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via email to Laurie.Huck@bciminerals.com.au

Status: Final
6 May 2020

Dear Laurie,

Reference # 12979.101.L1.Rev1_MardieMaintenanceDredgingEstimate

RE: Mardie Project – Maintenance Dredging Estimate

The following correspondence has been prepared to provide Mardie Minerals with an estimate of the annual maintenance dredging requirements for the Mardie Salt Project. The estimate of annual maintenance dredging volumes is based on sediment transport modelling of ambient wet and dry season periods applying a calibrated hydrodynamic model from the environmental approvals phase of the project; as reported in Baird 2020. The analysis of the maintenance dredging requirements incorporates available information from around the site including measured turbidity data, geotechnical borehole data and seabed sediment samples to provide estimates within the dredge footprint (channel and berth pocket).

Project Background

The Mardie Project is a greenfield high-quality salt project proposed in the Pilbara region of Western Australia. In early 2019 Baird Australia Pty Limited (Baird) were engaged by Mardie Minerals to develop a hydrodynamic model to support the environmental approvals process to assess:

- Modelling of dredge plumes associated with the initial dredging of the port facility and marine precinct; and
- Modelling of mixing and dilution of the planned bitterns discharge into the marine environment.

The hydrodynamic model establishment and validation to measured water level and current velocity data is presented in detail in Baird (2020a).

In November 2019, Mardie Minerals engaged Baird to determine maintenance dredging estimates for the development dredged areas (ie through the transhipment channel and berth pocket). Estimate of the expected maintenance dredge requirements were summarised in a letter report (Baird, 2019) based on projected ambient sedimentation in the wet and dry season as well as for an extreme cyclone case.

The project design was updated in January 2020, realigning the entrance channel and repositioning the berth pocket (Worley, 2020). Reconfiguration of the Marine precinct (berth pocket and approach) modified the overall dredge footprint. Dredge design depths have been maintained with the Berth pocket dredged to

-6.7m LAT and Main Channel at -3.9m LAT. The previous layout and current layout are shown side by side in Figure 1. Baird have revised and updated the sediment transport model for the latest dredge footprint and re-examined the maintenance dredging estimates.

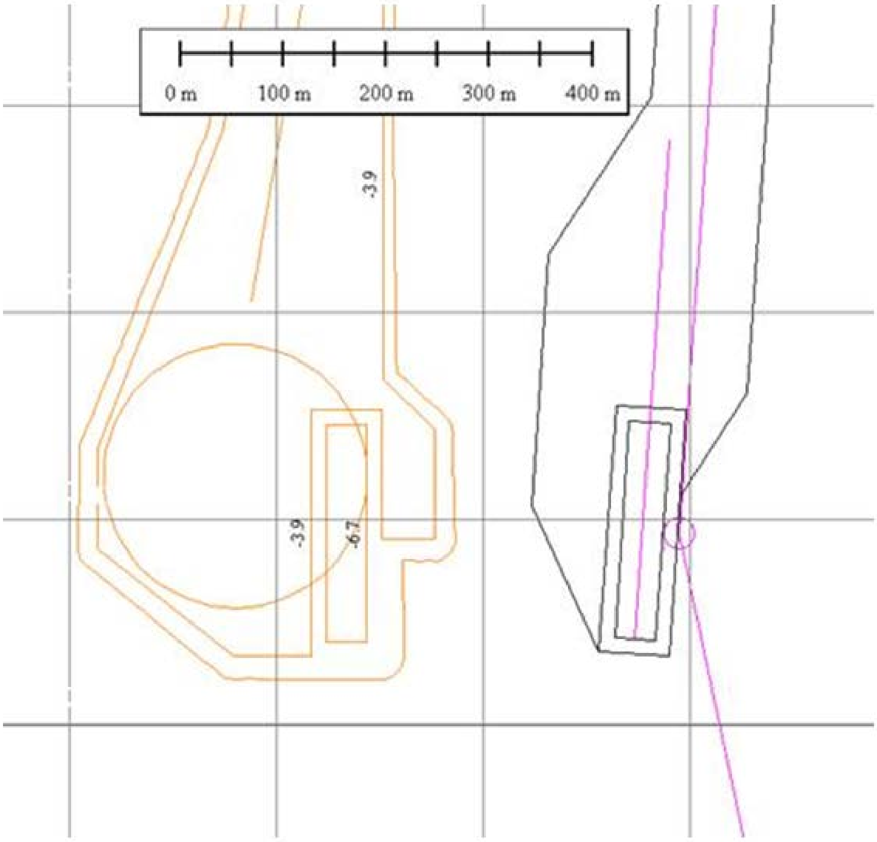

Figure 1: Dredge footprint for Mardie Berth pocket and surrounds. Left : Berth pocket and turning circle areas from 2019 concept analysis. Right : Berth pocket and access channel in revised concept (Worley, 2020) showing smaller comparative footprint area in the Marine Precinct.

Current Scope

The following items have been included as part of this reanalysis and update scope:

1. Reanalysis of the model results (wet season / dry season cases) to determine key drivers of the sediment transport and sedimentation in the model. This will confirm the movement of sediment through the ebb tide and flood tide cycles in seabed regions around the dredged area and over the shoal immediately south of the berth pocket.
2. Examination of wind conditions, tidal forcing and wave conditions applied in the model cases against the longer-term averages. Assessment will focus specifically if the 1-month model run time that has been completed and scaled up (i.e. 6 x scaling of wet season) is too conservative. Based on the outcome of this assessment, the model cases will either be run for a longer period (i.e. run model for 3 months with scale factor x 2) or scaling adjusted to appropriately reflect the annual conditions.
3. Reanalysis of the Geotech results and available literature from similar sites to determine if armouring of the upper layer of sediment across the shoal area can be assumed in the model. This process assumes the fines at the seabed surface have been winnowed out leaving behind coarser material overlaying seabed than are present in the sediment below. The coarse seabed provides resistance to fine sediments being mobilised under tidal and wave forcing

4. Model sensitivity cases will be run to examine the key sediment transport parameters (up to 3 cases allowed for). This will examine sensitivity of applied sediment fall velocity / settlement rate of sediment fractions on the model results.
5. A model sensitivity case in 3D will be examined to confirm the general sediment transport outcomes from 2D are representative through the dredged areas.
6. The relationship between NTU (turbidity measurements) and the modelled suspended sediment concentration (SSC in mg/l) will be examined in detail to provide confidence of the validation of the model to the measured data. Measured turbidity data from the dry season and recommendations from similar Pilbara locations where NTU/SSC has been studied will be provided by O2Marine.
7. The letter summary report will be updated with outcomes of the additional analysis and modelling cases completed. The recommendations for ambient wet and dry season Maintenance Dredging requirements will be updated based on the study findings.

Channel Design and Local Bathymetry

As part of the environmental approvals phase, several bathymetry sources were combined to describe the seabed areas around nearshore and offshore regions of the Mardie site (Baird, 2020a). Additional sources of information that have been included in this current study phase are as follows:

- The latest channel design for the berth pocket and transhipment channel was provided by the project (Worley 20200130) as shown in Figure 1. The Channel depth is -3.9m LAT and the berth pocket is -6.7mLAT.

Task 1. Overview of Key Sedimentation Drivers

A review of the model outcomes presented in the previous initial maintenance dredging modelling (Baird, 2019) was completed to understand the key sedimentation drivers with the following cited:

1. Erosion of the shoal feature, immediately to the southwest of the dredge footprint contributes to the overall sedimentation that impacts the dredged areas of the development footprint. The assumption of sediment size over the shoal was based on CMW (2019) geotechnical data from below the seabed which showed high proportion of fines (clays, silts). The shallow nature of the shoal location makes it more susceptible to wave action and strong tidal currents in the model, leading to erosion of the fines from the seabed. the material is then carried into the development footprint on the tidal currents and settles out in the relative calm of the deeper dredged areas. Once the material settles in the deep dredged areas, resuspension was not found to occur.
2. There is a direct correlation between the tidal phase and rate of sedimentation noted in the model cases. During Spring tide cycle the sedimentation rate increases as the tidal currents influence the rate of erosion of seabed areas and resuspension of fines into the water column that are redistributed. In neap tide phase there is a noted reduction in the overall sedimentation rate.
3. There is increased rate of sedimentation in the model in the wet season case compared to the dry season case, a process which is driven by the wave conditions in the wet season being generally higher and wind conditions comparatively stronger. The analysis of measured wind data from the site is shown in Figure 2 with wind roses for typical wet season month December shown as prevailing from the West-Northwest quadrant and those in typical dry season month of July dominated by easterlies and south easterlies. Modelled wave conditions in the model case for wet season and dry season are shown for comparison in Figure 3.
4. Sedimentation in the model is dominated by the silt fraction with minor contributions from the clay and sand fractions respectively.

