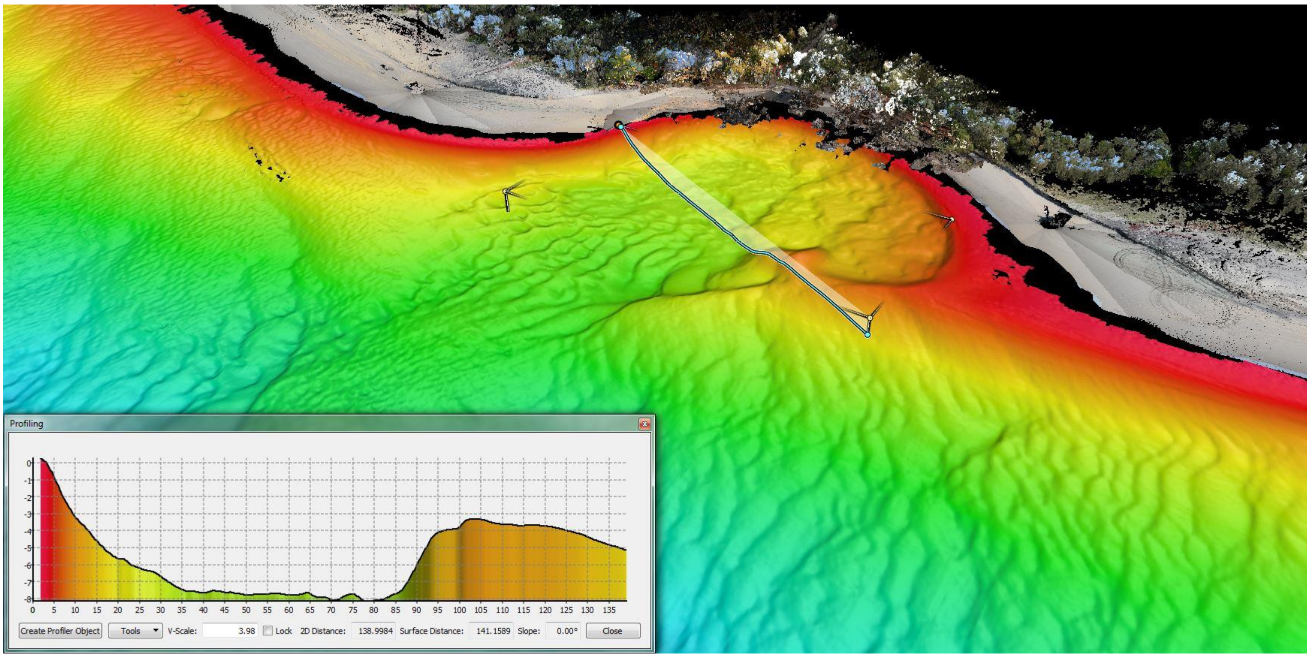
Risks associated with nearshore instability
Inskip Point, Qld



Prepared for:

Queensland Parks and Wildlife Service

Document Reference:

B01006-1AE

Version:

25 November 2015

Document:

Risks associated with nearshore instability
Inskip Point, Qld

Document Reference:

B01006-1AE Draft

Version:

25 November 2015

Prepared for:

Queensland Parks and Wildlife Service
Level 6, HQ South Tower
520 Wickham St
Fortitude Valley QLD 4006

Prepared by:

EDG Consulting Pty Ltd
91 Commercial Road
Teneriffe QLD 4005
t: +61 416 132 343
e: admin.edg@edgconsult.com.au

Author:

Ian Shipway – Principal

Reviewer:

Greg Hackney - Principal

Notes:

Final version following draft.

Table of Contents

Drawings

Table of Contents continued

Appendices

1 Introduction

On 26 September 2015, a nearshore landslide occurred within the north facing beachfront at Inskip Point, Qld, eventually regressing to a camping ground and engulfing a four-wheel drive vehicle, a caravan and a camper trailer. The nearshore landslide ("September 2015 instability event") occurred late in the evening and was in the form of a retrogressive which gradually increased in size over a period of several hours, eventually forming an arc shaped scarp over 200 m wide. At the request of Queensland Parks and Wildlife Service (QPWS), a Principal from EDG Consulting Pty Ltd (EDG) visited the site of the event on the afternoon of 27 September 2015. Following that site visit, a brief report was prepared providing a preliminary assessment of the mechanisms of instability and advice with respect to short term risk management measures.

Subsequently, QPWS commissioned EDG to conduct a study of instability events on the Inskip Point Peninsula and provide longer term risk management strategies. This report presents the results of that study, which was conducted in accordance of our proposal of 12 October 2015 (document reference: B01006-1AD).

1.1 Study Aims

The main aims of the instability risk study were to:

- Develop knowledge of the history of past instability events on the Inskip Point peninsula.
- Gain an understanding of the mechanism of instability, including triggers and the geographical constraints which may affect the morphology and location of future events.
- Provide the information required to assess and analyse the risks presented by future instability.
- Devise practical risk management options which QPWS could implement to reduce risks.

1.2 Study Scope

The study was based on data that was readily available, with a focus on providing risk management outcomes within a few weeks of the study initiation. The main elements of work conducted for the study comprised:

1. Desk study and research into past events based on QPWS records and other readily available data. Information was sought with respect to:
   a. The location, date and time of past events and under what conditions the events occurred, relative to tides, seismic activity and other natural cycles.
   b. Mechanisms of failure for similar events in Australia and elsewhere. This involved a literature review and conversations with those currently conducting research.
   c. The geology and geotechnical conditions of the peninsula.

2. A one-day field visit to view the surface geomorphology and geological conditions, and the sites of historic instability events where they could be identified.
3. A high resolution multibeam sonar and vessel mounted/terrestrial laser survey of the northern side of the full east-west extent of the peninsula. The intent of the survey was to measure the geometry – bathymetry of the nearshore zone, both at the location of the recent event and along the beachfront generally. The survey was conducted by Port of Brisbane Pty Ltd using the vessel Navigator for hydrographic and land survey up to about the high water mark, and land based laser survey for the upper parts of the beach. Appendix 1 presents detailed results of the survey and information on the methods used.
4. A preliminary risk assessment in accordance with the methodology of the Australian Geomechanics Society (AGS, 2007).

2 Physical Setting of the Study Area

2.1 Location

Inskip Point is a sand peninsula, north of Rainbow beach which forms the southern edge of the channel leading to the Great Sandy Strait (Figure 1.1).

Figure 1.1 Location of Inskip Point (Map Data: Google, Digital Globe, CNES/Astrium 2015)

The area of the study was limited to the east-west oriented area of the beach as shown on Figure 1.2.

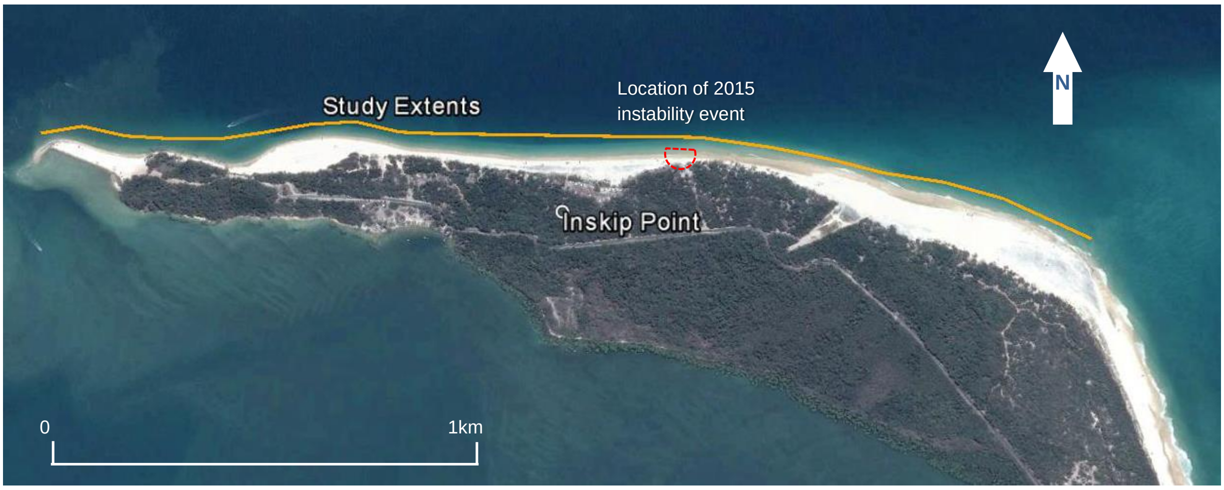


Figure 1.2 Extent of the study area – yellow line, relative to the zone of recent instability – red outline (Map Data: Google, CNES/Astrium 2015)

2.2 Surface Conditions

To the west of the location of the September 2015 instability event the beach slopes down from the tree line to the 0 m contour line (i.e. at 0m elevation relative to Australian Height Datum which is around or bit below the low water line) at about 3° to 4°. Towards the east, the beach increases in width from about 60 m to over 100 m over a distance of several hundred metres, and the slope down to the low water line flattens to about 1.5°. Figure 1.2 shows that to the west of the September 2015 instability event the tree line is irregular in shape, with broad scallops into the vegetation resulting in a widening of the beach. Drawing 1 is based on a topographic plot of the land based laser survey and bathymetry with a contour interval of 0.25m. The laser survey captures the trees as a series of closely spaced contours and so makes the tree line clear. This illustrates the varying widths of the beach, as defined by the position of the tree line, and shows the varying slope to different parts of the beach including the generally gentler grade down to the water-line east of the September 2015 instability event.

Within some of the broader scallops in the vegetation at the back of the beach, scarps are evident within the sand up to about 0.7m high, coinciding with zones of fallen trees (Figure 2.1). As these scarps are evident at elevations above the usual high water level of about 2m, we interpret them as the back scarps of previous instability events rather than the consequence of storm surge, as they are arc shaped and do not extend over the entire back beach area. In subsequent sections we present correlation with observed scarps and the locations of past instability events.

Figure 2.1 A small scarp at the rear of the vegetation line which is interpreted as the rear ward extent of past instability

Inland from the beach are variably shaped low dunes with vegetation cover ranging from low scrub to sparse trees varying in size up to about 600 mm in trunk diameter, but with most between about 50 mm to 300 mm. During our site visit we noted that there appeared to be more, larger diameter trees to the west of the 2015 instability event than to the east. Camp sites are situated within the trees and accessed by a series of unsealed roads. Drawing 1 shows the usage of the area, dividing it into the three named camping zones (Natone, Beagle, Sarawak) and an area designated as "Day Use" only.

2.2.1 The September 2015 instability event

Figure 2.2 is a publically available aerial photograph which shows the general shape of the September 2015 instability event. We made the following observations on our site visit of 27 September 2015, about 18 hours after the initiation of instability:

- The affected zone was in the form of an arc up to about 200 m wide.
- There was a sub vertical scarp at the back of the arc varying in height from 0.5 m to 1.5 m.
- Parts of the back scarp were being stabilised (i.e. held near vertical) by the roots of trees (Figure 2.3).
- A shallowly sloping (less than 10°) beach of about 5 m width had started to form below the back scarp.

- Out beyond the newly forming beach the sand dropped away at a much steeper angle, with dark blue water within the zone of instability suggesting a depth of 5 m or more quite close to the edge of the beach.
- Several trees up to about 8 m high had fallen into the zone of instability as their roots were undercut by the encroaching event.
- At this time the back scarp of the zone of instability did not appear to be retrogressing significantly.

We returned to the site at about 7:30 AM on Monday 28 September 2015 and noted that:

- The back scarp of the zone of instability had regressed only 2 m to 3 m metres from the position observed on Saturday evening and been reduced in slope in some parts to form a beach.
- Rapid and turbulent tidal flows and eddies were evident along the edge of the channel, where the adjacent beach falls to the sea floor.

Figure 2.2 Oblique aerial image of the 26 September 2015 instability event. Image source: ABC.Net.Au

Figure 2.3 View across the rear of the instability event looking west on the afternoon of 27 September 2013

During the visit on the morning of 28 September 2015 we were informed by staff on a Coast Guard vessel that the depth of water in the instability zone was a maximum of 9 m, shelving back to about 7 m closer to the beach.

In our follow up visit on 26 October 2015 to assess surface conditions along the whole peninsula we observed regression of the back scarp of about 3 m and some broadening of the beach below the scarp as shown on Figure 2.4.

Figure 2.4 Similar view from 26 September 2015 at around high tide (top) and 26 October 2015 at about low tide (bottom) illustrating several metres of further regression of the back scarp.

In our preliminary report following our initial site visit we concluded the following with respect to the mode of instability:

- The process triggering instability relates to over steepening of an off shore slope probably by erosion from rapid, turbulent tidal flows.

- The large tidal difference may have exacerbated the steepening by both creating more rapid, eroding flows and rapid draw-down effects near low tide higher up the beach than usual.
- Although the precise mechanics of instability are not clear, the outcome is rapid lateral movement of a large body of sand forming the nearshore zone and beach, with the scarp that initially formed rapidly retrogressing in-shore as the sand debris moved seaward.

2.3 Nearshore Bathymetry

Appendix 1 presents detailed results of the Hydrographic Survey carried out by Port of Brisbane. The bathymetric contours are illustrated on Drawing 1 with a false colour image derived from the sonar. Based on this data we interpret three distinct nearshore profiles along different parts of the beach, the main bathymetric features of which are illustrated in the three cross sections (Sections 1, 2 and 3) presented as Figure 2.5. Drawing 1 shows the locations represented by the cross sections.

One distinctive feature of the profiles is the relatively steep near-shore slope (slope angle typically 22° to 24°) which falls from around 0 m elevation down to about -7 m elevation. That steep slope is evident in the main portion of the beach as represented by Section 2, but is absent from the eastern and western extents of the beach (Sections 2 and 3). The steep submarine slope forms the southern side of the tidal channel, the orientation of which, is shown clearly by the darker blue water adjacent to the central part of the Peninsula in Figures 1.1 and 1.2.

Further offshore from the steepened section the sea floor profile drops at a gentler overall slope of about 9° but with numerous variably oriented sand ridges which we infer to be artefacts of the relatively rapid tidal currents which are frequently observed in the channel.

Drawing 2 shows detailed bathymetry of the September 2015 instability event which was conducted between 14 and 15 October 2015. At that time, the large bowl shaped depression in what is usually the in-shore zone had a maximum depth of about 6 m. A clear plume of sand can be seen as a raised mound over 50 m wide, extending for over 200 m off shore from the general location of the 0 m elevation contour line.

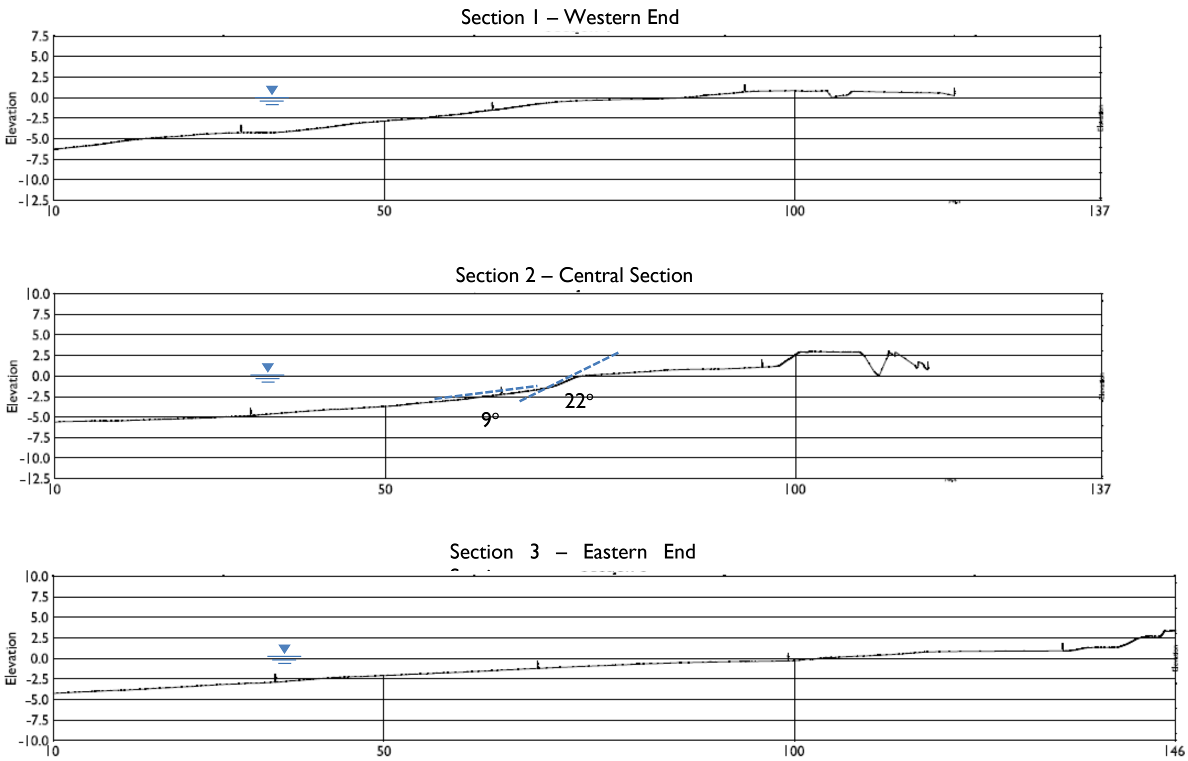


Figure 2.5 Cross Sections through three sections of the beach and near-shore zone. Section 1 represents the western most zone near the tip of the peninsula; Section 2, the main east-west extent of the beach; and Section 3 eastern end where the beach is oriented more towards the north-west.

