Friends of Stradbroke Island Association Inc.
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27 February, 2015

Supplementary Submission to Senate Select Committee on Certain Aspects of Queensland Government Administration related to Commonwealth Government Affairs

We refer to our submission dated 17 November, 2014.

This supplementary submission is provided because we have now received the further report of Dr. Stock. It provides further evidence that Federal laws are failing to protect Ramsar wetlands on North Stradbroke Island. There is an urgent need for the Enterprise mine to be assessed under the EPBC Act and we request the committee's assistance in bringing this about with a recommendation to the Minister, Mr Hunt, for him to use his powers to require assessment of the mine under Federal environment laws.

We made several references in our submission to the opinions of Dr Errol Stock, a geologist and expert on North Stradbroke Island hydrology. Dr Stock's initial report is dated 20 September, 2012 and was forwarded to the Director of the Compliance and Enforcement Branch, Department of Sustainability, Environment, Water, Population and Communities on 28 September, 2012. Because it is referred to in Dr Stock's latest report, a copy of his earlier report is now attached. We draw your attention in particular to section 8 in which he considers the significance of the changes in groundwater already caused and likely to be caused in the future by Enterprise Mine to the adjacent section of the Moreton Bay Ramsar Wetland, which includes an area known as Eighteen Mile Swamp. Dr Stock refers to the Department's guidelines on significant impacts to matters of national environmental significance to form his opinion. Dr Stock concludes in relation to the permanent change in the hydrology to the Ramsar Wetland the mine will cause that:

"The 8-kilometre-long disruption by the Enterprise Mine represents roughly 25 per cent of the 26-kilometre long length of Eighteen Mile Swamp that receives groundwater from the high dunes and escarpment. The mine is likely to cause permanent changes that lead to more rapid increases of groundwater flows along, about, a quarter of the length of Eighteen Mile Swamp. In relation to the EPBC Act the Enterprise Mine, in my opinion, will have "a substantial and measurable change in the hydrological regime of the wetland [through]... a substantial change to the volume, timing, duration and frequency of ground... water flows to ... the wetland". If the permanent and similar impacts of the Yarraman Mine already made in the far north of the Island are added to those from Enterprise (/Ibis), mining along the Island's eastern seaboard will have affected even more of the hydrological regime of Eighteen Mile Swamp."

We also referred in our submission to Dr Stock's opinion that the Enterprise mine has caused a significant impact to the Ramsar protected area to the west of the mine – in an area known as the Ibis lagoon system. His opinion was explained verbally to Federal environment department investigators at a meeting in Brisbane on 26 November, 2013, but his written report was delayed partly due to Dr Stock's ill health. It has now been completed and a copy will also be forwarded to the officer responsible for the investigation, Drew McLean. We attach a copy of this report, dated today. It relates to the death, in 2010, of vegetation in an area approximating 95 hectares, most of which is in a Ramsar protected area. We draw the committee's attention particularly to section 5.0 of the report, "Preliminary Conclusions" and section 6 of the report, "Significance of Impact of Mine-Sourced Discharges into the Ibis Lagoon System – Part of a Ramsar Wetland". In relation to the cause, at 6.2.1, Dr Stock concludes:-

"In this preliminary review I have attempted to document the evidence for a marked condition change in 2010 within the low-lying areas of the Ibis Lagoon system. In my opinion the dead leaves and twigs, as well as surface water evident in the 2010 imagery, indicate widespread inundation with stress and death of vegetated areas, terrestrial and littoral. Flooding from mine-sourced discharges was nominated the most likely source of the excess water.

At least 80 ha of the Moreton Bay Ramsar Wetland (or some 95 ha of the Ibis Lagoon system) was affected. This area is approximately 40 to 50 times larger than the area impacted by flooding from the Ibis Mine in 2000 which was restricted to the western part of the Ibis Lagoon system. The much smaller incident of 2000 generated a "Show Cause" notice from the regulatory agency; the 2010 flooding did not.

Given Sibelco's environmental concerns and the stated capacity of its mining and environmental team, it is difficult to conceive that their personnel were unaware of this impact so close to the Enterprise operations. Yet, there was no public announcement of this condition change in 2010 and I am unaware of any advice from the company to relevant Queensland and Australia agencies. There was no acknowledgement of these impacts in official reports such as the AER 2010 (released in 2011).

Because the mining company provided no information about, or data for, any 2010 flooding it is not possible to accurately assess the full range of impacts of this incident. The 2010 imagery suggests the inundation lasted at least 6 months but this is not necessarily indicative of the degree and kind of impacts. Groundwater levels took some 18 months to return to projected 'natural conditions' after the 2000 discharges. By comparison with other reported impacts from similar inundations on the island, including the Resource Strategies Pty Ltd (2000) report on flooding from the Ibis Mine in 2000, it is possible to rank the 2010 incident as largest in area of all the mine-sourced incidents ever noted on the island.

From the 2010 incident there would have been impacts from the inundation itself and associated impacts on soils, substrate and waterbodies followed by some recovery. I am unaware of additional studies of the likely impacts and sequelae, including: extent and mode of inundation; recovery of the groundwater system and free-surface levels and volumes; changes in water quality from both the mining discharges as well as dissolved and particulate loads from damaged and killed organisms; extent of morbidity, mortality and repopulation of flora and fauna in the affected terrestrial areas and the littoral surrounds of the waterbodies; and, impacts on water quality, flora and fauna of the lagoons/swamps. I am unaware of any program to rehabilitate and/or remediate the impacted areas, even in the most basic way."

Elsewhere in his report, Dr Stock explains the preliminary nature of his report due to the incomplete nature of the company's publicly available data contained in limited annual reports it has provided to the State government.

Dr Stock sets out in section 6.1 relevant parts of the Significant Impact Guidelines 1.1 to the EPBC Act 1999, including that:-

"*An action is likely to have a significant impact on the ecological character of a declared Ramsar wetland if there is a real chance or possibility that it will result in*

- *Areas of the wetland being destroyed or substantially modified*

- *A substantial and measurable change in the hydrological regime of the wetland, for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland*
- *The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetalnd being seriously affected*
- *A substantial and measurable change in the water quality of the wetland–for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health, or*
- *An invasive species that is harmful to the ecological character of the wetland being established (or an invasive species being spread) in the wetland."*

After his summary of the impact of the mine sourced discharges referred to earlier, he concludes in 6.2.1:-

"Thus, in my opinion, and in relation to the EPBC Act, the discharges sourced from the Enterprise Mine in 2010 will have generated over months to years "a substantial and measurable change in the hydrological regime of the wetland [through]... a substantial change to the volume, timing, duration and frequency of ground... water flows to ... the wetland."

In other words, the 2010 discharges have already resulted in a significant impact on the ecological character of the Ramsar wetland to the west of the mine.

If the committee shares our concerns about the Enterprise mine's compliance with the EPBC Act and the impact which the mine has had and is likely to continue to have on the ecological character of Ramsar wetlands, then the committee could assist. In all the circumstances, the committee could make a recommendation to the Minister that he use his powers under section 70 of the EPBC Act to ensure that Federal government environmental assessment of the mine takes place before it causes any further damage to "a matter of national environmental significance".

Please advise if you would like a representative to appear before a Committee hearing.

Yours sincerely,

Sue Ellen Carew

Sue Ellen Carew
President
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Preliminary review of the hydrological impacts of Enterprise Mine on the ecological character of Eighteen Mile Swamp within the Moreton Bay Ramsar Wetland

Floating dredge and disturbed dunes at Enterprise Mine with Eighteen Mile Swamp in background. Image: FOSI (2010)

Prepared by Dr Errol Stock

September 2012

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LIST OF ACRONYMS AND ABBREVIATIONS

AERs	Annual Environmental Reports
CRL	Consolidated Rutile Ltd
EA	Environmental authority [issued under the *Environmental Protection Act* 1994 (Qld)]
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999 (Cth)
ESR	Environmental Studies Report
FOSI	Friends of Stradbroke Island Inc (FOSI)
m	metre
ML	Megalitre (1,000,000 litres)
OSL	Olympic swimming pool (volume 2.5 megalitres)
PoOs	Plans of Operations
SAL	Sibelco Australia Limited
SIMO	Stradbroke Island Management Organisation Inc
t	tonne

1.0 INTRODUCTION

1.1 PURPOSE OF REVIEW

The purpose of this report is to provide a preliminary review of the hydrological impacts of Enterprise Mine on Eighteen Mile Swamp on North Stradbroke Island, Moreton Bay, Queensland, to determine whether the mine requires approval under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act). Eighteen Mile Swamp is part of the Moreton Bay Ramsar Wetland and provides habitat for migratory species and listed threatened species that are protected under the EPBC Act.

Enterprise Mine was operated by Consolidated Rutile Ltd (CRL) until being purchased by Sibelco Australia Limited (SAL) (formerly Unimin Australia Ltd). The mine commenced operation in 2004 and is approved under Queensland law to operate until 31 December 2019 but has not been approved under the EPBC Act.

The review was requested by the Friends of Stradbroke Island (FOSI) for the purpose of potentially undertaking litigation in the Federal Court of Australia for a contravention of the EPBC Act.

This is a preliminary review only as it has been prepared on the basis of information that is publicly available regarding the mine, particularly the mine's published Annual Environmental Reports (AERs). As discussed in this report, that information is deficient in many respects. The findings and opinions expressed in this preliminary review will be reconsidered if and when further information becomes available through the trial process, for example if SAL provides further documents regarding monitoring at the mine or if I am able to meet with and discuss the issues with experts acting for SAL.

1.2 DUTY TO THE COURT

I have been provided with a copy of the Federal Court's Practice Note for expert witnesses.[1] I have read, understood and complied with the Practice Note. In particular, I understand and I have prepared this review on the basis that:

- I have an overriding duty to assist the Court on matters relevant to my area of expertise.
- I am not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential.
- My paramount duty is to the Court and not to the person retaining me.

1.3 EXPERTISE

My curriculum vitae are provided in Attachment 1.

I have studied the geology, geomorphology and hydrology of North Stradbroke Island since 1964. My research and reports were generated first as a practicing economic geologist and later as a geomorphologist developing expertise in understanding the sand masses of the east coast of Australia and as an environmental scientist tracking the outcomes of rehabilitation and documenting the impacts of mining. In these fields I have prepared consultant reports on the Island for the Australian Heritage Commission, CRL, Redland Shire Council, Quandamooka Land Corporation, Stradbroke Island Management Organisation and Friends of Stradbroke Island.

[1] Federal Court of Australia (2011), "Practice Note CM7: Expert Witnesses in Proceedings in the Federal Court of Australia"

1.4 SCOPE AND STRUCTURE OF THIS REVIEW

In preparing this review I have referred to several relevant reports, which are listed in the references section. According to the 2003 Environmental Studies Report for the Enterprise Mine[2] (ESR 2003) CRL personnel and several consultants conducted a revised groundwater modelling of the proposed mining activities of the Enterprise Mine (and the remaining Ibis Mine path) "to evaluate the interaction of the Enterprise Mine with the prime groundwater table and predict the effects of the planned mining activities on it" (p.4-13). The ESR 2003 also summarised (pp 4-14 to 4-15) the MODFLOW model and its modifications including the 'ridge' and 'river' packages linked to the program. Based on CRL's past experience in operations some quantitative values of flows from the tailings were reduced before being 'plugged' into the revised model. Analysis and evaluation of the modelling was treated on page 4-16 and this section was expected to be read with the "preliminary model output for the planned mine path [as presented in] Figures 4-2 to 4-11 for the period 2003 to 2012" (p4-16). A collapsed version of the modelling results and forecast impacts from page 4-16 is extracted in Attachment 2 of this review for convenient reference.

Although the focus of the company's modelling was on the groundwater, its flows and elevations, the ESR 2003 did **not** provide details of quantitative forecasts of groundwater elevations of concern, or nominate which spears/piezometers (or boreholes) that should be used for monitoring the water table or for dewatering. As well, the authors of the ESR 2003 did not identify specific watertable elevations or 'triggers' that would generate actions from CRL, though these are considered in Plans of Operations (PoOs). No groundwater monitoring data are published in the Annual Environmental Reports (AERs.) The company has effectively redirected interest from the groundwater to monitoring surface water levels in Eighteen Mile Swamp. The following quote (p 4-16) could function as a summary of CRL's muting of concern and reassurance to the reader: "The predicted effect of the planned Enterprise Mine on the surface water levels in Eighteen Mile Swamp is for a small and temporary rise in the section of the Swamp nearest the Mine whilst it is above the prime water table in the period before December 2005".

Testing the accuracy of this quote and revealing the inadequacy of CRL's response in monitoring for potential impacts on water quantity and quality is the main subject of this review compiled in nine sections. As Eighteen Mile Swamp is a designated Ramsar Wetland assessing the significance of any impacts from the Enterprise Mine is of direct and important relevance under the EPBC Act.

Because the Enterprise Mine has been in planning, development and operation for over 10 years this review depends retrospectively on assessing the information, principles and limited data in the ESR 2003, several PoOs and the AERs 2003 through 2010. The author of this review has also drawn extensively on personal knowledge and other publications to provide historical details for such a critique.

Section 2.1, a summary of dredge-pond mining, is intended to provide perspectives of the scale of the wet mining in the high dunes of North Stradbroke Mining, including that at Enterprise Mine. Because mining by floating dredge had been practised on the Island for over 50 years there is considerable knowledge of the impacts of such mining; and for mining in the high dunes this knowledge extends to the potential to impact water at the surface and subsurface through various direct and indirect pathways. Section 2.2 draws on the historical evidence of the known impacts to raise concern for potential impacts at the Enterprise Mine, especially with respect to its potential to change water chemistry. Figure 1 shows the locations of Enterprise Mine, Vance Mine, Yarraman Mine, Ibis Mine (now closed) and Eighteen Mile Swamp on North Stradbroke Island. Figure 2 shows the vegetation communities on North Stradbroke Island with the locations of Enterprise Mine and Eighteen Mile Swamp identified. Eighteen Mile Swamp is shown as a Freshwater Wetland that

[2] Certified by an independent third party in November 2003 (AER 2004 Table 2 Item A4-4)

extends for approximately 26 kilometres along the eastern side of the island. It is approximately 1 kilometre wide to the east of Enterprise Mine. Figure 3 is a simple map of North Stradbroke Island with named surface water sites; and Figures 4 through 7 illustrate some of the points raised in the Section 2. Figures 8 through 15 provide photographs of Enterprise Mine and Eighteen Mile Swamp which were taken by FOSI members during formal mine visits and informal excursions related to concerns for environmental issues. Attachment 3 provides some key features about the hydrology of North Stradbroke Island and Eighteen Mile Swamp as described in two recent papers published by the Royal Society of Queensland.

Section 3 is a summary of the modelling results and predicted impacts and is based on relevant sections of the ESR 2003 for Enterprise Mine (Attachment 2). Sections 3.1 and 3.2 expand the critique by focusing, respectively, on the forecast of changes in groundwater elevations at the escarpment toe and on setting out the essential aspects of a monitoring program to respond to the company-generated forecasts. Figures 16 and 17 illustrate, respectively, island-wide contours on the prime watertable and isolines for the increased groundwater as predicted for June 2003 (Figure 17a) and June 2012 (Figure 17b).

Because the CRL authors of the ESR 2003, the PoOs and AERs never explicitly describe the logic and scientific objectives underpinning the actual water volume monitoring program for Enterprise Mine these reports have to be scrutinised for relevant information. The results of this research are contained in the two parts of Section 4 (Evaluation of CRL's Monitoring Program for Water Volume) namely, Section 4.1 Detection and Reporting of Changes in Groundwater Levels along the Toe, and Section 4.2 Detection and Reporting of Changes in Surface Water Levels in Eighteen Mile Swamp. Table 1 is a list of the monitoring sites actually used in Eighteen Mile Swamp.

Section 5 is a review of the approved but minimal monitoring program CRL was able to put in place to test for changes in "water chemistry". Materials are presented to show problems with CRL's position on water quality monitoring, including compromised reports by consultants and poor science. Section 5.1 is a critique of the assumptions the mining company relies on to misdirect attention away from the variable chemistry of the surface water bodies. Section 5.2 indicates with selected examples how monitoring could have been carried out for tracking the quality of the groundwater. Figures 18 through 20 are plots of some water chemistry attributes of three selected surface waterbodies for the period 1992-1995. Box 1 is a summary of known contamination of two of those waterbodies by mining water discharges. As the review concludes the monitoring program approved for Enterprise Mine was and is grossly inadequate, despite having passed through an independent environmental audit and scrutiny by regulatory agencies.

The yearly AERs, commencing in 2006, reported on an "escarpment vegetation condition assessment". This monitoring program of terrestrial flora provides insight into CRL's priorities in monitoring and raises additional concerns about design in monitoring and interpretation of results. The vegetation monitoring program is reviewed in Section 6 with verbatim extracts in Table 2.

Conclusions and recommendations are collected in Section 7 and the significance of these impacts to Eighteen Mile Swamp, a Ramsar Wetland under the EPBC Act, are summarised in Section 8.

The declaration to the court required by the Federal Court's Practice Note for expert witnesses is provided in Section 9.

References are listed in Section 10.

2.0 Summary of Mining Operations and Historical Record of Impacts of Dredge Mining

2.1 Summary of Mining Operations- General and Enterprise Mine

Large-scale wet mining (floating dredge and primary concentrator) is the dominant mining method at the Enterprise Mine. Prior drilling and assay had determined the ore volumes of economic interest. The land was cleared of vegetation ahead of mining and the stripped topsoil stored in locations according to the mine plan. Mining at Enterprise was a continuation from the earlier Ibis mine operation. Figures 4 and 5 are reproductions of schematic diagrams of wet mining operations as illustrated in, respectively, Figures 1-4 and 1-5 from the ESR 2003. Figures 6 and 7 give more realistic images of the topographic variation and scale of the dredge pond, tailings and rehabilitation activities. Figure 6 relates to the Enterprise Mine (Google Earth Image 6 February 2010) and Figure 7 is an oblique image of the Gordon Mine (no longer operating) and is a good representation of such mining operations. Figures 8 through 11 are recent oblique aerial images of the Enterprise Mine.

Across North Stradbroke Island wet mining rates have varied according to ground conditions and, historically, were usually between 2,700 and 3,200 tonnes/hour with peaks of 3,800 tonnes/hour. Operations at Enterprise were planned on a 24-hour 7-day week and heavy minerals are also extracted from several areas adjacent to the main dredge path by dry mining techniques. The ore from these places is excavated by dozers and/or scrapers, converted to a slurry stream and processed as if it was from the wet-mining dredge feed. Mineral concentrates are pumped ashore to dewatering cyclones and stockpiled nearby the dredge pond before trucking to barges at Dunwich and on to the mainland (Pinkenba) for additional processing.

The suction-cutter dredge and the mineral concentrator plant float in a pond approximately 10 to 15 metres deep. In Figure 6 the dredge pond of the Enterprise Mine (February 2010) was about 300 metres long and 200 metres wide. The elevation of the dredge pond is adjusted throughout the mine path to optimise access to the defined ore zones. Water levels of the dredge pond are maintained by managing the balance between water losses (from the pond and tailings as they drain into the subsurface) and adding make-up water. For the Enterprise Mine some make-up water comes from bores into the prime groundwater mound, but the bulk is pumped from surface water canals (see Figure 3) in the east (Herring Trench/'Lagoon' in Eighteen Mile Swamp) and west (Kounpee Trench[3] in Wallen Wallen Swamp[2]). According to the overview of the Planned Stage 1 (ESR 2003) the demand for makeup water was expected to be greatest early in the mine life (about 20 ML/day) and progressively be reduced to about 12 ML/day. It is significant that the water chemistry of the dredge pond at the Enterprise Mine would vary throughout its operating period according to the relative proportions of water from the three sources: water from the main island mound, Eighteen Mile Swamp (Herring Lagoon/Trench) and Wallen Wallen Swamp (Kounpee Trench).

Lighter-density sand tailings are pumped from the concentrator plant to areas behind the advancing dredge pond or to adjacent off-path tailings disposal areas, according to the overall plan for landform reconstruction. Topsoil is respread from stockpiles and revegetation proceeds according to the operations plan and other prevailing conditions. As with other mine areas on the Island CRL (and later Sibelco/SAL) planned to conduct progressive rehabilitation on a campaign basis to take advantage of expected seasonal variations and growing conditions (nominally January to June each year).

[3] These are informal but well-established names applied by mining company employees and were initially derived from local place names. The artificial Kounpee Trench is cut within the Wallen Wallen freshwater swamp near sea level and is *not* associated with other water bodies with apparently linked names but are a little further to the east and at higher elevations: Lake Kounpee North, Lake Kounpee and Kounpee Swamp.

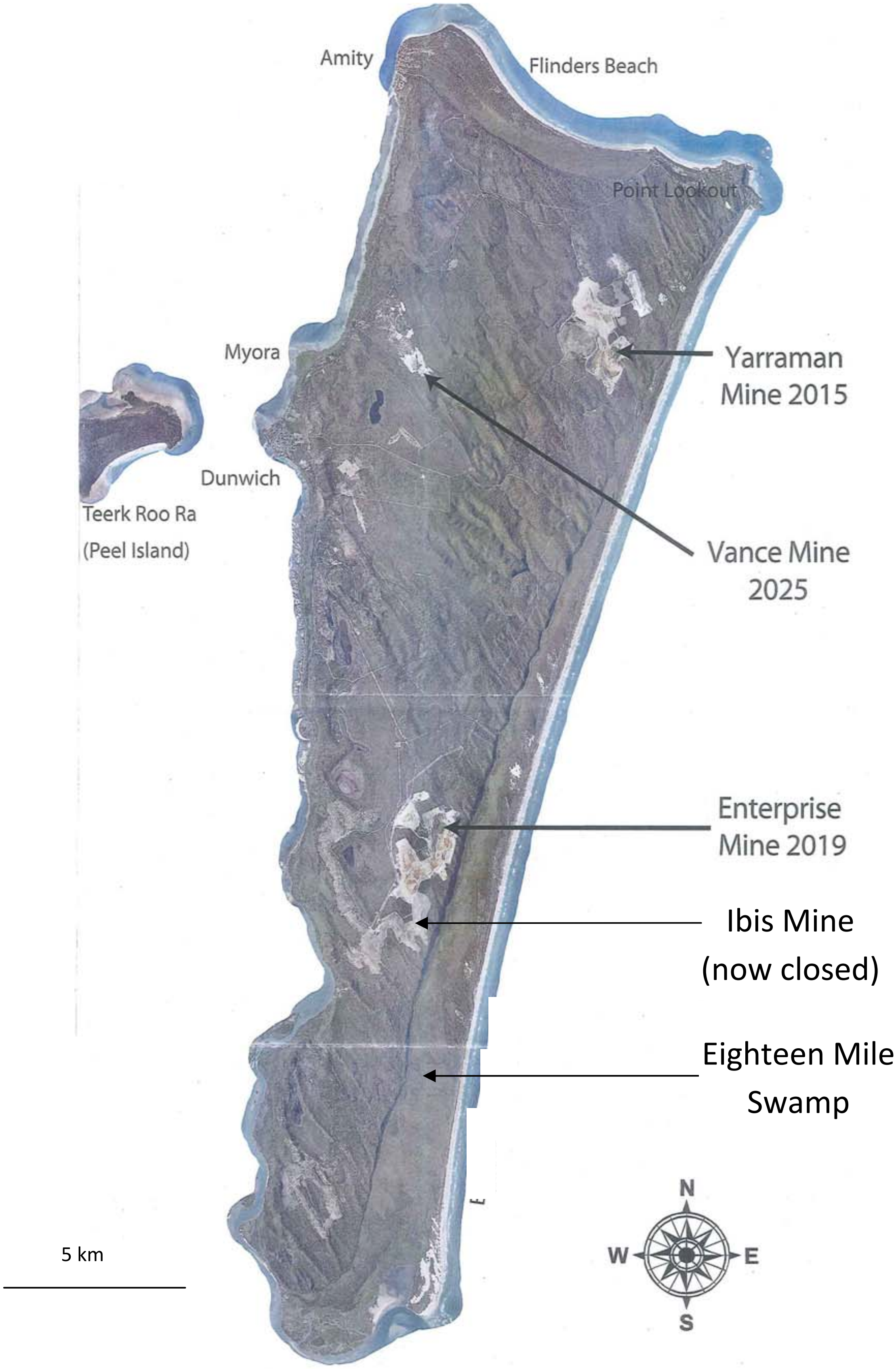

Figure 1: Locations of Enterprise Mine, Vance Mine, Yarraman Mine, Ibis Mine (now closed) and Eighteen Mile Swamp on North Stradbroke Island. The date is the current estimated year of closure.

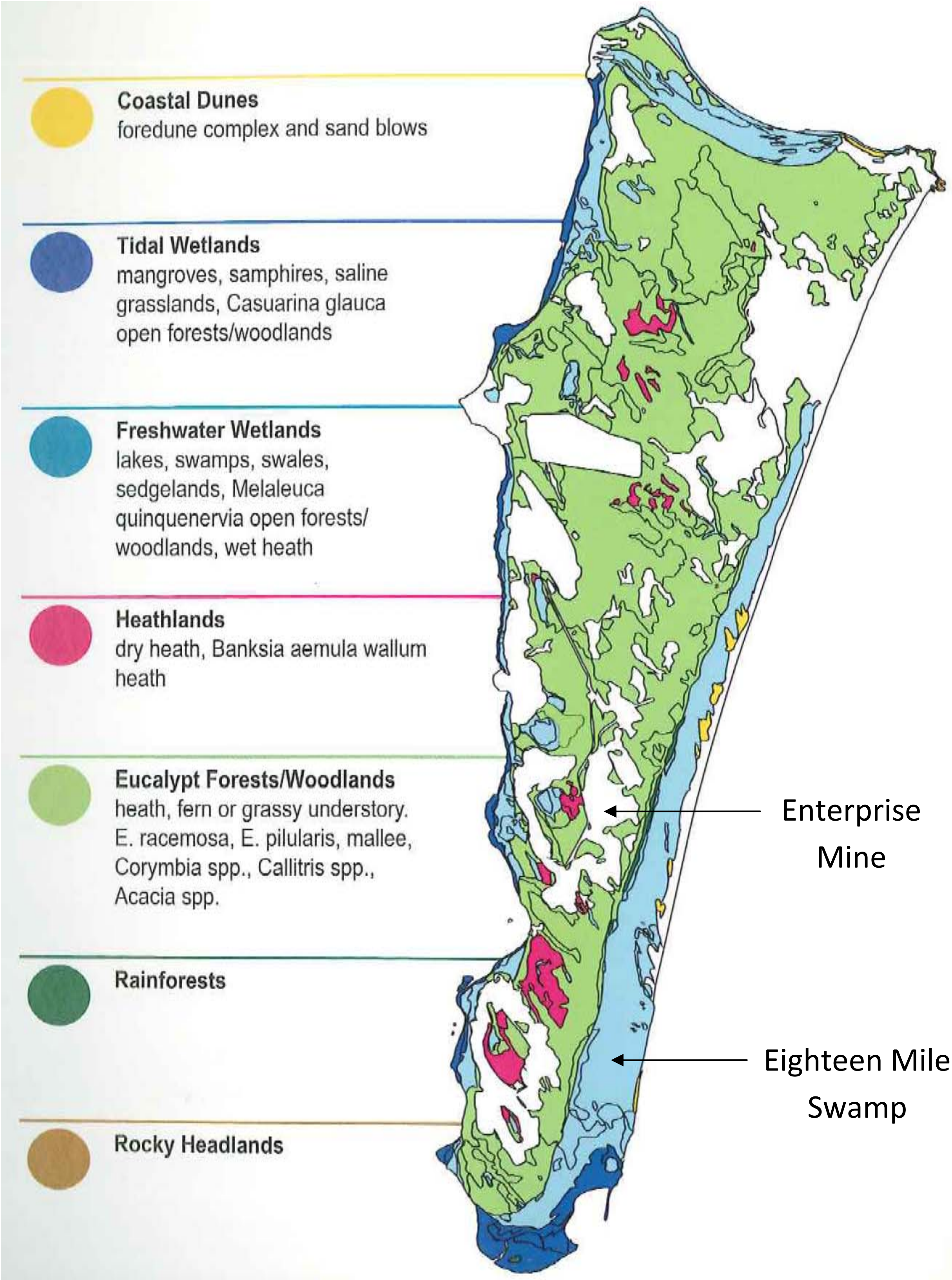

Figure 2: Vegetation communities on North Stradbroke Island with the locations of Enterprise Mine and Eighteen Mile Swamp identified (Source: Stephens and Sharp 2009). Eighteen Mile Swamp covers the area identified as Freshwater Wetlands on the eastern side of North Stradbroke Island. It is approximately 30 km (18 miles) in length and 1 km wide adjacent to Enterprise Mine.

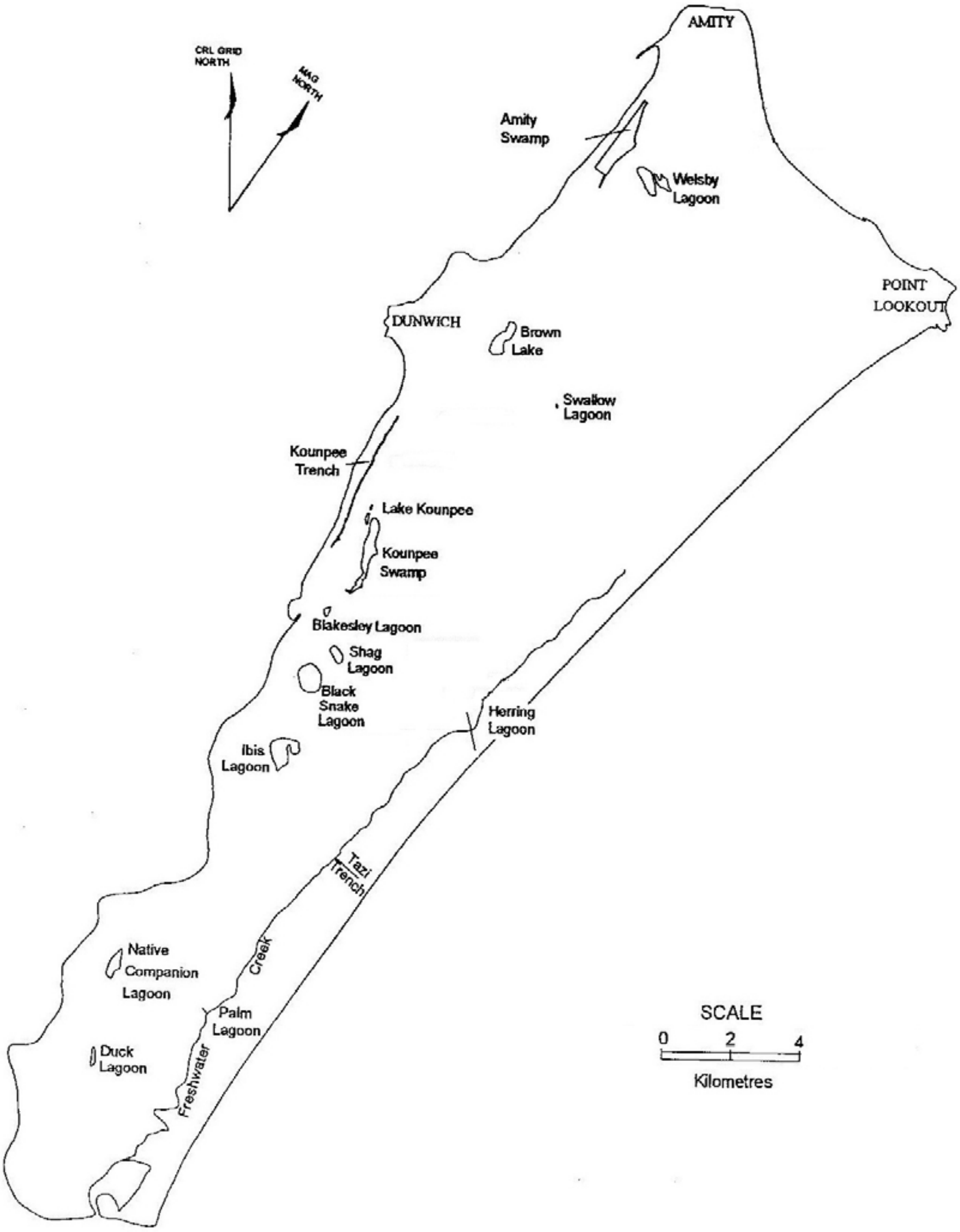

Figure 3: North Stradbroke Island with major natural waterbodies and artificial trenches that have been used to supply makeup water to maintain dredge-ponds at various mines. (See also footnotes Table 1)

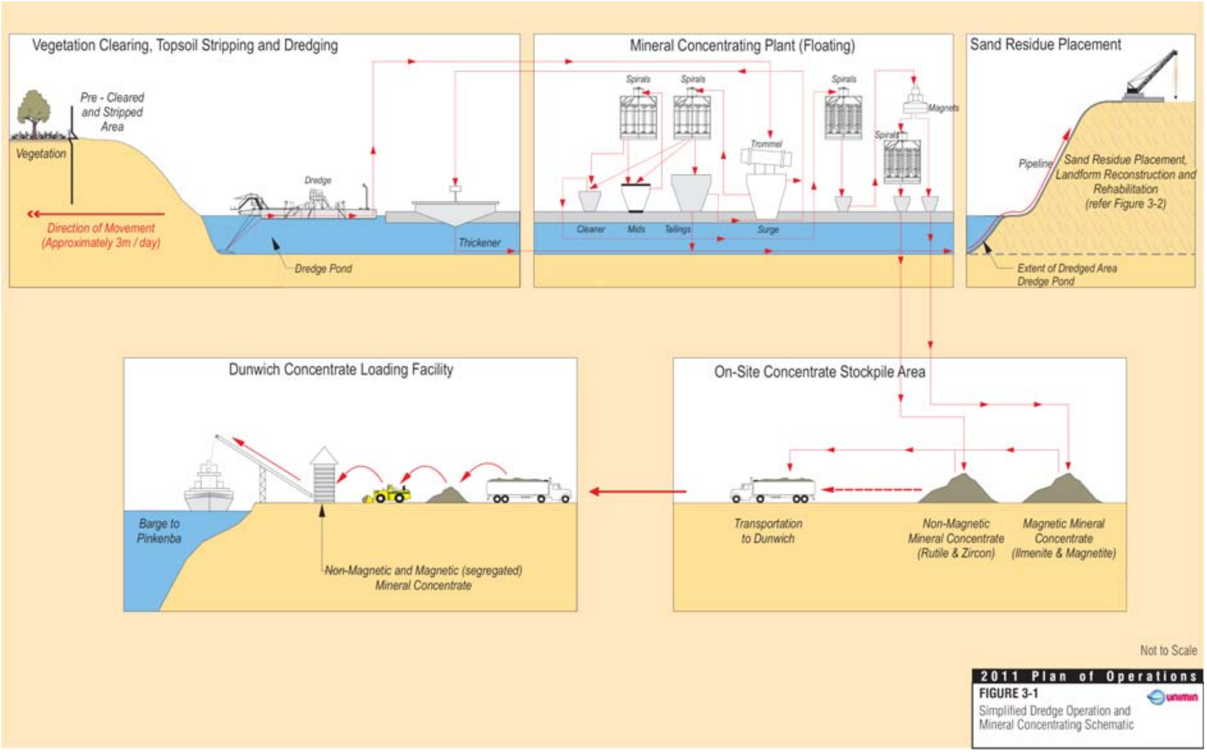

Figure 4: Simplified Dredge Operation and Mineral Concentration Schematic (ESR 2003, Figure 1-4 and PoO 2011, Figure 3-1).

