APPENDIX O11.3

Initial Modelling Assessments: Scenarios for a Desalination Plant in Spencer Gulf (report by BMT WBM, 2008)

See overleaf for report.

A part of BMT in Energy and Environment

Initial Modelling Assessments: Scenarios for a Desalination Plant in Spencer Gulf

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Initial Modelling Assessments: Scenarios for a Desalination Plant in Spencer Gulf

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1 INTRODUCTION

BHP Billiton (BHP) is considering constructing a desalination facility in the Spencer Gulf region of South Australia to supply water to the proposed expansion of the Olympic Dam project. This desalination facility will produce a brine wastewater stream, which will be discharged to Spencer Gulf. Due to the requirements for such a discharge, WBM and the Centre for Water Research (CWR) at the University of Western Australia were commissioned to develop, calibrate, validate and apply a modelling framework to the region and the outfall stream in order to assist with progression of impact assessments.

A previous report (R.B15583.004.04.Calibration.doc) describes the proposed project, the locality, field and desktop data collection programs, the scope of the required modelling, as well as model schematisations, set up, calibration and validation. That information is not repeated here. Rather, this report presents results from the modelling study that followed.

The report structure reflects the overall modelling framework: far field modelling (entire gulf), mid field modelling (northern gulf) and near field modelling (hundreds of metres surrounding the outfall). Details of all these models have been presented previously and as such are not repeated here.

2 FAR FIELD MODELLING

2.1 Simulations

The far field model was used to examine potential impacts of the proposed discharge on the broad scale circulation patterns and salinities across the entire Spencer Gulf. To this end, five simulations were executed. The forcing parameters for these are provided in Table 2-1. Run numbers are derived from modelling log references, and are maintained here for consistency. They do not imply an overall order of execution.

Table 2-1 Far Field Modelling Simulations

Run	Intake Location	Outlet Location	Plant Capacity (ML/day)		Simulation Period
			Seawater Intake	Brine Discharge	
18	N/A base case	N/A	N/A	N/A	5 years
19	Pt Lowly	Pt Lowly	452	272	5 years
20	Port Augusta	Port Augusta	452	272	5 years
21	Pt Lowly	Pt Lowly	5 times 452	5 times 272	5 years
22	Pt Lowly	Pt Lowly	10 times 452	10 times 272	5 years

The model domain is shown in Figure 2-1. Brine was introduced into the bottom cell of the model domain.