2.4 Geology and Geotechnical Conditions

The 1:100,000 scale Wide Bay map sheet shows that the area of Inskip Point is underlain by Holocene aged Beach Ridges of the Coastal Plain (Qhcb). Ward (1987) provides a more detailed description suggesting that the beach sand extends to at least 15 m depth and notes the presence of "coffee rock" (humus cemented sand) further south at Rainbow beach. Although no subsurface investigation of geology has been conducted for this study, we made surface observations for the full length of the beach and the back dune camping area. The materials observed on the beach are judged to comprise predominantly fine to medium grained sand with no significant silt, which is consistent with the published geological description and geological environment. Similar materials with some minor silt and organic material content were observed within the back dune camping areas. We observed no "coffee rock" or other rock strength materials exposed on or behind the beach.

The high water mark is a long way up the beach because of its relatively flat slope, so we consider it reasonable to judge that sand was deposited more by water current and tidal influences than wind. Based on our experience, we consider that the sand is likely to be at least medium dense, or dense rather than loose, however the overall deposit could include some loose pockets.

3 Brief History of Instability

The primary reasons for collecting information on past instability events were to:

- Establish an approximate geographic spread for the events.
- Gain an understanding of the size, shape and extents of past events.
- Investigate possible correlations for events with natural phenomena and cycles such as tides based on date/time data.
- Assess similarities in events with respect to their morphology and retrogressive nature.

3.1 Information Sources

The main source for information on historical instability events was records available from QPWS. Their records mainly comprised brief diary entries and photographs. Dates were sometimes recorded but in some cases had to be interpreted from the metadata of digital image files. For some events where two cameras were used to capture images, the date and time metadata conflicted significantly, casting some doubt on when the images were captured. We used our judgement and any other available reports found on the internet to make assessments of date and time.

We also conducted a brief internet search to locate information and imagery of other instability events. Although reference is made to a number of events similar to that of September 2015, there are few reliable references with respect to date, time and precise location. On-line video of previous events, although often ambiguous with respect to date and time, has been useful to allow observation of similar events retrogressing up the beach, and make comparison to the September 2015 event.

A more detailed research exercise over publically available sources as well as through local press records may reveal significantly more detailed records.

3.2 Summary of previous instability events

Table 1 presents a summary of the identified events, with associated date and time data, and references. Further links and notes are presented in Section 8. The instability events have been identified by year and a numeric counter. Drawing 1 shows their approximate location based information supplied by QPWS and our observations of scarps near the existing tree line. No events have been observed to occur east of the Lead Lights, the location of which is shown on Drawing 1.

Table 1 Summary of historic instability events at Inskip Point

Event No.	Month-Year	Day	Time	General Location	Source	Notes
1873-1	Jan 1873	17	PM		Internet	Brisbane Courier - Occurred in evening
1901-1	Jun 1901				Internet	Speculative - Report from Brisbane Courier 3/7/1901
1938-1	Nov 1938	?			Internet	Speculative - Cairns Post article
1993-1	1993			Barge Loading Area	Internet	Speculative - Based on a photograph
2006-1	May 2006	-		West of Beagle	QPWS	Day unknown - About 11:00 AM and Active based on shadow
2010-1	Sep 2010	27		Sarawak	QPWS	Photographs taken 27/9/2010 15:15. Looks like end of active phase
2011-1	Jun 2011	26	10:00	Sarawak	QPWS	Earliest Photographs taken 26/6/2011 13:22 Time from Fraser Coast Chronicle
2011-2	Aug 2011	27		West of Beagle	QPWS	Photographs taken 28/8/2011 10:08

Event No.	Month-Year	Day	Time	General Location	Source	Notes
2012-1	Jun 2012	16		West of Sarawak	QPWS	Photographs stamped 16/6/2012 12:05PM Based on consecutive date stamps - 2 events in 2012
2012-2	Jun 2012	30		-	QPWS	Video stamped 30/6/2012 - Active event
2013-1	Aug 2013	-		Near barge loading area	Youtube	Link posted on 12/8/2013 - May be film of an earlier event
2013-2	Dec 2013	5		Sarawak – Near 2011-1	QPWS	Photographs taken 5/12/2013 19:28 Date stamp confirmed on 2 cameras
2015-1	Jan 2015	23		West end of Beagle	QPWS	Minor event - No photographs or information
2015-2	Sep 2015	26	10:30		QPWS	Good data

There were other events referred to in public sources which included ambiguous date, time and location information, which we omitted from the list.

3.3 Brief description of past instability

Figure 3.1 shows photographs of four events which occurred between 2010 and 2013.

a. 2010-1

b. 2011-1

c. 2012-1

d. 2013-2

Figure 3.1 Photographs showing the head scarp of four separate instability events at Inskip Point either within the early stages of retrogression (a,b) or a within day following (c,d)

The photographs demonstrate that the general surface expression of the various events is similar, with the head scarp forming an arc shaped near vertical face which retrogresses up the beach. Once retrogression is complete, a beach forms below the scarp and increases in width on the fall of the tide following.

Other similarities between events based on site observations/video of the 2015-2 event and historic events are:

- Events move up the beach in a slow, episodic rate with blocks of sand of about 0.5 m to 1.0 m thickness successively calving off different parts of the scarp.
- Events take no longer than about 3 hours before they cease retrogressing.
- The dark colour of the water immediately below the scarp suggests quite deep water (i.e. greater than 4 m to 5 m depth).
- Foam on the surface of the water is common in the general vicinity of the failing face.
- Once the active mechanism driving the instability event ceases, a less steep beach slowly forms below the head scarp and further regression of the scarp occurs only due to local erosion.
- Instability events do not "re-start" once halted.

The significant aspect which does differ between events is the extent of their regression up the beach, with some events moving into the tree line and others halting well short. The locations for past events shown on Drawing 3 mainly takes into consideration those events which have moved further up the beach, whereas some such as 2015-1 barely affected the beach beyond the low water line.

4 Assessment of the Mode of Instability

Data from the 2015-2 event, general site observations and the historic record show clear common characteristics for instability events at Inskip Point which have been noted in previous sections. The arc shaped form, general proportions of depth to width and retrogressive movement of material suggest that movement is effected by a flow or sliding mechanism. The mechanism which we consider best fits the observed characteristics is that of a "retrogressive breach flow slide" which has been described by Beinssen *et al* (2014) and Van den berg *et al* (2002). Figure 4.1 illustrates the mechanism in cross section.

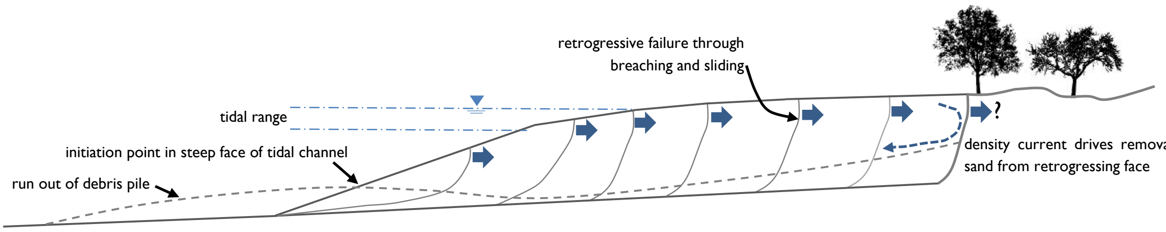


Figure 4.1 Diagrammatic cross section through breach flow slides at Inskip Point. Not to scale and with minor vertical exaggeration to demonstrate mechanisms.

Based on the references above, we consider that breach flow slides at Inskip Point develop in the following general manner:

- A triggering mechanism develops a localised overly steep face in dense sand which shears as a response to exceeding its angle of repose.
- Shearing generates negative pore pressures in the soil skeleton which allows a temporarily meta-stable sub-vertical face to develop.
- As the pore pressure progressively equalises at the face, sand is released grain by grain and falls from the wall.
- As the grains fall they develop a density current (a "fluid" with a higher density than seawater due to the presence of the sand grains, which flows downwards) which carry grains away from the face and beyond the immediate toe of the failure surface, allowing the face to remain steep.
- Where very steep slopes are developed by the process, a secondary mechanism involves sliding of blocks of sand from the scarp which has been observed in many instances of instability at Inskip Point.
- Retrogression continues until the density current lacks the strength to continue taking sand away from the over-steep face. This may be because either the sand supply is for some reason limited, or possibly because the system is "swamped" with an excessive amount of sand that it cannot carry and the sand falls out of suspension at the base of the face.

We also considered an alternative mechanism of a purely liquefaction based mass movement event. However, in a liquefaction flow slide a large proportion of the relatively loose mass moves in a single episode rather than a dense body of sand moving progressively, as is observed at Inskip Point.

Apart from the required geotechnical conditions comprising the presence of a dense body of fine to medium grained sand, the two other requirements for the development of a breach flow slide are:

- Sub-marine slopes steeper than 3 horizontal to 1 vertical (about 18°) over a height of 5 m or more – the bathymetry study shows that those along the main part of the beach at Inskip Point are 22° to 24°, as shown on Section 2 of Figure 2.5.
- An initiating mechanism must occur to disturb the lower parts of the sub-marine slope and create a locally over steepened section such that the breach mechanism becomes active.

Although we consider that the slope gradient and geotechnical requirements for the development of breach flow slides are generally met at Inskip Point, the precise initiating mechanism remains uncertain.

4.1 Initiating Mechanisms

Beinssen (2014) notes that the "trigger" event can be any event which changes the equilibrium soil stress state, occurring from either natural causes or human agency. Such events could include vibrations from pile driving, seismic accelerations from earthquakes, localised erosion from tidal currents or eddies formed due to tidal flow, erosion from ships propellers, or possibly even the effects of waves where they differ from the usual energy level.

To assess the validity of specific initiating mechanisms at Inskip Point we correlated instability events with several natural cycles.

4.1.1 Earthquake Inventory

Seismic accelerations generated by earthquakes can and do cause liquefaction (a reduction in soil strength due to increased pore water pressure between soil particles) at many scales. Liquefaction occurs during the period of seismic shaking and for a short time afterwards (i.e. minutes or hours), after which the induced pore pressures dissipate and the soil regains strength. Therefore, if seismic activity was the initiating mechanism at Inskip Point, earthquakes of sufficient magnitude and proximity would need to occur immediately prior to the instability events.

Reference to Geoscience Australia (2015) provides data on all earthquakes which have occurred in Qld. Correlating the times of earthquakes and instability events shows that there have been no earthquakes on the same day or even in the same week as events as shown on Table 4.1. In many cases, the closest earthquake in time occurred months before and was several hundred kilometres distant. The closest earthquake in time to the recent instability event was ten days before.

Table 4.1 Listing of earthquakes in Queensland which occurred closest in time to instability events

Event No.	Month-Year	Day	Nearest Earthquake					Location Notes	Distance (km)
			Mag	Date	Time	Lat	Long		
2006-1	May 2006	No Data	4.1	28/12/2005	19:05	-28.191	147.894	West of St George QLD.	577
2010-1	Sep 2010	27	2.5	15/08/2010	18:56	-26.701	152.283	East of Kingaroy	126
2011-1	Jun 2011	26	3.4	26/05/2011	22:29	-26.801	147.232	SE of Charleville	592
2011-2	Aug 2011	27	2.5	2/08/2011	11:20	-24.200	150.919	NE of Biloela	280
2012-1	Jun 2012	16	3.3	16/02/2012	20:49	-27.054	147.98	SW of Roma	525
2012-2	Jun 2012	30	3.3	16/02/2012	20:49	-27.054	147.98	SW of Roma	525
2013-1	Aug 2013	No Data	3.2	1/06/2013	15:59	-23.645	148.848	Near Blackwater	489
2013-2	Dec 2013	5	2.8	1/12/2013	20:51	-17.090	145.55	SW of Cairns	1239
2015-1	Jan 2015	23	3.3	5/09/2014	0:07	-16.949	143.895	NW of Chillagoe	1365
2015-2	Sep 2015	26	3.3	17/09/2015	9:37	-25.346	154.521	E of Fraser Island	156

4.1.2 Tidal Flow and Turbulence

In our visit to Inskip Point on 27 and 28 September 2015 we observed very distinct tidal flows, turbulence and eddies in the water immediately off shore over the submarine slope at around low tide. Others we have spoken to report seeing similar distinct tidal flows and turbulence in the past. We made these observations during a period of spring tides with a large tide range and have sought to assess whether erosion from these water movements could have triggered the instability events. We correlated the times when events initiated against:

- The diurnal tidal cycle.
- The cycle of neap and spring tides.

An example of a clear correlation would be if the events all occurred at about low tide within a period of spring tides, where the low tide had dropped down to below 0.5m elevation.

Unfortunately, information on the time of occurrence is available for only five instability events, and of these there are three for which a reasonably accurate start time can be established.

Drawing 4 shows a plot of the tidal fluctuation against time with information on the initiation of the five instability events where time data is available. On the plot, the event is signified by an orange circle where an accurate time for its initiation is known (events 2011-1 and 2015-2). Where only a time interval is known, the event start point is represented as an orange line representing that time interval. Although two of the events (2011-1 and 2015-2) appear to have initiated near the low tide, the others cannot be reliably correlated with a tidal period.

In our opinion, the data set is also insufficient to demonstrate a relationship or otherwise with high tidal range (i.e., spring tides). Although some events have occurred during such periods, others such as 2010-1 and 2011-1 appear not to have. Beinssen (*pers. com*) has collected data on over 50 inferred breach flow slide events at Amity Point and we understand even with this large data set has not been able to demonstrate a clear relationship between instability and either tidal flow or tidal range. We require significantly more accurate data on the timing of events at Inskip Point to draw firm conclusions on tidal correlation.

4.1.3 Discussion and Interim Conclusions on Initiation

Other mechanisms which could plausibly initiate nearshore instability mainly relate to human activities such as the actions of boat propellers which would occur at irregular times and places and so we lack the data on which to base any correlation.

We consider that the data on seismic activity provided above is adequate to rule out earthquakes as a trigger.

Consequently, our working hypotheses for initiating events is that they are caused, at least in part, by the rapid tidal flows and resulting eddies which are observed regularly off the peninsula. There may be some other factors related to tides or the physical condition of some pockets of sand which forms part of the mechanism. Further careful collection and correlation of data would be needed to prove or disprove this hypothesis.

4.2 Extents of Landward Regression

One aspect which does vary significantly between different breach flow slides is their termination point up the beach, with some stopping well short of the tree line and others encroaching. As noted previously, the events will stop when the density current is unable to continue to transport sand away and it builds up at the base of the developed face. At this stage the available literature suggests no definitive method to assess where a specific event may terminate.

We do not consider that the trees have a significant effect as they are generally undermined completely. In our opinion, breach flow slides at Inskip Point may stop because the volume of sand from above the water table being added is more than the density currents can remove, although this is not proven.

Consequently, our view is that until further information can be collected and understood, it would be prudent to base predictions of landward regression on the past extents of instability.

5 Hazard, Susceptibility and Risk Assessment

5.1 Hazards and Susceptibility

The hazard at Inskip Point comprises breach flow slides which retrogress up the beach forming sub-vertical scarps over an arc shaped area up to about 200 m wide. The geotechnical conditions immediately offshore are judged to be suitable for the initiation of such instability along the full length of the study area. Geometrically, breach flow slides have been found to initiate only in nearshore slopes steeper than 18° and over 5 m high. Consequently, we have divided the nearshore zone adjacent to Inskip Point into three categories of breach flow slide susceptibility based on these requirements and on the historical incidence of instability as shown in Table 5.1.

Table 5.1 Definition of flow slide susceptibility categories for Inskip Point

Susceptibility	Geotechnical Conditions Suitable?	Geometric Conditions Suitable?	History of Flow Slides?
Low	Yes	No	No
Medium	Yes	No	Yes
High	Yes	Yes	Yes

The Medium Susceptibility zone relates to areas where instability has occurred in the past, but where the prerequisite geometric conditions do not appear to be present at this point in time. If the nearshore slopes steepen due to the effects of tides, currents or other mechanisms, susceptibility to flow slides may increase.

Drawing 3 shows the peninsula divided into Low, Medium and High flow slide susceptibility zones based on the above classification.

5.2 Risk Assessment

The methods adopted for the risk assessment generally follow the principles published by the Australian Geomechanics Society in 2007 (AGS (2007) and Walker *et al* (2007)). We have provided general discussion of both risk to life and risk to property. We have conducted a preliminary quantitative risk assessment for one significant element at risk, but have addressed the risks to others only descriptively.

5.2.1 Description of the Risks in Qualitative Terms

The framework for the evaluation of risk provided in AGS (2007) is consistent with international practice and considers risk for each identified hazard as:

Risk = Likelihood x Consequences

Consequences are considered through the vulnerability of the specific elements at risk, be they people, property or less tangible assets. It is often useful to describe risks in simple terms within this framework.

How Often Will Flow Slides Occur?

The instability hazard which affects Inskip Point has an uncertain initiating mechanism, but based on QPWS records, breach flow slides have occurred with a frequency of a bit over one per year since 2006. On this basis, it is reasonable for those administering the area to expect an event every year while understanding that there could easily be none in a given year, but more than one the next.

When will they occur?

With our current understanding there is no evidence to suggest that events will occur at any specific time of year, season, or day more often than another, so they could occur during the day or night without warning. Observations suggest that flow slides cease retrogressing up the beach after 2 to 3 hours. None, either at Inskip or the many observed at Amity Point, have been known to restart once they have stopped (Beinssen *pers com*).

How fast do they move and how far will they extend?

Research at Amity Point shows that flow slides move at a rate of up to about 0.8 m laterally per minute (Beinssen, 2014). This seems to be generally consistent with observations of the rate of movement at Inskip Point. Although not all breach flow slides retrogress into the tree line and camping area, many do, possibly about half of those noted by QPWS. Flow slides at Inskip Point do not seem to have affected ground above about 2.5 m elevation.

Based on our understanding of the factors affecting susceptibility, flow slides are most likely to occur within the beachside fringe of the Sarawak camping area, the western end of the Beagle Camping Area, and the Day Use area to the west.

What are the elements at Risk and how vulnerable are they?

As the flow slides have a steep scarp at their rear and sides, and seem to be over 5 m deep, they can engulf anything founded/placed on the sand above in their path, as occurred in event 2015-2. This implies that vehicles and camping equipment would be at risk if in the path of a flow slide wherever they are on the beach. Those that were inside vehicles which fell from the scarp could be quite vulnerable.

