Technical Memorandum

Subject	Causeway Tidal Inundation Assessment		
Date	25 July 2022	Pages	22 body + 6 attachments
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Project no.	311012-001000	Doc no.	311012-01000-HYD-MEM-0034
Project	Mardie Salt & Potash Project - Civil & Earthworks; Detailed Design		

1 Introduction

An assessment has been undertaken to determine the sizing requirements for the culverts servicing the north-south alignment of the proposed causeway crossing, which falls under the MS1175 approved development area. The specific study area is presented in Figure 1-1 and Figure 3-1.

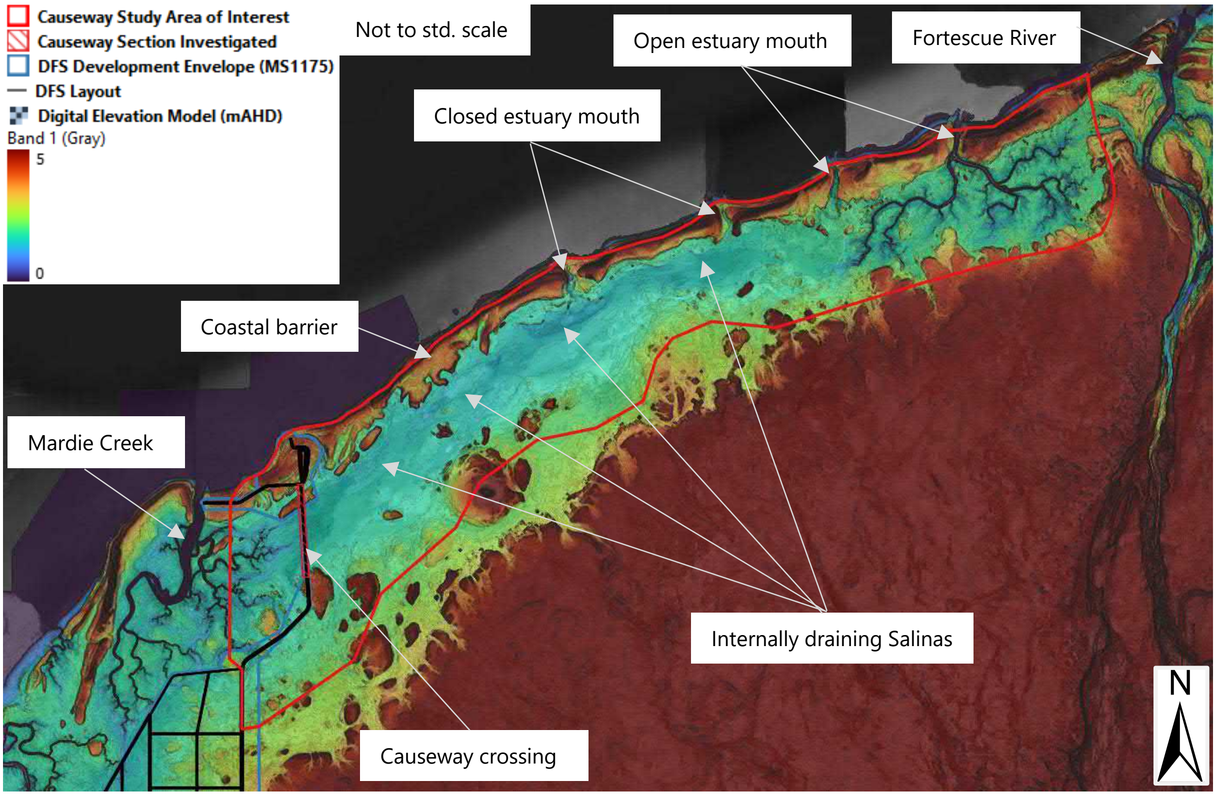

Figure 1-1: Study area and specific section of causeway being investigated

A key design constraint of this section of the causeway as part of the MS1175 approval was the environmental conditions required to be achieved by the causeway design. These conditions are detailed in Table 1-1.

The conditions that are **not** applicable to this memorandum relating to the causeway design are presented in a lighter text shade below:

Table 1-1: MS1175 conditions

Condition number	Condition detail	Section of memo	Comments
3-1 (1)	*no adverse impact to water levels or water quality in Mardie pool as a result of changes to groundwater regimes or groundwater quality;*	-	Groundwater based – N/A
3-1 (2)	*no adverse impact to water levels or water quality in Mardie pool as a result of surface water flows associated with the proposal;*	-	Mardie Pool is located approximately 10.5 km south of the causeway and is subject to freshwater inundation from different catchments. Storm tide inundation of Mardie Pool is not affected by the causeway.
3-1 (3)	*no changes to the extent of surface water flooding extent during a one (1)-year ARI or changes to tidal inundation as a result of the construction of the intertidal causeway that are greater than predicted in Mardie Project – Environmental Review Document (June 2020);*	5.2 – 5.4 and 6	Change is relative to that derived by RPS and used as the basis of the ERD, rather than comparing the results to the pre-development (baseline) condition.
3-1 (4)	*no changes to the health, extent of diversity of more than five (5) ha of intertidal benthic communities and habitat, including mangrove, samphire and algal mat as a result of changes to groundwater regimes or groundwater quality associated with the proposal*	N/A	Groundwater based – N/A
3-1 (5)	*decreased freshwater inundation attributable to the project of no more than fifty-two (52) ha of coastal samphire*	5-4 and 6	Limits relate to total project area, not just causeway
3-1 (6)	*decreased freshwater inundation attributable to the project of no more than thirteen (13) ha mangroves outside the RRDMMA*	5-4 and 6	Limits relate to total project area, not just causeway
3-1 (7)	*decreased freshwater inundation attributable to the project of no more than 130 ha mangroves within the RRDMMA, subject to the requirements of condition 2-3*	N/A	Causeway study area is appriomxaetly 25 km from the RRDMMA
3-2	*Prior to ground disturbing activities associated with the intertidal causeway, the proponent shall submit and have approved by the CEO the final design of the intertidal causeway, including*	6	

Condition number	Condition detail	Section of memo	Comments
	modelling to demonstrate that the impacts associated with the causeway do not exceed that predicted in Mardie Project – Environmental Review Document (June 2020).		

2 Previous Assessments

A conceptual causeway design that was drafted for the projects Definitive Feasibility Study (DFS) were assessed by RPS (2020) in *"Comparison of Inundation over the North-Eastern Floodway with Construction of a Road Causeway"* (MAW0616J.005). The conceptual design works associated with this study were used to inform the *Mardie Project – Environmental Review Document (June 2020)* and subsequent conditions in Ministerial Statement No. 1175 (MS1175).

The DFS causeway assessment undertaken by RPS was for a conceptual hydraulic design (combination of two at-grade floodways and culvert arrangements) of the north-south section of the causeway that is now superseded by the more mature design proposed in this memo. It is noted that the same DFS causeway crossing alignment is consistent between this previous study and the works summarised in this memo.

The proposed design changes to the causeway assessed in this memo are required to achieve the same (or less) impact on tidal inundation and 1 year ARI freshwater inundation extents as those detailed in these previous works that were used to inform the ministerial conditions.

2.1 Differences between current and previous study approaches

2.1.1 Model extent

The largest difference identified between the assessment undertaken by Advisian and that previously undertaken by RPS (which informs the environmental conditions of the project) is the model extent.

The RPS assessment used a discrete model area with the north eastern perimeter of the model located approximately 3.5 km NE of the causeway crossing location. Based on cross reference of the RPS predicted depths and depth-duration plots (presented in Figure 2-1), the RPS model employs a 'glass wall' model boundary, preventing tidal flow from propagating into the tidal flats toward Fortescue River. The limitations of this approach are discussed further in Section 5.2.1.

Advisian's hydraulic model covers the entire study area from the mouth of the Fortescue River to the Robe River. This allows for full assessment of hydrodynamic variations in tidal propagation through the salt flats to the northeast of the causeway, which only occur during the pulses at the very top of the tidal signal. This larger model area also allows for assessment of tidal ingress from open estuaries towards Fortescue River as presented in Figure 1-1 and is further discussed in Section 3 and Section 5.2.1.

Figure 2-1: Comparison of Advisian (Blue) vs RPS (hatched red) model domains (Advisian HAT tide shown)

2.1.2 Tidal boundary condition

The derived tidal planes for the project by Advisian (2021) are noted as being coastal tidal elevations. That is, the predicted tidal planes are for tide levels on the outside of the coastal barrier, rather than being predictions of the peak tide elevation at or near the causeway location.

Conversely, RPS' nominal 2.2 mAHD tide is noted as being derived from a logger that was located inside the coastal barrier on Mardie Creek (closer to the causeway alignment) for the period 2 to 10 January 2018. This is an important distinction, as the propagation of the peak coastal tidal predictions (Advisian) is limited to the coastal areas and regions closest to the mouth of Mardie Creek only. This is a result of the natural sinusoidal tidal signal, where the peak tide elevation (and maximum hydraulic driving head for the tide) is only achieved momentarily, limiting propagation of this coastal peak tide elevation into Mardie Creek as a pulse before the tide begins receding (ebbing) again, causing water to drain from Mardie Creek.

Advisian have reviewed their coastal-derived HAT tide results and compared the peak water surface elevations from the assessment model to that of the RPS study at their adopted model boundary location which is located inside the coastal barrier. It was shown that the peak water surface elevation from the Advisian (coastal) HAT tide at the RPS model boundary matched well with RPS' 2.2 mAHD tide peak at this location. This is presented in Figure 2-2 which presents the Advisian peak HAT tide result sampled across the RPS model boundary location.

This means that it is reasonable to use of the coastal HAT tide results from Advisian to compare to RPS' 2.2 mAHD tide as they represent the same tide level inside the coastal barrier.

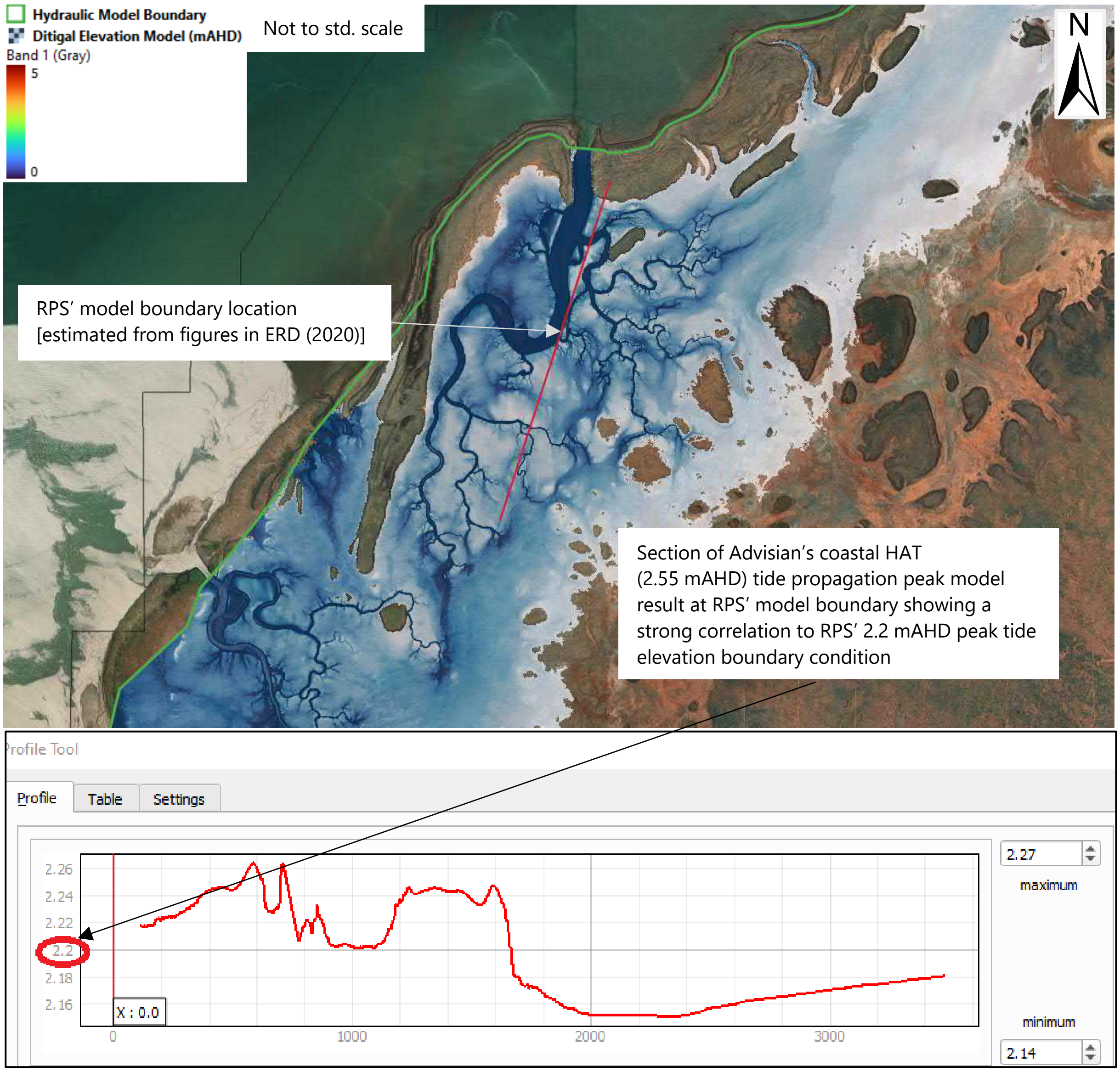

Figure 2-2: Plot of peak pre-development Advisian HAT tide sampled across RPS model boundary

3 Advisian assessment model

3.1 Model detail

The Advisian model extent covers the entire coastal and tidal flat extents from Fortescue River to Robe River and hence allows for detailed assessment of the tidal propagation across the entire study area and in particular, the salt flats/salina areas to the east of the proposed causeway location (as shown in Figure 1-1). Figure 3-1 presents the local topography around the proposed causeway crossing area.

The causeway crossing is located on an extremely flat region of natural terrain, with the lowest elevation along the causeway located at the northern end at approximately 1.43 mAHD. The next lowest location is at the midpoint of the crossing at approximately 1.53 mAHD. These two locations have been chosen as the ideal location for the culvert banks to ensure maximum engagement of flow through the causeway for all tide levels that reach the causeway location. The rest of the crossing alignment is situated at approximately 1.60 - 1.65 mAHD, presenting only very minor topographic variation along its entire approximate 1250 m length.

Advisian have used a TUFLOW HPC SGS GPU hydraulic model initially developed for the Mardie Salt Flood Study (and subsequently further refined for this study) to test the revised Causeway design against the required environmental conditions under MS1175 for tidal inundation and 1 year ARI fluvial flooding. TUFLOW is a two-dimensional (2D), internationally recognized, industry-leading hydraulic modelling software for flood, estuarine and coastal assessments. The model also utilises hydrodynamic linking from the 2D domain to the ESTRY 1D engine which is based on a full numerical solution of the one-dimensional (1D) unsteady St Venant fluid flow equations (momentum and continuity) including the inertia terms. This includes incorporation of friction losses, entry, exit and any other defined losses to accurately assess the hydraulic performance of the proposed culvert structures at a sub-grid scale.

The model has been specifically adapted for the tidal simulation assessment by increased model resolution over the area of interest (5 m model resolution from Mardie Creek to the mouth of the Fortescue River). The model also utilizes sub grid sampling at a resolution of 1 m, which enables the model to account for flow propagation through drainage lines that may be present at a sub-grid scale. This sub-grid detail is sampled from the baseline 1 m resolution Digital Elevation Model (DEM) supplied by BCI. This ensures the accurate progression of very shallow flow depths at the wetting front through minor drainage lines at a sub model resolution scale can still be achieved.

For the fluvial flooding model assessment and due to the rain-on-grid modelling approach and large model area, the same model resolution is not able to be achieved due to the high computational demand. Therefore, a variable model resolution has been adopted with much of the tidal flats area at a model resolution of 40 m due to the flat nature of the study area. It is noted that this model still utilizes the sub grid sampling at a resolution of 1 m to better represent flood propagation through sub-grid scale drainage features. Key outlets through the coastal barrier including the main estuary mouth adjacent to the causeway are at a model resolution of 10 m to ensure maximum hydraulic accuracy is achieved at these key features whilst maintaining manageable model simulation times.

