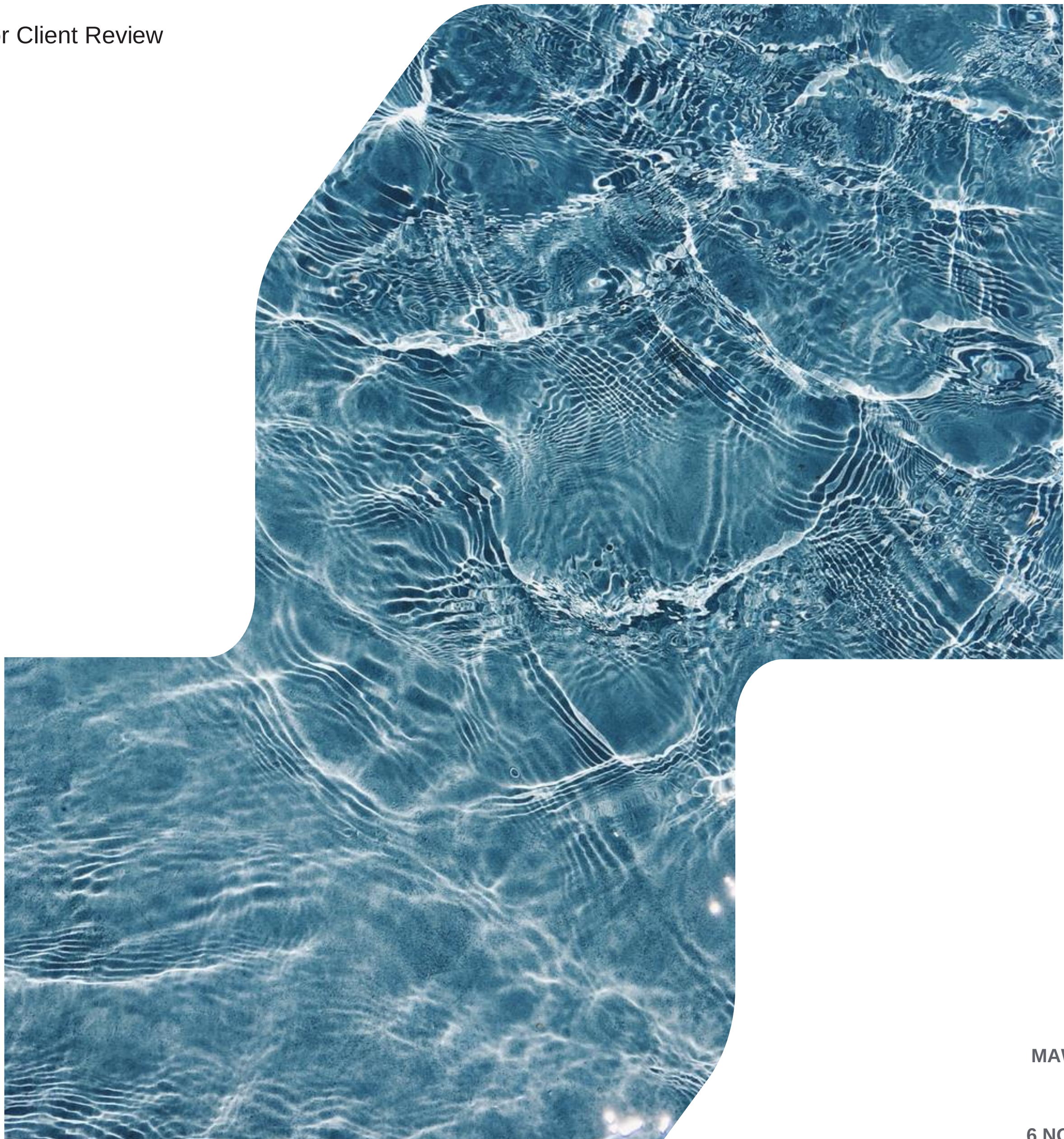
BCI MARDIE – ADDENDUM: SCOUR POTENTIAL– RETURN PERIOD ANALYSIS FOR WATER FLOW AND WAVES AT POND WALLS, NAVIGATION ROUTE AND PIPELINE EASEMENT

For Client Review



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1 INTRODUCTION

This document is an addendum to the RPS report “BCI Mardie - Return period analysis for water flow and waves at pond walls, navigation route and pipeline easement” Rev 0 (2020). The hydrodynamic and wave modelling results from the return period analysis study suggested that the current and or wave energy is indicative of potential scour issues for the *in-situ* sediments. Therefore, a desktop scour potential assessment has been conducted to investigate and quantify the potential scour under the extreme events modelled. The areas of concern for scour for the project include the existing gas-pipeline easement and the toe of the proposed pond walls and potential wave-break structure. Figure 1.1 and Figure 1.2 show the model domains and output point locations that have been applied to the coupled wave and hydrodynamic modelling as well as the proposed pond wall and potential wave-break locations. For details of the study background, the detailed methodology and outputs for the coupled hydrodynamic and waves models refer to the main report (RPS, 2020).

BCI have commissioned this additional desktop assessment to quantify further details:

1. Calculations of scour potential from waves and currents at locations along the pond walls (p-series on Figure 1.1), and gas-pipeline easement (transects on Figure 1.2) for water levels with return periods of 10, 20, 50 and 100 years.

2. Assessment for the effect of the pond walls on the scour potential at the easement by comparison to the case without pond walls in place (i.e. with no further development of the area).

3. Assessment of the effect of a wave-break, which BCI have proposed to construct near the seaward end of the easement to shield locations further along the easement from erosion due to water flow and waves generated during cyclones.

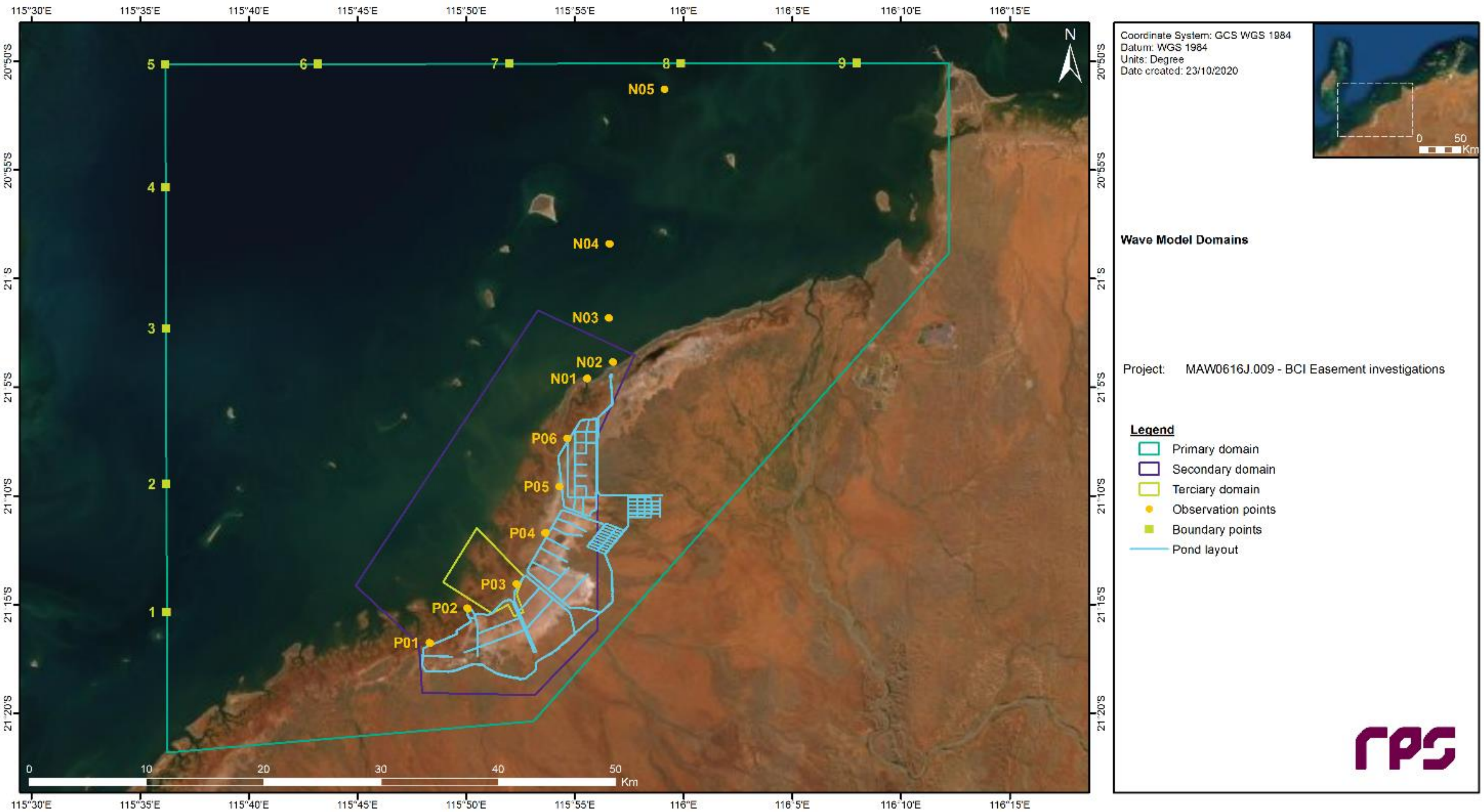

Figure 1.1: Domain boundaries for the grids applied to wave modelling. The numbered green points around the offshore boundary are input points of variables from the regional cyclone modelling. The yellow markers indicate output points for the calculations of water level and wave parameters along the pond walls (p-series) and navigation channel (n-series). The boundaries of the secondary grids are marked as purple lines. The boundaries of the tertiary grid of the wave model are marked in light green. The proposed pond walls are marked as light blue lines.

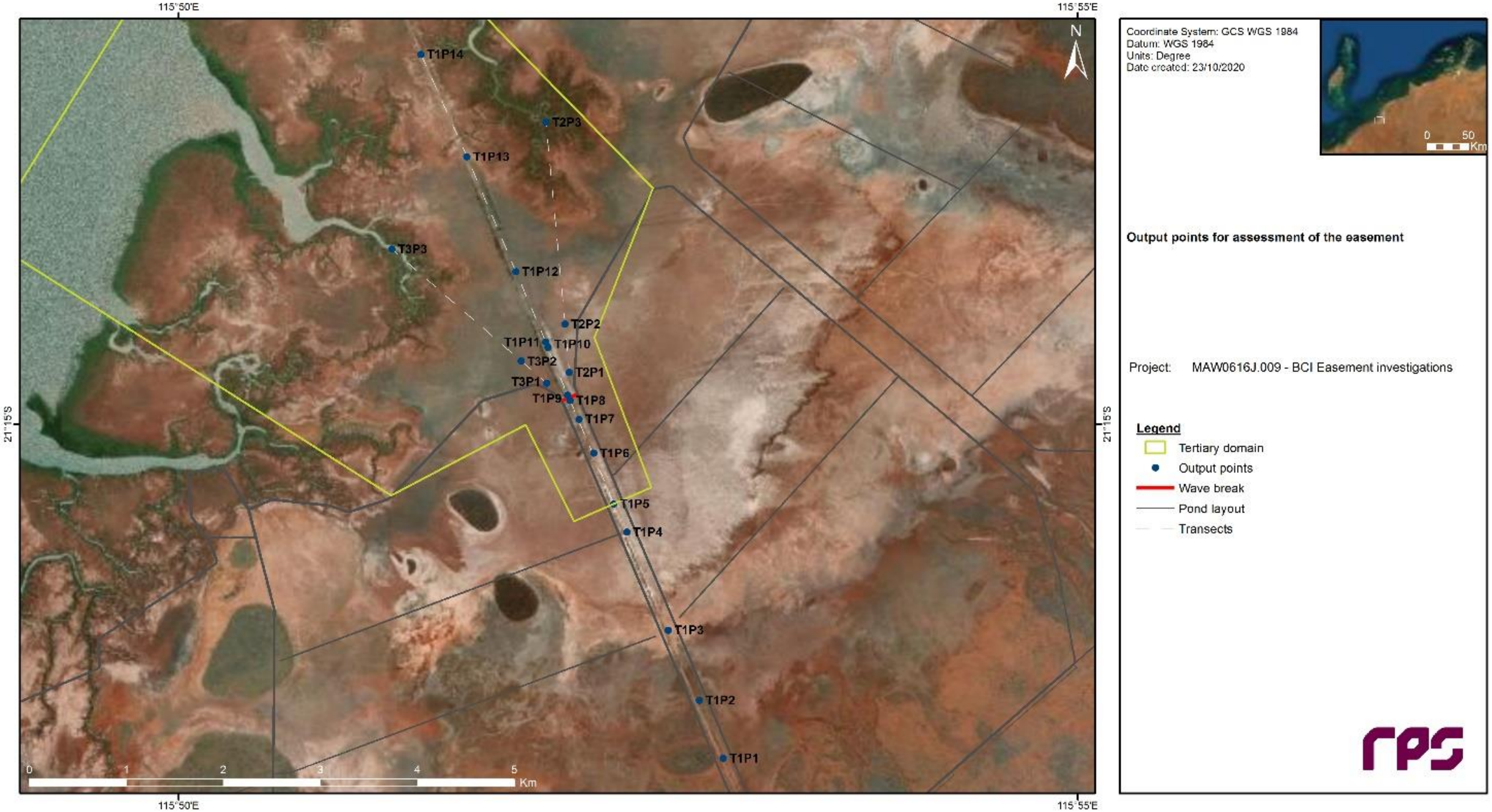

Figure 1.2: Closer view of the tertiary grid applied to wave modelling over the easement and approaches. The bounds of the grid are marked in yellow. Output points for the easement investigation are marked as blue points. The proposed alignments of the pond walls are marked as black lines. The proposed position of the wave-break is marked in red.

