APPENDIX 10

ARROW LNG PLANT

Supplementary Report - Technical Study of Estuarine Ecology (Calliope River)

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SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

TECHNICAL STUDY OF ESTUARINE ECOLOGY (CALLIOPE RIVER) FOR THE SUPPLEMENTARY REPORT TO THE ARROW LNG PLANT ENVIRONMENTAL IMPACT STATEMENT

PREPARED FOR ARROW CSG (AUSTRALIA) PTY LTD (ARROW ENERGY)

TECHNICAL STUDY OF ESTUARINE ECOLOGY (CALLIOPE RIVER) FOR THE SUPPLEMENTARY REPORT TO THE ARROW LNG PLANT ENVIRONMENTAL IMPACT STATEMENT

Prepared for Arrow CSG (Australia) Pty Ltd (Arrow Energy)

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EXECUTIVE SUMMARY

This technical study summarises the findings of supplementary work undertaken by Coffey Environments on behalf of Arrow Energy to validate impacts and evaluate any changes to the worst-case impact scenario assessed in the Arrow LNG Plant Environmental Impact Statement (EIS) (Coffey Environments, 2012a). Specifically, this technical study reviews the extent of change in extreme low tide levels in the Calliope River resulting from the maximum proposed project dredging at the river mouth, and uses the results to address the potential impacts of such changes in tidal height on the overall river ecology, particularly mangrove habitats and associated macro-invertebrate and fish faunas. The combined impacts on the change in tide levels, including the flow-on effects of the duration and extent of exposure of river banks on the intertidal zone ecology, were not addressed in the EIS. The study also addresses the impact from the direct loss of 2.01 ha of mangroves at the site proposed for the mainland launch site, as well as indirect impacts on adjacent subtidal habitats from the increased turbidity generated by the planned dredging works.

The main objectives of this technical study were to:

- Assess the extent and significance of changes in extreme low tide levels along the Calliope River following the dredging at the river mouth, particularly the area and duration of exposure of the expected additional intertidal zone.
- Investigate potential impact(s) expected from changes in extreme low tide levels on mangroves and dependent species (mainly fishes and macro-invertebrates).
- Assess direct and indirect impacts of the loss of estuarine habitat and dredging works proposed for the construction of the mainland launch site in the Calliope River.

Model simulations run over a 12-month period show that the predicted height difference in extreme tide levels between pre- and post-dredging conditions remains at around 0.50 m along the river zone located between 0.8 km and 5.5 km upstream of the river mouth, before decreasing to around 0.14 m at approximately 7.8 km upstream from the river mouth. Such changes in tidal amplitude become only evident at intertidal bed elevations below -0.5 m AHD and are greatest at elevations subjected to extreme low tides, i.e., those below -1.0 m AHD. Furthermore, while intertidal mudflats at -0.5 m AHD elevations are predicted to remain exposed for around 32% of the time during both pre- and post-dredging conditions, mudflats below -0.5 m AHD will remain exposed for an increasingly longer time following project dredging, before becoming completely inundated.

The overall additional intertidal area gained as a result of the drop in extreme low tide levels from pre- to post-dredging conditions was estimated to be 30.0 ha, and applies to the area from the river mouth to 12.5 km upstream from the mouth. The increased area of intertidal zone and duration of exposure of the lower tidal mudflats will provide extended foraging opportunities for shorebirds such as waders, at the expense of some reduced foraging opportunities for resident crustaceans and fishes. However, despite a 1 to 1.5 hour increase in the duration and a 12-fold increase in the frequency of exposure for elevations below -1.5 m AHD (i.e., 5 times pre- to 60 times post-dredging), the annual average represents no more than a 4% increase in exposure time as a worst case scenario, and any impacts are most likely to be undetectable.

Mangroves typically occur from the level reached by the highest astronomical tides to mean sea level, and do not survive inundation for more than 30% of the time. Model simulation outputs indicated that the predicted intertidal elevation that remains inundated for 30% of time (i.e., 70% of the time exposed) lies at around 0.75 m AHD. Since the lowest limit of mangroves is located well above the river elevation at which dredging-related differences in intertidal exposure are predicted to occur, i.e., below -0.5 m AHD, no mangroves along the Calliope River are expected to be impacted by the predicted changes in tidal pattern either during the existing (pre-dredging) or new (post-dredging) conditions.

The increase in percentage of time that the lower bed elevations are exposed may, to some extent, affect the benthic habitats and associated fauna at those locations. However, the generally soft, fully saturated nature of these habitats, coupled with the relatively small (<4%) increase in exposure time, is unlikely to result in desiccation or measurable change to macro-invertebrates, fishes or benthic communities.

The removal of an estimated 2.01 ha of mangroves required for the construction of the mainland launch site in Calliope River does not constitute a change to the worst-case scenario from the change in project description. Therefore, the significance of impact from the direct removal of this mangrove area continues to be **minor**, as assessed in the EIS. Likewise, the direct loss of <0.01 ha of reef habitat outside the river entrance expected during the dredging of the entrance channel to Calliope River does not constitute a change to the worst-case scenario from the change in project description. As such, the significance of direct impact from removing this small reef area continues to be **minor**, as assessed in the EIS. Furthermore, since the total volume to be dredged for the proposed access channel to the Calliope River as well as the dredging method and rate remain unchanged from the EIS (900,000 m^3), the significance of indirect impacts on adjacent estuarine and marine habitats from the increased turbidity levels generated by dredging works continues to be **minor** for mangroves and reef and rock substrate, and **moderate** for the intertidal zone.

1. INTRODUCTION

Arrow CSG (Australia) Pty Ltd (Arrow Energy) proposes to develop a liquefied natural gas (LNG) plant on Curtis Island off the central Queensland coast, near Gladstone. The project, known as the Arrow LNG Plant (the project), is a component of the larger Arrow LNG Project incorporating upstream coal seam gas field developments and transmission gas pipelines.

An environmental impact statement (EIS) has been prepared for Arrow Energy by Coffey Environments under Part 4 of the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) and s. 133 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). The EIS identified and assessed the potential impacts of the project works (design, construction and operations) as well as project infrastructure on the marine and estuarine ecology values of the area surrounding Port Curtis, including the Calliope River (see Chapter 19 of the EIS). A marine and estuarine ecology impact assessment was prepared by Coffey Environments in October 2011 on behalf of Arrow Energy to support the EIS (Coffey Environments, 2012b).

Since finalising and submitting the EIS, Arrow Energy has reviewed and revised the project description, and has subsequently proposed a number of changes which could affect the areas of disturbance and the conclusions of the impact assessment presented in the EIS on the ecology of the Calliope River. A detailed hydrographic survey of the Calliope River has been completed, and additional information on physical and biological aspects of the river is also available relevant to the assessment of project impacts on this estuarine environment.

This technical study summarises the findings of supplementary work undertaken by Coffey Environments on behalf of Arrow Energy to validate impacts and evaluate any changes to the worst-case impact scenario assessed in the EIS, following changes to the proposed facilities in the Calliope River, including the potential impacts from dredging the bar at the river mouth. The study also assesses the extent to which predicted residual impacts from these changes may alter the conclusions listed in the marine and estuarine ecology impact assessment (Coffey Environments, 2012b; see also Chapter 19 of the EIS). Potential impacts on the ecology within Port Curtis are addressed separately in the marine ecology technical study (Coffey Environments, 2012a).

This study focuses on assessing the impact on the hydrology and ecology of the river resulting from dredging a 3.02 km access channel required as part of the development of the proposed mainland launch site in the Calliope River. Particular attention is placed on the anticipated changes in extreme low tide levels following the dredging of the bar at the river mouth. The study examined the potential ecological impacts expected from the new low tide levels on mangrove habitats and dependent species (mainly fish and macro-invertebrates), including impacts from the changes in duration and extent of exposure of river banks at low tide. Impacts of turbidity related to dredging are addressed in the marine ecology technical study (Coffey Environments, 2012b), while impacts on water quality are addressed in the marine water quality study (Central Queensland University, 2012).

This technical study is to be appended to the Supplementary Report to the Arrow LNG Plant EIS.

2. PROJECT DESCRIPTION CHANGES AND STUDY OBJECTIVES

The objective of this study was to review changes to the project description and to validate the impact assessment on the ecology of the Calliope River completed for the EIS following these changes, particularly the impact and frequency of changes in the extreme low tide levels on the river's intertidal ecology. Details of relevant changes to the project description and main objectives of this technical study are provided below.

2.1 Project Description Changes

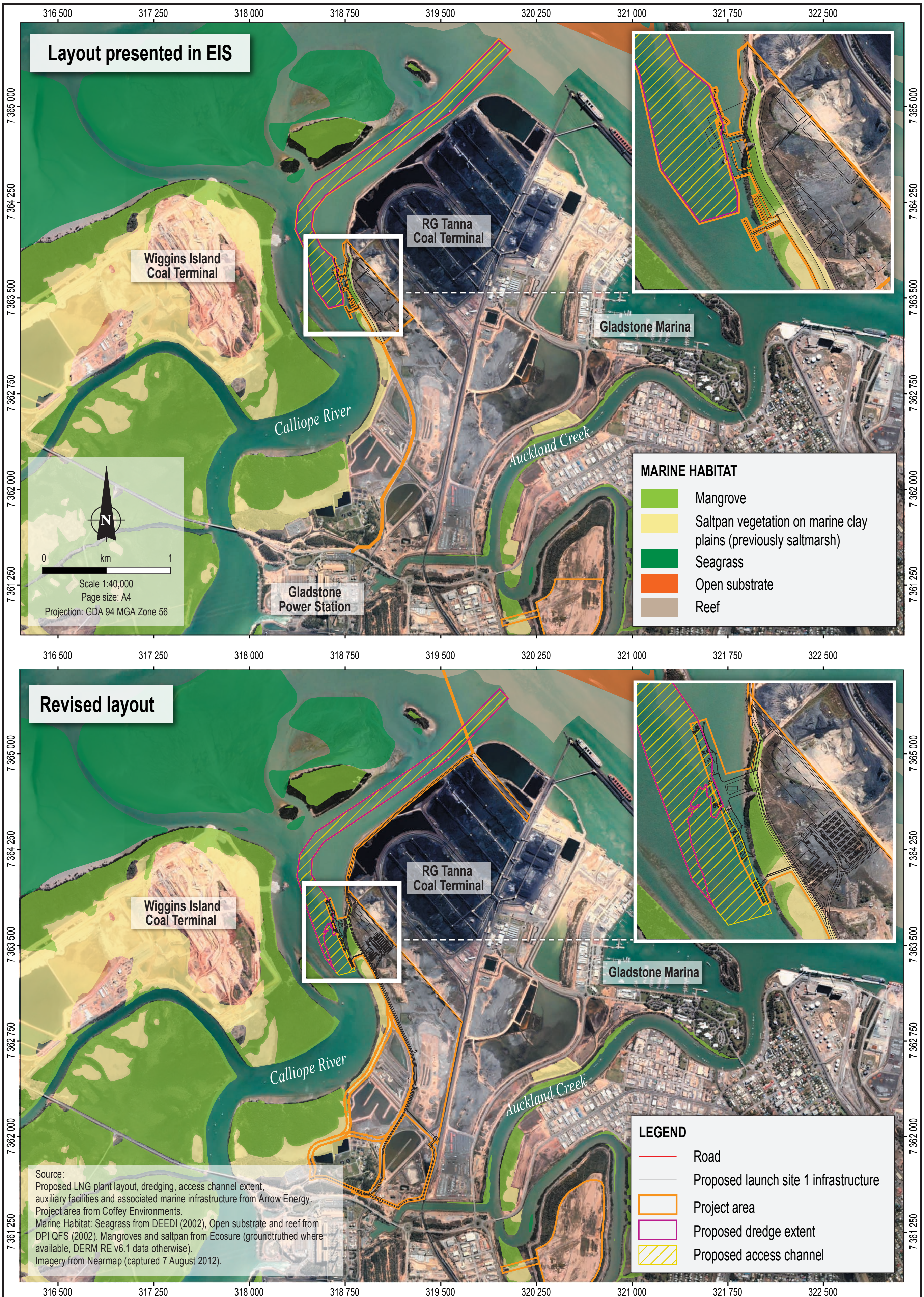
The main changes to the project description from the EIS comprise modifications to the footprint areas to be dredged and cleared as required to develop the proposed mainland launch site in the Calliope River. Proposed works include dredging of an access channel along the river entrance to facilitate the movement of large vessels, and the clearing of a mangrove area along the eastern shore of the river to accommodate the new facilities (Figure 1). Details of changes to the project description are provided below.

