it flows down the column counter current to the feed gas. A caustic polishing section is designed to further remove SO_2 with a circulate a dilute wash water containing caustic. The polishing section will use a single bed depth of structured packing in a counter-current contacting arrangement similar to the SO_2 absorption section. A chimney tray will be used to allow the flow of gas up from the absorption section while serving as both a liquid isolation device and a sump for recirculation via a water recirculation pump.

The design of the SO_2 absorber is a simple design which is equipped with 3 internals i.e. the liquid distributors and packing, as well as a mist eliminator. Structured packing is normally selected for the SO_2 absorber due to its low pressure drop and high gas capacity. The simplicity of this design ensures minimum maintenance and operating costs, and maximum reliability.

The absorbent losses at the stack are low in the CANSOLV SO_2 Scrubbing System. Losses from evaporation do not occur because the absorbent is in salt form in solution. Absorbent losses via entrainment are minimized by:

- Application of chevron type mist eliminator installed at the top of the absorber
- Application of trough type distributors instead of spray nozzles to distribute the absorbent over the packing.

3.3 SO_2 REGENERATION

The regeneration section of the CANSOLV system comprise of the lean-rich heat exchanger, the regenerator, reboiler and condenser, as well as associated pumps and tanks.

The stripper is a packed tower containing two beds of structured packing; a lower section of packing handling the SO_2 stripping and the upper packed section for reflux rectification. Structured packing will be used in order to achieve high mass transfer efficiency and a low pressure drop.

The SO_2-rich absorbent will be pumped to the regeneration column via the lean/rich heat exchanger (where sensible heat is recovered from the lean absorbent).

As the rich absorbent flows down the regeneration column, SO_2 will be stripped by vapour rising countercurrently. This vapour will be generated at the base of the column in steam-heated reboilers. Low pressure steam is used due to its low temperature which helps minimize absorbent degradation and SO_2 disproportionation.

The rising vapour will exit the top of the column loaded with the stripped SO_2. It will then be cooled in a condenser, where most of the water vapour will condense. Gas and liquid will be separated in the reflux accumulator: the gaseous SO_2 exiting the CANSOLV system at positive pressure of ~0.60 barg for downstream handling, while the SO_2 saturated water will be sent back as reflux to rectification section of the regeneration column.

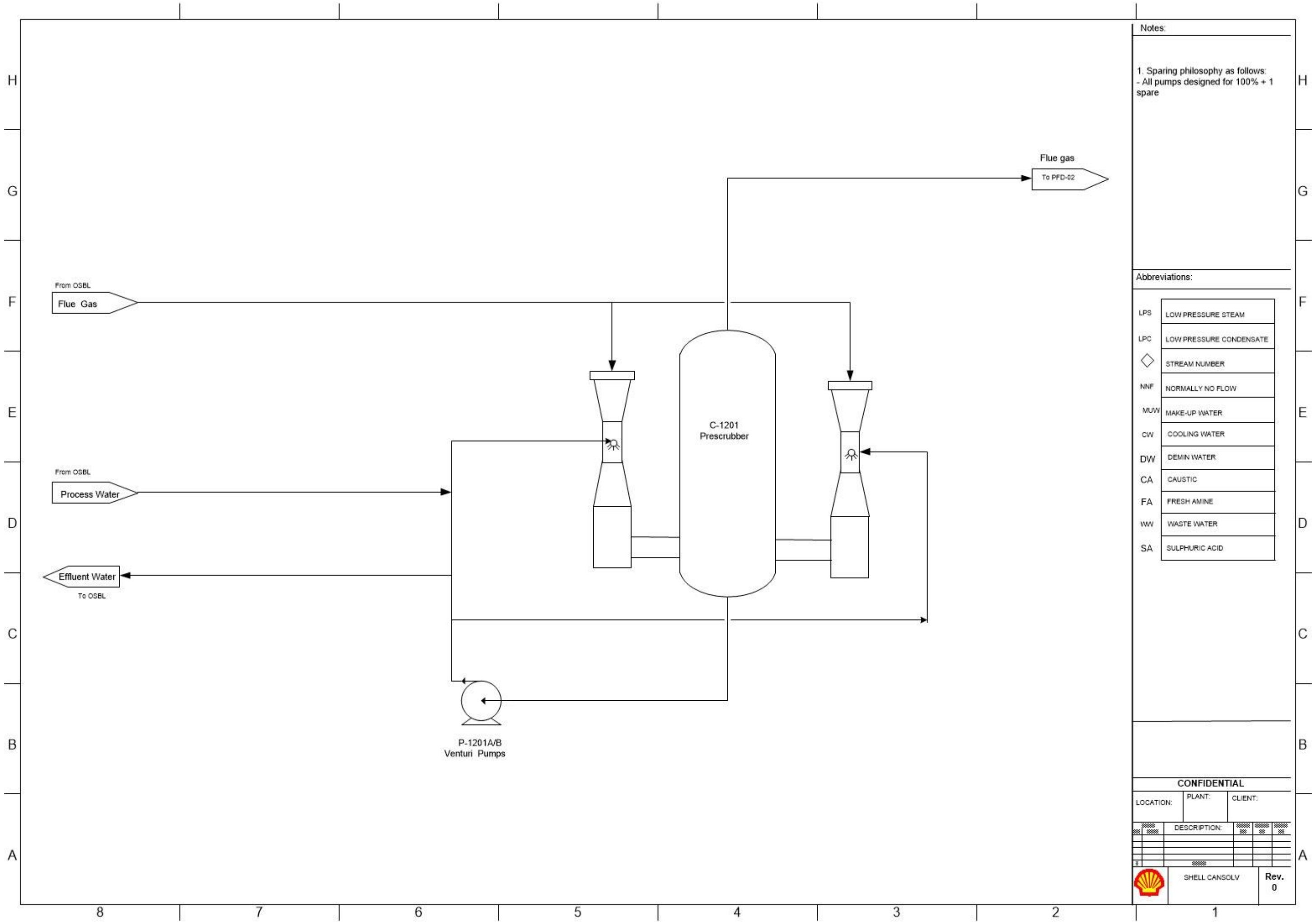
The lean absorbent leaves the Stripper sump and is pumped to the Lean Absorbent Tank via the Lean/Rich Exchanger and the Lean Absorbent Cooler. It is then pumped to the SO_2 Absorber Tower from the Lean Absorbent Tank by the Absorbent Feed Pump. A slipstream of this lean absorbent will be treated in the Absorbent Purification Unit.

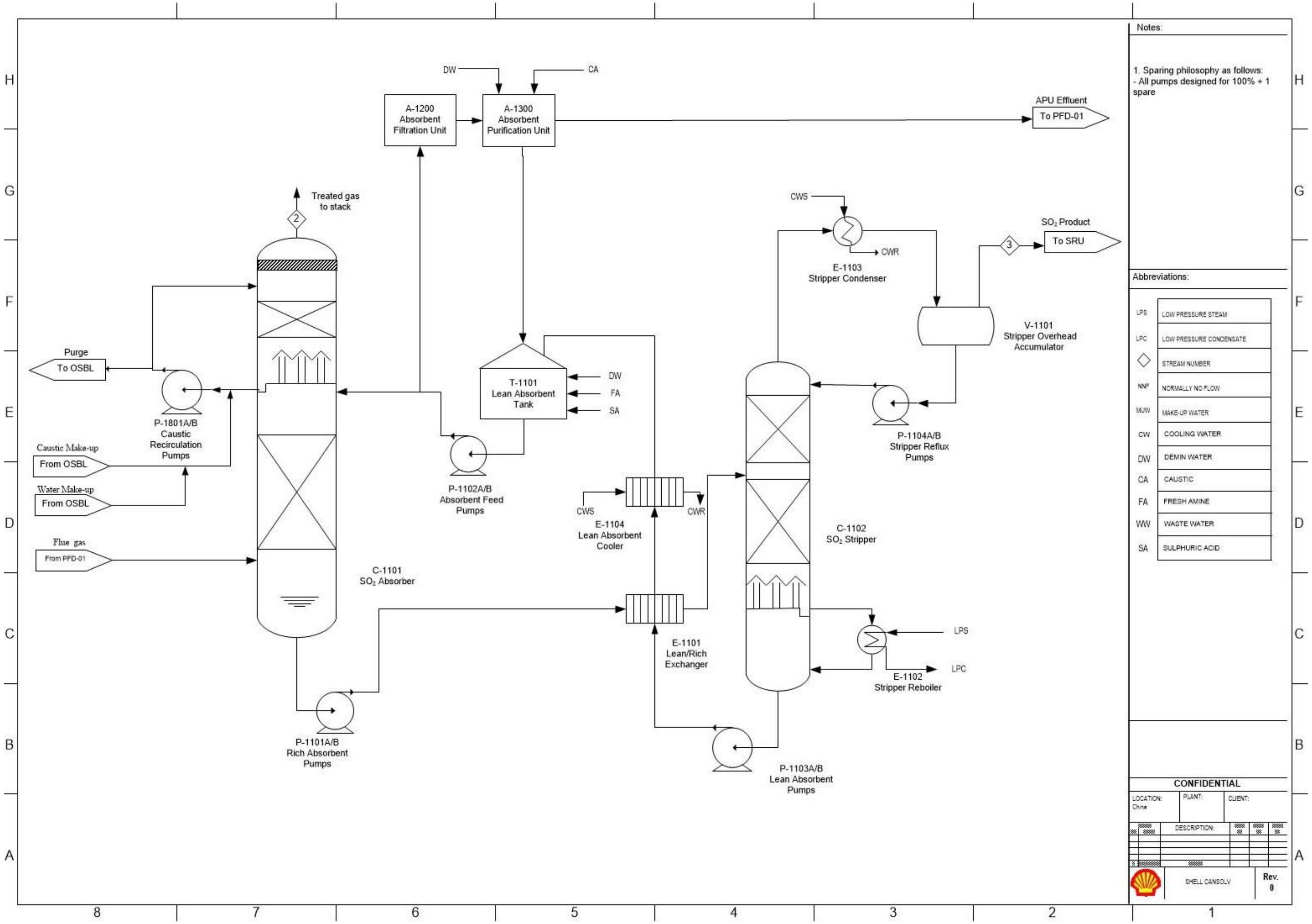
3.4 ABSORBENT PURIFICATION UNIT (APU)

The absorbent in the CANSOLV SO_2 Scrubbing System accumulates non-regenerable salts (referred to as Heat Stable Salts a.k.a. HSS), and it will capture a fraction of the dust contained in the gas. These contaminants must be removed from the absorbent continuously to avoid excessive build-up. This is achieved by treating a slipstream of the lean absorbent in the Absorbent Purification unit, which consists of an absorbent filtration unit (AFU) for the removal of suspended solids and activated carbon filtration, and ion exchange units (IX) for the removal of HSS. A slipstream of the lean absorbent will first be treated in the AFU. The filtered absorbent will then be sent to the IX unit to remove the HSS.

The APU will be operated in batch. Resin End of Run (EOR) conditions have been assumed for the resin performance to simulate worst case scenario for caustic, demineralized water consumption and waste generation.

4 TYPICAL CANSOLV PROCESS FLOW DIAGRAM




DW
CA
A-1200 Absorbent Filtration Unit
A-1300 Absorbent Purification Unit
APU Effluent
To PFD-01
Treated gas to stack
2
CWS
CWR
E-1103 Stripper Condenser
SO₂ Product
To SRU
3
V-1101 Stripper Overhead Accumulator
Purge
To OSBL
P-1801A/B Caustic Recirculation Pumps
T-1101 Lean Absorbent Tank
DW
FA
SA
P-1104A/B Stripper Reflux Pumps
Caustic Make-up
From OSBL
Water Make-up
From OSBL
P-1102A/B Absorbent Feed Pumps
E-1104 Lean Absorbent Cooler
C-1102 SO₂ Stripper
Flue gas
From PFD-01
C-1101 SO₂ Absorber
LPS
LPC
E-1101 Lean/Rich Exchanger
E-1102 Stripper Reboiler
P-1101A/B Rich Absorbent Pumps
P-1103A/B Lean Absorbent Pumps
Notes:
1. Sparing philosophy as follows:
- All pumps designed for 100% + 1 spare
Abbreviations:
LPS LOW PRESSURE STEAM
LPC LOW PRESSURE CONDENSATE
STREAM NUMBER
NNF NORMALLY NO FLOW
MUW MAKE-UP WATER
CW COOLING WATER
DW DEMIN WATER
CA CAUSTIC
FA FRESH AMINE
WW WASTE WATER
SA SULPHURIC ACID
CONFIDENTIAL
LOCATION: China
PLANT:
CLIENT:
DESCRIPTION:
SHELL CANSOLV
Rev. 0

5 UTILITY, EQUIPMENT & CHEMICALS/EFFLUENT SUMMARY

The Pre-cleaning and CANSOLV system use the following utilities:

5.1 LOW-PRESSURE STEAM

Low pressure steam (3.5 barg) is used to heat the absorbent in the stripper reboiler, and thus generate stripping vapor.

5.2 COOLING WATER

Cooling water has been assumed to be supplied at 26□C and returned at 40□C. it is used mainly to cool the absorbent sent to the absorber and the Overhead SO_2 stream.

5.3 ELECTRICAL POWER

It is used to drive the pumps that circulate the absorbent in the Precleaning and CANSOLV system.

5.4 CAUSTIC SODA (NAOH)

It is used in the caustic polisher section and APU to regenerate the Ion Exchange column used for Heat stable Salts removal. 4% caustic is used in the IX column, obtained by dilution of membrane grade caustic.

5.5 DEMINERALIZED WATER

It is used to wash the APU Ion Exchange columns between salt loading and regeneration cycles and maintain the water balance of the CANSOLV system.

5.6 PROCESS WATER

It is used as make-up water in the pre-cleaning unit.

The estimated requirements for utilities & chemicals for the Pre-cleaning and CANSOLV unit described in this proposal are given in the table below.

Table 4: Estimated Consumed Utilities & Chemicals Summary

Utility/Chemical Summary	Unit	Case
CANSOLV Absorbent DS initial Fill (48wt%)	MT	100
APU Resin (Anionic)	m3/yr	10.8
Inert Resin	m3/yr	1.8
Power & Electrical Load	kWh/h	1040
Demineralised Water [1]	ton/hr	19
Process Water	ton/hr	42.0
Steam (3.5 barg) [2]	ton/hr	33
Cooling Water [3]	m3/hr	1,170
Caustic (100 wt%)	kg/hr	155
Absorbent Make-up (48wt%) [4]	tons/year	20

NOTES:

[1] Demin Water could be saved by ~35% by using stripped reflux from the SO2 stripper.

[2] With DESF heat recovery option for CANSOLV unit, steam saving is approximately 25% of the values in base line-up. Steam consumption may be reduced by up to 50% by use of MVR configuration with additional power consumption. This should be evaluated at the next phase of the project.

[3] If only air cooling could be considered for the Overhead Condenser, significant savings in cooling water requirements can be realized. This should be evaluated at the next phase of the project as there would be a tradeoff in plot space requirements.

[4] Depending on the concentration of the impurities, the makeup absorbent to compensate for annual losses can range from ~10-25% per year of the initial absorbent inventory. At this stage of the project 20% is assumed.

6 MAJOR EQUIPMENT SUMMARY

The estimated sizes of the major equipment within CANSOLV SO2 Scrubbing System battery limits are provide in the table below. These estimates are based on proposal level accuracy and cannot be used to design the unit.

Table 5: Preliminary Equipment List

Equip. No.	Columns	Num.	Diam (m)	Height (m)	Material	Notes
C-1201	Venturi	2	3.0	14	254SMo	
	Pre-scrubber	1	8.5	23	254SMo/ FRP/ or Concrete with lining	
C-1101	SO2 Absorber	1	9.4	22	316L SS/ FRP/ or Concrete with lining	Packed Tower. Cold stack height not included as this will be based on local regulations.
C-1102	SO2 Stripper	1	2.6	18	316L SS	Packed Tower
Heights of towers to be confirmed during BDP Phase						

Equip. No.	Vessels & Tanks	Num.	Diam (m)	Height (m)	Material	Notes
V-1101	Stripper Overhead Accumulator	1	1.2	3.8	316L SS	
T-1101	Lean Absorbent Tank	1			316L SS	Dimensions will be based on total absorbent inventory.

Equip. No.	Heat Exchangers	Num.	Duty (GJ/ hr)	Type	Material	Notes
E-1101	Lean/Rich Exchanger	1		Plate & Frame	316L SS	Shell has the experiences for both Plate type and Shell & Tube heat exchangers. The type of each heat exchanger will be determined during the next stage of the project.
E-1102	Stripper Reboiler	1		Shell & Tube	316L SS	
E-1103	Stripper Condenser	1		Shell & Tube	316L SS	
E-1104	Lean Absorbent Cooler	1		Plate & Frame	316L SS	

Equip. No.	Pumps	Num.	Normal Flow (m3/hr)	Material	Notes
P-1101 A/B	Rich Absorbent Pumps	2	100	316L SS	A/B denotes running and installed spare.
P-1102 A/B	Absorbent Feed Pumps	2	100	316L SS	
P-1103 A/B	Lean Absorbent Pumps	2	100	316L SS	
P-1104 A/B	Stripper Reflux Pumps	2	25	316L SS	
P-1201 A/B	Venturi Pumps	2	800	F46	
P-1801 A/B	Caustic Pumps	2	680	316L SS	

Equip. No.	Packed Equipment	Num.	Notes
A-1200	Lean Absorbent Filter	1	Feed flow estimate 54 m3/hr, to be confirmed
A-1300	Absorbent Purification Unit	1	Proprietary Equipment supplied by Shell approved vendor

7 REFERENCES

The following table shows the current CANSOLV SO_2 Unit applications.

