RTA Weipa Pty Ltd

Amrun Project Port Dredging Water Quality Reporting

August 2017

A report prepared in accordance with requirements of the Amrun Project EPBC Act Approval 2010/5642 and Port Dredge Management Plan.

DOCUMENT CONTROL

Document number: CAL.01-4400-HH-REP-00003

Version	Purpose	Approval	Submission	Date
1.0	Publication on Amrun Website	Amrun Project Environmental Specialist	Not Applicable	10/08/2017

TABLE OF CONTENTS

1 INTRODUCTION

The Amrun Project (formerly South of Embley) involves the construction and operation of a bauxite mine and associated processing and port facilities to be located near Boyd Point on the western side of Cape York Peninsula.. A detailed description of the Project is provided in the Queensland EIS (RTA 2011), the Queensland SEIS (RTA 2012), and the Commonwealth Environmental Impact Statement (RTA 2013).

The marine works associated with the new port facility will include the construction of jetty, wharf and ship loaders and dredging of berth pockets and departure channel. Capital dredging operations were completed using a cutter suction dredge between 25 March and 09 April 2016 with a total dredge volume of 202,416m^3 of in-situ material removed by dredging over the campaign. This campaign was considerably smaller than the 2.6 million m^3 approved in the Dredge Management Plan (DMP) – Port (Initial Capital Dredging) (approved by EHP on 21 January 2016 and Department of Environment on 16 November 2015).

Amrun Project environmental approvals (EPBC 2010/5642, EPML00725113) required water quality and coral health monitoring to determine the impacts of dredging on local inshore coral communities. This report presents the survey methodology and results of the water quality and coral health monitoring associated with the 2016 port initial capital dredge campaign.

2 METHODOLOGY

The water quality monitoring program was conducted in accordance with Dredge Management Plan – Port (Initial Capital Dredging) which included monitoring of:

- Baseline dry season conditions (September to November 2015)
- Baseline wet season conditions (December 2015 to February 2016)
- Three months prior to dredging (26 December 2015 - 25 March 2016)
- Dredge monitoring (26 March – 09 April 2016)
- Four weeks after dredging (09 April – 08 May 2016)

The water quality monitoring program incorporated two components in situ water quality monitoring (primary monitoring method) and satellite imagery (secondary monitoring method).

In-situ water quality monitoring involved the following:

1. Continuous telemetered monitoring for turbidity and Photosynthetically Active Radiation (PAR) at seven (7) sampling locations: four (4) concern sites and three (3)

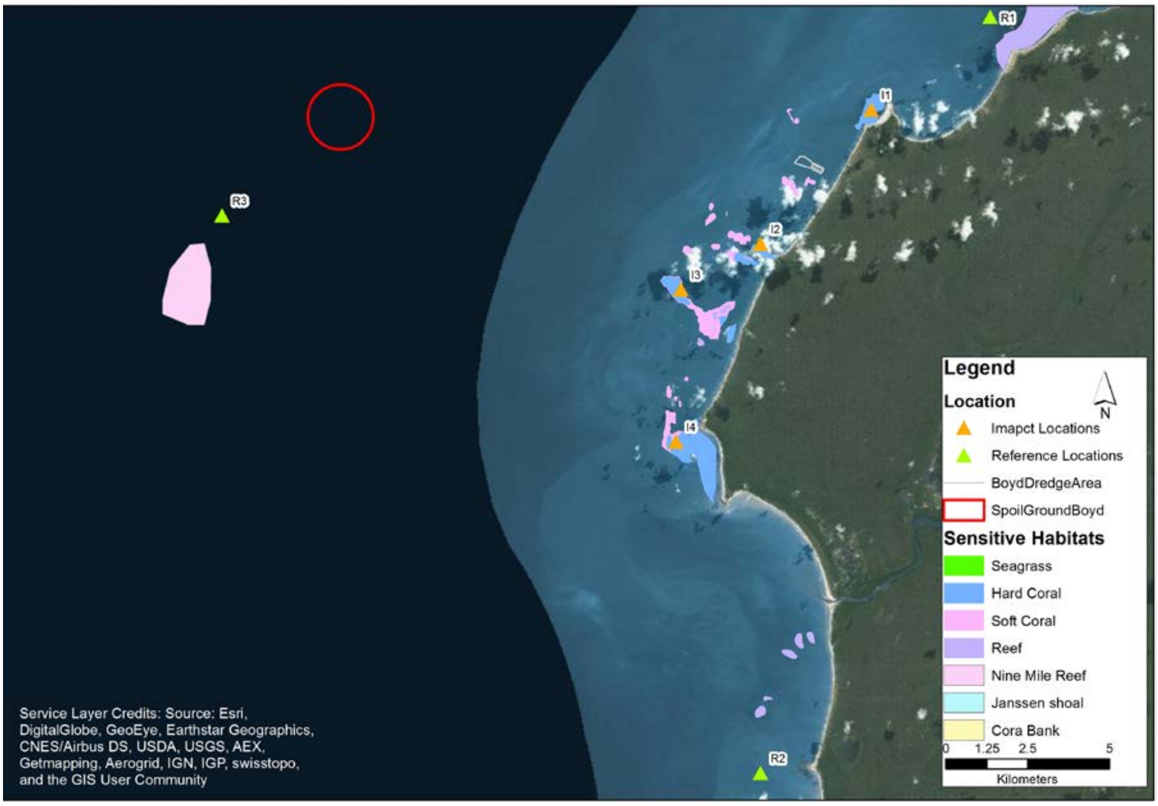
reference sites (Figure 1). Conducted throughout the entire program allowing for management responses in the event of dredging related impact.

2. Daily gross sedimentation rate (using sediment traps at four (4) concern sites and one (1) reference. Conducted during baseline only

3. Monthly water quality sampling for TSS (laboratory analysis) and turbidity (in-situ turbidity probe. Conducted during baseline only

Satellite imagery assisted in determining if a dredge plume extended to potential sites of impact and determine if high turbidity values were region wide. No plume was observed on the imagery throughout the dredging.

Figure 1 Continuous telemetered water quality monitoring sites



Rio Tinto

2.1. In-situ telemetered data collection

At each location two (2) turbidity loggers (primary and back up) and one (1) PAR logger were attached to the logger installation frame (LIF). The LIF was place on the seabed which was kept in place by anchor and chain. A cable connected the primary logger to the telemetry buoy which transmitted the data every 15 minutes using satellite telemetry (Figure 2). Data was accessible via a website in real time. Prior to deployment and on an approximately monthly basis all loggers were checked and calibrated to ensure collection of quality data.

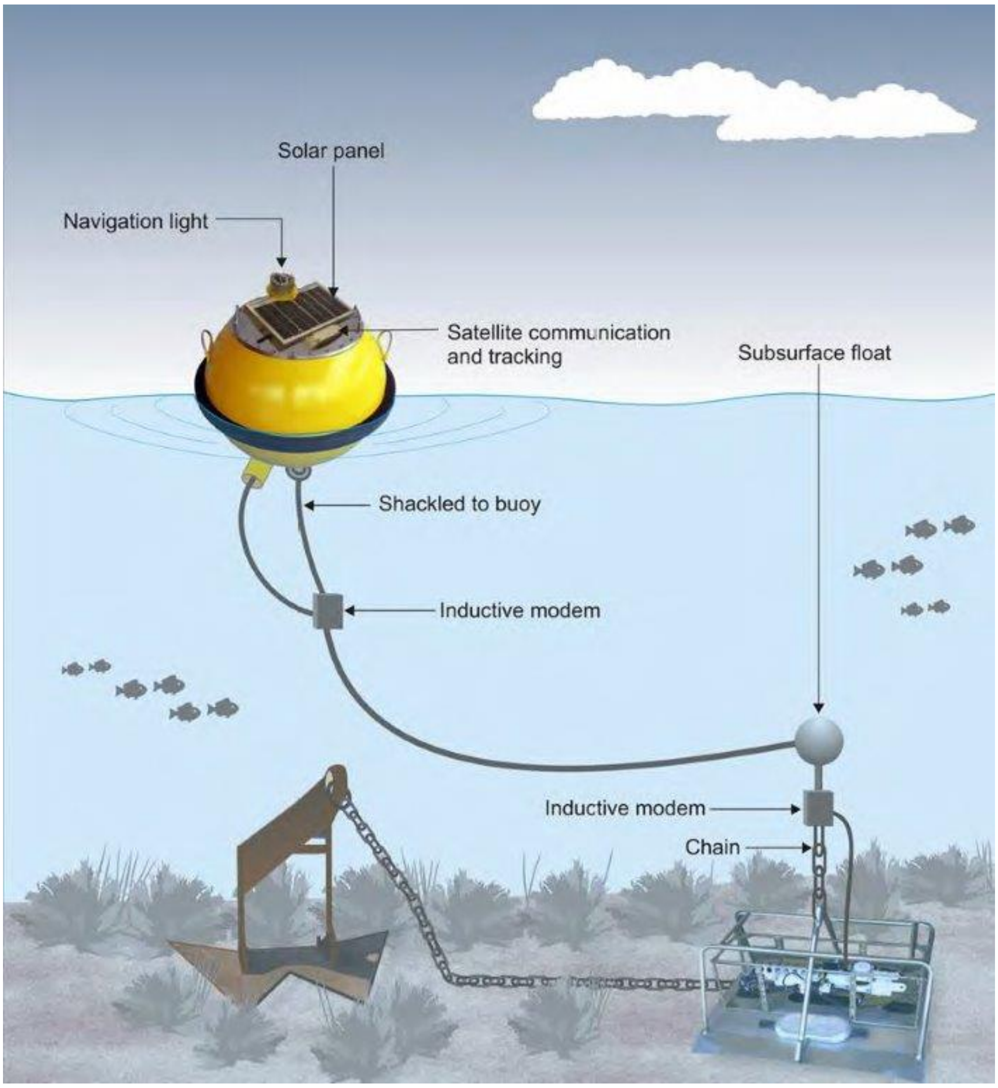


Figure 2 Schematic diagram of in-situ telemetered water quality logger

2.2. Sediment Traps

Gross sedimentation rates were monitored using sedimentation traps at the four concern sites and one reference site (R2). At each site three replicates were attached to the LIF. Samples were collected on a monthly basis during baseline sampling. Each sediment trap was placed in a bag, packed on ice and transported in an esky to the laboratory for analysis. The daily gross sedimentation rate (mg/cm^2/day) was calculated for each site.

2.3. In-situ water quality sampling

Water quality samples were collected using a Niskin bottle from 0.7 metres above the seabed, a depth equivalent to the height of the logger monitoring probe, prior to the LIF being retrieved. The Niskin bottle was weighted prior to deployment to reduce the effects of current and deployed using a rope marked every one (1) metre. One (1) 250 ml bottle sample is collected at each site for TSS, with a duplicate sample collected at one (1) site for QA/QC purposes. Samples are placed on ice, and transported in an esky under chain of custody documentation to the laboratory for analysis within holding times (approximately 7 days for TSS).

Turbidity was recorded 0.7 metres from the seabed using a handheld probe capable of recording depth. A minimum of five (5) samples were recorded and averaged at the same time the continuous loggers were recording turbidity. A multi parameter physicochemical profile of the water column was also recorded. A minimum of five (5) turbidity measurements was recorded every 0.5 metres and averaged.

2.4. Data control and analysis

A Standard Operating Procedure (SOP) was developed for analysis of telemetered data, which included a strict quality control process as provided in Appendix A. A summary of the data analysis is below:

- Trigger values for each respective season were calculated in accordance with the DMP using the 80th and 95th percentile of the respective season baseline data for each location.
- The median total daily PAR (mol/m^2/day) was calculated for each site for each season
- The daily gross sedimentation rate (mg/cm^2/day) was calculated for each site. Gross sedimentation for each sample was calculated by dividing the total dry sediment weight (mg) in each trap by the number of days the trap was deployed and then dividing by the area of the trap mouth in cm^2.

Rio Tinto

3 RESULTS

A summary of the turbidity, PAR and sedimentation data collected during the water quality monitoring program are presented below along with an analysis of relationships between the parameters where possible. Detailed reports for the dry and wet season are provided in Appendix B and Appendix C, respectively.

3.1. Turbidity data

Baseline data collected for the dry season from September to November 2015 (Figure 3) and wet season from December 2015 to February 2016 (Figure 4) are presented in Table 1 below. The baseline turbidity trigger values were calculated for an internal (80th percentile) and external (95th percentile) are provided in Table 2.

Table 1 Wet and dry season turbidity trigger values

Site	Depth (m)	Dry Season		Wet Season	
		Internal Trigger Level (80th percentile)	**External Trigger Levels (95th percentile)**	**Internal Trigger Level (80th percentile)**	**External Trigger Levels (95th percentile)**
I1	8.7	5	9	32	90
I2	8.9	4	6	11	42
I3	9.4	5	6	20	72
I4	9.2	6	8	15	57
Reference					
R1	9.3	7	11	35	85
R2	10.4	3	5	16	46
R3	26.5	4	8	8	89

Figure 3: Dry Season Baseline Turbidity Data

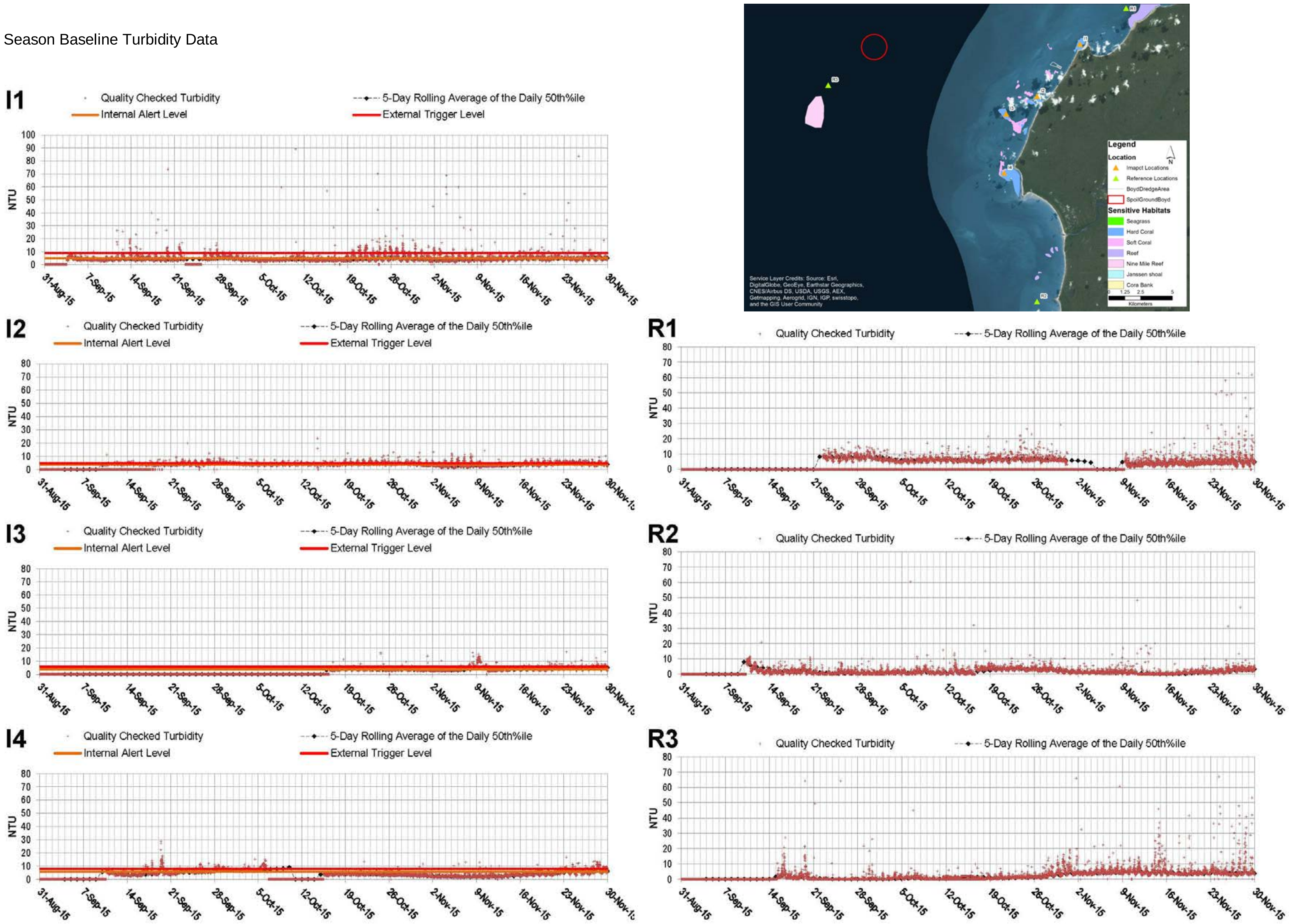
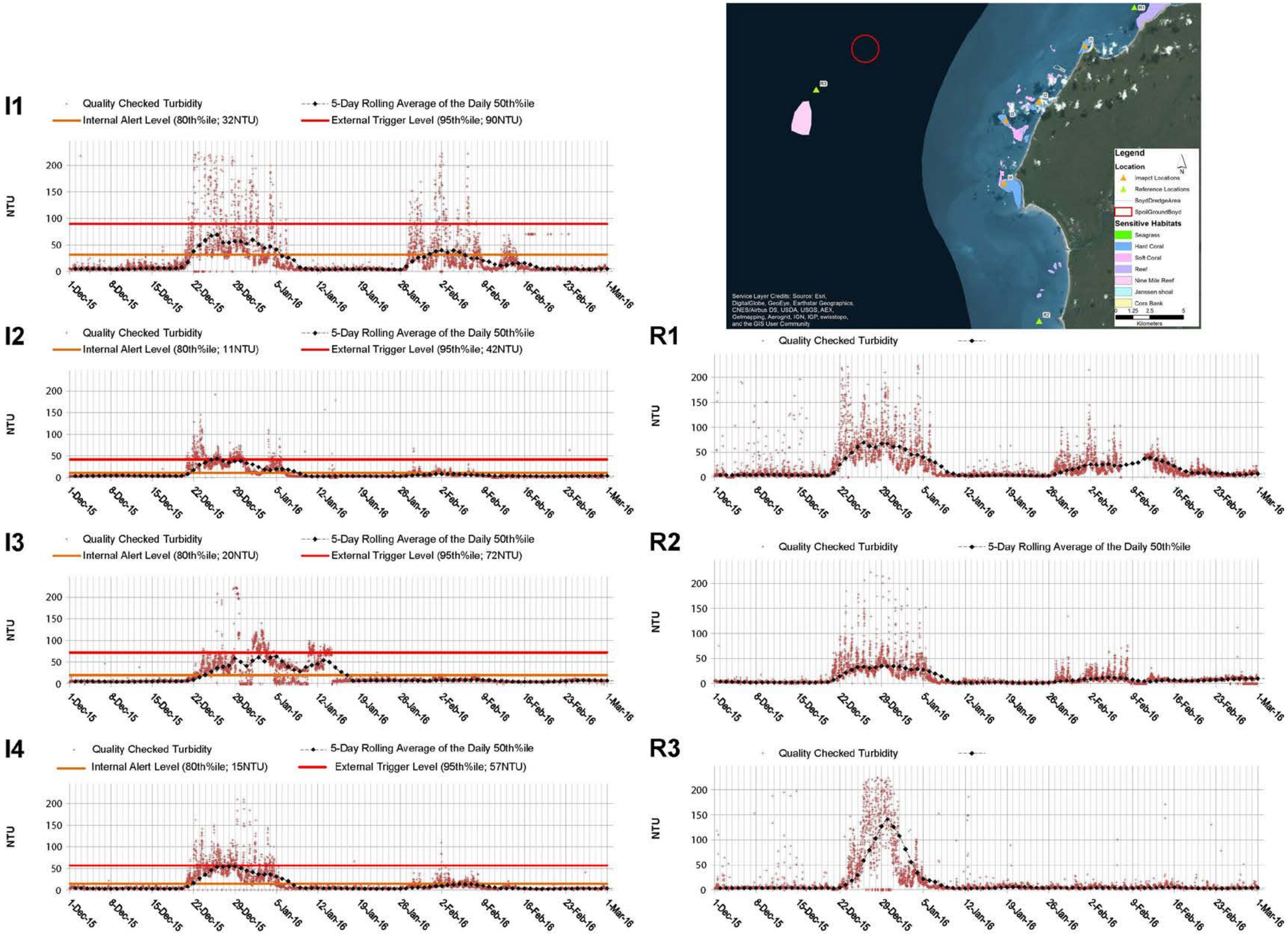


Figure 4: Wet Season Turbidity Data



Turbidity data for all locations from 01 March to 08 May 2016 is provided in Figure 5. Dredging was completed between 26 March (18:20) and 09 April (01:00) 2016 during which time there were no dredging related impacts recorded at the inshore monitoring locations. Results were well below the internal and external trigger levels. Results are displayed in Figure 5 and Table 3 below. Based on the short duration of the dredging and low levels of turbidity at the monitoring sites, plume water quality impacts are assessed as nil to low.

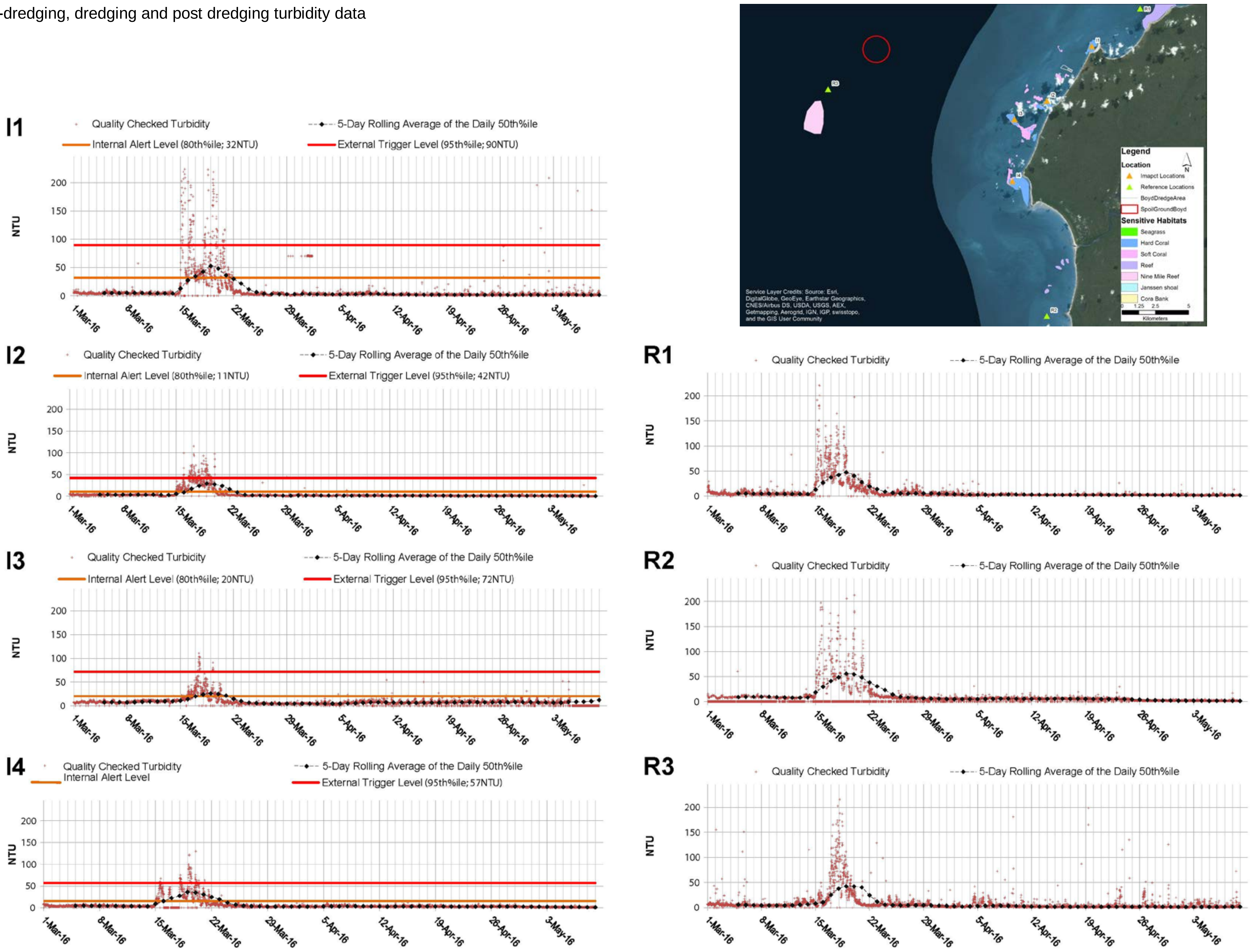
A number of telemetry issues were recorded throughout the program. A summary of the issues and the management actions are summarised in Appendix D

Elevated turbidity events were recorded from 15 to 22 March 2016. These can be attributed to a storm event and were a region wide occurrence.

Table 2 Five day rolling average of the daily median at each monitoring location

Site	Site I1	Site I2	Site I3	Site I4	Site R1B	Site R2	Site R3
Wet Season Internal Alert Level	**32**	**11**	**20**	**15**	**-**	**-**	**-**
Wet Season External Trigger Level	**90**	**42**	**72**	**57**	**-**	**-**	**-**
26-Mar-16	3.5	1.8	4.8	4.7	5.3	9.3	4.3
27-Mar-16	3	1.7	4.5	3.7	5	7.8	4.5
28-Mar-16	3	1.8	4.4	3.3	5.8	7.2	4.4
29-Mar-16	2.8	1.7	4.3	2.8	5.6	6.3	4.4
30-Mar-16	2.7	1.7	4.3	2.5	5.4	5.8	4.1
31-Mar-16	3.3	2.1	4.5	2.7	4.8	5.5	3.9
1-Apr-16	2.9	2	4.5	2.7	4.2	5.1	3.1
2-Apr-16	2.7	2	4.6	2.7	3.5	4.9	2.6
3-Apr-16	2.7	2	4.5	2.8	3.4	4.8	1.9
4-Apr-16	2.8	1.8	4.3	2.8	2.9	4.7	2.2
5-Apr-16	2.4	1.5	4.5	2.9	2.6	4.9	2.5
6-Apr-16	2.5	1.5	4.8	3.3	2.5	5.2	3.1
7-Apr-16	2.7	1.6	5.4	3.5	2.5	5.4	3.4
8-Apr-16	3.2	1.8	6.1	3.6	2.8	5.6	3.6
9-Apr-16	3.5	1.9	6.9	3.7	3.2	5.7	3.3

Figure 5 Pre-dredging, dredging and post dredging turbidity data



In field images taken of the plume are displayed below.

28/03/2016

29/03/2016 within 100 m of vessel

29/03/2016

30/03/2016

02/04/2016

04/04/2016

3.2. PAR data

PAR data was collected from September 2015 to 8 May 2016, data is displayed in Figure 6 (dry season baseline), Figure 7 (wet season baseline) and Figure 9 (pre-dredge, dredge and post dredge). Results were consistent with turbidity data with a decrease in PAR coinciding with increases in turbidity. Further information can be found in the Appendix B and C.