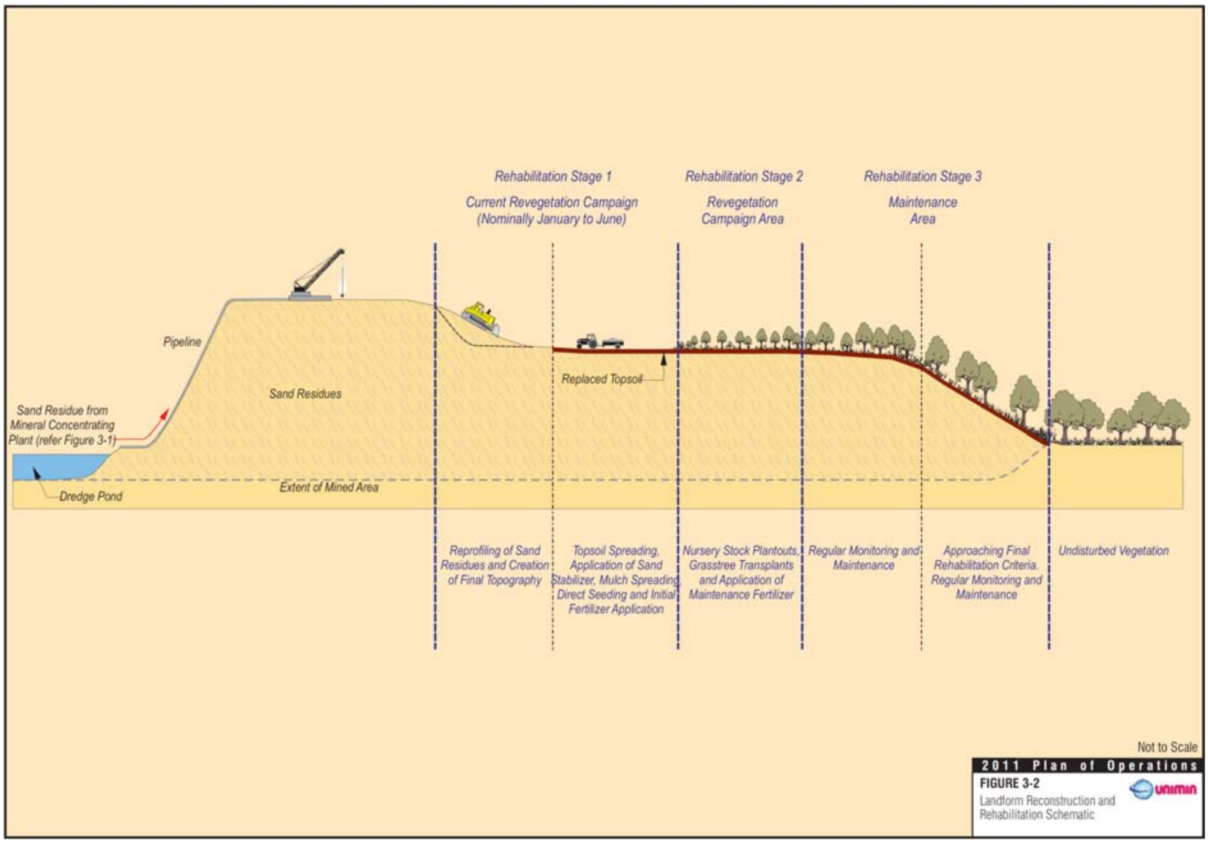

Figure 5: Landform Reconstruction and Rehabilitation Schematic (ESR 2003, Figure 1-5 and PoO 2011, Figure 3-2)

Figure 6: Enterprise Mine as in satellite image 6 February 2010. The yellow arrow indicates the dredge pond with the floating concentrator in the north. (Google Earth image)

Figure 7: Oblique aerial view to south of Gordon Mine (not in active operation today). Note the exposed soil profile in dredge-pond walls (yellow arrow), brown-coloured tailings of homogenised sand (orange arrow) and grey topsoil spread ready for revegetation (red arrow). (Photo by CRL)

Figure 8: Floating dredge and disturbed sand dunes at Enterprise Mine with Eighteen Mile Swamp in background (the opposite direction to that in Figure 9). Photo by FOSI (2010)

Figure 9: Floating dredge and disturbed sand dunes at Enterprise Mine looking west with Brisbane visible in the distance (the opposite direction to that in to Figure 8). Photo by FOSI (2010)

Figure 10: Enterprise Mine working area. Photo by FOSI (2009)

Figure 11: Enterprise Mine working area with floating dredge in distance and partially mined dunes in foreground and mid-ground. Photo by FOSI (2009)

Figure 12: View to south from escarpment at northern end of Eighteen Mile Swamp looking south. Photo by FOSI (2010).

Figure 13: Rainforest below the escarpment located between Enterprise Mine and Eighteen Mile Swamp. Eighteen Mile Swamp is visible through the trees. Photo by FOSI (2012)

Figure 14: View to north of a section of Eighteen Mile Swamp to the east of Enterprise Mine. Photo by FOSI (2012)

Figure 15: A section of Eighteen Mile Swamp close to the escarpment toe and east of Enterprise Mine. Photo by FOSI (2012)

The focus of this preliminary review is on the potential impacts on water volumes and chemistry that may follow from the additional water discharged from pond and tailings during essential mining operations when a dredge pond is maintained above the main natural water table. When a dredge pond is sited within the prime aquifer no additional make-up water is required and the discharge from the dewatering tailings may be considered as a relatively short-term redirection of water volumes. Other environmental concerns about the quality and stability of rehabilitation and losses of landscape values and terrestrial biodiversity are certainly important but are not considered here except in passing.

2.2 Record of Impacts of Mining on Waterbodies of North Stradbroke Island

The author of this review has been studying the impacts of mining on North Stradbroke Island since 1964, especially the impacts to surface waters and on the groundwater. Information about these impacts has been available in numerous sources including: the mining company's[4] Annual Environmental Reports 1991 through 2010, geotechnical and hydrogeological consultants' reports, other punished and unpublished documents (for example, Durbidge and Covacevich 1981, 2000; Durbidge and Stock 1986, Goosen and Stock 2000), correspondence files held by SIMO and FOSI and information from Redland Shire Council[5]). From these sources, it is possible to conclude that over the past 50 years different mining companies using dredging operations in the high dunes have affected almost all the lakes and lagoons that were adjacent to a mine path. The impacts include temporary and permanent damage to surface waterbodies and their surrounds, ecological damage through inter-catchment transfers and destruction of original hydrogeological conditions.

For example, Eighteen Mile Swamp itself was affected at its far northern end by earlier mining operations in the late 1960s and early 1970s. Competition for make-up waters[6] led to over-pumping of waters from the original Yarraman Lagoon and drying-out of the bottom substrate. There was also erosional effects in the Yarraman Valley and spilled tailings. The more recent mining at Yarraman has yet again markedly changed the topography, created a sculptured set of waterbodies linked by a constructed drainage line and affected flows to the Swamp. In the late 1970s works associated with supplying make-up water to the Amity Mine in the Island's northwest created damage to local intertidal areas through drowning in fresh water collected upstream of an illegal dam constructed off-lease; an associated discharge of salt water used to top-up the dredge pond killed over 2 hectares of terrestrial vegetation.

Blaksley Lagoon and Lake Kounpee on the west coast have been variously affected. Blaksley Lagoon suffered a permanent reduction in water levels through damaged aquitards. Lake Kounpee was similarly affected (1983) but it was so placed in the public attention at the time that CRL, under new management in the late 1990s, commenced a remediation program that appears to have restored water levels. Native Companion Lagoon, South Lagoon and Black Snake Lagoon have experienced flooding through elevated water tables and the peripheral habitats have been variously damaged. Duck Lagoon was affected by sand spillages. These losses and impacts occurred even though many of the water bodies were nominated as possessing heritage values (Commonwealth National Estate) and most of these lakes and lagoons were specifically noted for protection in mine plans approved by the responsible Queensland Agencies.

In all these examples, the groundwater systems in different part of North Stradbroke Island have been affected temporarily or permanently. The impacts are acknowledged by the companies concerned; State agencies have records of the impacts, some of which have been the subject of "Show Cause" notices; and, the informed public are very well aware of them.

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[4] CRL 1991-2008; Unimin 2009; Sibelco Australia 2010

[5] Redland City Council as from 15 March 2008

[6] Between CRL and Associated Minerals Consolidated

Another mode of mining-generated impact on the hydrological regime has been the contamination by inter-catchment[7] transfers. From the outset of dredging operations in the high dunes, companies have mixed waters from different water bodies and 'catchments' without giving attention to the potential for pollution by mining discharges and permanent ecological change to waters so affected.

During the mining of heavy minerals by floating dredge, different companies have pumped waters from different locations from across the Island to a distant dredge pond where it was used as make-up water. The companies variously pumped from *bores*, dammed *streams* (such as Yarraman Creek in the northeast and Wallum Creek near Amity), *lakes* and *swamps* (near Palm Lagoon and Kounpee Trench). The companies' preferred method was (and is) to pump from canals or trenches dug into swamps at different places in 18-mile Swamp (Herring Lagoon, Palm Lagoon, Tazi Trench), at Aranarawai (Amity Mine) and along the Wallen Wallen swamp (Kounpee Trench). Pumping stations and pipes are required to deliver the make-up water and small swamps and lagoons have been used as intermediate staging points or temporary reservoirs, depending on distances, engineering factors and geotechnical conditions.

While most of the volume of such make-up waters may eventually return to the main aquifer, whether and exactly how this happens depends on the location of the dredge pond and local conditions. It is significant that water moving in the subsurface from elevated dredge ponds has been implicated in many incidents of off- and on-lease discharges (seepages) and of the flooding of surface water bodies. Dredges operating at *lower* elevations may receive rather than lose groundwater flows. The preoccupation of a company operating a dredge in such a setting is to pump water out of the pond; this situation developed in the Gordon Mine and led to the long-term flooding of Native Companion Lagoon from 1988 through 1994.

Beyond documenting the impacts caused by mine-generated discharges of excess water *volumes* there has been little or no consideration of *water quality issues* that may follow from the mixing of mine discharges in the subsurface with other natural waters. One example of pollution by water transfers relates to attempts to remediate Lake Kounpee. Water from Eighteen Mile Swamp and Wallen Wallen swamp was pumped to recharge Lake Kounpee. Because the company's attempts at artificially recharging this damaged waterbody involved pumping of waters from Eighteen Mile Swamp and Wallen Wallen swamp, and even through there have been rainfall additions, at a basic biochemical level the remediated lake is an artificial construct. As well, pumping from Eighteen Mile Swamp transferred exotic aquatic plants and foreign fish to Lake Kounpee. During 1998, the introduced fish were eliminated with poisons on the advice of consultants (Harrison and Howland 1998). The impacts on the water quality of other waterbodies remains to be revealed.

The surface waterbodies of North Stradbroke Island range in elevation from near sea level (eastern and western swamps) to 154 metres (Swallow Lagoon). Their conditions of formation and function are very dependent on their geomorphological setting. The range of waterbodies includes small perched and isolated waterbodies (e.g. Swallow Lagoon), water table 'windows' (e.g. Blue Lake) created by natural sand-damming, as well as waterbodies that are known to be partly perched (e.g. Native Companion Lagoon).

Because of the intimate connection between a waterbody and its hosting/damming sand dune the waterbodies of North Stradbroke Island are highly variable in age, geochemistry, limnology and ecology. Unfortunately, no inventory was/is available to reveal the characteristics of the spectrum of waterbodies in their *unaffected* condition. It is not possible to fully redeem these losses as they are a function of the belated scientific recognition of the real, if sometime subtle, differences in attributes from waterbody to waterbody, the unquestioning use of the waterbodies in the companies' drive for mineral production and the lack of

[7] Of course, on a sand island like North Stradbroke it is difficult to attach exact scientific meaning to "water catchments" because so much water movement is in the subsurface. Consequently, the terms 'catchment' and 'inter-catchment transfers', in relation to mining operations, are used here as generics.

effective regulatory instruments and management systems to protect those waterbodies listed as in need of protection. The loss is not total as glimpses of their original integrity and diversity are available in early government reports, students' theses, scientific papers and extensive company records (consultants' reports), but the data are scattered and limited.

Recently, two directions of research have added significant insights into the current distribution of some aquatic species across the Island's waterbodies and potential explanations for the emergent phylogeographic patterns (Page and Hughes 2007a; Page and Hughes 2007b; Marshall, Negus, Steward and McGregor 2011; Page, Marshall and Hughes 2012). These researchers from Queensland agencies and universities with company cooperation have shown there is strong east-west divide in the distribution of many aquatic organisms.

Over the past 50 years mining by dredge at Yarraman, Amity, Bayside, Gordon, Ibis and Enterprise mines has destroyed, and is currently destroying, the original pile of sediments and the soil profiles (differentiated grey, white, brown, black, and yellow) developed within the *wind-deposited* sandy sediments. During mining and processing the sediments and parts of the soil profile are mixed and returned as *water-deposited* yellow-brown tailings (before topsoil is respread). Some appreciation of this process of homogenisation-by-mining can be seen in Figures 6 through 11 where the vast pile of brown tailings sand is spread out behind and beside the migrating dredge pond.

Several impacts on the water regime occur as a consequence of this method of mining and reconstructing the topography. Hydrogeological conditions are completely altered along the mine path in the volume of sand processed for heavy minerals. The post-mining sandy materials used progressively to fill the void created by mining and to construct the post-mining landscape are very homogeneous and of higher porosity and permeability than the original. One or more aquitards (primarily B-horizons of soils) are destroyed and/or truncated. The fines discharged into the dredge pond can settle separately and create special conditions. Subsequent recharge conditions and ground water regimes are changed permanently — but the effects are unknown. It is safe to say that water moving through this fill can no longer follow the complex pathways that existed in the undisturbed dunes. This may mean more rapid recharge to the main groundwater mound and possibly more rapid exit to the sea. It may also mean that habitats that were generated by circuitous and slow motion of groundwater may be stressed and/or compromised. Off to the side of the mine path the intact soil horizons severed by mining may be denied groundwater from the fill. These broad forecasts have never been tested by the mining companies nor identified by Queensland agencies.

Mining destroys the original soil profiles (various types of Podsols) of considerable age and maturity and substitutes them with two-component artificial soils[8] (Anthroposols) that have *no counterparts in the natural soils on the island*. Dating of the quartz sands at Bayside and Amity shows the sediment-soil pile there to be between 100 000 and 150 000 years old (some perhaps as old as 300 000 years, some up to 25 metres thick). As well, the original groundwater regimes along the mine paths, that took tens of thousands of years to evolve and develop, have been destroyed and replaced by simple regimes typical of a homogenous sand pile.

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[8] Post-mining Anthroposols on North Stradbroke Island match the Australian Soil Classification (Isbell 1996) definition because they are "Soils resulting from human activities which have led to a profound modification, truncation or burial of the original soil horizons, or the creation of new soil parent materials by a variety of mechanical means" (p.18). These Anthroposols would be correctly placed in the suborder Dredgic because the dominant post-mining substrates were sandy slurries positioned from the concentrator behind the dredge. The relatively minor effort in repositioning tailings sands and topsoils by bulldozers and front-end loaders is not enough to put them into the suborder Spolic as claimed by CRL/SAL. As well, the company is in error to claim (media releases and PoOs) that their "Spolic anthroposols exhibit similar characteristics to the natural soils".

3.0 Company-Identified Potential Impacts and Monitoring for Changes in Water Volumes

3.1 Identified Potential Impacts with Focus on Water Discharges from Enterprise Mine

Based on the modelling results described in the ESR 2003 for the Enterprise Mine (Attachment 2 this review), Section 3.1 contains a summary list of impacts generated from the combined experience of company personnel and out of special workshops that included other specialists. The company's list is dominated by impacts predicted by increased water volumes and not to impacts on water chemistry. In turn, this list would be expected to have been included in CRL's fundamental factors to consider in designing a water chemistry monitoring program. The problems that stem from CRL's failure to do this are considered in Section 5.

The indentified impacts include:

1. Temporary increase in natural groundwater volumes and rise in watertable: In the final year of the Ibis Mine and the commencement of the Enterprise Mine, along a section of Eighteen Mile Swamp immediately east of the mine, an expected impact will be to temporarily raise the existing groundwater levels near the toe of the escarpment by approximately 1 metre. However, the ESR 2003 did not suggest any other dimensions (length, width, area) of the predicted and localised increase in the groundwater table. A very rough idea of the location and varying size of the mound can be estimated from the time series of Figures 4-2 through 4-11 in ESR 2003 and as described in Section 3.2 of this review.

2. Temporary increase in surface water level of Eighteen Mile Swamp: The forecast increase in *groundwater* was likely to generate a temporary increase of approximately 0.1 to 0.3 metres on the *surface water* levels[9] along different sections of Eighteen Mile Swamp nearest the Mine during the period before December 2005. More exactly, the model prediction was for an increase in Eighteen Mile Swamp surface water level between CRL's surface water pumping stations at Palm Lagoon[10] and Herring Trench (Lagoon) in the north. Depending on the extent of CRL's and Redland Shire Council's (RSC's) pumping activities from Herring Trench, the model predicted that the small increase from mining activities may or may not be detectable and may or may not partially reduce/counter-balance the drawdown levels being monitored in Herring Trench. Sometime after December 2005, when the Enterprise Mine dredge pond was projected to be at or below the prime groundwater table, no increases were expected in either the groundwater elevation at the escarpment toe or, as a consequence, in the water level of Eighteen Mile Swamp.

[9] The ESR 2003 did not clarify exactly (in, say, mine coordinates) where this predicted range of increase would occur and no indications were given about dimensions of the localised increase (length, width, area, or shape). However, it seems reasonable to expect that the maximum increase would be close to the escarpment toe and slope outwards in a very gentle gradient somewhat like a half cone. Other methods would have to be used to infer the general size and movement of this 'half cone' or plume.

[10] Palm Lagoon (Figure 3 this review) is an artificial canal established to supply make-up water to the previous Gordon Mine. It is roughly 6 km south of Tazi Trench and 12 km south of Herring Trench. Because Figure 4-2 in the ESR 2003 showed that the southern end of the predicted increased groundwater mound would be no more than 1 km south of Herring Lagoon it is of no assistance to suggest to a reader that the mound could be expected as far south as Palm Lagoon. This misleading southern limit is also obvious in the yearly AER figures that show only a few monitoring/dewatering piezometers/spears are within 2 km south of Tazi Trench. Of course, some increase in the water level of Eighteen Mile Swamp could extend as far south as Palm Lagoon.

3. Environmental effects directly linked to these predicted changes in ground water and surface water levels may also include:

i) Localised changes to vegetation in areas inundated, either by rising groundwater at the toe and/or by flooding along the toe by elevated surface waters of the Swamp.

Initially, no specific monitoring program was proposed for this potential impact. However, as discussed in Section 6 of this preliminary review, CRL/SAL and their consultants did design and carry out a monitoring program that ran from 2006 through 2011.

ii) Impacts on aquatic fauna species abundance due to an increase or decrease in suitable food or habitat.

No specific monitoring program was proposed for this potential impact and none was carried out..

iii) Surface erosion (?minor) due to seepage/discharge from above and/or by rising groundwater and/or surface flow from localised areas.

No specific monitoring program was proposed for this potential impact and no impacts were reported.

4. Changes in water chemistry – groundwater and Eighteen Mile Swamp: CRL did not include the possibility of potential impacts through mining-induced changes in water chemistry and that decision is evaluated in Section 5 of this review. However, it may be noted here that the rejection of detailed monitoring for changes in water quality was said (ESR 2003 p3-13) to be based on the results of a consultant's study (WBM Oceanics Australia 2000) and also (ESR 2003 p4-17, Attachment 2 this review) because:

> "[b]ased on CRL's experience at Little Canalpin Creek (located on the western side of the Ibis Mine) in 2001/2002, no significant mine-induced changes to the water chemistry in Eighteen Mile Swamp are anticipated."

3.2 Identifying Implications of Modelled Forecast Rise in Groundwater along Escarpment

Accepting CRL's estimates used in the revised model, run-of-mine water discharges from the Enterprise Mine were forecast to be 15 ML/day (roughly 6 Olympic swimming pools[11] per day) from the dredge pond and 27 ML/day (about 10.8 Olympic swimming pools per day) from the tailings (ESR 2003 pp 4-16 and 4-15). This combined volume[12] can hardly be termed "seepage" as frequently repeated in CRL documents and by company personnel. In other words, the forecast was that up to 42 ML/day (about 16.8 Olympic swimming pools per day) of extra water would need to be accommodated in the subsurface sand as an expanding plume emanating from beneath the pond and tailings. In neither the ESR 2003 nor the annual AERs did the authors specify exactly how this descending and expanding 3-D plume of discharge water would intrude into the natural aquifer and if at different rates.

In the preceding paragraph the forecast mine-generated discharges were also given equivalent OSP volumes as this practice may help assist in visualising the quantities involved; but it is just as important is to provide local comparisons. For example, Leach's (2011) summary Table 2 shows discharges for the Island's major streams

[11] FINA specifies an Olympic swimming pool (OSP) as 50 m * 25 m *2 m (min depth) and this volume of 2.5 ML is also that used by Bureau of Meteorology. However, until very recently some agencies (e.g. Sydney Water) regarded an OSP volume as 1 ML.

[12] No allowance was made here for for variable ground conditions or for water from tailings that may return to the pond.

as: 15 to 17.8 ML/day for the Blue Lake outflow, 20 ML/day for Freshwater Creek above the junction with Blue Lake outflow and 87.5 ML/day (est.) for Freshwater Creek 5.6 km below the same junction. In other words, the discharge from the Enterprise Mine could be equivalent to 2 or 3 times the natural *surface* discharge from Blue Lake to Eighteen Mile Swamp. Some of Leach's (2011) observations about the hydrology of Eighteen Mile Swamp are relevant to this discussion and are reproduced in Attachment 3; complementary information about the hydrology of the Island (extracted from Cox, James, Raiber, Taulis, and Hawke, 2011:74) are also presented in Attachment 3.

The ESR 2003 did include ten (10) figures (Figures 4-2 through 4-11) to accompany the text. They allow some very rough measures of the size and location of the mine-generated groundwater mound but their designer does not appear to have had the questing reader in mind as criticised in this section. For this review Figures 16 and 17 are presented as aids to placing the predicted changes in groundwater levels in context. For more details on Figure 17 the reader is referred to the original paired figures.

Figure 16 is a reproduction of Figure 3-11 from the ESR 2003 and it shows the general trends of interpreted groundwater contours in a whole-island view. The blue arrows indicate the most likely directions of groundwater flow. The solid rectangle marks the boundary of Figures 17a and 17b which are, respectively, extracts from Figures 4-2 and 4-11 of ESR 2003. The bores at the southern end of the RSC water extraction field are plotted in Figures 16, 17a and 17b and these can be used to locate the positions of the mound of discharge water as predicted for June 2003 (Figure 17a) and June 2012 (Figure 17b). From a comparison of these figures it is apparent that the Enterprise Mine and forecast increase in the watertable lie entirely to the east side of the prime groundwater divide for the Island. Groundwater in this location naturally flows to the east, southeast and south. The shape of the isolines in Figure 17a (June 2003) suggests that the bulk of the descending plume will move generally eastward and emerge along a relatively narrow section of the escarpment and into the Swamp. Some may flow more to the southeast and south.

The ten figures show paired plan plots as generated by the modelling. The forecasts commence in June 2003 (Figure 4-2) and are repeated at (almost) yearly intervals for every June (or May) through to June 2012 (Figure 4-11). The part of North Stradbroke Island covered in the figures is a full width (west to east) and about 12 kilometres north to south, from near the Blue Lake outlet to about 2 kilometres south of Tazi Trench. The left-hand map of the pair is a kind of 'contour' map showing "Relative Water Table Variation" so that the predicted rise of the prime water table is pictured as a contoured mound and in different colours (for the chosen intervals) with the highest forecast in red. The right-hand map of the pair is a true contour map showing "Prime Water Table Levels in metres above Australian Height Datum (AHD)". Neither scale bar was drawn nor representative fraction stated. However, by comparison with other maps the scale of each map in a pair is about 1:80 000. As a result the reproduction of the maps side-by-side on a single A4 page makes their details, text and numerals difficult to read. Another factor that makes the maps less than easy to interpret is the non-standard intervals chosen between the isolines.

The isolines for the left-hand map show water 'thickness' (that is, the isolines are really isopachs). However, the intervals (in metres) chosen for the illustration are *not* arithmetic (e.g. 1, 2, 3, 4...) but are uneven: 1, 2, 3.5, 5, 7.5, 10, 15, 20, "?" and "?". The "?" mark is used because the two highest values are not shown on the legend of the map. In contrast, the interval in the legend showing the forecast reduction in the prime water thickness *is* arithmetic. The CRL authors provided no explanation to account for the apparently idiosyncratic choice of intervals in the isopach maps.

The right-hand map of the pair is a contour map (that also includes the predicted effects of CRL's activities and RSC's non-mining extractions). The contours (shown on the legend) are *not* at arithmetic intervals and, additionally, are *not at the some intervals on either side of the zero datum*. Intervals above 0 m AHD are: 0.2, 1, 5, 10, 15, 20, 25 (and probably 30 m); intervals below 0 m AHD are: -2 and -5 m. The colours in the right-hand map are **opposite in sense** to those shown in the left-hand map of isopachs: green with blue colours indicate elevations above zero datum and orange with red indicate elevations below. The authors provided no explanation to account for the apparently idiosyncratic choice of intervals.

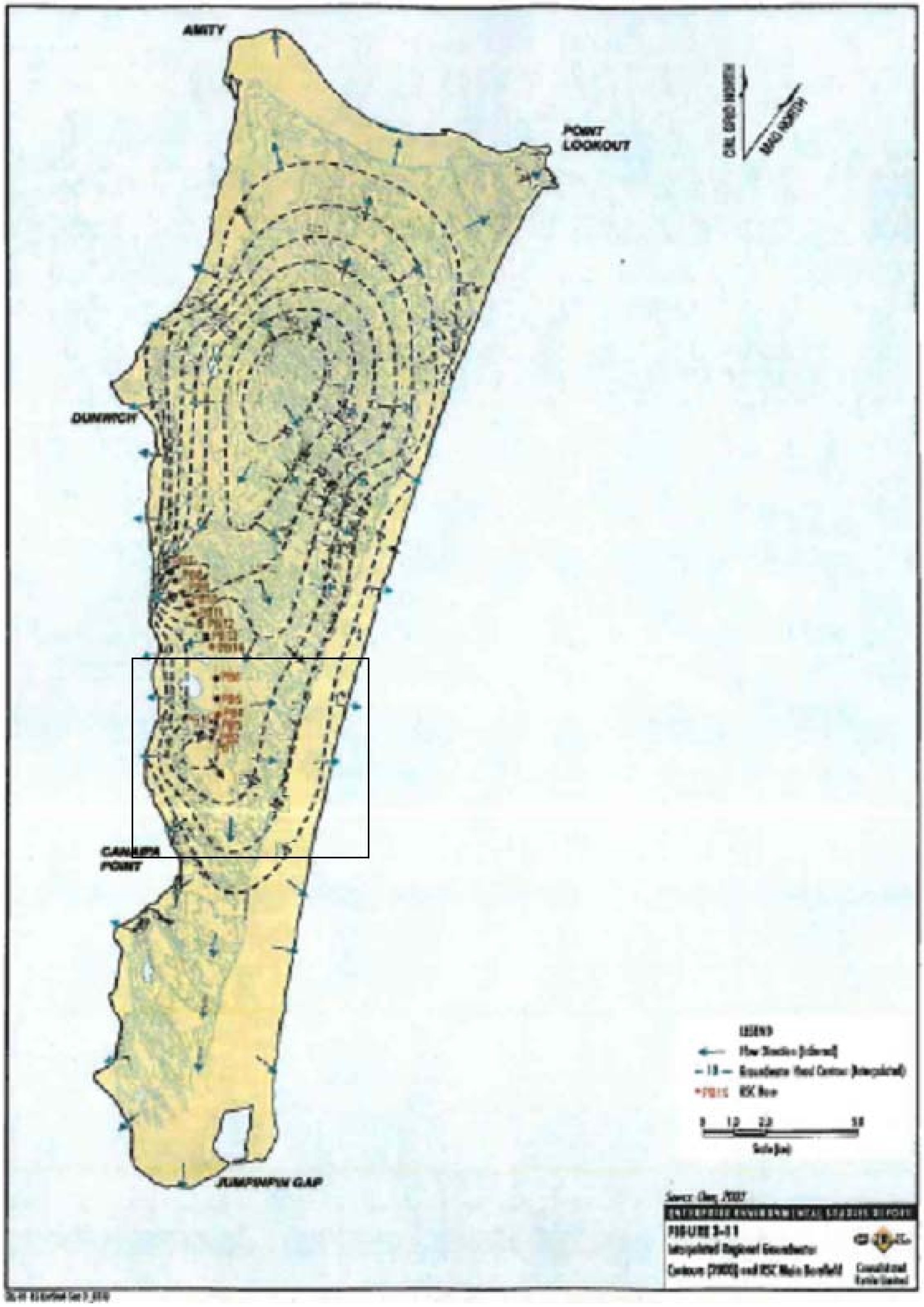

Figure 16: Interpolated Regional Groundwater Contours. Box shows area of Figures 17a and 17b. (Base Map Source: Figure 3-11 in ESR 2003)

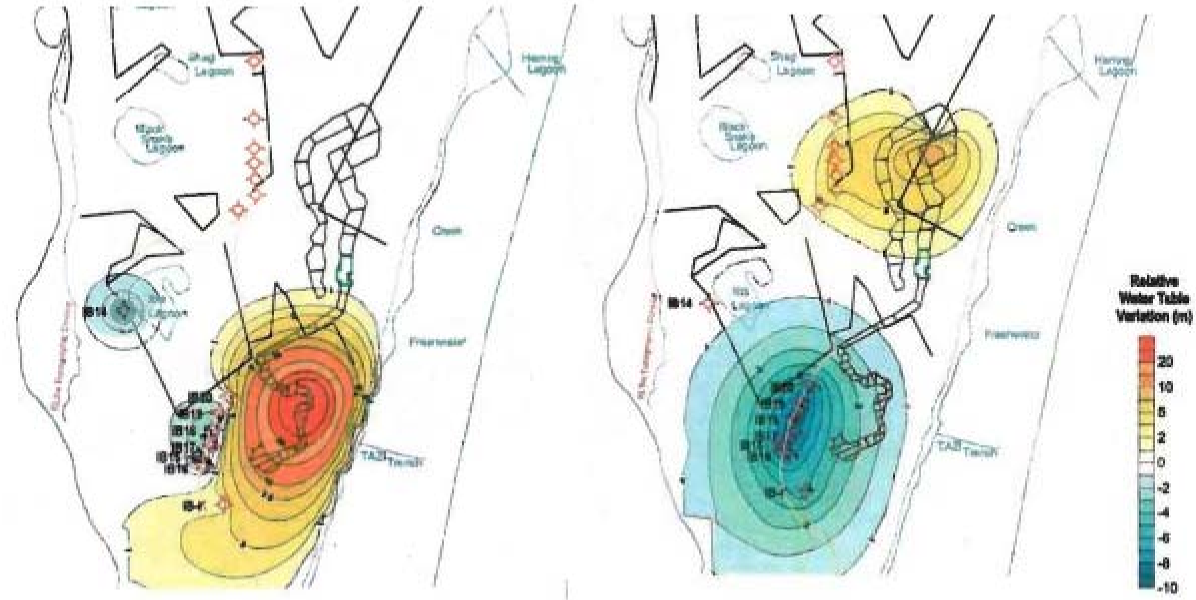

Figure 17a: Isopachs of Water Variation June 2003 **Figure 17b: Isopachs of Water Variation June 2012**

Figure 17: Predicted Changes in Groundwater near Enterprise Mine (Extracts from ESR 2003 Figures 4-2 and 4-11)

With respect to the forecast elevations of the prime water table along the toe of the escarpment the isolines of the left-hand map certainly reveal a crowding on the east of the (isopach) contours of the forecast mound. In June 2003 (Figure 4-2 in ESR 2003; Figure 17a this review) the crowded contours form a kind of 'contact zone' about 1 to 2 kilometres long with a central position of the 'zone' being close to the western end of the Tazi Trench. By June 2004 (Figure 4-3) the 'contact' zone at the toe of the escarpment was forecast to have moved northward, as it is directly coupled with the migration of the mine path, and the central part of the zone was shown to be a little less than 1 kilometres north of (the western end of) Tazi Trench. In a similar way,

in Figures 4-3 through 4-11, the 'contact' zone was forecast to track northwards and the isolines at the toe were plotted as being further apart (i.e. a gentler slope on the watertable).

Significantly, as shown in the original sequence of maps, no part of a groundwater mound rise was predicted to come any closer than about 1.5 kilometres south of (the western end of) Herring Trench (as in June 2012 ESR 2003 Figure 4-11; Figure 17b this review). Only for June 2009 (ESR 2003 Figure 4-8) was the edge of a groundwater change, in this case a drawdown or *fall*, forecast to be closer to Herring Trench.

Consequently, based on the experts' modelling, it should have been relatively easy to specify the spatial boundaries or limits for the monitoring of *water levels* – piezometers for groundwater and gauge boards for surface water – so as to track the movements of the mine-generated water. The experts predicted, via these maps, that there would be no point in having piezometers north of a point 1.5 to 2 kilometres south of Herring Trench: the mound rise was not expected to occur there. With respect to monitoring for changes in water levels within Eighteen Mile Swamp the expert's maps indicated there would no point in placing gauge boards in Herring Trench because this monitoring was **unlikely to detect any change from mining** except, perhaps, toward the end of the period of interest. Clearly, the ideal monitoring sites would be well to the south of Herring Trench.

Regardless of the quantitative values attached to these modelled forecasts of an increased *height* of the mine-generated groundwater mound, there is no doubt that, whatever the rise, an additional *volume* of water was expected to enter Eighteen Mile Swamp *through the subsurface* and along a front about 1 kilometre long and perhaps up to 2 kilometres long. This volume of water may be expected to vary over time and cause elevations of different heights in the surface water level of Eighteen Mile Swamp. The increased volume would be dissipated out into the Swamp, certainly some to the north and east but perhaps more to the south, given the known local topographic slope and direction of flow in the Swamp and in Freshwater Creek. No comment is made here of the forecast of any changes in water chemistry but this topic is taken up in Section 5 of the review.

3.3 Monitoring Requirements for the Forecast Changes in Water Volumes

In Section 3.2 I have criticized some of the illustrations and lack of explanations provided in company reports available to the public. Nevertheless, for this preliminary review it possible to identify general spatial limits, based on the maps of the experts' forecasts, of where the expected increased water discharges (subsurface and surface) should be expected. As well, the order of magnitude of water elevation changes can be identified. Thus, an interested member of the public could expect CRL to have designed and Queensland agencies to have approved a monitoring program to have at least the following boundaries/detection limits:

Northern Limits for expected discharges: About 1 kilometre south of Herring Lagoon/Trench.

Southern Limits for expected discharges: Water discharges should be expected at least to Tazi Trench.

Eastern Limits for expected discharges: Monitoring points close to escarpment toe and others at lesser density extending east into Eighteen Mile Swamp.

Detection Limits for gauge boards: Forecast elevation increase may be as limited as 0.1 metre and up to 0.3 metres

With all the technical details available to the company these basic parameters would be expected to be refined and recast into a best-practice monitoring program to track to track possibly very subtle changes of groundwater elevations along the escarpment toe and of surface water elevations in Eighteen Mile Swamp.

Other desiderata that could be expected in a high quality program would be some general statements about number of monitoring points, monitoring period and frequency, such as:

1. Sufficient **groundwater monitoring points**, in such positions along an extended length of the toe of the escarpment, as to reveal mining-induced increases and decreases in the prime watertable of magnitudes and duration forecast by the modelling and informed by company experience.

2. Sufficient **surface water level monitoring points** across Eighteen Mile Swamp in such positions as to reveal over time the arrival and dissipation of mining-induced increases in the water surface linked to changes in base flow of groundwater as forecast by the modelling and informed by company experience.

3. Where possible the period of monitoring should be started well before the arrival of the forecast groundwater mound from mining to give a pre-impact baseline and to be continued well past the forecast impact period to demonstrate that the system has returned to 'normal'.

4. Where possible sampling for water chemistry should be integrated with the monitoring of elevations of groundwater and surface water in terms of locations and frequency. Variations in water chemistry may be valuable in tracking the mixing of discharges and their rates of dissipation.

4.0 Evaluation of CRL's Monitoring Program for Changes in Water Volumes

In this section the essential objectives for a best-practice monitoring program (Section 4.2) are compared with CRL's monitoring scheme as actually adopted and reported on in the AERs 2004 through 2010. In simple but blunt words: CRL's so-called water monitoring program cannot be defended as professionally competent. Issues related to changes in water chemistry are considered in Section 5.

4.1 Detection and Reporting of Changes in Groundwater Levels along the Escarpment Toe

CRL established numerous spear/piezometer points along the toe of the escarpment. They were installed primarily to provide a capacity to dewater a rising groundwater mound but also to give information on groundwater elevations and, presumably, access for taking water samples. Other piezometers along the top of the escarpment allow watertable gradients to be monitored. The locations of piezometers are shown on maps in several AERs, including AER 2008 Figure 8 and AER 2009 Figure 6 where they were plotted against a green-coloured aerial-photo base.[13] These illustrations show a concentration of piezometers along the toe and south from Herring Trench/Lagoon for about 5.4 kilometres, with a lower concentration for almost 2 kilometres south of Tazi Trench. The piezometers appear to be well placed to intercept the mound forecast by modelling

As an overall recommendation to EA Condition A7-2 the environmental auditor recommended that "[t]he monitoring program for Eighteen Mile Swamp *surface* [my emphasis] water level increases due to mining activities should be reviewed and additional piezometers installed to ensure any increase in [*groundwater*] water levels above the trigger levels is detected" (AER 2004 Table 2 EA Condition A7-2). It is significant that no formal company response was noted on this independent recommendation for a review and the installation of additional piezometers.