2.1.1 Dredging of Calliope River Access Channel

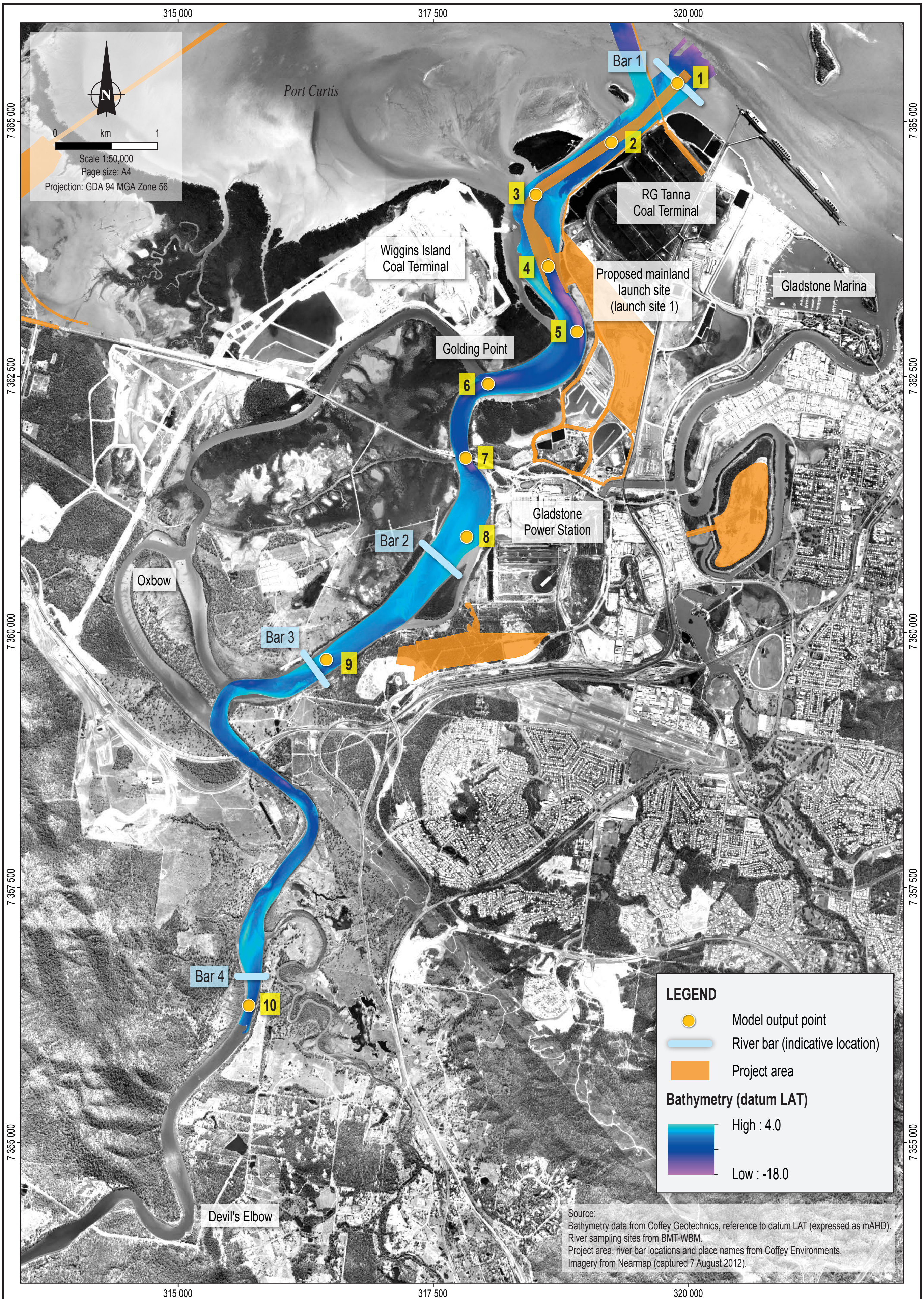
The proposed berthing facilities of launch site 1 in Calliope River are to be built on the former Gladstone Power Station ash ponds (Clinton ash ponds), adjacent to the RG Tanna Coal Terminal along the river's eastern shore (see Figure 1). The construction of these facilities requires dredging of a 3.0 km-long access channel to allow the movement of large vessels from and to the Boatshed Point MOF at Curtis Island. While the total footprint area to be dredged has decreased from 36.7 ha to 30.2 ha, the dredging volume of in-situ material required for construction and operation of the proposed launch site remains unchanged and is estimated to be 900,000 m^3.

The construction of the access channel to Calliope River requires dredging an existing bar located at an approximate depth of -5 m LAT across the river mouth. This bar is currently almost fully exposed at extreme low tides and dredging a channel through the bar will reduce its current retarding effect on the tidal flow along the river resulting in changes to the extreme low tide levels. Model simulations carried out by BMT WBM (2012), indicated that low tide levels after dredging of the bar would decrease by approximately 0.5 m in the area between the river mouth and just upstream of the NRG Gladstone Power Station (see Figure 1). In addition, the modelling showed dredging effects on low tide levels become significantly reduced upstream from the power station due to the presence of a gravel bar, with effects disappearing beyond around 15 km upstream from the river entrance, near Devil's Elbow (Figure 2).

The EIS describes the direct loss of up to 0.14 ha of reef habitat as a worst-case scenario following dredging along the entrance to the Calliope River. The potential impacted area is located at the north-eastern end of the proposed access channel and through revisions in the dredging footprint since the EIS was prepared has now been estimated to be <0.01 ha.



coffey environments	Date: 12.12.2012 MXT: 7033CC_16_GIS077_v1_1 File Name: 7033CC_EE_F001_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Changes to mainland launch site (lauch site 1)	Figure No: 1



coffey environments	Date: 12.12.2012 MXT: 7033CC_16_GIS078_v1_1 File Name: 7033CC_EE_F002_GIS_GL	Arrow Energy Arrow LNG Plant	arrow energy go further	Calliope River physiography and bathymetry	Figure No: 2

The indirect impacts of turbidity plumes and water quality from changes to dredging on mangrove communities, seagrass beds and various benthic habitats, as well as associated fauna in the Calliope River are addressed in the marine ecology technical study (Coffey Environments, 2012b) and the marine water quality study (Central Queensland University, 2012), respectively.

2.1.2 Changes to Mainland Launch Site

The layout for the mainland launch site in the Calliope River has been changed from that described in the EIS (see Figure 1). The main changes to the project description include a larger berth area to handle materials and plant equipment, with an additional link span berth and changes to the quay from a piled concrete deck structure to a sheet-piled retaining structure. The construction of this larger berth area will require the clearing of 2.01 ha of mangroves along the mainland launch site and haul road. Potential impacts to this mangrove area were not included in the EIS (Coffey Environments, 2012a).

2.2 Study Objectives

This technical study reviews the extent of change in extreme low tide levels in the Calliope River resulting from the proposed project dredging at the river mouth, and uses the findings to address the potential impacts of such changes in tidal height on the overall river ecology, particularly mangrove habitats and associated macro-invertebrate and fish faunas. The proposed dredging of the bar at the mouth of the Calliope River is likely to result in a reduction in extreme low tide levels, which will increase the overall area, and duration and frequency of exposure of the lower intertidal zone. These changes are likely to impact the river in two ways: the intertidal mudflats below the existing extreme low tide, which have never been previously exposed, will now be periodically exposed; and the intertidal mudflats above the existing extreme low tide will now be exposed more frequently and for longer periods of time because of the lowered extreme low tide. The combined impacts on the change in tide levels, including the flow-on effects of the duration and extent of exposure of river banks on the intertidal zone ecology, were not addressed in the EIS (Coffey Environments, 2012a).

The study also addressed the impact from the direct loss of 2.01 ha of mangroves at the site proposed for the mainland launch site, as well as indirect impacts on adjacent subtidal habitats from the increased turbidity generated by the planned dredging works.

The specific objectives of this technical study were to:

- Address key implications of the change in extreme low tide levels along the Calliope River following the dredging of the bar at the river mouth, particularly the area, and the duration and frequency of exposure of the expected additional intertidal zone.
- Investigate potential impact(s) expected from changes in extreme low tide levels on mangrove habitats and dependent species (mainly fishes and macro-invertebrates).
- Assess direct and indirect impacts of the loss of estuarine habitat and dredging works proposed for the construction of the mainland launch site in the Calliope River.

Cumulative impacts related to other activities in and/or near the Calliope River, including dredging works and changes in the marine logistics and transport system within the Port Curtis area, are addressed in the marine ecology technical study (Coffey Environments, 2012b).

3. LEGISLATIVE CONTEXT

There has been an important update to relevant legislation in relation to environmental offsets since the submission of the original marine and estuarine assessments.

Offset requirements at a state level are unchanged since the Arrow LNG Plant EIS was finalised, and governed by the *Queensland Government Environmental Offsets Policy*, June 2008 (EPA, 2008), which from November 2012 is currently under review. However, the state government has since released the *Ecological Equivalence Methodology Guideline* (DERM, 2011), intended to inform requirements for ecological offset required under the *Policy for Vegetation Management Offsets* and *Queensland Biodiversity Offsets Policy*.

Offsets concerned with the removal of marine habitats for the construction of the LNG plant and associated infrastructure will be included in an offset plan to be written before the commencement of construction in 2014.

4. METHODS

The methods followed in this technical study comprised a desktop review of existing and new information, and a staged approach to identifying the ecological impacts of reduced extreme tide levels and impact assessment.

4.1 Available Data

The desktop study included a review of the following reports and information:

- Coastal processes, marine water quality and hydrodynamic modelling information provided by BMT WBM (2011) that included simulations of spatial extent of turbidity plumes from different dredging sources associated with project works within Port Curtis.
- Coastal processes and hydrodynamic modelling information provided by BMT WBM (2012) that included simulations of the overall reduction in the extreme low tide levels following the dredging of the bar at the Calliope River mouth, as well as revised time and area of exposure of the intertidal area resulting from the changes in extreme low tidal levels.
- Review of updated bathymetry data provided by Coffey Geotechnics (2012) for the period 9 July through to 12 October, 2012, and by BMT WBM along the Calliope River to 12.5 km upstream from the river mouth (BMT WBM, 2012).
- LIDAR mapping data from DNRM (DERM, 2011).
- Field surveys undertaken along the Calliope River by the Gladstone-based Central Queensland University (CQU) in May 2010 (Phase I) and February 2011 (Phase II) (Alquezar, 2011), and more recently during the period of 21-30 August 2012 (Wilson, 2012). The 2012 CQU field survey was carried out concurrently with field sampling in Port Curtis marine waters, and included assessment of mangrove communities, and sampling of fishes and macro-invertebrates along Calliope River.

4.2 Desktop Review Approach

The available information was assessed following a 4-step approach. The first two steps employed results from model simulations (BMT WBM, 2012) to evaluate the changes in additional time and area of exposure of the intertidal zone of the Calliope River as a result of lowering in extreme low tides. Results of the above two steps were then used to assess the potential impacts of the revised time and area of exposed intertidal zone on the mangrove communities and to macro-invertebrate and fish habitats associated with the mangrove area and intertidal zone. These four steps are outlined below.

4.2.1 Additional Time of Exposure (Step 1)

Coffey Environments commissioned BMT WBM to provide additional information on predicted changes in the tidal regime along the Calliope River derived from the proposed dredging of the river mouth. The simulations were run for the 12-month period from 1 July 2009 to 1 July 2010, corresponding to the representative period for which boundary conditions data were available. This modelling timespan was chosen to cover a wide range of tidal conditions, which included several periods of large amplitude spring tides. Outputs comprised predicted tidal amplitudes, frequency (number of times in a year) and duration of exposure (percentage time exposed) of existing and additional intertidal bed areas during pre- and post-dredging conditions. Unless specified otherwise, all vertical levels provided correspond to metres (m) relative to AHD

(Australian Height Datum), noting that mean sea level (MSL) along the Calliope River lies between 0.09 m and 0.1 m above AHD. All plots provided in this technical report are based on modelled data corresponding to the 12-month simulation period (BMT WBM, 2012).

Simulated outputs provided by BMT WBM included average lowest low tide levels (m) at 10 points (survey sites) along Calliope River, with point 1 located at the river mouth and point 10 approximately 12.8 km upstream from the river mouth; the upstream extent of the study area ensured model coverage of the zone where the influence of dredging on low tide levels is deemed no longer detectable, estimated to be at Devil's Elbow (see Figure 2). Model outputs also included the percentage of time that a particular river bed elevation (m) is exposed during both pre- and post-dredging conditions. These data were compared across various bed elevations at 3 points located at increasing distances from the river mouth: point 3 (1.8 km), point 6 (4.4 km) and point 9 (8.0 km). Changes in minimum water levels along the Calliope River and number of low tides over a 12-month period were also provided by BMT WBM, along with the number of times and duration (hours) that the water level falls below -1.5 m over a year (BMT WBM, 2012).

