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Proposed Cruise Berthing Facility, Grand Cayman
Environmental and Engineering Consultancy Services
Environmental Statement
Appendix A - Alternatives Assessment

September 15, 2015
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Appendix A - Alternatives Assessment

Prepared for



**Ministry of District Administration Tourism & Transport
and The Port Authority of the Cayman Islands**

Prepared by

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12214.101

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1.0 INTRODUCTION

Chapter 7 of the Environmental Statement provides a summary and discussion of alternatives previously developed/considered by others for a new cruise berthing facility for Grand Cayman, including alternative sites around the island, as well as various concepts in George Town Harbour.

The starting point for the present Environmental Impact Assessment study was the preferred project layout developed in the Concept Study completed by Mott MacDonald (MM, 2013) and incorporated in the Outline Business Case by PricewaterhouseCoopers (PwC, 2013). This concept is presented in Figure 1.1, and includes two finger piers (with four berths for large cruise ships), dredging and land reclamation works, and limited onshore improvements.



Figure 1.1 – OBC Preferred Project Layout (MM, 2013)

At the outset of the EIA study, Baird identified two potential concerns with MM Option 7D, each of which may have an important effect on the overall project layout, functionality/cost and/or environmental impacts, as summarized below:

1. Cut/fill balance - the dredge volume is much greater than the fill volume, therefore requiring disposal of a significant volume of dredged material;

2. Impact on coral - the location of the northern dredged basin overlays a significant area of coral reef.

Based on discussions with the CIG's Project Steering Committee and Environmental Advisory Board, the spatial extent and volume of dredging, and the potential requirement for offshore disposal of excess dredged materials, were deemed to be critical considerations with respect to the anticipated impacts of project construction on the natural environment. As such, the Baird team undertook a comprehensive effort to develop and assess alternative layouts that would meet the functional requirements of the facility, minimize the spatial extent and volume of dredging, achieve a better balance between cut and fill, and reduce the requirement for offshore disposal.

In addition, alternative structure design concepts and construction methods were assessed for major project elements, including dredging and disposal methods and structural design concepts for the piers and shoreline protect structures.

This Appendix documents the development and assessment of alternative layouts, structural design concepts and construction methods undertaken as part of the EIA study.

2.0 DEVELOPMENT AND ASSESSMENT OF ALTERNATIVE LAYOUTS

This Chapter presents the development and assessment of alternative layouts for the proposed cruise berthing facility. In general, the primary objective of this effort was to develop a layout that meets the functional requirements of the facility, minimizes the spatial extent and volume of dredging, achieves a better balance between cut and fill, and reduces the requirement for offshore disposal.

2.1 Criteria for Assessment of Alternative Layouts

The evaluation of project alternatives undertaken for the EIA study included assessment and ranking of the different alternatives under numerous criteria. These criteria were grouped into the following general categories:

- Project functionality;
- Environmental impacts;
- Socio-economic impacts.

The following sections provide additional detail on the criteria used in the comparative assessment within each of these three categories. The estimated cost of construction was also incorporated into the comparative assessment of alternatives.

2.1.1 *Assessment Criteria for Project Functionality*

Assessment criteria for project functionality are summarized below:

- Ease of navigation – options with W pier orientation are best (in line with prevailing winds), with increasing rotation to N or S being progressively less desirable;
- Risk of downtime – options ranked based on results of moored ship response and downtime analyses; options with W-NW pier orientations are best;
- Additional land area – options providing 3 - 5 acres are preferred (< 3 acres is insufficient for landside cruise operations, and > 5 acres is unnecessary);
- Impact on cargo operations – reduced encroachment on existing cargo handling and staging areas, and greater separation of cruise and cargo operations, are better;
- Impact on existing anchorages – options which impact fewer of the existing anchorages (i.e. how many of the four can still be used with ships berthed at the new facility?) are better;
- Impact on tender operations – in general, the project layouts can incorporate a new tender landing facility on the north side (along with the existing tender landing facilities on the south side); options where the tender landing facility is sheltered from NW waves are better;
- Design uncertainty/risk of damage – structures located further offshore (closer to “The Wall”), or located over significant reef areas, are worse.

2.1.2 Assessment Criteria for Environmental Impacts

Assessment criteria for environmental impacts are summarized below:

- Project footprint – in general, a smaller footprint is better;
- Direct impact on reefs – reduced overlay of project footprint on reefs is better;
- Dredge volume – reduced volume is better;
- Disposal volume – reduced volume is better;
- Impact on shoreline (wave exposure) – dredging further from shore is better;
- Impact on coastal processes (sediment transport and water quality) – smaller land reclamation area and reduced dredging are better.

2.1.3 Assessment Criteria for Socio-Economic Impacts

Assessment criteria for socio-economic impacts are summarized below:

- Impact on diving and water sports – closer proximity of berths to dive sites (i.e. Cheeseburger Reef and Eden Rock) is worse; also, increased transit time between dive shops on one side of the project and dive sites on the other side of the project (i.e. from Diver Down to Eden Rock) is worse;
- Visual impact (aesthetics) – in general, development further from shore is better (unless architectural features are used to enhance the land/water interface and increase positive interaction with the marine environment for visitors and locals alike).

2.2 Alternative Project Layout Concepts

The EIA included four stages in the development of alternative project layout concepts, as summarized below:

- Interim Report 1 (May - Jun 2014);
- Interim Report 2 (Jul - Aug 2014);
- Refinement of Alternative Layouts and Discussions with Cruise Lines (Sep - Oct 2014);
- Refinement of Preferred Layout (Nov 2014 - Dec 2015).

These four stages are summarized below; additional detail is provided in Interim Reports 1 and 2, and various status reports submitted to the CIG.

2.2.1 Interim Report 1

IR1 included a preliminary comparative assessment of MM Option 7D and eight alternative layouts that were developed by the Baird team. This information was presented to members of the CIG Steering Committee and Environmental Advisory Board in George Town on July 4. Based on the

ensuing discussions, two options (Options 1C and 1D) were identified as appearing to provide the best balance with respect to project functionality, environmental impacts and construction costs.

In addition to specific feedback on the alternative layout concepts, the CIG provided important feedback provided on other topics of relevance to the ongoing environmental and engineering studies, including the following:

- **Operational downtime** - the CIG noted that it would be useful to compare downtime for the existing tender operation to that for the proposed new berthing facility.
- **Onshore disposal** - the CIG noted that an onshore disposal option should be considered, as the potential revenue stream associated with the sale of excess dredged material (suitably processed for use as general fill or beach fill) is significant; the CIG subsequently provided information on possible onshore locations for processing of excess dredged material.
- **Offshore disposal** - the DoE noted that oceanographic conditions in beyond “The Wall” are complex (i.e. current reversals at depth, thermoclyne, etc.), and suggested consultation with locals who have experience in this area (i.e. submarine operators, deep sea fishermen).
- **Turbidity** - the DoE is very concerned about elevated turbidity levels during construction, and impacts on corals and water sports (i.e. environmental, economic and public perception), and noted that it will be essential for CIG to “manage expectations” in this regard; the DoE also expressed concern about turbidity generated by facility operations (i.e. sediment re-suspension due to vessel arrivals/departures), particularly if the dredging operation leaves fines on the seabed.
- **Construction schedule** - the DoE noted that there are no specific “environmental windows” on construction operations, but that the timing of dredging should take into account typical winter weather patterns (ie. Nor’westers), the hurricane season and the cruise/tourist season.

These comments were considered by the Baird team in the subsequent refinement of alternative layouts, as well as in the modeling and analyses of nearshore hydrodynamics and coastal processes.

2.2.2 Interim Report 2

IR2 included an updated comparative assessment of project alternatives based on consideration of the feedback provided by the CIG on IR1, as well as the results of additional environmental and engineering studies being undertaken as part of the EIA study. In addition to minor “tweaks” to the various layouts, the following layouts significantly refined and/or developed:

- Option 1D – refined layout developed to reduce impact on coral reefs;
- Options 4A and 4B – new layouts developed to minimize dredging and impact on reefs.

Figure 2.1 presents MM Option 7D and the ten different project layout alternatives developed and assessed in IR2, while Table 2.1 provides a tabular comparison of key features of these alternatives. Appendix A.1 presents 11x17 figures of the eleven alternative layouts.

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Table 2.1 – Summary of Project Layout Alternatives (from IR2)

Project Element	MM Option 7D	Option									
		1A	1B	1C	1D	2A	2B	3A	3B	4A	4B
Land Rec Area (acres)	3.5	2.0	4.0	4.5	3.4	5.1	7.7	11.2	12.0	3.5	3.5
Dredge Area (acres)	37.4	36.6	36.7	31.5	34.2	37.7	27.4	26.7	28.9	18.7	3.3
Dredge Volume (K cy)	728	706	705	557	619	733	528	506	564	282	20
Fill Volume (K cy)	120	38	91	119	95	152	348	511	516	129	102
Disposal Volume (K cy)	608	668	613	437	524	580	180	(6)*	48	153	(82)*
Revetment Length/ Exposed (lf)	1,360	715	800	1,455	1,065	1,520	2,220	1,960	2,070	1,590	1,250
Revetment Length/ Sheltered (lf)	0	0	0	0	320	0	0	800	565	0	0
Pier Orientation	NW	W	W	W	W	NW	NW	NW	NW	SW, NNW	SSW, NNW

**Options 3A and 4B require imported material to fill land reclamation area*

These layouts were developed using pier and dredging geometries based on preliminary assumptions regarding design vessels and other functional requirements. In general, these layouts assumed a constraint of 50 ft for the maximum water depth at the outer end of the piers and dolphins (this is considered to be a practical/cost-effective design and construction).

An updated comparative assessment of these alternatives, incorporating feedback provided by the CIG on the evaluation/ranking criteria, as well as the results available from the ongoing environment and engineering studies, was undertaken in order to inform/guide the identification/development of a preferred alternative for implementation. Table 2.2 presents a summary of key advantages and disadvantages of each option with respect to key functional, environmental and socio-economic considerations, while Table 2.3 presents the results of the Baird team's comparative evaluation and ranking of the alternatives.

Table 2.2 – Project Layout Alternatives – Summary of Key Advantages and Disadvantages (from IR2)

Layout	Advantages	Disadvantages
MM Option 7D	<ul style="list-style-type: none"> Suitable land reclamation area (3.5 acres) Berths aligned with prevailing waves 	<ul style="list-style-type: none"> Significant impact on coral reefs to north Large dredge + disposal volumes Deep dredging close to shore Visual impact on properties to north
1A	<ul style="list-style-type: none"> Berths aligned with prevailing winds Reduced impact on coral reefs to north Potential for increased land/water interaction 	<ul style="list-style-type: none"> Insufficient land reclamation area (2.0 acres) Large dredge + disposal volumes Deep dredging close to shore Encroachment on cargo area Visual impact on properties to north Encroachment on private shorelines to north
1B	<ul style="list-style-type: none"> Suitable land reclamation area (4.0 acres) Berths aligned with prevailing winds Reduced impact on coral reefs to north Potential for increased land/water interaction 	<ul style="list-style-type: none"> Large dredge + disposal volumes Deep dredging close to shore Encroachment on cargo area Visual impact on properties to north Encroachment on private shorelines to north
1C	<ul style="list-style-type: none"> Suitable land reclamation area (4.5 acres) Berths aligned with prevailing winds Reduced impact on coral reefs to north Reduced dredge + disposal volumes Potential for increased land/water interaction 	<ul style="list-style-type: none"> Visual impact on properties to north Encroachment on private shorelines to north
1D	<ul style="list-style-type: none"> Suitable land reclamation area (3.4 acres) Berths aligned with prevailing winds Reduced impact on coral reefs to north Reduced dredge + disposal volumes 	<ul style="list-style-type: none"> Visual impact on properties to north
2A	<ul style="list-style-type: none"> Suitable land reclamation area (5.1 acres) Berths aligned with prevailing waves 	<ul style="list-style-type: none"> Significant impact on coral reefs to north Large dredge + disposal volumes Deep dredging close to shore Visual impact on properties to north Encroachment on private shorelines to north
2B	<ul style="list-style-type: none"> Berths aligned with prevailing waves Reduced dredge + disposal volumes 	<ul style="list-style-type: none"> Excessive land reclamation area (7.7 acres) Significant impact on coral reefs to north Deep dredging close to shore Visual impact on properties to north
3A	<ul style="list-style-type: none"> Berths aligned with prevailing waves Achieves cut/fill balance (no disposal) Possible sheltered basin for tenders, pleasure craft, etc. 	<ul style="list-style-type: none"> Excessive land reclamation area (11.2 acres) Significant impact on coral reefs to north Deep dredging close to shore Large visual impacts on properties to north Potential stagnant water area adjacent to shoreline
3B	<ul style="list-style-type: none"> Berths aligned with prevailing waves Achieves cut/fill balance (no disposal) Possible sheltered basin for tenders, pleasure craft, etc. 	<ul style="list-style-type: none"> Excessive land reclamation area (12 acres) Significant impact on coral reefs to north Deep dredging close to shore Large visual impacts on properties to north Potential stagnant water area adjacent to shoreline
4A	<ul style="list-style-type: none"> Suitable land reclamation area (3.5 acres) Reduced dredging volume Smallest impact on coral reefs to north Reduced disposal volume Potential for fifth berth for smaller cruise ships (LOA ~ 500-600 ft) 	<ul style="list-style-type: none"> Berths are oblique to prevailing wind and waves Outer end of north pier is deeper and more exposed Significant distance from north pier berths to shore Increased transit time from dive shops to reefs on opposite side of project
4B	<ul style="list-style-type: none"> Suitable land reclamation area (3.5 acres) Smallest dredging volume Smallest impact on coral reefs to north No disposal 	<ul style="list-style-type: none"> Berths are oblique to prevailing wind and waves Outer end of north pier is deeper and more exposed Significant distance from all berths to shore Fill material required for land reclamation area Increased transit time from dive shops to reefs on opposite side of project

The comparative evaluation and ranking of the alternatives presented in Table 2.3 (following page), incorporated revised evaluation criteria based on input received from the CIG, as well as weighting factors for each evaluation criteria. The ranking process is summarized below:

- A relative ranking is applied to each option under each criteria, with the best alternative(s) ranked 1, and the worst alternative(s) ranked 5 (i.e. smaller numbers are better);
- The weighting factors are then applied, and the resulting rankings are totalled to provide a weighted “score” under Functional Performance, Environmental Impacts and Socio-Economic Impacts, as well as a total score.

It is noted that certain elements of this comparative evaluation and ranking are subjective, and may vary depending on one’s perspective of the various issues. For example, the outcome of the evaluation process could be different if one ranked the options differently under certain evaluation criteria, and/or if one applied different weighting factors to the evaluation criteria.

Referring to Table 2.3 (following page), the total score for each alternative can be compared to the best possible score of 1 (i.e. the option would be ranked best for all criteria), or the worst possible score of 5 (i.e. the option would be ranked worst for all criteria). The range in estimated costs presented in Table 2.3 for each alternative reflects uncertainties in key design and cost considerations, in particular the structural design concept for the shoreline protection structure around the land reclamation area, and the unit costs associated with aggregates, quarried stone, concrete and steel.