The vulnerability of people, and consequently their risk profile, can be considered in several groups:

- Campers who are mainly outside during the day, but inside a tent or caravan at night.
- People who are in vehicles on the beach.
- People who are on the beach on foot during the day or night.
- People who sleep on the beach.

Campers are likely to be vulnerable if engulfed by a flow slide while within a caravan or tent, particularly if they were asleep. In many cases they may receive warning of the instability event and be able to leave as occurred with the recent event. During the day it is likely that they would be alerted to the event or observe it themselves.

Drivers on the beach would generally see a retrogressing scarp during the day, but may not at night. Drivers may not see a newly forming scarp as it retrogresses up from the water-line, but this situation where it was present but not easily visible, would be only in play for a few minutes of the flow slides.

People on the beach would generally be able to evade the hazard if they were awake. If engulfed it is likely that they would be able to swim out, assuming that they have that ability. If people were to be asleep on the beach in a sleeping bag, they could possibly be trapped.

Other elements which QPWS might consider to be at risk are:

- Property such as the toilet blocks, park fittings and roads which could be affected, and ensuing environmental damage from their loss.
- Reputation and community opinion.

5.2.2 Quantitative Risk Assessment

To provide a guide to the levels of risk to life posed to people by the flow slides we have conducted a preliminary, quantitative risk assessment to campers, as they are the people who have the potential for a longer stay at Inskip Point than most. We consider the risk assessment to be approximate. It could be refined with further research and information. The terminology used is from AGS (2007). In this case the assessment is based on "the person most at risk" who we have nominated as a person who spends all of their holidays and public holidays within the fringe of the tree line at Inskip Point.

Table 5.2 presents information on each of the terms in the risk calculation which are multiplied together to provide the risk to life for the person most at risk.

Table 5.2 Tabulated calculations of risk to life with notes

Risk $R_{(LoL)}$	Probability $P_{(H)}$	Probability of Spatial Impact $P_{(S:H)}$	Probability Temporal Spatial $P_{(T:S)}$	Vulnerability $V_{(D:T)}$
1×10^{-4}	1	0.4	8.6×10^{-4}	0.3
Notes:	Annual probability of a slide initiating, based on the count of events since May 2006	The probability that a flow slide will reach the elements at risk in the camping area	Based on: 1. Person present 31 days in a year 2. Instability may occur over only 62% of the beachside camping area 3. The rear of the breach flow slide is 50m wide	The person is able to avoid the flow slide through observation or warning 70% of the time

5.3 Risk Evaluation

Walker (2007) suggests a Tolerable Risk criteria level for an existing slope of 10^{-4} / annum for the "person most at risk". This level of risk is generally commensurate with that quoted as criteria by other government authorities in Australia and overseas for evaluating risks to the public.

The definition for a Tolerable Risk from AGS (2007) is: "Tolerable Risks are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable."

We note that the calculated level for risk to life to campers is at about the tolerable risk level. It would generally be prudent for those administering an area subject to such a level of risk to implement measures to reduce risk. Note that the risk calculation is approximate only and is based on some conservative judgements of probability for different factors affecting the risk. Risks to other individuals may differ from those modelled for the theoretical "person most at risk". A more accurate assessment could be conducted but it would require more data on the distribution of people at the site, realistic tenancy times and a better understanding of the likelihood of camping at different parts of the camping area.

The decision as to whether risk management options should be implemented in a specific instance should consider more than just the risk level. If cost effective measures which could provide a risk reduction are available, then they generally should be implemented where practical.

6 Risk Management Options

We have developed a number of risk management options which are outlined in Table 6.1. These will require careful consideration, and some may need further work prior to implementation to assess whether they would be effective and practical.

Table 6.1 Summary of risk management options

Category	Potential Measures	Management Option Details
Avoid the risk	Ensure that there is no camping on the beach and restrict camping to zones outside that which is most likely to be affected by flow slides.	In the first instance a buffer zone to camping would need to be established within the High Susceptibility zone on the basis of precedent with a suitable margin for safety. Consideration should be given to land use in the Medium Susceptibility zone.
	Prevent driving on the beach or limit driving on the beach to daylight hours only.	Risk could be avoided by not driving on the beach. Risk can be significantly reduced by not driving on the beach at night.
	Consider moving camping to other areas of Rainbow Beach further to the south which are subject to lower risk levels.	The practicality of this will depend whether other land is available. Any land opened to camping would also need to be assessed for the potential for flow sides or other risks.
Reduce the probability of unexpected instability	No practical measures currently identified with our current level of knowledge.	More research and understanding of initiation mechanisms would be required to be able to assess methods meaningfully. This will require collection of data on the timing and conditions of future events
Reduce the consequences of instability	Construct deep rock walls such as those at Amity Point or other structural barriers to intercept the flow slides.	Flow slides can be stopped by walls which extend below the base of the slide. To be useful, walls would need to be over 10 m deep, properly engineered and well maintained. We doubt that this would be practical or cost effective at Inskip Point.
	Conduct research and construct a wide sand bund to cut off the slides.	It is possible that a bund of sand over 2 m high could be effective at preventing flow slides from retrogressing further. Such a bund may have an environmental and social impact, be expensive to construct and would require significant research to ensure that it would be effective.
Manage the risk with monitoring or warning signs	Periodic monitoring of the geometry of the nearshore sand deposits with sonar.	Monitoring of the sea floor will allow continued assessment of where steeper slopes are forming that could lead to further breach flow slides. Advice would need to be sought from others on a suitable frequency of survey to ensure that changes could be detected. This is particularly important for the Medium Susceptibility zone.
	Install informative warning signs.	The warning signs should impart information to assist people to understand the causes and the associated risks that flow sides present to people and property. They should also explain the risks associated with driving or sleeping on the beach, or camping closest to the water.
	Install warning systems such as sirens.	Sirens and other warning systems have been suggested as an emergency response measure to alert people to an instability event. Advice should be sought from appropriate specialists on the practicality of such systems. It is not clear how people would respond appropriately to a warning signal without training on what was expected of them. False alarms may be common depending on who had responsibility for triggering the alarm.

To assist in the assessment of whether a restriction on camping for some parts of the peninsula would be practical, we have prepared a preliminary boundary to the buffer zone based on the location of past instability events with a safety margin to take into account the required offset from a potential scarp. Figure 6.1 shows the geotechnical basis for establishing the buffer zone. There are practical requirements such as the positioning of roads and other infrastructure which will also govern the precise location of the buffer zone. We worked with staff from QPWS on site to establish the practical position of the proposed buffer zone taking into account both geotechnical and practical considerations. Drawing 5 shows the proposed buffer zone boundary beyond which camping would need to be restricted in order to reduce risk to campers.

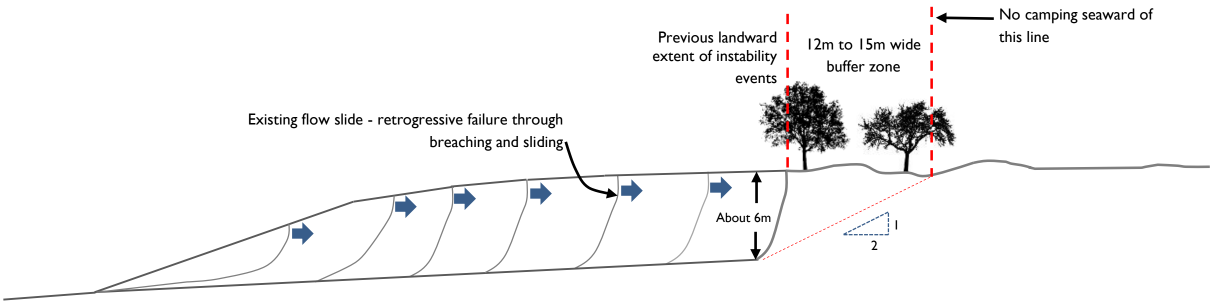


Figure 6.1 Diagrammatic cross section showing the geotechnical derivation of the buffer zone based on previous encroachment of the flow slides.

7 Further Work

The current study has been of short duration with a focus on developing some practical risk management options from a limited amount of data. QPWS could consider further study with universities, researchers and/or consultants to confirm some of the judgements made in this assessment or test other potential risk management strategies.

To this point we have not conducted any subsurface investigation of ground conditions by either drilling or geophysical methods. Either or both would be useful to assist in confirming the assumed ground model.

We also consider that consultation with marine engineers who are more able to interpret nearshore ocean processes may be helpful in gaining a better understanding of the failure mechanisms and developing a better model for the prediction of flow slide occurrence.

Further understanding of the flow slides could be gained if better records of each event could be made. Information that could be useful includes:

- Precise times for the initiation of events and when they cease retrogressing and details on how these times were derived, whether by observation or inference.
- GPS tracks around the perimeter of each event.
- Video and photographs with accurate time and date information.
- Observations of the general sea conditions (tides, turbulence etc) evident when the event began.

As noted previously, a more detailed literature search through library and press records could be beneficial in establishing the history of instability at Inskip Point including data on its extents and frequency of occurrence.

Sea level rise as a consequence of climate change could have an effect on the frequency and extent of instability events. Although our current understanding is limited, it seems logical to conclude that increasing sea level will lead to greater landward transgression of flow slides. Buffer zones may need to be reviewed in the coming years if evidence suggests that instability is encroaching further inland.

Please do not hesitate to contact the undersigned if you have questions or require further information on the contents of this report.

For and on behalf of EDG Consulting Pty Ltd

Ian Shipway
Principal

References

Australian Geomechanics Society Landslide Taskforce (2007) Commentary on Practice Note Guidelines for Landslide Risk Management, Australian Geomechanics Vol 42 No 1 March 2007 pp115 - 153

Beinssen K, Neil1 D T and Mastbergen D R (2014) "Field Observations of Retrogressive Breach Failures at two Tidal Inlets in Queensland, Australia", *Australian Geomechanics*, Vol 49 No 3 September 2014

Berg, J.H. van den, Gelder, A. van, Mastbergen, D.R., (2002) "The importance of breaching as a mechanism of subaqueous slope failure in fine sand", *Sedimentology* ,Vol 45, pp. 81-95.

Department of Transport and Main Roads (2015) *Tidal Data*, Mooloolaba Tide Gauge

Geoscience Australia (2015) *Earthquakes Database*, viewed 5 October 2015, http://www.ga.gov.au/earthquakes/searchQuake.do

Walker B., Davies W., and Wilson G. (2007) Practice Note Guidelines for Landslide Risk Management, Australian Geomechanics Vol 42 No 1 March 2007 pp63 - 113

Ward, W T (1987) "Coastal Geology of the Area Between Rainbow Beach and Inskip Point" in C G Murray and J G Waterhouse (eds) *Field Conference – Gympie District* Geological Society of Australia, Brisbane

Table 8.1 presents informal internet based references to past instability events at Inskip Point.

Table 8.1 Links to historic instability events

Event No.	Month-Year	General Location	Source	Links
1873-1	Jan 1873		Internet	http://indicatorloops.com/inskip.htm
1901-1	Jun 1901		Internet	http://indicatorloops.com/inskip.htm
1938-1	Nov 1938		Internet	http://indicatorloops.com/inskip.htm
1993-1	1993	Barge Loading Area	Internet	http://indicatorloops.com/inskip.htm
2006-1	May 2006	West of Beagle	QPWS	Labelled 2005 but probably 2006-1: https://www.youtube.com/watch?v=ILptlF7P6LI
2011-1	Jun 2011	Sarawak	QPWS	http://www.frasercoastchronicle.com.au/news/beach-slipping-away-inskip-point/888597/ https://www.youtube.com/watch?v=I9ieYvYdvdw https://www.youtube.com/watch?v=VpafAxjGq_Y
2013-1	Aug 2013	Near the barge loading area?	Youtube	https://www.youtube.com/watch?v=2oEiBveXbBA https://www.youtube.com/watch?v=8FfhLpWNx_s

Ground conditions and the natural environment often present the highest potential risks to project construction and operation. Helping our clients manage their geotechnical risk is fundamental to EDG. We have prepared these notes to assist our clients to understand the information we provide and help in managing risk.

Scope of Services

The information provided in this document is based on the scope of services defined in the client's agreement with EDG Consulting Pty Ltd (EDG). In undertaking the work, EDG has relied on information provided by the client and other individuals and organisations. Unless stated in the document, EDG has not verified the accuracy of that information and does not accept responsibility for the conclusions, recommendations or designs developed based on that information should it be incorrect, misrepresented or withheld.

Unless specifically stated to the contrary, this document does not cover geo-environmental issues, which require significantly different equipment, techniques and personnel. A geo-environmental specialist should be engaged to provide such advice.

The document is based on specific project details

The information provided in this document is relevant to the subject site and project only. The document has been prepared based on the specific details and requirements of your project and may not be relevant if any changes to the project occur. Should changes occur, review of the report by EDG must be undertaken to identify if and how such changes will affect the conclusions, recommendations or designs provided. EDG accepts no responsibility if the client elects not to consult in the event of changes to the project.

The document is prepared for a specific purpose

The information in the document has been prepared for specific purposes in relation to the project. The document must not be used for any purpose other than that for which it was prepared unless additional specific advice is sought from EDG. Information contained in the document must not be separated from the document, reproduced or redrawn in any way.

All site conditions cannot be identified

The scope of work undertaken represents a professional assessment of the information required to develop a basic geotechnical model of the site based on EDG's understanding of the client's risk profile. In some cases, increasing the frequency of investigations and/or sampling, or considering alternative investigation techniques may improve the interpretation, but should not be considered to identify all subsurface conditions at the site.

The document presents an interpretation

Geotechnical information is an interpretation of conditions evident based on a limited number of facts established during a site investigation[1]. Engineering logs are an interpretation of observations of samples and test results at discrete locations in the subsurface profile. A geotechnical model is an interpretation of site conditions, developed using information from discrete locations on the site and an understanding of geological processes. Interpreted conditions at and between investigation locations may be different to those inferred on the engineering logs and geotechnical model. The client must consider how variations in conditions could affect the project and seek advice to reduce risk if it is unacceptable.

Conditions can change

The geotechnical information provided is based on the conditions observed at the time of the investigation. Such conditions may be time dependent and subject to external influences. Many things could influence the site conditions, including geological processes, variation in groundwater or surface water levels, other natural cycles and influence from human activities (on this site or nearby sites). Specific advice should be sought if conditions on site change from those observed at the time the report was prepared.

The contents are not final

Geotechnical uncertainties can be managed by engaging EDG throughout the project life cycle, but particularly during construction. The information in this document is preliminary and must be further developed as conditions are exposed during construction and/or operation. Consideration of these exposed conditions and their impacts on the project can be made by engaging EDG to observe and interpret the conditions with respect to those presented in the document. EDG will not be liable to update or revise the document to take into account any events or circumstances or facts occurring or becoming apparent after the date of the report.

The document is for our client only

The document has been prepared for the benefit of EDG's client only. EDG assumes no responsibility and will not be liable to any other party in relation to the content of the document for any loss or damage suffered. Other parties must not rely upon the document in any way and should make their own enquiries and/or obtain independent advice.

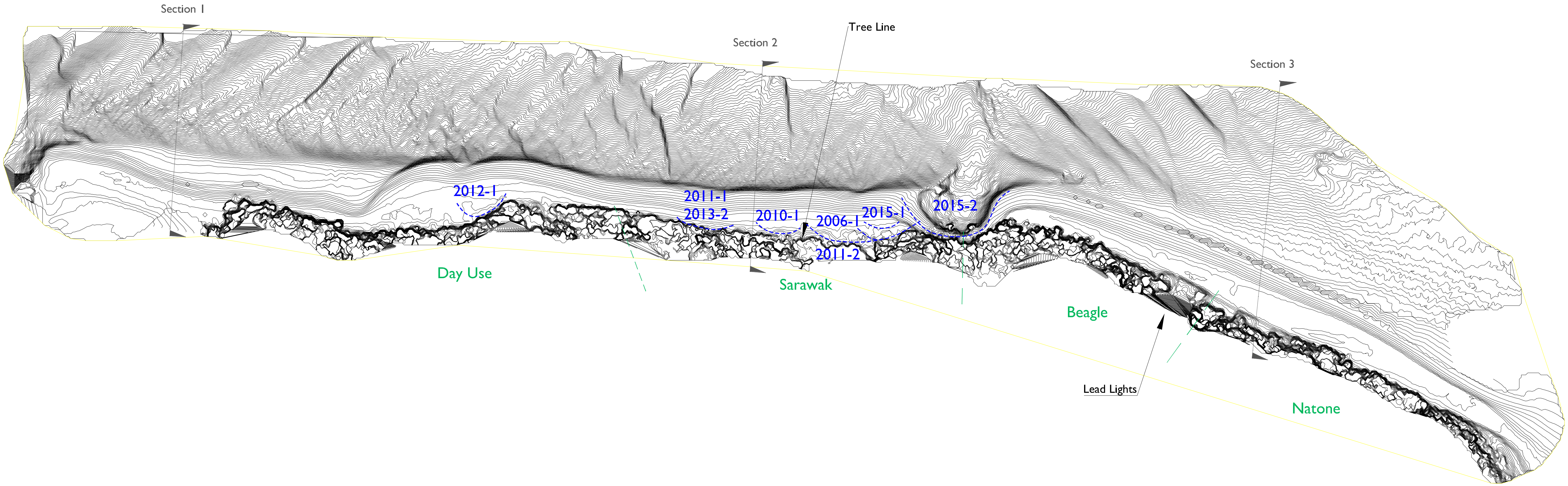
Should you choose to engage an alternative party for advice based on the information in the document, it must be understood that the alternative party will be less familiar with the site conditions and basis of information provided, and there is a potential for misinterpretation. EDG will not be held liable in any way from such misinterpretation.

