Department of Infrastructure and Regional Development

Crane and Moorings Replacement

30% Design Report

November 2017

Executive summary

The Department of Infrastructure and Regional Development has engaged GHD for the project management and design consultancy services for the crane and mooring replacement at Flying Fish Cove (FFC) and Smith Point on Christmas Island and decommissioning of crane and moorings at Nui Nui. This 30% Design Report forms part of the Stage 1 deliverables for the project and discusses the options assessment outcomes for the new crane platform and presents the concept sketches of the recommended crane platform, new moorings at rock berth, new moorings at crane berth and new moorings at Smith Point.

GHD had previously provided technical review of the two existing cranes to determine the preferred replacement option for the existing Favco M760D crane at Flying Fish Cove and the proposed removal and off-island disposal of the existing Favco M440D crane, currently located at Nui Nui/Norris Point. The details of the assessment are contained in the GHD report for Patrick Ports, *Flying Fish Cove Crane Replacement – Options Assessment*, December 2015. The User Requirements Brief confirmed the operational requirement for an offshore platform crane with a capacity of 45 t at a reach of 45 m, compared to 34.8 t at 25 m for the existing crane.

The four proposed options for the new crane platform at FFC were:

- Option 1 – Do Nothing
- Option 2 – Upgrade existing crane platform to allow for new crane
- Option 3 – New offshore platform/crane platform
- Option 4 – New location of crane, inland

During the 30% design phase with stakeholder consultation, a geotechnical and environmental review was undertaken to determine which option should be progressed to detailed design. The outcome of these studies, including cost estimates was to recommend Option 2, the upgrading of the existing crane platform with allowance for four new piles.

The three options for the mooring systems at FFC rock and crane berth were:

- Option 1 – Do nothing
- Option 2 – Separate moorings at rock and crane berth to allow for simultaneous mooring of vessels (A and B) – new componentry.
- Option 3 – Shared moorings at rock and crane berth with single vessel mooring, with minor new componentry.
- Option 4a – Shared moorings at rock and crane berth with single vessel mooring, with new outer mooring componentry.
- Option 4b – Shared moorings at rock and crane berth with single vessel mooring; combined new outer and inner componentry.

During the 30% design phase with stakeholder consultation, an assessment of the above options was undertaken. The outcome of the assessment including cost estimate review was to recommend Option 4b, shared moorings at rock and crane berth with single vessel mooring combined new outer and inner componentry.

The three options for the mooring systems at Smith Point were:

- Option 1 – Do nothing

- Option 2 – New moorings to allow for vessels to berth parallel to shore
- Option 3 – New moorings to allow for vessels to berth parallel and perpendicular to shore.

During the 30% design phase with stakeholder consultation, an assessment of the above options was undertaken. The outcome of the assessment including cost estimate review was to recommend Option 3, mooring system that provides for vessels to berth parallel and perpendicular to shore.

The User Requirements Brief provides guidance to the design team as to the objectives and design criteria moving forward into detailed design. This report considers the various criteria that will be included in detailed design for the crane and mooring systems.

The cost of decommissioning of the mooring systems and the crane replacement has been included in the Cost Estimate chapter of this report.

A cost estimate for the preferred option has been prepared by GHD's subconsultant, quantity surveyor Ralph Beattie Bosworth (RBB), refer Table 1.

Table 1: Cost Estimate of Preferred Option

Component	Crane Option 2	FFC Moorings Option 4b	Smith Pt Moorings Option 3	Nui Nui Decommissioning	Total Cost
Construction	$8,830,000	$4,585,000	$4,120,000	$275,000	
Design Contingency (7.5%) **	$662,000	$344,000	$309,000	$21,000	
Construction Contingency (10%) **	$949,000	$493,000	$443,000	$30,000	
Consultant Fees and Disbursementss	$1,520,000	$790,000	$710,000	$47,000	
Escalation to Commencement	$119,000	$62,000	$56,000	$4,000	
TOTAL	**$12,081,000**	**$6,274,000**	**$5,638,000**	**$377,000**	**$24,370,000**

**Note: These percentages are consistent with Industry Standards for an estimate with this level of risk profile.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.4 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Project Introduction

Christmas Island is a non-self-governing Australian Territory located in the Indian Ocean, approximately 2,600 km north-west of Perth and approximately 1,565 km from the Northwest Cape of Australia. The island is administered on behalf of the Australian Government by the Territories Division of the Department of Infrastructure and Regional Development (DIRD).

DIRD has responsibility for the management and operation of the Indian Ocean Territories (IOT) Port Facilities. The Australian Government owns all of the IOT Ports on-shore assets (fixed and mobile) and a number of offshore assets and vessels. The assets are maintained by the port facilities manager, and used by port users, stevedores, licensees and others involved in transacting port business.

1.2 Project Scope

GHD has been engaged (as the Project Manager and Design Consultant) to undertake a specialist technical review of the existing cranes and mooring systems on Christmas Island (CI). This includes the development of a fully costed design for the replacement, upgrade, decommissioning and off-island disposal of each major component of the infrastructure. GHD will also undertake the review of procurement and delivery services in preparation for an approach to market for the construction stage of the project - “Replacement and Upgrade of Crane and Mooring Systems on Christmas Island”.

The services are expected to be delivered by the end of April 2018, and comprise Stage One of a two-stage project.

The technical review will include testing DIRD’s preferred options for three of the mooring systems (based on 2015 stakeholder consultations), being the:

- Upgrade of the Flying Fish Cove (FFC) Moorings systems to increase capacity and improve safety;
- Reconfiguration of the Smith Point Moorings system to ensure safe fuel bunkering and refuelling, while maintaining the ability to moor smaller cruise ships; and
- Removal of the remaining components of the Nui Nui Mooring system.

GHD had previously provided technical review of the two existing cranes to determine the preferred replacement option for the existing Favco M760D crane at Flying Fish Cove and the proposed removal and off-island disposal of the existing Favco M440D crane, currently located at Nui Nui/Norris Point. The details of the assessment are contained in the GHD report for Patrick Ports, *Flying Fish Cove Crane Replacement – Options Assessment*, December 2015. The User Requirements Brief confirmed the operational requirement for an offshore platform crane with a capacity of 45 t at a reach of 45 m, compared to 34.8 t at 25 m for the existing crane.

1.3 Purpose of the Concept Report

The Concept Report provides a summary of the users’ requirements for the different Work Elements, provides an assessment of options for the crane platform and provides a design basis moving forward into detailed design.

1.4 This Report

This Concept Report (“Report”) has been prepared by GHD Pty Ltd for the Department of Infrastructure and Regional Development (DIRD) for the following;

- may only be used and relied on by DIRD and nominated stakeholders;
- must not be copied to, used by, or relied on by any person other than DIRD without the prior written consent of GHD; and
- may only be used for the purpose of Christmas Island – Crane and Mooring, Replacement and Upgrade (and must not be used for any other purpose).

The cost estimate has been prepared as a basis for comparison between design options to determine a cost effective option and must not be used for any other purpose.

The cost estimate provided is based on the 30% Concept Design. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for the scope of the design identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimate.

1.5 Abbreviations

Abbreviations	Definition
ABF	Australian Border Force
CD	Chart Datum
CIHD	Christmas Island Height Datum
CI	Christmas Island
CIP	Christmas Island Phosphates
DIRD	Department of Infrastructure and Regional Development
FFC	Flying Fish Cove
H_s	Significant wave height
ISLW	Indian Springs Low Water
kg/m^3	kilogram per metre cubed
LAT	lowest astronomical tide
LOA	length overall
m	metre
min.	minimum
mm	millimetre
MPa	megapascal
t	tonne

Abbreviations	Definition
tm	tonne meter
RAN	Royal Australian Navy
SPM	single point mooring
UCL	Undersea Constructions Ltd
URB	user requirements brief

1.6 User Requirements

The following user requirements were recorded during the meetings, interviews and workshops that were held between 02 May 2017 to 06 May 2017 and reported in the Christmas Island Crane and Moorings Replacement User Requirements Brief issued Rev 0 on 28 June 2017 (meeting minutes attached in Appendix A).

1.6.1 FFC Mooring Systems: Rock Berth and Crane Berth

The following are the key requirements as agreed at the Stakeholder Consultation Meeting for the FFC Mooring Systems - Rock Berth:

- Retain six-point configuration system.
- Preferred design vessels:
  - Rock Berth: 200 m design vessel (vessel class more easily available on market, safer and cheaper than existing smaller vessels) for all seasons.
  - Crane Berth: 110 m design vessel (vessel class more easily available on market, safer and cheaper than existing smaller vessels) for all seasons.
- Preferred vessel orientation/position:
  - Crane Berth: Ability to moor vessels with bow facing either north or south, dependent on the vessel crane port or starboard deck positioning.
  - Rock Berth: Min offset to cantilever arm to increase. Currently from ship bow to rock berth cantilever approx. min. 10 m offset.
- Existing wind and wave operational limitations be retained in design of new mooring infrastructure.
- Separate rock and crane berth use of mooring systems to be two completely independent systems (no sharing of mooring infrastructure), which will increase port efficiency and may allow simultaneous mooring at Harbourmaster's discretion.
- Preferred that all new buoys for replacement of existing are the same configuration, i.e. all buoys are peg buoys. This allows for safer operation and ease in maintenance and obtaining spare parts.

1.6.2 Smith Point Mooring System

The following are the key requirements as agreed at the Stakeholder Consultation Meeting for the Smith Point Mooring System:

- Primary consideration in the mooring replacement design to be given to the essential fuel transfer operations.
- Design vessel is the same as existing fuel tanker (150 m LOA).

- Maximise safety during tanker unloading and vessel refuelling.
- Consider reduction in vessel line lengths to less than 220 m to reduce line retrieval time, allowing for safer operation.
- Remove reliance on land based pickups.
- Allow for ship orientation to be same for unloading and refuelling i.e. parallel to shore. This will allow for cruise ships of similar dimensions to the fuel tanker to berth at Smith Point mooring.
- Consider a separate mooring system for larger cruise lines (cruise liners >150 m LOA), which is not part of this scope i.e. a separate single point mooring (SPM) in alternative location to Smith Point. GHD will include a high level SPM review as part of the options consideration.
- Existing wind and wave operational limitations be retained in design of new mooring infrastructure.

Discussions post workshop during the development of the concept report notes the following changes to requirements stated above:

- FFC port – rock and crane berth.
  - Simultaneous moorings is not considered critical for efficient operation of the rock and crane berth. An alternative option to address critical elements of the moorings systems for the port without simultaneous mooring has been provided in Section 3.5.
- Smith Point mooring
  - Based on review of options by the back-up pilot at Christmas Island, non-reliance on land-based pick-ups is no longer a requirement.
  - Vessels are required to have the capability to berth perpendicular and parallel to shore to account for use of fuelling facility all year round.

1.6.3 FFC Crane Replacement

The following are the key requirements as agreed at the Stakeholder Consultation Meeting for the Crane Replacement:

- Marine Crane with 45 t capacity at 45 m reach is acceptable – this will provide flexibility and options for vessel orientation.
- Users confirmed that average 28 t load capacity across the full vessel deck reach is acceptable; this is based on the crane pedestal location not changing from its existing location. It would be unusual to require 45 t carrying load across vessel full deck.
- Options discussed for structural foundation for new crane:
  - Subject to crane reach and load requirement, new crane platform may utilise existing wharf space to minimise seabed-piling works.
    - Users did not prefer this option as existing wharf space and operational area is already limited and would be negatively impacted by crane moving landward.
  - Standalone platform seaward side of the existing crane platform.
    - Comments were made regarding the requirement for accessibility to undertake crane maintenance works.
    - GHD notes that pending platform position and size of crane componentry, crawler crane may be able to support permanent crane maintenance works from shore and that the platform access gangway would suffice.
  - Land reclamation to be a consideration for new structural foundation.

- GHD also will review the minimum footprint required for crane maintenance and existing crawler crane specifications to determine if it can be used to carry new crane componentry loads during maintenance via review of preferred crane specifications.

1.7 User Requirements After Consultation Draft Issue

Stakeholder comments provided after issue of the Concept Design Report Consultation Draft is provided in Appendix B.

The following is a summary of stakeholder key issues with the recommended options in the Consultation Draft, and subsequent discussions with LINX:

- Reliance on land based pickups is considered unduly hazardous and avoided by use of peg buoys. However, the option to use land based pick ups should be made available as back up for buoy failure.
- Berthing of 130 m to 200 m vessels at Rock berth is required.
- Replacement of the C6 drum buoy with a peg buoy to allow for safer vessel mooring to buoy, i.e. personnel hooking vessel mooring lines to buoy.
- Separation of C6 from the R5 to shore pin line to replace existing floating line configuration.

1.8 Document and Drawings Reference

A review of available design drawings, design reports, inspection reports, and construction reports have been considered in the development of this report, refer Appendix C.

1.9 Safety in Design

A Safety in Design (SiD) review has been conducted by GHD in conjunction with preparation of this report. The Risk Register is presented in Appendix D.

2. Proposed Crane Replacement

2.1 Crane

The GHD report, *Flying Fish Cove Port Crane Replacement, Options Assessment*, December 2015 documented the issues considered in selecting the most suitable crane for replacing the existing crane.

The URB confirmed the requirement for an offshore platform crane with a capacity of 45 t at a reach of 45 m, compared to 34.8 t at 25 m for the existing crane.

The proposed arrangement and specification is included in Appendix E.

2.2 Geotechnical Considerations

GHD's review of geotechnical conditions at the site is based predominantly on a previous geotechnical report prepared by GHD for the Commonwealth Department of Transport and Regional Services to support an earlier upgrade of wharfing facilities. The report is entitled *Flying Fish Cove Wharf Upgrade Christmas Island*, and dated September 2002. GHD has also been able to access geotechnical design calculations, and as-built construction records, from the previous wharf upgrade works in various documents dated from 2003 to 2004.

The report documents the results of a geotechnical site investigation, which was based on both land and marine based geotechnical boreholes. The marine boreholes were principally performed to investigate dredging conditions, and were terminated at relatively shallow depths (ranging from 3.2 m to 7.4 m below seabed), which are generally above the toe levels of probable piling requirements for the current project. It is noted that the marine drilling was also performed with some difficulty due to adverse weather conditions affecting the position holding capability of the float work platform. This is likely to have adversely affected the quality of rock core samples retrieved, and resulted in a reduction of the intended scope of drilling. Three land-based boreholes were performed behind the cliff face, in close proximity to the existing crane location, with one borehole inclined seaward so as to emerge from the cliff face, and intersect the seabed in close proximity to the crane pedestal location. This inclined borehole was terminated at 8.6 m penetration below a seabed level of RL-2.0 m CD.

The marine borehole logs indicate the presence of coralline limestone, beneath a variable, but generally superficial coverage of sandy sediment. The limestone is highly variable, with intact strength range typically from very low to medium (measured UCS ranging from 1.3 to 19.0MPa), and containing abundant bioclasts, voids, rock mass defects, and zones of core loss (possibly sand filled voids/ poorly cemented zones). The rock samples were generally recovered as gravel size particles and highly fractured core, however, comments on the borehole logs suggest that core quality appeared to be significantly affected by drilling disturbance.

Logs of land-based boreholes indicate the presence behind the cliff face of about 1 to 3m depth of sandy limestone gravel (possible fill/ reworked colluvium), overlying coralline limestone of predominantly very low to medium strength. Core quality from the land based boreholes was significantly better than from the marine boreholes (probably largely due to reduced drilling disturbance), but appear to indicate a rock strength reduction (typically to very low and locally poorly cemented), with reduced core quality, beneath about RL-7 to RL-10 m CD. For each borehole, the poor rock quality appeared to continue to borehole termination depths ranging in elevation from about RL-10.3 to RL-11.7 m CD.

The geotechnical report also makes reference to the potential for instability in the sea cliff due to the observed undercut, and recommends that the overhang should not be used to support any structural loads, and that allowance should be made to support the overhang where potential failure would pose a risk to adjacent structures.

Pile capacity estimates for bored concrete/ grouted pile types, based on the rock/ grout bond strength have been based on an assumed design rock strength (UCS) of 5 MPa, and a closely to medium spaced rock mass defects. On this basis, the ultimate geotechnical bond strength has been assumed to be 600 kPa for piles and 500 kPa for rock anchors. A geotechnical reduction factor of 0.4 has been adopted for pile design and a design factor of safety of 3 will be adopted for anchors.

It should be noted that GHD does not have access to any relevant geotechnical information specific to Smith Point. However, since the geological conditions there are comparable to those at Flying Fish Cove, it has been assumed that the rock characteristics would be similar. This assumption would need to be verified during construction of rock anchors at Smith Point, which will be required for mooring shore pins.

2.3 Platform options

The new crane imposes a substantially larger overturning moment on its supporting foundation than the existing crane. The expected Ultimate Limit State overturning moment is 5664 tm, together with a vertical load of 405 t. Therefore, options for supporting the new crane have been considered as follows.

2.3.1 Option 1 – Do Nothing

The do nothing option is not a viable option as the existing crane has broken down and the crawler crane does not have the capacity to meet the user requirements as a permanent solution.

2.3.2 Option 2 - Upgrade existing crane platform

This option considers installing the new crane in the same location as the existing.

The existing crane support consists of a thick concrete platform on top of a reinforced concrete column, with backstay arms below the level of the pavement extending to a group of rock anchors.

Owing to the magnitude of the overturning moment of the new crane, the existing column cannot be incorporated into the support system. The new system will require two new piles, seaward of the crane platform, together with a new deck and strengthening of the backstay arms back to the rock anchors. Refer to Figure 1 for the proposed arrangement.