2 SUMMARY OF RELEVANT GEOTECHNICAL INFORMATION

RPS was provided with reports from three previous geotechnical investigations that have been conducted at the project site:

1. Arup, 2013. Sales Gas Onshore Pipeline – Geotechnical Advice
2. Advanced Geomechanics 2014. DomGas Onshore Intertidal Zone: Geotechnical Aspects
3. CMW Geosciences 2020. Mardie Salt Project – DFS Factual Geotechnical Report Mardie, WA

The first two investigations were specifically related to the pipeline easement corridor, with the third covering the entire project site.

The project site covers an area of intertidal (inundated during tidal events – from the shore up to approximately the start of the pond walls) and supratidal (inundated during exceptional events e.g. highest astronomical tide, storm surges – behind where the pond walls start) flats located east of a littoral fringe and west of an area of alluvial outwash (CMW 2020). Arup (2013) described the surficial sediments along the pipeline easement as predominantly sand near the shoreline (KP0 in the report) where the mangroves start, changing to finer grained (silts and clays) within the mangroves (KP0-2 in report) and behind them (KP2-11.5 in report). Note that in the Arup reference system the proposed pond walls are located from approximately KP5.6 to 11.5.

Arup (2013) describe the trench backfill material as a mixture of Clayey Silt with pockets of Silty Sand, with the proportion of each varying along the pipeline easement. The typical natural material away from the pipeline alignment at the project site is described as Clayey Silt of approximately 1m thickness, underlain by fine grained Silty Sand. Arup (2013) suggest that the pipeline backfill was a mixture of these two natural ground materials.

The critical geotechnical information required as input to the scour potential calculation is the particle size distribution (PSD) of the sediments and the proportion of mud (in the van Rijn [2005] cohesive sediment equation, this refers to silt and clay-sized particles <50 µm). For the calculation of scour potential, the full detail of the PSD down to clay-sized particles (2 µm) is ideal, particularly at this site, where there is a relatively high proportion of fine material. This information is not always available as it requires additional laboratory testing, as standard sieve tests only go down to particle sizes of 75 µm. Only the Arup (2013) report had detailed PSD data down to clay-sized particles available, therefore this was the data that has been used for the calculations. The PSD data was cross-checked against the summary data provided in the other reports to ensure it was representative of the project site. A summary of the PSD results extracted from Arup, 2013 is presented in Table 2.1 and Figure 2.1.

Table 2.1: Summary of PSD results extracted from Arup (2013)

Location	Sample mid depth (m)	D_{50} (mm)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	P_Mud* (% <50 µm)
HA013	0.15	0.028	31	41	28	0	63
HA020	0.15	0.040	25	52	23	0	61
HA028d	0.95	0.065	52		48	0	Not available
HA042a	0.15	0.098	6	39	44	11	38
HA050	0.15	0.078	8	41	51	2	42
HA050a	.015	0.044	10	52	36	2	54
HA071	0.2	0.039	11	52	33	4	56
HA071	0.7	0.038	29	42	29	0	59
HA082a	0.2	0.033	12	57	26	5	60
HA082b	0.25	0.023	13	61	22	4	66

*Interpolated from PSD curves - Figure 2.1

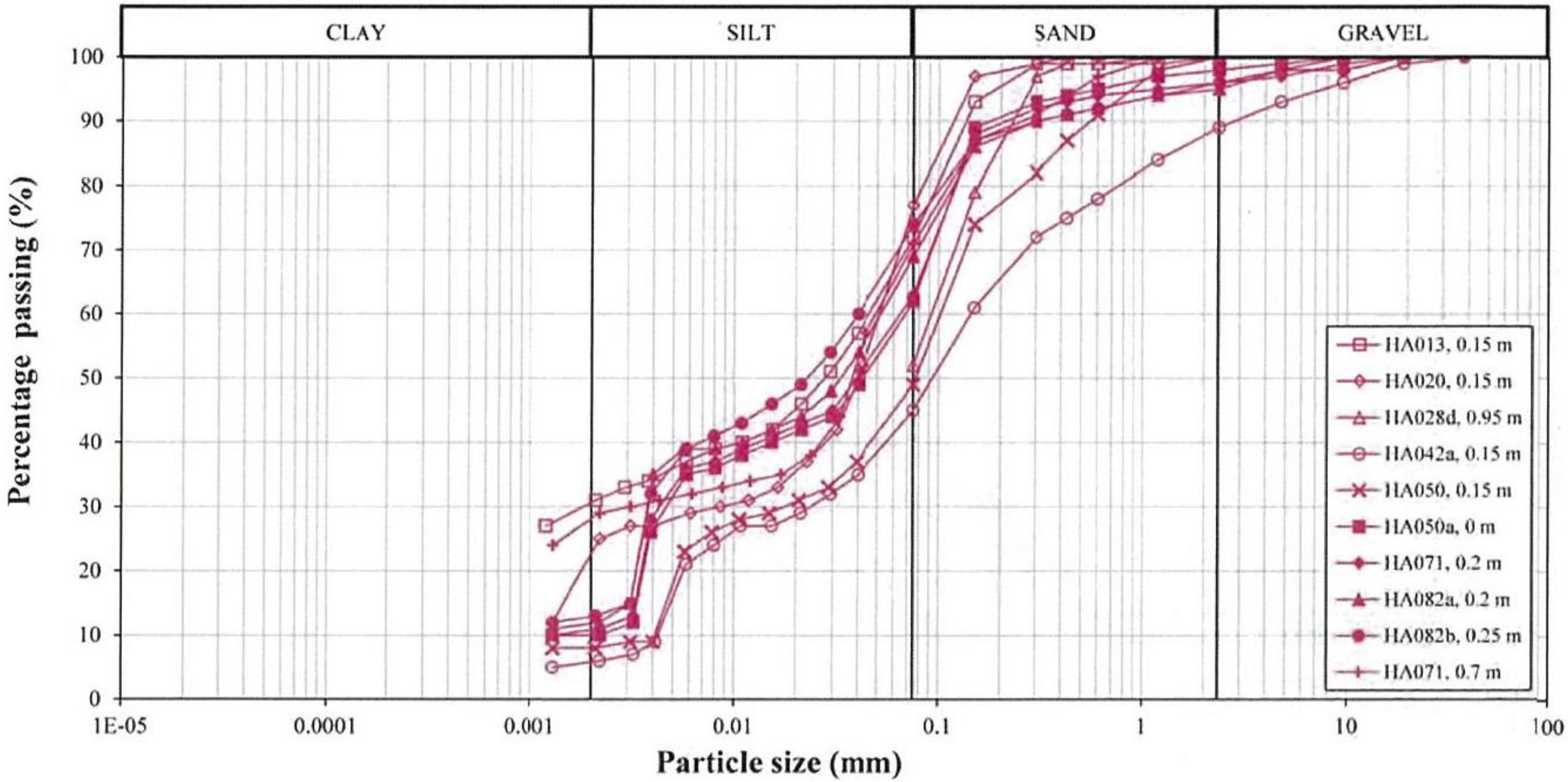

Figure 2.1: Particle-size distribution curves for samples taken along the pipeline easement extracted from the Arup (2013).

3 CALCULATION OF SCOUR POTENTIAL METHODOLOGY

Quantifying the potential scour associated with the extreme events modelled for each of the layouts was based on output of wave and current conditions at each of the output points identified along the three easement transects and for the pond wall locations (p-series; Figure 1.1 and Figure 1.2). The effect that the wave and current forcings have on sediment dynamics/scour is through the friction that they exert on the seabed, which is expressed as the bed shear-stress (frictional force exerted by the flow per unit area). The desktop assessment of scour potential was conducted by:

1. Calculating the threshold bed shear-stress required to mobilise (threshold of motion) the *in-situ* sediments at the project site according to equations outlined in Soulsby (1997) with additional terms added to the equations to account for cohesive sediments based on van Rijn (2005).
2. Calculating time-series of bed shear-stress based on the model predicted wave conditions, current conditions and the combined wave and current conditions, according to equations outlined in Soulsby (1997).
3. Determining if, and quantifying how often, the calculated bed shear-stresses exceeded the threshold of motion over the duration of the extreme events modelled for each of the output points.
4. Comparing the predicted scour potential between the no further development case, the base case pond wall layout and the base case pond wall layout with wave-break along the pipeline easement locations.

It should be noted that the scour calculations include an allowance for the cohesiveness of the sediments due to the typically high mud content (average proportion of mud, <50 µm, in samples outlined in Section 2 is 55%). The cohesive properties of muds increase the bed shear-stress required to mobilise the material. To be conservative, the lowest proportion of mud from the available samples (38%) has been used for the calculations.

There are other factors that will also lead to increased or decreased erosion potential at the site. Of note from previous geotechnical investigations, it was found that disturbance of the surface of the mudflat area through construction/traffic over the site, has caused increased erosion due to a breakdown of the surface crust that forms in the area when in an undisturbed state (Advanced Geomechanics, 2014). Therefore, in areas of traffic or disturbance due to construction the scour potential may be higher than predicted by the calculations within this addendum. The planning of construction activities will need to consider the disturbance to the mud flat surface and determine how to minimise disturbance to avoid increased scour.

4 RESULTS

4.1 Scour potential calculated at easement locations

This section compares the scour potential calculated for different return periods over the existing gas-pipeline easement for the cases where there were no further development; with pond walls without a wave-break; and with both pond-walls and a wave-break, to assess changes in the scour potential that would be imposed by the proposed development, and the effect of the wave-break in attenuating these changes.

Figure 4.1 to Figure 4.6 present time-series of the calculated bed shear-stress due to waves, currents and the combined waves and currents for the 10 and 100 year return period water level events modelled, for a selection of the points along transect 1 of the pipeline easement (T1P3, T1P6, T1P8 (immediately behind wave break), T1P9 (immediately in front of wave break), T1P10 and T1P12). Only the 10 and 100-year return period water level events and only a selection of the points are presented for simplicity and clarity while still showing the range of outcomes predicted. The calculated threshold of motion, for the average D_{50} of the *in-situ* sediment samples, is plotted on each panel to show times where bed-shear stress is predicted to exceed the threshold. Although a range of D_{50} values was investigated in the calculations, to simplify the reporting and for ease of comparison, all results presented in the report addendum are for the average D_{50} sediment size. Point T1P5 has been removed from the reporting, it was found to have boundary effects in the outputs due to being located very close to the boundary of the fine scale grid.

The figures for each of the return-period water level events over all the points, show that during the storm event the dominant bed shear-stress mechanism is due to currents. The wave-induced bed shear-stress becomes more pronounced after the peak of the storm, when higher elevation areas of the project site remain inundated due to a lag in draining away of the surge waters. This effect is more pronounced for the pre-development case which has large areas that have been flooded. Post development, the areas that can be inundated are more restricted. This results in lower bed shear-stress due to waves over the post-development layout overall. The greatest reduction is indicated for the points immediately seaward of the pond walls (Points T1P9 to T1P14).

It should be noted that prior to the storm in the time-series plots the bed shear-stress due to currents alone at many of the easement points is predicted to exceed the threshold of motion for short durations. This indicates that at times of typical spring tides there is predicted scour potential along the easement sites. Further investigation of the potential for scour during typical spring tides should be considered as, although the intensity and duration of each tidal peak would be far lower than that predicted for the extreme events, it will occur on a regular and ongoing basis and may have a cumulative impact on the erosion along the easement. This is reinforced by findings from a previous geotechnical investigation where scour has occurred along the pipeline easement, particularly for locations where the tidal creeks cross the easement (Arup, 2013). From the time-series plots it appears that the wave-break structure should be effective in reducing these ambient tidal current peaks in bed shear-stress for non-cyclone conditions (i.e. under natural tidal cycles), however further investigation is needed.