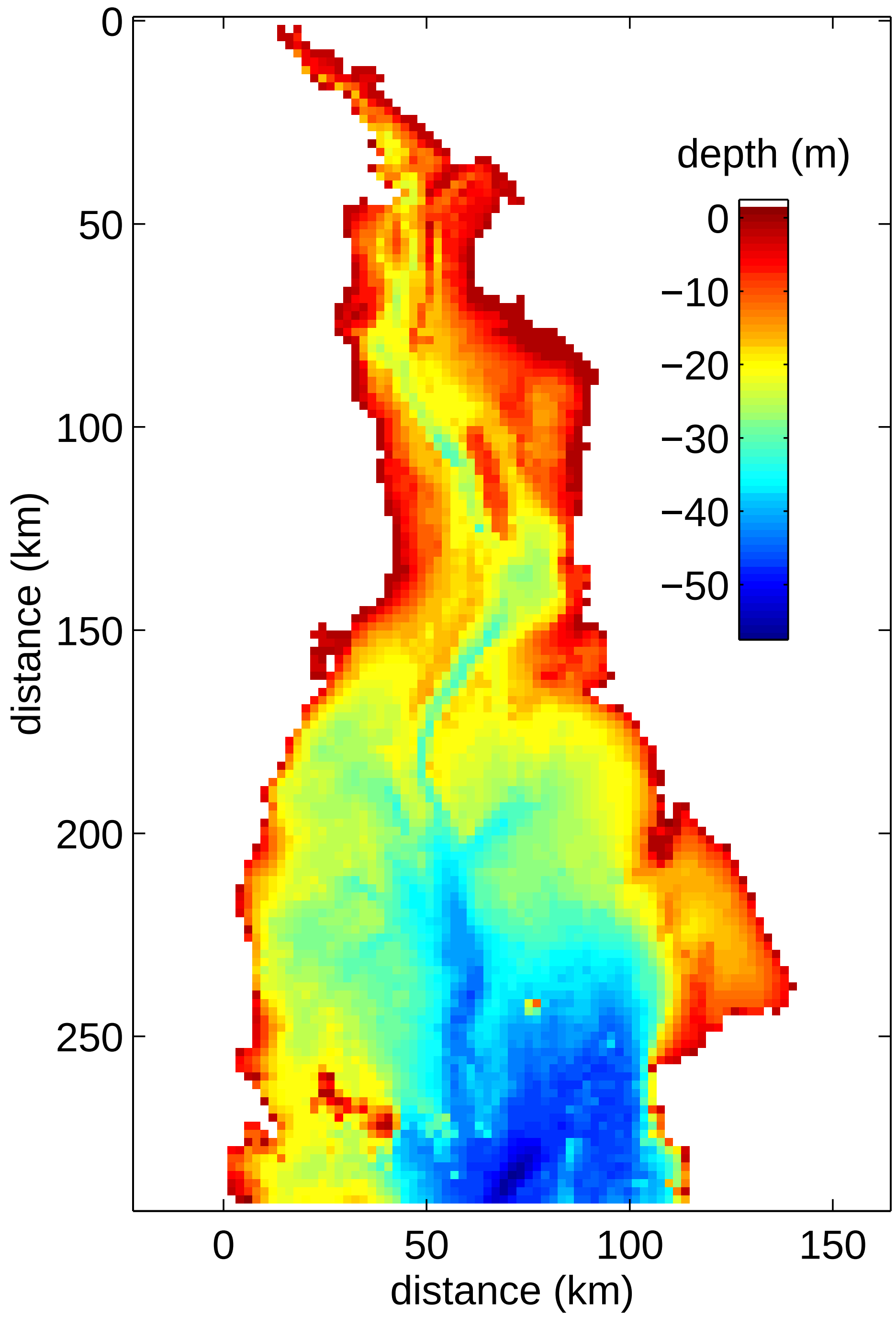


Figure 2-1 Far Field Model Domain (Rotated 36 Degrees Anticlockwise from North)

2.2 Results

The intent of the far field modelling was to determine likely broadscale impacts of the proposed discharge, relative to current conditions. As such, results have been presented here as 'difference plots' of salinity timeseries over the simulation period at a range of locations across the Gulf.

For example, salinity timeseries at a suite of representative locations have been extracted from model results for run 19. Salinity timeseries at corresponding locations for run 18 (the base case) have also been extracted, and then subtracted from those of run 19. This has produced a 'difference plot' for salinity at each location. This process was repeated for runs 20, 21 and 22, as compared to run 18.

Results are presented below. Each figure shows the difference plot (or plots) on the left, and the location of the particular timeseries on the right. The pairs of difference plots for Figure 2-2 to Figure 2-5 refer to outfalls at Port Augusta and Port Bonython, whereas the subsequent difference plots (Figure 2-6 to Figure 2-13) are for outfalls at Port Bonython only. Colours in each difference plot represent water column depth as per the colour bar.