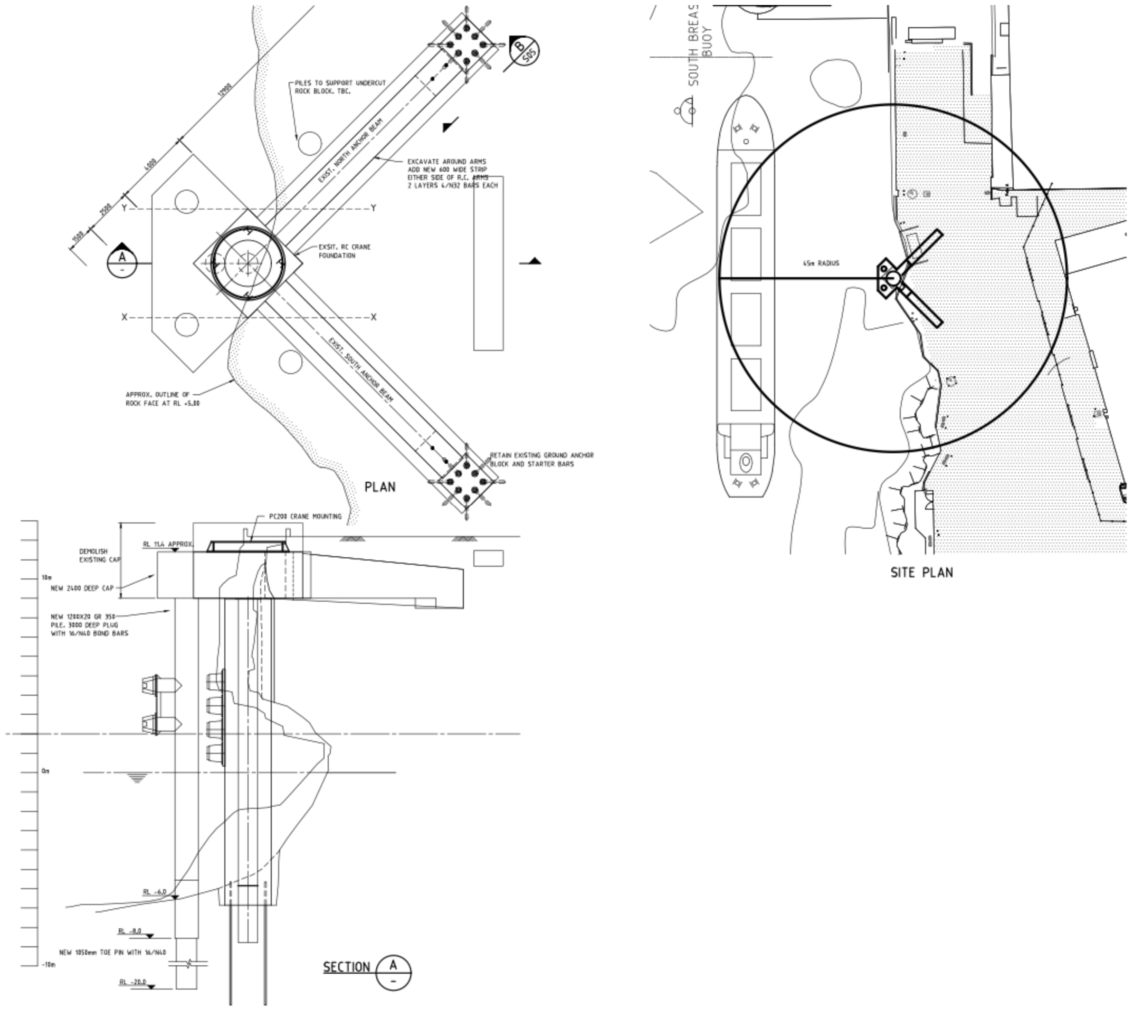

Figure 1: Option 2 – Concept sketch of upgraded platform

Due to the limited geotechnical and site information available, engineering design will be conservative and includes:

- Installation of piles of a 1200 mm diameter steel sleeve, followed by boring of a 1050 mm reinforced concrete pile 12 m into rock.
- Use of bored piles, which are able to develop considerably more shaft resistance within the low strength rock compared to driven piles. Therefore the use of a bored pile solution below seabed, helps to mitigate excessive length that would be likely to be required if a driven pile solution was adopted.

The existing rock anchors at the landward ends of the backstay arms are expected to have sufficient capacity.

The deck soffit has been set to suit the incorporation of the existing backstay arms into the new deck. At this elevation, the soffit will be subjected to significant uplift pressures due to the design waves. The deck is expected to be 2 m thick with 80 kg/m3 of reinforcement.

The backstay arms need to be strengthened to about twice their existing capacity (at the connection with the deck). This can be done by adding additional reinforced concrete width with chemical anchors drilled into the existing beam in order to ensure the new and old act together.

2.3.3 Option 3 – Offshore Platform

Another option for supporting the new crane is to build a new piled platform, offshore from the existing cliff line. This would allow the crane to be moved further south (seaward) and increase the clearance of the ships to the structure supporting the phosphate loader. Refer to Figure 2 for the proposed arrangement.

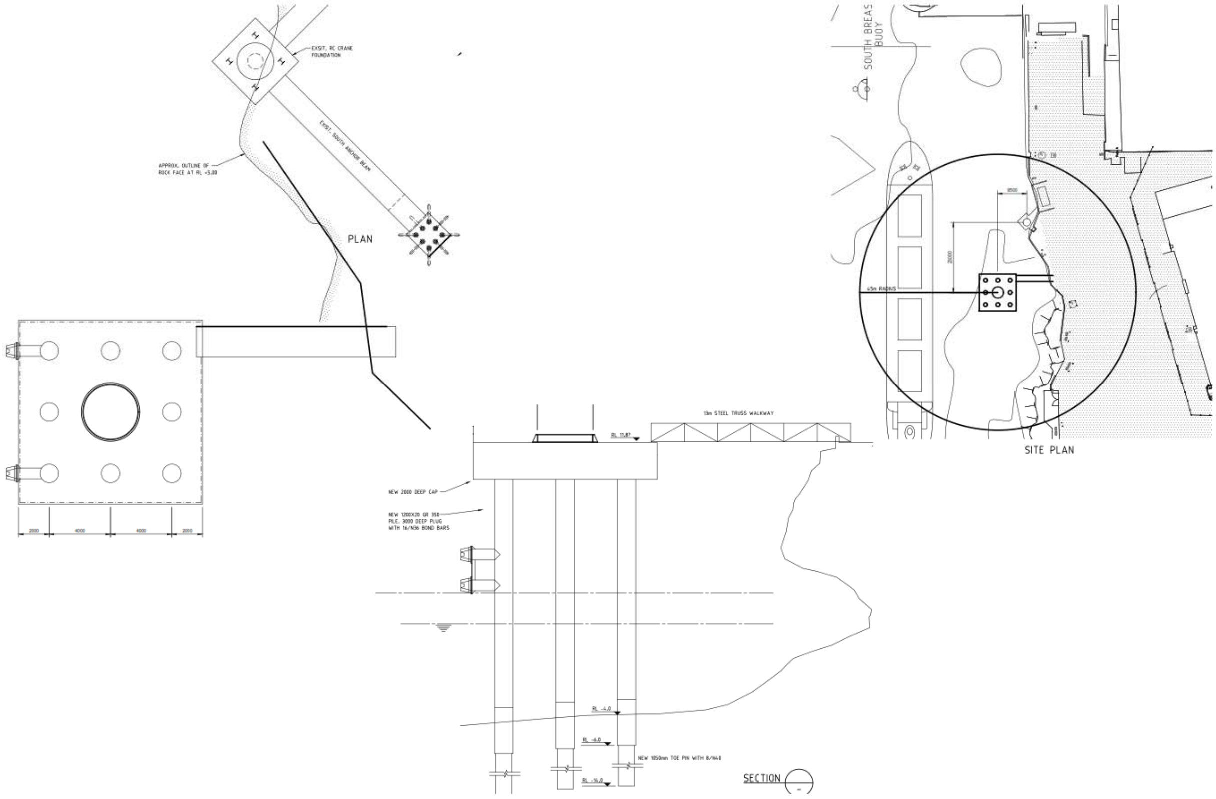

Figure 2: Option 3 – Concept sketch of offshore platform

The proposed piles would be similar to those nominated for the upgrade of the existing crane platform, although they are estimated to require less embedment, extending 8 m into the rock, and would require less reinforcing steel. As noted for in Section 2.3.2 however, there appears to be a risk that rock quality deteriorates beyond about 5 m depth below seabed, which could result in some increase in pile length requirements.

The deck is expected to be 2 m thick with a trussed walkway providing personnel access.

2.3.4 Option 4 – Landward Platform

A further option would see the crane installed ‘onshore’, simplifying the construction requirements. Figure 3 shows the proposed arrangement.

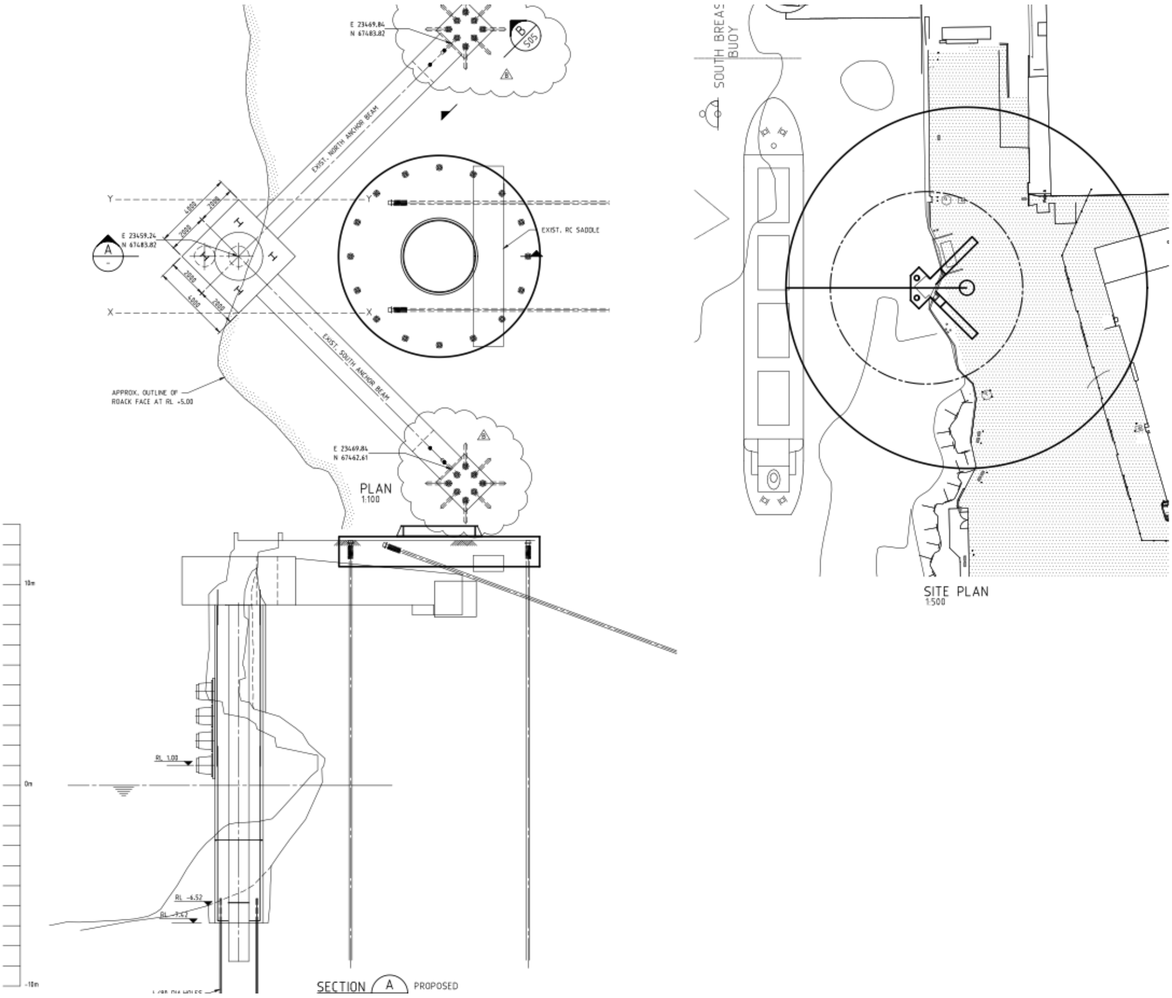

Figure 3: Option 4 – Concept sketch of landward platform

The option would require the installation of 16 rock anchors around the perimeter of the concrete foundation.

The disadvantage of this option is the operational hardstand space that is taken up across the existing wharf space and is considered by the stakeholders to be a fatal flaw. An additional disadvantage is that the outreach is only increased by approximately 5 m instead of 15 m over the existing crane.

3. Proposed Moorings Replacement

3.1 General

The FFC mooring systems consist of an outer mooring system and an inner mooring system, with shared componentry, which services the rock and crane berths.

The design life of the outer mooring system is past its serviceable life, and underwent shackle line repair in 2017.

The URB summarised in Section 1.6.1 for the rock and crane berth has prioritised requirements to allow for berthing of larger vessels and allowance for simultaneous mooring of vessels at each berth.

3.2 Geotechnical Considerations

Please refer to Section 2.2 for geotechnical considerations for the proposed mooring systems.

3.3 Option 1 – Do Nothing

The do nothing option for the Flying Fish Cove existing mooring system is not a viable option on the following basis:

- Significant risk and likely adverse effect on wharf operations in the reuse of existing mooring components that are beyond their design life and have not been inspected to account for current condition.
- Current configuration does not meet users' requirements in vessels sizes as deemed required by users.

3.4 Option 2 - Simultaneous Mooring Configuration

3.4.1 Rock Berth

The URB indicated a preference to increase the moorings capacity to accommodate a 200 m vessel, maintaining the existing environmental limitations. This represents an approximate increase in mooring force of 40% over the existing system.

For the primary, landward loads, the existing system consists of two breasting buoys with a single catenary anchor leg each. The buoys are restrained in position by spans to shore pins and an interconnector between the buoys. Owing to the steepness of the sea-bed, a similar system is proposed for the upgraded moorings at the rock berth. However, it is proposed to move the forward mooring buoy to be in a similar depth of water as the stern breasting buoy. The proposed six-point arrangement is shown in Figure 4 with the vessel positioned centrally to the existing cantilevers and approximately 30 m off the cantilever structure.

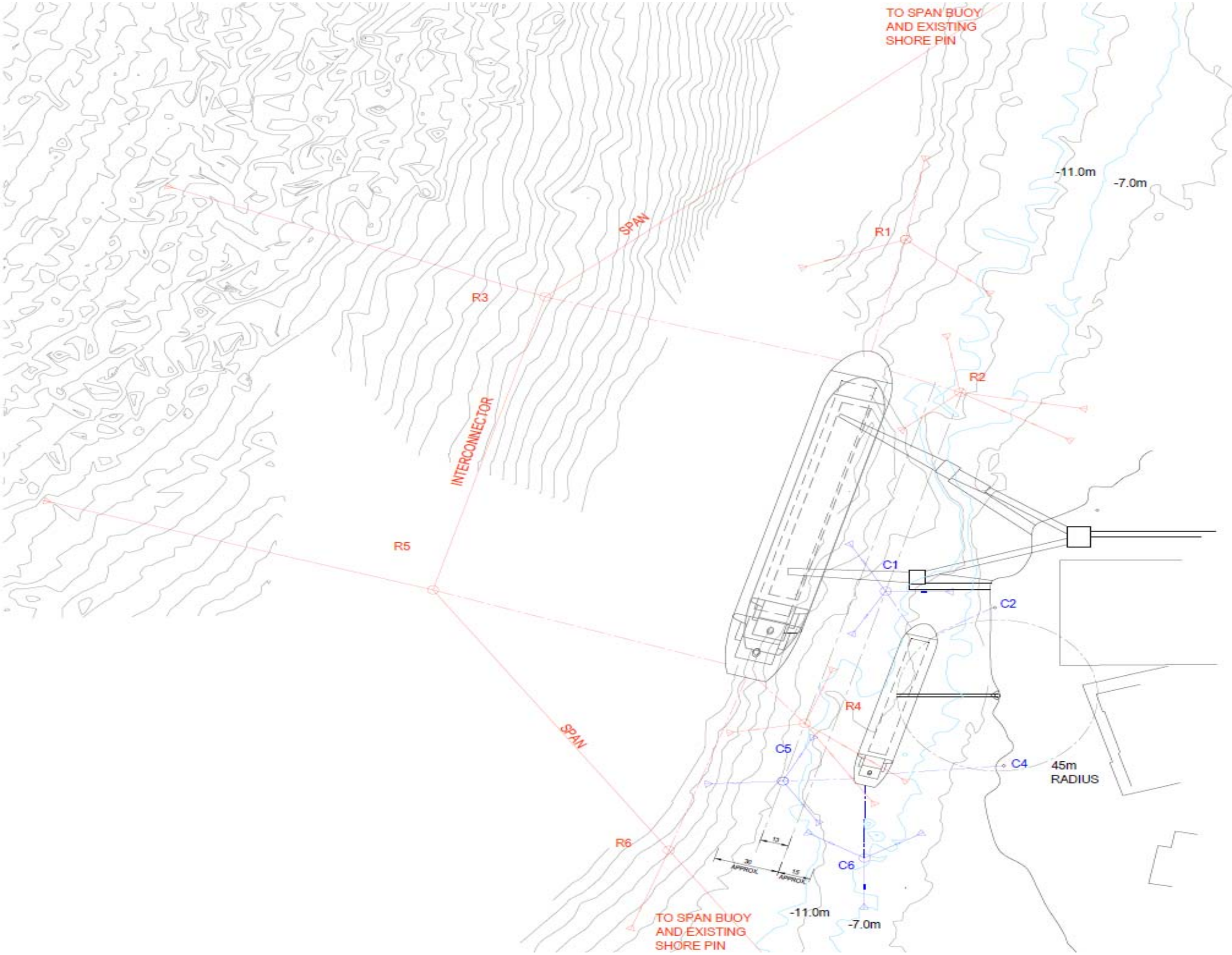

Figure 4: Option 2 – Rock and crane berth proposed mooring concept design

Mooring forces on the vessel have been estimated using Optimoor, based on the library of standard drag coefficients for a bulk vessel. The line loads were first estimated using a generic catenary anchorage, and then updated by using a model of the actual moorings and applying the vessel loads at midship).

The outer moorings (R3 & R5) have been designed to be similar to the existing “B” mooring, as described in the ‘A&B’ Vertical Exchange Report by UCL. This indicated that these anchors have some holding power beyond just friction on the seabed, with a capacity that is in the order of 22.5 t and suitable for the new moorings.

The inner moorings (R1, R2, R4 & R6) are designed with anchorage weights that rely only on seabed friction. This is heavily influenced by whether the load direction is up, or down the slope. The inner breasting buoys (R2 & R4) are expected to require a load capacity of 21 t whereas the head and stern buoys (R1 & R6) will require a nine tonne capacity.

The R4 mooring is positioned further aft of perpendicular to the vessel, in order to provide space for crane berth bound vessel to move southward into the crane berth.

The alternative anchorages considered for R2, included:

- Single lumped mass with “reef pin”. In order for this to be suitable, it would need to be positioned in about 2.5 m of water on a near-horizontal section of seabed. However, in this location, the block would then be subject to large forces during extreme wave events. These forces could be up to five times the load required by the restraint of a moored ship and therefore this option was discarded.
- Chain to the existing shore pin north of the northern cantilever. This would be similar to the current arrangement; however, the loading would be higher. The details of the existing shore pin are unknown, and therefore this option would require the installation of a new shore pin. It is also noted that this location is not easily accessible for equipment.

The anticipated movements of the 200 m vessel under beam on winds are (based on approx. three tonne pretension by ship’s winches):

- 8.3 m for 15 knot wind + 0.5 knot current.
- 19.4 m for 25 knot wind + 0.5 knot current.
- 20.6 m for 25 knot wind + 0.5 knot current + wave drift force (Hs=0.5 m).

3.4.2 Crane Berth

The proposed moorings for the crane berth are shown in Figure 4. Separate buoys to the rock berth moorings are used to allow for mooring at the crane berth at the same time as at the rock berth (at the Harbourmaster’s discretion).