Table 6: Part of CANSOLV references

Application	Location	Start-up	Flow rate (m^3/hr)	Feed Gas SO_2	SO_2 emissions (mg/Nm^3)	Notes
Oil & Gas Application						
SAP	USA	2002	40,000	0.35-0.50 %	50	
Sulfur Recovery Unit	USA	2006	20,000	4 %	400	
Fluid Coker	USA	2006	430,000	2,000 ppmv	80	
FCC	USA	2006	740,000	800 ppmv	80	
Fluid Coker and FCC	USA	2011	575,000	1,200 ppmv	30	With combined absorber for FCCU offgas and Coker offgas
Residue Fuel Fired Boiler	India	2012	1,550,000	3,000 ppmv	400	
Residue Fuel Fired Cogen Unit	Iraq	2014	1,050,000	8,400 ppmv	500	
FCC	China	2014	200,000	800ppmv	140	With combined absorber for FCCU offgas and SRU tail gas treatment
Sulfur Recovery Unit	Italy	2015	65,000	200ppmv	50	
Sulfur Recovery Unit	China	2017	7,000	10,500 ppmv	80	
Sulfur Recovery Unit	Oman	2019	100,000	4,500ppmv	50	
Sulfur Recovery Unit	China	2018	72,000	0.79 %	70	With multiple absorbers and combined regenerator
Sulfur Recovery Unit	China	2019	55,000	1.036 %	70	
Sulfur Recovery Unit	China	2019	2,000	0.93 %	100	
Sulfur Recovery Unit	China	2019	50,000	0.36 %	100	
Sulfur Recovery Unit	China	2019	11,500	0.1113 %	100	
Sulfur Recovery Unit	China	2020	62,000	0.805 %	35	
SAP	China	2019	65,000	0.14 %	50	
Reside Boiler	Russia	2020	1,300,000	0.21 %	200	

Application	Location	Start-up	Flow rate (m^3/hr)	Feed Gas SO_2	SO_2 emissions (mg/Nm^3)	Notes
Metallurgical & Chemicals Application						
Zinc Smelter	Canada	2002	4,000	7 - 10 %	300	
Sulphur Recovery Unit	Belgium	2002	12,000	0.6 - 1.0 %	30	With combined absorber for waste tar flue gas and SRU tail gas treatment
Lead Smelter	India	2005	35,000	0.1 - 12 %	500	
Spent Catalyst Roaster	Canada	2008	50,000	9,000 ppmv	500	
Sinter Machine	China	2009	550,000	2,200 ppmv	150	
Sinter Machine	China	2009	550,000	2,200 ppmv	150	
Lead Smelter and SAP	China	2010	60,000	0.1 - 10 %	400	With multiple absorbers and combined regenerator
Ferric Ball Sinter Machine	China	2010	300,000	2,400 ppmv	400	
Single Absorption SAP	USA	2011	130,000	3,500 ppmv	200	
Tin Smelter and SAP	China	2012	150,000	0.6 - 1.0 %	400	With combined absorber for smelting offgas and SAP tail gas treatment
Mo Smelter and SAP	China	2014	160,000	1514 ppmv	200	With multiple absorbers and combined regenerator
Tin Smelter	China	2016	350,000	4600 ppmv	200	
Rare Earth and SAP	China	2017	40,000	1.75%	200	With combined absorber for smelting offgas and SAP tail gas treatment
Zinc & Indium SAP	China	2019	141,000	8900 ppmv	200	
Coal to Chemicals SRU	China	2019	6,740	0.6%	100	
Power Application						
Coal Fired Boiler	China	2009	960,000	4,000 ppmv	400	
Coal Fired Power Plant	China	2013	5,200,000	4,000 ppmv	400	
Coal Fired Power Plant	Canada	2014	650,000	900 ppmv	50	

8.2 Appendix B – Discharge to Water

8.2.1 Appendix B1 - GWS Limited – Discharge to Land Cost Estimate

14th October 2019

Refining NZ
Private Bag 9024
Whangarei 0148
New Zealand

Attention: Jane Thomson

Subject: Refining NZ Alternative Options Assessment – Discharge of Water to Land

Dear Jane,

1. Introduction

Refining NZ are in the process of applying for a range of new resource consents for the continued operation of the Marsden Point Refinery. One of these consents permits the discharge of 8,000 m^3/d treated wastewater at the coastline via a diffuser and, under heavy rainfall, a directed ocean outfall. The wastewater stream is a combination of process water (including de ballast water and tank wash water) and groundwater. Section 105 of the RMA requires councils to have regard to any possible alternative methods of discharge, including discharge into any other receiving environment, when considering a discharge or coastal permit application. To this end, Refining NZ have engaged GWS Limited to undertake a high-level assessment of the alternative option of irrigating up to 8,000 m^3/d of treated wastewater to land. This letter report evaluates the feasibility, potential effects and indicative cost of implementing such an option.

2. Land Application Feasibility

2.1 Land Suitability

There are a number of fundamental considerations when undertaking land-based water disposal. The most important of these are:

- the nature of the soils
- the depth to groundwater
- the quality of the water being applied

These factors combined will ultimately determine the rate at which groundwater can be applied at the land surface, which in turn determines the land area required and the means of water application. The land area required; level of treatment required prior to discharge; and method of application, will be the key factors in determining the cost of such a system.

2.2 Soil Types

Figure 1 shows the distribution of soil types covering the Marsden Point – Ruakaka Peninsula and it is this area that has been considered for a potential land discharge of water due to its relative proximity to the Refinery. In summary there are three main soil types that are considered conducive to a land-based water discharge; dune sands on the eastern side of the Peninsula (Q1d), alluvial deposits in the central area (Q1a) and older, more cemented dune sands that occupy all but the eastern side of the Peninsula (IQd). There is a fault uplifted bock of greywacke basement rock on the western side of the Peninsula, however, this land area has not been considered in this assessment as it is generally considered unsuitable for a land discharge due to its poor drainage properties.

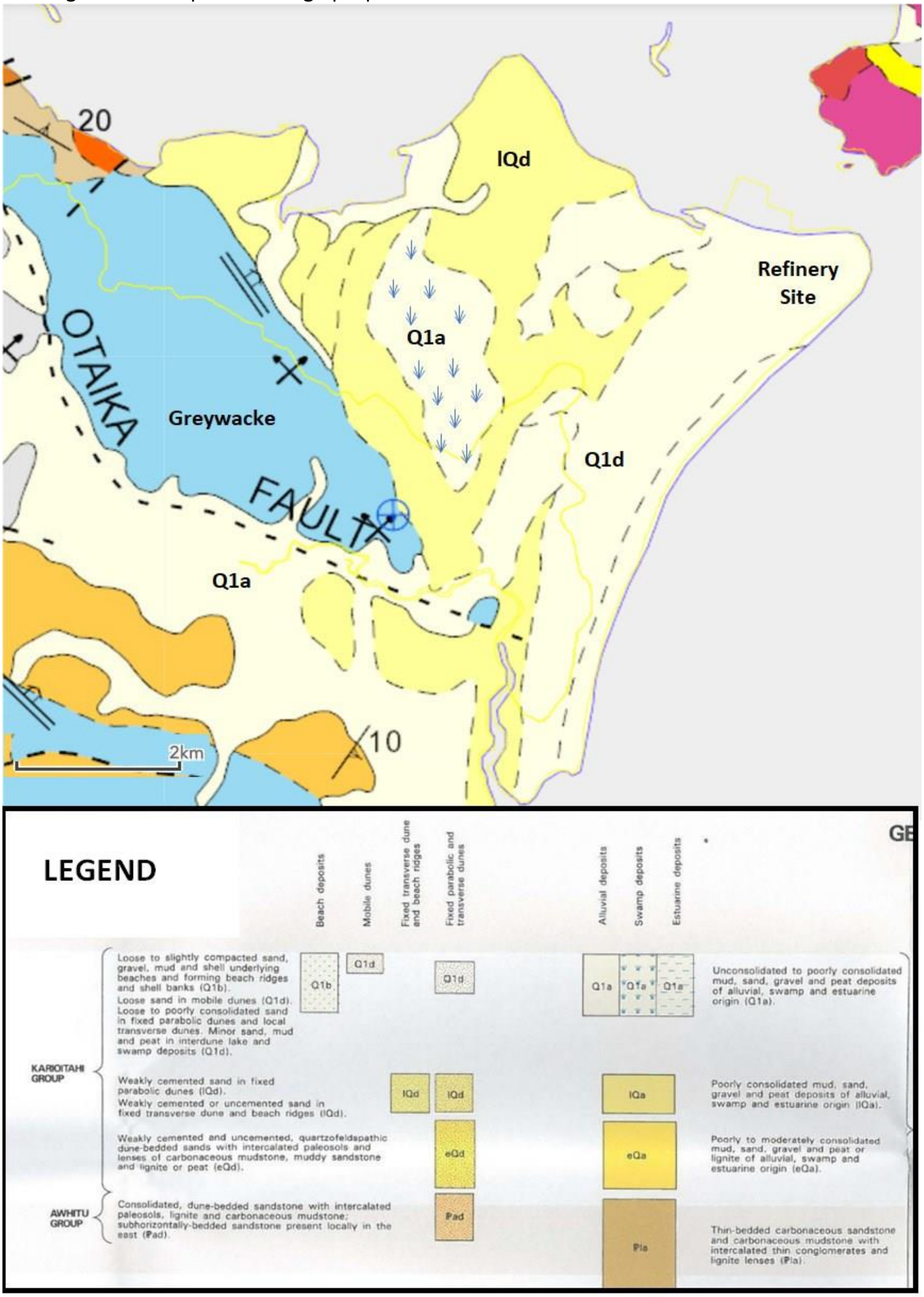


Figure 1 **Geology of the Marsden Point Peninsula (modified after NRC GIS geology and GNS geological map of Whangarei, 1:250,000)**

In summary, there is a land area in proximity to the Refinery that is considered potentially suitable for a water discharge. The soil types that exist can be grouped as being suitable for applying water at different rates based on the soil texture, with the dune sands (Q1d and IQd) having a high application rate potential, and the alluvial deposits (Q1a) having a lower application rate potential.

2.3 Depth to Groundwater

Northland Regional Council borehole records show the depth to groundwater over the Peninsula ranges between 1.5 to 4.5 m depending on the ground elevation locally. In general, the depth to groundwater is deeper beneath the dune sand formations due to their topographic expression. The alluvial deposits tend to be in lower lying areas with the depth to groundwater shallower. Where the depth to groundwater is greater, there is better potential for higher rates of water to be applied and for longer durations, giving more disposal capacity.

2.4 Water Quality

Typically, the quality of water being applied to the land is considered because there is some assimilative capacity in the soil profile to immobilise, reduce, or convert contaminant in the water being applied. Given the nature of the contaminants in the wastewater stream produced by the Refinery, being hydrocarbons derived and heavy metals, we have assumed that the water quality being applied is, at least, comparable to that permitted to discharge under the site to groundwater. A permit for the disposal of treated wastewater to land to a similar standard would be required to operate the system.

To achieve this, it is expected that there would need to be a reasonable level of treatment of the wastewater stream prior to land discharge occurring. For example, BOD_5 and Suspended Solids concentrations may need to be reduced to prevent clogging of the soils occurring due to the land application. Phenol, Ammoniacal N and Sulphide concentrations may need to be reduced further as these contaminants are not present in groundwater. It is possible that the existing treatment process could achieve this quality standard, however, some additional level of renovation could be required in order for the wastewater to be applied to land. The soils themselves have been assumed to provide no additional level of treatment, and with the additional renovation, the water could be applied at the maximum hydraulic loading rate for the various soil types.

3. Concept Design

3.1 High Rate Application (Dune Sands)

It is possible to undertake high rate land application in high permeability soils where there is some 3-4 m depth to groundwater present. This requires the disposal fields to be configured in rectangular strips, where shallow trenches or subsurface pipes are used to distribute the water. In some cases, the rates of disposal can be high (>1,500 mm/d), however for the purpose of this assessment we have assumed the soakage rates measured at the Refinery site of 15 mm/hr (0.36 m/d) presents a conservative assumption.

Assuming operation of the disposal fields for a full day, the daily disposal capacity would be 0.36 m/d per m^2. The duration of allowable disposal is a function of the vadose zone depth and profile available water capacity. Given a 3.5 m depth to groundwater and an effective porosity of 0.1, there is 0.35 m depth of water storage available in the profile. This would mean scheduling of 1 day of disposal within each field, with 5 days resting before returning required (based on the soil types and best practice). The total land area required for high rate land disposal would, therefore, be in the order of 11 ha as presented in Table 1.

Table 1 High Rate Land Disposal Option

Disposal Volume	8000	*m^3/d*
Disposal Rate	0.36	*m/d*
Area per Block	22,222	*m^2*
Area per Block	2.22	*ha*
Blocks Required	5	
Total Area Required	11	*ha*

A review of the Refinery site has been undertaken and this indicates there to be insufficient vacant land area available for high rate land disposal. Further, the areas of land that are currently vacant have been identified for future development (e.g additional bulk storage tanks), meaning on site land disposal of treated wastewater is not feasible now nor is it expected to be in the foreseeable future.

This being the case, off site land disposal would be the only other viable alternative and this would require obtaining a suitably sized land area on a nearby property with similar soils and with a similar depth to groundwater for a high rate option to be feasible. This would add the additional costs of purchasing the land and conveyancing pipeline to reach the property. While this is feasible in theory, as discussed later in this letter, it may be difficult to consent an off-site discharge for environmental reasons.

3.2 Low Rate Application (Alluvial Soils)

An alternate, low application rate, option has also been considered for an off site discharge where the depth to groundwater is limited. Lower infiltration rates and shallower depths to groundwater will ultimately mean a larger land area is required for the disposal. Again, this land area would need to be secured somewhere else within Marsden Point and would ideally be near the Refinery site.

Under these conditions, disposal would be undertaken as irrigation fields, and the maximum rate or daily application would be in the order of 50 mm/d or 0.05 m/d. Given a 1.5 m depth to groundwater and an effective porosity of 0.1, there is 0.15 m depth of water storage available in the profile. This would mean scheduling of 3 day of disposal within each field, with 6 days resting before returning required (based on the soil types and best practice). The total land area required for low rate land disposal would, therefore, be in the order of 48 ha as presented in Table 2.

Table 2 Low Rate Land Disposal Option

Volume	8000	*m^3/d*
Disposal Rate	0.05	*m/d*
Area per Block	160,000	*m^2*
Area per Block	16	*ha*
Blocks	3	
Total Area Required	48	*ha*

It is clear, therefore, that a much larger land area would be required in order to make a low rate disposal option feasible. As with the high rate option, it may be difficult to consent an offsite discharge for environmental reasons.

3.4 Conveyance System

In concept, a land application system would consist of a pipeline that conveys the treated wastewater from the Refinery site to the land application area. This would be minimal if the disposal were to take place within the Refinery site. If the discharge were to be on another site, based on the proximity of the Refinery to the suitable land areas, the conveyance pipeline could be up to 2-3 km in length and may require 2 or more road crossings.

3.5 Water Treatment

Onsite treatment of the wastewater is undertaken prior to it being discharged directly to the marine environment and the existing consent has limits for a number of contaminants. At this stage it has been assumed that the wastewater would need additional treatment prior to it being discharged to land given that is contains contaminants that do not presently exist in groundwater such as phenols, nutrients and possibly metals. Further, some additional reduction in BOD_5 and Suspended Solids concentrations may be required to avoid clogging of soils due to the irrigation of wastewater.

A detailed, quantitative environmental assessment would ultimately be required to determine the effects of the discharge on groundwater and then in the marine environment at the location of the discharge along the foreshore. The results of this assessment would be required to determine whether, in fact, a further level of treatment was required prior to land disposal and to what standard. At this time, the costs associated with plant equipment that may be needed to improve the quality of the wastewater has not been included in this document due to the number of uncertainties involved. The cost of such equipment could, however, be considerable.

4. Potential Environmental Effects

4.1 On Site Disposal

An on-site, high rate disposal option has been discounted due to there being insufficient land area available. Even if it were possible, there would need to be number of considerations in relation to the associated environmental effects. Firstly, the quality of the water being discharged would likely need to be treated to a high standard that is, essentially, the same quality as the existing groundwater discharging from the site unless a lesser discharge standard can be permitted. Assuming this can be readily achieved, any associated effects would be related to groundwater hydraulics.

A fundamental consideration related to groundwater hydraulics would be how the land application would perform during periods of heavy rainfall. For the most part, the soils are sufficiently permeable that they could accept some volume of rainfall depending of the size of the event (say up to 50 mm/day). Under heavy rainfall conditions, however, it is expected that land application may have to cease for a period of time. Under such a scenario the wastewater would instead need to be discharge via the diffuser or, as is permitted under the existing surface water discharge consent, via a direct ocean outfall. This would mean retaining this infrastructure and associated permits.

Initial calculations indicate that around 2.5 m mounding of the groundwater surface could occur based on the rate of discharge and size of the disposal fields. Given this degree of mounding, it is expected that the groundwater spring line along the coast would move up the beach, potentially affecting the amenity value of the beach if it were to be permanently saturated to a higher level than present. It is also possible that break out on the dune slopes could occur if low permeability layers are present in the soil sequence (such as iron pan), which would be an undesirable effect. The break out of groundwater along the dunes at a high elevation could also potentially result in ground instability issues that would need to be considered.

Even if a land discharge could be undertaken within the Refinery site, the groundwater would still continue to discharge into the marine environment. The discharge would, however, be diffuse and emanate from groundwater along the length of the coastline, as opposed to the point source discharge occurring from the existing discharge. The existing groundwater discharge along this length of coastline is of a high quality and this is verified by groundwater perimeter monitoring. Containment of the site is achieved by creating an inward gradient, pulling in potentially contaminated groundwater before it leaves the site boundary, but maintaining a divide such that outflow still occurs. If wastewater was disposed of to land on site, contaminated groundwater (to some level) would emanate directly into the marine environment, essentially compromising containment of the site from a groundwater perspective.

4.2 Off Site Disposal

Off site disposal of groundwater would result in the need for a new land discharge permit. Unlike the Refinery site, that already has contamination in the groundwater, a new site would need to be permitted to allow some contamination of the aquifer. This may be a difficult proposition for regulatory agencies to consider, as it is contamination from another source. This is, however, the case for community wastewater disposal schemes that are land based and the quality of the discharge and associated effects are important aspects of being able to obtain consent.

Assuming it were viable in a planning sense, the actual effects of the discharge would need to be considered in the context of the property location and environmental setting, which is presently unknown. The key aspects to be considered would be the discharges effect on surface water quality, groundwater quality and groundwater hydraulics. An appropriate level of site-specific testing and assessment would need to be undertaken to determine the feasibility and effects of such an option.

5. Indicative Costing

Indicative costings have been prepared by Tonkin & Taylor Ltd (T+T) for an off site, high rate and low rate land disposal system and is included in Attachment A. We note that this cost estimate does not include capital costs for plant equipment to provide additional treatment of the wastewater prior to land disposal if this were to be required.

6. Discussion & Conclusions

Based on this high-level assessment, it is not considered feasible that a land discharge could be a viable alternative to the existing surface water discharge within the Refinery site. An on-site option has been discounted principally on the basis that there is insufficient land area available.

In addition, however, this assessment has shown a range of potential issues with on-site disposal that could compromise the Refinery's environmental performance.

This being the case, off site disposal is the only land-based alternative. Off site disposal is, however, likely to be problematic in its own sense in that sufficient adjacent land would need to be obtained and permitting of such a system could be difficult. The effects of an off site disposal system would need to be considered in detail based on the location of the available land and assuming sufficient land could, in fact, be obtained. The cost of off site land disposal systems has been considered and ranges from $7.3M and $13.7M for a high rate option and $16.4M and $30.8M for a low rate option. These costs do not include the cost of purchasing land nor cost associated with obtaining resource consent.

7. Limitations

This document has been prepared by GWS Limited solely for the benefit of Refining NZ. It has been prepared on the basis of the instructions or brief given to GWS Limited by Refining NZ. This document may contain confidential material, data or opinions which may not be used for any other purposes or in other contexts without the expressed permission of GWS Limited.

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

This report is based on the ground conditions indicated from published sources and from reports that include subsurface investigations that have been undertaken by other parties based on accepted normal methods of site investigations. Only a limited amount of information has been reviewed in the preparation of this report which does not purport to completely describe all the site subsurface characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it must be appreciated that actual conditions could vary from those assumed.

8. Closure

Should you have any further questions please contact the undersigned.

Chris Simpson
Hydrogeologist

For and on behalf of GWS Limited

Attachments

- Indicative Cost Estimate

Job No: 1009695.2000.v3
14 October 2019

The New Zealand Refining Company Ltd (trading as Refining NZ)
Private Bag 9024
Whangarei 0148
by email: Riaan.Elliot@RefiningNZ.com

Attention: Riaan Elliot

Dear Riaan

Discharge of Water to Land - Cost Estimate

1 Introduction

Tonkin & Taylor Ltd (T+T) has been engaged by Refining NZ to prepare cost estimates for the disposal of wastewater to land. This is to feed into a report[1] prepared by GWS Ltd considering the technical feasibility of an option for disposal to land.

This estimate has been prepared in accordance with our variation (Variation 01) dated 10 July 2019. This v3 update of our original letter report includes a rough order cost estimate for off-site high rate and low rate irrigation systems and replaces details for a high rate option previously presented.

2 Background

GWS Ltd has identified options for disposal of treated wastewater to land from the Refinery at Marsden Point. The GWS report describes two options, high rate irrigation and low rate irrigation. The high rate irrigation option is suitable for the dune sands in the area, and occupies a smaller land area. Insufficient land area is available on site for this option and so options must be considered offsite. The preferred disposal method at this concept stage is pressure compensating drip irrigation. T+T has undertaken a concept level design for a high rate system to estimate the capital costs, and extended this design to include a low rate system.