In none of the yearly AERs did CRL publish a list of these monitoring points and their coordinates; but they were stated to be available in the 2005 Plan of Operations Monitoring Manual[14]. In the yearly AERs **CRL did not present data of any systematic sampling for levels and chemistry of the groundwater.** No doubt the groundwater levels were monitored in the event that dewatering became necessary, but it is unlikely samples were taken because of CRL's defensive position of denying that their operations have any effect on water chemistry (see Section 5 this review).

The reader of the AERs learns in two ways, almost by accident, of the presence and function of the spears/piezometers and how the water table had been moving. For example, there was a one-off report of a sudden increase in the water level in one spear point and CRL's response was to increase dewatering rates. In reporting the results and conclusions of the escarpment vegetation condition monitoring (see Section 6 this review) the AERs may contain comments such as "[ground] water levels within the southern sector [had] returned to normal" (AER 2009 p117) and "[a]ll recorded water table levels were within the predicted natural range" (AER 2008 p104). As usual, the CRL focus was on groundwater levels and no data on pH, conductivity,

[13] Because of the poor choice of font size their site names/codes are difficult to read in both illustrations, though the use of black font in AER 2008 was a little better and their locations are shown as black spots. The choice of white font for the AER 2009 version was no improvement. In other AERs the locations are shown in various colours on a plain white background.

[14] In AER 2004 Table 2 EA Condition A7-1 the CRL author stated (in response to comments from independent auditing agents of CRL's ESR 2003) that: *Coordinates and location plans for all monitoring locations are included in the 2005 Plan of Operations Monitoring Manual*.

turbidity, or any other attribute of the groundwaters, were reported in these few examples of vegetation condition.

CRL made available quantitative values of the groundwater rise but in very in limited form. The Plan of Operation 2009 p3-8 reported a 1.05 m rise "opposite the Enterprise Mine in 2006" and increases of up to 1.1 m were recorded from July to October [2008]". The 2008 rise exceeded the "preliminary 1 m internal trigger" so the company implemented stationary dredging and slimes additions to the pond to reduce the rise. At other mining sites similar strategies have been employed to limit unexpected or excessive rises in groundwater levels. The PoO 2009 also flagged (pp3-8 and 3-9) that additional measures would be employed at the Enterprise Mine if future rises at the toe were likely to exceed those forecast because of "variations in geology etc."

It is also significant that CRL did not indicate in the AERs the details of dewatering through the spears/piezometers (pipes, pumps, tracks) or give the location of the water discharge point(s). No data were presented of water volumes pumped or of its quality. Indeed, the CRL authors did not consider the issue of water discharges from dewatering in the ESR 2003, or the PoOs, or the yearly AERs for Enterprise Mine. This oversight is clearly the responsibility of the CRL personnel; but it also points to an apparent oversight by the supervising Queensland agencies.

4.2 Detection and Reporting of Changes in Surface Water Levels in Eighteen Mile Swamp

The ESR 2003 and yearly AERs made it clear that CRL/SAL rated Eighteen Mile Swamp very highly for environmental care. It was widely acknowledged that the Swamp would receive additional volumes of water as increased base flow from the west via an increased groundwater mound generated by the mining process. The simplified forecast enunciated by CRL was that along a section of the terrestrial margin of Eighteen Mile Swamp immediately east of the mine, existing groundwater levels would rise "temporarily" by approximately 1 metre. This **groundwater rise** that in fact would last for years along the toe of the escarpment was forecast to translate into **a rise of 0.1 to 0.3 metres in surface water levels** in the Swamp.

It is significant that CRL made no attempt to put these general public forecasts into at least seasonal[15] terms, even though extensive historical data were available to do so. Rather, the focus was to make sure that water levels conformed to ANZEEC standards and the company's use of 'triggers' based on the 20th and 80th percentiles of the previous 24-month record. Even so, where these triggers were exceeded, as reported in the AERs, the company invariably excused them as related to natural climatic and seasonal variations. Evidently company officers had done their own in-house analyses of the historical data.

For its mining operations on North Stradbroke Island, well before monitoring for impacts from the Enterprise Mine, CRL had established several water-level sampling points in Eighteen Mile Swamp as shown in Table 1. The sites here are in three groups (as shown in different fonts): Three sites – Herring Lagoon West, Herring Lagoon East and Eighteen Mile Swamp Enterprise – are those for which consistent monthly and/or quarterly measurements of water level and three attributes of water quality (pH, electrical conductivity and turbidity) had been reported at some period. Two sites, Tazi Trench and Palm Lagoon Pump Station, are places for which data were reported in early AERs but were discontinued. Two other sites, Eighteen Mile Swamp 1 and Eighteen Mile Swamp 2, are places for which data were reported in the ESRs as being within the group of sites linked to

[15] Published gauge board readings at Herring Lagoon show seasonal patterns related to groundwater base flows that are related in turn to seasonal patterns in rainfall. The effects of pumping are also evident in the record.

Enterprise; but this practice was/is very misleading as these two sites are well to the north and too far removed to have any relevance to monitoring for the forecast increases from the Enterprise Mine.

As summarised earlier a purposeful water level monitoring program would have included stations established across specific parts of Eighteen Mile Swamp, in places expected to be directly affected by the increased water volume before extensive dissipation had occurred. However, the evidence from CRL's actual choice of sites is that the company's critical monitoring of water levels in this part of Eighteen Mile Swamp, a Ramsar wetland, was centred on **only one monitoring point on the west of the swamp** — the so-called Enterprise site (see footnote c Table 1). Furthermore, monitoring at this site was unlikely to detect the initial changes in water level as predicted in 2003 but should have become important over time as the locus of groundwater discharge migrated to the north.

Herring Trenches West and East were/are too far north to intercept the predicted water level increase; but they were very convenient and relatively inexpensive because CRL was required to measure water levels there anyway. Herring Trench West was/is additionally unsuitable for the water-level monitoring task because of the 'noise' generated by CRL's and RSC's pumping activities. In the parts of the yearly AERs referring to the Enterprise Mine the CRL authors did not report on any serious attempt to filter out the water-level fluctuations introduced by the combined extractions and there was no report of longitudinal studies of water level fluctuations, including analyses for patterns as they may have been expressed at the temporal scale of seasons or El Niño/ La Niña 'cycles'. Knowledge from such studies, of water movement from the north and into that part of the Swamp likely to be impacted, could have been valuable to interpretation of a good data set of water levels.

It appears CRL personnel made no attempt to do this. Rather, the CRL authors of the AERs appear to have been content with monitoring and reporting water levels at the mandated frequency, followed by a pedestrian analysis of the data, including some vague comparisons with Residual Mass Rainfall Curves in some plots. There were no statements about any implications were for Eighteen Mile Swamp despite its declared environmental importance.

Based on Figures 4-2 through 4-11 in ESR 2003, CRL could have made Tazi Trench an important surface water level monitoring point for the life of the Enterprise Mine. In addition, CRL could have considered installing remote automatic water-level stations at selected sites across the Swamp. These sites could have been installed with the cooperation of DERM, especially given that agency's stated and demonstrated long-term interests in the hydrology of the island. There is no information to suggest this option was considered or discussed.

The independent auditor of the monitoring proposed in ESR 2003 recommended that "[a]dditional surface water level monitoring points should be established in Eighteen Mile Swamp in the potential zone of influence of the mining operations at the Enterprise Mine" (AER 2004 Table 2 EA Condition A7-1). CRL's response to this recommend action was "*Additional locations are detailed in the 2005 Plan of Operations Monitoring Manual*" (AER 2004 Table 2 EA Condition A7-1). Despite this response the results published in the annual AERs show that CRL failed to establish additional monitoring points that could give a best-practice outcome. Certainly the reinstated Enterprise 18MS was in an appropriate location; Herring Lagoon/Trench West was too far north and too 'noisy'; Herring Lagoon/Trench East was too far north and had access problems; Tazi Trench although in a suitable location was not utilised for monitoring.

Table 1: Monitoring Sites in Eighteen Mile Swamp as Reported in Yearly AERs for Enterprise Mine

Sample Site Name	Other Names/ Description	Monitoring Type (monthly WL)	Monitoring Type (monthly)
Herring Lagoon West[a]	Herring Trench, Herring Lagoon	Gauge board	pH, EC, turbidity
Herring Lagoon East[b]	Herring Trench East	Gauge board	pH, EC, turbidity
(Eighteen Mile Swamp) Enterprise [c]	18MS Enterprise	Gauge board	pH, EC, turbidity
Tazi Trench [d]	Tazi Trench	Gauge board	
Palm Lagoon Pump Station [e]	Palm Lagoon	Gauge board	
Eighteen Mile Swamp 1[f]	18M1	Gauge board	
Eighteen Mile Swamp 2[g]	18M2 (18M 2)	Gauge board	

[a] Herring Lagoon was originally a natural feature within Freshwater Creek, the channel conducting surface flows to the south along the western side of Eighteen Mile Swamp (see Figure 3 this review). In the 1950s an artificial canal or trench that subsumed the name Herring Lagoon was excavate to transport heavy mineral concentrate from the east coast mining areas across the Swamp. CRL established this Eighteen Mile Swamp monitoring position (aka Herring Lagoon **West**) as a condition of the DNRM water licence and has monitored water levels there since July 1987. Because of its convenient access CRL also used this site for monitoring water quality. (The term *Lagoon* is the euphemistic term applied by CRL personnel instead of the more accurate *Trench*). Commencing with the 2005 AER the mining company stopped reporting numerical values for water levels, pH, electrical conductivity and turbidity, only showing graphical plots of low resolution; consequently, a reader interested in checking the accuracy of statistical interpretations must first interpolate the values from published plots thereby introducing potential errors.

[b] CRL established this Eighteen Mile Swamp water-level monitoring position (aka Herring Lagoon **East**) in late 1997. Because of its relatively convenient access CRL also used this site for monitoring water quality. CRL reported that non-mining personnel have access to this site from the beach and at least in the 2003 AER considered “recreational campers [were] probably the cause of the high [electrical] conductivity [in December]”, even though no values or details were reported. In the yearly AERs there were many missing data values from this station and the AER authors usually accounted for these as being due to “difficult access” and “failure of equipment”. Commencing with the 2005 AER the mining company stopped reporting numerical values for water levels, pH, electrical conductivity and turbidity, only showing graphical plots of low resolution; consequently, a reader interested in checking the accuracy of statistical interpretations must first interpolate the values from published plots thereby introducing potential errors.

[c] CRL established the *Enterprise* 18 Mile Swamp *monitoring* site in June 2001. It had been a pumping site for make-up water but inactive since the early 1980s (2003 AER p5-45). It was also chosen because it was further away from the monitoring sites in Herring Trench (Lagoon) that were likely to be directly affected by CRL’s and RSC’s pumping activities (ESR 2003 for Enterprise Mine, Section 3.3.1, p.3-17). This site, about 2.7 km ‘south’ of Herring Trench (2003 AER p5-45) and about 3.2 km ‘north’ of Tazi Trench, was also used in the WBM baseline study (ESR 2003 Appendix K) as site FWC3. Because of its convenient access CRL chose this site for monitoring water quality. Commencing with the 2005 AER the mining company stopped reporting numerical values for water levels, pH, electrical conductivity and turbidity; consequently, a reader interested in checking the accuracy of statistical interpretations must first interpolate the values from published plots thereby introducing potential errors.

[d] Tazi Trench, about 5.7 km south of the western end of the Herring Trench, was established by an earlier sandmining company. CRL last reported water levels from this monitoring site in AER 2003 The plots (Figures 43 and 58) labelled as being for Tazi Trench in (respectively) AERs 2005 and 2006 are, in fact, for Tazi Causeway. Although ideally suited as a site for monitoring the arrival and dispersion of the predicted increased volume of water from the Enterprise mining operations, and of its water chemistry, CRL never used it as such. Reporting the data for Tazi Trench in AER 2003 is almost accidental as a residual of CRL’s style of reporting in earlier AERs.

[e] CRL established the Palm Lagoon Trench to supply make-up water to the Gordon Mine. The water levels at this site from June 1987 through December 2003 are published in Figure 23 of AER 2003. The water level records, ranging between 2 and 2.5 m AHD for the period when water table had recovered after pumping stopped about January 1999, could be useful in an analysis of surface waters throughout Eighteen Mile Swamp. CRL published no other *numerica*l data for this site after those in AER 2003. The (unnamed) figure on page 10 of AER 2004 shows the monthly water level data for two locations, Palm Lagoon (?Pump Station) **and** Palm Lagoon Swamp. By extrapolation from the AER 2003 data and plots, the dark blue line *plots* with a water level around 2.3 m AHD referred to simply as “Palm Lagoon” suggest it is for the Pump Station site.

[f] CRL first referred to water-level data from monitoring site Eighteen Mile Swamp 1 in AER 2003 within the Yarraman Mine influence. This site is at the far northern end of Eighteen Mile Swamp and was never relevant to the Enterprise Mine monitoring program.

[g] CRL first referred to water-level data from monitoring site Eighteen Mile Swamp 2 in AER 2003 within the Yarraman Mine influence. This site is at the far northern end of Eighteen Mile Swamp and was never relevant to the Enterprise Mine monitoring program.

CRL's formal response in AER 2004 Table 2 EA Condition A7-1 appears to be a mere platitude. Evidently, officers in the Queensland agencies responsible for scrutinising the scientific and technical soundness of the monitoring program were also satisfied with the non-specific recommendation by the environmental auditor, supplemented by CRL's reassurance, that the number of monitoring sites had been increased and that they were in appropriate locations.

Another failing in the CRL-designed State-approved monitoring program was the lack of a rainfall gauge at a convenient location in/near Eighteen Mile Swamp. Any serious attempt to monitor subtle water level changes such as those predicted by the modelling (0.1 to 0.3 metres) should have included the collection of local rainfall inputs. Data from this station could have been used along with those from Point Lookout to improve the modelling of the whole swamp.

Except in the most simplest of measures It is evident that CRL's monitoring program, vetted by an independent auditor and approved by Queensland agencies, could never reveal any of the changes stated in the essential objectives to care for Eighteen Mile Swamp. Indeed, it is hard to avoid the conclusion that the monitoring scheme appears to have been designed **never to detect or reveal** even the most extreme changes in water levels, let alone the subtle predicted increases.

5.0 Evaluation of CRL's Monitoring Water Chemistry Program (Groundwater and 18 Mile Swamp)

5.1 Chemistry of surface waterbodies and CRL's use of unreliable statistical study

Over many years mining company officers and their consultants have tended to avoid requests for a closer examination of the impacts on water chemistry as generated by mining — dredging, processing and tailings dispersal. They have dismissed attempts for closer scrutiny, generally with a simple but untested mantra in words like: The mining operations use natural water from the island and any waters that seep from the dredge pond or tailings return to the natural system after being filtered through sand. This notion relies, in part, on the inappropriate application of the well-know practice[16] that municipal authorities use sand as part of providing safe potable water supplies.

The mining companies' argument that mining does not affect water quality is maintained by another generalisation that all the natural waters are acidic (low pH), soft and pure (very low salt content). This notion relies on the public's general ignorance of the exponential pH scale, the variable sensitivities of organisms to different acidic conditions, and the subtle but distinctive differences in water chemistry between and within waterbodies on the island. CRL/SAL pursued, and continues to pursue, this view by yet another distraction such as presenting summaries of the ranges for water chemistry attributes in many surface waterbodies, such as in Table 3-11 of ESR 2003 Appendix K.

As indicated in Section 3.1 of this review, CRL's decision not to undertake detailed monitoring for changes in water chemistry was based, in part, on the WBM Oceanics Australia (2000) report "commissioned to determine if there were significant differences in the chemical properties of the waterbodies on North Stradbroke Island...[and] involved analysis of the available monitoring data for the period January 1992 to August 2000". I also have had the opportunity[17] to critique the WBM Oceanics Australia (2000) study and I concluded (Stock 2001) that parts of it had fundamental flaws. The two prominent problems were:

i) The data-set supplied to the consultant (WBM Oceanics Australia) contained some inappropriate data measured on samples collected from waterbodies that had been contaminated by mine-generated discharges for some of the sampling period; and,

ii) Parts of the data-set the consultant relied on for the core statistical analyses were compromised by being composites sourced from two different laboratories.

A fundamental premise of any statistical analysis of data from the waterbodies was that the data-set, from January 1992 through August 2000, should have been from waterbodies in natural condition. However, the WBM Oceanics Australia (2000) report indicated that CRL personnel had not scrutinised the data-set nor had removed any values that may have come from waterbodies in a non-natural state. Indeed, some were known from contemporary CRL reports to be contaminated by water discharges from nearby mining. For example, consider the waterbodies Swallow Lagoon, Ibis Lagoon and Black Snake Lagoon and the values for quarterly

[16] The sand in a water supply treatment plant operates, in part, as a physical/mechanical filter of suspended matter and some potentially harmful organisms.

[17] In February 2001 two CRL environmental personnel provided me with a copy of the WBM Oceanics Australia (2000) report and sought a formal peer critique. I examined that report and supplied detailed comments to the officers concerned, indicating critical problems with the data-set and other problems with the statistical analyses.

samples taken from them. Swallow Lagoon is widely accepted that it is probably the least-impacted[18] enclosed waterbody on North Stradbroke Island. It was and still is used as a baseline reference for studies of water quality changes in other water bodies. In contrast, as described in Box 1 of this review, the data for Ibis Lagoon and Black Snake Lagoon for the period 1995 to 2000 should have been excluded from the WBM Oceanics Australia study because of known mining impacts reported by CRL reported to Queensland authorities.

In addition to the very real problem of including data from contaminated samples, part of data-set supplied to the consultant was a compilation from sample analyses conducted at two different laboratories with no allowance made for inter-laboratory variation. There is nothing in the WBM Oceanics Australia (2000) report to suggest any concerns that the supplied water chemistry data-set may not have been coherent. Even though some preliminary checks (e.g. time series plots) could have been used to reveal potential discontinuities, the consultant completed the study without using subsets of analyses[19] generated by Simmonds and Bristow (January 1992 through June 1995) and the DNR-laboratory (September 1995 through August 2000).

In summary, the WBM Oceanics Australia (2000) report contained many useful insights into the geochemical attributes of the Island's waterbodies. However, many of the statistical analyses were based on unreliable data and/or conducted on an un-corrected data-set. Consequently, the complement of conclusions from that report were, and remain, open to question and need validation. In my opinion, it was not scientifically valid for CRL to use the WBM Oceanics Australia (2000) report in the ESR 2003 and to claim that the waterbodies on North Stradbroke Island show little geochemical differentiation.

5.2 Revealing some chemical differences between selected waterbodies

At page 3-13 of ESR 2003 the CRL authors stated the company's confidence, from the WMB Oceanics Australia (2000) report, "that based on the available data, the waterbodies studied on North Stradbroke Island could not be differentiated by their chemical composition and ionic speciation". As revealed in the previous section I dispute this simplistic summary of the consultant's report and regard CRL's continued use of that report, in documents such as ESR 2003, as indefensible.

I have conducted my own analyses of the two data-sets used by the consultants and draw very different conclusions. This review is not the place for a detailed coverage of my earlier analyses but it is appropriate to present some supporting examples relating to three named waterbodies: Swallow Lagoon, Ibis Lagoon and Black Snake Lagoon. Ibis Lagoon and Black Snake Lagoon were chosen as they are share some hydrological connections, were affected by the Ibis Mine but are quite separated from the reference Swallow Lagoon. In Figures 18 through 20 quarterly data for water levels, electrical conductivity (EC) and the sodium and chloride ions are used to illustrate the salient features in interpretation and presentation of water chemistry. In Figure 20 only data for the sodium and chloride ion concentrations[20] are used to show that, even without the support of additional geochemical attributes, ionic speciation has potential for differentiating the water bodies.

For Figure 20, the sodium and chloride values were selected from only one laboratory and only for the period January 1992 through June 1995 when Ibis Lagoon and Black Snake Lagoon were known to be uncontaminated by later mine discharges (Box 1). Water level and electrical conductivity values as shown in Figures 18 and 19

[18] Apart from some impacts from human visitors for picnics and swimming.

[19] CRL personnel had obtained values for some attributes (e.g. pH and EC) in the field and this data-set was not affected by different methods of analyses used by the two laboratories.

[20] It is widely recognised that the sodium and chloride contents in the surface and ground waters of North Stradbroke Island are initially sourced by aerial accession of marine salts transported by winds.

were measured in the field by CRL employees so it was not essential for these data to come only from the January 1992 to June 1995 period; but this period was selected for consistency and as coming before contamination by mining discharges was affirmed.

BOX 1: Mining impacts affected two waterbodies and compromised their status for biogeochemical studies, 1996-2000

Ibis Lagoon

During 1996/97 CRL artificially increased water levels in Ibis Lagoon due to water discharges redirected from the Ibis Mine dredge pond along the top of the perching layer. Water from Ibis Mine dredge pond was of different water quality to that in Ibis Lagoon. Queensland authorities served CRL with a "show cause" notice. CRL removed vegetation and installed dewatering equipment to mitigate mining-induced rises in water level and the mining program was also modified to prevent additional discharges. Consultants were engaged to study aspects of these events as part of official response to "show cause". In due course the authorities accepted CRL's revised water management plan. As can be detected in the published water-level data for Ibis Lagoon additional discharges of groundwater continued to come to the surface into 1999/2000.

Black Snake Lagoon

Pre-mine hydrological studies had predicted the potential for adverse impacts on Black Snake Lagoon by activities at the Ibis Mine. Increased water levels due to discharges (so-called seepages) occurred from the Ibis *dredge pond* during 1997/98 and from *tailings* placed in 1998. During July 1997 CRL installed an additional bore at the southwest bank of Black Snake Lagoon and constructed a spear line in December 1997. Water levels were temporarily controlled and ceased in March 1998. Slow rises in the ground water level in response to tailings placement led to a rise in the water table which contributed to water levels in the lake being artificially maintained within the normal range even though surface levels in other waterbodies were falling due to regional reductions in rainfall.

As revealed in **Figure 18** there is an inverse relation between water level (proxy for water volume) and electrical conductivity (read salinity) in Swallow Lagoon. As EC/salinity[21] in the Island's waterbodies is primarily linked to the ionic concentration of sodium and chloride ions the plot shows that, as natural recharge from rainfall appeared in the Lagoon (peaking about in mid-year), the concomitant dilution was registered as a diminution in EC/salinity. This inverse relation for the reference Swallow Lagoon also holds for most of the other waterbodies on North Stradbroke Island, to a greater or lesser degree, provided there has been no additions of waters sourced from mining.

Figure 19 shows the temporal variation in EC (salinity) for the three named water bodies including that for the reference Swallow Lagoon already shown in Figure 18. The plots for the waterbodies generally show sympathetic variations over time. The range in EC values is least for Swallow Lagoon and the highest EC value for Ibis Lagoon is almost four times higher than the mean for the reference lagoon .

The quarterly chloride and sodium ion concentrations for the same waterbodies over the restricted period are shown in the scatter plots of **Figure 20**. The pattern of points reveals that each of the water bodies, based here on only on their chloride and sodium ion chemistry, tend to be separated into distinctive (though partly overlapping) fields. The data for Swallow Lagoon fall into a relatively tight cluster. In comparison, the plots for Ibis Lagoon and Black Snake Lagoon are much more dispersed with the Ibis Lagoon ionic concentrations

[21] Mean sea water has a salinity (total dissolved solids TDS) of 35,000 mg/L and a mean electrical conductivity (EC) of 43,000 µS/cm. Consequently, with a mean EC of about 55 µS/cm (Figures 18 and 19), Swallow Lagoon has a mean salinity/EC roughly 1/800th that of sea water.

tending to be higher. As well, distribution of points of Ibis Lagoon has only a limited overlap with the 'field' for the Swallow Lagoon values.

These figures contain data for only 15 quarterly measurements but illustrate the importance of ensuring the data used for analysis was not obtained from mining-affected water bodies. The simple plots show it is possible to differentiate the waterbodies with only the two dominant ions and suggest greater resolution may be expected through the use of more powerful statistical analyses with additional ions and physico-chemical attributes.

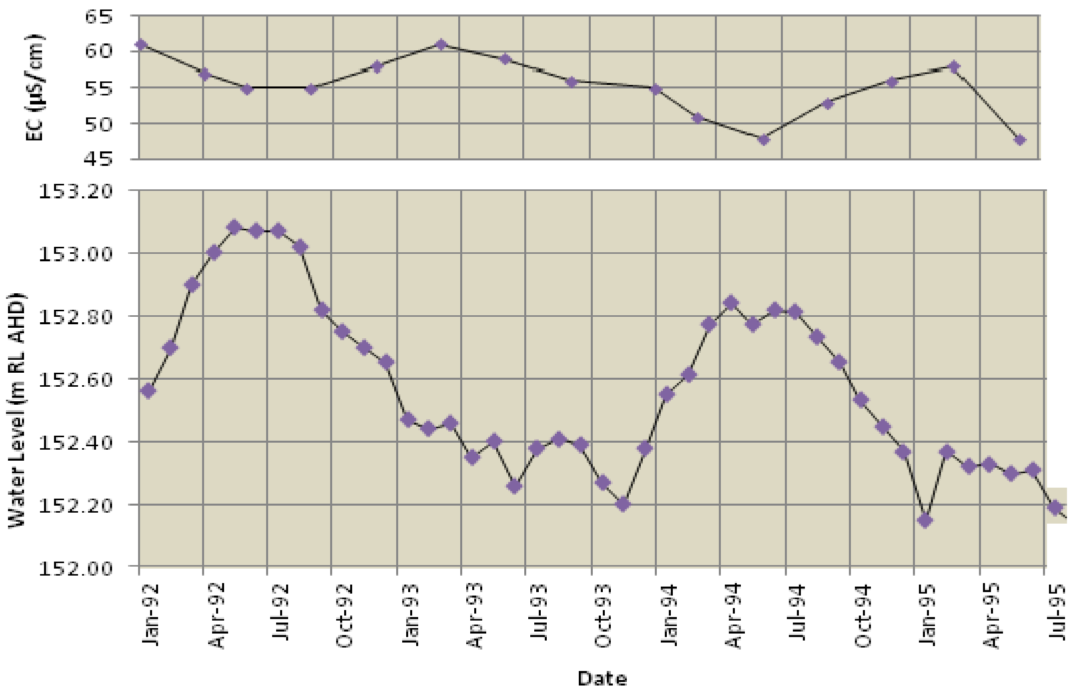

Figure 18: Temporal Variation in Water Level and Electrical Conductivity, Swallow Lagoon Jan'92 –Jun'95

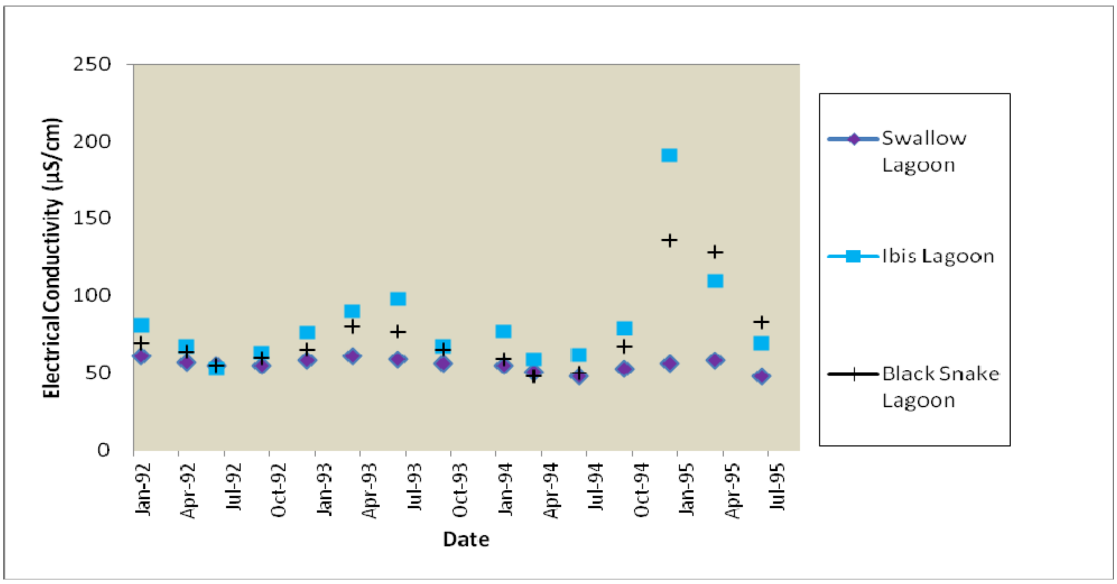

Figure 19: Temporal Variation in Electrical Conductivity for Three Waterbodies, Jan'92 – Jun '95

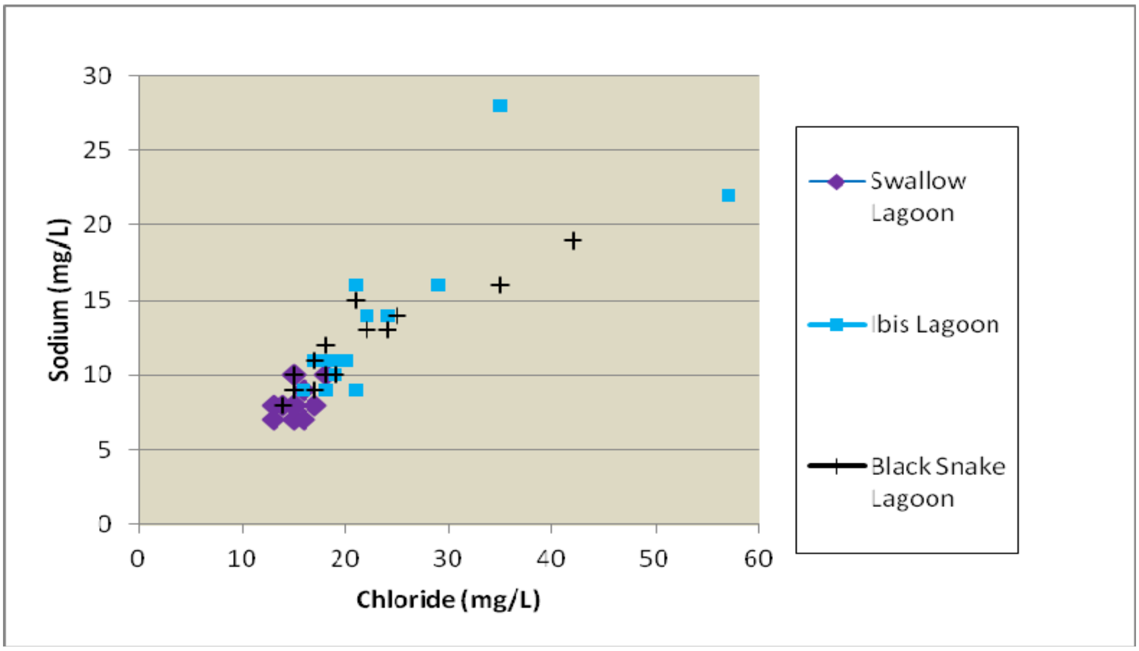

Figure 20: Chloride versus Sodium Concentration for Three Waterbodies during period Jan '92 and Jun '95

Recently, other researchers have sought improved differentiation between water masses on the Island and recognised the importance of allowing for improved knowledge of the hydrological regime. For example, researchers Cox, James, Raiber, Taulis and Hawke (2011) used geochemical data from 29 boreholes to identify three subpopulations/clusters in the groundwater based on: TDS, pH, calcium ion concentrations and ratios for Na/Cl and HCO_3/Cl. Cox, James, Hawke, Specht, Raiber and Taulis (2011) discussed some of the complex interconnections between surface and ground waters and categorised the surface waters into three groups based on geomorphology/discharge elevation (high, low, and coastal seepages). It is evident that careful investigations will be required to differentiate the surface water bodies and the distinctions may be subtle.

5.3 Evaluation of Limited Water Chemistry Data – Enterprise Mine

By referring to a consultant's compromised study of water chemistry and the company's in-house (but unexamined) 'experience' at the Ibis Mine-Little Canalpin Creek area, CRL promoted a limited range of attributes of water chemistry as being adequate for the monitoring of groundwater and surface waters related to the Enterprise Mine. CRL effectively closed off a scientific discussion of potential changes in water chemistry by directing a focus towards the low potential of contamination by hydrocarbons and claiming (without justification) that water from the dredge pond and tailings would 'seep' through the sand and be filtered to a quality just like the ''standard" acid waters typical of North Stradbroke Island.

Somehow, even the collection of **groundwater** samples was never included, or was removed, from the curtailed monitoring program. Without discussion or evaluation in the ESR 2003, in the various PoOs and the yearly AERs, the monitoring of discharge waters became a *minimal program of monthly monitoring the **surface** waters of Eighteen Mile Swamp* for water level and *three summary-style attributes: pH, electrical conductivity and turbidity.* This very narrow list was not questioned by the environmental auditor or by Queensland agencies.

From essentially the first AERs in the 1990s CRL had provided spreadsheet tables with the values from their own field measures (monthly and quarterly) and laboratory data (quarterly). Commencing with the 2005 AER the mining company stopped reporting numerical values for water levels, pH, electrical conductivity and turbidity. This change in 2005 meant that an independent reader, interested in following the outcomes of monitoring and in checking the accuracy of the company's interpretations, could not access a table of data but must first interpolate the values from published plots thereby introducing potential errors, especially for statistical analyses.

Monthly field measurements of water level, pH, EC and turbidity, were never likely to be fully suitable for the stated monitoring intentions and environmental care. Water samples could have been selected for a number of biogeochemical attributes, including some ionic components as for previous mines. A selection of special dissolved metals could have been considered, such as those detected in unusual concentrations in the baseline field studies by the consultants for the ESR 2003. Some of these metals had been part of the quarterly biogeochemical monitoring at the Yarraman Mine.

Even more concerning is that of the designated surface water sampling sites only one, the Enterprise site on the western side of Eighteen Mile Swamp, was likely to be in an appropriate location to intercept the waters discharging and dissipating in Eighteen Mile Swamp. As discussed in Section 4.2 of this preliminary review, the Herring Lagoon/Trench West and East sites were/are inappropriate because of their position too far north, their accessibility (HLE) or the 'noise' introduced by pumping for water extraction(HLW).

It may have been possible to use the monthly data from these sites, albeit from inappropriate locations, to reveal the subtle changes predicted by the modelling. This, of course, would have required close and informed scrutiny of the data. The evidence from the yearly AERs is that CRL/SAL personnel have not done this.

Because the Enterprise Mine used make-up water in variable proportions from Herring Trench (Eighteen Mile Swamp), Kounpee Trench (Wallen Wallen swamp) and a changing selection of production bores, the arrival and movement of water draining from the pond and tailings may have been detectable in water table changes and basic water chemistry. For example, the mining company has extensive data on the long-term variability of even the summary measure of salinity/ EC[22], and Herring Lagoon's EC (mean value about 128 µS/cm) is consistently higher than that for Kounpee Trench (88 µS/cm). The company was collecting data on water in Wallen Wallen swamp (Kounpee Trench) over the period relevant to the operations of the Enterprise Mine. So, provided allowances were made from the company's pumping records, it would have been a relatively simple procedure for CRL/SAL personnel to detect and track changes in salinity/EC by comparing measurements of make-up waters, dredge pond, groundwater in piezometers/boreholes, and water at sampling points in Eighteen Mile Swamp. CRL/SAL personnel have not reported on any such analyses in the AERs.

Indeed, in the yearly AERs CRL/SAL did not report on any serious attempt to allow for variations in water volume/dilution other than very simplistic 'explanations' for variations in water chemistry recorded for that year. Comparisons were made with yearly adjusted Residual Mass Rainfall Curves but these were mechanistic and no greater-than-yearly units were reported on. Certainly, triggers at the 20th and 80th percentiles were referred to and linked to the previous 24-month record. But there were no reports or analysis of longitudinal studies of variations over the longer term (even for the Enterprise water sampling site). Nor were there attempts to consider other patterns as they may be expressed at different temporal scales (seasonal, El Niño/ La Niña). Rather, the data are treated in a pedestrian manner, not as one of scientific interest and practical application, but as "another job" to do to comply with regulations as in all other AERs for earlier and other CRL mines. No special interest in the impacts on, or outcomes for, Eighteen Mile Swamp can be detected in the run-of-the-mill reporting.

[22] The summary measure of pH does not have the same forensic potential for post-hoc analysis because it is so easily affected by a variety of processes including the introduction of carbon dioxide into water during pumping of make-up supplies and into spear lines.