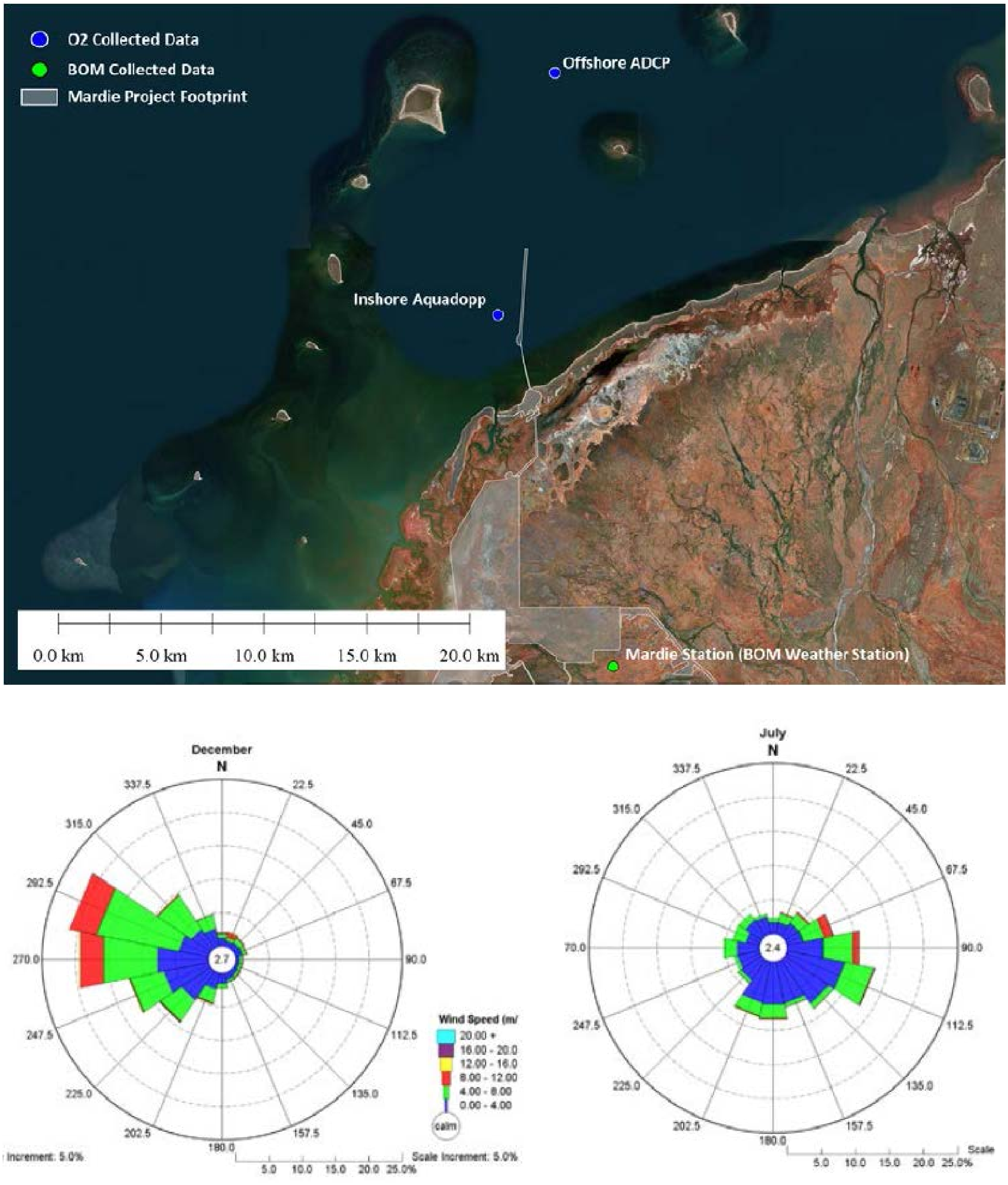

Figure 2: Mardie Measured data locations (upper plot) with the analysed wind record presented as wind roses for (left) Wet Season (December) and (right) Dry Season (July). Analysis is based on 7 years of data from the Mardie Station BoM site.

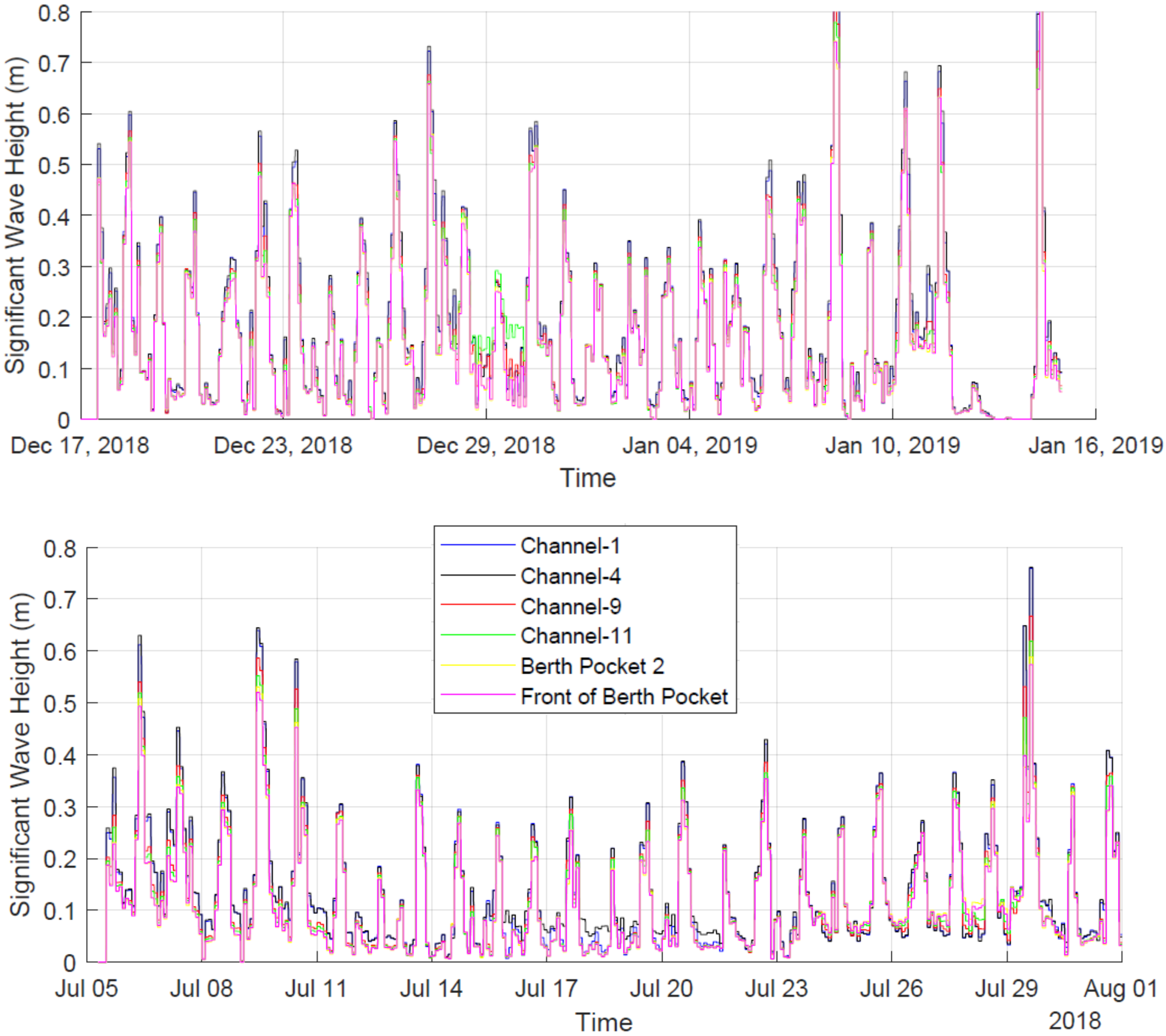

Figure 3: Modelled wave conditions. Upper plot shows wet season model wave height and the lower plot shows modelled dry season wave height.

Task 3. Reanalysis of the Seabed Composition – Geotech review

There are two key data sources that were collected for the project:

1. Site specific sediment samples were collected in the nearshore and offshore areas over the 2018 - 2019 period including seabed grab samples (O2 Marine, 2018, 2019); and
2. Geotechnical borehole information (CMW, 2019).

The data sources were combined in this study to provide a spatial description of the seabed in the sediment transport model in sediment categories for sand (fine sand and coarse sand) and fine sediments (silt and clay).

Based on the previous maintenance dredging analysis (Baird, 2019), one of the key sedimentation drivers was found to be the shoal feature, immediately to the southwest of the dredge footprint. The shallow nature of the location combined with the action of waves and tidal currents showed this was highly susceptible to erosion, with fines resuspended and carried into the dredge footprint where they would settle out.

A detailed reanalysis of the geotechnical data and seabed sampling around the latest development footprint and specifically the shoal area southwest of the dredge footprint was undertaken to examine if armouring of the upper layer of sediment across the shoal area was noted in the sediment sample data. This process assumes the fines at the seabed surface have been winnowed out leaving behind coarser material overlaying seabed than are present in the sediment below with the coarse seabed providing resistance to fine sediments below being mobilised under tidal and wave forcing.