The inclusion of a 45 m reach for the replacement crane, allows the vessel to be positioned further seaward and further south than the current arrangement, with the vessel approximately 20 m from the cantilever structure. Two mooring points are then used to the north (rather than existing three points), so that a buoy (C1) can be positioned just south of the cantilever structure. The existing shore pins (and cliff chains, C2 & C4) may be replaced for the inner moorings, since there is insufficient space to install suitable buoys.

C5 is positioned further south than perpendicular to the vessel, to provide space for a restraining leg toward R4. The same restraining anchor as for R4 may be able to be used for this; however, this would then affect the ability to re-lay the anchorage in the future. The use of an interconnector between the R4 and C5 buoys will be investigated further during detailed design.

The anticipated horizontal loads for a 110 m vessel are 8 t for the outer breast buoys, 7 t for the inner breasting lines and 2.5 t for the stern/head buoy. The movement of the ship after pre-tensioning is expected to be less than 2 m.

3.5 Alternate FFC Mooring Options

Based on the change in users requirements (refer Section 1.6.1), i.e. the non-critical requirement to have vessels simultaneously berthed at rock and crane berth, these options considers modifications to the existing moorings, to accommodate the larger vessels.

3.5.1 Option 3 – Shared Mooring Configuration - Adaptive re-use of existing mooring components

This concept option has minimal additional new mooring componentry to the rock and crane except for the following items (refer Figure 5):

- Two new shore pins.
- Replacement of existing line grab with new buoy (C1) for crane berth.
- New dumpers at head and stern buoy.

This mooring configuration allows for berthing of 200 m vessel at rock berth and a 110 m vessel at crane berth. This option will require capacity checks of Buoy A and B to determine if the new additional loads by the larger vessels can be accommodated.

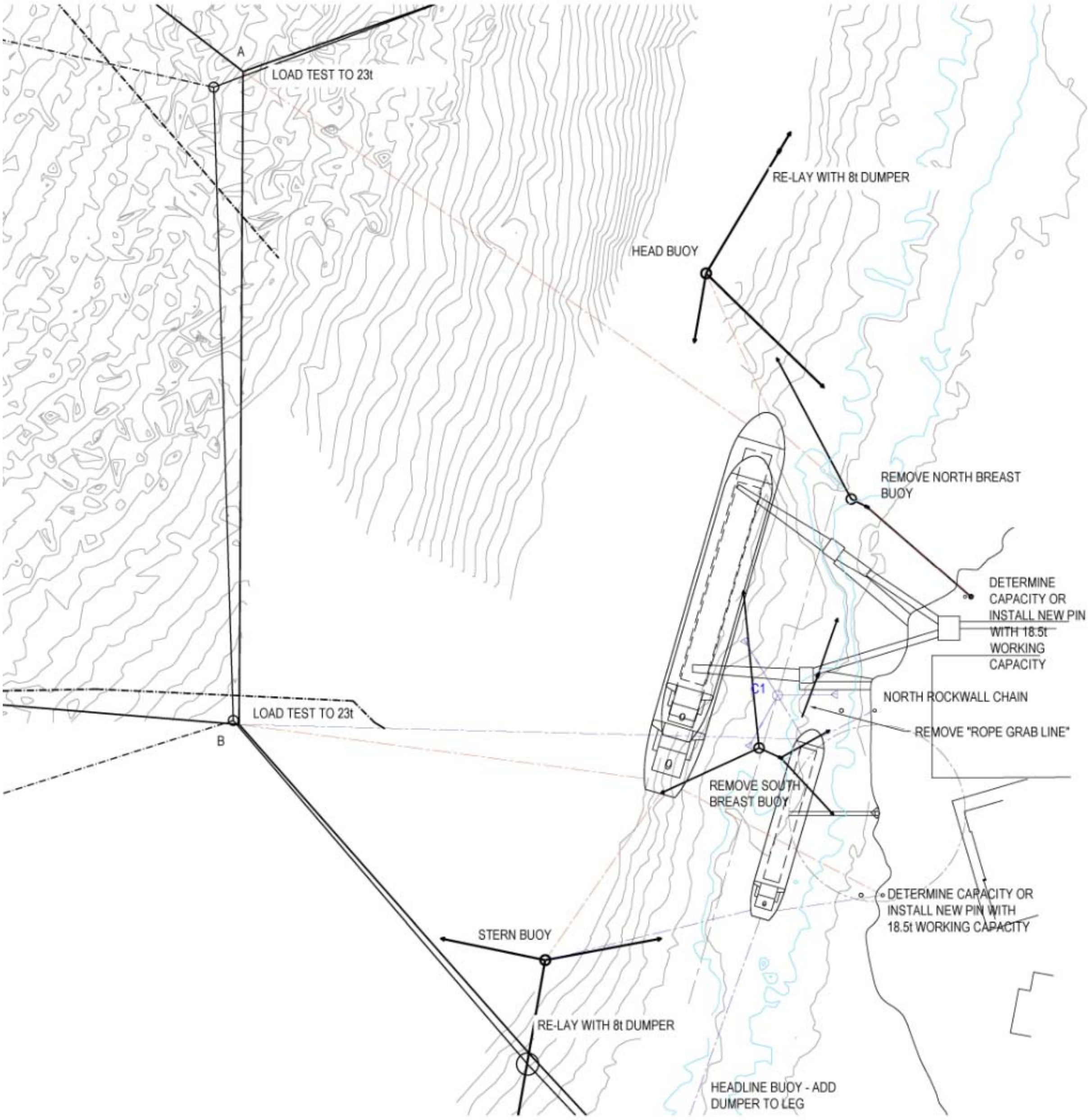

Figure 5: Option 3 - Alternate proposed mooring concept design #1 for rock and crane berth; with shared mooring elements utilising existing components

3.5.2 Option 4a – Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse

This concept option considers replacement of mooring componentry to the rock and crane berth as detailed below (refer Figure 6):

- Replacement of Buoy A and B (R5 and R3) including relocation of Buoy A further inland.
- Five new shore pins (shore pins to R5 and R3, C2, C4 and C7).
- Replacement of existing line grab with new buoy (C1) for crane berth.
- New dumpers at head and stern buoy.

This mooring configuration also allows for berthing of 200 m vessel at rock berth and a 110 m vessel at crane berth.

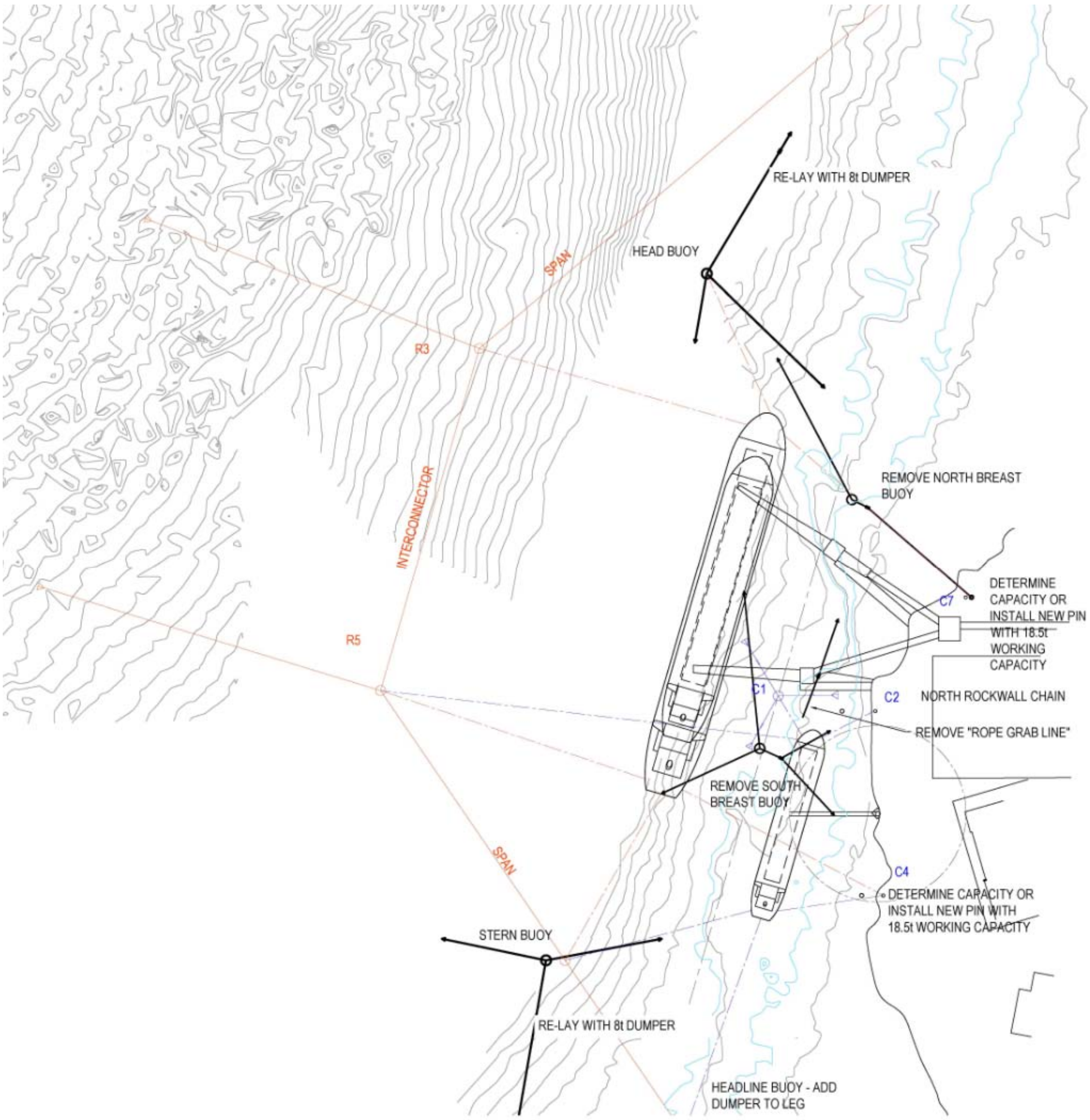

Figure 6: Option 4a - Mooring concept design for rock and crane berth; with shared mooring elements utilising new outer mooring and existing mooring components.

3.5.3 Option 4b – Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse

This concept option is a revision of Option 4a which considers removal of reliance on land based pick ups and componentry at Rock berth to allowing mooring of 130 m to 200 m vessels with the following items (refer Figure 7):

- Replacement of Buoy A and B (R5 and R3) including relocation of Buoy A further inland.
- Three new shore pins (shore pins to R5 and R3 and C7).
- Replacement of existing line grab with new buoy (C1) for crane berth.
- Addition of new buoy R2 to pick up land based shore pin C4 for 200 m vessels
- New head and stern buoys with additional weights, i.e. new dumpers at head and stern buoys.

This mooring configuration also allows for berthing of 130 - 200 m vessel at rock berth and a 110 m vessel at crane berth.

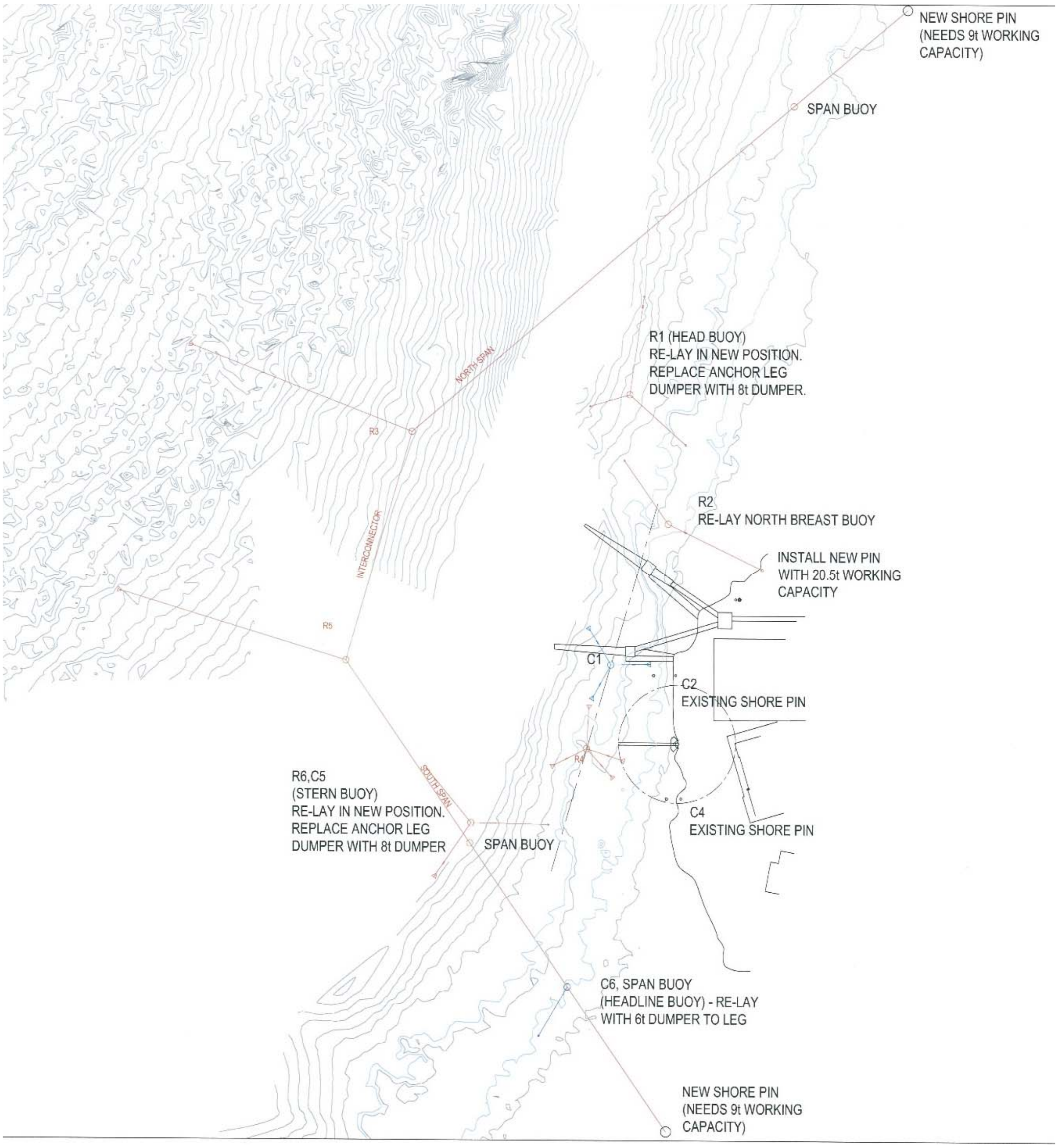

Figure 7: Option 4b - Revised Option based on Option 4a of proposed mooring concept design rock and crane berth; with shared mooring elements utilising new outer mooring and existing mooring components

3.6 Smith Point Mooring

3.6.1 Option 1 –Do Nothing

The do nothing option for the Smith Point existing mooring system is not a viable option on the basis that the existing mooring system is inherently unsafe for debunkering of fuel and refuelling and safe use of the mooring system is limited by seasonal swell throughout the year.

3.6.2 Option 2 – Parallel berthing

Primarily a six-point mooring is provided for parallel mooring of the 150 m cruise ship and 150 m tanker, as per Figure 8 to meet the users requirements identified in Section 1.6.2.

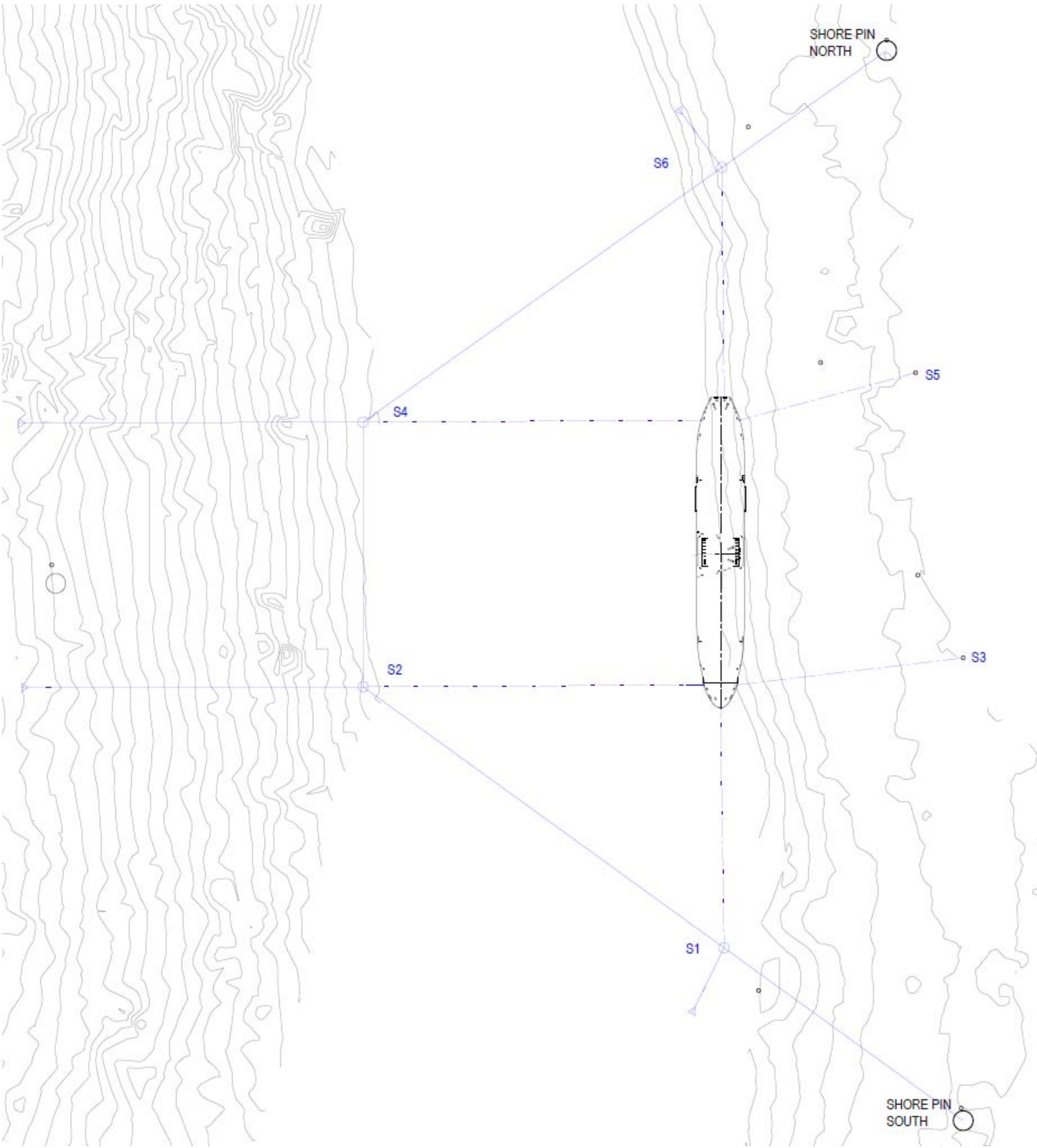

Figure 8: Option 2 - Smith Point proposed mooring system for parallel berthing

3.6.3 Option 3 – Parallel and perpendicular berthing

Additional reviews with stakeholders (refer 1.6.2) has identified that some flexibility is required at the Smith Point mooring, to allow for parallel and perpendicular mooring to account for safe fuel bunkering and vessel refuelling for all seasons. Figure 9 sets out a six-point mooring provided for parallel mooring of the 150 m cruise ship and 150 m tanker and a perpendicular mooring of the 150 m tanker; this mooring configuration is similar to that in Figure 8 with the addition of anchors at S4 and S2.