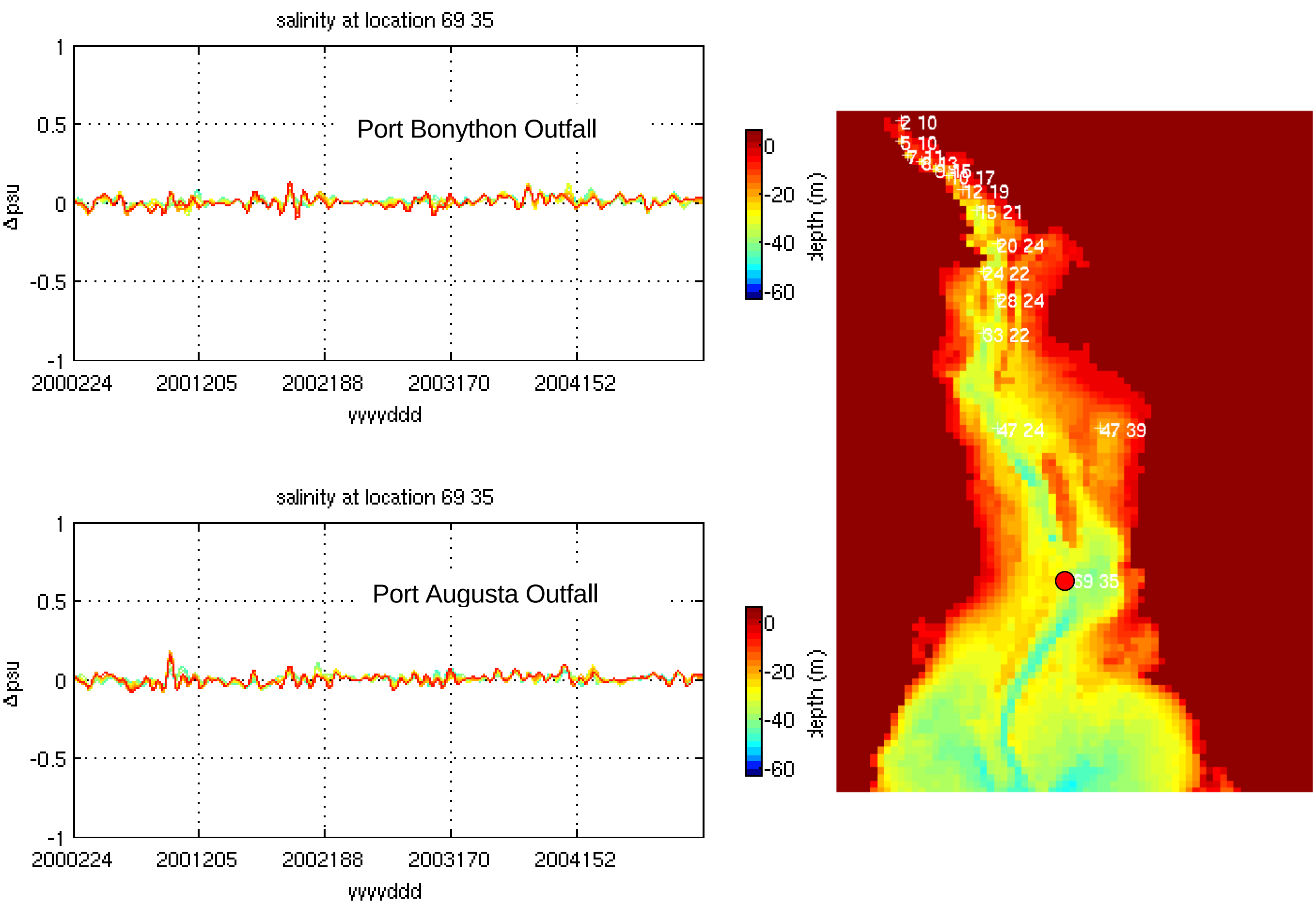


Figure 2-2 Predicted Far Field Salinity Increases – Lower Spencer Gulf, runs 19 and 20