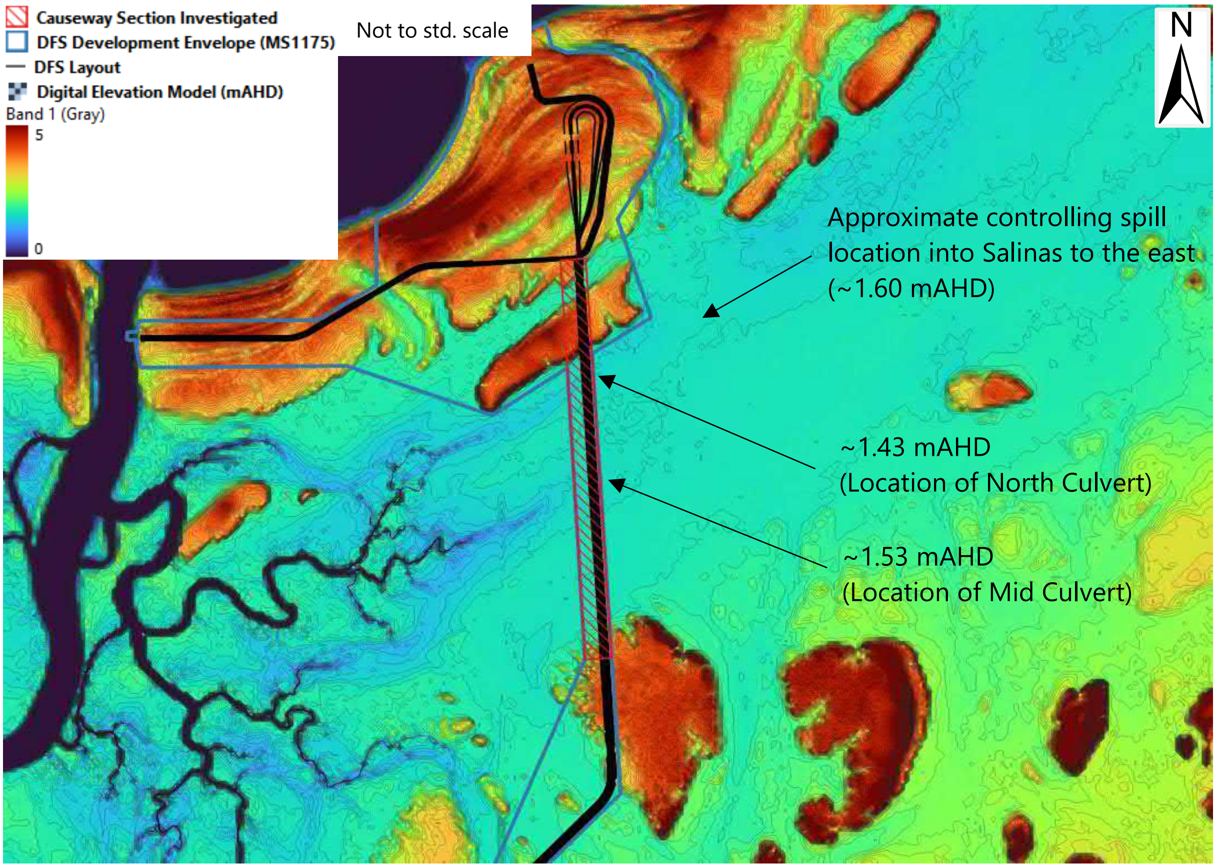

Figure 3-1: Plan view of Causeway crossing location and Digital Elevation Model

Manning's 'n' roughness adopted for the hydraulic model is presented in Table 3-1 and is consistent with industry literature such as Australian Rainfall and Runoff (2019) and site photos.

Table 3-1: Adopted Roughness Values

Description	Manning's 'n' roughness
Clear estuary	0.025
Salt pan	0.025
Sparse mangroves	0.06
Thick riparian mangroves	0.12

3.2 Design case

The causeway design was included as a design surface, with the proposed culverts included as 1D inserts, hydrodynamically linked to the 2D domain as detailed in Section 3.1.

To determine the required culvert sizes for the causeway to enable an appropriate transference of tidal flows across the causeway and also achieve the required flood immunity, existing case model outputs were used to enable initial assessments in simple desktop software (HY-8). These were further tested and refined in the detailed TUFLOW model.

The tidally derived culvert sizes are presented in Table 3-2 with relevant hydraulic parameters.

Table 3-2: Adopted culvert details

Culvert ID (refer Figure 1)	Eastern Invert Level (mAHD)	Western Invert Level (mAHD)	Culvert size & arrangement	Manning's 'n'	Entry Loss (K_e)	Exit Loss (K_o)
North Culvert	1.45	1.40	70/1500 mm Polyethene Coated Corrugated Steel Pipe (PCCSP) with concrete collars	0.024	0.5	1.0
Mid Culvert	1.55	1.50	70/1500 mm PCCSP with concrete collars	0.024	0.5	1.0

3.3 Tidal sequence derivation

A complete 16-day tidal signal was adopted for this assessment as the tidal propagation into the areas to the east of the Causeway is typified by shallow spilling over a series of minor ridgelines and filling of Salina storages. A complete 16-day tidal signal allows for full inundation potential of these storages to be realized when they become engaged during only the largest peaks of the tidal signal.

An observed tidal signal was derived from the publicly available Beardon Creek (Onslow) tidal gauge for a Spring Tide cycle, with the adopted tidal sequence from April 2020 (largest of 2020). The amplitude of the recorded historic tide signal was then factored to match the predicted coastal Highest Astronomical Tide (HAT) of 2.55 mAHD and is presented in Figure 3-1.

As previously noted in Section 2.1.2, the nominal RPS 2.2 mAHD tide is equivalent to the adopted coastal HAT boundary condition by Advisian.

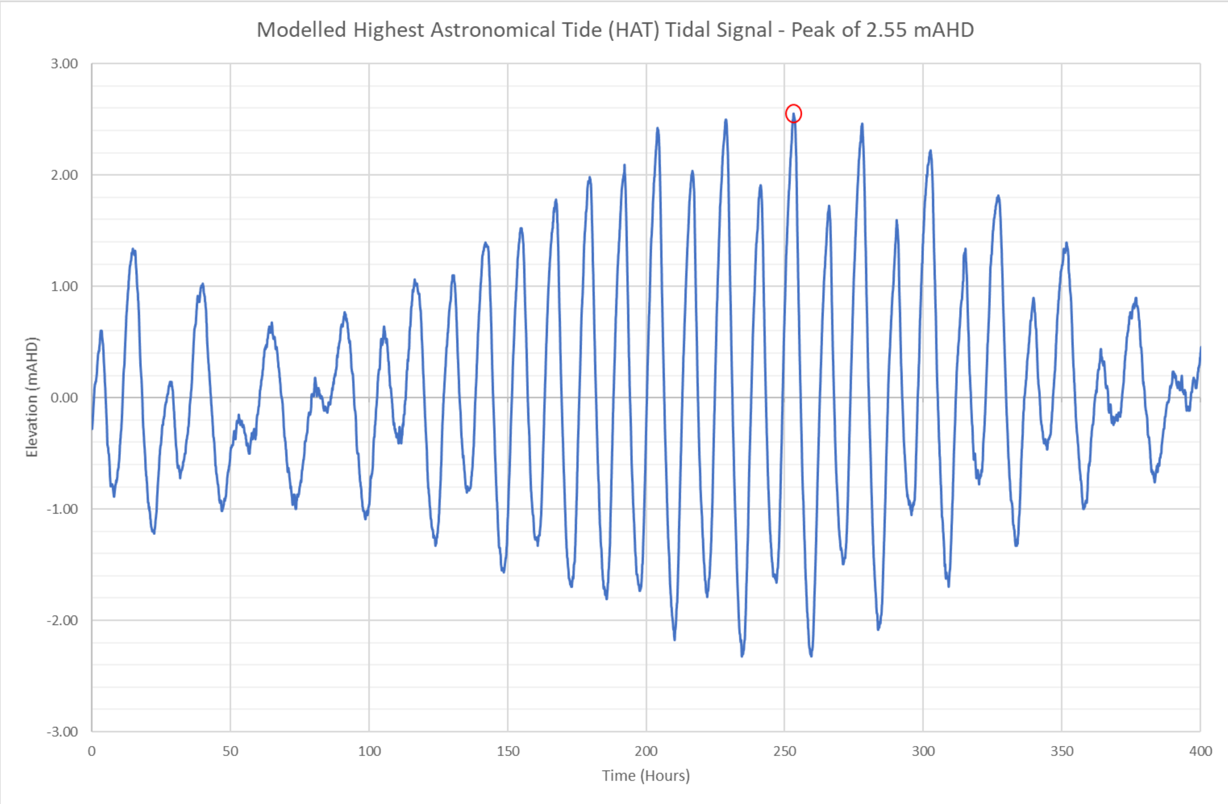

Figure 3-2: Adopted 16-day HAT tidal sequence

3.4 1 year ARI flood inundation assessment

A flood inundation assessment was also undertaken for the 1 Equivalent Year (EY) (1 year ARI) magnitude flood event. As the previous modelling [Mardie Salt Flood Study (Advisian, 2020)] had only assessed design rainfall events down to the 20% AEP (5 year ARI) event, model parameterisation changes were made to support this change in event magnitude consistently across both the existing and design cases.

The changes were limited to a change in adopted loss model from an empirical Initial Loss/Continuing Loss (IL/CL) model to a proportional loss (PL) model. This change was undertaken as in a high loss environment (such as the study area), AEP non-neutrality can occur for small magnitude events whereby high empirical loss parameterisation cannot be sufficiently satisfied by the design rainfall to produce an AEP commensurate runoff (i.e., runoff quantiles from a given rainfall do not correlate to expected values due to high loss parameterisation that favours replication of larger magnitude events). To overcome this problem, a PL loss model has been adopted with a PL value for the 1 year ARI of 0.78 as described in *Design flood estimation in Western Australian* (Flavell, 2012). This was undertaken for both the existing and design cases to enable a like for like comparison of the existing and proposed design cases for the 1 year ARI event.

A static tailwater level of Mean Sea Level (MSL) (0 mAHD) was adopted for the fluvial flooding assessment.

4 Assessment limitations

The following limitations are noted when considering the results of this assessment:

- Given the extremely flat nature of the study area and inundation extent sensitivity to even minor variations in topography, the spatially varying vertical topographic accuracy of the baseline LiDAR topographic dataset may cause inundation estimates to be over or underestimated in certain areas and modelling results should be considered within the context of this limitation.
- The impact of potential groundwater or lateral flows through the coastal barrier into the salt pans resulting from tidal signals has not been assessed. This assessment therefore represents a surface water only impact assessment of water ingress to the Salinas pre and post development. Given the coastal barrier between the causeway and Fortescue River has several estuary mouths that are currently closed due to longshore drift and sand aggradation, inflows through these areas (although likely small) at various times may also be a source of tidal ingress into the Salinas.
- Infiltration and/or evaporation losses of tidal ingress waters have not been included in the assessment.
- The assessment is based on a static topographic dataset. There are a number of currently closed estuary mouths toward Fortescue River which will potentially open after scour from a significant flood event in Fortescue River. This would also act as an inundation mechanism for the tidal flats whilst these estuary mouths remained open.

5 Assessment results

5.1.1 Advisian tidal model validation

The European Space Agency Sentinel-II satellite provides a range of publicly available data including continually updating 10 m resolution aerial imagery of the globe at varying collection times (depending on satellite location in a temporal and spatial context).

Advisian have cross referenced the largest predicted tides over the last two years and available aerial imagery to identify an appropriate imagery collection date to validate model results against.

Imagery from the 29th April 2021 was selected for this comparison. The imagery was collected just before the predicted tide peak at Onslow and hence serves as a useful point of reference for general comparison of inundation extents to ensure the model is replicating natural tidal flow behaviours.

The HAT tide was a considered a reasonable comparison to the historic tide which, according to tidal predictions for Beardon Creek at Onslow, was at or near HAT level according to Department of Transport submergence curves. The comparison location presented in Figure 5-1 is some of the flattest topography in the project area, and hence will exaggerate any differences in model predictions to actual observed tidal extents due to large extent changes from small tidal elevation differences. Comparisons of the same event at the causeway area is also presented in Figure 5-2 for reference.

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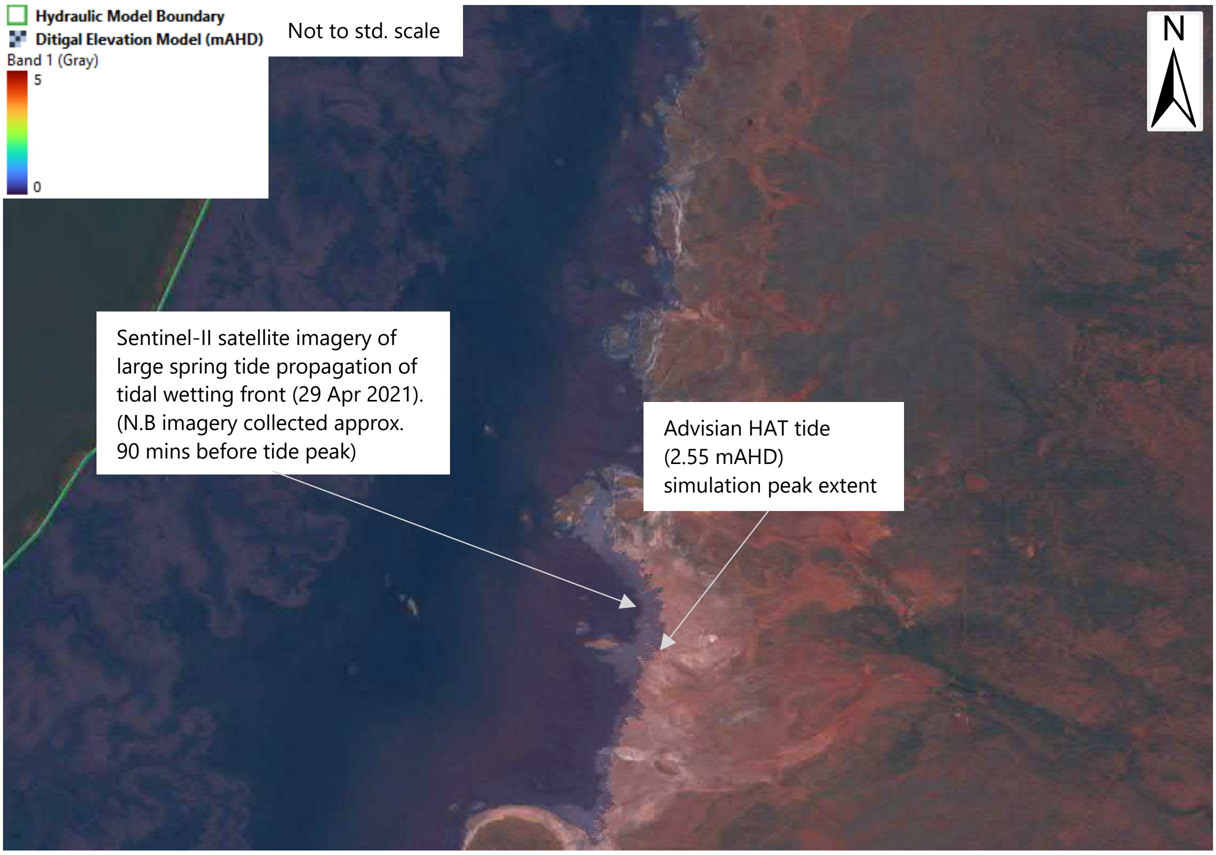


Figure 5-1: Comparison of Advisian HAT result and Sentinel-II satellite imagery of large spring tide (29 April 2021) – mid project area

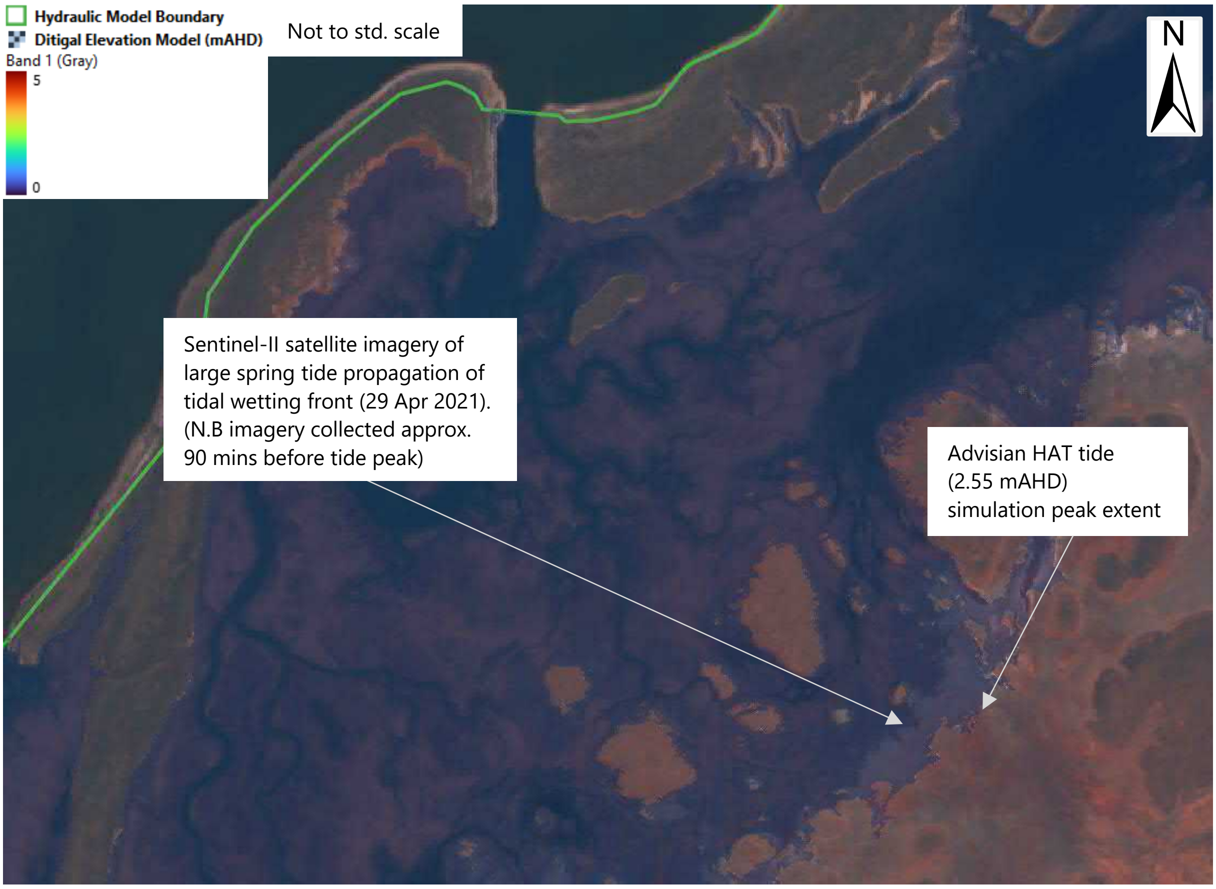


Figure 5-2: Comparison of Advisian HAT result and Sentinel-II satellite imagery of large spring tide (29 April 2021) – causeway area

It can be seen in Figure 5-1 and Figure 5-2 that the Advisian TUFLOW tidal model is accurately representing tidal propagation in the study area and hence was considered suitable for use in this assessment.

