D.1 Description of Water Balance Models Used for Integrated Water Management

D.1.1 The NABPond Model

The NABPond model is a dynamic water and mass balance model of the RDA that describes the daily changes in the refinery process, including process chemistry. It is designed to produce an accurate prediction of liquor balance and chemical changes for up to a 5-year period, and determines caustic soda and oxalate concentrations of a network of reservoirs (storage ponds) as a function of time. It can also determine the total overflow from a reservoir. The model accounts for plant effluents and SNL return, as well as seasonal variations in rainfall and evaporation. It does not quantify seepage rates or mud balance. Topographical changes at the RDA that occur as part of the progressive dry stacking placement of red mud are also built into the model structure.

Within the model, the RDA is assumed to consist of networks of the following elements:

- Reservoirs (Storage ponds)
- Flows
- Catchments
- Inter-Reservoir Flows
- Overflows

The NABPond model calculations for each pond or reservoir include water balance, soda balance, oxalate balance, evaporation and rainfall. Inflow and outflow parameters of the model are summarised in Table D.1.

Table D.1
NABPond Model Inflow and Outflow Components

Mechanism/ Element	Inflow Components	Outflow Components
Water Balance of Pond	Pumped Inflow to pond Net rainfall run-off from the pond catchment Direct rainfall to pond	Pumped Outflow from pond Evaporation from pond Overflow for the pond
Caustic Soda Balance of Pond	Inflow to pond and caustic soda concentrations in inflow water	Outflow from the pond and caustic soda concentrations in outflow water Soda depletion due to use of pond SNL for irrigation
Oxalate Balance of Pond	Inflow to pond and oxalate concentrations in inflow water	Outflow from the pond and oxalate concentrations in outflow water Oxalate depletion due to use of pond SNL for irrigation Oxalate depletion due to oxalate decomposition

The NABPond model was calibrated and validated against Pond 5 historical data from 1994 to 1998. Predictions from the model can be revised on a daily basis, but are normally checked every month.

D.1.2 The DAMSIM Model

DAMSIM is a water balance model that has been used to investigate the long-term performance of the water management system in the RDA. The catchment, storage and operating data are varied to model the physical changes in the RDA over the life of the facility. DAMSIM was used to undertake water balance calculations for long range residue disposal planning and for the sizing of Pond 7. The water balance and residue production schedule are combined to identify management issues over the operating life of the RDA. Predictions from this model are revised every three years with actual progress against planned progress being checked annually. Outputs from this model are used to define revegetation requirements and long term trends that exist in the liquor balance.

The DAMSIM model of the RDA includes the following components:

- Catchment areas.
- Pond surface areas and storage-volume data.
- Rainfall and evaporation.
- Discharge of run-off from non-contaminated catchments.
- Water consumed in the refinery (return SNL pumping).
- Stormwater runoff pumped from the refinery.
- SNL water used to transport residue sand.
- Decant water from red mud disposal areas and from residue sand.
- Outflow to the labyrinth neutralisation facility.
- Pump/pipe transfer and spillway capacities.
- Enhanced evaporation through sprinkler operation.

The DAMSIM model was calibrated against the observed performance of the RDA for the period January 1994 to December 1997 to ensure that the model was a correct representation of the system and that the base data assembled for pond characteristics, evaporation and rainfall were reliable.

DAMSIM is used to model the water balance in the RDA throughout its life. The storage capacities and neutralisation capacities required to ensure that all rain events up to the 200 year ARI design events were investigated using DAMSIM.

D.2. Water Quality Monitoring Program and Data

An overview of the Alcan Gove surface water monitoring program is described in Section 11.of the EIS report. This appendix provides additional information on the monitoring sites, water quality criteria and methods of assessment, statistics of available monitoring data, and interpretation of existing water quality conditions. Summary conclusions of the assessment of existing water quality conditions are also presented in Section 11.5 of the EIS report.

D.2.1 Representative Monitoring Sites

Alcan Gove water quality data for selected monitoring sites were reviewed and analysed for the purposes of describing baseline water quality conditions for this EIS. Although monitoring is undertaken at many other sites, most are internal to the operations and are monitored for information to assist with operational aspects and are not specifically relevant to the assessment of the effects on receiving water environments.

The monitoring sites of relevance to describe baseline water quality conditions or indicators of potential impacts on receiving water are summarised in Table D.2. Seven of these are Waste Discharge Licence monitoring sites. The locations of the selected water quality monitoring sites are presented on Figures 11.2.1 and 11.2.2.

Table D.2
Summary of Selected Water Quality Monitoring Sites

Site ID	Location/ Description	Monitoring Purpose
Refinery Catchments		
S001	Seawater Channel Plant Outfall	• To monitor and characterise the quality of water discharged from the Seawater Channel Plant Outfall to Melville Bay. • Waste Discharge Licence sampling site.
S004	Seawater intake (Melville Bay)	• Waste Discharge Licence Sampling Site • Operational control
S005	Western Channel	• Operational control of Seawater Channel discharge water quality, and characterisation of discharges to Seawater Channel
S030	Western pond	• Operational control of Seawater Channel discharge water quality • Characterisation of discharges to Seawater Channel .
S1033	Labyrinth Discharge to Seawater Channel	• Operational control of labyrinth return flow discharges to seawater channel. • To characterise discharges to seawater channel.
S034	Light Fuel Tank Farm Outlet	• Operational Control. • Waste Discharge Licence sampling site.
S036	Dundas Point	• Receiving Water monitoring.
S022	Evaporation cooling water	• Characterisation of discharges to the seawater channel.
S022A S022B	Evaporation Stages 1 and 2 Hotwell Discharges (respectively)	• Characterisation discharges to the seawater channel. • Operational control of discharges to the seawater channel.
S023A	Southern containment pond overflow to seawater channel.	• To characterise discharges to the seawater channel.
S006	Stockpile Creek	• Operational Control • Waste Discharge Licence sampling site.
S010	Northern Beach	• Operational Control • Waste Discharge Licence sampling site

Site ID	Location/ Description	Monitoring Purpose
Residue Disposal Area Catchments		
S1001	Duckpond	• Waste Discharge Licence reporting site • Operational Control
S1005	Road Bridge Creek (south of Wallaby Beach)	• Operational Control
S1006	Macassar Creek	• Waste Discharge Licence reporting site.
S1002	Borrow pit to northwest of Pond 5 near Dimbuka Rocks	• To monitor seepage from Pond 5.
S1003	Taylor's Pond Drain. Upper extent of catchment.	• To monitor seepage from Taylor's Pond.

D.2.2 Water Quality Criteria

The assessment of water quality presented herein is based on ANZECC 2000 Guidelines for Fresh and Marine Water Quality. These guidelines were developed under the National Water Quality Management Strategy (NWQMS) and provide a framework for the development of site-specific water quality objectives and discharge standards that can be used as triggers to initiate further investigation and ameliorative actions. Alcan Gove is currently developing site-specific water quality criteria for the receiving marine environment. Discharge standards will be then be developed to enable these criteria to be met.

The ANZECC 2000 guidelines specify default "trigger" values for specified environmental values and varying degrees of environmental protection, where site specific trigger water quality criteria are not yet developed.

The environmental values for the receiving waters around the refinery are based on the Declared Beneficial Uses for Melville Bay (declared 27 February 1998 under provisions of the NT *Water Act 1996*); *viz*:

- "Aquatic Ecosystem Protection and Recreational Water Quality & Aesthetics"

There are no beneficial uses of water resources for consumption, stock watering, or industrial use associated with surface waters around the refinery or the residue disposal area.

ANZECC (2000) Guidelines

It is suggested by Alcan Gove that the ANZECC guidelines most likely to be applicable to the receiving waters of Melville Bay are those that relate to moderately disturbed marine ecosystems in tropical Australia, with 95% level of species protection. Other current beneficial uses that may apply include:

- Industrial (cooling and treatment water supply)
- Primary Industries (future aquaculture and developments)
- Recreation and aesthetics (primary recreation)
- Cultural and spiritual

Some of the small catchments around the RDA that are upstream of the tidal limit for coastal waters are better represented as local freshwater systems with intermittent flow. Additional information for the application of freshwater aquatic ecosystem guidelines in preference to marine systems is presented in the description of specific monitoring sites.

ANZECC (2000) criteria are also available for recreational use of marine waters. In general, water quality criteria for recreational uses cover fewer water quality parameters and are less stringent than criteria for protection of aquatic ecosystems (refer Table D.3). Criteria for excessive algal growth constraints for recreational use are not specific. However it can be reasonably inferred that criteria for physico-chemical stressors in relation to eutrophication concerns for protection of aquatic ecosystems cover this aspect. This assessment of existing water quality conditions is therefore based primarily on ANZECC (2000) guidelines for the protection of aquatic ecosystems.

The relevant ANZECC water quality guideline trigger levels for protection of aquatic ecosystems and recreational uses are presented in Table D.3.

Table D.3
Applicable Receiving Water Quality Criteria at Gove

Water Quality Parameter	ANZECC Guideline for Marine Ecosystems (1)	ANZECC Guideline for Recreational Use
Total Suspended Solids	ne	ne
Total Phosphorus	15 µg/L	ne
Total Nitrogen	100 µg/L (2)	ne
Total Aluminium	ne	200 µg/L
Total Arsenic	ne	50 µg/L
Total Molybdenum	ne	ne
Total Vanadium	100 µg/L	ne
pH	8.0 - 8.4	5.0 – 9.0 (3) 6.5 – 8.5 (4)
Alkalinity (as $CaCO_3$)	ne	ne
Temperature	ne	15 – 35 deg C

Notes
(1) Trigger value for marine water (95% level of protection)- slightly-moderately disturbed marine ecosystems (ANZECC, 2000).
(2) Trigger value for slightly –moderately disturbed marine inshore ecosystems in Tropical Australia (ANZECC, 2000)
(3) ANZECC, 2000, Table 5.2.2
(4) ANZECC, 2000, Table 5.5.3
ne: not established

Discharge Water Quality Relevance To Receiving Water Quality

For protection of marine aquatic ecosystems, water quality criteria (outlined in Table D.3) apply to the receiving waters in Melville Bay and Arafura Sea, rather than directly to the quality of discharges into these receiving waters.