4.2.2 Additional Exposed Intertidal Zone (Step 2)

The area of the additional exposed intertidal zone created as a result of changes in tidal levels from dredging was estimated using BMT WBM's results of model simulations (Step 1 above; BMT WBM, 2012) combined with the updated bathymetric data collected by Coffey Geotechnics and BMT WBM along Calliope River. As the extreme low tide level height difference of up to 0.51 m identified in Step 1 was deemed as likely to result in a significant greater additional exposure of the river banks along both shores, the determination of additional exposed intertidal zone included both location and extent of exposure over a 12-month period.

Bathymetric cross-sections of the Calliope River at points 3, 6 and 9 were plotted to illustrate changes in extreme low tides during pre- and post-dredging conditions in relation to the lowest limit of mangroves along the river bed, i.e., approximately 0.0 m AHD. Information on bed elevations that remain exposed for 70% of the time (i.e., 30% inundated) were also provided in these cross-sections, along with the intertidal zone where most changes in tidal exposure are predicted to take place following dredging. The cross-sections used bathymetry data (m AHD) from sites as well as tide levels obtained from BMT WBM model runs.

Predicted extreme low water levels during pre- and post-dredging conditions, along with the newly acquired bathymetry of the Calliope River, were combined to estimate the area of intertidal zone under existing (pre-dredging) and new (post-dredging) conditions, as well as the area of additional intertidal zone (difference between post- and pre-dredging). Two contour levels were superimposed to the river bathymetry between the mouth and point 10 upstream: (1) the existing (pre-dredging) extreme lowest low tide level; and (2) the new (post-dredging) extreme lowest low tide level. The area between contours 1 and 2 was assumed to represent the additional intertidal area not previously exposed, and where changes to exposure times are predicted to be greatest as a result of dredging. Thus, the estimate was based on the overall difference between the areas that are inundated at the predicted extreme low tides during pre- and post-dredging conditions.

4.2.3 Impacts on Mangrove Communities (Step 3)

The potential response of mangrove communities to the changes in tidal conditions from dredging the Calliope River mouth was predicted using the information compiled from Steps 1 and 2 above, along with results of the survey undertaken by CQU in August 2012 (Wilson, 2012) and review of literature relevant to mangrove colonisation.

In general, the lower limit of mangroves corresponds approximately to mean sea level (MSL) (Dr. Ralph Dowling, DNRM, pers. com.), and survival is unlikely at bed elevations submerged in excess of 30% of the time, i.e., must be exposed for at least 70% of the time (Hutchings and Saenger, 1989). Considering that the existing upper limit of mangroves along the river is determined by the highest astronomical tide (HAT), and that the lower (i.e., riverward) limit is determined by MSL and elevation levels inundated no longer than 30% of the time (Hutchings and Saenger, 1989), the following three hypotheses were put forward as to the potential responses of mangroves to the reduction in the lowest low tide level:

- An increase in area, resulting from colonising the increased intertidal area (possible).
- A decrease in area because of increased inundation of the riverward fringe (unlikely).
- No change, if the existing lower mangrove limit is already exposed at low tide such that there will be no change in submergence or exposure after dredging (most likely).

These hypotheses were tested firstly by overlaying the simulated old and new low tide levels over the existing distribution of mangroves from remote imagery; examining cross-sections of the Calliope River at three separate points and overlying predicted lowest low tidal levels during pre- and post-dredging as well as lower limit of mangroves along river banks (m MSL = AHD). These levels were then compared against literature pertaining to factors controlling the upper and lower boundaries of mangroves, as well as recolonisation rates of mangrove propagules of intertidal areas subjected to increased exposure from changes in low tidal levels.

4.2.4 Impacts on Fish Habitats (Step 4)

The possible effects of changes to tidal patterns, and any consequential changes to mangrove areas on associated fishes and macro-invertebrates, were assessed from results of the field survey undertaken by CQU in the Calliope River in August 2012 (Wilson, 2012), results from an earlier estuarine and marine ecology field investigations along Calliope River (Alquezar, 2011), and review of literature relevant to mangrove dependent and associated fauna. The survey carried out by CQU collected information on the fishes and macro-invertebrate species that presently occupy the lowest tidal mangroves zones, and included 5 sampling stations distributed from the river mouth to about 15.3 km upstream at Devil's Elbow (see Figure 2). The assessment focused on the net positive/negative impact(s) on fish habitats, and on which fishes and macro-invertebrate species are likely to be affected by the habitat changes brought about by lowering the lowest tide level. To a large extent, the effects on local fishes and macro-invertebrates will depend on whether any changes occur to the exposed time experienced at the bed elevation corresponding to the lower (riverward) limit of mangroves, as this elevation is likely to be well exposed at low tide both during pre- and post-dredging conditions.

4.3 Approach to Impact Assessment

The assessment approach adopted in this technical study follows that used in the marine and estuarine ecology impact assessment for the EIS (Coffey Environments, 2012), i.e., it assesses the **sensitivity** of the environmental value being impacted in the existing environment along with the **magnitude** of such impact on those values. The interaction between sensitivity of an environmental value and magnitude of impact determines the **significance** of an impact, and is expressed in a matrix that takes into account factors such as geographical extent, duration and severity of impacts, and any formal status or sensitivity of each receptor.

The approach is based on information on the existing environment from the marine and estuarine ecology impact assessment for the EIS (Coffey Environments, 2012b), and the field surveys undertaken by CQU during 2010-2011 (Alquezar, 2011) and August 2012 (Wilson, 2012), as well as information available from pertinent literature and databases. The assessment focuses on the potential impacts and the significance of these impacts, if any, associated with the changes in project description not envisaged in the EIS, i.e., the potential impacts of the lowering of low tide levels on the ecology of the Calliope River.

The assessment of sensitivity of environmentally sensitive areas and species within the Port Curtis area is based on regulations by the *Environmental Protection Act 1994* (EP Act), the *EPBC Act 1999*, and the *Nature Conservation Act 1992*. The assessment of sensitivity of estuarine flora and fauna along Calliope River is based on information relevant to the conservation status of a species provided primarily from the *IUCN Red List of Threatened Species* (IUCN, 2012).This list provides categories of conservation status as outlined below.

Extinct. A taxon is Extinct when there is no reasonable doubt that the last individual has died.

Extinct in the Wild. A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.

Critically Endangered. A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered and it is therefore considered to be facing an extremely high risk of extinction in the wild.

Endangered. A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered and it is therefore considered to be facing a very high risk of extinction in the wild.

Vulnerable. A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable and it is therefore considered to be facing a high risk of extinction in the wild.

Near Threatened. A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Least Concern. A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Not Evaluated. A taxon is Not Evaluated when it is has not yet been evaluated against the criteria. This category includes a taxon for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.

If required, various engineering design measures are recommended to reduce as much as practicable the potential impacts of the lowering of low tide levels on the ecology of the Calliope River. However, if these are unavoidable, mitigation and management measures are proposed to reduce each impact. Furthermore, in the event that environmentally sensitive areas are severely impacted by the changes in the project description, and mitigation and management measures only provide a partial recovery, offset strategies are proposed to compensate for the loss. The assessment of significance for residual impacts is applied following the assignment of mitigation measures, assuming that all avoidance and mitigation measures are successful.

4.3.1 Identifying Impacts

The identification of impacts that may potentially occur from changes to the project description follows the same approach adopted in the marine and estuarine ecology impact assessment (Coffey Environments, 2011), and includes direct and indirect impacts. Cumulative impacts to the proposed works to the Calliope River have been addressed in the marine ecology (Port Curtis) technical study (Coffey Environments, 2012b).

Direct and Indirect Impacts

Direct impacts in the marine and/or estuarine environment include those that affect or disturb the environmental values directly, whereas indirect impacts are those that occur as a result of the project or activities related to the project. The removal of mangroves resulting in the loss of habitat once occupied by specific faunal communities is considered as a direct impact, whereas the increased turbidity in surrounding marine habitats from clearing or dredging works can be regarded as an indirect impact. Some direct impacts are positive, as in the case of creating new additional habitat for the colonisation of marine and/or estuarine fauna and flora. Indirect impacts, on the other hand, are harder to predict and they may not become instantly evident in the marine environment. Examples include localised, short to long-term changes to water quality and/or sedimentation, which may need modelling of dispersion and/or dilution processes for assessment.

For this technical study, direct and indirect impacts resulting from the changes in project description apply to mangroves to be cleared in the area proposed for the construction of the mainland launch site in the Calliope River; and changes to the river ecology as a result of changes in exposure of the river’s intertidal zone from dredging of the bar at entrance of the river. The area proposed for mangrove clearing is to be subsequently replaced by wharf and jetty infrastructure, whereas dredging proposed at the river entrance is aimed at deepening the channel to allow the large vessels to access launch site 1.

The worst case impacts to the estuarine ecology of the Calliope River were determined by comparing known habitat distributions over areas expected to be affected by direct and indirect disturbances from lowering the extreme tide levels following the dredging of the bar at the river mouth. The impacts were subsequently compared to those previously described in the marine and estuarine ecology impact assessment for the EIS (Coffey Environments, 2012).

Residual Impacts

Residual impacts are the potential impacts remaining after the application of mitigation measures and any design response. The extent to which potential impacts have been reduced is determined by undertaking an assessment of the significance of the residual impacts.

Sensitivity of an Environmental Value

The sensitivity of an environmental value, i.e., very low to very high, is based on nationally and internationally accepted conservation values, and is determined through desktop studies and field investigations that place the existing environment or baseline conditions of the environmental value into its holistic context (Table 1). If the environmental value has a conservation status under the IUCN, Commonwealth and/or state government, then it prevails over other recognised listings or importance, and it will determine its sensitivity. If there is no conservation status, then the listing or importance will determine its sensitivity. The sensitivity of an environmental value is fixed and cannot be changed.

Table 1 Sensitivity of the environmental value

Sensitivity	Definition
Very High	• An environmental value that is listed as 'critically endangered' under the IUCN and Commonwealth government or 'international' under state government. • An environmental value that has international listing or importance.
High	• An environmental value that is listed as 'endangered' under the IUCN, Commonwealth or state governments. • An environmental value that has national importance. • An environmental value of essential (local) commercial/recreational requirement or importance in maintaining ecological integrity (even if not otherwise listed).
Medium	• An environmental value that is listed as 'vulnerable' or 'rare' under the IUCN, Commonwealth or state governments. • An environmental value that has state importance. • An environmental value of common or frequent recreational/commercial importance locally.
Low	• An environmental value that is listed as 'near threatened' under the IUCN or 'conservation dependent' under the Commonwealth government or 'least concern' under the state government. • An environmental value that has regional importance. • An environmental value of occasional recreational/commercial importance locally.
Very Low	• An environmental value that is common and is not listed under the IUCN, Commonwealth or state governments. • An environmental value with local importance. • An environmental value of no reported recreational/ commercial importance locally.

Magnitude of Impact

The magnitude of an impact considers severity, geographical extent, duration or probability of an impact (Table 2). Selected criteria have been adopted from the Commonwealth government's '*Matters of National Environmental Significance, Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999*'(DEWHA, 2009) and the IUCN 'Red List Categories and Criteria' (IUCN, 2012).

Table 2 Magnitude of the impact

Magnitude	Definition
Very High	• Very large, widespread and severe impacts over large geographical areas, and which could be long lasting or irreversible. • Reduce the extent of an ecological community substantially (e.g., by 90%). • Destroy habitat necessary for an ecological community's survival. • Result in persistent and major adverse changes to an ecological community's life cycle, including breeding, feeding and migration.
High	• Regional impacts which may be long lasting. • Reduce the extent of an ecological community by ~50%. • Modify habitat necessary for an ecological community's survival. • Result in major adverse changes to an ecological community's life cycle, including breeding, feeding and migration.

Table 2 Magnitude of the impact (cont'd)

Magnitude	Definition
Medium	• Localised impacts which may be long lasting. • Reduce the extent of an ecological community by ~25%. • Fragment habitat necessary for an ecological community's survival. • Result in moderate adverse changes to an ecological community's life cycle, including breeding, feeding and migration.
Low	• Localised impacts which may be short lived. • Reduce the extent of an ecological community by <10%. • Disturb habitat necessary for an ecological community's survival. • Result in minor adverse changes to an ecological community's life cycle, including breeding, feeding and migration.
Very Low	• Impact undetectable or insignificant. • Extent and population of ecological community stable. • Habitat necessary for an ecological community's survival not expected to be impacted. • The life cycle of an ecological community, including breeding, feeding and migration not expected to be impacted.