Table 2.3 – Project Layout Alternatives – Comparative Evaluation and Ranking (from IR2)

Evaluation Criteria	Weight	Layout Option																					
		MM Option 7D		1A		1B		1C		1D		2A		2B		3A		3B		4A		4B	
Estimated Cost (Ct\$ Millions) (optimistic/pessimistic estimates)		116.5 / 137.2		110.0 / 120.9		110.3 / 122.5		109.7 / 131.9		108.6 / 127.6		117.7 / 140.9		115.1 / 149.0		115.9 / 151.8		116.6 / 152.4		123.5 / 147.8		126.4 / 145.5	
Functional Performance																							
Ease of Navigation	10%	3	0.300	1	0.100	1	0.100	1	0.100	1	0.100	3	0.300	3	0.300	3	0.300	3	0.300	5	0.500	5	0.500
Risk of Downtime	15%	2	0.300	1	0.150	1	0.150	1	0.150	1	0.150	2	0.300	2	0.300	2	0.300	2	0.300	5	0.750	5	0.750
Additional Land Area	5%	1	0.050	5	0.250	1	0.050	1	0.050	2	0.100	1	0.050	3	0.150	5	0.250	5	0.250	1	0.050	1	0.050
Impact on Cargo Operations	5%	2	0.100	5	0.250	5	0.250	5	0.250	4	0.200	2	0.100	1	0.050	1	0.050	1	0.050	1	0.050	1	0.050
Impact on Existing Anchorages	1.25%	3	0.038	1	0.013	1	0.013	1	0.013	1	0.013	3	0.038	3	0.038	3	0.038	3	0.038	5	0.063	5	0.063
Impact on Tender Operations (sheltered water)	2.5%	5	0.125	5	0.125	5	0.125	5	0.125	5	0.125	5	0.125	5	0.125	1	0.025	3	0.075	5	0.125	5	0.125
Design Uncertainty	1.25%	3	0.038	1	0.013	1	0.013	1	0.013	1	0.013	3	0.038	3	0.038	3	0.038	3	0.038	5	0.063	5	0.063
Sub-total - Functional	40.0%		0.95		0.90		0.70		0.70		0.70		0.95		1.00		1.00		1.05		1.60		1.60
Environmental Impact																							
Total Project Footprint	7.5%	5	0.375	4	0.3	5	0.375	4	0.3	3	0.225	5	0.375	4	0.3	4	0.3	5	0.375	2	0.15	1	0.075
Direct Impact on Reefs	15%	4	0.600	3	0.450	3	0.450	3	0.450	2	0.300	5	0.750	5	0.750	5	0.750	5	0.750	1	0.150	1	0.150
Dredge Volume	7.5%	5	0.375	5	0.375	4	0.300	3	0.225	3	0.225	5	0.375	3	0.225	3	0.225	3	0.225	2	0.150	1	0.075
Disposal Volume	5.0%	5	0.250	5	0.250	4	0.200	3	0.150	4	0.200	4	0.200	2	0.100	1	0.050	1	0.050	2	0.100	2	0.100
Shoreline Impact (wave exposure)	5.0%	5	0.250	5	0.250	4	0.200	2	0.100	2	0.100	5	0.250	3	0.150	3	0.150	3	0.150	1	0.050	1	0.050
Coastal Processes (sediment transport & water quality)	5.0%	3	0.150	3	0.150	4	0.200	3	0.150	2	0.100	5	0.250	3	0.150	5	0.250	4	0.200	1	0.050	1	0.050
Subtotal - Environmental	45.0%		2.00		1.78		1.73		1.38		1.15		2.20		1.68		1.73		1.75		0.65		0.50
Socio-Economic Impact																							
Loss of Reef/Dive Sites	10.0%	5	0.500	3	0.300	3	0.300	3	0.300	2	0.200	5	0.500	5	0.500	5	0.500	5	0.500	1	0.100	1	0.100
Diving and Water Sports (increased transit time)	2.5%	3	0.075	1	0.025	1	0.025	1	0.025	1	0.025	3	0.075	3	0.075	3	0.075	3	0.075	5	0.125	5	0.125
Visual Impact (aesthetics)	2.5%	3	0.075	3	0.075	5	0.125	3	0.075	2	0.050	4	0.100	3	0.075	5	0.125	5	0.125	1	0.025	1	0.025
Subtotal - Socio-Economic	15.0%		0.65		0.40		0.45		0.40		0.28		0.68		0.65		0.70		0.70		0.25		0.25
Overall Rank (excluding cost)	100%		3.60		3.08		2.88		2.48		2.13		3.83		3.33		3.43		3.50		2.50		2.35
For overall rank, 1 represents best possible score (i.e. best ranking under every criteria) while 5 represents the worst possible score (i.e. worst ranking under every criteria)																							

The IR2 comparative evaluation and ranking presented above identified Option 1D as the “best” overall option (i.e. lowest total score), followed closely by Options 4B, 1C and 4A. Options 1B, 1C and 1D were ranked “best” under the functional performance category, while Option 4B was ranked “best” under the environmental impact category, primarily due to reduced dredging volumes and reduced direct impacts on reefs. Options 4A, 4B and 1D were ranked “best” under the socio-economic impact category.

Based on the comparative assessment presented above, Options 1D and 4B were identified as the top two alternatives. From this point forward, Option 1D will be referred to as Concept A, while Option 4B will be referred to as Concept B. Concepts A and B are shown in Figure 2.2.

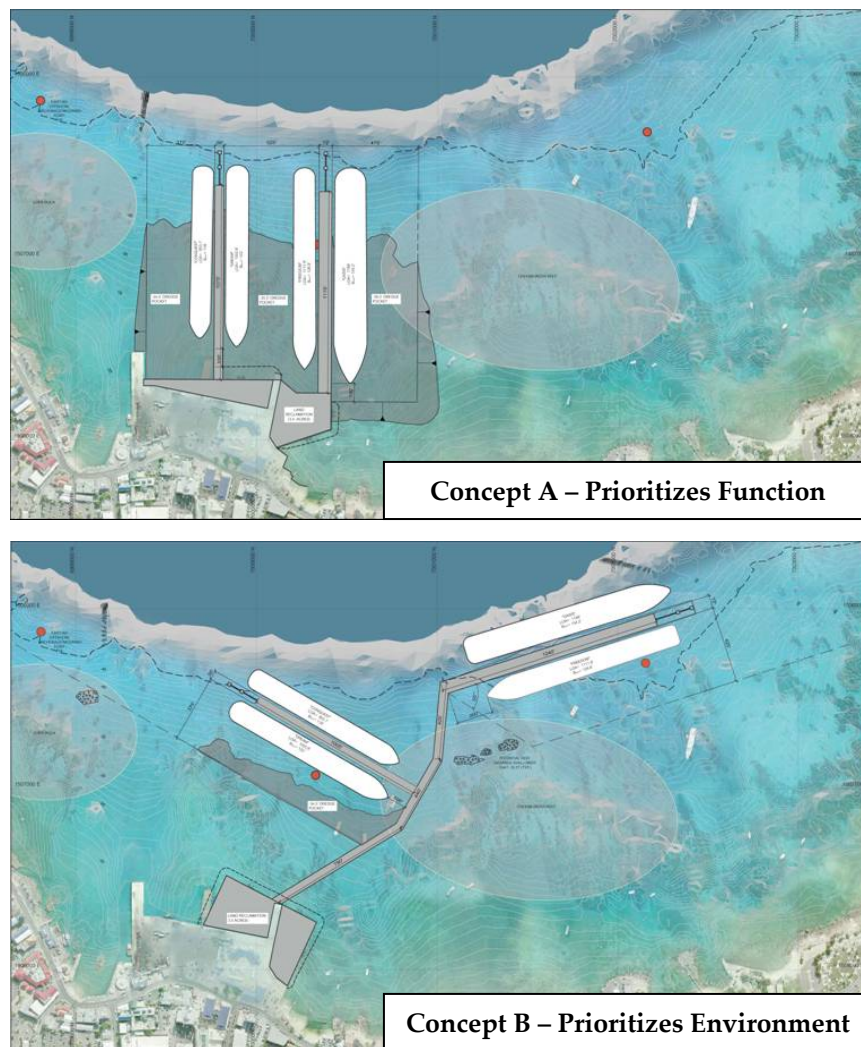


Figure 2.2 – Top Two Alternatives Identified in IR2

Interim Report 2, including Concepts A and B, was presented to the Steering Committee and Environmental Advisory Board in late August, 2014. This information was subsequently presented to Ministers of Tourism, Environment, Planning and Finance, as well as the PACI Board of

Directors, in early September, 2014. It was agreed that these concept layouts should be presented to the cruise lines in order to solicit their feedback.

2.2.3 Refinement of Alternative Layouts and Discussions with Cruise Lines

As noted above, the assessment of alternative project layouts completed in IR2 led to the identification of two very different concepts for consideration by the CIG. Concept A was optimized with respect to functional performance and capital cost, but will have significant negative impacts on the environment, in particular the nearshore reef system in George Town Harbour. Concept B prioritizes the environment, and minimizes the negative environmental impacts to the greatest extent possible, but, as a result, has reduced functionality and a higher cost.

Following the completion of IR2, and prior to meeting with the cruise lines, the project team developed refined versions of Concepts A and B. The general objective of this exercise was to “tweak” the layouts to reduce environmental impacts, improve functional performance and/or reduce capital cost. In addition, the project team developed a third alternative (Concept C), the objective of which was to reflect a “middle ground” with respect to the key issues of functional performance and environmental impacts. Figures 2.3, 2.4 and 2.5 present the three concepts as presented to the cruise lines in late October, 2014. Appendix A.2 presents 11x17 figures of these three layouts.

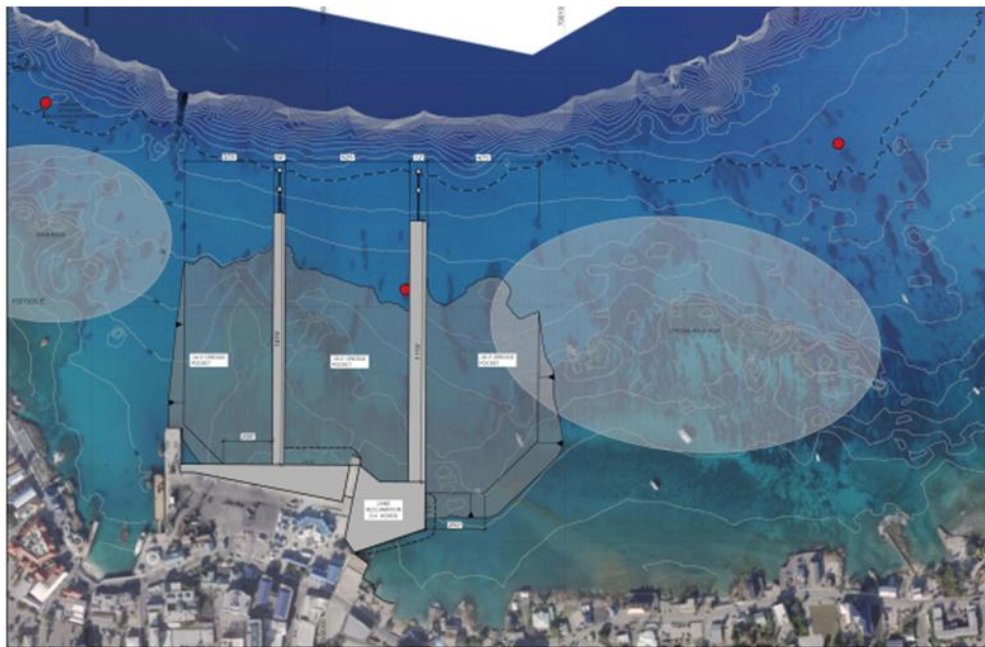


Figure 2.3 – Concept A/Refined – Prioritizes Function



Figure 2.4 – Concept B/Refined – Prioritizes Environment

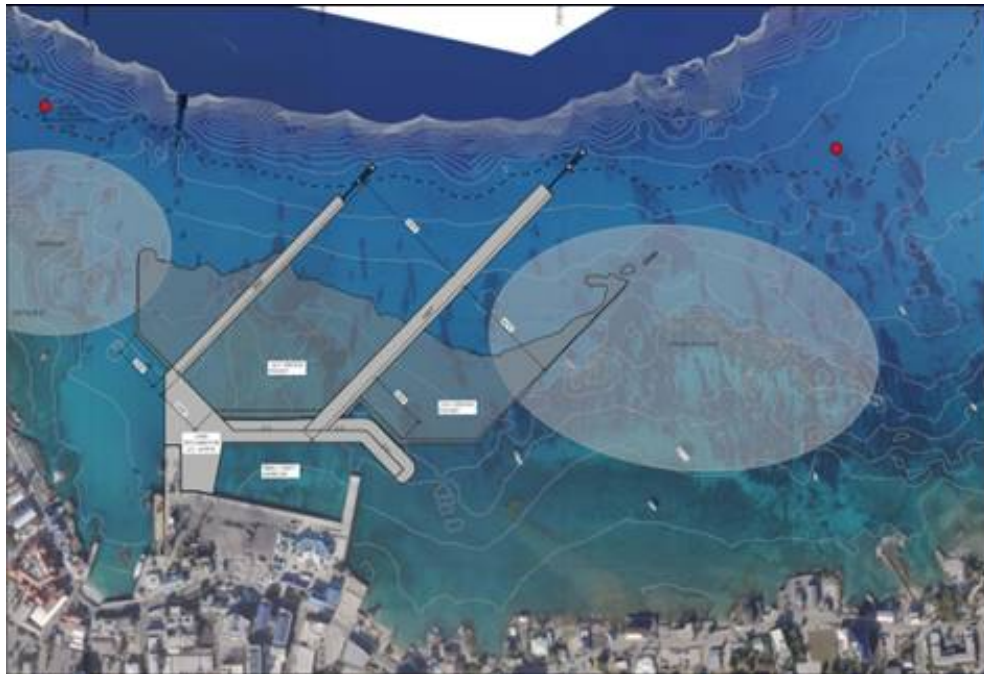


Figure 2.5 – Concept C – Middle Ground

Key advantages of Concept C include a reduction in dredging footprint and volume as compared to Concept A, and an improvement in functional performance as compared to Concept B, thereby representing the “middle ground” referenced above. In addition, Concept C includes an extension to the south cargo dock (to increase the capacity of the cargo operation), and the possible incorporation of a small craft harbour basin as an optional feature (in place of a larger land reclamation area).

Table 2.4 provides a high level comparison of Concepts A, B and C, including key factors related to environmental issues (as described earlier), as well as the key functional issue of operational downtime due to inclement weather conditions. This latter issue is predominantly a function of the pier orientation, and may have important implications on the financial viability of the project.

Table 2.4 – High Level Comparison of Concepts A, B and C

Description	Existing Conditions	Concept A	Concept B	Concept C
Key Environmental Considerations				
Total Project Footprint (acres)	n/a	33	9	29
Direct Impact on Reefs (acres)	n/a	18	4	9
Dredging Volume (yd³)	n/a	552,000	20,000	216,500
Disposal Volume (yd³)	n/a	457,000	None	81,500
Key Functional Considerations				
Estimated Annual Downtime (refer to Appendix M for additional information)	Tender Operation (PACI data, 4 yrs)		Cruise Berthing Facility (numerical model database, 34 yrs)	
	Missed Calls	Spotts Landing	Pier Azimuth 270°	Pier Azimuth 210° / 321° Pier Azimuth 315°
Average Downtime (%)	~ 4%	~ 4%	~ 0.5%	~ 4% / ~ 1%
Range in Downtime (%)	2 - 6%	2 - 9%	0 - 2.5%	1 - 10% / 0 - 4%

Baird and the CIG made technical presentations to four cruise lines in late October 2014, including Carnival, Royal Caribbean, Norwegian and Disney. In general, all four cruise lines indicated that they are very interested in the development of a cruise berthing facility at Grand Cayman. Technical feedback received from the cruise lines was clear and consistent, with all four expressing a strong preference for Concept C. It was also noted that additional land area would be preferable to a small craft harbor basin. Concept A was deemed less favourable by the cruise lines due to the westerly pier orientation. While all four cruise lines acknowledged the environmental advantages of Concept B, this layout was deemed unacceptable due to the fact that the two piers would be neither functionally nor commercially equivalent. In addition, the significant length of the North pier in Concept B was deemed to be unacceptable due to the excessive ship to shore distance. The strong resistance by the cruise lines to Concept B was regardless of its higher costs, which would be a further impediment to its acceptance.

