

MEMO REPORT

To	Vanessa Robinson (EPA)	CC	Michael Klvac
From	Neil Dixon	Date	21/01/2021
Subject	Further information on impacts of Mardie Proposal on BCH under additional climate change tide levels	Pages	17 (incl. this page)

1 INTRODUCTION

Further information has been requested as part of the project's current environmental impact assessment on the impacts of the proposed Mardie Project on intertidal benthic communities and habitats (IBCH) under climate change, supported by additional inundation modelling of the project area. While this aspect of the project was described in the Environmental Review Document (ERD, Preston Consulting, 2020), the request for further information specifically related to the assessment of sea level rise using mean sea level (MSL) and the average high tide level over the period of a year (taken to be the average of the Mean High Water Neap (MHWN) and Mean High Water Spring (MHWS) tide levels, which is currently 1.15 mAHD at Mardie, and 2.05 mAHD under climate change) to represent the effects under more normal conditions than the tidal inundation level of 2.2/3.1 mAHD discussed in the ERD.

1.1 ERD BASELINE ASSESSMENT

The ERD included the following assessment regarding the impacts of the proposal on the area's IBCH under climate change:

- a 0.9 m relative sea level rise is expected to alter the distribution of IBCH across the project area as a result of changing hydrodynamic and salinity regimes;
- distribution changes were believed to be a general landward shift, as the coastline presumably intruded further into the intertidal area;
- any landward migration is ultimately limited by an abrupt rise at the high-water shoreline located at the transition between the uplands (terrestrial) and lower-lying intertidal flats; and
- construction of ponds will further restrict landward migration, potentially expediting the gradual loss of IBCH values in the region that would be expected to result from sea level rise.

Using modelling results provided by RPS (2019) for a 'King tide' scenario, the ERD estimated that the pond walls would bring forward the effects of sea level rise by approximately 20 years.

1.2 APPROACH

In preparing this response to the request for further information and additional modelling, the following approaches and actions have been taken:

- liaison with RPS to obtain outputs of their inundation model corresponding to the MSL and annual average high tide scenarios specified in the request;
- revisit the ERD and supporting studies to prepare a summary of factors affecting the distribution of IBCH within the intertidal areas at Mardie and how those factors would be influenced by sea level rise;

- seek to subjectively predict the distribution of IBCH at Mardie in 100 years based on average conditions, and identify key assumptions and sensitivities inherent in the prediction;
- use the above to describe and assess the impacts of the proposed ponds on the future distribution of IBCH.

Discussions with RPS indicated that additional modelling was not required in order to provide the necessary model outputs, as the model included the entire tidal regime for the periods modelled. Consequently, additional figures were provided showing inundation at (2121) MSL and average high tide conditions for baseline and pond scenarios as well as figures showing the difference between the two scenarios.

2 BACKGROUND

It is understood that the distribution of IBCH is likely to be controlled by a range of factors, the primary factors are salinity and inundation, both of which are inter-related and also themselves strongly influenced by distance from the coast and tidal creeks, and ground elevation (topography). The following background information is provided to ensure a consistent understanding of the scale and role of these and other factors in the Mardie environment.

2.1 TOPOGRAPHY AND VEGETATION

The topographical profile of the Mardie landscape from coastline to shoreline (high water mark) follows the general trend of:

- the marine shoreline generally consists of sandy beaches and dunes (up to 6 mAHD) or mangrove communities on silty terraces and elevated embankments (from 0 to 1.5 mAHD);
- on the landward side of the sandy foredunes, the profile drops down to 1.5 – 2.0 mAHD, forming a wide (approx. 3 km) and periodically inundated basin of sandy silts, before rising quickly to the terrestrial shoreline at about 3.5 to 4.0 mAHD;
- on the landward side of the coastal mangroves, the profile tends to rise gradually to between 1.75 and 2.0 mAHD, where coastal samphire communities dominate, but which is interspersed with incised tidal creeks (mangroves) and scoured drainage fans (bare);
- between the elevated coastal platform supporting mangroves and samphire, and the terrestrial shoreline located 1 to 5 km to the east, the land profile drops to 1.5 mAHD and which coincides with the typical bank-heights of the numerous tidal creeks;
- depending on distance from the coast and local changes in ground level, these lower lying areas support algal mats or represent barren saltflats and claypans, with sporadic grass-covered small islands rising to 4 mAHD.

The reasons for the elevated coastal platform underlying the mangroves and coastal samphire communities, and its status over the longer term has not been studied; however, the ability of mangroves to trap and accumulate sediment, particularly in tide-dominated coastal and estuarine environments, is well documented, including in response to sea level rise (e.g. Spalding M, McIvor A, Tonneijck FH, Tol S and van Eijk P, 2014; Chaudhuri, Chaudhuri & Gosh, 2019).

2.2 MARDIE TIDES AND SEA-LEVEL RISE

The Mardie project location experiences a semi-diurnal tide (two highs and two lows a day) and the tidal planes have been defined by the National Tide Centre (NTC) based on field measurements from the offshore ADCP location (Baird, 2020). The Mardi Gauge (MardiLAT18) datum definition completed by the NTC shows that the offset between Lowest Astronomical Tide (LAT) and Mean Sea Level (MSL) is 2.75 m and the total

tidal range is 5.185 m with tidal planes shown in Table 1. The mean tide range is 3.6 m in springs and 1m in neaps. Figure 1 shows the submergence curve for Mardie, that is, the proportion of time the sea level (tidal influences only) is at or above a specific relative level.

To accommodate a 0.9 m increase in sea level over the next century owing to climate change, the change can be added directly to the current tidal planes and submergence curve, as has been done in Table 1 and Figure 1, respectively. Tidal range is not predicted to change; however storm surges are expected to be greater due to an increase in the severity of extreme weather events (Hadwen, 2012).

Table 1: Mardie Tidal Planes (location 21.03572 S, 115.92766 E, National Tide Centre)

TIDAL PLANE	2018 (mAHD)	2018 + 90cm
Highest Astronomical Tide (HAT)	2.44	3.34
Mean High Water Springs (MHWS)	1.81	2.71
Mean High Water Neaps (MHWN)	0.48	1.38
Mean Sea Level (MSL)	0.00	0.9
Mean Low Water Neaps (MLWN)	-0.48	0.42
Mean Low Water Springs (MLWS)	-1.81	-0.91
Indian Spring Low Water (ISLW)	-2.22	-1.32
Lowest Astronomical Tide (LAT)	-2.75	-1.85

The submergence curves in Figure 1 can be used to estimate the increase in the frequency of inundation due to sea level rise for any location of known elevation. For example, a location at the same elevation as the current MHWS (i.e. 1.8 mAHD) is currently submerged approximately 2.5% of the time due to tidal movement, which will increase to more more than 20% of the time under a 0.9 m seal level rise scenario. Further predictions based on the submergence curves shown in Figure 1 are discussed in the following sections.