The receiving waters are substantially larger than the quantity of most discharges to the receiving waters and the concentrations of contaminants and physical characteristics of discharge waters will diminish due to dilution effects, which vary depending on tidal flows and other hydrodynamic influences. These influences have been modelled and are covered in Section 13 of the EIS report.

D.2.3 Comparative Assessments

Some of the selected monitoring sites do not represent water quality conditions of receiving waters or discharges to receiving waters. Information for these sites is given herein to compare with other monitoring sites to assess changes in water quality within the water management system. Such comparisons are useful to assess the performance of particular water management strategies or to identify impacts from particular areas.

D.2.4 Water Quality In The Refinery Catchments

Seawater Channel Plant Outfall Quality

The seawater channel outfall site (S001) represents the majority of waters discharged from the refinery into Gove Harbour. Surface water quality sampling commenced at this site in 1993, and sampling has continued at regular intervals to date. Table D.4 presents statistical results of water quality data for this site.

Table D.4
Statistical Summary of Seawater Channel Plant Outfall Water Quality – Site S001

Analyte	Units	Start Date	ANZECC Guideline	No. of Samples	Median	Percentiles	
						20th	80th
Aluminium	µg/L	15/02/93	ne	296	43	11	100
Arsenic	µg/L	15/02/93	ne	247	5	4	7
Molybdenum	µg/L	09/07/93	ne	289	16	13	23
pH (Field)	pH	07/01/97	8.0-8.4 (2)	1,933	8.2	8.0	8.4
pH (Laboratory)	pH	15/02/93	8.0-8.4 (2)	279	8.3	8.2	8.4
Temperature	deg C	11/03/98	ne	1,563	45	42	47
Total Alkalinity	mg/L	15/02/93	ne	190	140	120	179
Total Alkalinity (NAB) (4)	mg/L	01/04/98	ne	1,903	163	139	193
Total Nitrogen	µg/L	06/05/98	100 (2)	55	300	238	412
Total Phosphorus	µg/L	15/02/93	15 (2)	222	19	7	40
Total Suspended Solids	mg/L	07/09/93	ne	256	60	28	121
Turbidity	NTU	03/11/98	1 - 20 (2)	1,892	9	6	15
Vanadium	µg/L	02/15/93	100 (1)	315	63	34	120

Notes

(1) Trigger value for marine water (95% level of protection)- slightly-moderately disturbed ecosystems (ANZECC, 2000).
(2) Trigger value for slightly –moderately disturbed marine inshore ecosystems in Tropical Australia (ANZECC, 2000)
(3) Interim Discharge Water Quality Standard – Subject to on-going review and refinement
(4) NAB – On site laboratory
na: not applicable
ne: not established

Table D.5
Seasonal Water Quality Variation in Seawater Channel Plant Outfall (S001)

Analyte	Units	Wet Season (November – March)		Late Wet Season (April – June)		Dry Season (July – October)	
		No. of samples	Median	No. of samples	Median	No. of samples	Median
Aluminium	µg/L	71	81	62	5	163	29
Arsenic	µg/L	55	14	48	10	144	3
Molybdenum	µg/L	70	22	56	32	163	17
pH (Field)	pH	592	8.0	504	8.9	836	8.2
pH (Laboratory)	pH	61	8.3	55	8.4	162	8.5
Temperature	deg C	492	47	465	45	605	40
Total Alkalinity	mg/L	57	125	47	238	86	219
Total Alkalinity (NAB) (1)	mg/L	577	154	498	276	828	182
Total Nitrogen	µg/L	17	340	15	470	23	444

Total Phosphorus	µg/L	44	83	45	4	133	400
Total Suspended Solids	mg/L	61	68	47	123	148	49
Turbidity	NTU	581	17	492	18	818	9
Vanadium	µg/L	78	110	67	210	170	45

(1) NAB – On site laboratory

Table D.6
5 Year Trend in Seawater Channel Plant Outfall Water Quality (S001)

Analyte	Year	1998		1999		2000		2001		2002	
	Rainfall	1,515 mm		2,572 mm		1,717 mm		1,777 mm		654 mm	
	Units	No.	Median	No.	Median	No.	Median	No.	Median	No.	Median
Aluminium	µg/L	18	175	26	26	59	30	60	54	15	100
Arsenic	µg/L	15	5	26	6.5	51	5	23	5	13	5
Molybdenum	µg/L	16	15	26	18	54	31	61	20	15	39
pH (Field)	pH	289	8.0	361	8.1	572	8.2	478	8.5	216	8.2
pH (Laboratory)	pH	18	8.2	26	8.4	59	8.5	47	8.3	na	na
Temperature	deg C	282	44	361	43	356	44	364	42	199	49
Alkalinity	mg/L	18	120	26	129	58	228	47	160	5	130
Alkalinity (NAB) (1)	mg/L	274	148	361	145	574	155	478	175	216	183
Nitrogen	µg/L	8	165	12	155	14	397	13	260	8	410
Phosphorus	µg/L	16	8	23	11	44	7	20	16	8	11
Suspended Solids	mg/L	13	132	26	24	54	136	49	63	12	44
Turbidity	NTU	277	7	359	5	565	8	475	10	215	16
Vanadium	µg/L	19	280	26	52	59	140	61	140	15	270

(1) NAB – On site laboratory

Water quality in the seawater channel is dominated by the major source of channel flow which is seawater that has been used for cooling in the evaporation plans. Little variability is evident in physical parameters such as temperature and pH. pH values are within ANZECC guidelines and the nominated Alcan Gove interim discharge standard. The majority of flow from the evaporation plant results in the temperature of waters discharged from the seawater channel being elevated approximately 15°C above ambient temperatures in Gove Harbour (median 29.5°C as recorded at the seawater intake – S004). The significance of temperature on marine aquatic ecosystems in Gove Harbour is described in Section 13 of the EIS.

There are no ANZECC guideline recommendations for the concentration of alkalinity (as $CaCO_3$), however the available data show moderate to high concentrations that marginally exceed the nominated Alcan Gove interim discharge standard. Few data are available on the toxic effects of alkalinity alone, however increased alkalinity will often decrease the toxicity of many metal contaminants (ANZECC, 2000). For environmental management purposes at Gove, alkalinity is relevant for identifying possible influences of caustic liquor on the quality of water discharged from the outfall channel. In particular, high alkalinity indicates a presence of caustic. Caustic that is discharged into Gove Harbour can neutralise upon contact with seawater and form a gelatinous precipitate with high suspended solids.

Nutrient concentrations in the seawater channel discharge have exceeded ANZECC guidelines relevant to eutrophication concerns in near shore marine waters. Median phosphorus concentrations are above the ANZECC guideline. Median nitrogen concentrations are above the ANZECC guideline.. High concentrations of nutrients are best considered as indicators of a potential cause of excess algal growth. Chlorophyll 'a' concentration data are normally preferred to assess the presence of excess algal growth together with dissolved oxygen concentrations. Together they would provide a more reliable assessment of possible eutrophication concerns. The discharge of nutrients in sufficient quantities could contribute to excess algal growth and eutrophication in localised areas of

Gove Harbour. To address the potential broader concern of eutrophication in Gove Harbour, the marine monitoring program will consider monitoring for chlorophyll 'a' concentrations in near shore marine waters.

Aluminium, molybdenum, arsenic, and vanadium concentrations are unlikely to cause adverse impact on aquatic ecosystems in the receiving waters.

Suspended solids concentration does not directly impact on the receiving water aquatic ecosystems. Rather, it is the indirect effects such as light penetration or deposition resulting in potential smothering of benthic fauna in the near shore marine environment that are more relevant. The quality of the outfall channel discharge in terms of light penetration (as indicated by turbidity levels) is within the recommended ANZECC guideline range and would be unlikely to pose problems for aquatic ecosystems in the receiving waters. However, continued discharge into the outfall channel with moderate to high levels of suspended solids is potentially significant for accumulation of solids/sediment on the seabed in the vicinity of the channel outfall.

Quality of Cooling Water Discharge From Evaporation

The predominant discharge from the refinery into Gove Harbour is seawater used for cooling in the evaporation plant. Seawater is pumped from Gove Harbour at a pump station jetty and water quality at the seawater intake is represented by monitoring site S004. Once it has been used for cooling, the seawater is discharged from the evaporation plant into the eastern seawater channel. Monitoring sites S022A and S022B represent the quality of seawater discharged from the Stage 1 and Stage 2 evaporation plants.

Occasionally, upsets occur in the evaporation plant when caustic liquor enters the saline cooling water. In addition, there is a continuous low level of contamination with caustic as a result of "entrainment" of caustic mist into the discharged seawater. The mixing of caustic liquor and seawater results in the formation of a precipitate.

To assess the influence of the evaporation process on seawater used for cooling, a comparison of the water quality between the seawater intake and the hotwell discharges is presented in Table D.7.