4.3.2 Significance

The significance of an impact involves an assessment of the sensitivity of an environmental value against the magnitude of potential impacts on that value, and it can be scored between negligible and major (Table 3). An environmental value is described as "a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety" (EP Act, 1994 (Qld)). The significance of an environmental value is derived from its sensitivity, whether that is as a consequence of threatening processes or as a consequence of its conservation status or intrinsic value. The magnitude of impact on an environmental value, on the other hand, is an assessment of the geographical extent, duration, severity and likelihood of the impact on that environmental value. The sensitivity of an environmental value (see below) is generally fixed, although it can change over time with changes in project phases (Table 1); by contrast the magnitude of impact, i.e., very low, low, medium, high or very high (Table 2), can be influenced by engineering design or option selection or other management solutions.

The significance of an impact is assessed pre- and post- mitigation to determine the need for mitigation and how effective the proposed mitigation is in reducing the potential effects of the proposed development. The result of the post mitigation assessment of significance of the impact comprises the residual impact of the project.

Predicting significance of an impact is partly objective and partly subjective in that it relies on the professional judgement of specialists as well as scientific evidence. However, it is guided by criteria or definitions, and the environmental impact assessment sets out the basis of the judgements so that others can understand the rationale underpinning such assessment.

Assessment of Significance

The significance of an impact to an environmental value is determined by the sensitivity of the value itself and the magnitude of the expected change (Table 3).

Table 3 Matrix of significance of impact

		Sensitivity of Environmental Value				
		Very High	**High**	**Medium**	**Low**	**Very Low**
Magnitude of impact	**Very High**	Major	Major	Major	Moderate	Negligible
	High	Major	Moderate	Moderate	Minor	Negligible
	Medium	Moderate	Moderate	Minor	Minor	Negligible
	Low	Moderate	Minor	Minor	Minor	Negligible
	Very Low	Negligible	Negligible	Negligible	Negligible	Negligible

The level of significance of an impact determined using Table 3 is defined below:

Major Significance. Impact that is assessed as either high or very high, and which has the potential to cause irreversible or widespread harm to an environmental value that has been listed as vulnerable, endangered or critically endangered. The values are unique and, if lost, cannot be replaced or relocated. An impact that is likely to be a key factor in the decision-making process and raise considerable stakeholder concern.

Moderate Significance. An impact regarded has having the potential to cause environmental harm. Typically, such impacts are likely to be important at a regional or district scale, and require the application of specific environmental controls to be managed. This level of impact will influence decision-making, particularly when combined with other similar effects.

Minor Significance. An impact that is assessed as low, medium or high in magnitude, and which has the potential to cause temporary harm to an environmental value that has been listed as near threatened; or an impact assessed as medium or low and which has the potential to cause temporary harm to an environmental value listed as vulnerable; or an impact assessed as low and which has the potential to cause temporary harm to an environmental value listed as endangered. Typically, its effect would be important at a local scale and, when combined with other impacts, could have a more material effect. It is likely to have negligible influence on decision-making, but could raise awareness and concern about possible cumulative effects from a range of minor impacts.

Negligible Significance. An impact that will not result in any noticeable environmental change or effects, and which would not influence the decision-making process.

5. EXISTING ENVIRONMENT

This section describes the Calliope River in terms of physiography, main fringing habitats, flora and fauna, bathymetry and tidal characteristics.

5.1 Physiography

The Calliope River is located to the west of Gladstone in central Queensland, between latitudes 23° 49’ S and 23° 58’ S and longitudes 151° 13’ E and 151° 04’ E (see Figure 2). The river flows into the central section of Port Curtis, a semi-enclosed bay constrained offshore by Facing and Curtis Islands (Jones et al., 2005), following a 100 km long winding path that starts in the Calliope Range. The catchment area is approximately 2255 km^2 encompassing the central valley area of the Calliope Shire and the western part of the Gladstone city. The width of the Calliope River coastal floodplain is between 5 km and 16 km, with most of the terrain laying less than 50 m above sea level (Coffey Environments, 2012a). The natural landscape of the river has been modified, having approximately two-thirds of the basin’s native vegetation cleared as well as site levelling and removal of small hills west of the river (Department of Natural Resources and Water, 2007; Coffey Geotechnics, 2011).

Mean annual rainfall in the area varies between 800 mm to 1000 mm, and contributes to most of the discharge from the Calliope River into Port Curtis, estimated to be 153,000 Ml y^{-1} (Department of Natural Resources and Water, 2007). Bottom sediments of the Calliope River consist of mud overlying rock or sand (Seanger et al., 1980).

5.2 Environmental Values

The estuarine habitats of the Calliope River are dominated by mangroves and intertidal mudflats; the latter extending subtidally forming submerged mudbanks and tidal channels. By contrast, samphire/saltpan areas dominate the mid to extreme high tidal communities. The wetlands between Fishermans Landing Wharf and the Calliope River are relatively undisturbed and are composed of saltpan vegetation in the upper intertidal zone, followed by mangroves in the middle and seagrass beds in the lower intertidal region (Coffey Environments, 2011; Wilson, 2012). The highest density of mangroves is found at Wiggins Island, opposite to the Calliope River mouth. Small areas of mangroves and saltmarshes also occur at the proposed mainland launch site on the eastern side of the Calliope River mouth (Alquezar, 2011).

The most recent survey by CQU recorded adult trees of five mangrove species at sites along the Calliope River (Wilson, 2012). In decreasing order of abundance, these species comprised river mangrove (*Aegiceras corniculatum*; 67%), red mangrove (*Rhizophora stylosa*; 17%), grey mangrove (*Avicennia marina*; 10%), yellow mangrove (*Ceriops tagal*; 6%) and black mangrove (*Lumnitzera racemosa*; <1%). By contrast, the 2010 and 2011 surveys found that the dominant mangroves included species of *Rhizophora* sp., *Ceriops* sp. and *Avicennia* sp., with *Aegiceras corniculatum* making up<1% of the total survey (Alquezar, 2011). Such difference was attributed to the fact that the sites surveyed in 2010/2011 were located predominantly around the mouth of the river and within the Gladstone Harbour (e.g., Wiggins Island and Boatshed Point), whereas the 2012 survey concentrated at sites only along the river not previously surveyed (Wilson, 2012).

Cast and gill-net sampling conducted by CQU in August 2012 at 6 sites along the Calliope River reported a total of 13 fish species and two macro-crustaceans, banana prawns and mud crabs (Wilson, 2012). By contrast, cast net and gill-net sampling conducted during the 2010 and 2011 surveys captured over 30 species of fish and macro-crustaceans (Alquezar, 2011). No significant differences were found in the latter surveys in terms of total nekton abundance, diversity or species evenness among the mangrove-lined, shallow water estuarine sites along the Calliope River for both sampling events.

The mudflats along Calliope River, which were only sampled during the 2010 and 2011 surveys, provide habitat for a wide diversity of benthic organisms. A total of 124 species of benthic macro-invertebrates belonging to 7 phyla have been recorded in the area around the Calliope River and Port Curtis, with polychaetes, molluscs and crustaceans comprising the most common groups (Alquezar, 2011). Overall, the most common organisms recorded throughout sites included the bivalve *Mactra abbreviate* (7%), the bloodworm *Glycera* sp. (6%), the amphipod *Corophium cf. acutum* (5%), and the marine crabs *Cleistostoma mcneilli* (4%) and *Ilyoplax strigicarpus* (4%). The most common taxa included polychaetes (38%), molluscs (31%), and crustaceans (28%), with nermeteans and pycnogonids being the least common taxa (< 1%). There were no significant differences in total abundance of macro-invertebrates or species evenness among sites for the May 2010 sampling event.

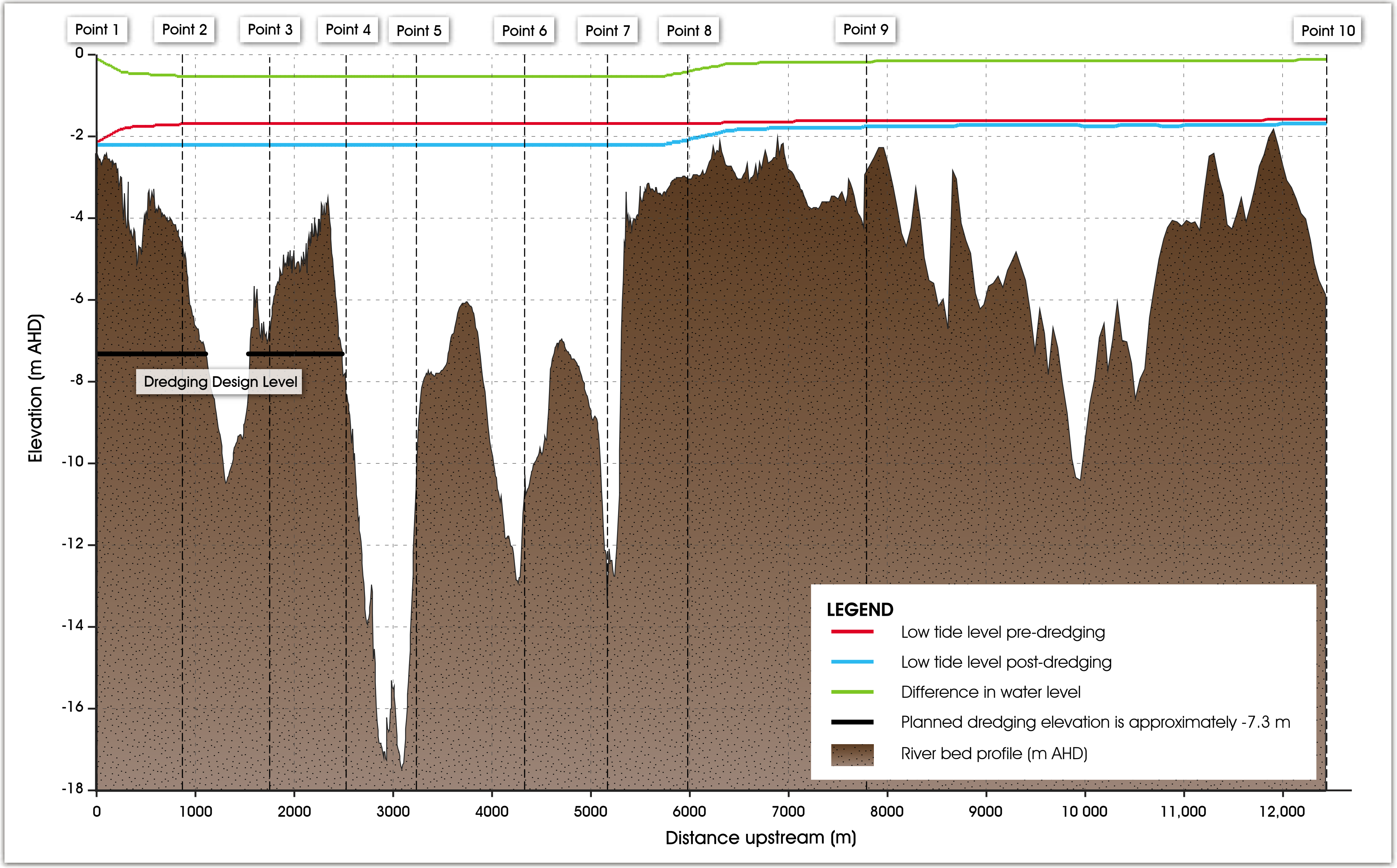
A total of 35 species of fish and nektonic macro-invertebrates have also been recorded in and around the Calliope River area. Of these, 53% are regarded as offshore spawners that use estuaries as nursery grounds during their juvenile stage, 31% correspond to offshore spawners that use estuaries throughout their entire life cycles, 13% to marine stragglers and 3% to either estuarine or freshwater spawners. In addition, megafauna observed in and around the Calliope River includes dugongs and cetaceans as well as marine turtles; of the latter, flatback turtles (*Natator depressus)* along with green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles are known to nest along Curtis Island (Limpus et al., 2006).

5.3 Bathymetry

Bathymetry varies markedly along the main channel of the Calliope River. Bed elevations range between -2.5 m AHD at the river entrance and -17.5 m AHD approximately 3.0 km upstream from the river mouth, corresponding to the deepest region of the main channel; another three deep holes between -10.5 m and -13.0 m AHD are located at 1.5, 4.3 and 5.2 km upstream (see Figure 2 and Figure 3). Besides the bar at the river mouth, two bars with an elevation of approximately -2 m AHD are present along the main channel at 6.3 km and 7.0 km from the river mouth; these become fully exposed during low tide periods (see Figure 3). Bed elevations after 7 km upstream gradually decrease from -2 m AHD to just over -10 m AHD some 10 km from the river mouth, before increasing to around -2 m AHD (BMT WBM, 2012).