2.3 GENERAL IMPACT OF PROPOSED PONDS ON (CURRENT DAY) TIDAL INUNDATION

RPS (2020) has modelled the effects of the proposed pond walls on the tidal inundation regimes of the intertidal areas at Mardie, which is reported extensively in the Environmental Review Document (Preston, 2020). In summary, the work by RPS found that:

- in the northern and southern ends of the project, where the pond walls are closest to the ocean and tidal creeks, tide levels above 1.2 mAHD (submergence < 11%) are required before the walls become partially inundated;
- in the central sections, where the walls are considerable distance from the ocean and creeks, tide levels above 1.8 mAHD (submergence < 2.5%) are required before the walls become partially inundated;
- when inundated, the walls prevent the landward progress of the tidal waters, which instead bank up against the walls, resulting in short-lived (15 – 30 minutes) increases in water depth (10 – 20 cm), mostly in the northern and southern sections of the project;
- due to the reduced catchment area, the discharge of tidal waters back to the ocean was observed to occur over a shorter timespan.

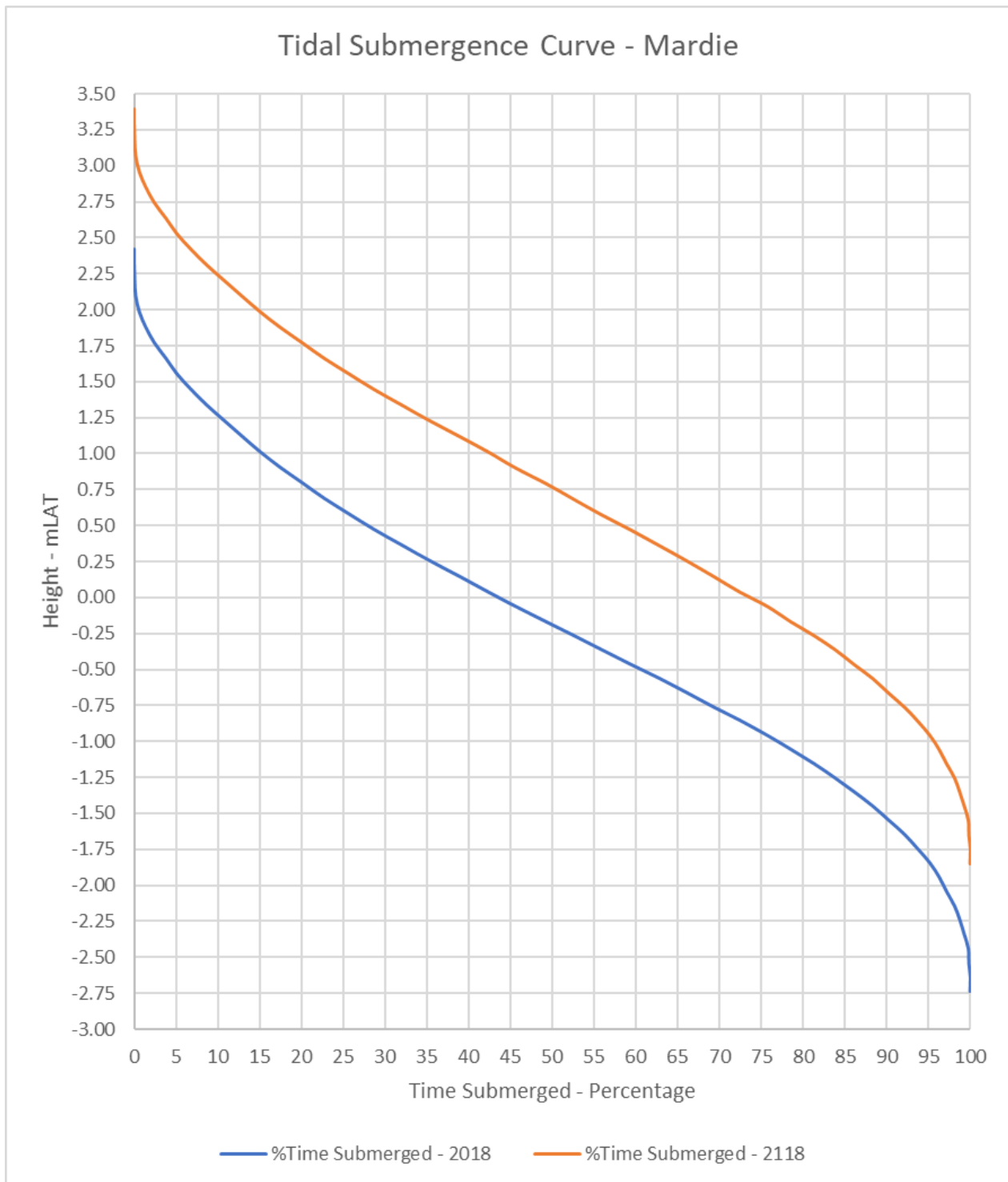


Figure 1: Tidal submergence curves for Mardie, using Mardie2018 datum

The modelling shows that areas of algal mat and mangroves would not experience a discernible change in the frequency of tidal inundation (i.e. submergence), but some areas of coastal mat in the northern and southern sections would experience a small increase in the depth of submergence. In its assessment of the modelling results, O2 Marine (2020), considered that the changes to inundation were highly unlikely to result in adverse outcomes for the algal mat and mangrove communities of the intertidal area.

2.4 DISTRIBUTION OF INTERTIDAL BENTHIC COMMUNITIES AT MARDIE

2.4.1 Mangrove distribution

As reported by O2 (2020), salinity gradients are the major contributing factor for Mangrove distribution. In the intertidal environment, salinity gradients are established through the regularity of tidal inundation of seawater which alters depending upon tidal elevation of the land, typically resulting in lower soil and groundwater salinities at the lower tidal elevations due to increased levels of inundation. In the higher tidal elevation areas, (i.e. tidal flats and upper reaches of tidal systems) reduced tidal regulation occurs resulting in greatly increased soil salinity levels.

At Mardie, the mangrove communities were mapped along the boundaries of the coastline and creeks, from sea level (0 mAHD) to a fairly consistent upper limit of 1.5 mAHD. In terms of submergence (section 2.2), these communities require tidal inundation for more than 7% of the time, and appear capable of withstanding periods of complete submersion (Figure 2).

RPS (2019) notes in its review of historical images (to 2004) conducted to calibrate the tidal inundation model, that the creeks at Mardie have become increasingly colonised by mangroves and that the creeks themselves have become more developed, with increased branching of their upper reaches. The cause for the increase was not investigated, but may be in response to increased inundation.