5.2 Advisian tidal results comparison with previous RPS works (ERD)

Condition 3-1 (3) from MS1175 requires that:

no changes to the extent of surface water flooding extent during a one (1)-year ARI or changes to tidal inundation as a result of the construction of the intertidal causeway that are greater than predicted in Mardie Project – Environmental Review Document (June 2020);

Review of the ERD however shows that no quantification of peak inundation extent (surface area inundated by the peak tide throughout the model simulation) change between the base case and proposed design case was undertaken or presented in the ERD. Qualitative descriptions are provided in the text (p 97 of ERD) regarding tidal inundation impacts, as well as the depth-duration plots.

The description of the causeway performance taken from p97 of the ERD is as follows:

"With the installation of appropriately sized and spaced floodways and culverts, the causeway is <u>not considered likely to significantly affect tidal inundation regimes</u>. RPS (2020) concluded that the design of the causeway should support maintenance of natural inundation patterns and exchange of water between the mangrove, saltmarsh and crusting algal habitats at the northern end of the Proposal.

Further modelling and monitoring will be undertaken prior to construction to ensure the above inundation outcomes for the base case are materially replicated following construction and during operations."

As such, the only avenue for quantitative comparison of the performance of the updated causeway design with that from the ERD is the depth-duration plots at the eight comparison locations presented in the ERD. Advisian's depth-duration plots are presented against RPS' plots for each location used in the ERD in Attachment 3.

Although the exact location of the comparison points was not available in GIS format, Advisian used the RPS documentation (Figure 5-3) to derive a best estimate of the eight different locations.

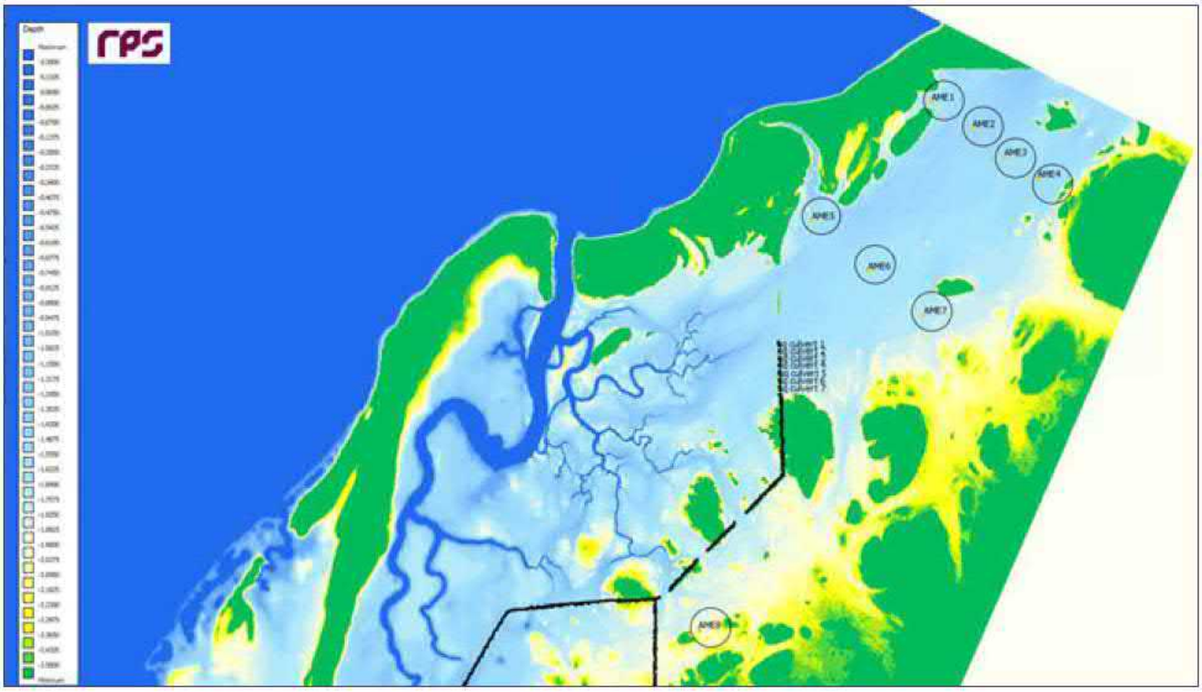


Figure 5-3: Eight depth-duration plot locations used by RPS and reported in the ERD

Comparison of the depth-duration plots show that there are minor differences between the base case and design case in Advisian's model results. The largest difference between the base case and design case was approximately 20 mm in peak depth (at a peak depth of 200 mm).

Perhaps more importantly, no notable difference in inundation duration was predicted at the 8 locations, with the tail end of the plots for the base and design cases reaching near equal depth by the end of the simulation.

It is noted that when the depth-duration plots are compared to those presented in the ERD, there are minor changes between the base case and design case. The cause of these differences is discussed in Section 5.2.2. The shapes of the plots are also slightly different due to a number of possible causes including the X-axis and Y-scales adopted, period of simulation undertaken by RPS, different tidal signal adopted (shape), as well as the model glass wall limitation further discussed below.

5.2.1 Alternative documentation - inundation extent comparison

As explained in Section 5.2, the ERD did not present inundation extents. Extents were presented in the Response to Submissions (Preston Consulting, 2021). Whilst there is no requirement in MS1175 to compare current design performance to information provided in the Response to Submissions, Advisian have undertaken this for the design cases from the respective model results. This is presented in Figure 5-4.

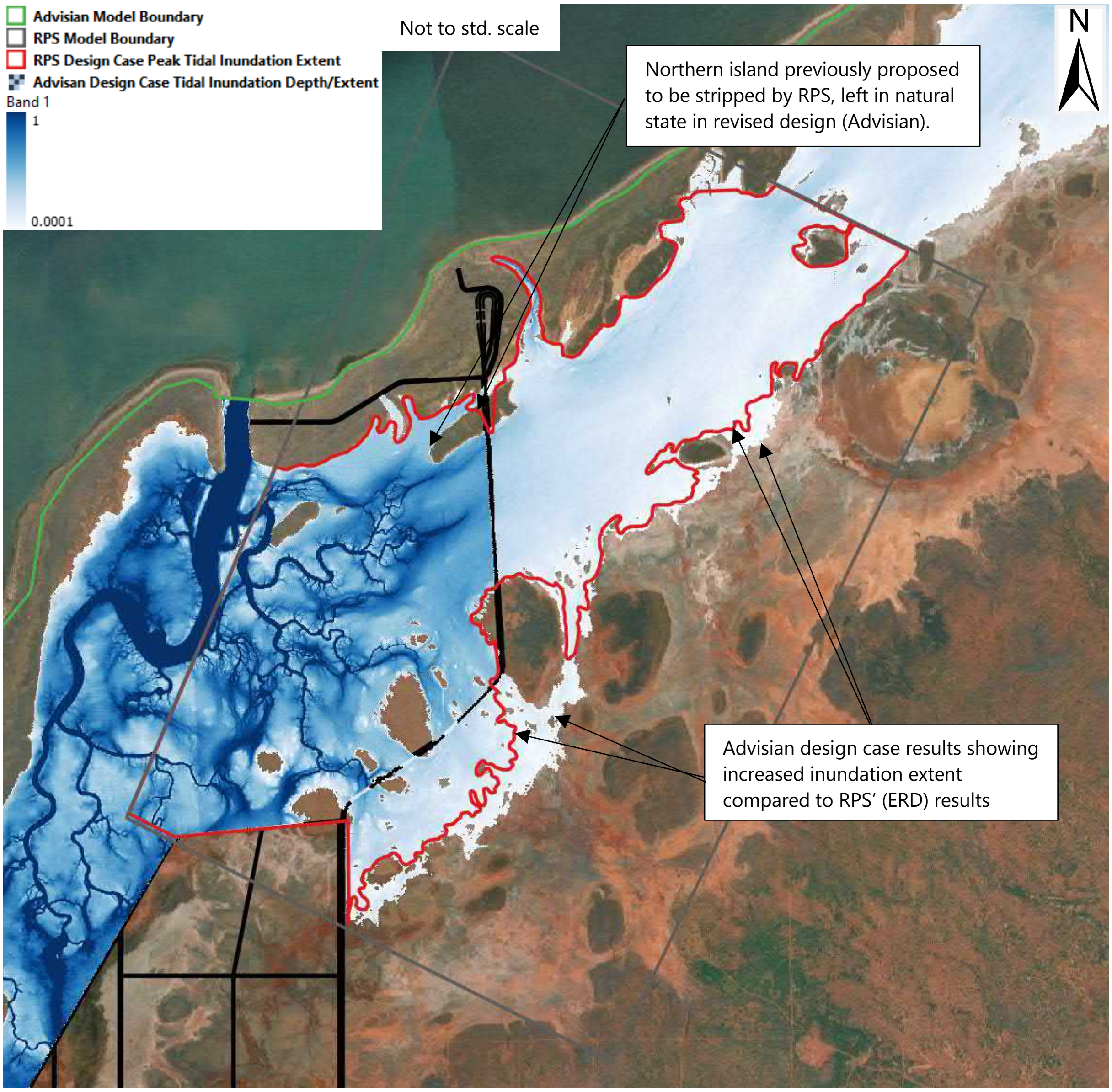


Figure 5-4: Response to Submissions Design Case inundation extent compared to Advisian (current design) inundation extent

Whilst the impact of model differences as previously discussed cannot be ignored in this comparison, the results nonetheless show that the revised design does not result in any reduction in inundation when compared to that presented in the ERD. As this is the only available form of tidal inundation extent comparison available, it can be stated that the impact of the revised design on inundation extent is not greater than that predicted by RPS.

The only location where the previous design is shown to have greater inundation is on the northern side of the causeway, where the island was previously proposed to be stripped and removed, hence inundation occurs in this area in the previous RPS model results. It is noted this island is not proposed to be stripped and removed in the revised design.

It should be noted that the previous works by RPS presented in the Response to Submissions (which also initially informed the ERD) showed clear tidal inundation extent changes (reductions) between the base case and design case. This is shown in Figure 1 of the Response to Submissions (2021).

5.2.2 Differences between Advisian and RPS tidal results

Advisian have reviewed the available literature pertaining to the RPS assessment including:

- Environmental Review Document (2020) including relevant supporting attachments:
    - A01-2 Causeway Inundation Modelling Assessment
    - A01-3 Surface Water Characterisation Assessment
- Response to Submissions (2021)

Review of these documents has identified several modelling limitations associated with the RPS works that were presented in the ERD (as discussed in Section 2.1).

The major cause of the differences between the Advisian and RPS tidal inundation results has been concluded to be the adopted model extents and resultant 'glass walling' of model results at the north-eastern boundary. The RPS assessment used a discrete model area (presented in Attachments 2 and 3) with the north-eastern perimeter of the model located approximately 3.5 km NE of the causeway crossing location. This north-eastern model extent acts as a 'glass-wall', effectively preventing the natural propagation of the shallow tidal wetting front into the tidal flats towards Fortescue River. This causes artificial ponding between the natural ridgeline to the east of the causeway (as presented in Figure 3-1) and the model boundary.

This is noted in the ERD depth duration plots where next to no difference in peak depths are predicted (despite a causeway embankment blocking half of the tidal flats flow area) and depth plots finishing at or are arriving toward a steady state ponding depth. This artefact at the end of the plots is a result of the difference between the comparison location natural topographic elevation and the slightly higher ridgeline elevation closer to the causeway which controls flow back to Mardie Creek.

This model arrangement results in pulses of tidal ingress filling the fixed volume of the model area between the causeway and model extent like a bathtub, before draining back out of Mardie Creek in the next ebb tide, trapping water behind the controlling ridge near the causeway and the model boundary.

5.3 Advisian 1 Year ARI freshwater flooding results comparison with previous RPS works (ERD)

No inundation extent, depth duration or any freshwater flooding assessment for the causeway area and tidal flats to the northeast was undertaken by RPS to inform the ERD. This makes quantification of any changes to RPS' predictions unachievable.

Supporting documentation of the ERD [*A01-3 Surface Water Characterization Assessment (RPS 2020)*] shows that no hydrologic calculations or assessment was undertaken for the catchments contributing to the northern tidal flats. This is clearly shown in Figure 2 of the document which is replicated below for clarity in Figure 5-5.

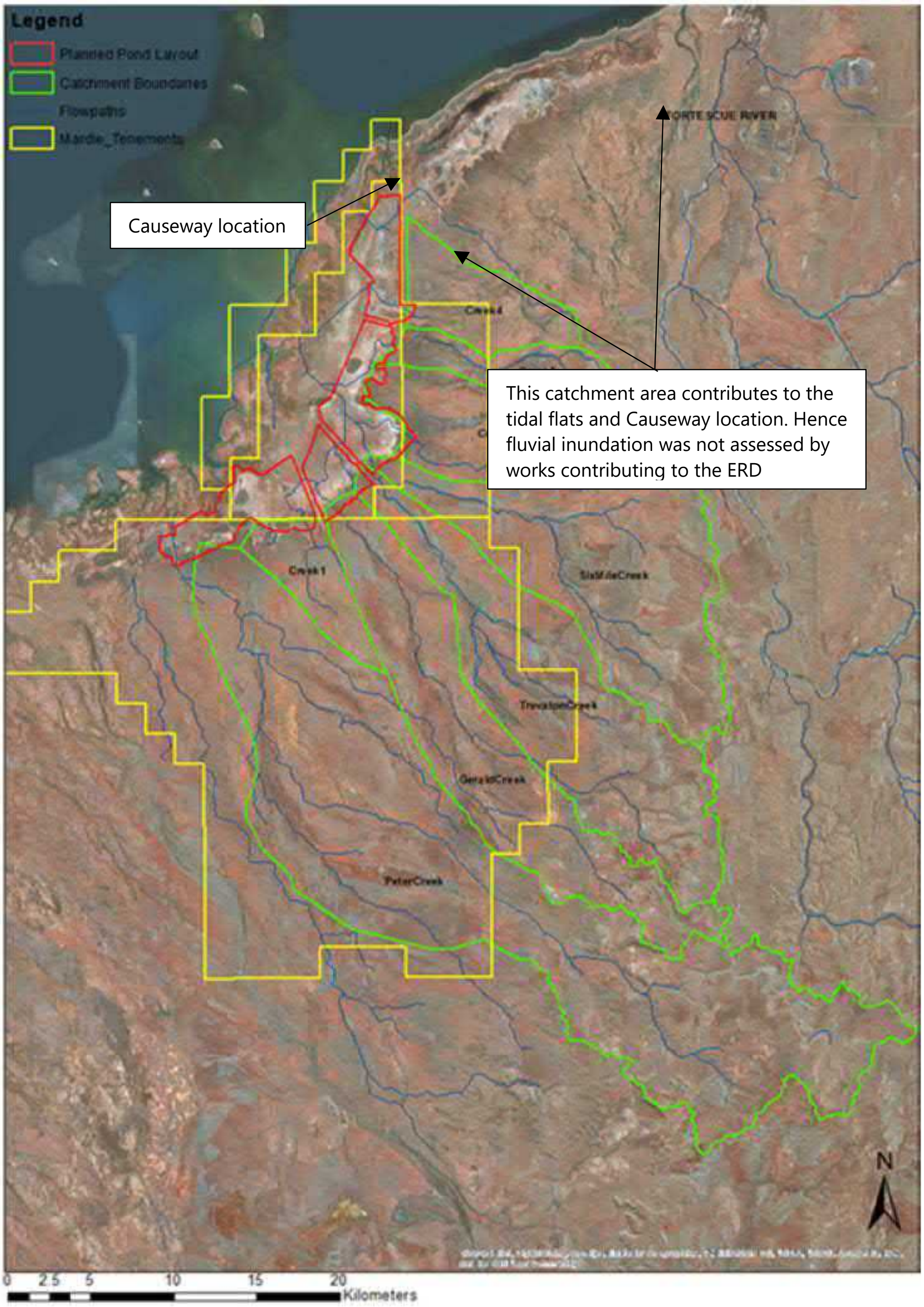


Figure 5-5: RPS (2020) catchments used to determine freshwater runoff (noting catchments contributing to the causeway and salt pans are north of 'Creek4' catchment)

The only discussion of freshwater impacts relating to the causeway design are presented in the Response to Submissions (2021) (again noting there is no requirement to assess against information provided in this document) where results are qualitatively discussed for a nominal 'extreme 4.2 m' flood in Table 1 Item 18 (replicated below):

An extreme flood level of 4.2 m would result in connection of all floodplains in the development area with drainage possible from the Western Floodplain both to the east and the west across wide flow paths. Modelling of flood drainage with the proposed causeway and openings indicate that any restrictions to flow towards the west would be largely compensated by flows to the east through the creeks draining the Eastern Floodplain over a water level range of 4.2 m down to ~ 2.2 m (i.e. until the natural tidal height range). As the flood levels recede the RPS modelling identified that freshwater inundation would cover an almost identical area once the causeway was installed, however the reduction in water levels would be slower, with up to 200 ha remaining inundated at any one time where it would have become dry if the causeway was not in place (refer to Figure 6.8 in Appendix 22)

Based on Advisian's hydrologic assessment for the project, this would be near equivalent to a 1 in 100 year ARI flood magnitude and hence substantially different to the 1 year ARI event stipulated in MS1175.