The seabed description through this region is shown in Figure 4 with the sources of data providing description of the sediments indicated.

A description of the seabed composition of the shoal feature is provided from:

1. MS* Sediment samples extracted at various depths through the cores extracted as part of the geotechnical investigations (CMW, 2019)
2. C* Seabed surface samples of the upper 1m undertaken by O2Marine in 2018-2019.

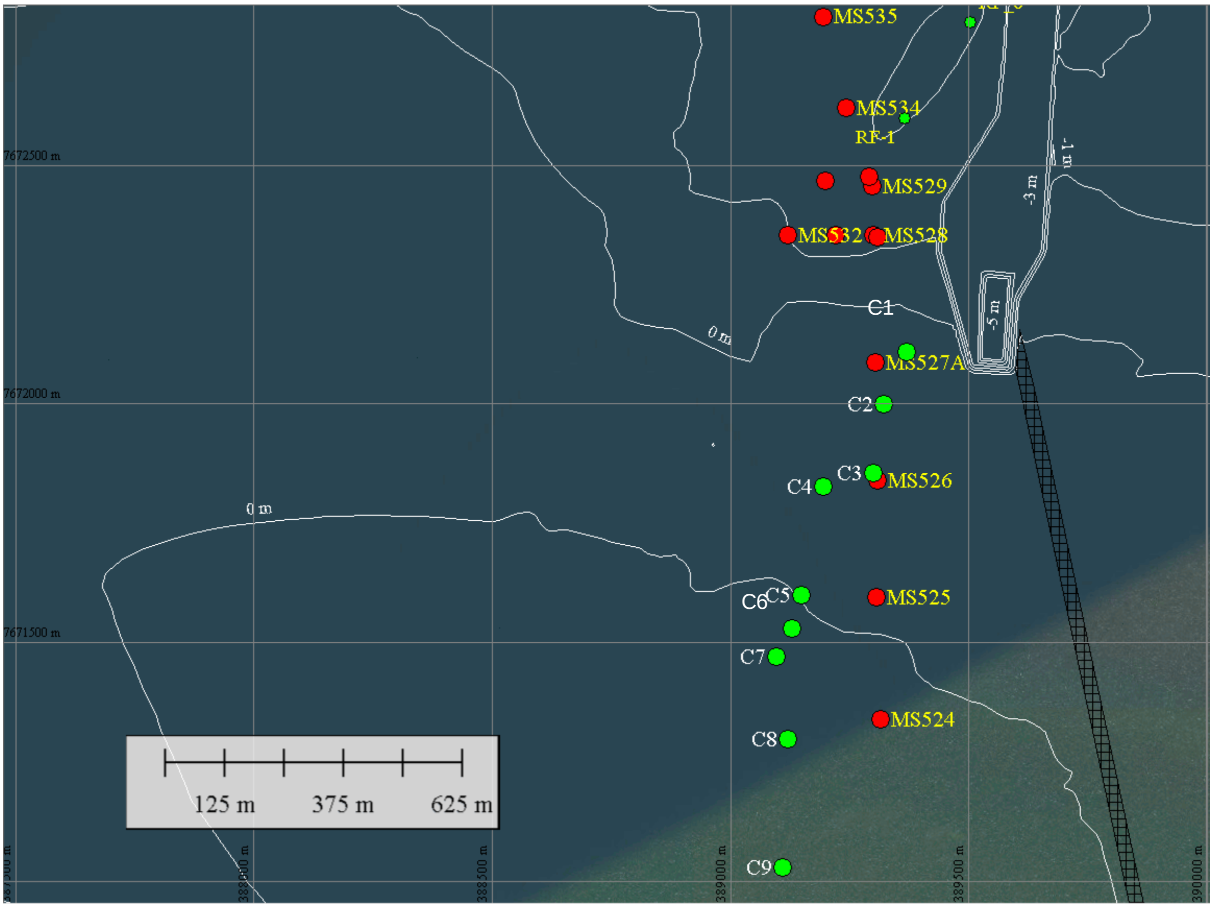

Figure 4: Dredge Footprint showing available sediment sampling data locations across the western side and over the shoal feature to the southwest. The geotechnical borehole data (CMW, 2019) locations are shown in Red, the seabed samples (O2Marine, 2018-2019) are shown in green.

A summary of the borehole data south of the dredge pocket and depths at which the sediment composition was analysed is presented in Table 1. There are four locations – MS524, MS525, MS526 and MS 527A. Sampling of the cores using PSD was completed and reported in CMW (2019) from various depths. The PSD samples are taken from a minimum 2.4m below the surface and the fines content is high ranging from 34% in MS524 to 51% in MS525. There are no surface samples analysed from the geotechnical boreholes.

Table 1: Borehole Summary of PSD Data

Test Location	Easting	Northing	Elevation (m AHD)	Depth Top	Depth bottom	Gravel	Sand	Fines	Silt	Clay
MS524	389316.1	7671339	-3.092	3	3.2	46	20	34	14	20
MS524	389316.1	7671339	-3.092	10	10.23	46	17	37	-	-
MS524	389316.1	7671339	-3.092	13.8	14	35	28	37	-	-
MS525	389306.9	7671594	-2.344	2.4	2.6	4	45	51	-	-
MS526	389311	7671838	-2.023	5.6	5.8	62	18	20	-	-
MS526	389311	7671838	-2.023	11.6	12	44	16	40	-	-
MS526	389311	7671838	-2.023	15	15.5	31	30	39	-	-
MS527A	389305.5	7672086	-2.3787	2.4	2.5	47	11	42	24	18
MS527A	389305.5	7672086	-2.3787	4	4.16	13	53	34	16	18
MS527A	389305.5	7672086	-2.3787	10.49	10.68	68	14	18	-	-
MS540	389471	7674743	-6.1865	0	0.3	31	62	7	-	-

Further investigation of the borehole logs in CMW (2019) based on the onsite descriptions was undertaken. The logs showed consistently that the upper layer (approximately 1m) of the core samples was described as “Sand” or “Gravelly Sand”. An example of this is shown in for location MS527A in Figure 5. At the depths that the PSD samples were taken at 2.4m and 4.0m below the seabed the sediment composition is “gravelly clay” and “clay”.

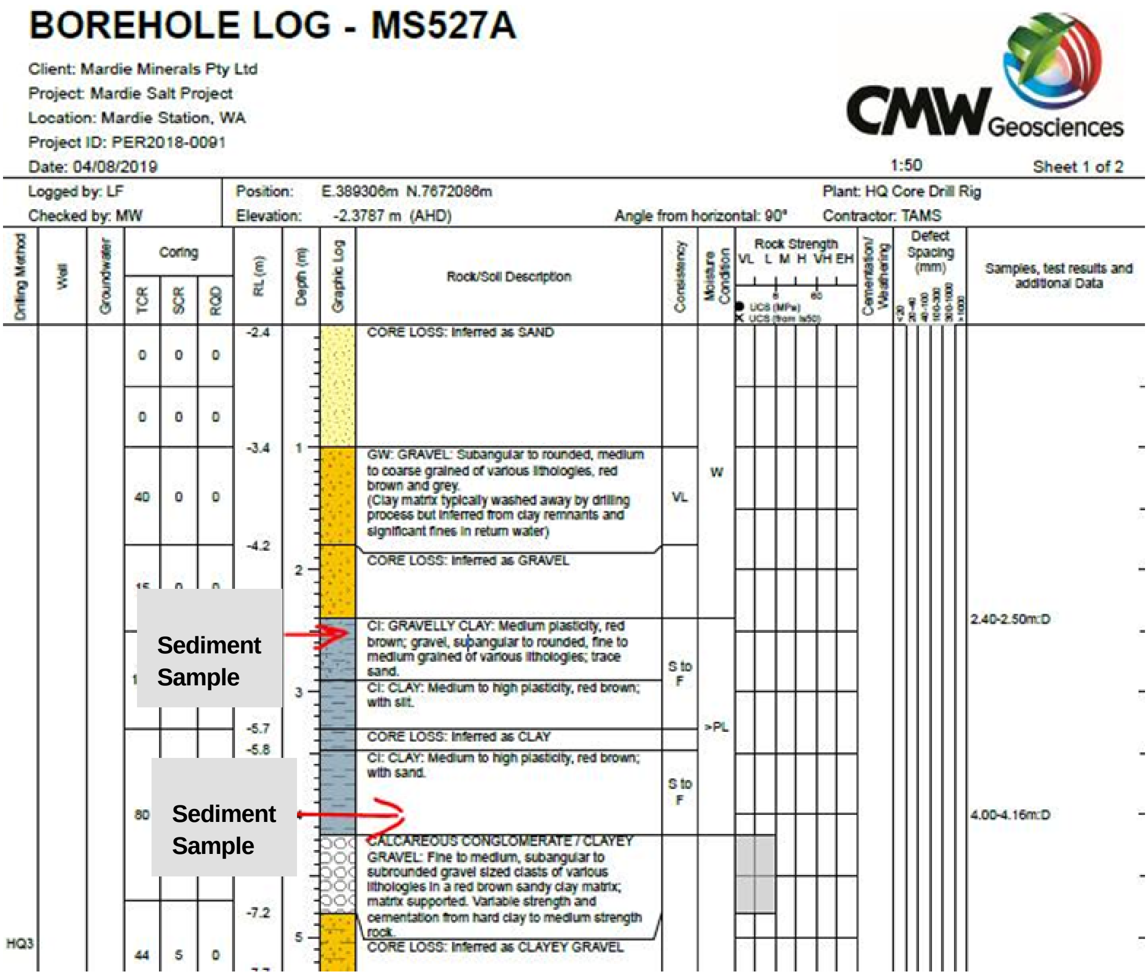

Figure 5: Borehole Log for location MS527A South of the Berth Pocket (from CMW2019). Location of the sediment samples for PSD reported in Table 1 are indicated at 2.4m depth and 4.0m depth.