In order to quantify and compare the scour potential for the modelled layouts, the percentage of time the calculated bed shear-stress due to waves only, currents only and combined waves and currents exceed the threshold of motion, over the modelled time period, was determined for the points along the pipeline easement for each return period water level event and modelled layout (Table 4.1, Table 4.2 and Table 4.3). Additionally, comparison plots of the calculated percentage of time that bed shear-stress exceeds the threshold of motion at transect 1 points, for each of the modelled layouts, for each of the return period water level events are presented in Figure 4.7 to Figure 4.10.

The tables and figures indicate that the points along the pipeline easement that are immediately seaward of the pond walls (Points T1P9 to T1P14) have a lower scour potential when compared to the pre-development case for all the return period water levels modelled. The presence of the wave break has minimal effect on all except for T1P9 which is immediately in front of the structure. At point T1P9, consistently lower scour potential is predicted with the wave-break in place for all the return period water level events modelled.

The points along the easement transect that are between the proposed pond walls from the seaward end to approximately two thirds of the way to the landward end (T1P3 to T1P8), do not follow a consistent pattern for all the return period water level events. This is because these points are relatively high, being only inundated by extreme water levels, as such the wave conditions are very sensitive to the return period of the water level. Some points through this section of the transect are predicted to increase in scour potential post-development while others decrease. For this section of the pipeline easement the scour potential due to currents alone is predicted to be higher for points T1P8 to T1P4 with the pond walls in place, due to an increase in current magnitude from the restriction of flow between the pond walls. The inclusion of the wave-break structure is predicted to reduce the current magnitudes along this section and subsequently reduce the scour potential due to currents to similar or lower levels to the pre-development case.

However, the simulations indicated that the wave-break structure would have limited to no reduction in the scour potential due to waves along this section of the pipeline easement and therefore the scour potential due to combined waves and currents is not predicted to decrease due to the wave break structure. The ineffectiveness of the wave-break structure to reduce the scour potential due to waves along this section of the pipeline easement is attributed to the increased lag time in the draining of surge waters from behind the wave break. As noted in the main report (RPS, 2020), the design of the wave break structure could be improved by raising the height (allowing less water to overtop) and including drainage for water that becomes trapped behind the wave-break.

Inundation of Points T1P1 and T1P2 (at the most landward section of the easement) in the undeveloped case is only predicted for the peak of the water level surge, with only very small waves calculated for a short duration, resulting in a low predicted scour potential. Including the pond walls at these sites indicated increased scour potential due to higher water levels caused by the restriction of the area of flooding by the development. Including the wave-break reduced the scour-potential calculated by limiting the inundation level such that minimal waves are then expected at these higher elevation sites.

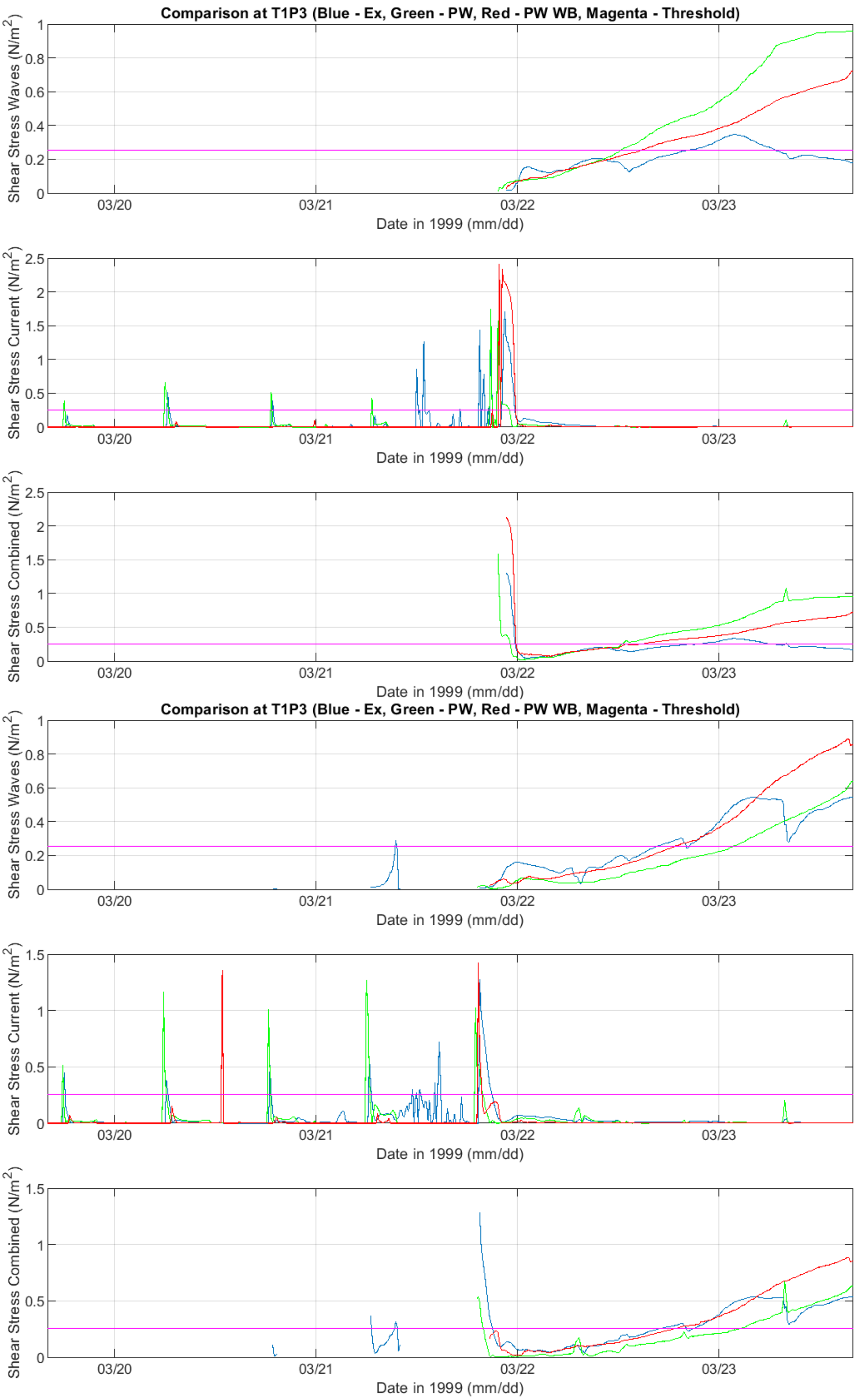

Figure 4.1: Time-series plots comparing calculations of bed shear-stress at T1P3, for return periods of 10 (top) and 100 years (bottom), for each model layout; blue – no further development, green – with pond walls and red – with pond walls and wave-break. The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

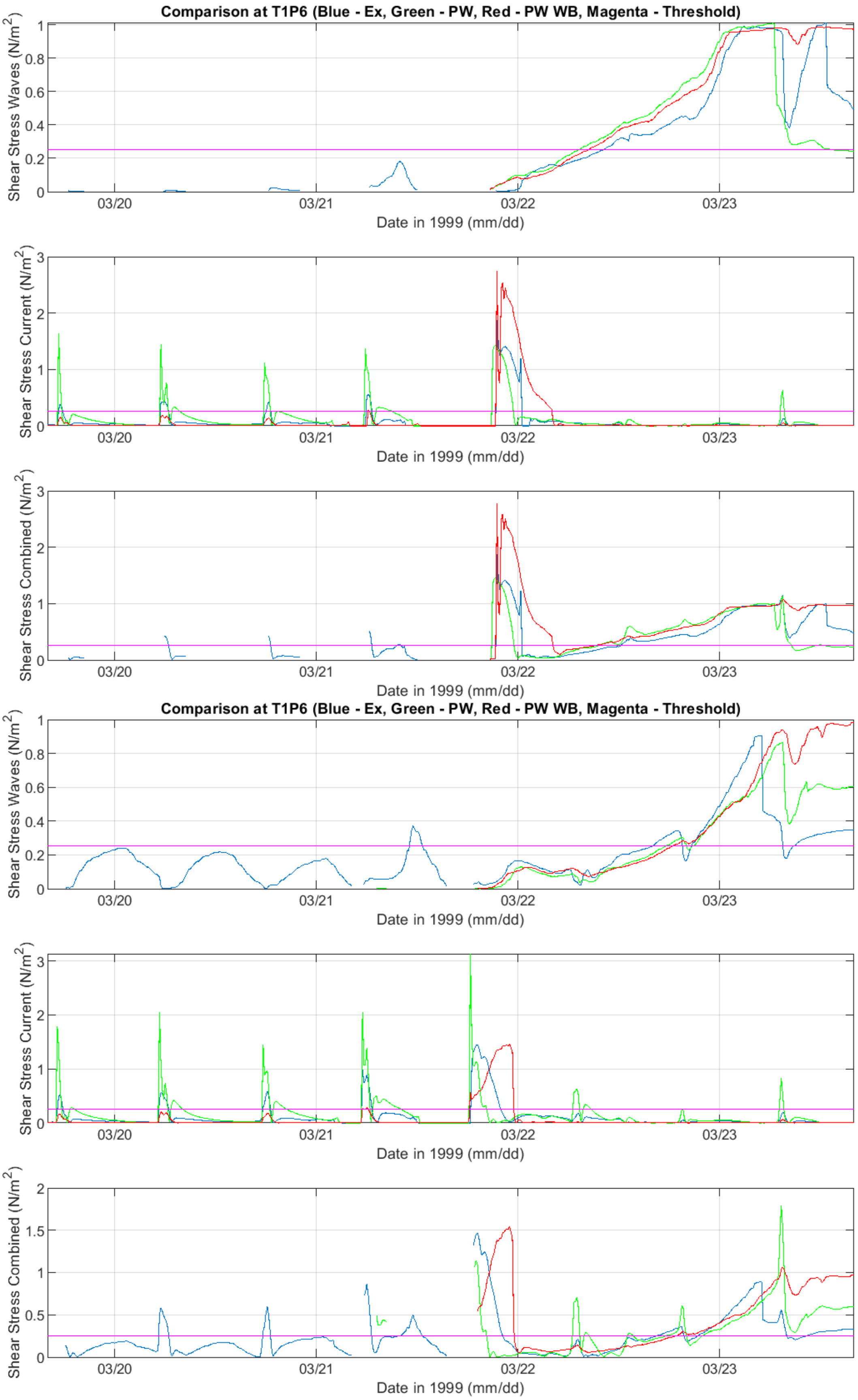

Figure 4.2: Time-series plots comparing calculations of bed shear-stress at T1P6, for return periods of 10 (top) and 100 years (bottom), for each model layout; blue – no further development, green – with pond walls and red – with pond walls and wave-break.. The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