6.0 DETECTING AND REPORTING IMPACTS ON FLORA – ESCARPMENT VEGETATION CONDITION ASSESSMENT

At the Enterprise Mine, transitioning from the Ibis Mine, CRL began mining economic-grade ore in October 2005 (AER 2005 p14). One of the concerns for potential impacts was for an elevated groundwater table at the toe of the escarpment and east of the moving pond and tailings as covered earlier in this review. An elevated watertable had the potential for impacts on terrestrial flora and fauna.

In 2006 personnel from CRL with collaborators from the Centre for Mine Land Rehabilitation (CMLR at University of Queensland) developed a program to monitor some changes in vegetation that may have been responding to increases in elevation of the water table along the escarpment facing 18 Mile Swamp. As reported in the AER 2005 (p68) the monitoring program followed the discovery of a dead bloodwood tree (*Corymbia intermedia*) in September (cause of death unknown)).

Eventually, biannual[23] monitoring in May/June and November/December (said to be equivalent to post-'wet' and pre-'wet' in AER 2006 p79) at 26 permanent vegetation monitoring sites was established along the forecast zone of potential impact. There were two 3-year monitoring phases: 2006-2008 and 2009-2011. (It is expected that the AER 2011, due early 2012, will contain a final report of the monitoring.) Initially, of the 26 sites, 19 were along the toe of the escarpment with 6 in the south (ESC1–ESC6) and 13 (ESC7 – ESC19) in the north. During the first 3-year phase the CRL/CMLR monitoring determined that mining had moved to the north and "[ground] water levels within the southern sector [had] returned to normal". Subsequently, monitoring points ESC1–ESC6 were discontinued and replaced in 2009 as a northern extension of 7 new points (ESC20–ESC26) along a 3-km length "adjacent to Herring Lagoon". It is surprising that monitoring of the southern sites was discontinued so early and that no control sites were established far away from the locations of potential impact.

Nine species of trees were determined to be potentially "sensitive to water level changes" (AER 2007 p 100) or "non water tolerant" (AER 2008 p104). Within this list of species a total of 207 trees (AER 2010 p107)) were tagged and at each time of assessment their condition measured/recorded for the following attributes: height, canopy density, foliar chlorosis index, necrosis, insect and disease injury, branch dieback, and presence of buds or flowers. It is instructive to follow the monitoring results and explanations as recorded for canopy density and branch dieback in sequential AERs commencing in 2006. Table 2 (this review) contains extracts from the AERs in which explanations for changes in vegetation were provided along with comments about relative positions of the groundwater table.

In reporting the results and assessment of the vegetation monitoring program across several AERs, CRL (Unimin, Sibelco) personnel never provided quantitative data of watertable elevations at specific monitoring sites (bores or spear points). Rather, the authors of the AERs generally preferred to use euphemistic terms of "fluctuating water levels" instead of increased groundwater levels and explanations that mask the actual vegetation damage. In AER 2007 there were also confusing statements about water level increases yet they were normal: At page 101 the author referred to changes (as predicted) for vegetation attributes "in the central portion of the study area, which coincided with an area of elevated water table. All recorded water table levels were within the predicted natural range". Elsewhere in the same section the author was clearly discussing rising water tables due to mining.

[23] Biannual monitoring reported in the 2007 and 2008 AERs occurred slightly earlier in those years, in April and October and, incorrectly, were reported to have "coincide[d] with pre- and post-wet seasons".

In the later AERs the authors introduced other possible explanations for the observed changes in vegetation such as “due to other factors than a systematic change in water level” and “pests and pathogens cannot be excluded as possible causes” (AER 2009 p117). The AERs did have verbal descriptions of recorded changes in canopy density and branch dieback. But an open assessment of these was hidden (AER 2010) in gobbledegook of variations between sites and within a site but with no statements of statistical measures to support the conclusions. There were no maps and no attempts to link (say, via graphical plots) to seasonal changes and movements of groundwater levels that may have been evident in the monitoring records for bores and spears. There were no indications in the AERs of the identification and/or collection of the postulated pests or pathogens referred to in AER 2010.

All 26 of the toe-of-escarpment sites may fall within the western boundary of the Ramsar-designated wetland but CRL/SAL’s reports of vegetation monitoring do not provide any grid co-ordinates to assess this. Given the unsatisfactory reporting and analysis of this monitoring several actions should be done including: i) a review of any study reports (interim or final) so the exact locations of the vegetation plots can be determined; ii) a retrospective critique by independent vegetation specialists of the monitoring program in terms of location of sites, adequacy of design, frequency of measurements, interpretation of results, etc.

TABLE 2: Verbatim Extracts about Vegetation Condition from AERs 2006 - 2010

AER (year)	**Canopy Density/ Branch Dieback**	**Note on associated factors**	**Other comments on observed recovery**	**Overall assessment**
2006 (p79)	*(Nothing recorded in 2006 AER for canopy density or branch dieback)*	*(Nothing recorded in 2006 AER)*	*(Nothing recorded in 2006 AER. Study just 1 year completed)*	....findings so far [i.e. after 1 year] suggest there is a substantial degree of resilience in the tree species... and that moderate changes in water table depth should not have long-term adverse consequences[1]
2007 (pp100-101)	As predicted there was a decline in canopy density of the more sensitive species...and an increase in an index of branch dieback in the central portion of the study area...	[These changes]coincided with an area of elevated water table[2]. / All recorded water table levels were within the predicted natural [?] range.	[A]s predicted there was an improvement in plant condition in the area previously subjected to an elevated water table but now experiencing a decline in water table depth [sic] to[wards] pre-mine levels[2]	....findings of the 2006 and 2007 reports [i.e. after 2 years' study] confirm there is a substantial degree of resilience in the tree species... and that moderate changes in water table depth from the mining activities are not expected to have long-term adverse consequences[2]
2008 (p104)	Decline in canopy density of more sensitive (non water-tolerant) species. / Increase in an index of branch dieback in the central portion of the study area.	[These changes] coincided with an area of elevated water table	[I]mprovement in plant condition in the area previously subjected to an elevated water table but now experiencing a decline in water table depth [sic] to[wards] pre-mine levels	...there is a substantial degree of resilience in the tree species... and moderate changes in water depth from the mining activities are not expected to have long-term adverse consequences on the vegetation community
2009 (pp116-117)	Canopy density at 4 sites decreased between June and November. One site (14) had almost complete loss of foliage from four trees. / Branch dieback ... almost mirrored the patterns of canopy density *[although with the exception of Site 17 the author discussed different sites.]*	This variation in the seasonal change in canopy density and between sites suggests that factors other than a systematic change in water level may have been responsible. / Branch dieback after dry season is more variable than is canopy density, but the variation between years is generally less that the variation between sites.	Pests or pathogens cannot be excluded as possible causes.	This suggests that there may be local site factors that impact on the health of the trees.[3]

2010 (pp107-108)	Canopy densities[4] high[4] in May 2010. / Slight decrease[3] in canopy densities in December 2010. / Branch dieback in both 'seasons' generally less than in previous years. / No clear differences between southern and northern portions...or between seasons.	[Canopy densities in May were] possibly associated with a rise[4] in [ground]water level [Canopy densities in December consistent with increases[4] in water table elevation.	Both tree condition and water table elevations suggest that, although there is a continuation of an elevated groundwater mound from the area of the mine path and tailings placement sites, the escarpment is approaching a condition of environmental normality [5]	...adds weight to view that proximity of mine path and associated hydraulic gradients [down] to 18 Mile Swamp did not have detectable effect on crown condition
2011	*AER for 2011 due early 2012*	*AER for 2011 due early 2012*	*AER for 2011 due early 2012*	*AER for 2011 due early 2012*

1 The wording in the AER 2006 implies the author knew that groundwater elevations along the toe were already "markedly increased". However, it seems over-zealous, to have concluded as early as 2006, after only 1 year of monitoring, that the vegetation was resilient.

2 The wording in the AER 2007 confirms explicitly there was a rise in groundwater and a reduction in an earlier area. However, it still seems over-zealous, to have concluded only after two years of study that the vegetation was resilient. The author of AER 2007 was evidently keen to reassure the reader that the changes in vegetation attributes were "predicted" and even so early in monitoring the system appeared to be "resilient". These remarks written in 2008 should be placed in contrast with those written in 2011 for the AER 2010.

3 This overall assessment is rather trivial.

4 The stated records in 2010 for observed canopy densities and proposed explanation are conflicting. Different directions of seasonal change in canopy density, increasing **and** decreasing, are explained by the **same trend in groundwater rise**.

5 The author of this section (AER 2010 p108) was also keen to record that elevated groundwater was "...within the predicted range of ... groundwater model and trigger levels" and that the [claim for a] return to "...normality could easily be disrupted by an unusual [natural] event such as... a short but severe dry period..." *[Presumably, the author expected the reader then to join the dots with "so don't blame the mining company".]*

7.0 CONCLUSIONS AND RECOMMENDATIONS

Groundwater discharges from the Enterprise Mine operations (pond and tailings) was/is monitored at piezometer locations for water table fluctuations but not, it appears, for water chemistry. CRL/SAL did/does not report on the groundwater levels in the yearly Annual Environmental Reports but certainly rely on them as input to decisions on dewatering strategies and the interpretation of monitoring vegetation condition along the escarpment toe. Consequently, without these data the interested reader is unable to evaluate the progress of the mining company’s efforts to minimise impacts. Mine discharges from pond and tailings were/are estimated at about 42 ML/day, that is, about 16.8 Olympic swimming pools per day. These volumes should be consistently termed “discharges” and not euphemistically labelled as “seepages”.

The full extent of potential impacts of the mine on **groundwater** that recharges Eighteen Mile Swamp are not assessable due to the gaps in information as identified in this preliminary review. Public interest in Eighteen Mile Swamp could have been better served by the company releasing the piezometer water levels in numerical form, perhaps even as an Excel spreadsheet. A retrospective study of the groundwater levels as monitored should be undertaken, with particular attention being given to checking actual behaviour of the groundwater against the predictions. Given the current (2012) position of the Enterprise Mine some may regard such a study somewhat belated but it will still be very useful to have for ongoing monitoring and assessment of the company’s operations.

The full extent of potential impacts of mine discharges in elevating **surface water levels of Eighteen Mile Swamp** are also not assessable. From the outset, **CRL failed to establish enough monitoring points in appropriate positions to allow measurement of, and to track the dissipation of, increased volumes added via groundwater.** Only one site, Enterprise (18MS), on the west of the Swamp and closely associated with the channel of Freshwater Creek, was likely to be able to detect the forecast changes. None of the AERs contain a scientifically defensible analysis of the water-level data, even if the data was collected at inappropriate locations. Public interest in Eighteen Mile Swamp could be better served by the company releasing data of all the monitored water levels in numerical form, perhaps even as an Excel spreadsheet. The company should conduct a **retrospective study of all the surface water levels** as monitored and make the report available to the public. This study should be based on scientific principles and not run-of-the-mill minimal reportage as exhibited in the yearly AERs. The aim of this study should be to determine what can justifiably be said about the impacts of discharge waters on water levels of Eighteen Mile Swamp, a Ramsar wetland.

Understanding the impacts of increased water levels may be assisted by incorporating complementary consideration of water chemistry data. Even though sites for monitoring of water levels and water chemistry were inadequate and poorly placed, the company should conduct a **retrospective study of all data on water quality** and make the report available to the public. This study should be based on scientific principles and not run-of-the-mill minimal reportage as exhibited in the yearly AERs. The aim of this study should be to determine what can justifiably be said about the impacts on Eighteen Mile Swamp, of the identified variations in water quality. Public interest in Eighteen Mile Swamp could be better served by the company releasing all the monitored water quality data in numerical form, perhaps even as an Excel spreadsheet.

Impacts on aquatic fauna (especially different species of frogs and fish) in Eighteen Mile Swamp do not appear to have been part of monitoring attached to the Enterprise Mine. This is in marked contrast to the various programs at Yarraman Mine. The company should extend the recommended retrospective study/studies of available water level and water chemistry data from the monitoring sites in Eighteen Mile Swamp, and conduct **a retrospective study and make projections of the possible impacts on sensitive fauna** such as different frog species and fish species. Considering that sites for monitoring were inadequate and poorly placed there is a **strong case for field surveys to duplicate those conducted for inputs to the Environmental Study Report 2003**.

Physical impacts include damage (soils, slopes) along the escarpment toe through the installation, servicing and demobilisation of geotechnical equipment (bores, spear points, drill sites, etc.) and access for ongoing monitoring. As well, tree damage was noted in the dedicated vegetation assessment and this monitoring and evaluation need additional and independent assessment to see if the vegetation damage needs to be treated by rehabilitation. The overall needs for specialised rehabilitation of physical damage were not considered in the Plans of Operations and other documents. Given the now-curtailed mining future, the determination of any specialized rehabilitation effort should be determined as soon as possible.

The discharge site(s) for groundwaters extracted through spears and bores were not specified or identified for rehabilitation. As such sites on other mines tend to be considered as waste water discharges of little note, CRL personnel, office and field, may not have given this aspect of environmental care the consideration appropriate for a Ramsar wetland. Dewatering activities from escarpment locations should be investigated and modifications made for remediation and/or rehabilitation if required. The discharge site(s), as well as associated pipes, pumps, refuelling bases and service tracks, should be part of the environmental management plan for the mine. As well, the dewatering program with details of extraction points, quantities collected by time, chemistry of those waters by time and other details of discharge should be reviewed so that an assessment can be made of the likely impacts of those discharges on Eighteen Mile Swamp.

8.0 Significance of Impacts of Enterprise Mine on Eighteen Mile Swamp – a Ramsar Wetland

The predicted and ongoing flooding of Eighteen Mile Swamp from along a section of the escarpment, that has never before carried water of this quality or in these continuous and concentrated volumes, may be classified correctly as a mining-generated inter-catchment transfer of water. Some of the known impacts of mining-sourced inter-catchment transfers on North Stradbroke Island were summarised in this review (Section 2.2) and are recast in this section with its focus on "significance" under the EPBC Act.

A concern of the mining company, knowing the predicted discharges of groundwater and the declared environmental qualities of Eighteen Mile Swamp, has been to avoid slope failure and tree damage along the escarpment, as well as visible impacts on and contamination of the Swamp. A main focus has been to minimise or avoid such damage occurring while mining is underway and these are valuable objectives. However, mining impacts on Eighteen Mile Swamp are not limited to those that occur just from the increases in ground and surface waters during mining operations over 10 to 20 years. As with other dredge-pond mining on the Island, the Enterprise Mine will cause permanent hydrogeological changes and create significant impacts to the Swamp.

In Section 8 brief reference is made to the likely hydrological, water quality and ecological impacts. For practical application the significance of the impacts is given in relation to the EPBC Act and associated definitions as presented in (Commonwealth of Australia 2009) Matters of National Environmental Significance, Significant Impact Guidelines 1.1, *EPBC Act 1999*.

8.1 Significant impact criteria for Eighteen Mile Swamp

The cited text is an extract from pages 3 and 14 of Significant Impact Guidelines 1.1 to the *EPBC Act 1999*:

> "Approval is required for an action occurring within or outside a declared Ramsar wetland if the action has, will have, or is likely to have a significant impact on the ecological character of the Ramsar wetland."
>
> "A 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts. You should consider all of these factors when determining whether an action is likely to have a significant impact on matters of national environmental significance."
>
> "To be 'likely', it is not necessary for a significant impact to have a greater than 50% chance of happening; it is sufficient if a significant impact on the environment is a real or not remote chance or possibility. If there is scientific uncertainty about the impacts of your action and potential impacts are serious or irreversible, the precautionary principle is applicable. Accordingly, a lack of scientific certainty about the potential impacts of an action will not itself justify a decision that the action is not likely to have a significant impact on the environment."
>
> "The 'ecological character' is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. The phrase 'at a given point in time' refers to the time of designation for the Ramsar List."
>
> "An action is likely to have a significant impact on the ecological character of a declared Ramsar wetland if there is a real chance or possibility that it will result in
>
> - Areas of the wetland being destroyed or substantially modified

- A substantial and measurable change in the hydrological regime of the wetalnd, for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland
- The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetalnd being seriously affected
- A substantial and measurable change in the water quality of the wetland – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health, or
- An invasive species that is harmful to the ecological character of the wetland being established (or an invasive species being spread) in the wetland."

8.2 Alteration of hydrological regimes

Despite the gaps in the monitoring program identified earlier in this preliminary review, in my opinion the Enterprise Mine has had and will have an effect on the hydrological regime of Eighteen Mile Swamp in two different ways. One impact is the increased water volume generated by mining, and the mining company has concentrated its modelling, prediction and monitoring on this so-called temporary increase, meaning up to 10 years. The second, a permanent change in the hydrological regime, has been ignored. Both require consideration for this Ramsar wetland.

8.2.1 Summary of hydrological impacts from locally increased water volumes

Modelling the water management factors at the Enterprise Mine has established that mining could deliver some 42 to 12 ML/day (16.8 to 4.8 Olympic swimming pools per day). This extra volume of water will be delivered as base flow along a linear front into the western side of Eighteen Mile Swamp. It will generate a 'bulge' or mound in the surface of the Swamp and eventually that will dissipate through parts of the Swamp.

Because the discharges will occur on a 24/7 basis a bulge in the water surface will become a permanent feature of the western side of the Swamp for as long as the Enterprise Mine dredge pond operates at elevations higher than the main island aquifer. Although the locus of the discharges will progressively move northwards as the dredge pond and latest tailings migrate, this movement is not very fast — about 500 to 800 metres annually. The modelling indicated that discharges will continue for at least 9 years. Nine years is longer than the 6 years of drowning that Native Companion Lagoon experienced by water discharges from the Gordon Mine.

It cannot be argued that such sustained flooding of Eighteen Mile Swamp is within natural tolerances, like those of other waterbodies of North Stradbroke Island that have periods of higher and lower water levels related to El Niño/ La Niña rainfall patterns and other longer-term trends. The predicted decade-long increase in water levels is not like that associated with La Niña conditions and has no seasonal variations. The forecast mining-generated discharges are similar in volume to the measured surface flows of *natural* discharges into Eighteen Mile Swamp such as at Blue Lake outflow (15 to 17.8 ML/day)

The style of predicted on-going flooding is not likely to generate flows that would cause erosion or substantial changes in water body morphology. Based on the historical experience of mining impacts on the Island, and considering the material in the ESR 2003, the PoOs and AERs, the most likely impacts from the elevated and sustained 6- to 9-year submergence of up to 30 centimetres will be biological. Such impacts of flooding may also be magnified if they are accompanied by changes in water quality. These are considered in Sections 8.3 and 8.4.

8.2.2 Permanent change in groundwater supply to Eighteen Mile Swamp

When Enterprise Mine is completed a mass[24] of near-homogeneous water-deposited yellow-brown tailings will replace the original pile of wind-deposited sediments and dependent soil profiles. Depending on when mining actually ceases, under a revised mining timetable, a tailings-filled super-trench, roughly with a trapezoidal cross-section, will stretch northwards for about 8 kilometres from south of Tazi Trench (including part of the contiguous Ibis Mine). As shown in Figure 6 of this preliminary review the eastern edge of the disturbed sand generally will be about 500 metres from the escarpment toe (but much closer in the south).

The tailings will have higher porosity and permeability than the original so hydrogeological conditions and dependent groundwater regimes will be changed permanently. It is likely that along this 8-kilometre stretch the groundwater recharge will be increased and delivered more rapidly as base flow to Eighteen Mile Swamp. This prospect for permanent change appears has not to have been examined, or proposed as part of a monitoring program, or requiring evaluation after mining. Certainly, in some documents referring to dewatering along the escarpment toe the company has acknowledged a level of uncertainty about existing geological and hydrogeological conditions.

The 8-kilometre-long disruption by the Enterprise Mine represents roughly 25 per cent of the 26-kilometre long length of Eighteen Mile Swamp that receives groundwater from the high dunes and escarpment. The mine is likely to cause permanent changes that lead to more rapid increases of groundwater flows along, about, a quarter of the length of Eighteen Mile Swamp. In relation to the EPBC Act the Enterprise Mine, in my opinion, will have "a substantial and measurable change in the hydrological regime of the wetland [through]... a substantial change to the volume, timing, duration and frequency of ground... water flows to ... the wetland". If the permanent and similar impacts of the Yarraman Mine already made in the far north of the Island are added to those from Enterprise (/Ibis), mining along the Island's eastern seaboard will have affected even more of the hydrological regime of Eighteen Mile Swamp.

8.3 Changes in water quality

In this review I have referred (Section 5) to the lack of water quality data in the limited monitoring program CRL/SAL have operated. Given the very limited published data from the only potentially useful monitoring site (Enterprise/18MS), and in the absence of information about volumes and quality of make-up water from the different supply sources, only some very general statements can be made.

The make-up waters used in the Enterprise Mine have had, over time, a variable water chemistry signature according to the volume proportions of water derived from Eighteen Mile Swamp (Herring Lagoon), Wallen Wallen swamp (Kounpee Trench) and other production bores drawing directly from the prime aquifer. From this starting point the water chemical properties would have been affected during mining, processing and tailings-stacking by: sand particles releasing ions from their skins of clay, iron and aluminium minerals; saturation with carbon dioxide; and by interaction with additives for reducing water losses from tailings. In turn, the descending drainage water from pond and tailings would have interacted with the subsurface sands in soil profiles encountered en route to Eighteen Mile Swamp.

Whatever the variable chemical nature of the drainage water entering the Swamp, it cannot be considered as simple recycled natural swamp water, purified by passage through sand and with properties unrecognisable from that of other natural waterbodies on the island. In the absence of data from all stages of the mining-dependent water system such statements are simply untested claims.

[24] The cosmetics of rehabilitation with topsoil and revegetation are useful for landscape stability and aesthetics and are required by lease conditions. However, such activities cannot reverse or disguise the permanent changes to hydrogeological conditions in the subsurface.

In the much longer term, different terrestrial ecosystems will be established in the tailings-plus-topsoil mass of the mined area and rainfall will recharge a different groundwater regime. It is likely that over time (decades to hundreds of years) this groundwater will approach the same chemical character as that of the prime aquifer.

8.4 Biological changes induced by changes in water volumes and water quality

Although the wording in the ESR 2003 and other company documents refers to raised water levels as 'temporary', a 6- to 9-year-long increase of water levels along a western section is likely to affect food and habitat conditions of some fauna such as frogs. Some natural species may be advantaged, others may be disadvantaged. For some species in these low-acidic low-conductivity waters, even apparently subtle elevations in water levels combined with changes in water chemistry can generate more antagonistic effects. An extended immersion with slight changes in water chemistry may be sufficient to allow an invasive exotic species to extend its geographical range.

Whether these potential impacts are significant or not cannot be stated without further investigations. The company has generated only limited data of summary measures: acidity (pH), salinity (EC) and turbidity. There has been no monitoring of potential index species or species known to have sensitivity to, say, water acidity in its various life stages. No periodic or end-of-mining fauna surveys have been proposed.

9.0 Declaration

Subject to the proviso in the next paragraph, I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance that I regard as relevant have, to my knowledge, been withheld from the Court.

This is a preliminary review only as it has been prepared on the basis of information that is publicly available regarding the mine, particularly the mine's published AERs. As discussed in this report, that information is deficient in many respects. The findings and opinions expressed in this preliminary review will be reconsidered if and when further information becomes available through the trial process, for example if SAL provides further documents regarding monitoring at the mine or if I am able to meet with and discuss the issues with experts acting for SAL.

Dr Errol Stock
Date: 20 September 2012

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ATTACHMENT 1: RESUME OF DR ERROL STOCK

Errol Stock is a director of Triple-E Consultants. He is responsible for input to projects that require knowledge and expertise in applied geosciences, geoarchaeology, geosciences heritage assessment and natural resource management associated with development projects (particularly mining and settlement infrastructure). With other colleagues he also provides assistance in projects with a focus on environmental education and community development.

This résumé is an extract from Errol Stock's CV and relates primarily to his coastal geomorphology research, environmental impacts, consultancies and associated legal reports and court appearances. These entries relate to both his employment in tertiary education and as well as an independent consultant.

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This résumé contains the following sections:

1. Summary Points of Consultancy Projects
2. Research /Consultant Reports, Institute of Applied Environmental Research, Griffith University
3. Consultant Reports
4. Expert Evidence to State Courts
5. Expert Evidence to Inquiries
6. Written Submissions to Public Inquiries
7. Selected Refereed Publications
8. Conference Papers and Proceedings

1. Summary Points of Consultancy Projects

Errol Stock's consulting work in the coastal zone (geomorphology, geoarchaeology and environmental impacts) has been as a member of a multi-disciplinary team (up to 12 people) or as the sole contractor. Consultancies to various agents are summarised in the dot point list and/or under full titles of reports and publications.

- Australian National Parks and Wildlife Service (survey and resurvey monitoring sites in the mangrove wetlands the East Alligator River, Kakadu National Park; landscape setting and ecology of patterned fens in the Fraser Island World Heritage Area).
- Australian Heritage Commission (inventories of dune masses in coastal Queensland and New South Wales and re-assessment of project proposals that may affect the Register of the National Estate).
- Australian Defence Forces (inventory of land management recommendations for dunefields in the Shoalwater Bay Defence Training Area)
- Federal Airports Corporation (assessment of environment impacts associated with different runway alignments at Brisbane Airport located near the mouth of the Brisbane River)
- Cape York Peninsular Land Use Study, Taskforce of Commonwealth and Queensland Governments (assessment of the environmental and social impacts associated with exploration and mining projects on Cape York Peninsula).
- Beach Protection Authority, Queensland (mapping the soils and vegetation along the Hervey Bay coastal strip from the Kolan River to Urangan).
- Local Governments (preparation of a range of land and water management studies for single projects and components in planning and management studies).
- Esso Australia (various studies of long-term planning and land management requirements of an oil shale mining project on the central Queensland coast).
- Cape Flattery Silica Mines (report on characteristics of coastal dunes in the Spalenka Area, Cape Flattery area, Far North Queensland).
- Development Companies with projects in coastal Queensland and New South Wales (various studies of coastal geomorphology in relation to dune types and sensitivity to development, archaeological potential and natural heritage values — reports and court appearances).
- Community Groups (preparation of a range technical reports and professional opinions).

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ATTACHMENT 2: EXTRACTS OF PAGES 4-15 TO 4-17 FROM THE ESR 2003 FOR ENTERPRISE MINE

- In the case of solution convergence, changes were introduced to prevent MODFLOW-96 execution being halted.
- For convenience, the total elapsed time from the onset of the simulation was stored in the header to each cell-by-cell term array.

The model grid for the whole of Island DNRM model was constructed in Australian Map Grid (AMG) and was 40 km long in the north-south direction and 15 km long in the east-west direction. The DNRM model grid was uniformly 200 m by 200 m.

The grid for CRL's revised Ibis model was reduced to 50 m by 50 m to improve the spatial resolution of the model and allow more accurate specification of the planned mining activities. The refined model grid comprised 800 rows and 300 columns, with the AMG coordinate system maintained.

Depending on where the water level in the dredge pond is (ie. compared with the relative height of the prime water table), water either flows out of the dredge pond and into the groundwater system (ie. if the dredge water level is above the prime water table), or from the groundwater system into the dredge pond (ie. if the dredge water level is below the prime water table). The 'river' package of the MODFLOW-96 modelling programme was used to accommodate this process.

The movement of the dredge pond was simulated using specialised software developed by Watermark Numerical Computing to interpolate pond positions and mine paths to the model grid both spatially and temporally.

Initial groundwater conditions for the model were based on three factors: prior model simulations, bore hydrographs and the operational setup of CRL's mining activities. Regionally, the initial conditions were determined from water table elevations predicted for January 2002 by the DNRM model. Thus, simulated heads were interpolated to the new model grid and adopted as initial conditions in areas outside the anticipated zone of impact of the Ibis Mine. Where applicable, initial conditions in and around the Ibis Mine were set according to January 2002 data from nearby DNRM observational bores and CRL's existing piezometers.

Natural recharge over the model domain was assumed to occur at a spatially and temporally uniform rate of 35% of mean annual rainfall (ie. approximately 600 millimetres per year [mm/yr]), which is consistent with the recharge used in the DNRM model. On-site tailings deposition provides an additional source of water recharge to the natural groundwater system, with the initial model simulations adopting a tailings recharge rate of 35 ML/day. However this was subsequently revised to 27 ML/day on the basis of metallurgical studies of achievable tailings densities. The 'well' package of the MODFLOW modelling programme was used to accommodate the tailings recharge process as well as the effect of abstraction from the nearest RSC water supply bores (located to the west of the Enterprise Study Area – refer to Figure 3-11).

Analysis and Evaluation of the Groundwater Modelling Results

Due to the recognised environmental values of Eighteen Mile Swamp and the main escarpment, an analysis and evaluation of risks associated with adjacent mining activities has been conducted in accordance with CRL's risk assessment and management system. An overview of the model output, and how the risks associated with the predicted results have been evaluated, is provided in the following text.

Results of the groundwater modelling for the final 12 months of the Ibis Mine indicate that as the dredge pond level will be above the prime water table, average flows from the base and sides of the pond of greater than 40 ML/day may be experienced. However, this is likely to be an overestimate, as it does not take into account lower permeability materials sealing the base of the dredge pond. Regression analysis of actual pond losses suggests a maximum of around 15 ML/day will be experienced.

The modelled hydrological effect (expected impact) of the above on the section of Eighteen Mile Swamp adjoining the final year of the Ibis Mine and the commencement of the Enterprise Mine will be to temporarily raise the existing groundwater levels near the toe of the escarpment by approximately 1 m. CRL's previous experience with surface waterbodies on the Island indicates this is likely to result in a temporary rise of approximately 0.1 to 0.3 m in surface water levels in the adjoining section of Eighteen Mile Swamp. This minor increase in Eighteen Mile Swamp surface water levels will be located between CRL's two authorised surface water pumping stations (located at Herring Lagoon and Palm Lagoon).

Authorised pumping activities in Eighteen Mile Swamp by CRL and RSC have resulted in surface water level variability of up to 1 m in the vicinity of the Herring Lagoon pump station (Section 3.3.1). Although the predicted 0.1 to 0.3 m increase in surface water levels in Eighteen Mile Swamp associated with the Ibis/Enterprise Mine will be temporary, it may partially offset the reductions in natural surface water levels that occur from authorised pumping activities.

Modelling of the planned Enterprise Mine path indicates the effect on Eighteen Mile Swamp will be less than the final stages of the Ibis Mine path. The preliminary model output for the planned mine path is presented on Figures 4-2 to 4-11 for the period from 2003 to 2012. The model output is presented as the predicted variation in the prime water table shown as contours (refer to left hand side of Figures 4-2 to 4-11), with the yellow/orange colours indicating where mounding is predicted to occur and the blue colours indicating where a drawdown effect is predicted. The model output is also presented as the predicted cumulative effect of the planned operation on the prime watertable (ie. includes the effect of RSC groundwater abstraction – refer to the right hand side of Figures 4-2 to 4-11).

The results of the modelling indicate that the degree of groundwater mounding associated with the dredge pond and tailings deposition area will decrease as the mine descends and moves north along the path. The groundwater mounding effect in any one area will be temporary as the mine moves away and water contained in the deposited tailings dissipates.

The water level in the pond is expected to be at or slightly below the water table around December 2005 onwards, after which time inflows to the dredge pond are expected to average around 16 ML/day. As a result, once the planned dredge mining operation is operating at or below the prime water table, no increases in surface water levels in Eighteen Mile Swamp are anticipated. The predicted effect of the planned Enterprise Mine on surface water levels in Eighteen Mile Swamp is for a small and temporary rise in the section of the Swamp nearest the Mine whilst it is above the prime water table in the period before December 2005.

Some minor and temporary effects on environmental values (eg. terrestrial and aquatic flora, and aquatic fauna values) could potentially occur in the zone of impact where groundwater mounding and increases in surface water levels are predicted. Similar types of effects have been observed as both natural and mine-induced phenomenon in the past and may result in the following:

- localised changes to vegetation in temporarily inundated areas;
- impacts on aquatic fauna species abundance due to an increase or decrease in suitable food or habitat (eg. increased frog activity); and
- minor surface erosion due to increased seepage and/or surface flow from localised areas.

Based on CRL's experience at Little Canalpin Creek (located on the western side of the Ibis Mine) in 2001/2002, no significant mine-induced changes to the water chemistry in Eighteen Mile Swamp are anticipated.

Groundwater Quality

As detailed in Section 4.2.5, CRL implements a range of hydrocarbon and chemical management control measures to minimise the possibility of land or water contamination.

CRL has conducted a risk assessment of the potential for environmental harm associated with the use of hydrocarbons, flocculant and other chemicals at its operations on North Stradbroke Island. The assessment concluded that risks to groundwaters associated with the use of these products was moderate and primarily related to spills or leaks from storage and transfer areas.

The control measures utilised in Section 4.2.5 apply to these risks.

Trigger Levels

The principle indicator for the key environmental values associated with Eighteen Mile Swamp will be the effect on surface water levels within the zone of impact surrounding the mining activities.

As described above, the groundwater modelling predicts an increase in surface water levels of approximately 0.1 to 0.3 m in the section of the Swamp adjacent to the active mining/tailings placement areas. Accordingly, a trigger level of 0.25 m increase within this zone of impact will be used. CRL will determine the effect of its operations on surface water levels within the zone of impact by comparing the monitoring results from a series of sites located along the western edge of Eighteen Mile Swamp. The monitoring locations will include sites within and outside the predicted zone of impact.

Where the water level in the zone of impact increases by more than 0.25 m, and the increase cannot be explained through natural phenomena (eg. rainfall event), the trigger level will be deemed to be exceeded and CRL will implement the risk evaluation and treatment process described in the Monitoring Plan (as required by Environmental Authority Condition A7.4). This process will be based on the Australian Standard for risk management (AS/NZS 4360:1999) and is illustrated on Figure 1-7.

A lowering of surface water levels within Eighteen Mile Swamp is not predicted by the groundwater modelling conducted for the Stage 1 mining activities and it is not an expected impact. However, if CRL's on-going monitoring programme detects a measurable decrease (ie. 0.10 m), and the decrease cannot be explained through natural phenomena (eg. dry period), the risk evaluation and treatment process described in the Monitoring Plan will also be implemented.

As discussed in Section 4.2.5, CRL also has trigger levels that relate to spills of hydrocarbons and chemicals. Spills of more than 20 L, or spills that are located in sensitive areas or off-lease are classified as major spills and invoke an appropriate emergency response and reporting to the administering authority.

Risk Management Monitoring and Control Measures

The expected impacts of the planned Enterprise Mine on surface water levels in Eighteen Mile Swamp will be temporary and localised, as a result, no significant adverse effects on the environmental values of the Swamp are anticipated.

ATTACHMENT 3: SUMMARY FEATURES OF WATER RESOURCES OF NORTH STRADBROKE ISLAND AND EIGHTEEN MILE SWAMP BASED ON TWO EXTRACTS

"North Stradbroke Island is a declared subartesian area proclaimed under Queensland's Water Regulation 2002. Reported estimates for North Stradbroke Island's groundwater volume vary, but the following are representative (L. Leach, writ. comm., 2008) based on 2007 data: volume of sand 24.8s x 10^9 m^{-3}; total volume of saturated sand 12.79 x 10^9 m^{-3}; total volume of fresh groundwater 2.81 x 10^9 m^{-3} of which around 25% is above sea level. Estimates of the overall groundwater recharge to the island is in the order of 140,000 to 166,000 ML a^{-1} (Laycock 1975a; L. Leach writ. comm., 2008). The total surface water discharge from obvious surface flows falls to the coastline via Freshwater Creek (Eighteen Mile Swamp) and the frontal dunes has been estimated in the order of 45,000 ML a^{-1}; discharge from Blue Lake to Eighteen Mile Swamp has been estimated at 1.5 ML a^{-1}. The current gross extraction of round and surface water is around 20 x 10^6 m^3 a^{-1} (20 ML d^{-1}), based on 1999-2000 data provided by Redland City Council (RCC) and Consolidated Rutile Ltd (CRL). Estimates of the overall groundwater pumping yield of North Stradbroke Island in the order of 100,000 to 150,000 ML a^{-1} appear to be reasonable." *[Cox, James, Raiber, Taulis, and Hawke, 2011:74]*

"Chen (2003) considered the hydrology of Eighteen Mile Swamp to be influenced by direct rainfall, runoff and groundwater discharge. Owing to their low permeability, the [underlying] marine muds and peats act as a local semi-confining layer to the regional aquifer. There are several notable hydrological aspects relating to Eighteen Mile Swamp. The headwater of Eighteen Mile Swamp is at the confluence of Yarraman Creek and the Keyholes. The first is the relative low overall gradient of 4.45 m over a distance of 25.4 kilometres (km) or 0.000175 m m^{-1} compared to its lateral west to east gradient of 0.0005 m m^{-1} to 0.001 m m^{-1}. ...