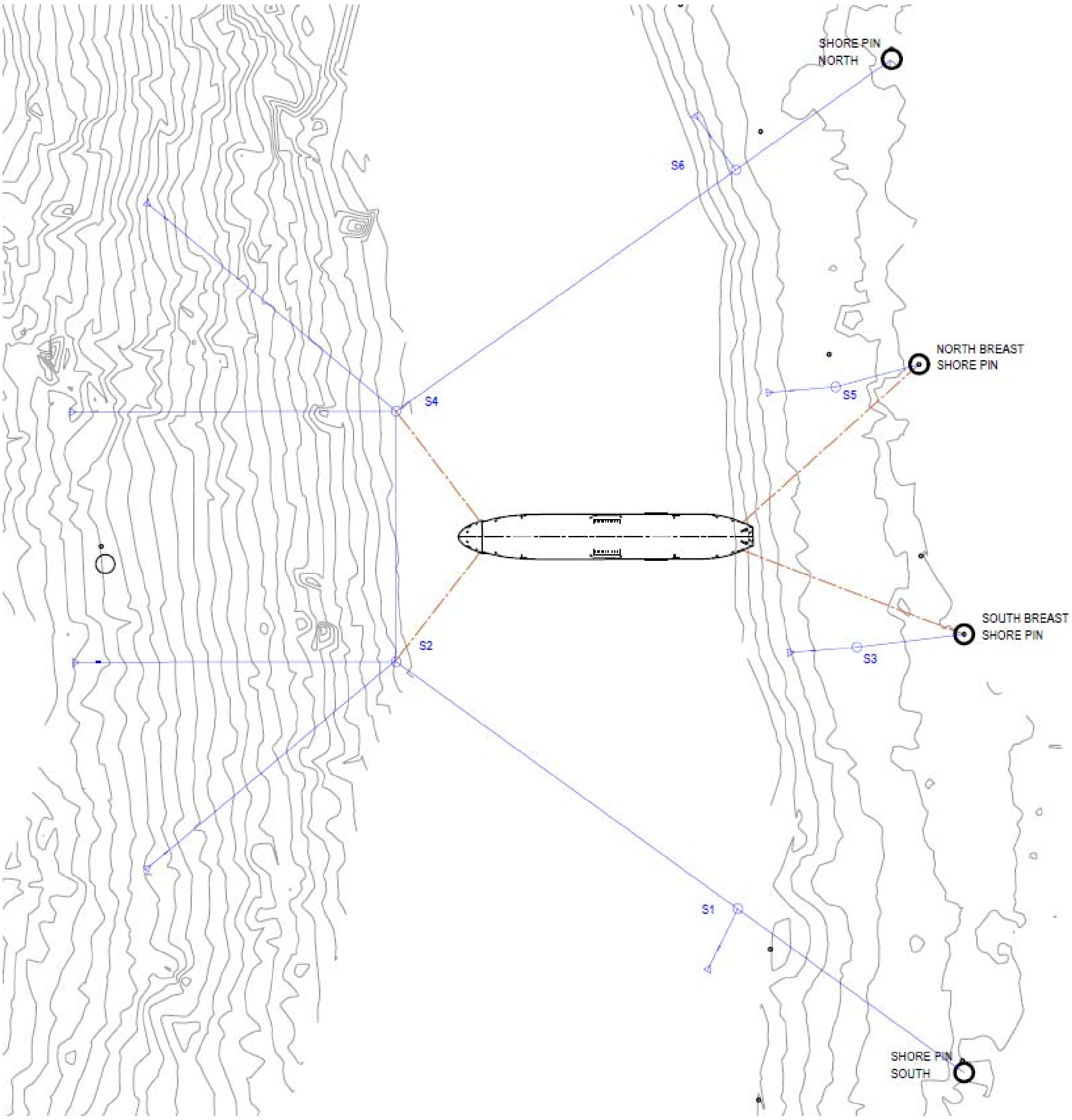

Figure 9: Option 3 - Smith Point proposed mooring system for parallel and perpendicular berthing

The outer breasting mooring lines for the six-point configuration are in the order of 160 m with an expected maximum load of 12 t.

Shore pins are shown in their existing location, but are subject to capacity verification or replacement. The required load is expected to be 10 t.

Based on stakeholder reviews (refer Section 1.7), two additional buoys (S5 and S3) were added to support the north and south breast shore pins and remove reliance on land based pickups.

3.7 Cruise Ship SPM

A single point mooring (SPM) for a 217 m cruise ship would be expected to be similar to the existing outer buoy at Smith Point. However, this cannot be located at Smith Point with the proposed mooring system in Section 3.5. Spans to shore pins in a new location would be required due to the steepness of the seabed, which limits the loads that can be carried in a direction away from the shore.

4. Cost Estimate

4.1 Cost Estimate of GHD Design

The cost estimate (Rev 0 report) based on the current design drawings has been developed by GHD's subconsultant, quantity surveyor, Ralph Beattie Bosworth (RBB).

A summary of the cost estimate is included in Table 2.

Table 2: Summary of options and associated costs

Options	Description	Cost ($)	Design Contingency (7.5%)	Construction Contingency (10%)	Consultant Fees and Disbursements	Escalation to Commencement (1%)	**TOTAL**
Crane Platform Option 1	Do Nothing						
Crane Platform Option 2	Upgrade existing platform	$8,830,000	$662,000	$949,000	$1,520,000	$120,000	$12,081,000
Crane Platform Option 3	Offshore platform	$8,759,000	$657,000	$942,000	$1,508,000	$119,000	$11.985,000
FFC Moorings Option 1	Do Nothing						
FFC Moorings Option 2	Separate new mooring systems for rock and crane berth (including installation of 4 new shore pins)	$8,503,000	$638,000	$914,000	$1,464,000	$115,000	$11,634,000
FFC Moorings Option 3	Adaptive re-use of existing mooring components with 1 new buoy	$1,542,000	$116,000	$166,000	$266,000	$21,000	$2,111,000
FFC Moorings Option 4a	Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse; additional 3 buoys and 5 new shore pins	$2,782,000	$209,000	$299,000	$479,000	$38,000	$3,807,000
FFC Moorings Option 4b	Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse; additional 6 new buoys and 3 new shore pins	$4,585,000	$344,000	$493,000	$790,000	$62,000	$6,274,000
Smith Point Moorings Option 1	Do Nothing						

Options	Description	Cost ($)	Design Contingency (7.5%)	Construction Contingency (10%)	Consultant Fees and Disbursements	Escalation to Commencement (1%)	**TOTAL**
Smith Point Moorings Option 2	New mooring system for vessel berth parallel to shore	$2,781,000	$209,000	$299,000	$479,000	$38,000	$3,086,000
Smith Point Moorings Option 3	New mooring system for vessel berth parallel and perpendicular to shore	$4,120,000	$309,000	$443,000	$710,000	$56,000	$5,638,000
Decommissioning Crane and Moorings at Nui Nui	Decommissioning and removal of crane and moorings, if required.	$275,000	$21,000	$30,000	$47,000	$4,000	$377,000
Single Point Mooring for 217 m cruise ship	New single point mooring system for 217 m cruise vessel at new location CI	$2,092,000	$157,000	$225,000	$360,000	$28,000	$2,862,000

The following assumptions and qualifications are applicable to the above estimate:

- The estimate is based on the current design information.
- The estimate assumes the works will be carried out from a specialised barge and support vessels mobilised from Australia. Should acceptable equipment be available from Singapore, Indonesia or Malaysia, reduced mobilisation costs may be realised.
- The estimate assumes that any offsite fabrication works will be undertaken in Perth, Australia.
- The estimate assumes a tender award date of 1 August 2018.
- The estimate assumes that service connections are available at the existing wharf without the need for onshore infrastructure upgrades.
- The estimate assumes an allowance of 20 days stand down time for the piling equipment due to inclement conditions (weather, swell, etc.) or 20% of the anticipated piling programme.
- The cost estimate does not include any costs to relocate existing buoys (if required) as the specific cost is not known, however the quantum can be covered within the design contingency allowed for in the cost estimate.

4.2 Order of Accuracy

RBB has provided the highest level of accuracy possible based on the design information above. In doing so, RBB have addressed the following.

- Assessment of Costs.
- Quantification/ preparation of Material Take Offs where possible for elements of the scope of work.
- Application of unit rates and prices.
- Application of the regional cost loading applicable to Christmas Island region.
- Assessment of levels of confidence associated with the current documentation and level of cost confidence requirements and application of appropriate contingencies.
- Incorporation of professional fees associated with project management, design of all necessary disciplines, administration & inspections and relevant disbursements for the full duration of the project.
- Assessment of escalation costs to tender target date.

4.3 Level of Confidence

The estimate is prepared on the basis of determining the likely tender outcome for the documented works in the current market conditions.

Given the nature of the work, stage of document development, project location and risk associated with possible alternative methodologies for the piling works, it must be considered that the results obtained from the market will likely have considerable variance with a tender range of 50% difference between the lowest and highest tenders not unexpected.

In relation to the piling works, due to the site remoteness, and the time and cost associated with mobilising for geotechnical investigation works, no additional geotechnical information is expected to be obtained for the detailed design. The design will proceed on the basis that parameters will be confirmed during the early phases of construction, and that design adjustment (e.g. pile length requirements) will be made if and as required. Since it is preferable to avoid late design amendments if possible, a conservative approach will be taken during detailed design, based on interpretation of existing geotechnical information, which is generally deficient in coverage and depth, compared to what would typically be available for design support.

A design contingency of 7.5% has been added to mitigate risk associated with the level of design completion.

Application of a P80 assessment would further clarify the cost confidence and allow further refinement of project contingencies.

5. Options Assessment

5.1 General

In consideration of the concept options described in Section 2.3 and 3, a review of the crane options platform is undertake separately to the mooring options.

5.2 Options

5.2.1 Crane

The GHD report Flying Fish Cove Port Crane Replacement, Options Assessment, December 2015 documented the issues considered in selecting the most suitable crane for replacing the existing crane.

Based on the user requirements brief and details summarised in Section 1.6, the recommended option remains as is, with no further assessment required.

5.2.2 Crane Platform

The options for the crane platform are detailed below:

- Option 1 – Do nothing.
- Option 2 – Upgrade existing platform at current location. The new platform includes a thick concrete platform on top of a reinforced concrete column with two new piles, seaward of the crane platform, with backstay arms below the level of the pavement extending to a group of rock anchors, and
- Option 3 – Offshore platform: A new piled platform, offshore from the existing cliff line with 8 piles and the deck approximately 2 m thick with a trussed walkway providing personnel access.
- Option 4 – Landward platform: the crane installed across the existing wharf space and includes the installation of 16 rock anchors around the perimeter of a concrete foundation.

5.2.3 FFC Mooring Options

The options for the FFC moorings are detailed below:

- Option 1 – Do nothing
- Option 2 – Separate mooring systems for rock and crane berth
  - Six point mooring at rock berth
  - Five point mooring at crane berth
  - Generally new mooring elements to be installed with use of existing where practicable
  - Replace existing shore pins
- Option 3 – Utilises existing mooring components at crane and rock berth
  - Shared mooring components between rock and crane berth
  - Load testing of mooring elements required
  - Replacement of existing line grab with new buoy for crane berth
  - New dumpers for head and stern buoy

- Replace two existing shore pins

- Option 4 – Utilises existing and new componentry at rock and crane berth
  - Shared mooring components between rock and crane berth
  - New mooring components for outer mooring system
  - Replacement of existing line grab with new buoy for crane berth
  - New dumpers for head and stern buoy
  - Replace existing shore pins, i.e. allowance for five new shore pins

5.2.4 Smith Point Mooring Options

The options for the Smith Point mooring system are detailed below:

- Option 1 – Do nothing
- Option 2 – Six point mooring system
  - Replace existing shore pins with new
  - Only provides for parallel berthing
- Option 3 – Six point mooring system
  - Replace existing shore pins with new
  - Provides for parallel and perpendicular berthing (four point mooring system)

5.2.5 Nothing

5.3 Assessment Criteria

In the qualitative assessment of options, the following categories are key factors in the evaluation and selection of the recommended option(s). Each of these categories has secondary or contributing influence:

Category	Criteria	Description
Costs	CAPEX	Crane related: marine based construction vs land based construction Mooring related: asset testing to confirm reliance vs new elements
	OPEX	Effect on operational costs due to maintaining new assets vs existing
Operation	Operational safety	Effect on operations due to new works
	Operational efficiency	Increase efficiency of port operations
Environment	Effect on existing environment	Impact on environment based on option design footprint

Category	Criteria	Description
Stakeholders	Achieving users' requirements	Ability of the crane and mooring replacement options to meet identified user requirements The main stakeholders include LINX, ABF, RAN, CIP and the local community. Some options will not meet all user's requirements pending budget and construction constraints.
Constructability	Effect on operations	Impact on existing wharf operations during construction
	Design Uncertainty	Design development has required use of assumptions based on limited background information – this will increase design uncertainty of the options including understanding current capacity of elements to accommodate new loads with possible increase in cost estimate of total works.
	Ease of construction	Construction complexity due to unknown existing conditions including impact with construction schedule

5.4 Assumptions

The following assumptions are applicable for all options detailed in this section:

- That construction works will not be delayed or interrupted by wharf operations.
- That protective measures for components are maintained for the life of the asset.

5.5 Assessment Method

In the absence of a weighted quantitative assessment for each of the categories outlined above, GHD has qualitatively assigned a rating to each factor as set out in this Section 5.2.5.

Each of the assessment criteria listed uses a different measure of rating in evaluating the upgrade options. The qualitative rating scale utilized assesses each criteria on a high, medium or low basis and is applied and discussed for each option in detail below.

These options with associated ratings are summarised in the sections below.

5.5.1 CAPEX and OPEX Estimates

Based on review of previous reports on the replacement of crane and mooring systems, a summary of capital cost budget estimates is detailed below. RBB has provided independent capital cost estimates (refer Section 4) and a comparison between the two are provided in Table 4, Table 5 and Table 6:

Report	Description	Reported budget
The Department, Christmas Island Moorings Replacement Options Paper, Dec 2016	Works to replace outer mooring system	$3,335,000

Report	Description	Reported budget
The Department, Christmas Island Moorings Replacement Options Paper, Dec 2016	Potential works for inner mooring system due to new crane	$1,500,000
The Department, Christmas Island Moorings Replacement Options Paper, Dec 2016	Works for Smith Point mooring to allow for safer fuel bunkering and vessel refuelling	$2,625,000
GHD, Flying Fish Cove Crane Replacement – Options Assessment Report, Dec 2015	Replace crane and develop new platform	$8,780,000
TOTAL		$16,240,000.00

Cost estimates are discussed in more detail in Section 4, however for this exercise the cost estimate as reported in Section 4 are comparatively reviewed with budget estimates listed above with associated ranking scale, **L** = under budget, **M** = at budget, **H** = over budget for capital expenditure consideration.

Operational expenditure is ranked based on potential maintenance required for the elements, with **L** = minimal maintenance to achieve design life, **M** = some maintenance required, and **H** = major maintenance required prior to achieving design life.

5.5.2 Operation

Operational Safety

The options are assessed to determine if there are any new safety issues that are introduced with the new design to normal (existing) wharf and vessels mooring at FFC port. This category will be assessed based on the following classification: L – no new safety issues with new design, M – some changes to normal operations will be required with new design, H – significant changes to port operations with new design.

Operational Efficiency

The options are assessed to determine if wharf operations efficiency is increased with works. This category will be assessed based on the following classification: **L** – increase in operational efficiency/productivity, **M** – some increase in normal operation efficiency, **H** – no change to operational efficiency with new works.

5.5.3 Environment

Options are assessed to determine environmental impact works will have on Christmas Island, taking into account reuse of existing disturbed area and any new area disturbance. This category will be assessed based on the following classification: **L** – minimal impact or extent of seabed area affected, **M** – some increased disturbance in seabed area affected with minor disturbed sedimentation and/or noise pollution, **H** – significant change to seabed area including disturbed sedimentation and noise pollution during piling.

5.5.4 Meeting Users Requirements

The concept options developed were to achieve to meet users requirements detailed in Section 1.6.

Some of the options outlined in Section 5.2 carry a probability of not meeting users' requirements. This category will be assessed based on the following risks: **L** – meets all users requirements, **M** –meets most of the users requirements, **H** –meets least of the users requirements.

5.5.5 Constructability

Design Uncertainty

There is a probability when a product or system may require testing or further scoping to confirm assumptions on site. In addition, there is also the risk that the design cannot be constructed as anticipated. These factors will need to be considered when classifying an option as: **L** – lowest uncertainty, **M** – medium level uncertainty and **H** –high-level uncertainty.

Ease of Construction

The complexity of the construction process is likely to include access to site, relative ease of setting up site, construction method and especially complexity in construction that may arise when adjoining new to existing structure to ensure they act compositely. These risks are classified as: **L** – straightforward construction, **M** – moderately difficult construction and **H** – difficult construction.

Effect on Operations (during construction)

Pending the ease of construction for the options, there is a risk on adversely affecting wharf operations, i.e. restrictions of vessels berthing for a period for loading and unloading of cargo at crane berth.

These factors will be taken into consideration in the assessment with the following classification: **L** – minimal impact to wharf operations < 1 month, **M** – some impact to wharf operations, <3 months, **H** – significant impact to wharf operations, >6 months.

5.6 Recommendation

Based on the above assessment criteria and rating scale a qualitative comparative analysis of the options has been made and the following recommendations are suggested.

5.6.1 Crane Platform

Based on the options assessment outlined in Table 4, the recommended option is Option 2, due to significant increased risks in Option 3 including maintenance issues identified in an offshore platform, larger environmental footprint/impact as well as constructability risks in the increased number of piles to be installed.

5.6.2 FFC Moorings

Based on the options assessment outlined in Table 5, the recommended option is Option 4b, based on this design being most aligned with stakeholder requirements, including safer mooring operations in replacing all drum buoys with peg buoys, which will also support streamlining maintenance works to one type of buoy.

5.6.3 Smith Point Moorings

Based on the options assessment outlined in Table 6, the recommended option is Option 3 based on this design being most aligned with stakeholder requirements, including operational safety and use of the fuel facility all year.