Table D.7
Statistical Comparison of Water Quality at Sites S004 and S022A/B

Analyte	Units	S004 (Seawater Intake)				S022A-S022B (Evaporation Plant Discharge)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Aluminium	µg/L	164	19	10	40	71 - 74	81-82	50-52	100-114
Arsenic	µg/L	119	5	2	5	23 - 24	5	5	5
Molybdenum	µg/L	159	12	11	14	68 - 71	12	10	14
pH (Field)	pH	1751	8.2	8.0	8.3	1131	8.2	8.1	8.3
pH (Laboratory)	pH	156	8.3	8.2	8.4	64 - 67	8.2	8.1	8.3
Temperature	deg C	1524	30	28	31	-	-	-	-
Alkalinity	mg/L	119	120	110	130	64 - 67	114-120	110	120
Alkalinity (NAB)	mg/L	1726	118	112	133	1411-1413	118-121	112-113	130-138
Total Nitrogen	µg/L	49	190	106	260	10	290	na	na
Total Phosphorus	µg/L	112	15	8	37	18	7	na	na
Suspended Solids	mg/L	144	10	6	18	64-67	45-52	20-21	100-148
Turbidity	NTU	1628	2	1	4	1125	6-7	4	10-12
Vanadium	µg/L	165	5	3	22	71-74	24-25	12	51-56

The comparison of water quality between the seawater intake and evaporation hotwell discharge shows that the evaporation process has minimal or no impact on median pH (as expected because of the rapid process of neutralisation and buffering capacity of seawater), and variable impact on alkalinity, and concentrations of arsenic and molybdenum. The evaporation process increases the dissolved concentration of aluminium and vanadium. The turbidity and concentration of suspended solids also increases.

Inferences on the changes of dissolved nitrogen and phosphorus concentrations are not conclusive due to low sampling rates.

The predominant change in seawater quality due to the evaporation plant is increased temperature. Temperature data for the outfall channel discharge to Gove Harbour (refer Table D.4) show that the evaporation process increases the temperature of seawater by approximately 15°C.

The evaporation plant discharge quality shows little variability for the majority of water quality parameters. The greatest variability is evident for suspended solids concentrations with approximately 3 times difference in the 20th to 80th percentile range for the seawater intake and 5 to 7 times difference in the 20th to 80th percentile range for the evaporation plant discharge. This is a reflection of the episodic nature of the carry-over events.

Influence of labyrinth Return Flow Discharge to Seawater Channel

The labyrinth return flow discharges to the seawater channel near the southern containment pond at a maximum rate of approximately 8% of the seawater flow used in the evaporation plant. The labyrinth discharge to the seawater channel is not continuous, and on a time-average basis, the labyrinth discharge represents approximately 4% of the seawater channel flow. A comparison of labyrinth return flow quality with the evaporation plant discharge quality is presented in Table D.8 to assess the influence on this return flow on water quality in the seawater channel.

Table D.8
Statistical Comparison of Water Quality at Sites S022A/B and S1033

Analyte	Units	S022A-S022B (Evaporation Plant Discharge)				S1033 (Labyrinth Return Flow)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Aluminium	µg/L	71 - 74	81-82	50-52	100-114	247	7	5	14
Arsenic	µg/L	23 - 24	5	5	5	206	61	34	150
Molybdenum	µg/L	68 - 71	12	10	14	243	110	74	160
pH (Field)	pH	1131	8.2	8.1	8.3	871	8.7	8.5	9.0
pH (Laboratory)	pH	64 - 67	8.2	8.1	8.3	240	8.6	8.5	8.9
Temperature	deg C	-	-	-	-	33	28	26	30
Alkalinity	mg/L	64 - 67	114-120	110	120	238	550	396	960
Alkalinity (NAB)	mg/L	1411-1413	118-121	112-113	130-138	839	809	562	1,184
Total Nitrogen	µg/L	10	290	na	na	35	830	568	1,144
Total Phosphorus	µg/L	18	7	na	na	100	10	6	18
Suspended Solids	mg/L	64-67	45-52	20-21	100-148	138	14	4	40
Turbidity	NTU	1125	6-7	4	10-12	818	4	3	7
Vanadium	µg/L	71-74	24-25	12	51-56	245	650	370	1,104

Table D.8 shows that the labyrinth discharge has lower turbidity and concentrations of aluminium and suspended solids. The temperature of the labyrinth discharge is substantially less than the seawater channel temperature (as inferred from the outfall channel Table D.4). The concentration of dissolved phosphorus in the labyrinth discharge is similar to the seawater channel.

The labyrinth discharge has pH levels approximately 0.5 pH units above the seawater channel flow. However this does not produce substantial change in the seawater channel pH due to the buffering capacity of seawater and the large difference in flow rates.

Relative to the quality of the evaporation plant discharge to the seawater channel, the dissolved concentrations of arsenic, molybdenum, alkalinity, and nitrogen in the labyrinth discharge are substantially higher by factors in the order of 3 to 12 times. For dissolved vanadium concentrations, the labyrinth discharge is approximately 24 times the seawater channel (evaporation plant discharge) concentrations.

The differences in concentrations between the labyrinth discharge and evaporation plant discharge indicate that the labyrinth discharge can increase the concentrations of these chemicals in the outfall channel. However the relatively large difference in the rate of flow means that the increase in concentration in the seawater channel is not as great as the differences in concentration.

Plots of the outfall water quality data (Site S001) against respective flow rates are shown in Figures D.1 to D.9. If water quality at the outfall channel is significantly influenced by the quality of the labyrinth discharge, these plots would show a distinct trend in outfall water quality relative to the labyrinth discharge rate. However these plots show that there is no clear correlation between water quality at the outfall and the rate of flow at the labyrinth discharge or total flow at the outfall. It is therefore unlikely that the labyrinth discharge has a persistent and distinct influence on the seawater outfall quality.

Southern Containment Pond

The southern containment pond can overflow to the eastern seawater channel following prolonged heavy rainfall events. However this rarely occurs. This water is normally reused in the process or sent to the RDA. It is only discharged to the eastern seawater channel if discharge criteria are met.

Few water quality sample results are available for the southern containment pond overflow and the majority of monitoring results represent the quality of water within the pond rather than actual overflows into the eastern seawater channel. A comparison of the southern containment pond water quality with the evaporation plant discharge quality is given in Table D.9 indicating why the pond water is rarely discharged to the seawater channel.

Table D.9
Statistical Comparison of Water Quality at Sites S022A/B and S023

Analyte	Units	S022A-S022B (Evaporation Plant Discharge)				S023 (Southern Containment Pond)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Aluminium	µg/L	71 - 74	81-82	50-52	100-114	16	13,000	na	na
Arsenic	µg/L	23 - 24	5	5	5	14	29	na	na
Molybdenum	µg/L	68 - 71	12	10	14	15	140	na	na
pH (Field)	pH	1131	8.2	8.1	8.3	11	9.5	na	na
pH (Laboratory)	pH	64 - 67	8.2	8.1	8.3	10	9.9	na	na
Temperature	deg C	-	-	-	-	-	-	na	na
Alkalinity	mg/L	64 - 67	114-120	110	120	10	455	na	na
Alkalinity (NAB)	mg/L	1411-1413	118-121	112-113	130-138	7	na	na	na
Total Nitrogen	µg/L	10	290	na	na	2	na	na	na

Analyte	Units	S022A-S022B (Evaporation Plant Discharge)				S023 (Southern Containment Pond)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Total Phosphorus	µg/L	18	7	na	na	4	na	na	na
Suspended Solids	mg/L	64-67	45-52	20-21	100-148	8	34	na	na
Turbidity	NTU	1125	6-7	4	10-12	7	na	na	na
Vanadium	µg/L	71-74	24-25	12	51-56	16	685	na	na

Notes
na: not applicable (insufficient number of samples to report median and/or low and high percentiles)

The available data indicate that stormwater runoff contained in the southern containment pond can have very high dissolved concentrations of aluminium. Concentrations of arsenic, molybdenum, alkalinity, and vanadium are high as are pH values.

On rare occasions when the southern containment pond overflows to the seawater channel, the discharge would be unlikely to have sufficient quantity and over sufficient duration to substantially impact on the overall quality of the seawater channel at the outfall.

Western Containment Pond Discharge To Western Seawater Channel

The western containment pond captures stormwater runoff from a substantial portion of the western seawater channel catchment. The water contained in the pond is routinely pumped to the RDA circuit or reused in the process circuit. However the pond can be discharged to the western channel when discharge criteria are met. Occasionally, the pond overflows to the western seawater channel. The quality of the western containment pond water at the outlet is monitored at site S030. The overall water quality in the western seawater channel is monitored at site S005 immediately upstream of the junction with the eastern seawater channel.

A comparison of water quality between the site S030 and site S005 is presented in Table D.10 to assess the potential influence of the western containment pond on water quality in the western seawater channel should an overflow occur. It should be noted that seawater is occasionally discharged from the steam power station into the western seawater channel and this will have some influence on the percentile statistics of water quality for monitoring site S005.

Table D.10
Statistical Comparison of Water Quality at Sites S005 and S030

Analyte	Units	S005 (Western Seawater Channel)				S030 (Western Containment Pond)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Aluminium	µg/L	171	110	19	3,200	112	15,850	6,560	34,600
Arsenic	µg/L	127	5	5	8	73	8	5	26
Molybdenum	µg/L	170	19	12	29	96	21	13	36
pH (Field)	pH	1175	9.0	8.3	11.3	972	12.1	11.8	12.5
pH (Laboratory)	pH	145	8.6	8.1	11.6	101	11.8	11.5	12.2
Temperature	deg C	8	31	na	na	4	na	na	na
Alkalinity	mg/L	135	98	33	272	100	534	298	1,100
Alkalinity (NAB)	mg/L	1142	111	72	219	950	559	397	938
Total Nitrogen	µg/L	41	430	250	690	3	na	na	na

Analyte	Units	S005 (Western Seawater Channel)				S030 (Western Containment Pond)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Total Phosphorus	µg/L	113	140	33	302	24	13	2	44
Suspended Solids	mg/L	93	14	6	53	61	43	16	120
Turbidity	NTU	1118	8	4	20	953	33	15	114
Vanadium	µg/L	168	30	8	89	111	180	63	390

na: not applicable (insufficient number of samples to report median and/or low and high percentiles)

The water quality data for the western containment pond shows high variability, which reflects the variability of stormwater runoff in response to rainfall variation. The catchment to the western containment pond also contains some of the most intensive process areas of the refinery and water quality data for the pond may exhibit some variability due to infrequent operational incidents or spills within the catchment.