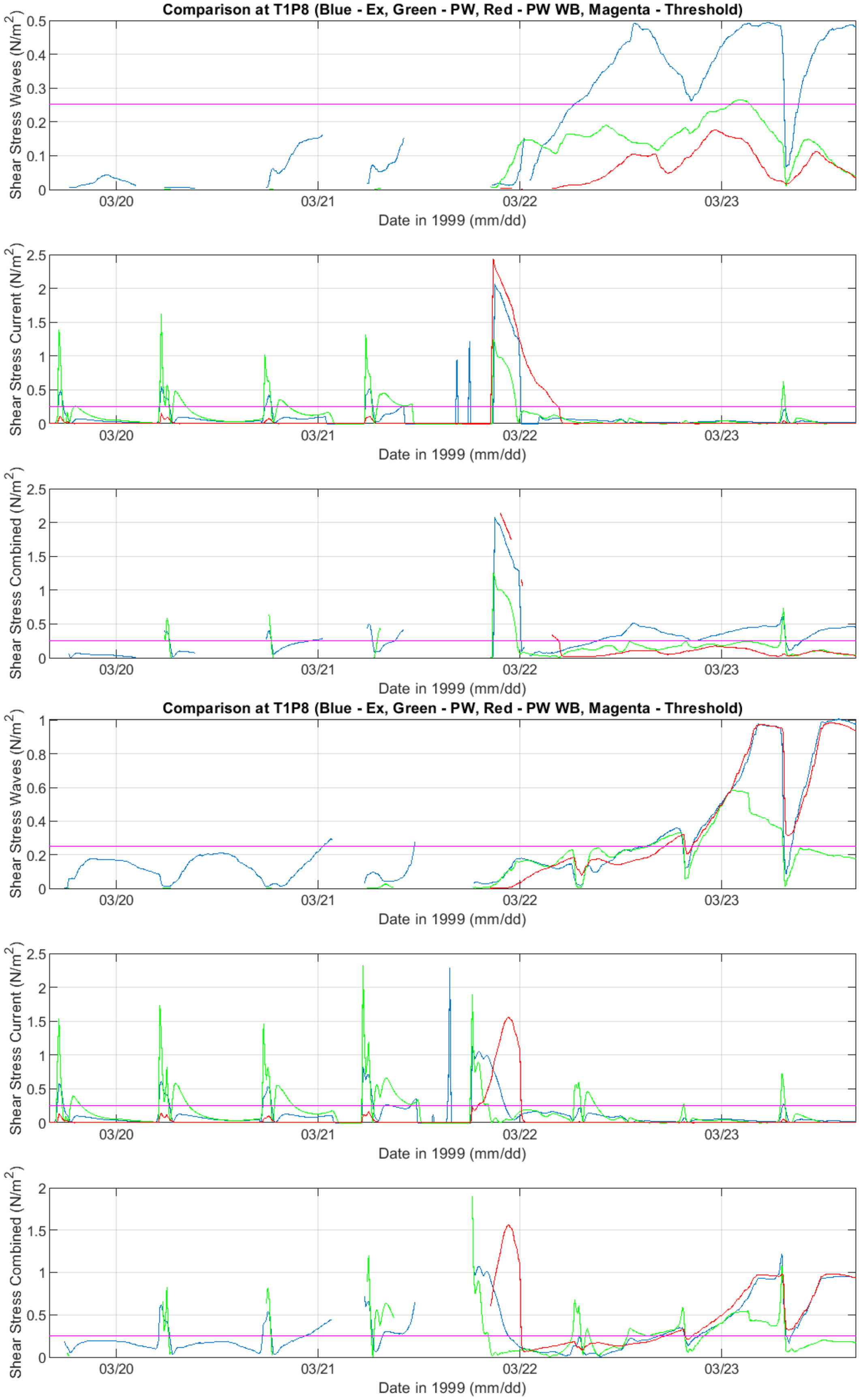

Figure 4.3: Time-series plots comparing calculations of bed shear-stress at T1P8, for return periods of 10 (top) and 100 years (bottom), for each model layout; blue – no further development, green – with pond walls and red – with pond walls and wave-break.. The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

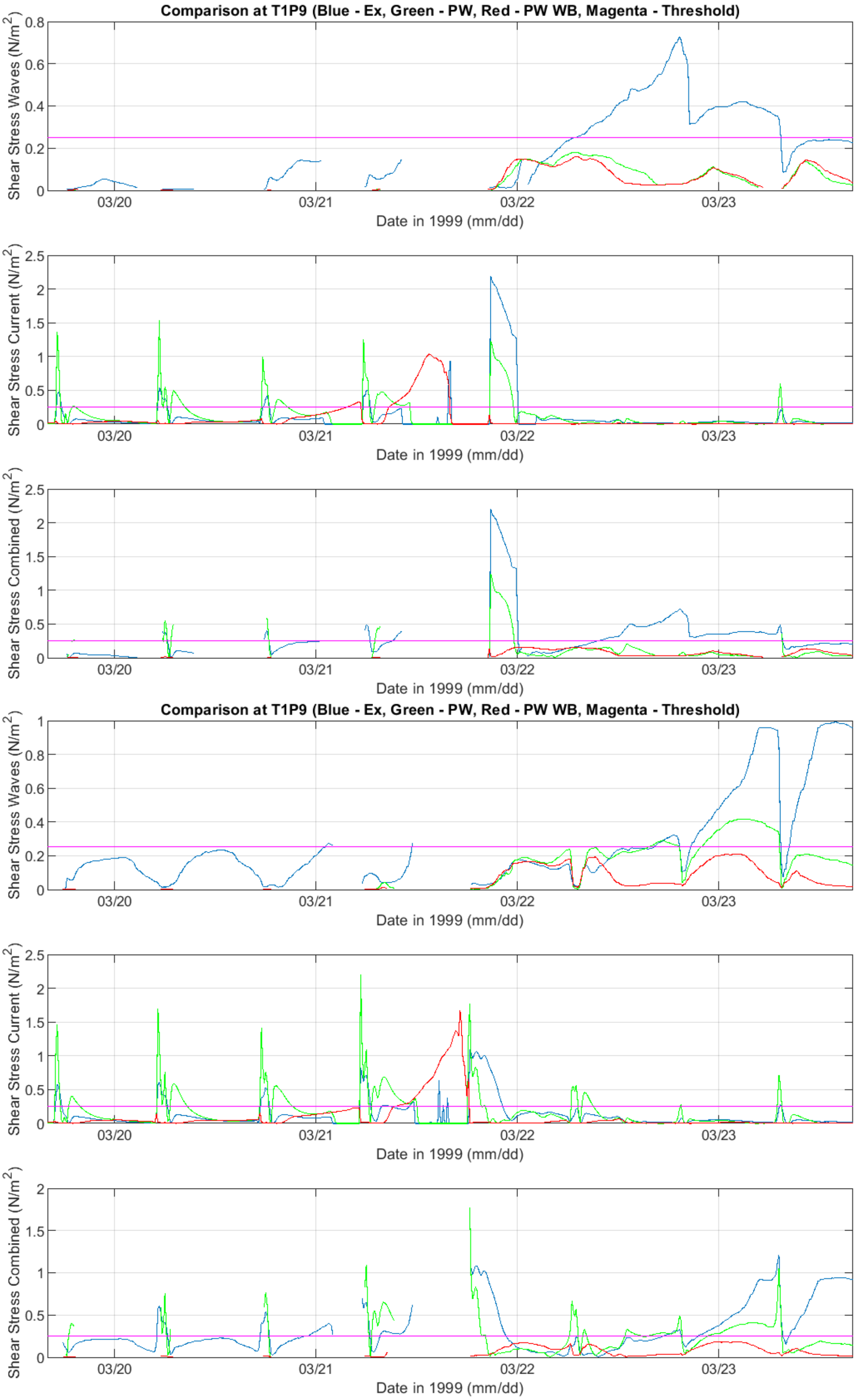

Figure 4.4: Time-series plots comparing calculations of bed shear-stress at T1P9, for return periods of 10 (top) and 100 years (bottom), for each model layout; blue – no further development, green – with pond walls and red – with pond walls and wave-break.. The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

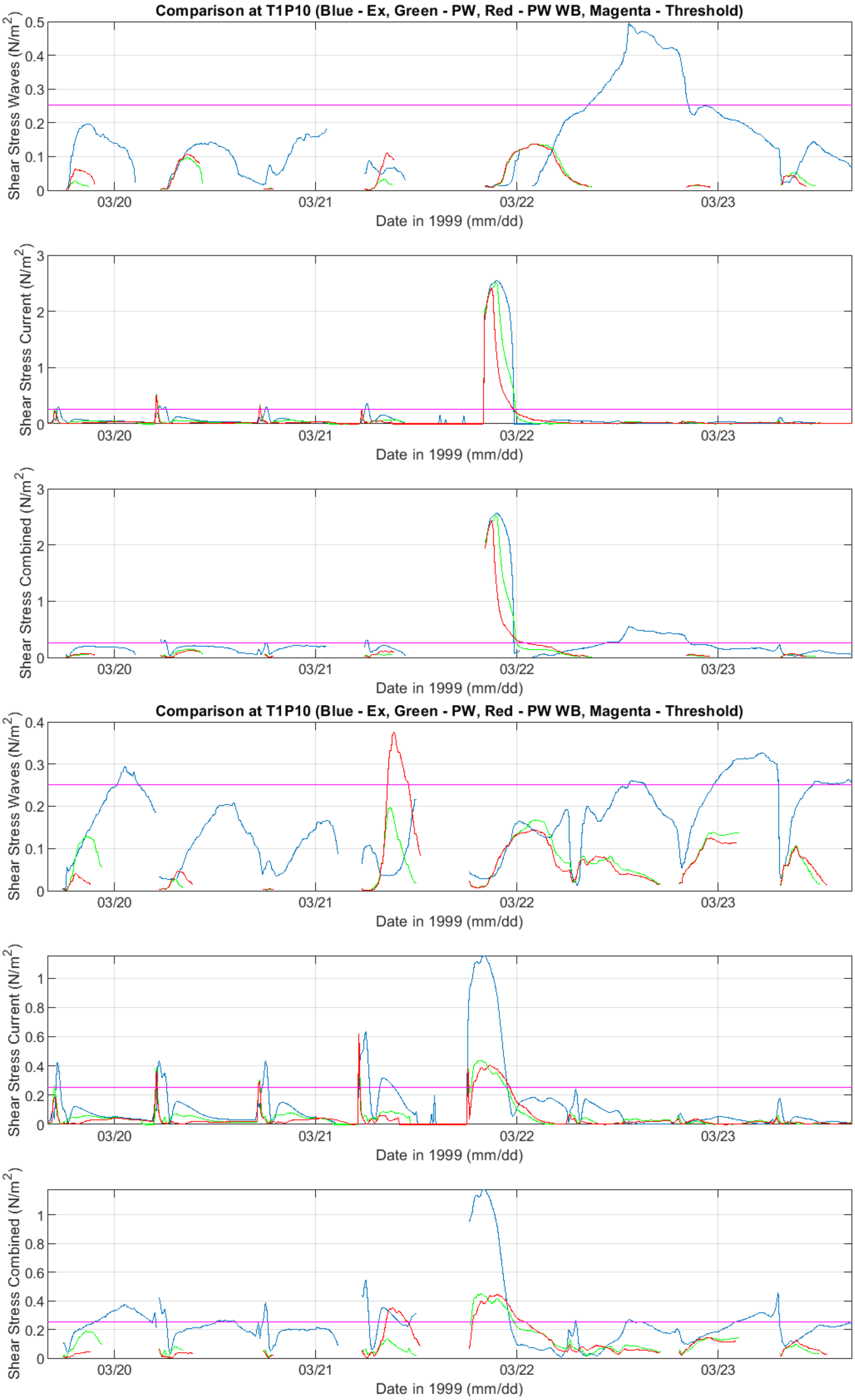

Figure 4.5: Time-series plots comparing calculations of bed shear-stress at T1P10, for return periods of 10 (top) and 100 years (bottom), for each model layout; blue – no further development, green – with pond walls and red – with pond walls and wave-break.. The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

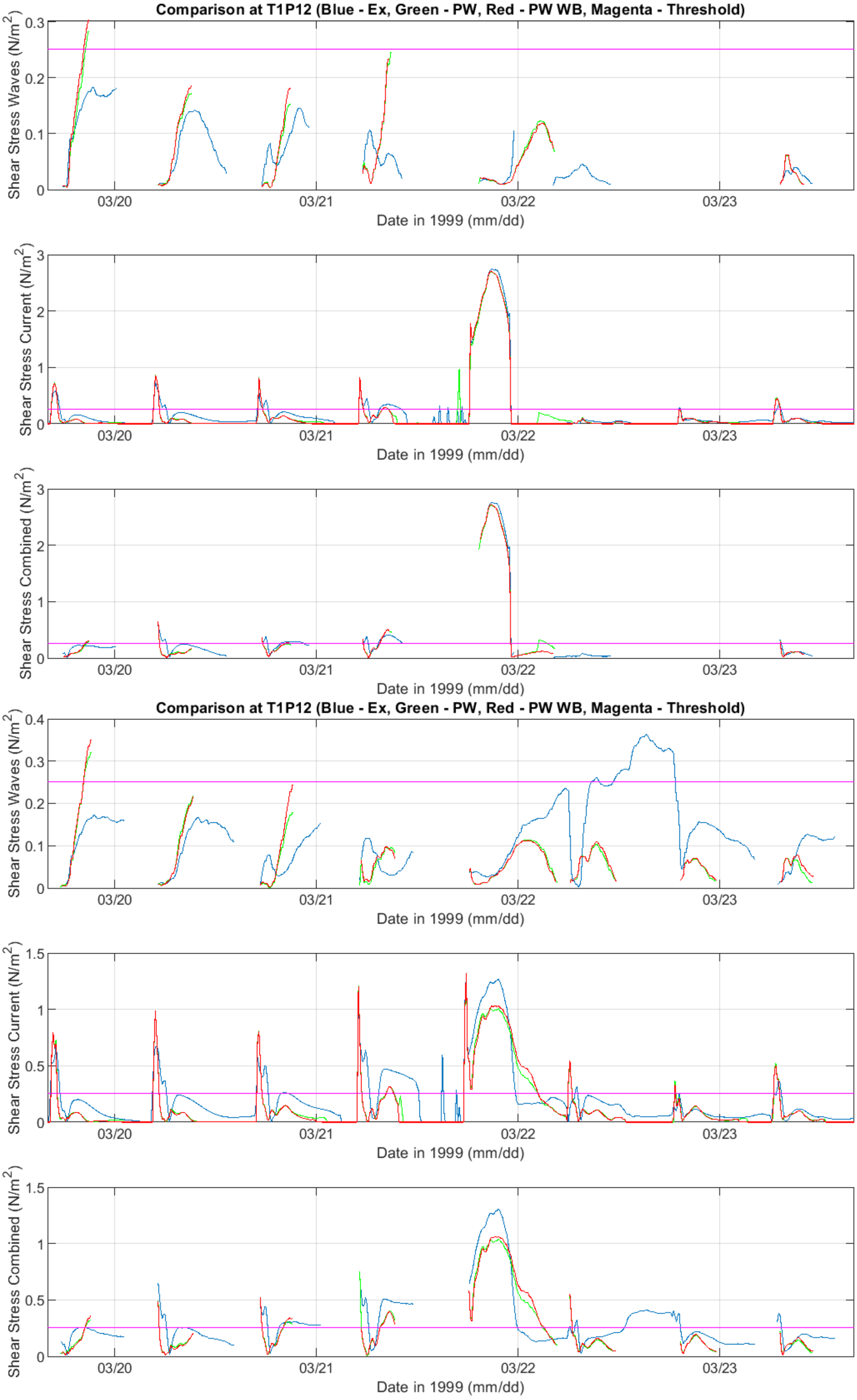

Figure 4.6: Time-series plots comparing calculations of bed shear-stress at T1P12, for return periods of 10 (top) and 100 years (bottom), for each model layout; blue – no further development, green – with pond walls and red – with pond walls and wave-break.. The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