As such, there is no data in the ERD and no reasonable data be it quantitative or qualitative in other approvals documentation such as the Response to Submissions (2021) to enable a like for like comparison to the RPS works in order to satisfy Condition 3-1 (3) of MS1175 for the 1 year ARI event. Accordingly, Advisian have undertaken a comparison of the design case vs base case as is presented in Section 5.4.

5.4 Advisian model comparison – proposed design vs. base case

Given the technical limitations of the previous assessment that was used to inform the MS1175 conditions as well as lack of available data as previously described, Advisian believe it is pertinent to also compare relevant inundation areas between the base case (pre-development) and proposed design case for the tide scenario and 1 year ARI flood scenario for the total tidal flats area to Fortescue River.

The assessment has been undertaken to assess the hydraulic performance of the updated causeway design and more accurately estimate the potential impacts to the intertidal habitats.

This assessment has included quantifying the total inundation area, and inundation areas of intertidal bethnic communities to show conformance of the design to Conditions 3-1 (5) and 3-1 (6) which require area impact assessment against specific vegetation areas. As was noted in Section 1, the area limits detailed in Condition 3-1 (5) and 3-1 (6) are project wide limits, and not assigned specifically to the causeway. This memo presents impacts associated with the causeway only.

It is noted that as there is no change in BHC Mangrove inundation as a result of the causeway, this has not been tabulated. The results are presented in Table 5-1, Table 5-2 and Table 5-3.

It is noted that due to the design footprint of the causeway, there are resultant impacts on inundation area differences in the model results (i.e. the footprint of the causeway is shown as dry and hence counts as an impact). The area that was wet in the base case but is now dry in the design case caused by the causeway footprint has been calculated for each assessment scenario and excluded from the difference calculations. The different footprint areas between assessment scenarios is due to some was wet now dry not being located in the relevant BCH vegetation areas when compared to the overall inundation scenario. The calculated footprint areas are presented in each scenario detailed in the tables below.

Table 5-1: Existing and design case total inundated area comparison

Inundation Source	Scenario	Pre-development case total tidal inundation area (ha)	Design case total tidal inundation area (ha)	% Difference Inundation area
Tidal Simulation	HAT (2.2 m RPS tide equivalent)	2572	2518 (10.9 reduction due to causeway footprint)	-1.7%
Fluvial Flooding Simulation	62.3% AEP (1 year ARI/1EY)	1312	1351 (3.3 reduction due to causeway footprint)	+3.2%

Table 5-2: Existing and design case algal mat inundation area comparison

Inundation Source	Scenario	Pre-development case tidal inundation area of defined Algal Mat region (ha)	Design case tidal inundation area of defined Algal Mat region (ha)	% Difference Inundation area
Tidal Simulation	HAT (2.2 m RPS tide equivalent)	801.8	796.4 (4.1 reduction due to causeway footprint in Algal Mat area)	-0.2%
Fluvial Flooding Simulation	62.3% AEP (1 year ARI/1EY)	636.8	645.1 (2.3 reduction due to causeway footprint I Algal Mat area)	+1.7%

Table 5-3: Existing and design case Coastal Samphire vegetation inundation area

Inundation Source	Scenario	Pre-development case tidal inundation area of defined Coastal Samphire region (ha)	Design case tidal inundation area of defined Coastal Samphire region (ha)	% Difference Inundation area	Absolute area change (excluding Causeway footprint) (ha)
Tidal Simulation	HAT (2.2 m RPS tide equivalent)	974.7	954.5 (1.4 reduction due to causeway footprint in Coastal Samphire area)	-1.9%	N/A

Inundation Source	Scenario	Pre-development case tidal inundation area of defined Coastal Samphire region (ha)	Design case tidal inundation area of defined Coastal Samphire region (ha)	% Difference Inundation area	Absolute area change (excluding Causeway footprint) (ha)
Fluvial Flooding Simulation	62.3% AEP (1 year ARI/1EY)	105.2	103.9	-1.3%	+1.7/-3.0

In the HAT tidal scenario, model results predict that total inundation extents, inundation extents over the Algal Mat areas and inundation extents over Coastal Samphire areas are all comparable to the existing case with no significant change. Importantly, only a 0.2% reduction in inundation area over the Algal Mats occurs. As was previously described, there is no change in inundation area over the GIS mapping for the maximum inundation extent and depth for the HAT event is presented in Attachment 1 (base case) and Attachment 2 (design case).

As discussed in Section 5.2, depth-duration plots (Attachment 3) for the same locations presented in the ERD also show no significant change to the depth and importantly duration of tidal inundation.

Fluvial floodwater (1 year ARI) inundation of the total inundation area, Algal Mats and Coastal Samphire was shown to result in a small net increase in inundation area due to a minor increase on the eastern side of the causeway and a minor decrease on the western side of the causeway. The net reduction of 1.3 ha (or alternatively a total reduction of 3.0 ha) are both well within the total project allowance of 52 ha under Condition 3-1 (5) of MS1175.

6 Conclusions

The key conclusions from this assessment are:

<u>Technical</u>

- The original modelling assessment used to inform the conditions of MS1175 had significant technical limitations that likely resulted in an under-estimate of tidal impacts from the proposed causeway design at that time.
- Advisian’s hydraulic model has covered the entire coastline and tidal flats area from Fortescue River to Robe River to allow for all coastal/tidal plane interactions to be represented.
- Advisian’s coastal tidal plane prediction of Highest Astronomical Tide (HAT) is equivalent to the nominal 2.2 mAHD tide inside the coastal barrier as was used by RPS in the initial study, and hence represents a like-for-like assessment boundary condition to assess against the Ministerial Statement conditions (and RPS’ previous works used to inform the ERD).
- Limited quantifiable data is presented in the ERD (or other approvals documentation at that time) to enable like for like comparisons for either the tidal or 1 year ARI flooding assessment.

Ministerial Condition Conformance

The ability of the proposed revised DFS causeway design to achieve the required environmental conditions is summarised in Table 6-1.

Table 6-1: Applicable MS1175 conditions and discussion on causeway design conformance

Approval MS1175 Required Condition	DFS Causeway Design Conformance
Condition 3-1 (3) *No changes to the extent of surface water flooding extent during a one (1)-year ARI or changes to tidal inundation as a result of the construction of the intertidal causeway that are greater than predicted in Mardie Project – Environmental Review Document (June 2020)*	No quantification of inundation area change is presented in the ERD to enable a direct comparison for either the tidal or 1 year ARI flooding events. Inundation extents are presented in the Response to Submissions (2021), and Advisian's tidal results show no worsening of inundation extents (in fact larger inundation extents are predicted) over the same model area as used by RPS. It is noted that RPS' model results presented in the Response to Submissions also clearly show inundation extent change as a result of the design when compared to the base case. Depth-duration plots (Figure 59 in the ERD) are the only available avenue for comparison however it was shown that the impact of the model setup (glass walling) used to inform the ERD resulted in improbable difference plots and ponding artifacts. Advisian's depth duration plots show only minor changes to peak depths (which is replicated in the small inundation area changes) and extremely similar inundation durations for the comparison locations. Qualitative descriptions on p97 of the ERD describe a design performance as follows "*With the installation of appropriately sized and spaced floodways and culverts, the causeway is not considered likely to significantly affect tidal inundation regimes. RPS (2020) concluded that the design of the causeway should support maintenance of natural inundation patterns and exchange of water between the mangrove, saltmarsh and crusting algal habitats at the northern end of the Proposal. Further modelling and monitoring will be undertaken prior to construction to ensure the above inundation outcomes for the base case are materially replicated following construction and during operations.*" Both depth-duration and inundation area change assessments by Advisian have shown that for the revised design case only very minor changes when compared to the base case are predicted. This suggests no significant impacts on existing hydrologic regimes and hence the design should support maintenance of natural inundation patterns and exchange of water between the mangrove, saltmarsh and crusting algal habitats at the northern end of the Proposal. The intent and performance of the conceptual design assessed by RPS has therefore been materially replicated in the revised design.

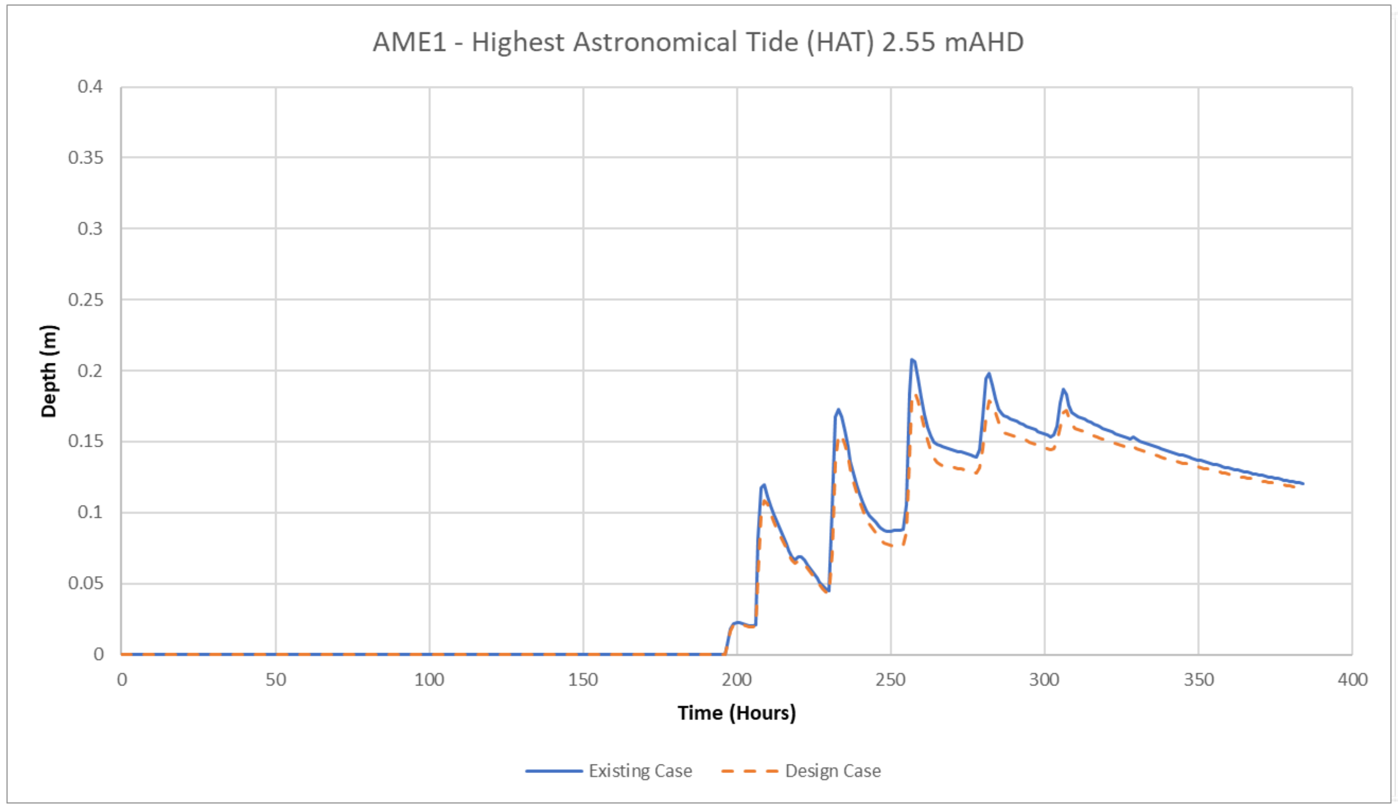
Approval MS1175 Required Condition	DFS Causeway Design Conformance
Condition 3-1 (5) *decreased freshwater inundation attributable to the project of no more than fifty-two (52) ha of coastal samphire*	Model results predict a net decrease in freshwater inundation area of Coastal Samphire compared to the base case as a result of the causeway of 1.3 ha (+1.7 ha/-3.0 ha) out of the total project allowance of 52 ha.
Condition 3-1 (6) *decreased freshwater inundation attributable to the project of no more than thirteen (13) ha mangroves outside the RRDMMA*	No change in freshwater inundation of Mardie Creek Bethnic Habitat Communities (BHC) mangrove areas was predicted as a result of the causeway.
Condition 3-2 *Prior to ground disturbing activities associated with the intertidal causeway, the proponent shall submit and have approved by the CEO the final design of the intertidal causeway, including modelling to demonstrate that the impacts associated with the causeway do not exceed that predicted in Mardie Project – Environmental Review Document (June 2020).*	Fulfilment of conditions 3-1 (3), 3-1 (5) and 3-1 (6) relating to the causeway would by association result in this condition being satisfied.

7 Attachments

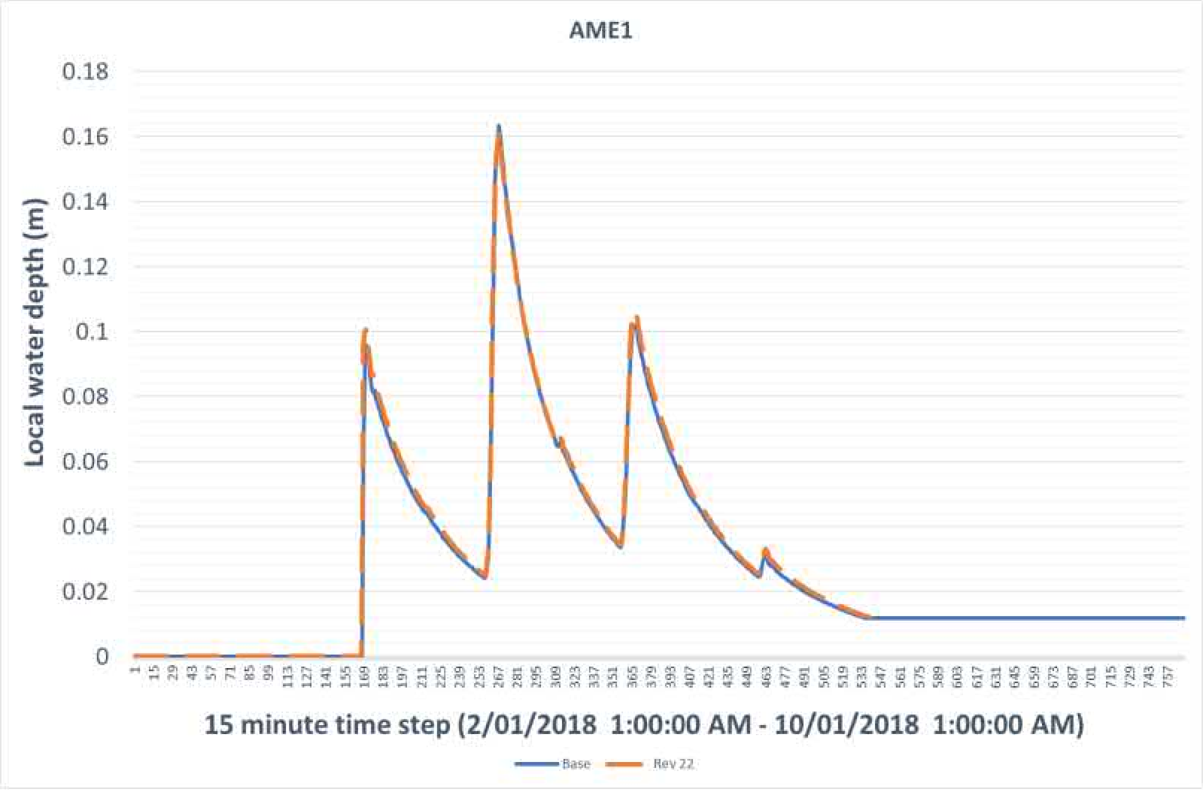
1. Existing and Design Case HAT Tide Depth-Duration Plots – Advisian and RPS
2. Existing Case HAT Tide Inundation Map
3. Design Case HAT Tide Inundation Map
4. Existing Case 1 Year ARI Flood Event Inundation Map
5. Design Case 1 Year ARI Flood Event Inundation Map