3 Concept design

3.1 High rate irrigation on site

Based on the information provided by GWS, a rough order cost estimate has been prepared for a system comprising:

- Five irrigation lots each with a minimum area of 22,222 m^2, giving a total irrigation area of 11 ha;

- The source of the wastewater will be adjacent to the jetty and the existing stormwater surge basin. A new pump station will be constructed at this location in a new structure comprising a duty and standby pump each sized for the design flow of 185 L/s (assuming pumping to each lot over a 24 hour period). These will be approximately 120 kW pumps and consideration should be given to multiple pumps at further stages of design;
- The delivery pipe to the irrigation lots will be a 560 mm OD PE pipe, sized for a velocity of approximately 1 m/s to control head losses in the pipeline to reasonable levels;
- Within each irrigation lot a distribution pipe will be laid approximately central, requiring dripper lines with a maximum length of approximately 80 m. The distribution pipe will branch off the main pipe approximately central in each lot and thus will be sized for 50% of the maximum design flow as the flow will be split. This will be a 400 mm OD PE pipe;
- Control valves will be installed on the distribution pipes to each lot to allow selection of that lot for irrigation and exclusion of all other lots;
- The dripper lines will connect directly to the 400 mm PE pipe; and
- Two routes were considered for the main pipeline from the pump station to the southern site boundary. The shortest route is through the refinery. However, a slightly longer route was selected around the foreshore to minimise the potential for crossing other services and associated risks.

While a specific site for a high rate system has not been identified, the suitable land lies immediately to the south of the Refinery, along the sand dune areas. We have thus assumed that an additional 1 km of rising main would be required from the southern site boundary to a disposal area.

3.2 Low rate irrigation off site

Again, no specific site has been identified for this option. Suitable land for low rate irrigation lies further inland and cost estimates have been prepared on the basis that a suitable site could be found within 2 to 3 km from the site. In order to prepare this cost estimate, it has been assumed that the rising would extend by 2.5 km beyond the southern site boundary.

From the information provided in the GWS report, an irrigation area of 48 ha is required for the low rate system, comprising three lots each of 16 ha. We have used a lower per ha rate for estimating the cost of the drip irrigation system for the low rate system due to the lower density of pipework required. Lateral/distribution pipes will be required within the irrigation area. As the estimate is not based on a specific layout, we have simply pro-rated the length of lateral pipes determined for the high rate option.

4 High level cost estimate

We have prepared a high level cost estimate for the schemes described above. This has been prepared on the basis of rates available to us from other projects for similar items of work, our general experience and limited discussions with suppliers. The aerial rate for the drip irrigators was provided to us by GWS (Chris Simpson, pers. com) based on similar high rate and low rate irrigation projects elsewhere.

The estimate is based on a very coarse concept design for the high rate scheme, as described above, and not all elements of the scheme will have been identified. It is based on indicative rates for other projects and does not necessarily reflect market conditions at the site and at the time of construction. We have included a 30% contingency to allow for the low level of project definition and risk items which cannot be realistically identified at this level of concept design. An allowance has been made for Contractor’s P&G (20%), Engineering (10%) and construction administration (6%). We have assumed that the contractor’s profit is included in the rates adopted. We consider that the estimate will have an accuracy of -20 to +50%.

The estimates are for the schemes as described and do not include costs for any additional treatment measures. Any changes to this will affect the estimated costs.

The estimates do not include the cost for any land purchase or for obtaining resource consents, and these should be included if considering these options against other options.

The base estimate for the high rate option is approximately $9,100,000 excluding GST. Therefore the estimated cost is expected to be in the range between $7.3M and $13.7M excluding GST.

The base estimate for the low rate option is approximately $20,500,000 excluding GST. Therefore the estimated cost is expected to be in the range between $16.4M and $30.8M excluding GST.

A breakdown of the estimates is provided in Appendix A.

Given that the schemes include continuous pumping there will be significant ongoing operational costs.

5 Applicability

This report has been prepared for the exclusive use of our client The New Zealand Refining Company Ltd (trading as Refining NZ), with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Tony Bryce Technical Director Environmental Engineering	Sarah Schiess Project Director

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Appendix A Cost schedule___________________

Refining New Zealand

Wastewater Irrigation by rapid infiltration (using drippers)

Capital Cost Estimate

Item	Description	Quantity	Unit	Rate	Amount
1	Intake structure and short length of raw water pipeline	1	LS	$50,000.00	$50,000
2	Pump station structure	1	LS	$180,000	$180,000
3	Pumps and pump station pipework	1	LS	$150,000	$150,000
4	Pump station electrical	1	LS	$70,000	$70,000
5	Rising main to irrigation field and through the field, 500 OD PE, in greenfield conditions, i.e. no conflicting services or road reinstatement	3080	m	$800	$2,464,000
6	Distribution mains in disposal fields, 360 mm OD PE	1170	m	$550	$643,500
7	Control valves at each field	5	Ea	$10,000	$50,000
8	Drip irrigation lines	11	ha	$150,000	$1,650,000
	Base Estimate =				$5,207,500
	Additional Items				
	Contractor's preliminary and general	20%			$1,041,500
	Engineering	10%			$624,900
	Construction administration	6%			$374,940
	Contingency	30%			$1,874,700
	TOTAL ESTIMATED COST				$9,120,000

Refining New Zealand

Wastewater Irrigation by low rate infiltration (using drippers)

Capital Cost Estimate

Item	Description	Quantity	Unit	Rate	Amount
1	Intake structure and short length of raw water pipeline	1	LS	$50,000.00	$50,000
2	Pump station structure	1	LS	$180,000	$180,000
3	Pumps and pump station pipework	1	LS	$150,000	$150,000
4	Pump station electrical	1	LS	$70,000	$70,000
5	Rising main to irrigation field and through the field, 500 OD PE, in greenfield conditions, i.e. no conflicting services or road reinstatement	4600	m	$800	$3,680,000
6	Distribution mains in disposal fields, 360 mm OD PE	5100	m	$550	$2,805,000
7	Control valves at each field	3	Ea	$10,000	$30,000
8	Drip irrigation lines	48	ha	$100,000	$4,800,000
	Base Estimate =				$11,715,000
	Additional Items				
	Contractor's preliminary and general	20%			$2,343,000
	Engineering	10%			$1,405,800
	Construction administration	6%			$843,480
	Contingency	30%			$4,217,400
	TOTAL ESTIMATED COST				$20,520,000

8.3 Appendix C – Discharge to Land

Tonkin+Taylor

Job No: 1009695.2000.Rev3
11 September 2019

The New Zealand Refining Company Ltd
Marsden Point Refinery
Ralph Trimmer Drive,
Marsden Point, 0171,
New Zealand

Attention: Riaan Elliot

Dear Riaan

Environmental Remediation Options Assessment
Marsden Point Refinery

Introduction

Tonkin & Taylor Ltd (T+T) has been commissioned by The New Zealand Refining Company Ltd (trading as Refining NZ) to prepare an Environmental Remediation Options Assessment (EROA) to support the application for renewal of existing resource consents for the Marsden Point Refinery site, Ruakaka (the site) (Figure 1 in Appendix A). As part of re-consenting works, Refining NZ is reviewing the current approach (hydraulic containment with pump and treat) and is considering the feasibility of alternative approaches.

This report was prepared in accordance with our proposal of 10 July 2019.

Background

Refining NZ operates New Zealand's only oil refinery (the Refinery) at Marsden Point on the southern headland of Whangarei Harbour. It is an independently operated "tolling" refinery, meaning that it owns neither the feed-stocks nor the finished products.

The Refinery receives crude oil and other feed-stocks delivered by ships from the Far East, Middle East, Australia and New Zealand. The bulk of the products produced by the Refinery are distributed via dedicated coastal tankers or via the Refinery to Auckland Pipeline (RAP).

The Refinery has operated on the site since 1964. Since that time there have been various practices in terms of managing operations, and the waste and sludge generated onsite. The site also has a dedicated fire training ground which has been in use since the 1970s. As a result of losses to ground over the Refinery's operational period soil and groundwater at the site has become contaminated.

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The main contaminants of concern at the site include total petroleum hydrocarbons (TPH), benzene, toluene, xylene and ethylbenzene (BTEX), polycyclic aromatic hydrocarbons (PAH), phenols, metals, per- and poly-fluoroalkyl substances (PFAS) and nutrients (nitrate). Refining NZ has undertaken groundwater monitoring at the site since 1980. The long term monitoring programme shows that hydrocarbon contamination (TPH/BTEX) is present beneath the site, in the form of dissolved phase hydrocarbons and also light non-aqueous phase liquid (LNAPL). Further investigation of potential site-sourced contamination from phenols, metals, PFAS and nitrate is currently underway.

A hydraulic containment system has operated at the site since 1983 to manage hydrocarbon contamination of groundwater. Extracted LNAPL and groundwater is pumped to the site's "Continuously Oil Contaminated System" ('the COC') and slops system for separation and treatment. Treated water is discharged under the resource consent. As part of re-consenting works Refining NZ is reviewing the current approach and is considering the feasibility of alternative approaches.

Site characteristics

The following section provides a summary of information obtained from GHD/GWS 2014[26] and historical bore logs attached to that report.

The Marsden Point peninsula is generally described as comprising Holocene dune sand interspersed with lenses of coarse shelly marine sands and clays with an aquitard at around 27 m depth. Previous intrusive investigations undertaken by GHD and others have reported the site conditions as being a fine to coarse sand profile with inconsistent shell grit and gravel layers to greater than 14 m depth (refer 'Kiwi' well log in GHD/GWS 2014). Some drilling locations have noted the presence of peat in the upper 2-3 m and more rarely at depth (refer RW15A log in GHD/GWS 2014, peat 15-19m). Testing undertaken during the commissioning of the Kiwi well indicates high aquifer transmissivity which is consistent with a sand aquifer. Prior to groundwater abstraction, groundwater levels were reported to have been around 1-4 m below ground level. The current extraction system comprises continuous pumping from recovery wells RW15A, RW19B, RW22 and the Kiwi well (also referred to as RWSEQ). The recovery well locations are shown on Figure 1 (Appendix A). Until 2017, recovery well RW02 in the northwest portion of the Refinery was also included in the containment system, but operation ceased as there was no longer an immediate need to provide containment and recovery in that portion of the site.. Typical pumping rates at the recovery well locations are:

- RW02: historically (~2014) 210-260 L/min. Has only pumped once since August 2017;
- RW15A: highly variable, 80-300 L/min. Currently ~120 L/min;
- RW19B: 500-700 L/min;
- RW22: 450 – 500 L/min; and
- RWSEQ: Very variable, 80 – 200 L/min. Currently ~70 L/min.

Groundwater extraction/discharge flow rates are generally at or below current consent limits.

Scope of work

To inform the 'Assessment of Environmental Effects' report being prepared in support of the reconsenting application, Refining NZ require a high level overview of alternative remedial approaches to the ongoing management of hydrocarbon impacts in groundwater. This review will consider the following key areas of each alternative approach:

[1] GHD/GWS 2014. The New Zealand Refining Company Limited, Hydrogeological Characterisation. August 2014.

- Technical feasibility and effectiveness (practicality, required capabilities/expertise, refining operational considerations);
- Time;
- Sustainability;
- Protection of the environment; and
- Financial (capital expenditure [CAPEX] and ongoing operational expenditure [OPEX]).

At this preliminary stage, potential alternatives considered comprised:

- Insitu chemical oxidation (ISCO);
- Insitu bioremediation / biosparging;
- Physical containment / funnel & gate (cut-off wall);
- Pump and treat (expansion of current); and
- Hydraulic control via reinjection.

These alternative technologies were selected for evaluation based on professional experience and with reference to the United States (US) Federal Remediation Technology Roundtable (FRTR) Remediation Technologies Screening Matrix[27]. All selected technologies are rated 'above average' for groundwater treatment of 'fuels' by the US FRTR, with the exception of ISCO which is related 'below average'. Insitu options have been selected (apart from the expansion of the current pump and treat system) to minimise potential effects on Refinery operations.

As the Refinery is operational, it is important to note that there are both potential primary sources (e.g. tanks and product transfer infrastructure) and secondary sources (e.g. impacted soil and stormwater systems) that are present at the site. We understand that Refining NZ is assessing internally the feasibility of primary source control through a plant upgrade / repair programme to further minimise discharge of hydrocarbons to land / groundwater. This high level overview is relevant to the ongoing management of the operating Refinery. Other options may become relevant and/or preferred if remediation is being considered after cessation of operation of the Refinery. However, this scenario is not considered by this assessment.

Results and conclusions

T+T has completed a high level overview of alternative remedial approaches to the ongoing management of hydrocarbon impacts to control LNAPL and dissolved phase hydrocarbons in groundwater. Our review of technologies and approaches is documented in attached Appendices B to F. Costs provided in the review are indicative only for comparative purposes.

A matrix graphically presenting the relative constraints of each technology is presented over page.

[2] Available at https://frtr.gov/matrix2/section3/table3_2.pdf.

Considerations	Technologies / Approaches				
	Insitu chemical oxidation	**Insitu bioremediation**	**Physical containment**	**Pump and treat *(current method)***	**Hydraulic control by reinjection**
Technical feasibility and effectiveness					
Time					
Sustainability					
Protection of the environment					
Financial					

Red – severe constraints for application (such as being unable to treat LNAPL)
Orange – moderate constraints for application
Green – mild constraints for application

Overall, the current approach to the management of hydrocarbon impacts to control LNAPL and dissolved phase hydrocarbons in groundwater is considered the most appropriate method. A summary of the alternative approaches that were assessed as being less suitable than the current approach is provided below.

- ISCO is not suitable for implementation at the site based on technical constraints, such as being unable to treat LNAPL, the extent of the likely treatment area, and infrastructure required to treat dissolved phase contamination.
- Physical containment is not suitable for implementation at the site based on financial (primarily CAPEX) and technical considerations (in particular the depth and lateral extent of a cut-off wall)
- Insitu bioremediation/sparging is potentially suitable for management of residual/trace hydrocarbons at the site boundary but not for remediation of the main Refinery site. This technology would be an add-on to the current approach and not a replacement. Further assessment would be required to establish the relative value in the context of contaminant concentrations that may currently be escaping the existing system. Where the current system can demonstrate sufficient hydraulic control, the cost of adding this technology may outweigh the benefits.
- Pump and treat is an appropriate method but cannot be readily expanded without amendments to the existing consents to take groundwater and discharge treated water.
- Hydraulic control by reinjection is feasible at the site. Additional investigation would be required to determine the aquifer response to injection and relative effectiveness. This technology would be an add-on to the current approach and not a replacement. Where the

current system can demonstrate sufficient hydraulic control, the cost of adding this technology may outweigh the benefits.

- All alternative approaches will require additional resource consents or consent amendments.

Historical and recent monitoring data collected by Refining NZ and others generally shows the current pump and treat method is effective for management of the dissolved phase hydrocarbon plume within Refining NZ's site boundary. Hydrocarbon concentrations appear to be reducing over time and with ongoing management it is expected that this will continue to improve.

Notwithstanding the above, should unacceptable impacts to the environment be found to occur from groundwater contamination present outside of the containment area in the future, we recommend that further consideration be given the addition of insitu bioremediation / biosparging and / or hydraulic control by reinjection. This would require additional site investigation, review of historical data, groundwater modelling, field trials and full scale detailed design and is realistically a medium to long-term consideration.

Applicability

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

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

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:

....	pp Moore.	Authorised for Tonkin & Taylor Ltd by:
Damien McKay	Sarah Schiess	
Principal Environmental Consultant	Technical Director	

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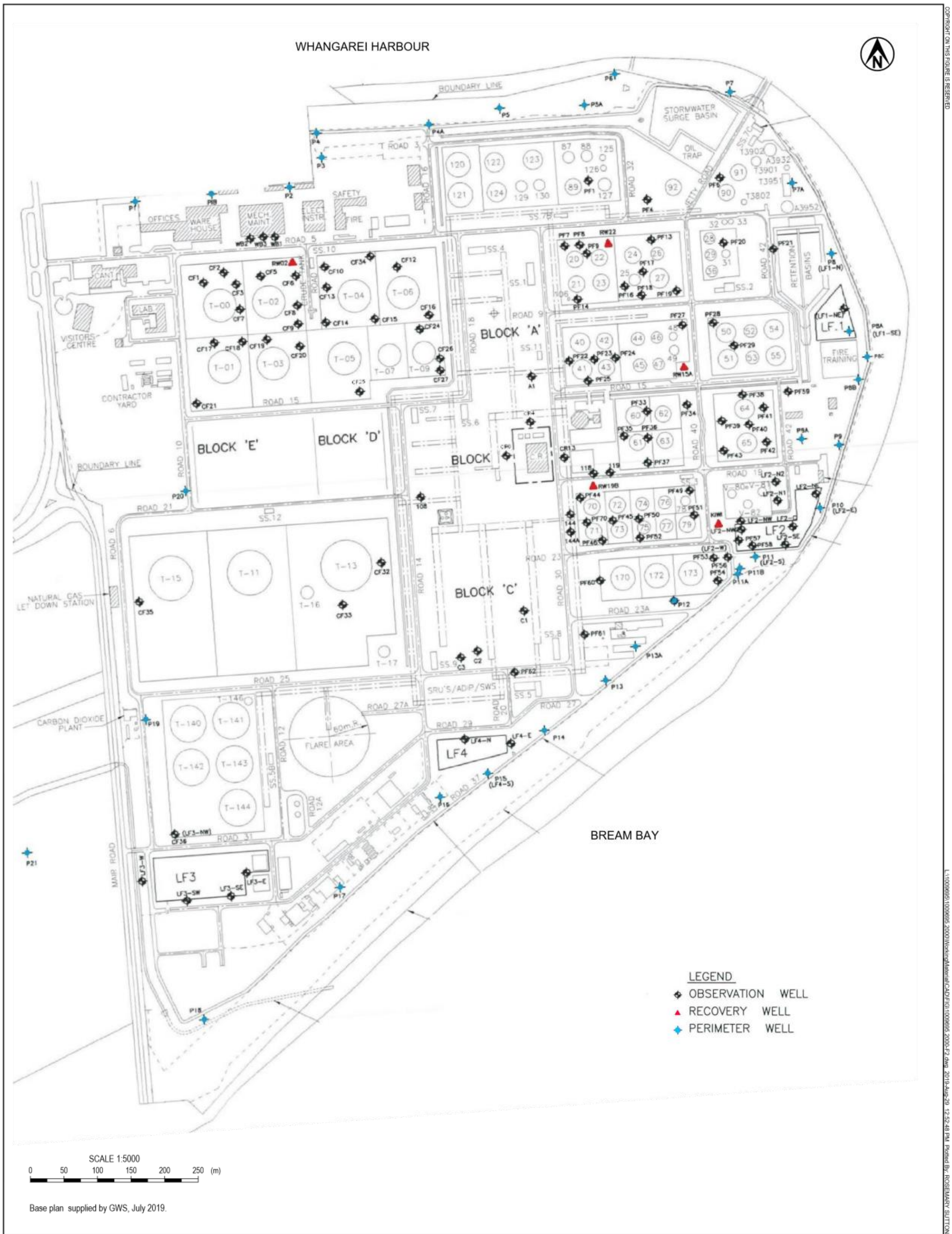
Appendix A: Figures



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PROJECT No.	1009695.2000	
DESIGNED	NOR	Aug.19
DRAWN	RBS	Aug.19
CHECKED		
APPROVED	DATE	

CLIENT: THE NEW ZEALAND REFINING COMPANY LIMITED

PROJECT: REFINING NZ RE-CONSENTING

TITLE: MARSDEN POINT, WHANGAREI
Site and Well Location Plan

SCALE (A3): 1:5000 | FIG No.: Figure 1 | REV: 1

Appendix B: Insitu chemical oxidation

B1 Technology overview

Chemical oxidation generally involves the destruction of hydrocarbon concentrations through electron transfer from the contaminant to the oxidant resulting in the breakdown of the hydrocarbon molecules into degradation by-products. The specific degradation by-products depend on the form of the hydrocarbon contaminant as well as the particular oxidant used. Insitu oxidation requires the introduction of an oxidant in the contaminated portion of the aquifer, usually by pressurised injection of the oxidant in a liquid form (ozone being an exception that is introduced as a gas).