Following the meetings with the cruise lines, the CIG selected Concept C as the preferred layout for the proposed cruise berthing facility. The selection of Concept C was based on the following key considerations:

- Strong negative reaction to Concept B by the cruise lines;
- Good balance between functional and cost considerations;
- Reduced environmental impact as compared to Concept A, as well as the OBC layout developed by MM (2013) and PwC (2013).

2.2.4 Refinement of Preferred Layout

Based on the feedback from the cruise lines, as well as additional input from the Steering Committee, Concept C was further developed and refined to provide the following features:

- North pier and dredge pocket increased to provide two *Oasis* class berths;
- Larger land reclamation area (through elimination of small craft harbour basin);
- Improved/expanded cargo facilities (extension to South cargo dock, new RO/RO ramp).

The final concept layout is shown in Figure 2.7. An 11x17 figure of this layout is provided in Appendix A.3.

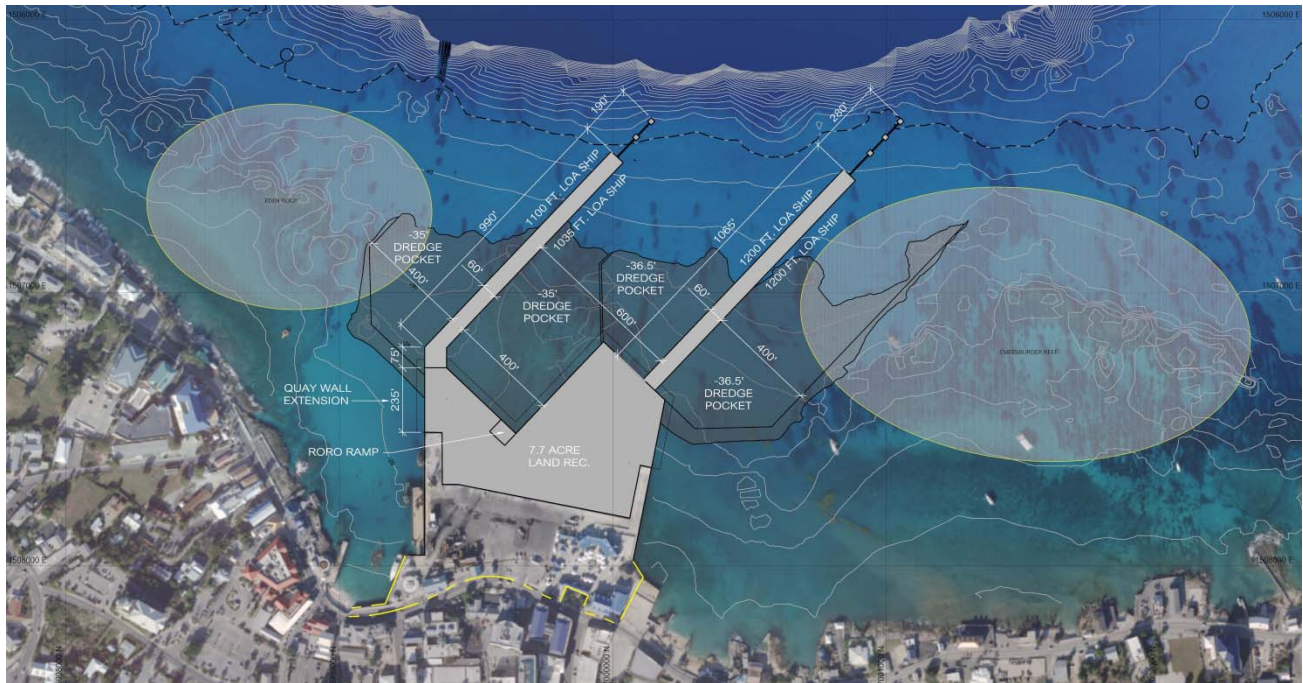


Figure 2.7 - Final Concept Layout

3.0 DISCUSSION OF DREDGING AND DISPOSAL OPTIONS

3.1 Dredging Method

Based on a review of available information regarding the subsurface conditions, it is anticipated that either hydraulic or mechanical dredging may be feasible for this project. Hydraulic dredging would likely be undertaken using a large cutter suction dredge (CSD), while mechanical dredging would likely be undertaken using a large backhoe dredge (BHD). Typically, a CSD would pump the dredged material (as a slurry) through a floating pipeline to the land reclamation or disposal area, whereas a BHD would discharge the dredged material into a barge for transfer to the land reclamation or disposal area.

Figures 3.1 and 3.2 (on the following page) present photographs of these two types of dredges. A summary of key advantages and disadvantages of the two dredging approaches is provided below.

Hydraulic Dredging (CSD)

- Faster operation (~ 4 to 6 week duration expected), but generates large volumes of water (dredge slurry may be 5-25% solids, depending on the nature of the material being dredged);
- Disposal area must be of sufficient size to allow solids to fall out of suspension and to limit suspended sediment concentration (SSC) in discharge and resulting turbidity plume;
- Small land reclamation areas are problematic (i.e. high SSC in discharge);
- Primary source of turbidity is the discharge (turbidity at dredge cutterhead is limited);
- Downtime (due to inclement weather, environmental constraints) is very expensive;
- Land reclamation area may require “ground improvements” prior to development.

Mechanical Dredging (BHD)

- Slower operation (~ 12 to 16 week duration expected), but is relatively easy to control;
- Operation does not generate large volumes of water;
- Primary source of turbidity is at the dredge (i.e. as the bucket is pulled up through the water column);
- Increased duration of dredging as compared to CSD (generally by a factor of three), but not necessarily higher cost.

In either case, the absence of a comprehensive subsurface investigation at the project site represents an uncertainty with respect to size of dredge required, and the associated cost of dredging. This uncertainty will be included in the dredger’s cost. In addition, the disposal method and environmental controls (i.e. allowable turbidity) will have an impact on the methodology and cost of dredging for this project; these items are discussed below. Finally, the availability of a suitable dredge may dictate the approach proposed by a particular contractor.

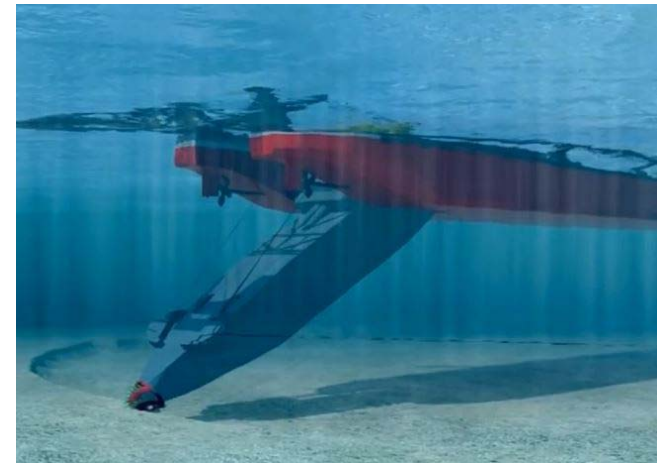
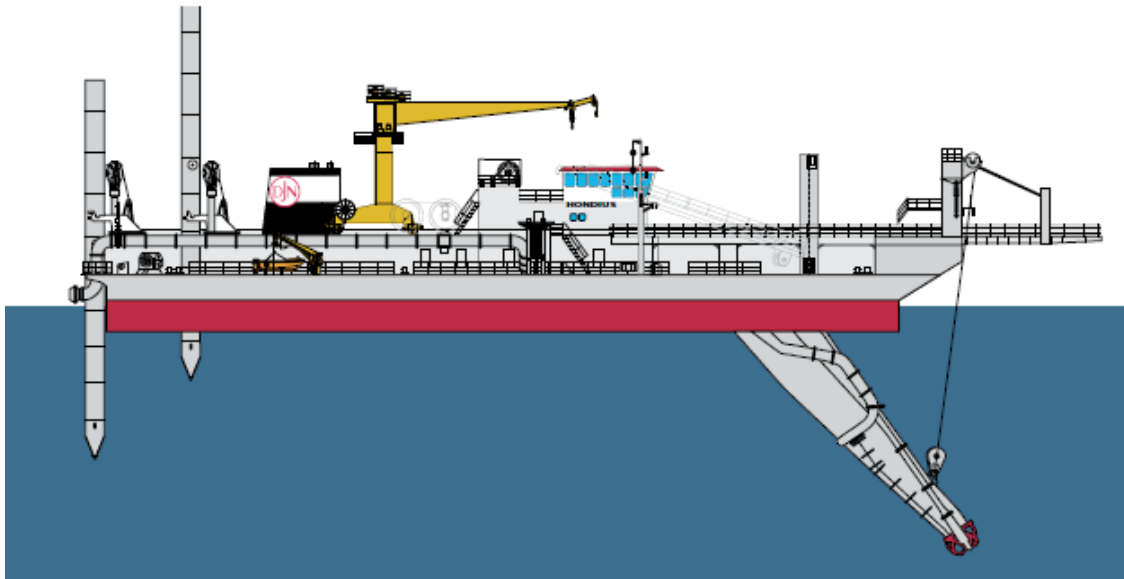


Figure 3.1 Cutter Suction Dredge (images courtesy of Jan de Nul)



Figure 3.2 Backhoe Dredge (images courtesy of Van Oord)

3.2 Disposal Options

As noted earlier (refer to Table 2.1), most of the project layouts that were considered during the EIA result in excess dredged material, as the dredge volume is greater than the fill volume. For the final concept layout, the excess volume is estimated to be in the order of 174,000 cubic yards. Various options may be feasible for the disposal of excess dredged material, including disposal/dumping at an offshore location or disposal at an onshore location.

The Baird team completed empirical and numerical model simulations to assess the anticipated characteristics of turbidity plumes associated with dredging and land reclamation works under the following scenarios:

- Turbidity generated by dredge (CSD or BHD);
- Turbidity generated by overflow of CSD process water from land reclamation area;
- Turbidity generated by offshore disposal (pipeline or barge) beyond “The Wall”.

These results are summarized in Chapter 11 and Appendix D.2 of the Environmental Statement.

Onshore disposal would be more complicated and expensive than offshore disposal, but could provide the opportunity to process the material for sale as fill in the future. The processing operation would require the construction of a containment dike to allow settlement and dewatering of the sediment. In addition, a suitable discharge path for the discharge water to return to the sea would be required. For a hydraulic dredging operation, the slurry would be pumped via a large diameter pipeline to the disposal site (with various challenges associated with road crossings, etc.). For a mechanical dredging operation, multiple handling of the dredged material (dredge bucket → barge → shore → truck → processing site) would be required, with significant truck traffic through George Town.

It is Baird’s opinion that onshore disposal is more likely to be a viable option with a mechanical dredging operation (BHD) than with a hydraulic dredging operation (CSD), as dealing with the huge volumes of water generated by a CSD would be a significant challenge. The CIG has identified several sites in reasonable proximity to the project site that may be suitable for onshore processing of excess dredged materials. Should the CIG wish to pursue this option, additional investigations will be required to select a suitable onshore disposal site.

3.3 Environmental Controls

Regardless of the methods adopted, the dredging and land reclamation operations will generate suspended sediment and turbidity plumes. The nature, extent/severity and duration of turbidity plumes will be dependent upon numerous factors, including the dredging operation, the nature of the material being dredged and prevailing metocean conditions (i.e. wind, waves and currents). As noted above, the Baird team completed empirical and numerical model simulations to assess the

anticipated characteristics of turbidity plumes associated with dredging, land reclamation and offshore disposal operations; this information is presented in Chapter 11 and Appendix D.2 of the Environmental Statement.

Regardless of the dredging method and equipment adopted, best practice generally involves the use of real time monitoring and adaptive management techniques to minimize turbidity and sedimentation associated with dredging, reclamation and disposal operations. Specific recommendations for mitigation measures have been developed, including the definition of allowable turbidity and sedimentation thresholds, as discussed in the ES (Section 16.6.3) and Appendix J.1 (Section 7.1.3). Should the CIG decide to proceed with the project, selected mitigation measures and monitoring protocols will be defined in an Environmental Management Plan (EMP), which will be included in the tender documents for the project. Should monitoring detect turbidity or sedimentation levels in excess of the specified threshold conditions, the Contractor would be required to adjust, modify or cease operations.

3.4 Summary

Originally (prior to discussions with dredgers), it was anticipated that hydraulic dredging (using a cutter suction dredge) and offshore disposal (using spider barges with no overflow) would be the most likely approach to be adopted by the contractor for this project. Based on subsequent discussions with several dredgers, it appears that mechanical dredging (using a large backhoe dredge) and offshore disposal (using barges) is more likely. The key advantages of a mechanical dredging approach for this project are as follows:

- Mechanical dredging is likely to be more cost-effective given the relatively small quantity of dredging and the relatively small land reclamation area;
- Mechanical dredging is easier to control, and is expected to generate less turbidity, than hydraulic dredging.

Considering this information, a mechanical dredging approach appears to be the preferred approach for this project. Prior to dredging (and regardless of the dredging method adopted for the project), a containment dike should be constructed around the outer perimeter of the new land reclamation area in order to limit the loss of dredged materials (and associated turbidity and sedimentation in George Town Harbour) during the land reclamation (filling) operation.

Regarding excess dredged materials, the preferred method for offshore disposal is a barge operation with no overflow. The disposal site should be located in large water depths (> 1000 ft) at least 1.25 miles west (offshore) of the project site in order to limit the impacts of the disposal operation on the nearshore environment.

Onshore disposal may be a possibility, particularly with a mechanical dredging operation, as it seems likely that the excess dredged materials could be processed for use as fill in other projects; the sale of these materials could offset, to some degree, the increased costs with this approach.

Finally, it is Baird's opinion that the dredging approach should not be specified in the tender documents, as this would limit the options available to tenderers, potentially resulting in fewer tenderers and increased costs; however, onshore disposal could be included as an option in the tender documents. Regardless of the approach to dredging and disposal, the Contractor will be required to meet the requirements of the EMP, including the specified turbidity and sedimentation limits.

4.0 DISCUSSION OF STRUCTURAL DESIGN OPTIONS

4.1 Shore Protection around Land Reclamation Area

The exposed perimeter of the land reclamation area requires protection against the severe loads associated with wave action, including hurricanes. In addition, in order to limit the extent of turbidity and sedimentation plumes during construction, the placement of dredged materials should be done within a contained area. From a practical perspective, this containment structure should be incorporated into the final shore protection structure.

There are a number of structural design concepts that could be considered for the shore protection structure, with the selection of the preferred concept dependent upon functional, constructability and cost considerations. Possible concepts include the following:

- Vertical bulkhead wall: steel sheet pile (ssp), combi-wall, pipe pile wall, caissons;
- Sloping rubble mound: quarried armour stone, concrete armour units over rock fill;
- Hybrid wall/revetment: ssp wall fronted by submerged armour stone slope.