For the geotechnical boreholes in summary:

- MS524 – Borehole Record has 'Sand' described in top 1.0m. Below that is 'Clayey and Gravelly Sand' where a sediment sample 3.0m below surface is taken (Gravel 46%, Sand 20%, Fines 34%)
- MS525 – Borehole Record has 'Gravelly sand' described in top 1.5m. Below that is 'Gravelly Clay' where a sediment sample 2.5m below surface is taken (Gravel 4%, Sand 45%, Fines 51%)
- MS526 - Borehole Record has 'Gravelly sand' described in top 1.0m then 'Gravelly Sand becoming Clayey Gravel' where a sediment sample is taken at 5.6m below bed (Gravel 62%, Sand 18%, Fines 20%)
- MS527 - Borehole Record has 'Sand' described in top 1.0m then 'Gravel' down to 2m. Where a sediment sample is taken at 2.5m below bed its Gravelly Clay (Gravel 47%, Sand 11%, Fines 42%)

As previously noted, the upper surface of the cores was not analysed for PSD. A description of the surface sediment composition was obtained from the surface grab sediment samples collected by O2Marine in 2018 and 2019.

The PSD data from the surface grab sample is shown for the locations C1 to C6 over the shoal in Figure 6 .

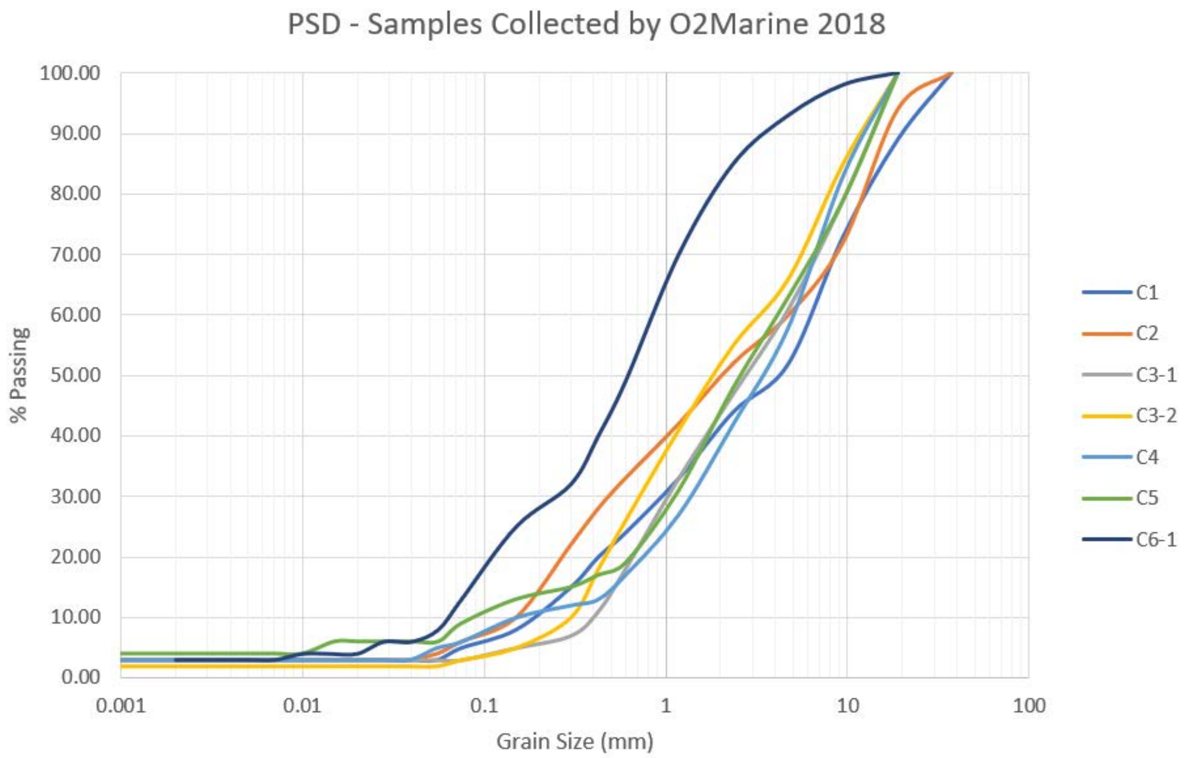

Figure 6: Sediment Sampling Results – Particle Size Distribution of seabed samples (O2Marine 2018).

In summary the PSD curves in Figure 6 show:

- the PSD from the seabed at all locations shows a relatively low fines content
- based on the percent of sample which was smaller than 0.075 microns which is representative of the fines fractions, the samples showed 5%, 6%, 3%, 3%, 6%, 9% and 13% respectively.
- The median particle size ranged from 0.6mm (C6-1) to 3.6mm (C4) indicating the sample material is generally coarse (sand to gravel)

- The percent of the samples made up of coarse sand and gravel (>2.36mm) was 56%, 48%, 53%, 45%, 58%, 52% and 15% (C6-1). This confirms the nature of the seabed across all locations is coarse material, apart from location C6-1 which is the most southerly.

Geotech Reanalysis - Conclusion

From the analysis of the seabed samples it was confirmed that the fines at the seabed surface over the shoal feature have been winnowed out leaving behind coarser material. The upper surface essentially provides an armoured layer against the erosion of fines in the deeper layers of the seabed over the shoal. This understanding was used to inform the modelling of the seabed composition in a revised modelling approach. The seabed layer over the shoal was assigned with a reduced fines content and more resistant to erosion than the previous modelling assumptions in Baird (2019). For the model cases in Task 4, the fines content will be tested with a seabed composition of 7% fines and 14% fines over the shoal.

It is noted that for other areas around the dredged footprint this armouring was not observed in the seabed samples that were assessed and their seabed composition is unchanged from the previous modelling approach (Baird, 2019).

Task 4. Revised Sediment Transport Modelling

Hydrodynamic and Wave Model System Overview

The hydrodynamic model and wave model framework applied in this project was developed and calibrated as part of the environmental approvals phase of the Mardie project. The model is developed using the Delft3D modelling system (Deltares, 2018) an integrated modelling suite, which simulates two-dimensional (in either the horizontal or a vertical plane) and three-dimensional flow, sediment transport and morphology, waves, water quality, and ecology and can handle the interactions between these processes.

The model system established for the project is detailed in Baird (2020a) with three components summarised as follows:

1. A regional scale hydrodynamic model extending across the northwest of Australia using Delft-Flow Flexible Mesh (D-Flow FM) model. The model is driven by tidal constituents along its open boundaries with bathymetry defined from hydrographic chart data and local scale bathymetry sources where available. For this project, winds and atmospheric pressure have been sourced from the NCEP Climate Forecast System (CFSR). The climatic conditions were then applied spatially in D-FLOW FM and updated hourly across the regional model in conjunction with the tides, so their influence was captured in the determination of hydrodynamic forces acting in the domain.
2. A local scale hydrodynamic model established over the Mardie area with boundary conditions defined by the Regional model. The local model is setup in a domain decomposition grid arrangement to optimise the efficiency of the model performance. The outer grid extends along the shoreline approximately 70km with a cross shore extent of approximately 45km. The outer grid is setup on a 200m grid size, and a smaller domain within sized at 40m extends around the marine precinct of the port and channel area. An 8m grid is focussed over the key region of interest encompassing the port area and southern transhipment channel (Figure 7).
3. A SWAN wave model was developed to cover the local scale domain with the following attributes:
    - The model is setup with an outer grid domain extending across the hydrodynamic grid, with a grid size of 400m. A nested grid of 40m grid size describing the key port facility area is nested within.
    - The wave conditions inside the SWAN model develop under the local wind forcing applied in the model. Swell conditions are applied at the boundary based on the measured data from the offshore ADCP in the Dry Season.
    - Wave conditions are updated in the local hydrodynamic model every 2 hours using Delft3D FLOW-WAVE-FLOW.

The validation of the hydrodynamic model against available measured data is presented in Baird (2020a) confirming good model validation metrics calculated for water level, depth averaged current velocity and direction.

For this current study the latest developed case bathymetry has been applied using the revised design of the berth pocket, turning circle and transhipment channel (refer Figure 1).