A sufficient volume of the oxidant must be introduced such that the required stoichiometric ratio of oxidant to contaminant is met or exceeded to achieve complete oxidation of the contaminant. Accordingly, it is common to introduce an excess of oxidant. It is also essential that the oxidant is distributed within the aquifer to so as to contact all hydrocarbon concentrations and that the oxidant has sufficient residence time to react with the hydrocarbon concentrations.

The selection of a particular oxidant and injection strategy requires the consideration of a number of factors including by not limited to those set out in the following subsections.

B1.1 Health and Safety

Strong, highly reactive oxidants such as peroxide, require special handling procedures to ensure the safety of remediation workers both in terms of product handling (potential for chemical burns) and when introducing the contaminant into the aquifer. Oxidation can be very violent, producing high temperatures (in excess of 200°C), steam and in extreme cases, explosion in addition to potentially harmful vapours. Experienced operators are required to ensure that oxidation occurs in a safe and controlled manner.

B1.2 Aquifer chemistry

Aquifer chemistry is an important consideration as the majority of oxidants result in a (temporary) lowering of the pH and in some cases require a specific pH to activate the oxidant. Accordingly, the capacity for natural pH buffering of the aquifer needs to be taken into account when determining the level of pH adjustment required prior to or during oxidant introduction. Similarly, some oxidants require an iron-based catalyst which can either be naturally occurring, or may have to be introduced to the aquifer – either before the oxidant or in parallel depending on the specific product.

B1.3 Oxidation by products

Although oxidation is an effective method of hydrocarbon destruction, by-products are formed. Byproducts formed by most oxidants are harmless and can include carbon dioxide, water and metal salts. However, the use of permanganate results in purple/pink staining of the groundwater and can lead to clogging of the aquifer through mineral precipitation. The potential for production of daughter/degradation products arising from incomplete oxidation must also be considered. For example, incomplete oxidation of trichloroethene can result in the formation of more toxic vinyl chloride.

B1.4 Oxidant dispersal and retention time

Chemical oxidation requires that the oxidant contacts the contaminant. In the case of ozone gas, the gas has a relatively short half-life and thus residence time and as such requires a closer well spacing that would be required by alternative oxidants. By contrast, some purpose designed oxidants, such as Regenox and Klozur, have been shown to persist for weeks to months in an aquifer, allowing for greater dispersion of the oxidant and longer-term oxidation.

B1.5 Native Organic Content

Oxidants are non-specific and will oxidise any available organic compounds, including naturally organic compounds (NOC) occurring naturally within the aquifer. An aquifer with high NOC may require an increased volume of oxidant to overcome losses to NOC.

B1.6 Contaminant rebound

Following insitu oxidation it is common (and expected) to see an increase in dissolved phase contaminant concentrations. This is generally the result of contaminants in lower permeability zones diffusing into solution. As a result, oxidation generally occurs as several events with the rebound effect typically reducing with each event. For treatment of a potential ongoing source (such as at an operational Refinery), events would also need to be staged/ongoing.

B1.7 Below ground infrastructure and services

Belowground infrastructure (including those relating to the operational Refinery) and services can be damaged through contact with the oxidant solution. Service corridors can also provide a path of least resistance and act as a conduit for the unintended spread of oxidant solution.

B2 Technical feasibility and effectiveness

ISCO is a well recognised technology that is effective at destroying a wide range of organic contaminants including the range of petroleum hydrocarbons present at the site. However ISCO is generally not recommended for application where LNAPL is present (such as at the site). This is generally due to the significant oxidant requirement that an LNAPL product incurs as well as the potential to ‘push’ the LNAPL product as a result of groundwater mounding at the injection site. This can be controlled through simultaneous ground water extraction and a carefully sequenced injection.

ISCO requires good contact and mixing with the contaminant plume to achieve the required destruction. For a plume with a large vertical and/or lateral extent this can require an unfeasibly high number of injection points. This is particularly the case with low-permeability aquifers where the injection point has a small radius of influence.

ISCO is an event based remediation technique with each event providing an effective treatment window of days to weeks. As such it is best suited to sites where the source has been removed and recontamination is not expected (e.g. from ongoing leaks and spills).

ISCO has been shown to be effective at the treatment of TPH, BTEX, some PAHs and phenols. ISCO may have an effect on some metals. Some PFAS compounds can be oxidised from one form of PFAS to another however oxidation has not been demonstrated at field scale to be effective at the complete destruction of PFAS. Nitrate is the end product of oxidation of ammonia/nitrite and is not typically treated by ISCO.

The detailed design phase of an ISCO programme will generally include an extensive soil and groundwater programme to determine the site specific natural oxidant demand, hydraulic conductivity and related aquifer parameters. Bench scale oxidation trials will be conducted to determine target chemical addition rates. Generally this is completed in specialist laboratories operated by the ISCO chemical manufacturers in the US.

Following the bench scale trials a field scale trial would be undertaken with injection into a dense network of monitoring wells to provide a detailed understanding of the distribution and migration of the ISCO chemicals in the aquifer. Repeat trial events are often completed to optimise the injection programme. Based on the lateral extent and varied geology of the site we envisage that trials would be required at several locations.

To avoid the migration of unreacted injection chemicals from the site either the existing pump and treat system would be required to maintain hydraulic control, or the injection points would need to be set back from the Site boundary. The set back from the site boundary would likely require the injection points to be located within and around critical refining infrastructure and it is likely that gaps would be present in the injection network. Gaps in the network could lead to the release of untreated hydrocarbons from the site.

ISCO is not considered an appropriate remediation technology at the site as:

- The LNAPL plume will require an unfeasible volume of oxidant;
- Critical infrastructure at the site will prevent a comprehensive injection grid being established and this can lead to the loss of untreated hydrocarbons from the site;
- Operation of the existing pump and treat system may still be required during injection to prevent the release of un-reacted oxidants from the site. This would also complicate the injection grid design due to the maintenance of artificial groundwater flow gradients;
- Subsurface pipework and utilities are at risk of contact with the oxidant; and
- ISCO is an event based approach that is not necessarily suited to ongoing / continuous cleanup (like at the Refinery).

B3 Time

ISCO is an iterative approach with contaminant concentrations typically being reduced over progressive injection events. The time required is dependent on the number of injection points, the subsurface geology and contaminant mass loading and distribution. It is not uncommon for ISCO remediation to take over 12 months to complete. Noting that treatment at the site will likely be ongoing, staged ISCO events would need to be undertaken of the over the operational life of the Refinery.

B4 Sustainability

Typically ISCO injection events are completed using either pneumatic or electric mixers and pumps attached to a specialised injection system. These systems are most commonly mobile units powered by diesel gensets. The diesel consumption and related emissions are relatively minor.

The ISCO chemicals are commercially available and do not (to our knowledge) require the depletion of scarce resources in their production.

Oxidation of hydrocarbon contaminants will result in the generation of carbon dioxide in the subsurface at the site of the oxidation reaction. The carbon dioxide produced will generally vent to the surface and the atmosphere over a period to time.

Considerations with respect to sustainability are no greater than the status quo or alternative methods and do not preclude ISCO as a technology at the site.

B5 Protection of the environment

The ISCO chemicals used have potential to cause damage to the environment in the event of an accidental release to ground or water and through a release unanticipated preferential pathway flow or daylighting. The first can be controlled using typical chemical handling procedures and implementing emergency spill control systems. The latter issue can be controlled by assessing existing and historic infrastructure at and around the injection location(s) while also monitoring groundwater levels. Monitoring groundwater levels is crucial to ensuring that groundwater mounding does not exceed above design levels or impinge on service corridors.

Considerations with respect to protection of the environment are manageable using standard procedures and does not preclude ISCO as a technology at the site however, the groundwater flow time to the Bay and pumping locations will need to be understood to ensure un-spent oxidant is not release to the Bay or drawn into pumping/treatment systems.

Ongoing ISCO events can lead to groundwater chemistry changes and clogging of the aquifer, which can represent a limitation on the number of events that can be completed without introducing impact to the environment. The implementation of an ISCO programme would likely require additional resource consents relating to the injection wells.

B6 Financial

ISCO chemicals are relatively expensive and are a one-shot application with new chemicals required each event. As the site is anticipated to have an ongoing contaminant load from the site operations this will require ongoing cycles of ISCO to manage contamination as it enters and moves through the site.

We estimate an indicative cost for the implementation of an ISCO system on the north, east and south side to the Refinery site to have an initial design, asset proving and CAPEX cost of around $1.5 M and a per ISCO event cost of $0.8 M. Assuming four injections events per year this represents an annual OPEX cost of around $3.2 M. This is comprised of:

- Pilot scale trial & detailed design;
- Asset proving survey;
- Drilling and installation of ISCO wells (~280 wells at 10 m spacing);
- Pre-remediation groundwater sampling; and
  - Per ISCO event:
  - Injection of ISCO batches;
  - ISCO oxidant (200kg oxidant /well); and
  - ISCO activator products.

On this basis the cost of sourcing and injecting ISCO chemicals on a routine and on-going basis precludes the use of ISCO at the site.

Appendix C: Insitu bioremediation

C1 Technology overview

Insitu bioremediation generally involves adjusting aquifer conditions to increase microbial activity leading to degradation of organic contaminants. Common additives include:

The addition of a nutrient/food source to the aquifer to promote an increase in the population and activity of naturally occurring biota within the aquifer; and/or

The introduction of additional oxygen to promote the more affective aerobic degradation processes over the much slower anaerobic degradation process.

In most cases both a nutrient source and oxygen source are introduced together.

Biosparging is the use of above-ground blowers/ air compressors to deliver ambient air to the subsurface to shift the aquifer from anaerobic to aerobic conditions. Biosparging differs from air sparging/stripping in that the flow rates are kept to a level where direct volatilisation does not occur.

Oxygen introduction can also be achieved by the injection of an Oxygen Release Compound (ORC).

C2 Technical feasibility and effectiveness

Insitu bioremediation and biosparging are mature technologies that have been field proven on a wide range of remediation projects. Insitu bioremediation is typically used at the tail end of a remediation process to cleanup residual / trace concentrations of organic compounds and is not suited to LNAPL or high concentrations of hydrocarbons.

Insitu bioremediation may be suitable for implementation at the perimeter of the site (plume fringes) where hydrocarbon concentrations are relatively low. In this scenario the technology would act as a final 'polish' step rather than direct remediation.

The biosparge air flow rate required to provide sufficient air flow to enhance biological activity is site specific and will need to be determined by a pilot test. Typical air flow rates are in the order of 540m^3/hour/well. Pulsing of the air flow can provide better distribution and mixing of the air with the groundwater while allowing the use of smaller air compression equipment.

Intrusion of marine/saline groundwater at the fringe of the site may require further assessment as this may impact on the viability of microbial populations.

Insitu bioremediation has been shown to be effective at the treatment of TPH, BTEX, some PAHs and phenols. Bioremediation has generally not been shown to be effective for the treatment of metals, PFAS or nitrate.

As has been noted for ISCO methods, the opportunity to install a comprehensive network of injection wells is likely to be limited by the presence of existing critical infrastructure. Gaps in the injection network can lead to the release of untreated hydrocarbons from the site.

C3 Time

Bioremediation is a slow process but is not precluded given the ongoing operation of the facility. The use of ORC or biosparging would potentially decrease overall remediation times, but would be needed to staged over the lifetime of the Refinery.

C4 Sustainability

Bioremediation is a sustainable technology as it requires minimal energy inputs instead relying on natural microbial activity. The use of ORC or biosparging also requires relatively minimal energy inputs other the construction of related injection/sparging wells.

C5 Protection of the environment

By-products of the ORC addition and digestion can change the water chemistry and introduce new species (such as magnesium hydroxide and calcium complexes). Where a microbial inoculation is injected care must be taken to ensure that it is compatible with existing microbial population. Outside of these considerations bioremediation does not have significant impacts on the environment and can reduce organic contaminants. The implementation of insitu bioremediation / biosparging would require resource consents in relation to the injection wells. Addition of amendments may also trigger the need for resource consent.

Existing elevated concentrations of nitrate at the site may limit the selection of nutrient compounds to avoid increasing nitrates to concentrations above guidelines at the site boundary. Increases in nitrate concentrations may trigger the need for additional assessment and remediation.

C6 Financial

The initial setup requires the construction of injection/sparging wells. Ongoing biosparging utilises compressed air and this will require the acquisition and installation of a compressed air system. Given the size of the Refinery site is likely that several systems will be required. An approach utilising ORC may require periodic injection of the ORC compound.

We estimate an indicative cost for the implementation of a biosparge system on the north, east and south side to the Refinery site to have a CAPEX cost of around $10M. This is comprised of:

- Pilot scale trial;
- Drilling and installation of biosparge wells (~280 wells at 10 m spacing);
- Pre-remediation groundwater sampling;
- Construction of air sparge piping infrastructure;
- Electrical, valving and instrumentation; and
- Oil-free air compressors and air receiver vessels.

We note that the Refinery working environment is likely to have safety considerations over and above that typically required for remediation sites and this will impact of costs, e.g. requirements for intrinsically safe / hazardous area rated plant. The location of existing infrastructure may also limit the ability to connect infrastructure between well locations and require additional blowers and related infrastructure.

Operating costs will include routine regular servicing of the air compressors, certification of pressure vessels. Ongoing assessment of the effectiveness of biosparging will likely also increase the overall environmental monitoring expenditure.

Appendix D: Physical containment / funnel & gate

D1 Technology overview

Physical containment involves the construction of a subsurface barrier around areas of contamination. This can be limited to only the downgradient side of the contamination, however, this introduces the potential for contaminated groundwater to go around the barrier. Typically a containment structure will extend around all sides of the impact. The barrier needs to have sufficient height and depth (socketing into an impermeable layer) to prevent migration over and under the barrier.

Funnel and gate is a variation of containment that leaves a 'gate' in the downgradient side of the barrier. The gate is then used to capture migrating contamination for treatment. This limits the lateral extent of the treatment zone. Treatment can be via a permeable reactive barrier, pump and treat, bioremediation or other technology.

Refining NZ are understood to have previously constructed a cut-off wall around the Refinery Control room. The cut-off wall is of bentonite construction and is reported to have been installed to a depth of ~7 m. It is targeted at controlling the migration of LNAPL not dissolved phase hydrocarbons. It is understood the control room containment system within the bentonite walls is not currently operational due to degradation of the bentonite walls, however the control room is within the hydraulic containment of the wider site system.

Based on the various monitoring well logs, and understanding of the current continuously operating hydraulic containment system, a physical containment system is expected to require installation to depths of 20-25 m.

D2 Technical feasibility and effectiveness

A containment system is technically effective and has been implemented on a range of sites. However, containment alone does not reduce contaminant concentrations and ongoing releases at the site are likely to result in a progressive increase in contaminant concentrations.

Construction of a 25 m cut-off wall, even if only a partial wall with gate and funnel, is a significant and technically challenging approach. Excavation would be required and would require temporary support such as slurry / grouting, sheet piling, or under slurry conditions using a clam- similar techniques. Significant volumes of likely contaminated soil would be generated and require treatment and/or landfill disposal. The design would also need to consider the longevity of the wall if in contact with LNAPLs as hydrocarbons can have a negative effect on bentonite products (typically used in cut-off wall construction). Depending on the specific design, construction of a guide wall and/or excavation of a trial trench will generally also be required.

The use of large, top heavy piling equipment with a shallow water table requires consideration of the ground bearing strength to ensure that the equipment can be safely operated without risk of toppling. Subject to the completion of a detailed geotechnical investigation, it is likely that an engineering piling platform will need to be constructed. Typically this will entailed the excavation of surface filled materials, placement of a geotextile product and then the import, placement and compaction of crushed rock along the wall alignment. Allowing for a factor of safety, the piling platform will be 50-100% wider than the piling rig itself and in the order of 10-15m in width.

As the piling rig tracks parallel and adjacent to the cut-off wall a clear work zone of 30 – 40 m across is not uncommon, however, this essentially depends on the rig. Supporting infrastructure needed for a cut-off wall would generally include a slurry batching plant plumbed to the cut-off wall trench, bulk water storage, materials yard and laydown areas. Accommodating these on an active refinery site is likely to be challenging and incur additional costs.

Existing infrastructure is likely to preclude the construction of a cut-off wall in many areas of the site without significant supporting works such as the relocation of existing utilities that cross the boundary. It is unlikely that this can be achieved without periodic maintenance turnarounds of some (or all) of site operations.A cut-off wall would be expected to contain all groundwater and would therefore be applicable to all contaminants of concern.

Ongoing operation of the existing pump and treat system inside a full containment wall could be problematic with significant drawdown of groundwater likely and potentially leading to settlement issues at the site. In the case of a partial cut-off wall, ongoing operation of the existing pump and treat (albeit in a reduced form) would still be required to prevent migration of contaminants around the partial cut-off wall.

D3 Time

Significant upfront drilling and investigation works to would need to be completed to prepare a cutoff wall design. The physical construction process would be very slow with production rates likely to be less than a metre per day (at 25 m depth). The cut-off wall would need to be maintained for the duration of operation of the site plus an extended period afterwards, unless other source removal/treatment is also implemented.

D4 Sustainability

A cut-off wall requires significant construction materials in the form of cement, bentonite and specialist additives as well as the mobilisation and construction of a slurry batching plant. Soil removed from the excavations would need to be removed to landfill or managed onsite. In exchange for these energy inputs the contamination is not destroyed or altered, just trapped. A physical containment system for this site is not overly environmentally sustainable.

D5 Protection of the environment

An effective cut-off wall would prevent the release of contamination into the environment. Resource consents would be required for the construction of the cut-off wall and potentially for soil disturbance (depending on the volume) and management.

D6 Financial

A cut-off wall is relatively expensive to construct and may require modification to existing refinery infrastructure (e.g. pipe crossings and utilities in-feeds). The contamination is not remediated with this approach and would remain as an ongoing liability.

A similar style cut-off wall was constructed in along one side of the Stevensons Road landfill in Cranbourne, Australia around ten years ago for a cost of ~$5 M. A cut off wall around the Refinery would be around three times the length and in more challenging ground conditions (high water table and sand aquifer). Extrapolating from this project and allowing for inflation a cut-off wall solution is unlikely to cost under $20 M and based on the recent construction of a seawall at the refinery site a capex cost of $60 M maybe more realistic.

Ongoing assessment of the effectiveness of the cut-off wall will likely also increase the overall environmental monitoring expenditure.

The containment wall approach does not treat the onsite contamination and the eventual treatment cost represents a deferred liability that is likely to increase over time through ongoing releases and inflation. Ongoing operation of a reduced pump and treat system for a partial cut-off wall represents an OPEX cost.

Appendix E: Pump and treat

E1 Technology overview

Ex-situ groundwater treatment requires the extraction of groundwater via pumping (or similar means). The extracted water would then be treated onsite rather than disposing offsite due to the large volumes realised by such a system. Pump and treat systems generally require the removal of significantly greater groundwater volumes than the actual volume of contaminated groundwater as sorbed or trapped hydrocarbons are dissolved into solution as fresh groundwater enters the aquifer and is contaminated i.e. inflows of uncontaminated groundwater is required to mobilise the full extent of contamination. This is particularly the case in an aquifer with fluctuating groundwater levels where a smear zone can be present.