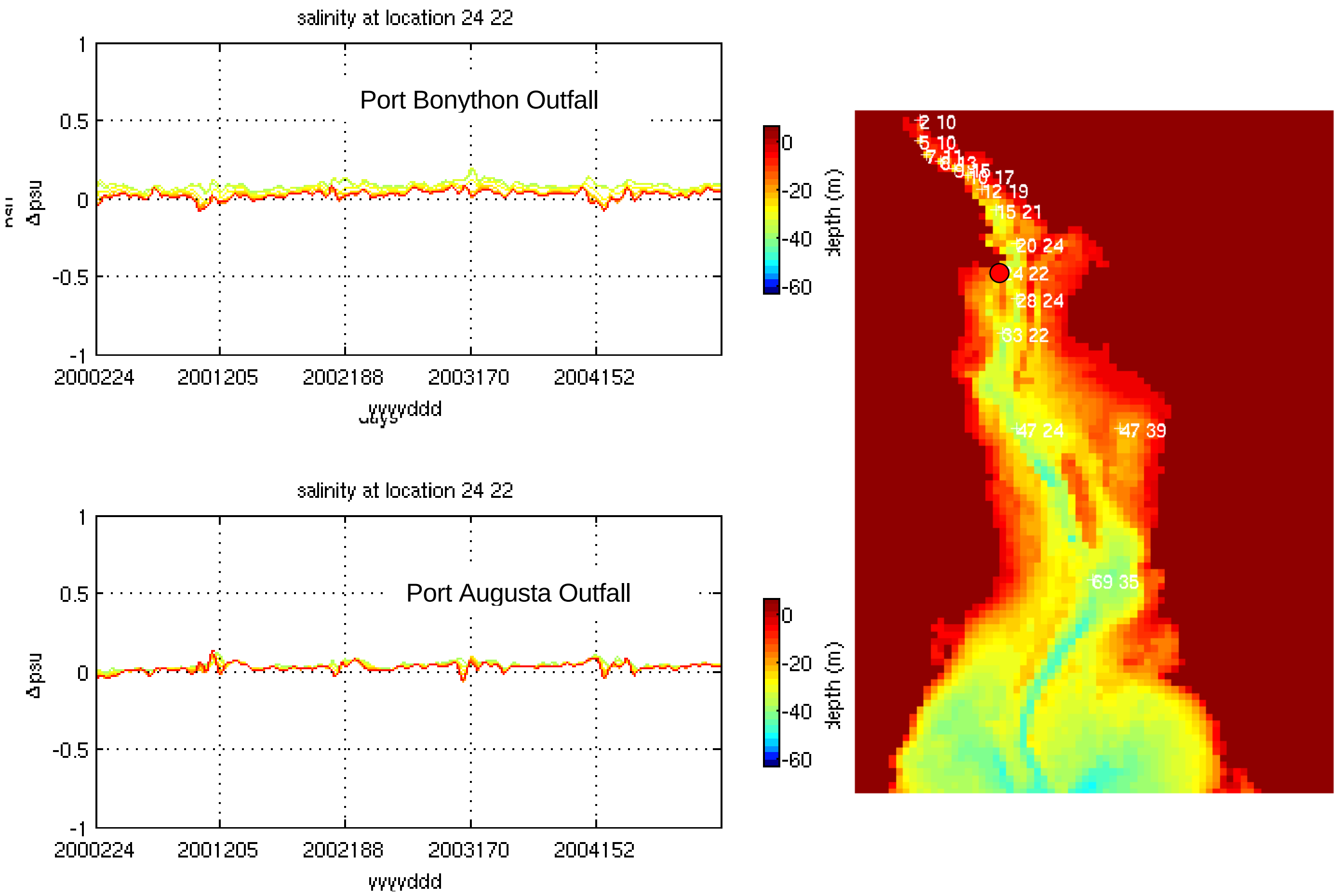


Figure 2-3 Predicted Far Field Salinity Increases – Adjacent Port Bonython, runs 19 and 20