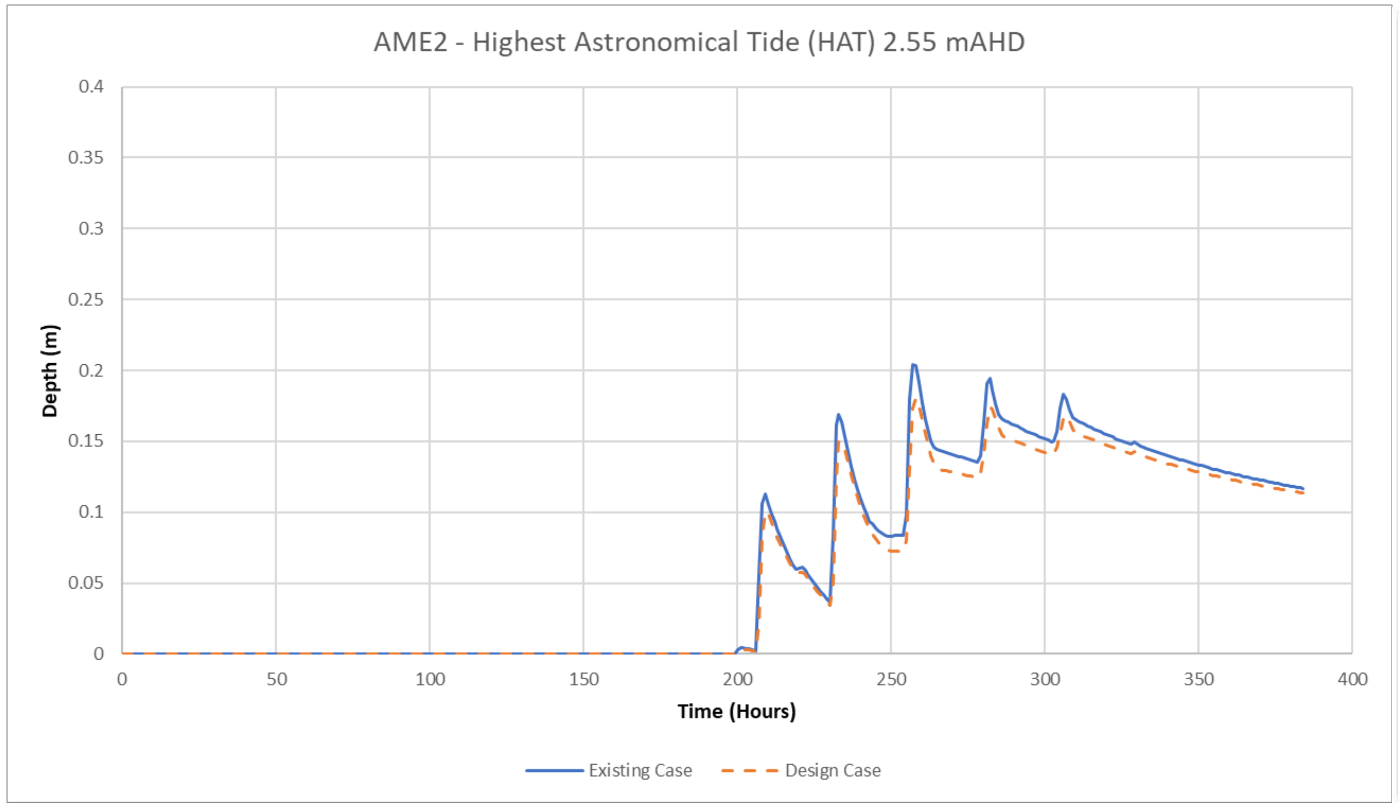
ATTACHMENT 1 – TIDAL INUNDATION DEPTH-DURATION PLOTS

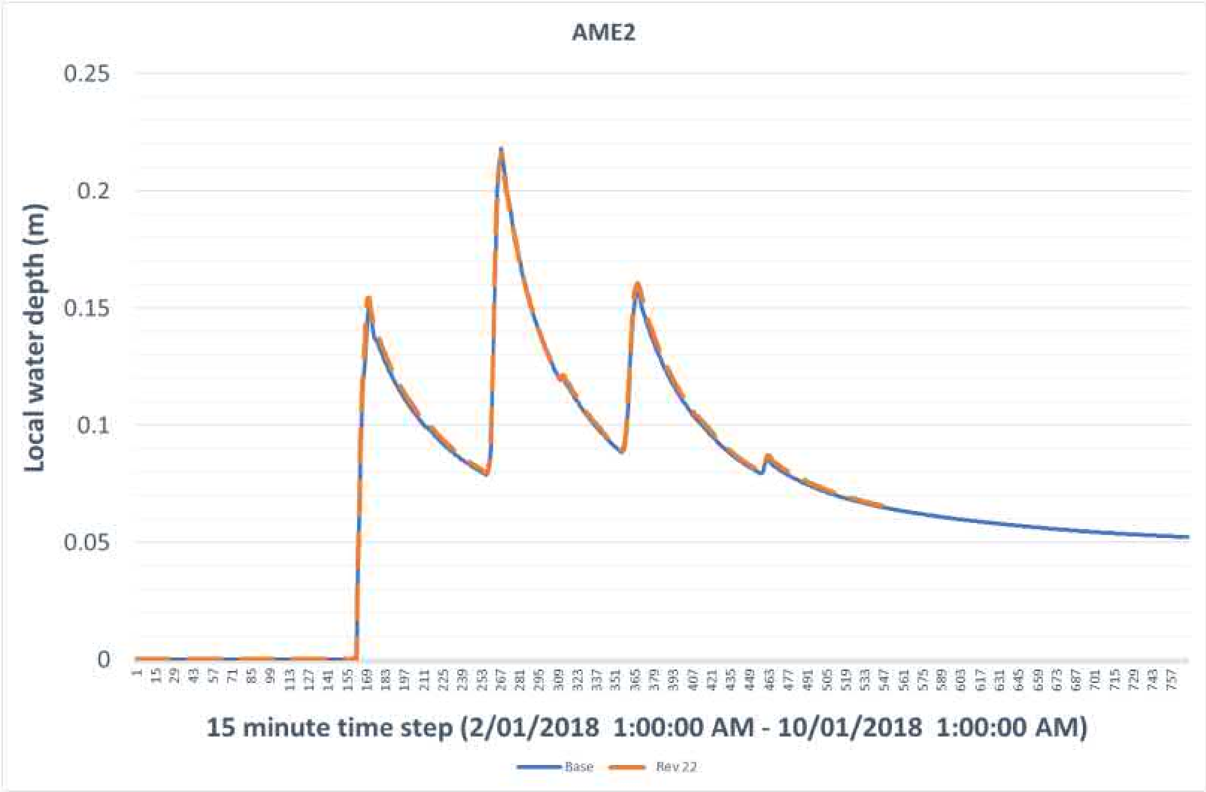
ADVISIAN MODELLING



RPS MODELLING (ERD 2020)