The current approach is a pump and treat system with pumping rates in part set to achieve drawdown at particular locations to control the distribution of LNAPL and dissolved phase hydrocarbon impacted groundwater. Ongoing monitoring is undertaken to review hydraulic containment and the potential for saline intrusion.

E2 Technical feasibility and effectiveness

Pump and treat is a well-established method and has been implemented at the site for decades. The current system is generally effective at controlling LNAPL migration and dissolved phase hydrocarbons.

The speed and efficacy of the system is limited or controlled by the maximum achievable pumping rate (or treated discharge rate). The current pumping regime is at or approaching the permitted discharge limits and cannot be increased without consent changes to discharge additional treated water.

As pump and treat removes groundwater and entrained contaminants the pumping side of this method would be expected to be effective across all contaminants. The treatment side would require further evaluation to confirm the adequacy of treatment of all contaminants. Our understanding of the current treatment process suggests that all contaminants other than PFAS are likely suitable. PFAS typically would require additional adsorption/filtration by granular activated carbon (GAC) or synthetic media.

E3 Time

Pump and treat is an ongoing remediation technique in the context of ongoing releases at the site. However, even once operation of the site ceases this option will need to operate over a long time period unless other source removal/treatment is also implemented.

E4 Sustainability

The current system utilises existing infrastructure required as part of the general Refinery operations. The down-well pumps are reasonably energy efficient.

E5 Protection of the environment

The current pump and treatment is generally protective of the environment and is designed to prevent release of contaminated water to the environment. The treated water discharge is subject to consent conditions and is set to be protective of the receiving environment.

E6 Financial

The current system is installed and operational and we understand that it requires relatively minimal ongoing financial expenditure to maintain. Costs to expand the system (such as by installing one of two more recovery wells) are also relatively low (e.g. less than $100,000 CAPEX). Should treatment of PFAS in groundwater be considered as part of future pump and treat operations, the cost for treatment would increase (and would depend on the PFAS concentrations required to be treated).

Appendix F: Hydraulic control by reinjection

F1 Technology overview

Hydraulic control by reinjection of water involves injecting water into the aquifer to create local mounding of groundwater levels and the formation of a hydraulic divide. This is essentially the inverse of the cone of depression created around a pumping well. The raised groundwater levels prevent the migration of LNAPL in that direction and can also control dissolved phase flow direction. Potable water is suitable for this application, however, extracted and treated groundwater is more commonly utilised.

F2 Technical feasibility and effectiveness

Hydraulic control by reinjection is commonly utilised during excavation dewatering projects and is technically feasible. Key limitation and considerations include:

- Balance and control of flow rates (extraction and injection) to achieve sufficient hydraulic containment;
- Ensuring the water used for reinjection is of sufficient quality that there is no adverse impact from the injection.
- Adequately designing the injection layout to ensure hydraulic containment while also ensuring that existing contamination is not pushed to an unwanted direction
- Ensuring that injection rates are not excessive leading to daylighting of the injected water.

The hydraulic control approach has an added potential benefit of allowing for an increase in pumping rates (and/or lateral distribution) as the additional extracted water is injected rather than being discharged under the current consent. A groundwater model informed by further hydraulic assessment would be required to establish the required pumping rates and discharge rates needed to establish an effective hydraulic control (by injection) divide. Consideration in the modelling exercise would also include contingency measures in the event of pump failure. Given the shallow water table, assessment is also needed as to the potential for surfacing of injected water.

As hydraulic control includes the pumping of groundwater and entrained contaminants the pumping side of this method would be expected to be effective across all contaminants. The treatment side prior to reinjection would require further evaluation to confirm the adequacy of treatment of all contaminants. Our understanding of the current treatment process suggests that all contaminants other than PFAS are likely suitable. PFAS typically would require additional adsorption/filtration by GAC or synthetic media. The TPH/BTEX treatment may also require additional treatment depending on the discharge consent requirements.

As has been noted for ISCO and bioremediation methods, the opportunity to install a comprehensive network of injection wells is likely to be limited by the presence of existing critical infrastructure. Gaps in the injection network can lead to the release of untreated hydrocarbons from the site.

F3 Time

Hydraulic containment is an ongoing remediation technique in the context of ongoing releases and pump and treat at the site. Once operation of the site ceases this option will need to operate over a long time period unless other source removal/treatment is also implemented.

F4 Sustainability

This approach is relatively sustainable as it largely uses existing resources with a relatively minor upfront consumption of resources in the form of injection well construction and pumping setup.

F5 Protection of the environment

This approach should be protective of the environment by preventing release of contaminants to the environment. There is the potential for impacts to flora through an elevated groundwater level, however, this is considered unlikely in the context of an operating Refinery. Resource consents will be required for injection of potable water and/or treated groundwater.

F6 Financial

Following the initial injection point construction ongoing operational costs are minimal as the system is largely an extension of the existing. There would likely be an increase in monitoring and compliance costs (mostly at the front end) to confirm adequate containment is achieved on an ongoing basis. The preparation of a detailed ground water model to assess the potential effectiveness of a reinjection would cost $50-$100k depending on extent and format of available information to feed into the model. Additional site investigation work would likely be required to refine and calibrate the model prior to proceeding with detailed design. Additional work in the form of a pilot trial (or trials depending on locations) would also be required.

We estimate an indicative cost for the implementation of a reinjection / hydraulic containment system on the north, east and south side to the Refinery site to have a CAPEX cost of around $1 M.

Additional likely costs include potential upgrades to the existing water treatment system to handle additional flow rates and / or improve treatment to a higher standard for reinjection.

Operating costs will include routine regular servicing and potentially defouling of the injection pumps and any increase to the maintenance requirements of the water treatment system relating to an increase in capacity or treatment standard. A higher flow rate will also increase consumable (e.g. GAC) replacement and disposal. Ongoing assessment of the effectiveness will likely also increase the overall environmental monitoring expenditure.

8.4 Appendix D – Marine Structures

8.4.1 Feasibility Report: Reduction in Marine Structures at Refining NZ

Advisian
Worley Group

intertek Advisian KBC
GLOBAL REFINING PARTNERSHIP

Memorandum

To:	Ms Jane Thomson, Business Development Manager – Refining NZ	**Date:**	30th July 2019
CC:	Carl Anderson, Senior Project Engineer - Worley	**From:**	Michael Turner, Senior Associate -Advisian
Doc no.:	401010-01563-MA-MEM-001-1	**File location:**	RNZ CMS – Case 2149
Subject:	RNZ Resource Consent Renewals – Indicate Estimate for Case 2 Reduction in Marine Structures	**Project no.:**	40101-01563

1.1 BACKGROUND

Refining NZ (RNZ) are putting together a paper as part of their Resource Consent renewals. Section 105 of the RMA requires an analysis of all alternatives as part of the consent submission i.e. looking at no, reduce and retain options for all consents.

This analysis applies to the marine infrastructure including the jetties and dolphins at Marsden Point. RNZ require indicative costs for reducing the number of jetties at Marsden Point and for the consent submission analysis it is proposed to do this by considering the following proposal;

- Demolish Jetties 2 and 3,
- Retaining Jetty 1,
- Provide facilities at Jetty 1 to accommodate current operations at Jetty 2 and 3, including;
    - Constructing a small facility "Jetty 3.1" as part of Jetty 1 to facilitate the Awanuia (*the small fuel oil tanker that Jetty 3 was specifically built for in 2008*),
    - Provide additional product pipelines to Jetty 1 including bunker fuel and jet.

This memorandum provides details for a very high-level estimate of the capital required for this reduction in marine structures to assist with compliance with the Resource Consent renewals requirements.

1.2 SCOPE OF WORK

The basis for the estimate would be as follows;

- Modifications to Jetty 1 such that we would no longer require Jetties 2 and 3,
- Ability to ship Jet A1 from Jetty 1,
- An indicative project cost with an accuracy in the realm of +150%/-50%

In addition, the following comments were provided by RNZ;

.~192 m 12 inch line work to facilitate jet shipping from Jetty 1

- *Could reuse existing valves from Jetty 2 arrangement*
- *Currently no room on over water pipe rack, so would require pipe supports above water*
- *Jetty hose modifications*
  - *There is room for 1 additional hose (where hose 14(?) used to be – an old crude hose no longer used)*
  - *Hoses may require re-aligning*

1.3 DISCUSSION

With the re-location of Jetty 3 (Jetty 3.1) the immediate approach would be to mirror the current arrangement and locate the new berth to the south of the Jetty 1 dolphins, similar to the current arrangement at Jetty 2. This would ensure that Jetty 1 & Jetty 3.1 would be able to operate independently. However, it is apparent from aerial photography that shoaling is occurring in the vicinity of the Jetty 1 dolphins This is most likely due to long-shore transportation of sediments from the south. The shoaling appears to be significant and more recent aerial photographs suggests that some areas in this vicinity dry at times – refer **Figure 1**.

The Awanuia has a 6m draft and considerable dredging work would be required to provide access for the vessel into this location. In addition, the aerial photography shows that between 2002 and 2006 the location has gone from having deep water to becoming dry at times and so it seems that there is a rapid rate of shoaling occurring. As a result, it would appear that ongoing maintenance dredging at least every five years would be required. This is thought to be unsustainable and so is not recommended. In addition, the process of obtaining approvals for the initial dredging and ongoing works would be time consuming, expensive and uncertain and accordingly, for this exercise, we have assumed that the Awanuia would have to be moored at Jetty 1. This will reduce the capital costs associated with the project but will prevent use of Jetty 1 when the Awanuia is at the berth.

Jetty 1 appears to be relatively high above the water as would be expected for a facility servicing larger vessels. To accommodate the Awanuia it would be necessary to construct separate berthing dolphins placed closer to the water level. Also, modifications to Jetty 1 may be necessary to provide loading access.

It is anticipated that at least two new product lines would be required at Jetty 1 to maintain current operations. It is understood that there is inadequate room for new pipelines on the existing pipe racks and an allowance has been made for the provision of new pipe racks for these services. It is assumed that they would be attached to existing structures and would not be independently supported.

The product pipelines would need to be cleaned prior to cutting up into lengths (*say 6 to12m*) and removed using cranes and suitable transport. If the pipelines are contaminated or cannot be easily cleaned the demolition process would be more onerous to prevent contamination of the environment. It is considered that most of the pipelines would be terminated at the branch location with the main line servicing Jetty 1 and 2.

Removal of piles can be done by cutting them off at the seabed, but this leaves a potential liability and Authorities often prefer piles to be fully removed from the seabed where this is possible. In this location it is thought that the piles are embedded in sand and it would be possible to fully remove them. The estimate has allowed for the full removal of piles.

It is understood that there are significant tidal currents in this location and that these currents will affect the operations of floating plant.

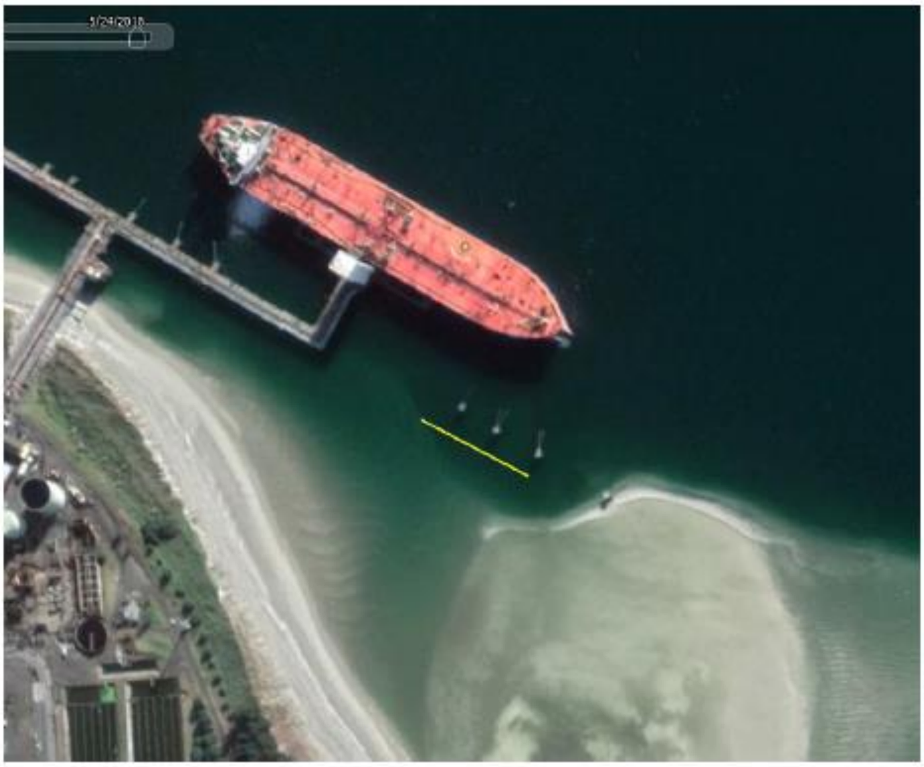


Figure 1 – Shoaling in Vicinity of Dolphins. Note that it appears that there may have been some recent dredging prior to this photograph being taken to provide access for line boats. The Awanuia would require much more substantial access. The yellow line on the figure is 75m long – the same length as the Awanuia.

1.4 ASSUMPTIONS

To complete this high-level estimate a number of assumptions have been made as follows;

- To maintain current handling capacity 10 inch lines for jet shipping and diesel would be provided to Jetty 1.
- There is inadequate capacity for access of more product lines to Jetty 1 and allowance has been made for additional capacity to be provided.
- 12 product lines currently service Jetty 2 and would have to be de-commissioned and demolished.
- Subject to relatively minor improvements and modifications, Jetty 1 can accommodate the relatively smaller Awanuia.
- Dolphins A1 and A2 at Jetty2 have been demolished previously (*probably as part of the Jetty 3 construction*).
- Full removal of piles from the seabed would be possible due to piles being embedded in sands. If this is not the case piles would have to be cut-off at seabed level, which may be a concern to Authorities. If piles need to be cut-off at sea-bed level another study is needed to determine technical feasibility (Geotech/piling reports) vs acceptability of leaving in place and determining the ALARP cost position between the two.
- Works at Jetty 2 and 3 would not be impacted or delayed by normal operations at Jetty 1 – allowance has been made in the work on Jetty 1 rates for operational delays.
- Estimated costs are based on Australian based projects and quoted in Australian Dollars. This has been converted to NZD at a rate of 1.0AUD=1.1NZD.
- The estimate includes nominal allowances ($500k each) for non-productive time associated with working on the jetty (e.g tidal changes) and for operational disruptions (e.g. requirement to use part of the jetty during the project). When we utilise the factors which are commonly used for this type of work at RNZ (non-productivity factor of 2.2 on labour & operational disruption of 20% on construction costs), the P90 cost increases significantly to circa $24m. Whilst this value appears very high, it reflects just how much downtime that the labour force and equipment could be subjected to. It could therefore be construed as a P95 or P99 value.

1.5 FINDINGS

A high-level cost estimate based on the above discussion and assumptions has been completed. The P50 estimate for the proposal to reduce the facilities is NZD$10.5M.

The approximate breakdown of costs is as follows, refer to the **Appendix A.1.1** for details;

Item	Cost NZD$
Mobilisation	$110,000
De-commissioning	$40,000
Demolition	$5,400,000
Construction of new works	$1,300,000
Operational Disruption, Non-Productive Time & Waiting on Weather (nominal allowance only)	$1,050,000
Engineering and Management	$800,000
Contingency	$1,800,000

1.6 SUMMARY / CONCLUSION

As part of Refining NZ's Resource Consent renewals, a high-level estimate has been completed for the reduction in marine infrastructure at Marsden Point. The reduction involves the demolition of Jetties 2 and 3 and re-locating their facilities to Jetty 1 (*namely, a jet line and bunkering facility*).

Due to shoaling in the vicinity of Jetty 1 from natural coastal processes, the Jetty 3 facility has been assumed to need to be incorporated as part of Jetty 1 and as a result Jetty 1 operations will not be possible when the operations previously at Jetty 3 are being carried out.

It was found that the cost to demolish the Jetty 2 and 3 facilities and to re-locate operations to Jetty No.1 is approximately NZ$10.5m (P50). Based on an estimate accuracy of -30%+50% (representative for this type of estimate), this corresponds to a P10 estimate of NZ$7.4m and P90 estimate of NZ$15.7m.