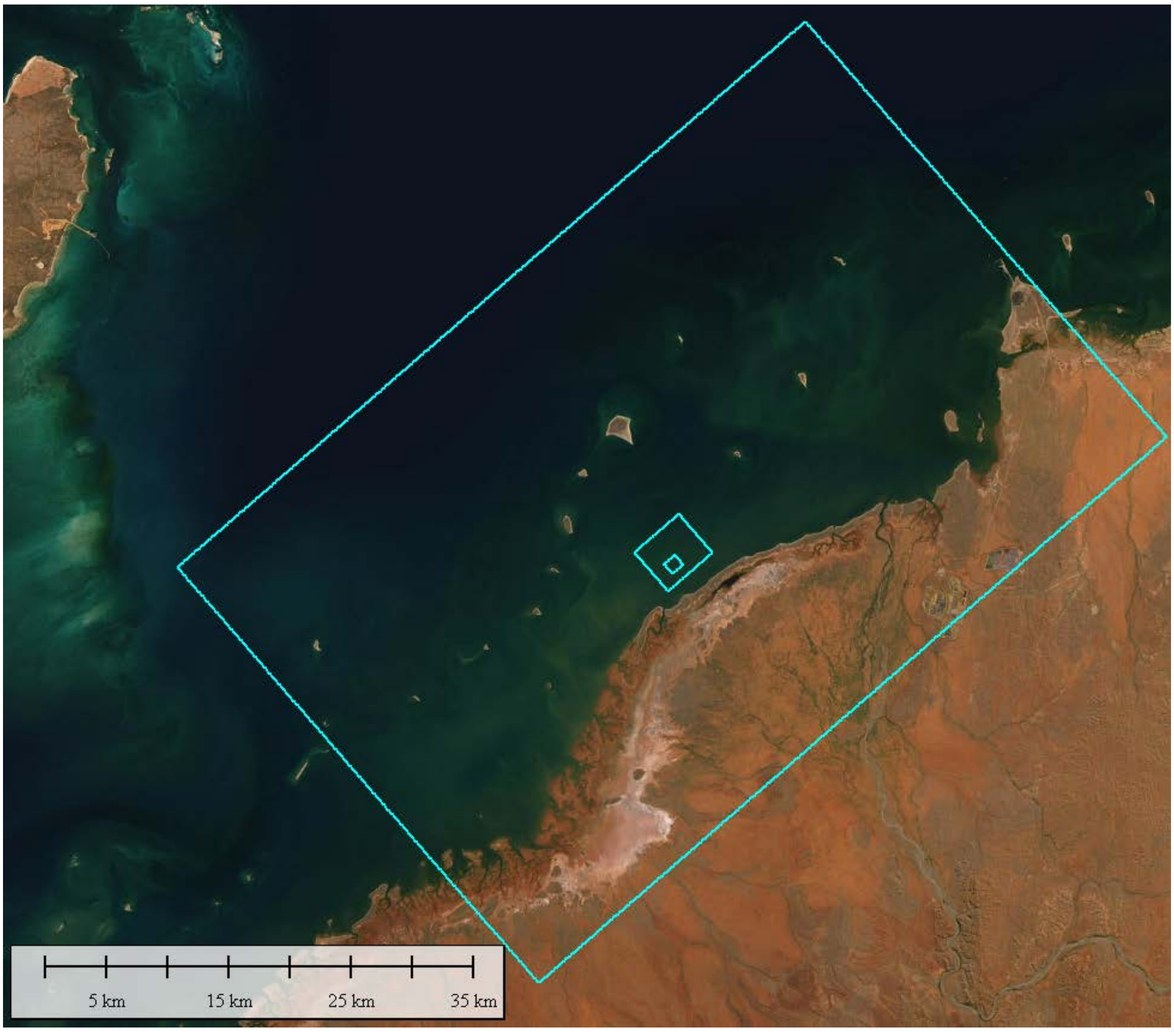

Figure 7: Numerical Model Grid setup. Left: Grid extents for the Outer 200m grid, and two finer resolution inner grids (40m and 8m).

Sediment Transport Model System

The validated hydrodynamic and wave model is applied to simulate tides, wind and wave conditions in the model scenarios. The Delft3D Online Sediment model (Online-MOR) has been activated in the model to investigate the erosion, suspension and deposition of fine sediments in the model domain. Four representative sediment classes are modelled – fine sand, silt, fine silt and clay.

The seabed composition has been determined from data collected in sediment sampling campaigns through the nearshore and offshore area. Within the model the processes of erosion, resuspension and deposition of the seabed material is determined based on the hydrodynamic forcing (water levels, winds, waves, currents). Suspended sediment is assigned at the model boundary based on measured suspended sediment concentration (SSC) measured from the offshore location (O2 Marine, 2019).

The seabed description in the model has adopted a 'mixed bed' approach in which the four sediment fractions are available in the seabed layer proportional to the available measured data, that is, there is active interaction between the sediment fractions. Further, the bed stratigraphy module was activated, which allows for different bed compositions to be applied both horizontal and vertically (into the seabed) in the model. A surface layer was established for all seabed areas above -4mMSL with a sediment composition reflecting the geotechnical properties over the shoal area. A second layer covered all seabed areas below -4mMSL, which was composed of a higher fines fraction consistent with the available PSD information.

Seasonal Conditions

The modelling simulations are based on wet and dry season scenario cases of four weeks duration that are representative of the dry season and wet season at Mardie, as outlined in Baird (2019). The scenario modelling approach is used to optimise the model run times, as continuous modelling of environmental conditions over the full year would be impractical due to the long run times of the model system. The two periods are as follows:

- dry season period is 4 July – 1 August 2018.
- wet season period is 18 December 2018 – 15 January 2019.

The wet and dry seasonal cases are evaluated in the model with results scaled to represent an annualised total sedimentation. It is noted the extreme wind and wave conditions associated with tropical cyclones have not been assessed in the model cases.

Sediment Sources

The sources of sedimentation that can affect the dredged areas in the model are:

1. Sediment from the seabed which is eroded under the current and wave conditions and which is transported along the seabed into the relative calm of the deeper channel areas (bedload transport);
2. Sediments in suspension under natural seasonal conditions combined with fine material which is eroded from the bed under the current and wave conditions, which eventually settles in the relative calm of the deeper areas (suspended sediment transport);

Model Sensitivity Cases

Based on the reanalysis of the geotechnical data around the site and over the shoal feature the sediment description applied in the model cases examined:

1. A 'lower bound' estimate of sedimentation case which assumes the armouring of the shoal results in approximately 7% fines at the seabed layer.
2. An 'upper bound' estimate of sedimentation case which assumes the armouring of the shoal results in approximately 14% fines at the seabed layer.

Sediment Transport Model Outcomes – Fine Sediments

The modelled sedimentation outcomes are assessed through the development footprint in six regions as shown in Figure 8. The modelled volume of sedimentation has been scaled up from the one-month wet season case and dry season case to be representative of a full 12-month period.

Overall sedimentation estimates and depth of sedimentation is summarised in Table 2. The calculation of sedimentation volumes includes the combined contribution of the four sediment fractions (fine sediment fractions and fines).

The model outcomes show:

- The rate of sedimentation in the wet season is approximately twice that of the dry season. This is due to lower suspended sediment concentration in the model during dry season conditions associated with the relatively calmer metocean conditions (lower waves);
- the highest sedimentation rates are within the berth pocket with 0.23m to 0.36m sedimentation of fine sediments modelled annually (Table 2). The sedimentation rate is highest toward the south of the berth pocket;
- The combined sedimentation in Area 1, Area 2 and Area 3 is modelled at between approximately 16,900m^3 and 25,600m^3 annually.
- Sedimentation in Area4, Area 5 and Area 6 combined is modelled at between 22,100m^3 and 34,900m^3 annually. The sedimentation depth reduces moving offshore along the channel.