Figure 7: Dry Season Baseline PAR Data

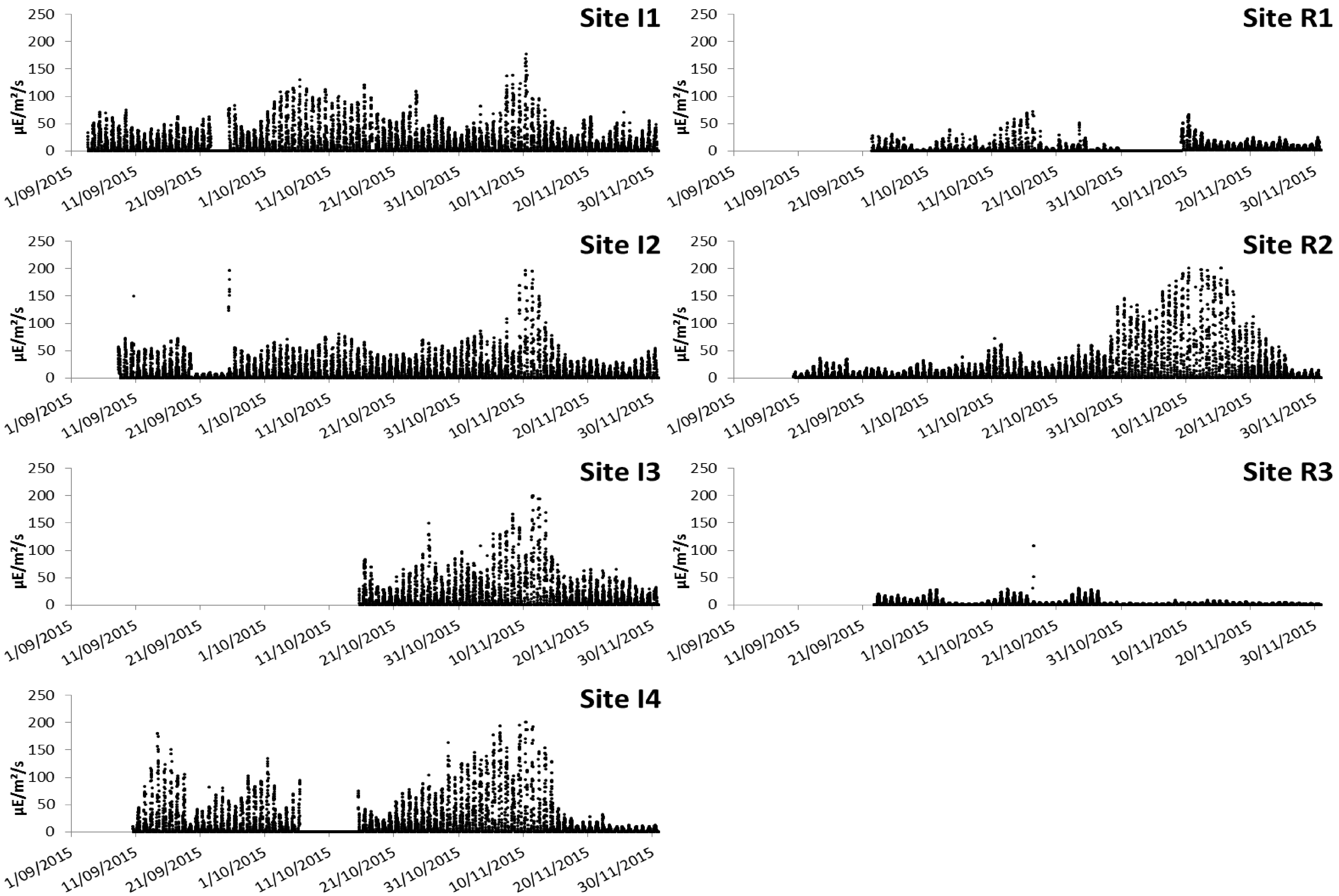


Figure 8: Wet Season Baseline PAR Data

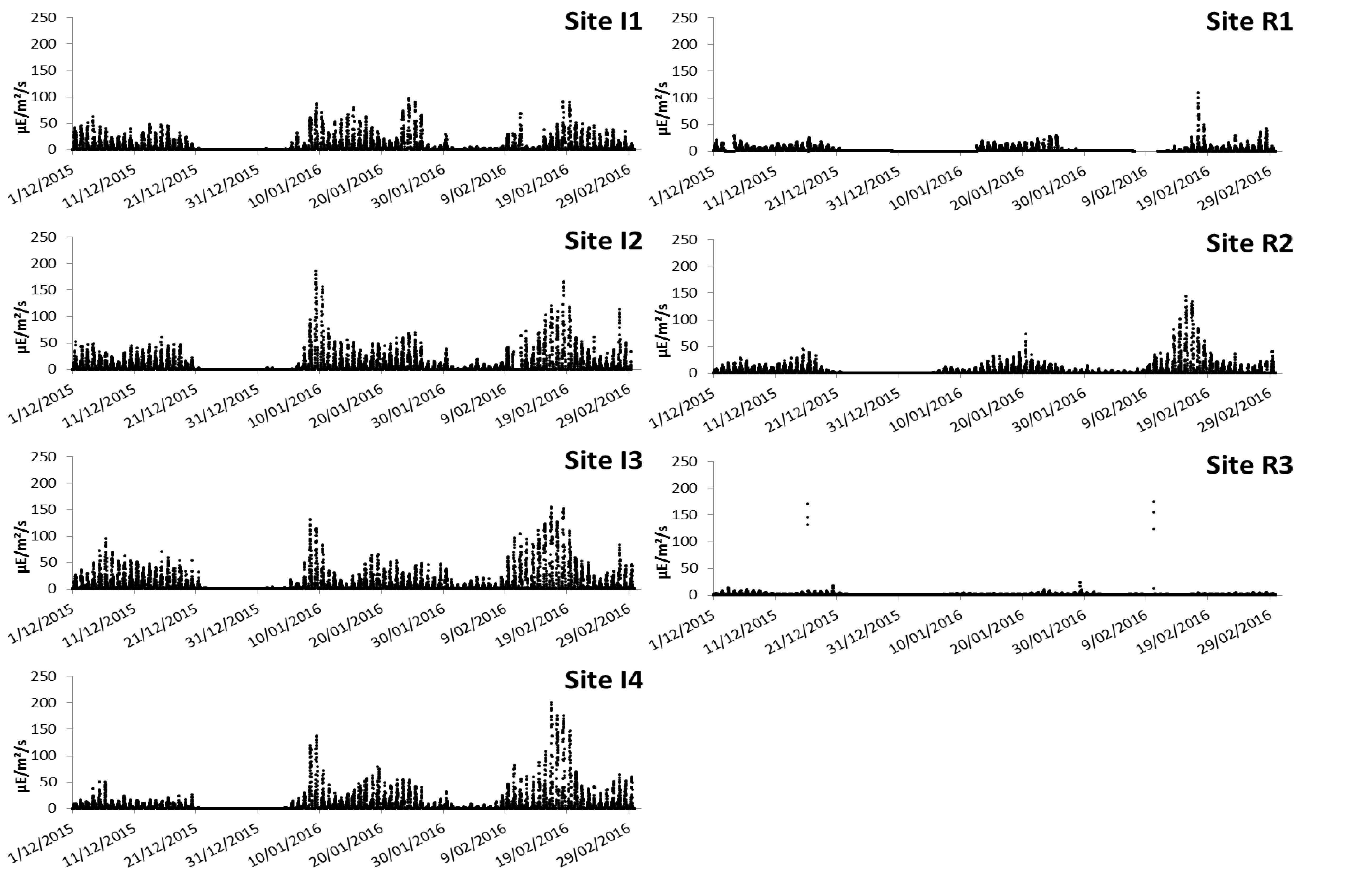
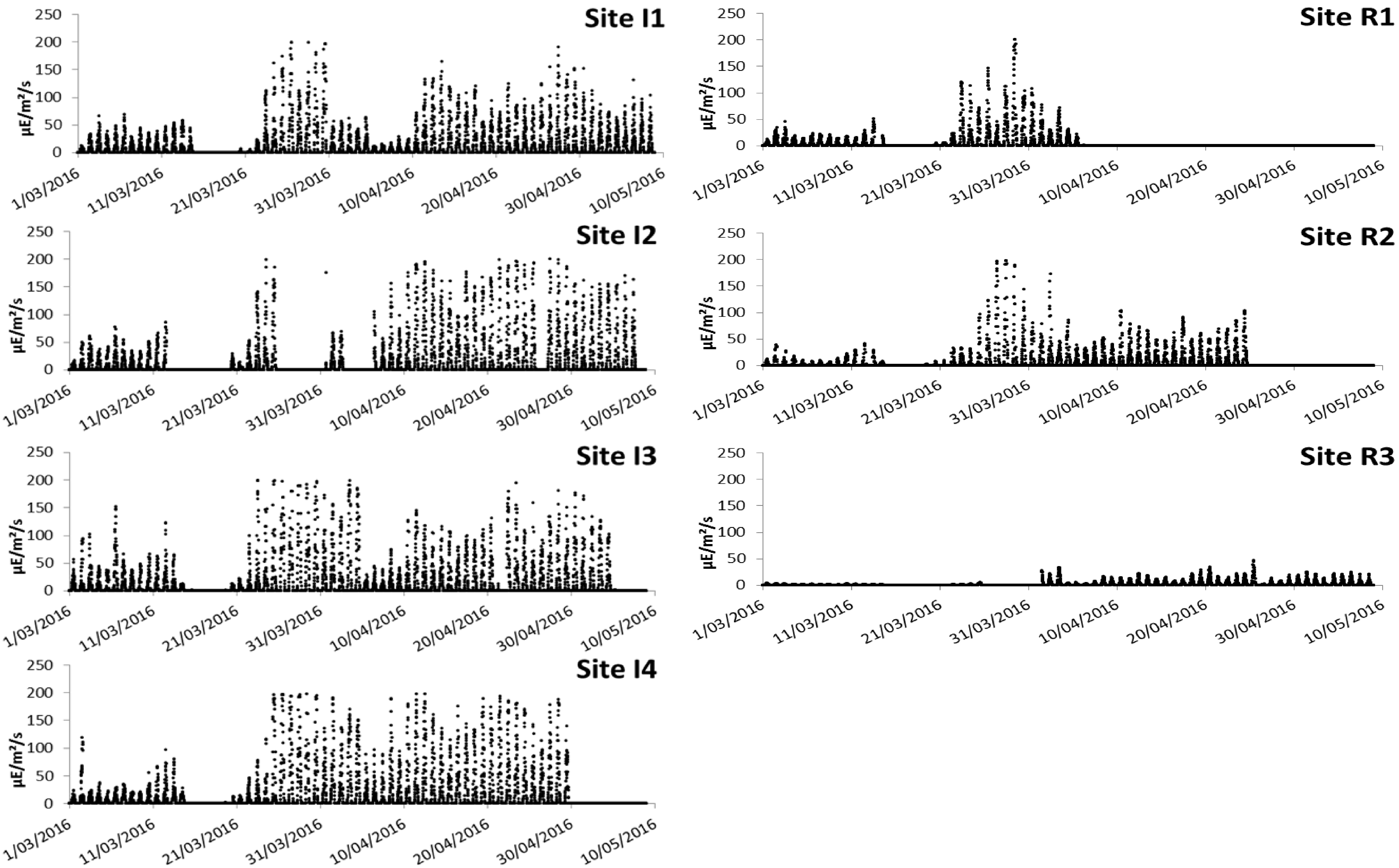


Figure 9 Pre-dredging, dredging and post dredging PAR data



3.3. Turbidity and PAR

The relationship between turbidity and PAR was examined for both the dry and wet season for each site. For both the wet and dry season an exponential relationship was the line of best fit between the two variables. This relationship was significant ($p<0.05$) at all locations except I3 during the dry season and R3 during the wet season. Further detailed results can be found in Appendix B and Appendix C.

3.4. TSS and turbidity

No statistical relationship was found between TSS and turbidity for either season.

3.5. Gross Sedimentation

The daily gross sedimentation rates are provided in Appendix B and Appendix C.

4 CONCLUSIONS

Based on the data collected plume water quality impacts associated with dredging are assessed as nil to low.

APPENDIX A: DATA ANALYSIS STANDARD OPERATING PROCEDURE

Memorandum

To:	Linda Wells (RTA Weipa)	**Date:**	12 May 2016
CC:	David Parry, Jordan Gailey, Glenn Woodrow	**From:**	Kennedy, John (Brisbane)
Doc No:	301310-08460-00-EN-MEM-0003	**File Loc:**	G:\301310\08460 PROJ - South of Embley (SOE) Project\10.0 Engineering\10 MA-Marine\SOP\2 - Data Processing SOP\Rev 2
Subject:	Turbidity and PAR Data Quality Control Standard Operating Procedure	**Project:**	301310-08460

AMRUN PROJECT – RECEIVING ENVIRONMENT MONITORING FOR BOYD DREDGING

STANDARD OPERATING PROCEDURE:

QUALITY CONTROL OF TURBIDITY AND PHOTOSYNTETICALLY ACTIVE RADIATION DATA

Purpose:

The purpose of this document is to describe the standard operating procedure (SOP) for quality control (QC) applied to turbidity and photosynthetically active radiation (PAR) monitoring for the Amrun (formerly, South of Embley) Project.

Background:

The *South of Embley Project Dredge Management Plan – Port (Initial Capital Dredging)* (DMP) (RTA, 2015) describes a water quality monitoring program to be developed to monitor the impacts of dredging on local water quality at Boyd Point where capital dredging is to be undertaken. The objective of the water quality monitoring program is to provide continuous water quality data to assist in the management of initial capital dredging and spoil disposal activities. Water quality data at Concern and Reference Sites would be collected to:

- monitor the spatial extent of turbidity in relation to predicted plumes;
- adaptively manage the risk of impacts to coral in the Sites of Concern from increases in turbidity;
- provide "early warning indicator" of potential impacts on coral health; and,
- validate the appropriateness of coral health Reference Sites. Water quality monitoring will confirm they have not been impacted by increased turbidity or sediment deposition from dredging and spoil disposal activities.

Data are being collected in two phases:

- **Phase 1:** Baseline – for the purposes of collecting information to support development of seasonal internal alert and external trigger levels that are to be applied to environmental management of dredging during the second phase.
- **Phase 2:** Dredging – to monitor water quality during the dredging campaign to provide early warning of potential impacts to corals from turbidity.

Baseline monitoring is being undertaken at Concern (I1, I2, I3, I4) and Reference (R1, R2, R3) Sites, with loggers monitoring, turbidity and photosynthetically active radiation (PAR). The DMP identified that readings are to be logged every 15 minutes and updated daily. Data are to be transferred at least once daily and this is accomplished by access to real-time telemetered data. Data quality control is required subsequent to receipt of data to remove unreliable data. Quality controlled data sets for the dry season (September to November) and wet season (December to February) are used to develop site specific, seasonal turbidity internal alert level (80th%ile) and external trigger level (95th%ile) for comparison during dredging.

Dredge monitoring requires telemetered water quality loggers be deployed at each of the Concern and Reference Sites. Systems are required to be equipped with turbidity sensors and have remote data transfer capabilities. Data are required to be digitally logged in the unit and then transmitted using satellite telemetry to the base station receivers for storage, display and analysis. The use of telemetered loggers provides practicable real-time water quality data during dredging and spoil disposal activities. Turbidity data collected from the telemetered loggers would be analysed daily against turbidity trigger levels set for the Concern Sites to provide early warning of potential coral impacts associated with the initial capital dredging and/or spoil disposal plumes. In the event of an exceedance of the trigger levels, an analysis of data quality is to be undertaken as a key first step as defined in the Water Quality (Turbidity) Management Process in Figure 12 of the DMP.

Context and Scope of this Standard Operating Procedure:

High quality marine observations and data require consistent and sustained quality assurance (QA) and quality control (QC) practices to ensure credibility and value to operators and data users. Quality Assurance practices involve processes that are employed with instrumentation and hardware to support the generation of high quality data. Quality control involves follow-on steps that support the delivery of high quality data and requires both automation and human interpretation.

This Data QC Standard Operating Procedure (SOP) relates to the QC of downloaded and telemetered turbidity and PAR data being collected for the Amrun Project Receiving Environment Monitoring Project (REMP) for Amrun Port Dredging. The purpose of the REMP is to undertake water quality monitoring during baseline and dredging periods in accordance with the DMP.

This SOP has been developed considering the requirements of both the baseline and dredging QC requirements.

This version of the SOP considers the outcomes of an iterative process of QC data optimisation conducted during January 2016 by Advisian using a purpose-built data analysis tool developed in MS Excel. This iterative process followed development of a QC SOP that was provided to RTA on 18 December 2015 and contained initial parameter values for several proposed QC tests. The iterative optimisation process conducted in January sought to refine the values of parameters applied to the QC tests to reduce the occurrences of a) good data being excluded or b) poor data being included in an optimised data set. The parameter values presented in the QC tests within this SOP version reflect the outcomes of the optimisation process based on dry season data.

During this optimisation process, a review of the relative value of each test was undertaken to identify key QC tests that benefit data quality, and considers their application via web-site application.

Reference documentation:

The procedures described in this SOP are based on the recommendations contained in the following reference, which has been developed to provide guidance to the United States Integrated Ocean Observing System and the larger community of optics professionals for real-time QC of optics measurements. This reference was developed by a committee of ocean optical specialists and is considered of suitable rigor to support real-time data QC for the Amrun REMP.

U.S Integrated Ocean Observing System, 2015. Manual for Real-Time Quality Control of Ocean Data: A Guide to Quality Control and Quality Assurance of Coastal and Oceanic Optics Observations. 46pp. (USIOOS, 2015)

USIOOS (2015) focuses on real-time data, presenting a series of 13 tests that operators can incorporate into practices and procedures for QC of optical measurements, including turbidity and PAR. These tests are identified as required, recommended or suggested.

This SOP also draws upon the recommendations contained in the associated USIOOS document regarding Data Quality Control Flags.

U.S Integrated Ocean Observing System, 2014. Manual for the use of Real-Time Ocean Data Quality Control Flags. 19pp. (USIOOS, 2014)

Approach

This SOP considers the application of each of these 13 tests to support QC of downloaded and real-time data collected and transmitted for the Amrun REMP. The web-site hosting the telemetered data (Fastwave) provides some ability to view automated QC data online, but provides a facility for download of data that can be subject to more comprehensive desktop analysis. Data can also be directly downloaded from instrumentation during on-site visits and subject to QC testing.

Tests used in this SOP are specified along with QC flags that reflect associated conditions. The tests presented are similar to those presented in USIOOS (2015).

Data are evaluated using QC tests and results of those tests are recorded by inserting flags in the datasets. For the detailed QC evaluation of data, the set of flags used in this SOP reflect the Intergovernmental Oceanographic Commission (IOC) Primary Level flags (IOC 54:V3) (UNESCO, 2013) and adopted by USIOOS. These flags are provided in Table 1, and are colour coded using a 'stop light' format.

Table 1 Flags for real-time QC data

Flag	Description
Pass = 1	Data has passes critical real-time QC tests and are deemed adequate for use as preliminary data.
Not evaluated = 2	Data have not been QC tested, or the information on quality is not available.
Suspect or of high interest = 3	Data are considered to be either suspect or of high interest to data providers and users. They are flagged suspect to draw further attention to them by operators.
Fail = 4	Data are considered to have failed one or more critical real-time QC checks. If they are disseminated at all, it should be readily apparent that they are not of acceptable quality.
Missing data = 9	Data are missing; used as a placeholder. (Note: Missing data for the SoE REMP is presented on the web-site as NULL.)

QC flags provide important information to those who may use the data in decision making. Apart from providing routine review of general data quality, the DMP for the Amrun Project initial capital dredging identifies that QC data review is required when an exceedance of a trigger level occurs, whereby detailed QC analysis of data is a first step in identifying whether further actions are required to manage turbidity impacts. Such detailed QC review warrants download of data and professional review and interpretation.

The purpose built QC data analysis spreadsheet developed for the Amrun Project REMP provides detailed flag information and summary statistics for the various flag types for each QC test for each logger site.

This enables rapid review of data quality overall. Graphical outputs of data using ‘stop light’ colour coding of QC outcome assists in identifying individual data points that contain failed or suspect data for review.

The 13 real-time QC tests that are identified by USIOOS (2015) as Required, Recommended or Suggested as outlined in Table 2. The applicability of each test to the Amrun REMP is included in that table along with the tests application for use on the telemetry website and detailed data QC upon the Advisian compiled database.

Quality Baseline Data

For the Amrun REMP, a key outcome for baseline water quality monitoring is the provision of quality data from which alert and trigger levels can be developed for subsequent comparison against dredging phase monitoring data.

It is not uncommon that data collected and telemetered by instruments includes data that contain anomalies and hence require further assessment for inclusion (or exclusion) in a quality data set. For example, cloudy conditions or high seas may limit the transmission of complete data packages. Ideally, collection of similar telemetered data using a parallel system for comparative analysis and validation purposes would allow direct real-time comparison, however a duplicate telemetered system is not within the scope of this REMP.

Data collection for the baseline period however is not reliant on telemetered data, with monthly downloads of primary and backup logger data occurring. This does allow for comparative analysis of turbidity to occur where the primary data downloaded from site is considered to possibly be erroneous. In such circumstances, or where data is missing, the backup logger data may be input into the baseline data program to improve completeness of the dataset, within which the source of data is recorded.

Subjecting the raw collected (not quality controlled) baseline data to the QC tests selected for the REMP has enabled detailed review and interrogation of data. The output QC data from the baseline forms the basis of data analysis for the purposes of developing Site Specific Seasonal Alert and Trigger levels.

Table 2 Outline of 13 Real-Time QC Tests

Test Group	Test No.	Test Title	Test Description	Applicability to Amrun REMP	Applicable to Website and/or Internal Database
Group 1 - Required	Test 1	Timing/Gap Test	Check for arrival of data and timestamp	Applicable	Web-site
	Test 2	Syntax Test	Check to ensure that the message is structured properly	Applicable	Web-site
	Test 3	Location Test	Check for reasonable geographic location.	Not applicable (NA). Fixed logger locations.	Not applicable
	Test 4	Gross Range Test	Data point exceeds sensor or operator-selected minimum/maximum.	Applicable.	Both. Web provides de-facto Test 7 for PAR.
	Test 5	Decreasing Radiance, Irradiance, and PAR Test	Test that subsurface radiance, irradiance, and PAR decrease with increasing depth.	NA. Not testing profiles as the loggers are at a fixed depth.	NA
Group 2 - Strongly recommended	Test 6	Photic Zone Limit for Radiance, Irradiance, and PAR Test	Test that radiance, irradiance, and PAR are nearly zero below the photic zone.	NA in relation to photic zone. Modify for application for night time observations.	Both
	Test 7	Climatology Test	Test that data point falls within seasonal expectations.	NA during baseline which establishes seasonal trends. NA during dredging: -Turbidity sensor range is not sufficiently high to warrant separate climatology test given wide range of turbidity levels recorded. -PAR seasonal extent can be accommodated within Test 4 Gross Range Test particularly as PAR sensor theoretically has no sensor max.	NA
	Test 8	Spike Test	Data exceeds a selected threshold relative to adjacent data points.	Limited applicability to turbidity given natural variability in shallow, nearshore area and application of sensor maxima. PAR considered within Gross Range Test (Test 4).	Internal database.

Test Group	Test No.	Test Title	Test Description	Applicability to Amrun REMP	Applicable to Website and/or Internal Database
	Test 9	Rate of Change Test	Excessive rise/fall test.	NA. Value of test is limited due to dynamic nature of turbidity and PAR in the nearshore marine environment. Test not considered further. Spike test (Test 8) will act as surrogate for rate of change test.	NA
	Test 10	Flat Line Test	Invariant value.	Applicable in concept. Not applicable in practice, as test is confounded by missing data. Run as part of internal database checks. Regular observation of web-site data to be undertaken to identify potential logger failure. Check 1-2 times per day.	Internal database.
Group 3 - Suggested	Test 11	Multi-Variate Test	Comparison to other variables.	Advance family of tests, typically providing a more restrictive form of Rate of Change Test. Not considered further here given Rate of Change Test is considered not applicable.	NA
	Test 12	Attenuated Signal Test	A test for inadequate variation of the time series.	As for Test 10, not applicable. Test is confounded by missing data. Run as part of internal checks only.	Internal database.
	Test 13	Neighbour Test	Comparison to nearby sensors.	Not applicable to telemetered data as backup system is not telemetered.	NA

QC Tests Relevant to Amrun REMP Telemetry

The identified applicable tests are expanded upon separately below, with discussion of approach for test specifications.

Each data packet received via telemetry contains information, including the raw voltages of data to be converted to turbidity and PAR, etc. Below are two examples of data packets, the first one being from a telemetry buoy with communication issues to the Seabird, and the second a full data packet with reasonable data voltages.

a) 32:06.75200S,115:48.82881E,52E2,invalid,12.84,invalid data from sensor after 3 retries
b) 12:54.57496S,141:37.71829E,3585,2015-10-14 10:00:05,14.13, IMEI300234060453050, 26.2028, 5.37782,8.262,0.0759,2.7942

Once the data has been received by Fastwave, it is processed by dividing the data up into the parameters required. Date, time, battery voltage, temperature and the other voltages are identified and split for the data processing.

Test 1: Timing/Gap Test

Check for arrival of data		
Test identifies that the most recent data point has been measured and received within the expected time window (TIM_INC) and has the correct time stamp (TIM_STMP)		
Flags	**Condition**	**Model Code Instructions**
Fail = 4	Data have not arrived as expected	If NOW – TIM_STMP > TIM_INC, Flag 4
Suspect = 3	N/A	N/A
Pass = 1	Data has arrived as expected	N/A
Test exception: None		
Test specifications: TIM_INC = 15 minutes		
QC actions: **Flag 4:** Automatic - Note in data point metadata. Operator – Investigate possible system issue for resolution.		

Test 2: Syntax Test

Check to ensure that the message is structured properly		
Test checks that the data packet received contains the expected structure without any indicators or flawed transmission errors. If invalid data is in the packet the data is input into the web-site as a NULL value. Re-engineering of data is not proposed and subject to error.		
Flags	**Condition**	**Model Code Instructions**
Fail = 4	Data sentence cannot be recognised to provide a valid observation.	If invalid data is in the data packet, the resultant inputs into the website are NULLs and are automatically inserted; Flag 4.
Suspect = 3	N/A	N/A
Pass = 1	Expected data sentence received.	N/A
Test exception: None		
Test specifications: Received in following format (example): 12:54.57496S,141:37.71829E,3585,2015-10-14 10:00:05,14.13, IMEI300234060453050, 26.2028, 5.37782,8.262,0.0759,2.7942		
QC actions: **Flag 4:** Automatic – Replace invalid data with NULL in web-site data and note in data point metadata. Operator – Investigate potentially wider system issue for resolution. Consider within context of other flags. Mobilise to site if necessary to resolve anticipated equipment issues.		

Test 4: Gross Range Test

Data point exceeds sensor or operator-selected min/max.

Data point exceeds sensor or operator-selected min/max.

No optics observation value (OO_n) is less than a minimum value or greater than the maximum value the sensor can output are acceptable (SENSOR_MIN, SENSOR_MAX).

There is no theoretical upper limit to PAR sensor maximum. During dredging, use maximum PAR value based on maximum recorded on daily PAR wave from baseline.

The operator can also select a smaller span (OP_MIN, OP_MAX) based upon knowledge or a desire to draw attention to extreme values.

Flags	**Condition**	**Model Code Instructions**
Fail = 4	Reported value is outside of sensor span.	If OO_n <SENSOR_MIN, or OO_n > SENSOR_MAX, Flag = 4
Pass = 1	Applies for test pass condition	

Test exception: None

Test specifications: TURB_SENSOR_MAX = 225 NTU; TURB_SENSOR_MIN = 0;

PAR_SENSOR_MAX = 200 NTU; TURB_SENSOR_MIN = 0;

OP_MIN = Not Used; OP_MAX = Not Used

Notes:

SENSOR-MAX sensor details to be provided. SENSOR_MIN will be set to 0 for turbidity and PAR. Neither of these parameters can have values less than 0.

QC actions:

Flag 4: Automatic –

For turbidity and PAR SENSOR_MIN, replace negative values with 0 and note in data point metadata.

For turbidity SENSOR_MAX, remove data point and replace with NULL.

For PAR SENSOR_MAX, replace data value with point averaging of next valid point either side of failed data so that total PAR calculation is not underestimated due to data removal. Note action in data point metadata.

Operator – monitor for persistent issue possibly requiring resolution at site. Confirm status within 24 - 48 hours and mobilise to site if required, within required timeframe, to resolve issues with equipment on site.

Test 6: Photic Zone Limit for Radiance, Irradiance, and PAR Test

Test that radiance, irradiance, and PAR are nearly zero below the photic zone (adaptable to night time monitoring).		
This test would typically be used to check for upwelling/downwelling radiance, irradiance and PAR as the sensor is lowered and raised below the photic zone. Such a test is not relevant to the Amrun Project, however this test can be modified to check for PAR during night time when light should not be present.		
Flags	**Condition**	**Model Code Instructions**
Fail = 4	Reported value Eu_n greater than operator selected Eu_{night}.	If TIM_STMP>TIM_SSET or TIM_STMP<TIM_DAWN, if $Eu_n > Eu_{night}$, flag = 4
Suspect = 3	No suspect flag is identified for this test.	N/A
Pass = 1	Applies for test pass condition	N/A
Test exception: None		
Test specifications: Eu_{night} = 0.5 µE/m²/s; TIM_SSET = refers to table of sunset times for day of year; TIM_DAWN = refers to table of dawn times for day of year.		
QC actions: **Flag 4:** Automatic – Replace failed night time data to be 0 µE/m²/s PAR at night. Note action in data point metadata.		