A.1 APPENDICES

A.1.1 Spreadsheet Estimate

A.1.2 Reference Drawings

REFINING NZ

Option 2 - Reduce Facilities

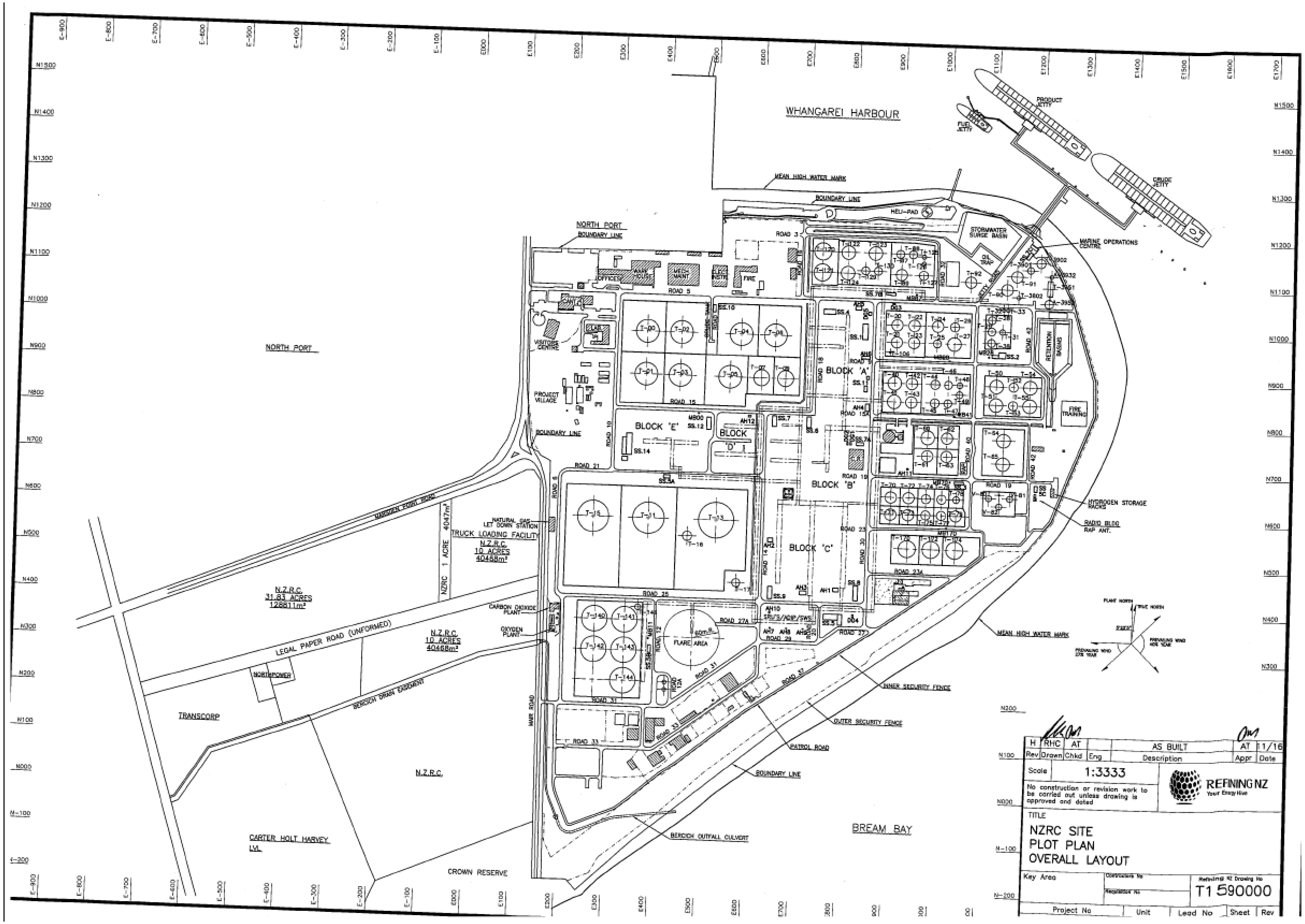
AUD:NZD Conversation Rate 1.1 AUD:NZD

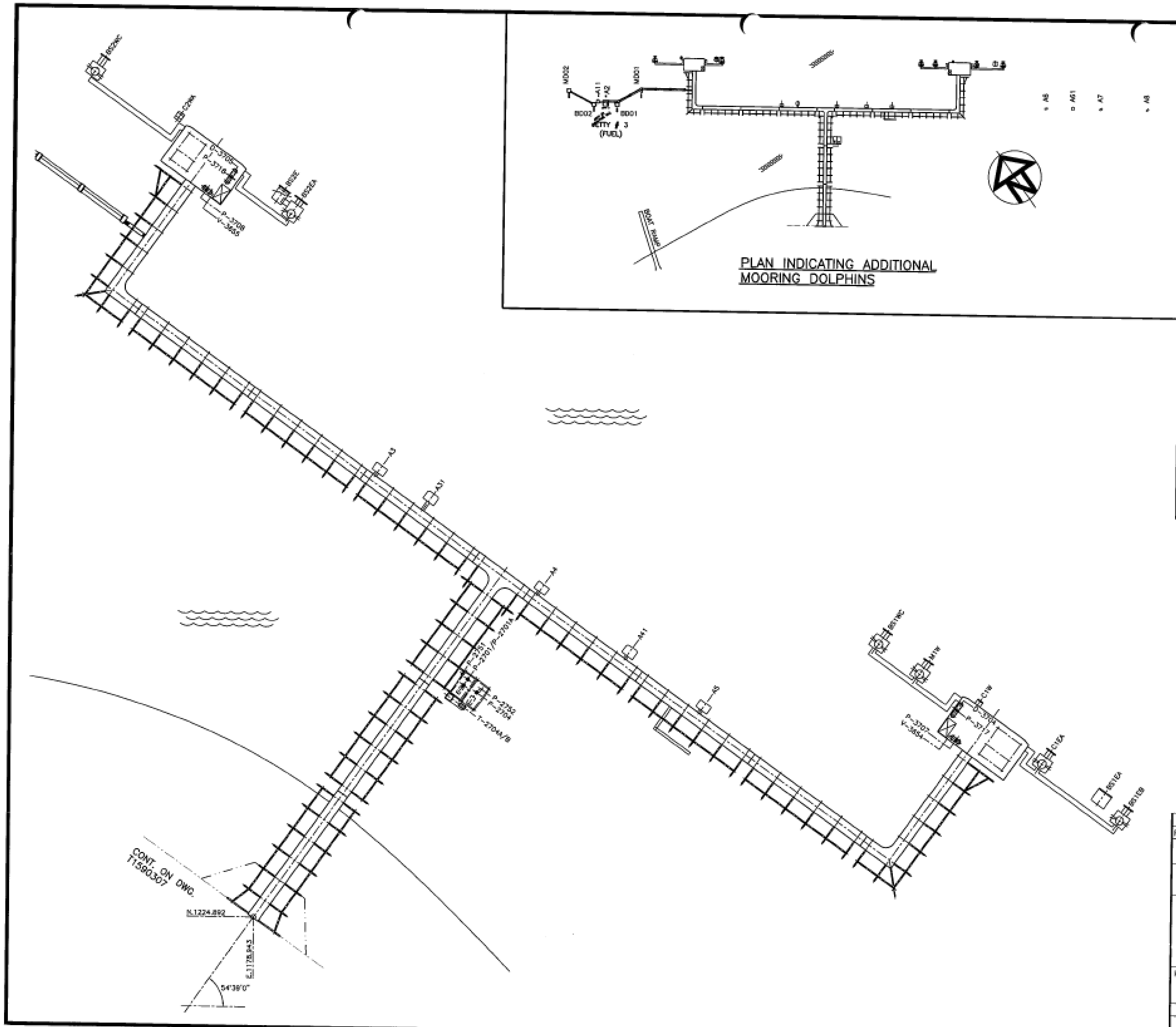
Description: Demolish Jetty 2 & 3. Relocate Jetty 3 to Jetty 1

Client	Refining NZ		
Job No.	401010-01563		
Prepared	MJT	Rev	0
Checked	PMcC	Date	22-Jul-19

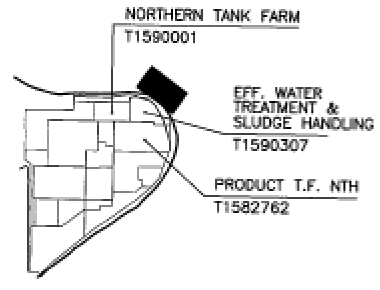
STAGE	DESCRIPTION	QUANTITY	UNIT	RATE (AUD)	TOTAL (NZD)	SUM (NZD)	REMARKS
Mobilisation						$ 110,000.00	
	Site establishment	1	LS	$ 100,000	$ 110,000		Allowance
	Procurement (included below)		LS		0		
Construction						6,753,560	
	Decommissioning						
	Decomission product lines to Jetty 2	1	ITEM	$ 15,000	$ 16,500		12 services, 3 crew one week
	Decommision product lines to Jetty 3	1	ITEM	$ 2,500	$ 2,750		1 service 1 crew 1 day
	Removal of all furniture and minor services (handrails, lightpoles etc)	1	ITEM	$ 15,000	$ 16,500		Allowance
	Demolition Jetty 2						
	Topsides structures and equipment	308	m2	$ 150	$ 50,820		loading equipment, buildings etc. Allowance
	Demolish product lines	2400	m	$ 180	$ 475,200		12 services, 40m/day, 200m, 5 man crew + crane and truck
	Cut up and remove decking to top of piles	308	m2	$ 800	$ 271,040		AIE estimate Item 3.2 (references Stanvac). $2,000/m3 assume deck 400 thk on average. 22m x 14m
	Demolish piles - full removal from seabed by vibration	12	No.	$ 22,500	$ 297,000		AIE $12,000 each. AGL $17,315 482 x 12.7. Assume 3 x 4 pile grid
	Cut up and remove trestle decking	900	m2	$ 800	$ 792,000		Assume 5m wide
	Demolish Trestle Piles - full removal from seabed by vibration	36	No.	$ 22,500	$ 891,000		Adopt pile supports at 12m
	Jetty 2 Dolphins A11, A3, A31, BS2WC, BS2E, BS2EA						
	Remove furniture	6	No.	$ 10,000	$ 66,000		
	Demolish topsides	192	m3	$ 2,000	$ 422,400		6 average size dolphins, four piles each, 32m3 top sides, $2,000/m3 demolish, $15,000 to demolish piles, $10,000 to demolish services / QRH / fenders / misc furniture etc
	Demolish Piles - full removal from seabed	24	No.	$ 22,500	$ 594,000		
	Demolish Jetty 2 Walkways	45	m	$ 1,000	$ 49,500		45m $1,000/m based on AGL
	Demolish Jetty 2 Pipe rack	180	m	$ 500	$ 99,000		$500/m based on AGL
	Demolition Jetty 3						
	Topsides structures and equipment	30	m2	$ 150	$ 4,950		Allow for 30m2 structure
	Demolish Product Lines	250	m	$ 180	$ 49,500		1 services, 40m/day, 250m, 5 man crew + crane and truck
	Cut up and remove decking to top of piles	30	m2	$ 800	$ 26,400		none
	Demolish piles - full removal from seabed	6	No.	$ 22,500	$ 148,500		5m x 6m
	Piled walkways	125	m	$ 1,000	$ 137,500		125m
	Demolish Jetty 3 Walkway Piles	9	No	$ 22,500	$ 222,750		9 No.
	Demolish Jetty 3 Piperack	125	m	$ 500	$ 68,750		125m
	Demolish Jetty 3 Dolphins - four off						
	Remove furniture	4	No.	$ 10,000	$ 44,000		
	Demolish topsides	128	m3	$ 2,000	$ 281,600		4 average size dolphins, four piles each, 32m3 top sides, $2,000/m3 demolish, $15,000 to demolish piles, $10,000 to demolish services / QRH / fenders / misc furniture etc.
	Demolish Piles	16	No.	$ 22,500	$ 396,000		
	Jetty 1 New Works						
	New product lines to Jetty 1	200	m	$ 1,600	$ 352,000		Antony Perri 4/7 $80/"/m, 2 x 10" say $1600/m
	New pipe racks	200	m	$ 1,000	$ 220,000		
	Topside facilities for new product lines	1	Item	$ 25,000	$ 27,500		Allowance
	New Fendering For Awanuia				$ -		Awanuia
	Piling	8	No.	$ 25,000	$ 220,000		$25,000 each supply and installed 4 per dolphin.
	Pile Cap	40	m3	$ 10,000	$ 440,000		$10,000/m3 placed insitu 20m3 each
	Fenders	2	No.	$ 17,000	$ 37,400		2 off. SCN 700 4l 9580kg $400k = $40/kg
	Bollards / QRHs	2	No.	$ 5,000	$ 11,000		Bollards $5k each
	Modifications to Jetty to accommodate Awanuia	1	Item	$ 20,000	$ 22,000		Allowance
	Non-Productivity Allowance - Working on Jetty					500,000	Nominal allowance included for non-productive time. Historically RNZ have used a factor of 2.2 on all labour costs (assumed to be 50% of total construction costs). This factor is consistent with that used on other projects at RNZ.
	Operational Disruption					500,000	Nominal allowance for disruption to construction activities due to RNZ Operational requirements - eg. jetty usage. To be reviewed by RNZ and adjusted as required.
	Waiting on Weather Allowance					50,000	Allow 4 off 1 day weather events
Engineering and Management						819,000	
	Engineering (Design and Specifications)	3	PERCENT		234,000		
	Project Management	5	PERCENT		390,000		
	Certification	0	PERCENT		0		
	Insurance	2.5	PERCENT		195,000		
	TOTAL COST $					8,732,560	
	CONTINGENCY	20	PERCENT			1,746,512	
TOTAL COST WITH CONTINGENCY $ (P50)						10,479,000	
TOTAL COST WITH CONTINGENCY $ (P10): P50 less 30%						7,335,300	
TOTAL COST WITH CONTINGENCY $ (P90): P50 plus 50%						15,718,500	

NOTES: Factor of 1.5 x rate for full removal of piles compared to cutting off at seabed.
Assumed that operations work will not interfere with J1&2 works and that rates for J1 work includes this.


WHANGAREI HARBOUR
PRODUCT JETTY
FUEL JETTY
CRUDE JETTY
MEAN HIGH WATER MARK
BOUNDARY LINE
HELI-PAD
STORMWATER SURGE BASIN
MARINE OPERATIONS CENTRE
NORTH PORT
NORTH PORT BOUNDARY LINE
OFFICES
MECH MAINT
FIRE
ROAD 5
VISITORS CENTRE
PROJECT VILLAGE
BLOCK 'A'
BLOCK 'B'
BLOCK 'C'
BLOCK 'D'
BLOCK 'E'
RETENTION BASINS
FIRE TRAINING
HYDROGEN STORAGE RACKS
RADIO BLDG RAP ANT.
MARSDEN POINT ROAD
NATURAL GAS LET DOWN STATION
TRUCK LOADING FACILITY
N.Z.R.C. 10 ACRES 40468m²
NZRC 1 ACRE 4047m²
N.Z.R.C. 31.83 ACRES 128811m²
LEGAL PAPER ROAD (UNFORMED)
N.Z.R.C. 10 ACRES 40468m²
CARBON DIOXIDE PLANT
OXYGEN PLANT
FLARE AREA
NORTHPOWER
TRANSCORP
BERCICH DRAIN EASEMENT
MARR ROAD
N.Z.R.C.
CARTER HOLT HARVEY LVL
CROWN RESERVE
BERCICH OUTFALL CULVERT
BREAM BAY
INNER SECURITY FENCE
OUTER SECURITY FENCE
PATROL ROAD
PLANT NORTH
TRUE NORTH
H RHC AT AS BUILT AT 11/16
Rev Drawn Chkd Eng Description Appr Date
Scale 1:3333
No construction or revision work to be carried out unless drawing is approved and dated
REFINING NZ
TITLE
NZRC SITE
PLOT PLAN
OVERALL LAYOUT
Key Area
T1 590000
Project No Unit Lead No Sheet Rev



KEY PLAN

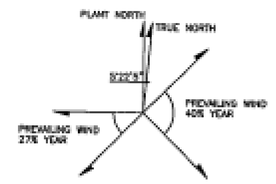


GENERAL NOTES

1. COORDINATES ARE GIVEN IN METRES.
2. ELEVATION 100.000 EQUALS PLANT DATUM. ZERO EQUALS 4.27M.S.L.

REFERENCE DRAWINGS

T1590000	OVERALL SITE LAYOUT
T1583061	PIPING AREA IDENTIFICATION



Rev	Drawn	Chkd	Description	Appr	Date
C	MEG	MEG	UPDATED : FOR INFORMATION	LAC	08.09

Scale 1:2000 1:500 — No construction or revision work to be carried out unless drawing is approved and dated

THE NEW ZEALAND REFINING COMPANY LTD

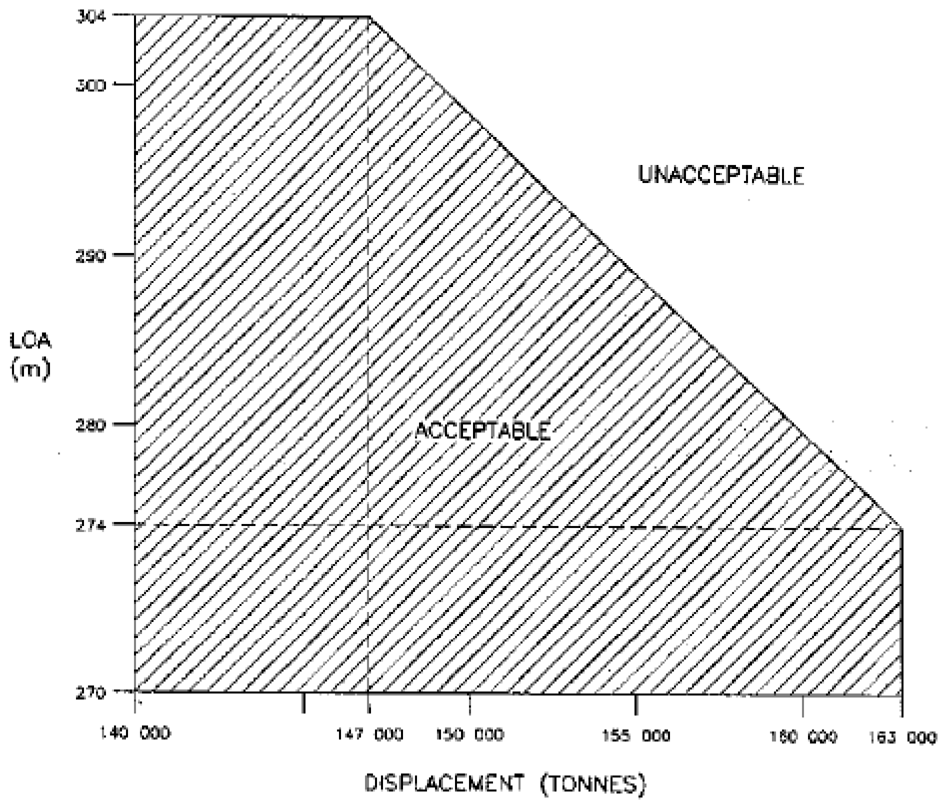
TITLE

OVERALL PLOTPLAN JETTY AREA

Key Area | Contractors No | Requisition No | T3015977

Project No	Unit	Lead No	Sheet	Rev
N/A	3700	101	1	C

TANKER DISPLACEMENT ENVELOPE FOR No 1 JETTY – NZRC



NOTE:

i)	DISPLACEMENT K TONNES = 309133 – 533 x (LOA).	FOR 274 ≤ LOA ≤ 304
ii)	DISPLACEMENT K TONNES = 163 000.	FOR LOA < 274
iii)	NOT ACCEPTABLE.	FOR LOA > 304

Ref Drawings

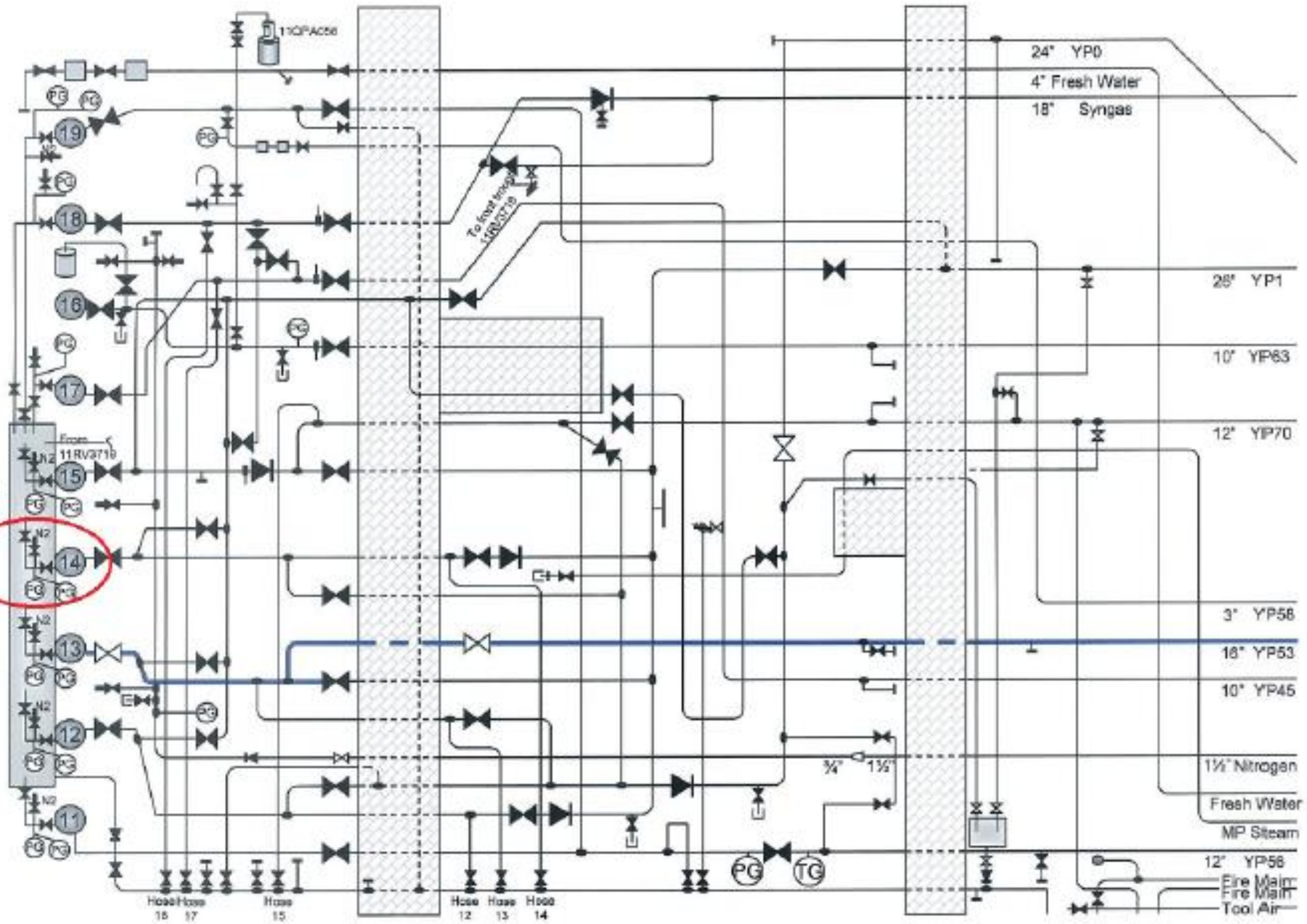
Rev	Drawn	Chkd	Description	Appr	Date
01	RHC		FOR INFORMATION	SL	11/97