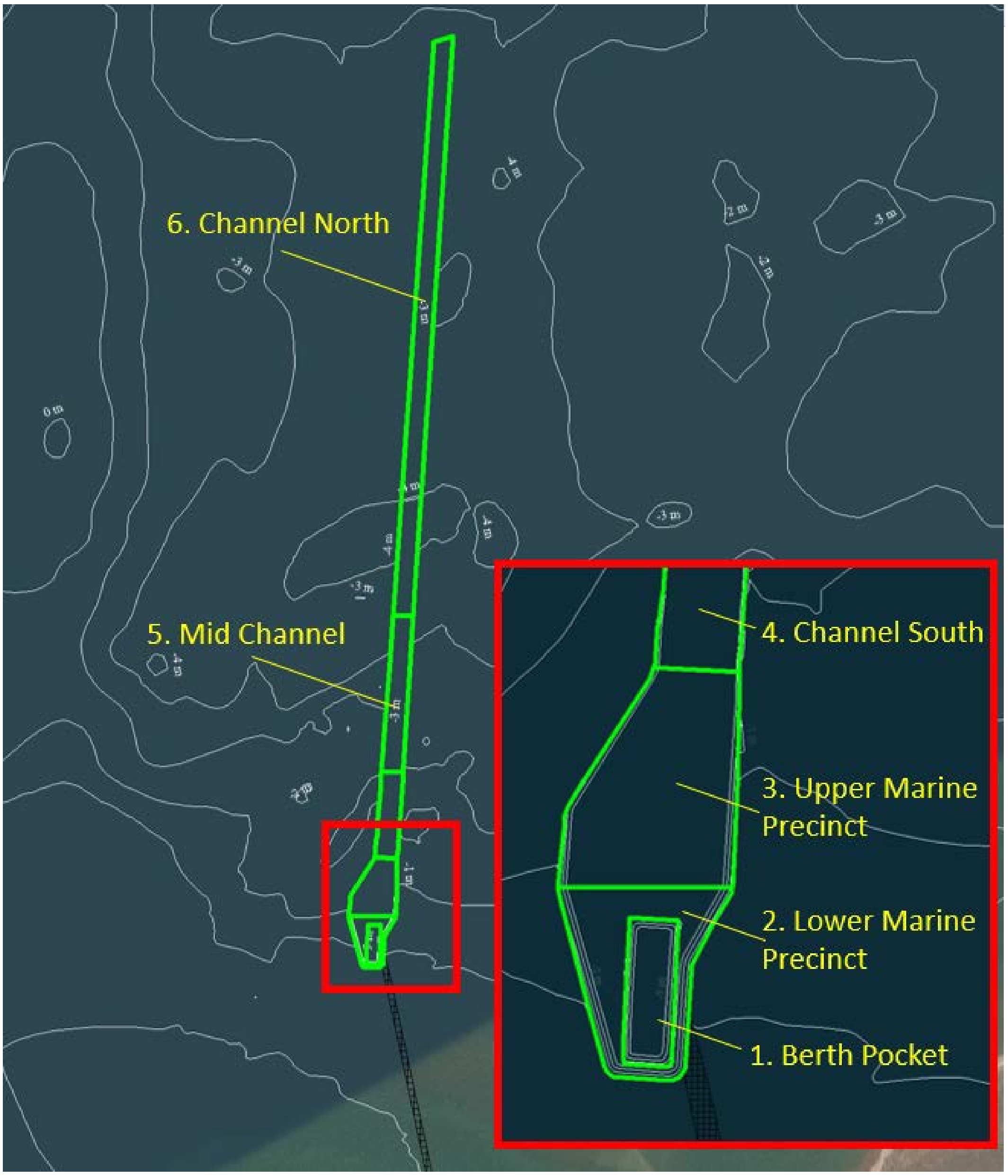

Figure 8: Areas used for calculation of sedimentation volume through the developed case footprint

Table 2: Modelled Annual Sedimentation Rate in Developed Channel Areas – Upper Bound

Areas	Enclosed Area (m^2)	Modelled Sedimentation Volume			
		Dry Season sedimentation (m^3)	Wet Season sedimentation (m^3)	Annual Sedimentation (m^3)	Average Depth (m)
1. Berth Pocket	12,800	1,200	3,400	4,600	0.36
2.Lower Marine Precinct	26,600	1,700	5,500	7,200	0.27
3.Upper Marine Precinct	55,300	3,600	10,200	13,800	0.25
4. Channel South	45,600	2,300	6,200	8,400	0.18
5. Mid Channel	81,700	2,800	8,200	11,000	0.14
6. Channel North	281,200	5,700	9,800	15,500	0.05
TOTAL		17,300	43,300	60,500	

Table 3: Modelled Annual Sedimentation Rate in Developed Channel Areas – Lower Bound

Areas	Enclosed Area (m^2)	Modelled Sedimentation Volume			
		Dry Season sedimentation (m^3)	Wet Season sedimentation (m^3)	Annual Sedimentation (m^3)	Average Depth (m)
1. Berth Pocket	12,800	800	2,200	2,900	0.23
2.Lower Marine Precinct	26,600	1,200	5,200	6,400	0.24
3.Upper Marine Precinct	55,300	2,100	5,500	7,600	0.14
4. Channel South	45,600	1,300	3,100	4,400	0.10
5. Mid Channel	81,700	1,700	4,400	6,100	0.07
6. Channel North	281,200	5,000	6,600	11,600	0.04
TOTAL		12,100	27,000	39,000	

Task 6. Review of Turbidity Data from Similar Sites

There are 2 reference studies which were reviewed to provide a basis for confirming the understanding of measured Suspended Sediment Concentration (SSC) data from the Mardie project location. The following studies from Onslow were reviewed:

1. Wheatstone Project State of the Marine Environment Surveys Baseline Report. Document No: WS0-0000-HES-RPT-CVX-000-00155-000, Chevron Australia Pty Ltd, Rev0 11/7/2013
2. MScience 2009, Wheatstone LNG Development, Baseline Water Quality Assessment Report, November 2009. Report Number MSA134R3 11/7/2013

Both reports are available from the EPA website as supporting references for Wheatstone project and are from similar marine environments to that of Mardie.

Report 1 Wheatstone Baseline Data

The baseline monitoring for Wheatstone involved water quality data being collected in-situ at 18 coral habitat sites and one non-coral site for greater than 22 months. One of the reported findings from the study is that turbidity was highest in summer at almost all sites (ie in wet season), with the lowest turbidity recorded in either winter or spring (dry season).

The locations in the campaign were separated into inshore, mid-shore and offshore areas. The inshore locations are considered to be most representative of the Mardie location where the aquadopp is sited. There were 6 locations termed inshore in depths of between 5.8m and 10.7m (relative to Mean sea level).

The turbidity statistics for Inshore, mid-shore and offshore sites are shown in Figure 9 based on approximately 2 years of data (units is NTU). The data is shown as median, 20th percentile and 80th percentile range. It can be seen that the Inshore ranges are higher than for the mid-shore and offshore sites in Figure 9. Turbidity statistics are generally in the range of 1 to 10 NTU for most Inshore sites. The Tubridgi Point location has the highest range at 3 to 19 NTU.

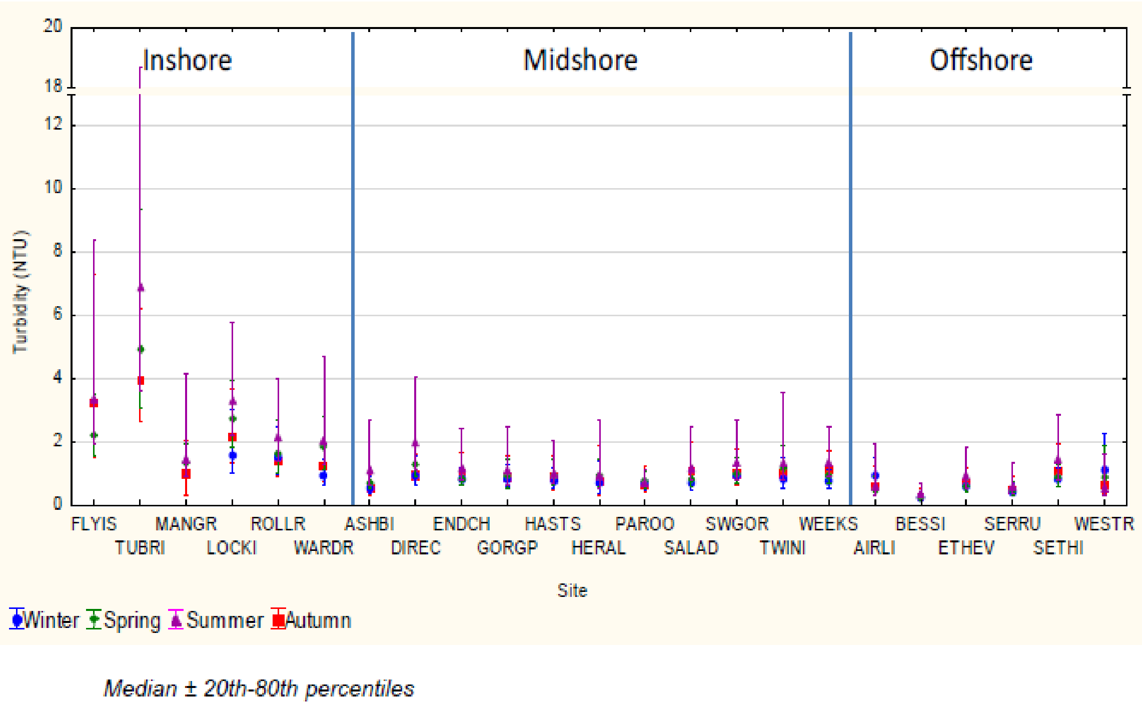

Figure 9: Statistics of Seasonal Turbidity measured from locations around Onslow (Wheatstone 2013). Data is arranged by distance offshore collected from May 2011 – April 2013.

The report details that gross sediment deposition rates were estimated using sediment traps. Three sediment traps were attached to each existing WQ logger mooring. The average gross sedimentation rate Sites typically recorded higher gross sediment deposition rates in summer and autumn, with lowest sedimentation at sites recorded during spring. This correlates with the turbidity measurements that peak in the summer (wet season Dec -Feb).