Test 7: Climatology Test (NO LONGER PROPOSED FOR USE)

Test that data point falls within seasonal expectations

This test would only applicable following baseline data collection for wet season and dry season where seasonal expectations are developed. Use of climatology test during dredging program would highlight readings outside baseline conditions and potentially due to dredging operations.

This test is a variation on the gross range check, where the gross range SEASON_MIN_FAIL and SEASON_MAX_FAIL are at some operator-selected time period (TIM_TST).

Review of Amrun REMP data indicates that this test would provide negligible benefit given the application of the Gross Range Test and the spread of data up to the maximum sensor levels. Such a test would only be relevant in the event that there was a substantial difference between sensor maxima and observed data maxima.

Flags	Condition	Model Code Instructions
Fail = 4	Reported value is below baseline seasonal minimum for turbidity and PAR. Reported value is above seasonal PAR maximum.	If for turbidity, OO_n <SEASON_MIN, or OO_n > SEASON_MAX, Flag = 4 If for PAR, OO_n > SEASON_MAX, Flag = 4
Fail = 3	Reported value is above baseline seasonal maximum.	If for turbidity OO_n > SEASON_MAX, Flag = 3
Pass = 1	Applies for test pass condition	

Test exception:

For use only following collection of baseline data for selected time-period. In the case of the SoE Project, the time periods of relevance are wet-season and dry-season.

Test specifications:

For turbidity, SEASON_MAX = TBA (see notes below); SEASON_MIN = 0;

Notes:

SEASON-MAX details would be based on maximum value determined following completion of baseline data collection.

SEASON_MIN would be set to 0 for turbidity and PAR. Neither of these parameters can have values less than 0.

QC actions:

Flag 4: Automatic –

For turbidity and PAR SEASON_MIN, replace negative values with 0 and note in data point metadata. Note that this may be redundant if a similar action for has been undertaken in Test 4 Gross Range test for SENSOR_MIN. Note action in metadata.

For PAR SEASON_MAX, replace data with point averaging next valid point either side of failed data so that total PAR calculation is not underestimated due to data removal. Note action in data point metadata.

Flag 3: Operator – Triggering of climatology for turbidity SEASON_MAX may indicate dredging related impacts, where by the baseline conditions are exceeded. Operator to consider data in light of dredging operations and across reference and other impact locations for trends in turbidity.

Test 8: Spike Test (Internal Database)

Data point n_{-1} exceeds a selected threshold relative to adjacent data points		
Optical data can spike due to the presence of aggregates in the water, so care must be taken setting high-spike thresholds. Frequent high spikes, however, may indicate a faulty sensor. This check is for single- value points. Large spikes are easier to identify as outliers and flag as failures. Smaller spikes may be real and should be flagged as suspect. For turbidity, this test consists of two operator selected thresholds: $THRSHLD\_LOW_{turb}$, $THRSHLD\_HIGH_{turb}$. The threshold values are dynamically established, computing the mean and standard deviation for a series of moving window 1.5 hours (6 data points at15 mins duration) either side of OO_n. For PAR, this test is not proposed in lieu of the Gross Range Test (Test 4) for PAR.		
Flags	**Condition**	**Model Code Instructions**
Fail = 4	High spike threshold exceeded.	If OO_n > THRSHLD_HIGH, Flag = 4
Suspect = 3	Low spike threshold exceeded.	If THRSHLD_LOW < OO_n < THRSHLD_HIGH, Flag = 3
Pass = 1	Applies for test pass condition	N/A
Test exception: None		
Test specifications: For turbidity: $THRSHLD\_HIGH_{turb} = mean_{window} + 100*SD_{window}$ $THRSHLD\_LOW_{turb} = mean_{window} + 10*SD_{window}$ (Note: The SD multipliers used in these test specifications were developed iteratively to retain apparently good data. Due to the variable nature of turbidity, data was only flagged for further inspection for both test failures and suspect data. Failed data was not automatically removed.)		
QC actions: **Flag 4:** Automatic – Note in data point metadata. Operator – If frequent spikes are detected this may be indicative of equipment issues. Confirm status within 24-48 hours and mobilise to site if required, within required timeframe, to resolve issues with equipment on site. Retain if not considered erroneous. **Flag 3:** Automatic – Note in data point metadata. Operator – Review spike along with other flags. If spike data considered erroneous, treat as for Flag 4. Retain if not considered erroneous.		

Test 10: Flat Line Test (Internal database)

Invariant value

When some sensors or telemetry systems fail the results can be a continuously repeated observation of the same value. This test compares the present observation n to a number (REP_CNT_FAIL or REP_CNT_SUSPECT) of previous observations. Observation n is flagged if it has the same value as previous observations within a tolerance value, EPS, to allow for a numerical round-off error.

Note: Use of this Flat-Line Test during baseline monitoring program has identified that this test is confounded by missing data.

Flags	**Condition**	**Model Code Instructions**
Fail = 4	When the five most recent observations are equal, OO_n is flagged fail.	For i= 1,REP_CNT_FAIL, if $OO_n - OO_{n-1}$<EPS, flag = 4
Suspect = 3	It is possible but unlikely that the present observations and the two previous observations would be equal. When three most recent observations are equal, OO_n is flagged suspect.	For i= 1,REP_CNT_SUSPECT, if $OO_n - OO_{n-1}$ <EPS, flag = 3
Pass = 1	Applies for test pass condition	N/A

Test exception: PAR data at night when it is expected that data should consistently remain effectively at $0\mu E/m^2/s$.

Test specifications: REP_CNT_FAIL = 10; REP_CNT_SUSPECT = 5, EPS_{ntu} = 0.0001 ntu, EPS_{par} = 0.000001 $\mu E/m^2/s$

QC actions:

Flag 4: Automatic – For turbidity and PAR, replace flat-line data with NULL in web-site data and note in data point metadata.

Operator – Investigate likely flat line cause. Confirm status within 24-48 hours and mobilise to site if required, within required timeframe, to resolve issues with equipment on site.

Flag 3: Automatic – Note in flat line data point metadata.

Operator – Review flat line data along with other flags. If flat-line data considered erroneous, treat as for Flag 4. Retain if not considered erroneous.

Test 12: Attenuated Signal Test (Internal database)

A test for inadequate variation of the time series

A common sensor failure mode can provide a data series that is nearly but not exactly a flat line (e.g. from biofouling on sensor). This test inspects for an SD value or range variation (MAX-MIN) value that fails to exceed threshold values (MIN_VAR_WARN, MIN_VAR_FAIL) over a selected time period (TST_TIM).

Noe: This test provided very limited contribution to QC of Amrun Project baseline data.

Flags	Condition	Model Code Instructions
Fail = 4	Variation fails to meet the minimum threshold MIN_VAR_FAIL	If during TST_TIM,SD < MIN_VAR_FAIL, or During TST_TIM, MAX-MIN<MIN_VAR_FAIL, flag = 4
Suspect = 3	It is possible but unlikely that the present observations and the two previous observations would be equal. When three most recent observations are equal, OO_n is flagged suspect.	If during TST_TIM,SD < MIN_VAR_WARN, or During TST_TIM, MAX-MIN < MIN_VAR_WARN, flag = 3
Pass = 1	Applies for test pass condition	N/A

Test exception: PAR data at night when it is expected that data should consistently remain effectively at 0μE/m²/s.

Test specifications: TST_TIM = 24 hours

$MIN\_VAR\_WARN_{turb}$ = 0.01 NTU; $MIN\_VAR\_FAIL_{turb}$ = 0.05 NTU.

$MIN\_VAR\_WARN_{par}$ = 0.0004 μE/m²/s; $MIN\_VAR\_FAIL_{par}$ = 0.0002 μE/m²/s.

QC actions:

Flag 4: Automatic – For turbidity and PAR, replace attenuated data with NULL and note in data point metadata.

Operator – Investigate likely attenuation cause. Confirm status within 24-48 hours and mobilise to site if required, within required timeframe, to resolve issues with equipment on site.

Flag 3: Automatic – Note attenuated data point metadata.

Operator – Review attenuated data along with other flags. If attenuated data considered erroneous, treat as for Flag 4. Retain if not considered erroneous.

Monitoring QC Outcomes and Relevance of QC Tests

Advisian developed a purpose built QC analysis tool in Excel for assessing the quality of downloaded data. Data were subject to the range of tests identified in the previous QC memorandum provided to RTA on 18 December 2015.

The data QC process included an iterative optimisation process for the various parameters used in the QC tests. This process proved highly useful in identifying data that were likely erroneous. The graphical method applied to summarise the data in the data analysis tool included the stop-light colouration indicative of data quality, allowing for rapid identification of areas of QC concern. Further, summaries of data included performance across each QC test, allowing for determination of which tests were primarily responsible for identifying fails or suspect data. This data QC analysis tool will form the basis of detailed QC analysis of data used for calculation of wet season internal alert and external trigger levels and detailed analysis of data performed by Advisian on behalf of RTA during the dredging phase.

The baseline data QC process has highlighted which tests are most beneficial in identifying potentially erroneous data, and which are essentially redundant. Despite their redundancy, Advisian would maintain these tests as part of the detailed QC data checks. The redundant nature of several QC tests warrants their exclusion from QC performed on the telemetered data on the web-site, noting that raw data would remain available for download and detailed analysis. Quality control tests considered most relevant to the web-site include:

- Test 1: Timing/Gap Test – already performed
- Test 2: Syntax/ Test – already performed
- Test 4: Gross Range Test
- Test 6: Photic Zone Test

Review and Response

Telemetered data is typically reviewed by Advisian at the beginning and end of each business day to identify issues of telemetry data failure. On weekends, data review is typically undertaken once a day during baseline. This review includes:

- Visual assessment of graphed data to identify that transmissions are still being transmitted/received
- Frequency of NULL data, as an indicator of logger function or potential issues that may be arising and requiring on-site maintenance
- Review of data records considered suspect

Frequency of review during the Phase 2 dredging period will similarly be twice a day on business days and once a day on weekends unless there is a developing turbidity issue that has been identified during Thursday/Friday of the work week or there is an increasing trend in turbidity due to dredging, when more than one review will be conducted daily. In addition, the web-site provider will issue daily data reports to Advisian in a format that can be incorporated into the QC database for testing. Data can also be downloaded directly from the web-site.

Where an internal alert or external trigger level is exceeded, the detailed internal QC check will be performed by Advisian using the telemetered data to confirm whether data quality is an issue. Following confirmation of good data quality, further analysis will be undertaken by Advisian and other the relevant parties to determine whether any turbidity changes are dredging related or due to unrelated factors. Such analysis will occur within 48 hours of the exceedance being identified.

In the event that telemetry fails during the monitoring program, contractual arrangements are in place between RTA and Advisian requiring mobilisation to site to rectify the issue within 7 days of the initial error or loss. Data downloaded during site visit would be uploaded to website in place of non-transmitted data within 48 hours of on-site logger download. Given that final resolution of any QC issues may require a visit to site to ascertain fault with equipment, final data can only be confirmed subsequent to site visit in such events. At other times, the stop-light approach of demonstrating data quality on detailed QC would provide indication of data quality at any point that there was a trend toward trigger levels or where those levels were exceeded.

Exceedance / Data Failure Process during dredging

In the event that an internal alert or external trigger exceedance occurs during dredging, the following process will occur:

1. Email and SMS alerts will be provided to requested RTA Weipa personnel in the event the rolling daily median exceeds either the internal alert (80^{th}) or external trigger (95^{th}) values. These alerts would be issued daily on a midnight to midnight basis. Advisian would also receive daily data reports for the same time period.
2. Email and SMS alerts will identify the exceedance type, site of exceedance, site specific alert/trigger level exceeded, and 5-day rolling average of the daily median
3. Advisian will incorporate the provided daily data (or download it from the web-site) into the internal QC database and perform QC testing and review
4. On the day of exceedance notification, Advisian will provide to RTA the updated turbidity chart for the alert/trigger site in questions and an updated summary chart of turbidities across sites. These charts will provide detail regarding QC test performance and provide a visual overview of and turbidity trends more widely across sites
5. Based on review of data, Advisian will provide a conclusion regarding data quality.

Telemetry Failure Process during dredging

The Contractor is required to rectify loss of data (e.g. via telemetry) or evidence of errors within 7 days of the initial error or loss. Boat-based in-situ monitoring is required until the system is re-instated. Accordingly, in the event of data failure during dredging the following process will occur:

1. Telemetry failure identified within 24-hours of the initial system error (allowing for once-daily checks on weekends)
2. Notify RTA/ Bechtel that a particular logger is not transmitting and that an internal investigation process has commenced to determine the cause
3. Undertake internal review and discussions with Fastwave to determine whether the cause is due to web-site issue or due to receipt of nil or corrupt data packets via satellite
4. Notify RTA/Bechtel of results of internal investiagtion, rectification plan and field mobilisation timeframes (if required) within 48 hours of initial system error
5. If mobilisation is required field sampling plan to be issued within 48 to 72 hours of logger error or failure
6. Mobilise to site in accordance with sampling plan and undertake rectification maintenance to reinstate system. Download data from primary and backup logger prior to placing logger back into the water.
7. Provide at least daily updates to RTA/Bechtel of implementation of rectification plan
8. If telemetry is not able to be restored, undertake daily download of logger data on-site. An additional back up logger may be deployed for daily data collection.
9. Convert data collected on-site and provide to Fastwave for replacement of lost or erroneous data, within 24 hours of return to shore. Incorporate replaced data into QC spreadsheet.

Determining if exceedance is dredging related

If an exceedance was identified during dredging, and data quality was identified as being acceptable, the following review process would be undertaken by Advisian to identify whether the exceedance was localised (e.g. potentially due to a point source such as dredging) or more widespread (in which case dredging would not likely be responsible). Additional review of field operations may be undertaken by RTA and/or dredging contractor to identify if dredging operations were likely responsible.

1. Advisian prepare summary graphs of turbidity across Concern and Reference sites using the QC spreadsheet tool.
2. Advisian recommend to RTA whether the exceedence was localised to a particular site, or trend is observed at several sites indicating more widespread phenomenon such as from a weather event.
3. Advisian review graphs of nearest sites to identify whether there is any gradient of turbidity observed decreasing from the dredging area out, as might occur from a point source.
4. Advisian review 5-day rolling average of the daily medians for relevant monitoring location to identify whether an increasing trend was evident over several prior days.
5. Advisian provide graphical output to RTA along with recommendation as to whether event could be dredging related.
6. RTA liaise with dredging contractor to confirm actual operations for the day and prior few days to confirm that dredging had been occuring.
7. RTA review satellite pictures for evidence of turbidity plume extending to the logger where exceedance was notified. RTA may seek professional opinion from Advisian.
8. RTA determine likelihood that exceedence was likely dredging related on the basis of supporting information. RTA may seek professional opinion from Advisian.

References

Intergovernmental Oceanographic Commission of UNESCO, 2013. Ocean Data Standards, Vol.3: Recommendation for a Quality Flag Scheme for the Exchange of Oceanographic and Marine Meteorological Data. (IOC Manuals and Guides, 54, Vol. 3.) 12 pp. (English.)(IOC/2013/MG/54-3)

U.S Integrated Ocean Observing System, 2015. Manual for Real-Time Quality Control of Ocean Data: A Guide to Quality Control and Quality Assurance of Coastal and Oceanic Optics Observations. 46 pp. (USIOOS, 2015)

APPENDIX B: BASELINE DRY SEASON REPORT

Advisian
WorleyParsons Group

RioTinto

RTA Weipa

Water Quality Trigger Report

Port Initial Capital Dredging

31 May 2016

Advisian is a global advisory firm that provides project and business solutions to clients who develop, operate and maintain physical assets in the infrastructure and resources sectors.

301310-08460-00-EN-REP-0012

Advisian Pty Ltd
Level 3,60 Albert St
Brisbane QLD 4000
Australia
PO Box 15081
City East Brisbane Qld 4002

P +61 7 3221 7444
F +61 7 3221 7791
ABN: 50098008818

Disclaimer

This report has been prepared on behalf of and for the exclusive use of RTA Weipa, and is subject to and issued in accordance with the agreement between RTA Weipa and Advisian.

Advisian accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party.

Copying this report without the permission of RTA Weipa and Advisian is not permitted.

PROJECT NO 301310-08460– WATER QUALITY TRIGGER REPORT: PORT INITIAL CAPITAL DREDGING

Rev	Description	Author	Review	Advisian Approval	Date
2	Re-Issued For Use	S Neale	J Kennedy	J Kennedy	31/05/16

Table of Contents

List of Appendices

List of Figures

List of Tables

1 Introduction

1.1 Background

The Amrun (formerly South of Embley) project requires the construction and operation of a new Port facility located between Boyd Point and Pera Head. The marine works will include construction of a jetty, wharf and ship loaders, requiring dredging for berth pockets and an approach/departure channel.

The initial Amrun Port Capital Dredging involves the excavation of approximately 240,000 m^3 of seabed material using a large Cutter Suction Dredge (CSD) and transport and disposal to the approved dredge material relocation ground by hopper barge. The expected time frame for the completion of the dredging and relocation works is three (3) weeks, nominally commencing 22 March and completing on approximately 8 April 2016, subject to weather delays.

1.2 Objectives

The objective of this report is to present dry season water quality trigger levels based on the most recent data collected during the Amrun Project - Baseline Receiving Environment Monitoring for Amrun Port Dredging. In this report, trigger levels are developed for the dry season based on baseline data collection across September to November 2015. A similar but separate report will be developed regarding wet season trigger levels and be based on data collected between

The trigger levels are designed to address the requirements of the Environmental Authority (EA) conditions (EMPL00725113) as outlined in condition J13b (extracted in Table 1-1 below). An extract from the EA conditions - Table J1- Initial Boyd Port Capital Dredge Monitoring: Water Quality Trigger Levels is provided in Table 1-2. Specific trigger levels will be developed at Sites of Concern[1] only, as per the requirements outlined in Table 1-2.

The methods of developing the trigger levels and the management responses have been outlined in the South of Embley Project Dredge Management Plan – Port (Initial Capital Dredging) (DMP), which was approved by Commonwealth in November 2015 and Queensland regulators in January 2016 (RTA, 2015). Section 1.2.1 summarises the process described in the DMP for the development and application of the trigger levels.

[1] *Also referred to as Sites of Influence.*

Table 1-1 Extract of EA section relevant to establishing water quality trigger levels.

J13 (b) establish turbidity-based trigger values as shown in Table J1- Initial Boyd Port Capital Dredge Monitoring: Water Quality Trigger Levels, that:	(i)	Considers, and is informed by, the findings of all relevant publish studies, including available water quality guidelines, trigger values from other comparable dredging programs with similar environmental conditions, and site specific baseline data;	See Section 3.2, Section 3.3 and Section 3.4.1
	(ii)	Considers the most sensitive receptor type and the most relevant water quality parameters (e.g. turbidity, PAR, sedimentation rate) and the reported impacts of turbidity on coral health from the literature and other dredging programs in areas of nearshore coral reefs;	See Section 3.1, Section 3.2 and Section 3.3
	(iii)	Includes season-specific turbidity trigger values;	See Section 3.4.1
	(iv)	Considers sediment plume intensity, duration and frequency of occurrence in establishing trigger values;	See Section and 1.2.1 and 3.4.1
	(v)	Considers the additive effect of multiple stressors; and	See Section 3.2
	(vi)	Considers the effect of depth and water column variation predicted from the 3D modelling	See Section 3.4.4

Advisian provided to RTA Weipa a method to ensure compliance with the requirements of EA Condition J13(b) (Water Quality Triggers - 301310-08460-00EN-MEM-002-Revision 0, December 16 2015). Each of the conditions listed in Condition J13(b) are addressed individually in this report in the relevant sections as described in Table 1-1.

Table 1-2 Initial Port Capital Dredge Monitoring: Water Quality Trigger Levels (reproduced from Table J1 of the EA)

Monitoring Locations	Coordinates (GDA 94)	Quality Characteristic	Unit	Wet Season Trigger level	Dry Season Trigger Level	Frequency
Reference Sites (R1, R2 and R3)	TBA	Turbidity (as a surrogate WQ parameter for PAR and SR)	NTU	N/A	N/A	Continuous Telemetered, Logged at 15 minute intervals
		PAR	mol/m²/day	N/A	N/A	TBD
		SR	mg/cm²/day	N/A	N/A	TBD
Concern sites (I1, I2,I3 and I4)	TBA	Turbidity (as a surrogate WQ parameter for PAR and SR)	NTU	TBD	TBD	Continuous Telemetered, Logged at 15 minute intervals
		PAR	mol/m²/day	N/A	N/A	TBD
		SR	mg/cm²/day	N/A	N/A	TBD

PAR – Photsynthetically Active Radiation; **SR** – Sedimenation Rate; **TBA** – To be advised based on results of monitoring;
TBD – To be determined in approved Dredge Management Plan: statistically derived turbidity trigger based on site specific baseline data and trigger values from other dredging programs with similar environmental conditions together with literature on potential impacts of turbidity on coral health;
Note: Trigger values may vary at different monitoring locations and the number of monitoring locations will be determined through the DMP

1.2.1 Dredge Management Plan Water Quality Triggers

The South of Embley project Dredge Management Plan – Port (Initial Capital Dredging) (RTA, 2015) outlines stages in the development and application of trigger levels. These include:

- **Draft Initial Trigger Levels** – Preliminary trigger values developed using historical data (prior to 2012) for consideration by the Determining Authority when approving the DMP (P36 Table 5 of DMP). These are presented in Table 1-3.
- **Site Specific Trigger Levels** – defined process in the DMP for developing site specific trigger levels for wet and dry seasons using baseline data collection (P36 of the DMP)
- **Trigger Level application during dredging** – initiation of defined water quality management processes if trigger levels are exceeded during dredging (P37-40 of DMP).

The DMP clearly identifies the required approach for developing the Site Specific Trigger Values for wet and dry season for subsequent application during the dredging period.

Site specific turbidity trigger levels for the Sites of Concern are calculated for wet and dry seasons respectively from the data currently being collected during baseline monitoring. These trigger values are used to establish **internal alert levels** and **external trigger levels** as reporting requirements for the program.

The alert levels will be based on the 80^{th} (**internal alert**) and the 95^{th} (**external trigger level**) percentiles with levels determined for both the wet and dry season as follows:

- **Internal Alert Levels** would be triggered if the site specific internal alert turbidity concentration for a Site of Concern is exceeded by the five day rolling average of the daily median turbidity on three consecutive days. Exceedance would trigger investigations to determine the cause of the high turbidity measured.
- **External Trigger Levels** would be triggered if the site specific external trigger turbidity concentration for a Site of Concern is exceeded by the five day rolling average of the daily median turbidity on three consecutive days. Triggering would result in application of the Water Quality Management Process as depicted in Figure 12 of the DMP (RTA, 2015).

Table 1-3 Draft initial Boyd Port Capital Dredging Monitoring: Water Quality Trigger Levels extract from DMP 2015.

Monitoring location	Quality Characteristic	Unit	Initial Alert Level		Trigger level		Frequency
			Wet season	Dry season	Wet season	Dry season	
Concern Sites (I1, I2, I3 and I4)	Turbidity	(NTUe)	7.7	6.1	23.8	14.3	Continuous Telemetered, logged at 15 minute intervals

2 Methods

The process used to develop the turbidity triggers from the baseline data is:

1) Examine the coral community information from the Sites of Concern and rank the coral community in terms of susceptibility to elevated suspended solids and sedimentation rates (see Section3.1 and Section 3.2).

2) Using the baseline Quality Control (QC) turbidity data, calculate the median, 80th, 90th and 95th percentile turbidity values[2] for the Reference Sites and Sites of Concern, for each season (dry – September to end of November, wet - December to end of February). (see Section 3.4)

3) From the perspective of biological relevance to the receiving environment, identify appropriate turbidity percentile metric depending upon the response category (sub-lethal and lethal effect) as outlined in Table 6 of Erftemeijer et al (2012) and the sensitivity of the dominant coral community growth forms outlined in Figure 5 of the same study. (see Section 3.2,)

4) Compare the seasonal site specific turbidity trigger to trigger levels developed for previous dredging programs in similar environments and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ, 2000) for context, and also examine the outcomes in terms of coral community impacts of previous dredging campaigns where information is available (see Section 3.3).

5) Develop a relationship between photosynthetically active radiation (PAR) and turbidity by plotting the baseline QC data for both parameters against each other (see Section3.4.3)

6) Develop a relationship between gross sedimentation and turbidity based on data collected at each site for gross daily sedimentation and median daily turbidity (see discussion in 3.4.6).

7) Examine the literature and results of the dredging programs to determine an appropriate duration of low light which will preclude any sub-lethal or lethal impacts to the coral communities at the Sites of Concern (see Section 3.2).

---

[2] *Statistical criteria for establishing the alert trigger levels are already defined in the DMP (RTA, 2015), being the 80th and 95th percentiles of the baseline for internal alert and external alert respectively*

3 Results

3.1 Existing Coral Community

The closest coral communities to the proposed port facilities are located on fringing reefs situated ~1.7 km to the north at Boyd Point and ~2.8 km to the south at Pera Head, as depicted in the DMP (RTA, 2015) (refer Figure 3-1). Drop video surveys completed as part of EIS and Supplementary EIS studies at Boyd Point and Pera Head found large areas of coarse and silty sand punctuated by occasional outcrops of hard substrate up to 2m high. These outcrops were sparsely covered in algae, soft corals, sponges and hard corals. The percentage cover of hard coral was approximately 1-3% at both locations. The drop video surveys indicated that shoals were primarily composed of isolated patches of undulating hard substrate up to 1 m high with sand and rubble patches in between. There were large aggregations of sea whips in some areas and only occasional hard coral colonies at one shoal location, with approximate percentage cover of hard coral of below 1%.

The sparse hard coral communities were dominated by small (<20cm diameter) to medium (20-40cm diameter) sized colonies of corals from the families Dendrophylliidae, Faviidae and Poritidae. The visibility at all sites was approximately 1–2m. There were occasional larger (>2m) *Porites* spp bommies. The hard coral genera and species present at these locations are typical of corals that grow in marine environments that experience extremes in turbidity and/or temperature. The growth form or shape of the more common genera found, such as *Turbinaria* spp (cup shaped or foliose) and *Porites* spp (domed shaped or massive) appeared flattened indicating a change in the ‘typical’ growth form to adapt to consistent low light conditions.