2.4.2 Algal mat distribution

Stantec (2018) identified that algal mats were typically located between samphire communities on the coastal side and mudflat/saltflats on the landward side, in the elevation range of 1.1 to 1.3 mAHD. Note that since the Stantec surveys in 2018, Mardie Minerals has undertaken numerous high-accuracy land and topographical surveys of the project area, and the areas mapped as algal mat by Stantec are now classed as being within the 1.50 to 1.75 mAHD range.

O2 (2020) discusses at depth the factors affecting the distribution of algal mats at Mardie, and how their presence/ absence across the project site and also to the north and south is not consistent with studies elsewhere by other authors, but that the algal mats, being largely found in basins that experience extended alternating periods of inundation and drying, as well as very high salinities, may be the only benthic community to survive under such conditions.

This different understanding could be used to explain the almost total absence of algal mat in the southern end of the project and also with the remainder of the Robe River Mangrove Management Area (Figure 3). In this area, mangrove communities are very widespread and dense, while coastal samphire communities are less so than in the northern areas. Site contours show that the elevated coastal platforms are also absent and that areas in the 1.5 – 1.75 mAHD elevation range are small and intersected by creeks, with the improved drainage minimising the opportunity for the formation of the saline ponds that support algal mats. Modelling by RPS (2019) shows that the southern areas experience a significantly more ‘intrusive’ rising tide, and that the falling tide does not leave behind any pools (c.f. figures 3.1 and 3.2 of that report).

2.4.3 Samphire distribution

At Mardie, coastal samphire communities occupied the intertidal areas with elevation ranging of 1.75 to 2.0 mAHD. Areas closest to the mangroves and also to 1.75 mAHD had the highest proportion of cover, with higher areas continuously showing poor cover. At these elevations, only very high tides result in habitat being inundated.

Landward samphire communities, which are associated with the terrestrial shoreline, are less diverse and dense, occupied the 2.5 to 3.25 mAHD elevation range, where they would receive little to no tidal influences, but would still experience the effects of storm surges and the associated extreme inundations.

Table 2: Summary of habitat characteristics of mangroves and algal mat at Mardie

Community	Topographic Range	Range of Median Depths (MSL & 1.15 mAHd)	Inundation Frequency (approx.)
Mangroves	0.00 – 1.50 mAHd	2 – 115 cm	10% to 50%
Coastal Samphire	1.75 – 2.0 mAHd	Dry	15% to 20%
Algal Mat	1.50 – 1.75 mAHd	0 – 8 cm, but from previous higher tides	Min 4%, but reliant on ponding in the landscape

3 EFFECTS OF SEA-LEVEL RISE

3.1 MODELLING RESULTS

At the request of Mardie Minerals, RPS has made additional outputs available from its inundation model (2019). The associated figures are provided in section 5, at the end of this document. Figure 4 and Figure 5 (inundation at MSL and 1.15 m tide, respectively) show that the effects of sea level rise vary along the length of the project and are most notable in the middle of the project where the intertidal area is over 10 km wide. There is little change in the southern areas that already experience a greater level of inundation.

3.2 HABITAT SHIFT

In the first instance, a 90 cm increase in (tidal) sea levels over the next 100 years would be expected to increase the frequency and depth of inundation/submergence for all points currently below the forecast Highest Astronomical Tide (HAT) level of 3.34 mAHd (refer to Table 1). As a result, there would be large shifts in the hydrological and salinity regimes of the intertidal landscape; the immediate effects of which would be an increase in the frequency and depth of tidal inundation, reduced scope for ponding of seawater, and a less saline habitat, overall.

Such a shift would be expected to significantly favour mangroves, particularly if they are able to accumulate coastal sediments in their root zones at a sufficient rate¹. However, it is highly likely that algal mats would be largely displaced from the region between Mardie Creek to the north and Robe River to the south.

Along the central and northern sections of the Mardie Project where algal mat is present, one of the key defining parameters is the degree of connectivity of the low-lying basin with regular tidal inputs. As discussed in section 2.4.2, the relative isolation of the basin regularly results in hypersaline conditions, as well as extended dry periods, that are mostly suitable to algal mats. This isolation is enforced by a topographic sill of approximately 1.5 mAHd – once tide levels fall below this sill, seawater becomes trapped in the basin, where, through evaporation and seepage, it becomes hypersaline before disappearing altogether.

Currently, the basin would receive tidal inflows and also be able to discharge through overtopping on the receding tide approximately 6% of the time, equivalent to 25 days per year. The influence of a 90 cm rise in sea level would be to increase that connectivity to around 22%, or approximately 100 days per year. In addition to increasing physical connectivity with the ocean, this change would see the basin decrease in salinity and aridity, possibly to the extent of being inundated for most if not all of the time.

It may be intuitive to expect algal mat cover to migrate eastwards towards the terrestrial shoreline in response to the rising sea level; however, because the algal mat is associated with a catenary depression or basin located between the coastline and shoreline, any migration of the algal mat would first require this physical landscape feature to migrate as well. This may eventuate if mangrove sediment accumulation, both

¹ Woodroffe, Rogers & McKee, et al (2016) indicate that this may be possible, but that there is insufficient understanding of nonlinear feedbacks to realistically forecast or model the future behavior of most mangrove shorelines.

vertically and horizontally, can keep pace with sea level rise; however researchers indicate this outcome cannot yet be predicted (Woodroffe, Rogers & McKee, et al (2016)).

3.3 EFFECTS OF PROPOSAL UNDER FUTURE SEAL-LEVEL RISE SCENARIO

The additional outputs from RPS (section 5) show that, in addition to the physical impact on the landscape, the ponds will influence the tidal inundation patterns under a climate change scenario in much the same way as in the modelled current scenarios, that is, the intertidal area will fill faster and therefore tide levels will be slightly earlier and higher (Figure 6 and Figure 7), while on a receding tide, inundation levels will drop faster (Figure 8 and Figure 9).

The areas of algal mat at Mardie appear strongly to be associated with wide, flat landscape depressions that occupy the 1.5 – 1.75 mAHD elevation range and receive episodic inflows of seawater during sufficiently high tides, some of which becomes trapped in the depressions as the tide falls. While even higher tides would result in a degree of flushing of these features, the trapped seawater is left to evaporate in the arid conditions. Movement of trapped seawater downward as seepage is likely to be minimal, given the very low hydraulic transmissivity of the underlying sediments and algal mats.

It is postulated that increased flushing of these habitats by seawater as a result of sea-level rise would be likely to reduce soil salinities, probably to the point where increased grazing by marine fauna and competition from other intertidal benthic community types (e.g. mangroves) would see the extent of suitable algal mat habitat gradually diminish and even disappear. Analogues to this scenario appear to already exist in the southern areas of the project.