Also of note is the existence of Freshwater Creek that drains much of the swamp in wet conditions. It has an overall length of 30 km from the Keyholes to its mouth at Swan Bay and has a longitudinal gradient of 0.00013 m m^{-1}. In some locations south of Herring Lagoon, the stream channel is well defined and is congested with plant material making stream gauging difficult; in other locations it is either featureless, or forms a chain of waterholes with no visible flow. ...

Owing to the difficulty in gauging the flow, it is not possible to quantify the magnitude of this discharge from the entire length of the scarp. The absence of any surface flow in Freshwater Creek in 2006 to 2008 at some locations would suggest that most of the groundwater discharge emanating from the escarpment was transpired via the vegetation at that time.

During wetter periods surface flow has been observed in Eighteen Mile Swamp following rainfall. While there may have been a slight increase in the groundwater discharge due to higher groundwater level gradients, the bulk of the surface flow is attributed to rainfall and runoff." *[Leach, 2011:27]*

Preliminary review of hydrological impacts of Enterprise Mine on the ecological character of the Ibis Lagoon system within the Moreton Bay Ramsar Wetland

Ibis Lagoon and western boundary of Enterprise Mine on 6 May 2010. Source: Nearmap

Prepared by Dr Errol Stock

February 2015

TABLE OF CONTENTS

List of Acronyms and Abbreviations

AERs	Annual Environmental Reports
AHD	Australian Height Datum (The nationwide datum surface used to refer locations linked by key and supplementary surveying/levelling)
API	Aerial Photo Interpretation (Airphoto Interpretation)
CRL	Consolidated Rutile Ltd
cumecs	Cubic metres per second
DME	Department of Mines and Energy
EMOS	Environmental Management Overview Statement
EA	Environmental Authority [issued under the *Environmental Protection Act* 1994 (Qld)]
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999 (Cth)
FOSI	Friends of Stradbroke Island Inc.
m	metre
ML	Megalitre (1,000,000 litres)
OSP	Olympic swimming pool (volume 2.5 megalitres)
PoOs	Plans of Operations
QALSMA	Quandamooka Aboriginal Land and Sea Management Agency
QLC	Quandamooka Land Corporation
QYAC	Quandamooka Yoolooburrabee Aboriginal Corporation
RL	Reduced Level (A surveying term for the elevation of a location reduced, or equated, to above or below an adopted datum.)
RSC	Redland Shire Council
SAL	Sibelco Australia Limited (previously Unimin)
SIMO	Stradbroke Island Management Organisation Inc.
t	tonne

1.0 INTRODUCTION

1.1 Purpose of Review

The purpose of this report is to provide a preliminary review of the hydrological impacts of Enterprise Mine[1] on the Ibis Lagoon system on North Stradbroke Island, Moreton Bay, Queensland, to determine whether the mine requires approval under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act). The Ibis Lagoon system is an informal name for the collection of water bodies and wetlands in a topographic depression that is west of the Enterprise Mine and is part of the Moreton Bay Ramsar Wetland, providing habitat for migratory species and listed threatened species that are protected under the EPBC Act.

The review was requested by the Friends of Stradbroke Island (FOSI) for the purpose of potentially undertaking litigation in the Federal Court of Australia for a contravention of the EPBC Act. It is complementary to and should be read in conjunction with my earlier review about hydrological impacts on Eighteen Mile Swamp (Stock 2012). My earlier review set out the general context of the mine but focused on its impacts on Eighteen Mile Swamp on the eastern side of the mine. I was not asked to consider impacts on Ibis Lagoon to the west of the mine and since my earlier review was written further information has been provided to me regarding the potential impacts on the Ibis Lagoon system.

FOSI has provided me with remote sensing records consisting of photomaps and satellite imagery of the Ibis Lagoon area during 2010 (Appendix 1). In preparing this report, I reviewed these documents and the data of monthly monitoring by the mining company. I also undertook an independent interpretation of the photomaps and satellite imagery.

A satellite image in Figure 1 indicates the general position of the Ibis Lagoon system in relation to the mine. Figure 2, based on online sources provided by the Queensland Department of Environment and Heritage Protection, shows the local boundaries of the Ramsar Moreton Bay Wetland. Figure 3 is an extract from the mining company's AER 2005 Figure 5 and shows the general position of the Ibis Lagoon system and identifies the surface water bodies as named formally in the Queensland Gazette or less formally, but authoratively, by Quandamooka elders. These names are used throughout the review and are complemented by footnotes to explain variability as necessary. They include: Ibis Lagoon West, Ibis Lagoon Central, Dakka Bin North, Dakka Bin Central, Dakka Bin South and Bumbaree Swamp.

This is a preliminary review only as it has been prepared on the basis of information that is publicly available regarding the Enterprise Mine, particularly the company's published Annual Environmental Reports (AERs) and the initial Environmental Studies Report (ESR 2003) for the mine prepared by CRL. As noted in this report, information in the AERs and the ESR (2003) is deficient in many respects. The findings and opinions expressed in this preliminary review will be reconsidered if and when further information becomes available through the trial process, for example, if Sibelco Australia Limited (SAL) provides further documents regarding monitoring at the mine, or if I am able to meet with and discuss the issues with experts acting for SAL.

[1] Enterprise Mine was operated by Consolidated Rutile Ltd (CRL) until being purchased by Sibelco Australia Limited (SAL).

1.2 Duty to the Court

As for my earlier report, I have been provided with a copy of the Federal Court's Practice Note for expert witnesses.[2] I have read, understood and complied with the Practice Note in preparing this report. In particular, I understand and I have prepared this review on the basis that:

- I have an overriding duty to assist the Court on matters relevant to my area of expertise.
- I am not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential.
- My paramount duty is to the Court and not to the person retaining me.

1.3 Expertise

My curriculum vitae was provided as Attachment 1 to my earlier report (Stock 2012).

I have studied the geology, geomorphology and hydrology of North Stradbroke Island since 1964. My research and reports were generated first as a practicing economic geologist and later as geomorphologist developing expertise in understanding the sand masses of the east coast of Australia and as an environmental scientist tracking the outcomes of rehabilitation and documenting the impacts of mining. In these fields I have prepared consultant reports on the Island for the Australian Heritage Commission, Redland Shire Council, Quandamooka Land Corporation, Stradbroke Island Management Organisation and Friends of Stradbroke Island. The interpretation of various formats of remote sensing is an established technique used in my profession.

1.4 Scope and structure of this Review

Testing the potential for water discharges from the Enterprise Mine to affect the ecological character of the Ibis Lagoon system, especially the terrestrial vegetation within the system, is the main subject of this review compiled in eight sections. Aerial photographic images captured in January, May and September 2010 are highly suggestive of a condition change in the system. Because most of the Ibis Lagoon system is a designated Ramsar Wetland, assessing the significance of any impacts from the Enterprise Mine is of direct and important relevance under the EPBC Act.

In preparing this preliminary review I have referred to relevant reports and correspondence, which are listed in the references section. According to the Consolidated Rutile Limited (2003) Environmental Studies Report for the Enterprise Mine[3] (ESR 2003) company personnel and several consultants conducted a revised groundwater modelling of the proposed mining activities of the Enterprise Mine (and the remaining Ibis Mine path) "to evaluate the interaction of the Enterprise Mine with the prime groundwater table and predict the effects of the planned mining activities on it" (p.4-13). The ESR 2003 also summarised (pp 4-14 to 4-15) the MODFLOW model and its modifications including the 'ridge' and 'river' packages linked to the program. Based on CRL's past experience in operations some quantitative values of flows from the tailings were reduced before being 'plugged' into the revised model. Analysis and evaluation of the modelling was treated on page 4-16 and this section was expected to be read with the "preliminary model output for the planned mine path [as presented in] Figures 4-2 to 4-11 for the period 2003 to 2012" (p4-16). For convenient reference a collapsed version of the modelling results and forecast impacts from page 4-16 is presented in Attachment 1 of this review.

[2] Federal Court of Australia (2011), "Practice Note CM7: Expert Witnesses in Proceedings in the Federal Court of Australia"
[3] Certified by an independent third party in November 2003 (AER 2004 Table 2 Item A4-4)

Figure 1: Location of the Ibis Lagoon System to the west of Enterprise Mine. The white arrow indicates the location of the Ibis Lagoon system. The orange arrow indicates the dredge pond. (DEHP 2013 based on composite Google Earth images from 2011 and 2013)

Figure 2: Enterprise Mine with overlay in red of Moreton Bay Ramsar Wetland (DEHP 2013)

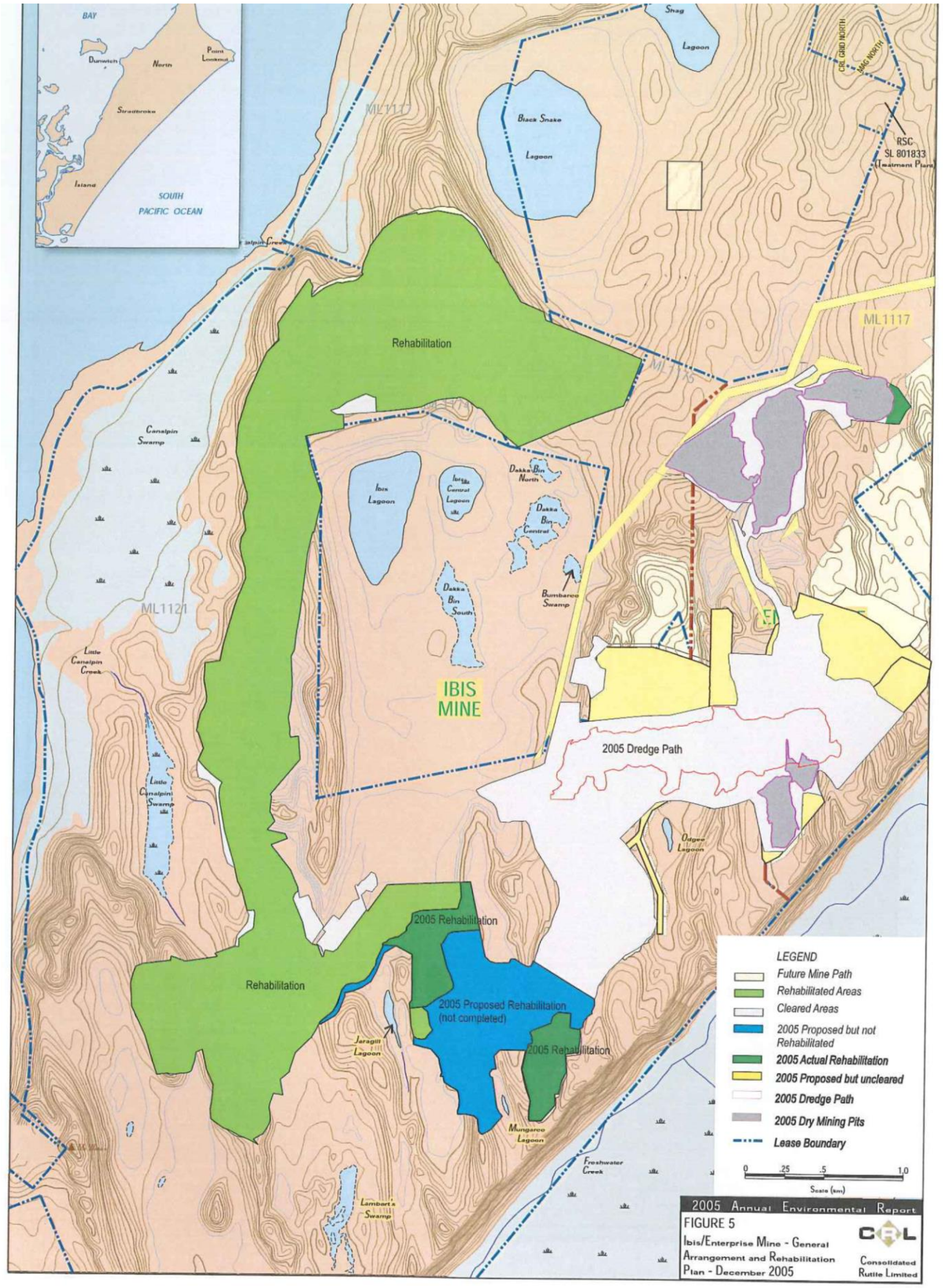

Figure 3: Ibis Lagoon system and named water bodies in relation to the previous Ibis Mine and current Enterprise Mine. Light green areas refer to Ibis Mine rehabilitation; dark blue and white areas to proposed mining areas for Enterprise as in 2005**.** (Source: AER 2005 Figure 5; Features as at December 2005)

Although the focus of the company's modelling was on the groundwater, its flows and elevations, the ESR 2003 did not provide details of quantitative forecasts of groundwater elevations of concern, or nominate which spears/piezometers (or boreholes) that should be used for monitoring the water table or for dewatering. As well, the authors of the ESR 2003 did not identify specific watertable elevations or 'triggers' that would generate actions from CRL, though these are considered in Plans of Operations (PoOs). No groundwater monitoring data are published in the Annual Environmental Reports (AERs). Throughout the mine planning process the company effectively redirected interest from the groundwater to monitoring surface water levels and restricted the spatial focus to Eighteen Mile Swamp. The following quote (p 4-16) could function as a summary of CRL's muting of concern and reassurance to the reader: "The predicted effect of the planned Enterprise Mine on the surface water levels in Eighteen Mile Swamp is for a small and temporary rise in the section of the Swamp nearest the Mine whilst it is above the prime water table in the period before December 2005".

This muting and redirection with respect to the Ibis Lagoon system was even more profound: The wetlands and water bodies in this location may not have even existed or had ever been of concern to the company. Yet as this review shows, the Ibis (- Enterprise) Mine has had ongoing impacts on the Ibis Lagoon system and has been the subject of several consultant reports forecasting mine-sourced discharges to the system.

Because the Enterprise Mine has been in planning, development and operation for over 11 years this review depends retrospectively on assessing the information, principles and limited data in the ESR 2003 as well as the AERs 2003 through 2012. As well, I have drawn extensively on personal knowledge and documents to provide historical details, especially those relating to the 1980s through to the early 2000s.

Section 2 is a short history of mine-sourced discharges of water from the original Ibis (- Alpha) Mine and their impacts within the Ibis Lagoon system (location map Figure 3) well before operations were moved to mine the Enterprise ore-body. As early as 1994 CRL's consultants in their pre-mining studies were forecasting the distinct possibility of discharges. Later events showed that the nature of the predicted discharges was relatively accurate but their timing was less so, primarily because of field conditions and operational factors. Section 2.1 records examples of the physical disruption of sand and vegetation caused by groundwater coming to the surface. Section 2.2 charts a similar but less vigorous 'day-lighting' of groundwater in 2000/2001 that caused an extended period of higher water levels and inundation as well as impacts to terrestrial vegetation and the littoral surrounds[4] of Ibis Lagoon (West). The later discharge led to a Show Cause notice from the Queensland regulatory authorities. Because of their relevance in explaining the condition changes observed in the Ibis Lagoon system Section 2.3 is a short statement about the mechanisms of vegetation losses through inundation by water.

Section 3 draws on the mining company's ESR 2003 and relevant extracts from the company's AERs 2003 through 2012 to establish context for assessing the condition change observed in the remote sensing imagery for 2010. Although the Ibis Lagoon system (in the central west of the island) was ignored in the risk assessment linked to planning the Enterprise Mine the hydrological forecasts in ESR 2003 identify impacts to its groundwaters. In Section 3.1 small illustrations from ESR 2003 are used to identify the hydrological changes revealed in the modelling and to give a possible time frame for when the maximum impacts may have occurred – namely, 2005 through 2007. However, by using the limited information in AERs 2003 through 2012, the analysis in Section 3.2 shows that the period 2005 through 2007 was relatively dry and that hydrological impact may have been delayed, perhaps as late as 2009/2010. Moreover in the AERs 2009 through 2012, apart from general references to increased rainfall, the company does not indicate there was any condition change within the Ibis Lagoon system. As outlined in Section 3.3, this 'silence' is in contrast to company personnel and consultants who, in reference to proven and measured discharges over at least 10 months at the Yarraman Mine (in the northeast of the island), have pointed to natural rainfall as the agent to blame for excess water emerging from the mine

[4] In this setting "littoral" refers to the peri-lacustrine sub-aerial zone (of a lake, lagoon or swamp) that is exposed over the long term as the surface water level fluctuates between its low- and high-water extremes.

operations in 2012/2013. Indeed, one employee identified above-average rainfall in 2011/2012 as contributing to condition change in the form of "vegetation death from immersion" at many locations across the island.

In Section 4 conventional aerial photo interpretations (APIs) of Nearmap imagery captured at three different times in 2010 provide the bases for a systematic exploration of how best to account for the marked condition change in the Ibis Lagoon system. Nearmap images for 27 January, 6 May and 16 September 2010 are reproduced here at three different scales in photomaps collected in Appendix 1. In Section 4.1 the APIs, presented as photomaps at the three scales in Photomaps 1 through 10, are combined as one description at each date. My emphasis in the aerial photo interpretations is on identifying the features of the main land cover characteristics and making comparisons with photo-patterns in other relevant imagery in the time series. Photomap 11 (Appendix 1) shows the 'terrain' of the Ibis Lagoon system (after processing the 16 September 2010 imagery via Nearmap procedures) and this view gives an important perspective of the topographically constrained extent of the conditional change highlighted in blue and measured in Photomap 12. The descriptions of each photomap, based on API and measurements of the condition change in the 6 May 2010 image are integrated and given special attention in Section 4.2. The three 'snapshots' taken over a period of almost 8 months are sufficient to provide a consistent explanation that accounts for: the death of leaves and stems at this time in 2010; a recovery, at least in part, of the damage within the 95 ha area of impact; the contribution of weather conditions, especially rainfall; and, the spatial restriction of damage to low-lying parts west of the Enterprise operations.

I outline in Section 5, Preliminary Conclusions, that the damage in 2010 of at least 95 ha in the Ibis Lagoon system, or about 80 ha to the Moreton Bay Ramsar Wetland, was probably caused by excessive immersion of sedgelands and terrestrial vegetation. The flooding was most likely caused by excess water draining from the tailings being stacked on the western side of the Enterprise Mine. I propose that the water-based impacts in 2010 occurred despite experience and knowledge of past environmental damage associated with the operations of the Ibis-Enterprise Mine, especially the flooding on the western side of the Ibis Lagoon system in 2000/2001 from the Ibis Mine. I also indicate that such ecological impacts should have been avoided, given the company's expertise and support by consultant's specialist reports and advice for best-practice water management. The significance of these impacts to this part of the Moreton Bay Ramsar Wetland, under the EPBC Act, are summarised in Section 6.

My declaration to the court required by the Federal Court's Practice Note for expert witnesses is provided in Section 7. References and other cited documents are listed in Section 8.

2.0 History of Mine-Water Discharges from Ibis Mine

In Section 2 I provide a summary of previous incidents of mine-water discharges from the Ibis Mine as they occurred in the late 1990s through to the early 2000s. The purpose is to show that discharges are not uncommon from these mine operations which commenced in 1996 as the Ibis-Alpha Mine, became the Ibis Mine and thence morphed into the Enterprise Mine. As the operations migrated west and south around the Ibis Lagoon system the mine-sourced discharges affected Ibis Lagoon West by flooding into the subsurface aquifer and also disrupted sections of the escarpment facing Moreton Bay. This history of mine-sourced damage is relevant to assessing the more detailed descriptions (Section 4) of condition change observed in 2010 but elsewhere in the Ibis Lagoon System as the (Ibis-) Enterprise operations once more returned, this time on the east.

2.1 Impacts of Mine-Water Discharges from Ibis Mine prior to May 2000

2.1.1 Forecasts of Potential Discharges

The Ibis Mine (initially known as the Ibis-Alpha Mine) commenced operations in late 1996. Following good pre-mining practices and apparently anticipating the need for timely advice about the potential for mining to have impacts on groundwater and surface water bodies[5], CRL engaged Golder Associates to prepare a report. Golder Associates Pty Ltd (1994) identified several water bodies of interest including "Black Snake Lagoon, Ibis Lagoon, an un-named [Southern] lagoon further to the south, … two lowland areas ,… one area of heath vegetation …[and] an adjacent area of swampland to the west." The consultant provided advice on water management to prevent impacts on the identified water bodies, especially damage through destruction of subsurface aquitards that provided conditions for perched aquifers. Golder Associates also referred to options in changing mine path alignments and elevations to achieve objectives in water management.

Some of the water bodies identified in this 1994 report were later given refined or new names, (e.g. Ibis Lagoon is now Ibis Lagoon West). As well, Quandamooka elders later applied "Jaragill Lagoon (Swamp)" to the loosely designated "Southern Lagoon", located to the south of the Ibis-Enterprise Mine path. Together with the two lowland areas A and B and the area of heath vegetation these sites were considered as being potentially affected by mine-sourced waters, some not for another 10 years or so according to mine planning. However, although these sites are *not* within the Ibis Lagoon system, and are not considered further in this preliminary review, they are listed here to indicate that a consultant gave professional advice in 1994 about potential impacts of the Ibis (- Enterprise) Mine.

Despite this consultant's advice and CRL's sensitivity to mine-related discharges of water and unknown ground conditions, the company made no changes to the mine path near Ibis Lagoon (West). With the prospect of the company's lack of response, one example of interested non-company attempts to improve environmental protection occurred in July 1996. At this time, and before mining commenced, Quandamooka Land Corporation (QLC 1996) raised concerns with the Queensland Department of Mines and Energy that:

> … [CRL officers had confirmed] the mine path has not been altered adjacent to Ibis Lagoon since the Golder Associates report of December 1994. … Accordingly the risk of seepage occurring at Ibis Lagoon as identified in the Golder Associates report remains. Golder Associates assessed that risk as being a "possibility"; however, our consultant Dr Errol Stock considers the risk of seepage to be substantially greater, to the point of being a "probability". …

In an Order to Comply[6] dated 6 November 1996, issued by the Queensland Department of Mines and Energy, CRL (operating as Stradbroke Rutile Pty Ltd) was required to "undertake an independent hydrological assessment of the entire Ibis-Alpha deposit and to review the Ibis-Alpha mine path based on this assessment to be completed by 28 February 1997". Subsequently, A.J. Peck and Associates Pty Ltd (1997) conducted a review using two independent models and, inter alia, included (executive summary) predictions (page iii) that:

> [1.]… [There is an area of] potential seepage on the south-west fringe of Black Snake Lagoon, developing in June 1997. Without suitable control seepage is predicted to extend to encompass essentially all of Black Snake Lagoon by December 1998.
>
> [2.] Potential seepage is also indicated in the north-east of Ibis Lagoon [West] developing in June 1998 and extending across the northern section of this lagoon by March 1999.
>
> [3.] Some potential for increased seepage is predicted for the western scarp[7] of the dunal system, particularly in a valley which trends towards the proposed location of the dredge pond in June 1998. However, part of this valley is scheduled to be mined in the future. ...

[5] Consider two examples of different impacts: Since late 1987 CRL had been involved in attempting various remediation techniques for the *draining/drying out* of Lake Kounpee as a result of activities associated with the Bayside Mine. At the Gordon Mine, mine-sourced discharges had *flooded* Native Companion Lagoon commencing in 1988 and continuing to 1996.

[6] This Order to Comply applied to the Ibis-Alpha Mine was primarily prompted by water discharges and slope failures associated with the Gordon Mine (well to the south) and also included a direction "to undertake an independent hydrological assessment of the present and future mine areas of the Gordon Mine…" A.J. Peck and Associates Pty Ltd (1997) issued a separate report for the Gordon Mine.

[7] This potential seepage site would be on the *opposite* side of the reconstructed dune to that of the other possible seepages to Black Snake Lagoon and Ibis Lagoon [West]. Because the dredge would be heading south at this time this side is also referred to as "starboard".

Based on these 1997 forecasts it is evident that, soon after the Ibis (-Alpha) Mine commenced operations, CRL received definitive advice of potential discharges from the Ibis Mine and at several locations over the 2-year period to March 1999. The consultants, A.J. Peck and Associates, were clear in their report that water management was going to require attention and would involve a review of the proposed mine path and require close monitoring of groundwater. They were confident that (page iii) “[s]eepage can be prevented and water recovered by pumping from sumps, spear points and/or sub-surface.”

As the Ibis Lagoon system is the focus of this preliminary review no expanded comments are made here about the forecasts and outcomes for mine-sourced waters to enter Black Snake Lagoon (Item [1.] above), about 2 kilometres to the north. However, in passing, it is relevant to note that CRL’s efforts to prevent impacts on this lagoon appear not to have been fully successful. Unimin/Sibelco consultant GEO-ENG (2010 p11) noted that: “From 1996 to 1999, the water level [in Black Snake Lagoon] was likely effected [*sic*] by seepage from [Ibis] mine tailings...” In contrast, when reporting on the perched lakes investigation in its AER 2010, Sibelco Australia Limited (2011 p19) apparently disagreed with this consultant by stating: “Ibis Mine and Bayside Mine were investigated for any potential harm to Black Snake Lagoon. … The data suggest there is no evidence of any mine impact on Black Snake Lagoon”.

The Peck and Associates forecast of potential flooding from the Ibis Mine into Ibis Lagoon (West), especially at the northern end, during the period June 1998 through March 1999 (as expressed in Item [2.] above), was not realised until a little after the specified period. Flooding of Ibis Lagoon West is summarised in Section 2.2 of this preliminary review because of its relevance to mine-sourced discharges from the (Ibis -) Enterprise Mine.

2.1.2 Impacts of Actual Discharges on the Western Scarp

The Peck and Associates’ Item [3.] forecast of increased seepage *on the western scarp* was later confirmed. Two sites of discharge with associated slope failures occurred in late 1999 and early 2000. The circumstances of environmental disturbance at these sites were reported by CRL in various formats, including the AER 1998-1999 (CRL 2000a pp 5-99, 5-100 and 5-102) and I visited these sites[8] and provided observations (Stock 2000) to QLC/QALSMA. A brief summary follows of these slope failures on the western side of the dune — that is, *not* on the eastern slope facing into the Ibis Lagoon system.

In late October 1999 a slope failure occurred on the lower slope of the west-facing sand-based escarpment opposite what was then a main tailings area of the active Ibis Mine. In November 1999 the discharge of mine-sourced waters close to spear bore IS14 led to a slump of sand into the nearby coastal swamp and the death of some vegetation over a small area. The water via the subsurface from the mine was still flowing to the surface during the May 2000 inspection. In its AER 1998-1999 CRL (2000a, pp. 5-101 to 5-102) referred to this slope failure as the “Ibis groundwater seepage/discharge/blowout” and classified it as a Level 4 incident.

In February 2000, following a power outage caused by a failure in a bundled power cable, groundwater levels rose and the gradient increased on the watertable. Before the usual dewatering conditions could be restored the natural slope failed to the south and north of the October 1999 “blowout” (Ibis spear lines IS12 to IS14A and 14B). Maximum movement of the toe of the dune on the south was over about 100 m and a translocation about 1 m toward the west. As well as the explanation that “no one could have foreseen the power outage” company personnel (CRL 2000b) also suggested other factors of “special ground conditions (indurated B horizon) and commitments to mine paths prepared much earlier by another employee” were involved. As I reported in Stock (2000) the slope failure on the north involved a sand slide some 150 m long and the dune toe had moved westward about 2 to 3 m. There was an associated loss of vegetation as well as the development of “rough ground” backed by a scarp about 2 m high. CRL had to rearrange the dewatering spear line because many of the spears had been rotated from their vertical position.

[8] Site visits 23 November 1999, 18 May 2000 and 12 August 2000.

Thus within three and a half years of starting the Ibis (-Alpha) Mine, CRL's operations, especially water management, had led to conditions of mine-water discharges to the subsurface (with consequent slope failures on the *western* escarpment). Such problems had been predicted by the consultant Peck and Associates (1997). Unfortunately these were soon followed by mine-water *discharges into the Ibis Lagoon system*; these, too, had been forecast by the consultant.

2.2 Mine-Water Discharges into Ibis Lagoon System from Ibis Mine in 2000

2.2.1 Brief Summary of Events and Formal Actions

CRL personnel first noted surface expressions of ground water from the Ibis Mine on 24 May 2000. This flooding or 'day-lighting' at the surface was off-lease, on the eastern slope *facing into Ibis Lagoon system* and at an elevation higher than that of Ibis Lagoon West; there was no flow of free water from the mine across the ground surface. By 15 June 2000 the surface water level in Ibis Lagoon West was also increasing at a rate faster than the water level in other water bodies that CRL was monitoring, including that for Ibis Lagoon Central[9]. Subsequently a CRL study (CRL 2000c) established that the mine waters were discharging into the subsurface from tailings along at least a 300-metre-long front. It is important to note that the discharged waters originated on lease but were directed off-lease and eastward into the Ibis Lagoon system by a subsurface aquitard.

CRL commenced additional groundwater management actions[10] on 8 July (CRL 2000). The company provided an Incident Notification on 25 July. This notification was for the subsurface discharge resulting in changes to the Ibis Lagoon West water level as required under CRL's EMOS Section 4.4.3 *Water Monitoring Programs* and Section 13.1.2 *Notification of Emergencies and Incidents*.

Because the DME agreed on the effectiveness of the company's control measures an approved and revised tails-stacking plan formally allowed the Ibis Mine to return to full production on 31 August. Belatedly, the DME (Minister for Mines and Energy) issued a *Notice to Show Cause* for Mineral Lease 1121 on 1 September 2000.

2.2.2 Associated Patterns of Water Levels in Ibis Lagoons

On 24 May 2000, when the mine-sourced discharge was first noticed coming to the surface off-lease[11], the water level in Ibis Lagoon West was at about RL 27.97 m (AHD). This level was close to the lowest point of a seasonal decreasing trend. On 21 July, just before CRL made the Incident Notification, the surface water level was at RL 28.39 m. The lagoon eventually peaked[12] at RL 28.52 m on 15 August before, through company actions and natural drainage, there was a slow reversal of this impact of mine-induced flooding. The mining company records show that it was not until mid-November 2000 that the water level in Ibis Lagoon West returned to about RL 28.4 m and not until May/June 2001 before it returned to about RL 28 m as it was when the 'day-lighting' groundwater was first noticed off-lease.

Plots of CRL's record of *monthly* water levels for Ibis Lagoon West over the 10-years 1990-through-1999 provide reference patterns of surface water movements in the lagoon. The well-known seasonal fluctuation of water level, common to many water bodies on North Stradbroke Island, is evident and within a general trend of declining water levels to early 1995 followed by increasing levels. Plots of CRL's record of monthly water levels for Ibis Lagoon West over the 5-years 1999-through-2003 provide information to track the impact of flooding by mine-sourced waters. Of particular interest is the trend of a steadily decreasing water level, especially in the

[9] What is now termed Ibis Lagoon West in Sibelco's AERs was, in 2000, simply Ibis Lagoon or Ibis Lagoon (west). The "Central" in Ibis Lagoon Central was added later for clarity. Comments here on surface water levels are based on both CRL documents (CRL 2000c) and on data supplied by CRL.

[10] These measures by CRL included: the installation of a line of groundwater spears along the eastern lease boundary to extract discharge water from entering the subsurface zone above the aquitard; reduced times of stacking tailings so that the local groundwater would be directed below the aquitard; and, reduced production of minerals to assist with options for tailings management.

[11] This area was later informally referred to as Beehives and became a site for water sampling.

[12] According to CRL (2000c) the known maximum pre-mining natural level of RL 28.59 m was recorded in May 1989.

pre-March 2000 and post-September 2001 period. By my assessment the data and plots suggest the addition of mine-sourced discharge waters *via the subsurface* to Ibis Lagoon West may have commenced as early as March/April 2000 and the pre-flooding natural trend[13] was not resumed until about September 2001.

To summarise: The addition of waters from the Ibis Mine operations, that is the *mixing of mine-sourced drainage and natural groundwater in the subsurface* and appearing as an un-natural rise in the water surface of Ibis Lagoon West, probably lasted almost 18 months before the water levels returned to the pre-disturbance trajectory. Although the highest flooded level of RL 28.52 m was about 7 cm short of the known natural maximum for this lagoon the period of inundation was longer than the mid-year peak normally experienced seasonally in these perched lakes.

2.2.3 Known and Likely Environmental Impacts

The addition of these excess waters from the Ibis Mine in 2000/2001 generated different impacts according to where and when the waters interacted with terrestrial and aquatic environments. A range of impacts occurred in the terrestrial areas higher than Ibis Lagoon West where the waters emerged or 'day-lighted' after their passage in the subsurface. One impact was in terrestrial areas at elevations above that normally inundated by natural increases in the lagoon. Other impacts were generated in the terrestrial areas around the variable littoral margins of the lagoon as a direct response to an increased surface water level. Within the lagoon there may have been some effects on aquatic plant and animals.

Mine-sourced groundwater, rising to the surface at a distance and higher elevation from Ibis Lagoon West, created over-wet soil conditions within the mining lease as well as off lease. According to a consultant's report (Resource Strategies 2000) and company documents (CRL 2000a, 2000c) the excess water for at least 3 months killed terrestrial vegetation (heathland with large banksias) over several hectares. The mechanisms of vegetation death through inundation are summarised in Section 2.3 below.

In the lower northern margins of Ibis Lagoon West a heathland re-establishing after a fire in the early 1990s was partly submerged by the rising lagoon waters but with limited loss of plants (CRL 2000c). With respect to plant species in this fluctuating ephemeral zone "the primary melaleuca and reed plant species surrounding and within the lagoon are not expected to be influenced by the elevated water levels" (CRL 2000c).

Preliminary advice (CRL 2000c) from a consultant (WBM Oceanics Australia) on potential impacts in the aquatic environment of Ibis Lagoon West was that:

> a short-term increase in water level is unlikely to adversely affect the aquatic invertebrate fauna. This is because the increase in water level is similar to that experienced by the lagoon under normal seasonal conditions i.e. the lagoon experiences a seasonal peak in water level during mid-winter. The growth and reproduction of the aquatic fauna will have evolved to respond to the seasonal changes in water level. However, a prolonged lagoon water level at or near the seasonal peak may disrupt the growth and reproduction of the aquatic fauna.

Based on my analysis of detailed surface water-level records provided by CRL the mine-induced flooding possibly lasted 18 months, and would be considered a "prolonged period" beyond a 'normal' mid-year peak. This incident which generated a Show Cause notice from the regulatory authorities was noted in the company's AER 2000 and prompted the Resource Strategies' (2000) report. However, it appears that no detailed follow-up study was conducted to give a full report of associated environmental impacts on the terrestrial vegetation, the terrestrial-littoral vegetation, or the lagoon's flora and fauna.

2.3 Mechanisms of Terrestrial Vegetation Loss through Inundation

The mechanisms of vegetation losses through inundation by water are well known from the extensive literature on impacts of natural and human-made flooding of agricultural crops and natural ecosystems. The extent of

[13] Several rainfall events with falls up to 36.5 mm have been accounted for as adding *natural* waters to the lagoons.

vegetation losses depends primarily on the length of inundation and the quality of the flooding waters. If the flooding is relatively short lived, say a week, many plants are able to resist major problems, though this may depend on the type of supporting soils. As water logging persists the vegetation first loses leaves, and soon root-death occurs followed by death of the whole plant in the extreme. Silt-laden waters can be particularly injurious and inundated lands may require extensive rehabilitation.

The progression of overlapping events that follow with extended saturation of a soil generally can be summarised as: expulsion of essential gases (air) as water infiltrates and fills pores and interstices; death of root hairs; increase in anaerobic bacteria (and complementary reduction in supportive micro-organisms); death and shedding of leaves; loss of nitrogen nutrients; increase in soil acidity; full death of root systems; death of plants.

As already described in Section 2.2, based on the company's and their consultant's reporting of impacts associated with flooding and inundation on the west and north of Ibis Lagoon West (CRL 2000a, 2000c; Resource Strategies 2000), at least several hectares of more elevated terrestrial heathland were killed and the heathland stressed by earlier fires in the lower northern margin experienced additional losses. While the full tally of impacts remains unknown the mechanisms of death through inundation would have been as summarised in this section.

3.0 Potential Impacts of Enterprise Mine on Ibis Lagoon system

In the ESR 2003 CRL made no direct statements about potential impacts of Enterprise Mine on the Ibis Lagoon system because the focus of the company was almost wholly on Eighteen-Mile Swamp and the escarpment. The company's thrust was to downplay any concerns about the type and size of potential impacts including: sand slips; the loss of vegetation on the escarpment caused by groundwater coming to the ground surface (so-called 'day-lighting'); and, the size and duration of the expected elevation of surface waters in Eighteen-Mile Swamp as groundwater discharged into the swamp via base flow suffused with mine-sourced waters.