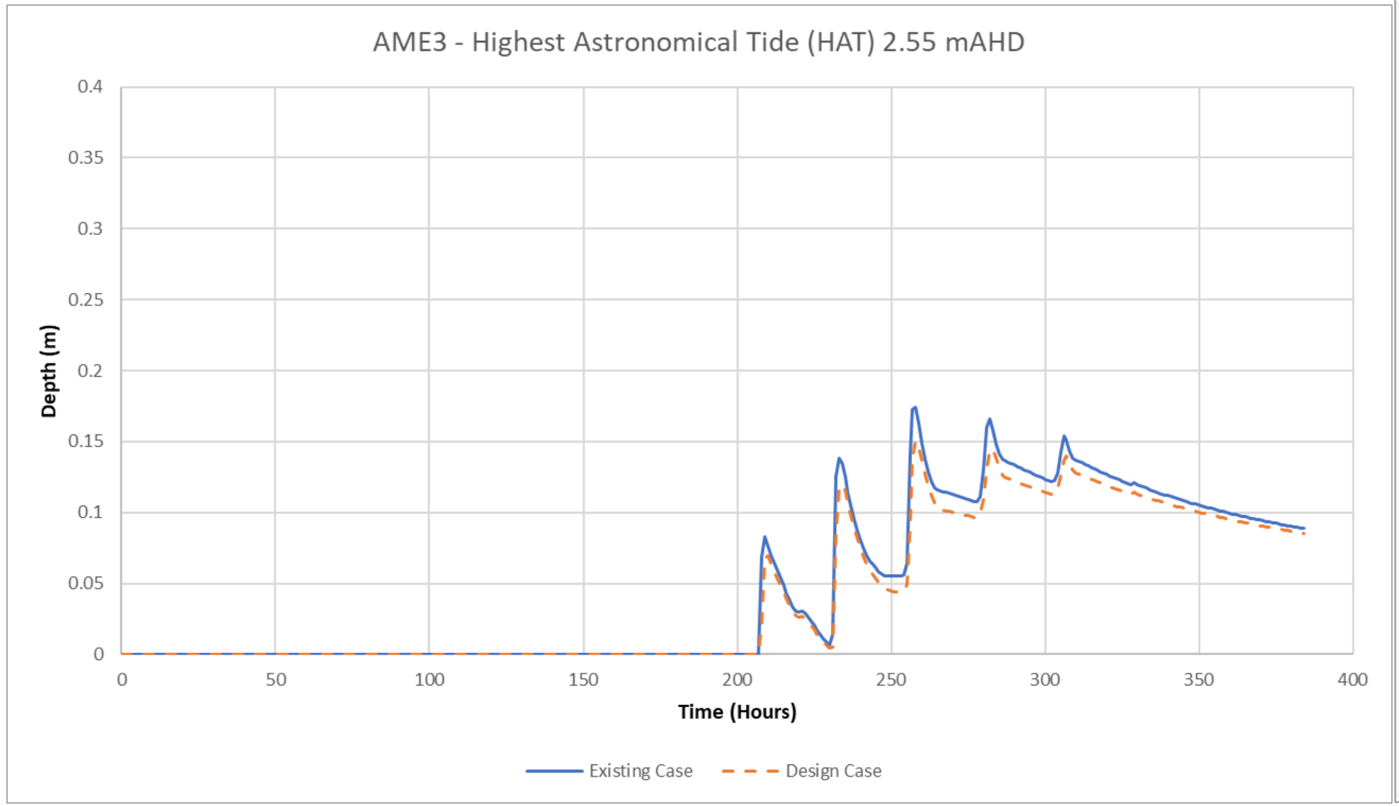


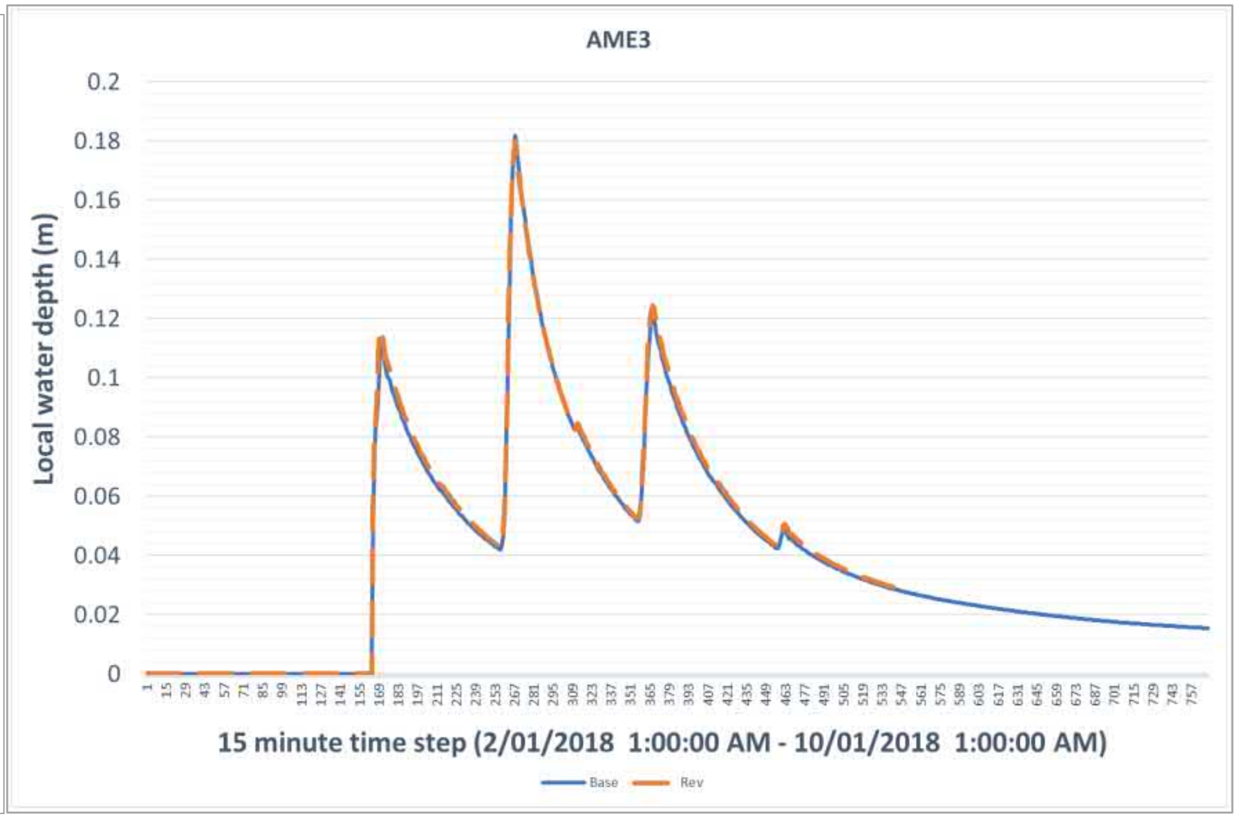


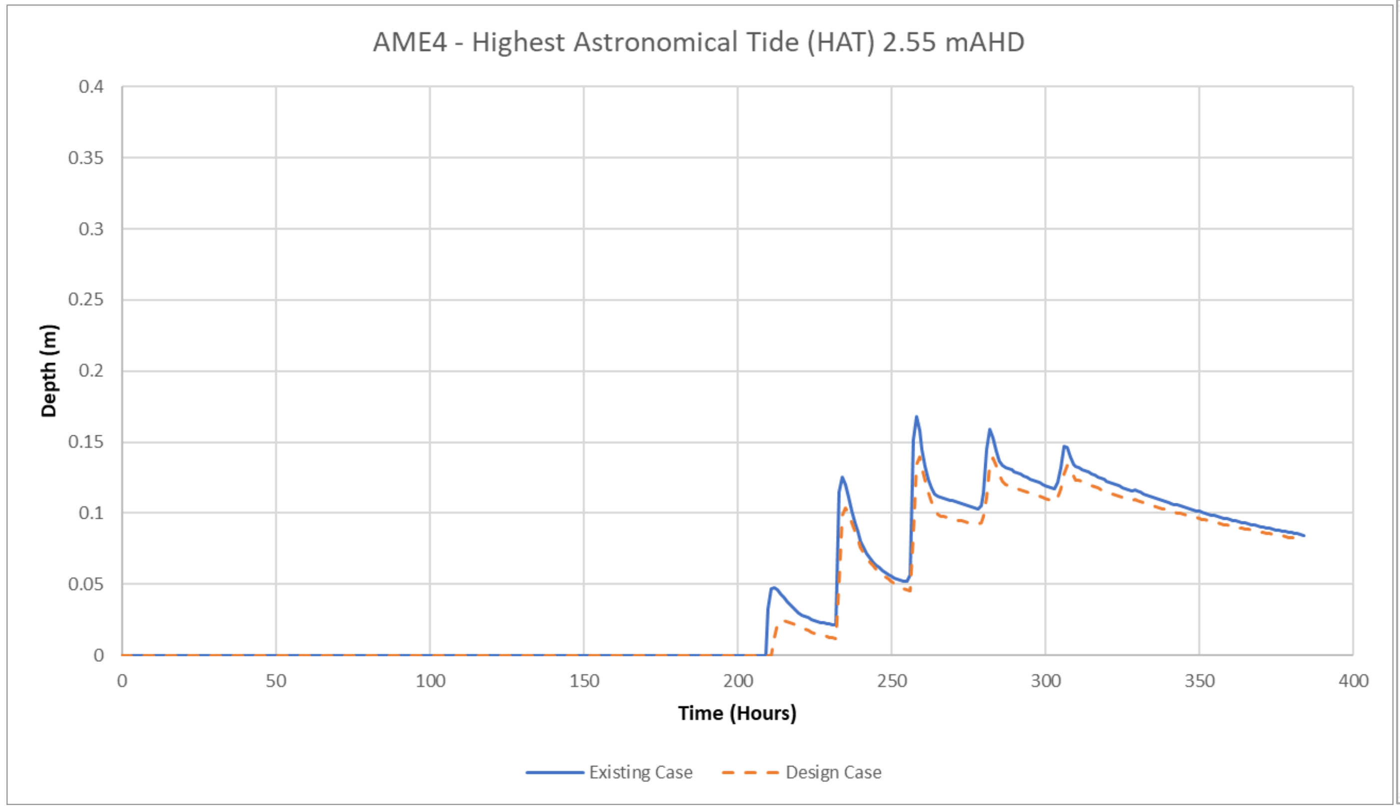
ATTACHMENT 1 – TIDAL INUNDATION DEPTH-DURATION PLOTS

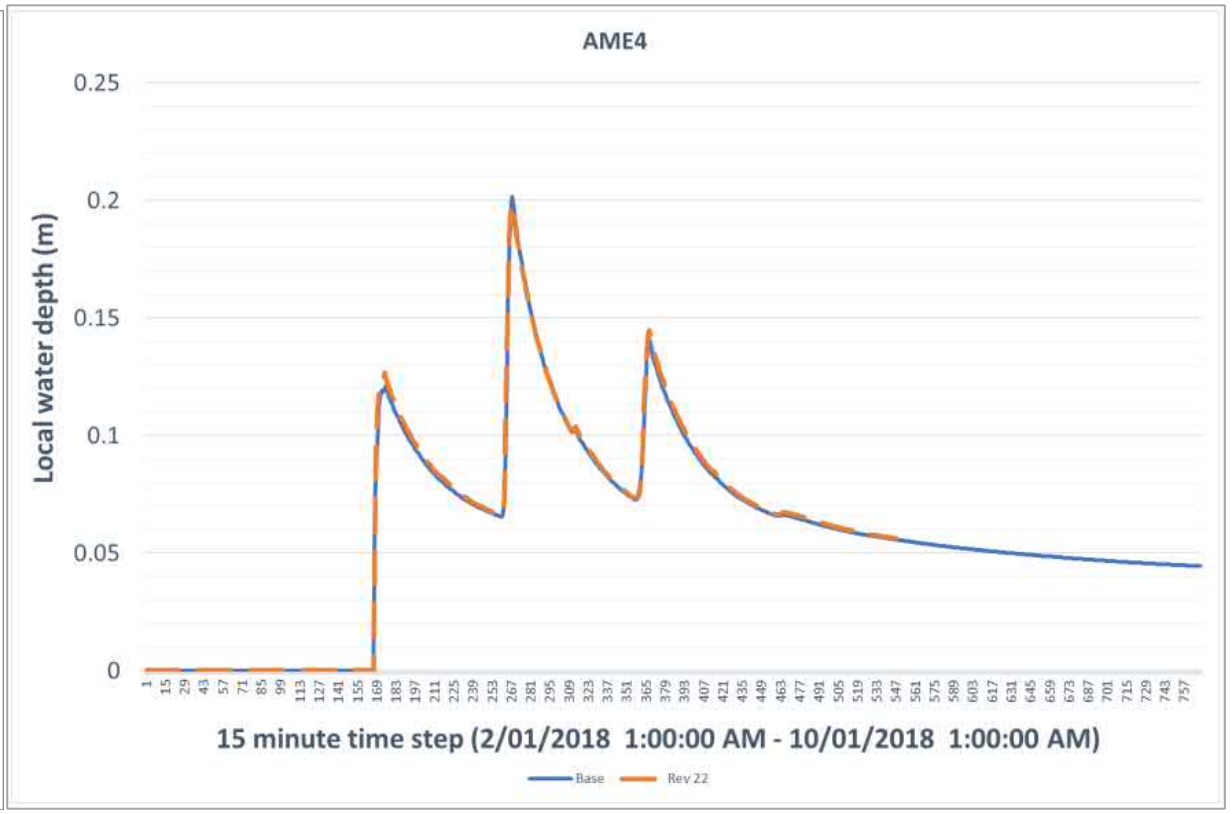
ADVISIAN MODELLING

RPS MODELLING (ERD 2020)





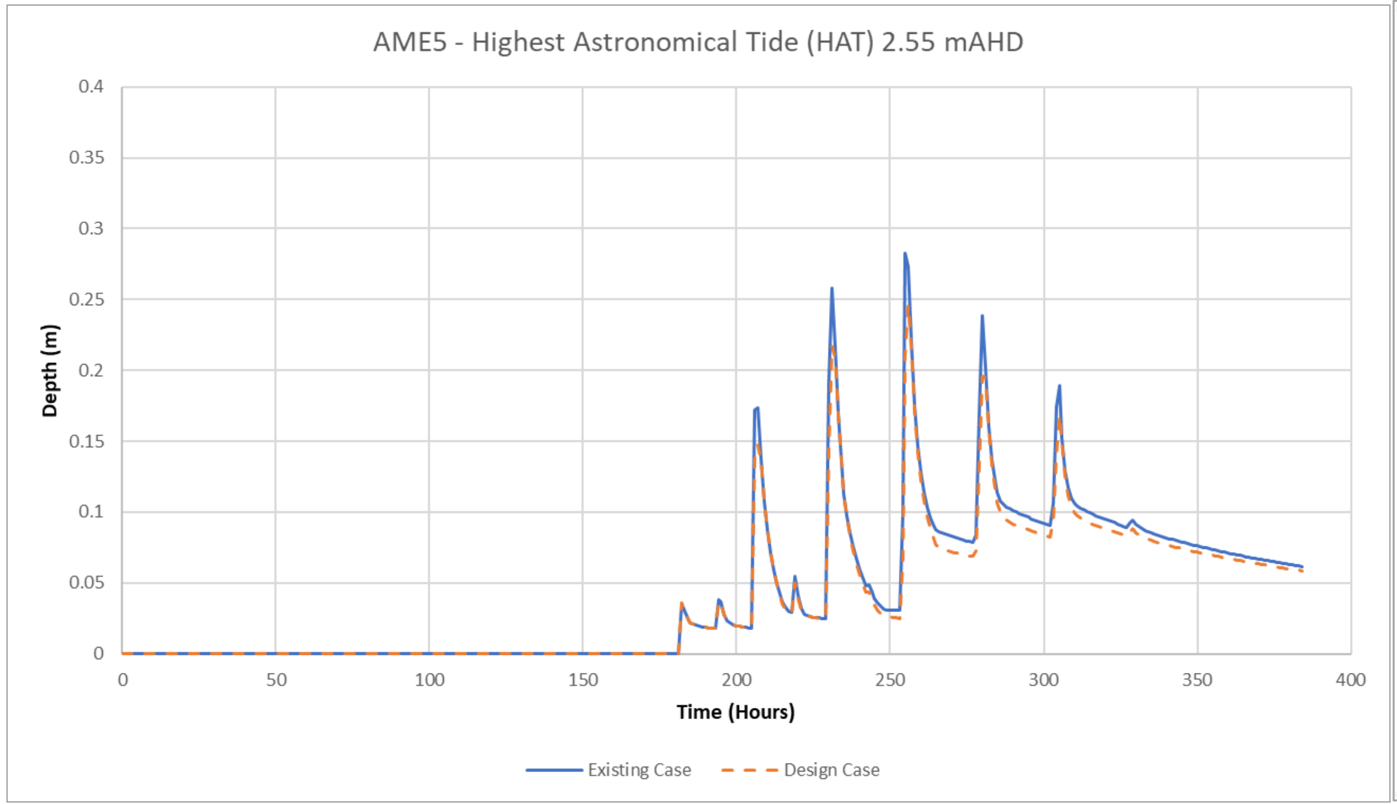


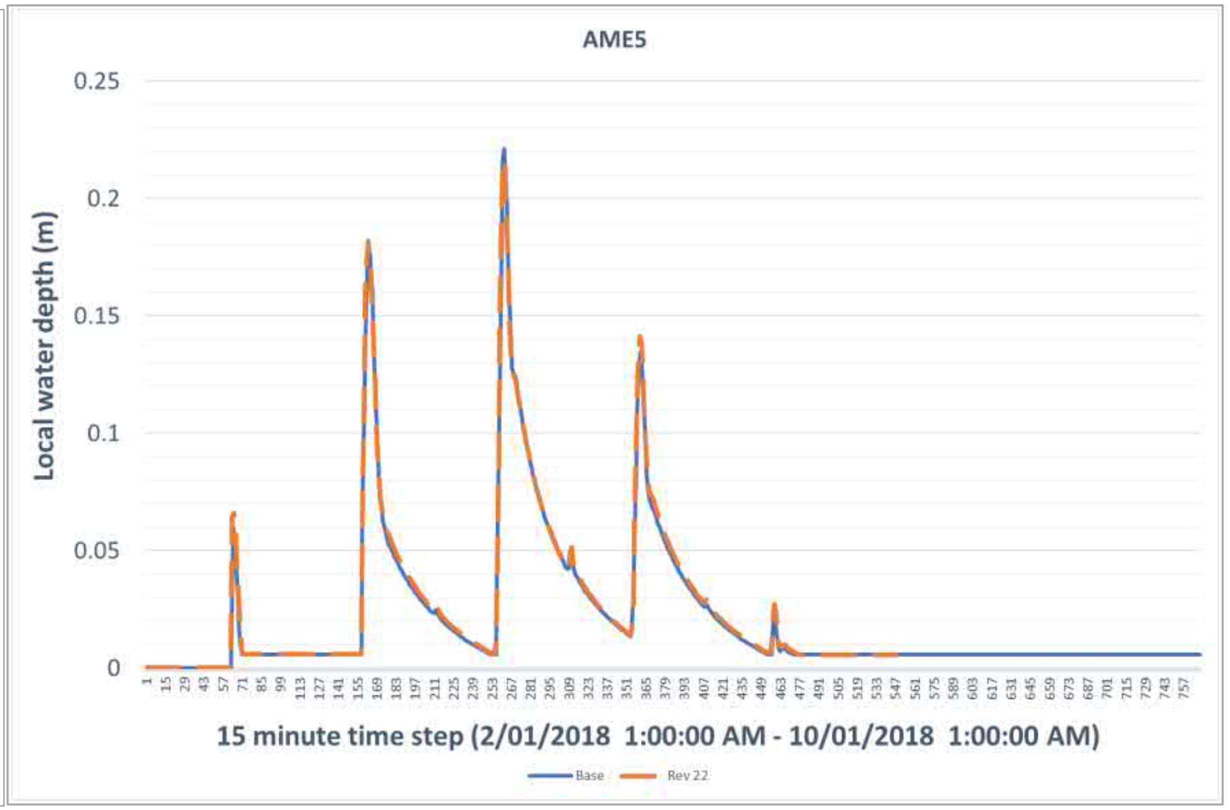


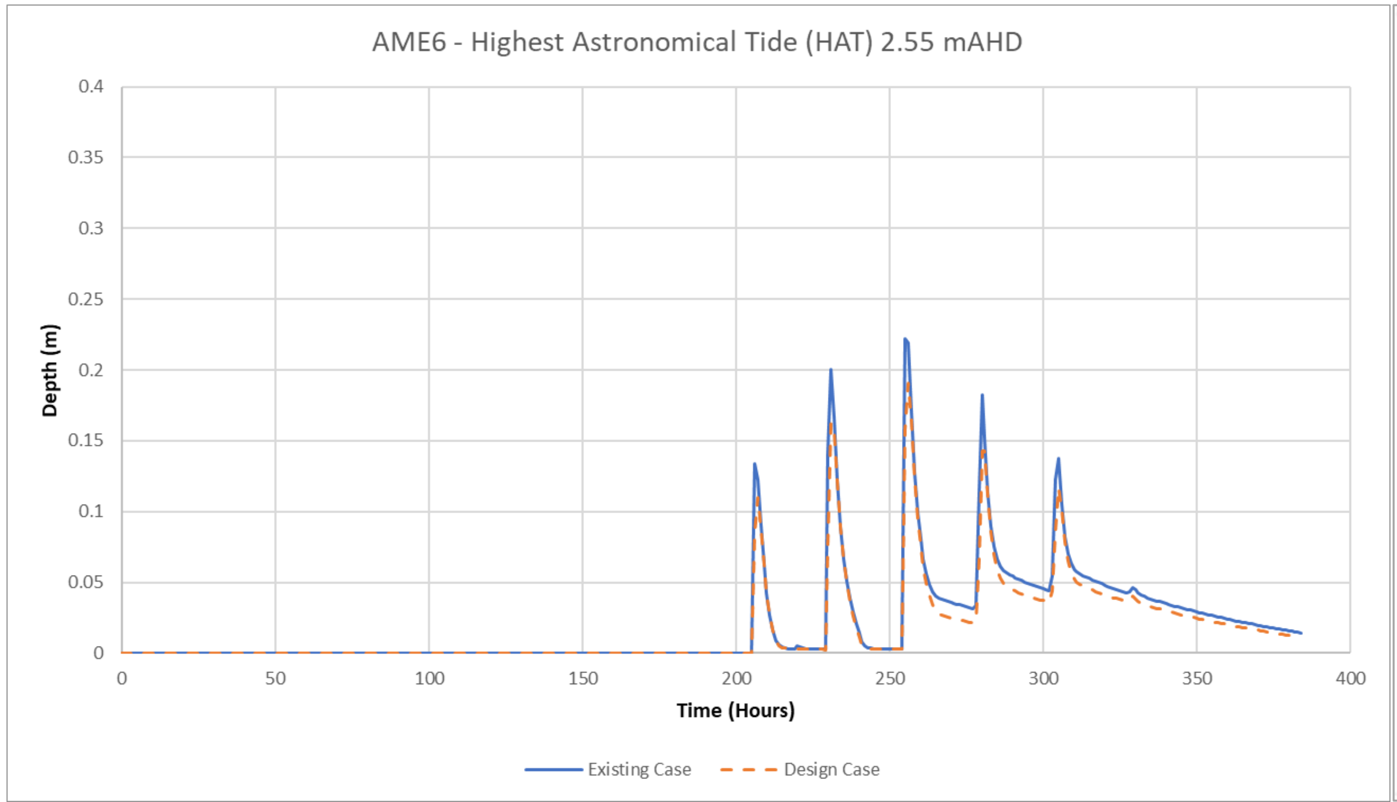
ATTACHMENT 1 – TIDAL INUNDATION DEPTH-DURATION PLOTS

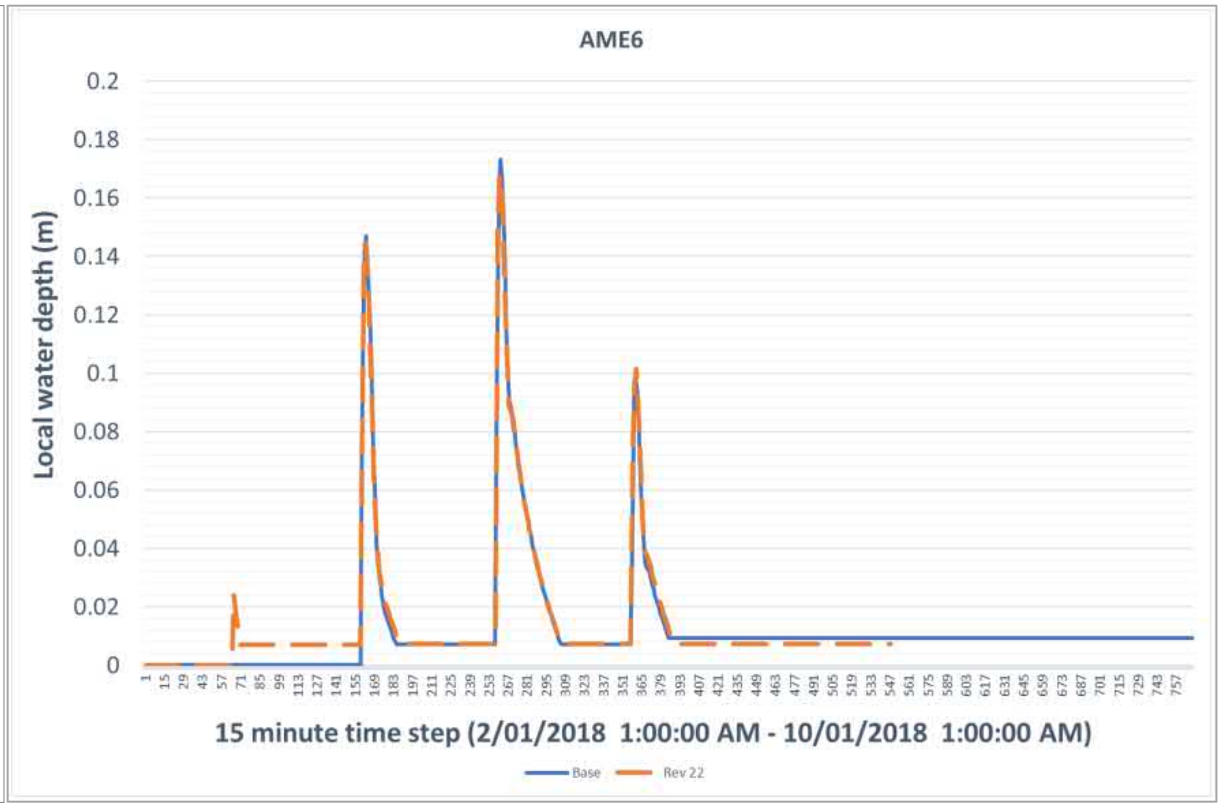
ADVISIAN MODELLING

RPS MODELLING (ERD 2020)