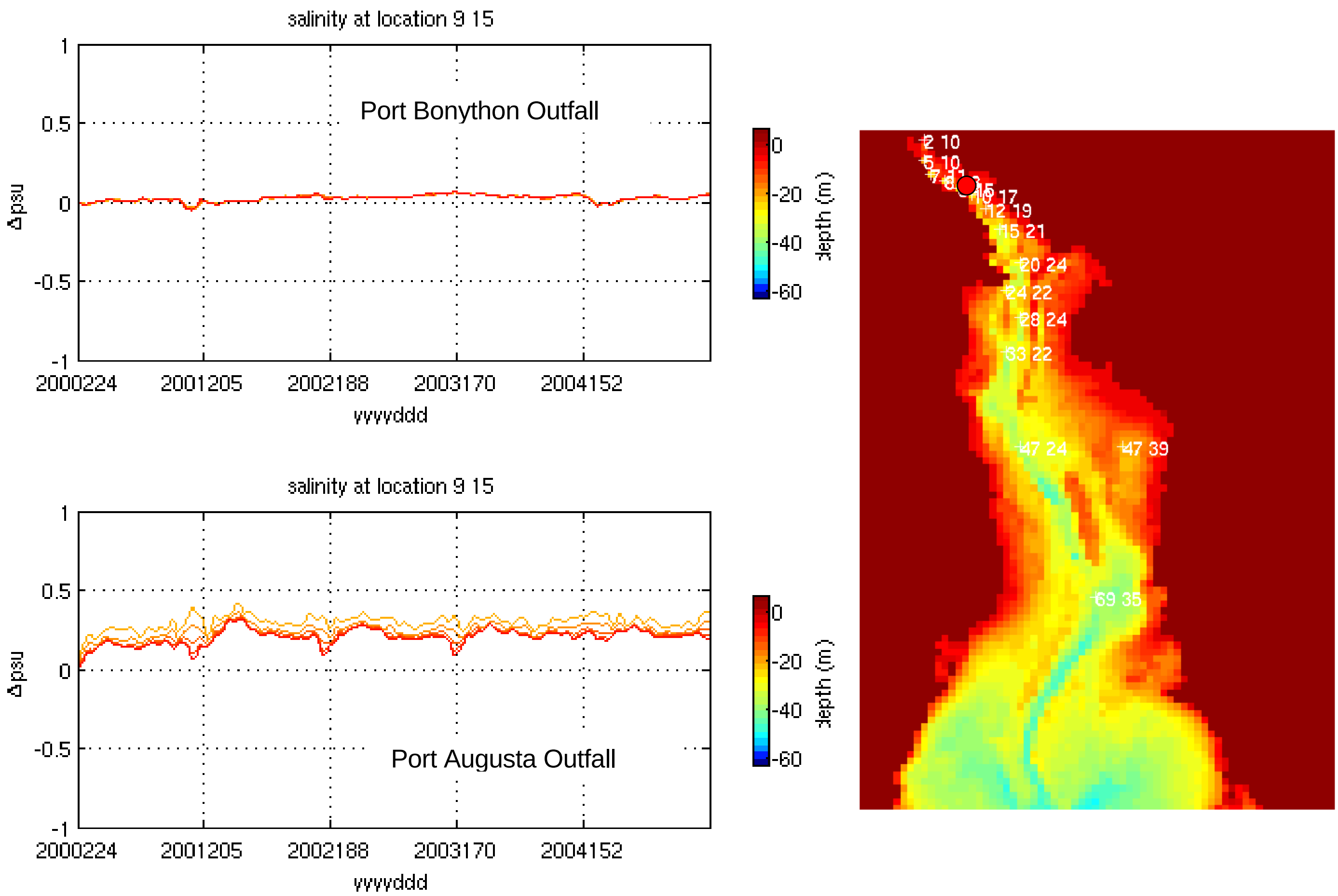


Figure 2-4 Predicted Far Field Salinity Increases – Adjacent Port Augusta, runs 19 and 20