Higher elevation intertidal mudflats landward of the existing algal mat extent would be expected to provide opportunities for algal mats to become established under higher sea-level conditions, but this would be reliant on future sediment dynamics creating additional extensive, relatively isolated depressions where resultant high salinity and alternating periods of waterlogging and aridity support algal mat survival more than that of other intertidal benthic community types. Published reviews indicate that the information and processes necessary for the accurate prediction of future sediment dynamics in coastal and intertidal areas does not yet exist.

With the abruptness of the landward margins of the intertidal area at 3.0 – 3.5 mAHD, opportunities for migration would diminish over time, becoming almost negligible in the next 100 years. The establishment of brine ponds would largely remove any such future opportunities, with the exception of the project's diversion channels and possibly within some of the ponds themselves, where algal mats are known to occur in other salt projects (e.g. Williams, 2012).

Conversely, the improved flushing of the Mardie intertidal area as a result of rising sea levels would seem to be to the overall benefit of the area's mangrove communities, particularly given the capabilities of mangroves to stabilise coastal sediments in low energy conditions, such as generally exist at Mardie. Areas of mangroves in and to the south of the project are considered to be among the best examples in the region (EPA, 2001), and also coincide with the zone in the RPS (2019) inundation model that receives much more regular and deep inland tidal inundation than most other areas within the model domain.

A large intertidal basin located to the immediate north of the Mardie project with similar elevation ranges but largely absent of mangroves, currently supports over 4,500 ha of algal mat. Owing to its severely constricted ocean connectivity compared to the Mardie intertidal basin, a rising sea level could see the extent of algal mat in the basin expand by as much as 500 ha before becoming constrained by abrupt landscape margins.

While the impacts of sea level rise on the current distribution of coastal samphire communities is likely to express as both a change in community make-up as well as distribution, the ultimate outcomes are difficult to predict; however the area in and to the south of the project, which is already regularly inundated at depth, does support an extensive samphire community in addition to the plentiful mangroves previously described.

4 REFERENCES

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5 FIGURES

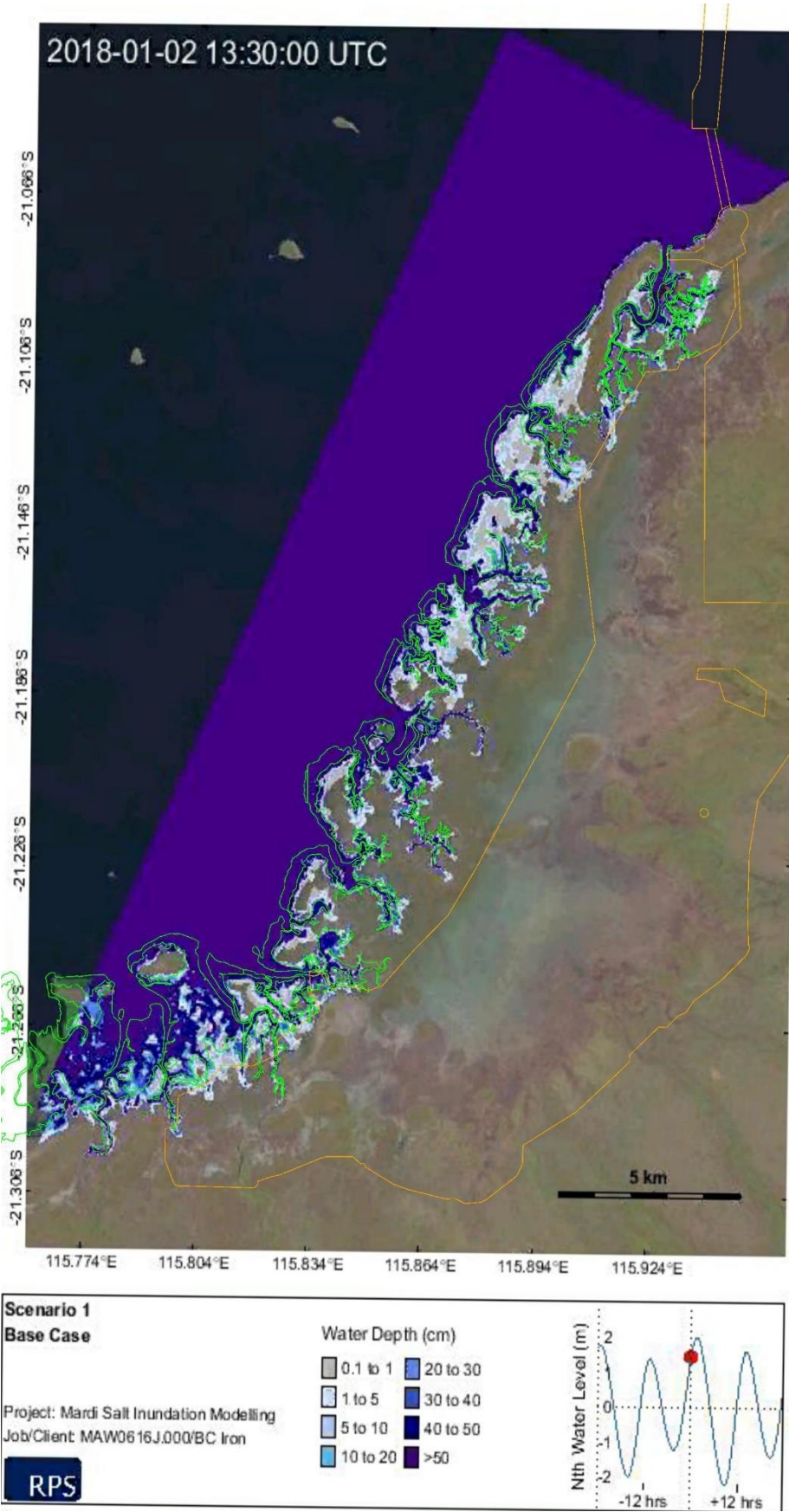


Figure 2: Tidal inundation at 1.5 mAHd, showing mangrove distribution and inundation depth