From a functional perspective, the primary advantage of a vertical structure is spatial efficiency; specifically, a vertical structure allows one to reduce the overall project footprint and/or increase the land reclamation area as compared to a sloping structure. The primary disadvantages of a vertical structure, as compared to a sloping structure, are increased wave reflection and increased wave overtopping. The hybrid structure attempts to find a “middle ground” between these two concepts.

Considering the total height of the structure (approximately 45 ft from the top of the land reclamation area to the dredge depth), and based on prior experience with similar structures, it is Baird’s opinion that the most likely design concepts are a pipe pile wall (with a tie-back system) or a sloping revetment protected by large armour stones or concrete armour units. Given the spatial constraints at the project site (i.e. proximity to adjacent reefs and “The Wall”), the final project layout assumes a vertical wall around the exposed perimeter of the land reclamation area. This structure would be comprised of the primary (pipe pile) wall, a tie-back system (tie rods connecting the primary wall to a secondary anchor wall) and structural fill. The first stage in the construction of this structure would be the construction of a rockfill dike to provide containment of the dredged materials as they are placed within the land reclamation area; this structure would be part of the structural fill required for the permanent shore protection structure.

Wave reflections from a vertical wall can create challenging navigation conditions for small craft in close proximity to the wall, as presently exist with tenders at the Royal Watler pier during Nor’Westers. However, wave reflections will not have a significant impact on moored cruise ships due to the size of these vessels. In addition, small craft will generally not be navigating to the immediate west of the new land reclamation area, where the wave reflections will be greatest.

Based on this information, wave reflections from a vertical wall are not considered to be a significant concern for the proposed cruise berthing facility.

Wave overtopping, and the risk of site flooding, will be an important design consideration regardless of whether the shore protection structure consists of a vertical wall, a sloping rubble mound or a hybrid structure. In order to mitigate this issue, specifically to reduce the risk of site flooding due to wave overtopping during severe storms, a wave/flood barrier is recommended. The concept design for the project includes a wave/flood barrier, as discussed in Chapter 13 and Appendix F of the Environmental Statement. It is noted that the specific layout, cross-section and design of the wave/flood barrier will be dependent upon the final design of the shoreline protection structure, as well as the site grading/drainage plan and the landside master plan.

As noted above, a sloping rubble mound revetment may be viable alternative for the shore protection structure. The core of this structure could function as the containment dike, with filter and armour layers subsequently added to provide protection against hurricane waves. Although not critical to the design or performance of the proposed facility, this type of structure would result in reduced wave reflections and wave overtopping as compared to a vertical wall structure. On the other hand, the use of a sloping rubble mound revetment would significantly reduce the land area available for cruise and cargo operations and landside development. A preliminary assessment of the footprint of a revetment structure (1.5:1 slope, plus toe and crest berms, gives a total structure width of approximately 100 ft) indicates that it would reduce the land reclamation area from 7.7 acres to approximately 4.7 acres.

4.2 Piers and Dolphins

The proposed project includes two piers measuring (nominally) 1,000 ft long by 60 ft wide (with a deck elevation of approximately +10 ft), each with two or three separate dolphin structures to allow berthing and mooring of the largest cruise ships. Various structural design concepts may be possible for these structures, including the following:

- Continuous gravity based structures (i.e. parallel steel sheet pile (ssp) walls, ssp cells, caissons, etc.);
- Intermittent gravity based structures with spans;
- Pile-supported deck;
- Mono-piles (dolphins only).

Continuous gravity based structures are considered to be unacceptable for environmental reasons, as they will have a significant impact on nearshore hydrodynamics and coastal processes; however, the other options may all be viable at this site.

It is noted that the majority of cruise ship piers in the Caribbean region consist of open, pile-supported deck structures; hence, this is considered to be the most likely design concept for this project; as such, this concept has been assumed in the development of an opinion of probable

construction cost for the project. Mono-piles may be a viable alternative to a piled structure for the dolphins.

4.3 Floating Pier Concept

During the course of the present study, an independent proponent proposed a floating pier concept for the cruise berthing facility (refer to www.cruisetogeorgetown.com), as illustrated in Figure 4.1. At the request of the CIG, Baird undertook a preliminary technical review of the floating pier concept.

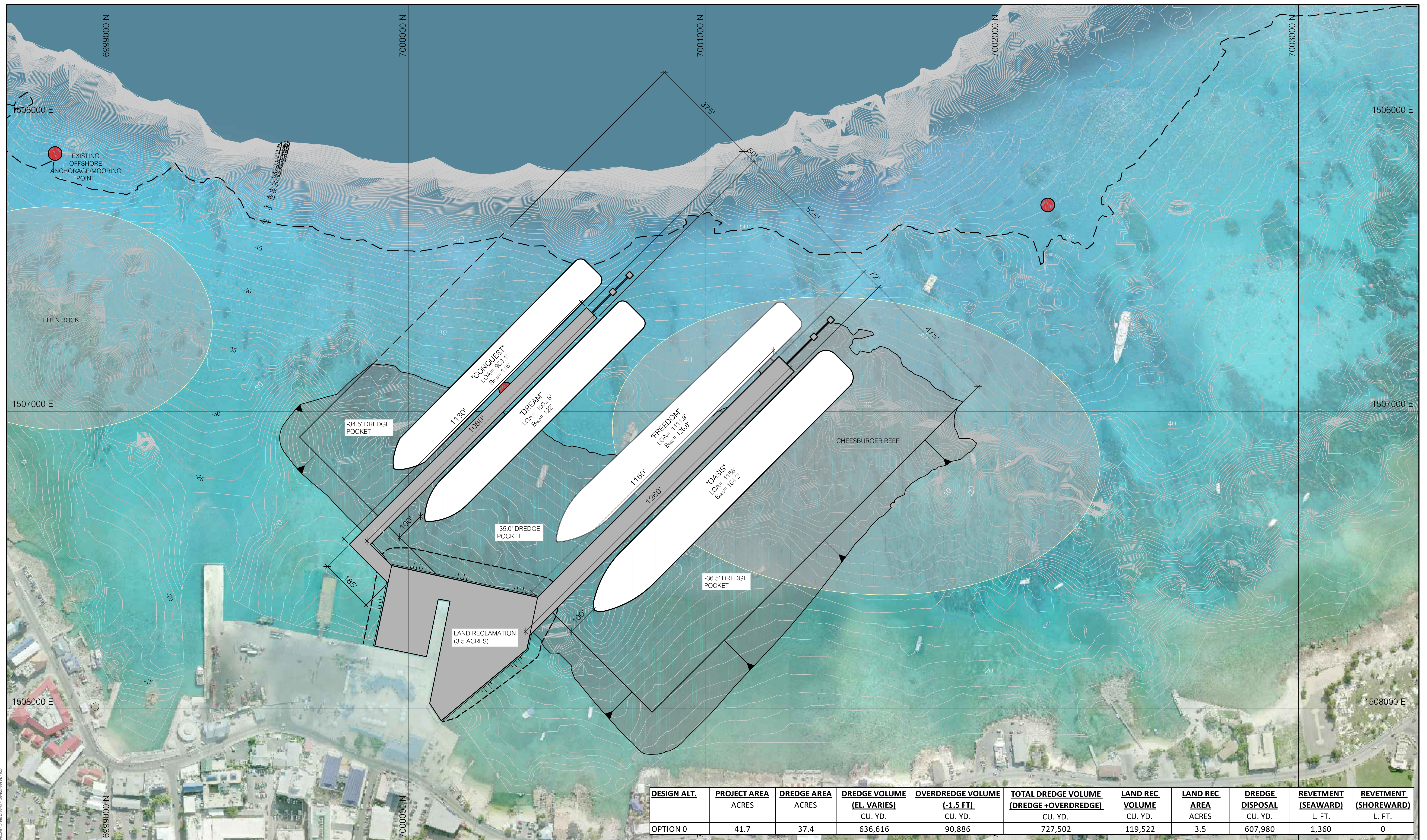


Figure 4.1 – Schematic Rendering of Floating Pier Concept

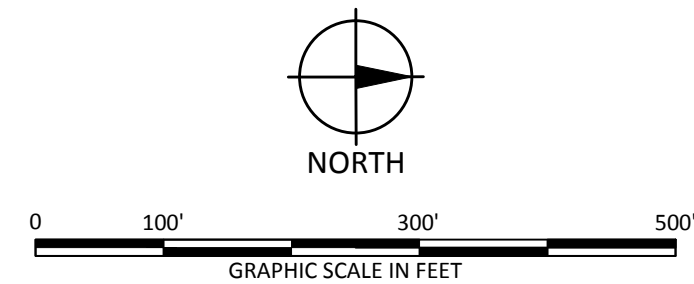
(Source: www.caymancompass.com (31Oct14))

Baird's review (which is included in Appendix A.4) concluded that the proposed floating pier concept provides a number of potential significant benefits as compared to a fixed pier concept, including reduced environmental impacts (i.e. elimination of dredging, and reduced damage to corals), as well as a reduced duration of on-site construction activities and the associated reduction in impacts (disruption) to existing businesses and operations. However, Baird identified a number of significant technical challenges to address in the design of such a facility that do not appear to have been addressed by the proponent. In particular, Baird questions the ability to develop a sufficiently robust mooring system given the significant water depths into which the floating piers would extend. Further, the proposed concept is unique, and without precedent, for a site exposed to hurricane waves. Based upon the information available at this time regarding the floating pier concept, Baird questions whether the concept is technically feasible.

APPENDIX A.1
PROJECT LAYOUT ALTERNATIVES FROM INTERIM REPORT 2



<u>DESIGN ALT.</u>	<u>PROJECT AREA</u> ACRES	<u>DREDGE AREA</u> ACRES	<u>DREDGE VOLUME</u> <u>(EL. VARIES)</u> CU. YD.	<u>OVERDREDGE VOLUME</u> <u>(-1.5 FT)</u> CU. YD.	<u>TOTAL DREDGE VOLUME</u> <u>(DREDGE +OVERDREDGE)</u> CU. YD.	<u>LAND REC</u> <u>VOLUME</u> CU. YD.	<u>LAND REC</u> <u>AREA</u> ACRES	<u>DREDGE</u> <u>DISPOSAL</u> CU. YD.	<u>REVTMENT</u> <u>(SEAWARD)</u> L. FT.	<u>REVTMENT</u> <u>(SHOREWARD)</u> L. FT.
OPTION 0	41.7	37.4	636,616	90,886	727,502	119,522	3.5	607,980	1,360	0

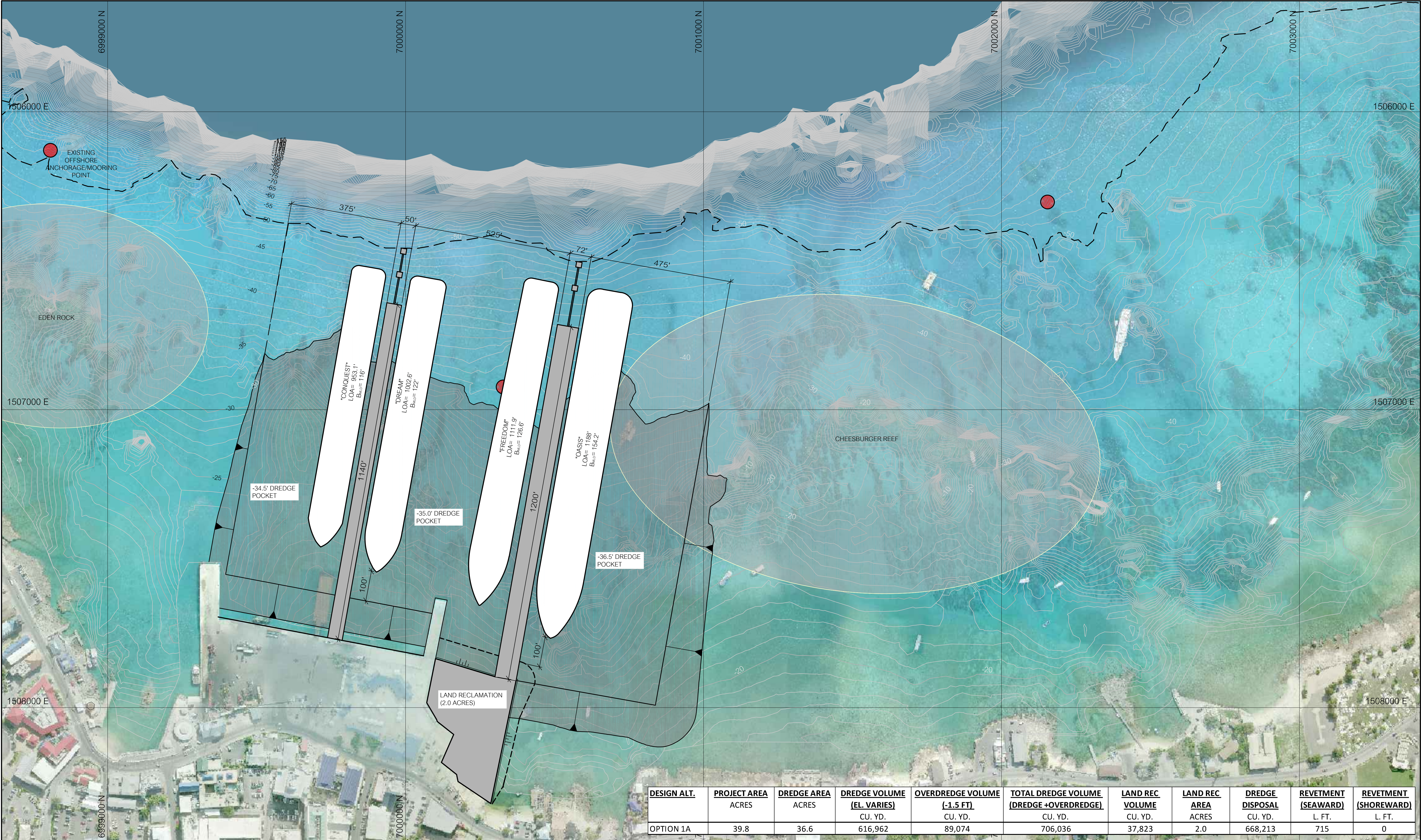
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Baird
W.F. Baird & Associates
Coastal Engineers Ltd.

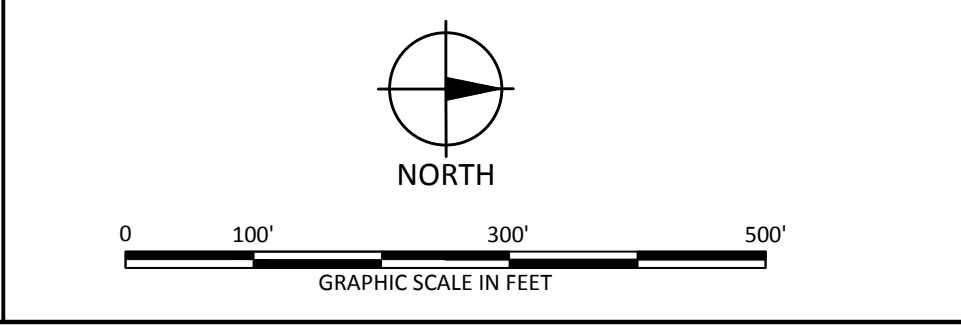
CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 0

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			2014/07/30



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE + OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVETMENT (SEAWARD) L. FT.	REVETMENT (SHOREWARD) L. FT.
OPTION 1A	39.8	36.6	616,962	89,074	706,036	37,823	2.0	668,213	715	0



REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT (B) PRELIMINARY	(C) PERMIT (D) CONTRACT DOCUMENT	(E) CONSTRUCTION DOCUMENT (F) AS-BUILT	(G) CANCELLED (H) OTHER		



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Coastal Engineers Ltd.