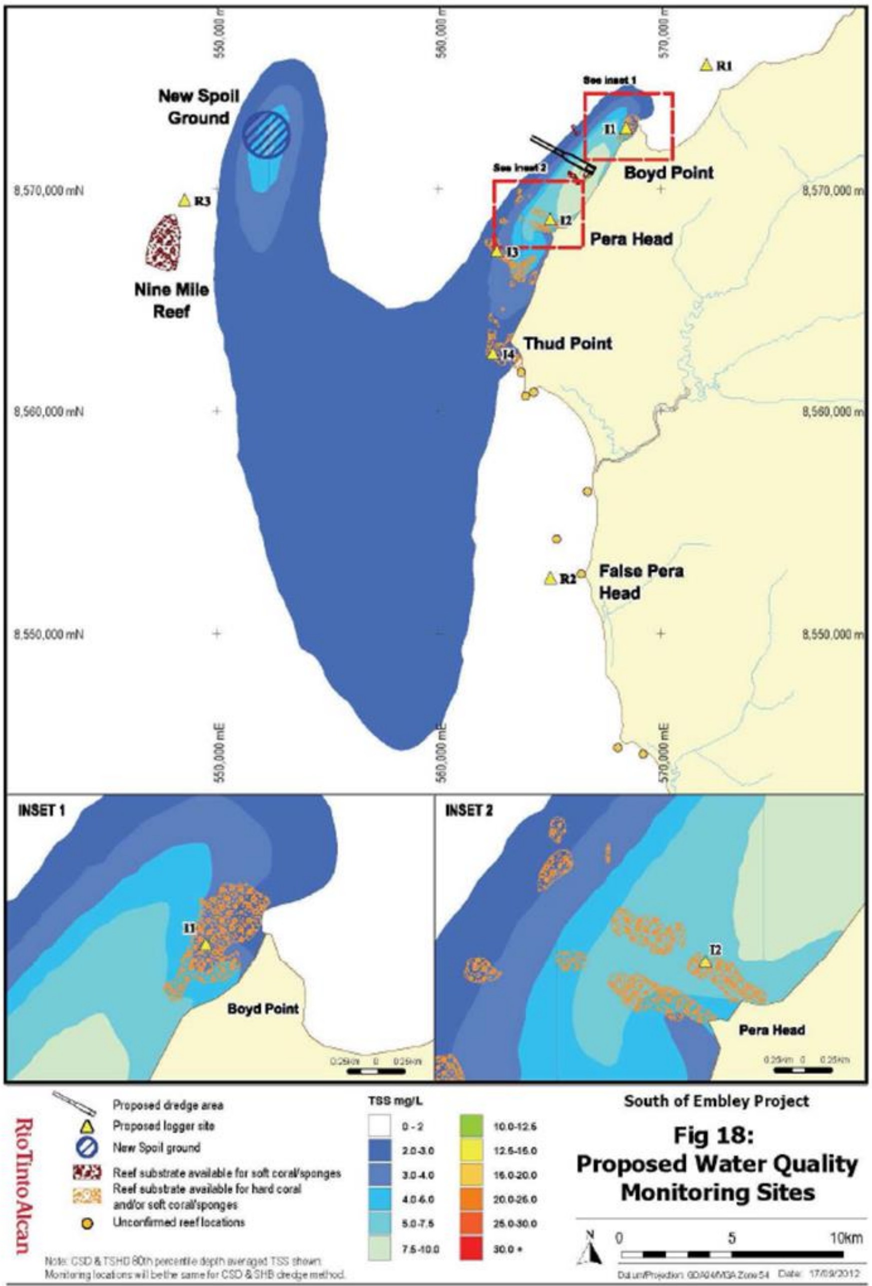


Figure 3-1 Water Quality Monitoring Sites and Coral Locations (RTA, 2015)

3.2 Susceptibility of the Coral Community to Total Suspended Solids, Turbidity and Sedimentation

The genera and growth forms of the coral community at each site (as described above) provide information on the susceptibility of that community to elevated turbidity and elevated sedimentation. The relationship between the coral growth form (and genera) and the susceptibility to elevated sedimentation and suspended solids is described in a study by Erftemeijer *et al* (2012), refer to Table 6 and Figure 5 (Suspended Solids/Turbidity) and Table 10 and Figure 6 (Sedimentation) in that publication[3].

The relative sensitivities of each coral genus and growth form compared to levels of suspended sediment in the water column and rates of sedimentation as described are outlined in Table 3-1.

The TSS values provided are converted turbidity (NTU) based on the laboratory experiments undertaken by James Cook University. The converted turbidity values are provided in parenthesis after the TSS value. The relationship between TSS and turbidity was calculated as 1mg/L (TSS) equals 0.67 NTU (see Section 4.2 of the DMP).

The growth forms of the three most dominant coral families found near Boyd Point and Pera Head are those growth forms which have a high (foliose or laminar) or intermediate (massive or dome shaped) tolerance to suspended solids. This suggests that extended periods of TSS values of 40mg/L (27 NTU) may have sub-lethal impacts on corals of these growth forms, partial mortality impacts to coral colonies may not occur until these colonies are exposed to prolonged periods (several weeks) of TSS in the water column of 100mg/L (67 NTU) or more (refer Table 3-1).

In terms of net sedimentation rates the growth forms of the three most dominant coral families found near Boyd Point and Pera Head are those growth forms which have a sensitive (foliose or laminar) or intermediate (massive/dome shaped) tolerance to elevated sedimentation rates. This suggests that extended periods of sedimentation values of 10mg/cm^2/day may have sub-lethal impacts on corals of these growth forms, lethal impacts may not occur until these colonies are exposed to extended periods of sedimentation (up to two weeks) of greater than 50mg/cm^2/day (refer to Table 3-1).

[3] *http://www.sciencedirect.com/science/article/pii/S0025326X12001981*

Table 3-1 Coral communities and their sensitivity categories for elevated TSS and sedimentation

Location	Overall Hard Coral cover (%)	Dominant coral family	Growth Form	Total Suspended Solids (mg/L) converted NTU values in brackets[1]			Max Sedimentation Rates [2]		
				TSS Growth form Sensitivity Category	Minor Sub-lethal effect after 5-6 weeks	Lethal effects (Partial Mortality) after 2-4 weeks	Sedimentation rate growth form Sensitivity category (Figure 6)	Sub-lethal effects (minor) (mg/cm^2/day) after 3 weeks	Lethal effects (partial mortality) (mg/cm^2/day) after 2-3 weeks
Boyd Point and Pera Head	1-3%	Dendrophylliidae	Laminar and Foliose	Tolerant (category 2)	40 (27 NTU)	100 (67 NTU)	Sensitive (category >3.5)	10	50
		Faviidae	Massive	Intermediate (category 3)	40 (27 NTU)	100 (67 NTU)	Intermediate (category 3)	10	50
		Poritidae	Massive	Intermediate (category 3)	40 (27 NTU)	100 (67 NTU)	Intermediate (category 3)	10	50

1 Values in these columns are taken from Figure 5 and Table 6 of Erftemeijer *et al* 2012 (pp 1752)

2 Values in these columns are taken from Figure 6 and Table 10 of Erftemeijer *et al* 2012 (pp 1758).

3.3 Previous Dredging Programs

A review of the turbidity trigger levels utilised for a number of dredging projects in similar environments is presented in Table 3-2. Only the most recent (last 10 years) capital dredging projects located in tropical Australian coastal environments in close proximity to coral communities were chosen for comparison.

The table describes the turbidity trigger levels used for each project and brief summary of the overall impacts on the coral communities due to the dredging programs is provided. This affords context to the turbidity trigger levels proposed for the Amrun Port capital dredging. Much of the information in this table with the exception of the trigger levels is an extract from Ports Australia(2014) - Appendix A – Capital and Maintenance dredging projects and monitoring program information for subtropical and Tropical Australian Ports. The trigger levels are gathered from individual reports (referenced in the 'Description' column) or appendices related to the environmental approval documents published for each of the projects.

Note there are no specific water quality guidelines for open coastal regions of Western Cape York or the Gulf of Carpentaria. In the event there is no baseline data for a specific area, the relevant guidelines for the region default to the broader ANZECC/ARMCANZ guidelines (ANZECC/ARMCANZ, 2000) or the Queensland Water Quality Guidelines (QWQG) for the wet tropics (DEHP, 2009).

The ANZECC/ARMCANZ (2000) guidelines state that in wet-dry tropical areas such as Weipa which are influenced by strong seasonal events, separate trigger levels for the wet and dry seasons are required.

Table 3-2 A summary of the trigger levels used and results of the Capital Dredging Programs in tropical waters in the last 10 years

Location	Description	Year	Duration (months)	Volume (m^3)	Distance to nearest coral community	Trigger Level	Durations	Outcome
Hay Point, Queensland	Apron and Departure Path Capital Dredging (Trimarchi and Keane 2007).	2006	6	8.6 million	Victor Islet <4km, Round Top ~4 km	>100mg/L for at least 6 continuous hours	Continuous 6 hours	An assessment of all TSS data recorded pre-dredging, during dredging and post-dredging identified a total of 31water quality trigger exceedences at Victor Islet and none at Round Top Island. Only six exceedence events were recorded during the dredging period at Victor Islet. Coral condition monitoring undertaken showed evidence that sediment deposition associated with the migration of the dredge plume occurred at both Round Top Island and Victor Islet. This deposition resulted in damage to some corals between three and six months after the start of dredging, with a maximum of about 4% (Round Top Island) and 6.5% (Victor Islet) of corals showing some patches of mortality. Approved coral mortality at impact location was set at 20% loss.
Hay Point, Queensland	Hay Point Coal Terminal expansion (BMA 2012)	2010-2011	Dredging and blasting over 2 stages (approx. 4 months per stage) over a 14 month period.	258,000	Hay reef <1km, Round Top Island ~4 km	6-hour rolling median of 110 NTU during daylight hours.	Rolling median 6 hours	Several water quality trigger exceedances (primarily during non-dredging periods). No detectable impact of dredging as pattern of change was the same at reference and impact sites. Major declines in coral and increases in macroalgae at both impact and reference sites. Plumes did not reach coral receptors. Major influences from a cyclone prior to baseline survey complicated impact assessment.
Port Hedland, Western Australia	Rapid Growth Project 5 (BHP 2011)	2008-2010	18	3.9 million	<1km	80^{th}%ile seasonal and tidal state turbidity triggers at Finucane Island Coral (FIC) monitoring site. Dry season (neaps 5.3 NTU, spring 12.4 NTU) Wet Season (neaps 13.5 NTU and springs 15.9 NTU)	Single value	No formal exceedances1 of turbidity trigger breaches at any site. Turbidity ranged between 5 and approximately 30 NTU across sites. No impact to coral communities at FIC impact site.
Port Hedland, Western Australia	South west Creek Tug Boat cyclone mooring facility (GHD 2012)	2011	4	2.5 million	<1km	Seasonal triggers. Tier 1 trigger level – Rolling 14 day median at impact sites over a full spring and neap tidal cycle>80^{th}%ile baseline turbidity and significant difference from reference sites	Rolling 14 day median	One exceedance of 80th percentile trigger threshold. No higher level exceedances. Sediment levels at greater depth on corals at one impact site than other sites (predicted in EIA). The increase had no measurable impact on benthic cover at this site.

Location	Description	Year	Duration (months)	Volume (m^3)	Distance to nearest coral community	Trigger Level	Durations	Outcome
Port Hedland, Western Australia	South West Creek Dredging and reclamation Project. (WorleyParsons 2012)	2011-2012	12	14.2 million	<1km	Upper trigger of 32 NTU (80^{th}%ile of baseline data) at SEC coral Impact site. Upper trigger of 18.3 NTU (80^{th}%ile of baseline data) at SWC coral Impact site.	24 hour rolling median is greater than the upper trigger threshold for a continuous period of more than 14 days	One exceedance of 80th percentile trigger threshold for turbidity. Sediment levels increased at one impact site (predicted in EIA). Subsequent surveys found that the coral health at that site had improved post-dredging indicating impacts were temporary and rapid recovery.
Port Hedland, Western Australia	Stingray Creek cyclone moorings Project (WorleyParsons 2012)	2012	4	5.88 million	<1km	Upper trigger of 32 NTU (80^{th}%ile of baseline data) at SEC coral Impact site. Upper trigger of 18.3 NTU (80^{th}%ile of baseline data) at SWC coral Impact site.	24 hour rolling median is greater than the upper trigger threshold for a continuous period of more than 14 days	Brief exceedances of investigation trigger levels (not at levels requiring formal reporting to regulator or reactive management actions). Coral health parameters did not change significantly at inshore sites between the baseline and the post-dredge survey.
Cape Lambert, Western Australia	RIO Port A expansion (SKM 2011)	2007	4	3.6 million	<1km	Water quality triggers based on Intensity Duration and Frequency of baseline turbidity data (80^{th} and 95^{th}%ile)	Rolling median 6 hours	Permitted impact of <10% net coral mortality at any impact site. Actual impact was <3% net mortality at impact sites.
Cape Lambert, Western Australia	Rio Port B expansion (SKM 2011)	2008-2009	10	301 million	<1km	Site specific water quality early warning criteria - 99^{th}%ile of the baseline rolling 6hr median turbidity data at each site (see tabulated values extract from SKM (2011) in Appendix A coral health triggers used for compliance	Rolling median 6hrs	<3% net coral mortality at impact sites compared to an allowable loss of <10% net mortality.
Dampier, Western Australia	Woodside Pluto- Mermaid sound dredging (MScience 2009, SKM 2007, WorleyParsons 2011	2007-2010	30	14 million	<1km	Turbidity triggers based on 80^{th}%ile and 95^{th}%ile of baseline data.		Permitted impact of 5 -10% coral mortality at impact sites depending upon zone of impact. Actual impacts were <5% net mortality at impact sites. Water quality threshold were too conservative and well below those needed to cause coral mortality

Location	Description	Year	Duration (months)	Volume (m^3)	Distance to nearest coral community	Trigger Level	Durations	Outcome
Barrow Island, Western Australia	Gorgon Gas Development (Chevron 2011)	2010-2011	18	7.6 million	<200m	Adaptive Management triggers based on ongoing coral mortality measures. Initial water quality criterion used to trigger a response, but primarily coral health triggers used.		Net area of coral loss was 3.26 ha, less than the allowed limit of 8.47 ha. Coral assemblages were variable and some changes (e.g. % coral cover in Zones of High and Moderate Impact) were likely to be dredging related.
Port of Darwin	East Arm Ichthys Project (INPEX 2013)	2014	14	16.1 million	<2km	See extract of DSMP detail on turbidity triggers in Appendix B. Wet and dry season triggers. Level 1 trigger occurs when the daily average turbidity was: ▪ Greater than the 99th%ile (intensity) ▪ Greater than the 95th%ile for more than X consecutive days (Duration) ▪ Greater than the 95th%ile for more than X number of days within a 7 day period (frequency)	Variable up to 7 days	Based on the first 8 months of dredging: No turbidity exceedances (intensity, duration or frequency). No impacts attributable to dredging. Five bimonthly surveys during dredging have been completed. Substantial coral thermal bleaching recorded from survey 3.
Port of Darwin	East Arm Wharf Expansion (AECOM 2011)	2012-2013	4	685,000	<2km	Low trigger level of median daily turbidity >80th%ile, high trigger of >95th%ile. See Appendix C for extract from the DSDMP.	Low trigger levels for 3 consecutive days	Several exceedances of water quality triggers during periods of spring tides (not thought to be dredging related). Plume limited to 50m of dredge footprint. Authors report no adverse effects from dredging. No changes in filter feeder indicators. Decreases (<10%) in coral cover at 2 of 3 designated impact sites. Changes in coral health were ascribed to both natural and dredge factors.

The most common triggers utilised were the 80th, 95th and 99th percentile metrics for turbidity. This is consistent with advice provided in the ANZECC guidelines and the methods for calculating internal alert level and external alert level for turbidity as detailed in the Amrun (South of Embley) Project DMP (RTA, 2015). Durations range from daily to weekly, in some instances neap and spring tidal triggers are provided due to the macrotidal nature of some locations. In most cases seasonal triggers are applicable.

Examples of turbidity trigger levels used in other projects which may be applicable when comparing to those developed for the Amrun project are from the Cape Lambert Port B projects, the Ichthys Project, Darwin East Arm Wharf project and the Hay Point Apron and Departure Path Capital Dredging project. It is worth noting that all of these projects are substantially larger in scale and of longer durations (>4 months) when compared to the Amrun Port Initial Capital Dredging (240,000m^3, approximately 3 weeks).

The 99th%ile trigger levels developed from baseline data proposed for the monitoring sites at Cape Lambert ranged between 7 NTU (Delambre Island) and 34 NTU (Power Station) (Appendix A). The Power station site (PWR) was located in the impact area and closest to the dredging operations and consisted of a sparse turbidity tolerant coral community. Durations and frequencies above this trigger value were set at 7 instances of >34 NTU allowed in a two week period. Coral monitoring of 60 tagged colonies at the PWR site was undertaken every two weeks. Despite several elevations above the turbidity trigger levels, no statistically significantly impacts on the coral community due to dredging activities were measured at the PWR site during the 10 month monitoring period.

The Level 1 trigger levels used on the Ichthys Project in Darwin for turbidity tolerant coral communities in the area of impact at Channel Island was set at <15 NTU in the dry season. Additional management actions were taken if the rolling daily average turbidity was >15 NTU for 5 consecutive days. Based on the first 8 months of dredging, no turbidity exceedances were noted and no impacts on the coral communities attributable to dredging were observed.

The rolling average 6hr trigger level of >100mg/L (~67 NTU) used at Hay Point was exceeded on several occasions at the nearest high turbidity adapted coral community site located approximately 4km away at Victor Islet. Results of coral surveys at Victor Islet after dredging suggested there was dredging related partial coral mortality and bleaching at monitoring sites. The compromised coral colonies recovered four months after dredging had ceased.

Based on the review by Erftemeijer et al (2012) summarised in Section 3.2, turbidity tolerant coral communities (such as those found at Boyd Point and Pera Head) may experience some nonlethal impacts when turbidity is elevated for long periods (5-6 weeks) above 27 NTU and lethal impacts when turbidity exceeds 67 NTU for long periods up to 2-4 weeks.

A review by Hanley (2011) on the results of capital dredging environmental monitoring programs in the Pilbara region of Western Australia found generally that trigger levels set to predict the areas of impact were often very conservative. This lead to overly large predicted areas of impact, costly and complex and intensive monitoring program designs and implementations. The actual impacts to the benthic communities in the areas of impact due to the dredging and relocation activities were often negligible or not statistically significant even for the very large dredging programs over years (refer to the 'outcome' column information for each project in Table 3-2).

Most monitoring programs use a very conservative approach when adopting site specific triggers or thresholds due to the lack of specific information on the benthic community in the vicinity of the dredging operations (Ports Australia 2014). In more recent times (Gladstone – Western Basin Dredging project for example), site specific thresholds for the sensitive receptor which is most likely to be impacted upon by dredging (seagrass) were developed in partnership with specific scientific studies into these thresholds (Chartrand et al 2012). The results were then incorporated into the dredging management plans as triggers for management actions.

3.4 Dry Season Data Results

3.4.1 Turbidity

The dry season trigger levels are based on the 80th and 95th percentile of the combined dry season data.

The dry season turbidity 80th and 95th%ile values for each site (NTU) are provided in Table 3-3. The 80th%ile correspond to the internal trigger levels and the 95th%ile correspond to the external trigger levels (rounded down to the nearest whole number). In terms of management actions during dredging, only the trigger levels from the Sites of Concern are applicable; trigger levels for Reference Sites are provided for comparison only. The highest internal turbidity trigger for dry season at the Sites of Concern was Site I4 (6 NTU) and the lowest was Site I2 (4 NTU). The highest external turbidity trigger for Sites of Concern was also measured at site I1 (9 NTU) and the lowest at Site I2 and Site I3 (6 NTU).

Table 3-3 Dry season turbidity triggers (NTU) for each site

Site	Average Depth as measured by logger (m)	Turbidity samples (n)	Internal Turbidity Trigger Level (NTU) 80th%ile	External Turbidity Trigger Level (NTU) 95th%ile
Sites of Concern				
I1	8.7	8515	5	9
I2	8.9*	7407	4	6
I3	9.4	4611	5	6
I4	9.2	7171	6	8
Reference Sites				
R1	9.3	4028	7#	11#
R2	10.4	8202	3#	5#
R3	26.5*	7184	4#	8#

* Depth estimate based on field vessel depth sounder measurements reported in daily reports during field maintenance. Logger does not include depth sensor.

\# Reference site percentile values added for comparison. Reference sites do not have internal alert or external trigger values.

3.4.2 PAR

The median total daily PAR (i.e. cumulative PAR across 24 hour period) was calculated for each site during the dry season period and the results are presented in Table 3-4. The lowest total daily PAR was measured at site R3 and the highest total daily median PAR measured at site I4. This data was used to examine the relationship between median daily PAR and depth at each site. The results are presented as a box plot in Figure 3-2. The sites on the x-axis are arranged in increasing depth. The regression analysis undertaken in STATISTICA found there is a significant linear relationship between median daily PAR and depth ($p<0.05$); the shallower the site the higher the sunlight reaching the seafloor.

Table 3-4 Median Dry Season Median Total Daily PAR at each site when all data is considered

Site	Average Depth as measured by logger (m)	PAR samples (n)	Median Total Daily PAR (mol/m^2/day)
Sites of Concern			
I1	8.7	8427	1.01
I2	8.9*	7996	0.89
I3	9.4	4581	0.96
I4	9.2	7023	1.28
Reference Sites			
R1	9.3	3949	0.27
R2	10.4	8019	1.09
R3	26.5*	6630	0.07

* depth estimate based on field vessel depth sounder measurements reported in daily reports during field maintenance. Logger does not include depth sensor.

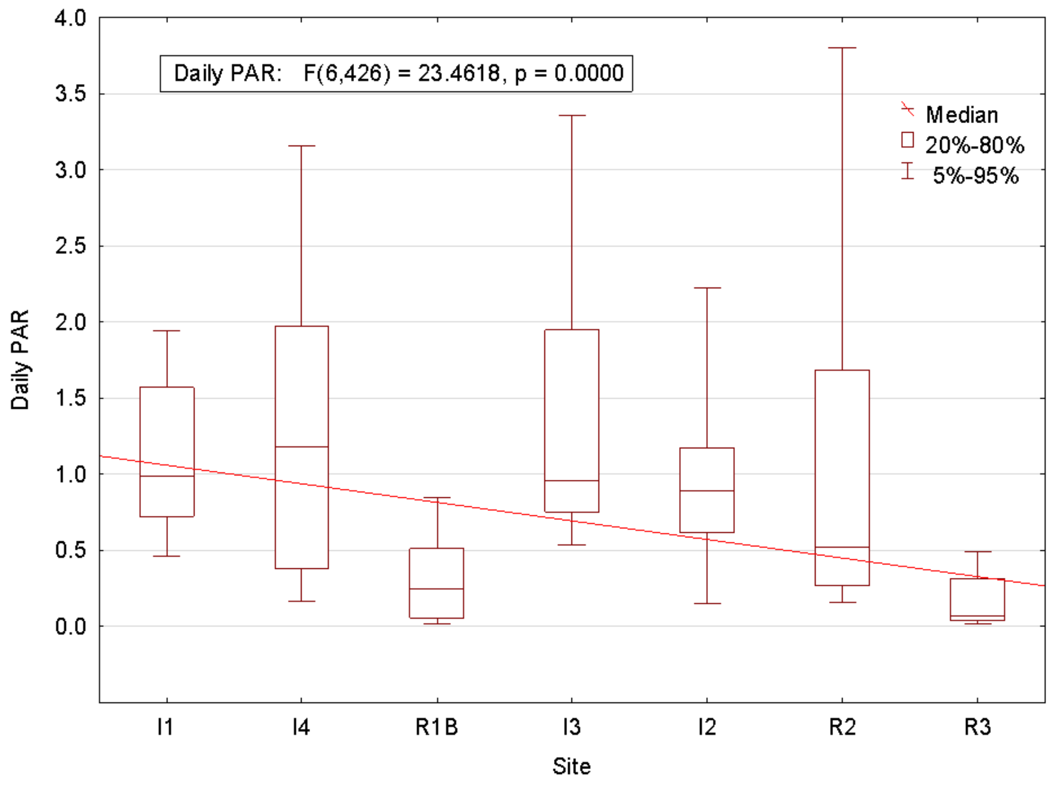


Figure 3-2 Box Plot of Median Total Daily PAR at each site after cloudy day data is removed. Sites (x-axis) arranged from shallowest to deepest

3.4.3 Turbidity and PAR

The relationship between the turbidity and PAR measured at depth at each site was examined by comparing the median total daily PAR plotted against the median daily turbidity. Because the light reaching the seafloor is influenced by the amount of cloud in the sky at the time the PAR data is recorded, these PAR data (and associated turbidity data for that day) need to be removed. The data on daily solar radiation measured at the Weipa Airport Bureau of Meteorology (BOM) site (BOM 2016) was examined to look for falls in solar radiation on a given day. The decreases in daily solar radiation correspond with clouds passing over the sun and the total daily PAR data on these days (and corresponding turbidity data) is removed from the analysis. The line of best fit shown on each graph indicates an exponential relationship best describes the relationship between the two variables. A regression comparing median total daily PAR and median daily turbidity from each site (Figure 3-3) found a significant relationship between the two variables ($p<0.05$) in all cases except at Site I3. Provision of individual site graphs removes depth as a variable between sites.

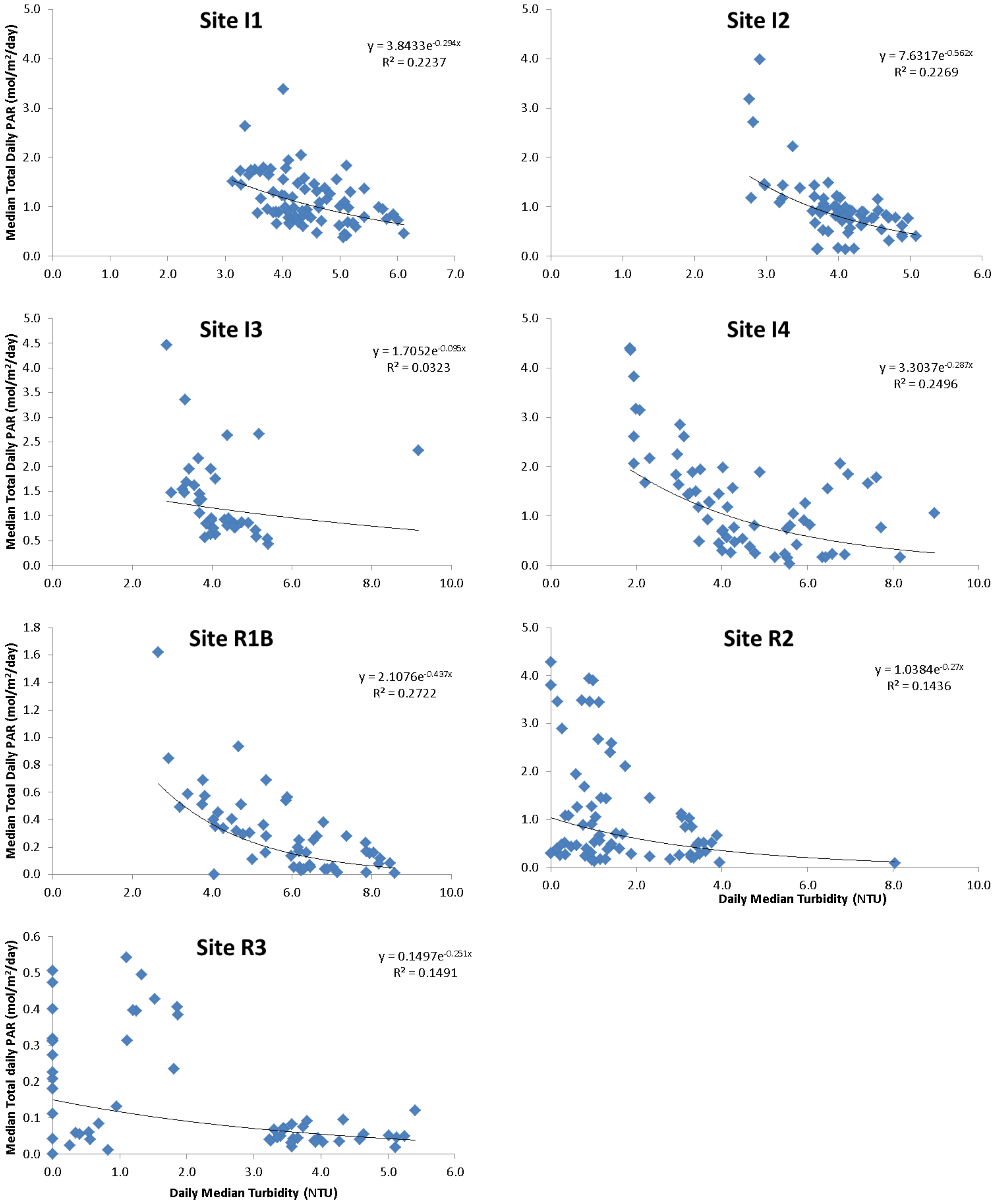


Figure 3-3 Daily median turbidity compared to median total daily PAR at each site; exponential line of best fit equation and R^2 values are provided in each graph in the top right corner.

3.4.4 Depth Profiling

Turbidity depth profiling was undertaken at all sites during each dry season water quality logger maintenance trip (approximately monthly). The changes in turbidity values as depth increases at each site from data collected in the dry season from MT1 and MT2 is presented in Figure 3-4 and Figure 3-5, respectively.