The highest range of sedimentation coincided with the passage of TC Iggy (March 2012) and TC Peta Jan 2013 as well as a period in the last week of January 2012 (i.e. wet season).

Report 2 MScience – Field Work MODIS Data Analysis

The MScience report developed a relationship between total suspended solids (TSS, mg/L) and Turbidity (NTU) based on measured data at 113 sites offshore of Onslow during two sampling trips in 2009. The relationship is as follows:

y=2.04+1.07x Where y=TSS (units mg/L) and x=Turbidity (units NTU)

The study reported analysis of MODIS imagery data between 2006 and 2009 to determine long term estimates of SSC in nearshore and offshore areas. Analysis of MODIS was completed on 4560 data locations at 30 sites over the 4 years of data. The analysis provided long term mean, median, 80th percentile and 95th percentile for turbidity as summarised in for the nearshore sites which are considered generally representative of the Mardie location. Summer values for TSS (i.e. wet season) are noted as higher than winter.

Table 4: MODIS Statistics for Water Quality at Nearshore Sites in Onslow. Total Suspended Sediments (TSS). Analysis reported in MScience 2009

Turbidity	N	Mean	Median	80th Percentile	95th Percentile
Summer	1012	6.9	4.6	8.1	17.6
Winter	2332	4.6	2.8	5.2	14.0
Full Year	3344	5.3	3.2	6.6	15.3

Sediment traps (Figure 10) were deployed as part of the study and these showed sedimentation rates were highest in January to March (wet season months) as noted in the Wheatstone Study. Higher deposition rates were noted at nearshore sites compared with offshore sites.

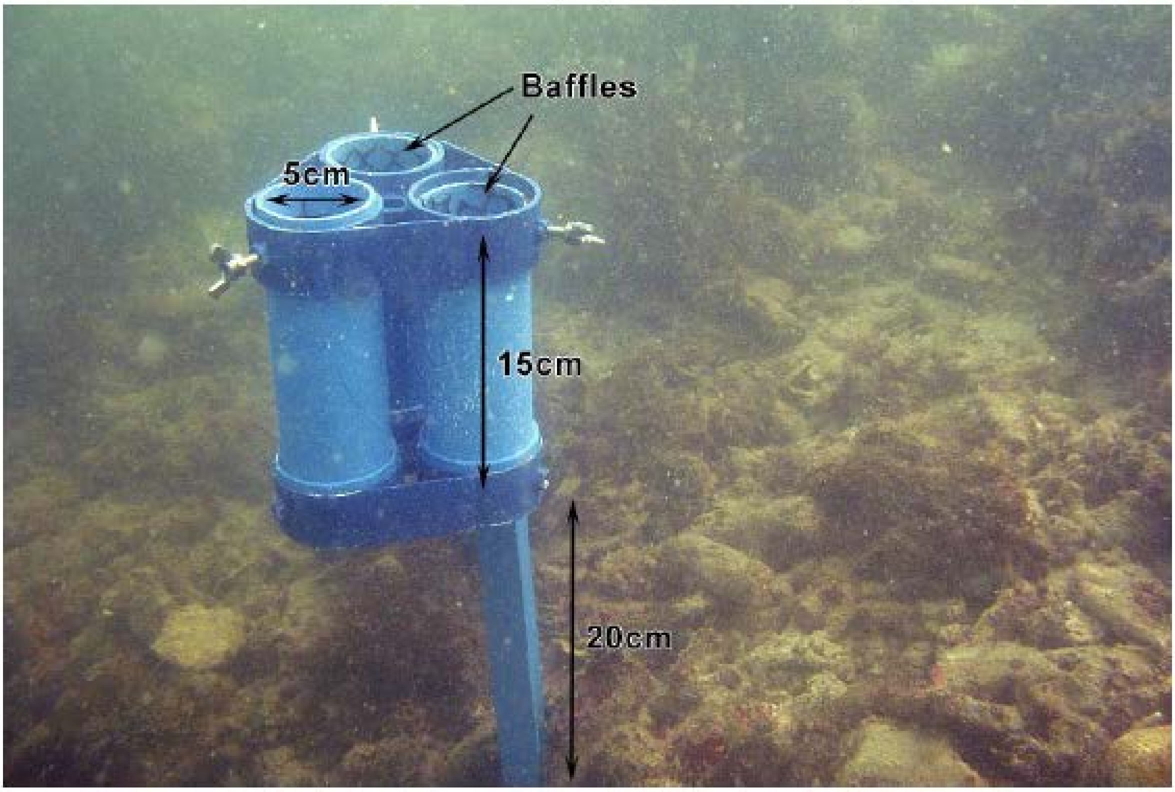

Figure 10: Sediment Traps deployed by MScience to measure sedimentation rates around Onslow (MScience 2009)

Model Validation to Measured Data Sources

The model validation was reviewed based on the updated model setup. The comparison of the modelled statistics against the measured data sources is shown in Table 5. The comparison is presented for the 'lower bound' model case in Table 3 and the reference site from Wheatstone for nearshore Onslow at 'Turbridgi Point'.

Wet Season statistical comparisons of Measured vs Modelled SSC show the following (refer Table 5):

- Mean values compare well, 15.2 mg/L (measured) to 15.8 mg/L (modelled), with median values being 12.3mg/L (measured) to 7.8 mg/L (modelled).
- At the 20th percentile the model SSC is lower than the measured SSC value at the Aquadopp
- The comparison of statistics in wet season shows at the 80th percentile the SSC agrees well between the model and the two measured data sources (Mardie Aquadopp and Onslow reference site).
- At the 90th percentile and 95th percentile the model SSC at the Aquadopp is higher than the measured data which is a conservative basis for the modelling.

The Measured SSC from the Mardie Aquadopp location in wet season is shown in Figure 11. The modelled data is shown in Figure 12 showing reasonable agreement to the scale of the measured data.

Dry Season comparison of Measured vs Modelled SSC:

- The dry season modelled data statistics for SSC are lower in comparison to the wet season modelled data. This finding is in agreement with the two reference studies where the Wet Season SSC is noted as being higher the dry season period.

- The measured data from the Mardie location shows significant increases in the dry season data vs wet season measured data for all SSC statistics by a factor of 3 or more. This finding is not supported by the reference studies and has not been relied upon in the model validation of dry season.
- The comparison of the model to the measured reference site at 'Turbridgi Point' is made by scaling the wet season data by factors from similar inshore sites. This is not actual measured data but provides a reference level at which high level dry season comparison can be made. The median from the model for the dry season case is 2.7mg/L vs 3.9mg/L for the reference site, which suggests the model case is biased low for SSC.

Table 5: Measured and Modelled Statistics for SSC at the Aquadopp location

Statistic	Wet Seanson			Dry Season		
	Measured Inshore[1]	Reference Site Turbridgi Point Wheatstone[2]	Modelled Inshore Lower Bound Case[3]	Measured Inshore[4]	Reference Site Turbridgi Point Wheatstone[5]	Modelled Inshore Lower Bound Case
Median	12.3 mg/L	6.9 mg/L	**7.8 mg/L**	32.4 mg/L	3.9 mg/L	**2.7 mg/L**
Mean	15.2 mg/L	24.4 mg/L	**15.8 mg/L**	44.3 mg/L	19.9 mg/L	**4.9 mg/L**
20th Percentile	7.2 mg/L	3.6 mg/L	**2.8 mg/L**	17.4 mg/L	1.9mg/L	**0.9 mg/L**
80th Percentile	20.5 mg/L	18.7 mg/L	**23.0 mg/L**	62.2 mg/L	13.1mg/L	**6.6 mg/L**
90th Percentile	28.8 mg/L	NA	**43.5 mg/L**	150.9 mg/L	NA	**9.3 mg/L**
95th Percentile	51.4 mg/L	NA	**62.2 mg/L**	158.9 mg/L	NA	**17.8 mg/L**

Notes.