Table 4.1: Calculated percentage of time bed shear-stress from waves only exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for return periods of 10, 20 , 50 and 100 years. Values provided for each layout modelled Ex - no further development, PW - with pond walls and PW WB – with pond walls and wave-break. Grey bar marks points immediately in front of (T1P9) and behind (T1P8) the proposed location of the wave-break.

Point	10-year Return Period			20-year Return Period			50-year Return Period			100-year Return Period		
	Ex	PW	PW WB	Ex	PW	PW WB	Ex	PW	PW WB	Ex	PW	PW WB
T1P1	0.0	8.3	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	8.3	0.0
T1P2	0.7	2.6	0.0	0.0	2.6	0.0	0.0	2.6	0.0	0.0	24.3	0.0
T1P3	11.1	28.9	26.5	23.9	25.0	28.6	24.1	18.2	26.3	24.3	15.1	22.4
T1P4	26.9	26.5	26.7	27.0	22.2	27.7	21.7	14.6	19.2	20.8	12.3	13.9
T1P6	31.0	31.5	32.9	31.5	16.8	32.8	24.6	26.0	23.1	24.3	22.7	22.5
T1P7	33.3	32.2	34.1	30.3	31.4	19.9	32.2	23.2	28.4	24.3	22.2	23.2
T1P8	33.3	2.4	0.0	31.2	7.5	18.2	25.6	20.3	29.5	25.3	14.6	22.7
T1P9	25.3	0.0	0.0	30.5	7.5	0.0	32.8	8.5	6.1	23.7	13.7	0.0
T1P10	12.5	0.0	0.0	28.8	0.0	0.0	22.0	0.0	0.0	17.5	0.0	2.6
T1P11	0.0	0.0	0.0	13.9	0.7	0.3	20.6	0.0	0.0	0.0	0.0	0.9
T1P12	0.0	0.5	0.9	7.6	0.0	0.7	10.9	1.2	0.9	8.5	1.0	1.0
T1P13	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.5	0.0	0.2
T1P14	0.2	0.0	0.5	0.0	0.0	0.3	0.0	0.5	0.0	0.5	0.0	0.0

Table 4.2: Calculated percentage of time bed shear-stress from currents only exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for return periods of 10, 20 , 50 and 100 years. Values provided for each layout modelled Ex - no further development, PW - with pond walls and PW WB – with pond walls and wave-break. Grey bar marks points immediately in front of (T1P9) and behind (T1P8) the proposed location of the wave-break.

Point	10-year Return Period			20-year Return Period			50-year Return Period			100-year Return Period		
	Ex	PW	PW WB	Ex	PW	PW WB	Ex	PW	PW WB	Ex	PW	PW WB
T1P1	0.9	0.7	1.4	0.9	0.7	1.6	1.2	0.7	1.0	1.6	0.7	0.9
T1P2	1.4	1.4	2.9	1.0	1.0	1.9	2.3	1.4	1.6	1.9	1.6	1.4
T1P3	3.8	2.9	2.1	3.1	2.8	1.0	4.7	2.6	0.5	4.0	2.6	0.7
T1P4	3.8	4.7	5.2	5.0	4.9	5.0	5.7	5.2	4.7	5.2	5.4	3.6
T1P6	5.9	9.9	7.3	7.3	11.4	6.4	7.6	13.3	6.6	7.8	15.6	6.2
T1P7	8.5	12.5	5.2	9.7	14.2	6.8	10.1	16.5	6.6	10.2	19.8	5.5
T1P8	7.3	14.6	8.3	9.0	16.8	8.0	9.9	18.9	6.9	10.9	20.8	5.4
T1P9	7.3	14.9	9.2	9.2	17.0	9.5	10.6	18.9	9.5	11.3	21.3	9.2
T1P10	5.7	4.5	4.5	8.3	4.7	5.0	10.1	5.4	5.2	10.9	5.4	5.5
T1P11	7.1	4.3	5.2	10.4	4.7	5.0	12.1	5.5	5.9	12.8	6.1	6.2
T1P12	14.4	9.7	9.0	15.3	13.3	11.8	17.2	13.5	14.0	20.1	14.2	14.2
T1P13	20.1	14.6	15.3	23.7	17.3	17.0	28.8	18.9	18.5	30.7	20.5	20.5
T1P14	12.3	11.4	11.8	14.4	13.7	13.5	17.3	16.5	16.3	17.7	16.8	17.0

Table 4.3: Calculated percentage of time bed shear-stress from combined waves and currents exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for return periods of 10, 20 , 50 and 100 years. Values provided for each layout modelled Ex - no further development, PW - with pond walls and PW WB – with pond walls and wave-break. Grey bar marks points immediately in front of (T1P9) and behind (T1P8) the proposed location of the wave-break.

Point	10-year Return Period			20-year Return Period			50-year Return Period			100-year Return Period		
	Ex	PW	PW WB	Ex	PW	PW WB	Ex	PW	PW WB	Ex	PW	PW WB
T1P1	0.9	8.3	0.0	0.9	8.3	0.0	1.4	0.0	0.0	2.1	8.3	0.0
T1P2	6.1	3.3	0.0	2.3	3.3	0.0	2.6	3.3	0.0	3.3	24.6	0.0
T1P3	10.7	30.3	28.1	25.0	26.2	30.2	24.8	18.7	26.3	25.3	15.1	22.4
T1P4	29.6	30.2	32.6	30.3	23.9	32.9	24.8	16.6	23.4	23.2	14.6	17.2
T1P6	34.0	28.1	39.3	36.9	14.9	38.5	32.6	27.7	26.7	30.3	26.5	26.9
T1P7	39.9	34.1	41.4	38.6	34.1	25.0	35.5	29.3	34.3	34.0	27.6	28.6
T1P8	38.0	5.0	2.8	39.2	13.0	22.4	34.7	24.3	34.5	37.6	25.1	26.7
T1P9	29.8	5.4	0.0	39.2	14.2	0.2	47.1	13.0	5.2	35.5	24.8	0.0
T1P10	15.6	4.0	5.4	40.7	4.5	5.2	38.0	5.2	6.8	27.6	5.4	9.4
T1P11	19.1	4.9	9.2	27.6	4.9	9.0	43.7	5.5	8.5	34.1	6.1	8.3
T1P12	12.7	8.1	7.3	24.1	11.4	9.9	33.1	12.3	13.7	29.5	14.4	14.2
T1P13	15.9	10.6	11.3	21.0	13.5	13.5	26.9	14.2	14.4	27.7	17.5	17.3
T1P14	12.0	11.3	12.0	14.9	14.0	12.7	17.3	16.6	15.3	19.1	15.9	15.3

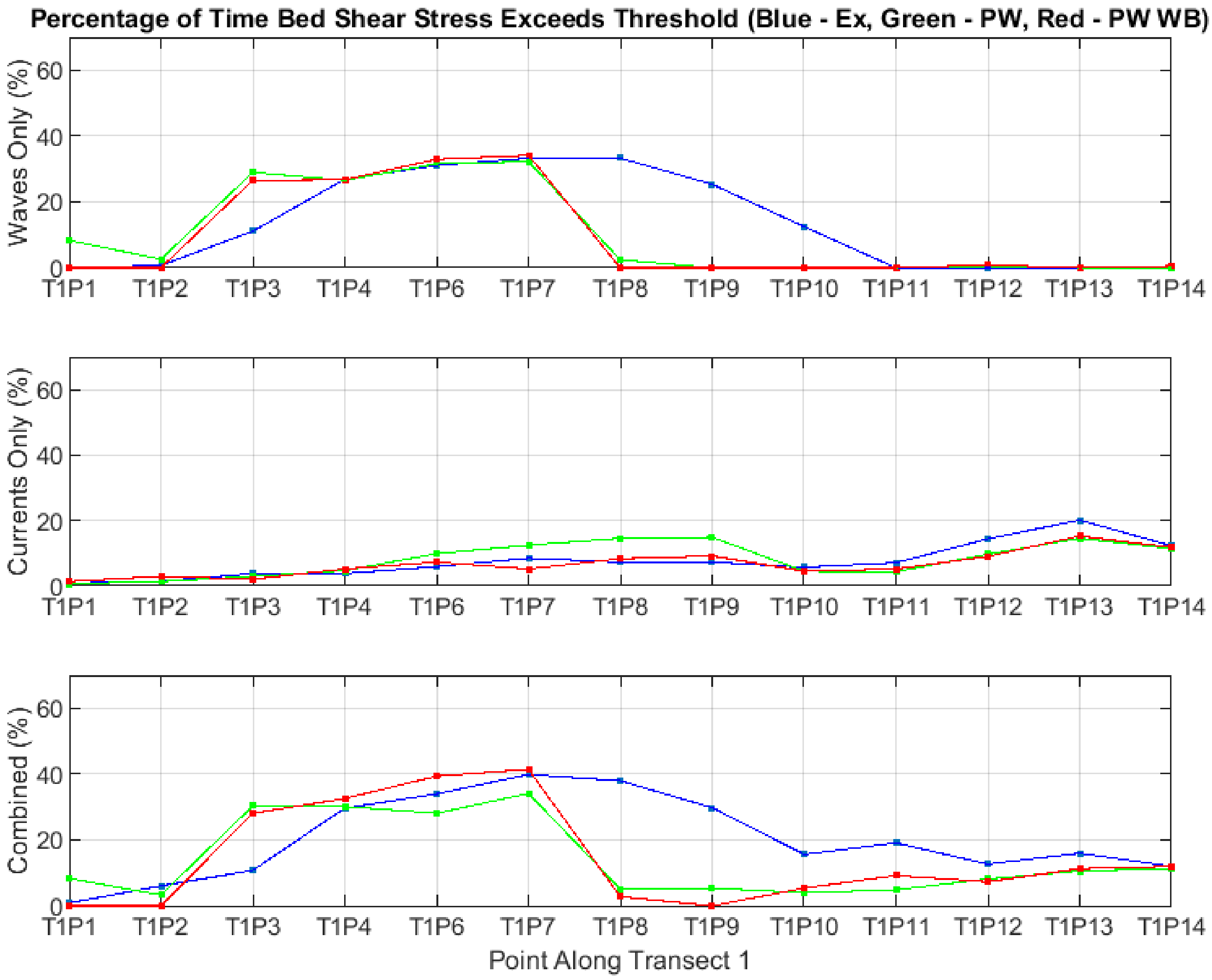

Figure 4.7: Calculated percentage of time bed shear-stress exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for a return period of 10 years. Blue line – no further development, green line- with pond walls and red line – with pond walls and wave-break.