The profile data collected during MT1 indicates that at all sites turbidity increased with depth. At six if the seven monitoring sites the increase in turbidity with depth was small (1-2NTU), at the Reference Site R2 the increase in depth was larger in the order of >3NTU.

The profile data collected during MT2 indicates that at the majority of sites the turbidity increased with depth, with the exception of Reference Sites R1 and R2 where no increases in turbidity with depth were observed. Increases in turbidity with depth at the four Sites of Concern (I1, I2, I3 and I4) were approximately between 0 – 2 NTU over the depth profile. The measured turbidity increased most markedly at the deepest site - Reference Site 3 (R3) at depths greater than 16m. At this depth the turbidity values started to increase until eventually the turbidity measured near the seafloor at 25m was over five times (5.5NTU) the turbidity values measured at the shallower depths (<1NTU).

Three dimensional modelling of the fate of sediments from dredging was undertaken as part of the South of Embley EIS across a number of tidal and seasonal scenarios. The modelling outputs showed the spatial scales of the depth averaged concentrations of TSS throughout the water column and predicted potential impacts based on this. Examples of the model outputs can be found in the DMP (RTA 2015).

The depth profiling data collected during MT1 and MT2 (outlined above) shows that turbidity is generally homogenous through the water column, increasing slightly with depth. There are some exceptions which are likely due to depth profiling measurements being undertaken at peak of tidal flow potentially during the largest tidal ranges (spring tides) when the seafloor sediments are resuspended more readily leading to elevated turbidity measurements near the seafloor. Generally, the model predictions using depth averaging of the TSS through the water column is therefore good approximation of what occurs (homogenous TSS throughout the water column) at the monitoring sites.

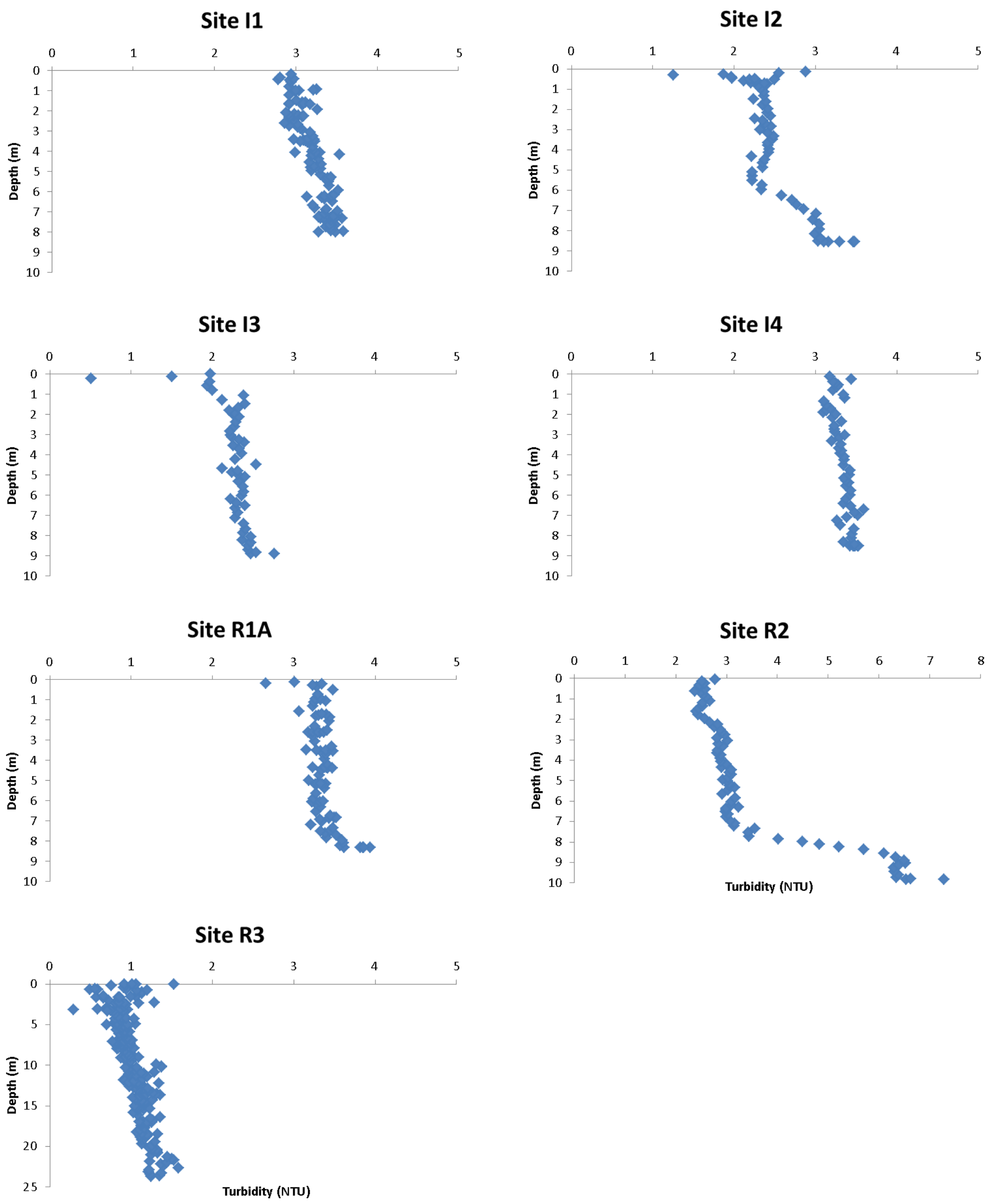


Figure 3-4 Turbidity depth profile at each site during maintenance trip 1 (MT1) – October 2015

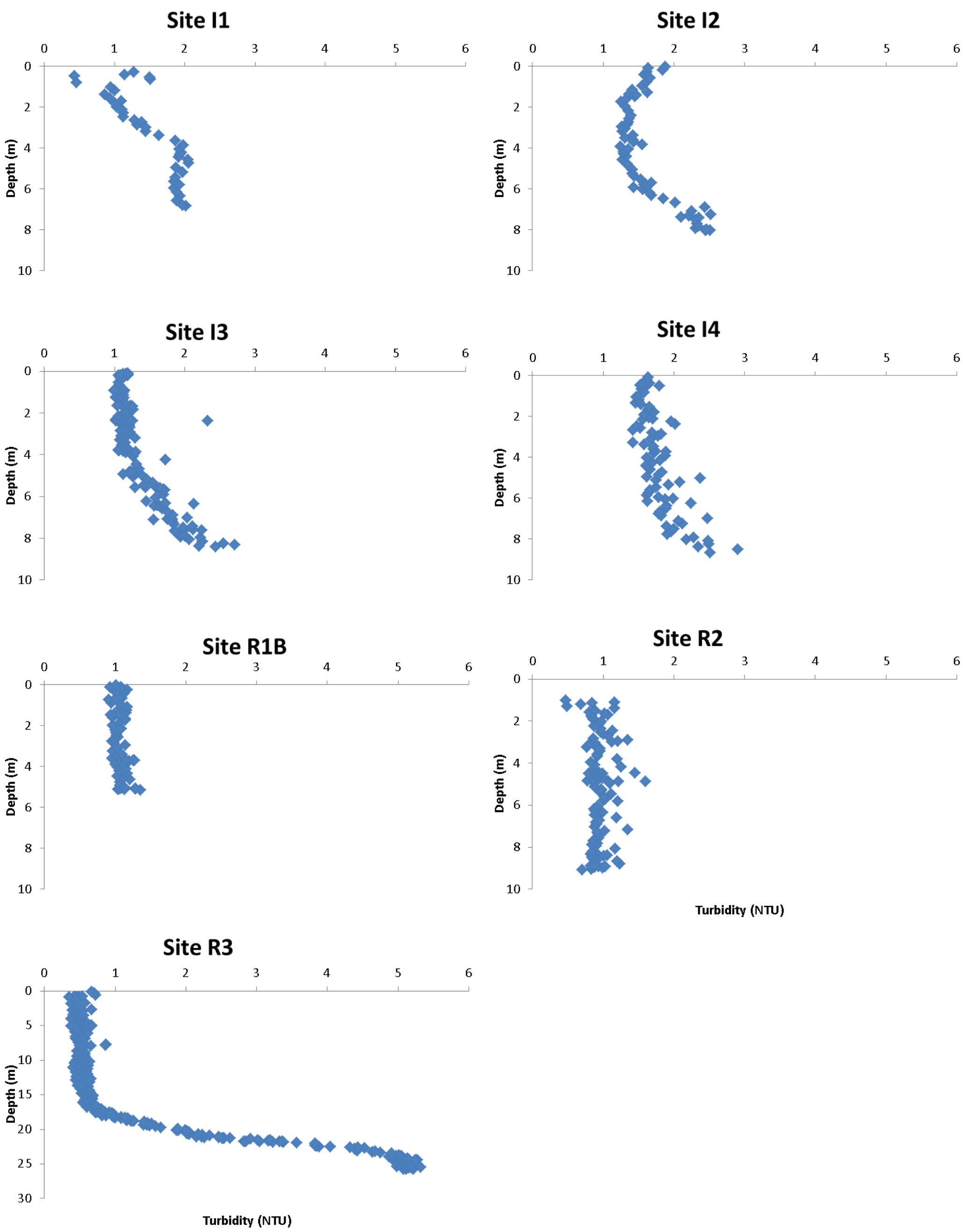


Figure 3-5 Turbidity depth profile at each site during maintenance trip 2 (MT2) – November 2015

3.4.5 TSS and Turbidity

At all sites during each field trip in the dry season TSS samples were collected from the lower water column adjacent to the seafloor at the same time as turbidity measurements were being undertaken during the depth profiling exercise. The turbidity values represented are the average of at least 20 turbidity measurements taken during the depth profiling exercise at the same depth as the TSS sample was taken. The results are presented in Table 3-5 and Figure 3-6. There is no linear relationship between TSS and turbidity (see Figure 3-6, R^2=0.0039).

Table 3-5 Total Suspended Solid (TSS) data and average turbidity data at all sites

Site	Field trip code	Date sampled	Season	TSS (mg/L)	Average Turbidity (NTU)
I1	MT0	02/09/2015 @4:00	dry	3	2.1
I1 Duplicate	MT0	02/09/2015 @4:00	dry	3	2.2
I2	MT0	08/09/2015 @8:15	dry	1.5	1.8
I3	MT0	09/09/2015 @13:40	dry	3	2.8
I4	MT0	10/09/2015 @13:40	dry	4	2.7
R1	MT0	02/09/2015 @5:05	dry	2	2.1
R1 Duplicate	MT0	02/09/2015 @5:05	dry	1.5	1.9
R2	MT0	10/09/2015 @5:05	dry	3	3
R3	MT0	09/09/2015 @10:00	dry	4	0.3
I1	MT1	17/10/2015 @ 14:45	dry	3	3.4
I1 Duplicate	MT1	17/10/2015 @ 14:45	dry	1.5	3.4
I2	MT1	14/10/2015 @ 12:00	dry	3	2.6
I3	MT1	15/10/2015 @ 13:15	dry	4	2.5
I4	MT1	15/10/2015 @ 13:15	dry	2	3.5
R1	MT1	15/10/2015 @ 8:00	dry	2	3.4
R1 Duplicate	MT1	18/10/2015 @ 9:15	dry	1.5	3.4
R2	MT1	16/10/2015 @ 8:45	dry	3	3.9
R3	MT1	17/10/2015 @ 13:05	dry	2	1.4
I1	MT2	09/11/2015 @13:45	dry	1.5	1.6
I1 Duplicate	MT2	09/11/2015 @13:45	dry	1.5	1.6
I2	MT2	09/11/2015 @ 10:00	dry	1.5	2.8
I3	MT2	10/11/2015 @ 13:45	dry	1.5	2.6
I4	MT2	12/11/2015 @ 7:30	dry	2	3.1
R1	MT2	09/11/2015 @ 08:45	dry	1.5	1.2
R2	MT2	10/11/2015 @ 09:15	dry	1.5	1.2
R3	MT2	11/11/2015 @ 08:30	dry	1.5	5.4

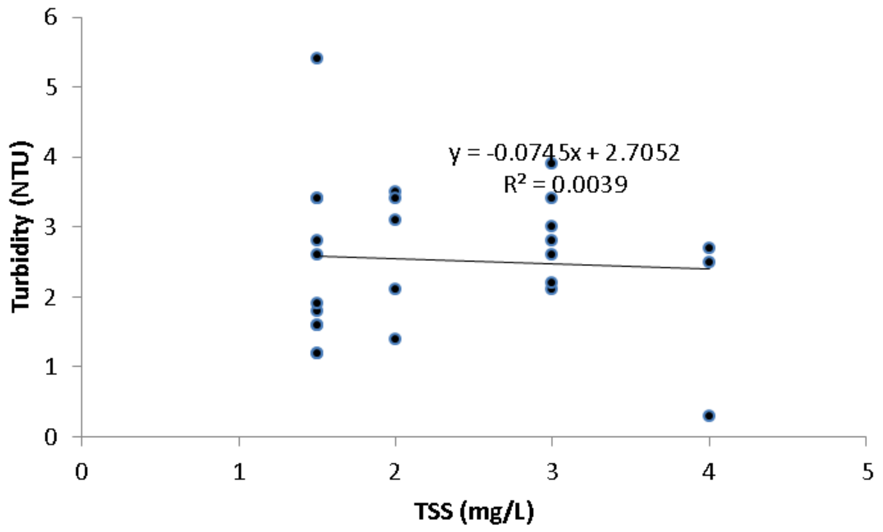


Figure 3-6 Total Suspended Solid (TSS) data compared to turbidity data at all sites

3.4.6 Gross Sedimentation

The daily gross sedimentation rates at each site were calculated from replicate sediment trap data collected during each field trip. Three sediment traps were attached to the logger frame at each site. Before redeployment of the logger system, the sediment in the traps was collected and despatched to the laboratory after the field trip for dry weight analysis. For the Sites of Concern (I1, I2, I3 and I4), nine separate samples (three replicates at each site per three trips) were collected during the dry season period. For comparison, only three sediment trap samples were collected from Reference Site 1 (R1) during a MT3 due to issues with sediment trap retrieval during previous field trips. Gross sedimentation for each sample was calculated by dividing the total dry sediment weight (mg) in each trap by the number of days the trap was deployed and then dividing by the area of the trap mouth in cm^2. The results of the average gross sedimentation rates in $mg/cm^2/day$ (±Standard Errors) are presented in Table 3-6 and Figure 3-7.

Table 3-6 Average dry season gross sedimentation rates ($mg/cm^2/day$) and average turbidity at each site during the dry season

Site	Average Gross sedimentation rates ($mg/cm^2/day$)	Standard Error	Average turbidity (NTU)
Site I1	28.5	7.1	5.2
Site I2	16.6	3.3	4.1
Site I3	24.6	4.1	4.3
Site I4	32.5	5.6	4.7
R1	19.0	0.8	6.4

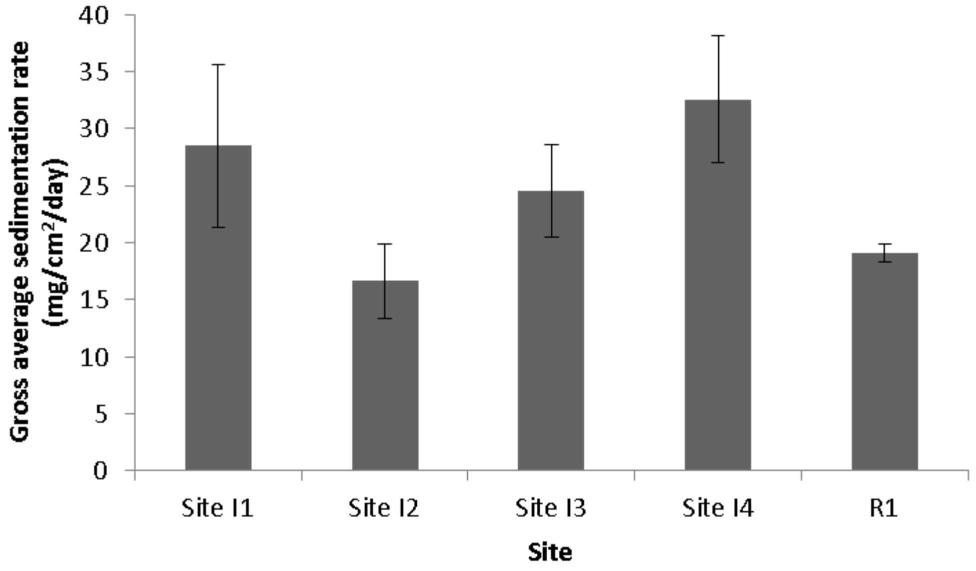
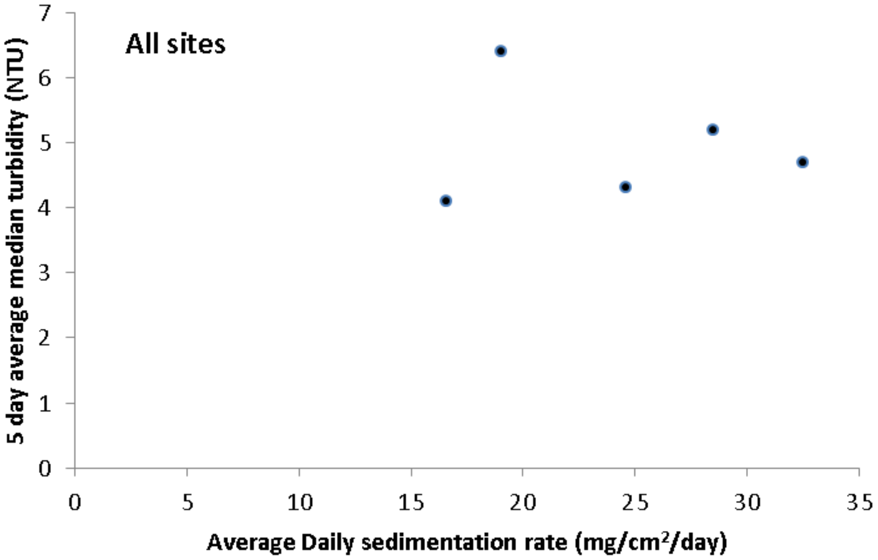


Figure 3-7 Average gross sedimentation rates (mg/cm^2/day) at each site during the dry season (± Standard Error)

The highest gross daily sedimentation rates (mg/cm^2/day) occurred at Site I4 (32.5±5.6) and I1 (28.5±7.1), the lowest at I2 (16.6±3.3) and R1 (19.0±0.8). At all sites the gross daily average sedimentation rate was above the GBRWQG (GBRMPA 2010) daily net average sedimentation maximum of 15mg/cm^2/day and daily net average of 3mg/cm^2/day. These guidelines are specific to coral communities growing in the Great Barrier Reef region and are presented for potential comparison to the Gulf of Carpentaria coral communities.

The sediment trap method of measuring sedimentation rates overestimates the actual sedimentation (net) the benthic community is experiencing on a daily basis. The trap acts to draw out and retain suspended solids which would otherwise be re-suspended via currents or wave action during the different tidal phases. Gross sedimentation measures are a good measure of the relative sedimentation rates between sites. They also provide baseline sedimentation regimes to compare against whilst dredging operations are underway.

The average turbidity value for each site is also included in Table 3-6 and Figure 3-7 for comparison. If the data from R1A/R1B is removed and the average turbidity is plotted against the average daily sedimentation rate (lower graph Figure 3-7), there is a linear relationship (R^2=0.5346). Turbidity is lowest at the site which experiences the least sedimentation.



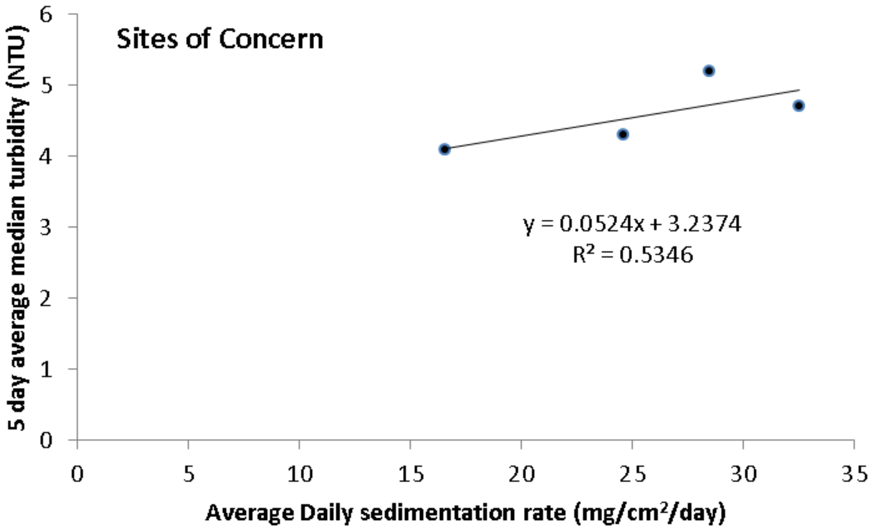


Figure 3-8 The average turbidity against the average daily sedimentation rate at all sites (top graph) and Sites of Concern only (bottom graph)

4 Discussion

The coral communities growing at Pera Head and Boyd Point are well adapted to low light, high suspended solids regimes. The growth forms they exhibit are designed to maximise benthic light capture and effectively deal with elevated sedimentation rates.

Fugitive suspended solids from dredging activities can cause a partial or total loss of sunlight reaching the seafloor. This impact may have consequences for benthic organisms that rely on sunlight to survive depending upon the duration of these low or no light events. Recent studies into the temporal patterns in water quality from dredging in tropical environments (Jones *et al* 2015) found high temporal variability in the levels of suspended solids in the water column close to dredging (<500m) which ranged from 100mg/L to 500mg/L over several hours. During longer periods (days to weeks to months) the average concentrations of suspended solids in the water column decrease markedly toward background baseline levels. The main feature the study found of the water quality during the dredging operations was the persistent daylight twilight periods due to persistent small elevations of TSS above background TSS, where sunlight reaching the seafloor was not fully extinguished, but very low.

For the Amrun Port Initial Capital Dredging, the dry season turbidity levels measured at the Sites of Concern range between 4 and 6 NTU (80^{th}%ile –internal) and 6 and 9 NTU (95^{th}%ile-external). It is difficult to compare these values with other trigger levels used for other dredging projects, which may also have a tidal component or no seasonal component. Compared to the values outlined in Erftemeijer et al (2012), the proposed trigger levels are extremely conservative. The wet season triggers will be developed once the wet season dataset is collected. These triggers are likely to be higher, as reflected in the previous turbidity measurements outlined in the DMP (RTA 2015).

The use of turbidity as a trigger appears to be a good surrogate for the amount of light reaching the seafloor on a given day (daily PAR) and the average gross daily sedimentation rate. Both measures appear to have a strong statistically significant relationship with the turbidity in the water column. There is no relationship between TSS and turbidity as measured so far during the first three field trips. Developing relationships between these two variables, should a relationship exist, is likely to require more sampling over a range of water quality extremes such as those that would be experienced during the wet season.

The Amrun Port Initial Capital Dredging involves the dredging of approximately 240,000m^3. The volume of material to be dredged is one tenth of the volume proposed in the EIS and DMP and on which predictive hydrodynamic modelling was undertaken. The temporal and spatial distribution of fugitive sediments and the concentrations of these sediments will be considerably less than predicted by the modelling impact assessment.

Based on this, only the areas in close proximity (100's of meters) to the dredging will likely experience elevated levels of TSS in the water column and twilight periods over the course (up to three weeks) of the dredging. It is unlikely that impacts will occur to the low light tolerant coral communities located further afield at Boyd Point and Pera Head, located approximately two kilometres to the north and three kilometres south of the dredging footprint respectively.

The turbidity triggers outlined in this report for the dry season are highly conservative (an order of magnitude lower) when compared to those levels considered to be biologically relevant (refer Table 3-1). Trigger levels defined for the wet season will be developed following completion of baseline data collection from December 2015 to February 2016. Triggers levels for future dredging operations should be reviewed following completion of monitoring and works for the Amrun Port Initial Capital Dredging.

5 References

AECOM (2011) East Arm Wharf Expansion Project – Dredge Management Plan. Prepared for Northern Territory Department of Land and Planning, 29 March 2011

ANZECC/ ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Canberra.

BHP(2011). Hunt Point Marine Precinct – Dredge Management Plan. November 2011

BMA (2012). *Annual Ecological Monitoring Summary Report – 2011. Hay Point Coal Terminal Expansion Phase 3*. Report prepared by SKM for BM Alliance Coal Operations, 23 February 2012.

BOM (2016). Weipa Aero – 2016 daily calculations. Accessed online 21 January 2016 at: http://www.bom.gov.au/watl/eto/tables/qld/weipa_aero/weipa_aero.html

Chartrand KM, Ralph PJ, Petrou K, Rasheed MA. (2012) Development of a light-based seagrass management approach for the Gladstone Western Basin Dredging Program. DEEDI Publication. Fisheries Queensland, Cairns, 92pp.

Chevron(2011). Gorgon Gas Development and Jansz Feed Gas Pipeline: Dredging and Spoil Disposal Management and Monitoring Plan, 8 June 2011

Department of Environment and Heritage Protection (DEHP) (2009) Queensland Water Quality Guidelines, version 3, July 2013

Ports Australia (2014). Dredging and Australian Ports – Subtropical and Tropical Ports, April 2014.

Erftemeijer P.L.A, Riegl B., Hoeksema B.W. and Todd P.A. (2012). Environmental impacts of dredging and other sediment disturbances on corals: A review. *Marine Pollution Bulletin* 64:1737-1765.

GHD (2012). Report for Small Vessel Cyclone Mooring Protection Facility – Dredge Management Plan. Report prepared for the Port Hedland Port Authority, March 2012.

GBRMPA (2010). Great Barrier Reef Water Quality Guidelines. Great Barrier Reef Marine Park Authority.

Hanley J.R. (2011). Environmental Monitoring Programs on Recent Capital Dredging Projects in the Pilbara (2003-2010): a review. *APPEA Journal* 2011:273-293.

INPEX (2013). Ichthys Project – Dredging and Spoil Disposal Management Plan – East Arm, 16 December 2013.

Jones R., Fisher R., Stark C., and Ridd P. (2015). Temporal Patterns in Seawater Quality from Dredging in Tropical Environments. PLoS ONE 10(10):e0137112. Doi:10.1371/journal.pone.0137112

MScience (2009). Dampier Marine Services Facility: Water Quality Impacts of the Pluto Program in an area of intensive dredging. Report prepared for the Dampier Port Authority, 18 December 2009.

Rio Tinto Alcan (2015). South of Embley Project, Dredge Management Plan – Port (Initial Capital Dredging). 16 November 2015.

SKM (2007). Pluto LNG Development. Addendum to Public Environmental Report/Public Environmental Review Supplement and Response to Submissions. Revision 2.

SKM (2011). Cape Lambert Port B Development – Dredging and Spoil Disposal Management Plan. Report prepared by SKM on behalf of RioTinto, 12 December 2011.

Trimarchi S. and Keane J. (2007). Port of Hay Point Apron Areas and Departure Path Capital Dredging project Environmental Review. *EcoPorts Monograph Series No.24*. Report prepared by Ports Corporation of Queensland. 63pp.