The concentrations of aluminium, alkalinity, suspended solids, and vanadium in the western containment pond are substantially higher than water quality in the western seawater channel at site S005. The western containment pond waters have turbidity that is approximately 4 times higher than the western seawater channel with a similar difference in suspended solids concentrations. The pH values in the western containment pond waters are very high and are substantially greater than the pH values in the western seawater channel.

The existing unpaved laydown area between the precipitation plant and calcination plant that is occasionally used for temporary storage of intermediate product is a likely major source of aluminium, alkalinity, suspended solids, and vanadium in stormwater runoff to the western containment pond. Runoff from this area, occasional overflows from the lime plant bunds and wind blown lime from the lime plant, are the most likely causes of high pH in the western containment pond.

The western containment pond overflow is not a substantial source of arsenic and molybdenum as the concentrations are relatively low and similar to the quality of water in the western seawater channel at site S005.

Dissolved phosphorus concentrations in the western containment pond overflow waters are in the order of 10 times lower than dissolved phosphorus concentrations in the seawater channel. Part of this difference may be due to the higher pH of waters in the western containment pond that would allow a greater portion of phosphorus to be absorbed to particulate matter and hence may not be reflected in the filtered sample phosphorus concentrations. However, the difference in phosphorus concentrations is sufficiently large to indicate that there is probably a source of phosphorus in the western seawater channel catchment from stormwater runoff entering the seawater channel downstream of the western containment pond.

Should the western containment pond overflow in periods of heavy rain, it is likely to be a source of contaminants in the western seawater channel. However this is unlikely to be reflected as high concentrations in the median water quality at the seawater channel discharge into Gove Harbour due to its relatively small flow and the infrequency of such an event.

Western Channel Water Quality

The flows in the western channel are highly variable due to a flow regime dominated by stormwater runoff with occasional seawater flushes of cooling water from the steam power station. This channel joins the seawater channel that is largely dominated by consistent seawater flow from the evaporation plant discharge

Table D 12 provides comparisons of water quality in the Western Channel between wet and dry seasons (wet season water quality is heavily influenced by rainfall run-off from various areas of the refinery).

Table D.12
Seasonal Water Quality Variation in Western Channel (S005)

Analyte	Units	Wet Season (November – March)		Late Wet Season (April – June)		Dry Season (July – October)	
		No. of samples	Median	No. of samples	Median	No. of samples	Median
Total Nitrogen	µg/L	15	900	10	325	16	310
Total Phosphorus	µg/L	34	183	20	74	59	15
Suspended Solids	mg/L	25	34	18	54	50	9
Turbidity	NTU	358	26	229	4	531	15

The western channel is a source of dissolved nitrogen and phosphorus nutrients. The seasonal variation of dissolved nitrogen and phosphorus concentrations in the western channel is an indicator of stormwater runoff during the wet season. Higher turbidity levels (indicative of finer particulate matter) are also evident in the wet season runoff to the western channel. The highest suspended solids concentrations in the western channel occur in late wet season runoff, which indicates that wash off of larger (heavier) suspended solids particles from catchment surfaces may be delayed. Nitrogen and phosphorus concentrations are typically associated with fine particulate matter, and the seasonal observations of turbidity and suspended solids indicate that the predominant source of these nutrients may be fine particulate matter which accumulates on catchment surfaces during the dry season and is washed off in the early to mid wet season. The discharge of effluent from the sewage treatment plant is also likely to contribute to the high nutrient concentrations.

The western channel has median concentrations of aluminium and vanadium approximately 20% to 35% higher than the evaporation plant discharge to the seawater channel.

Elevated pH in the western seawater channel is due to stormwater runoff overflows from the lime plant bunded area and other contaminant sources in its catchment.

Seawater Channel Catchment Influences on Outfall Channel Discharge Quality

The assessment of individual monitoring data for discharges to the seawater channel catchment (presented above) provides an indication of potential individual discharge influences on water quality in the outfall channel. For the overall seawater channel catchment, the flow from the evaporation plant discharge to the seawater channel is clearly the dominating influence. To identify specific significant influences on the outfall channel water quality that could be targeted for improvement, a comparison of water quality from the evaporation plant discharge (into the seawater channel) with water quality at the outfall channel to Gove Harbour is presented in Table D.13.

Table D.13
Statistical Comparison of Water Quality at Sites S022A/B and S001

Analyte	Units	S022A-S022B (Evaporation Plant Discharge)				S001 (Outfall Channel)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
Aluminium	µg/L	71 - 74	81-82	50-52	100-114	296	43	11	100
Arsenic	µg/L	23 - 24	5	5	5	247	5	4	7
Molybdenum	µg/L	68 - 71	12	10	14	289	16	13	23

Analyte	Units	S022A-S022B (Evaporation Plant Discharge)				S001 (Outfall Channel)			
		No. of Samples	Median	Percentile		No. of Samples	Median	Percentile	
				20th	80th			20th	80th
pH (Field)	pH	1131	8.2	8.1	8.3	1,933	8.2	8.0	8.4
pH (Laboratory)	pH	64 - 67	8.2	8.1	8.3	279	8.3	8.2	8.4
Alkalinity	mg/L	64 - 67	114-120	110	120	190	140	119	179
Alkalinity (NAB)	mg/L	1411-1413	118-121	112-113	130-138	1,903	163	139	193
Total Nitrogen	µg/L	10	290	na	na	55	300	238	412
Total Phosphorus	µg/L	18	7	na	na	222	19	7	40
Suspended Solids	mg/L	64-67	45-52	20-21	100-148	256	60	28	121
Turbidity	NTU	1125	6-7	4	10-12	1,892	9	6	15
Vanadium	µg/L	71-74	24-25	12	51-56	315	63	34	120

The influences on seawater channel quality between the evaporation plant discharge and the outfall include temperature, turbidity, and concentrations of alkalinity, phosphorus, vanadium, and suspended solids. Temperature, suspended solids and to a lesser degree, phosphorus sources in the seawater channel catchment are the most significant water quality parameters that should be targeted to improve outfall water quality. Additional information to identify key influences on outfall quality can be inferred from plots of the outfall water quality data (Site S001) against respective flow rates at the time of each sample (total flow, labyrinth return flow, and western pond discharge) as shown in Figures D.1 to D.9.

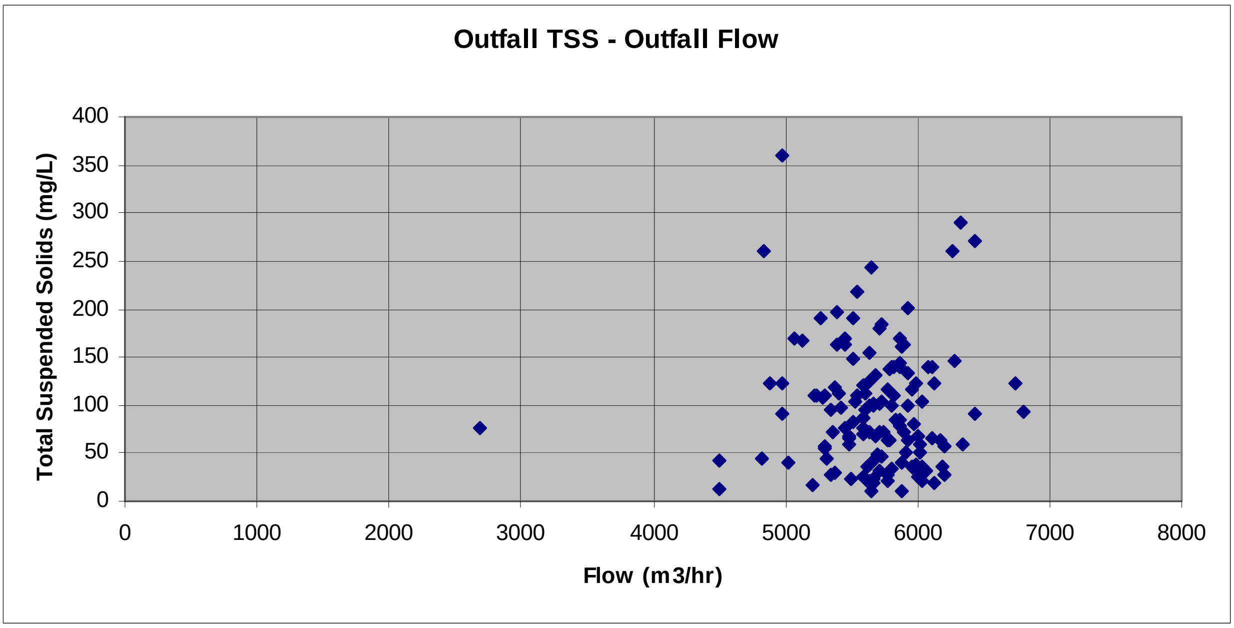

Figure D.1
Correlation of Outfall Suspended Solids Concentration With Outfall Flow Rate