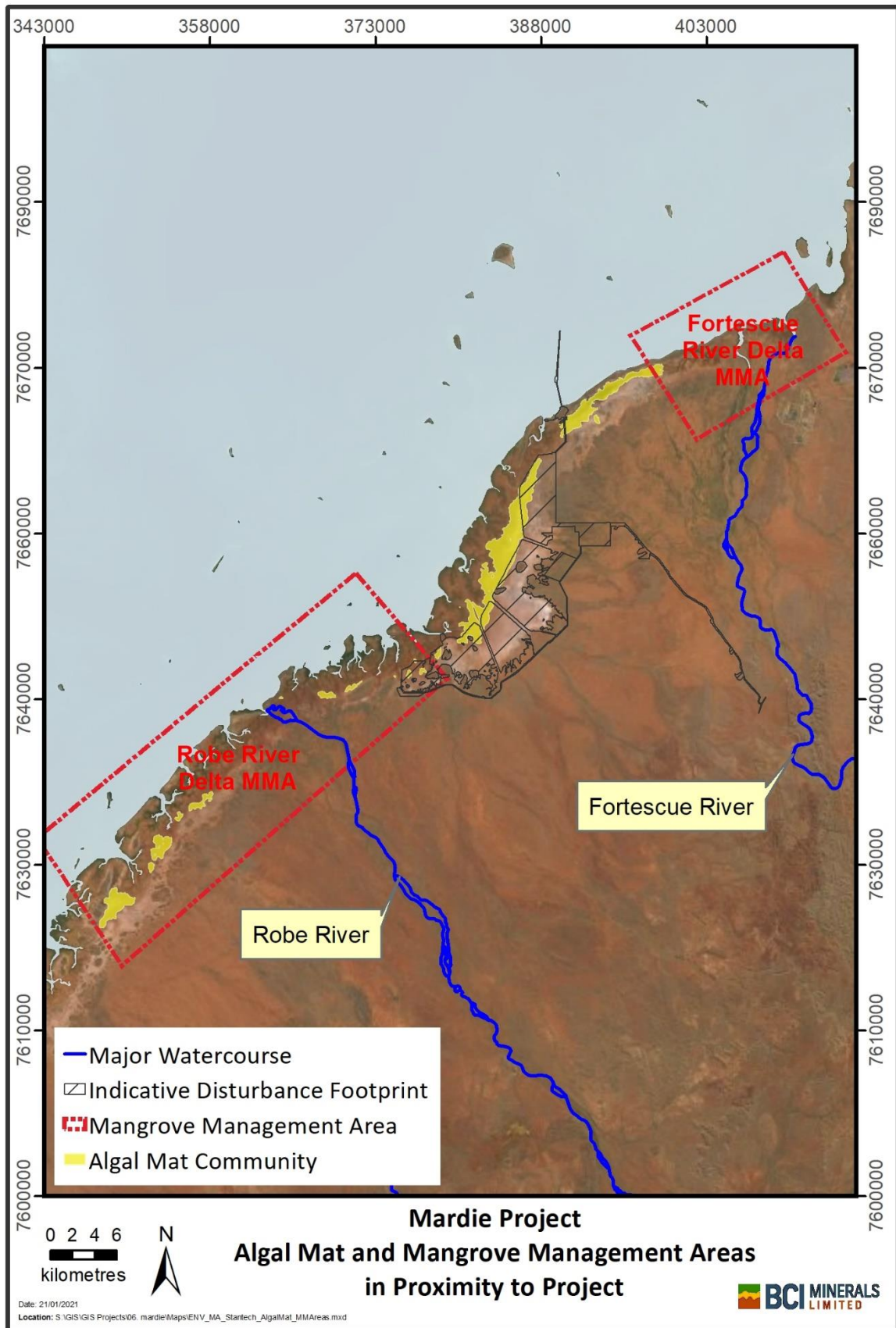


Figure 3: Distribution of Algal Mat along the Mardie and Robe River coasts

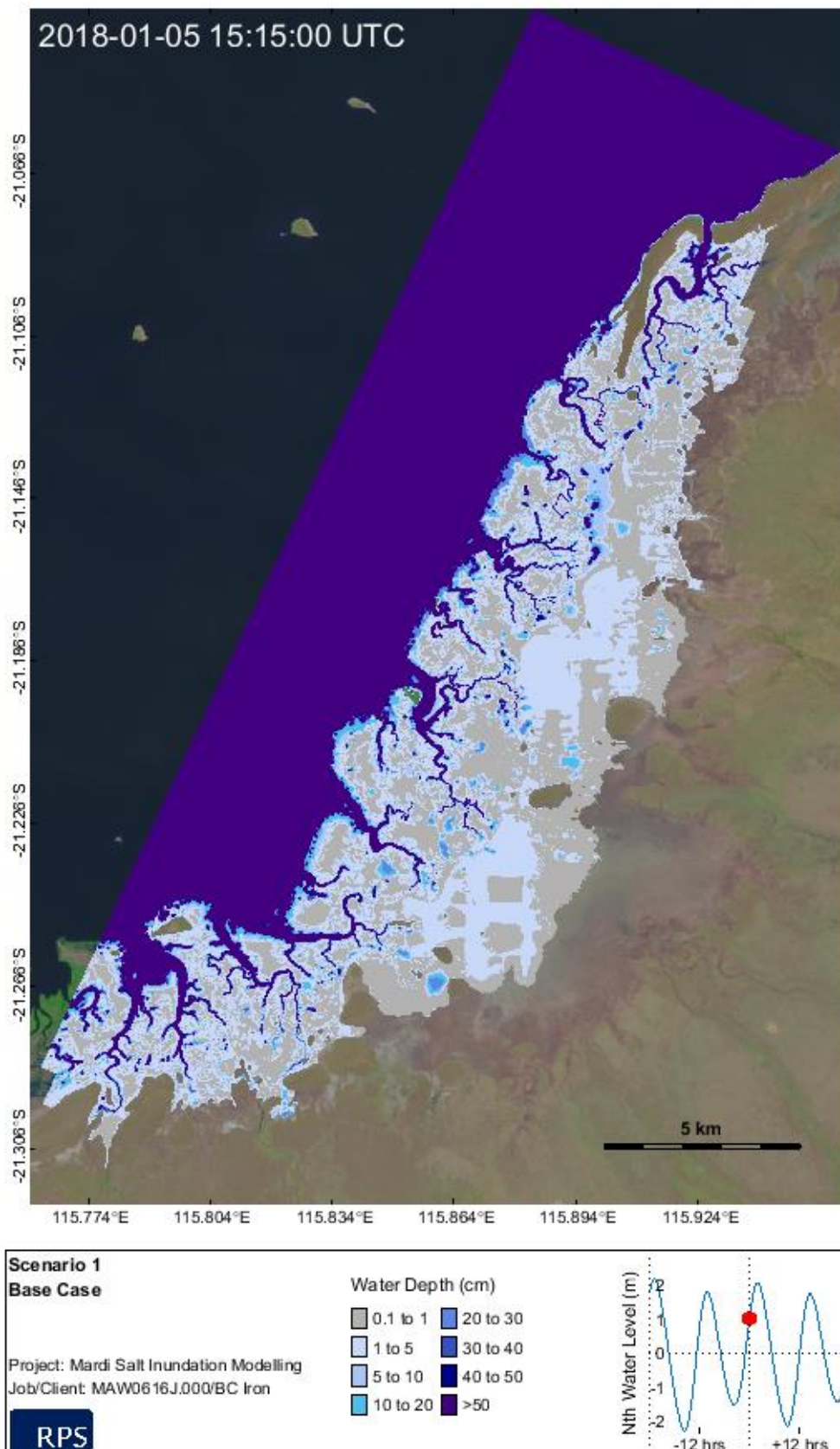


Figure 4: Inundation at MSL + 90 cm (Basecase @ 0.9 mAHd)