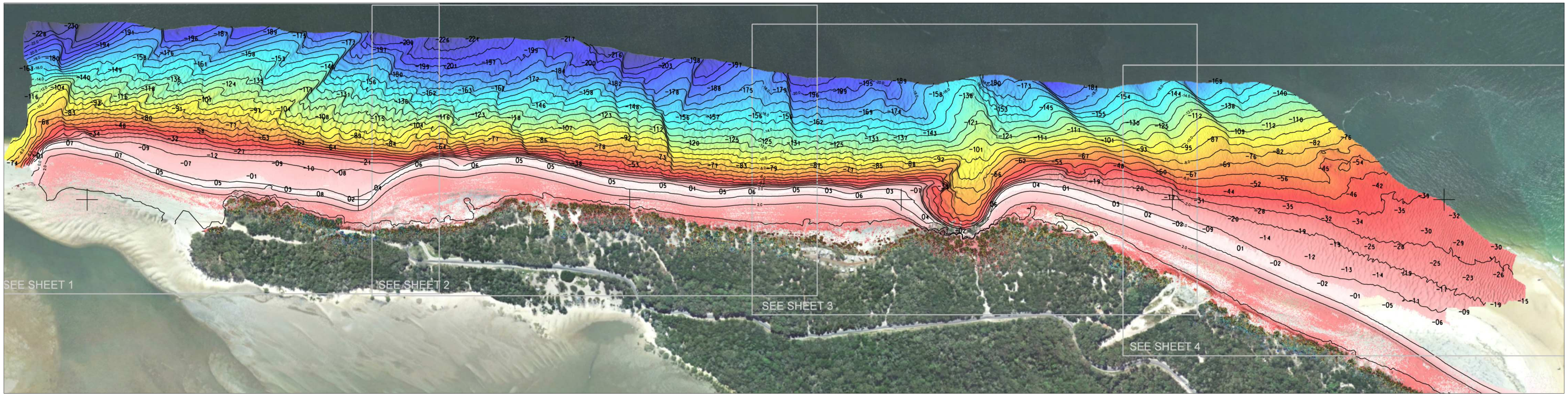
If in doubt seek additional assistance

Where there is uncertainty about your site, project or the geotechnical conditions evident, contact EDG for additional assistance.

1. Guidelines for the Provision of Geotechnical Information in Construction Contracts, Institution of Engineers, Australia, 1987.

Drawings





rev	description	drawn	approved	date

revision

100 0 100 200 300 400

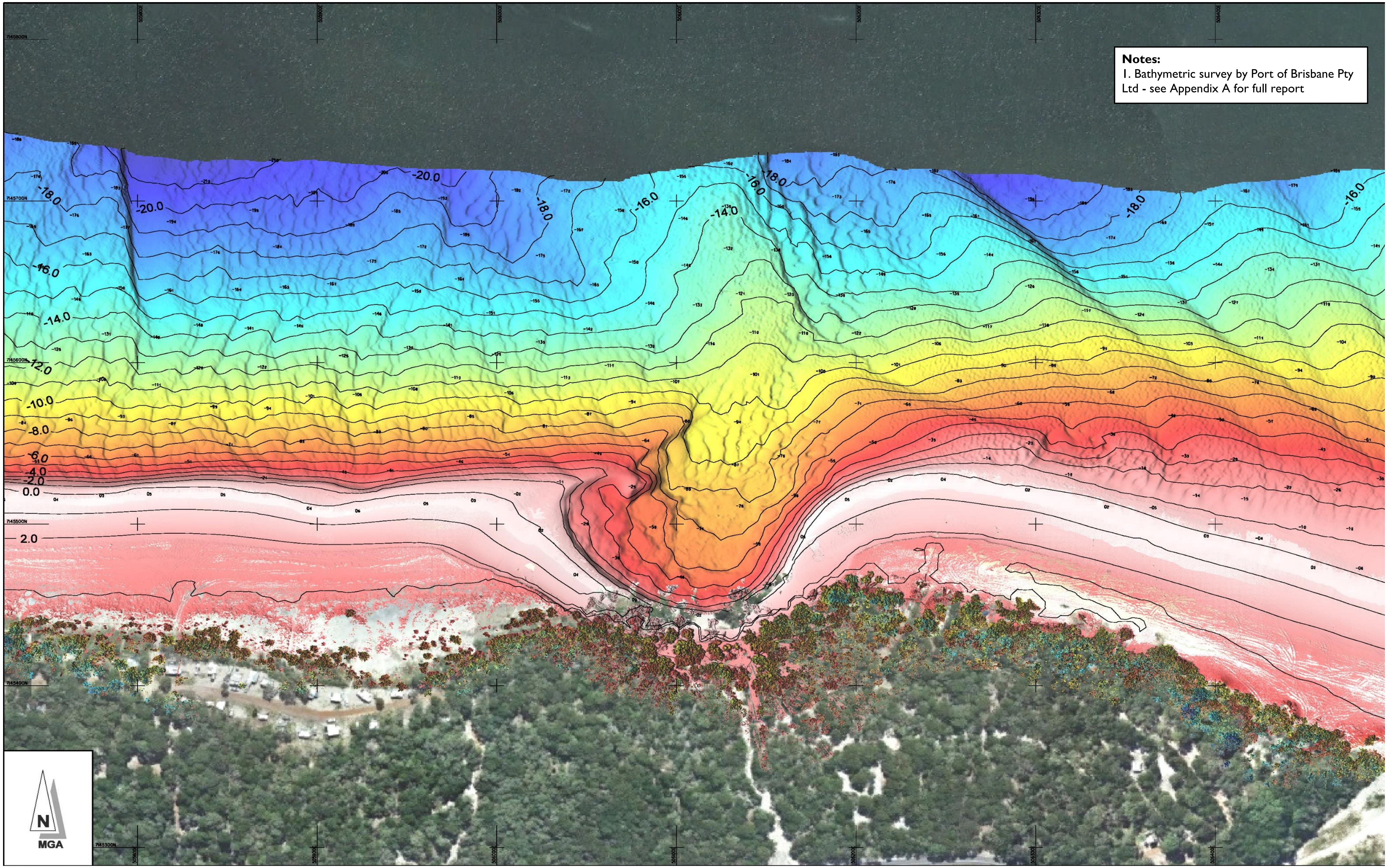
Scale (metres)

drawn:	GAH
approved:	IS
date:	11/11/15
scale:	1:7,500
original size:	A3

client:	Queensland Parks and Wildlife Service
project:	Assessment of Instability
location:	Inskip Point
title:	Site Plan showing Topography/Bathymetry
job no:	B01006-1

EDG consulting
engineering | design | geosciences

drawing no: 1 rev: A



revision:	description:	by:	approved:	date:

scale: 0 20 40 60 80 100

BATHYMETRY COLOUR MAP (m)

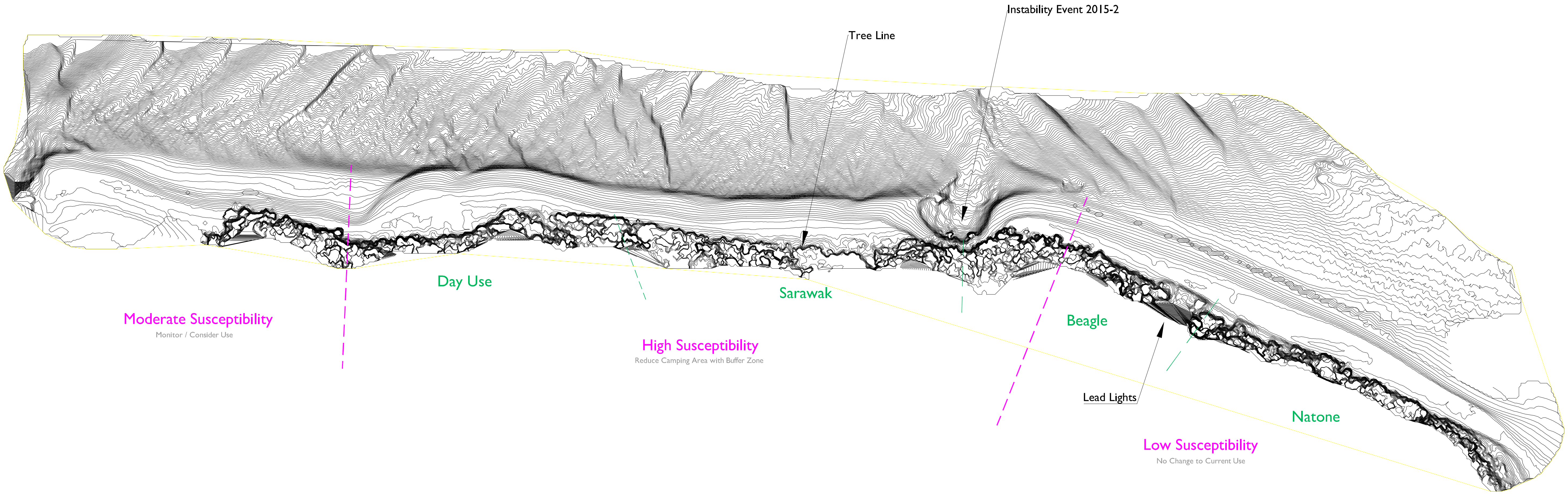
1.0 -5.0 -10.0 -15.0 -20.0 -25.

by:	IS
date:	9-10-2015
approved:	IS
scale:	1:2000@A3

client:	QPWS
project:	Assessment of Near Shore Instability
location:	Inskip Point
title:	**Bathymetry - September 2015 Event**
job no:	B01006/1

EDG consulting
engineering | design | geosciences

drawing: 2



revision	rev	description	drawn	approved	date

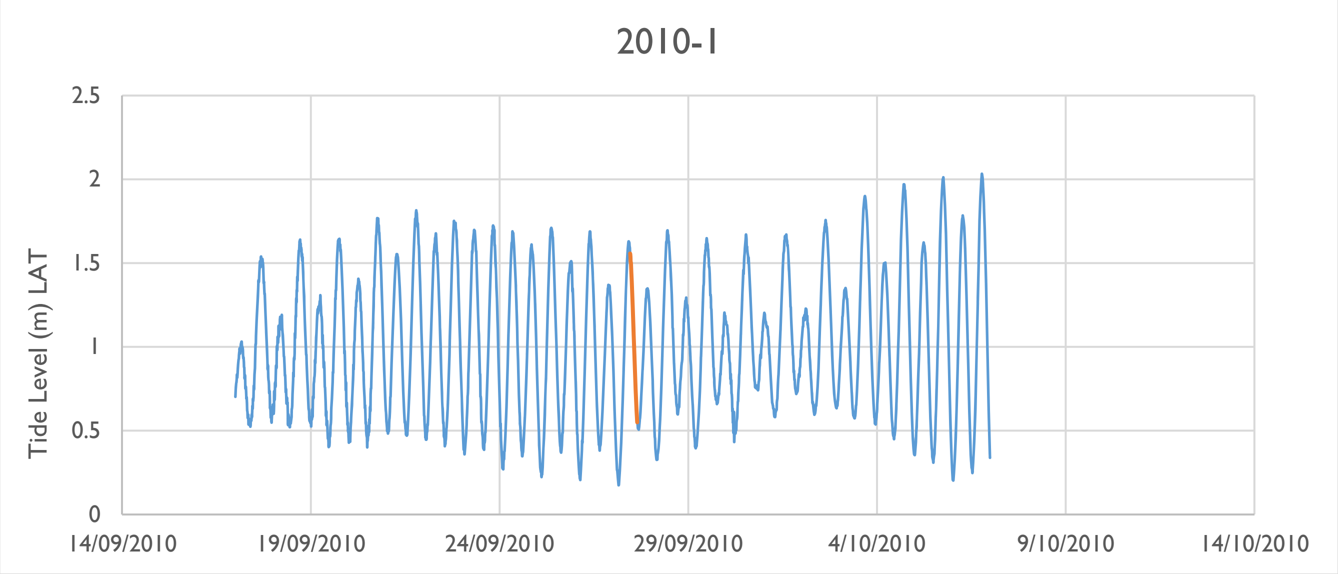
100 0 100 200 300 400
Scale (metres)

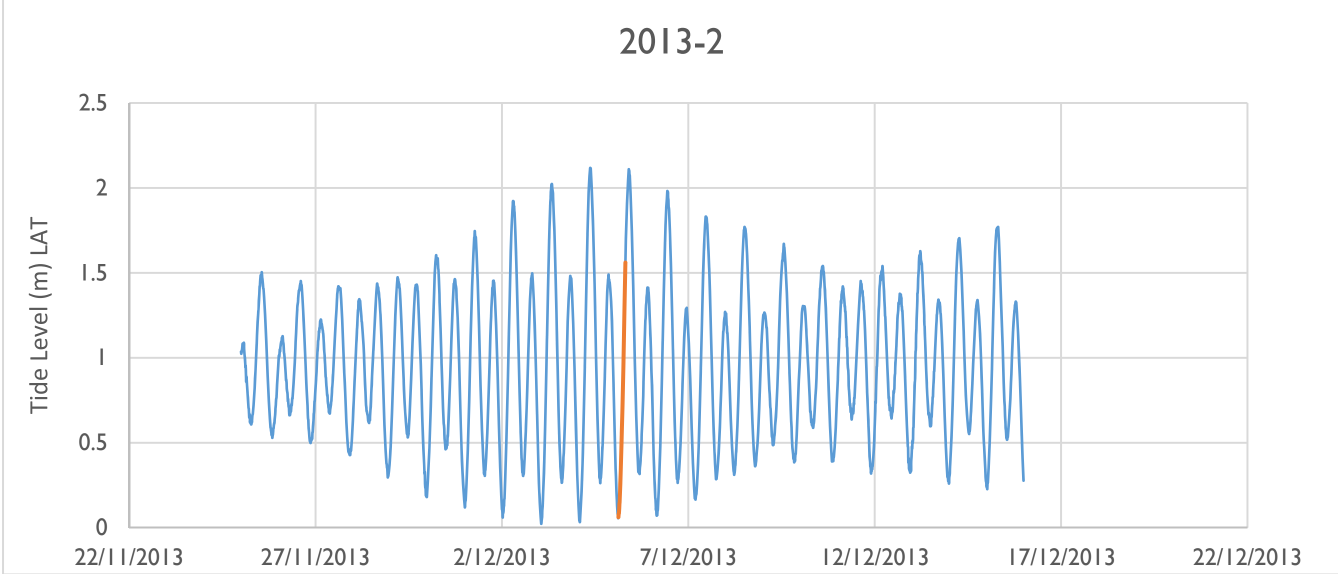
drawn:	GAH
approved:	IS
date:	11/11/15
scale:	1:7,500
original size:	A3

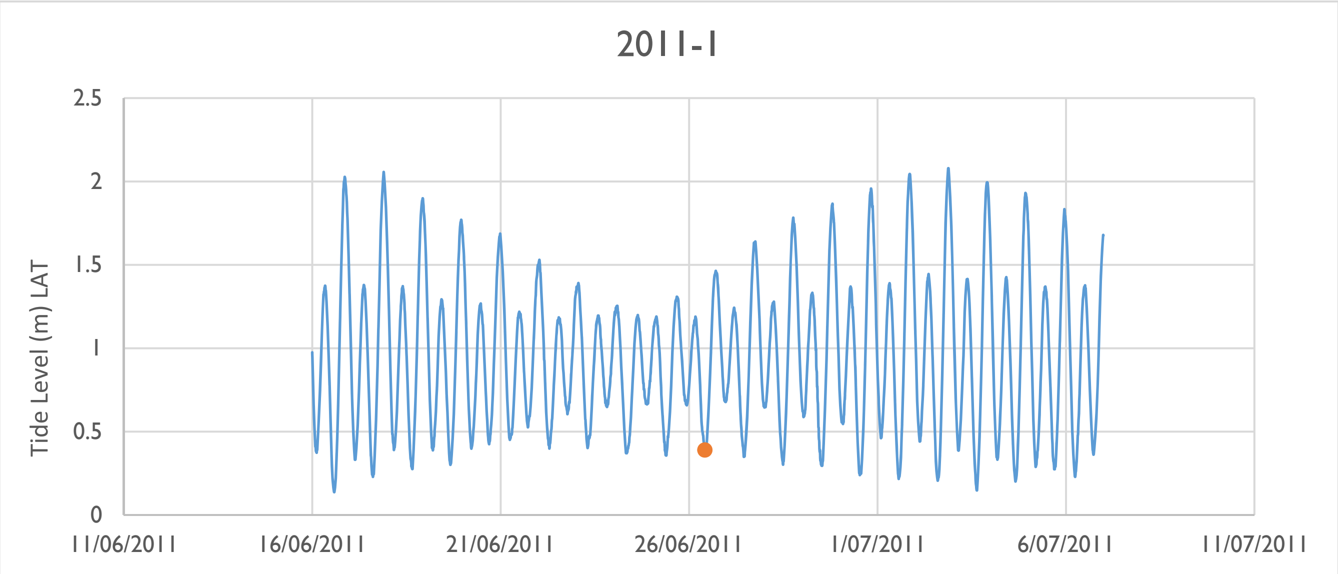
client:	Queensland Parks and Wildlife Service
project:	Assessment of Instability
location:	Inskip Point
title:	Site Plan showing Susceptibility Zones
job no:	B01006-1