WorleyParsons (2012). South West Creek Dredging and Reclamation Project – Water Quality Monitoring Report6: 21 March – 28 May 2012. Report prepared for the Port Hedland Port Authority, 29 August 2012

Appendix A

Cape Lambert Port B turbidity triggers (SKM 2011)

- **Table 3-6 Indicative water quality criteria**

Site names	Site	Duration class	Days of baseline data	SKM 2009 - 99%ile		
				Criteria (median NTU)	Frequency during baseline	Allowable exceedences per 2 weeks
Bells Reef	BLR	6 hours	411	18	191	7
Boat Rock	BTR	6 hours	428	10	206	7
Bezout Island	BZI	6 hours	525	11	269	7
Bezout Rock	BZR	6 hours	366	15	190	7
Cape Lambert West	CLW	6 hours	346	17	168	7
Dixon Island East	DIE	6 hours	381	25	186	7
Delambre Island	DLI	6 hours	408	7	191	7
Hat Rock	HAT	6 hours	368	25	177	7
Mangrove Point	MAN	6 hours	355	23	174	7
Middle Reef	MDR	6 hours	403	21	193	7
Pelican Rocks	PLR	6 hours	366	23	180	7
Power Station	PWR	6 hours	353	34	167	7
Samson Beach	SMSB	6 hours	446	15	189	6

Appendix B

Ichthys Project turbidity triggers from DSDMP (INPEX 2013)

Table 7-11: Channel Island and Weed Reef coral response TARP

Components	Normal Situation	Level 1 Trigger			Level 2 Trigger		Level 3 Trigger
		Daily average turbidity			Coral Bleaching	Coral Mortality Rate of Change	Coral Mortality Rate of Change
		Intensity	Duration	Frequency			
Channel Island							
Trigger value (Wet Season) (1 Nov to 31 April)	Not triggered	>44 NTU	>26 NTU over 7 consecutive days	>26 NTU > 3 days per 7-day rolling period	>20% gross coral bleaching OR	Measured coral mortality greater than the upper 95% confidence limit for the predicted coral mortality	Measured coral mortality greater than the 95% confidence interval for the predicted coral mortality, for two consecutive surveys. In addition to a statistically significant decrease in coral cover calculated from transects that is considered ecologically significant.
Trigger value (Dry Season) (1 May – 30 Oct)		>21 NTU	>15 NTU over 5 consecutive days	>15 NTU > 3 days per 7-day rolling period			
Weed Reef 1 and Weed Reef 2							
Trigger value (Wet Season) (1 Nov to 31 April)	Not triggered	>65 NTU	>46 NTU over 6 consecutive days	>46 NTU > 3 days per 7-day rolling period	>20% gross coral bleaching OR	Measured coral mortality greater than the upper 95% confidence interval limit for the predicted coral mortality	Measured coral mortality greater than the 95% confidence interval for the predicted coral mortality for two consecutive surveys. In addition to a statistically significant decrease in coral cover calculated from transects that is considered ecologically significant.
Trigger value (Dry Season) (1 May – 30 Oct)		>14 NTU	>11 NTU over 4 consecutive days	>11 NTU > 3 days per 7-day rolling period			

Appendix C

East Arm Dredging Draft DSDMP turbidity triggers (AECOM 2011)

Table 21 Draft management trigger criteria for Zone of Effect for Water Quality

Management Response level	Turbidity Levels for Daylight Hours within Zone of Effect	
	Low Trigger Level (LTL) or	High Trigger Level (HTL)
Conformance	Median < LTL each day in three consecutive days	Median< HTL on any six of seven consecutive days
Level 1 exceedance ("Watching")	Median >10% and <50% higher than LTL for 3days	Median >10% and <30% higher than HTL for any six of seven consecutive days
Level 2 exceedance ("Responding")	Median >50% higher than LTL for 3days	Median >30% higher than HTL for any five of seven days
Level 3 exceedance ("Adapting")	Median >100% higher than LTL for 3 days	Median >50% higher than HTL for any five of seven days
Level 4 exceedance ("Correcting")	Median >200% higher than LTL for 3 days	Median >100% higher than HTL for any five of seven days

APPENDIX C: BASELINE WET SEASON REPORT

RTA Weipa

Water Quality Trigger Report

Port Initial Capital Dredging

1 August 2016

Advisian is a global advisory firm that provides project and business solutions to clients who develop, operate and maintain physical assets in the infrastructure and resources sectors.

301310-08460-00-EN-REP-0017

Advisian Pty Ltd
Level 3,60 Albert St
Brisbane QLD 4000
Australia
PO Box 15081
City East Brisbane Qld 4002

P +61 7 3221 7444
F +61 7 3221 7791
ABN: 50098008818

Disclaimer

This report has been prepared on behalf of and for the exclusive use of RTA Weipa, and is subject to and issued in accordance with the agreement between RTA Weipa and Advisian.

Advisian accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party.

Copying this report without the permission of RTA Weipa and Advisian is not permitted.

PROJECT NO 301310-08460– WATER QUALITY TRIGGER REPORT: PORT INITIAL CAPITAL DREDGING

Rev	Description	Author	Review	Advisian Approval	Date
2	For Use	S Neale	J Kennedy	J Kennedy	01/08/16

Table of Contents

List of Appendices

List of Figures

List of Tables

1 Introduction

1.1 Background

The Amrun (formerly South of Embley) Project requires the construction and operation of a new Port facility located between Boyd Point and Pera Head. The marine works will include construction of a jetty, wharf and ship loaders, requiring dredging for berth pockets and an approach/departure channel.

The Amrun (Boyd) Port Initial Capital Dredging involves the excavation of approximately 240,000 m^3 of seabed material using a large Cutter Suction Dredge (CSD) and transport and disposal to the approved dredge material relocation ground by hopper barge. The expected time frame for the completion of the dredging and relocation works is three (3) weeks commencing end of March 2016, with dates subject to completion of Embley River dredging.

1.2 Objectives

The objective of this report is to present wet season water quality trigger levels based on the most recent data collected during the Amrun Project - Baseline Receiving Environment Monitoring for Amrun Port Initial Capital Dredging. In this report, trigger levels are developed for the wet season based on baseline data collection across December 2015 to February 2016.

The trigger levels are designed to address the requirements of the Environmental Authority (EA) conditions (EMPL00725113) as outlined in condition J13b (extracted in Table 1-1 below). An extract from the EA conditions - Table J1- Initial Boyd Port Capital Dredge Monitoring: Water Quality Trigger Levels is provided in Table 1-2. Specific trigger levels will be developed at Sites of Concern[1] only, as per the requirements outlined in Table 1-2.

The methods of developing the trigger levels and the management responses have been outlined in the South of Embley Project Dredge Management Plan – Port (Initial Capital Dredging) (DMP) which was approved by Commonwealth in November 2015 and Queensland regulators in January 2016 (RTA, 2015). Section 1.2.1 summarises the process described in the DMP for the development and application of the trigger levels.

The development of the wet season turbidity trigger levels and general data analysis follow those used in the Water Quality Dry Season Trigger Report (301310-08460-00-EN-REP-0012) produced by Advisian and approved for use by RTA Weipa.

[1] *Also referred to as Sites of Influence.*

Table 1-1 Extract of EA section relevant to establishing water quality trigger levels.

J13 (b) establish turbidity-based trigger values as shown in Table J1- Initial Boyd Port Capital Dredge Monitoring: Water Quality Trigger Levels, that:	(i)	Considers, and is informed by, the findings of all relevant publish studies, including available water quality guidelines, trigger values from other comparable dredging programs with similar environmental conditions, and site specific baseline data;	See Section 3.2, Section 3.3 and Section 3.4.1
	(ii)	Considers the most sensitive receptor type and the most relevant water quality parameters (e.g. turbidity, PAR, sedimentation rate) and the reported impacts of turbidity on coral health from the literature and other dredging programs in areas of nearshore coral reefs;	See Section 3.1, Section 3.2 and Section 3.3
	(iii)	Includes season-specific turbidity trigger values;	See Section 3.4.1
	(iv)	Considers sediment plume intensity, duration and frequency of occurrence in establishing trigger values;	See Section and 1.2.1 and 3.4.1
	(v)	Considers the additive effect of multiple stressors; and	See Section 3.2
	(vi)	Considers the effect of depth and water column variation predicted from the 3D modelling	See Section 3.4.4

Advisian provided to RTA Weipa a method to ensure compliance with the requirements of EA Condition J13(b) (Water Quality Triggers - 301310-08460-00EN-MEM-002-Revision 0, December 16 2015). Each of the conditions listed in Condition J13(b) are addressed individually in this report in the relevant sections as described in Table 1-1.

Table 1-2 Initial Port Capital Dredge Monitoring: Water Quality Trigger Levels (reproduced from Table J1 of the EA)

Monitoring Locations	Coordinates (GDA 94)	Quality Characteristic	Unit	Wet Season Trigger level	Dry Season Trigger Level	Frequency
Reference Sites (R1, R2 and R3)	TBA	Turbidity (as a surrogate WQ parameter for PAR and SR)	NTU	N/A	N/A	Continuous Telemetered, Logged at 15 minute intervals
		PAR	mol/m²/day	N/A	N/A	Continuous Telemetered, Logged at 15 minute intervals
		SR	mg/cm²/day	N/A	N/A	Sediment traps (approx. monthly)
Concern sites (I1, I2,I3 and I4)	TBA	Turbidity (as a surrogate WQ parameter for PAR and SR)	NTU	TBD	TBD	Continuous Telemetered, Logged at 15 minute intervals
		PAR	mol/m²/day	N/A	N/A	Continuous Telemetered, Logged at 15 minute intervals
		SR	mg/cm²/day	N/A	N/A	Sediment traps (approx. monthly)

PAR – Photsynthetically Active Radiation; **SR** – Sedimenation Rate; **TBA** – To be advised based on results of monitoring;
TBD – To be determined in approved Dredge Management Plans: statistically derived turbidity trigger based on site specific baseline data and trigger values from other dredging programs with similar environmental conditions together with literature on potential impacts of turbidity on coral health;
Note: Trigger values may vary at different monitoring locations and the number of monitoring locations will be determined through the DMP

1.2.1 Dredge Management Plan Water Quality Triggers

The South of Embley project Dredge Management Plan – Port (Initial Capital Dredging) (RTA, 2015) outlines stages in the development and application of trigger levels. These include:

- **Draft Initial Trigger Levels** – Preliminary trigger values developed using historical data (prior to 2012) for consideration by the Determining Authority when approving the DMP (P36 Table 5 of DMP). These are presented in Table 1-3.
- **Site Specific Trigger Levels** – defined process in the DMP for developing site specific trigger levels for wet and dry seasons using baseline data collection (P36 of the DMP)
- **Trigger Level application during dredging** – initiation of defined water quality management processes if trigger levels are exceeded during dredging (P37-40 of DMP).

The DMP clearly identifies the required approach for developing the Site Specific Trigger Values for wet and dry season for subsequent application during the dredging period.

Site specific turbidity trigger levels for the Sites of Concern are calculated for wet and dry seasons respectively from the data currently being collected during baseline monitoring. These trigger values are used to establish **internal alert levels** and **external trigger levels** as reporting requirements for the program.

The alert levels will be based on the 80th (**internal alert**) and the 95th (**external trigger level**) percentiles with levels determined for both the wet and dry season as follows:

- **Internal Alert Levels** would be triggered if the site specific internal alert turbidity concentration for a Site of Concern is exceeded by the five day rolling average of the daily median turbidity on three consecutive days. Exceedance would trigger investigations to determine the cause of the high turbidity measured.
- **External Trigger Levels** would be triggered if the site specific external trigger turbidity concentration for a Site of Concern is exceeded by the five day rolling average of the daily median turbidity on three consecutive days. Triggering would result in application of the Water Quality Management Process as depicted in Figure 12 of the DMP (RTA, 2015).
-

Table 1-3 Draft initial Boyd Port Capital Dredging Monitoring: Water Quality Trigger Levels extract from DMP 2015.

Monitoring location	Quality Characteristic	Unit	Initial Alert Level		Trigger level		Frequency
			Wet season	Dry season	Wet season	Dry season	
Concern Sites (I1, I2, I3 and I4)	Turbidity	(NTUe)	7.7	6.1	23.8	14.3	Continuous Telemetered, logged at 15 minute intervals

2 Methods

The process used to develop the turbidity triggers from the baseline data is:

1) Examine the coral community information from the Sites of Concern and rank the coral community in terms of susceptibility to elevated suspended solids and sedimentation rates (see Section3.1 and Section 3.2).
2) Using the baseline Quality Control (QC) turbidity data, calculate the median, 80th, 90th and 95th percentile turbidity values[2] for the Reference Sites and Sites of Concern, for each season (dry – September to end of November, wet - December to end of February). (see Section 3.4)
3) From the perspective of biological relevance to the receiving environment, identify appropriate turbidity percentile metric depending upon the response category (sub-lethal and lethal effect) as outlined in Table 6 of Erftemeijer et al (2012) and the sensitivity of the dominant coral community growth forms outlined in Figure 5 of the same study. (see Section 3.2,)
4) Compare the seasonal site specific turbidity trigger to trigger levels developed for previous dredging programs in similar environments and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ, 2000) for context, and also examine the outcomes in terms of coral community impacts of previous dredging campaigns where information is available (see Section 3.3).
5) Develop a relationship between photosynthetically active radiation (PAR) and turbidity by plotting the baseline QC data for both parameters against each other (see Section3.4.3)
6) Develop a relationship between gross sedimentation and turbidity based on data collected at each site for gross daily sedimentation and median daily turbidity (see discussion in 3.4.6).
7) Examine the literature and results of the dredging programs to determine an appropriate duration of low light which will preclude any sub-lethal or lethal impacts to the coral communities at the Sites of Concern (see Section 3.2).

---

[2] *Statistical criteria for establishing the alert trigger levels are already defined in the DMP (RTA, 2015), being the 80th and 95th percentiles of the baseline for internal alert and external alert respectively*

3 Results

3.1 Existing Coral Community

The closest coral communities to the proposed port facilities are located on fringing reefs situated ~1.7 km to the north at Boyd Point and ~2.8 km to the south at Pera Head, as depicted in the DMP (RTA, 2015) (refer Figure 3-1). Drop video surveys completed as part of EIS and Supplementary EIS studies at Boyd Point and Pera Head found large areas of coarse and silty sand punctuated by occasional outcrops of hard substrate up to 2m high. These outcrops were sparsely covered in algae, soft corals, sponges and hard corals. The percentage cover of hard coral was approximately 1-3% at both locations.

The sparse hard coral communities were dominated by small (<20cm diameter) to medium (20-40cm diameter) sized colonies of corals from the families Dendrophylliidae, Faviidae and Poritidae. There were occasional larger (>2m) *Porites* spp bommies. The hard coral genera and species present at these locations are typical of corals that grow in marine environments that experience extremes in turbidity and/or temperature. The growth form or shape of the more common genera found, such as *Turbinaria* spp (cup shaped or foliose) and *Porites* spp (domed shaped or massive) appeared flattened indicating a change in the 'typical' growth form to adapt to consistent low light conditions.

In February 2016, more targeted towed video surveys of the coral communities in close proximity to the water quality monitoring logger sites (I1, I2, I3, I4, R1 and R2) along four 30m transects were undertaken (301310-08460-EN-REP-0002 – Baseline Coral Health Monitoring Report Rev 0, April 2016)). The analysis of the video footage found the hard coral percentage cover (± Standard Error) was highest at Site R2 (23.6±4.5%) and lowest at site I1 (4.4±1.0%). As previous surveys found, the seafloor at all sites was dominated by sand, turf algae or macroalgae or combinations of these three groups with occasional hard and soft coral colonies. As per the previous study (Supplementary EIS) , the dominant corals families were Dendrophylliidae, Faviidae and Poritidae and the dominant hard coral growth forms were foliose, massive and encrusting.

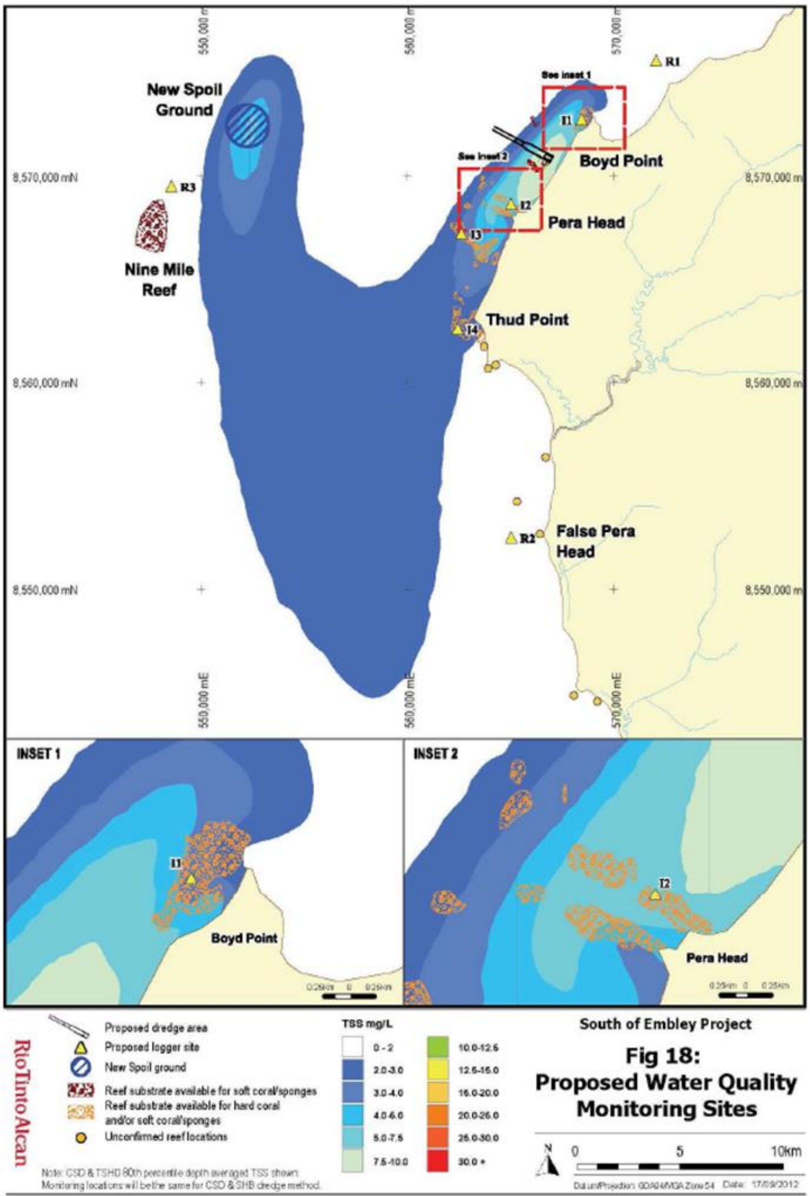


Figure 3-1 Water Quality Monitoring Sites and Coral Locations (RTA, 2015)

3.2 Susceptibility of the Coral Community to Total Suspended Solids, Turbidity and Sedimentation

The genera and growth forms of the coral community at each site (as described above) provide information on the susceptibility of that community to elevated turbidity and elevated sedimentation. The relationship between the coral growth form (and genera) and the susceptibility to elevated sedimentation and suspended solids is described in a study by Erftemeijer *et al* (2012), refer to Table 6 and Figure 5 (Suspended Solids/Turbidity) and Table 10 and Figure 6 (Sedimentation) in that publication[3].

The relative sensitivities of each coral genus and growth form compared to levels of suspended sediment in the water column and rates of sedimentation as described are outlined in Table 3-1.

The TSS values provided are converted turbidity (NTU) based on the laboratory experiments undertaken by James Cook University. The converted turbidity values are provided in parenthesis after the TSS value. The relationship between TSS and turbidity was calculated as 1mg/L (TSS) equals 0.67 NTU (see Section 4.2 of the DMP).

The growth forms of the three most dominant coral families found near Boyd Point and Pera Head are those growth forms which have a high (foliose or laminar) or intermediate (massive or dome shaped) tolerance to suspended solids. This suggests that extended periods of TSS values of 40mg/L (27 NTU) may have sub-lethal impacts on corals of these growth forms, partial mortality impacts to coral colonies may not occur until these colonies are exposed to prolonged periods (several weeks) of TSS in the water column of 100mg/L (67 NTU) or more (refer Table 3-1).

In terms of net sedimentation rates the growth forms of the three most dominant coral families found near Boyd Point and Pera Head are those growth forms which have a sensitive (foliose or laminar) or intermediate (massive/dome shaped) tolerance to elevated sedimentation rates. This suggests that extended periods of sedimentation values of 10mg/cm^2/day may have sub-lethal impacts on corals of these growth forms, lethal impacts may not occur until these colonies are exposed to extended periods of sedimentation (up to two weeks) of greater than 50mg/cm^2/day (refer to Table 3-1).

[3] http://www.sciencedirect.com/science/article/pii/S0025326X12001981

Table 3-1 Coral communities and their sensitivity categories for elevated TSS and sedimentation

Location	Overall Hard Coral cover (%)	Dominant coral family	Growth Form	Total Suspended Solids (mg/L) converted NTU values in brackets[1]			Max Sedimentation Rates [2]		
				TSS Growth form Sensitivity Category	Minor Sub-lethal effect after 5-6 weeks	Lethal effects (Partial Mortality) after 2-4 weeks	Sedimentation rate growth form Sensitivity category (Figure 6)	Sub-lethal effects (minor) (mg/cm^2/day) after 3 weeks	Lethal effects (partial mortality) (mg/cm^2/day) after 2-3 weeks
Boyd Point and Pera Head	1-3%	Dendrophylliidae	Laminar and Foliose	Tolerant (category 2)	40 (27 NTU)	100 (67 NTU)	Sensitive (category >3.5)	10	50
		Faviidae	Massive	Intermediate (category 3)	40 (27 NTU)	100 (67 NTU)	Intermediate (category 3)	10	50
		Poritidae	Massive	Intermediate (category 3)	40 (27 NTU)	100 (67 NTU)	Intermediate (category 3)	10	50

1 Values in these columns are taken from Figure 5 and Table 6 of Erftemeijer *et al* 2012 (pp 1752)

2 Values in these columns are taken from Figure 6 and Table 10 of Erftemeijer *et al* 2012 (pp 1758).

3.3 Previous Dredging Programs

A review of the turbidity trigger levels utilised for a number of dredging projects in similar environments is presented in Table 3-2. Only the most recent (last 10 years) capital dredging projects located in tropical Australian coastal environments in close proximity to coral communities were chosen for comparison.

The table describes the turbidity trigger levels used for each project and brief summary of the overall impacts on the coral communities due to the dredging programs is provided. This affords context to the turbidity trigger levels proposed for the Amrun Port capital dredging. Much of the information in this table with the exception of the trigger levels is an extract from Ports Australia(2014) - Appendix A – Capital and Maintenance dredging projects and monitoring program information for subtropical and Tropical Australian Ports. The trigger levels are gathered from individual reports (referenced in the 'Description' column) or appendices related to the environmental approval documents published for each of the projects.

Note there are no specific water quality guidelines for open coastal regions of Eastern Cape York or the Gulf of Carpentaria. In the event there is no baseline data for a specific area, the relevant guidelines for the region default to the broader ANZECC/ARMCANZ guidelines (ANZECC/ARMCANZ, 2000) or the Queensland Water Quality Guidelines (QWQG) for the wet tropics (DEHP, 2009).

The ANZECC/ARMCANZ (2000) guidelines state that in wet-dry tropical areas such as Weipa which are influenced by strong seasonal events, separate trigger levels for the wet and dry seasons are required.

Table 3-2 A summary of the trigger levels used and results of the Capital Dredging Programs in tropical waters in the last 10 years

Location	Description	Year	Duration (months)	Volume (m^3)	Distance to nearest coral community	Trigger Level	Durations	Outcome
Hay Point, Queensland	Apron and Departure Path Capital Dredging (Trimarchi and Keane 2007).	2006	6	8.6 million	Victor Islet <4km, Round Top ~4 km	>100mg/L for at least 6 continuous hours	Continuous 6 hours	An assessment of all TSS data recorded pre-dredging, during dredging and post-dredging identified a total of 31water quality trigger exceedences at Victor Islet and none at Round Top Island. Only six exceedence events were recorded during the dredging period at Victor Islet. Coral condition monitoring undertaken showed evidence that sediment deposition associated with the migration of the dredge plume occurred at both Round Top Island and Victor Islet. This deposition resulted in damage to some corals between three and six months after the start of dredging, with a maximum of about 4% (Round Top Island) and 6.5% (Victor Islet) of corals showing some patches of mortality. Approved coral mortality at impact location was set at 20% loss.
Hay Point, Queensland	Hay Point Coal Terminal expansion (BMA 2012)	2010-2011	Dredging and blasting over 2 stages (approx. 4 months per stage) over a 14 month period.	258,000	Hay reef <1km, Round Top Island ~4 km	6-hour rolling median of 110 NTU during daylight hours.	Rolling median 6 hours	Several water quality trigger exceedances (primarily during non-dredging periods). No detectable impact of dredging as pattern of change was the same at reference and impact sites. Major declines in coral and increases in macroalgae at both impact and reference sites. Plumes did not reach coral receptors. Major influences from a cyclone prior to baseline survey complicated impact assessment.
Port Hedland, Western Australia	Rapid Growth Project 5 (BHP 2011)	2008-2010	18	3.9 million	<1km	80^{th}%ile seasonal and tidal state turbidity triggers at Finucane Island Coral (FIC) monitoring site. Dry season (neaps 5.3 NTU, spring 12.4 NTU) Wet Season (neaps 13.5 NTU and springs 15.9 NTU)	Single value	No formal exceedances1 of turbidity trigger breaches at any site. Turbidity ranged between 5 and approximately 30 NTU across sites. No impact to coral communities at FIC impact site.
Port Hedland, Western Australia	South west Creek Tug Boat cyclone mooring facility (GHD 2012)	2011	4	2.5 million	<1km	Seasonal triggers. Tier 1 trigger level – Rolling 14 day median at impact sites over a full spring and neap tidal cycle>80^{th}%ile baseline turbidity and significant difference from reference sites	Rolling 14 day median	One exceedance of 80th percentile trigger threshold. No higher level exceedances. Sediment levels at greater depth on corals at one impact site than other sites (predicted in EIA). The increase had no measurable impact on benthic cover at this site.

Location	Description	Year	Duration (months)	Volume (m^3)	Distance to nearest coral community	Trigger Level	Durations	Outcome
Port Hedland, Western Australia	South West Creek Dredging and reclamation Project. (WorleyParsons 2012)	2011-2012	12	14.2 million	<1km	Upper trigger of 32 NTU (80^{th}%ile of baseline data) at SEC coral Impact site. Upper trigger of 18.3 NTU (80^{th}%ile of baseline data) at SWC coral Impact site.	24 hour rolling median is greater than the upper trigger threshold for a continuous period of more than 14 days	One exceedance of 80th percentile trigger threshold for turbidity. Sediment levels increased at one impact site (predicted in EIA). Subsequent surveys found that the coral health at that site had improved post-dredging indicating impacts were temporary and rapid recovery.
Port Hedland, Western Australia	Stingray Creek cyclone moorings Project (WorleyParsons 2012)	2012	4	5.88 million	<1km	Upper trigger of 32 NTU (80^{th}%ile of baseline data) at SEC coral Impact site. Upper trigger of 18.3 NTU (80^{th}%ile of baseline data) at SWC coral Impact site.	24 hour rolling median is greater than the upper trigger threshold for a continuous period of more than 14 days	Brief exceedances of investigation trigger levels (not at levels requiring formal reporting to regulator or reactive management actions). Coral health parameters did not change significantly at inshore sites between the baseline and the post-dredge survey.
Cape Lambert, Western Australia	RIO Port A expansion (SKM 2011)	2007	4	3.6 million	<1km	Water quality triggers based on Intensity Duration and Frequency of baseline turbidity data (80^{th} and 95^{th}%ile)	Rolling median 6 hours	Permitted impact of <10% net coral mortality at any impact site. Actual impact was <3% net mortality at impact sites.
Cape Lambert, Western Australia	Rio Port B expansion (SKM 2011)	2008-2009	10	301 million	<1km	Site specific water quality early warning criteria - 99^{th}%ile of the baseline rolling 6hr median turbidity data at each site (see tabulated values extract from SKM (2011) in Appendix A coral health triggers used for compliance	Rolling median 6hrs	<3% net coral mortality at impact sites compared to an allowable loss of <10% net mortality.
Dampier, Western Australia	Woodside Pluto- Mermaid sound dredging (MScience 2009, SKM 2007, WorleyParsons 2011	2007-2010	30	14 million	<1km	Turbidity triggers based on 80^{th}%ile and 95^{th}%ile of baseline data.		Permitted impact of 5 -10% coral mortality at impact sites depending upon zone of impact. Actual impacts were <5% net mortality at impact sites. Water quality threshold were too conservative and well below those needed to cause coral mortality

Location	Description	Year	Duration (months)	Volume (m^3)	Distance to nearest coral community	Trigger Level	Durations	Outcome
Barrow Island, Western Australia	Gorgon Gas Development (Chevron 2011)	2010-2011	18	7.6 million	<200m	Adaptive Management triggers based on ongoing coral mortality measures. Initial water quality criterion used to trigger a response, but primarily coral health triggers used.		Net area of coral loss was 3.26 ha, less than the allowed limit of 8.47 ha. Coral assemblages were variable and some changes (e.g. % coral cover in Zones of High and Moderate Impact) were likely to be dredging related.
Port of Darwin	East Arm Ichthys Project (INPEX 2013)	2014	14	16.1 million	<2km	See extract of DSMP detail on turbidity triggers in Appendix B. Wet and dry season triggers. Level 1 trigger occurs when the daily average turbidity was: ▪ Greater than the 99^{th}%ile (intensity) ▪ Greater than the 95^{th}%ile for more than X consecutive days (Duration) ▪ Greater than the 95^{th}%ile for more than X number of days within a 7 day period (frequency)	Variable up to 7 days	Based on the first 8 months of dredging: No turbidity exceedances (intensity, duration or frequency). No impacts attributable to dredging. Five bimonthly surveys during dredging have been completed. Substantial coral thermal bleaching recorded from survey 3.
Port of Darwin	East Arm Wharf Expansion (AECOM 2011)	2012-2013	4	685,000	<2km	Low trigger level of median daily turbidity >80^{th}%ile, high trigger of >95^{th}%ile. See Appendix C for extract from the DSDMP.	Low trigger levels for 3 consecutive days	Several exceedances of water quality triggers during periods of spring tides (not thought to be dredging related). Plume limited to 50m of dredge footprint. Authors report no adverse effects from dredging. No changes in filter feeder indicators. Decreases (<10%) in coral cover at 2 of 3 designated impact sites. Changes in coral health were ascribed to both natural and dredge factors.