5.4 Tidal Regime

The Calliope River is a tidally-dominated estuarine system with large semidiurnal tides that can extend up to 25 km upstream (BMT WBM, 2012). Mean tidal range during spring tidal conditions is approximately 3.3 m at the mouth, with tidal flow and occasional flood flows controlling the hydrodynamics of the main channel. The tidal prism in the river is significantly reduced by bars located some 2 m deep along the entrance of the river; these presently become exposed at low tides. Tidal velocities in the main channel range from 0.4 m s^{-1} (upstream) to 1.6 m s^{-1} (mouth) during spring ebb tides; and from 0.2 m s^{-1} (upstream) to 1.4 m s^{-1} (mouth) during spring flood tides. Flow exchange between the Calliope River and Port Curtis is limited, and tracer concentrations along the river may take more than 20 days to decrease by a factor of 1/e, i.e., an exponential decline where tracer concentration decreases approximately 37%. Temperature, pH and salinity are relatively homogenous vertically due to the strong tidal mixing which could affect as far as Devil's Elbow, approximately 15 km upstream (BMT WBM, 2012; Central Queensland University, 2012).



Source: BMT WBM	coffey environments	Date: 12.12.2012	Arrow Energy	arrow energy go further	Predicted lowest low tide levels (m AHD) in Calliope River under pre- and post-dredging conditions	Figure No: 3
		File Name: 7033CC_EE_F003_VS	Arrow LNG Plant			

6. VALIDATION AND ASSESSMENT OF IMPACTS AND RISKS

This section assesses the impacts on estuarine ecology of lowering the extreme low tide level as a result of dredging the bar at the mouth of the Calliope River. These impacts were not assessed in the marine and estuarine ecology impact assessment or the EIS. The impacts of changes to the layout of mainland launch site are also assessed.

6.1 Dredging the Bar at the Calliope River Entrance

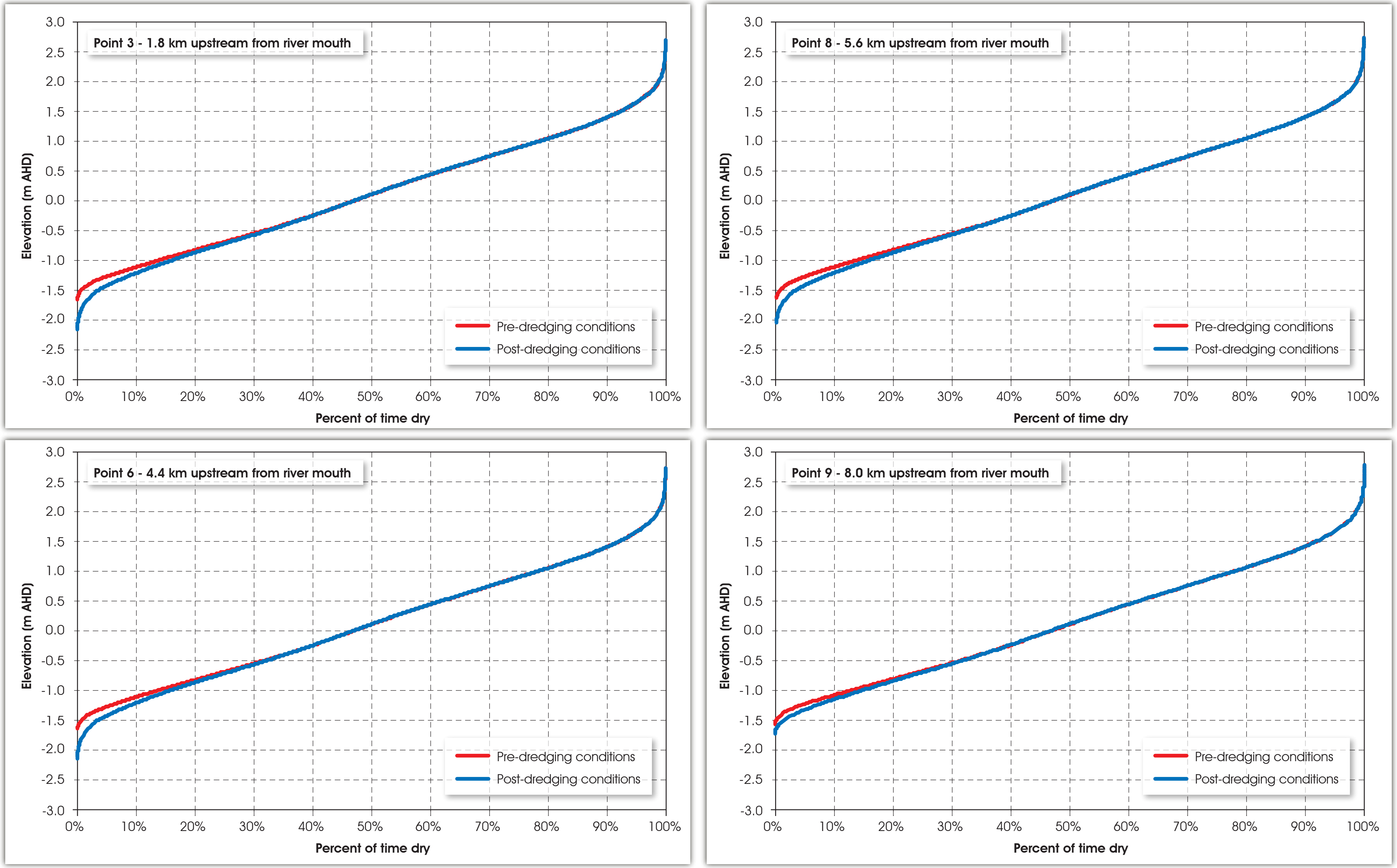
This section provides predicted lowest low tide levels during pre- and post- dredging conditions, including changes to extent of exposure (area) and time (% time) of exposure of increased intertidal area, along with potential impacts expected from changes in extreme low tide levels on mangrove habitats and dependent fauna (mainly fishes and macro-invertebrates). Predicted changes in tidal levels along the first 13.5 km of Calliope River are based on simulations run for the 12-month period between 1 July 2009 and 1 July 2010 (BMT WBM, 2012). These changes to the extreme low tides along the river are shown in Figure 3 for pre-dredging as well as post-dredging conditions; changes in percentage time exposed with bed elevations are shown in Figure 4 and Figure 5, while bathymetric cross-sections of the Calliope River at points 3, 6 and 9 are provided in Figure 6, Figure 7 and Figure 8, respectively.

The dredging of the bar at the entrance to the Calliope River will not affect high tide levels along river. Thus, highest tide levels predicted by BMT WBM remain at around 2.7 to 2.8 m for the 12-month simulation period at various points along the river. However, changes from proposed dredging works are predicted to affect the extreme low tides along the river and hence impact lower river elevations below 0 m (AHD); such change will also be reflected in an increase in the overall tidal amplitude following dredging.

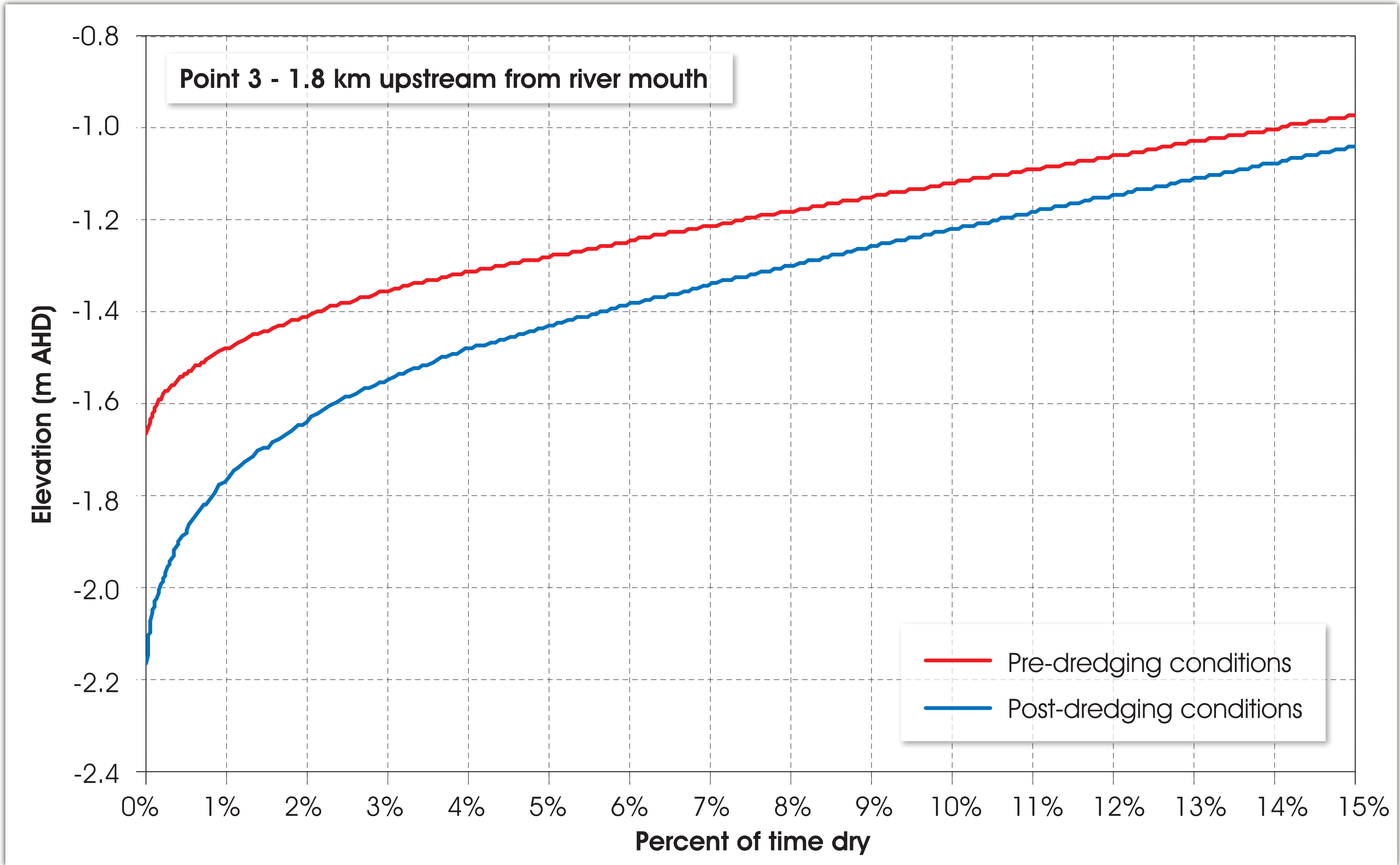
The broadscale nature of the impacts is shown in Figure 3, which combines bed elevations along the first 13.5 km of Calliope River and minimum water levels at the 10 points during pre- and post-dredging conditions. The difference in predicted extreme low tidal levels between both dredging conditions is around 0.50 m at point 3 upstream of the river mouth, and continues to be of similar magnitude as far as point 7, decreasing to 0.40 m at point 8 just before the Gladstone Power Station, about 5.6 km upstream from the river mouth (see Figure 2). Upstream of point 8, the magnitude of the drop in extreme tidal level is reduced further and drops to as little as 0.14 m at point 9, located nearly 8 km upstream from the mouth (see Figure 3).

This difference in lowest tidal levels up river reflects the retaining effect of shallow gravel bars above the power station (between points 7 and 8) and above point 9, which restrict the extent further upstream of the effect of dredging the bar at the mouth.