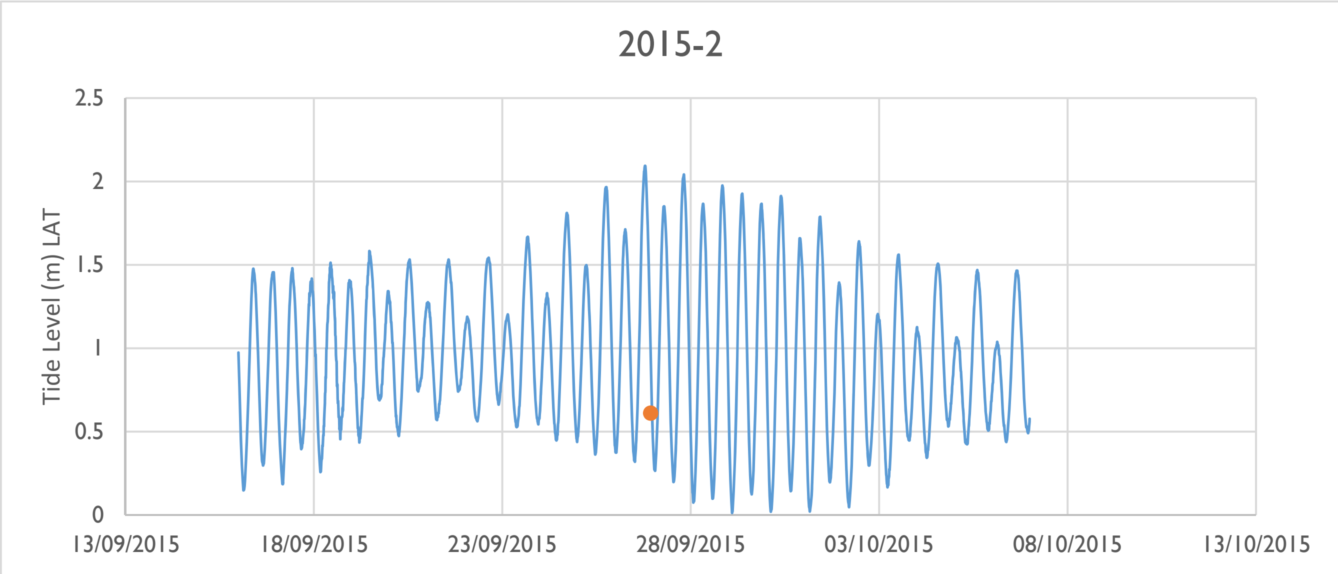
EDG consulting
engineering | design | geosciences

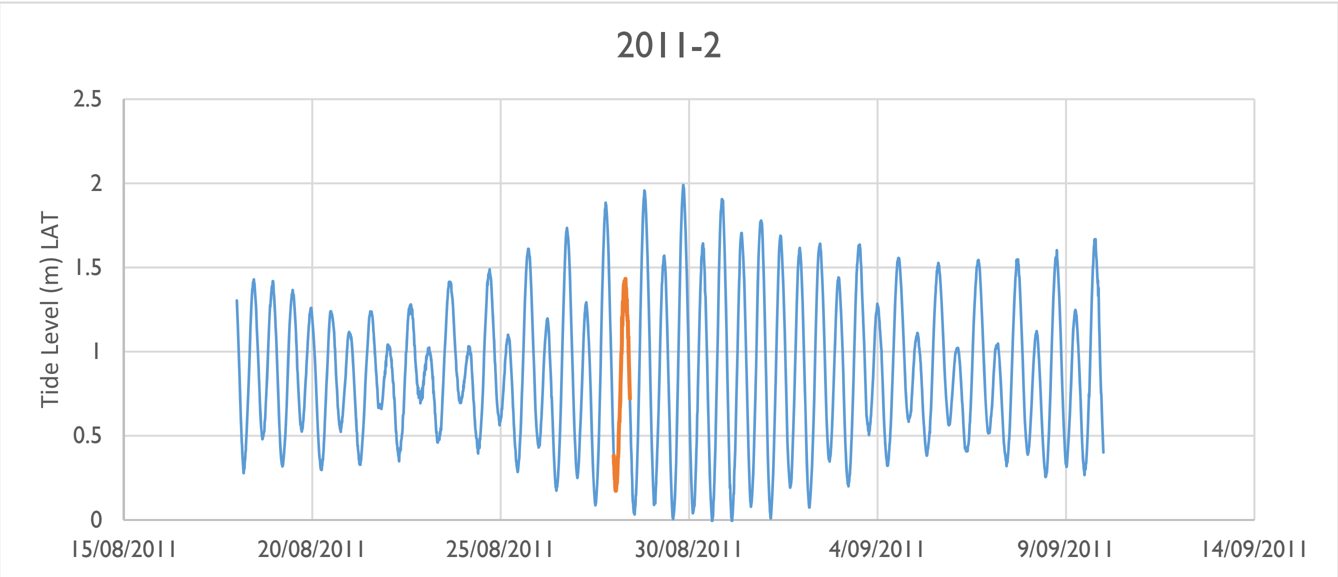
drawing no: 3 rev: A











Legend:

- tidal variation at 10 minute intervals
- time that instability event occurred - where known
- time interval over which instability may have occurred - where exact time is not nknown

Source:

Department of Transport and Main Roads (2015), Tidal Data

revision:	description:	by:	approved:	date:	scale:

by:	IS	client:	QPWS
date:	9-10-2015	project:	Assessment of Near Shore Instability
approved:	IS	location:	Inskip Point
		title:	**Tide/Instability Summary**
scale:	NTS	job no:	B01006/1

EDG consulting
engineering | design | geosciences

drawing: 4

Proposed seaward boundary to camping buffer zone

Map Data: Google, CNES/Astrium 2015

revision:	description:	by:	approved:	date:

scale: 0 50 100 150 200 250 300

by:	IS
date:	25-11-2015
approved:	GAH
scale:	1:5,000@A3

client:	QPWS
project:	Assessment of Near Shore Instability
location:	Inskip Point
title:	**Site Plan showing proposed buffer zone**
job no:	B01006/1

EDG consulting
engineering | design | geosciences

drawing: 5

Appendix I

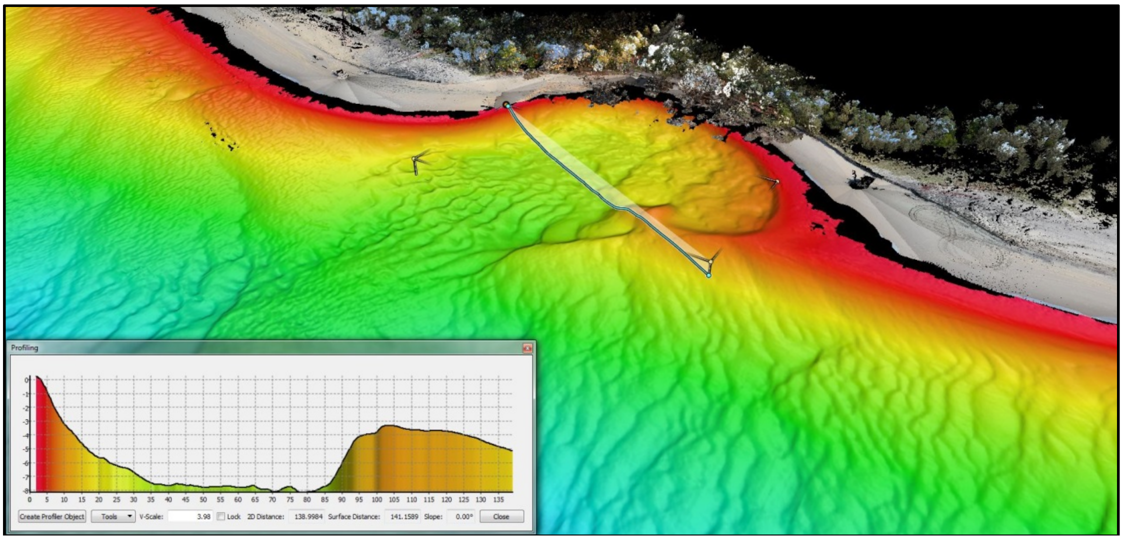
Combined High Resolution Multibeam Sonar and Vessel Mounted/Terrestrial Laser Survey Data

Port of Brisbane Pty Ltd

Combined High Resolution Multibeam and Vessel Mounted & Terrestrial Laser Survey of Inskip Point

Survey Report

Queensland Parks and Wildlife Service - October 2015



Port of Brisbane Pty Ltd. Hydrographic Solutions - Locked Bag 1818. Port of Brisbane QLD.
Australia 4178. Phone +61 7 3258 4800. www.portbris.com.au

Blank Page

Contents

List of Appendices

1.0 Introduction

This document outlines the Survey Works performed by the Port of Brisbane Pty Ltd (PBPL) whilst carrying out a combined high resolution multibeam and vessel mounted & terrestrial laser survey of the northern side of Inskip Point on the Inskip Peninsula. The survey would be used to provide point data along the length of the northern side of the Inskip Spit. It includes approximately 200m of hydrographic data parallel to the shore line and topographic data filled in using a combination of vessel mounted terrestrial laser and stationary terrestrial laser techniques.

All hydrographic survey operations are prepared and executed in accordance with the Maritime Safety Queensland (MSQ) "Standards for Hydrographic Surveys within Queensland Waters".

2.0 Personnel

Hydrographic surveys undertaken by PBPL are only to be performed by experienced and suitably trained employees. All hydrographic surveyors employed by the Port of Brisbane have Tertiary level survey degrees or Post Graduate degrees. In addition, hydrographers are either Certified Professionals (Level 1) from the Australasian Hydrographic Surveyors Certification Panel (AHSCP) or undergoing certification. A Certified Hydrographic Professional (Level 1) will supervise all field work, processing and reporting on this project. Personnel involved or providing support with this project were:

Manager Hydrographic Surveys

Giles Stimson - Certified Professional in Hydrographic Surveying (Level 1)

Project Manager

Robert Slater - Certified Professional in Hydrographic Surveying (Level 1)

Supervising Surveyor

Aaron Willcock - Certified Professional in Hydrographic Surveying (Level 1)

Field Surveyor

John Wylie - 10 years hydrographic experience

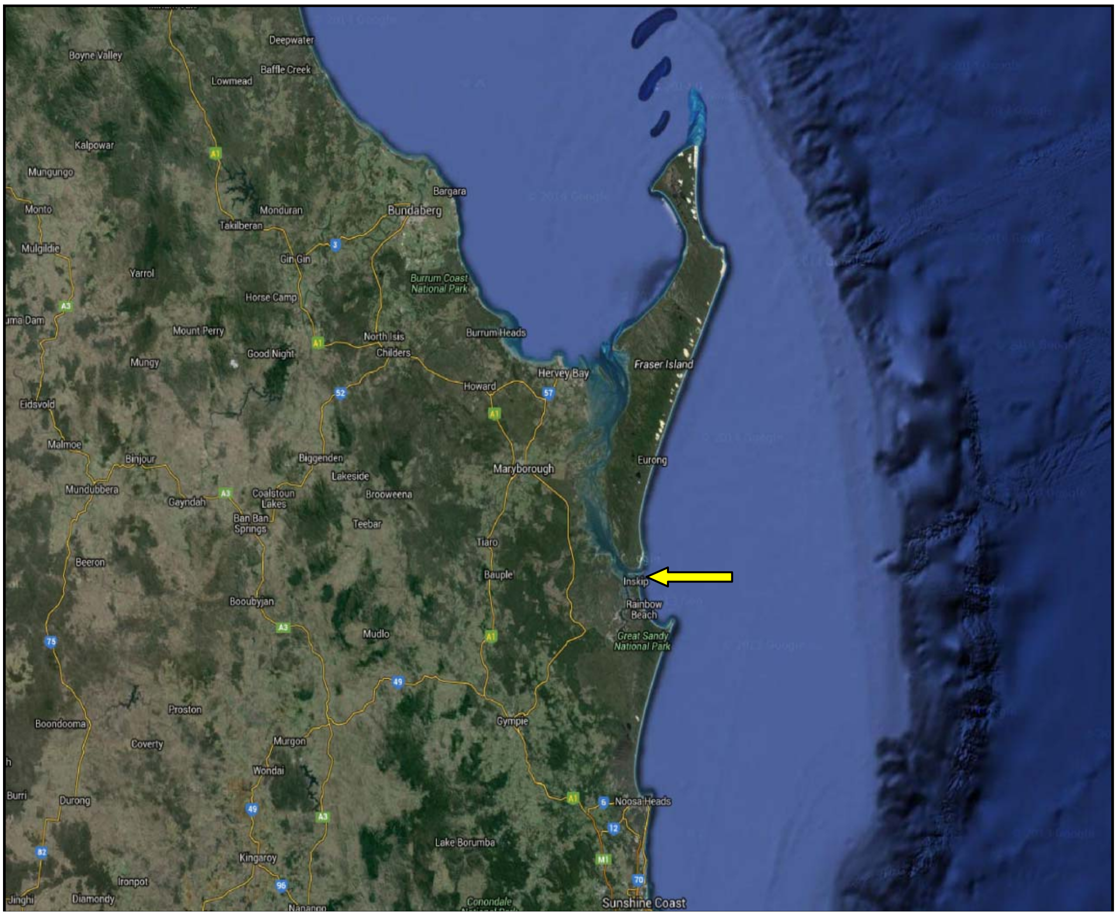
Only the people listed above performed survey operations in accordance with the scope of works previously supplied by PBPL. By signing the survey reports and plans, the Survey Manager, Project Manager and Supervising Surveyors declare that the survey meets the requirements for the declared survey class as defined in "Standards for Hydrographic Surveys within Queensland Waters"

3.0 Methodology

3.1 Site Conditions

The survey area is located in the Great Sandy National Park and is on Inskip Point. The location of the site is shown in Image No.1 below and is approximately 300km north from the Port of Brisbane's Operation Base.

The requirement was to detail the shoreline, including the recent sink hole that has formed to the north of the spit, and provide information to the client & consultant.



(Image No.1) Location of the Proposed Survey Area – Inskip Point

Image No.2 shows the approximate survey area (yellow line) which is approximately 2.8km along the point's beach line. The site is approximately 3 km from the Inskip boat ramp, which is to south of the site on the inner side of the spit.

(Image No.2) Extract of Inskip Point from Google Earth

3.2 Scope of Works

The brief on the project was to carry out a Class 'A' Shallow water Multibeam and Vessel mounted Terrestrial Laser survey of 2.8km of the Northern Shoreline of Inskip Point. The survey would extend out approximately 200m from the shoreline. PBPL would also conduct an additional Land Based Terrestrial Laser Survey with integrated photography.

3.3 PBPL Survey Vessel

The "Navigator" (7m) was the vessel used to undertake hydrographic survey work. It is fitted out with a RESON 8125 Hybrid shallow water multibeam system and an Applanix POSMV motion sensor.

(Image No.3) PBPL 7m Survey Vessel “The Navigator”

The multibeam sonar head is mounted in a purpose built moon pool and is permanently tilted at an angle of 15° towards starboard. The RESON 8125 Hybrid system is capable of horizontally steering the sonar ping electronically, enabling the surveyor to choose in real-time whether they want to survey directly below the vessel or to the side. The location of the moon pool is close to the centre of gravity of the vessel to enable maximum stability and accuracy of acoustic data collected. The precise positioning of all soundings is achieved by using an Applanix POSMV motion sensor system.

A Riegl VZ-2000 Laser Scanner was mounted to the roof of the Navigator at a 15° pitch to help pick up circular vertical objects like light posts and beacons. The VZ-2000 contains a Class 1 Laser with a maximum measurement range of up to 2000m. The laser has a measurement rate of up to 230,000 measurements per second at a range of 750m with a 100° Field of View. This provided an extremely high detail dataset of the Inskip coastline within the survey area.

(Image No.4) Laser mount configuration on the 'Navigator"

The "Navigator" was towed to Rainbow Beach with a PBPL 4WD. See Appendix A for the Navigator Node Locations and Appendix B for the QINSY Vessel Database (db) file.

3.4 Equipment Listing

Survey Vessel

- Multibeam Echosounder:
  - RESON 8125 Hybrid
- Laser Scanner
  - Riegl VZ-2000
- Positioning System :
  - Applanix POSMV 320 V5
- Seabird SBE-37 Sound Velocity Sensor
- Intuicom RTK Bridge for receiving SmartNet Corrections
- YSI Castaway CTD Sensor
- QINSy Acquisition software
- Applanix POSView

Data Processing

- QINSy Processing Manager and Qloud
- Hysurv Survey Software
- Bentley Microstation
- QINSy Fledermaus
- Applanix POSPAC
- Riegl RiScan

Land Survey

- Trimble R8 GNSS Receiver
- Laser Scanner
  - Riegl VZ-2000
  - Nikon D610 Camera

3.5 Survey Checks and Calibrations

3.5.1 Patch Test

To calculate the mounting angle corrections associated with the multibeam transducer/vessel mounted laser scanner with respect to the motion sensor, an industry standard patch test was conducted prior to the Inskip Point Beach survey.

The Port of Brisbane conducts regular patch tests on all its multibeam vessels over a well-known site in the Brisbane River, with the average calibration angles used. The roll angle was calculated with two lines run in opposite directions over the deeper flat seabed patch. For pitch to be calculated, two lines over the top of the rock high spot run in opposite directions were collected. For Yaw to be calculated, 2 lines run either side of the rock high spot in the same direction were collected. For the tilted head patch test, electronic steering in the echosounder was applied for the Yaw run-lines in order to be able have appropriate multibeam overlap over the rocky outcrop. See Table 2 below for the current Patch Test results for the Navigator Survey Vessel used for survey.

Navigator Patch Test Values RESON 8125 Hybrid	
Roll	-15.41°
Pitch	-1.13°
Yaw	+0.47°

(Table No. 1) Navigator Multibeam Patch Test Values

A similar process was conducted with the laser patch test with the exception of using terrestrial targets instead.

Navigator Patch Test Values Riegl VZ-2000 Laser	
Roll	+0.67°
Pitch	+15.60°
Yaw	-1.23°

(Table No. 2) Navigator Laser Patch Test Values

3.5.2 RTK GPS Corrections and Position Checks

The Port of Brisbane subscribes to the SmartNet DGNSS RTK CORS network for RTK corrections. For the Inskip Point Beach survey, Smartnet's Nearest Base Station corrections were utilised in Real-Time online and then the survey position results post-processed back in the office. To check the online positional accuracy of the Survey Vessel systems, position checks were conducted by logging GPS positions (using Smartnet corrections) on a permanent survey mark (PSM121815) located at the Inskip Point. Two other PSM's were investigated in the area but could not be found. See Appendix C for the PSM Information and the Permanent Mark checks conducted by PBPL.