The most common triggers utilised were the 80^{th}, 95^{th} and 99^{th} percentile metrics for turbidity. This is consistent with advice provided in the ANZECC guidelines and the methods for calculating internal alert level and external alert level for turbidity as detailed in the Amrun (South of Embley) Project DMP (RTA, 2015). Durations range from daily to weekly, in some instances neap and spring tidal triggers are provided due to the macrotidal nature of some locations. In most cases seasonal triggers are applicable.

Examples of turbidity trigger levels used in other projects which may be applicable when comparing to those developed for the Amrun project are from the Cape Lambert Port B projects, the Ichthys Project, Darwin East Arm Wharf project and the Hay Point Apron and Departure Path Capital Dredging project. It is worth noting that all of these projects are substantially larger in scale and of longer durations (>4 months) when compared to the Amrun Port Initial Capital Dredging (240,000m^3, approximately 3 weeks).

The 99^{th}%ile trigger levels developed from baseline data proposed for the monitoring sites at Cape Lambert ranged between 7 NTU (Delambre Island) and 34 NTU (Power Station) (Appendix A). The Power station site (PWR) was located in the impact area and closest to the dredging operations and consisted of a sparse turbidity tolerant coral community. Durations and frequencies above this trigger value were set at 7 instances of >34 NTU allowed in a two week period. Coral monitoring of 60 tagged colonies at the PWR site was undertaken every two weeks. Despite several elevations above the turbidity trigger levels, no statistically significantly impacts on the coral community due to dredging activities were measured at the PWR site during the 10 month monitoring period.

The Level 1 trigger levels used on the Ichthys Project in Darwin for turbidity tolerant coral communities in the area of impact at Channel Island was set at <15 NTU in the dry season. Additional management actions were taken if the rolling daily average turbidity was >15 NTU for 5 consecutive days. Based on the first 8 months of dredging, no turbidity exceedances were noted and no impacts on the coral communities attributable to dredging were observed.

The rolling average 6hr trigger level of >100mg/L (~67 NTU) used at Hay Point was exceeded on several occasions at the nearest high turbidity adapted coral community site located approximately 4km away at Victor Islet. Results of coral surveys at Victor Islet after dredging suggested there was dredging related partial coral mortality and bleaching at monitoring sites. The compromised coral colonies recovered four months after dredging had ceased.

Based on the review by Erftemeijer et al (2012) summarised in Section 3.2, turbidity tolerant coral communities (such as those found at Boyd Point and Pera Head) may experience some nonlethal impacts when turbidity is elevated for long periods (5-6 weeks) above 27 NTU and lethal impacts when turbidity exceeds 67 NTU for long periods up to 2-4 weeks.

A review by Hanley (2011) on the results of capital dredging environmental monitoring programs in the Pilbara region of Western Australia found generally that trigger levels set to predict the areas of impact were often very conservative. This lead to overly large predicted areas of impact, costly and complex and intensive monitoring program designs and implementations. The actual impacts to the benthic communities in the areas of impact due to the dredging and relocation activities were often negligible or not statistically significant even for the very large dredging programs over years (refer to the 'outcome' column information for each project in Table 3-2).

Most monitoring programs use a very conservative approach when adopting site specific triggers or thresholds due to the lack of specific information on the benthic community in the vicinity of the dredging operations (Ports Australia 2014). In more recent times (Gladstone – Western Basin Dredging project for example), site specific thresholds for the sensitive receptor which is most likely to be impacted upon by dredging (seagrass) were developed in partnership with specific scientific studies into these thresholds (Chartrand et al 2012). The results were then incorporated into the dredging management plans as triggers for management actions.

3.4 Wet Season Data Results

3.4.1 Turbidity

The wet season triggers levels are based on the 80th and 95th percentile of the combined wet season data. The wet season turbidity 80th and 95th%ile values for each site (NTU) are provided in Table 3-3, and based on data that has been through QC process. In this table, the dry season trigger values are provided in brackets next to the wet season triggers for comparison. The 80th%ile correspond to the internal trigger levels and the 95th%ile correspond to the external trigger levels (rounded down to the nearest whole number). In terms of management actions during dredging, only the trigger levels from the Sites of Concern are applicable; similar percentile values for Reference Sites are provided for comparison. The highest internal turbidity trigger for wet season at the Sites of Concern was Site I1 (32 NTU) and the lowest was Site I2 (11 NTU). The highest external turbidity trigger for Sites of Concern was also measured at site I1 (90 NTU) and the lowest at Site I2 (42 NTU).

Table 3-3 Wet season turbidity triggers (NTU) for each site. Dry season values provided in brackets for comparison

Site	Average Depth as measured by logger (m)	Turbidity samples (n)	Internal Turbidity Trigger Level (NTU) 80th%ile[1]	External Turbidity Trigger level (NTU) 95th%ile[t]
Sites of Concern				
I1	8.7	8486	32 (5)	90 (9)
I2	8.9*	8442	11 (4)	42 (6)
I3	9.4	8667	20 (5)	72 (6)
I4	9.2	8628	15 (6)	57 (8)
Reference Sites				
R1	9.3	8126	35 (7)#	85 (11)#
R2	10.4	8544	16 (3)#	46 (5)#
R3	26.5*	8588	8 (4)#	89 (8)#

* Depth estimate based on field vessel depth sounder measurements reported in daily reports during field maintenance. Logger does not include depth sensor.

t Dry season turbidity trigger values provided in brackets for comparison with wet season triggers

\# Reference site percentile values added for comparison. Reference sites do not have internal alert or external trigger values.

3.4.2 PAR

The median total daily PAR (i.e. cumulative PAR across 24 hour period) was calculated for each site during the dry season period and the results are presented in Table 3-4. The lowest median total daily PAR was measured at site R3 and the highest total daily median PAR measured at site I2 and I3. This data was used to examine the relationship between median daily PAR and depth at each site. The results are presented as a box plot in Figure 3-2. The sites on the x-axis are arranged in increasing depth. The regression analysis undertaken in STATISTICA found in the wet season there is a significant linear relationship between median total daily PAR and depth ($p<0.05$); the shallower the site the higher the amount of sunlight reaching the seafloor. This relationship between depth and PAR was also evident in the dry season.

Table 3-4 Wet Season Median Total Daily PAR at each site when all data is considered.

Site	Average Depth as measured by logger (m)	PAR samples (days)	Median Total Daily PAR ($mol/m^2/day$)[1]
Sites of Concern			
I1	8.7	8687 (91)	0.40 (1.01)
I2	8.9*	8565 (91)	0.60 (0.89)
I3	9.4	8711 (91)	0.60 (0.96)
I4	9.2	8657 (91)	0.30 (1.28)
Reference Sites			
R1	9.3	7199 (74)	0.20 (0.27)
R2	10.4	8697 (91)	0.30 (1.09)
R3	26.5*	8721 (91)	0.00 (0.07)

* Depth estimate based on field vessel depth sounder measurements reported in daily reports during field maintenance. Logger does not include depth sensor.

[1] Dry season median daily PAR ($mol/m^2/day$) provided in brackets for comparison

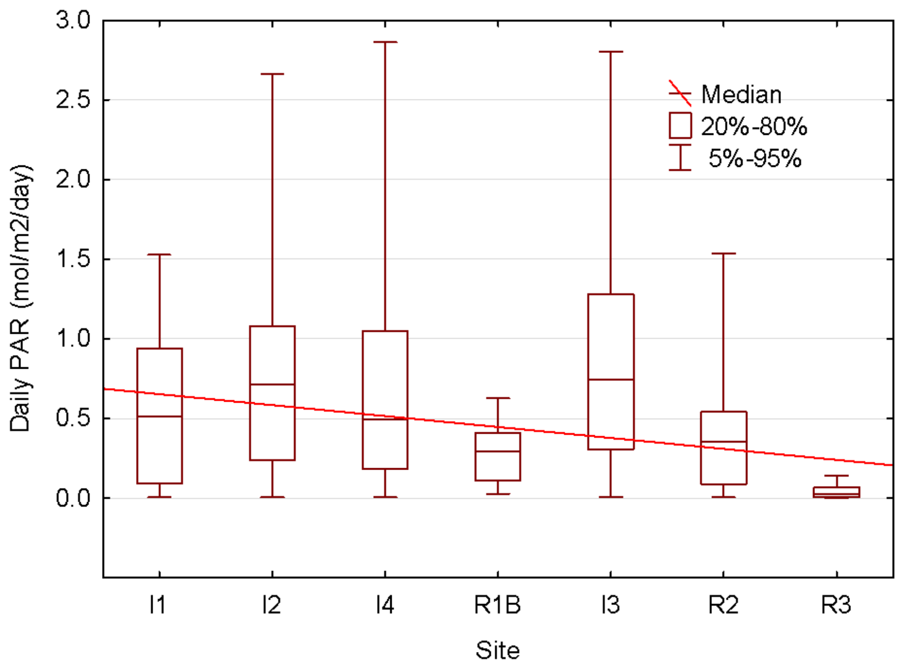


Figure 3-2 Box Plot of Median Total Daily wet season PAR at each site after cloudy day data is removed. Sites (x-axis) arranged from shallowest to deepest

3.4.3 Turbidity and PAR

The relationship between the turbidity and PAR measured at depth at each site was examined by comparing the median total daily PAR plotted against the median daily turbidity. Because the light reaching the seafloor is influenced by the amount of cloud in the sky at the time the PAR data is recorded, these PAR data (and associated turbidity data for that day) need to be removed. The data on daily solar radiation measured at the Weipa Airport Bureau of Meteorology (BOM) site (BOM 2016) was examined to look for falls in solar radiation on a given day. The decreases in daily solar radiation correspond with clouds passing over the sun and the total daily PAR and daily turbidity data on these days is removed from the analysis. The line of best fit shown on each graph indicates an exponential relationship best describes the relationship between the two variables. A regression comparing median total daily PAR and median daily turbidity at each site (Figure 3-3) found a significant relationship between the two variables at all sites ($p<0.05$) except Reference Site R3. Provision of individual site graphs removes depth as a variable between sites.

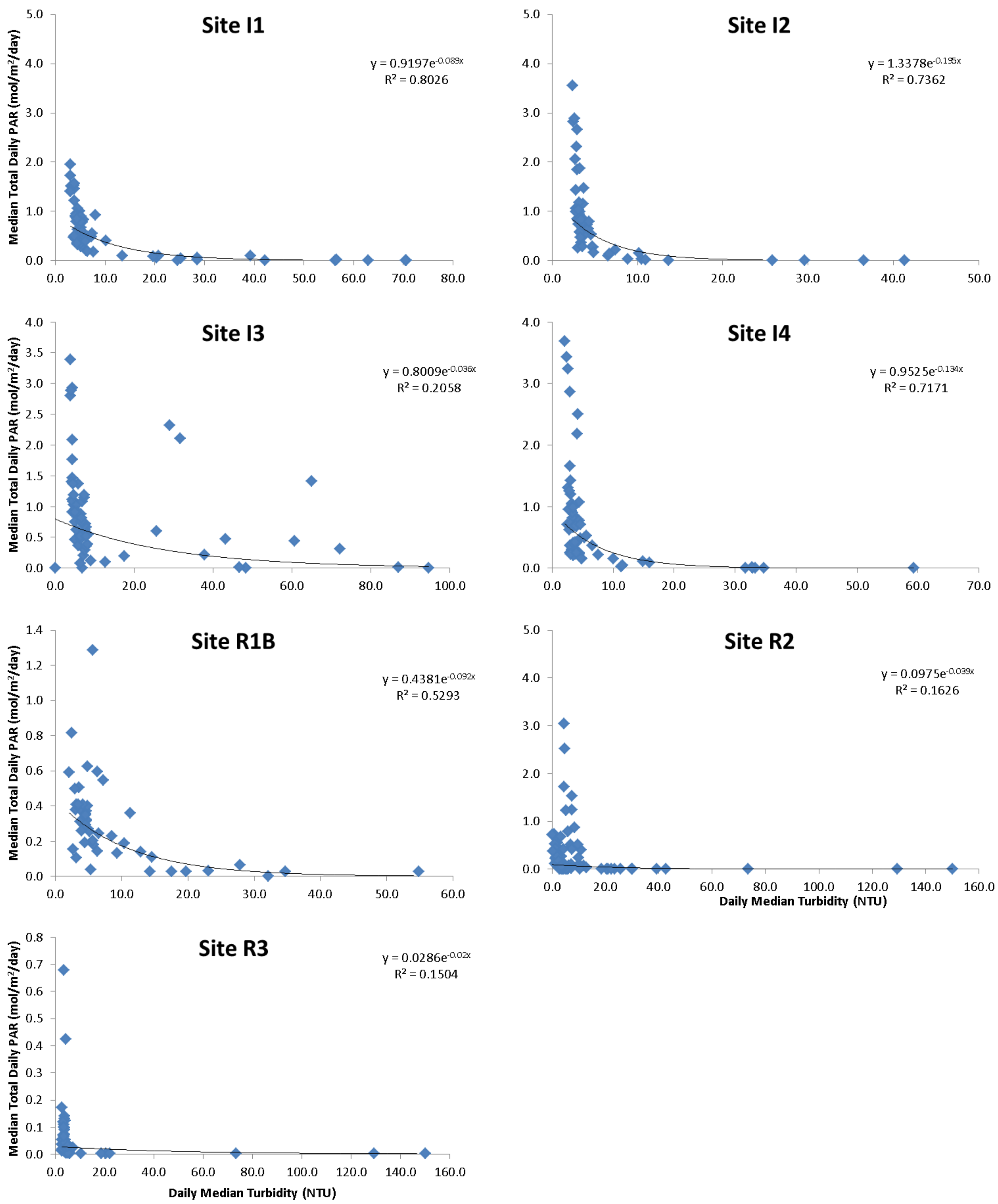


Figure 3-3 Daily median turbidity compared to median total daily PAR at each site; the exponential line of best fit equation and R^2 value are provided in each graph in the top right corner.

3.4.4 Depth Profiling

Turbidity depth profiling was undertaken at all sites during each wet season water quality logger maintenance trip (approximately monthly). The changes in turbidity values as depth increases at each site from data collected during maintenance trip 3 (MT3) in December 2015 and maintenance trip4 (MT4) in January 2016 are presented in Figure 3-4 and Figure 3-5 respectively.

During MT3, the turbidity generally increased with depth. Changes in turbidity with depth at the four Sites of Concern (I1, I2, I3 and I4) were approximately between 0 – 5 NTU over the depth profile, with site I3 showing the most marked change. The measured turbidity also increased with depth at the reference sites, increases between1-4NTU with depth were observed at the reference sites.

During MT4, the turbidity generally increased with depth. Changes in turbidity with depth at the four Sites of Concern (I1, I2, I3 and I4) and Reference Sites (R1B, R2 and R3) were approximately between 0 – 5 NTU over the depth profile. The measured turbidity increased slightly at Reference Site 3 (R3) at depths greater than 17m. At this depth the turbidity values started to increase until eventually the turbidity measured near the seafloor at20m (3NTU) was over three times the turbidity values measured at the shallower depths (1NTU).

Three dimensional modelling of the fate of sediments from dredging was undertaken as part of the South of Embley EIS across a number of tidal and seasonal scenarios. The modelling outputs showed the spatial scales of the depth averaged concentrations of TSS throughout the water column and predicted potential impacts based on this. Examples of the model outputs can be found in the DMP (RTA 2015).

The depth profiling data collected during MT3 and MT4 (outlined above) shows that turbidity is generally homogenous through the water column, increasing slightly with depth. There are some exceptions which are likely due to depth profiling measurements being undertaken at peak of tidal flow potentially during the largest tidal ranges (spring tides) when the seafloor sediments are resuspended more readily leading to elevated turbidity measurements near the seafloor. Generally, the model predictions using depth averaging of the TSS through the water column is therefore a good approximation of what occurs (homogenous TSS throughout the water column) at the monitoring sites.

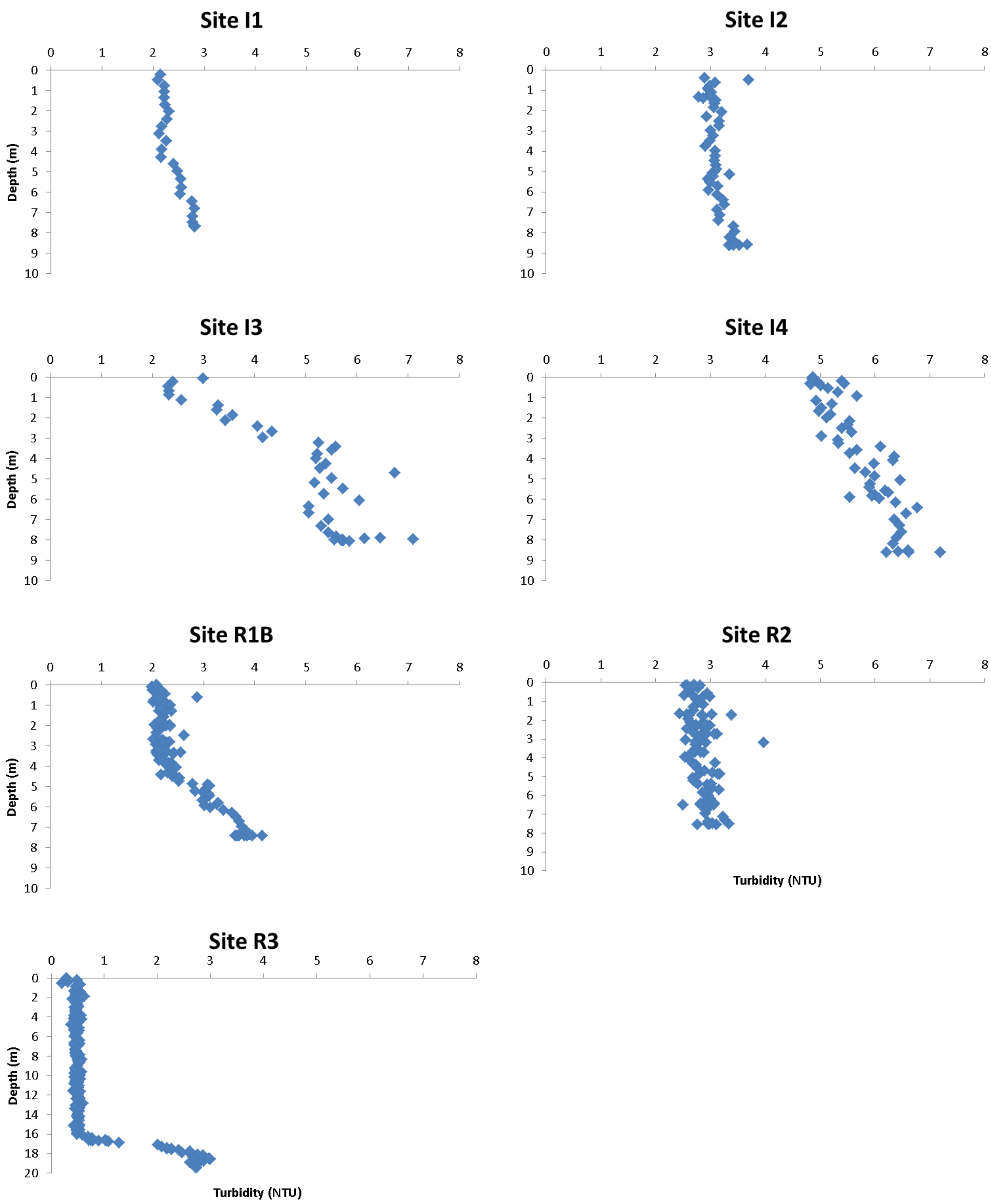


Figure 3-4 Turbidity depth profile at each site during maintenance trip 3 (MT3) – December 2016

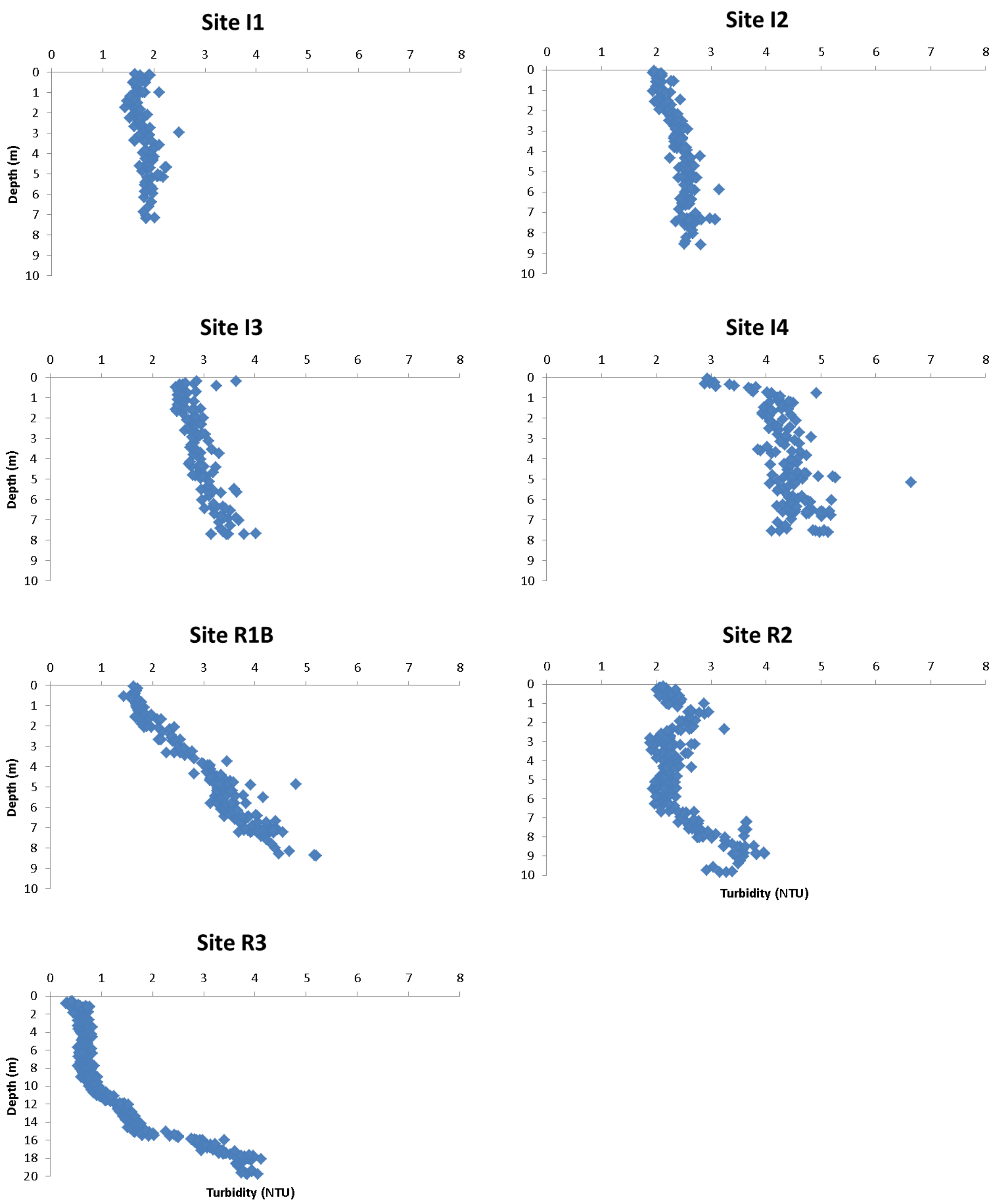


Figure 3-5 Turbidity depth profile at each site during maintenance trip 4 (MT4) – January 2016

3.4.5 TSS and Turbidity

At all sites during each field trip TSS samples were collected from the lower water column adjacent to the seafloor at the same time as turbidity measurements were being undertaken during the depth profiling exercise.

During all sampling trips except MT5, the turbidity values represented are the average of at least 20 turbidity measurements taken during the depth profiling exercise at the same depth as the TSS sample was taken. During MT5 the TSS samples were taken from the surface waters and the turbidity measured at the surface is used. This does not pose an issue because TSS and turbidity are not depth dependant.

The wet season results are presented in Table 3-5 and Figure 3-6. Based on this data there is no significant linear relationship between TSS and turbidity (see Figure 3-6, R^2=0.1524, p>0.05).

Table 3-5 Total Suspended Solid (TSS) data and average turbidity data at all sites

Site	Field trip code	Date sampled	Season	TSS (mg/L)	Average Turbidity (NTU)
I1	MT3	04/12/20145 @ 10:20	wet	4	2.7
I2	MT3	02/12/20145 @ 09:27	wet	6	3.3
I2 duplicate	MT3	02/12/20145 @ 09:27	wet	1.5	3.3
I3	MT3	03/12/20145 @ 12:53	wet	1.5	6
I4	MT3	03/12/20145 @ 10:45	wet	3	6.8
R1B	MT3	04/12/20145 @ 07:20	wet	3	4.2
R2	MT3	05/12/20145 @ 07:52	wet	1.5	3.2
R3	MT3	03/12/20145 @ 07:30	wet	7	3.2
I1	MT4	12/01/2016 @ 09:45	wet	3	1.9
I2	MT4	15/01/2016 @ 07:25	wet	7	2.9
I3	MT4	14/01/2016 @ 08:23	wet	4	3.4
I4	MT4	13/01/2016 @ 12:00	wet	9	4.8
I4 Duplicate	MT4	13/01/2016 @ 12:00	wet	7	4.8
R1B	MT4	12/01/2016 @ 12:45	wet	4	2.6
R2	MT4	13/01/2016 @ 09:00	wet	4	2.4
R3	MT4	14/01/2016 @ 13:30	wet	2	1.8
I1	MT5	11/02/16 @ 09:20	wet	19	5.5
I2	MT5	09/02/16 @ 12:15	wet	1.5	1.4
I3	MT5	11/02/16 @ 07:15	wet	4	2.1
I4	MT5	10/02/16 @ 11:15	wet	1.5	2.6
I4 Duplicate	MT5	10/02/16 @ 11:15	wet	1.5	2.6
R1B	MT5	09/02/16 @ 15:30	wet	6	4.8
R2	MT5	10/02/16 @ 07:45	wet	2	3.6
R3	MT5	09/02/16 @ 08:00	wet	1.5	3.0

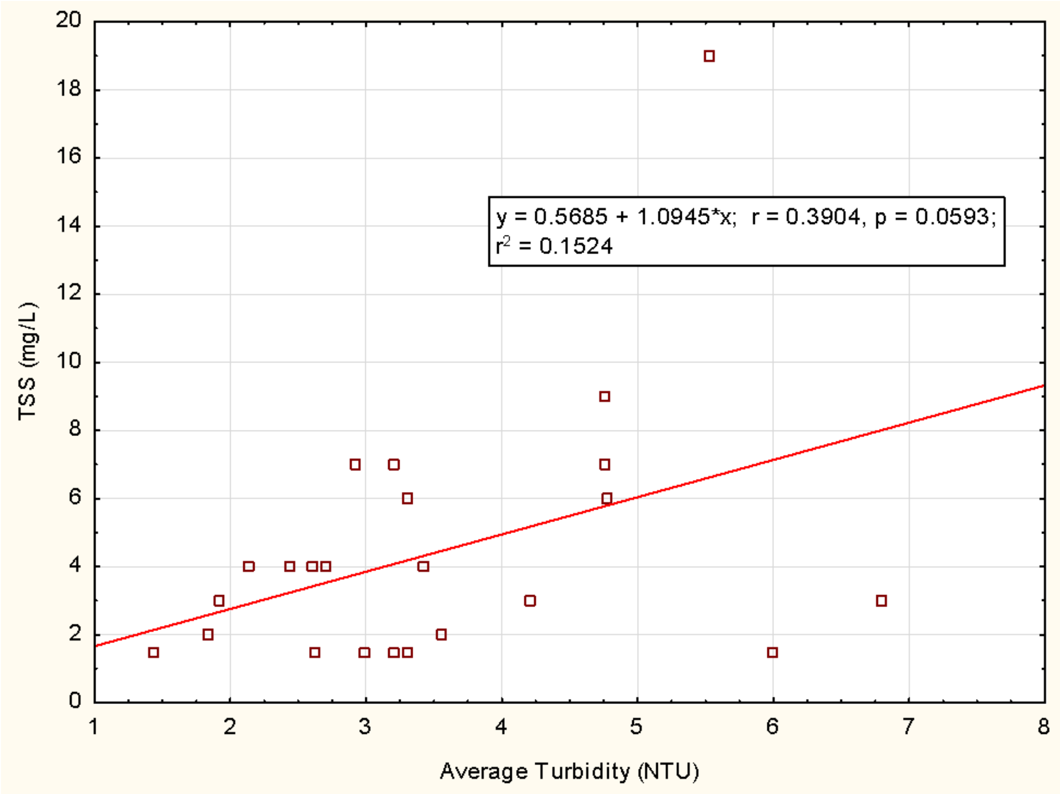


Figure 3-6 Total Suspended Solid (TSS) data compared to turbidity data at all sites for the wet season

3.4.6 Gross Sedimentation

The daily gross sedimentation rates at each site were calculated from replicate sediment trap data collected during each field trip in the wet season. Three sediment traps were attached to the logger frame at each site. Before redeployment of the logger system, the sediment in the traps was collected and despatched to the laboratory after the field trip for dry weight analysis.