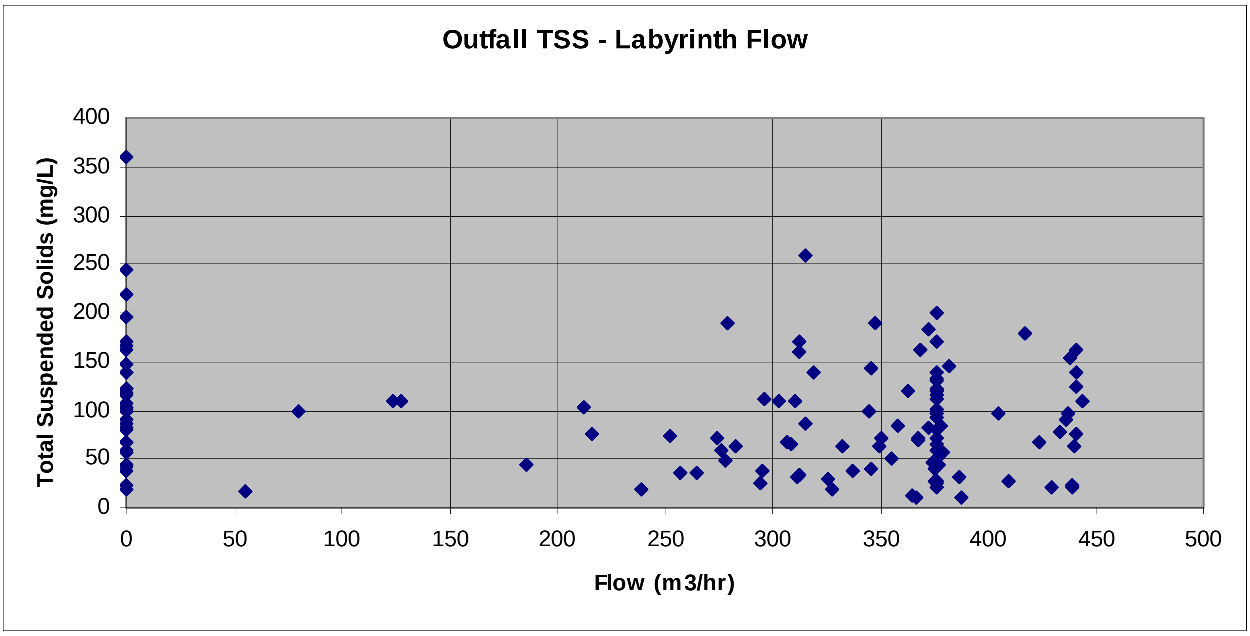

Figure D.2
Correlation of Outfall Suspended Solids Concentration With labyrinth Discharge

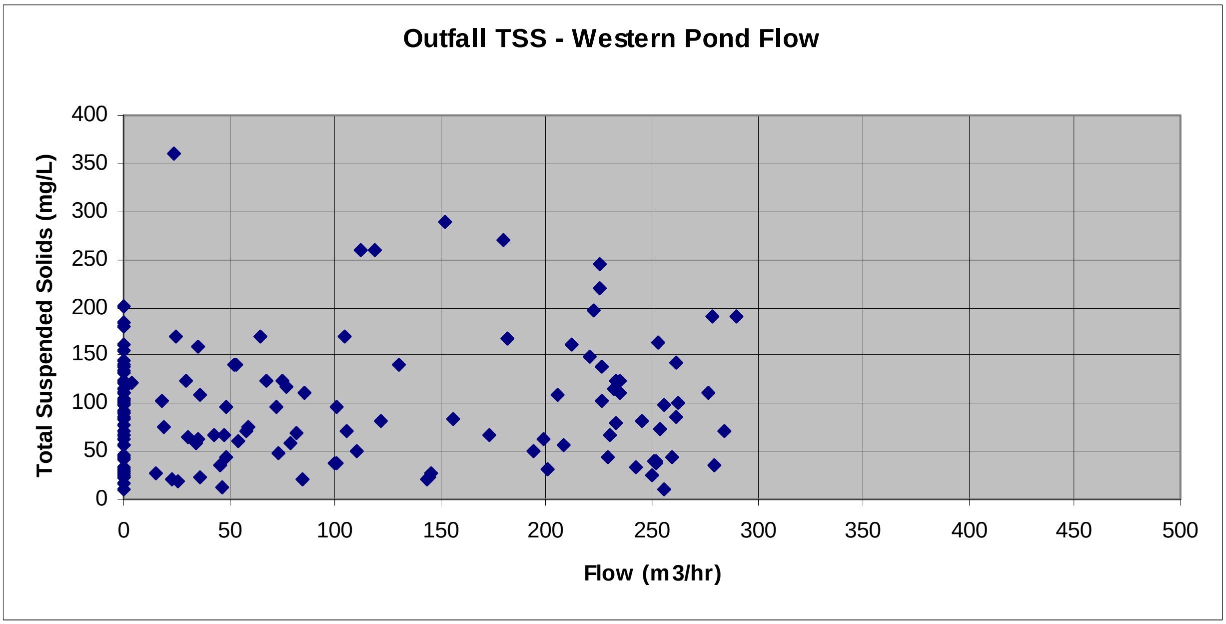

Figure D.3
Correlation of Outfall Suspended Solids Concentration With Western Pond Discharge

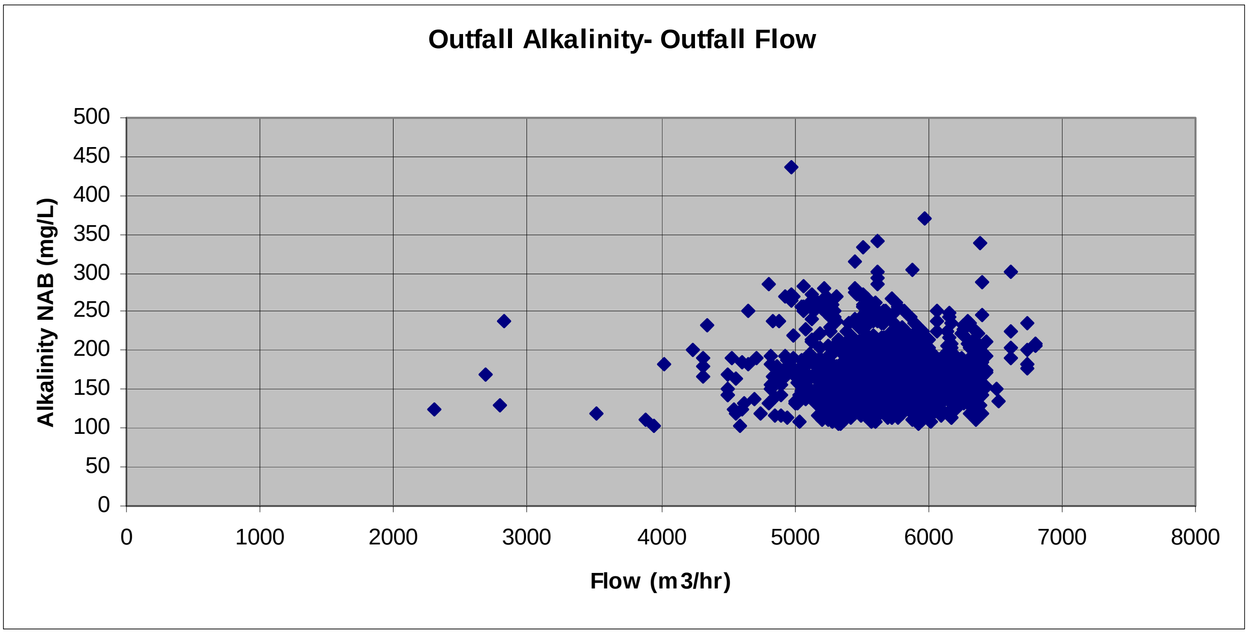

Figure D.4
Correlation of Outfall Alkalinity Concentration With Outfall Flow Rate

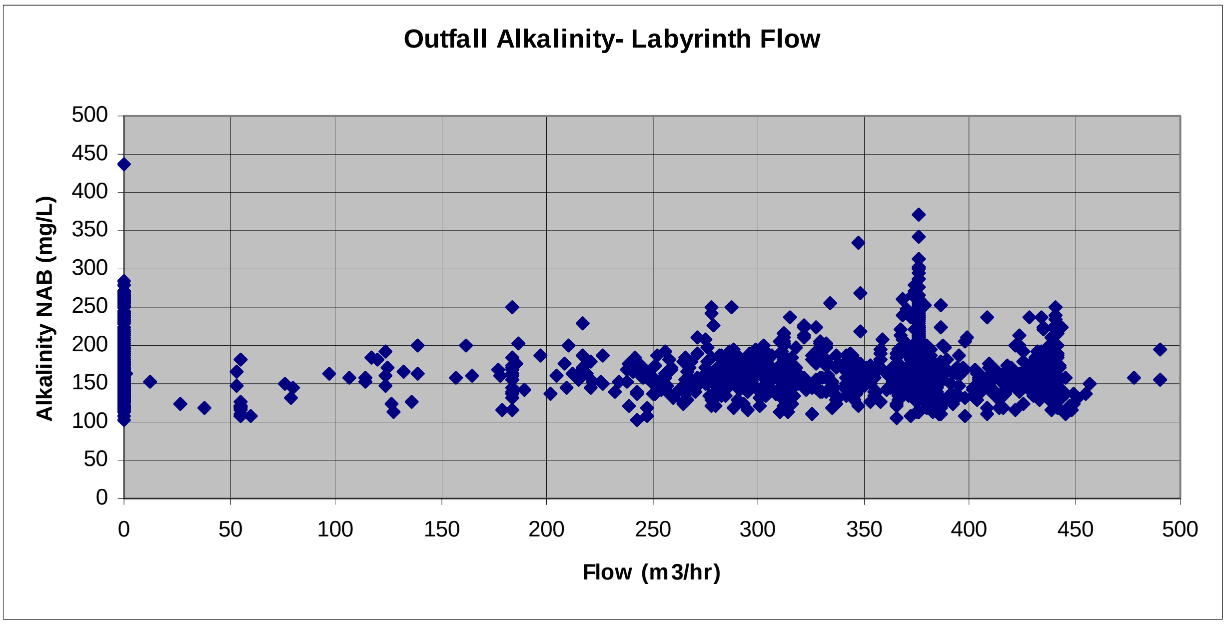

Figure D.5
Correlation of Outfall Alkalinity Concentration With labyrinth Return Discharge