5.6.4 Recommended Options Cost

The table provides a summary of the recommended options with associated costs:

Table 3: Summary of recommended options and cost estimates

Component	Crane Option 2	FFC Moorings Option 4b	Smith Pt Moorings Option 3	Nui Nui Decommissioning	Total Cost
Construction	$ 8,830,000	$4,585,000	$4,120,000	$275,000	
Design Contingency (7.5%) **	$662,000	$344,000	$309,000	$21,000	
Construction Contingency (10%) **	$949,000	$493,000	$443,000	$30,000	
Project Management and Engineering Costs	$1,520,000	$790,000	$710,000	$47,000	
Escalation to Commencement	$120,000	$62,000	$56,000	$4,000	
TOTAL	**$12,081,000**	**$6,274,000**	**$5,638,000**	**$377,000**	**$24,370,000**

** Note: These percentages are consistent with Industry Standards for an estimate with this level of risk profile.

5.6.1 SPM for cruise vessels

GHD has provided cost estimate for a concept SPM for a 217 m vessel. However, this is considered to be outside of the approved project scope and is therefore not recommended.

Table 4: Option Assessment for Crane Platform

Option	Option 1	Option 2		Option 3		Option 4
Description	**Do nothing**	**Upgrade existing platform at current location**		**Offshore platform at new location**		**New landward platform:**
Assessment Criteria		**Description**	**Ranking**	**Description**	**Ranking**	
CAPEX	This is not a viable option as the existing crane has broken down and the crawler crane does not have the capacity to meet the user requirements as a permanent solution	Estimated $8.8M vs RBB $12.1M	H	Estimated $8.8M vs RBB $12.0M	H	Not a viable option due to new crane location taking up existing wharf working space which will significantly affect wharf operations safety and productivity. The flow on consequences are decreased useability of the port with significant impact on wharf operations during construction
Operational expenditure		Some maintenance will be required to piles, pending method of protection	M	Significantly more piles and introduction of access walkway will require increased maintenance	H	
Operation safety		No new safety issues as crane has not changed in location	L	New location of crane allows for safer vessel berthing	L	
Operation efficiency		Increase in port operation efficiency with new crane with greater load capacity and reach of crane	L	Increase in port operation efficiency with new crane with greater load capacity and reach of crane	L	
Environment		Addition of 4 piles to existing crane platform footprint, with 2 in seabed and concrete infill below cliff undercut. Environmental management will require assessment of potential noise impacts and any exclusion zones around the works	M	New area for crane platform and increased footprint impact on seabed	H	
Meeting users' requirements		Crane and crane platform at existing location will meet users requirement (45 tonne @ 45 m reach)	L	Crane and crane platform at existing location will meet users requirement (45 tonne @ 45 m reach)	L	
Design uncertainty		Less uncertainty than option 3 with 2 piles in seabed. Geotechnical investigation into rock will be required to confirm design for piles and anchor arms	M	Geotechnical investigation into rock and seabed area will be required to confirm design for piles and anchor arms	H	
Ease of construction		Proposed new platform is extension of existing, although modification to arms may be required and 2 piles into seabed	M	Increased piling in marine environment more complex than Option 2. Pending geotechnical investigation in seabed to confirm piling method, based on previous experience piling works at Christmas Island can be problematic	H	
Construction effect on wharf operations		During crane platform works, use of crane berth and adjacent wharf area will be limited, approx. 6 months	M	Offshore crane platform construction works will take greater than 6 months	H	

Table 5: Options Assessment for Flying Fish Cove Moorings

Option	Option 1		Option 2		Option 3		Option 4a		Option 4b	
Description	**Do nothing**		**Simultaneous Mooring Configuration**		**Shared Mooring Configuration - Adaptive re-use of existing mooring components**		**Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse**		**Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse**	
Assessment Criteria	**Description**	**Ranking**	**Description**	**Ranking**	**Description**	**Ranking**	**Description**	**Ranking**	**Decription**	**Ranking**
CAPEX	N/A		Estimated $4.8M vs RBB $11.6M	H	Estimated $4.8M vs RBB $2.1M	L	Estimated $4.8M vs RBB $3.8M	M	Estimated $4.8M vs RBB $6.3M	M
Operational expenditure	Significant costs due to mooring elements are past design life	H	New elements introduced, less maintenance required than existing. Design life of new elements is greater than existing elements Outer mooring buoys are brought inland (out of deep-water) making maintenance of these elements easier.	L	Mixed use of mostly existing and with minor new mooring elements will require maintenance to meet certain design life. Also note that existing outer moorings are in deep water which has increased maintenance costs	H	Replacement of outer mooring components only. Retain existing inner mooring components Outer mooring buoys are brought inland (out of deep-water) making maintenance of these elements easier.	M	Replacement of outer mooring and new shore pins. Replacement of some inner mooring components. Outer mooring buoys are brought inland (out of deep-water) making maintenance of these elements easier.	L
Operation safety	Reuse of existing without inspection and maintenance may adversely impact safe operation of wharf	H	Vessels berthed simultaneously at crane and rock berth introduces additional safety issues. This design will require review of existing port operations and changes required to accommodate change in port use	M	No change to port operations management as no change to design that introduces new capability, except for vessel size. Noted that majority of existing components are not replaced – potential safety issue with use of components that are beyond design life and current condition not checked.	H	Minimal change to port operations management as no change to design that introduces new capability, except for vessel size. Current design relies on land based pick ups and does not support 130 m vessel at rock berth	L	No change to port operations management as no change to design that introduces new capability, except for vessel size, including 130 m vessel at rock berth. New buoy at C4 shore pin to remove reliance on land based pick ups	L
Operation efficiency	Existing mooring elements will require some ongoing maintenance and restricted use of berth during maintenance works.	H	Vessels berthing simultaneously can increase efficiency of port operations compared to Option 3	L	No change to port operations efficiency	M	No change to port operations efficiency.	M	No change to port operations efficiency	M
Environment	No impact	L	Increased number of anchors = greater footprint area impact on seabed area	H	Less footprint on seabed areas with limited new anchor installation	L	New buoys at new locations, will have some impact on seabed area	M	New buoys at new locations, will have some impact on seabed area	M
Meeting users' requirements	Current configuration does not meet users' requirements in simultaneous berthing of vessels at rock and crane, and does not accommodate for vessels sizes preferred by users	H	Design provides for simultaneous mooring and for the vessels as nominated by users at rock and crane berth	L	Design does not allow for simultaneous mooring but can accommodate larger size vessels as nominated by users at crane and rock berth.	M	Design does not allow for simultaneous mooring but can accommodate larger size vessels as nominated by users at crane and rock berth. Noted that 130 m vessel can not be accommodated at Rock berth, and there is more reliance on land based pickups	M	Design does not allow for simultaneous mooring but can accommodate vessels ranging from 130 m to 200 m at Rock berth and removes reliance from land based pick ups.	L

Option	Option 1		Option 2		Option 3		Option 4a		Option 4b	
Description	**Do nothing**		**Simultaneous Mooring Configuration**		**Shared Mooring Configuration - Adaptive re-use of existing mooring components**		**Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse**		**Shared FFC Mooring Configuration - Combination of New and Adaptive Reuse**	
Assessment Criteria	**Description**	**Ranking**	**Description**	**Ranking**	**Description**	**Ranking**	**Description**	**Ranking**	**Decription**	**Ranking**
Design uncertainty	N/A		Design will allow for new shore pins	**L**	Design will allow for new shore pins. Design uncertainty is in existing capacity of outer mooring system – capacity check required.	**M**	Design will allow for new shore pins and outer mooring system components. Cliff undercut stabilisation is uncertain	**L**	Design does not change use of existing shore pins; minimal modification required. Noted outer mooring system and one new shore pin has been included. Cliff undercut stabilisation is uncertain	**L**
Ease of construction	N/A		Installation of buoys and associated infrastructure is not complicated but due to number of new components to be installed, works will not be straightforward.	**M**	Reuse of some existing elements, e.g. anchors will require capacity checks and detailed review of contractors' method for connecting to new infrastructure.	**M**	Reuse of some existing elements will require review of contractors method for connection onto new infrastructure	**M**	Reuse of some existing elements will require review of contractors method for connection onto new infrastructure	**M**
Construction effect on wharf operations	N/A		Mooring works will require restriction to existing berths but not more than 3 months	**M**	Reuse of existing with minimal new installation, not more than 1 month	**L**	Reuse of existing with minimal new installation, not more than 3 month	**M**	Reuse of some existing with new installation >6 months	**M**

Table 6: Options Assessment for Smith Point Moorings

Option	Option 1		Option 2		Option 3	
Description	**Do nothing**		**Mooring system with vessels berthing parallel to shore**		**Mooring system with vessels berthing parallel and perpendicular to shore**	
Assessment Criteria	**Description**	**Ranking**	**Description**	**Ranking**	**Description**	**Ranking**
CAPEX	N/A		Estimated $2.6M vs RBB $3.8M	H	Estimated $2.6M vs RBB $5.6M	H
Operational expenditure	Significant costs in maintenance due to mooring elements past design life	H	Majority of system will be new elements; maintenance is less cost and effort to retain existing.	L	Majority of system will be new elements; maintenance is less cost and effort to retain existing. Increased anchors to allow perpendicular mooring increases future maintenance cost.	M
Operation safety	Viewed as inherently unsafe by users. Reuse of existing without inspection and maintenance may further adversely impact safe operation for bunkering of fuel or refuelling	H	This mooring configuration will allow for safer operation of vessels for fuel bunkering and/or refuelling except during swell season.	M	This mooring configuration will allow for safer operation of vessels for fuel bunkering and/or refuelling including during swell season	L
Operation efficiency	Existing mooring elements will require some ongoing maintenance and restrict use of berth for vessels bunkering fuel to island or vessels refuelling.	H	This mooring configuration will limit vessels bunkering fuel to island and/or refuelling during swell season limiting operation efficiency	M	This mooring configuration will allow for vessels bunkering fuel to island and/or refuelling during all seasons including swell season	L
Environment	N/A		New mooring system has new anchors for placement on seabed – this will have environment impact footprint on seabed areas not previously used (note that areas are adjacent to existing mooring facility)	M	New mooring system has two additional anchors compared to Option 2 – this will have larger environment footprint on seabed areas not previously used (note that areas are adjacent to existing mooring facility)	H
Meeting users' requirements	Users have highlighted safety concerns with use of current mooring configuration for vessel bunkering fuel to island and/or vessels refuelling	H	This design will partially meet users requirements	M	This design will meet all users requirements	L
Design uncertainty	N/A		Design will allow for new shore pins	L	Design will allow for new shore pins	L
Ease of construction	N/A		Design nominates new elements to be installed, with some design uncertainty on seabed levels for new anchors.	M	Design nominates new elements to be installed, with some design uncertainty on seabed levels for new anchors.	M
Construction effect on wharf operations	N/A		Mooring works will require restriction to existing berths but not more than 3 months	M	Mooring works will require restriction to existing berths but not more than 3 months	M

6. Detailed Design Requirements - General

6.1 Occupational Health, Safety and Environment

The infrastructure is to comply with the requirements of the Occupational Health and Safety (Commonwealth Employment) Act, 1991.

All design works for the facility shall provide a safe environment for operations and maintenance personnel and conform to all relevant legislative and project requirements.

6.1.1 Project / Client Safety Requirements - Commonwealth

The following Commonwealth legislation and requirements shall be conformed to as appropriate:

- Consolidated Occupational Safety and Health Act 1984
- Occupational Safety and Health Regulations 1996
- Environmental Protection Regulations 1987 & 1997
- Environment Protection and Biodiversity Conservation Act 1999
- Explosives and Dangerous Goods Regulations 1992
- Sea Installations Act 1987
- Construction Safety Management Plan
- Operational Safety Management Plan
- Oil Spill Response Management Plan
- Safety in Design Management Plan

6.1.2 Project / Client Environmental Approvals / Requirements - State

Any required approvals under the following State Legislation will be obtained:

- Environmental Protection Act 1986;
- Aboriginal Heritage Act 1972;
- Port Authorities Act 1999;
- Occupational Safety and Health Regulations 1996;
- Explosive and Dangerous Goods Regulations 1992;
- Maritime Transport and Offshore Facilities Security Act 2003; and
- Approvals of Fire Equipment in accordance with FESA.

6.2 References

The following references have been used within this Section 6, and are provided in detail below:

1. AusTides 2017, Australian Hydrographic Service, Department of Defence.
2. Bicknell C, 2010, Sea Level Change in Western Australia: Application to Coastal Planning, prepared by the Department of Transport, WA.

3. GHD 2013, Report for Flying Fish Cove Jetty Extensions: Wave Modelling Study, May 2013 prepared for the Department of Regional Australia. Report 61/27527/117454 Rev 1

4. Damara WA Pty Ltd, 2011, Christmas Island: Metocean Analysis and Preliminary Assessment of Landing Facility Access, Report 119-01-Rev C

6.3 Survey Information

6.3.1 Datum

Chart Datum (CD), approximately equivalent to Lowest Astronomical Tide (LAT) and Indian Springs Low Water (ISLW) for Christmas Island is generally to be used to ensure that one consistent level is adopted for all drawings and documentation for the Flying Fish Cove (FFC) mooring project unless noted otherwise. This level is 0.8 m below Christmas Island Height Datum (CIHD).

Representative tidal planes for FFC have been obtained from the Australian National Tidal Tables [1] are shown in Table 7 relative to CD and Christmas Island Height Datum.

Table 7: Tidal Planes - Christmas Island

Tidal Plane	Level above CD	Level above CI Height Datum (MSL)
Highest Astronomical Tide (HAT)	1.9	1.1
Mean Higher High Water (MHHW)	1.5	0.7
Mean Lower High Water (MLHW)	0.9	0.1
Mean Sea Level (MSL)	0.8	0.00
Mean Higher Low Water (MHLW)	0.8	0
Mean Lower Low Water (MLLW)	0.2	-0.6
Indian Spring Low Water (ISLW)	0.1	-0.7
Lowest Astronomical Tide (LAT)	0.0	-0.8
Chart Datum (CD)	0.00	-0.8

6.3.2 Sea Level Rise

For a 20-year design life of the moorings to 2040 and for a 50-year design life to 2070 for the crane platform, the recommended allowances for sea level rise are 0.15 m and 0.4 m respectively [2].

6.3.3 Bathymetry

Three bathymetric surveys available for the Flying Fish Cove area and at Smith Point include:

- XMAS 1603-1-1 (2008) Christmas Island – Flying Fish Cove Soundings, Bebbington Cartographics Pty Ltd; and
- Chart 01 – Bathymetry / Seabed Features (2011) Extension to Christmas Island Wharf – Flying Fish Cove, EGS Survey.
- Navy bathymetry data 2012 as provided by DIRD via email on 09 June 2017.

From the available data, the seabed level is approximately -3 m CD at the end of the existing jetty and approximately -5 m CD at the end of the proposed extension. The seabed does drop off sharply to over 200 m deep once outside the confines of the Cove.

6.4 Climate

6.4.1 Climate

Climate data for the site is available on the Bureau of Meteorology website http://www.bom.gov.au/products/IDW60801/IDW60801.96995.shtml. It should be noted that the climate data is collected at Christmas Island Airport, which is higher, and on the opposite side of the island from Flying Fish Cove, so data should be used with caution.

6.4.2 Temperature

Structures shall be designed to accommodate movements due to thermal expansion and contraction. Material surface temperature when exposed to direct sunlight shall be (AS 1170) as detailed in Table 8.

Table 8: Summary of materials surface temperate at ambient temperature conditions

	Maximum (ºC)	Minimum (ºC)	Mean (ºC)
Ambient	45	20	35
Steel	60	10	40
Concrete	50	15	35

6.5 Met-Ocean Data

6.5.1 Water levels

Design water levels have been derived from data presented in Damara WA Pty Ltd [4] and wave study undertaken by GHD [3]. The design water level includes an allowance for surge, tide (joint distribution of tides and storm surge). A summary of the water levels is provided in Table 9. The third column includes sea level rise allowance of 0.4 m to obtain design water levels towards the end of design life of the crane platform at 2070.

Table 9 : Design Water Levels for FFC

ARI Years	Design Level (m CD)	Design Level by 2070 (m CD)
5	+1.84	+2.24
10	+2.09	+2.49
20	+2.34	+2.74
50	+2.67	+3.07
100	+2.93	+3.33

6.5.2 Wind

Table 10 provides a summary of the wind conditions for structure design to AS 1170.2 and LINX Christmas Island Port Information Guide May 2017.

Table 10: Summary for wind conditions for design and as per current port operations

Wind Condition	Parameters	Reference
Structural Design	Region B Terrain Category 1 Recurrence Interval, R = 500 years Regional Wind Speed, Vu = 57 m/s	AS1170.2
Operating	Limiting wind speed for operation of berths – 15 knots for crane berth and Smith Point moorings, 25 knots for rock berth moorings. (30 second gust speed)	LINX Christmas Island Port Information Guide May 2017

6.5.3 Waves

Wave information is from the GHD wave modelling report (2013). This indicated that near the jetty 85% of waves were less than 0.5 m and that 75% of waves had a peak period between 11 and 15 seconds. The wave height at the moorings could be slightly higher, however this generally confirms the limit specified in the LINX Christmas Island Port Information Guide May 2017.

The parameters for extreme wave heights to be considered for structural design of the crane platform are provided in Table 11.

Table 11: Design Wave Heights and Periods

Case	Hs (m)	Wave period (sec)
		Tp
10 year non-cyclonic	3.8	15
10 year cyclonic	4.0	9
100 year non-cyclonic	4.4	15
100 year cyclonic	6.2	9

6.5.4 Current

The maximum tidal current velocity is unknown but not considered to be critical for the designs. The specified maximum operational current for the moorings is 0.5 knots as detailed in LINX Christmas Island Port Information Guide May 2017.

7. Detailed Design Requirements – Crane

Crane is to be an offshore platform crane. The manufacturer shall confirm the following information in Appendix E for the detailed design.

7.1 Design Life

The new crane shall have a design life of 20 years.

7.2 Codes

Crane shall be compliant with the recommendations of API 2C. Refer to Appendix E for the design parameters and specification.

7.3 Crane Platform Details

Details of the required anchorage of the crane platform into the concrete deck shall be obtained from the Manufacturer.

Any requirements for the crane to be stowed, prior to storm conditions, shall also be obtained from the Manufacturer.

8. Detailed Design Requirements – Crane Platform

8.1 Design Life

The new facilities and associated works for the Option 2 platform (refer Figure 1) shall be designed to achieve a design life of 50 years.

8.2 Codes and References

8.2.1 Project Specific Standards

All work shall be carried out in accordance with the current and applicable Australian Standards. Other reference information including international standards shall be used to supplement/clarify design requirements.

8.2.2 Main Design Codes

The latest edition of the following design standard codes will be the basis of the design for the crane platform. Codes referenced in these standards will also be considered to form part of the Design Criteria.