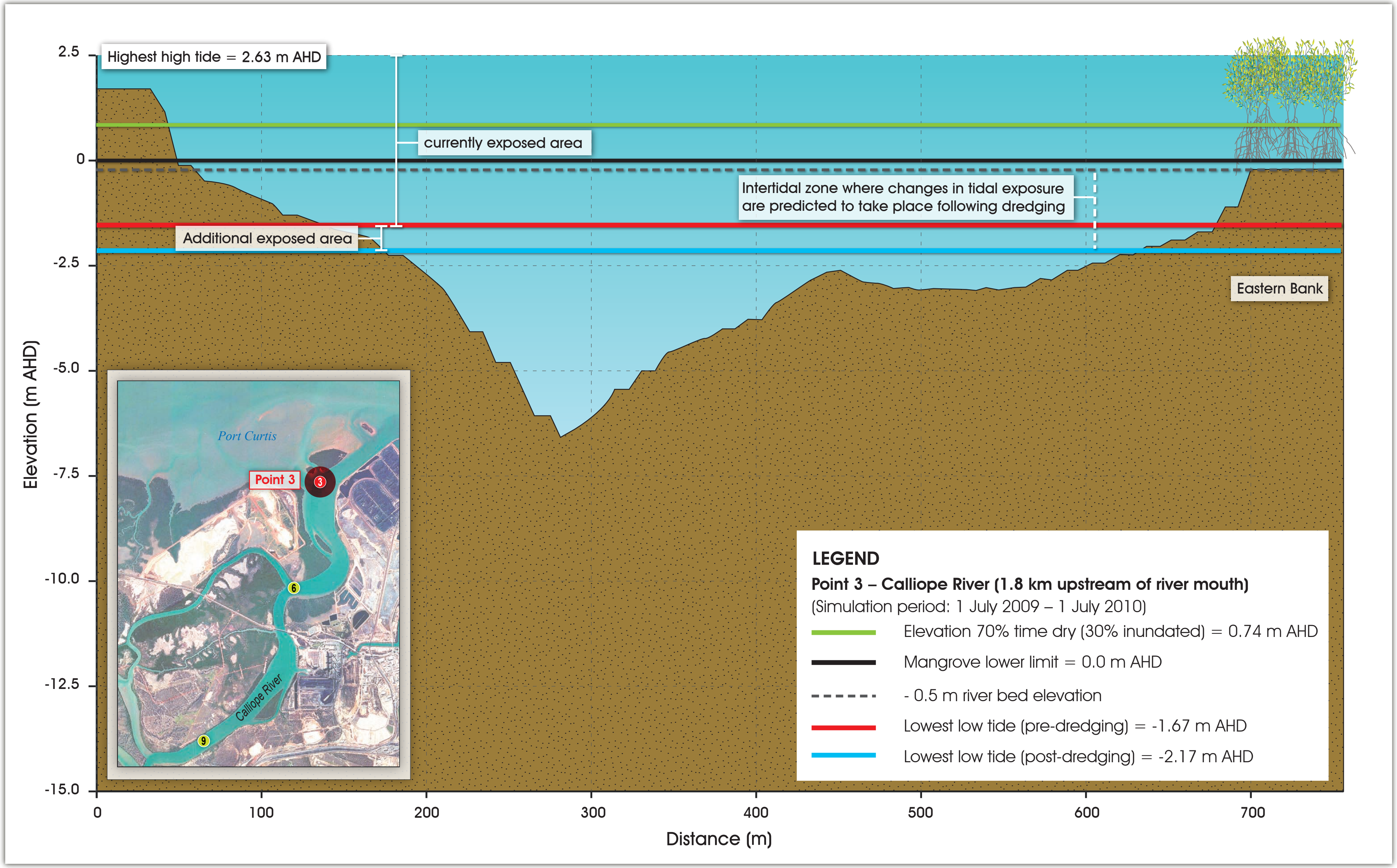
The predicted overall tidal amplitude increases following dredging but the difference between pre- and post-dredging conditions decreases with distance from the river mouth. Thus, the tidal amplitude at site 3 increases from 4.4 m to 4.8 m during post-dredging conditions, whereas at the upstream site 9 it only increases from 4.4 m to 4.5 m after dredging.



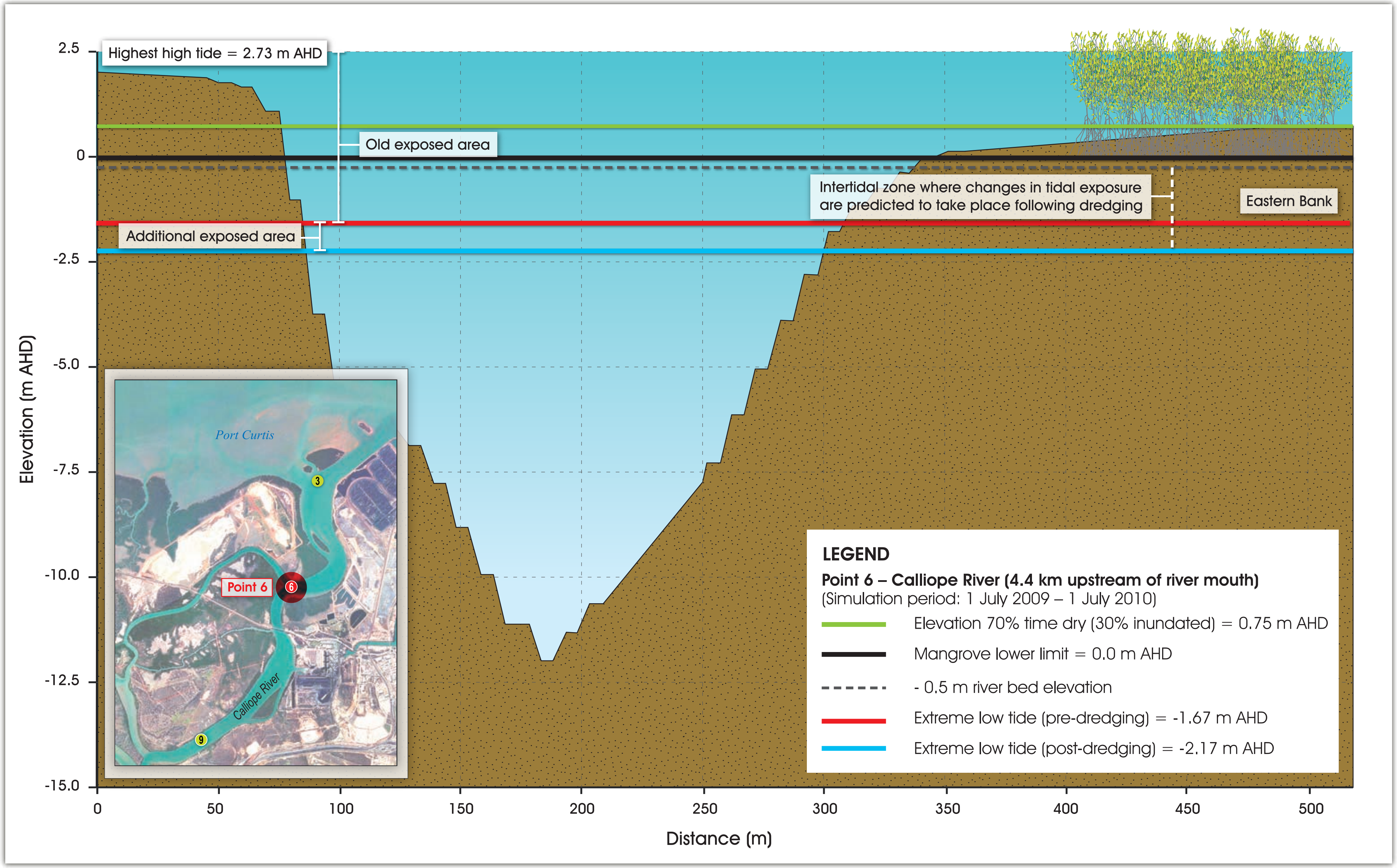
Source: BMT WBM	coffey environments	Date: 30.10.2012	Arrow Energy	arrow energy go further	Changes in percentage exposed time with bed elevations at four separate points along the Calliope River	Figure No: 4
		File Name: 7033_EE_F004_GL	Arrow LNG Plant			



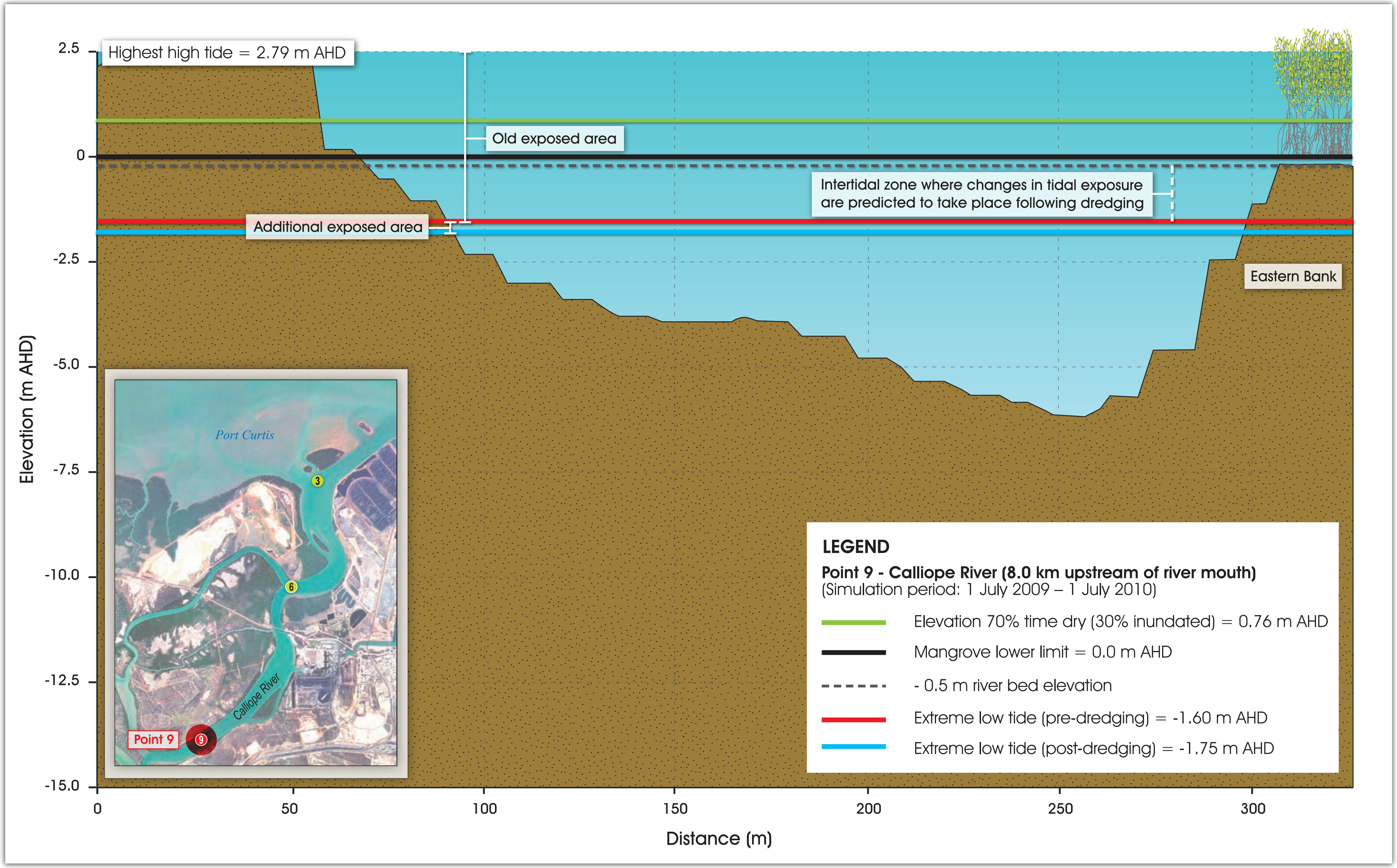
Source: Coffey	coffey environments	Date: 30.10.2012	Arrow Energy	arrow energy go further	Changes in percentage exposed time at lower bed elevations at point 3 in Calliope River	Figure No: 5
		File Name: 7033_EE_F005_GL	Arrow LNG Plant			



Source: Coffey	coffey environments	Date: 12.12.2012 File Name: 7033_EE_F006_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Cross-section at point 3 along the Calliope River showing the lowest low-tide levels and mangrove intertidal habitat riverward limits	Figure No: 6



Source: Coffey	coffey environments	Date: 13.11.2012	Arrow Energy	arrow energy go further	Cross-section at point 6 along the Calliope River	Figure No: 7
		File Name: 7033_EE_F007_VS	Arrow LNG Plant			



Source: Coffey

coffey environments

Date: 13.11.2012

File Name: 7033_EE_F008_VS

Arrow Energy

Arrow LNG Plant

arrow energy go further

Cross-section at point 9 along the Calliope River

Figure No: 8

Bed elevations currently not exposed to tidal influence, i.e., those elevations that are permanently inundated and hence below the extreme low tide, are located between -1.66 m AHD at point 3 and -1.60 m AHD at point 9. Following dredging, however, water levels at those bed elevations will drop further, and are predicted to reach -2.17 m AHD at points 3 and 6, -2.06 m AHD at point 8 and -1.75 m AHD at point 9 (see Figure 4). In the post-dredging conditions, the lower drop in water level during extreme low tide point 9 compared to those at points 3 and 6 reflects the effect of gravel bars above the power station near point 8 and upstream of point 9 (see Figure 2).

The outputs of the BMT WBM simulations indicate that the main changes resulting from dredging the bar across the Calliope River entrance are confined to the areas below -0.5 m AHD, with the strongest effects at elevations below -1.5 m AHD between the entrance and approximately 10 km upstream from the mouth. The effects include measurable changes in the exposure time of lower river bed elevations during low tide periods, as well as changes to the area of the intertidal zone exposed during those periods. These changes are described below.

6.1.1 Additional Exposure Time

The model simulations run predicted changes in percentage of time exposed at each of the 10 points between the Calliope River mouth and point 10, located 12.8 km upstream from the river mouth (BMT WBM, 2012).