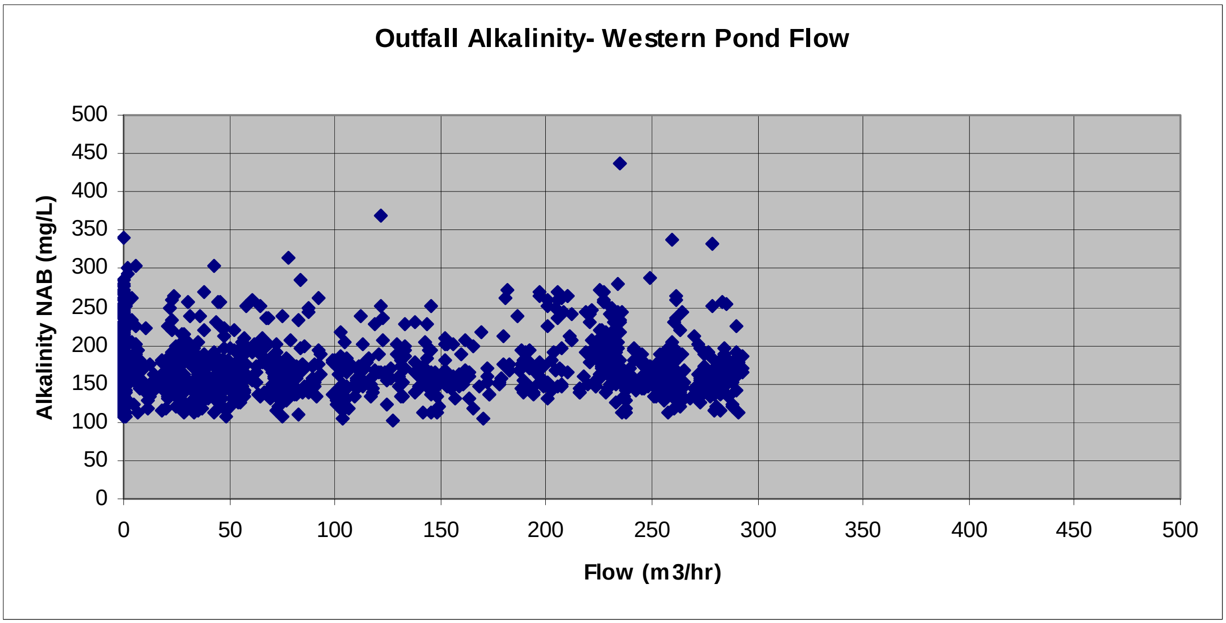

Figure D.6
Correlation of Outfall Alkalinity Concentration With Western Pond Discharge

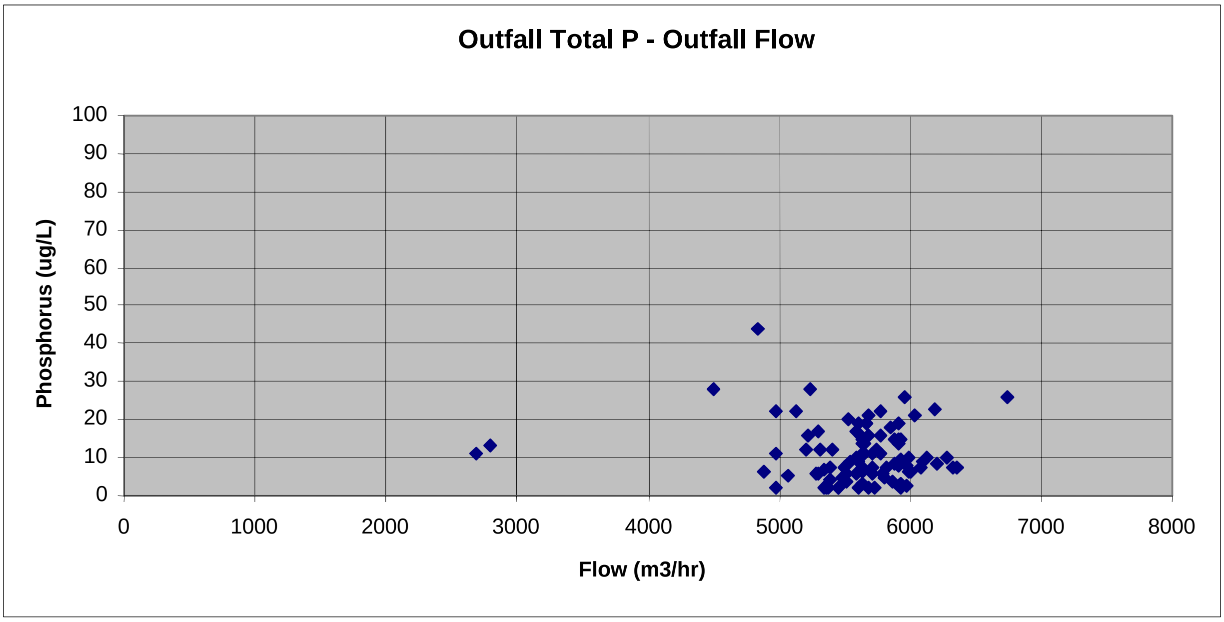

Figure D.7
Correlation of Outfall Phosphorus Concentration With Outfall Flow Rate

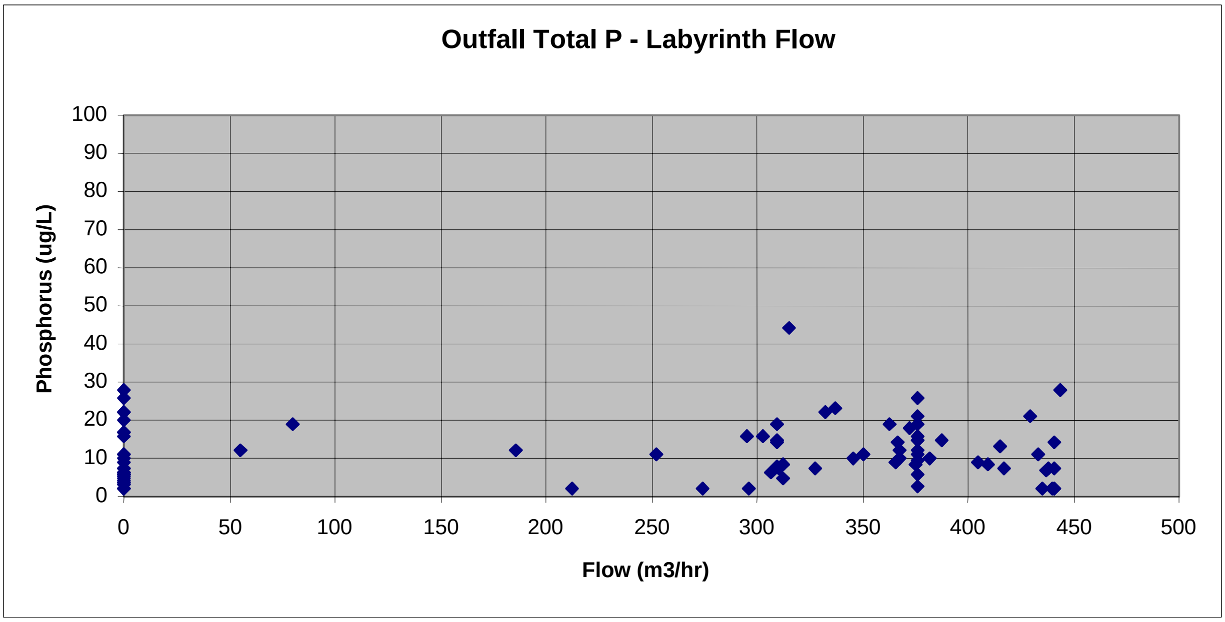

Figure D.8
Correlation of Outfall Phosphorus Concentration With labyrinth Discharge

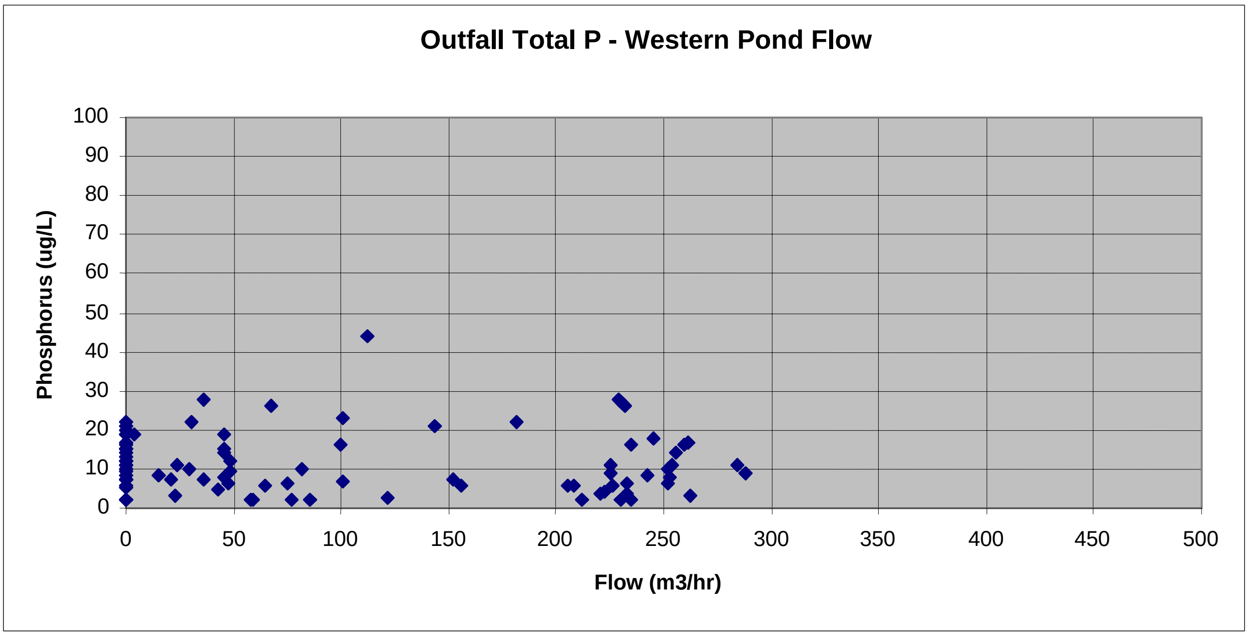

Figure D.9
Correlation of Outfall Phosphorus Concentration With Western Pond Discharge