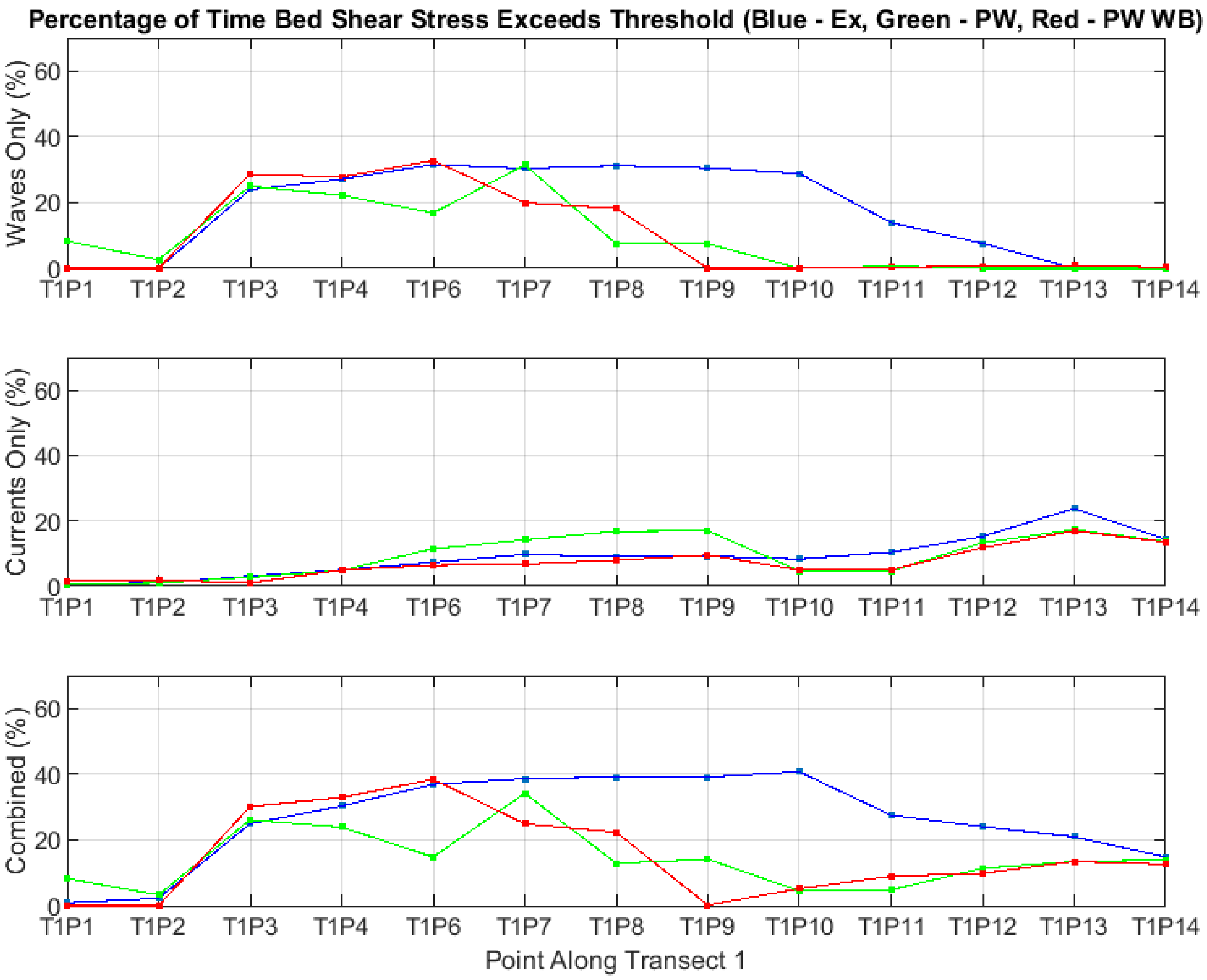

Figure 4.8: Calculated percentage of time bed shear-stress exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for a return period of <u>20</u> years. Blue line - no further development, green line- with pond walls and red line – with pond walls and wave-break.

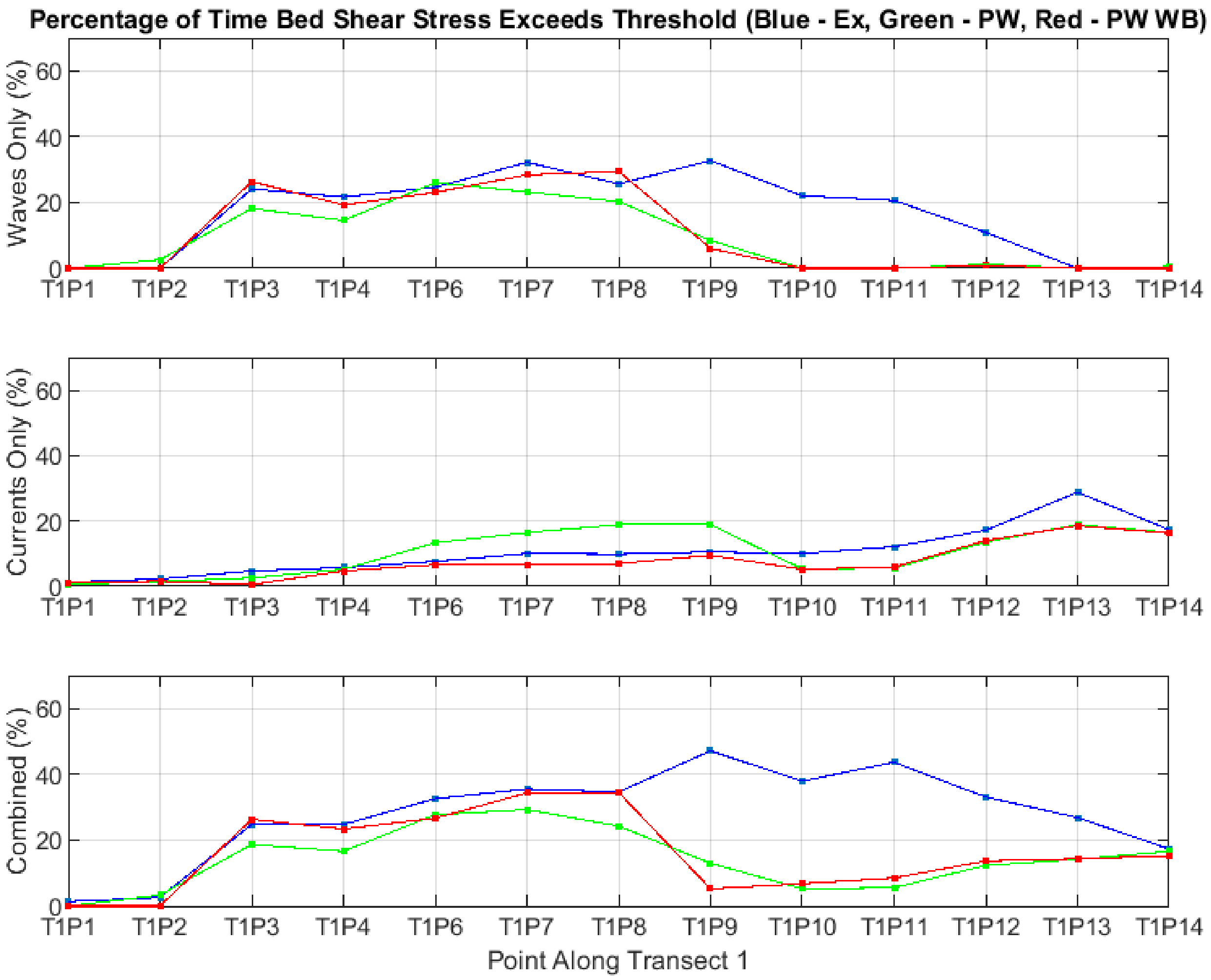

Figure 4.9; Calculated percentage of time bed shear-stress exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for a return period of <u>50</u> years. Blue line - no further development, green line- with pond walls and red line – with pond walls and wave-break.

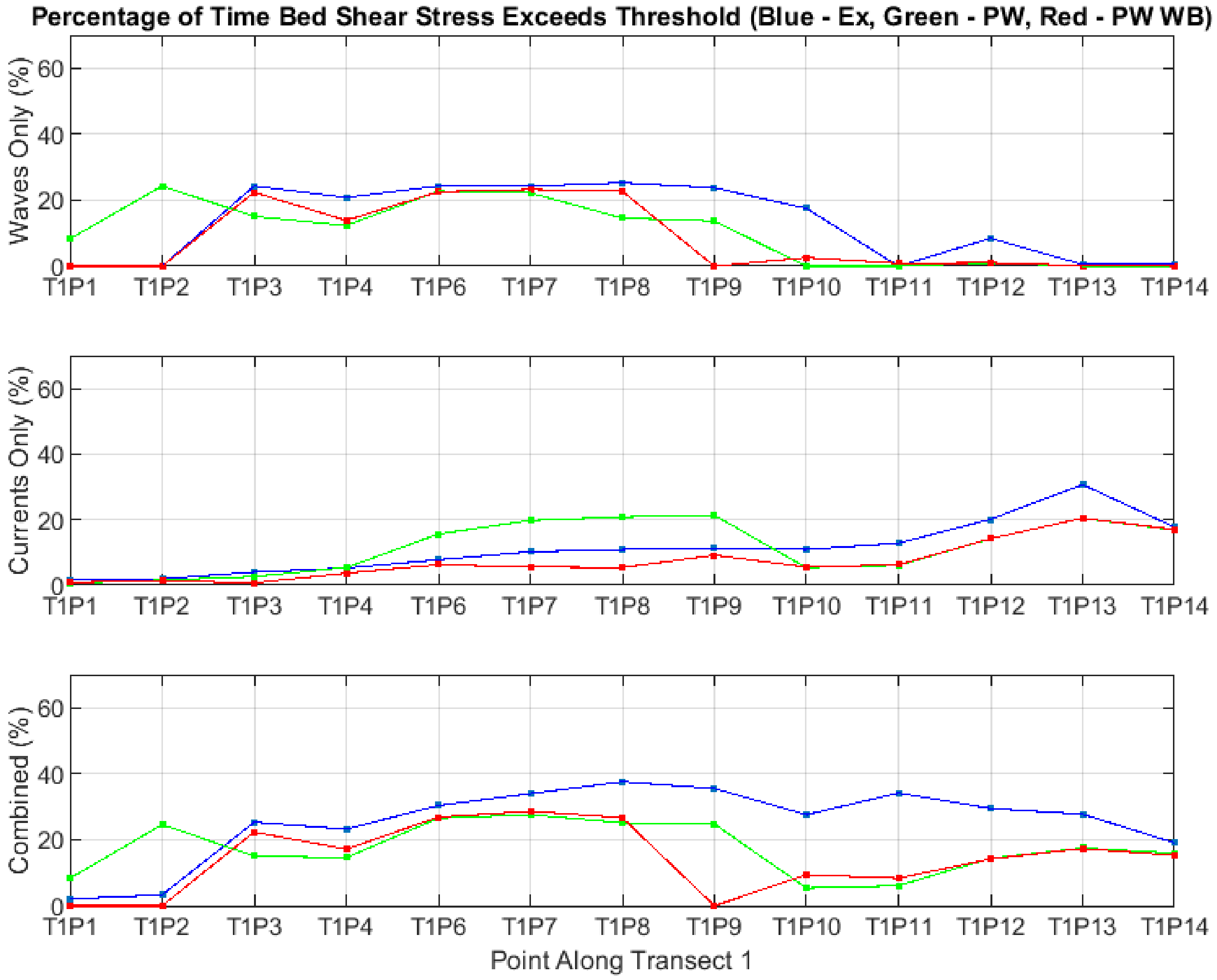

Figure 4.10: Calculated percentage of time bed shear-stress exceeds the threshold of motion for the average D_{50} sediment size at transect 1 points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for a return period of 100 years. Blue line - no further development, green line- with pond walls and red line – with pond walls and wave-break.

4.2 Scour potential at pond wall locations

This section considers the calculated scour potential at the pond wall locations (P01 to P06 and at T2P1 and T2P1 which are also close to the base of the pond walls) associated with the modelled extreme events. Results concentrate upon outcomes of modelling on the geographic setting that has the pond walls and causeway imposed, to assess the scour forces that might be imposed at the toe of the proposed pond walls by extreme weather events.

Figure 4.11 to Figure 4.18 present time-series of the calculated bed shear-stress due to waves, currents and the combined waves and currents for each of the return period events modelled for each of the pond wall output points. The calculated threshold of motion, for the average D_{50} of the *in-situ* sediment samples, is plotted on each panel to show times where bed-shear stress is predicted to exceed the threshold. Note although a range of D_{50} values was investigated in the calculations, to simplify the reporting and for ease of comparison all results presented in the report addendum are for the average D_{50} sediment size. The figures show that the bed shear-stress due to waves alone is relatively small at the pond wall locations with only short durations of predicted exceedance of the threshold or none at some of the points. The calculated bed shear-stress due to currents alone is predicted to be significantly larger with a sustained duration above the threshold during the period of the storm surge at each of the return period levels. It should be noted that prior to the storm in the modelled time-series the bed shear-stress due to currents alone is predicted to exceed the threshold required for sediment mobilisation for short durations. This indicates that at times of typical spring tides there is scour potential along the pond walls. This is significant because of the much shorter return periods of such events (multiple times per month).