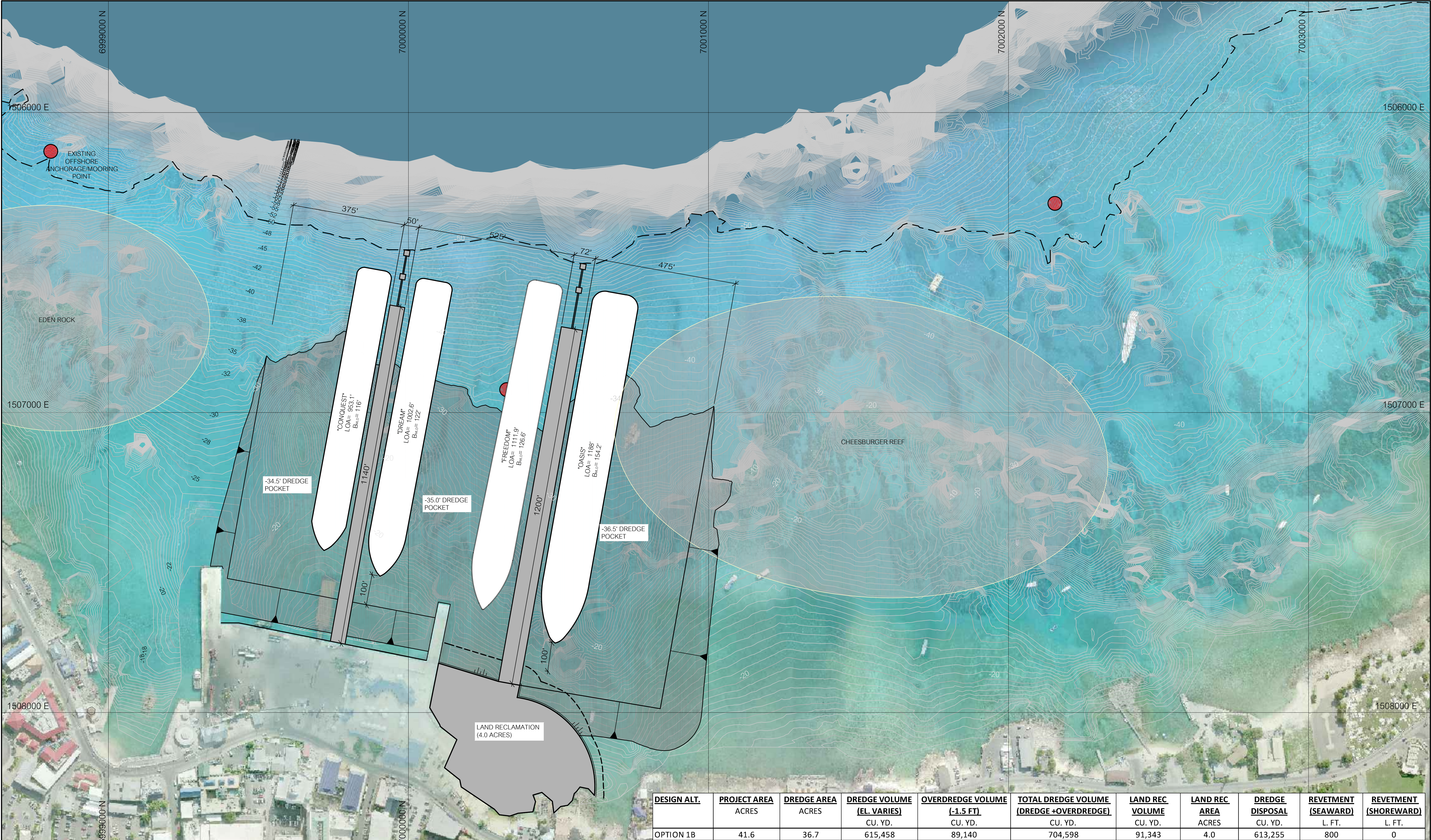
IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 1A

DRAWING NUMBER: 12214 — SKT —

REV. DATE: 2014/07/30



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GRAPHIC SCALE IN FEET

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
	(B) PRELIMINARY	(D) CONTRACT DOCUMENT	(F) AS-BUILT	(H) OTHER		

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Coastal Engineers Ltd.

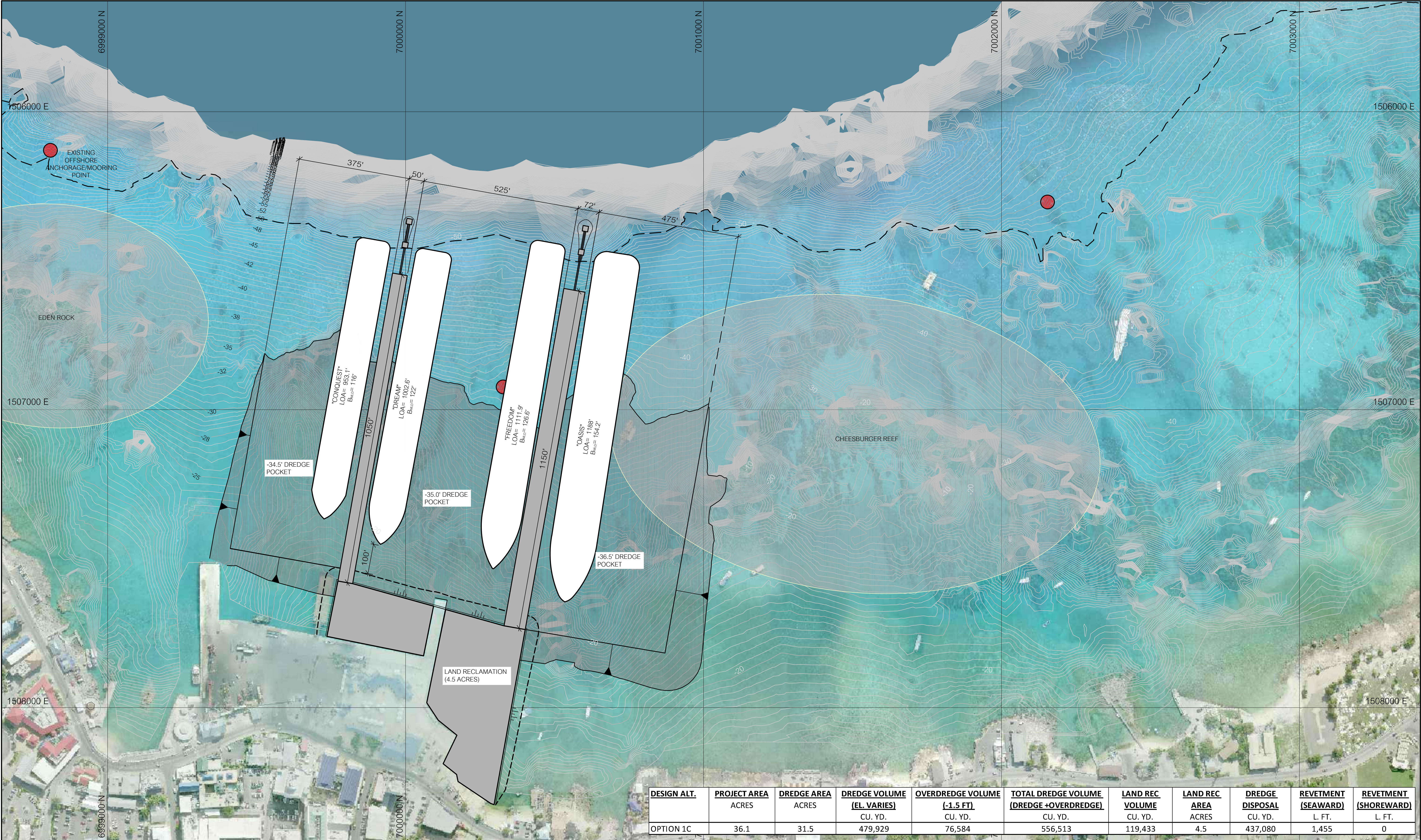
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CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 1B

DRAWING NUMBER: 12214 — SKT —

REV. DATE: 2014/07/30



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE +OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVETMENT (SEAWARD) L. FT.	REVETMENT (SHOREWARD) L. FT.
OPTION 1C	36.1	31.5	479,929	76,584	556,513	119,433	4.5	437,080	1,455	0

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT (B) PRELIMINARY	(C) PERMIT (D) CONTRACT DOCUMENT	(E) CONSTRUCTION DOCUMENT (F) AS-BUILT	(G) CANCELLED	(H) OTHER	

PREPARED BY:
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W.F. Baird & Associates
Coastal Engineers Ltd.

IN ASSOCIATION WITH:

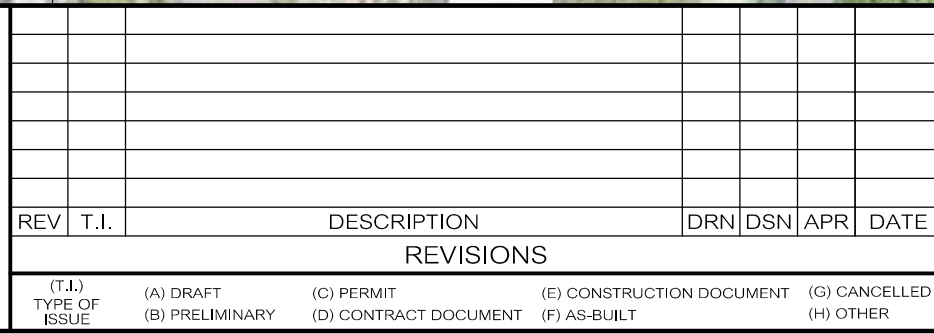
CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 1C

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REV. DATE: 2014/07/30

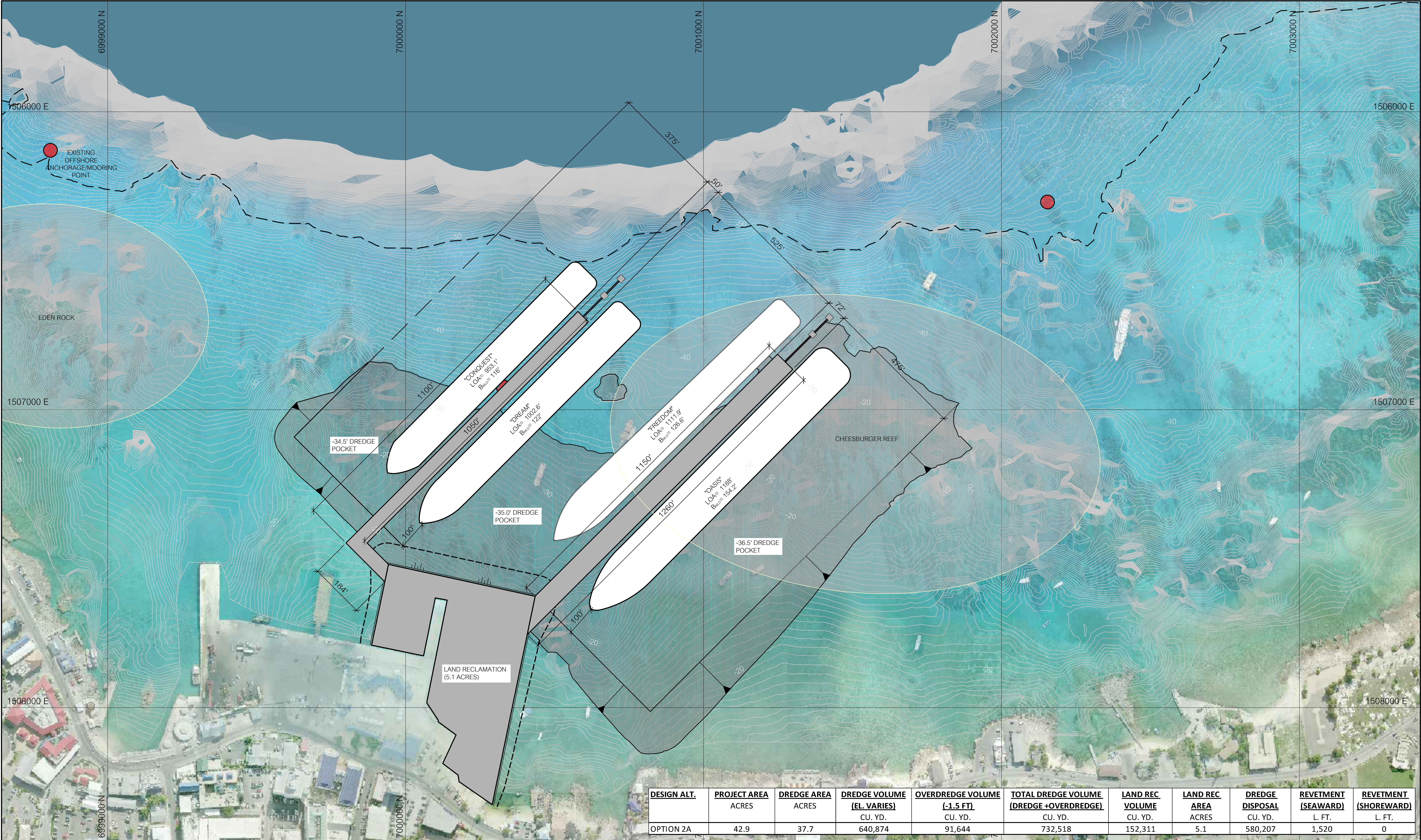
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OPTION 1D

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DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE + OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVETMENT (SEAWARD) L. FT.	REVETMENT (SHOREWARD) L. FT.
OPTION 2A	42.9	37.7	640,874	91,644	732,518	152,311	5.1	580,207	1,520	0