At point 3, the intertidal bed elevation at which differences between pre- and post-dredging conditions start to become apparent lies at approximately -0.5 m AHD (see Figure 4). At that elevation, the river bed remains exposed for 32% of the simulation period during both pre- and post-dredging conditions. Below -0.5 m AHD, however, there is clear divergence in the pattern of change and equivalent exposure periods occur at progressively lower bed levels for the post-dredging conditions as the tide drops to lower levels, i.e., equal bed elevations will experience 2%-3% greater exposure (% time exposed) following dredging. For example, at point 3 the percentage of exposed time experienced at the -1.5 m AHD bed elevation would increase from 0.8% before dredging (i.e., existing conditions) to 3.7% after dredging, while the lowest bed elevation that is totally submerged and therefore not subjected to existing tidal exposure before dredging (-1.65 m AHD) is predicted to become exposed for just under 2.0% of the time following dredging (see Figure 5). Given the small increase in percentage exposure of lower river elevations following dredging of the river mouth, the significance of impact is assessed as **low**.

The change in percentage time exposed at point 3 follows a similar pattern to that predicted for bed elevations at points 6, 8 and 9, with equal elevations below -0.5 m expected to experience longer exposure periods during post- compared to pre-dredging conditions. This divergent pattern, however, ends at the point where bed elevations are predicted to be exposed for periods exceeding around 30% of the time (see Figure 4).

Exposure frequency of the low to extreme low intertidal bed elevations predicted for the 12-month period increases 12-fold during post-dredging conditions. Models run by BMT WBM (Technical Memorandum from BMT WBM, dated 1 August 2012) predict that water levels would fall below -1.5 m AHD for periods of 1.0-1.5 hours for up to 60 times, compared to less than 5 times during pre-dredging conditions. Furthermore, and regardless of distance from the river mouth, predicted water levels would never fall below -1.5 m AHD for periods longer than 1.5 hours during pre-dredging conditions; whereas levels would remain exposed for up to 2.5 hours below -1.5 m AHD during post-dredging conditions (refer to Figure 10 of BMT WBM Technical Memorandum). Nevertheless, these times represent increases in exposure time of no more than 4% of the time averaged over a year.

6.1.2 Additional Intertidal Area

The additional intertidal area to be gained as a result of dredging of the bar at the Calliope River mouth will be restricted to river bed elevations well below 0 m AHD (approximately MSL) (see Figure 6, Figure 7 and Figure 8). Within this zone, the actual gained area will depend on the gradient of the intertidal riverbed; thus, the shallower the gradient, the greater the area of intertidal mudflat exposed.

The additional intertidal exposed area between the river mouth (point 1) and 12.5 km upstream (point 10) from the mouth was estimated to be 30.0 ha. This estimate was based on the overall difference between the areas that are inundated at the predicted extreme low tides during pre- and post-dredging conditions (Figure 9).

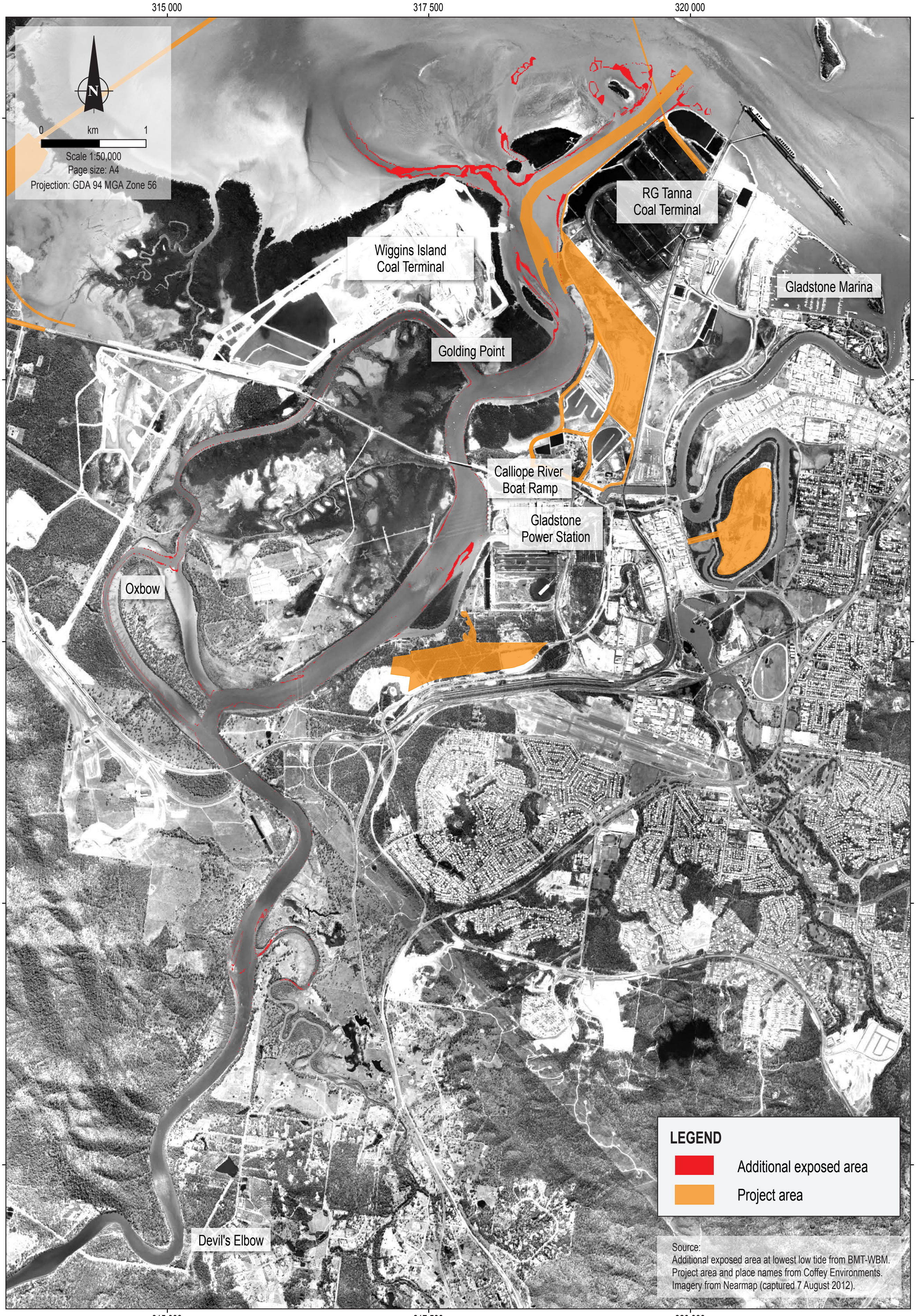
6.1.3 Potential Impacts on Mangroves and Associated Fauna

The zonation of mangrove species and boundaries of their distribution depend on many physical factors. Mangroves typically occur from the level reached by the highest astronomical tides to mean sea level, and generally do not survive inundation for more than 30% of the time (Hutchings and Saenger 1987; Mann, 2000). Hutchings and Saenger (1987) reported that the lower tidally-induced boundary conditions for mangroves in Port Curtis were defined by the point at which submergence exceeds 30% of the time. Comparing the 30% submergence criterion for mangrove distribution with the changed conditions along Calliope River, the bed elevation predicted to be submerged for 30% of the time, i.e., around 0.75 m AHD, is located well above the point at which dredging-related differences in intertidal exposure are predicted to occur (below -0.5 m AHD) (see Figure 4). Therefore, since the proposed dredging works will not affect high tide levels, no changes are expected to the period or frequency of tidal inundations of mangroves along the Calliope River during post-dredging conditions. This implies that the habitat for fish provided by mangrove roots will not be altered following dredging of the river mouth.

The typically extensive mudflats below the lower mangrove boundary are shown in Plate 1, Plate 2 and Plate 3. Since the bed elevation at the mangrove fringe will not experience any change in inundation pattern as a result of the dredging, no mangrove accretion or recession responses are likely. There is no evidence therefore to suggest that the changed duration of exposure and frequency of low tides per year will affect the mangroves in any way.

The increase in percentage of time exposed at the lower bed elevations will, to some extent, affect the benthic habitats, including fish habitats, at those locations. However, the soft muddy habitats in these areas are fully saturated and the relatively small (<4%) increase in exposure time is unlikely to cause any desiccation or significant habitat alteration. Benthic communities of the soft muddy substrates do not differ markedly between the intertidal and subtidal levels.

The studies conducted by CQU for the EIS (Alquezar, 2011) found significant differences in species richness and diversity between sites, with macro-invertebrate biodiversity being highest at The Narrows (see Figure 1) and significantly lower at the closest sampling site to the Calliope River mouth compared to all other sites along the river. Furthermore, site-specific differences in biodiversity between the intertidal and subtidal sites were only observed at the Calliope River mouth, where abundance and diversity were higher at intertidal sites, and at The Narrows, where numbers of organisms, species richness and diversity were significantly higher at subtidal sites (Alquezar, 2011).



coffey environments	Date: 11.12.2012 MXT: 7033CC_16_GIS097_v1_1 File Name: 7033_16_F009_GIS_GL	Arrow Energy Arrow LNG Plant	arrow energy go further	Additional exposed area at lowest low tide	Figure No: 9

Plate 1

Mangroves and exposed intertidal mudflats upstream of the Gladstone Power Station along Calliope River (eastern shore)

Plate 2

Mangroves and exposed intertidal mudflats further upstream from Gladstone Power Station along Calliope River (eastern shore)

Plate 3

Inundated mangroves upstream from bridge along Calliope River (western shore)

The increased area and duration of exposure of the lower tidal mudflats is likely to provide extended foraging opportunities for shorebirds such as waders, at the expense of some reduced foraging opportunities for local crustaceans and fishes. On the other hand, the slight reduction in foraging opportunities for fishes and crustaceans will be balanced by a slight increase in foraging opportunities for shorebirds. In either case, however, given the relatively slight increase in duration of exposure any impacts are most unlikely to be measurable.

6.2 Changes to Mainland Launch Site

Changes to the layout of mainland launch site in the Calliope River will incur direct impacts from the scheduled loss of mangrove habitat, and indirect impacts on adjacent estuarine habitats and associated fauna as a result of increased turbidity from dredging works. The extent of both impacts is discussed in the following sections.

6.2.1 Direct Impacts

The direct impact from the proposed changes to mangroves located in the area proposed for the construction of the mainland launch site in the Calliope River is addressed below. The impact assessment has been reviewed in light of the substantially reduced area of reef and rock substrate that will be lost.

Mangroves

The changes proposed for the mainland launch site in the Calliope River will require clearing an estimated 2.01 ha of mangroves to facilitate the construction of the infrastructure and haul road. Clearing of this area, located approximately 2.2 km upstream from the river mouth on the eastern shore (see Figure 1), was not specified in the EIS (Coffey Environments, 2012). Instead, the EIS specified that the total mangrove area to be cleared over the entire Arrow LNG Plant project area was 5.80 ha, and that most comprised direct loss due to the construction of the LNG plant and associated infrastructure in North China Bay. This area has been revised following the front-end engineering design and subsequent changes to the project description and is now estimated to be 5.46 ha.

The EIS classified mangroves as having a **medium** sensitivity in the Port Curtis area, based on the fact that the area to be disturbed is listed as a regional ecosystem of least concern within South Eastern Queensland Bioregion. Furthermore, the direct impact from the loss of 5.78 ha of mangroves through clearing was assessed as having a **low** magnitude and as being of **minor** significance. The **low** magnitude rating was based on the small area of impact in absolute and percentage terms (i.e., <1% of the total mangrove area estimated to be currently present in the Port Curtis region), and the consequent localised area of disturbance (Coffey Environments, 2011b). Consequently, the clearing of 2.01 ha of mangroves along the area planned for the construction of the mainland launch site in the Calliope River does not imply a change to the worst-case scenario from this change in project description, and therefore the magnitude and significance of impact from the loss of such area remain **low** and **minor**, respectively, as assessed in the EIS.

Reef Habitats

The original dredging footprint of the access channel to the mainland launch site in Calliope River required the direct loss of an estimated 0.14 ha of reef habitat outside the river entrance. The EIS classified reef habitats as having a **medium** sensitivity in the Port Curtis area on the basis of vulnerability of these systems to sedimentation, and their overall contribution to the community assemblage and species diversity of the Great Barrier Reef World Heritage Area. Furthermore, the magnitude of the impact of the direct loss of 0.14 ha of reef habitat was assessed as **low** because of the small area of impact in absolute and percentage terms, and the impact significance assessed as **minor**.

This reef area that will be impacted has been considerably reduced following changes in project description, and has been re-estimated to be <0.01 ha; however, the location has remained unchanged. Such a significant reduction in the impacted reef habitat area can be attributed to the narrowing of the footprint channel access area previously envisaged for dredging. Given the markedly reduced reef habitat area to be directly affected by dredging, the magnitude and significance of impact continues to be **low** and **minor**, respectively, as assessed in the EIS.