In order to quantify the scour potential, the percentage of time that calculated bed shear-stress exceeded the threshold of motion for the average D_{50} sediment size over the modelled time period was determined at the pond wall points (Table 4.4). The table indicates that at all the pond wall points, over all of the return period water level cases, there is potential for scour with the currents being the dominant force. The proportion of time where there is potential for scour increases as the return period increases due to the longer duration of elevated water levels.

Based on the scour potential calculations it is recommended that toe protection be included in the pond wall designs to protect from scour during both extreme events and more frequent tidal inundation. Further investigation of the potential for scour during typical spring tides should also be considered, as although the intensity and duration of each tidal peak would be far lower than that predicted for the extreme events, it will occur on a regular basis and may have a cumulative impact on the stability of the toe of the pond walls.

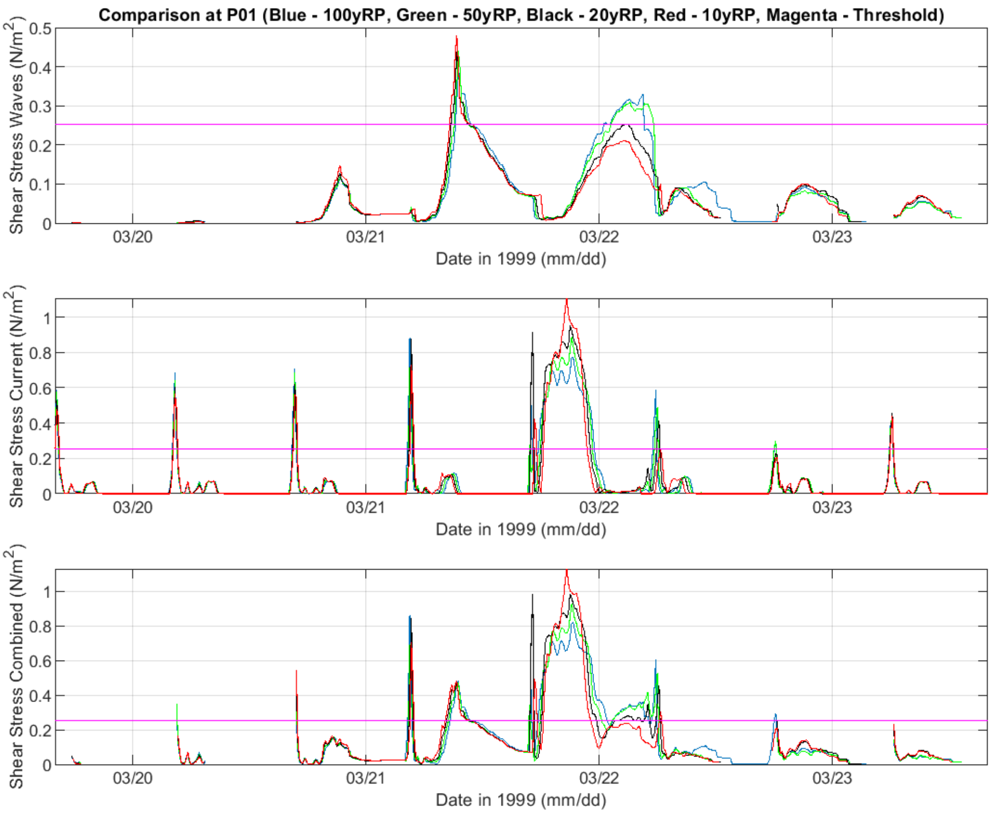

Figure 4.11: Time-series plots comparing calculations of bed shear-stress at P01, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

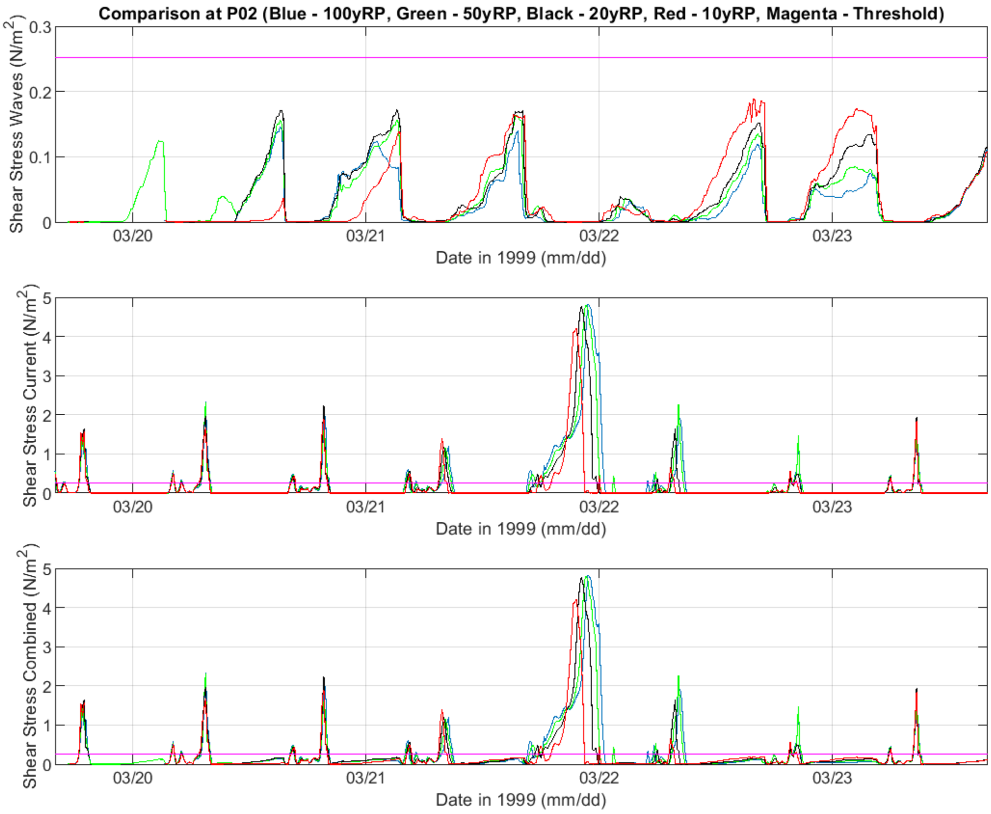

Figure 4.12: Time-series plots comparing calculations of bed shear-stress at P02, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

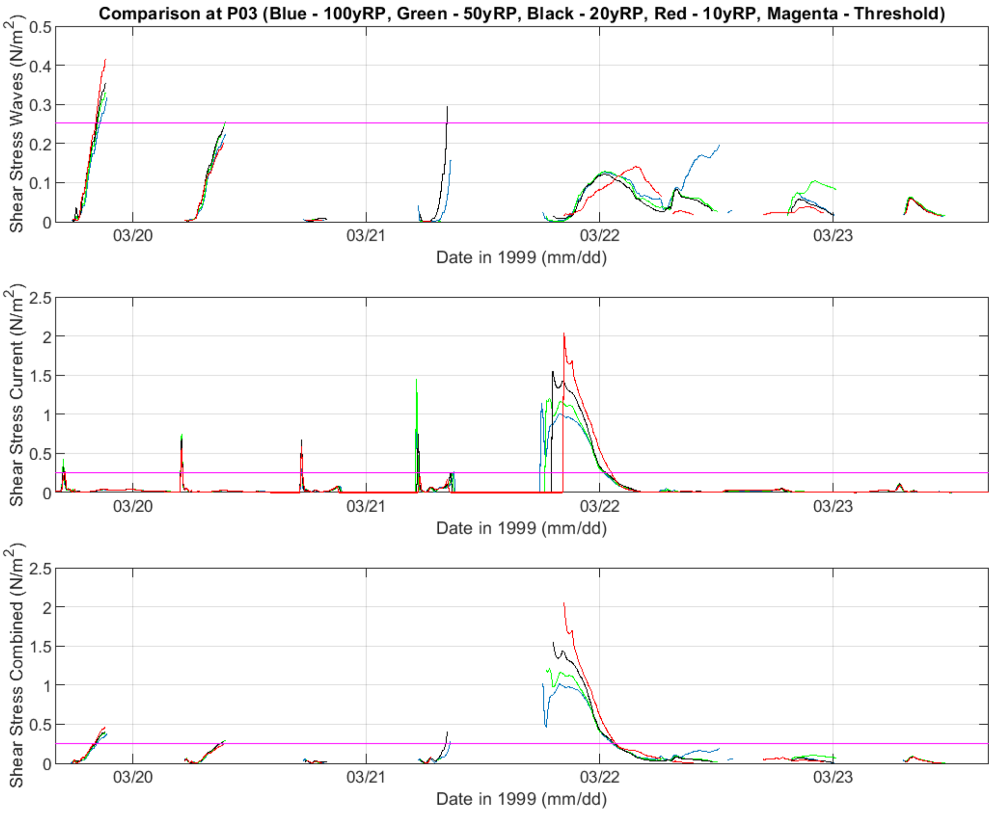

Figure 4.13: Time-series plots comparing calculations of bed shear-stress at P03, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

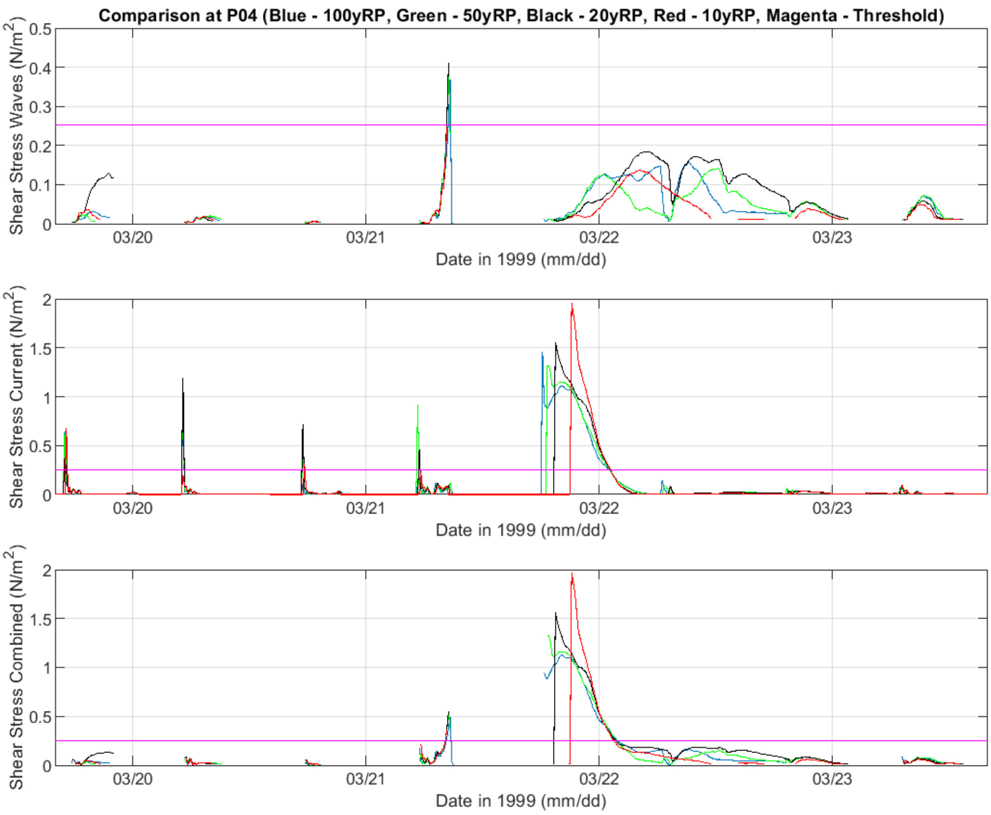

Figure 4.14: Time-series plots comparing calculations of bed shear-stress at P04, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