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(1) TYPE OF ISSUE	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
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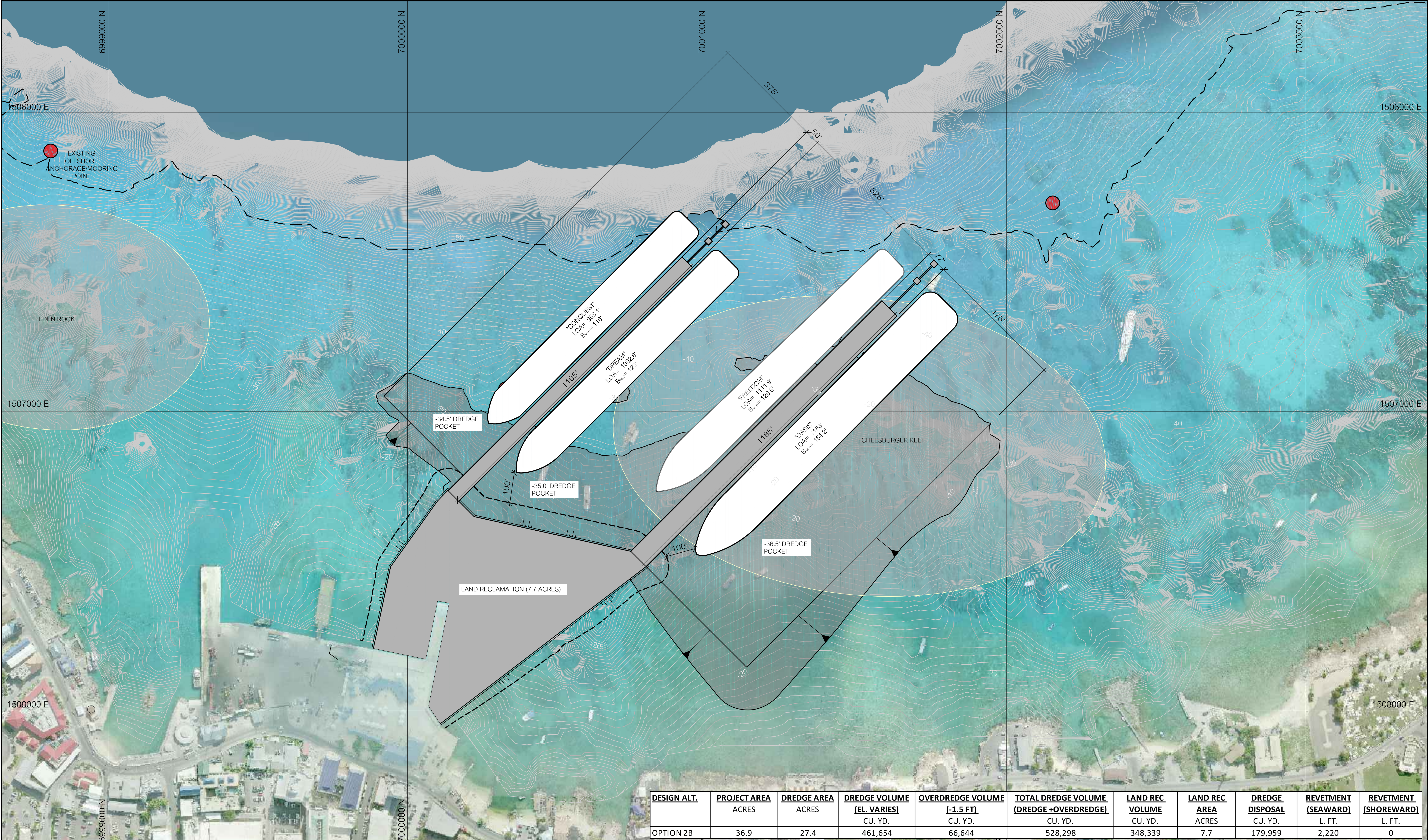
PREPARED BY:
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Coastal Engineers Ltd.

IN ASSOCIATION WITH:

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OPTION 2A

DRAWING NUMBER: 12214 — SKT — REV. DATE: 2014/07/30



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE +OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVTMENT (SEAWARD) L. FT.	REVTMENT (SHOREWARD) L. FT.
OPTION 2B	36.9	27.4	461,654	66,644	528,298	348,339	7.7	179,959	2,220	0

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
	(B) PRELIMINARY	(D) CONTRACT DOCUMENT	(F) AS-BUILT	(H) OTHER		

PREPARED BY:
Baird
W.F. Baird & Associates
Coastal Engineers Ltd.

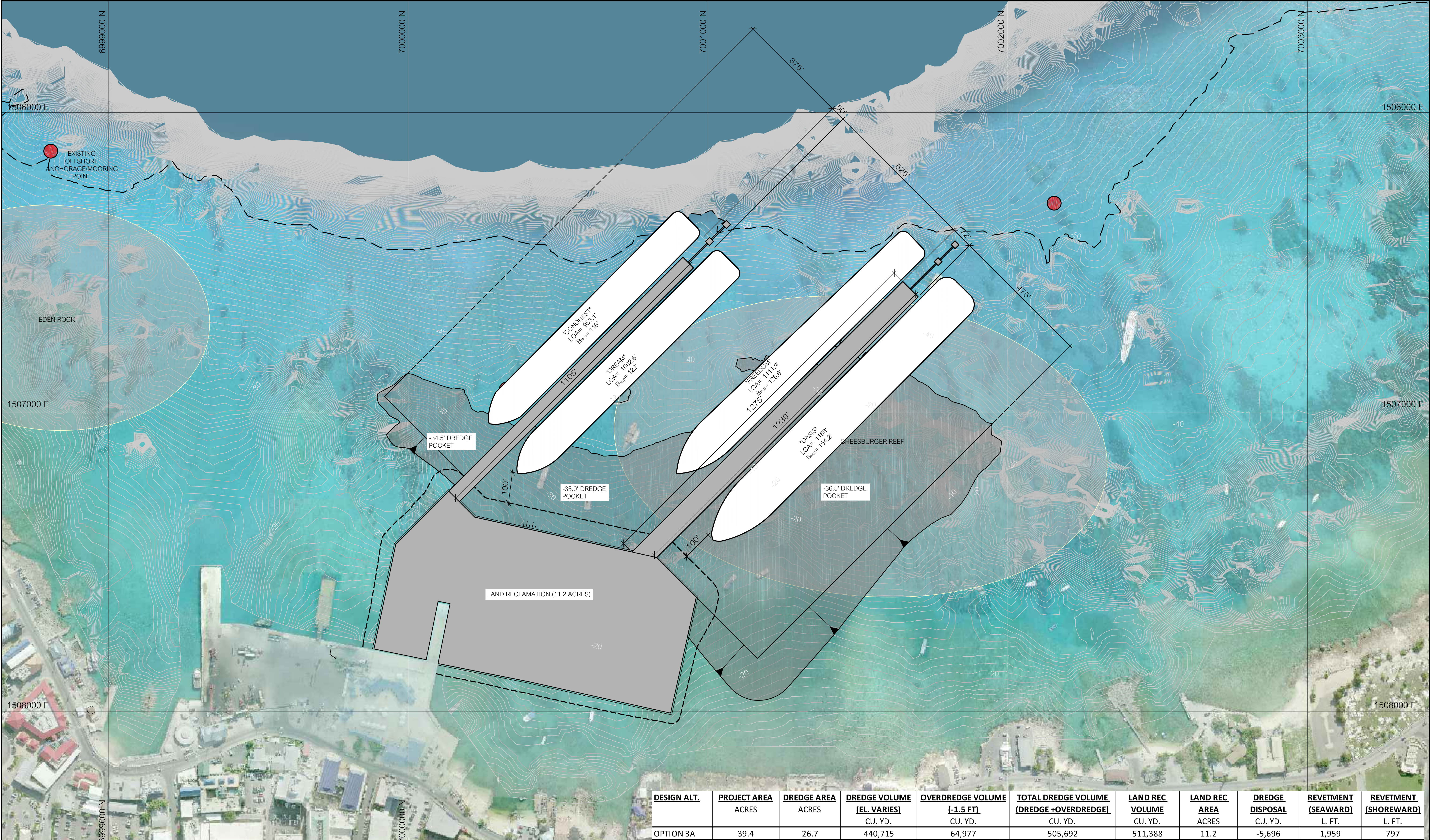
IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 2B

DRAWING NUMBER: 12214 — SKT —

REV. DATE: 2014/07/30



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE + OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVTMENT (SEAWARD) L. FT.	REVTMENT (SHOREWARD) L. FT.
OPTION 3A	39.4	26.7	440,715	64,977	505,692	511,388	11.2	-5,696	1,959	797

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
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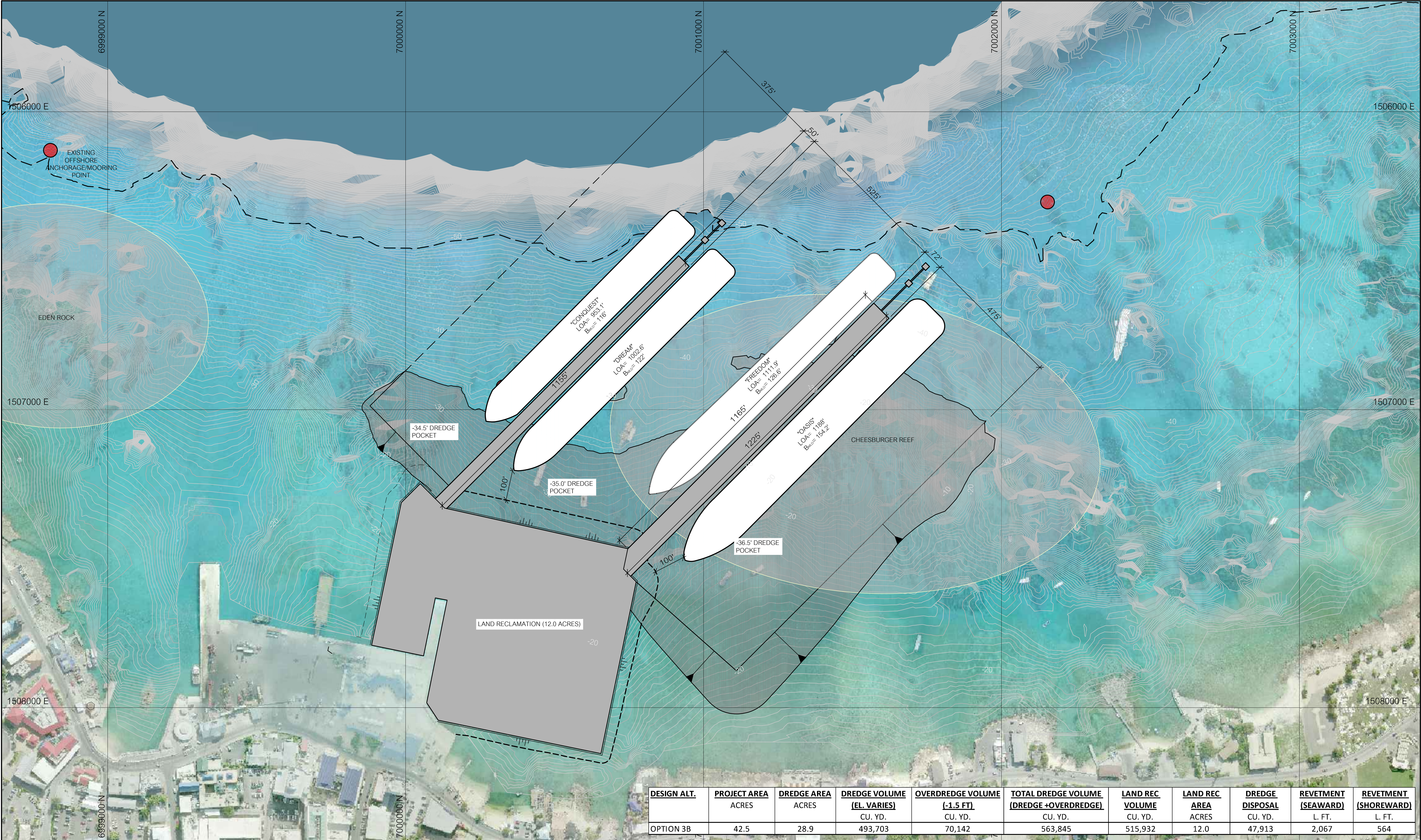
PREPARED BY:
Baird
W.F. Baird & Associates
Coastal Engineers Ltd.

IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 3A

DRAWING NUMBER: 12214 — SKT — REV. DATE: 2014/07/30



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE + OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVETMENT (SEAWARD) L. FT.	REVETMENT (SHOREWARD) L. FT.
OPTION 3B	42.5	28.9	493,703	70,142	563,845	515,932	12.0	47,913	2,067	564

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
	(B) PRELIMINARY	(D) CONTRACT DOCUMENT	(F) AS-BUILT	(H) OTHER		

PREPARED BY:
Baird
W.F. Baird & Associates
Coastal Engineers Ltd.

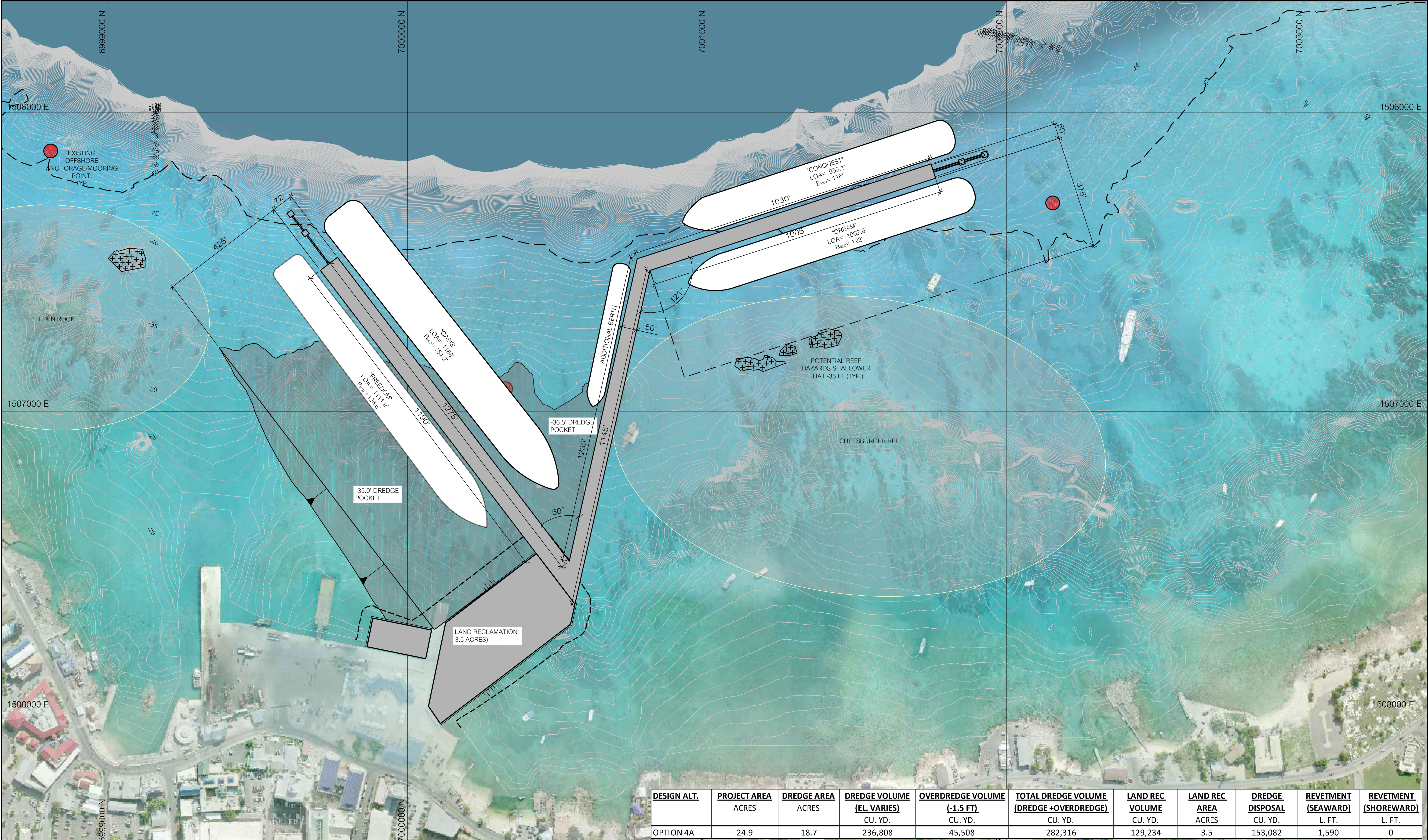
IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 3B

DRAWING NUMBER: 12214 — SKT —

REV. DATE: 2014/07/30



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE + OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVETMENT (SEAWARD) L. FT.	REVETMENT (SHOREWARD) L. FT.
OPTION 4A	24.9	18.7	236,808	45,508	282,316	129,234	3.5	153,082	1,590	0

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT (B) PRELIMINARY	(C) PERMIT (D) CONTRACT DOCUMENT	(E) CONSTRUCTION DOCUMENT (F) AS-BUILT	(G) CANCELLED	(H) OTHER	

PREPARED BY:
Baird
W.F. Baird & Associates
Coastal Engineers Ltd.