With respect to *water quantities* expected to be released from the Enterprise Mine pond and tailings there are illustrations in the ESR 2003 (Figures 4-2 through 4-11) showing "Predicted Water Table Effects" of the Enterprise Mine that are accompanied by some simplified and incomplete discussion of the relevance of these diagrams to groundwaters and surface waters to the *east* of the mine. However, there was no discussion of the connection between the subsurface hydrology and any predicted effects to the *west*, the location of the Ibis Lagoon system. With respect to the *changes in water quality* associated with the discharge of mine waters, and the mixing of these waters in the subsurface, the company essentially denied that changes of water quality could be of significance because, it claimed, waters would be purified by filtration through the sand pile[14].

My aim in Section 3 is to establish context for assessing the condition change observed west of the Enterprise operations in the remote sensing imagery for 2010. In Section 3.1 I use illustrations from parts of ESR 2003 to suggest likely hydrological changes and timing. In Section 3.2 I refer to relevant extracts from the company's AERs 2003 through 2012 for any reports of condition change in monitored values and other environmental attributes such as vegetation; details of these summarised extracts from ESR 2009, 2010 and 2011 are available in Appendix 2. I also discuss natural rainfall (Section 3.3) as a potential factor in mine-sourced discharges.

3.1 Hydrological Changes Identifiable in ESR 2003

Based on CRL's estimates used in the revised hydrological model, run-of-mine water discharges from the Enterprise Mine were forecast (ESR 2003 pp 4-16 and 4-15) to be 15 ML/day (roughly 6 Olympic swimming

[14] This claim appears to be contradicted by WBM Oceanics Australia's preliminary results of detailed monitoring in Ibis Lagoon West (reported in Resource Strategies (2000) pp22-23). The consultant reported that data from two stations in the Lagoon during September 2000 revealed the input of mine-sourced groundwater as based on comparisons of values for pH, dissolved oxygen, conductivity, iron and silica.

pools[15] per day) from the dredge pond and 27 ML/day (about 10.8 Olympic swimming pools per day) from the tailings. This forecast indicated that up to 42 ML/day (about 16.8 Olympic swimming pools per day) of extra water would need to be accommodated in the subsurface sandmass. In neither the ESR 2003, nor the later AERs, did the authors specify exactly how a descending and expanding 3-D plume of discharge waters would intrude into and interact with the natural aquifers (unconfined and perched). Certainly, they gave no specific attention or concern to how the relevant parts of the mine-sourced discharges could or would affect the Ibis Lagoon system to the west of Enterprise operations.

The ESR 2003 did include ten (10) illustrations (Figures 4-2 through 4-11) to accompany the text and they allow some very rough measures of the size and location of the predicted mine-generated groundwater mound. These figures should be read in conjunction with ESR 2003 Figure 3-11. Attachment 2 of this review is a critique of the original figures from the ESR 2003 in which it is clarified that the isolines ('contours') of the left-hand map of each pair are actually isopachs indicative of water 'thicknesses.

Figure 4 of this review is a reproduction of Figure 3-11 from the ESR 2003 and it shows the general trends of interpreted groundwater contours in a *whole-island* view. The blue arrows indicate the most likely directions of groundwater flow. Because the bores at the southern end of the Redland Shire Council water extraction field are plotted in both Figure 4 and Figure 5 they can be used to locate the general positions of the main island groundwater divide and the mound of mine-discharge water as predicted by modelling. The solid-line rectangle in Figure 4 marks the boundary of that part of the island shown in Figure 5, which is a reproduction of Figure 4-5 of ESR 2003.

From a comparison of ESR 2003 Figure 3-11 for the whole island with Figures 4-2 through 4-11 it is apparent that the Enterprise Mine, and its impact on the local groundwater mound and watertable, occur almost entirely to the east side of the natural prime groundwater divide. Nevertheless, by June 2004 (ESR 2003 Figure 4-3) the CRL forecast, as indicated by isopach contours and water table elevation, shows an involvement with the Ibis Lagoon system. The subsequent maps (ESR 2003 Figures 4-4 through 4-11) suggest a potential for: an increasing then a reducing influence of mine-sourced discharges during June 2005 through June 2012; a maximum involvement, across most of the Ibis Lagoon system, from about June 2005 through June 2007. Figure 5 of this review shows the predicted changes in groundwater as in May 2006 (ESR 2003 Figure 4-5), a good representative from within the forecast over the 2005 to 2007 period.

[15] FINA specifies an Olympic swimming pool (OSP) as 50 m * 25 m *2 m (min depth) and this volume of 2.5 ML is also that used by Bureau of Meteorology. However, until very recently some agencies (e.g. Sydney Water) regarded an OSP volume as 1 ML.

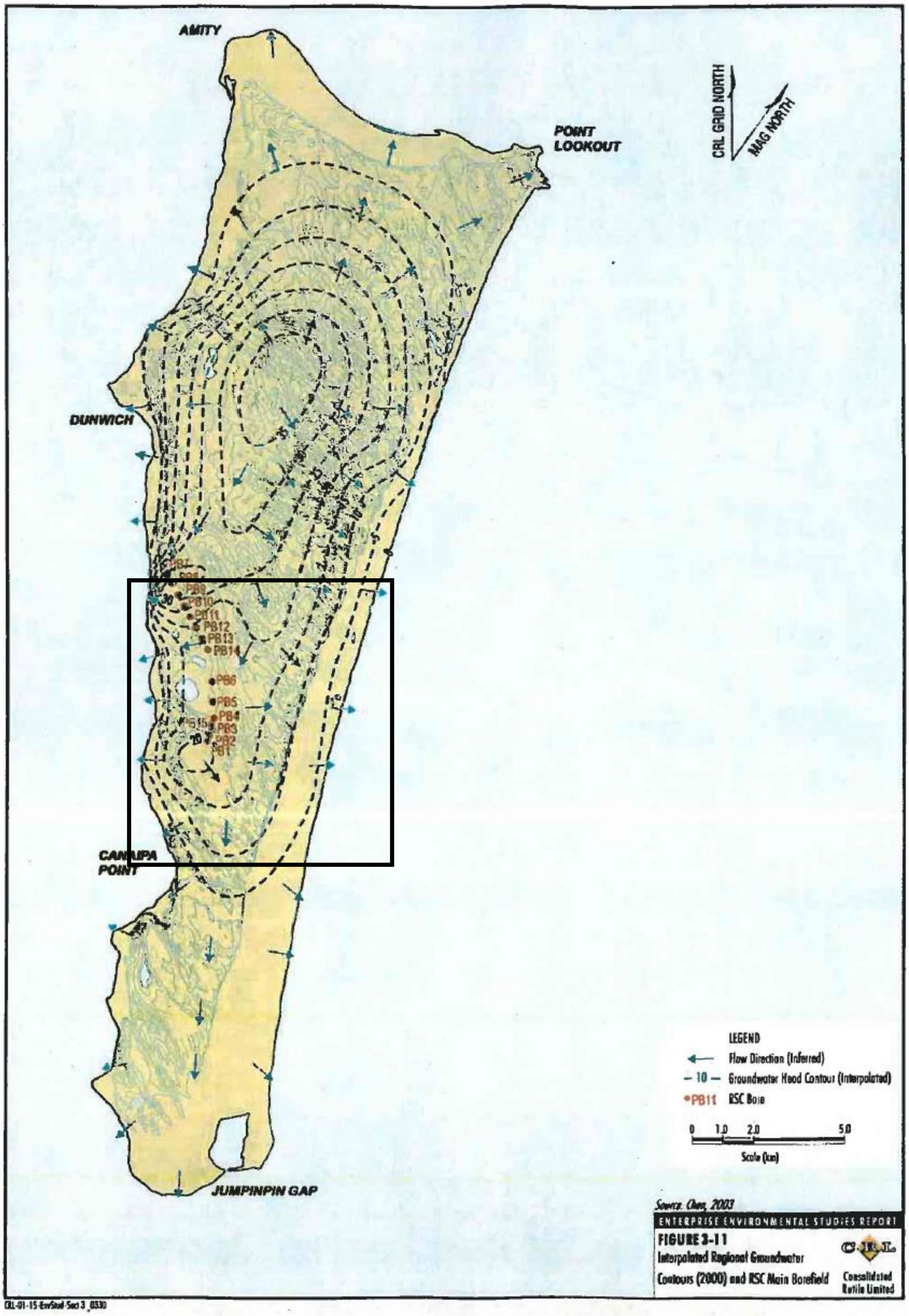

Figure 4: Interpolated Regional Groundwater Contours. Box shows the area of the island illustrated in each half of Figure 5. (Base Map Source: Figure 3-11 in ESR 2003)

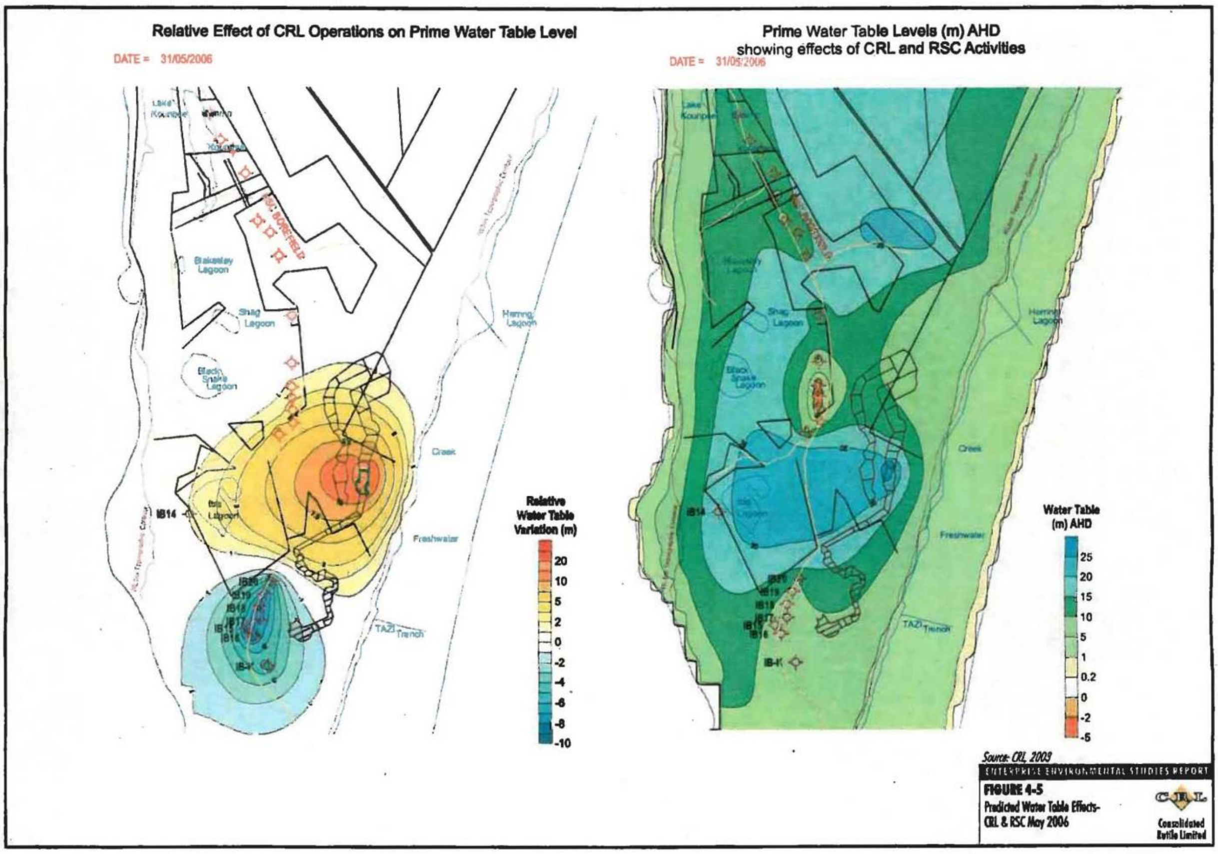

Figure 5: Predicted Changes in Groundwater near Enterprise Mine in May 2006 (Extracts from ESR 2003 Fig. 4-5)

Although the predictions from the modelling indicated the potential for mine-sourced discharges from the Enterprise operations to generate impacts in the Ibis Lagoon system, CRL did not explore these matters. Rather, via its risk assessment procedures in the early 2000s, the company excluded the Ibis Lagoon system from specific monitoring for impacts from the Enterprise Mine[15]. Whatever the reason(s) for excluding the Ibis Lagoon system from targeted monitoring, the company has not presented specific data or interpretations, in the ESR 2003 or later AERs[16] of any potential impacts to the west from the mine operations. No explanation of why this occurred is available in ESR 2003. Perhaps, for example, the company considered its spearlines and bores to the east of the wetland system could intercept any mine-sourced discharges moving to the west from the Enterprise operations, as stated in AER 2003 pp5-16 to 5-17). Exclusion of the Ibis Lagoon system from all but basic consideration is difficult to understand, especially when in 2003 the evidence of impacts from mine-sourced discharge from the Ibis (-Enterprise) Mine in the late 1990s and early 2000s was well known, and is summarised in Section 2 of this review.

Despite the mining company's shutdown and silence about potential links between Enterprise Mine and the Ibis Lagoon system, aspects of surface water levels and water quality in the main lagoons were included in abbreviated form in the AERs prepared for reporting years 2003 through 2012. These are considered in Section 3.2 following.

[16] Of course, as discussed in Section 3.2, the mining company did publish some limited graphical plots and interpretations about the two Ibis lagoons in the AERs; but this was under the long-standing heading "Water Quality Results – Ibis/Enterprise" and were not specifically related to Enterprise operations as, for example, are the values for the Enterprise station on the western edge of Eighteen-Mile Swamp.

3.2 Data and Information in the AERs 2003 through 2012

In my earlier preliminary review with a focus on Eighteen-Mile Swamp and the escarpment (Stock 2012) I explored, in part, the shortcomings of the company's approach in these matters of monitoring water quantities and quality. Although I do not revisit these aspects in this preliminary review about the potential for water discharges to the Ibis Lagoon system it is still relevant to examine the significance of Figures 4-2 through 4-11 in ESR 2003 and the limited information in the company's AERs.

Section 3.2.1 is a four-point summary of the basic and limited character of data and information about water quantity and quality in the company's AERs 2003 through 2012. In Section 3.2.2 I narrow the focus and consider selected extracts from AERs 2009, 2010 and 2011 so as to set the scene for interpreting the condition change observed in 2010. Details of the extracts sourced for the discussion in Section 3.2.2 are available in Appendix 2.

3.2.1 AERs 2003 through 2012

During the period 2003 through 2012 CRL/Unimin/Sibelco issued Annual Environmental Reports of variable and generally decreasing quality. (Because CRL chose to locate some incomplete data for 2000 through 2002 in AER 2003 I note this for completeness not for relevance to the review.) For the Ibis Lagoon system several summary points can be made about the nature of the data and information available in the AERs, including:

1. Appendix D in AER 2003 contains numerical data tables of monthly surface water levels and monthly water quality (acidity (pH) and electrical conductivity but not turbidity) over the years 2000 to 2003. With respect to water levels there is an almost complete record for the 2-year period January 2000 through December 2001 for Ibis Lagoon West but only limited data for 3 months in 2003; there are no data for 2002. The data for Ibis Lagoon Central is much more restricted: 11 months in 2001, 4 months in 2003. Figure 17b in AER 2003 has plots of water level variations for each lagoon: late 1988 through to mid-2003 (gap for 2002) for Ibis Lagoon (West); 2001 and mid 2003 for Ibis Lagoon Central. Figure 18 illustrates with expanded attribute scales the variations in water level, pH, electrical conductivity and turbidity for Ibis Lagoon (West). Appendix D also contains (apparently incomplete) data for a variety of attributes relating to *quarterly* geochemical sampling in: July 2001, December 2001 and January 2002 for Ibis Lagoon (West); and, July 2001, October 2001 and July 2003 for Ibis Lagoon Central. (The AER 2003 also refers to the existence of two studies[17] in the area of the Ibis lagoons: Ibis Mine Terrestrial flora study and Ibis Mine aquatic flora study.)

2. In AER 2004 a table (p11) has only one result for the surface water level for Ibis Lagoon Central in March 2004. The text (p1) refers to missing data from all tables as "due to insufficient water being available or due to equipment failure". Numerical data for electrical conductivity and turbidity are reported only for Ibis Lagoon Central (except for some missing values) and also these are illustrated as temporal variation plots on page 4. There are no data or illustrations of attributes for Ibis Lagoon West. Presumably there was generally sufficient water in Ibis Lagoon Central in most months to measure these attributes so it is surprising no pH data are presented to complement those for conductivity and turbidity. Appendix 1 of AER 2004, records data of Quarterly Geochemical Results for several monitoring stations in October 2004, but no values are presented for the Ibis lagoons. The text explains that data for July 2004 are not presented due to closure of the DNRM Laboratories and the October 2004 samples were analysed by Simmonds and Bristow. No data were presented for expected quarterly sampling in January and April 2004.

[17] Lewis Environmental Consultants (1995) had prepared an earlier flora and fauna survey: "Ibis-Alpha Mining Operation North Stradbroke Island: Flora and a Survey of Four Areas" Consultant report to CRL, June 1995.

3. None of the AERs from 2005 through 2012 provide numerical data or graphical plots of monthly water levels[18] in any Ibis Lagoons or observation bores to the west of the Enterprise operations. Temporal variations in three water quality attributes, namely pH, electrical conductivity and turbidity, are presented as graphical plots[19] with various relevant "triggers". The company makes no direct comments about impacts that might have been anticipated on water levels from reference to Figures 4-2 through 4-11 in the ESR 2003.

In summary, there are some useful numerical data in the AERs, especially for the period 2000 through 2004. However, it is disappointing the company did not continue this practice. While the AERs from 2005 and later contain graphical plots and variable and limited comments on the water quality (monthly pH, conductivity and turbidity) of the Ibis lagoons, they provide no specific data or information on surface water levels. This shortcoming significantly restricts what comments can be made about the hydrology of the Ibis Lagoon system for the period 2005 through 2007 that was predicted in ESR 2003 to be of heightened significance (Section 3.1 this review). It is equally restrictive for 2010, the year of interest for this review (Section 3.2.2. and Section 4).

The AERs do show that the Ibis lagoons contained relatively little water prior to 2008

3.2.2 Changes Identified in the AERs 2009-2011

Despite the company's restricted statements and absence of data in the AERs, as indicated in Section 3.2.1 of this review, some indirect information on water levels may be gauged from them, albeit in a limited way. The summary in Section 3.2.2 refers to the more detailed analysis of extracts about water quality attributes from AERs 2009, 2010 and 2011 as presented in Appendix 2. Only the transcripts from these three years are presented in Appendix 2 because of their relevance to exploring the evidence for condition change in 2010.

The ESR 2003 Figures 4-4 through 4-6 indicated the two-year period June 2005 through June 2007 had been forecast to be associated with a time of maximum exchange in mine-sourced groundwater into the Ibis Lagoon system. However, as already recorded in Footnote 18, the reports in AERs for 2005 through 2007 pointed out that there were overall dry conditions in Ibis Lagoons West and Central[20]. Consequently no verbatim extracts from these earlier AERs are presented in this review.

The extracts in Appendix 2 relate to the water quantity and water quality aspects of Ibis Lagoon Central and Ibis Lagoon West as formally published in AERs 2009, 2010 and 2011. With respect to water *quantity* they are unable to provide the public with explicit information about the variation in surface water levels because the AERs contain neither numerical data nor graphical plots of this basic attribute.

With respect to water *quality* in the Ibis Lagoons the AER extracts (Appendix 2) show the record for three water quality attributes obtained during monthly monitoring for pH, electrical conductivity and turbidity. However, their focus is on a specific year and monthly variations, along with standard procedural references to means, maxima, and minima, and to 80th and 20th percentile triggers. The AER authors make no reference to longitudinal trends. For 2010, the year with condition change evident in the photomaps of the Ibis Lagoon system, they offer only basic and simple explanations for different trends in the water quality attributes, relating them to variations in natural weather elements such as rainfall and wind conditions.

[18] CRL's footnotes for graphical plots in AER 2005 (pp 52 and 53) indicate, respectively, "Ibis [Lagoon] Central was dry prior to June [2005] and, "Ibis Lagoon West was dry prior to June [2005]". Some later AERs also refer to difficulties in obtaining samples/results. In contrast, because the water quality attributes are presented fully in the plots for 2006 it is evident there was sufficient water for sampling in 2006, yet CRL did not provide surface water level data.

[19] I have used these graphical plots to interpolate and extract approximate numerical values to generate a data set for my analyses and interpretations.

[20] CRL (AER 2007 p82) stated that "Ibis Lagoon and Ibis Lagoon Central had intermittent sampling throughout the year due to insufficient surface water for sampling. As a result, the increase in pH levels above the maximum trigger in June and November for Ibis Lagoon was thought to be the results of temperature caused by the limited surface water, and as such were considered to be of low risk".

Thus indirectly, and in a very general way, the text about water quality in AER 2010 implies there were some changes in water volumes in both Ibis lagoons. This is not definitive, such as an explicit statement of specific quantitative changes in surface water level would be. Rather, it must be inferred from the company's explanations for changes in (say) pH values being due to "natural variations most likely from the high rainfall received through the year and the elevated water levels within Ibis Lagoon Central (p86) and "rapid increase/decrease of water levels due to rainfall [into Ibis Lagoon West]" (p86).

Nothing can be recognised in AER 2010, nor in the earlier (2009) and later (2011) AERs, as a statement that the company detected mine-sourced discharges entering Ibis Lagoon West, or Ibis Lagoon Central, or anywhere else in the system. Nor do the AERs contain any comment about vegetation condition in the Ibis Lagoon system, although this was done in some detail for vegetation on the escarpment east of Enterprise operations as I discussed in Section 6 of Stock (2012). If CRL had wished to define a condition change in the Ramsar wetlands of the Ibis Lagoon system during 2010, then AER 2010 would have been one logical and expected place for such a report.

Another important and overarching observation is that in all the AERs the company accepts it is appropriate to make comparisons with temporal variations in the water quality attributes from the monthly sampling of other water bodies, such as "water bodies outside the 'zone of impact', but still within the Ibis Mine complex" (AER 2010 p86) and "other reference water bodies … outside the 'zone of influence' of mining activities" (AER 2011 p85). For this review, where I make observations in Section 4 about condition change in the Ibis Lagoon system, it will be consistent with established company procedures to make comparisons with other North Stradbroke Island water bodies and wetlands.

3.3 Rainfall as a Factor in Mine-Sourced Discharges

As already noted, the extracts from AER 2010 reveal the company's preference for linking changes in water quality attributes with natural variations in, say, rainfall. Yet the occurrence of "high rainfall throughout the [2010] year" (AER 2010 p86) did not make it special because the company explained variations of pH in 2009 in a similar way: "… The minor variations in pH above the 80^{th} percentile trigger [for Ibis Lagoon Central] are thought to be a result of natural variation most likely from the high rainfall received through the year" (AER 2009 p93). Clearly for the company releasing the AERs to the public, there was nothing to distinguish the rainfall (total, intensity) in 2010 from that in 2009. The following comments, drawn from recent (i.e. 2013) correspondence and technical reports, also indicate that there is some mismatch between the different observers about what constitutes above-average rainfall on the island and how this may affect mine-sourced discharges.

At mines other than Enterprise company consultants also suggest that rainfall can generate "unexpected discharges". For example, south of the Yarraman Mine, in the northeast of the island, large volumes of water were discharged to the surface for at least 10 months commencing in late 2012. I visited this area on 22 January 2013 and provided technical advice to QYAC. In response to the discharges, with surface flows of at least 0.5 cumecs, the company moved first to protect the local Fisherman's track from damage. As well, there was damage to off-lease sites such as vegetation death through submersion inland (westward) from the foredunes and on the Native Title Exclusive Possession Land.

In a letter to the Queensland Minister for Environment and Heritage Protection (Hon. Andrew Powell MP) the company Sustainability Manager – Development outlining the situation from Sibelco's perspective, (Smith 2013) indicated that a hydrological assessment was underway. He suggested these discharge conditions were not unusual, and that:

> The water level is also declining in this area[21], as would be consistent with a return to more normal flows…
>
> The entire island is still experiencing elevated water table levels after above average rainfall seasons in 2011 and 2012. This is evidenced at many locations across the island by vegetation death from immersion.

Sibelco's hydrological consultant (GEO-ENG 2013)[22] later concluded (from simulation modelling) that above-average rainfall for the period 2009 to 2012 had contributed, in part, to the unexpected discharges at Yarraman. Leach (2013), acting for the Queensland regulator, reviewed the GEO-ENG report and concurred with this interpretation (p4). Both GEO-ENG and Leach acknowledged, but did not emphasise, that it was the placement of tailings that had aggravated the situation at the mine by adding extra volumes of mine-sourced discharges. In other words the standard mining activities, as planned and executed (as approved by the regulator), together with insufficient water management at Yarraman, contributed to flooding off lease. This discharge 'incident' at Yarraman occurred under Sibelco's management and about two years after the noted condition change in 2010 at Enterprise.

However, what is noteworthy about the recent Yarraman Mine discharges is that it appears the 2012-2013 discharges could have been anticipated with better modelling. Leach (2013 p3) states:

> … The YGM_2013 model was used to assess simulated groundwater levels for the pre-mine conditions during the period 1950 to 1984.
>
> The model results show the area adjacent to keyholes #1 and the upslope seepage area is a natural groundwater seepage discharge area. The average simulated seepage rate for this period was calculated to be 24 litres/second (L/s) with a corresponding standard deviation of 17 L/s. The [GEO-ENG 2013] report mentions that following the 1974 rainfall event … the simulated seepage rate may have been up to 130 L/s and this decreased to 41 L/s over a 10[-]month period.

Evidently at Yarraman the hydrological modelling the company had employed for mine planning, and continued to rely on during operations, had been inadequate: it was not able to account for natural, albeit above-average rainfall, known to have occurred in 1974. This lack of attention to the basics has exposed the company to criticism in 2013 that its water management strategies were/are not best practice. At Enterprise, as for Yarraman, tailings placement is also important in contributing to overall water management and to avoiding mine-sourced discharges.

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[21] That is, on the Native Title Exclusive Possession Land.

[22] The GEO-ENG (2013) report is structured as a technical report of a model update, now called YGM_2013. Similarly, the Leach (2013) review of the consultant's work is couched as a basic and standard assessment of whether the GEO-ENG report conformed to all the current technical requirements and if the outputs and conclusions where acceptable to the reviewer (i.e. Leach).

4.0 NEARMAP IMAGES FROM 2010 INDICATING CONDITION CHANGE IN IBIS LAGOON SYSTEM

4.1 Photomaps at Different Scales in Appendix 1

Photomaps 1, 2 and 3 are images/photomaps prepared from aerial photographs taken at three different times in 2010 and originally provided as photomaps by Nearmap Ltd[23]. These are grouped together with other similar photomaps as Appendix 1 of this review. All three images, captured respectively on 27 January, 6 May and 16 September, 2010, are reproduced here (A3 pages) at approximately 1:21 200 photo-scale and a scale bar is shown at lower left. They provide three 'snapshots' of the same area of central North Stradbroke Island (about 30 square kilometres) and include parts of the rehabilitating Ibis Mine, the Ibis Lagoon system with several water bodies and the Enterprise Mine operations. Specific water bodies and other features are identified in the images. The local boundaries of the Moreton Bay Ramsar Wetland are not shown in these photomaps but are plotted in others that follow. (Figure 2 earlier also shows the local part of the Wetland.)

Photomaps 4, 5 and 6 are images/photomaps captured respectively on 27 January, 6 May and 16 September, 2010, of a smaller area (about 2 square kilometres) over the northern half of the Ibis Lagoon system and several hundred metres into the western side of the Enterprise Mine operations. The reproductions here on A3 pages (Appendix 1) are at approximately 1:5 300 photo-scale with a scale bar at lower left. The white rectangles in each of these photomaps mark the approximate position of the areas chosen for enlargement to about 1:4 300 photo-scale (a scale bar is shown at lower right) as reproduced, respectively, in photomaps 7, 8, and 9. Photomap 10, also at about 1:4 300, provides an improved resolution of another area closer to the Enterprise mine as at 6 May 2010; it is not located with a white rectangle in Photomap 5 but its position can be identified in Photomap 2. Taken together, viewing the Nearmap images at different scales, like the examples in Photomaps 1 through 10, provide a range of perspectives and detail for improved resolution of the condition change in the aerial photo interpretation (API).

Photomap 11 is a "Terrain" image/map of the same area shown in Photomaps 1, 2 and 3. It was generated using the 16 September 2010 photomap and the Nearmap Ltd custom procedure provided for clients. The impression of topographic relief so created is not intended to be absolute in terms of contour intervals. This illustration provides an important spatial reference for the description and evaluation of the API.

Photomap 12 shows the same area as in Photomap 2 and thus refers to imagery captured on 6 May 2010. Five smaller areas are annotated in blue, and labelled A, B, C, D and E, to delineate the distinctive brown-coloured photo-pattern of vegetation as noted in the API of the larger area map. Control points on the perimeter of Area A are identified but are omitted from the others. Note that the brown-grey areas around Ibis Lagoon West and Ibis Lagoon Central, to the northwest of Area A, are not highlighted in blue. The perimeter of each brown area was selected with care but some small brown-coloured areas, especially some single trees, have been excluded[24] and small areas of green-coloured vegetation will have been included. Consequently, even though the calculated values (in Photomap 11 and summarised in Table 1) appear accurate to the square metre they should be considered as "conservative estimates".

In Section 4.2 the selected photomaps/images for each of the three dates are systematically summarised as aerial photo interpretations (APIs). The focus of the descriptions/interpretations is to account for the main changes in the images over time, especially in the vegetation and water expressions. The reader is assumed to understand the basic principles of API. In general, all the images appear to have 'standard' appearances (colours,

[23] Data for nearmap (NearMap) Ltd products are captured by high-resolution aerial photography via light aircraft flying at high altitude. Imagery is supplied to clients as web-based PhotoMaps. Repeated coverage of specific areas is irregular.
[24] Brown-coloured areas that have been excluded are evident around the perimeters of locations B, C and E.

textures, other photo-pattern elements) of photomap imagery and are suitable for API. Stereo imagery was not available to assist in the API.

Section 4.3 draws on the APIs to suggest the most likely explanation for the changes in the images over the 8-month period in 2010. As already noted in Section 3.2, the Sibelco AER for 2010 does not refer to any distinctive changes in condition within the Ibis Lagoon system — water levels, water quality, soil or flora condition.

4.2 Aerial Photo Interpretation of Three 2010 Photomap Imagery

In the aerial photo interpretation (API) descriptions that follow Photomaps 1, 2 and 3 provide the largest area for consideration. Photomaps 4 and 7, 5 and 9, and 6 and 9 provide the bases for more detail where required, respectively, for 27 January, 6 May and 16 September, 2010. The APIs for each pair of photomaps are integrated under the appropriate date of image capture. Photomap 10 provides an improved resolution of another area closer to the Enterprise mine as at 6 May 2010.

4.2.1 Photomaps from 27 January 2010

The following descriptions are based on an assessment of photo-patterns in imagery captured on 27 January 2010. Examples at different photo scales are shown in Photomaps 1, 4 and 7.

Open water is evident in Ibis Lagoon West (whole lagoon) and Ibis Lagoon Central (in southeast corner). Sedgelands in low-lying (moist?) parts are coloured light brownish green. Long-term boundaries of sedgelands and shrublands/woodlands (i.e. average shoreline positions) are very sharp. There is a slight grey coloration in the shrubland/woodland edge along east side and southeast corner of Ibis Lagoon West.

No water is evident in the three other named water bodies of the Ibis Lagoon system: Dakka Bin North, Central and South. Long-term boundaries of sedgelands with shrublands/woodlands are very sharp. No water is evident in Bumbaree Swamp. (See Figure 3 of this review for a map of these water bodies.)

On the east of the Ibis Lagoon system (and west of 18-Mile Swamp) the bare sand of the active Enterprise Mine is coloured in brown, yellow and orange, except for the green of the dredge pond. Rounded mounds of the post-mining lands of the rehabilitating area of the once-active Ibis Mine, coloured grey (topsoiled sand) and green (revegetating sand), are to the north and west of the Ibis Lagoon system. Similar rehabilitating mounds on the southern limit of the image link the renamed Ibis and active Enterprise Mine.

4.2.2 Photomaps from 6 May 2010

The following descriptions are based on an assessment of photo-patterns in imagery captured on 6 May 2010. Examples at different photo scales are shown in Photomaps 2, 5, 8 and 10.

Open water is evident in Ibis Lagoon West (whole lagoon) and Ibis Lagoon Central (in a crescentic arc open to northwest and sweeping from northeast corner to near southwest corner). Elsewhere sedgelands in low-lying (moist?) parts are coloured light brown (not brownish green as in the 27 January 2010 image). Long-term boundaries of sedgelands with shrublands/woodlands are very sharp.

The smallish area of light grey coloration in the vegetation edge along east side and southeast corner of Ibis Lagoon West in the 27 January 2010 image is now significantly larger, more grey-white in colour and in several parts. The largest part is within the shrublands/woodlands between Ibis Lagoon West and Ibis Lagoon Central, linking their respective eastern and western shores. A second part and thinner rim of grey colouration extends in the shrublands/woodlands along the northern and western shore edge/ littoral of Ibis Lagoon West. There is also a grey colouration extending from the eastern and southern long-term boundary of Ibis Lagoon Central; but significantly this is within sedgelands not within shrublands/woodlands. It is difficult to account for the areas of greyish colour and their appearance; these are not 'expected' image characteristics. Some of the grey colouration is likely to be due to bare sand. The possibility of these characteristics being related to an artefact of generating the image is very unlikely.

Water is evident in water bodies Dakka Bin North, Dakka Bin Central and Dakka Bin South (in two/three separate and irregular pools); there is also a narrow sinuous drainage path running southward from Dakka Bin Central. Long-term boundaries of sedgelands with shrublands/ woodlands are very sharp. No water is evident in Bumbaree Swamp.

As in the 27 January 2010 photomaps, on the east of the Ibis Lagoon system (and west of Eighteen-Mile Swamp) the bare sand of the active Enterprise Mine is coloured in brown, yellow and orange. The water of the dredge pond is more olive green in colour, and a comparison indicates the pond is located a little further to the southwest. The pond itself is about 1.2 km from the eastern side of the Ibis Lagoon system but the orange-coloured bare sand indicates moist tailings are as close as 400 m.

Of particular note in the 6 May photomaps are several brown-coloured areas west of the boundary of Enterprise Mine operations (i.e. west of the road and services alignment). In Photomap 8 the brown canopies of large single trees appear to have leaves and twigs dead and/or dying and occupy the margins of the low-lying wetland area. The two northern-most of the areas closer to the mine extend from the services alignment to the narrow track located to the east of the Dakka Bin water bodies. These areas are sedgelands and are contiguous with the sedgelands around Dakka Bin Central Lagoon. They have patterns best interpreted as moist sedgelands. Other brownish or greyish-brown areas in the south are within shrublands/woodlands; of note is that some sections of their margins with the green coloured vegetation are relatively straight. Photomap 10 is a good example of the areas of relatively regular brown colours with sharper boundaries of green vegetation. Within and separate from these brown areas are brown (-orange) individual canopies of trees with, apparently, almost all the leaves are dead or dying.

In Photomap 12 brownish areas A through D have been identified for measurement. These brownish areas are noticeably spatially associated with the low-lying 'terrain' areas in the 'Terrain' Nearmap image of Photomap 11 (prepared from 16 September 2010 imagery). These matters are discussed in Section 4.3.

4.2.3 Photomaps from 16 September 2010

The following descriptions are based on an assessment of photo-patterns in imagery captured on 16 September 2010. Examples at different photo scales are shown in Photomaps 3, 6 and 9.

The quality of the Nearmap images/photomaps for 16 September 2010 is not as high as for those captured earlier in 2010 so it is difficult to allocate an interpretation based on inherent photo patterns. The main problem appears to be a lower level of resolution/sharpness. For example, for various reasons the contrast between water surfaces and other surfaces is not as strong as that in the 6 May 2010 photomap. Based on comparisons with the 27 January and 6 May 2010 photomaps the photomap for 16 September 2010 appears to display the largest area of free water surface.

Open water is quite evident in Ibis Lagoon West (whole lagoon) and Ibis Lagoon Central (much of the lagoon). Elsewhere sedgelands in low-lying (damp?) parts are coloured light brownish grey (not brownish green as in the 27 January 2010 image and not brown as in the 6 May 2010 image). Long-term boundaries of sedgelands and shrublands/woodlands are very sharp.