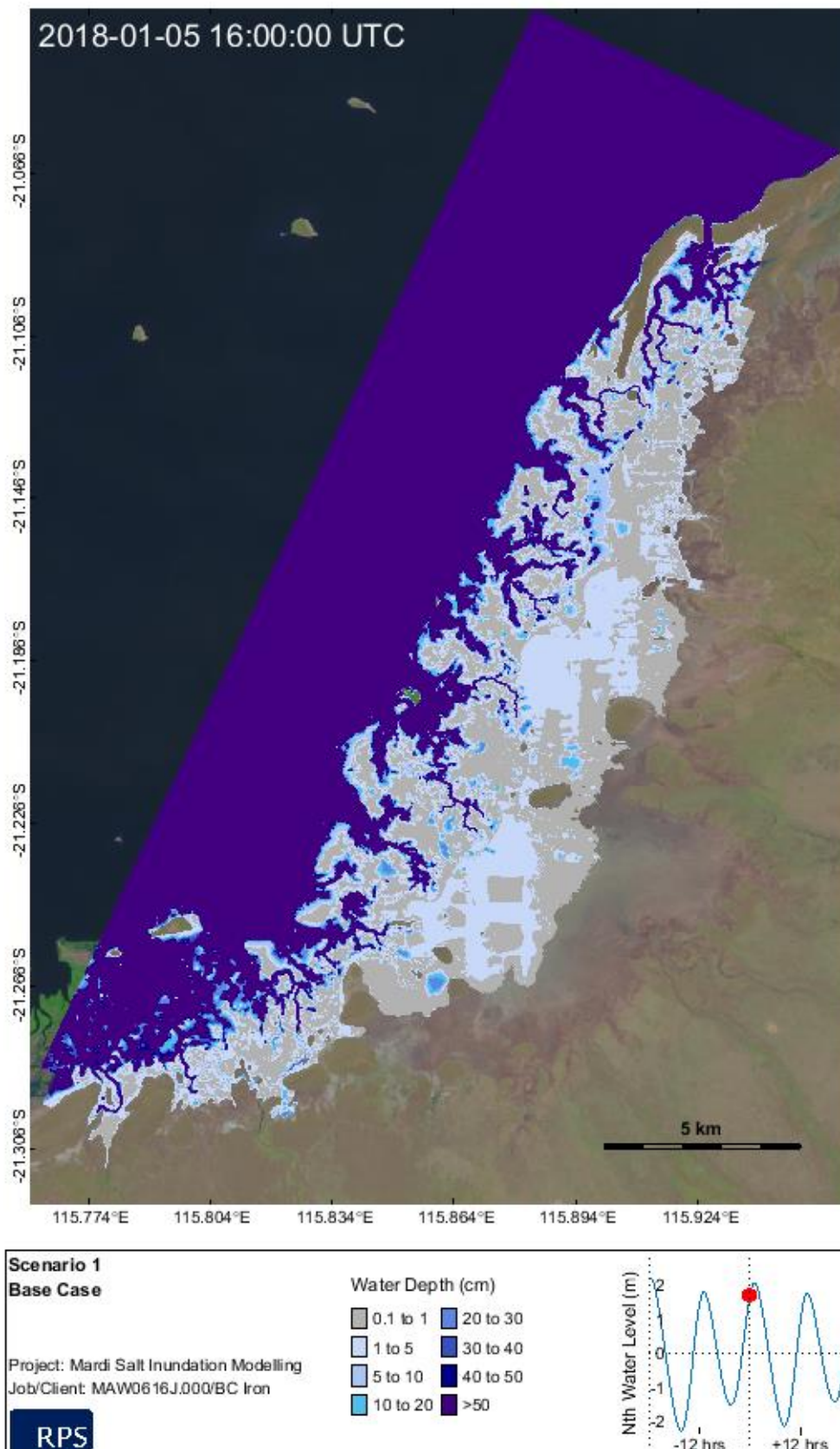


Figure 5: Inundation at 1.15 m tide + 90 cm (Basecase @ 2.0 mAHd)