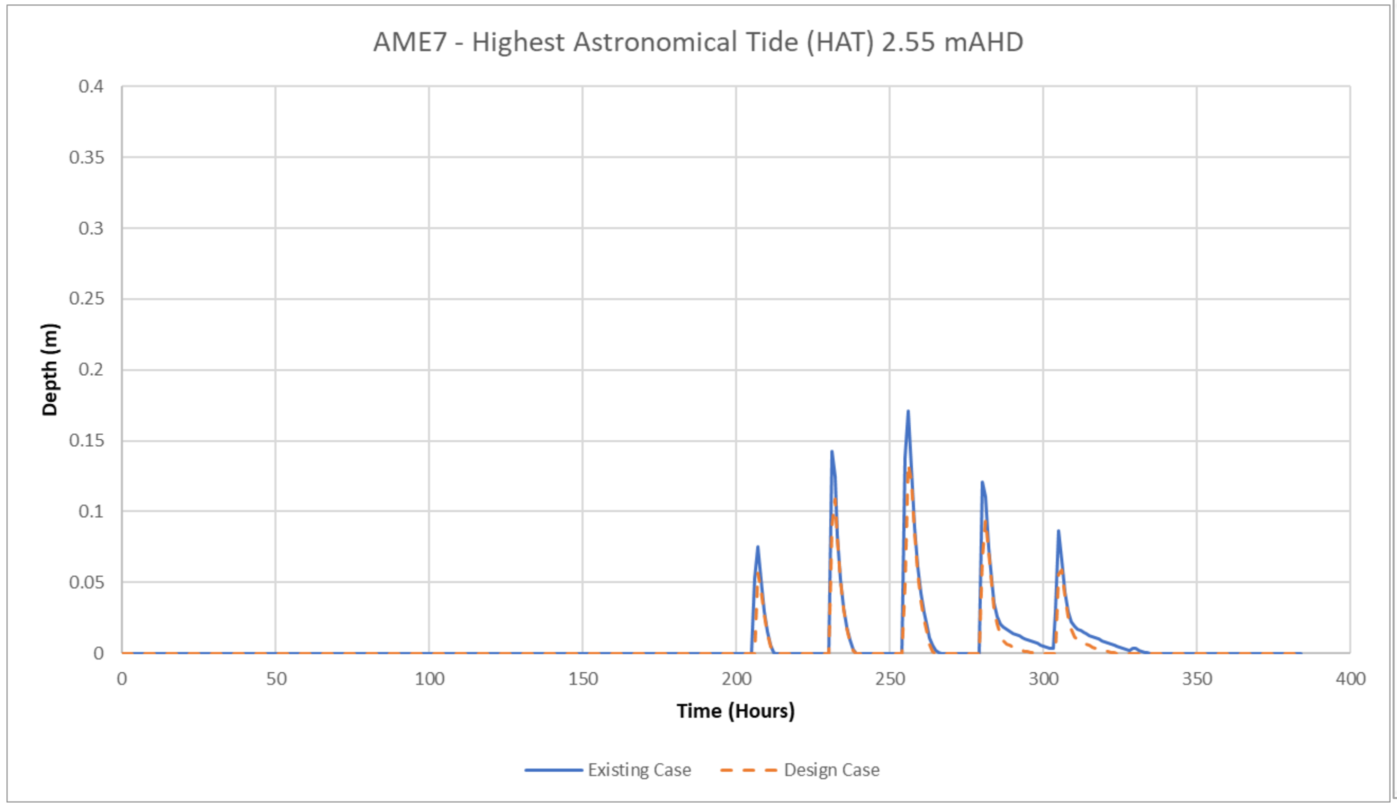


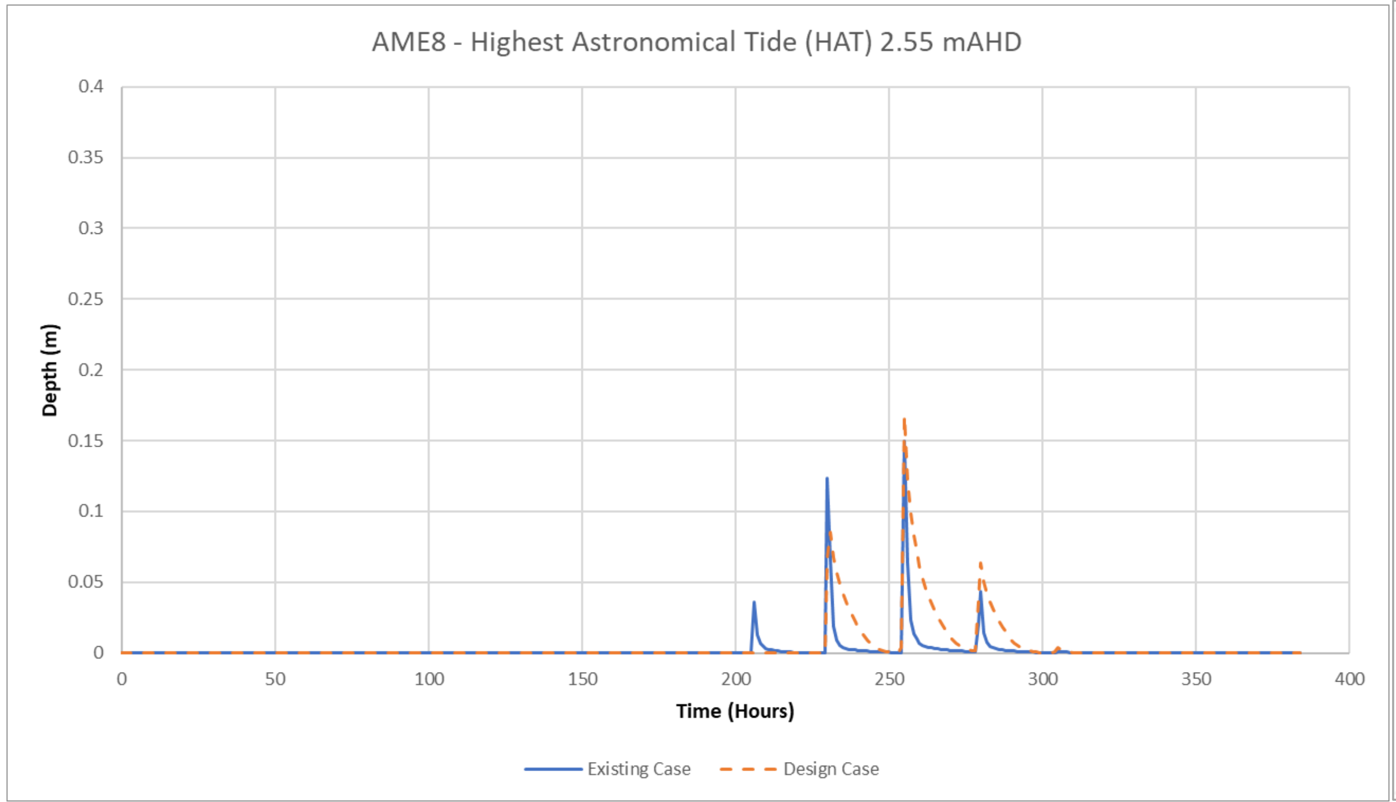




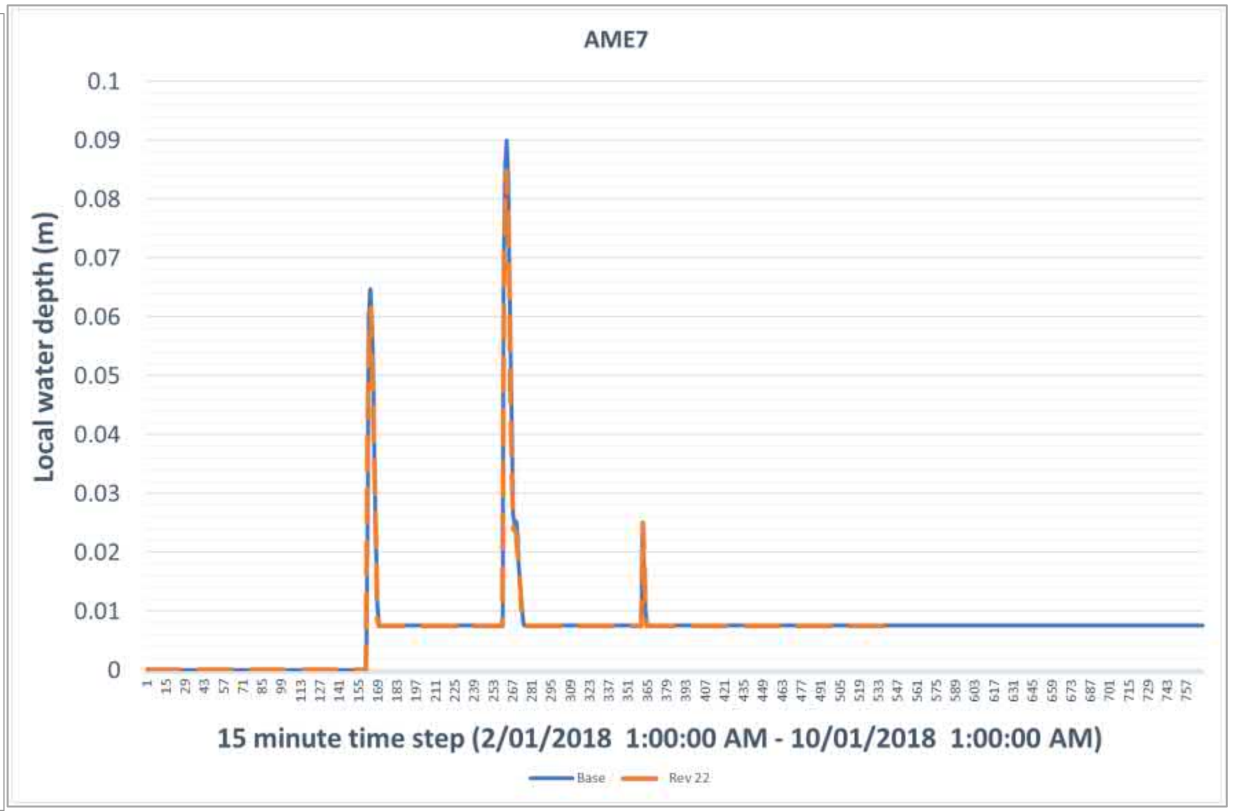
ATTACHMENT 1 – TIDAL INUNDATION DEPTH-DURATION PLOTS

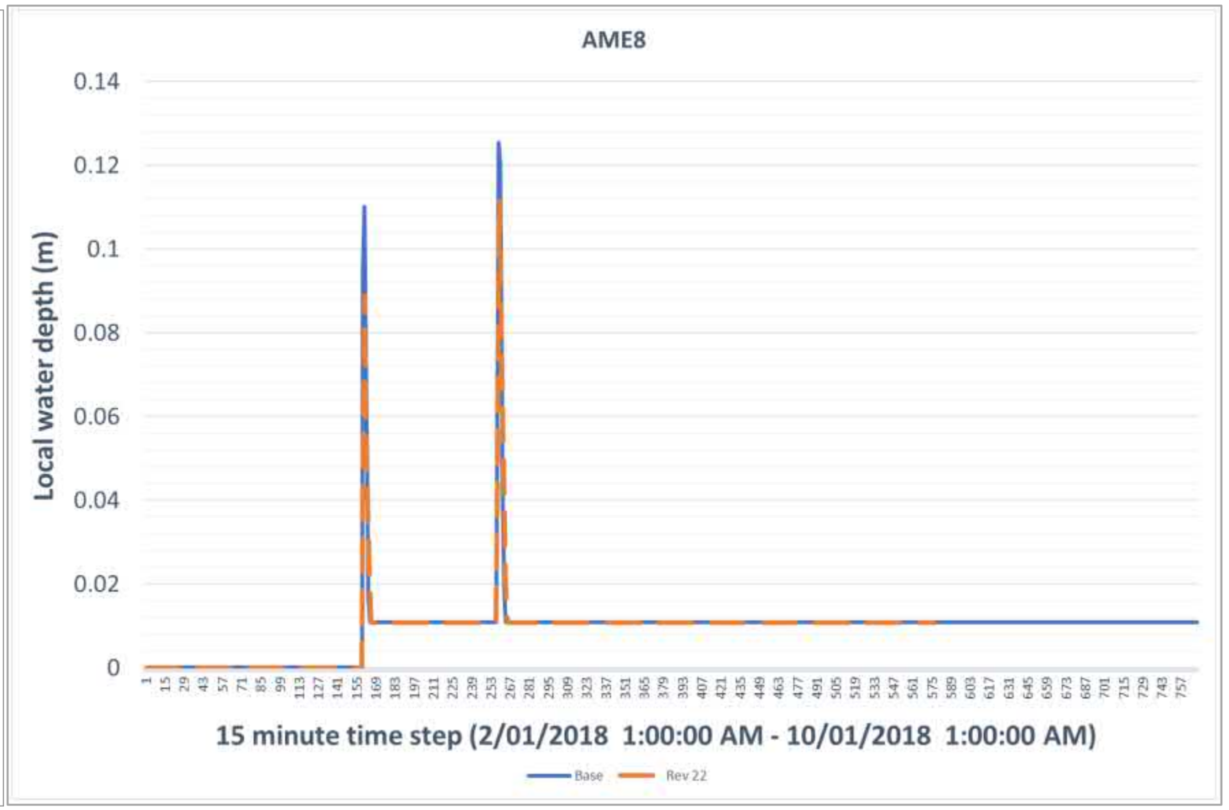
ADVISIAN MODELLING





RPS MODELLING (ERD 2020)





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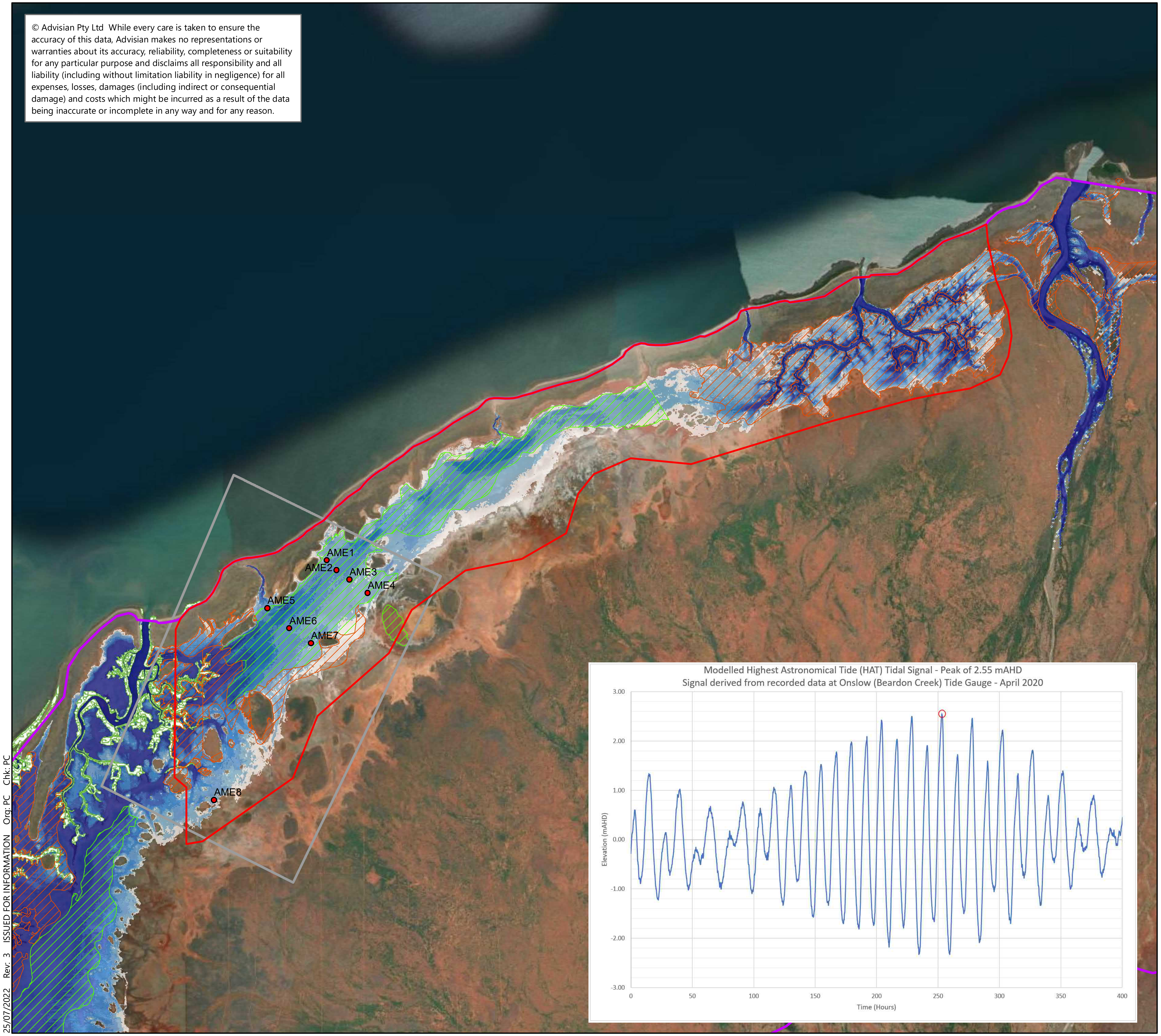
ATTACHMENT 2