6.2.2 Indirect Impacts

Dredging volumes from the proposed access channel to the Calliope River have not changed from that specified in the EIS. The assessment of the magnitude of impact on nearby habitats from increased turbidity levels and sedimentation has been addressed separately in the marine ecology technical study (Coffey Environments, 2012), while the impacts on water quality are addressed in the marine water quality study (Central Queensland University, 2012).

7. MANAGEMENT MEASURES

The EIS project area included dredging a 3.02 km access channel between the mainland launch site in the Calliope River (dredge footprint for launch site 1) and the main shipping channel in Port Curtis to support the construction and operation of the LNG plant. The works include dredging a channel through an existing bar at the mouth of the river, with dredging planned to extend to a depth of approximately 5 m LAT. The combined potential impacts of the channel deepening on the extreme low tide levels in the river, including flow-on effects of the duration and extent of exposure of river banks on the intertidal zone ecology, were not addressed in the EIS (Coffey Environments, 2011a).

There are no practicable methods, nor is there a need to mitigate the changes in extreme low tide conditions that will result from dredging the bar at the Calliope River entrance. To some extent, the three natural bars upstream of the dredging grounds reduce the upstream effect of tidal changes along the river.

The area of mangroves to be directly removed during the construction of the mainland launch site is 2.01 ha, while the revised net loss of mangrove habitat for all project construction activities expected following changes from FEED is 4.78 ha. Proposed options for offsetting these losses are discussed in the marine ecology technical study (Coffey Environments, 2012b).

8. CONCLUSIONS

This technical study reviewed the extent of change in and frequency of extreme low tide levels in the Calliope River resulting from the dredging of the bar at the river mouth, and used the results to address the potential impacts of such changes in tidal height on the overall river ecology, particularly mangrove habitats and associated macro-invertebrate and fish faunas. The study also addressed the impact from the direct loss of 2.01 ha of mangroves at the site proposed for the mainland launch site; the magnitude of impact on nearby habitats from increased turbidity levels and sedimentation has been addressed separately in the marine ecology technical study (Coffey Environments, 2012).

Specifically, the study was undertaken to address the following objectives:

- Address key implications of the change in extreme low tide levels along the Calliope River following the dredging of the bar at the river mouth, particularly to the area and duration of exposure of the additional intertidal zone.
- Investigate potential impact(s) expected from changes in extreme low tide levels on mangroves and dependent species (mainly fishes and macro-invertebrates).
- Assess direct and indirect impacts of the loss of estuarine habitat and dredging works proposed for the construction of the mainland launch site in the Calliope River.

8.1 Implications of Changes in Extreme Low Tide Levels

Simulations run by BMT WBM covered a 12-month period which encompassed a wide range of tidal conditions, including several periods of large amplitude spring tides, and which corresponded to the representative period for which boundary conditions data were available. The model boundaries and year-long timespan was found to be appropriate to examine the extreme tidal changes to the Calliope River following the dredging of the river mouth.

The outputs of model simulations show that the predicted height difference in extreme tide levels between pre- and post-dredging conditions remains at around 0.50 m along the river zone located between 0.8 km and 5.5 km upstream of the river mouth, before decreasing to around 0.14 m at approximately 7.8 km upstream from the river mouth. Such predicted changes in tidal amplitude become only evident at intertidal bed elevations below -0.5 m AHD and are greatest at elevations subjected to extreme low tides, i.e., those below -1.0 m AHD.

Intertidal mudflats at -0.5 m AHD elevations are predicted to remain exposed for around 32% of the time during both pre- and post-dredging conditions. Following dredging of the river mouth bar, intertidal mudflats below -0.5 m AHD elevations will remain exposed for an increasingly longer period of time before becoming completely inundated.

The additional intertidal area gained as a result of the drop in extreme low tide levels varies with the slope of the river bed; thus, the shallower the gradient the greater the new exposed area. The overall additional area of intertidal zone gained as a result of the change in extreme low tides from pre- to post-dredging conditions was estimated to be 30.0 ha, and applies to the area from the river mouth to 12.5 km upstream from the mouth.

8.2 Impacts to Mangroves and Associated Fauna

Mangroves typically occur from the level reached by the highest astronomical tides to mean sea level, and do not survive inundation for more than 30% of the time. Model simulation outputs indicated that the predicted intertidal elevation that remains inundated for 30% of time, i.e., elevation that remains 70% of the time exposed, lies at around 0.75 m. Since the lowest limit of mangroves is located well above the river elevation at which dredging-related differences in intertidal exposure are predicted to occur, i.e., below -0.5 m AHD, no mangroves along the Calliope River are expected to be impacted by the predicted changes in tidal pattern either during the existing (pre-dredging) or new (post-dredging) conditions. Such conclusion implies that the habitat for fish provided by mangrove roots will not be altered from the pre-dredging condition.

The increase in percentage of time dry at the lower bed elevations may, to some extent, affect the benthic habitats, including fish habitats and associated fauna at those locations. However, the generally soft, fully saturated nature of these habitats, coupled with the relatively small (<4%) increase in exposure time, is unlikely to cause any desiccation or measurable change to fishes, macro-invertebrates or benthic communities.

The increased area of intertidal zone and duration of exposure of the lower tidal mudflats will provide extended foraging opportunities for shorebirds such as waders, at the expense of some reduced foraging opportunities for resident crustaceans and fishes. However, given the slight increase in duration of exposure, any impacts are most likely to be undetectable.

8.3 Impacts from Habitat Loss

The changes proposed for the mainland launch site in Calliope River require the removal of an estimated 2.01 ha of mangroves to facilitate the construction of the infrastructure. Based on the small area of impact in absolute and percentage terms compared to the total mangrove area estimated for the Port Curtis region, the clearing of such small area due to changes in the project description does not imply a change to the worst-case scenario from the EIS. Therefore, the significance of impact from the direct removal of this mangrove area continues to be **minor**, as assessed in the EIS.

The dredging of the access channel to the mainland launch site in Calliope River requires the direct removal of an estimated 0.14 ha of reef habitat outside the river entrance. As the removal of this habitat has been reduced to less than 0.01 ha following changes in project description, the magnitude of direct impact from removal continues to be **minor**, as assessed in the EIS.

9. REFERENCES

Alquezar, R. 2011. Arrow LNG Plant Estuarine and Marine Ecology Field Investigations 2010-2011 (Phase I & II). Report prepared for Arrow CSG (Australia) Pty Ltd and Coffey Environments Pty Ltd. Central for Environmental Management – Central Queensland University, Gladstone. 85 p.

Arrow Energy, 2012. Draft Environmental Offset Strategy 2012-2015. Arrow Energy. Brisbane, Queensland.

BMT WBM. 2011. Coastal processes, marine water quality, hydrodynamics and legislation assessment. October. Report prepared for Arrow CSG (Australia) Pty Ltd and Coffey Environments Australia Pty Ltd, Brisbane, Queensland.

BMT WBM, 2012. Arrow LNG Plant EIS Supplementary Report – Coastal processes and marine water quality technical study. November. Report prepared for Coffey Environments.

Central Queensland University. 2012. Arrow LNG Plant Supplementary Report to the EIS. Report prepared by Central Queensland University, Gladstone, Queensland.

Marine Water Quality Report. October. Report prepared for Coffey Environments.

Coffey Environments. 2011a. Arrow LNG Plant Environmental Impact Statement. Report prepared by Coffey Environments for Arrow CSG (Australia) Pty Ltd, Brisbane, Queensland.

Coffey Environments. 2011b. Marine and estuarine ecology impact assessment. Arrow LNG Plant. October. Report prepared by Coffey Environments for Arrow CSG (Australia) Pty Ltd, Brisbane, Queensland.

Coffey Environments. 2012a. Arrow LNG Plant Environmental Impact Statement: Surface water hydrology and water quality. March. Report prepared by Coffey Environments for Arrow CSG (Australia) Pty Ltd, Brisbane, Queensland.

Coffey Environments. 2012b. Technical study of Port Curtis marine ecology for the supplementary report to the Arrow LNG Plant environmental impact assessment. Report prepared by Coffey Environments for Arrow CSG (Australia) Pty Ltd, Brisbane, Queensland.

Coffey Geotechnics. 2012. Geology, landform and soils impact assessment Arrow LNG Plant. October. Report prepared for Arrow CSG (Australia) Pty Ltd and Coffey Environments Australia Pty Ltd. Cove West, NSW.

Department of Natural Resources and Water. 2007. Calliope River Basin water resource plan consultation report. Queensland.

DERM, 2011. Ecological Equivalence Methodology Guideline Policy for Vegetation Management Offsets Queensland Biodiversity Offset Policy Version 1. Department of Environment and Resource Management. Brisbane, Queensland.

DEWHA. 2009. Matters of national environmental significance. Significant impact guidelines 1.1. Environment Protection and Biodiversity Conservation Act 1999. Department of the Environment, Water, Heritage and the Arts. Australian Capital Territory.

DEWR. 2007. Draft policy statement. Use of environmental offsets under the Environmental Protection and Biodiversity Conservation Act 1999. Department of Environment and Water Resources. Canberra, Australian Capital Territory.

EPA. 2008. Queensland government environmental offsets policy. Environmental Protection Agency, Queensland Government. Brisbane, Queensland.

Hutchings, P. and Saenger, P. 1987. Ecology of Mangroves. University of Queensland Press, Box 47, St Lucia, Queensland Australia. ISBN 0 7022 2015 9.

IUCN, 2012. The IUCN Red List of Threatened Species. A WWW publication accessed on 19 October 2012 at http://www.iucnredlist.org. IUCN Global Species Programme Red List Unit. Cambridge, United Kingdom.

Jones, M., Stauber, J., Apte, S., Simpson, S., Vicente-Beckett, V., Johnson, R. and Duivenvoorden, L. 2005. A risk assessment approach to contaminants in Port Curtis, Queensland, Australia. Marine Pollution Bulletin 51:448-458.

Limpus, C. J., McLaren, M., McLaren, G., Knuckey, B. 2006. Queensland Turtle conservation project: Curtis Island and Woongarra Coast Flatback Turtle studies, 2005-2006. In: Jones, M. (Ed.), Conservation Technical and Data Report. ISSN: 1449-194X, vol. 2006 Number 4.

Mann, K. H. 2000. Ecology of Coastal Waters, with Implications for Management. Blackwell Science Inc., 2nd Ed. ISBN 0 86542 550 7.

Saenger, P., Stephenson, W., Moverley, J. H. 1980. The estuarine macrobenthos of the Calliope River and Auckland Creek, Queensland. Memoirs of the Queensland Museum 20:143-161.

Wilson, S. 2012. Arrow LNG Plant Supplementary Report to the EIS Ecological Health Report. Report prepared by CQ University, Gladstone, Australia.

Wood, O. 2012. Arrow LNG Plant Project Logistics Execution Study. Arrow Energy, Brisbane, Queensland.

10. ACRONYMNS AND GLOSSARY

10.1 Acronyms

AHD	Australian Height Datum.
CUQ	Central University of Queensland (Gladstone).
DERM	Department of Environment and Resource Management.
DEWHA	Department of Environment, Water, Heritage and the Arts.
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities.
EIS	Environmental Impact Statement.
EPA	Environmental Protection Agency (Queensland) – see DERM.
HAT	Highest Astronomical Tide.
LAT	Lowest Astronomical Tide.
LNG	Liquefied Natural Gas.
MSL	Mean Sea Level.
Ml y^{-1}	Megalitres per year.
m AHD	Elevation relative to Australian Height Datum in metres.
mg/L	milligrams per litre.
m s^{-1}	metres per second.
MOF	Materials Offloading Facility.
TSS	Total Suspended Solids.

10.2 Glossary

Abundance. Total number of organisms.

Accretion. Deposition of material (e.g., sand, sediments) as a result of coastal or fluvial processes

Benthic. Pertaining to the seabed or river bed.

Benthic community. Living organism (aquatic flora and fauna) attached to, living on, in or near the seabed or river bed; bottom-associated.

Benthic habitat. The seabed or river bed zone inhabited by aquatic flora and fauna.

Ebb tide. Outgoing or receding tide.

Flood tide. Incoming tide.

Intertidal zone. The shore zone between the highest and lowest tides; also referred to as the littoral zone; the alternately submerged/exposed zone below the mean higher high water mark

Neap tide. Tide of minimum amplitude occurring at the time of first and last quarter of the moon, when the difference between high and low water is less than at any other part of the month.

Samphire. Common name for a group of succulent sub-shrubs, shrubs and annuals commonly associated with saline environments of some kind.

Semidiurnal tide. Tide having a two high and two low waters each lunar day.

Spring tide. Tide of maximum amplitude occurring at the time of full and new moon.

Subtidal zone. The zone extending from the lower margin of the intertidal zone to the outer edge of the continental shelf at a depth of 200 m; also referred to as the sublittoral zone; the entirely submerged zone deeper than the mean lower low water mark.

Turbidity. Degree of opaqueness of water column due to suspended matter.