THE NEW ZEALAND REFINING COMPANY LTD

Title: DISPLACEMENT ENVELOPE FOR NZRC NO 1 JETTY	Contrs No		SIOP No T3014894
	Req No		Key Area
	Scale	NONE	
	Project No	Unit 3700	Lead No / Sht 1 / Rev 01

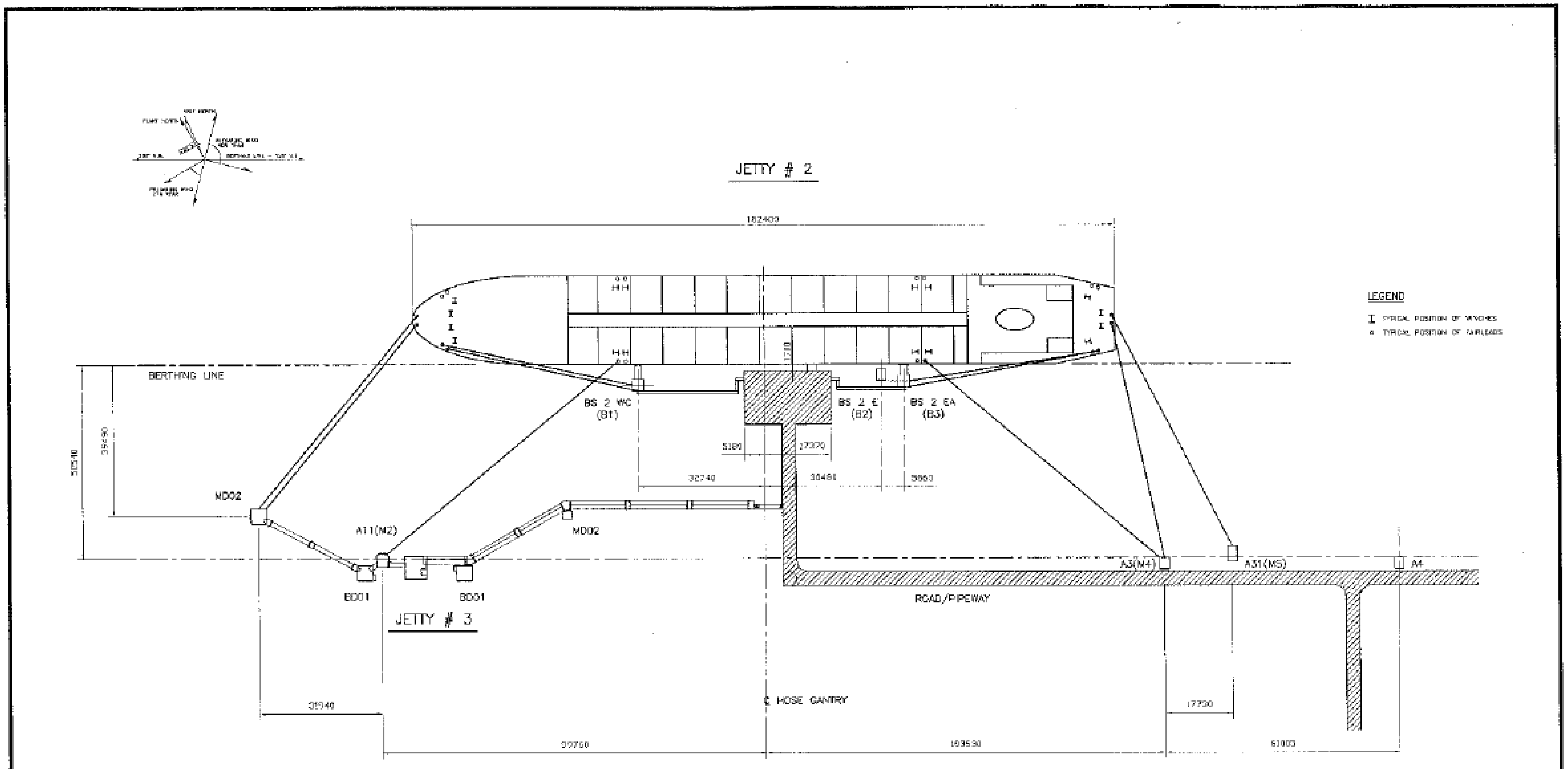
Jetty 1 YP53

Hose 14 (an old crude hose) has been removed, but linework upstream of the block valve still exists



ignore blue highlighted line (this is a fuel oil line)

WIPT.3750.357



DOLPHIN	RATED CAPACITY REF. T-2.084.665	NOMINAL QRH CAPACITIES AND CAPSTANS AS INSTALLED
MD02	75 TONNES	1 x 75T QRH + 1 CAPSTAN 3T
A11	150 TONNES	3 x 75T QRH + 1 CAPSTAN 3T
A3	125 TONNES	2 x 75T QRH + 1 CAPSTAN 3T
A31	150 TONNES	2 x 75T QRH + 1 CAPSTAN 3T
BS2WC	150 TONNES	2 x 75T QRH + 1 CAPSTAN 3T
BS2E	80 TONNES	1 x 75T QRH + 1 CAPSTAN 3T
BS2EA	150 TONNES	2 x 75T QRH + 1 CAPSTAN 3T

Rev	Drawn	Chkd	Description	Appr	Date
B	MEG	MS	FOR INFORMATION	IAC	06.09
A	PGS	PGS	FOR INFORMATION	S.Lee	2/96

Scale 1:500

THE NEW ZEALAND REFINING COMPANY LTD

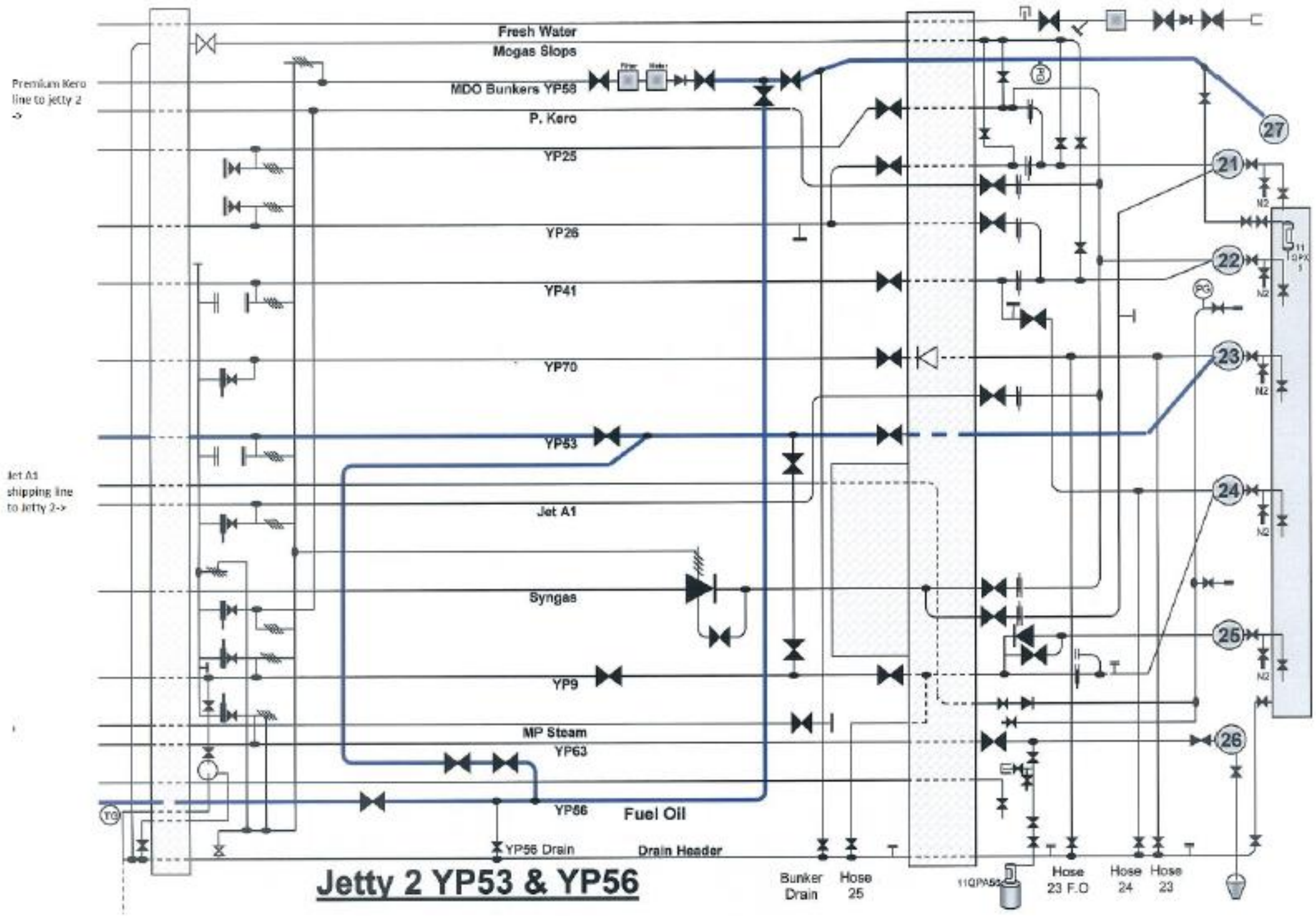
TITLE

PRODUCT JETTY No.2
DEDICATED MOORING LINE LAYOUT
35000 TONNE DWT – TOANUI

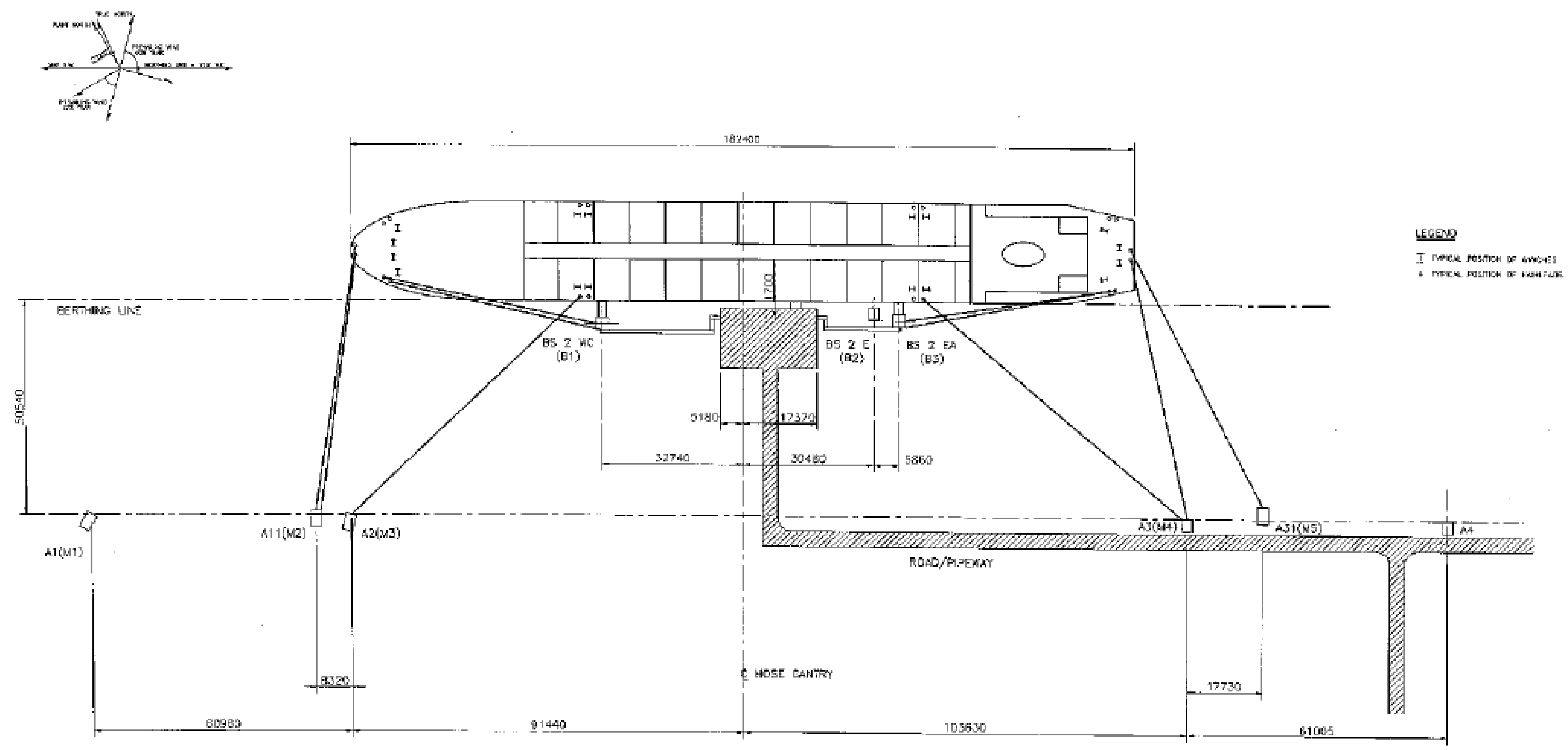
Key Area

T3014777

Project No	Unit	Lead No	Sheet	Rev
N/A	3700	701	1	B



Jetty 2 YP53 & YP56



DOLPHIN	RATED CAPACITY REF. T-2.084.665	NOMINAL QRH CAPACITIES AND CAPSTANS AS INSTALLED
A1	75 TONNES	1 x 75T QRH + 1 CAPSTAN 3T
A11	150 TONNES	3 x 75T QRH + 1 CAPSTAN 3T
A2	75 TONNES	1 x 75T QRH + 1 CAPSTAN 3T
A3	125 TONNES	2 x 75T QRH + 1 CAPSTAN 3T
A31	150 TONNES	2 x 75T QRH + 1 CAPSTAN 3T
BS2WC	150 TONNES	2 x 75T QRH + 1 CAPSTAN 3T
BS2E	80 TONNES	1 x 75T QRH + 1 CAPSTAN 3T
BS2EA	150 TONNES	2 x 75T QRH + 1 CAPSTAN 3T

Rev	Drawn	Chkd	Description	Appr	Date
A	PGS	PGS	FOR INFORMATION	S.Lee	2/96

Scale 1:500

No construction or revision work to be carried out unless drawing is approved and dated

THE NEW ZEALAND REFINING COMPANY LTD

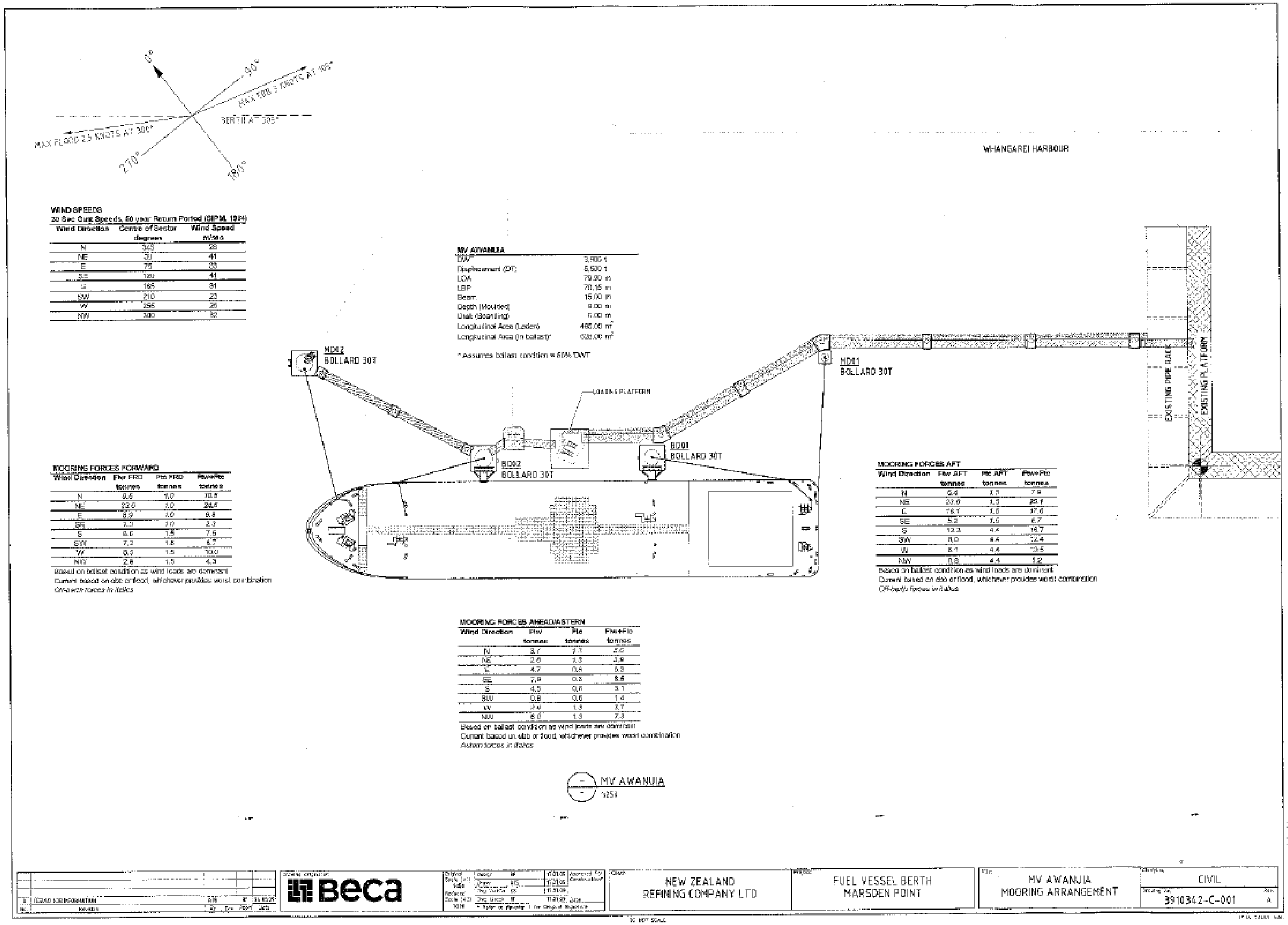
TITLE

PRODUCT JETTY No.2
DEDICATED MOORING LINE LAYOUT
35000 TONNE DWT

Key Area

T3014777

Project No	Unit	Loc No	Sheet	Rev
	3700		1	A



WIND SPEEDS

30 Sec Gust Speeds, 50 year Return Period (SIPM, 1984)

Wind Direction	Centre of Sector degrees	Wind Speed m/sec
N	345	28
NE	30	41
E	75	33
SE	120	41
S	165	31
SW	210	23
W	255	26
NW	300	32

MV AWANUIA

DW*	3,900 t
Displacement (DT)	5,500 t
LOA	79.90 m
LBP	70.15 m
Beam	15.00 m
Depth (Moulded)	8.00 m
Draft (Scantling)	6.00 m
Longitudinal Area (Laden)	465.00 m²
Longitudinal Area (In ballast)*	530.00 m²

* Assumes ballast condition = 60% DWT

MOORING FORCES FORWARD

Wind Direction	Fw FRD tonnes	Fc FRD tonnes	Fw+Fc tonnes
N	9.5	1.0	10.5
NE	23.0	1.0	24.0
E	8.9	1.0	9.9
SE	1.3	1.0	2.3
S	6.0	1.5	7.5
SW	7.2	1.5	8.7
W	8.5	1.5	10.0
NW	2.8	1.5	4.3