Stockpile Creek

The Stockpile Creek monitoring site (S006) represents the quality of runoff from the bauxite stockpile, a portion of the digestion and thickening areas, and areas of undeveloped catchment, into Wanake Bay. Surface water quality sampling commenced at this site in 1995 and monitoring has continued at regular intervals to date. Table D.14 presents statistical results of water quality data for this site.

Table D.14
Statistical Summary of Stockpile Creek Water Quality - Site S006

Analyte	Units	Start Date	ANZECC Guideline	No. of Samples	Median	Percentiles	
						20th	80th
Aluminium	µg/L	29/03/95	ne	38	160	26	756
Arsenic	µg/L	29/03/95	ne	33	5	5	7
Molybdenum	µg/L	29/03/95	ne	33	11	10	19
pH (Field)	pH	09/01/97	8.0-8.4 (2)	144	9.0	8.7	9.5
pH (Laboratory)	pH	29/03/95	8.0-8.4 (2)	34	8.9	8.4	9.5
Total Alkalinity	mg/L	09/01/97	ne	30	117	40	164
Total Nitrogen	µg/L	06/05/98	100 (2)	22	180	96	370
Total Phosphorus	µg/L	28/12/95	15 (2)	32	3	2	30
Total Suspended Solids	mg/L	29/03/95	ne	30	18	7	49
Turbidity	NTU	06/05/98	1 - 20 (2)	10	22	na	na
Vanadium	µg/L	29/03/95	100 (1)	38	61	13	230

Notes

(1) Trigger value for marine water (95% level of protection)- slightly-moderately disturbed ecosystems (ANZECC, 2000).

(2) Trigger value for slightly –moderately disturbed marine inshore ecosystems in Tropical Australia (ANZECC, 2000)

(3) Interim Discharge Water Quality Standard – Subject to on-going review and refinement

na: not applicable (insufficient number of samples)

ne: not established

Discharge flows from Stockpile Creek to Melville Bay are infrequent, occurring only after heavy rains, mainly in the wet season. Much of the water quality data for Stockpile Creek was collected at times when there was no flow.

The pH value and relatively low flow from Stockpile Creek into Wanake Bay are unlikely to result in a substantial change of pH in the receiving waters. The high pH values in Stockpile Creek may be due to runoff from the digestion and thickener areas (at the far western end of Stockpile Creek catchment) and/or seepage of caustic contaminated groundwater into Stockpile Creek. Although pH levels are high, corresponding alkalinity concentrations are low. This indicates that the cause of high pH is not entirely attributable to caustic sources.

Concentrations of aluminium and vanadium are generally lower than ANZECC criteria.

Concentrations of arsenic and molybdenum are low.

Median phosphorus concentrations in the Stockpile Creek discharge are well below ANZECC guideline values.

D.2.5 Residue Disposal Area Catchments

Duck Pond Creek – Site S1001

Water quality in Duck Pond Creek is monitored at site S1001 (approximately 600 m upstream of the outlet into Drimmie Arm). This monitoring site is a Waste Discharge Licence sampling site, and has been routinely monitored since 1997. A statistical summary of water quality data at site S1001 is presented in Table D.15. Further information to delineate water quality trends is presented as seasonal water quality variation in Table D.16, and historical annual median water quality over the last 5 years in Table D.17.

Table D.15
Statistical Summary of Duck Pond Creek Water Quality - Site 1001

Analyte	Units	Start Date	ANZECC Guideline	No. of Samples	Median	Percentiles	
						20th	80th
Aluminium	µg/L	09/01/97	ne	117	38	14	388
Arsenic	µg/L	09/01/97	ne	79	20	9	34
Molybdenum	µg/L	09/01/97	ne	113	31	20	51
pH (Field)	pH	09/01/97	8.0-8.4 (2)	983	8.7	8.5	9.1
pH (Laboratory)	pH	09/01/97	8.0-8.4 (2)	100	9.1	8.6	9.4
Total Alkalinity	mg/L	09/01/97	ne	99	434	236	784
Total Alkalinity (NAB)	mg/L	01/03/99	ne	136	338	222	809
Total Nitrogen	µg/L	06/05/98	100 (2)	59	770	506	1,140
Total Phosphorus	µg/L	09/01/97	15 (2)	78	7	3	22
Total Suspended Solids	mg/L	03/09/97	ne	109	21	14	46
Turbidity	NTU	06/05/98	1 - 20 (2)	136	18	13	57
Vanadium	µg/L	09/01/97	100 (1)	117	170	39	300

Notes

(1) Trigger value for marine water (95% level of protection)- slightly-moderately disturbed ecosystems (ANZECC, 2000).

(2) Trigger value for slightly –moderately disturbed marine inshore ecosystems in Tropical Australia (ANZECC, 2000)

(3) Interim Discharge Water Quality Standard – Subject to on-going review and refinement

na: not applicable (insufficient number of samples)

ne: not established

Table D.16
Seasonal Water Quality Variation in Duck Pond Creek (S1001)

Analyte	Units	Wet Season (November – March)		Late Wet Season (April – June)		Dry Season (July – October)	
		No. of samples	Median	No. of samples	Median	No. of samples	Median
Aluminium	µg/L	39	1800	28	885	50	35
Arsenic	µg/L	28	22	16	34	35	100
Molybdenum	µg/L	38	28	25	10	50	35
pH (Field)	pH	344	9.0	245	8.5	393	8.6
pH (Laboratory)	pH	31	9.5	25	9.6	44	8.9
Total Alkalinity	mg/L	32	427	24	470	43	700
Total Alkalinity (NAB)	mg/L	42	300	57	879	37	274
Total Nitrogen	µg/L	22	580	11	460	26	805
Total Phosphorus	µg/L	26	15	18	25	34	8
Total Suspended Solids	mg/L	35	160	25	32	49	17
Turbidity	NTU	42	79	24	14	69	13
Vanadium	µg/L	39	220	28	170	50	93

Table D.17
5 Year Trend in Duck Pond Creek Water Quality (S1001)

Analyte	Year	1998		1999		2000		2001		2002	
	Rainfall	1,515 mm		2,572 mm		1,717 mm		1,777 mm		654 mm	
	Units	No.	Median	No.	Median	No.	Median	No.	Median	No.	Median
Aluminium	µg/L	9	49	18	131	15	38	47	44	12	44
Arsenic	µg/L	6	14	18	86	13	46	14	16	12	8
Molybdenum	µg/L	6	51	18	108	14	56	47	27	12	27
pH (Field)	pH	40	9.1	52	10.0	42	9.4	306	8.5	411	8.1
pH (Laboratory)	pH	9	9.3	18	9.6	15	9.3	45	8.4	na	na
Alkalinity	mg/L	9	780	18	1002	15	794	45	330	na	na
Alkalinity (NAB)	mg/L	na	na	39	820	1	na	30	319	50	277
Nitrogen	µg/L	8	1	10	1,456	12	770	14	550	12	1,150
Phosphorus	µg/L	9	4	15	5	13	9	14	4	12	4
Suspended Solids	mg/L	6	43	18	98	14	11	47	21	12	12
Turbidity	NTU	37	100	6	12	na	na	26	12	50	15
Vanadium	µg/L	9	260	18	1,190	15	260	47	86	12	27

Notes
na: not applicable (no monitoring or insufficient number of samples)

pH values tends to be slightly higher in the wet season most likely as a result of runoff from the upper catchment (around Northern and Taylor’s Ponds) reaching this monitoring site (refer to assessment of monitoring site S1003). Historical trends show a peak in pH values in 1999 when annual rainfall was approximately twice the median annual rainfall and the RDA release pond overflowed into Duck Pond Creek. Since 1999, pH values in Duck Pond Creek have gradually declined to 2002 pH values.

Historical high concentrations of aluminium were evident in the wet year of 1999 and have subsequently declined to consistent concentrations in 2000 to 2002. Distinctly higher concentrations of aluminium occur in the wet season probably as a result of early wet season flushing of aluminium rich waters from the upper reaches of Duck Pond Creek near Northern and Taylor’s Ponds (refer to assessment of monitoring site S1003).

Historical concentrations of arsenic and molybdenum above background levels were evident in the wet year of 1999 and have subsequently declined to 2002 concentrations. Seasonal trends indicate that peak arsenic concentrations occur in the dry season, which indicates a likely groundwater source of arsenic.

Since 1999, concentrations of vanadium have gradually declined. Higher vanadium concentrations are evident in the wet season most likely as a result of early wet season flushing of waters from the upper reaches of Duck Pond Creek near Northern and Taylor’s Ponds.