1. Measured data from Aquadopp for period 16 Nov 2018 – 28 Feb 2019, which only includes non-cyclonic conditions.
2. Statistics based on 3 months measured data from inshore areas around Onslow in Wet Season (Dec – Feb)
3. Modelled one-month representative Wet Season for Mardie Location. Data analysis based on Aquadopp location
4. Measured data from Aquadopp for period 1 May 2019 – 8 Sep 2019
5. Scaled Wet Season Data based on reduction at other inshore sites in Dry Season vs Wet Season data
6. Modelled one-month representative Dry Season period for Mardie Location. Data analysis based on Aquadopp location in model

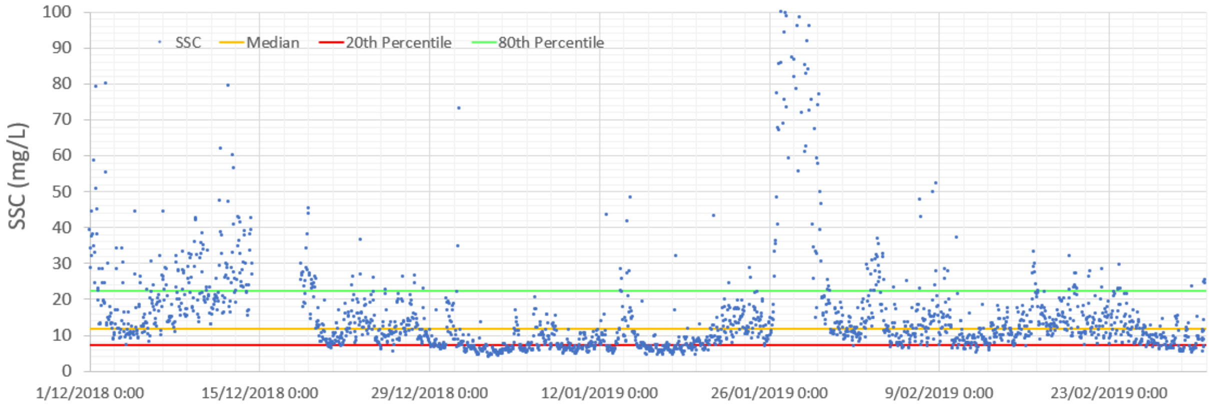

Figure 11: Measured SSC from Aquadopp Location Summer Period December to Feb Inclusive

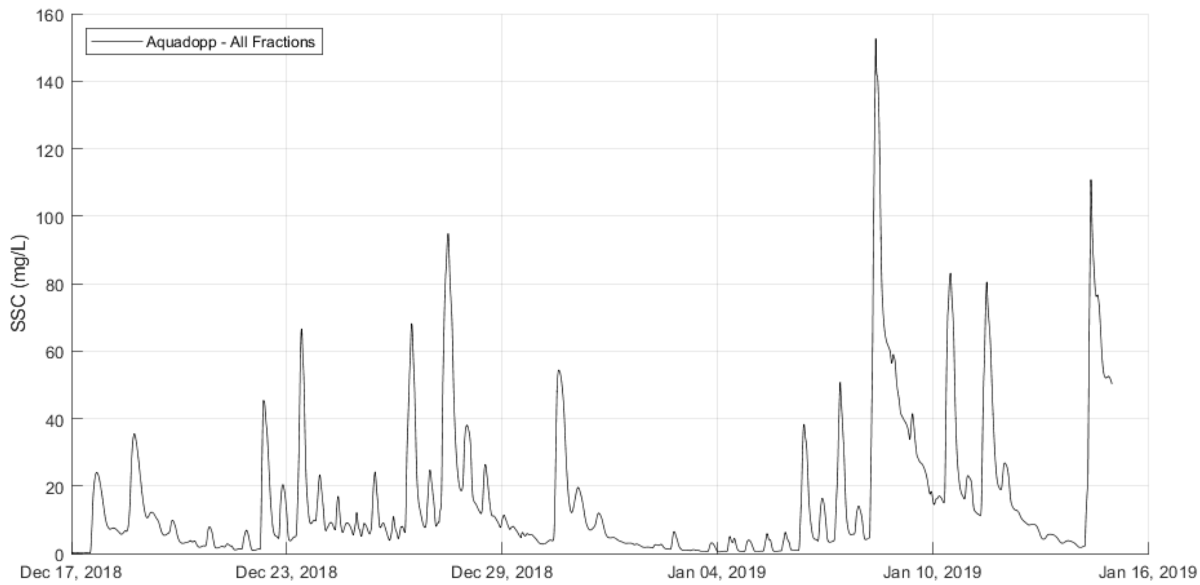

Figure 12: Modelled SSC at Aquadopp Location – Wet Season Case combined sediment fractions

Model Limitations

There are a number of assumptions and limitations in the modelling process that are summarised as follows:

1. The sedimentation estimates are based on seasonal model periods of 4-weeks duration for representative seasonal cases that are scaled up to represent an annualised total. It is assumed that the short duration model cases are generally descriptive of annual (one year) outcomes, however sediment transport rates will vary year on year depending on a range of environmental factors. Additional analysis of the representative periods in the model to historical longer-term averages will be completed in the next revision of this report;
2. The sedimentation model has been developed from measured data collected from around the site including seabed sediment samples, bathymetry data and measured turbidity. The modelling is reliant on the accuracy of each of these input data sources. It has been noted that the Dry Season measured turbidity data from Mardie has not been relied upon in this report based on the current understanding

of mechanisms that generate SSC and measured data reported at similar measurement locations in nearshore waters around Onslow in wet and dry seasons. The model outcomes have been benchmarked against the measured SSC data during the wet season, which shows good agreement between measured and modelled;

3. The model does not account for vessel induced currents or propeller forces in the transhipment channel that may resuspend and redistribute the fine material. Baird will provide advice to BCI regarding the influence of vessel movement on sedimentation, noting that it is not expected to reduce sedimentation volumes, rather redistribute the sediment around the dredged areas;
4. Large rainfall events have not been modelled. For the Mardie location, tropical cyclones have the potential to bring significant rainfall events as they move onshore that could result in large runoff from the land areas carrying sediment laden flows into the nearshore;
5. Tropical cyclones have not been modelled. For the Mardie location, the passage of tropical cyclones can increase wave conditions and currents at the site which could lead to an increase in the suspended sediment concentration and enhanced erosion and deposition of sediment in the nearshore areas. The measured turbidity data for the Wet Season (2018 – 2019) has been analysed in Baird 2019 to provide an estimate of the increase in suspended sediment concentration for a cyclone event based on TC Riley, a Category 3 cyclone that passed offshore of Mardie in January 2019. This is the only cyclone event in the measured record that the analysis can be undertaken for. Site specific cyclone modelling is recommended to further understand the sedimentation risk from tropical cyclones.

Final Recommendations

The sediment transport modelling presented herein has used available measured data sources from around the Mardie project area and incorporated the latest channel design (Worley, 2020) to estimate annual maintenance dredging requirements for the Mardie Salt Project.

Significant reanalysis of the geotechnical cores and seabed grab samples from around the shoal feature on the southwest of the development dredge footprint has concluded that the fines content (clays, silts) seabed surface compared with layers beneath the surface is much reduced. This supports the understanding that the seabed over the shoal feature has had the fines winnowed out over time, leaving behind coarser material. The upper surface essentially provides an armoured layer against significant erosion of fines in the deeper layers of the seabed over the shoal. This understanding was used to inform the modelling of the seabed composition in the revised modelling presented herein.

The modelled sedimentation has been estimated from representative wet season and dry season cases. Sedimentation rates are higher in the wet season period compared with the dry season period, a finding which is supported by the reference studies from similar nearshore sites of the Pilbara cited in this report (Wheatstone 2013, MScience 2009) and is consistent with the understanding of driving mechanisms for sediment transport in the area. The model validation shows reasonable agreement with the measured data for SSC at the inshore location for the wet season. Measured dry season data collected from Mardie over the 2019 dry season has not been relied upon for model validation due to the SSC values being significantly higher compared to wet season, a finding which is not supported by the literature. The sedimentation in the model is dominated by the contribution from fine sediments and predominantly silts that are eroded from the seabed under current and wave forcing and settle out of suspension in the deepest sections of the channel and berth pocket during slack water conditions at low tide.

Annual maintenance dredging estimates have been calculated in six sections of the development footprint. Sedimentation rates have been provided as an upper and lower bound ranging from a total 39,000m^3 to 65,500m^3 annually in the dredged areas under ambient conditions. No allowance for cyclones is made in these estimates. Based on analysis in Baird 2019 an allowance of 10 - 25% of the annual sedimentation total could be experienced by an event magnitude of 1yr to 10yr return period (1yr ARI to 10yr ARI). To better understand and define the sedimentation risk from tropical cyclones an extended modelling study with cyclone tracks representative of return period events should be completed at the Mardie project location.

The sedimentation modelling assumes a dry bed density of fines (silts and clays) of 550kg/m^3. This value is representative of reasonably consolidated fine bed material with available literature (e.g. Van Rijn and Barth, 2018) suggesting that a period of 2-4 weeks is required for such a density to be achieved following initial deposition. This assumption has implications for sedimentation depths following large episodic events (e.g. cyclones, wet season rains), where the initially deposited sediment volume will result in a higher siltation depths before gradual consolidation takes place.

The ranges of annual sedimentation by section of the dredged design (Figure 8) are estimated as :

1. Berth Pocket – 2,900m^3 to 4,600m^3
2. Turning Circle and Lower Basin – 6,400 m^3 to 7,200 m^3
3. Offshore Channel Section 1 – 7,600 m^3 to 13,800 m^3
4. Offshore channel Section 2 – 4,400 m^3 to 8,400 m^3
5. Offshore Channel Section 3 – 6,100 m^3 to 11,000 m^3
6. Offshore Channel Section 3 – 11,600 m^3 to 15,500 m^3

Concluding Comments

We hope this addresses the requirements of BCI Minerals. Please feel free to call or email me to discuss any of the information contained herein.

With thanks,

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