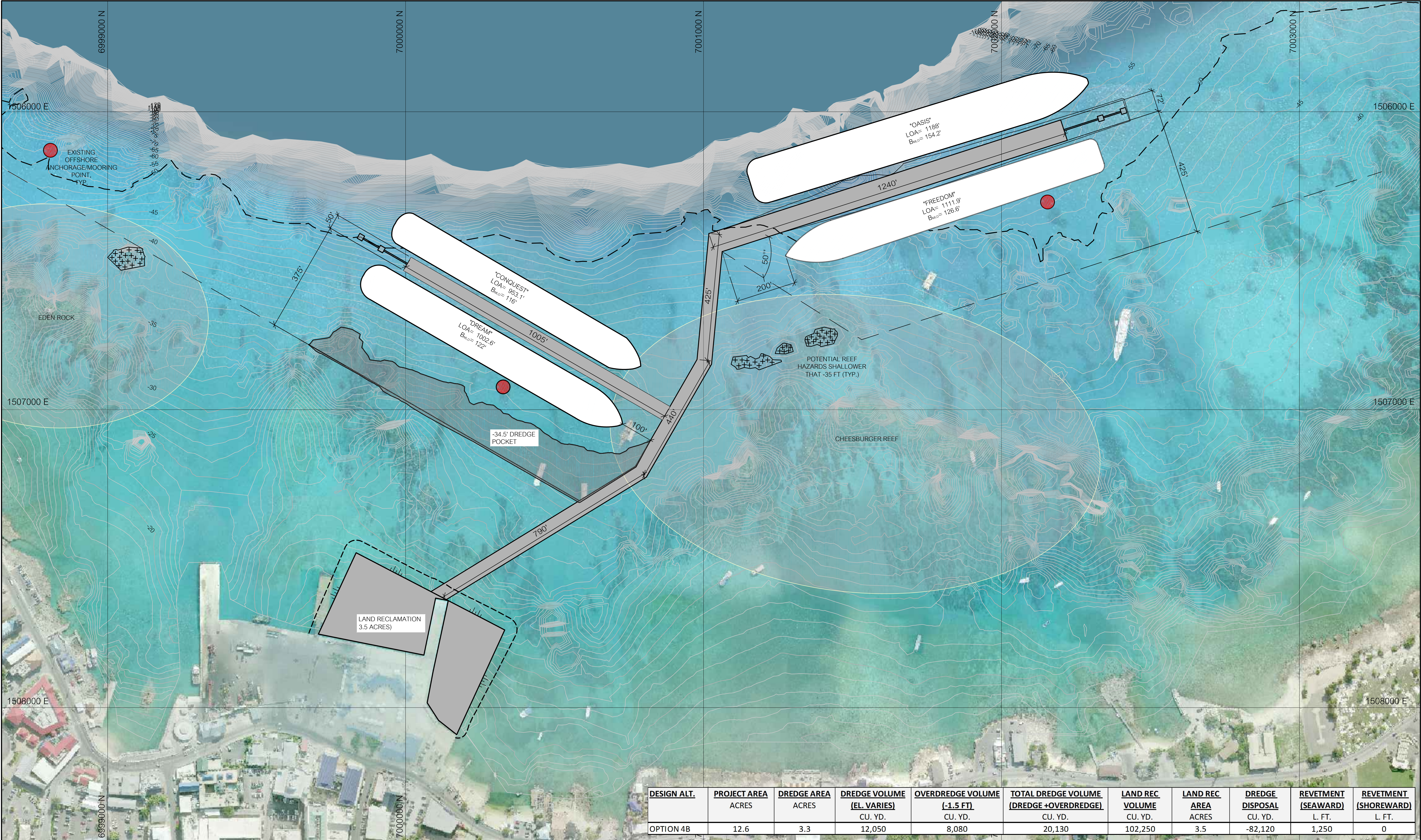
IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 4A

DRAWING NUMBER: 12214 — SKT —

REV. DATE: 2014/08/01



DESIGN ALT.	PROJECT AREA ACRES	DREDGE AREA ACRES	DREDGE VOLUME (EL. VARIES) CU. YD.	OVERDREDGE VOLUME (-1.5 FT) CU. YD.	TOTAL DREDGE VOLUME (DREDGE +OVERDREDGE) CU. YD.	LAND REC VOLUME CU. YD.	LAND REC AREA ACRES	DREDGE DISPOSAL CU. YD.	REVTMENT (SEAWARD) L. FT.	REVTMENT (SHOREWARD) L. FT.
OPTION 4B	12.6	3.3	12,050	8,080	20,130	102,250	3.5	-82,120	1,250	0

REV	T.I.	DESCRIPTION	DRN	DSN	APR	DATE
REVISIONS						
(T.I.) TYPE OF ISSUE	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
	(B) PRELIMINARY	(D) CONTRACT DOCUMENT	(F) AS-BUILT	(H) OTHER		

PREPARED BY:
Baird
W.F. Baird & Associates
Coastal Engineers Ltd.

IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION 4B

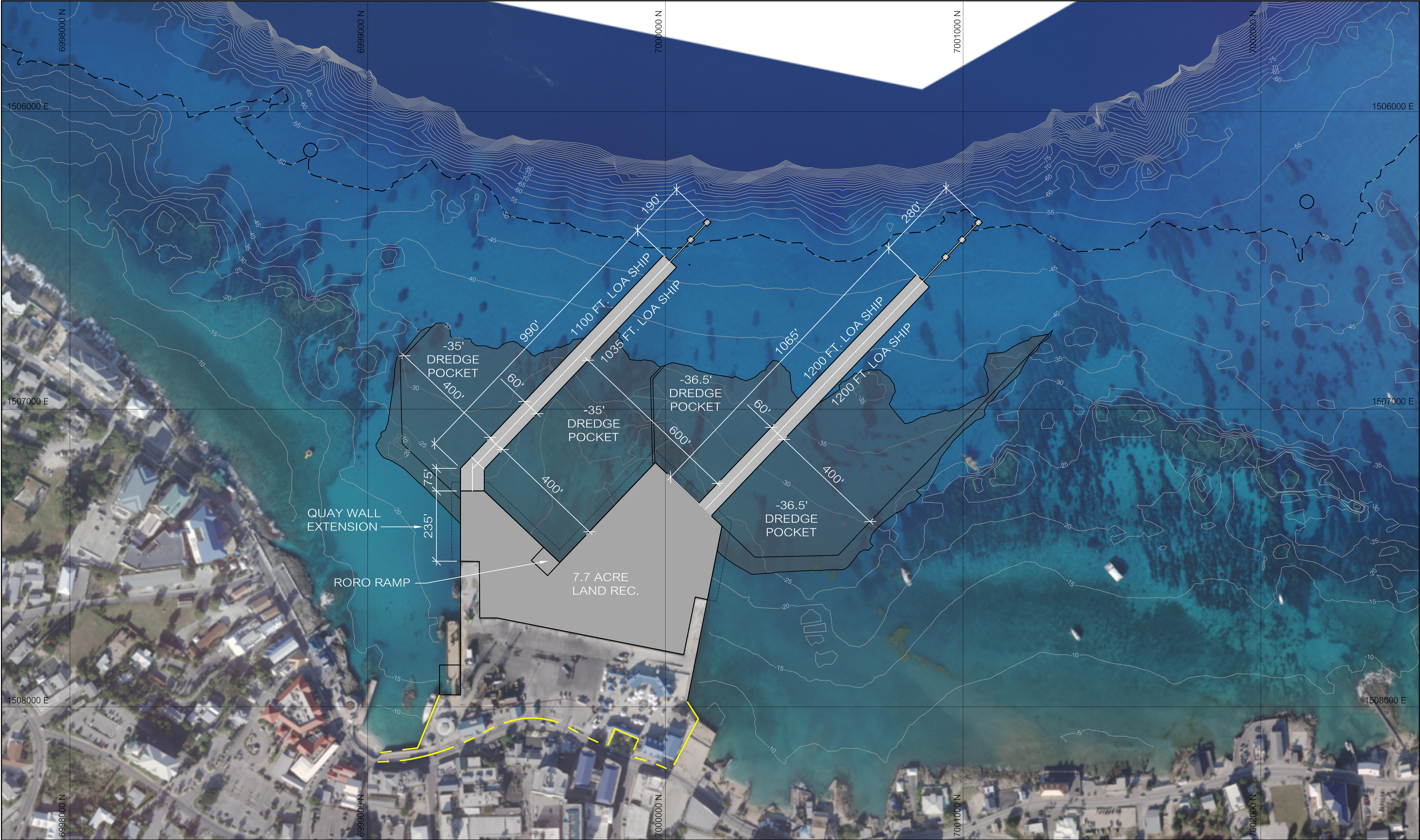
DRAWING NUMBER: 12214 SKT

REV. DATE: 2014/08/01

APPENDIX A.2
PROJECT LAYOUT ALTERNATIVES PRESENTED TO CRUISE LINES

APPENDIX A.3

FINAL PROJECT LAYOUT



NORTH

0 100' 300' 500'

GRAPHIC SCALE IN FEET

REV	T.I.	DESCRIPTION	JULH	CDA	CDA	08-12-14
A	A	ISSUED FOR REVIEW				
REVISIONS						
(T.I.)	(A) DRAFT	(C) PERMIT	(E) CONSTRUCTION DOCUMENT	(G) CANCELLED		
TYPE OF	(B) PRELIMINARY	(D) CONTRACT DOCUMENT	(F) AS-BUILT	(H) OTHER		
ISSUE						

PREPARED FOR:

PREPARED BY:

Baird

W.F. Baird & Associates
Coastal Engineers Ltd.

IN ASSOCIATION WITH:

CAYMAN ISLANDS CRUISE SHIP FACILITY

OPTION C / REFINED

DRAWING NUMBER: 12214 — SKT — 020

REV: A DATE: 09/12/2014

APPENDIX A.4
PRELIMINARY TECHNICAL REVIEW OF FLOATING PIER CONCEPT

February 4, 2015

Mr. Stran Bodden
Permanent Secretary & Chief Officer
Ministry of District Administration, Tourism and Transport
Cayman Islands Government
George Town
Grand Cayman KY1-9000

Baird & Associates
1145 Hunt Club Road, Suite 500
Ottawa, Ontario Canada K1V 0Y3
T. 613 731 8900
F. 613 731 9778

Re: Grand Cayman Cruise Berthing Facility - Review of Floating Pier Concept

Dear Stran,

Further to your request, this letter presents Baird's preliminary technical review of a floating pier concept for the proposed cruise berthing facility, including a summary of key advantages (opportunities) and disadvantages (challenges) associated with the concept. As summarized herein, the floating pier concept does offer some advantages over a fixed pier solution. However, Baird has significant concerns regarding the technical feasibility of a floating pier concept in George Town Harbour.

Concept Overview

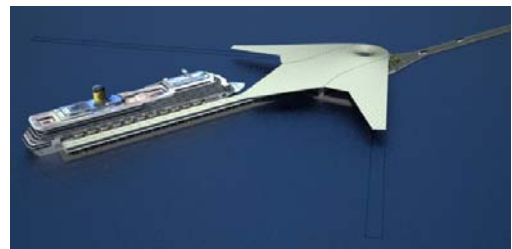
The concept of a floating cruise berthing facility has been around for several years, and includes variations on the theme of a long pier extending to the edge of "The Wall", with an arrivals hall and three finger piers accommodating six ships. The primary impetus behind the concept is to reduce dredging and environmental impacts, which are key concerns with the conventional concept presented in the Outline Business Case (PwC, 2013).

The adjacent figures show artistic renderings of the proposed concept. It is Baird's understanding that a group of businessmen have developed the concept with technical input from two Dutch companies, Beladon (a development firm) and Witteveen+Bos (an engineering firm). This group (the Proponent) has also suggested that the project could be financed using a private sector investment scheme, specifically local entrepreneur Bo Miller's proposed "infrastructure fund".

In general, it appears that the level of concept development undertaken to date is limited, with a number of key technical issues yet to be addressed. The Proponent claims that a "fully financed proposal" could be prepared within 90 days for CIG review. Such a proposal would likely address some of the technical issues highlighted in this letter. Baird would be pleased to support the CIG in the review/assessment of such a proposal should it be submitted.



Source: www.caymancompass.com (31Oct14)



Source: www.cruisetogeorgetown.com

Baird

The following pages provide further discussion of some of the key advantages and technical challenges associated with the design and construction of a floating cruise berthing facility in George Town Harbour. It is important to recognize that this review is based on the limited information available regarding this proposed alternative, specifically that included in the website www.cruisetogeorgetown.com, two local newspaper articles (www.compasscayman.com) and a recent presentation made by the Proponent to the Chamber of Commerce in George Town.

Potential Advantages of a Floating Cruise Berthing Facility

The Proponent has identified a number of potential advantages that a floating pier would offer over a fixed pier in George Town Harbour. For example, the following information is presented on the website www.cruisetogeorgetown.com:

- 1. Virtually no environmental impact; NO dredging will be required*
- 2. The least visual impact; since ships are not docked as close to the shore*
- 3. Portability; repositioned for rough weather*
- 4. Shorter construction period; operational within 6-9 months; whereas, conventional docking requires considerably more time - up to 2-3 years*
- 5. Zero business disruption; during installation and overall, provides a better passenger experience; no tendering required*
- 6. Economically feasible; estimated project expense is US\$100M, nearly half of the expected US\$200M to be spent on the concept discussed in the business case submitted to the Cayman Islands Government*

Some additional information on the concept has also been presented in articles in the *Cayman Compass* on June 24, 2014 and October 31, 2014, the latter reporting on a presentation made by the Proponent to the Chamber of Commerce in George Town on October 28, 2014. Based on a review of the available information, the following paragraphs present Baird's perspective on the six advantages noted above. A more detailed discussion on key technical issues is provided later in this letter.

1. Virtually No Environmental Impact/No Dredging

Baird agrees that a floating pier may cause less damage to corals than a fixed pier, particularly if dredging can be avoided by shifting the piers into deep water. However, Baird is concerned that the project concept may not be technically feasible without dredging, specifically due to the requirement to robustly anchor the piers in very deep water off "The Wall". This critical technical challenge is discussed in more detail later in this letter.

Even in the absence of dredging, there is still the potential for damage to corals associated with the anchors. Specifically, at the Chamber of Commerce meeting on October 28, the Proponent noted that the design includes 20 pontoons, each requiring 12 anchor lines. This suggests a total of 240 seabed anchors, with potential impacts on corals depending on the locations and design the anchors. The Proponent also noted that the first 900 ft of the pier would be "fixed", presumably using a

Baird

conventional pile-supported or gravity-based design, either of which would have impacts on corals within the footprint of the fixed pier.

2. Reduced Visual Impact

Baird agrees that the floating pier concept would have a reduced visual impact, assuming it can be designed to berth the cruise ships further offshore. However, as noted above, Baird is concerned that the project concept may not be technically feasible with the piers extending beyond “The Wall”, due to challenges associated with designing a sufficiently robust anchoring system in very deep water. This critical technical challenge is discussed in more detail later in this letter.