Standard Reference	Title
AS 4997	Guidelines for the Design of Maritime Structures
AS 1170	Structural Design Actions – Loading Codes
AS 3600	Concrete Structures
AS 4100	Steel Structures
AS 1554	Structural Steel Welding
AS 2159	Piling Code
AS 1657	Fixed Platforms, Walkways, Stairways and Ladders
AS/NZS 2312	Guide to the Protection of Structural Steel against Atmospheric Corrosion by the use of Protective Coatings
AS 2832.3	Cathodic Protection of Metals – Part 3: Fixed Immersed Structures

8.2.3 References

The latest edition of the following references will be used to augment the design codes where necessary.

– DNV-RP-C205 Environmental conditions and environmental loads

8.2.4 Supporting Studies

- Wave Modelling Study, May 2013, GHD
- Flying Fish Cove Port Crane Replacement, Options Assessment, Dec 2015, GHD
- Christmas Island Flying Fish Cove Outer Mooring System ‘A&B’ Vertical Exchanges, May 2017, Undersea Constructions Ltd

8.3 Loads

8.3.1 Dead Loads

Dead loads to consider the characteristic density of the materials used.

Crane dead weight (and location) to be as per the Manufacturer's supplied information.

8.3.2 Live Loads

The operational loading for each design element considered is as per Table 12.

Table 12: Operational Live Loads

Element	UDL	Point Load
Crane platform deck	5 kPa	
Crane lifting	Primary loads as supplied by the Manufacturer (refer Appendix E), with hoisted load a maximum of 45 t at 45 m outreach in any direction. A dynamic factor of 1.29 shall be applied to the overturning moment components.	Crane boom & hook weights to be considered as live loads.

8.3.3 Wave Loads

Wave loads shall be developed from the corresponding wave data indicated in Section 6.5.3 considering the advice in the reference documents regarding wave theory and drag/inertia coefficients.

Deck soffit level shall be set at RL+9.0 m to suit the existing backstay arm positions, and therefore uplift due to the clapotis effect on the cliff face shall be considered.

A coincident current does not need to be considered in conjunction with the extreme wave events.

8.3.4 Wind loads

Wind loads shall be developed from the corresponding wind data indicated in Section 6.5.2. Wind loading on the platform due to the crane shall be obtained from the crane Manufacturer.

8.3.5 Seismic Loads

Seismic loads are considered negligible compared to the crane overturning moment and wave loads.

8.3.6 Ship impact

The platform shall be protected from ship impact, in the event of a mooring line failure, by the use of fenders attached to the piles. The fenders at each pile shall be sized to absorb the energy of the vessel listed in Section 9.3 (for the crane berth), for a speed of 0.15 m/s. The ULS load on the platform shall then correspond to the specified maximum fender reaction including 10% tolerance.

8.4 Durability

Materials and finishes are to be selected to provide durability and ease of maintenance in a marine environment, in a tropical region.

8.4.1 Structural Steelwork

Corrosion Protection for piles	Buried below sea bed	None
	Submerged	Protective paint system (epoxy or similar) Sacrificial Anode type Cathodic Protection System (if required, based on the requirements of design).
	Tidal	30 mm thick HDPE lining with the annular space grouted.
	Atmospheric	Protective paint system (epoxy or similar)
Corrosion Allowance	Piles	Allow 2 mm corrosion
	Replaceable, non-structural fittings in splash zone, such as ladders, fittings etc.	Stainless steel / FRP ladders Stainless steel fittings.
Detailing	All structural and miscellaneous steelwork shall be detailed such that all hollow sections are sealed, ponding of water on steelwork is not possible, and all sharp corners rounded. Detailing for galvanized steel items shall be such as to facilitate screw threads etc.	
Corrosion Protection for other steelwork.	Miscellaneous steelwork (including, but not limited to gratings, handrail systems, guardrail systems, light standards) shall be hot dip galvanized with 0.9 kg/m^2 of zinc. Steelwork for which a specific protective coating is not explicitly specified shall be painted with an ultra-high build epoxy coating.	
Replaceable Fittings	Items such as ladders shall be designed to be easily replaceable both in terms of connection details and in terms of manageable module size.	
Cast-In Fittings	All cast-in fittings shall be grade 316 stainless steel. A review in accordance with AS 2312 will be conducted. Special attention will be paid to ensuring dissimilar metals are not in contact and creating galvanic cells	

8.4.2 Reinforced Concrete

Minimum Cover to Reinforcement	Deck slab	75 mm

Crack control	Crack control shall be achieved by limiting steel stresses to the recommendations of AS 4997. The Contractor's method of construction, environmental conditions of the year, time of casting the concrete, etc. will all influence the thermal assessment and risk of cracking. The specification will require the contractor to determine the risk of cracking due to concrete early age thermal/restraint and shrinkage behaviour.
Protective Coating	Xypex or Caltite incorporated into the concrete mix will be used. Xypex may not be required to achieve the 50-year design life however, its inclusion could be a useful risk management approach to minimise unexpected reinforcement corrosion repairs during the 50-year design life. A saline external coating to the concrete may also be incorporated.
Reinforcement	All reinforcement shall be N Grade deformed bars to AS3600 and AS4671 (500 MPa). The bars will not be stainless steel or galvanised, the durability will be ensured through adequate cover, admixtures or external coating to the concrete design and, if need be, a Cathodic Protection System.

8.4.3 Maintenance Regime

The design lives detailed above are based on suitable maintenance systems being implemented, with the intention that minimal maintenance be required to major structural items within the design life.

It is expected that a maintenance inspection schedule to monitor the condition of the structures. This will need to include as a minimum:

- Inspection and testing of cathodic protection systems (if provided) every 2 years;
- Inspections of marine structures every 5 years;
- Inspections of marine furniture every 3 years;
- Inspection of coating systems with intermittent touch ups as necessary every 5 years; and
- Mechanical and electrical equipment to be inspected in accordance with manufacturer's recommendations.

The adoption of a design life represents the duration the asset will be expected to possess the structural integrity and capacity to resist the specified design loads and continue to be serviceable. The adoption of the design life assumes the above inspections and maintenance schedule are implemented. The design and detailing shall fully take into account this requirement for durability.

At completion of the construction phase, the Construction Contractor will be responsible for developing an Operating and Maintenance Manual for the platform.

8.5 Access Requirements

Stairs, walkways and ladders shall be designed to prevent slips and falls and in accordance with AS1657.

Grating for walkways and platforms shall comply with the requirements of the Standards and shall be fibre reinforced plastic as a minimum. Stair treads shall be an approved non-slip design, with non-slip, high visibility nosing including top landing.

8.6 Geotechnical

Due to the site remoteness, and the time and cost associated with mobilising for geotechnical investigation works, no additional geotechnical information is expected to be obtained for the detailed design. The design will proceed on the basis that parameters will be confirmed during the early phases of construction, and that design adjustment (e.g. pile length requirements) will be made if and as required. Since it is preferable to avoid late design amendments if possible, a conservative approach will be taken during detailed design, based on interpretation of existing geotechnical information, which is generally deficient in coverage and depth, compared to what would typically be available for design support.

Allowance will also be made to stabilise the undercut rock near the crane. This is a prudent, precautionary measure, given the close proximity of overhanging rock to the crane location; particularly because loading of shore pins above the cliff crest locally increases the natural gravitational loading within the overhanging rock.

8.7 Pavement reinstatement

Upgrading the crane platform will require the demolition of segments of the pavement. These shall be reinstated after construction of the platform to reinstate pavement profile to existing surface profile prior to works.

8.8 Construction Methodology

The likely construction method for the Option 2 platform (Figure 1) is detailed below:

- Conduct geotechnical assessment & confirm pile design
- Mobilisation & site setup
- Carry out stabilisation of rock overhang
- Materials procurement & delivery
- Dismantle & dispose existing tower crane
- Cut pavement & excavate around back reach arms, scrabble arms and ground anchor blocks.
- Drill in dowels and construct new back span arms around existing. Backfill to near the crane deck.
- Erect falsework at crane deck, demolish deck concrete and cut-off existing column
- Drive piles, construct pile toe inserts, cut-off piles to level
- Erect formwork for new crane deck
- Construct deck, including plugs in the top of piles, connection to arms and anchors/mounting platform for crane
- Construct fender supports
- Reinstate pavement
- Install crane

9. Detailed Design Requirements – Flying Fish Cove Moorings

9.1 Codes & References

There are no Australian Standards governing the design of moorings. The following documents shall be used to inform the design.

- BS6349-6 (withdrawn in 2014): Maritime structures. Design of inshore moorings and floating structures
- GL Noble Denton guidelines for moorings 0032/ND
- ISO 19901-7 : Petroleum and natural gas industries -- Specific requirements for offshore structures -- Part 7: Station keeping systems for floating offshore structures and mobile offshore units
- API-2SK (superseded by the ISO document): Design and Analysis of Station keeping Systems for Floating Structures
- PIANC Guidelines for the design of fender systems (for vessel parameters)

9.2 Design Life

The design life for the purposes of durability shall be 20 years.

9.3 Design Vessels

9.3.1 Rock berth

The design vessels as nominated by User Requirement Brief, refer Section 1.6.1 is summarised below in Table 13

Table 13: Rock Berth Design Vessel Parameters

Parameter	Bulk Carrier Parameter
L_{oa}	200 m
L_{bp}	190 m*
B	32 m*
Depth	17.7 m*
Draft – laden	12.2 m
Draft – ballasted	6.5 m
Windage –transverse above deck	835 m^2*
Windage –longitudinal above deck	365 m^2*
Mooring lines	68 mm polyester (assumed)

*Values estimated using PIANC data

9.3.2 Crane Berth

The design vessels as nominated by User Requirement Brief, refer Section 1.6.1 is summarised below in Table 14

Table 14: Crane Berth Design Vessel Parameters

Parameter	General Cargo Parameter
L_{oa}	110 m
L_{bp}	100 m*
B	15.5 m*
Depth	8.6 m*
Draft – laden	6.2 m
Draft – ballasted	5 m
Windage –transverse above deck	84 m^2*
Windage –longitudinal above deck	447 m^2*
Mooring lines	40 mm nylon (assumed)

*Values estimated using PIANC data

9.4 Operating Conditions

9.4.1 Wind, wave & current

Table 15 is summary of operational conditions for vessels berthing at the rock and crane berth as described in LINX Christmas Island Port Information Guide May 2017

Table 15: Summary of Port operational conditions for vessels berthing

Berth	Wind (knot)	Wave (m)	Current (knot)
Rock	25	0.5	0.5
Crane	15	0.5	0.5

9.4.2 Excursions

Movement of the vessels due to the environmental conditions, under the loaders or crane, would generally be limited to about +/- 1.5 m as per PIANC recommendations; however, this is not practical for these berths.

Anticipated excursions are to be reported, but will need to be managed by the ship's crew, as must occur under current operations.

Pretensions, via ship's winches, in the order of 3 t are to be considered.

The arrangement is to be similar to Figure 6.

9.5 Durability

Wear and corrosion allowances shall be made considering the guidance in Clause 7.6 of API-2SK. Cathodic protection shall also be included by way of sacrificial anodes in a similar manner to the current arrangement. The maximum loss of section, until replacement, shall be defined for chains and shackles in detailed design to achieve design life (refer Section 9.2).

9.6 Furniture

Mooring buoys are to be peg top buoys with a minimum of three watertight compartments and have a mooring hook connection suitable for loads angles from 0^{o} to 90^{o} in a vertical plane and +/-45^{o} in a horizontal plane. Alternatively, buoys may be closed-cell foam specifically detailed for offshore use.

9.7 Geotechnical

"Christmas Island Moorings - 2015 Condition Assessment" report by UCL provides a visual impression of seabed conditions generally within the area of existing anchors, and discussions with the Harbourmaster on the subject of anchorage conditions. This information has formed the basis for our assessment of likely anchorage conditions for proposed new anchors.

The inner moorings are to assume no anchor embedment is possible, with resistance to mooring loads only resisted by friction on the seabed. A maximum friction coefficient of 0.8 shall be used with a factor of safety of two.

The outer moorings are assumed to hold a 25 t horizontal load as described in the "A&B Vertical Exchange" report by UCL for the existing outer mooring buoys. They shall be proof-load tested.

New shore pins will be designed for the rock berth moorings to suit the required loads. Conservative detailed design will be undertaken on the assumption that rock characteristics will be comparable to those of the rock close to the crane location for which some geotechnical information is available. It is intended that the assumed characteristics will be verified during construction of rock anchors for the new shore pins, and that an ability to make any necessary modifications (e.g. additional anchor lengths or additional anchors) would be maintained.

10. Detailed Design Requirements – Smith Point Moorings

10.1 Codes & References

There are no Australian Standards governing the design of moorings. The following documents shall be used to inform the design.

- BS6349-6 (withdrawn in 2014): Maritime structures. Design of inshore moorings and floating structures
- GL Noble Denton guidelines for moorings 0032/ND
- ISO 19901-7 : Petroleum and natural gas industries -- Specific requirements for offshore structures -- Part 7: Station keeping systems for floating offshore structures and mobile offshore units
- API-2SK (superseded by the ISO document): Design and Analysis of Station keeping Systems for Floating Structures
- PIANC Guidelines for the design of fender systems (for vessel parameters)

10.2 Design Life

The design life for the purposes of durability shall be 20 years.

10.3 Design Vessels

The design vessels as nominated by User Requirement Brief, refer Section 1.6.1 is summarised below in Table 13

Table 16: Smith Point Mooring Design Vessels

Parameter	Tanker	Cruise
L_{oa}	150 m	150 m
L_{bp}	140 m*	146 m*
B	24 m*	23.9 m*
Depth	12 m*	13.7 m*
Draft – laden	9 m*	7.3 m*
Draft – ballasted	6 m*	7.5 m*
Windage –transverse above deck	560 m^{2}*	2040 m^{2}*
Windage –longitudinal above deck	236 m^{2}*	460 m^{2}*
Mooring lines	68 mm polyester (assumed)	68 mm polyester (assumed)

*Values estimated using PIANC data

10.4 Operating Conditions

10.4.1 Wind, wave & current

The condition specified in the LINX Christmas Island Port Information Guide May 2017 for Smith Point is the same as crane berth in Table 15.

10.4.2 Excursions

Movement of the tanker due to the environmental conditions is not critical since the connection is a flexible floating hose.

The arrangement is to be similar to Figure 9.

10.5 Durability

Wear and corrosion allowances shall be made considering the guidance in Clause 7.6 of API-2SK. Cathodic protection shall also be included by way of sacrificial anodes in a similar manner to the current arrangement.

10.6 Furniture

Mooring buoys are to be peg top buoys with a minimum of three watertight compartments and have a mooring hook connection suitable for loads angles from 0^o to 90^o in a vertical plane and +/-45^o in a horizontal plane. Alternatively, buoys may be closed-cell foam specifically detailed for offshore use.

10.7 Geotechnical

Only anecdotal evidence is available regarding the geotechnical conditions for the anchorages.

The moorings are to assume no anchor embedment is possible, with resistance to mooring loads only resisted by friction on the seabed. A maximum friction coefficient of 0.8 shall be used with a factor of safety of two.

New shore pins will be designed to suit the required loads. Conservative detailed design will be undertaken on the assumption that rock characteristics will be comparable to those of the rock close to the crane location at Flying Fish Cove for which some geotechnical information is available. Although this location is considerable distance away, it is noted that the geological conditions at both locations are similar. It is intended that the assumed rock characteristics will be verified during construction of rock anchors for the new shore pins, and that an ability to make any necessary modifications (e.g. additional anchor lengths or additional anchors) would be maintained.

Appendices

Appendix A – Stakeholder Consultation Meeting Minutes

Minutes

11 May 2017

Project	Christmas Island Mooring and Crane Replacement	From	Sharyn Long
Subject	Stakeholder Consultation Meeting	Tel	08 6222 8222
Venue/Date/Time	Christmas Island Court House 03 May 2017 @ 10.00am	Job No	6135581
Copies to	Mohd Fauzi Kasim – IOOC Danny Ma Peng Seng – CIP Mike Fawke – IOS Brad McLaughlin – IOOC James Patterson – Navy Craig Kitson – CSFS		Kelana Arshad – CSFS Dave Robertson – LINX Steve Tempra – LINX Wayne Angus – UCL Sharon Greenshields – DIRD
Attendees	Mohd Fauzi Kasim – IOOC (Indian Ocean Oil Company) Danny Ma Peng Seng – CIP (Christmas Island Phosphates - Ports Operations Manager) Mike Fawke – IOS (Indian Ocean Stevedores - Pilot) Brad McLaughlin – IOOC James Patterson – Navy (LSE-CI) Craig Kitson – CSFS (Complete Stevedoring and Freight Services) Kelana Arshad – CSFS		Dave Robertson – LINX Steve Tempra – LINX Wayne Angus – UCL (Undersea Construction Limited) Sharon Greenshields – DIRD (Department of Infrastructure and Regional Development) Peter Seman – GHD Billy Cilliers – GHD Sharyn Long – GHD
Apologies	-		

Notes

Introductions

The following are key summary notes recorded in the meeting

FFC Mooring Systems: Rock Berth

Current use:

- 130 m (LBP) vessel in wet season and 170 m (LOA) in dry season, with harbour master authorisation for rock berth.
- A six point mooring configuration is utilized to moor vessels at the rock berth; which uses outer moorings A buoy and B buoy and 4 buoys from inner moorings.

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Notes

- Limiting conditions were discussed and are set out in the Christmas Island Ports – Port Information Guide for Ship Masters (Linx):
  - Wind – maximum onshore wind speed 25 knots.
  - Wave – significant wave height not to exceed 0.5 m.
  - Underkeel clearance of 1.5 m.
- Berthing window is dependent on two parameters, wind and swell. Review of internet based forecast sites (e.g. Bureau of Meteorology) with visual confirmation of swell / wind is taken from Flying Fish Cove (FFC) jetty and the Marine Pilot makes the final decision on vessel entry.
- Conditions also limit stevedore operations from motorised barges.
- Operability parameters at rock berth – same limiting conditions as crane berth.

Issues with existing rock berth mooring system at FFC:

- Existing mooring configuration and limitations means that only smaller class cargo vessels can be moored at Christmas Island. These smaller class vessels typically have an older age profile and are considered less safe than larger vessel classes. Availability of the smaller vessels is limited, uneconomic and constrain vessel supply opportunities.
- Smaller vessels have low de-ballast rates. To allow faster loading rates, existing vessels come into the port in fully de-ballasted conditions. This means that the vessels are less “stable” on entry to the port, often with propellers partially submerged, a sub optimal condition for mooring operations.
- Reconfiguration of inner mooring is required. The outer mooring buoys do not require adjusting. Buoys A and B are in good position for the sized ships to be used.
- The buoy system is rated for wind and that is the limiting factor, which coincides with the cantilever operating conditions. Recovering barges is not wind critical as much as wave critical.