The separated parts with grey-white coloration in the 6 May 2010 image are now part of a significantly larger area, mostly associated with the terrain of low elevation dominated by sedgelands. The largest part of shrublands/woodlands in the 6 May 2010 image, and linking the respective eastern and western shores between Ibis Lagoons West and Central, now has a definite green colouration. This is also true of the thinner rim of previously grey-coloured shrublands/woodlands along the northern and western shore edge/ littoral of Ibis Lagoon West. The largest part is within the shrublands/woodlands between Ibis Lagoon West and Ibis Lagoon Central, linking their respective eastern and western shores. A second part and thinner rim of grey colouration extends in the shrublands/woodlands along the northern and western shore edge/ littoral of Ibis Lagoon West.

Water is evident in water bodies Dakka Bin North, Central and South. The two/three separate pools in Dakka Bin South in the 6 May 2010 image are merged into a larger water body in the September image. The sinuous drainage path, running southward from Dakka Bin Central, is distinctive. Long-term boundaries of sedgelands with shrublands/woodlands are very sharp. Open water may be present in Bumbaree Swamp, visible through the vegetation cover.

As in the earlier photomaps for 2010, on the east of the Ibis Lagoon system (and west of Eighteen-Mile Swamp) the bare sand of the active Enterprise Mine is coloured in brown, yellow and orange. The water of the dredge pond is a darker green in colour, more like that in the photomap for 27 January 2010. After continuing on the mine plan the pond has migrated further south. The pond itself is still at least about 1 km from the eastern side of the Ibis Lagoon system but the orange-coloured bare sand indicates moist tailings are as close as 400 m.

What were several brownish areas west of the boundary of Enterprise Mine operation (i.e. west of the road and services alignment) in the 6 May 2010 image are not as distinctly brown in colour as those in the 16 September photomaps; rather their colour is brownish-grey. Most of the single trees that showed brown (-orange) canopies can still be recognised as single trees with some leaf cover or without (as stark leafless branches). Many green areas surrounded by brown areas in the 6 May 2010 photomap can still be recognised but without evident expansion of the brown areas. This observation suggests that the 6 May 2010 image probably is indicative of the maximum extent of brown area as seen in the three available images for 2010. That is, there was unlikely to have been much additional loss of green areas after 6 May and before 16 September 2010.

4.2.4 Nearmap Terrain® Photomap from 16 September 2010

Photomap 11 of 'terrain' of the Ibis Lagoon system and surrounds was prepared with the proprietary procedures created by Nearmap Limited. Horizontal slices and colours are quite adequate for visual comparisons. The major features of human-made 'terrain' are generally easily distinguishable from the natural 'terrain' and include: the main topographic depression of the Enterprise dredge pond, tailings placement areas, rehabilitating areas (including those of the older Ibis Mine), service roads and tracks of various alignments and dimensions, and multiple sub-parallel drilling lines from pre-mining exploration. The finer subtleties of the low-lying 'terrain' within the Ibis Lagoon system is also relatively easy to see, even for those not well practised in aerial photo interpretation. A comparison of the brown vegetation areas visible on 6 May 2010 in Photomaps 2, 5, 8 and 10, and the five annotated areas in Photomap 12 show a clear association with low-lying 'terrain' evident in Photomap 11 (prepared from 16 September 2010 imagery). This association is more completely discussed in Section 4.3.

4.3 Specific Interpretation of Condition Change Observed in 2010

Section 4.3 draws on the APIs presented in Section 4.2 and Photomaps 11 and 12. Additional illustrations include: Figure 6, a within-report illustration; and, Photomaps 13 and 14 in Appendix 1, that provide northern-half and southern-half coverage of North Stradbroke Island from imagery captured on 6 May 2010. The focus of Section 4.3 is to progressively explore the character of the marked condition change in 2010 and to propose a preferred explanation of its cause/s and timing.

The description of the aerial photo interpretations in Section 4.2 assumed the reader would consult Photomaps 1 through 10, with some reference to Photomaps 11 and 12. Accessing the Appendix-1 photomaps while also checking the API descriptions requires some effort. Consequently, it is useful to have a compact illustration, albeit at lower resolution, of the comparisons across the imagery of three different dates in 2010. Figure 6 provides a side-by-side placement of the three images that reveal the condition change in the Ibis Lagoon system; the fourth image in Figure 6 is a reduced version of the Nearmap "Terrain" of Photomap 10 showing there is variability in the 'virtual' image of the topographic depression hosting the Ibis Lagoon system. Photomaps 13 and 14 show, respectively, the northern-half and southern-half of the island as at 6 May 2010.

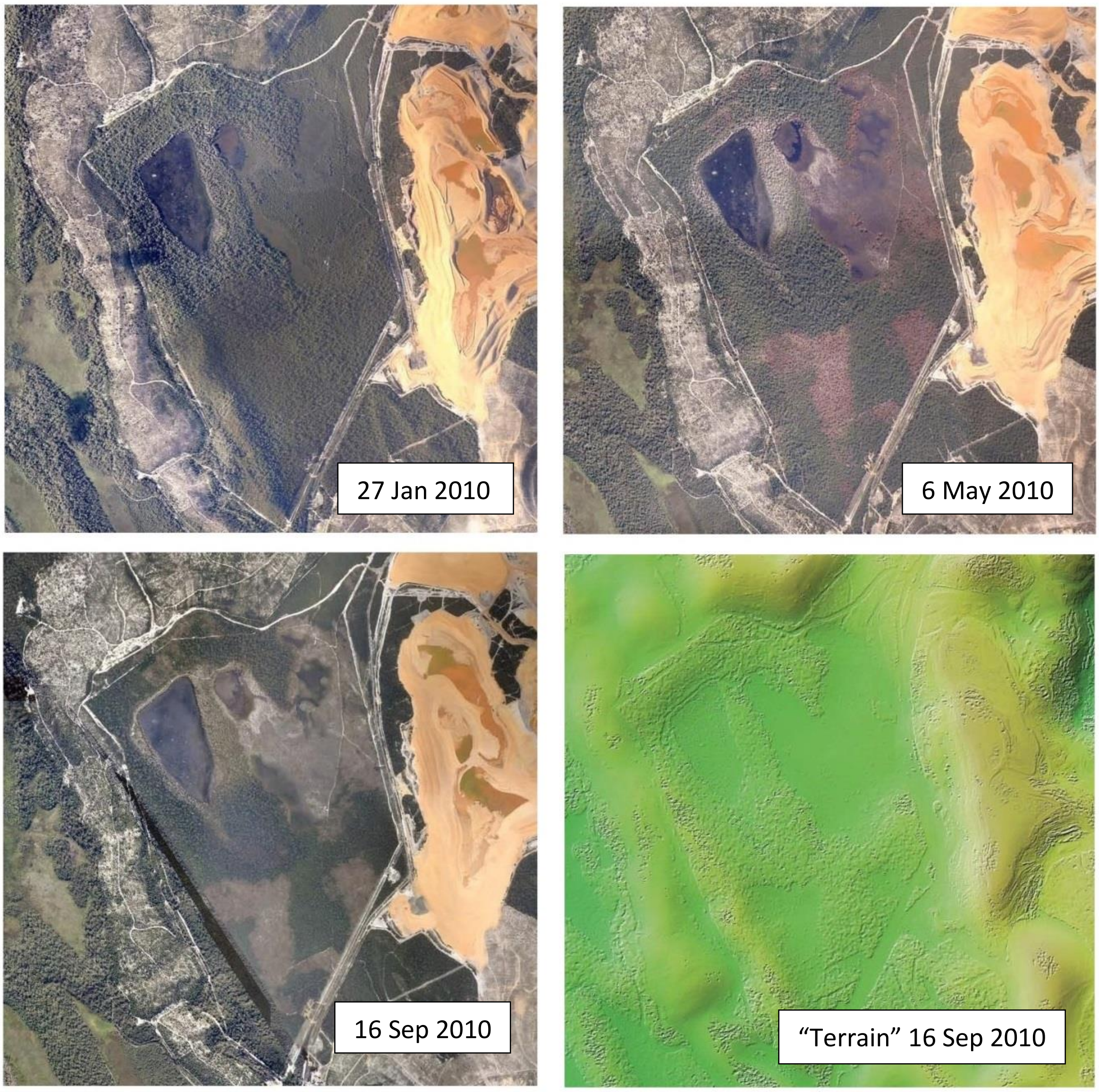

Figure 6: Comparison of Condition Change and Nearmap Terrain® in the Ibis Lagoon system as shown in Three Photomaps for 2010. (Sources: Extracts from Nearmap images as shown in Photomaps 4, 5, 6 and 7)

The brown to orange areas in Photomaps 2, 5, 8 and 10 (see upper-right in Figure 6), located in the east and south parts of the Ibis Lagoon system, are very noticeable and indicate some environmental factor/s has/have led to the death of leaves and stems between 27 January and 6 May 2010 (compare upper-left and upper-right). The affected vegetation types include plants of quite different structure, from those typical of the sedgelands to isolated individual and clusters of mature trees. Such a range of affected vegetation types suggests some specific common causation factor/s. Considering the large trees, and based on my experience in API, the onset of conditions leading to the extensive leaf and stem death are likely to have occurred some 1 to 2 weeks before 6 May, at least by mid-April

As recorded in Table 1 the annotated blue areas of brown vegetation in Photomap 12 have measured sizes (using the Nearmap Limited measurement tool) that range from 0.1 ha for Area D to 64.5 ha for Area A. The total of the five annotated blue areas here is about 95 ha. If the brown-grey areas closer to the lagoons are added to this measured value then perhaps half the area of the system enclosed by the service tracks and roads may have been affected.

Table 1: Estimated Size of Image Brown Areas Circumscribed in Blue in Photomap 12

Annotated Label	A	B	C	D	E	Total
Estimated Area (m^2)	645,973	70,420	15,678	1,165	217,611	950,847
Estimated Area (ha)	64.5	7	1.6	0.1	21.8	95

A reference to the relevant part of the Moreton Bay Ramsar Wetland plotted in Figure 2 of this report shows that the whole of areas C and D and the southern ‘tips’ of areas B and E fall outside the Wetland. As an approximation, then, at least 80 ha of the Ramsar Wetland has had a noticeable condition change between 27 January and 6 May 2010.

There have been wildfires and controlled burns on North Stradbroke Island and other locations on the sand masses of South East Queensland that caused extensive fire-damaged land and vegetation, ranging from light singeing to extreme charring and full combustion. I have examined aerial photographs of such areas in images captured soon after damage had occurred through to many years after the fire. The brown areas of interest in Photomaps 2, 5, 8 and 10 have some similarity to those known to have been burned by fire; but there are at least two features of difference. The edges/margins of the brown areas (that would have carried a postulated fire) do not have the shapes of an advancing front with or without wind effects. There is little or no variation to the brown colours exhibited by the mature trees that would show the canopy had been variously exposed to a range of temperatures, from burning to lightly heated air, that natural fires induce and can be seen in aerial photographs. Consequently, I do not favour an explanation that a fire or fires caused the brown areas within the Ibis Lagoon system, as evident in Photomaps 2, 5, 8 and 10.

The brown-coloured leaves and stems could indicate a response to some extreme heat event of high but steady temperature, but no fire to cause combustion. However, I cannot go beyond this basic description of heat requirements to propose a realistic natural (or human-made) generation of those extreme heat conditions. Some heated atmospheric air-mass would affect much larger areas of the island and not in this particular arrangement of areas of variable size within the Ibis Lagoon system. The period February through April is remotely possible as a time of high heat conditions in the atmosphere. No other areas with brown colours have been reported beyond the Ibis Lagoon system and none have been visible in the photomaps elsewhere on the island (Photomaps 13 and 14). Consequently, I exclude a locally restricted (i.e. Ibis Lagoon system) extreme or high heat source as an agent causing the loss of leaves and stems and being involved in condition change exhibited in the image of 6 May 2010.

Rather than a drying mass of heated air another possible agent is extreme drying out of the ground, such as extreme desiccation of the upper soil hosting the roots (see Section 2.3). The photomaps of 27 January and 6 May 2010 show free water and moist soil so the removal of water from the system would have to have been rapid and reversible during the February to April period. As well, the vegetation away from the brown areas would have to have been protected and/or reinstated without damage. Natural conditions to achieve such outcomes are ‘impossible’ to conceive so this “hypothesis/explanation” is rejected. Similarly, some natural event/s of super-cooled air can be rejected as being impossible, even though chilled air is able to cause death of leaves and stems and technically satisfies the set physical requirements of likely to accumulate in the low-lying parts of the Ibis Lagoon system.

The significant feature of a comparison of Photomaps 11 and 12 (and the smaller images in Figure 6) is the spatial association between the lowest parts of the "terrain" and the areas with evident death or stress in leaves and stems. Consequently, one compelling line of interpretation is that some agent, liquid or gaseous, that naturally occupies low-lying land may be involved in contributing to the condition change evident in the 6 May 2010 images. Heated air has already been rejected as a general agent and can also be excluded in a local sense: heated air would rise away from low-lying topography.

Thus, the most likely explanation is that, at some period during February to mid-April 2010, water (of ambient temperature) has moved into the Ibis Lagoon system, and caused stress and death of leaves and stems through extended immersion. The period of immersion/inundation was at least 1 to 2 weeks. The central question is to account for the appearance and disappearance of this water. It is important to note that the browning off would probably have been progressive and the total of 95 ha is unlikely to have been evident immediately. Nevertheless, a well-operated monitoring program should have detected the early stages of water pooling at the surface and triggered a response from those charged with environmental care of this public land, a Ramsar site.

Natural rainfall is unlikely to have been the source of excess water that pooled in the low parts of the Ibis Lagoon system thereby causing the extended immersion to stress and kill the leaves and stems. If excess rainfall is posed as an island-wide experience in the period February to mid-April there are at least two factors that have to be considered. First, the evidence from just the three Nearmap images available for 2010 (Section 4.1) shows that the 16 September 2010 photomap exhibits the largest area of free water surface. This is quite consistent with the usual pattern of water fluctuation on the island with high water levels in the mid-winter, as already noted in Section 2.2. It would be unusual, though quite possible, to have long periods of inundation in the February to mid-April period.

Second, there is no evidence reported in official documents (such as the AER 2010) to support a proposal that natural water occupied the Ibis Lagoon system for an extended period so as to cause damage up to 95 ha in area. Photomaps 13 and 14 (Appendix 1) are reproduced as a summary, as at 6 May 2010, of the whole island as a northern- and southern-half, respectively. I have closely examined the HD imagery for the photomaps on a large screen and at various scales, and can confirm that Photomaps 13 and 14 provide a fair representation of the situation on 6 May 2010. The photomaps do not show that any other water body on the North Stradbroke Island, or any other low-lying location, has brown-coloured areas like those identified in the Ibis Lagoon system. There are some minor grey-coloured littoral/terrestrial margins to some water bodies, such as Brown Lake (in the north) and Native Companion Lagoon (in the south). However, these margins are consistent with the usual natural patterns for Brown Lake and at Native Companion Lagoon which is still recovering from its earlier inundation. To make this statement I rely on my experience in aerial photo interpretation over many years, while studying the island's environment and its variations as revealed in coloured and black and white aerial photographs as well as satellite imagery. The loss of vegetation condition in the Ibis Lagoon system is severe, unique and restricted in a definitive spatial sense.

Table 2 is a summary of the Bureau of Meteorology's monthly and yearly rainfall record at Point Lookout for the years 2009 through 2012. These data show some of the extremes that company employees refer to for the different years and while discussing events at either Yarraman and/or Enterprise (Section 3.3 this review). Clearly, 2010 was an unusual year in terms of the yearly total and some daily records as shown in the notes at the base of the table. With respect to the 2010 photomaps the rainfall tallies[25] between image-capture dates are: 28 January to 6 May − 697 mm; 7 May to 16 September − 555.5 mm. However, there is nothing in these

[25] Based on BoM daily rainfall records

data that can assist with explaining the condition change of widespread loss of leaves and stems exhibited between the photomaps for 27 January and 6 May 2010.

The spatial evidence is clear in the 6 May 2010 image. The condition change observed after 27 January is located immediately west of the Enterprise Mine, especially the tailings area well southwest of the pond position on that date. The most likely explanation is that excess waters were discharged from the tailings to the subsurface; thence the mine-sourced discharges passed through the growing mound of bare sand, exiting in a series of spring points and/or along a spring line to merge and mix with the natural groundwater that was already receiving recharge from natural rainfall. The mine-sourced waters generated a commensurate rise of the watertable within the Ibis Lagoon system which was rising in response to the substantial natural rainfall after 28 January 2010. At some stage during February to mid-April the groundwater of mixed natural and mine-sourced water 'day-lighted' in such amounts that water-logging occurred of sufficient duration to cause the condition change over at least 95 ha observed between the 27 January baseline image and that for 6 May 2010.

The exact role and quantities of tailings-charged waters entering the system cannot be estimated here. Evidently it was of sufficient volume/s and rate/s to overwhelm any spearlines and other dewatering arrangements the company had in place. This preferred explanation is based only on water quantities. There is no reason to introduce water quality as being a factor as the mine processing does not involve deleterious chemicals. There is nothing in the limited published water quality data for the Ibis Lagoons (AER 2010) to suggest this factor need be considered, but it should not be excluded entirely from a more detailed study.

Table 2: Rainfall Received at Point Lookout during 2009 through 2012

Year	2009	2010	2011	2012
January	[d] 121.2	45.2	290.1	525.8
February	152.8	177.4	87.5	175.8
March	82.1	[a] 267.8	252.7	189.7
April	327.8	166.4	228.3	317.6
May	379.5	246.2	207.9	89.6
June	252.4	58.2	69.3	247.4
July	26.3	[c] 162.0	57.4	128.7
August	7.1	[b] 118.7	96.9	1.0
September	33.2	91.9	25.9	38.8
October	99.8	266.3	88.5	50.0
November	23.6	106.6	16.0	109.0
December	151.2	379.0	135.1	26.8
Yearly Total	[d] *1657.0*	[c] *2085.7*	*1555.6*	*1900.2*

a On 2 March 2010 Point Lookout received 102.6 mm, the highest March total on BoM's record for this station.

b On 10 August 2010 Point Lookout received 85.8 mm, the highest August total on BoM's record for this station.

c A missing value for 29 July 2010 constrains this record so that the July total and the dependent yearly total are not complete to BoM standards.

d A missing value for 11 January 2009 constrains this record so that the January total and the dependent yearly total are not complete to BoM standards.

In Section 4.2 I have attempted, with the limited information available, to account for the condition change evident in the imagery covering the Ibis Lagoon system between 27 January and 6 May 2010. If the most likely explanation of mine-induced inundation is correct, the company cannot direct attention to 'subsurface geological and/or lithological conditions' to account for this mining discharge. Even before mining commenced in 1996 the company has insisted that their personnel's knowledge of ground conditions has been critical to best water management within the Ibis Lagoon system. It would be disingenuous in the extreme if the company was to suggest that it was the natural heavy rainfall of early 2010 that 'caused' the extended immersion leading to the condition change so evident in the 6 May 2010 photomap. The potential of natural rainfall to change recharge conditions should have been built into the hydrological model used at the Enterprise Mine. If my interpretation and the proposed stages that led to water inundation are correct, the company must take the responsibility for damage to the ecology of this part of the Moreton Bay Ramsar Wetland through overconfidence in ability, inadequate preparation, and substandard water management.

5.0 Preliminary Conclusions

In Section 5 I outline my preliminary conclusions about the condition change evident in 2010 based on the material presented here and using remote sensing imagery, documents of previous mine-associated flooding and other documents and data in the public record. In Section 6 I link these conclusions directly to relevant parts of Significant Impact Guidelines 1.1 to the *EPBC Act 1999.*

There is an extensive historical record over some 50 years that the mining companies operating the Amity, Bayside, Gordon, Yarraman, Ibis and Enterprise Mines created conditions that caused damage to water bodies and nearby ecosystems. In some instances the damage has been extreme and permanent, as clarified in company documents, and some of these have prompted efforts at remediation. Other examples, especially those caused by mine-sourced discharges of water, have been of relatively short duration—months to years—leading to various impacts on littoral margins and terrestrial vegetation.

The environmental record for the Ibis (-Alpha) cum Enterprise Mine, especially during the early years of operation, is one of physical disruption to landscape, flooding of the Ibis Lagoon system (especially Ibis Lagoon West) and loss of terrestrial vegetation through inundation by mine waters. One of these led to a Show Cause notice. I outlined this history in Section 2. Yet the pre-mining stage of the Ibis (-Alpha) mine was also one in which consultants provided both general and specific forecasts of the potential damage that eventually did occur. Evidently, this professional and early advice was not sufficient for mine personnel to act with knowledge and adequate attention to risk management.

A decade later yet another mine-sourced impact is indicated by a marked condition change evident in the 2010 remote sensing record of the Ibis Lagoon system, within the Moreton Bay Ramsar Wetland. The photomap imagery captured by Nearmap Limited indicates that after 27 January and before 6 May 2010 at least 95 ha on the eastern side of the system underwent a condition change, primarily visible in the imagery as death of leaves and stems. There would have been many other ecological impacts associated with this most visible impact. Mature trees through to sedgelands were affected. This notable and substantial change is interpreted to have occurred by about mid-April. While some vegetation loss may have been permanent the 16 September 2010 imagery indicates regrowth had been restored, at least in part. The area of impact is in a different location to that in the early 2000s and about fifty (50) times larger. As well, the affected area in 2010 was close to the western margin of bare sand receiving tailings as part of operations at the Enterprise Mine. There is a marked spatial association between the location of the damaged vegetation in the eastern half of the Ibis Lagoon system and the low-lying 'terrain' as defined by Nearmap Limited procedures.

In a step-by-step consideration of possible agents of the condition change I reject various possible factors of fire and extreme conditions of heated and cooled air. Instead, the most likely explanation is that mine-sourced waters increased the local water table leading to excessive inundation on the east side of the Ibis Lagoon system and death of leaves and stems. Natural flooding from rainfall is rejected as the agent of the described condition change because other Nearmap imagery for the whole island on 6 May 2010 shows no similar effects in comparable wetlands. Rather, it is the restriction of the damage to the side nearest the mine operations that prompts the conclusion that the mine is the source of the excess water.

If the damage-causing inundation occurred because the groundwater was receiving tailings water so as to make the Ibis Lagoon system over-sensitive to natural rainfall then clearly the company was operating without a sufficient safety margin and care.

If the condition change of at least 95 ha occurred without the company being aware that it had occurred then the company's environmental monitoring was substandard and in need of major revision. If the change was noted and not reported as soon as possible to relevant agencies, the company may be at fault in their fiduciary duty.

If the company noted the damage and attributed it to natural rainfall adding to mine-induced recharge that was already raising the watertable, this was clear evidence to the company, in 2010, of the potential of rainfall to require attention to overall water management at Enterprise. Such a lesson should have been transferred generally within the company to revisit water management strategies at the both the Enterprise and Yarraman operations. As the company appears to be invoking natural rainfall (during 2012) as part of its explanation for mine-sourced discharges at Fisherman's Track in 2012/13, this action suggests the company has continued to underplay risk-management problems in water management. Such an approach raises concern for the potential for additional discharges that could affect other parts of the Ramsar wetland near to the Enterprise operations.

I consider the damage in 2010 to the Ibis Lagoon system in the Moreton Bay Ramsar Wetland is demonstrable and I suggest it was caused by poor environmental management and monitoring by the company. Physical impacts like those to the Ibis Lagoon system provide additional weight to the arguments in my preliminary report on Enterprise Mine and Eighteen-Mile Swamp (Stock 2012) and more evidence to question the capabilities of the company and its capacity to care for matters regarded as being their responsibility.

6.0 Significance of Impacts of Mine-Sourced Discharges into the Ibis Lagoon system – Part of a Ramsar Wetland

The stimulus for this review came from a condition change observable in aerial photography captured in 2010. For all the comments here I have assumed my interpretation is correct that: mine-sourced water discharges to the subsurface generated a marked condition change by water inundation, thereby causing death of terrestrial and littoral vegetation with attendant impacts on the wetlands. Although this "most likely" interpretation remains to be confirmed in detail I am able to build a number of likely scenarios which I consider to be "significant" impacts on this part of the Moreton Bay Ramsar Wetland.

Throughout Section 6 of this review I have attempted to recast the comments from earlier sections and the preliminary conclusions with a focus on clarifying "significance" under the EPBC Act. The significance of impacts in relation to the EPBC Act and associated definitions as presented in (Commonwealth of Australia 2009) Matters of National Environmental Significance, Significant Impact Guidelines 1.1, *EPBC Act 1999*, are reproduced in Section 6.1. In Sections 6.2, 6.3 and 6.4, I summarise the likely hydrological, water quality and ecological impacts.

I have already emphasised in my review of the Enterprise operations (Stock 2012) that the predicted (ESR 2003) hydrological impacts to Eighteen Mile Swamp on the east may be classified correctly as a mining-generated inter-catchment transfer of water. As well, some of the known impacts of mining-sourced inter-catchment transfers on North Stradbroke Island (Stock 2012, Section2.2) are relevant to the Ibis Lagoon system, but are not repeated here.

The overarching principle for considering impacts on the Moreton Bay Ramsar Wetland is that impacts can occur at different times and scales. During specific times along the mine path (according to forecasts in the ESR 2003) the Enterprise Mine would have added water discharges of variable and undisclosed volumes and quality to the Ibis Lagoon system. In the subsurface the discharged waters (supplied initially as make-up water from both east- and west-side swamps and groundwater bores) mixed with natural groundwaters and may not have appeared at the surface in such a dramatic way as during the incident of 2010. After mining and rehabilitation the mound of tailings will operate as a new geohydological entity. It will have some ongoing long-term impacts on the Ramsar Wetland, not only the parts of the Ibis Lagoon system as emphasised here but also on Eighteen Mile Swamp as considered in Stock (2012).

6.1 Significant impact criteria for the Ibis Lagoon system

The cited text is an extract from pages 3 and 14 of Significant Impact Guidelines 1.1 to the *EPBC Act 1999*:

> "Approval is required for an action occurring within or outside a declared Ramsar wetland if the action has, will have, or is likely to have a significant impact on the ecological character of the Ramsar wetland."
>
> "A 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts. You should consider all of these factors when determining whether an action is likely to have a significant impact on matters of national environmental significance."
>
> "To be 'likely', it is not necessary for a significant impact to have a greater than 50% chance of happening; it is sufficient if a significant impact on the environment is a real or not remote chance or possibility. If there is scientific uncertainty about the impacts of your action and potential impacts are serious or irreversible, the precautionary principle is applicable. Accordingly, a lack of scientific certainty about the potential impacts of an action will not itself justify a decision that the action is not likely to have a significant impact on the environment."
>
> "The 'ecological character' is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. The phrase 'at a given point in time' refers to the time of designation for the Ramsar List."
>
> "An action is likely to have a significant impact on the ecological character of a declared Ramsar wetland if there is a real chance or possibility that it will result in
>
> - Areas of the wetland being destroyed or substantially modified
> - A substantial and measurable change in the hydrological regime of the wetalnd, for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland
> - The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetalnd being seriously affected
> - A substantial and measurable change in the water quality of the wetland – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health, or
> - An invasive species that is harmful to the ecological character of the wetland being established (or an invasive species being spread) in the wetland."

6.2 Alteration of hydrological regimes at different time scales

In my opinion the (Ibis-) Enterprise Mine has had and will have an effect on the hydrological regime of the Ibis Lagoon System, and this part of the Moreton Bay Ramsar Wetland, in at least three different ways. One is the impacts that specific and excessive mine discharges cause by flooding of waterbodies and their surrounds for a period of months to years, such as the known flooding in 2000 and the suspected inundation of 2010. Another impact is the increased water volume generated during the actual operations, which for the Enterprise Mine, is likely to be for at least 10 years. The third impact, a permanent change in the hydrological regime, has been ignored by the mining company and regulatory agencies. All three can generate impacts on the Moreton Bay Ramsar Wetland and these are outlined, respectively, in Sections 6.2.1, 6.2.2 and 6.2.3.

6.2.1 Summary of the impacts of discharge/s in 2010

In this preliminary review I have attempted to document the evidence for a marked condition change in 2010 within the low-lying areas of the Ibis Lagoon system. In my opinion the dead leaves and twigs, as well as surface water evident in the 2010 imagery, indicate widespread inundation with stress and death of vegetated areas, terrestrial and littoral. Flooding from mine-sourced discharges was nominated the most likely source of the excess water.

At least 80 ha of the Moreton Bay Ramsar Wetland (or some 95 ha of the Ibis Lagoon system) was affected. This area is approximately 40 to 50 times larger than the area impacted by flooding from the Ibis Mine in 2000 which was restricted to the western part of the Ibis Lagoon system. The much smaller incident of 2000 generated a "Show Cause" notice from the regulatory agency; the 2010 flooding did not.

Given Sibelco's environmental concerns and the stated capacity of its mining and environmental team, it is difficult to conceive that their personnel were unaware of this impact so close to the Enterprise operations. Yet, there was no public announcement of this condition change in 2010 and I am unaware of any advice from the company to relevant Queensland and Australia agencies. There was no acknowledgement of these impacts in official reports such as the AER 2010 (released in 2011).

Because the mining company provided no information about, or data for, any 2010 flooding it is not possible to accurately assess the full range of impacts of this incident. The 2010 imagery suggests the inundation lasted at least 6 months but this is not necessarily indicative of the degree and kind of impacts. Groundwater levels took some 18 months to return to projected 'natural conditions' after the 2000 discharges. By comparison with other reported impacts from similar inundations on the island, including the Resource Strategies Pty Ltd (2000) report on flooding from the Ibis Mine in 2000, it is possible to rank the 2010 incident as largest in area of all the mine-sourced incidents ever noted on the island.

From the 2010 incident there would have been impacts from the inundation itself and associated impacts on soils, substrate and waterbodies followed by some recovery. I am unaware of additional studies of the likely impacts and sequelae, including: extent and mode of inundation; recovery of the groundwater system and free-surface levels and volumes; changes in water quality from both the mining discharges as well as dissolved and particulate loads from damaged and killed organisms; extent of morbidity, mortality and repopulation of flora and fauna in the affected terrestrial areas and the littoral surrounds of the waterbodies; and, impacts on water quality, flora and fauna of the lagoons/swamps. I am unaware of any program to rehabilitate and/or remediate the impacted areas, even in the most basic way.

Thus, in my opinion, and in relation to the EPBC Act, the discharges sourced from the Enterprise Mine in 2010 will have generated over months to years "a substantial and measurable change in the hydrological regime of the wetland [through]... a substantial change to the volume, timing, duration and frequency of ground... water flows to ... the wetland".

6.2.2 Summary of hydrological impacts from locally increased water volumes

Modelling the water management factors at the Enterprise Mine (ESR 2003) has established that mining could deliver some 42 to 12 ML/day (16.8 to 4.8 Olympic swimming pools per day). During operations this extra volume of water drains as a descending plume from the dredge pond and tailings areas, adding to natural base flows. The forecast mining-generated discharges are similar in volume to the measured surface flows of *natural* discharges into Eighteen Mile Swamp such as at Blue Lake outflow (15 to 17.8 ML/day). (Of course, groundwater naturally recharges with much greater volumes to Eighteen Mile Swamp and elsewhere.)

Because discharges from the Enterprise Mine occur on a 24/7 basis the descending variable plume is a permanent feature between Eighteen Mile Swamp and the Ibis Lagoon system for as long as the dredge pond operates at elevations higher than the main island aquifer. Since mining operations commenced the locus of the discharges has progressively moved northwards as the dredge pond and latest tailings migrate along the planned mine path. However, this movement is not very fast — about 500 to 800 metres annually. Modelling indicated that discharges would continue for at least 9 years. However, if mining ceases in 2019 as nominated by the legislation the discharges will have occurred over 14 years. I understand the legislation was amended in November 2013 to allow Sibelco to apply, in 2019, for an extension of operations beyond this time limit, perhaps doubling the life of the mine.

The style of on-going discharges as predicted in the ESR 2003 are not likely to generate flows that would cause erosion or substantial and permanent changes in water bodies of the Ibis Lagoon system. Rather, the over-charged groundwater would most likely well up towards the ground surface, mixing with natural groundwaters. Based on the historical experience of mining impacts on the Island, and considering the material in the ESR 2003, the PoOs and AERs, the most likely impacts from mining will be biological, prompted by changes in water levels and water quality. These aspects are considered in Sections 6.3 and 6.4.

6.2.3 Permanent change in groundwater supply to Ibis Lagoon system

When the Enterprise Mine is completed a mass[26] of near-homogeneous, water-deposited yellow-brown tailings will replace the original pile of wind-deposited sediments and dependent soil profiles. Depending on when mining actually ceases, under a revised mining timetable, a tailings-filled super-trench, roughly with a trapezoidal cross-section, will stretch northwards along the central eastern part of the island for about 8 kilometres, from south of Tazi Trench to east of Black Snake Lagoon. As evident in Figures 1 and 2, as well as Photomap 14, the Enterprise Mine as a continuation of the earlier Ibis Mine will almost completely surround the Ibis Lagoon system. It is logical to expect such physical disruption will have some impact on the original hydrological flows between now-mined ridges and the Ibis Lagoon system.

It can be stated confidently that the tailings of the Ibis-Enterprise operations will have higher porosity and permeability than in the intact dunes, so hydrogeological conditions and dependent groundwater regimes will be changed permanently. It is likely that on both sides of this annulus-shaped rehabilitating mound the groundwater recharge will be increased and delivered more rapidly as base flow to the Ibis Lagoon system (and to Eighteen Mile Swamp as indicated in Stock 2012).

In my opinion and in relation to the EPBC Act, the Enterprise Mine will generate “a substantial and measurable change in the hydrological regime of the wetland [through]... a substantial change to the volume, timing, duration and frequency of ground... water flows to ... the wetland”. If the permanent and similar impacts of the earlier Ibis Mine (the proto-Enterprise Mine) already made on the west and south of the Ibis Lagoon system are added to those from the Enterprise operations, mining in this area of North Stradbroke Island will have affected profoundly most of the original hydrological regime of this part of the Moreton Bay Ramsar Wetland. With respect to the prospect for permanent change to areas nearby the Ibis-Enterprise operations, the company appears not to have examined or proposed a monitoring program, or required an evaluation after mining. For these reasons it is not possible to give numerical values to the permanent changes in water flows (volumes, quantities, directions) and water quality.

[26] The cosmetics of rehabilitation with topsoil and revegetation are useful for landscape stability and aesthetics and are required by lease conditions. However, such activities cannot reverse or disguise the permanent changes to hydrogeological conditions in the subsurface.

6.3 Changes in water quality

In this review I have focussed on accounting for the condition change evident in aerial photography during 2010 so an emphasis on water volumes and timing was relevant to the Ibis Lagoon system. I referred to the lack of water quality data in the limited monitoring program the company has operated; some of this was unavoidable because of natural dry conditions in the Ibis Lagoons. In any case, because of the very limited published data in the AERs and the absence of information about volumes and quality of make-up water from the different supply sources, only some very general statements can be made about changes in overall water quality.

The make-up waters used in the Enterprise Mine have had, over time, a variable water chemistry signature according to the volume proportions of water derived from Eighteen Mile Swamp (Herring Lagoon), Wallen Wallen Swamp (Kounpee Trench) and other production bores drawing directly from the prime aquifer. From this starting point the water chemical properties would have been affected during mining, processing and tailings stacking by: sand particles releasing ions from their skins of clay, iron and aluminium minerals; saturation with carbon dioxide; and by interaction with additives for reducing water losses from tailings. In turn, the descending drainage water from pond and tailings would have interacted with the subsurface sands in soil profiles encountered en route to this part of the Ramsar Wetland/part of the Ibis lagoon system.

Whatever the variable chemical nature of the drainage water entering the Ibis Lagoon system, it cannot be considered as simple recycled natural (swamp plus ground) water, purified by passage through sand and with properties unrecognisable from that of other natural waterbodies on the island. In the absence of data from all stages of the mining-dependent water system such statements are simply untested company claims.

In the much longer term, different terrestrial ecosystems will be established in the tailings-plus-topsoil mass of the rehabilitated mining area and rainfall will recharge a different groundwater regime. It is likely that over time (decades to hundreds of years) this groundwater will approach the same chemical character as that of the prime aquifer. In my opinion, before these long-term adjustments are effected the mine-induced changes in water quality are “likely to have been significant”.

Under lease conditions some waterbodies of this part of the Moreton Bay Ramsar Wetland are monitored for a few water quality attributes. Sibelco reports the values annually as graphical plots in the AERs, along with basic comparisons and interpretations of significance in that year. I know of no proposals from the company to expand the monitoring program or to conduct more detailed evaluations of water quality during and even after after mining. Consequently, it is not possible to use numerical values to track and test for the likely permanent changes in water quality.