Data from field trip MT4 are not included because all traps were full of sediment upon retrieval and therefore provide no accurate sedimentation rate. During field trip MT5 three samples were collected from each site except R1B where two samples were collected (one trap was missing).

Gross sedimentation for each sample was calculated by dividing the total dry sediment weight (mg) in each trap by the number of days the trap was deployed and then dividing by the area of the trap mouth in cm^2. The results of the average gross sedimentation rates in $mg/cm^2/day$ (±Standard Errors) for the wet season are presented in Table 3-5 and Figure 3-7 .

Table 3-6 Average wet season gross sedimentation rates (mg/cm^2/day) and average turbidity at each site during the wet season

Site	Season	n	Average Gross sedimentation rates (mg/cm^2/day)	Standard Error	Average turbidity (NTU)
Site I1	wet	3	61.1	4.3	21.4
Site I2	wet	3	41.9	2.9	9.6
Site I3	wet	3	36.4	6.9	16.9
Site I4	wet	3	71.0	17.7	12.9
R1B	wet	2	52.7	14.9	21.7

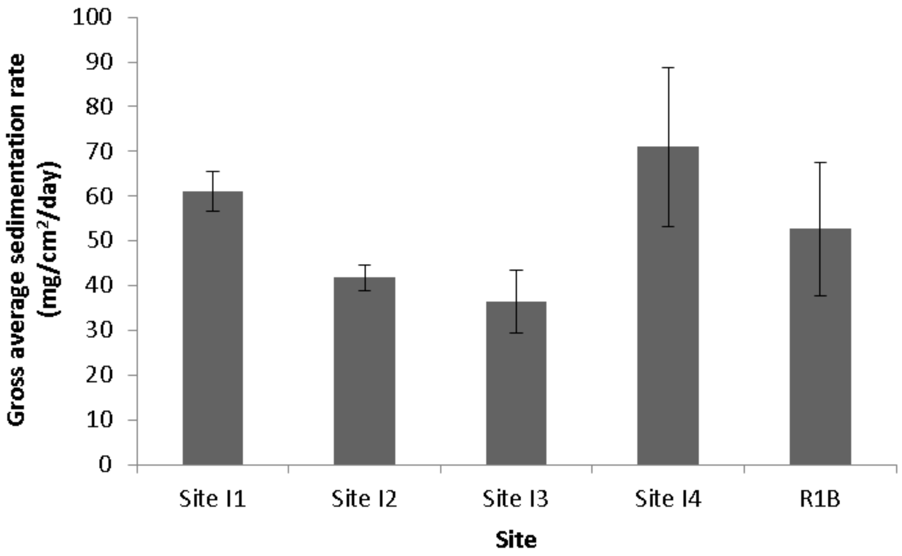


Figure 3-7 Average gross sedimentation rates (mg/cm^2/day) at each site during the wet season (± Standard Error)

In the wet season the highest gross daily sedimentation rates (mg/cm^2/day) occurred at Site I4 (71.0±17.7) and the lowest at I3 (36.4±6.9).

The average turbidity value for each site is included in Table 3-6 and Figure 3-8 for comparison. There is no significant linear relationship (R^2=0.0390, $P>0.05$) between daily gross sedimentation rates and turbidity when wet season data is considered.

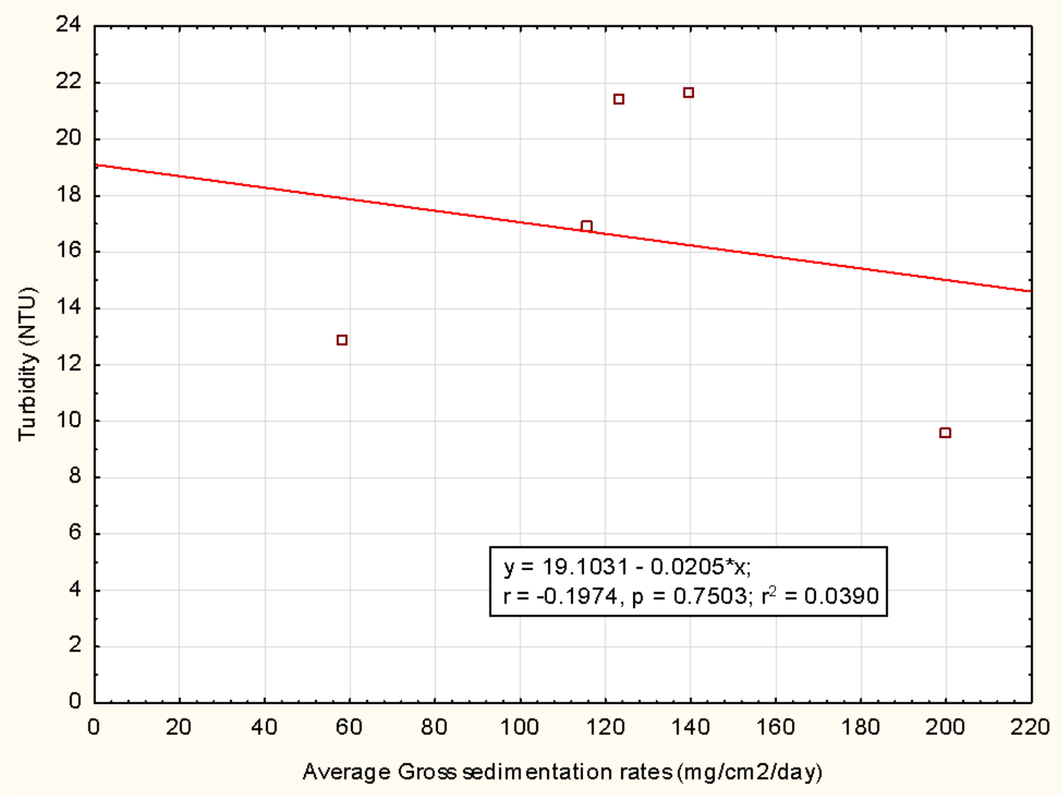


Figure 3-8 The average turbidity against the average gross daily sedimentation rate at all sites for the wet season data

4 Discussion

The coral communities growing at Pera Head and Boyd Point are well adapted to low light, high suspended solids regimes. The growth forms they exhibit are designed to maximise benthic light capture and effectively deal with elevated sedimentation rates.

Recent studies into the temporal patterns in water quality from dredging in tropical environments (Jones *et al* 2015) found high temporal variability in the levels of suspended solids in the water column close to dredging (<500m) which ranged from 100mg/L to 500mg/L over several hours. During longer periods (days to weeks to months) the average concentrations of suspended solids in the water column decrease markedly toward background baseline levels. The main feature the study found of the water quality during the dredging operations was the persistent twilight periods during the day due to persistent small elevations of TSS above background TSS, where sunlight reaching the seafloor was not fully extinguished, but very low.

For the Amrun Port Initial Capital Dredging, the wet season turbidity levels measured at the Sites of Concern range between 11 and 32NTU (80^{th}%ile –internal) and 42 and 90 NTU (95^{th}%ile-external). In some cases the wet season values are ten times the dry season trigger values. Compared to the turbidity threshold values outlined in Erftemeijer et al (2012), the proposed wet season trigger levels can be considered to be more biologically relevant than the much lower dry season trigger values (refer Table 3-1).

The use of turbidity as a trigger appears to be a good surrogate for the amount of light reaching the seafloor on a given day (daily PAR); daily PAR appears to have a statistically significant relationship with the turbidity in the water column.

The Amrun Port Initial Capital Dredging involves the dredging of approximately 240,000m^3. The volume of material to be dredged is one tenth of the volume proposed in the EIS and DMP and on which predictive hydrodynamic modelling was undertaken. The temporal and spatial distribution of fugitive sediments and the concentrations of these sediments will be considerably less than predicted by the modelling impact assessment.

Based on this, only the areas in close proximity (100's of meters) to the dredging will likely experience high levels of TSS in the water column and twilight periods over the course (up to three weeks) of the dredging. It is unlikely that impacts will occur to the low light tolerant coral communities located further afield at Boyd Point and Pera Head, located approximately two kilometres to the north and three kilometres south of the dredging footprint respectively.

5 References

AECOM (2011) East Arm Wharf Expansion Project – Dredge Management Plan. Prepared for Northern Territory Department of Land and Planning, 29 March 2011

ANZECC/ ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. Canberra.

BHP(2011). Hunt Point Marine Precinct – Dredge Management Plan. November 2011

BMA (2012). *Annual Ecological Monitoring Summary Report – 2011. Hay Point Coal Terminal Expansion Phase 3*. Report prepared by SKM for BM Alliance Coal Operations, 23 February 2012.

BOM (2016). Weipa Aero – 2016 daily calculations. Accessed online 21 January 2016 at: http://www.bom.gov.au/watl/eto/tables/qld/weipa_aero/weipa_aero.html

Chartrand KM, Ralph PJ, Petrou K, Rasheed MA. (2012) Development of a light-based seagrass management approach for the Gladstone Western Basin Dredging Program. DEEDI Publication. Fisheries Queensland, Cairns, 92pp.

Chevron(2011). Gorgon Gas Development and Jansz Feed Gas Pipeline: Dredging and Spoil Disposal Management and Monitoring Plan, 8 June 2011

Department of Environment and Heritage Protection (DEHP) (2009) Queensland Water Quality Guidelines, version 3, July 2013

Ports Australia (2014). Dredging and Australian Ports – Subtropical and Tropical Ports, April 2014.

Erftemeijer P.L.A, Riegl B., Hoeksema B.W. and Todd P.A. (2012). Environmental impacts of dredging and other sediment disturbances on corals: A review. *Marine Pollution Bulletin* 64:1737-1765.

GHD (2012). Report for Small Vessel Cyclone Mooring Protection Facility – Dredge Management Plan. Report prepared for the Port Hedland Port Authority, March 2012.

GBRMPA (2010). Great Barrier Reef Water Quality Guidelines. Great Barrier Reef Marine Park Authority.

Hanley J.R. (2011). Environmental Monitoring Programs on Recent Capital Dredging Projects in the Pilbara (2003-2010): a review. *APPEA Journal* 2011:273-293.

INPEX (2013). Ichthys Project – Dredging and Spoil Disposal Management Plan – East Arm, 16 December 2013.

Jones R., Fisher R., Stark C., and Ridd P. (2015). Temporal Patterns in Seawater Quality from Dredging in Tropical Environments. PLoS ONE 10(10):e0137112. Doi:10.1371/journal.pone.0137112

MScience (2009). Dampier Marine Services Facility: Water Quality Impacts of the Pluto Program in an area of intensive dredging. Report prepared for the Dampier Port Authority, 18 December 2009.

Rio Tinto Alcan (2015). South of Embley Project, Dredge Management Plan – Port (Initial Capital Dredging). 16 November 2015.

SKM (2007). Pluto LNG Development. Addendum to Public Environmental Report/Public Environmental Review Supplement and Response to Submissions. Revision 2.

SKM (2011). Cape Lambert Port B Development – Dredging and Spoil Disposal Management Plan. Report prepared by SKM on behalf of RioTinto, 12 December 2011.

Trimarchi S. and Keane J. (2007). Port of Hay Point Apron Areas and Departure Path Capital Dredging project Environmental Review. *EcoPorts Monograph Series No.24*. Report prepared by Ports Corporation of Queensland. 63pp.

WorleyParsons (2012). South West Creek Dredging and Reclamation Project – Water Quality Monitoring Report6: 21 March – 28 May 2012. Report prepared for the Port Hedland Port Authority, 29 August 2012

Appendix A

Cape Lambert Port B turbidity triggers (SKM 2011)

- **Table 3-6 Indicative water quality criteria**

Site names	Site	Duration class	Days of baseline data	SKM 2009 - 99%ile		
				Criteria (median NTU)	Frequency during baseline	Allowable exceedences per 2 weeks
Bells Reef	BLR	6 hours	411	18	191	7
Boat Rock	BTR	6 hours	428	10	206	7
Bezout Island	BZI	6 hours	525	11	269	7
Bezout Rock	BZR	6 hours	366	15	190	7
Cape Lambert West	CLW	6 hours	346	17	168	7
Dixon Island East	DIE	6 hours	381	25	186	7
Delambre Island	DLI	6 hours	408	7	191	7
Hat Rock	HAT	6 hours	368	25	177	7
Mangrove Point	MAN	6 hours	355	23	174	7
Middle Reef	MDR	6 hours	403	21	193	7
Pelican Rocks	PLR	6 hours	366	23	180	7
Power Station	PWR	6 hours	353	34	167	7
Samson Beach	SMSB	6 hours	446	15	189	6

Appendix B

Ichthys Project turbidity triggers from DSDMP (INPEX 2013)

Table 7-11: Channel Island and Weed Reef coral response TARP

Components	Normal Situation	Level 1 Trigger			Level 2 Trigger		Level 3 Trigger
		Daily average turbidity			Coral Bleaching	Coral Mortality Rate of Change	Coral Mortality Rate of Change
		Intensity	Duration	Frequency			
Channel Island							
Trigger value (Wet Season) (1 Nov to 31 April)	Not triggered	>44 NTU	>26 NTU over 7 consecutive days	>26 NTU > 3 days per 7-day rolling period	>20% gross coral bleaching OR	Measured coral mortality greater than the upper 95% confidence limit for the predicted coral mortality	Measured coral mortality greater than the 95% confidence interval for the predicted coral mortality, for two consecutive surveys. In addition to a statistically significant decrease in coral cover calculated from transects that is considered ecologically significant.
Trigger value (Dry Season) (1 May – 30 Oct)		>21 NTU	>15 NTU over 5 consecutive days	>15 NTU > 3 days per 7-day rolling period			
Weed Reef 1 and Weed Reef 2							
Trigger value (Wet Season) (1 Nov to 31 April)	Not triggered	>65 NTU	>46 NTU over 6 consecutive days	>46 NTU > 3 days per 7-day rolling period	>20% gross coral bleaching OR	Measured coral mortality greater than the upper 95% confidence interval limit for the predicted coral mortality	Measured coral mortality greater than the 95% confidence interval for the predicted coral mortality for two consecutive surveys. In addition to a statistically significant decrease in coral cover calculated from transects that is considered ecologically significant.
Trigger value (Dry Season) (1 May – 30 Oct)		>14 NTU	>11 NTU over 4 consecutive days	>11 NTU > 3 days per 7-day rolling period			

Appendix C

East Arm Dredging Draft DSDMP turbidity triggers (AECOM 2011)

Table 21 Draft management trigger criteria for Zone of Effect for Water Quality

Management Response level	Turbidity Levels for Daylight Hours within Zone of Effect	
	Low Trigger Level (LTL) or	High Trigger Level (HTL)
Conformance	Median < LTL each day in three consecutive days	Median< HTL on any six of seven consecutive days
Level 1 exceedance ("Watching")	Median >10% and <50% higher than LTL for 3days	Median >10% and <30% higher than HTL for any six of seven consecutive days
Level 2 exceedance ("Responding")	Median >50% higher than LTL for 3days	Median >30% higher than HTL for any five of seven days
Level 3 exceedance ("Adapting")	Median >100% higher than LTL for 3 days	Median >50% higher than HTL for any five of seven days
Level 4 exceedance ("Correcting")	Median >200% higher than LTL for 3 days	Median >100% higher than HTL for any five of seven days

APPENDIX D: DAILY SUMMARY OF RECORDED TELEMETRY ISSUES DURING DREDGING

Date (2016)	Issue	Turbidity monitored in accordance with DMP	NOTES	Compliant with DMP
13/03 – 15/03	Maintenance of loggers prior to commencement of dredging	• Telemetry – turbidity (R1, I3, I4, R2 and R3) • Telemetry – PAR (I1 and I2) • Turbidity recorded on backup loggers (all locations) • MODIS imagery	• Maintenance of loggers was conducted but was unable to be completed due to poor weather preventing safe access to R3. A team will be mobilised to site as soon as possible to rectify the remaining issues. • R3 logger maintenance to be completed. *It is important to note that there is no concern of the quality of data provided at R3 with calibration consistent with previous records.* • I1 was displaying occasional erroneous values • I2 required calibration file to be installed on website. Data collecting correctly.	Yes
15/03 –25/03	I1 and I2 erroneous telemetered turbidity data. R3 logger maintenance (data is still acceptable); prior to commencement of dredging.	• Telemetry – turbidity (R1, I3, I4, R2 and R3 • Telemetry – PAR (I1 and I2) • MODIS imagery • Turbidity recorded on backup logger (all locations) • MODIS imagery	• I1 telemetry for turbidity erroneous (19/03) and I2 telemetry for turbidity erroneous (18/03). As an alternative PAR data will be used to monitor turbidity. If daily median of PAR is greater than zero daily median turbidity is less than 10 and no trigger event has been recorded. • The consultant was scheduled to mobilise to site on 28/03 (due to Easter public holidays). Team was onsite on 28-30 will be downloading turbidity data from I1 and I2 back-up loggers. Technical repair team attempted to fix telemetry issues with equipment on 31/03.	Yes
26/03	Erroneous turbidity data at I1 and I2.	• Telemetry – turbidity (R1, I3, I4, R2 and R3 • Telemetry – PAR (I1 and I2) • MODIS imagery • Turbidity recorded on backup logger (all locations) • MODIS imagery	• *Dredging commenced at 18:20* • Consultant is scheduled to be on site and will download data from back-up turbidity loggers at I1 and I2 on 29/03 • PAR data was used to monitor light levels (alternate for turbidity). No issues identified with both loggers recording median daily PAR greater than zero. • MODIS Imagery for 26/03 was collected prior to commencement of dredging	*Yes*
27/03	Erroneous turbidity data at I1 and I2.	• Telemetry – turbidity (R1, I3, I4, R2 and R3 • Telemetry – PAR (I1 and I2) • MODIS imagery • Turbidity recorded on backup logger (all locations) • MODIS imagery	• Consultant is scheduled to be on site and will download data from back-up turbidity loggers at I1 and I2 on 29/03 • PAR data was used to monitor light levels (alternate for turbidity). No issues identified with both loggers recording median daily PAR greater than zero.	Yes

Date (2016)	Issue	Turbidity monitored in accordance with DMP	NOTES	Compliant with DMP
28/03	Erroneous turbidity data at I1. I2 and R3 data package issues (pm)	• Telemetry – turbidity (R1, I3, I4, R2, R3 - am) • Telemetry – PAR (I1, 12 -am) • MODIS imagery • Turbidity recorded on backup logger (all locations) • MODIS imagery • In situ boat based monitoring • MODIS imagery • In-field plume observations	• MODIS imagery monitoring of plume - – no plume evident • On-site monitoring of plume and in situ boat based monitoring. Plume was localised around vessel. Plume returned to 2 NTU within 500m of vessel. • *Internal trigger alert was recorded at I1 (day 1). The management process was followed and an investigation identified erroneous data at I1. PAR data has not shown any reduction from pre-dredge observations. False exceedance recorded.*	Yes
29/03	Erroneous turbidity data at I1 and I2 and R3 data package issues	• Telemetry (R1, I3, I4, R2) • Data downloaded daily from back-up turbidity loggers (I1 and I2) • In-field plume observations • MODIS imagery	*Consultant arrived on site and team members were present on site for the remainder of the dredge period* • Turbidity was monitored using the downloaded turbidity data collected by the consultant at I1 and I2 in accordance with the DMP. All data was recovered from back up loggers and no erroneous data was identified. Data from loggers was analysed, no trigger events were recorded. Data was consistent with previous infield observations and in situ monitoring. • Consultant recorded observations on plume (localised around vessel and slight surface plume to 500m south (not evident in pictures). • MODIS imagery monitoring of plume - – no plume evident • Erroneous data issues were corrected at I1.	*Yes*
30/03	I2 and R3 data package issues	• Telemetry (R1,I1, I3, I4, R2) • Data downloaded daily from instruments (I2 and R3) • In-field plume observations • In-situ boat based monitoring • MODIS imagery	• Plume was recorded as being localised at vessel. • All data was recovered from back up loggers and no erroneous data was identified. Data from loggers was analysed, no trigger events were recorded. Data was consistent with previous infield observations and in situ monitoring In-situ plume monitoring conducted surrounding the vessel. Plume localised to around the vessel. • MODIS imagery monitoring of plume - – no plume evident	Yes
31/03	Erroneous turbidity data at I1 being recorded R3 data package issues	• Telemetry (R1,I2 , I3, I4, R2) • Data downloaded daily from instruments (I1 and R3) • In-field plume observations • In-situ boat based monitoring • MODIS imagery	• Consultant downloaded data at I1 and rectified telemetry in accordance with DMP. Data from loggers was analysed and data was consistent with observations and in situ monitoring with no impact recorded. • In-situ boat based plume monitoring conducted surrounding the vessel. Plume localised to around the vessel and within 500m of the vessel. . • MODIS imagery monitoring of plume - – no plume evident	Yes
01/04	R3 data package issues and erroneous data at I1	• Telemetry (R1,I2 , I3, I4, R2) • Data downloaded daily from turbidity loggers (I1 and R3) • In-field plume observations	• Consultant downloaded turbidity data at I1 and rectified problem in accordance with the DMP. Completed maintenance at R3, downloaded turbidity data and rectified telemetry. • All data was recovered from back up loggers and no erroneous data was identified.	Yes

Date (2016)	Issue	Turbidity monitored in accordance with DMP	NOTES	Compliant with DMP
		• In-situ monitoring • MODIS	Data from loggers was analysed, no trigger events were recorded. Data was consistent with previous infield observations and in situ monitoring • MODIS imagery monitoring of plume - – no plume evident	
02/04	No issues	• Telemetry (R1, I1, I2, I3, I4, R2 and R3) • In-field plume observations • MODIS imagery	• All equipment operational. All operations in accordance with DMP.	Yes
03/04	I2 telemetry stopped working	• Telemetry (R1, I1, I3, I4, R2 and R3) • In-situ boat based monitoring I2 • In-field plume observations • MODIS imagery	• Issues were identified at I2 logger early AM. • In-situ plume monitoring conducted surrounding the vessel. Plume localised to within 400 m of the vessel. Monitoring in accordance with DMP • MODIS imagery monitoring of plume - – no plume evident.	Yes
04/04	No telemetry at I2	• Telemetry (R1, I1, I3, I4, R1, R2 and R3) • In-situ monitoring (I2) and plume turbidity monitoring around vessel • In-field plume observations • MODIS imagery	• In-situ water quality logging was completed at I2 (including depth profiles) in accordance with the DMP. An additional autonomous logger was deployed at I2. • In-situ plume monitoring conducted surrounding the vessel. The plume was most prevalent in the first 300-500m from the active dredge, with a less evident plume extending for around ~1km • MODIS imagery monitoring of plume - – no plume was visible. This indicates plume was only slightly higher than background elevations. This was confirmed in the field with plumes not evident in field photos	Yes
05/04	No telemetry at I2	• Telemetry (R1, I1, I3, I4, R2 and R3) • Turbidity data downloaded daily from instrument (I2) • In-situ plume monitoring • In-field plume observations • MODIS imagery	• Data downloaded from instrument at I2 in accordance with DMP. Data downloaded was analysed and no trigger events were recorded. Date was consistent with observations and in situ monitoring with no impact recorded. No plume evident at location. • Plume from the dredge was travelling in a north westerly direction heading away from the coast. The plume was most prevalent in the first 200-250m from the active dredge, with a less evident plume extending for around ~500m. • In-situ plume monitoring conducted surrounding the vessel. • MODIS imagery monitoring of plume - – no plume evident.	Yes
06/04	No telemetry at I2	• Telemetry (R1, I1, I3, I4, R2 and R) • Turbidity data downloaded daily from instrument (I2) • In-field plume observations • MODIS	• Loggers at R1 and I2 swapped for compatibility with telemetry systems to allow real time management. • Data was downloaded from instrument at I2 in accordance with DMP. Data downloaded was analysed and no trigger events were recorded. Date was consistent with observations and in situ monitoring with no impact recorded. No plume evident at location. • No dredge plume was visible.	Yes

Date (2016)	Issue	Turbidity monitored in accordance with DMP	NOTES	Compliant with DMP
			• MODIS imagery monitoring of plume - – no plume evident.	
07/04	No telemetry at R1	• Telemetry (I1, I2 I3, I4, R2 and R3) • Data downloaded daily from instrument (R1) • In-situ plume monitoring • In-field plume observations • MODIS imagery	• Data downloaded from instrument at R1 in accordance with DMP. Data downloaded was analysed and compared to impact sites. Date was consistent with observations and in situ monitoring with no impact recorded. No plume evident at location. • In-situ plume monitoring conducted surrounding the vessel. • MODIS imagery monitoring of plume - – no plume evident. • *An Internal alert notification was received for I2 with the 5 day rolling median greater than the site internal trigger level for the first time (1 consecutive day). The management process was followed and an investigation identified a website problem. This was determined to be a false exceedance with turbidity below the trigger value.*	Yes
08/04	No telemetry at R1	• Telemetry (I1, I2 I3, I4, R2 and R3) • Data downloaded daily from instrument (R1) • In-situ plume monitoring • In-field plume observations • MODIS imagery	• Data downloaded from instrument at R1 in accordance with DMP. Data downloaded was analysed and compared to impact sites. Date was consistent with observations and in situ monitoring with no impact recorded. No plume evident at location. • No plume was recorded. • MODIS imagery monitoring of plume - – no plume evident.	Yes
09/04	No telemetry at R1	• Telemetry (I1, I2 I3, I4, R22 and R3) • Data downloaded daily from instrument (R1) • In-situ plume monitoring • In-field plume observations • MODIS	• Dredging completed at 01:30 am. • Data downloaded from instrument at R1 in accordance with DMP. Data downloaded was analysed and compared to impact sites. Date was consistent with observations and in situ monitoring with no impact recorded. No plume evident at location. • No plume was evident. • MODIS imagery monitoring of plume - – no plume evident.	Yes