3. Portability

The Proponent suggests that the floating structure could be repositioned during rough weather. While this is possible, several questions arise, including the identification of a suitable “safe haven” for the pontoons, and the logistics (manpower, equipment and time) required to detach, tow and store the pontoons, and subsequently re-install them. For example, while a location on the South Coast might provide sufficient protection from Nor’Westers, it is understood that these events are not easy to predict, and can develop with very little warning. Also, considering tropical storms and hurricanes, there is some uncertainty in forecasting storm tracks, thereby resulting in uncertainty and risk in the selection of a suitable “safe haven” for the pontoons in the face of a approaching storm.

At the Chamber of Commerce meeting on October 28, 2014, the Proponent noted that the access pier (900 ft long) would be fixed, and that the outer three floating arms (each 900 ft long) would be anchored with “tension legs” and submerged during rough weather (Nor’Westers, tropical storms and hurricanes) in order to reduce their exposure to wave action. As discussed later in this letter, Baird has a number of questions/concerns regarding this approach.

4. Shorter Construction Period

Baird agrees that a floating pier concept may be implemented in a shorter time frame than a conventional project, at least with respect to the duration of construction activities on-site. However, the procurement (design and fabrication) of the pontoons would require significant lead time prior to their installation at the site.

5. Zero Business Disruption

Further to the preceding comment, Baird agrees that a shorter construction period on-site would result in reduced disruption to existing businesses, in particular cruise and cargo operations.

6. Economically Feasible

The web site indicates that the estimated project expense is US\$100M, while the October 31, 2014 article in the *Cayman Compass* notes “around \$200M”. Baird cannot comment on the accuracy of either estimate without more detailed information on the design and associated quantities, in particular the pontoon structures and anchoring system.

Baird

Summary of Advantages

Considering the information presented above, the primary advantages of the floating pier concept, as presently envisioned by its Proponent, are reduced environmental impacts (i.e. elimination of dredging, and reduced damage to corals), as well as a reduced duration of on-site construction activities and associated reduction in impacts (disruption) to existing businesses and operations.

However, based on a review of the limited information presented on the web site, at the Chamber of Commerce meeting, and in the *Cayman Compass* articles, Baird questions the technical feasibility of the concept, in particular the ability to develop a sufficiently robust mooring system for the significant water depths into which the floating piers will extend. Further, while Baird is aware of numerous large floating marine structures around the world, the proposed concept is unique, and without precedent, for a site exposed to hurricane waves. Additional discussion on these and other key technical challenges that must be addressed in order to prove the technical (and economic) feasibility of a floating pier concept for this project is provided below.

Key Technical Challenges for a Floating Cruise Berthing Facility

While there are a number of potential significant advantages associated with a floating pier concept, there are also a number of significant technical challenges that do not appear to have been addressed at this time. While some of these challenges may be considered “design details” that could be overcome through the design development process (potentially at some increase in cost), several may be “fatal flaws”. The following bullet points highlight some of the key technical challenges identified by Baird at this time.

- Based on the information presented at the Chamber of Commerce meeting on October 28, it is understood that the access pier will extend 900 ft from shore to the arrivals hall, with three 900 ft long “finger” piers extending radially out from the arrivals hall. Based on these dimensions, the outer ends of the piers, and the associated anchors, will be located beyond “The Wall”, potentially in water depths in excess of 500 ft (a scale drawing of the proposed concept is required to confirm this). The ability to design a suitable anchor system to restrain the piers and resist the significant loads associated with winds, currents and waves acting on the cruise ships is questionable. Further, the installation of anchors on a steep slope at these depths would be very challenging **(Baird opinion: possible fatal flaw)**.
- An anchored platform will act as a “soft mooring”. In addition, one must consider the relative motions of the ships and the pier. Larger ship motions, and an associated increase in facility downtime, may be expected for a floating pier as compared to a fixed pier. Given the frequent occurrence of Nor’Westers (several times each winter), this may be a significant concern **(Baird opinion: possible fatal flaw)**.
- Two approaches have been suggested to accommodate storm waves (i.e. severe Nor’Westers, tropical storms and hurricanes), the first being to relocate the floating pontoons to a sheltered

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location in advance of such an event, and the second being to submerge the pontoons to reduce the hydrodynamic loads to which they are exposed. Regarding the first approach, Baird does not believe that this is a practical solution, given the size of the structure (reported to be twenty pontoons, each measuring 300 by 75 by 25 ft) and the lack of a suitable sheltered water area around Grand Cayman. Regarding the second approach, Baird does not believe that submergence will provide a significant reduction in the hydrodynamic loads during severe storm events, as discussed further in Attachment A (**Baird opinion: possible fatal flaw**).

- The design of the connections between the pontoons represents a significant technical challenge. These connections must be designed accommodate and resist the motions and loads associated with the complex interaction of winds, currents and waves with the berthed vessels and the floating pontoons, and must also consider fatigue and corrosion (**Baird opinion: possible fatal flaw**).
- The major cruise lines all have ships with overall lengths (LOA) in excess of 1,000 ft, with the largest being the Oasis (LOA = 1,187 ft). A 900 ft long pier is not long enough to accommodate typical mooring arrangements for these vessels, in particular the bow and stern lines, which ideally should be aligned at 45° to the axis of the ship. Hence, longer piers may be required (**Baird opinion: design detail**).
- The pier length in the concept as proposed is 1,800 ft in order to eliminate the requirement for dredging (as noted above, this pier length may be insufficient). The cruise lines have advised that pier lengths in excess of 1,000 ft should be avoided, particularly considering the aging demographic of their passengers. While a tram or bus could be used to transport passengers onshore from the arrivals hall, this would face similar constraints as boat tendering (**Baird opinion: possible fatal flaw**).
- Recent meetings with representatives from four cruise lines highlighted the preference for a NW pier orientation, with one cruise line stating they would not use a facility that had W or SW pier orientations. The floating pier concept, as presently proposed, includes three piers, with NW, W and SW orientations. A revised layout may be required to meet the requirements of the cruise lines (**Baird opinion: design detail**).
- Typical navigation requirements dictate a minimum separation of four times the beam of the design vessel between piers. A refined layout for the floating pier concept may be required to provide sufficient space between the piers for safe navigation (**Baird opinion: design detail**).
- The schematic renderings show an arrivals hall on the pier, but no additional land area. Additional land area may be required to support the expanded cruise berthing facility. The cost to create additional land area may be significant, particularly given the lack of dredged material to use as fill (**Baird opinion: design detail**).

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- The floating pontoons are reported to be 25 ft high; assuming a deck level of 10 ft above sea level (typical for cruise ship piers), the pontoon draft would be 15 ft. As a result, the pontoons would block flow in the upper 15 ft of the water column, forcing the flow to pass under the pontoons. Conversely, a pile-supported pier would allow flow throughout the water column, although there would be intermittent blockage due to the piles. The relative impacts of the two pier concepts on nearshore hydrodynamics and circulation is not known at this time (**Baird opinion: design detail**).
- The project site is exposed to Nor'Westers that may reach Hs/Tp ~ 10 ft/8-10s, and to hurricane waves that may reach Hs/Tp ~ 30 ft/10-12 s. Based on a review of existing large floating marine structures (refer to Attachment 2), Baird is not aware of any similar floating structures that have been constructed in a location exposed to such large storm waves (**Baird opinion: possible fatal flaw**).

Comments on Economic Considerations for a Floating Cruise Berthing Facility

As noted earlier, the website www.cruisetogeorgetown.com indicates that the cost of the floating cruise berthing facility is estimated to be US\$100M, while the *Cayman Compass* article of October 31, 2014 indicates a cost of “around \$200M”. This significant difference suggests uncertainty regarding the actual cost of the project. Baird cannot comment on the accuracy of either estimate without more detailed information on the design and associated quantities, in particular for the pontoon structures and anchoring system. Further, as noted in the preceding section, Baird has identified a number of key technical challenges that do not appear to have been addressed by the Proponent at this time; the development of suitable solutions to these technical challenges may increase the cost of the floating pier concept.

Regarding construction, the conventional approach to fabricate large floating concrete structures utilizes a large dry dock. No such facility exists in Grand Cayman, and it is unlikely to be practical to construct a temporary dry dock facility for this project. Further, the concrete supply requirements for such a project are very large, as one has to undertake continuous concrete pours to minimize the number of joints. This is a highly specialized engineering and construction field. Considering these factors, the fabrication of the floating pontoons would likely be done at a suitably equipped dry dock, possibly in Mexico. Alternatively, pontoon fabrication could be done (perhaps at lower cost) at an overseas dry dock (e.g. China); however, the pontoons would need to be small enough to be placed on a ship, as towing the pontoons over long distances would be risky, and unlikely to be practical.

Also, the Proponent has indicated that the project could be financed by private investors, and noted this as an advantage as compared to having one or more cruise lines finance the project. In either case, the use of private financing for the project is a concern to the Cayman Islands Government, as it would require that the CIG give up at least some control over the design and operation of the facility.

Finally, while improvement to/expansion of the existing cargo facilities is not presently envisioned as part of the development of the cruise berthing facility, this issue is being considered in the present EIA

Baird

and concept design study being undertaken for the CIG, as the cargo facility is expected to reach the physical limits on its capacity within the next decade. It is unlikely that this potential requirement has been considered by the Proponent of the floating pier concept.

Conclusions

The proposed floating pier concept provides a number of potential significant benefits as compared to a fixed pier concept, including reduced environmental impacts (i.e. elimination of dredging, and reduced damage to corals), as well as a reduced duration of on-site construction activities and the associated reduction in impacts (disruption) to existing businesses and operations. However, there are a number of significant technical challenges to address in the design of such a facility, and it is not apparent that these issues have been considered by the Proponent at this time. In particular, Baird questions the ability to develop a sufficiently robust mooring system given the significant water depths into which the floating piers would extend. Further, the proposed concept is unique, and without precedent, for a site exposed to hurricane waves.

Based upon the information available at this time regarding the floating pier concept, Baird questions whether the concept is technically feasible. That being said, it is suggested that the Proponent be provided with the opportunity to respond to the technical issues raised in this letter, as it is possible that they may have a strategy to address them. If the Proponent is able to demonstrate, with relevant supporting information, that it is confident that it can address the key technical issues discussed herein, it is suggested that they be invited to submit a full proposal to the Request for Proposals for Design-Build-Finance Tenders when it is issued.

Yours truly,

W.F. Baird & Associates Coastal Engineers Ltd.



Dave Anglin, P.Eng.
Principal

Encl. as noted

Attachment A - Discussion of Pontoon Submergence to Reduce Exposure

The Proponent has suggested submerging the pontoons to reduce the hydrodynamic loads to which they are exposed during storm events.

Ballasting (adding weight to) the structure has the effect of increasing the natural period of motion of the structure due to the additional mass involved. In general terms, more mass will result in less motion and higher anchor loads. That being said, there is a limit to how much ballasting can practically be carried out due to the relatively low deck elevation of the structure.

Specifically, the operating freeboard of the floating pier (height above sea level) would be approximately 10 ft; assuming the 25 ft pontoon height referenced by the Proponent, this gives a 15 ft operating draft. It might be possible to ballast the pontoon down to a 3 ft freeboard (22 ft draft) for a storm event, resulting in a 46% increase in mass. This would shift the natural period of heave and roll by approximately 20%. However, given the relatively long wave periods associated with Nor'Westers, tropical storms and hurricanes ($T_p > 8$ s), it is Baird's opinion that such small changes in mass and natural period will not offer much benefit. However, more detailed analyses would be required to assess this issue.

Ballasting the structures to full submergence may be impractical, as it will be difficult to de-ballast the structure following a storm. Further, it is noted that ballasting systems need to be carefully designed. Specifically, floating structures need to be compartmentalized to avoid sinking in the event of damage or leakage. In addition, significant movement (sloshing) of ballast water must be avoided, as this would contribute to structure movement and anchor loads.

Attachment B - Review of Other Large Floating Marine Facilities

Large floating structures have been used for various applications in both offshore and coastal areas. Offshore applications are typically related to the oil & gas industry, and include floating structures such as tension leg platforms (TLPs) and semi-submersibles. These types of structures are typically used in deep water (> 1,000 ft), and are designed to minimize wave-structure interactions, thereby limiting the wave-induced loads on the structure. More specifically, the working platform and topside facilities are located well above sea level (generally above the crest elevation of the maximum design wave), the surface area close to sea level is minimized, and there is a significant submerged mass at depth in order to maximize the stability of the platform and minimize the wave-induced motions and loads.

Regarding coastal applications, a number of floating marine terminals have been constructed to serve the maritime shipping industry. For example, the website www.cruisetogeorgetown.com references floating cruise ship facilities in a number of locations on the west coast of North America (Long Beach, CA; Ketchikan and Juneau, AK; Prince Rupert and Nanaimo, BC). These structures are all significantly smaller than the floating pier proposed for Grand Cayman, and the project sites are in relatively sheltered locations.

Baird has identified several other large floating structures, including a floating breakwater (which also serves as a cruise ship pier) in Monaco, a nuclear submarine facility in the UK, oil storage facilities at Kami-goto and Shirashima in Japan, and floating bridge structures on Lake Okanagan, Canada and Lake Washington, USA. These project sites are in relatively sheltered locations that are not directly exposed to severe swell and storm waves. Finally, a number of floating storage units have been built, or are planned, by the oil and gas industry. However, these facilities utilize purpose built vessels designed for severe wave conditions, or will be located in sheltered sites.

As the Monaco floating breakwater and cruise ship pier is of particular interest, key technical details for this project are summarized below (this information is based information provided on websites of various companies who were involved in the design and construction of the project):

- The Monaco floating breakwater is a double hulled concrete caisson, measuring 1,160 ft by 92 ft, wide by 80 ft high, with a draft of 52 ft and a displacement of 165,000 t. The structure was also designed to accommodate cruise ships up to 660 ft in length.
- The floating breakwater is anchored by a 8 ft diameter, 650 t “ball and socket” joint at the landward connection, and eight anchor chains (total weight of 1,000 t) at the seaward end of the structure connected to 115 ft long piles driven into the seabed; the maximum anchor depth is approximately 200 ft.
- The design wave condition for the Monaco structure was $H_s/T_p = 9.2 \text{ ft}/7.2 \text{ s}$ (significant wave height and peak wave period). This is similar to a severe Nor’Wester at George Town, but is much lower than the extreme wave conditions that may occur during a hurricane.
- The floating pier was built in a dry dock in Spain and towed to Monaco.

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- Fabrication and installation of the structure took 3.5 years (Oct. 1999 to Apr. 2003).
- The Monaco pier cost approximately 150M Euros; assuming a 2% annual inflation rate from 2003 to 2014, this corresponds to approximately C\$190M in 2014.



Source: www.fccco.es



Source: www.fccco.es

Based on the information presented above, the Monaco floating breakwater appears to be a much more robust structure than that envisioned for Grand Cayman, despite the fact that it was constructed in a less exposed location. In addition, it is noted that the Monaco floating breakwater was designed to accommodate cruise ships up to 660 ft in length, while the Grand Cayman facility will need to accommodate cruise ships almost double that length.

Finally, it is understood that the Proponent referred to a floating pier that is part of a new cruise ship facility in Belize that is being developed by Norwegian Cruise Lines. While only limited information on this facility was found through an online search, it appears that this floating pier is a much smaller structure (designed to accommodate tender vessels), and is located in a sheltered area. Hence, this structure is not a comparable structure to that envisioned for Grand Cayman.