BASE CASE
HIGHEST ASTRONOMICAL TIDE
16 DAY TIDAL SIGNAL SIMULATION
PEAK INUNDATION DEPTH AND EXTENT



Legend

- Tidal Inundation - Study Area of Interest
- Hydraulic model boundary
- Depth Duration Plot Locations [ERD (2020)]
- RPS Model Extent (informs MS1175 conditions)
- BCH Coastal Samphire
- BCH Algal Mat
- BCH Mangroves

Peak Tide Inundation Depth (m)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020
False Easting: 500,000.0000

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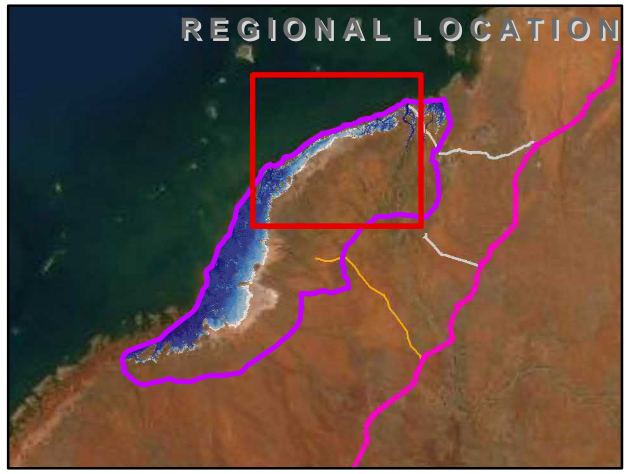
Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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25/07/2022 Rev: 3 ISSUED FOR INFORMATION Org: PC Chk: PC

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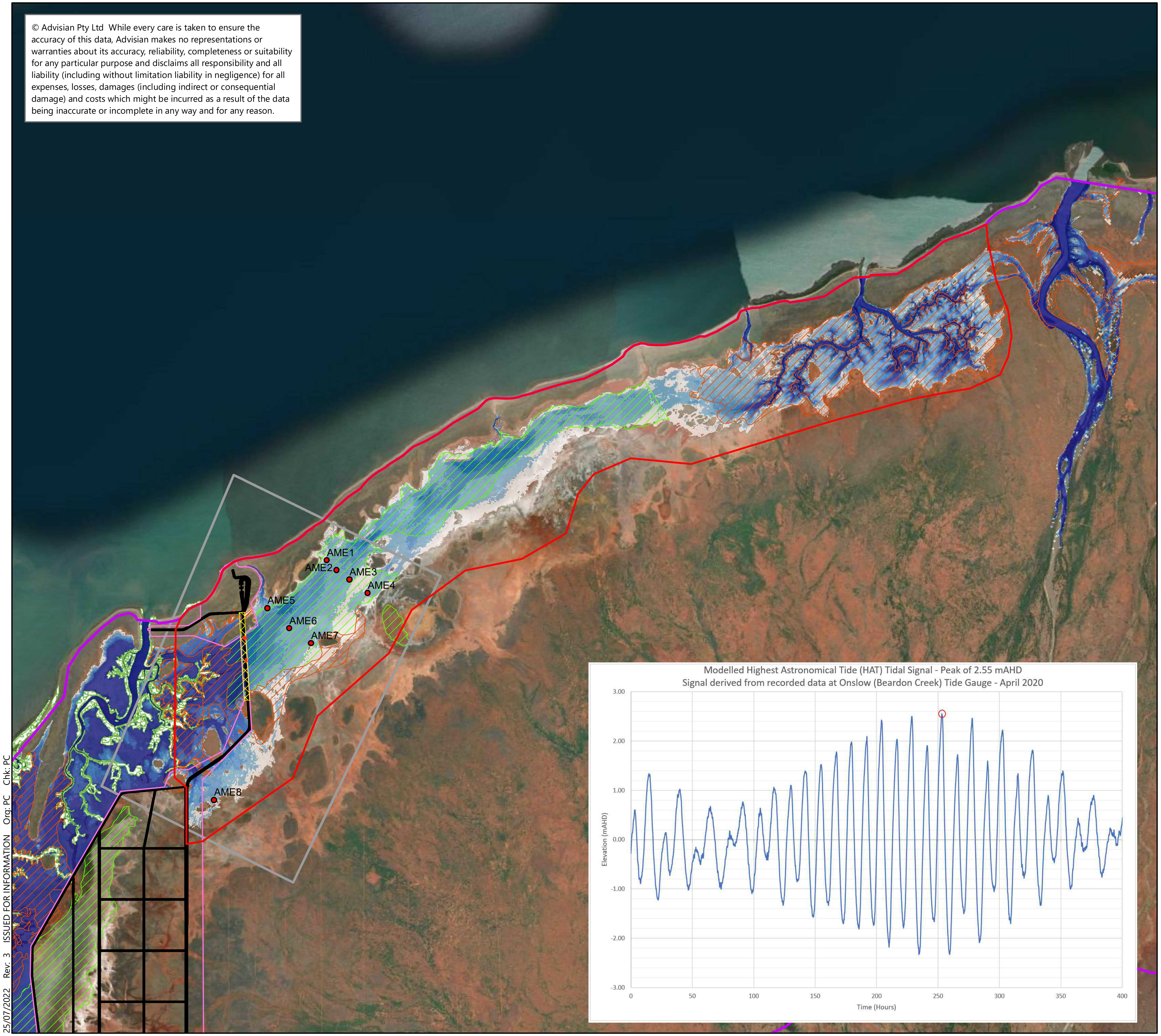
ATTACHMENT 3

DESIGN CASE
HIGHEST ASTRONOMICAL TIDE
16 DAY TIDAL SIGNAL SIMULATION
PEAK INUNDATION DEPTH AND EXTENT



Legend

- Tidal Inundation - Study Area of Interest
- Hydraulic model boundary
- Proposed culvert bank
- Section of Causeway Design Assessed
- MS1175 Development Envelope
- MS1175 Layout
- RPS Model Extent (informs MS1175 conditions)
- Depth Duration Plot Locations [ERD (2020)]
- BCH Coastal Samphire
- BCH Algal Mat
- BCH Mangroves

Peak Tide Inundation Depth (m)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020
False Easting: 500,000.0000

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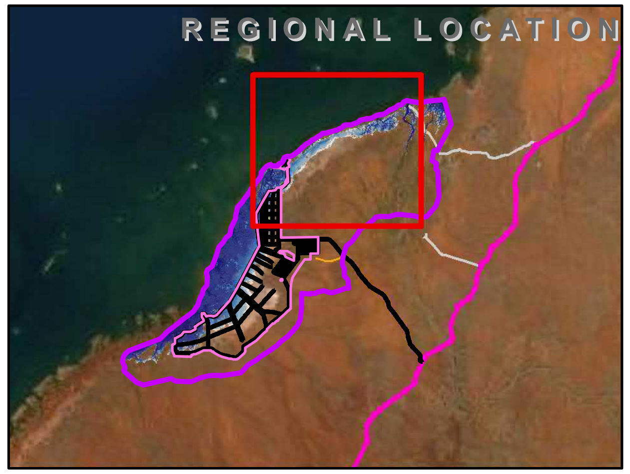
Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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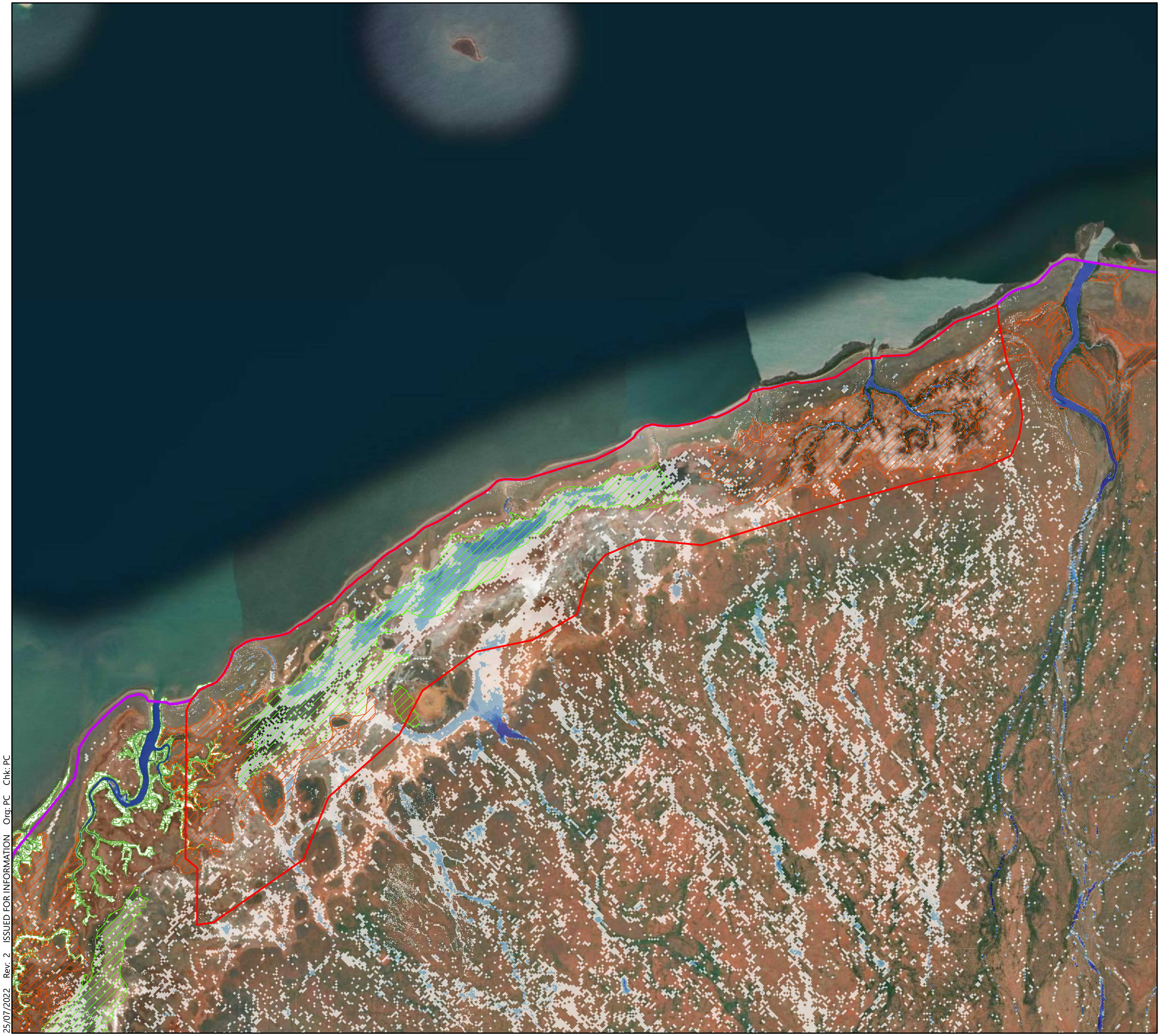

MARDIE SALT

ATTACHMENT 4

EXISTING CASE
1EY (1 YEAR ARI) FLOOD
PEAK INUNDATION DEPTH AND EXTENT

Legend

- Tidal Inundation - Study Area of Interest
- Model boundary
- BCH Coastal Samphire
- BCH Algal Mat
- BCH Mangroves

Peak Inundation Depth (m)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020
False Easting: 500,000.0000

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Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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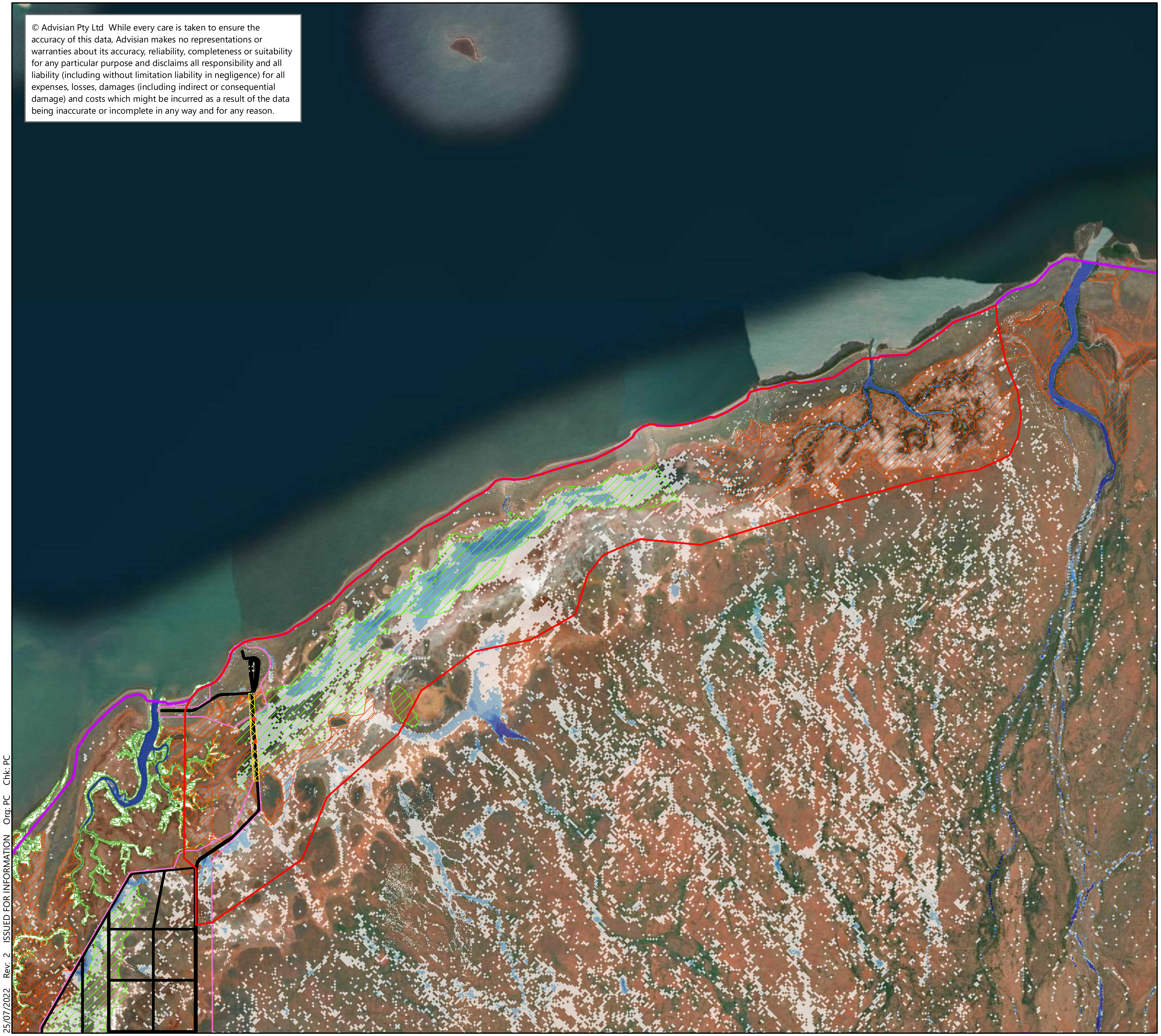

MARDIE SALT

ATTACHMENT 5

DESIGN CASE
1EY (1 YEAR ARI) FLOOD
PEAK INUNDATION DEPTH AND EXTENT

Legend

- Tidal Inundation - Study Area of Interest
- Model boundary
- Proposed culvert bank
- Section of Causeway Design Assessed
- MS1175 Development Envelope
- MS1175 Layout
- BCH Coastal Samphire
- BCH Algal Mat
- BCH Mangroves

Peak Inundation Depth (m)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- >1

Coordinate System: GDA2020 MGA Zone 50
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Scale at A3 - 1:70,000

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Meters

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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25/07/2022 Rev: 2 ISSUED FOR INFORMATION Org: PC Chk: PC