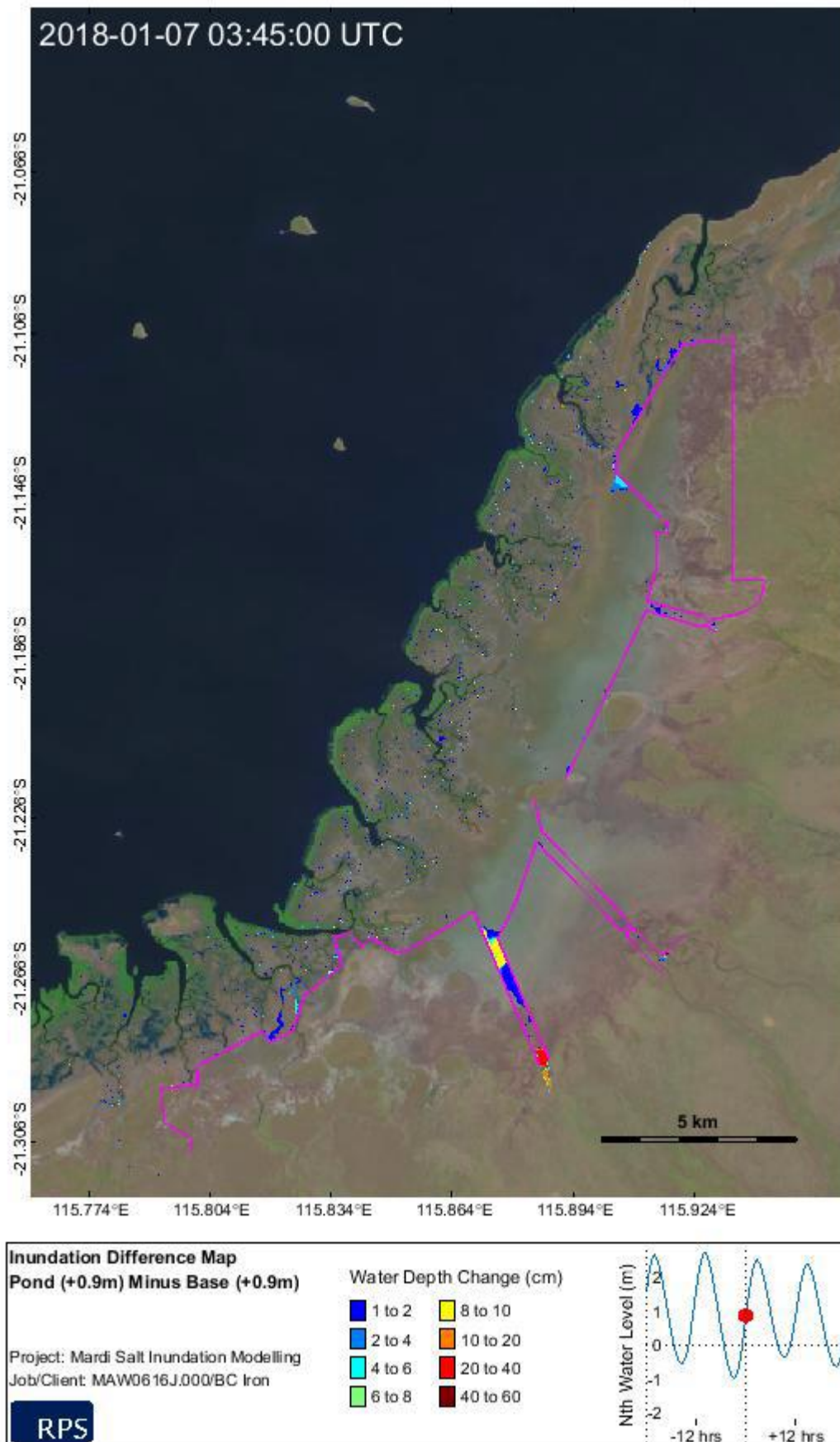


Figure 6: Increase in inundation as a result of the ponds - MSL + 90 cm

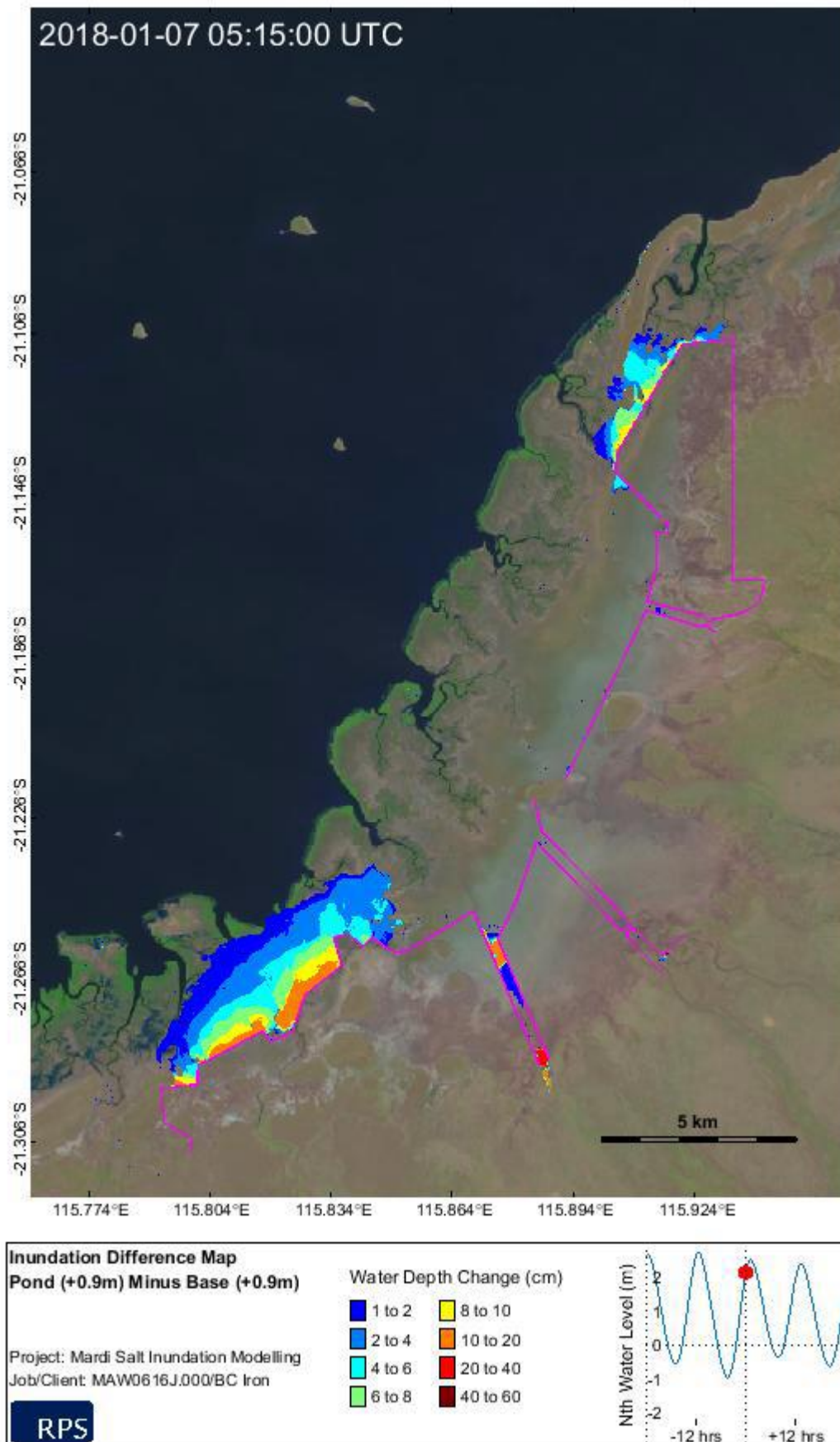


Figure 7: Increase in inundation as a result of the ponds – 1.15 m tide + 90 cm