6.4 Biological changes induced by changes in water volumes and water quality

Although the wording in the ESR 2003 and other company documents refers to mining as generating ‘temporary’ changes, it is hardly a term that should be applied to a decade-long period (or more) of discharges from the Enterprise operations. Subsurface flows would not necessarily be directed into the Ibis Lagoon system for the whole of that period but certainly would move into Eighteen Mile Swamp (as I discussed in Stock 2012). The impacts on food and habitat conditions of some aquatic fauna will depend, in part, on how long the mine-sourced discharges of variable geochemical signatures mix with natural groundwaters of the Ibis Lagoon system that supply the lagoons and swamps. The mining company is not publishing information or data to reveal whether the elevations and duration of increased groundwater levels as forecast in ESR 2003 are being realised. Similarly, the company is not publishing monitoring data for surface water levels in the lagoons, nor reporting any analyses of longitudinal changes in elevations, for the public to be informed about trends over the longer term.

Some natural species may be advantaged, others may be disadvantaged. For some species in these low-acidity low-conductivity waters, even apparently subtle changes elevations in water levels combined with changes in water chemistry can generate more antagonistic effects. For example, an extended immersion with slight changes in water chemistry may be sufficient to allow an invasive exotic species to extend its geographical range.

Whether these potential impacts are significant or not cannot be stated without further investigations. The company has generated only limited data of summary measures: acidity (pH), salinity (EC) and turbidity. There has been no monitoring of potential index species or species known to have sensitivity to, say, water acidity in its various life stages. The mining company has not proposed any periodic, end-of-mining, or post-rehabilitation surveys to follow trends in fauna (or flora) that may have been affected by the Enterprise operations.

7.0 DECLARATION

Subject to the proviso in the next paragraph, I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance that I regard as relevant have, to my knowledge, been withheld from the Court.

This is a preliminary review only as it has been prepared on the basis of information that is publicly available regarding the Enterprise Mine, particularly in the company’s published AERs. As discussed in this report, that information is deficient in many respects. The findings and opinions expressed in this preliminary review will be reconsidered if and when further information becomes available through the trial process, for example, if Sibelco Australia Limited (SAL) provides further documents regarding monitoring at the mine, or if I am able to meet with and discuss the issues with experts acting for SAL.

Dr Errol Stock
27 February 2015

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APPENDIX 1: PHOTOMAPS 1 THROUGH 14

List of Photomaps **Page**

Photomap 1: Nearmap image of Enterprise Mine on 27 January 2010. Note light brown photo-pattern indicative of sedgelands in northern part of Ibis Lagoon Central (see Figure 3 for the locations of other waterbodies in the Ibis Lagoon System).

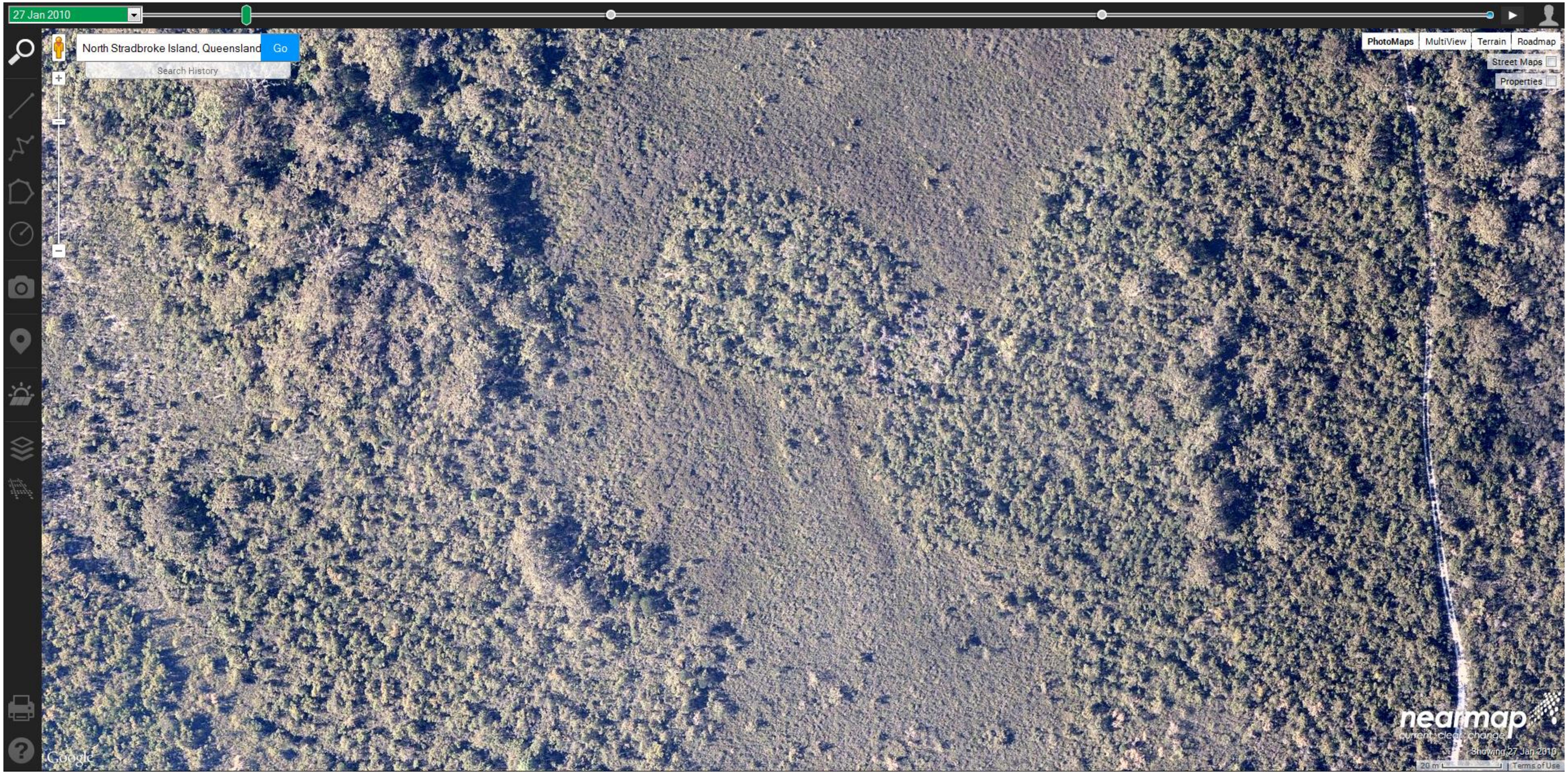
Photomap 2: Nearmap image of Enterprise Mine on 6 May 2010. Note areas of grey and colours of brown vegetation within the Ibis Lagoon system. No areas of similar photo-pattern were present at any other location on North Stradbroke Island at this time.

Photomap 3: Nearmap image of Enterprise Mine on 16 September 2010. Note photo-pattern areas of grey to the west of the mine within the Ibis Lagoon system.

Photomap 4: Nearmap image on 27 January 2010 showing detail of photo-patterns in northern half of the Ibis Lagoon system, west of the Enterprise Mine. Red dotted line indicates the approximate location of the boundary of the Ramsar Wetland between the Ibis Lagoon system and the Enterprise Mine (DEHP 2013). Compare to Photomaps 5 and 6 showing, respectively, the identical area as at 6 May 2010 and 16 September 2010. Photomap 7 provides a more detailed image of photo-patterns within the white rectangular area (approximately 200 m x 500 m) immediately east of Ibis Lagoon Central on 27 January 2010.

Photomap 5: Nearmap image on 6 May 2010 showing detail of photo-patterns in the northern half of the Ibis Lagoon system, west of the Enterprise Mine. Red dotted line indicates the approximate location of the boundary of the Ramsar Wetland between the Ibis Lagoon system and the Enterprise Mine (DEHP 2013). Compare to Photomaps 4 and 6 showing, respectively, the identical area as at 27 January 2010 and 16 September 2010. No areas of similar brown photo-patterns were present at any other location on North Stradbroke Island at this time. Photomap 8 provides a more detailed image of photo-patterns within the white rectangular area (approximately 200 m x 500 m) immediately east of Ibis Lagoon Central on 6 May 2010.

Photomap 6: Nearmap image on 16 September 2010 showing detail of photo-patterns in the northern half of the Ibis Lagoon system, west of the Enterprise Mine. Red dotted line indicates the approximate location of the boundary of the Ramsar Wetland between the Ibis Lagoon system and the Enterprise Mine (DEHP 2013). Compare to Photomaps 4 and 5 showing, respectively, the identical area as at 27 January 2010 and 6 May 2010. Photomap 9 provides a more detailed image of photo-patterns within the white rectangular area (approximately 200 m x 500 m) immediately east of Ibis Lagoon Central on 16 September 2010.

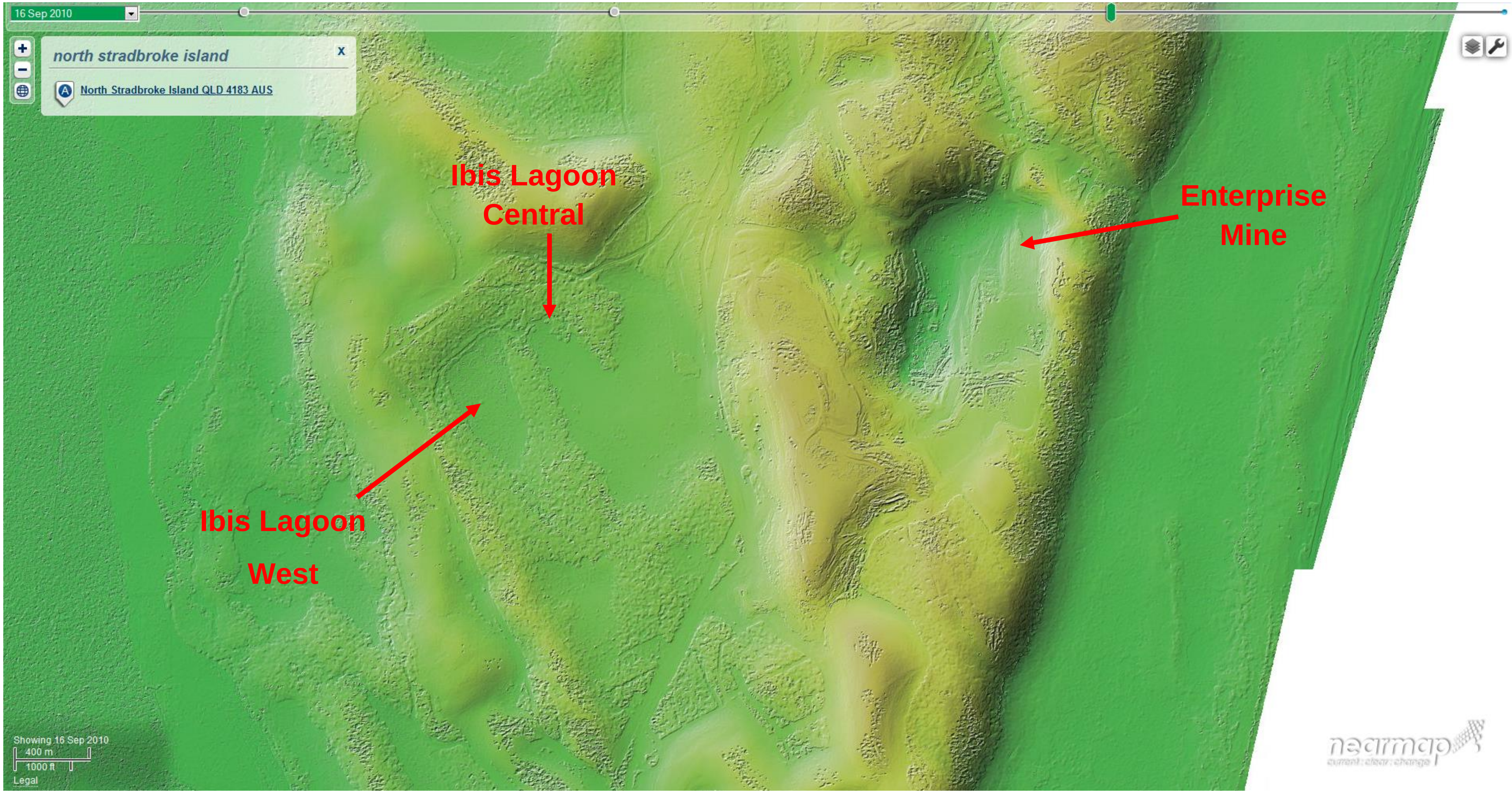


Photomap 7: Nearmap image on 27 January 2010 showing detail of photo-patterns in an area of approximately 200 m x 500 m immediately east of Ibis Lagoon Central in northern half of the Ibis Lagoon system, west of the Enterprise Mine. See white rectangle marked in photomap 4. This area is wholly within the Moreton Bay Ramsar Wetland.

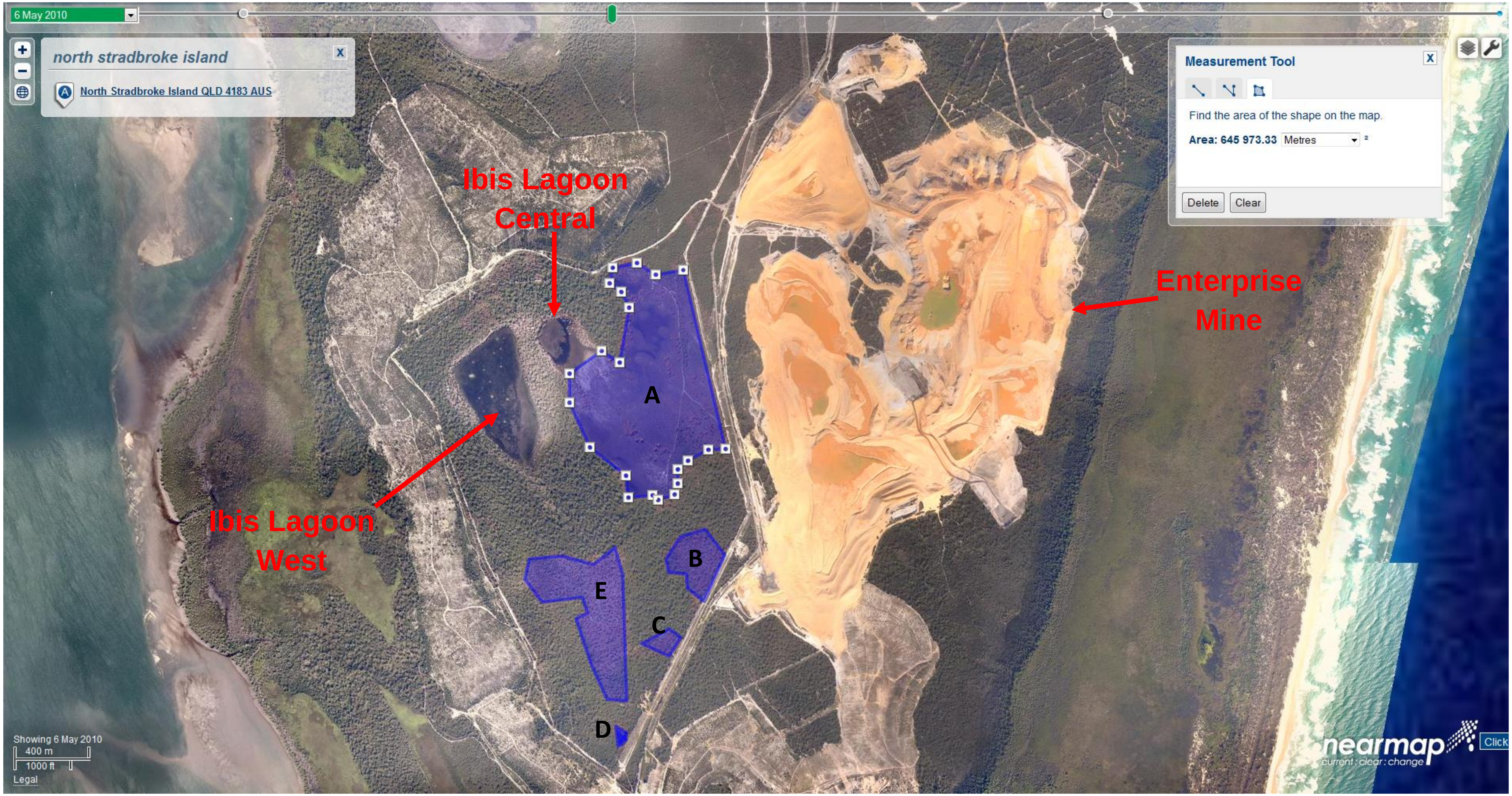
Photomap 8: Nearmap image on 6 May 2010 showing detail of photo-patterns in an area of approximately 200 m x 500 m immediately east of Ibis Lagoon Central in northern half of the Ibis Lagoon system, west of the Enterprise Mine. See white rectangle marked in photomap 5. This area is wholly within the Moreton Bay Ramsar Wetland.

Photomap 9: Nearmap image on 16 September 2010 showing detail of photo-patterns in an area of approximately 200m x 500m immediately east of Ibis Lagoon Central in northern half of the Ibis Lagoon system, west of the Enterprise Mine. See white rectangle marked in photomap 6. This area is wholly within the Moreton Bay Ramsar Wetland.

Photomap 10: Nearmap image on 6 May 2010 showing detail of photo-patterns in southern half of the Ibis Lagoon system, west of the Enterprise Mine. Red dotted line indicates the approximate location of the boundary of the Ramsar Wetland (DEHP 2013). The area north of the red dotted line is within the Ramsar Wetland.



Photomap 11: "Terrain" image of Enterprise Mine on 16 September 2010 showing changes in elevation. Note that photo-pattern areas of brown shown in Photomap 2 to the west of Enterprise Mine correspond with areas of lowest elevation.



Photomap 12: Five areas delineated of marked condition change to the west of Enterprise Mine in the Ibis Lagoon system on 6 May 2010. Calculation of areas using Nearmap area tool. Source: Nearmap. Note that the whole of areas C and D and the southern tips of areas B and E are outside of the Ramsar Wetland.

A = 645,973m^2 B = 70,420 m^2 C=15,678 m^2 D=1,165m^2 E=217,611 m^2 Total=950,847 m^2 (95ha)

Photomap 13: Northern section of composite Nearmap image of North Stradbroke Island on 6 May 2010
(joins Photomap 14 showing southern section of island).

Photomap 14: Southern section of composite Nearmap image of North Stradbroke Island on 6 May 2010 (joins Photomap 13 showing northern section of the island (note that the photo-pattern areas of brown immediately west of Enterprise Mine are not found at any other location on the island at that time or any time in the Nearmap record for 2010).

APPENDIX 2: EXTRACTS FROM AERS 2009-2011

The following verbatim transcripts from AERs 2009, 2010 and 2011 show the information available on water quality attributes for waterbodies within the Ibis Lagoon system. Several comments have been added at places within the quoted transcripts. Only the transcripts for these three years are presented because of their relevance to exploring the evidence for condition change in 2010 as described in this review. The ESR 2003 Figures 4-4 through 4-6 indicated that maximum change in groundwater in the Ibis Lagoon system was likely to occur during the period June 2005 through June 2007. However, as noted in Section 3.2.2 of the main text, AERs for 2005 through 2007 recorded that there were overall dry conditions in ibis Lagoons West and Central. Consequently no verbatim extracts from these earlier AERs are presented in this Appendix.

Extracts from AER 2009

Extract from p93:

> Although monthly monitoring is carried out at Enterprise dredge pond, results are not presented [in the AER 2009], as triggers for the dredge pond level have not been established. Triggers were deemed unnecessary as these waters are confined to the dredge pond or tailings lines and are not discharged to any other waters without prior filtration through sand (for instance, seepage from pond [and tailings] into aquifer).

Extract from p93:

> … [M]easured pH fluctuated throughout the year for Ibis Lagoon Central. … The minor variations in pH above the 80th percentile trigger [for the lagoon] are thought to be a result of natural variation most likely from the high rainfall received through the year. …
>
> … Measured pH was above the 80th percentile trigger during January, April, September and October for Ibis Lagoon West [i.e. for 4 out of 12 months or one-third]. … The fluctuations throughout the year are due to natural variation (i.e. climatic conditions [*sic*], site conditions such as rapid increase/decrease of water levels due to rainfall). Similar trends in pH were observed at other water bodies outside the 'zone of impact', but still within the Ibis Mine complex. …

Extract from p97:

> … The increase above the [conductivity 80th percentile] trigger during these months [Oct, Nov, Dec for Ibis Lagoon Central; Jul, Nov, Dec for Ibis Lagoon West] was attributed to natural variation such as receding water levels.

Extract from p100:

> … The increase in turbidity [at Ibis Lagoon West] above the 80th percentile trigger [during Sep, Oct, and Nov] was thought to be the result of the decreasing water levels.

Extracts from AER 2010

Extract from p86:

> Although monthly monitoring is carried out at Enterprise dredge pond, results are not presented [in the AER 2010], as triggers for the dredge pond level have not been established. Triggers were deemed unnecessary as these waters are confined to the dredge pond or tailings lines and are not discharged to any other waters without prior filtration through sand (for instance, seepage from pond [and tailings] into aquifer).

[Note that this is an exact repetition of the statement in AER 2009 p93 but it was not repeated in AER 2011 as shown below.]

Extract from p86:

> … [At Ibis Lagoon Central] [a]ll months with the exception of January, February, August, September and October were below the [pH] 80th percentile trigger [i.e. for 5 out of 12 months or almost half]. The variations in pH above the 80th percentile trigger are thought to be a result of natural variations most likely from the high rainfall received through the year and the elevated water levels within Ibis Lagoon Central. …
>
> … Measured pH was at or below the 80th percentile trigger for all months with the exception of February, March, August, September and October for Ibis Lagoon West [i.e. for 5 out of 12 months or almost half]. The fluctuations throughout the year are due to natural variation (i.e. climatic conditions [*sic*], site conditions such as rapid increase/decrease of water levels due to rainfall). Similar trends in pH were observed at other water bodies outside the 'zone of impact', but still within the Ibis Mine complex.

Extract from p90:

> Conductivity levels were low during the 2010 monitoring period at Ibis Lagoon Central and Ibis Lagoon West, remaining below the maximum trigger in all months with the exception of January for Ibis Lagoon West. A maximum reading of 140µS/cm was recorded during January at Ibis Lagoon West. Average conductivity for Ibis Lagoon Central and Ibis Lagoon West was 70µS/cm and 63.4µS/cm, respectively. Conductivity levels remained at or below the 80th percentile trigger in all months with the exception of November for Ibis Lagoon West.

[Note that this verbatim transcription from p90 in the AER 2010 is exactly the same as that for conductivity in the AER 2011 (see below).]

Extract from p93:

> Turbidity levels were low for Ibis Lagoon Central and Ibis Lagoon West … Turbidity levels at Ibis Lagoon Central were at or above the 80th percentile trigger during January, June and July [i.e. for 3 out of 12 months or about one-quarter] and a maximum turbidity level of 27 NTU was recorded during March. The one off observation was most likely a result of natural variation (i.e. high rainfall).

Extracts from AER 2011

Extract from p85:

> Although monthly monitoring is carried out at Enterprise dredge pond, results are not discussed in detail as the dredge pond is contained and not released to the receiving environment.

[Note that this statement is not correct because the company had acknowledged that losses do occur from pond and tailings. It was not repeated in the AER 2012.]

Extract from p85:

> … pH levels fluctuated at Ibis Lagoon Central … All months with the exception of March, July and August were below the [pH] 80th percentile trigger [i.e. for 3 out of 12 months or about one-quarter]. The variations in pH above the 80th percentile trigger are thought to be a result of natural variations most likely from the rainfall received. …
>
> … At Ibis Lagoon West pH ranged between 4.34 and 6.23 … March, July and August were above the [pH] 80th percentile trigger [i.e. for 3 out of 12 months or about one-quarter]. All months other than January and December were at or above 20th percentile trigger. Similar trends in pH were observed at other reference water bodies (e.g. Kounpee Trench) outside the 'zone of influence' of mining activities. …

[With respect to the latter of the two extracts from p85 it is quite pointless, if not misleading, of the AER authors to cite Kounpee Trench as an example. This is a human-made structure in a coastal swamp in an entirely different hydrological setting to conditions for the perched water bodies. Indeed, at p89 the text says the company takes samples here "to monitor any possible occurrence of saltwater intrusion [from Moreton Bay]". As well, some make-up waters for the Enterprise dredge pond could have been sourced from Kounpee Trench and could reappear as drainage from the pond and tailings.]

Extract from p89:

> Conductivity levels were low during the 2010 [*sic*] monitoring period at Ibis Lagoon Central and Ibis Lagoon West, remaining below the maximum trigger in all months with the exception of January for Ibis Lagoon West. A maximum reading of 140µS/cm was recorded during January at Ibis Lagoon West. Average conductivity for Ibis Lagoon Central and Ibis Lagoon West was 70µS/cm and 63.4µS/cm, respectively. Conductivity levels remained at or below the 80^{th} percentile trigger in all months with the exception of November for Ibis Lagoon West.

[Note that this verbatim transcription from p89 in the AER for 2011 is exactly the same as that for conductivity on p90 in AER 2010. It appears the authors of the 2011 report made a cut-and-paste error and some other wording and numerical values should have been used. The temporal plots for the two Ibis lagoons, in Figures 46 and 47 in AER 2011, indicate quite different numerical values from those cited on p89. A comparison of the text for “Monthly Conductivity” in AER 2011 p89 shows that (except for the first sentence) it is exactly the same as that in AER 2010 p90. Clearly the author had not proofread the AER 2011 to correct the error before publication.]

Extract from p92:

> Turbidity levels recorded at Ibis Lagoon Central and Ibis Lagoon West were low … At Ibis Lagoon West turbidity levels recorded were below the 80^{th} percentile trigger during the monitoring period with the exception of August. … This reading was attributed to natural weather conditions such as rainfall or wind conditions.

ATTACHMENT 1: EXTRACTS OF PAGES 4-15 TO 4-17 FROM THE ESR 2003 FOR ENTERPRISE MINE

- In the case of solution convergence, changes were introduced to prevent MODFLOW-96 execution being halted.
- For convenience, the total elapsed time from the onset of the simulation was stored in the header to each cell-by-cell term array.

The model grid for the whole of Island DNRM model was constructed in Australian Map Grid (AMG) and was 40 km long in the north-south direction and 15 km long in the east-west direction. The DNRM model grid was uniformly 200 m by 200 m.

The grid for CRL's revised Ibis model was reduced to 50 m by 50 m to improve the spatial resolution of the model and allow more accurate specification of the planned mining activities. The refined model grid comprised 800 rows and 300 columns, with the AMG coordinate system maintained.

Depending on where the water level in the dredge pond is (ie. compared with the relative height of the prime water table), water either flows out of the dredge pond and into the groundwater system (ie. if the dredge water level is above the prime water table), or from the groundwater system into the dredge pond (ie. if the dredge water level is below the prime water table). The 'river' package of the MODFLOW-96 modelling programme was used to accommodate this process.

The movement of the dredge pond was simulated using specialised software developed by Watermark Numerical Computing to interpolate pond positions and mine paths to the model grid both spatially and temporally.

Initial groundwater conditions for the model were based on three factors: prior model simulations, bore hydrographs and the operational setup of CRL's mining activities. Regionally, the initial conditions were determined from water table elevations predicted for January 2002 by the DNRM model. Thus, simulated heads were interpolated to the new model grid and adopted as initial conditions in areas outside the anticipated zone of impact of the Ibis Mine. Where applicable, initial conditions in and around the Ibis Mine were set according to January 2002 data from nearby DNRM observational bores and CRL's existing piezometers.

Natural recharge over the model domain was assumed to occur at a spatially and temporally uniform rate of 35% of mean annual rainfall (ie. approximately 600 millimetres per year [mm/yr]), which is consistent with the recharge used in the DNRM model. On-site tailings deposition provides an additional source of water recharge to the natural groundwater system, with the initial model simulations adopting a tailings recharge rate of 35 ML/day. However this was subsequently revised to 27 ML/day on the basis of metallurgical studies of achievable tailings densities. The 'well' package of the MODFLOW modelling programme was used to accommodate the tailings recharge process as well as the effect of abstraction from the nearest RSC water supply bores (located to the west of the Enterprise Study Area – refer to Figure 3-11).

Analysis and Evaluation of the Groundwater Modelling Results

Due to the recognised environmental values of Eighteen Mile Swamp and the main escarpment, an analysis and evaluation of risks associated with adjacent mining activities has been conducted in accordance with CRL's risk assessment and management system. An overview of the model output, and how the risks associated with the predicted results have been evaluated, is provided in the following text.

Results of the groundwater modelling for the final 12 months of the Ibis Mine indicate that as the dredge pond level will be above the prime water table, average flows from the base and sides of the pond of greater than 40 ML/day may be experienced. However, this is likely to be an overestimate, as it does not take into account lower permeability materials sealing the base of the dredge pond. Regression analysis of actual pond losses suggests a maximum of around 15 ML/day will be experienced.

The modelled hydrological effect (expected impact) of the above on the section of Eighteen Mile Swamp adjoining the final year of the Ibis Mine and the commencement of the Enterprise Mine will be to temporarily raise the existing groundwater levels near the toe of the escarpment by approximately 1 m. CRL's previous experience with surface waterbodies on the Island indicates this is likely to result in a temporary rise of approximately 0.1 to 0.3 m in surface water levels in the adjoining section of Eighteen Mile Swamp. This minor increase in Eighteen Mile Swamp surface water levels will be located between CRL's two authorised surface water pumping stations (located at Herring Lagoon and Palm Lagoon).

Authorised pumping activities in Eighteen Mile Swamp by CRL and RSC have resulted in surface water level variability of up to 1 m in the vicinity of the Herring Lagoon pump station (Section 3.3.1). Although the predicted 0.1 to 0.3 m increase in surface water levels in Eighteen Mile Swamp associated with the Ibis/Enterprise Mine will be temporary, it may partially offset the reductions in natural surface water levels that occur from authorised pumping activities.

Modelling of the planned Enterprise Mine path indicates the effect on Eighteen Mile Swamp will be less than the final stages of the Ibis Mine path. The preliminary model output for the planned mine path is presented on Figures 4-2 to 4-11 for the period from 2003 to 2012. The model output is presented as the predicted variation in the prime water table shown as contours (refer to left hand side of Figures 4-2 to 4-11), with the yellow/orange colours indicating where mounding is predicted to occur and the blue colours indicating where a drawdown effect is predicted. The model output is also presented as the predicted cumulative effect of the planned operation on the prime watertable (ie. includes the effect of RSC groundwater abstraction – refer to the right hand side of Figures 4-2 to 4-11).

The results of the modelling indicate that the degree of groundwater mounding associated with the dredge pond and tailings deposition area will decrease as the mine descends and moves north along the path. The groundwater mounding effect in any one area will be temporary as the mine moves away and water contained in the deposited tailings dissipates.

The water level in the pond is expected to be at or slightly below the water table around December 2005 onwards, after which time inflows to the dredge pond are expected to average around 16 ML/day. As a result, once the planned dredge mining operation is operating at or below the prime water table, no increases in surface water levels in Eighteen Mile Swamp are anticipated. The predicted effect of the planned Enterprise Mine on surface water levels in Eighteen Mile Swamp is for a small and temporary rise in the section of the Swamp nearest the Mine whilst it is above the prime water table in the period before December 2005.

Some minor and temporary effects on environmental values (eg. terrestrial and aquatic flora, and aquatic fauna values) could potentially occur in the zone of impact where groundwater mounding and increases in surface water levels are predicted. Similar types of effects have been observed as both natural and mine-induced phenomenon in the past and may result in the following:

- localised changes to vegetation in temporarily inundated areas;
- impacts on aquatic fauna species abundance due to an increase or decrease in suitable food or habitat (eg. increased frog activity); and
- minor surface erosion due to increased seepage and/or surface flow from localised areas.

Based on CRL's experience at Little Canalpin Creek (located on the western side of the Ibis Mine) in 2001/2002, no significant mine-induced changes to the water chemistry in Eighteen Mile Swamp are anticipated.

Groundwater Quality

As detailed in Section 4.2.5, CRL implements a range of hydrocarbon and chemical management control measures to minimise the possibility of land or water contamination.

CRL has conducted a risk assessment of the potential for environmental harm associated with the use of hydrocarbons, flocculant and other chemicals at its operations on North Stradbroke Island. The assessment concluded that risks to groundwaters associated with the use of these products was moderate and primarily related to spills or leaks from storage and transfer areas.

The control measures utilised in Section 4.2.5 apply to these risks.

Trigger Levels

The principle indicator for the key environmental values associated with Eighteen Mile Swamp will be the effect on surface water levels within the zone of impact surrounding the mining activities.

As described above, the groundwater modelling predicts an increase in surface water levels of approximately 0.1 to 0.3 m in the section of the Swamp adjacent to the active mining/tailings placement areas. Accordingly, a trigger level of 0.25 m increase within this zone of impact will be used. CRL will determine the effect of its operations on surface water levels within the zone of impact by comparing the monitoring results from a series of sites located along the western edge of Eighteen Mile Swamp. The monitoring locations will include sites within and outside the predicted zone of impact.

Where the water level in the zone of impact increases by more than 0.25 m, and the increase cannot be explained through natural phenomena (eg. rainfall event), the trigger level will be deemed to be exceeded and CRL will implement the risk evaluation and treatment process described in the Monitoring Plan (as required by Environmental Authority Condition A7.4). This process will be based on the Australian Standard for risk management (AS/NZS 4360:1999) and is illustrated on Figure 1-7.

A lowering of surface water levels within Eighteen Mile Swamp is not predicted by the groundwater modelling conducted for the Stage 1 mining activities and it is not an expected impact. However, if CRL's on-going monitoring programme detects a measurable decrease (ie. 0.10 m), and the decrease cannot be explained through natural phenomena (eg. dry period), the risk evaluation and treatment process described in the Monitoring Plan will also be implemented.

As discussed in Section 4.2.5, CRL also has trigger levels that relate to spills of hydrocarbons and chemicals. Spills of more than 20 L, or spills that are located in sensitive areas or off-lease are classified as major spills and invoke an appropriate emergency response and reporting to the administering authority.

Risk Management Monitoring and Control Measures

The expected impacts of the planned Enterprise Mine on surface water levels in Eighteen Mile Swamp will be temporary and localised, as a result, no significant adverse effects on the environmental values of the Swamp are anticipated.

ATTACHMENT 2: CRITIQUE OF FIGURES 4-2 THROUGH 4-11 FROM THE ESR 2003 FOR ENTERPRISE MINE

CRITIQUE OF FIGURES 4-2 THROUGH 4-11 IN ESR 2003

Figures 4-2 through 4-11 in the ESR 2003 show paired plan plots as generated by the hydrological modelling that provided input to the design of the Enterprise Mine operations. They allow some very rough measures of the size and location of the mine-generated groundwater mound but their designer does not appear to have given the potential reader sufficient consideration with respect to easy of reading.

The forecasts commence in June 2003 (Figure 4-2) and are repeated at (almost) yearly intervals for every June (or May) through to June 2012 (Figure 4-11). The part of North Stradbroke Island covered in the figures is a full width (west to east) and about 12 kilometres north to south, from near the Blue Lake outlet to about 2 kilometres south of Tazi Trench. The left-hand map of the pair is a kind of 'contour' map showing " Water Table Variation" so that the predicted rise of the prime water table is pictured as a contoured mound and in different colours (for the chosen intervals) with the highest forecast in red. The right-hand map of the pair is a true contour map showing "Prime Water Table Levels in metres above Australian Height Datum (AHD)". For these maps no scale bar was drawn nor was a representative fraction stated. However, by comparison with other maps of North Stradbroke Island the scale of each of the maps in the 10 pairs is about 1:80 000. As a result the reproduction of the maps side-by-side on a single A4 page makes their details, text and numerals difficult to read. Another factor that makes the maps less than easy to interpret is the non-standard intervals chosen between the isolines.

The isolines for the left-hand map show water 'thickness' (that is, the isolines are really isopachs). However, the intervals (in metres) chosen for the illustration are *not* arithmetic (e.g. 1, 2, 3, 4...) but are uneven: 1, 2, 3.5, 5, 7.5, 10, 15, 20, "?" and "?". The "?" mark is used because the two highest values are not shown on the legend of the map. In contrast, the interval in the legend showing the forecast reduction in the prime water thickness *is* arithmetic. The CRL authors provided no explanation to account for the apparently idiosyncratic choice of intervals in the isopach maps.

The right-hand map of the pair is a contour map (that also includes the predicted effects of CRL's activities and RSC's non-mining extractions). The contours (shown on the legend) are *not* at arithmetic intervals and, additionally, are *not at the some intervals on either side of the zero datum*. Intervals above 0 m AHD are: 0.2, 1, 5, 10, 15, 20, 25 (and probably 30 m); intervals below 0 m AHD are: -2 and -5 m. The colours in the right-hand map are opposite in sense to those shown in the left-hand map of isopachs: green with blue colours indicate elevations above zero datum and orange with red indicate elevations below. The authors provided no explanation to account for the apparently idiosyncratic choice of intervals.