Over the entire monitoring period, the concentrations of alkalinity and nitrogen were elevated above background. There are no conclusive seasonal trends in alkalinity or nitrogen concentrations, which indicates that alkalinity and nitrogen sources are probably a combination of flushing of waters from the upper catchment of Duck Pond Creek and local groundwater influences from around the RDA. Nitrogen concentrations were high in the dry year of 2002, which indicates a groundwater influence on nitrogen sources.

Both turbidity and suspended solids show a distinct peak in the wet season but not significantly elevated above background levels.

Road Bridge Creek (Wallaby Beach Creek) – Site S1005

The catchment area of Road Bridge Creek (Wallaby Beach Creek) has been reduced by historical deposition of residue in the Northern Pond area and the current active RDA has excised a small portion of the original upper catchment. There are no activities within the current natural catchment area that would substantially affect water quality and the majority of the catchment is undisturbed. Flows in the creek occur only after heavy rains.

Road Bridge Creek is monitored near the main access road to the refinery. Water quality data for this site are very limited with insufficient numbers of sample results to determine median water quality conditions. Available water quality data is summarised in Table D.18, and it is important to note that cautious interpretation of this data is required due to the limited number of samples.

Table D.18
Statistical Summary of Road Bridge Creek Water Quality - Site S1005

Analyte	Units	Start Date	ANZECC Guideline	No. of Samples	Median	Percentiles	
						20th	80th
Aluminium	µg/L	08/01/02	ne	5	5	na	na
Arsenic	µg/L	08/01/02	ne	3	5	na	na
Molybdenum	µg/L	08/01/02	ne	3	10	na	na
pH (Field)	pH	12/02/02	8.0-8.4 (2)	4	6.8	na	na
Total Alkalinity (NAB) (4)	mg/L	08/01/02	ne	6	184	na	na
Total Nitrogen	µg/L	08/01/02	100 (2)	3	540	na	na
Total Phosphorus	µg/L	08/01/02	15 (2)	3	3	na	na
Total Suspended Solids	mg/L	08/01/02	ne	5	26	na	na
Turbidity	NTU	12/02/02	1 - 20 (2)	4	54	na	na
Vanadium	µg/L	08/01/02	100 (1)	5	<1	na	na

Notes
(1) Trigger value for marine water (95% level of protection)- slightly-moderately disturbed ecosystems (ANZECC, 2000).
(2) Trigger value for slightly –moderately disturbed marine inshore ecosystems in Tropical Australia (ANZECC, 2000)
(3) Interim Discharge Water Quality Standard – Subject to on-going review and refinement
(4) NAB – on site laboratory
na: not applicable (insufficient number of samples)
ne: not established

Although data for Road Bridge Creek are limited, the available data indicate that water quality is within ANZECC guidelines.

Turbidity and suspended solids data slightly exceed ANZECC (2000) water quality guidelines and the probable source is elevated sediment loads from small areas of disturbed land in the upper catchment and off-lease disturbed lands in the lower catchment.

The concentrations of nitrogen and alkalinity in Road Bridge Creek are elevated above background levels.. As there are no activities in the catchment that would be a substantial source of nitrogen and alkalinity, it is expected that the predominant source is likely to be groundwater seepage from Northern Pond and Taylor's Pond.

Borrow Pit North-west of Pond 5 near Dimbuka Rocks - Site S1002

The RDA has substantially reduced the catchment area of Macassar Creek. The current catchment area is mostly undisturbed with mixture of estuarine tidal flats and terrestrial vegetation cover. The perimeter of the catchment is the external vegetated embankments of the RDA ponds that contribute some freshwater runoff to the creek. Water quality at the edge of Pond 5 embankment is sampled at site S1002, which is known to be influenced by periodic tidal interchange. This monitoring site is primarily used to identify potential groundwater seepage impacts from adjacent RDA Pond 5.

A statistical summary of water quality at monitoring site S1002 is presented in Table D.19. Information on seasonal water quality variation at this site is presented in Table D.20, and historical variation in water quality is presented in Table D.21.

Table D.19
Statistical Summary of Borrow Pit Quality - Site S1002

Analyte	Units	Start Date	ANZECC Guideline	No. of Samples	Median	Percentiles	
						20th	80th
Aluminium	µg/L	19/01/96	ne	62	15	5	54
Arsenic	µg/L	19/01/96	ne	53	5	5	5
Molybdenum	µg/L	19/01/96	ne	45	100	52	132
pH (Field)	pH	19/01/96	8.0-8.4 (2)	35	9.1	8.7	9.3
pH (Laboratory)	pH	19/01/96	8.0-8.4 (2)	46	9.1	8.6	9.2
Total Alkalinity	mg/L	09/01/97	ne	46	5,400	1,600	7,667
Total Alkalinity (NAB) (4)	mg/L	07/01/02	ne	17	3,665	na	na
Total Nitrogen	µg/L	21/07/99	100 (2)	25	1,400	986	2,160
Total Phosphorus	µg/L	19/01/96	15 (2)	46	12	7	26
Total Suspended Solids	mg/L	19/01/96	ne	26	12	5	24
Turbidity	NTU	10/09/98	1 - 20 (2)	19	19	12	56
Vanadium	µg/L	19/01/96	100 (1)	60	8	4	12

(1) Trigger value for marine water (95% level of protection)- slightly-moderately disturbed ecosystems (ANZECC, 2000).
(2) Trigger value for slightly –moderately disturbed marine inshore ecosystems in Tropical Australia (ANZECC, 2000)
(3) Interim Discharge Water Quality Standard – Subject to on-going review and refinement
(4) NAB – on site laboratory
na: not applicable (insufficient number of samples)
ne: not established

Table D.20
Seasonal Water Quality Variation in Macassar Creek (S1002)

Analyte	Units	Wet Season (November – March)		Late Wet Season (April – June)		Dry Season (July – October)	
		No. of samples	Median	No. of samples	Median	No. of samples	Median
Aluminium	µg/L	22	413	11	7	29	8
Arsenic	µg/L	17	5	9	5	27	5
Molybdenum	µg/L	17	57	6	79	22	103
pH (Field)	pH	13	9.1	8	8.9	14	9.1
pH (Laboratory)	pH	16	8.6	8	8.9	22	9.1
Alkalinity	mg/L	15	1,780	8	2,068	23	4,971
Alkalinity (NAB) (1)	mg/L	7	12,469	5	4,613	5	9,691
Total Nitrogen	µg/L	9	1,800	6	825	10	1,015
Total Phosphorus	µg/L	16	9	8	9	22	17
Total Suspended Solids	mg/L	11	2	6	9	9	2
Turbidity	NTU	7	31	5	10	7	12
Vanadium	µg/L	22	3	9	1	29	17

(1) NAB – on site laboratory
na: not applicable (insufficient number of samples)

Table D.21
5 Year Trend in Macassar Creek Water Quality (S1002)

Analyte	Year	1998		1999		2000		2001		2002	
	Rainfall	1,515 mm		2,572 mm		1,717 mm		1,777 mm		654 mm	
	Units	No.	Median	No.	Median	No.	Median	No.	Median	No.	Median
Aluminium	µg/L	5	5	11	220	11	37	10	42	12	8
Arsenic	µg/L	5	11	11	5	10	5	4	na	10	5
Molybdenum	µg/L	5	91	7	85	10	90	4	na	6	na
pH (Field)	pH	3	na	na	na	na	na	na	na	14	9.0
pH (Laboratory)	pH	5	9.1	11	8.9	10	8.9	9	9.0	na	na
Alkalinity	mg/L	5	7,000	11	4,971	11	2,980	9	5,300	na	na
Alkalinity (NAB) (1)	mg/L	na	na	na	na	na	na	na	na	13	6,765
Nitrogen	µg/L	na	na	4	na	10	775	3	na	6	2,800
Phosphorus	µg/L	5	4	10	9	10	9	3	na	6	11
Suspended Solids	mg/L	na	na	na	na	1	na	10	6	12	5
Turbidity	NTU	2	na	na	na	na	na	na	na	13	12
Vanadium	µg/L	5	13	9	13	11	8	10	9	12	2

Notes
(1) NAB – on site laboratory
na: not applicable (no monitoring or insufficient number of samples)

Water quality at site S1002 shows marked variation across the range of water quality indicators, across seasons, and with no distinct historical trends. The variation across water quality indicators is not unexpected because the catchment has been modified and currently exists in a regime with reduced surface runoff flow and potentially greater groundwater influences.

pH values in Macassar Creek marginally exceed the ANZECC. There is no distinct seasonal or historical trend in pH.

Alkalinity concentrations are significantly elevated compared to background. They are consistently high across seasons and across the last five years. This indicates a consistent influence from a contaminant source. .

Concentrations of aluminium, arsenic and vanadium are below ANZECC (2000) guideline trigger levels. Aluminium concentrations are distinctly higher in the wet season, however similar trends were not evident in the seasonal variation of the concentration of other metals.

A historical trend or seasonal trend in the concentration of molybdenum is not clearly identifiable, however the available data show a slight tendency for higher concentrations to occur in the dry season and in drier years. Although not conclusive, this observation indicates that groundwater seepage is the possible source of molybdenum.

Nitrogen concentrations are substantially above ANZECC guidelines. The concentrations of nitrogen appear higher in the dry season and early wet season, and were highest in the 2002 dry year. In general, the nitrogen data are not conclusive, however there are slight trends that may indicate an influence from groundwater seepage.

Turbidity levels and the concentrations of phosphorus and suspended solids were below ANZECC guideline trigger values and the nominated Alcan Gove interim discharge standards with no distinct seasonal trends in the data.