Frigate vessel (Anzac class, 118m LOA) is considered acceptable design vessel for future use of FFC moorings.

Smaller vessels can utilise existing mooring system.

Main concern lies when RAN assets connect up to either of the outside buoys, A buoy or B buoy with a single mooring line forward and then using them as a Single Point Mooring (SPM). This is a potential issue in the event the vessel may weathervane around the SPM, and pull against the lay of the anchors. The Smith Point outside buoy is designed as a SPM but only between the spans.

When the navy comes in for respite, mooring configuration to be provided by LINX.

Notes

Requirements of new rock berth mooring system

- Future mooring system to retain 6 point configuration system
- Preferred design vessels: 180-200 m design vessel (vessel class more easily available on market, safer and cheaper than existing smaller vessels)
- Mooring system to allow design vessel (LOA<200 m) to berth and operate in both wet and dry season within the limiting conditions
- Preferred that all new buoys for replacement of existing are the same configuration, i.e. all buoys are peg buoys. Makes for safer operation and better maintenance and spare parts stock easier to manage.

FFC Mooring Systems: Crane Berth

Current use:

- Vessel size: 100 m LOA (but up to 115 m is permitted pending approval from Harbourmaster).
- A six point mooring configuration is utilized to moor vessels at the crane berth.
  - Rock and crane berths have shared elements e.g. the Stern buoy and South breast buoy is shared by both inner and outer mooring systems.
- Limiting conditions were discussed and are set out in the Christmas Island Ports – Port Information Guide for Ship Masters (Linx):
  - Wind – maximum onshore wind speed 25 knots.
    - The crane berth is a subset of the FFC mooring system. The rock berth has a limiting condition of 25 knots, however the crane berth has a local condition set of 15 knots during cargo operations due to operating limitations for the use of the Favelle Favco M760.
  - Wave – significant wave height not to exceed 0.5 m
  - Underkeel clearance of 1.5 m
  - Maximum draft of vessel on berth south side is 5.2 m and north side is 6 m.
  - Minimum offset of vessel side to crane pedestal is 25 m.

Issues with existing crane berth mooring system

- Predominant number of existing vessels have on-board cranes situated on port side. This sets up the ship mooring configuration facing bow into north (into the cantilever). This limits the ability of the vessel to quickly release and clear for exit. Movement restrictions of cantilever ship loaders cannot move arm to be clear of ships, i.e. if arm moves north, the counterweight moves south again preventing quick exit of vessel.

Notes

- Min offset to cantilever arm – from ship bow to cantilever approx. min 10 m offset – prefer for increased offset.
- Cantilever mooring line is definitely an operability issue and preferred to be removed.
- Landside mooring pins (north and south) have harps that requires barge to be between vessel and cliff face (not ideal) Southern landside mooring pin should preferably be further south to be more effective as a breast line, however due to bathymetry limitations in this area cannot be accessed by barge to pick up the harp / alongside chain.
- Shared mooring buoys between rock and crane berth is not preferred. During simultaneous mooring, ship movement at the crane berth is magnified due to sharing buoys, i.e. outer ship movement influences inner ship movement.
- Simultaneous mooring is preferred without sharing components. Note that a vessel can be berthed for 2-3 days which means rock berth cannot be used for other vessels.
- A minor increase in vessel length (LOA); for instance 10 m, will allow a different class of vessel to operate at Christmas Island. Larger vessels (e.g. Handysize Bulker) are easier to handle as they can come in with sufficient ballast which allows better manoeuvrability and safer operating conditions. Larger class vessels will only part load due to the cargo parcel size (tonnage product) based on the mine supply. Vessel air draft restrictions will not change regardless of vessel type/size. Larger vessels will be subject to the existing operability limits.
- Emergency release and egress of vessels may be an issue when simultaneous mooring condition occurs as there is only one pilot. It was noted that after release of vessels from moorings and immediate access to deep water (within 5-10 minutes) somewhat mitigates this risk.

  Also stated that presently a vessel could be berthed at Smith Point mooring at either of the rock or crane berths and in the event of a severe change of weather conditions would have access to a single pilot.

Requirements of new crane berth mooring system:

- Future mooring system to retain 6 point configuration system.
- Mooring configuration to allow for increase in vessel length, minimum increase of 10 m.
- Ability to moor vessels with bow facing either north or south, dependent on the vessel crane positioning.
- Min offset to cantilever arm – from ship bow to rock berth cantilever approx. min 10 m offset – prefer for increased offset
- Maximise the North West orientation of moored vessel i.e. pass the south cantilever arm to provide fastest exit condition.
- Mooring systems for the rock and crame berth to be two completely independent systems, which may allow simultaneous mooring.

Notes

- Additional mooring (to create additional bow or spring line) is preferable to remove reliance on cantilever line. New mooring buoy will have to be completely clear of the south arm cantilever and well anchored to sea bed to minimise movement – scope has to be very clear on buoy boundary to avoid contact with south arm cantilever should the buoy move due to weather events.
- Maximise offset of the vessel side of the cliff face / crane pedestal i.e. via crane with greater load at reach potential.
- Minimum of a 10 m horizontal offset between the vessel side/bottom and the sea bed with shallowest draft meeting the port vessel draft limitations (5.2 m).
- Landside harps position for existing ships is too high however, if larger design vessels are used then existing position is acceptable.
- Future mooring system to retain 6 point configuration system.
- Relocation of the southern land side mooring pin and pickup chain is preferable but the depth limitations for barge pick up need to be considered. Potential solutions need to factor in various factors, i.e. operability, maintenance, snagging.

Smith Point Mooring System:

Current use vessel types:

- Tanker – 150 m LOA, 23.2 m beam, 10 m draft.
- Cruise – 224 m LOA, 27.3 m beam and 7.4 m depth, air draft 30 m.
- Refuelling – Cape Class and Frigate: AWD dimensions: 147.2 m LOA, 18.6 m beam and maybe LHDs same size as cruise ships (Defence benefit).

Primary objective is for refuelling and bunkering:

- Tanker unloading use floating hose with vessel parallel to coastline.
- Refuelling – fixed manifold but ship orientation is perpendicular with slight angle.

Issues with existing mooring systems at Smith Point:

- Dual functionality of Smith Point mooring to accommodate cruise vessels (off the SPM buoy) and tankers (6 point mooring, parallel to shore) creates operational and safety issues. The head and stern lines (South and North Buoy) are not positioned to hold the vessels safely of the cliff.
- Tanker vessel usually do not carry 400 m mooring line length necessary to reach the SPN buoy.
- The existing mooring line lengths are significant and take approx. 15-20 minutes to retrieve lines – not ideal /safe.

Notes

- Vessels refuelling at Smith Point mooring presently orientate perpendicular to the shore (bow to sea) to reduce risk. If the Smith Point mooring were reconfigured then all vessels would moor parallel to shore.
- Limits in hose length also influence position of vessel alongside shore.
- Land based pickups are less safe and not ideal for mooring system adjacent to shore cliff faces.

New requirements for Smith Point mooring system:

- Design vessel is the same as existing fuel tanker
- New mooring system to maximise safety during tanker unloading and vessel refuelling.
- A separate mooring system for larger cruise lines is preferable but does not form part of this scope i.e. a separate single point mooring with multi anchor in alternative location to Smith Point. However, GHD will include as part of the options consideration.
- New Smith Point mooring configuration to allow for ship orientation to be same for unloading and refuelling i.e. parallel to shore. This will allow for cruise ships of similar dimensions to the fuel tanker to berth at Smith Point mooring.
- New mooring system to reduce vessel line lengths required to less than 220m to increase vessel availability and reduces line retrieval time – allows for safer operation.
- Remove and replace landside chain lines to remove reliance from land based pickups.

Crane replacement issues:

GHD crane option report notes users request for over 50 m reach of crane.

A 45 m crane reach was recommended as anything greater will lead to operation and control issues of crane.

Crane capability requirements:

- Users confirmed that a 45 tonne capacity at 45 m reach is acceptable – this will provide flexibility and options for vessel orientation.
- One user noted email request for 59 tonne cargo to be offloaded; however it was agreed that average 28 tonnes at full vessel deck reach is acceptable. It would be unusual to require 45 tonne carrying load across vessel full deck.
- Options discussed for structural foundation for new crane:
    - Subject to crane reach and load requirement, may use existing wharf space to minimise piling works. Users did not prefer this option as existing wharf space and operation area is already limited and would be negatively influenced by crane moving landward. Standalone pedestal – not preferred due to limited catwalk / bridge access for maintenance purposes. GHD notes that pending pedestal position and size of

Notes

crane componentry, crawler crane may be able to support permanent crane maintenance works from shore and that the pedestal access gangway would suffice.

- Land reclamation to be a consideration for new structural foundation.

GHD will review the minimum foot print required for crane maintenance and existing crawler crane specifications to determine if it can be used to carry new crane componentry loads during maintenance via review of preferred crane specifications.

Peter Seman
Project Manager

Appendix B – Stakeholders Comments Register (on Consultation Draft – 30% Concept Design Report)

CLIENTS | PEOPLE | PERFORMANCE

Department of Infrastructure and Regional Development			Christmas Island Crane and Mooring Upgrade and Replacement Project 30% Concept Design Report	Combined Feedback and Responses As At : 15 September 2017	
Page	**Section**	**Para.**	**Comment**	**From**	**Response**
			Review Comments and Feedback	**From**	**Response**
I	Executive Summary		FFC rock and crane berth Option 4 - Needs further definition! The description is at odds with the concept design at Figure 4 on page 12. It is stated that there is shared moorings in the executive summary but there are separate moorings shown for each berth in Figure 4.	David Robertson Port Manager	Section 3 of report to state - Option numbers to provide clarification on option reference to the figures in Section 3. The description of Option 4 is associated with Figure 6 in Section 3, and not Figure 4.
I	Executive Summary		FFC rock and crane berth Option 4 - Needs further definition! Makes reference to new outer mooring componentry only! Are we going to replace ground tackle on the inner moorings & the shore chains? Are new outer mooring buoys and span buoys included in the proposal? Has the replacement of all other buoys been considered or are they deemed fit-for-purpose and have sufficient life expiration for the timeframe of this project and beyond. The concept design shows additional shore pins, is replacement ground tackle included for these?	David Robertson Port Manager	See above - additional description will be added to Secton 3 and associated subsections, 3.5.1 and 3.5.2.
18	Smith Point Mooring	Figure 8	No anchor arrangement or connection to shore pins shown for S5 & S3.	David Robertson Port Manager	Agreed - Design will be revised to show breast buoys and connections to shore pins S3 and S5.
General			What type are buoys are proposed?	David Robertson Port Manager	Part of 90% Design
General			What type of buoy mooring hooks are proposed? Double/single? Closed pelican hook/open QRC?	David Robertson Port Manager	Part of 90% Design
General			Will the buoyancy of the mooring buoys be sufficient to provide 1 - 1.2m of freeboard?	David Robertson Port Manager	Part of 90% Design
3	FFC mooring		At the stakeholder consultation that I attended, users recommended Option 2. See 1.6.1.	Mike Fawke Marine Pilot (IOS)	Discussed with Dave Robertson post Risk Workshop
12	Discussions post workshop		FFC - I disagree that simultaneous moorings are not critical to efficient operation of the berths. Whilst it is acknowledged that there are many days that the berths are unoccupied, ships cannot be scheduled accurately on a liner service due to unknown weather and port delays which are experienced in this region. To have the Island supply vessel waiting for a CIP cargo vessel or vice versa costs time and demurrage. In this day and age we should be able to safely use both berths at the same time.	Mike Fawke Marine Pilot (IOS)	Simultaneous not recommended to achieve Commonwealth Operational requirements
12	Ditto		Smith Point - Having spoken with the "Back up Pilot" it is evident that his review of options has been misinterpreted. I, as the Full Time Pilot confirm that the reliance on land based pick up is unduly hazardous and should be avoided whenever possible by use of peg buoys. However, the option to use land based pick up should still be available as back up for buoy failure.	Mike Fawke Marine Pilot (IOS)	Agreed - Design to be updated
20	Figure 4		This would be my preferred option with independent moorings for each berth, although C1 would probably have to be used for sub 130m vessels in the Rock berth as R4 would be too far aft for those vessels. Vessel on Crane berth would ideally be orientated head west of north with stern closer to cliff than shown. This orientation though is good for vessels head south.	Mike Fawke Marine Pilot (IOS)	Simultaneous not recommended to achieve Commonwealth Operational requirements
23	Figure 5		I'm not clear on intention here. If N & S Breast removed are land based pick ups suggested? If so a bad idea and would deny opportunity for two vessel working.	Mike Fawke Marine Pilot (IOS)	Only south breast buoy is to be removed.
24	Figure 6		As above	Mike Fawke Marine Pilot (IOS)	As above
26	Figure 8	Smiths Point	Inner breast buoys required between vessel and S3/S5 with facility to connect at S3/S5 as back up.	Mike Fawke Marine Pilot (IOS)	Agreed - Design to be updated
General			I was noted as a key stakeholder in the minutes of the Risk Workshop held in Perth 12th July and my apologies were noted yet I was not to my knowledge invited. I was not party to any "Discussions post workshop".	Mike Fawke Marine Pilot (IOS)	DIRD agreed to invite Kevin Edwards as the PRL (CIP) Representative

Appendix C - Reference Drawings and Documents

Reference No.	Document Title	Company	Document Reference No.	Date
1	Flying Fish Cove Wharf Upgrade Christmas Island - Geotechnical Report	GHD	61/11569/376	Sep -02
2	Attachment to Viking SeaTech Report - Mooring GA and End Elevation	CORTLAND		Mar-15
3	Attachment to Viking SeaTech Report - Typical Line Configuration	CORTLAND		Apr-15
4	CI Mooring Status Report	Lloyd W Honeycombe		May - Aug 13
5	Christmas Island Moorings 2015 Condition Assessment Report	Undersea Construction LTD		May-Jun 15
6	Patrick Ports: Flying Fish Cove Port Crane Replacement - Options Assessment	GHD	61/30140	Dec-15
7	FFC Outer Mooring System - "B" Mooring Repair	Undersea Construction LTD	CI-FFC-B-10/2016	Nov-16
8	Generic Bulk Carrier at FFC Dynamic Mooring Analysis	Viking SeaTech	VS-04-20450-E-ANA-100	May-15
9	Christmas Island Moorings Replacement Options Paper	DIRD		Dec-16
10	Project Observation Report Christmas Island Port Site Visit	BHAGWAN marine	1200-02	Jun-16
11	Port Information Guide for Ship's Masters	LINX		May-17
12	Christmas Island Ports Operating Handbook including Harbour Master's Directions	Patrick Ports	V2.0_04_16	Apr-16

Reference No.	Document Title	Company	Document Reference No.	Date
13	Smith Point - Details of 5-Point Mooring System - AS LAID	CI Ports	SP-SK004	Jun-09
14	Smith Point - Details of 5-Point Mooring System - List of Component Details	CI Ports	SP-SK005	Jun-09
15	Composition of Verticals And Inshore Spans	CI Ports	06-X15H-1	Nov-16
16	Christmas Island - Flying Fish Cove Outer Mooring System 'A & B' Vertical Exchanges	Undersea Construction LTD		May-17

Appendix D – Safety in Design

HSE040 Safety in Design Risk Assessment

Notes: *Designs with significant quantities of dangerous goods may require detailed risk assessments under Dangerous Goods or Major Hazard legislation
* Most industrial processes will require an industry specific assessment, e.g. HAZOP and/or Quantitative Risk Assessment for facilities that have chemical or high-pressure processes under Dangerous Goods or Major Hazard legislation.

Design Life Cycle:	Investigation and Design	Setup, Construction and Commissioning	Operation	Maintenance	Disposal		**Date:**	8/08/2017	**Revision No:**	A
Job Name:	CI Crane Replacement & Moorings		**Job No:**	61/35581	**Client:**	DIRD	**Design:**	Design of infrastructure to support a new crane to replace the existing.	
People involved in Risk Assessment:	Ben Giles, Sharyn Long, Steve McKean								

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating			Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating			Comments
					C	L	RR					C	L	RR	
Concept design	Investigation and Design	Insufficient information for design			E- Catastrophic	1 - Very Unlikely	Moderate								
	Investigation and Design	Insufficient information for design	Rock geotech capacity not sufficient for use as designed	Include geotech testing works to confirm assumptions	C- Severe	3 - Possible	Moderate	Carry out geotechnical inspection and testing of rock	Contractor	After contractor mobilisation, prior to start of construction works					
	Investigation and Design	Required Pile/toe pin capacity not achieved	Time and Cost	Geotechnical information to be obtained by contractor prior to construction mobilisation. Address as part of Geotech investigations	C- Severe	2 - Unlikely	Low		Contractor/Design Consultant	After contractor mobilisation, prior to start of construction works					
	Setup, Construction and Commissioning	Floating plant	fall overboard, collision with cliff face	standard maritime safety procedures (qualified coxswain/master, life jackets, vessel anchorages)	D - Critical	2 - Unlikely	Moderate		Contractor	Contractor method statement prior to mobilisation					
	Setup, Construction and Commissioning	Interaction with port operations	Communication	The contract will outline communication order which defines authority levels; develop control plan and procedures including emergency response plans	D - Critical	2 - Unlikely	Moderate		Contractor and linx	Contractor method statement prior to mobilisation					

					Initial Risk Rating							Residual Risk Rating			
Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	C	L	RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	C	L	RR	Comments
	Setup, Construction and Commissioning	Floating plant in close proximity to cliff	Collision with cliff, instability due to reflected waves	Mandatory site tender briefing. Contract to be specific on Contractor providing construction methodology for use of floating plant in proximity to cliff, if required. define operating wave conditions, reviews of weather forecasts Consider other methods of working platforms;platform supported from cliff and existing column, consider possible wave loads	D - Critical	2 - Unlikely	Moderate		Contractor/Design Consultant	Contractor method statement prior to mobilisation					
	Setup, Construction and Commissioning	Extreme events, e.g. cyclones	Damage to plant, loss of life	Cyclone management plan as per CI Ports management requirements	D - Critical	2 - Unlikely	Moderate	Construct outside swell and cyclone season	Contractor	Contractor method statement prior to mobilisation					
	Setup, Construction and Commissioning	Demolition	Environmental impact	Contractor to provide method to retrieve concrete waste during demolition, i.e. encapsulation requirements	C- Severe	2 - Unlikely	Low		Contractor	Contractor method statement prior to mobilisation					
	Setup, Construction and Commissioning	Failure of significant equipment during construction at a critical time	Time and cost	Request alternate methodology to be specified by contractor in tender documentation. Contractor to provide details of critical equipment (Age, condition etc.).	D - Critical	2 - Unlikely	Moderate		Contractor/Design Consultant	Contractor method statement prior to mobilisation/tender documentation					
	Setup, Construction and Commissioning	Materials not to Australian / International Standards	Time, Cost and Reputational damage	Details of relevant Australian Standards to be requested in tender documents.	D - Critical	2 - Unlikely	Moderate								
	Operation	proximity to berthing/moored vessels	collision- damage to crane support & ship	ship further from cliff than existing arrangement (crane boom length), moorings designed for the anticipated conditions	D - Critical	2 - Unlikely	Moderate	design fendering to protect the piles	Design Consultant			C- Severe	2 - Unlikely	Low	
		geotechnical failure of piles	collapse of crane	design using available information and conservative assumptions	E- Catastrophic	2 - Unlikely	Significant	carry out geotechnical borehole investigation to confirm design	Contractor's geotechnical engineer / Design Consultant	Geotech testing period, prior to commencement of works		E- Catastrophic	1 - Very Unlikely	Moderate	
		failure of structural support during operation of new crane	collapse of crane	assume reinforcement in arms is as per the information in the calculations in GHD's archive	E- Catastrophic	2 - Unlikely	Significant	breakout and inspection	Design Consultant/Contractor	Geotech testing period, prior to commencement of works		E- Catastrophic	1 - Very Unlikely	Moderate	