Based on ballast condition as wind loads are dominant
Current based on ebb or flood, whichever provides worst combination
Off-berth forces in italics

MOORING FORCES AFT

Wind Direction	Fw AFT tonnes	Fc AFT tonnes	Fw+Fc tonnes
N	6.4	1.5	7.9
NE	23.6	1.5	25.1
E	16.1	1.5	17.6
SE	5.2	1.5	6.7
S	12.3	4.4	16.7
SW	8.0	4.4	12.4
W	6.1	4.4	10.5
NW	0.8	4.4	5.2

Based on ballast condition as wind loads are dominant
Current based on ebb or flood, whichever provides worst combination
Off-berth forces in italics

MOORING FORCES AHEAD/ASTERN

Wind Direction	Fw tonnes	Fc tonnes	Fw+Fc tonnes
N	3.7	1.3	5.0
NE	2.6	1.3	3.9
E	4.7	0.6	5.3
SE	7.9	0.3	8.6
S	4.5	0.6	5.1
SW	0.8	0.6	1.4
W	2.4	1.3	3.7
NW	6.0	1.3	7.3

Based on ballast condition as wind loads are dominant
Current based on ebb or flood, whichever provides worst combination
Astern forces in italics

MV AWANUIA

Beca

Client: NEW ZEALAND REFINING COMPANY LTD

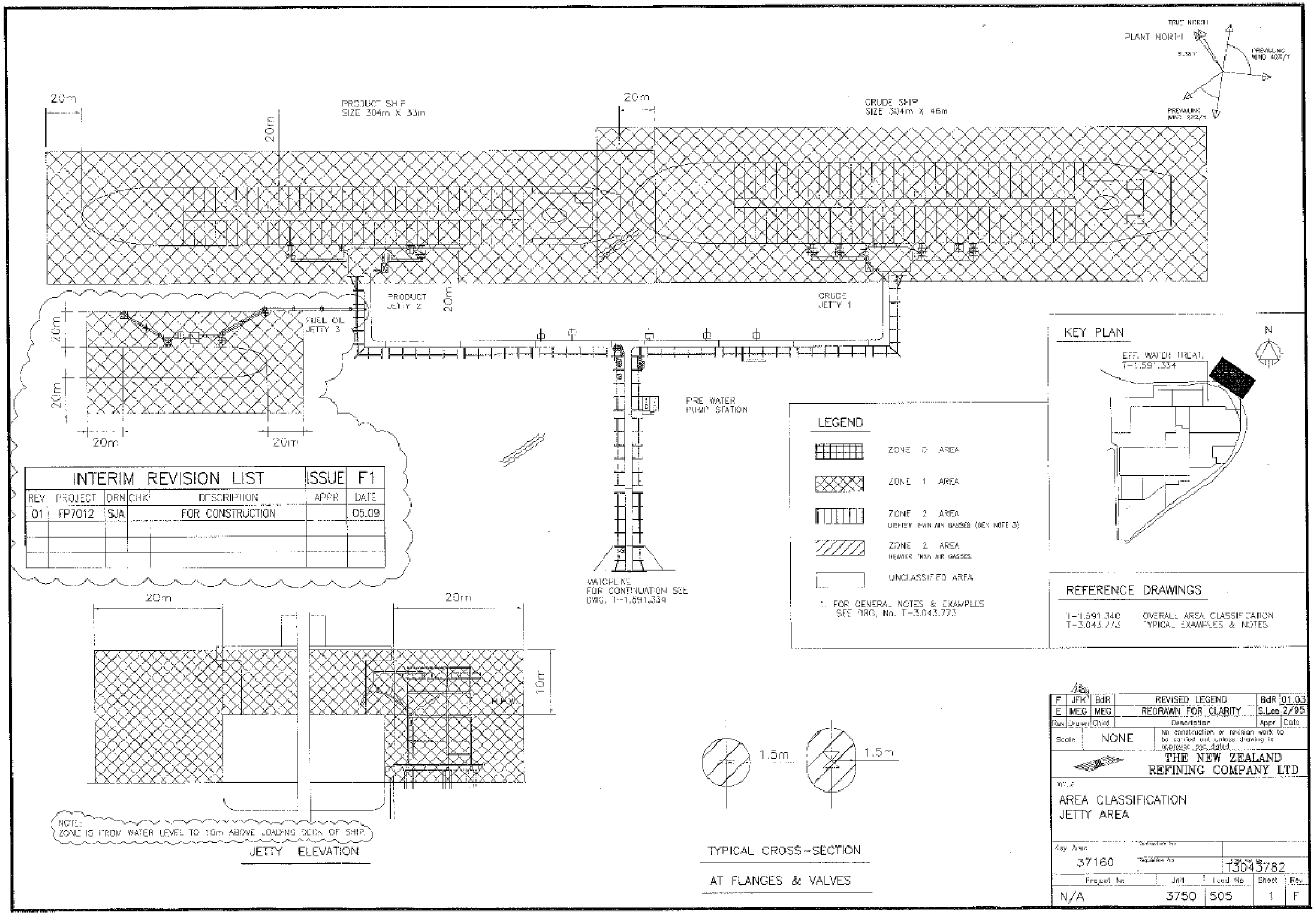
Project: FUEL VESSEL BERTH MARSDEN POINT

Title: MV AWANUIA MOORING ARRANGEMENT

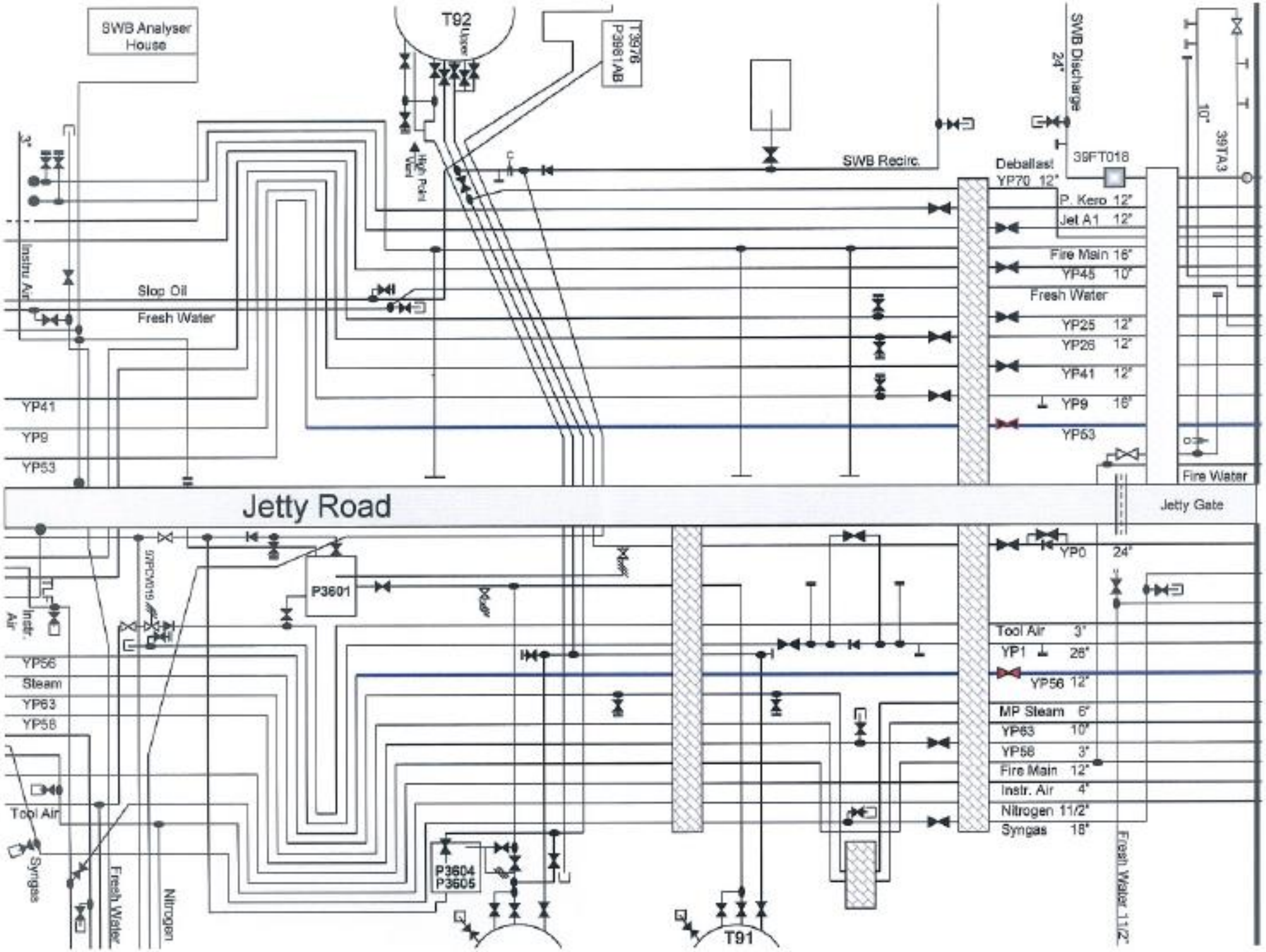
Discipline: CIVIL

Drawing No. 3910342-C-001 Rev. A

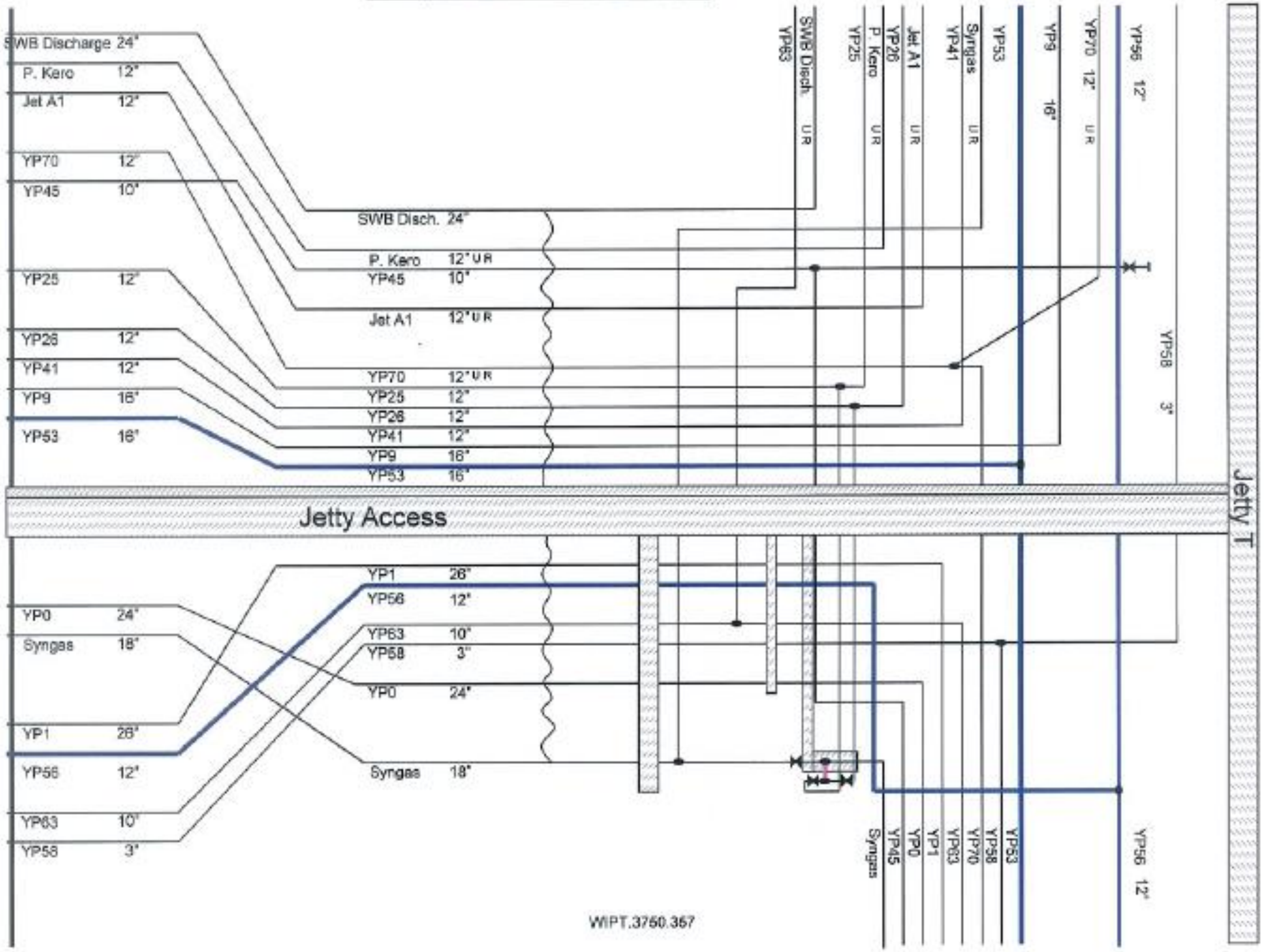
DO NOT SCALE



PRODUCT SHIP
SIZE 304m X 33m
CRUDE SHIP
SIZE 304m X 46m
PRODUCT JETTY 2
CRUDE JETTY 1
FUEL OIL JETTY 3
FIRE WATER PUMP STATION
INTERIM REVISION LIST
ISSUE F1
REV PROJECT DRN CHK DESCRIPTION APPR DATE
01 FP7012 SJA FOR CONSTRUCTION 05.09
KEY PLAN
LEGEND
ZONE 0 AREA
ZONE 1 AREA
ZONE 2 AREA
ZONE 2 AREA
UNCLASSIFIED AREA
1. FOR GENERAL NOTES & EXAMPLES SEE DRG. No. T-3.043.773
REFERENCE DRAWINGS
T-1.591.340 OVERALL AREA CLASSIFICATION
T-3.043.773 TYPICAL EXAMPLES & NOTES
JETTY ELEVATION
NOTE:
ZONE IS FROM WATER LEVEL TO 10m ABOVE LOADING DECK OF SHIP
TYPICAL CROSS-SECTION
AT FLANGES & VALVES
F JFK BdR REVISED LEGEND BdR 01.03
E MEG MEG REDRAWN FOR CLARITY S.Lee 2/95
Scale NONE
THE NEW ZEALAND REFINING COMPANY LTD
AREA CLASSIFICATION
JETTY AREA
37160
T3043782
N/A 3750 505 1 F


SWB Analyser House
T92
T39/6
P3961AB
SWB Recirc.
SWB Discharge
24"
Deballast
YP70 12"
39FT018
39TA3
10"
P. Kero 12"
Jet A1 12"
Fire Main 16"
YP45 10"
Fresh Water
YP25 12"
YP26 12"
YP41 12"
YP9 16"
YP53
Fire Water
Instru Air
3"
Slop Oil
Fresh Water
High Point Vent
YP41
YP9
YP53
Jetty Road
Jetty Gate
YP0 24"
P3601
Instr. Air
YP56
Steam
YP63
YP58
Tool Air
Syngas
Fresh Water
Nitrogen
Tool Air 3"
YP1 26"
YP56 12"
MP Steam 6"
YP63 10"
YP58 3"
Fire Main 12"
Instr. Air 4"
Nitrogen 11/2"
Syngas 18"
Fresh Water 11/2"
P3604
P3605
T91

Jetty T for YP53 & YP56



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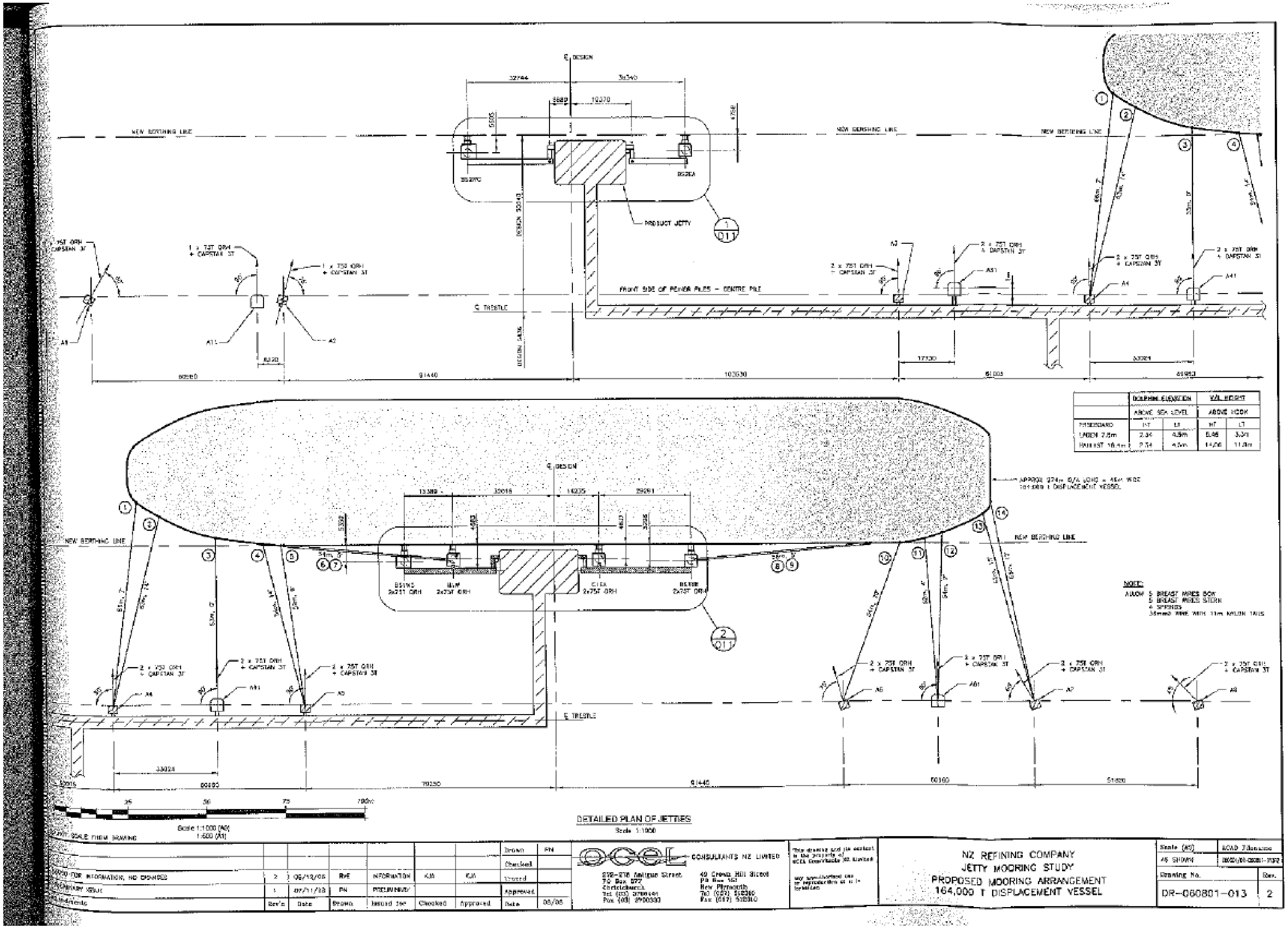

NEW BERTHING LINE
PRODUCT JETTY
FRONT SIDE OF FENDER PILES - CENTRE PILE
DETAILED PLAN OF JETTIES
Scale 1:1000
CONSULTANTS NZ LIMITED
NZ REFINING COMPANY
JETTY MOORING STUDY
PROPOSED MOORING ARRANGEMENT
164,000 T DISPLACEMENT VESSEL
Scale (A3)
AS SHOWN
Drawing No.
Rev.
DR-060801-013
2