3.5.3 Multibeam Bar Check

An industry standard bar check is conducted every time the multibeam transducer is removed from the mount. This was completed prior to conducting the Inskip Point Beach survey. A metal bar is lowered to 3m below the multibeam transducer. The multibeam is set to a range that zooms in enough to see the bar in the echosounder display. The power and gain settings are adjusted to remove as much of the noise artefacts and second returns as possible. In the multibeam echosounder display, the bar depth as well as the Beam Number that picks up the bar the best are noted. Using the Time Plot Display in QINSy, the system raw data and system results for that particular Beam number are averaged over approximately 1 minute or until the Standard Deviation of the measurements is as low as possible. The Raw multibeam value should match the echosounder display as a check. The Multibeam System Results show the Depth of the Bar that QINSy calculates (Reduced to Water Level).

The QINSy Mean Bar Height is calculated by:
Raw Multibeam Depth + Z Value of Transducer -Draft = QINSy Bar Depth
Note that a Positive Draft value in QINSy refers to the Centre of Gravity (COG) being above the water, where the COG is the IMU of the POSMV.

3.5.4 Squat Measurement

Squat is the amount the vessel moves vertically at the Centre of Gravity (COG) location, as the survey vessel changes speed through the water. On the PBPL survey vessels, the Applanix POSMV IMU is set as the COG in QINSy. Squat tests are performed yearly for each of the PBPL survey vessels and when major changes are made to that vessel that may affect the squat profile. Squat tests are performed using RTK GPS Heights and measuring the height of the COG (IMU) at different speeds. A squat profile for each multibeam vessel has been measured for each RPM value of the vessel. Squat is only applied when RTK Heights are not used for survey. The vessels RPM is noted for every survey line in the field book.

3.5.5 Draft Measurement

On every PBPL Survey vessel, a Draft measurement node is picked up when the node survey is conducted (see Appendix A). These Draft measurement nodes are always in the vessels moonpool as close to the transducer as possible. With a tape measure, the water level is measured before the vessel departs from the wharf and the measurement is subtracted or added from the Draft Node Z Height. This calculated Draft is then entered into the vessel Database (db) file before the commencement of the survey and noted in the fieldbook.

3.5.6 Motion Sensor Calibrations

An Applanix POS MV is permanently installed on-board the “Navigator” survey vessel. The POSMV requires a GPS Azimuth Measurement Subsystem (GAMS) calibration whenever the GPS antennas are removed. This involved putting the vessel through a series of dynamic manoeuvres, such as ‘figure of eights’ and varying the speed of the vessel to give the motion sensor system enough information to resolve the ambiguities and commence full system operation. The GAMS uses both the primary and secondary GPS antennas to determine a GPS-based heading that is accurate to ±0.02° and their separation represents the length of the baseline vector for the system. The calculated distances of the GAMS calibration was compared to the offset tape measurements and proved to be to be within the 5mm tolerance recommended by the manufacturers. With the baseline and offsets resolved, the system was fully operational according to manufacturer's specifications.

3.6 Field Operations

The survey team departed Fisherman Islands, Brisbane on the 14th October and arrived onsite before midday. The survey vessel "Navigator" was dropped at National Parks depot south of Rainbow Beach and the stationary stop go laser survey was commenced. The tide was ebbing so this was the most advantageous time to be performing laser operations as maximum coverage would be obtained at low tide.

On the 15th October the survey vessel was launched early in the morning at Rainbow Beach boat ramp. Travel time to Inskip point by water was about 30 minutes. Once on site a tide gauge system was deployed and all necessary checks were made to ensure a high standard of data quality. The hydrographic survey was started at 8:00 am to coincide with high tide which was at 9:04 am. This allowed a large portion of the intertidal zone along the 2.8 km beach to be surveyed. The hydrographic survey was completed for the day at 11:30 am and the vessel mounted laser survey was started. One run line in both directions along the survey area was performed. Once completed the equipment including the tide gauge were demobilised and the vessel returned to Rainbow Beach boat ramp.

In the afternoon the remainder of the stationary stop go laser survey was completed. Laser data was checked onsite to ensure that as much of the intertidal and sand-dune areas was captured.

On the 16th October the survey vessel was again launched early in the morning at Rainbow Beach boat ramp. The tide gauge was once again deployed and hydrographic survey operations were recommenced. This was mainly to fill in any gaps that were unsurveyed from the previous day's work and to utilise high tide which occurred at 9:30 am. The survey was completed by 11:00 am and the vessel was demobilised and trailered back to Brisbane in the afternoon.

3.7 Hydrographic Survey - Multibeam Component

As per the scope of works, the Port of Brisbane was responsible for providing an accurate Class 'A' multibeam survey of Inskip Point Beach area.

3.7.1 RESON 8125 Hybrid Technical Specifications

- Frequency = 455 kHz
- Ping Rate = Up to 50 pings/second
- Beam Density = 256 Beams
- Swath Width = 120°
- Along Track Transmit Beamwidth = 1.0°
- Across Track Receive Beamwidth = 0.5° (at nadir)
- Depth Resolution* = 6mm
- Pulse Length Used = 51 μsec

* Depth Resolution refers to the sensors measurement accuracy and not the absolute survey accuracy. Refer to the Survey Accuracy Section on page 20.

3.7.2 Sound Velocity

The multibeam system is calibrated using an industry standard Patch Test, in conjunction with regular water column sound velocity profiles at the survey site. A Seabird SBE37 sound velocity sensor is mounted at the transducer head, in order to measure instantaneous sound velocity, which is interfaced to the sonar processor for the integral ‘beam-forming’ process of the system to occur. The water column sound velocity profiles were measured with an YSI Castaway Sound Velocity profiler. Velocity profiles were conducted before and during survey operations. The sound velocity was monitored throughout the survey and new velocity profiles were conducted when noticeable differences in sound velocity occurred.

3.7.3 Seabed Coverage

During multibeam survey operations, adjacent multibeam lines were carried out in order to ensure that the minimum depth has been determined and to provide data redundancy enabling the detection of errors and inconsistencies. The survey vessel operated no faster than 5 knots while conducting multibeam surveying operations. Surveying was conducted at varies run line centres due to dynamic depth changes to ensure full esonification was achieved of the seabed structures within survey area.

3.7.4 Method to Compensate for Vessel Motion

When using the RESON 8125H Multibeam Echosounder, vessel position and motion compensation were provided by an Applanix POS MV 320. The motion sensor provides accurate attitude, heading, heave, position and velocity data to be interfaced with the other vessel sensors. This is calibrated during the patch test process, GAMS calibration and by analysis of overlapping data.

3.7.5 Horizontal Positioning

SmartNet Nearest BaseStation corrections were used to provide RTK positioning in conjunction with the motion sensors throughout the multibeam surveys. The Inertial Navigation System (INS) provides a positional accuracy better than ±0.10m (at 95% confidence interval).

Survey data was rejected at any time during the survey when any of the following conditions were experienced:

- Real Time Kinematic (RTK) correction age greater than 15 seconds
- Positional Dilution of Precision (PDOP) exceeded 6.0
- Less than 5 Healthy satellites were being tracked at elevations of no less than 13° from the horizontal.

3.7.6 Applanix POSMV 320 Technical Specifications

- Horizontal Position Accuracy* : RTK = ±0.008m + 1 ppm x baseline length
- Vertical Position Accuracy* : RTK = ±0.015m + 1 ppm x baseline length
- Roll & Pitch Accuracy : 0.01°
- Heave Accuracy : 2 cm (True Heave)

* Horizontal and Vertical Position accuracy refers to the sensors measurement accuracy and not the absolute survey accuracy. Refer to the Survey Accuracy Section on page 20.

3.7.7 Connection to Vertical Datum

Survey work was conducted using RTK corrections for the vertical datum connections. Regular checks were made and recorded against the PBPL measured tides throughout survey operations.

When using RTK GPS, the vertical component of the position solution may be used to connect soundings to the vertical datum. The AUSGeoid09 model was applied to the raw RTK GPS height to connect to the AHD vertical datum. The Lowest Astronomical Tide (LAT) datum is defined by MSQ as 1.12m below 0.0m AHD at Inskip Point.

3.8 Hydrographic Survey - Laser Scanning Component

The combination of surveying with sideward looking multibeam at high tide and laser scanning at low tide allows the entire intertidal surf zone slope to be surveyed.

The requirement was to pick up as much data of the Inskip Beach area, above and below water, as possible. The laser data was collected at lower tides to try to join with the multibeam data for both coverage and data integrity.

3.8.1 Riegl VZ-2000 Laser Scanner Technical Specifications

- Classification : Class 1 Laser Product according to IEC60825-1:2007
- Scan Angle Range : Total 100° (+60° / -40°)
- Scanning Mechanism : Rotating Multi-facet mirror
- Scan Speed : Up to 240 lines/second
- Effective Measurement Rate : Up to 396,000 measurements/second at 1MHz
- Angle Measurement Resolution : Better than 0.0015°
- Laser Wavelength : Near Infrared
- Beam Divergence = 0.3mrad
- Accuracy* = 8mm
- Precision = 5mm

* Accuracy refers to the sensors measurement accuracy and not the absolute survey accuracy. Refer to the Survey Accuracy Section below.

3.8.2 Scanning Coverage

At least two overlapping laser lines were carried out along the beach area in order to capture as much data in and around structures and to provide data redundancy which enables the detection of errors and inconsistencies. During survey operations, the survey vessel operated no faster than 5 knots. Run lines for the laser scanner surveys were generally conducted as close to the beach as safely possible.

3.8.3 Method to Compensate for Vessel Motion

When using the Riegl VZ-2000 Laser Scanner, vessel position and motion compensation were provided by an Applanix POS MV 320. The POSMV provides accurate attitude, heading, heave, position and velocity data to be interfaced with the other vessel sensors. This is calibrated during the patch test process, and by analysis of overlapping data.

3.8.4 Horizontal Positioning

Trimble RTK positioning was used in conjunction with an Applanix POSMV motion sensor throughout the laser scan surveys.

Survey data was rejected at any time during the survey any of the following conditions were experienced:

- Real Time Kinematic (RTK) correction age greater than 15 seconds
- Positional Dilution of Precision (PDOP) exceeded 6.0
- Less than 5 Healthy satellites were being tracked at elevations of no less than 13° from the horizontal.

3.8.5 Connection to Vertical Datum

The Laser Scan Survey work was conducted using only RTK corrections for the vertical datum connections. Regular checks were made and recorded against the local tides measured onsite when the vessel was surveying afloat.

When using RTK GPS, the vertical component of the position solution may be used to connect the laser data to the vertical datum. The AUSGeoid09 model in conjunction with the LAT to AHD differences for the survey area, as supplied by MSQ, were applied to the raw laser data from the laser scanner together with RTK GPS heights to give real time heights reduced to the vertical datum.

3.9 Terrestrial Laser Scanning Component

In conjunction with the hydrographic survey component, a Vehicle mounted laser scan was conducted to provide high accuracy laser data around the beach areas that could not be scanned from the vessel.

3.9.1 Vehicle Mounted Terrestrial Laser Survey Configuration

Image No.5 below shows a typical setup of the terrestrial laser mounted on a survey vehicle. The vehicle mounted configuration allows the beach line to be surveyed with the laser in the same geodetic reference as surveyed with the vessel system. A high resolution camera was also installed and interfaced to collect high resolution photography to be merged with the laser data.

(Image No.5) A typical laser mount configuration on a survey vehicle

3.9.2 Terrestrial Laser Survey Data Collection

The laser system was installed on a PBPL vehicle and the RTK “stop and go” method was undertaken along the beach shoreline using multiple setups. High Resolution photos were collected in conjunction with the laser data to be used in the processing procedure of colouring the laser points files with the actual colour.

The laser data was acquired using the RiSCAN software which is standard for Riegl terrestrial laser units. At each scan position, the laser and calibration target position was measured prior to scanning with an RTK GPS Position using the Smartnet Nearest Base Corrections. At each scan position along the beach, the laser would collect data from 30^0 to 130^0 in the vertical with a spacing 0.040 of a degree at the laser. The horizontal was scanned from 0^0 to 360^0 also with a spacing of 0.040 of a degree. This provides a representative 3D snapshot of all objects within the field of view the instrument at the time of acquisition. Using the software the reflective target positioned on the vehicle is located in the scanned image and a high resolution scan is conducted.

4.0 Project Configuration

4.1 Geodetic Parameters

All coordinates supplied in this report are referenced to the Geocentric Datum of Australia (GDA94), which is based on the global mathematical reference frame ITRF92 (fixed to a number of points in Australia). All surveys were referenced to GDA94 by connection to suitable benchmarks. The geodetic parameters are listed below:

Datum :	**WGS84**
Reference Spheroid :	World Geodetic Spheroid 1984
Semi-Major Axis :	6378137.000m
Inverse flattening (1/f) :	298.257223563

Datum :	**GDA94**
Reference Spheroid :	Geocentric Reference System 1980 (GRS80)
Semi-Major Axis (a) :	6378137.000m
Inverse flattening (1/f) :	298.257222101

Projection :	**Universal Transverse Mercator**
Grid :	Map Grid of Australia (MGA94)
Central Meridian (CM) :	153° East (UTM Zone 56)
Origin Latitude :	0°
Hemisphere :	South
False Easting :	500000m
False Northing :	10000000m
Scale Factor on CM :	0.999600
Units :	International Metres

4.2 Vertical Datum

Soundings are reduced to Lowest Astronomical Datum (LAT) using the AUSGeoid 2009 model. 0.0m LAT is 1.12m below 0.0m AHD (Australian Height Datum) as defined by MSQ.

5.0 Survey Data Processing Procedures

5.1 Bathymetry and Vessel Laser Processing

All bathymetric survey data collected was processed in QINSy Processing Manager and QLOUD. QINSy Processing Manager was used to conduct tide checks, squat comparisons and apply Post Processed GPS (SBET) tracks to the survey files. Survey data was then imported into QINSy's 3D editing package QLOUD. An IHO S44 Special Order (0 – 20m) filter – using a 3D surface spline algorithm, was then applied to the data. A sounding will be flagged as an outlier if it meets the criteria displayed in the equation below.

A Sounding is Flagged if $x > \sqrt{a^2+(b*d)^2}$

Where a = 0.25 and b = 0.0075 and d= water depth as set out in the S44 guidelines.

Once the filter finished cleaning the obvious artefacts out of the data, a visual inspection over the entire survey area was conducted to check that the survey data had no artefacts missed by the cleaning filter. This involves a combination of visualising the survey data in 3D, stepping through the data in profile view and also analysing the online sounding grids standard deviations. Once the data has been validated, a 50cm x 50cm MEAN Gridded Surface was exported out of QLOUD.

5.2 Terrestrial Laser and Photo Processing

The raw data is processed using the RiSCAN software. The GPS file for all scanner positions and reflective target positions are imported into the software and ten registered using these coordinates. The scans are then corrected using a multi-station adjustment (using least squares) to fit each scan as closely as possible. The scans are then cleaned, removing erroneous data. Once cleaned the scanned points are able to be coloured from the photos captured at the time of scanning giving a realistically coloured 3D point cloud. This data can then be incorporated with the bathymetry to produce a complete 3D model of the target area.

5.3 Data Presentation and Visualisation

Once the 50cm x 50cm MEAN Gridded surface had been created a subsequent 50cm x 50cm MEAN Depth point's file (PTS) was produced. The 50cm PTS file was used in PBPL's in house "Build Array" program to build 25m x 25m and 50m x 50m Minimum Depth Priority Sounding Arrays (ARR) and a 50cm x 50cm "Multibeam Model" (MBM).

5.3.1 Method Used for Sounding Selection

When using multibeam in all navigable waters PBPL has found that the best representation of the navigable seabed is to display the minimum of soundings from the 50cm x 50cm MEAN gridded surface. The minimum depth is displayed on the plans at an interval of 25m x 25m and 50m x 50m (depending on the plan scale) at the location of the minimum depth sounding.

5.3.2 Process for Rounding of Soundings

Soundings are rounded about the 0.05m. 0.050m and greater are rounded up and 0.049m and less are rounded down. For example, 10.949m will be displayed 10.9m, whereas 11.550m will be displayed as 11.6m.

5.3.3 Method of Surface (Model) Generation

Colour banded imagery was created based on the DTM of 50cm x 50cm MEAN gridded surface as a GEOTIFF. The software used to create the GEOTIFF was the QINSy Sounding Grid utility.

5.3.4 Contour Generation

Contours were created based on the 50cm x 50cm MEAN gridded surface detailed above. However to smooth the contours and to ensure only the significant structures are visualised, the 50cm x 50cm MEAN surface was reduced to a 4m x 4m MEAN gridded surface for contour generation. A minimum contour length of 100m was also applied. A contour interval of 0.25m was provided to the client in a 3D DXF file format and the 1m contours were shown on the survey plan.

5.3.5 3D Model Generation

The 3D model was created in a software package called Fledermaus Professional. PBPL format the data such that it can be used and viewed in 3D, in a free downloadable version of the software called iView 4D. This enables the user to "fly" through the survey area, zooming in and targeting areas of interest. The 3D viewer is very functional to use and is an extremely useful and powerful visualisation tool.

6.0 Data Quality and Retention

6.1 Survey Accuracies

The accuracy of the survey data is not just the sensors measurement accuracy but a combination of all the small measurement uncertainties within the system as a whole. The accuracies stated in the sensor technical specifications refer to each measurement collected by each sensor within the survey system.

However, for the creation of models, sounding grids and arrays, the soundings are exported to a 0.5m x 0.5m Mean Gridded DTM Grid. This surface has a larger error associated with it because it is a **MEAN** surface so there is an associated uncertainty in position and height on top of the absolute accuracies stated above.

Horizontal Accuracies for MEAN Gridded DTM Surfaces:

- 0.50m Grid = ±0.353m

To determine the vertical accuracy of the DTM surface, redundant data was collected by at least 1 line run perpendicular to the main survey lines. The average absolute difference between the mean depths of the main survey lines and check lines, in each 0.5m x 0.5m cell, were computed as well as the standard deviation.