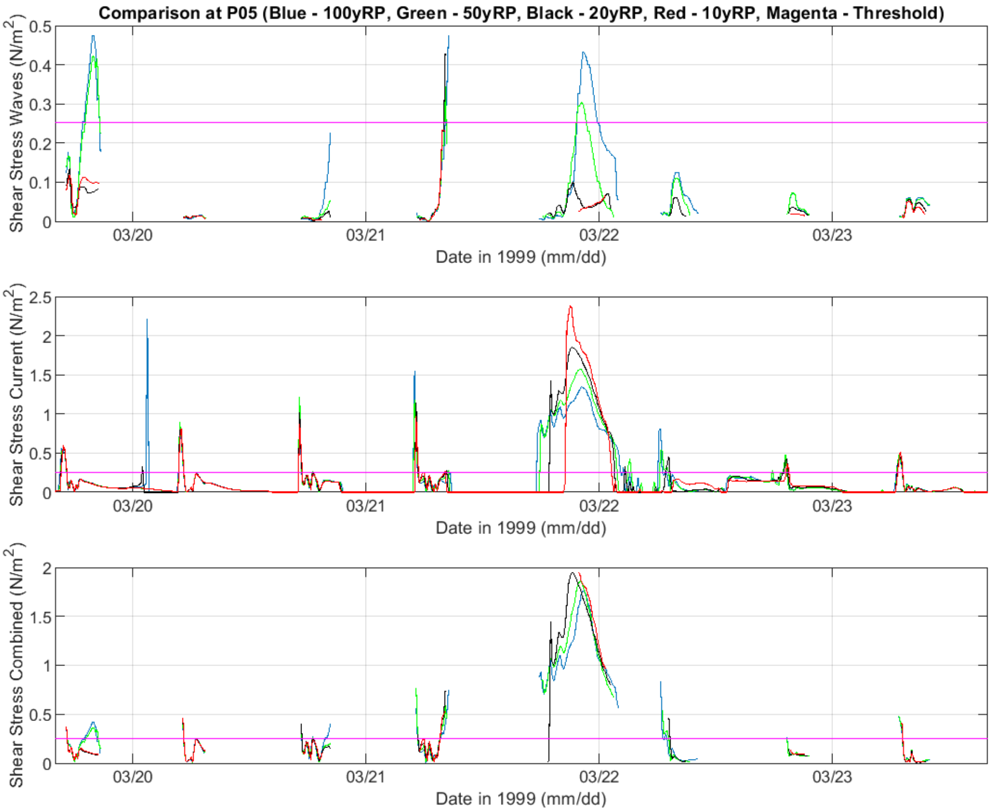

Figure 4.15: Time-series plots comparing calculations of bed shear-stress at P05, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

Figure 4.16: Time-series plots comparing calculations of bed shear-stress at P06, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

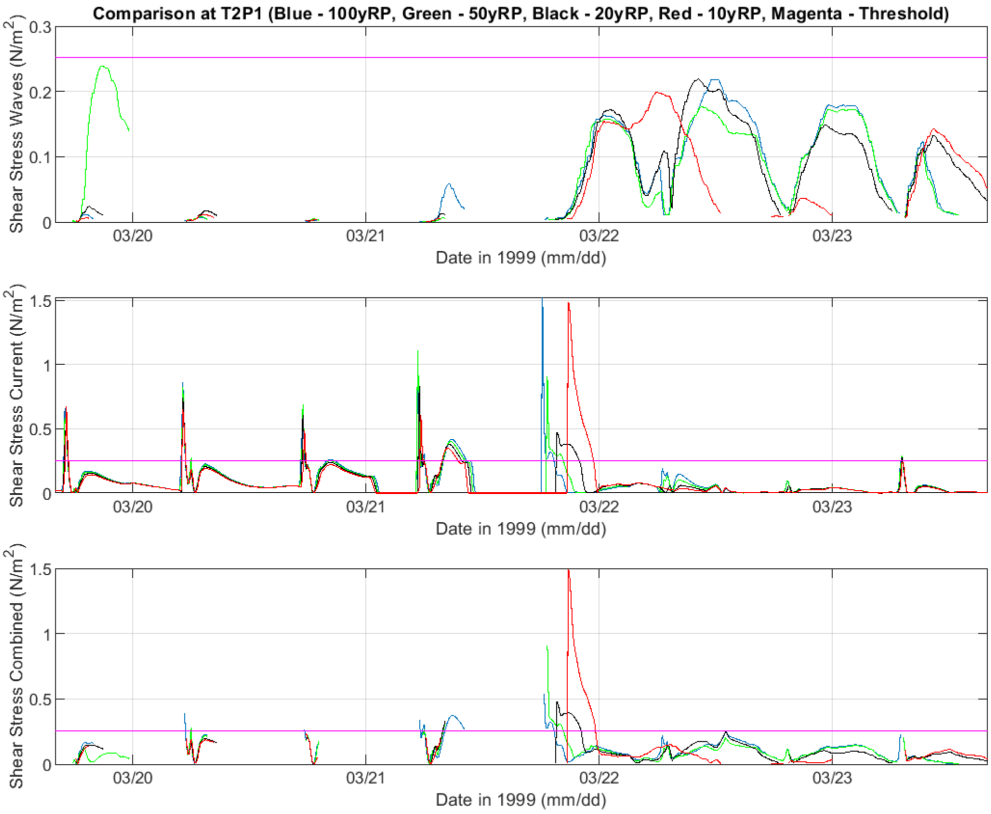

Figure 4.17: Time-series plots comparing calculations of bed shear-stress at T2P1, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

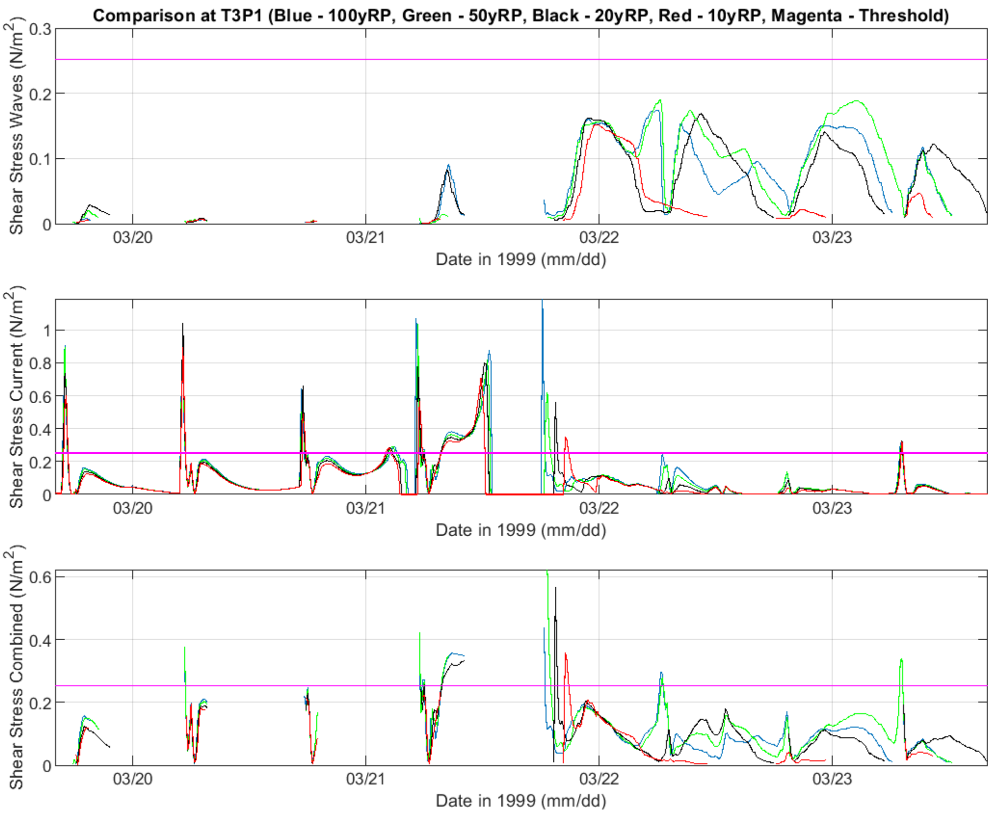

Figure 4.18: Time-series plots comparing calculations of bed shear-stress at T3P1, for return periods of 10 (red), 20 (green), 50 (black) and 100 years (blue). The magenta line is the threshold of motion for the average D_{50} sediment size. Note y-axes scales differ.

Table 4.4: Calculated percentage of time bed shear-stress from waves only and currents only and combined waves and currents, exceeds the threshold of motion for the average D_{50} sediment size at the pond wall points, under forcing conditions calculated for Cyclone Vance.1999.S009 after adjustment of peak water-levels offshore for return periods of 10, 20 , 50 and 100 years. Values provided for the model layout with pond walls.

Point	10-year Return Period			20-year Return Period			50-year Return Period			100-year Return Period		
	Waves	Currents	Combined	Waves	Currents	Combined	Waves	Currents	Combined	Waves	Currents	Combined
P01	2.6	7.1	9.2	2.4	8.3	13.2	6.1	8.7	14.7	5.9	8.8	15.4
P02	0.0	12.7	12.1	0.0	14.9	14.9	0.0	17.9	17.5	0.0	17.9	17.3
P03	1.2	5.7	6.9	1.2	6.8	8.5	1.0	7.1	9.0	0.9	7.6	9.0
P04	0.0	4.7	4.7	0.3	6.6	7.1	0.3	7.5	8.1	0.3	7.6	8.5
P05	0.0	8.0	4.3	0.2	10.9	8.5	2.9	13.0	12.1	4.3	13.5	13.5
P06	0.0	7.5	7.5	0.0	9.2	8.8	0.0	11.4	11.1	0.0	13.7	13.0
T2P1	0.0	5.7	2.9	0.0	6.2	3.1	0.0	6.1	2.4	0.0	7.1	4.5
T3P1	0.0	7.5	0.5	0.0	8.1	3.1	0.0	9.2	2.4	0.0	9.2	3.8

5 CONCLUSIONS AND RECOMMENDATIONS

The main conclusions and recommendation from the scour potential assessment for the pipeline easement and pond wall locations are outlined in the following sections.

5.1 Scour potential along the pipeline easement

- The results of the scour potential assessment for the pipeline easement indicate that there is scour potential at most of the points along the pipeline easement for all the extreme event return period water level cases modelled.
- The presence of the development infrastructure is not predicted to consistently and markedly increase the scour potential overall: there were some points where it was predicted to increase but also some where it was predicted to decrease.
- The proposed wave-break structure appears to be effective in reducing the scour potential due to currents along the section of easement landward of its proposed location.
- The proposed wave-break structure may be effective in protecting the section of easement landward of its proposed location during ambient spring tide current conditions, however further investigation of the scour potential for the ambient spring tide water level case is recommended.
- The proposed wave-break structure is not as effective at reducing the scour potential due to waves, due to the increased lag time in the draining of surge waters from behind the wave break, resulting in longer exposure to waves.
- The design of the wave-break structure could be improved by raising the height and including drainage for water that becomes trapped behind the wave-break.

5.2 Scour potential at pond wall locations

- The results of the scour potential assessment at the pond wall locations indicate that there is potential for scour for all the return period water level cases, with the currents being the dominant force.
- Based on the scour potential calculations, it is recommended that toe protection be included in the pond walls designs to protect from scour during extreme events.
- Further investigation of the potential for scour during typical spring tides should also be considered as although the intensity and duration of each tidal peak would be far lower than that predicted for the extreme events, it will occur on a regular bases and may have a cumulative impact on the stability of the toe of the pond walls.

5.3 General

- Of note, from review of previous geotechnical investigation at the site, it was found that disturbance of the surface of the mudflat area through construction/traffic over the site has caused increased erosion due to a breakdown of the surface crust that forms in the area when in an undisturbed state (Advanced Geomechanics, 2014).
- Based on the finding from previous geotechnical investigation, the planning of construction activities will need to consider the disturbance to the mud flat surface and determine how to minimise disturbance to avoid increased scour.

6 REFERENCES

Advanced Geomechanics, 2014. Gorgon Upstream – DomGas Onshore Intertidal Zone: Geotechnical Aspects Technical Note, Rev A. (Document No. G1-TE-V-UP00-TCN0083). Prepared for Chevron.

Arup, 2014. Sales Gas Onshore Pipeline – Geotechnical Advice – Geotechnical Interpretive Report Rev 0. 20 January 2014 (Document ref – 232030-AP-REP-001_A.docx Rev 0). Prepared for Apache Energy Limited.

CMW Geosciences, 2020. Mardie Salt Project – DFS Factual Geotechnical Report Mardie, WA Rev 1. 13 August 2020 (PER2018-0091AN Rev 1). Prepared for Mardie Minerals Pty Ltd.

RPS, 2020. BCI Mardie - Return period analysis for water flow and waves at pond walls, navigation route and pipeline easement, Rev 0 October 2020 (Report ID MAW0616J.009). Prepared by RPS for BCI Minerals Pty Ltd.

Soulsby, R., 1997. Dynamics of Marine Sands – A Manual for Practical Applications. Thomas Telford Services Limited. London.

van Rijn L, 2005. Principles of Sedimentation and Erosion Engineering in Rivers, Estuaries and Coastal Seas. Aqua Publications, The Netherlands.