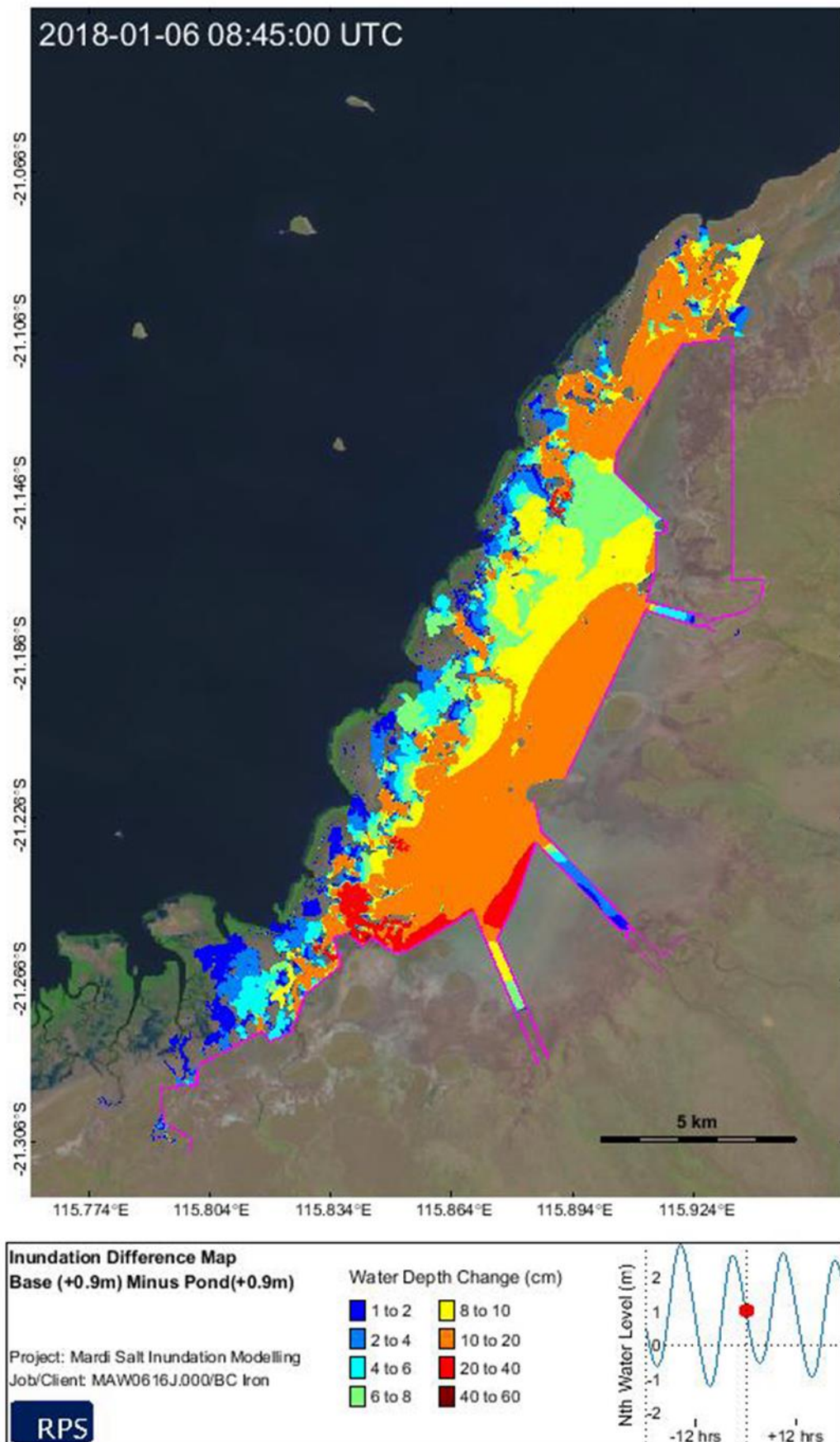


Figure 8: Decrease in inundation on a falling tide as a result of the ponds - MSL + 90 cm

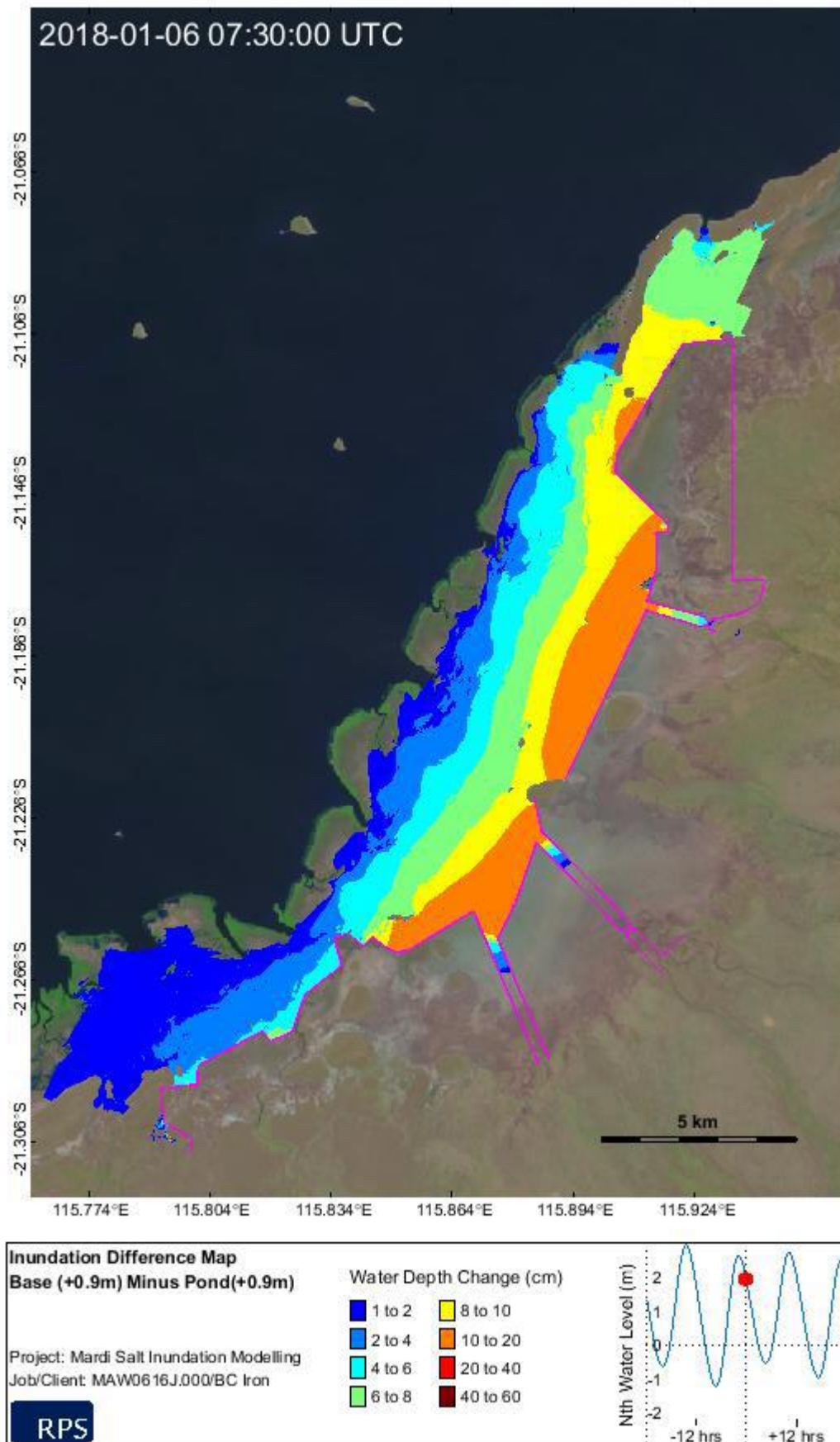


Figure 9: Decrease in inundation on a falling tide as a result of the ponds – 1.15 m tide + 90 cm