The survey accuracies achieved for the Inskip Beach survey were:

- Horizontal Accuracy (at 95% Confidence) = Better Than ±0.50m
- Vertical Accuracy (at 95% Confidence) = ±0.15m

To meet "Class A" accuracy requirements, the accuracies must be better than:

- Horizontal Accuracy (at 95% Confidence) = ±0.50m
- Vertical Accuracy (at 95% Confidence) = ±0.15m

The Horizontal and Vertical Tolerances quoted on the PBPL plans state the accuracy requirements for "Class A" surveys as specified by Maritime Safety Queensland's document titled 'Standards for Hydrographic Surveys within Queensland Waters'. The Inskip Beach survey accuracies are **better than** these "Class A" requirements.

6.2 Data Summary

Survey Metadata Summary:

- Horizontal Datum : Geocentric Datum of Australia 1994 (GDA94)
- Vertical Datum : Lowest Astronomical Tide (LAT)
- Points File Coordinate System : Map Grid of Australia 1994 (MGA94)
- Survey Class : A

6.3 Data Archival Time Frames and Responsibility

Raw electronic hydrographic survey data will be stored by PBPL for at least 7 years. Sufficient data will be stored to enable independent reprocessing of survey data within this period. Electronic copies of final plans will also be stored by PBPL for at least 7 years.

Hardcopy hydrographic survey data and hardcopy final plans will be kept for 7 years by PBPL, before being archived and maintained off-site.

7.0 Data Deliverables

7.1 Survey PTS Files

Survey ASCII points files (PTS) were exported out of QINSy once the data processing procedures had been completed. The following PTS files were provided to the client:

- 50cm x 50cm MEAN Grid

All PTS files have the following characteristics:

- Horizontal Datum = Map Grid of Australia (MGA94)
- Vertical Datum = Lowest Astronomical Tide (LAT)
- Depths are negative numbers.

7.2 Survey Plans

Two survey plans were provided in PDF and DXF formats to the client to display the survey results. The following were provided to the client:

- 132361 – 1 : 1:1000 Scale Plan of The Near Shore Instability Area
- 132361 – 2 : 1:5000 Scale Overview Plan of Inskip Point

Bentley Microstation was used to create the final CAD drawings of the Survey Plan. See Appendix D for each Survey Plans.

7.3 GeoTIFF Imagery

The following GeoTIFF Images were provided to the client:

- Multibeam Sounding Imagery:
    - 50cm x 50 cm MEAN

7.4 Contours

A 3D DXF containing contours at an Interval of 25cm was provided to the client. A contour interval of 1m was used for the 1:1000 survey plan.

7.5 3D Model

A 3D Model presenting all the above deliverables was created in QPS Fledermaus. A Scene file was provided to the client to be viewed in the freely downloadable software package iView4D.

8.0 Certification

I certify that this Survey Report and the results described herein conform to the hydrographic survey meeting Survey Class A standard as defined by MSQ's 'Standards for Hydrographic Surveys within Queensland Waters'.

G Stimson Giles Stimson 10-11-15
....
(Signature) (Print Name) (Date)

Manager of Port Surveys
Certified Professional in Hydrographic Surveying (Level 1)

AARON WILLCOCK 10/11/2015
....
(Signature) (Print Name) (Date)

Supervising Surveyor
Certified Professional in Hydrographic Surveying (Level 1)

ROBERT SLATER 10/11/15
....
(Signature) (Print Name) (Date)

Hydrographic Surveyor
Certified Professional in Hydrographic Surveying (Level 1)

Appendix A

Navigator Node Locations

POS Coordinates

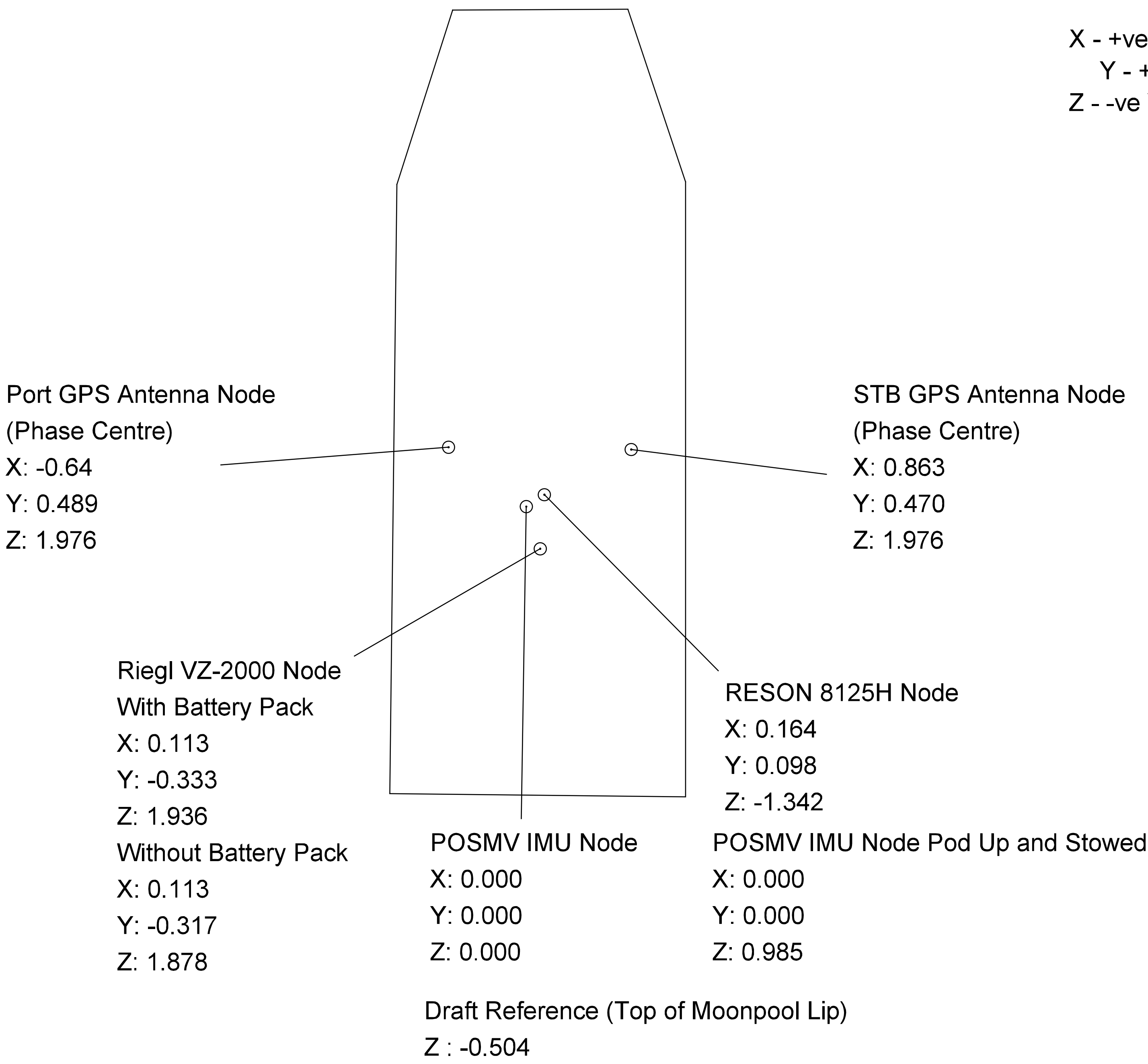
IMU to Centre of Rotation

X = 0.535
Y = 0.125
Z = 0.460

Sensor Layout on Navigator

Refers to the Reference Frame in QINSy

X - +ve Value to Starboard Direction
Y - +ve Value to Bow Direction
Z - -ve Value to Downward Direction



IMU to Centre of Rotation (POS Coordinates)

X = 0.535
Y = 0.125
Z = 0.460

Surveyor: AW, RS, JW, DI
Field Book: 318 page 62-63
Vessel: Navigator
Data Type:
Data File:

DESIGN DIMENSIONS
Length: Depth:
Width: Ins. Depth:

VERTICAL MEASURMENTS
Equipment:
Calibration:
Tide Gauge:

HORIZONTAL POSITIONING
Equipment:
Mode:
Base Station:

SPECIFIED SYSTEM ACCURACY
Vertical Tolerance (95%): ± Typical Coverage:
Horizontal Tolerance (95%): ± Survey Class:

CLIENT:

PURPOSE OF SURVEY:
Calibration

Robert Slater
SURVEYED AND CHECKED

Aaron Willcock
SUPERVISING SURVEYOR (AHSCP LEVEL 1)

APPROVED DATE

Navigator

Node Survey 6/10/2015
RESON 8125H and Riegl VZ-2000

GDA

LEVEL DATUM: <V DATUM> AZIMUTH DATUM: <H DATUM> SCALE 1:<PLOT SCALE> (A3 sheet)

PORT OF BRISBANE PTY LTD 3 PORT CENTRAL AVENUE PORT OF BRISBANE QUEENSLAND 4178 Phone 07 32584888

PORT of BRISBANE
Here for the future

Dwg. No. 132324
Proj. File: <PROJECT FILE>

Appendix B

Navigator Vessel Database Setup

SURVEY DEFINITIONS

General Definitions

Line name	:	Inskip
Line sequence number	:	29
Line description	:	
UTC to GPS time correction	:	17.000 s
Survey unit name	:	Meters
Conversion factor to metres	:	1.000000000000000

Geodetic Definitions

Magnetic Variation Information

Undefined

Datum Definitions

Survey Datum	:	Australia GDA 1994
Spheroid name	:	GRS 1980
Prime meridian	:	Greenwich
Conversion factor to metres	:	1.0000000000000
Semi-major axis (a)	:	6378137.000 m
Semi-minor axis (b)	:	6356752.314 m
Inverse flattening (1/f)	:	298.25722210100
First eccentricity squared (e**2)	:	0.0066943800229
Second eccentricity squared (e'**2)	:	0.0067394967754
Additional Datum	:	WGS84
Spheroid name	:	WGS 1984
Prime meridian	:	Greenwich
Conversion factor to metres	:	1.0000000000000
Semi-major axis (a)	:	6378137.000 m
Semi-minor axis (b)	:	6356752.314 m
Inverse flattening (1/f)	:	298.25722356300
First eccentricity squared (e**2)	:	0.0066943799901
Second eccentricity squared (e'**2)	:	0.0067394967422

Datum Shift Definitions

WGS84 to Australia GDA 1994 — Helmert 7-Parameter Transformation
Position vector rotation — Arc Seconds

X shift	:	0.000 m	X rotation	:	0.000000 "
Y shift	:	0.000 m	Y rotation	:	0.000000 "
Z shift	:	0.000 m	Z rotation	:	0.000000 "
Scale correction	:	0.00000000 ppm			

Rotation center point	:	Not Defined
Reference epoch	:	Not Defined

Chart Datum / Vertical Datum Definition

Chart datum	:	AUSGeoid09 (Australia)
Height file	:	AUSGeoid09.BIN
Height level	:	No Level Correction
Height file	:	N/A
Height offset	:	-1.120 m
MWL model	:	AUSGeoid09 (Australia)
MWL file	:	AUSGeoid09.BIN
MWL level	:	No Level Correction
MWL file	:	N/A
MWL offset	:	-1.120 m
MWL st.dev.	:	0.013 m
DTM mode	:	Absolute DTM's
DTM datum	:	AUSGeoid09 (Australia)
DTM file	:	AUSGeoid09.BIN
DTM level	:	No Level Correction
DTM file	:	N/A
DTM offset	:	-1.120 m

Projection Definition

Projection type	:	0002
Projection name	:	Universal Transverse Mercator (South Oriented)
Conversion factor to metres	:	1.0000000000000
UTM zone number	:	56
UTM central meridian	:	153;00;00.00000 E
Latitude of grid origin	:	0;00;00.00000 N
Longitude of grid origin	:	153;00;00.00000 E
Grid Easting at grid origin	:	500000.000 m
Grid Northing at grid origin	:	10000000.000 m
Scale factor at longitude of origin	:	0.999600000000

Local Construction Grid Definition

Not Applicable

Offset Convention

Offset mode	:	Rectangular
Offset distances units	:	Meters
Offset angles units	:	Degrees

OBJECT DEFINITIONS

General Summary Information

Number of survey vessels or objects	:	1
Number of relay vessels or buoys	:	0
Number of external network nodes	:	0
Number of datums/ellipsoids defined	:	2

Vessel Definitions

Navigator

Streamers	:	0	Gun arrays	:	0
Buoys	:	0	Echosounders	:	0
Satellite receivers	:	0	USBL systems	:	0
Network nodes	:	5	Pitch/Roll/Heave sensors	:	Yes

Correction to GMT (UTC)	:	0.000 h
Correction to master vessel's time	:	0.000 s
Height above draft reference	:	0.584 m
Description of reference point	:	Navigator IMU

Point	X	Y	Z	Pen	Fill	Style
1	-1.200	-2.400	0.000	Up	On	Solid
2	-1.200	2.700	0.000	Down	On	Solid
3	-0.600	4.100	0.000	Down	On	Solid
4	0.840	4.100	0.000	Down	On	Solid
5	1.300	2.700	0.000	Down	On	Solid
6	1.300	-2.400	0.000	Down	On	Solid
7	-1.200	-2.400	0.000	Down	On	Solid

Gun Array Definitions

NETWORK DEFINITIONS

Fixed Node Definitions

Variable Node Definitions

Navigator IMU

Object location	:	Navigator
X (Stbd = Positive):	:	0.000 m
Y (Bow = Positive):	:	0.000 m
Z (Up = Positive):	:	0.000 m
A-priori SD	:	0.010 m

8125 Tx

Object location	:	Navigator
X (Stbd = Positive):	:	0.164 m
Y (Bow = Positive):	:	0.098 m
Z (Up = Positive):	:	-1.342 m
A-priori SD	:	0.010 m

Draft Reference

Object location	:	Navigator
X (Stbd = Positive):	:	0.000 m
Y (Bow = Positive):	:	0.000 m
Z (Up = Positive):	:	-0.504 m
A-priori SD	:	0.010 m

Riegl VZ-2000

Object location	:	Navigator
X (Stbd = Positive):	:	0.113 m
Y (Bow = Positive):	:	-0.346 m
Z (Up = Positive):	:	1.948 m
A-priori SD	:	0.010 m

Variable Node Definitions (continued)

Water Level		
Object location	:	Navigator
X (Stbd = Positive):	:	0.000 m
Y (Bow = Positive):	:	0.000 m
Z (Up = Positive):	:	-0.579 m
A-priori SD	:	0.010 m

Observation Definitions

POS MV Heading	:	Bearing (True)
'At' node	:	Navigator IMU
'To' node 1	:	Ship's axis
Measurement unit code	:	Degrees
System description	:	POS MV Heading
Propagation speed	:	0.0000000000 m/s
Lanewidth on baseline	:	0.0000000000 m/s
Scale factor	:	1.0000000000
Fixed system (C-O)	:	0.00000000 °
Variable (C-O)	:	0.000000 °
A-priori SD	:	0.05 °
Quality indicator	:	No quality info recorded

Realtime Heave	:	Generic
'At' node	:	Undefined
System description	:	True Heave
Propagation speed	:	0.0000000000 m/s
Lanewidth on baseline	:	0.0000000000 m/s
Scale factor	:	1.0000000000
Fixed system (C-O)	:	0.00000000 m
Variable (C-O)	:	0.000000 m
A-priori SD	:	1.00 m
Quality indicator	:	No quality info recorded

True Heave	:	Generic
'At' node	:	Undefined
System description	:	True Heave
Propagation speed	:	0.0000000000 m/s
Lanewidth on baseline	:	0.0000000000 m/s
Scale factor	:	1.0000000000
Fixed system (C-O)	:	0.00000000
Variable (C-O)	:	0.000000
A-priori SD	:	1.00
Quality indicator	:	No quality info recorded

Reference Station Definitions

ATT Node Definitions

SYSTEM DEFINITIONS

Gyro Compass

POS MV Heading

Interfacing

Type	: Gyro Compass			
Driver	: Network - POS MV V5 (Binary Groups 1/102/103)			
Executable and Cmdlir	: DrvQPSCountedUDP.exe POSMV PPS			
Port	: 5602	Latency	:	0.000 s

Acquired by : [Directly into QINSy] (No additional time tags)
Observation time from : N/A

Number of slots : 1

Connected Observations

POS MV Heading : Bearing (True)
Slot 1 : 102

Connected Nodes

Navigator IMU : Navigator

Pitch Roll Heave Sensor

POS MV Motion

Interfacing

Type	:	Pitch Roll Heave Sensor		
Driver	:	Network - POS MV V5 (Binary Groups 1/102/103)		
Executable and Cmdlir	:	DrvQPSCountedUDP.exe POSMV PPS		
Port	:	5602	Latency :	0.000 s

Acquired by	:	[Directly into QINSy] (No additional time tags)
Observation time from	:	N/A
Number of slots	:	1

System Parameters

POS MV Motion

Object	:	Navigator
Location on object (Lever arm)	:	Navigator IMU
PRH sensor reference number	:	1
Rotation convention pitch	:	Positive bow up
Rotation convention roll	:	Positive heeling to starboard
Angular variable measured	:	HPR (roll first)
Angular measurement units	:	Degrees
Sign convention heave	:	Positive downwards
Measurement units heave	:	Meters
Conversion factor to degrees decimal	:	1.0000000000000
Conversion factor to metres	:	1.0000000000000
Quality indicator type pitch and roll	:	No quality info recorded
Quality indicator type heave	:	No quality info recorded
Description of quality indicator type	:	
X (Stbd = Positive):	:	0.000 m
Y (Bow = Positive):	:	0.000 m
Z (Up = Positive):	:	0.000 m
A-priori SD	:	0.010 m
(C-O) pitch offset	:	0.000 °
(C-O) roll offset	:	0.000 °
(C-O) heave offset	:	0.000 m
Heave time delay	:	0.000 s
SD roll and pitch	:	0.020 °
SD heave (fixed)	:	0.050 m
SD heave (variable)	:	5.000 %
SD roll offset	:	0.050 °
SD pitch offset	:	0.050 °
SD heave offset	:	0.050 m

Description of pitch, roll and heave system
POS MV Motion
Slot
102

Position Navigation System

POS MV Position

Interfacing

Type	:	Position Navigation System		
Driver	:	Network - POS MV V5 (Binary Groups 1/102/103)		
Executable and Cmdlir	:	DrvQPSCountedUDP.exe POSMV PPS		
Port	:	5602	Latency :	0.000 s