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	L	RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating C	L	RR	Comments
				assume rock anchors are as per the information on the drawings in GHD's archive	E-Catastrophic	2 - Unlikely	Significant	expose heads and test anchors	Contractor	Geotech testing period, prior to commencement of works		E-Catastrophic	1 - Very Unlikely	Moderate	
	Maintenance	Access for maintaining/inspecting protective coatings & concrete condition	Working at heights	Design to account for design life, and likely maintenance free approach or develop allowances in design for access where practicable	D - Critical	2 - Unlikely	Moderate		Design Consultant	Detailed design					
	Maintenance	Inappropriate mooring line layout used, or inappropriate winching by moored vessel during normal operations.	Operational / replacement costs due to damage casued to mooring	•Include information in Operations & Maintanance (O&M) Manual that can be used to update the port information document. •Included in documentation for normal operations (Stevedores documentation). •Agencies (RAN, ABF) to review risk assessment on first use of new mooring systems.	C- Severe	2 - Unlikely	Low		Design Consultant/Contractor	As-built documentation					
	Maintenance	Defined operational conditions are exceeded while at mooring.	Operational / replacement costs due to damage casued to mooring	Design will allow for a safety factor. Weather Conditions are monitored by the Port Manager. Linx has a risk control tool for vessels at crane berth.	D - Critical	2 - Unlikely	Moderate		Design Consultant/Contractor/LINX						
	Maintenance	Inability to meet Design life due to lack of maintenance.	Replacement cost expenditure prior to design life	Assessment of existing componentry to achieve design life of new system. Design for effective and achievable maintenance. Spare buoys to allow for maintenance. O&M manuals. Investigate WOL costs and Review of Life cycle costs. Funding for maintenance (SAMP). Additional corrosion allowance on new components.	D - Critical	2 - Unlikely	Moderate		Design Consultant						

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	Initial Risk Rating L	Initial Risk Rating RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating C	Residual Risk Rating L	Residual Risk Rating RR	Comments
	Maintenance	Lack of readily available critical spares on the island.	Inability to use equipment during maintenance	To keep one set of critical spares on Island at all times: Design with critical spares identified and delivered. Include supply of critical spares as part of tender documentation. Ensure Crane specialist availability during DLP for technical support and Warranty items are outlined in tender documents.	D - Critical	2 - Unlikely	Moderate		Design Consultant						

HSE040 Safety in Design Risk Assessment

Notes: *Designs with significant quantities of dangerous goods may require detailed risk assessments under Dangerous Goods or Major Hazard legislation
* Most industrial processes will require an industry specific assessment, e.g. HAZOP and/or Quantitative Risk Assessment for facilities that have chemical or high-pressure processes under Dangerous Goods or Major Hazard legislation.

Design Life Cycle:	Investigation and Design	Setup, Construction and Commissioning	Operation	Maintenance	Disposal		Date:	8/08/2017	Revision No:	A
Job Name:	CI Crane Replacement & Moorings	Job No:	61/35581	Client:	DIRD		Design:	Replacement moorings for maritime operations at Flying Fish Cove and Smith Point.		
People involved in Risk Assessment:	Ben Giles, Sharyn Long, Steve McKean									

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	Initial Risk Rating L	Initial Risk Rating RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating C	Residual Risk Rating L	Residual Risk Rating RR	Comments
Concept design	Investigation and Design	Floating plant	fall overboard, collision with cliff face	standard maritime safety procedures (qualified coxswain/master, life jackets, vessel anchorages)	D - Critical	2 - Unlikely	Moderate		Contractor	Contractor method statement prior to mobilisation					
		Design not sufficient due to incorporation of existing components that are found not to be of sufficient capacity (e.g. shore pins, outer anchorages, existing backstay arms).	Damage to components and/or vessel	Design accounts for new shore pins	C- Severe	2 - Unlikely	Low		Design Consultant	detailed design					
	Setup, Construction and Commissioning	tensions in catenary legs	sudden release of tension	experienced contractor, standard safety procedures for handling anchor lines	D - Critical	2 - Unlikely	Moderate		Contractor	during construction					
	Setup, Construction and Commissioning	shore pin installation	fall from height	design to review pin location to minimise working at height risk	D - Critical	2 - Unlikely	Moderate	fall arrest equipment during installation	Contractor/Design Consultant	detailed design/during construction					
	Operation	structural inadequacy of existing mooring components	loss of restraint of vessel leading to collision with infrastructure or cliff	review of existing inspection reports to determine component condition	C- Severe	3 - Possible	Moderate	where there is significant design uncertainty, e.g. shore pins, these will be replaced and form part of works	Design Consultant	Detailed Design					
	Operation	access to cliff chains from line boat	collision with cliff	large diameter component (Jew's harp/oblong link) for easier connection	C- Severe	3 - Possible	Moderate		Design Consultant	detailed design					not enough space for buoy, consider incorporating a cantilever connection (slewing?) so chain hangs clear of cliff - only applicable at FFC
		access from line boat to mooring buoy	fall from boat/buoy, crush between boat & buoy	design to include safe access and line hook up to bouys, e.g. near horizontal top surface for all new buoys, include mooring hook on new mooring buoys to allow easier rope connection	D - Critical	2 - Unlikely	Moderate		Design Consultant	detailed design					need to check if is possible to access hooks directly from the line boat - may not be practical for removing a line
		load on cliff top shore pin causes failure of limestone overhang	equipment damange, inability to berth vessesl	include support of overhang in design	D - Critical	2 - Unlikely	Moderate		Design Consultant						

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	L	RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating C	L	RR	Comments
		broken mooring line	collision of ship with cliff or loaders	Port checks weather conditions and defines when moorings are operational	C- Severe	3 - Possible	Moderate	update manual with new configurations including requirements for broken mooring line, i.e. run two lines to each outer breasting buoy, ensure port information document is up-to-date	Design Consultant/LINX	O&M / As-built documentation					two lines may have more capacity than the anchorage, but better to drag the anchor than to break the only mooring line
		broken anchor line	collision of ship with cliff or loaders	corrosion/wear allowance to be clear on drawings	C- Severe	3 - Possible	Moderate	Maintenance and inspection programme	Design Consultant/LINX	Detailed design/O&M					
		dragging of anchor	collision of ship with cliff or loaders	Design allows factor of safety of 2 on friction coefficient, Port checks weather conditions and defines when moorings are operational	C- Severe	3 - Possible	Moderate		Design Consultant/LINX	Detailed design/O&M					no redundancy, but failure by dragging the anchor should consist of incremental movement of the ship, recognizable by the crew
		damaged buoy - loss of buoyancy due to impact or deterioration	loss of restraint of vessel leading to collision with infrastructure or cliff	steel buoys with multiple compartments/closed cell foam buoys and review with LINX	C- Severe	2 - Unlikely	Low		Design Consultant/LINX	Detailed design					
		Design does not allow safe access and use of the Buoys (Buoy Jumping)	fall into water	Handrail Pod to be placed in middle of Buoys/ hook for easy access without requiring to buoy jump	C- Severe	2 - Unlikely	Low		Design Consultant	Detailed design					
		Inappropriate mooring line layout used, or inappropriate winching by moored vessel during normal operations.	Damage to components and/or vessel	Include information in Operations & Maintanance (O&M) Manual that can be used to update the port information document. Included in documentation for normal operations (Stevedores documentation). Agencies (RAN, ABF) to review risk assessment on first use of new mooring systems.	C- Severe	2 - Unlikely	Low		Design Consultant/LINX /stakeholders	Detailed design/O&M /Port guide					
	Operation	Defined operational conditions are exceeded while at mooring.	Damage to components and/or vessel	Design will allow for a safety factor. Weather Conditions are monitored by the Port Manager. Linx has a risk control tool for vessels at crane berth.	D - Critical	2 - Unlikely	Moderate		Design Consultant/LINX /stakeholders	Detailed design/O&M /Port guide					

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	Initial Risk Rating L	Initial Risk Rating RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	By When	Decision / Status	Residual Risk Rating C	Residual Risk Rating L	Residual Risk Rating RR	Comments
	Maintenance	Inability to meet Design life due to lack of maintenance.	Cost and restricted operations at port	Assessment of existing componentry to achieve design life of new system. Design for effective and achievable maintenance. Spare buoys to allow for maintenance. O&M manuals. Investigate WOL costs and Review of Life cycle costs. Funding for maintenance (SAMP). Additional corrosion allowance on new components.	**D - Critical**	**2 - Unlikely**	**Moderate**		Design Consultant/LINX	Detailed design/O&M					
		Lack of readily available critical spares on the island.	Cost and restricted operations at port	To keep one set of critical spares on Island at all times: Design with critical spares identified and delivered. Include supply of critical spares as part of tender documentation. Warranty items are outlined in tender documents.	**D - Critical**	**2 - Unlikely**	**Moderate**		Design Consultant	Detailed design/tender documentatio n					

GHD RISK ASSESSMENT MATRIX

Risk Assessment Matrix		CONSEQUENCE				
		MINOR	MAJOR	SEVERE	CRITICAL	CATASTROPHIC
LIKELIHOOD		A	B	C	D	E
ALMOST CERTAIN	5	Low	Moderate	Significant	Extreme	Extreme
LIKELY	4	Low	Low	Moderate	Significant	Extreme
POSSIBLE	3	Negligible	Low	Moderate	Significant	Extreme
UNLIKELY	2	Negligible	Negligible	Low	Moderate	Significant
VERY UNLIKELY	1	Negligible	Negligible	Low	Moderate	Moderate

GHD SAFETY IN DESIGN RISK ASSESSMENT CONSEQUENCE & LIKELIHOOD DESCRIPTORS

SAFE YOU ME GHD
ENVIRONMENT & PEOPLE

GHD CONSEQUENCE DESCRIPTORS

Select the **MOST LIKELY/PROBABLE** consequence descriptor for the information available).

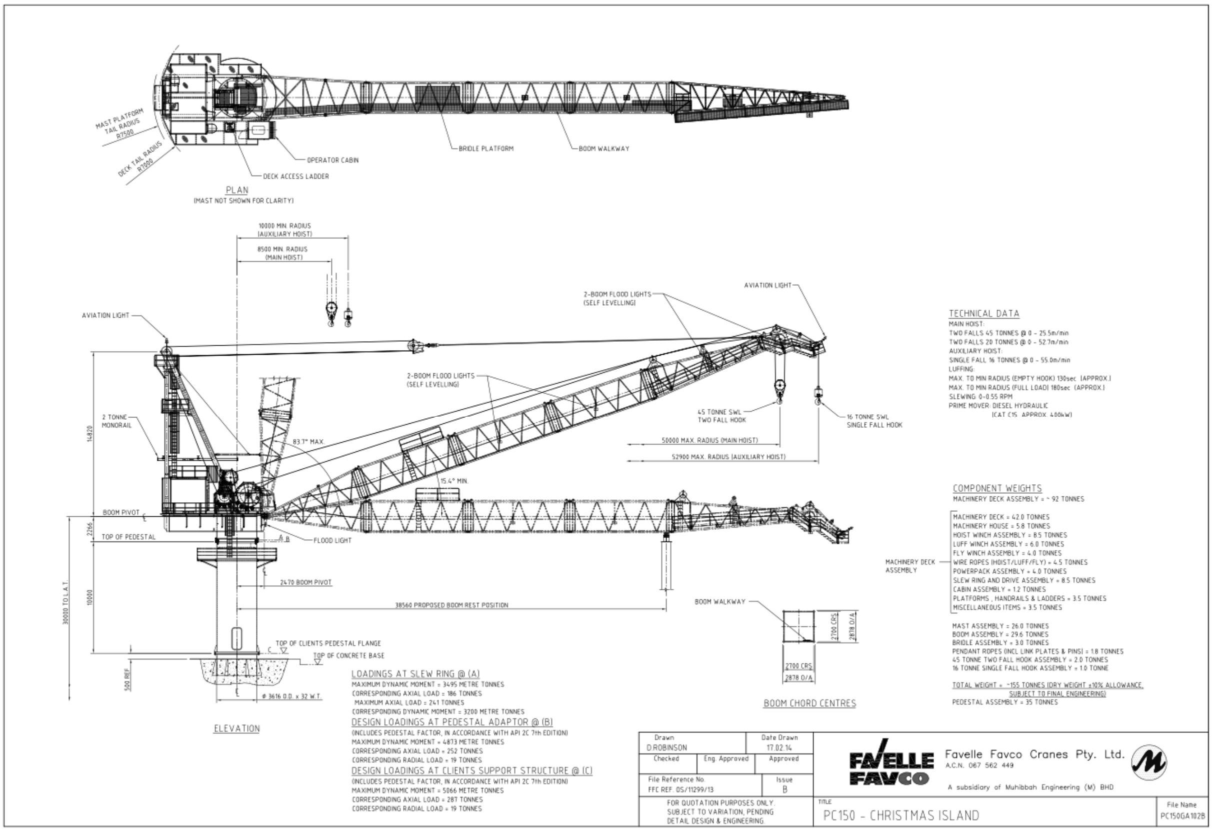
Risk Consequence	Design Consequence Descriptors
E- Catastrophic	Could result in fatality.
D – Critical	Could result in permanent total disability.
C- Severe	Could result in permanent partial disability, injuries or illness that may result in hospitalisation of persons.
B - Major	Could result in injury or illness resulting in one or more lost work days(s)
A – Minor	Could result in injury or illness not resulting in a lost work day.

GHD LIKELIHOOD DESCRIPTORS

Select the best likelihood descriptor for the information available).

Likelihood Descriptor	Design Likelihood Descriptors
5 – Almost Certain	Industry experience suggests design failure is almost certain to occur during the life of the product.
4 – Likely	Industry experience suggests design failure is likely to occur during the life of the product.
3 – Possible	Industry experience suggests design failure is possible some time during the life of the design.
2 – Unlikely	Industry experience suggests design failure is unlikely to occur in the life of design.
1 – Very Unlikely	Industry experience suggests design failure is very unlikely. It can be assumed failure occurrence may not be experienced,

Appendix E – Example of Crane that meets User Requirements



PC150 LOAD CHART
48.95m BOOM
MAIN HOIST: TWO FALLS

RADIUS (METRES)	BOOM ANGLE (DEGREES)	SAFE WORKING LOAD (SWL) IN TONNES					
		MIN. DF = 1.28	SIGNIFICANT WAVE HEIGHT 0.5 METRES MIN. DF = 1.33	SIGNIFICANT WAVE HEIGHT 1.0 METRE MIN. DF = 1.46	SIGNIFICANT WAVE HEIGHT 2.0 METRES MIN. DF = 1.73	SIGNIFICANT WAVE HEIGHT 3.0 METRES MIN. DF = 2.05	SIGNIFICANT WAVE HEIGHT 4.0 METRES MIN. DF = 2.17
		ONBOARD	OFFBOARD	OFFBOARD	OFFBOARD	OFFBOARD	OFFBOARD
8.5	83.7	45.0	45.0	45.0	45.0	45.0	45.0
10.0	81.9	45.0	45.0	45.0	45.0	45.0	45.0
12.0	79.5	45.0	45.0	45.0	45.0	45.0	45.0
14.0	77.1	45.0	45.0	45.0	45.0	45.0	45.0
16.0	74.7	45.0	45.0	45.0	45.0	45.0	45.0
18.0	72.3	45.0	45.0	45.0	45.0	45.0	45.0
20.0	69.8	45.0	45.0	45.0	45.0	45.0	45.0
22.0	67.3	45.0	45.0	45.0	45.0	45.0	45.0
24.0	64.7	45.0	45.0	45.0	45.0	45.0	45.0
26.0	62.1	45.0	45.0	45.0	45.0	45.0	41.9
28.0	59.4	45.0	45.0	45.0	45.0	43.4	38.0
30.0	56.6	45.0	45.0	45.0	45.0	39.6	34.7
32.0	53.7	45.0	45.0	45.0	45.0	36.2	31.7
34.0	50.7	45.0	45.0	45.0	42.0	33.3	29.2
36.0	47.6	45.0	45.0	45.0	38.9	30.8	26.9
36.5	46.8	45.0	45.0	45.0	38.2	30.2	26.4
38.0	44.3	45.0	44.8	44.8	36.1	28.6	25.0
40.0	40.8	41.8	41.4	41.4	33.7	26.6	23.3
42.0	37.1	38.7	38.4	38.4	31.6	24.9	21.9
44.0	32.9	35.9	35.6	35.6	29.7	23.5	20.6
46.0	28.3	33.3	33.2	33.2	28.1	22.3	19.6
48.0	22.7	31.0	30.9	30.9	26.9	21.4	18.9
50.0	15.4	28.9	28.8	28.8	26.1	21.0	18.7

AUXILIARY HOIST : SINGLE FALL
16 TONNES @ ALL RADII AND ALL WAVE CONDITIONS
PERSONNEL LIFT 5 TONNES @ ALL RADII UNDER WIND SPEED NO MORE THAN 10m/s

NOTES
1. THIS CRANE IS INSTALLED ON A WHARF AND IS DESIGNED AND BUILT IN ACCORDANCE WITH API 2C 7th EDITION.
2. DIMENSIONS IN mm.
3. RATED LOAD IS IN TONNES AND IS THE LOAD BELOW THE HOOK.
4. MAIN HOIST IS REEVED IN TWO FALLS
5. AUXILIARY HOIST IS REEVED IN SINGLE FALL.
6. MAX. IN SERVICE HEEL 0.5°, TRIM 0.5°
7. IN SERVICE WIND SPEED 25m/sec
8. ALL LIFTS ARE OPERATED ABOVE SEA LEVEL

Drawn D.ROBINSON | Date Drawn 17.02.14
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FOR QUOTATION PURPOSES ONLY. SUBJECT TO VARIATION, PENDING DETAIL DESIGN & ENGINEERING.
FAVELLE FAVCO — Favelle Favco Cranes Pty. Ltd. A.C.N. 067 562 449 — A subsidiary of Muhibbah Engineering (M) BHD
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File Name PC150GA102B

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