Acquired by	:	[Directly into QINSy] (No additional time tags)
Observation time from	:	N/A

Number of slots	:	1

Satellite System Definition

Position datum	:	WGS84
Satellite system name	:	WGS84

Satellite Receiver Definition

Receiver number	:	102
Receiver description	:	
Node identifier	:	Navigator IMU
Object location	:	Navigator
X (Stbd = Positive):	:	0.000 m
Y (Bow = Positive):	:	0.000 m
Z (Up = Positive):	:	0.000 m
A-priori SD	:	0.010 m

SD latitude	:	0.050 m
SD longitude	:	0.050 m
SD height	:	0.100 m

Horizontal datum	:	WGS84	
Vertical datum	:	WGS84	N/A
Height level	:	No Level Correction	N/A
Height offset	:	0.000 m	

Connected Observations

Connected Nodes

Multibeam Echosounder

Seabat 8125H

Interfacing

Type	: Multibeam Echosounder			
Driver	: Reson Seabat 7K (TCP/Network)			
Executable and Cmdlir	: DrvSeabat7K.exe			
IP address	: 11. 0. 11. 2			
Update rate	: 0.000 s			
Port	: 7000	Latency	:	0.000 s

Acquired by	: [Directly into QINSy] (No additional time tags)
Observation time from	: N/A

Number of slots	: 0

System Parameters

Node name	: 8125 Tx
X (Stbd = Positive):	: 0.164 m
Y (Bow = Positive):	: 0.098 m
Z (Up = Positive):	: -1.342 m
A-priori SD	: 0.010 m

Description	: Seabat 8125H
Object	: Navigator
Number of transducers	: Single
Transducer node TX	: 8125 Tx
Heading offset	: 0.470 °
Roll offset	: -15.410 °
Pitch offset	: -1.130 °

Unit is roll stabilized	: No
Unit is pitch stabilized	: No
Unit is heave compensated	: No
Beam steering (flat transducer)	: Yes
Beam angle width along	: 1.000 °
Beam angle width across	: 0.500 °
Maximum number of beams per ping	: 512
Use sound velocity from unit	: Yes

Slot	: 1

SD type	: Angle, Range
SD beam angle	: 0.030 °
SD beam range	: 0.010 m
SD roll offset	: 0.050 °
SD pitch offset	: 0.050 °
SD heading offset	: 0.500 °
SD roll stabilization	: 0.000 °
SD pitch stabilization	: 0.000 °
SD heave compensation	: 0.000 m
SD sound velocity	: 0.050 m/s

Time Synchronization System

Time In

Interfacing

Type	:	Time Synchronization System		
Driver	:	POS MV V5 (Binary Group 112 - NMEA ZDA) (Network)		
Executable and Cmdlir	:	DrvQPSCountedUDP.exe POSMV PPS		
Port	:	5602	Latency :	0.000 s

Acquired by	:	[Directly into QINSy] (No additional time tags)
Observation time from	:	N/A

Number of slots : 1

PPS Pulse System

PPS Pulse System

Interfacing

Type	:	PPS Pulse System		
Driver	:	QPS PPS Adaptor		
Executable and Cmdlir	:	DrvPpsPulse.exe		
Port	:	1		
Baud rate	:	1200	Data bits :	0
Parity	:	None	Stop bits :	1
Update rate	:	0.000 s	Latency :	0.000 s

Acquired by	:	[Directly into QINSy] (No additional time tags)
Observation time from	:	N/A

Number of slots : 0

AIS System

AIS

Interfacing

Type	:	AIS System		
Driver	:	AIS Standard VDO/VDM Messages		
Executable and Cmdlir	:	DrvQPSTerminated.exe AIS		
Port	:	12		
Baud rate	:	9600	Data bits :	8
Parity	:	None	Stop bits :	1
Update rate	:	0.000 s	Latency :	0.000 s

Acquired by	:	[Directly into QINSy] (No additional time tags)
Observation time from	:	N/A

Number of slots : 0

Miscellaneous System

True Heave

Interfacing

Type	:	Miscellaneous System		
Driver	:	Network - POS MV V5 (Binary Group 111 - True Heave)		
Executable and Cmdlir	:	DrvQPSCountedUDP.exe POSMV PPS		
Port	:	5602	Latency :	0.000 s

Acquired by	:	[Directly into QINSy] (No additional time tags)
Observation time from	:	N/A

Number of slots : 1

Connected Observations

Realtime Heave			: Generic
Slot 1	:	Real	
True Heave			: Generic
Slot 1	:	True	

Connected Nodes

Sidescan Sonar

8125H Sidescan

Interfacing

Type	: Sidescan Sonar			
Driver	: Reson Seabat 7K (TCP/Network)			
Executable and Cmdlir	: DrvSeabat7K.exe			
IP address	: 11. 0. 11. 2			
Update rate	: 0.000 s			
Port	: 7000	Latency	:	0.000 s

Acquired by	: [Directly into QINSy] (No additional time tags)
Observation time from	: N/A

Number of slots	: 0

System Parameters

Manufacturer	: Reson
Model	: Reson 8125
Number of beams	: 1
Number of channels	: 2
Associated multibeam system	: Seabat 8125H
Object location	: Navigator
Use sound velocity from unit	: Yes

Node name	: 8125 Tx
Orientation	: Port
Sidescan Sonar Channel:	: 0
Slot ID	: 0
Roll offset	: 0.000 °
Pitch offset	: 0.000 °
Heading offset	: 0.000 °
Frequency	: 455.000 kHz
Number of beams	: 1
Horizontal beam width	: 0.000 °
Vertical beam width	: 0.000 °
Vertical tilt angle	: 0.000 °

Node name	: 8125 Tx
Orientation	: Starboard
Sidescan Sonar Channel:	: 1
Slot ID	: 0
Roll offset	: 0.000 °
Pitch offset	: 0.000 °
Heading offset	: 0.000 °
Frequency	: 455.000 kHz
Number of beams	: 1
Horizontal beam width	: 0.000 °
Vertical beam width	: 0.000 °
Vertical tilt angle	: 10.000 °

Multibeam Echosounder

Riegl VZ-2000

Interfacing

Type	: Multibeam Echosounder			
Driver	: Laser Scanning - RIEGL VZ-2000 (With UTC)			
Executable and Cmdlir	: DrvLaser.exe RIEGL_VZ2000 PPS			
IP address	: 192.168. 0.125			
Update rate	: 0.000 s			
Port	: 20002	Latency	:	0.000 s

Acquired by	: [Directly into QINSy] (No additional time tags)
Observation time from	: N/A

Number of slots : 0

System Parameters

Node name	: Riegl VZ-2000
X (Stbd = Positive):	: 0.113 m
Y (Bow = Positive):	: -0.346 m
Z (Up = Positive):	: 1.948 m
A-priori SD	: 0.010 m

Description	: Riegl VZ-2000
Object	: Navigator
Number of transducers	: Single
Transducer node TX	: Riegl VZ-2000
Heading offset	: -1.230 °
Roll offset	: 0.670 °
Pitch offset	: 15.600 °

Unit is roll stabilized	: No
Unit is pitch stabilized	: No
Unit is heave compensated	: No
Beam steering (flat transducer)	: No
Beam angle width along	: 1.500 °
Beam angle width across	: 1.500 °
Maximum number of beams per ping	: 40000
Use sound velocity from unit	: Yes

Slot : 1

SD type	: Angle, Range
SD beam angle	: 0.050 °
SD beam range	: 0.050 m
SD roll offset	: 0.050 °
SD pitch offset	: 0.050 °
SD heading offset	: 0.500 °
SD roll stabilization	: 0.000 °
SD pitch stabilization	: 0.000 °
SD heave compensation	: 0.000 m
SD sound velocity	: 0.050 m/s

AIS System

D700 Camera

Interfacing

Type	: AIS System
Driver	: DSLR Camera - Nikon D90/D5000
Executable and Cmdlir	: DrvQPSFreeBaseUI.exe NIKON_D5000

Appendix C

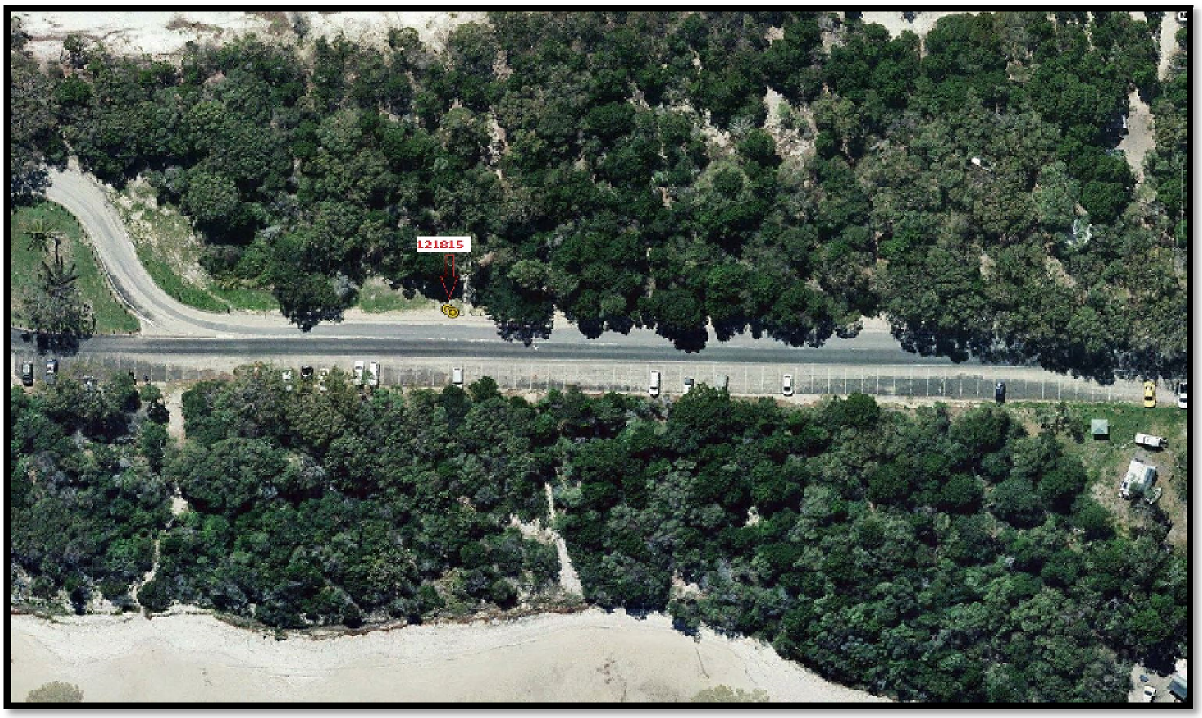
PSM Information and Checks

Rainbow Beach (Inskip Point) Control Survey 14th - 16th October 2015

Conducted by R Slater using Trimble R8 and Smartnet NB (Nearest Base)

All Coordinates are in GDA and Heights are AHD

	PSM	Easting	Northing	Elevation
QLD Globe	121815	505187.834	7145394.194	1.367
OBS		505187.835	7145394.113	1.306
OBS - Known		0.001	-0.081	-0.061



Images are courtesy of Google Earth and QLD GLOBE/Location

Queensland Government

Survey Control Mark Report

ADMINISTRATIVE

Mark Number	**121815**		
Alternate Names		Town	
		Local Authority	**GYMPIE REGIONAL**
Locality Description	**INSKIP POINT CAR PARK**		
Related Information			

DETAILS

Mark Type	**DDM**		
Installed By	**DNR**	Connections	
Installed Date	**09-May-1998**		
Mark Condition	**GOOD**		
Last Visited	**10-Jun-2005**		
Sketch Available	**Yes**		

GDA94 COORDINATES

Lineage	**Derived**		
Latitude	**25º 48' 34.76370" S**	Horizontal Uncertainty	**CLASS A / 1st ORDER**
Longitude	**153º 03' 06.31783" E**		
Ellipsoidal Height		Vertical Uncertainty	
MGA94 Easting	**505187.834m**	MGA94 Point Scale	**0.99960033**
MGA94 Northing	**7145394.194m**	MGA94 Grid Conv	**0º 01' 21.12"**
MGA94 Zone	**56**		
Published	**25-Oct-2000**	Fixed By	**GPS**
Adjustment	**GDA - TRANSFORMED QLD_0900 GRID**		

AHD HEIGHT

Lineage	**Derived**		
Height	**1.367m**	Vertical Uncertainty	**Class A / 4th ORDER**
Published	**01-Jun-1998**	Fixed By	**GPS**
Origin Mark	**44679**	NLN Section	
Source	**Model: AUSGEOID93 INTERPOLATED / N Value: 11.107m**		

QUEENSLAND GOVERNMENT

QUEENSLAND - DEPARTMENT OF NATURAL RESOURCES

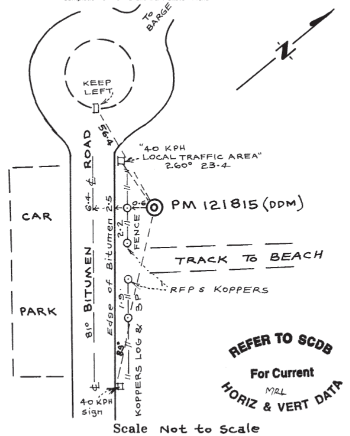
PERMANENT MARK SKETCH PLAN

REGD NO. 121815

NATURAL RESOURCES

Bearings are MAG (Magnetic, AMG) Distances are metres

Sketch plan to be completed in accordance with the Department's QA document; "Completion of Permanent Mark Sketch Plans"



Scale Not to Scale

Suited to GPS
Yes/No YES
Date 5/98

SCDB DETAILS ON REVERSE ARE TO BE COMPLETED

I certify that the permanent mark sketch has been prepared in accordance with the "The Survey Co-ordination Act of 1952-1989".

Date 3-8-98 Signature [signature]

Appendix D

Survey Plans

132361 (2 Sheets)

Surveyor: Robert Slater Field Book: H15696/9 Vessel: Navigator Data Type: MINIMUM DEPTHS Data File: 18455004	DESIGN DIMENSIONS Depth: N/A Ins. Depth: N/A	VERTICAL MEASUREMENTS Equipment: Seabat 8125H/Riegl VZ2000 Calibration: 13/10/2015 Tide Gauge: Smartnet iMax Benchmark: Smartnet iMax Datum: L.A.T.	HORIZONTAL POSITIONING Equipment: POS MV Mode: RTK Base Station: Smartnet Datum: GDA94	CLIENT: Queensland Parks and Wildlife Service PURPOSE OF SURVEY: Investigation

Notes:
- Image Courtesy of Google Earth
- 0.0m AHD = 0.0m LAT + 1.12m
- Positive Heights ; Negative Depths
- Contour Interval = 1m

SPECIFIED SYSTEM ACCURACY

Vertical Tolerance (95%):	± 0.15 m
Horizontal Tolerance (95%):	± 0.5 m
Typical Coverage:	100%
Survey Class:	A

ROBERT SLATER
SURVEYED AND CHECKED — DATE

AARON WILLCOCK
SUPERVISING SURVEYOR (AHSCP LEVEL 1) — DATE

GILES STIMSON
APPROVED — DATE

BATHYMETRY COLOUR MAP (m)

1.0 -5.0 -10.0 -15.0 -20.0 -25.0

SCALE 1:1000 (Before Reduction from A1 sheet)

Metres

0 20 40 60 80 100

LEVEL DATUM: L.A.T. AZIMUTH DATUM: GDA94

Assessment of Near Shore Instability

Inskip Point (Sheet 1 of 2)

INVESTIGATION SURVEY 14/10/2015 to 15/10/2015

GDA

PORT OF BRISBANE PTY LTD 3 PORT CENTRAL AVENUE PORT OF BRISBANE QUEENSLAND 4178 Phone 07 32584888

PORT of BRISBANE
Here for the future

Dwg. No.
132361 - 1
Proj. File: Inskip.lwf

Surveyor: Robert Slater
Field Book: H15696/9
Vessel: Navigator
Data Type: MINIMUM DEPTHS
Data File: 18455004

DESIGN DIMENSIONS
Depth: N/A
Ins. Depth: N/A

VERTICAL MEASUREMENTS
Equipment: Seabat 8125H/Riegl VZ2000
Calibration: 13/10/2015
Tide Gauge: Smartnet iMax
Benchmark: Smartnet iMax
Datum: L.A.T.

HORIZONTAL POSITIONING
Equipment: POS MV
Mode: RTK
Base Station: Smartnet
Datum: GDA94

Notes:
Image Courtesy of Google Earth
0.0m AHD = 0.0m LAT + 1.12m
Positive Heights ; Negative Depths

SPECIFIED SYSTEM ACCURACY
Vertical Tolerance (95%): ± 0.15 m
Horizontal Tolerance (95%): ± 0.5 m
Typical Coverage: 100%
Survey Class: A

CLIENT: Queensland Parks and Wildlife Services
PURPOSE OF SURVEY: Investigation
ROBERT SLATER — SURVEYED AND CHECKED — DATE
AARON WILLCOCK — SUPERVISING SURVEYOR (AHSCP LEVEL 1) — DATE
GILES STIMSON — APPROVED — DATE

BATHYMETRY COLOUR MAP (m)
1.0 -5.0 -10.0 -15.0 -20.0 -25.0

SCALE 1:5000 (Before Reduction from A1 sheet)
Metres
0 100 200 300 400 500

LEVEL DATUM: L.A.T.
AZIMUTH DATUM: GDA94

Assessment of Near Shore Instability

Inskip Point (Sheet 2 of 2)

INVESTIGATION SURVEY 14/10/2015 to 15/10/2015

PORT OF BRISBANE PTY LTD 3 PORT CENTRAL AVENUE PORT OF BRISBANE QUEENSLAND 4178 Phone 07 32584888

GDA

PORT of BRISBANE
Here for the future

Dwg. No. 132361 - 2
Proj. File: Inskip.lwf