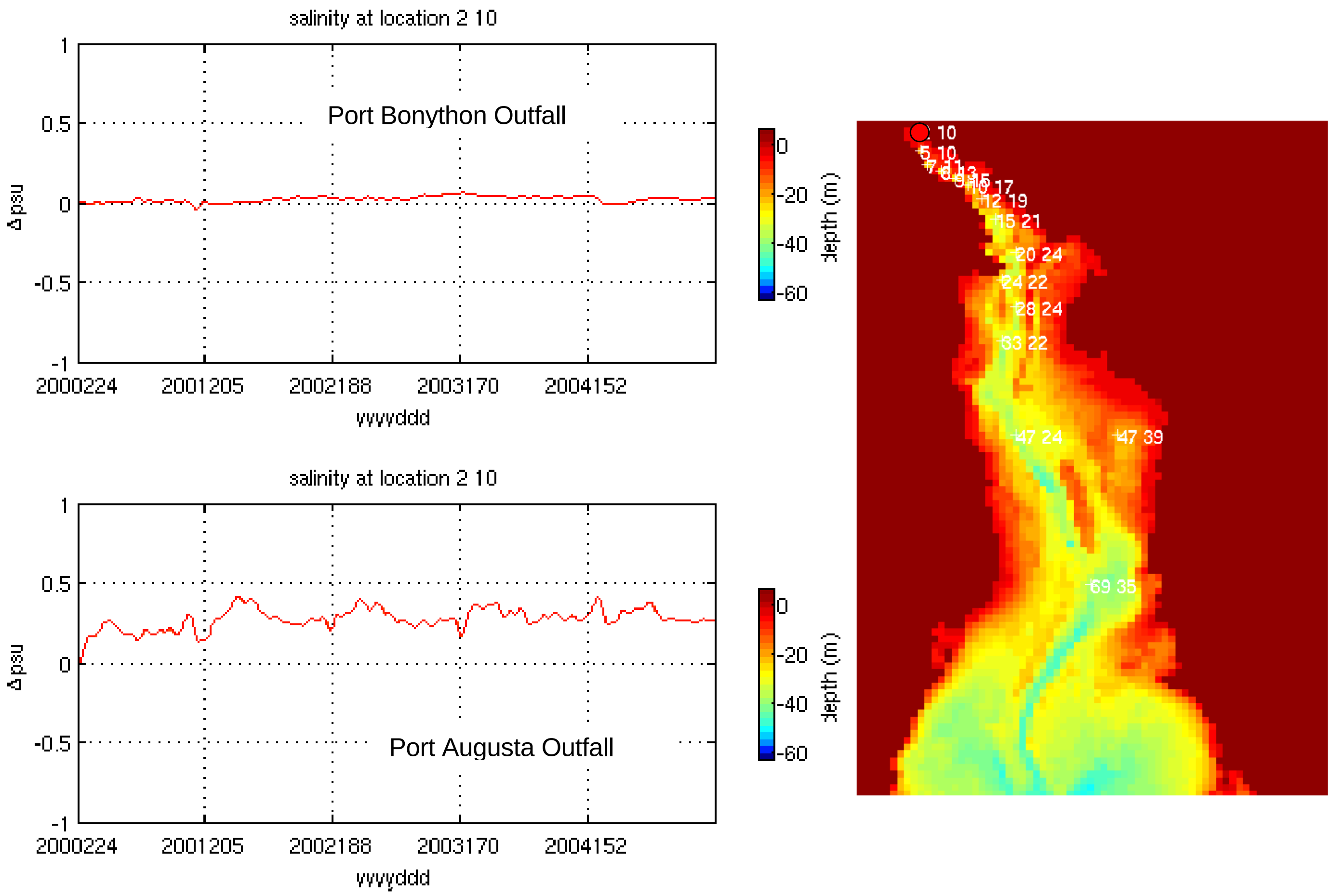


Figure 2-5 Predicted Far Field Salinity Increases – Upper Spencer Gulf, runs 19 and 20

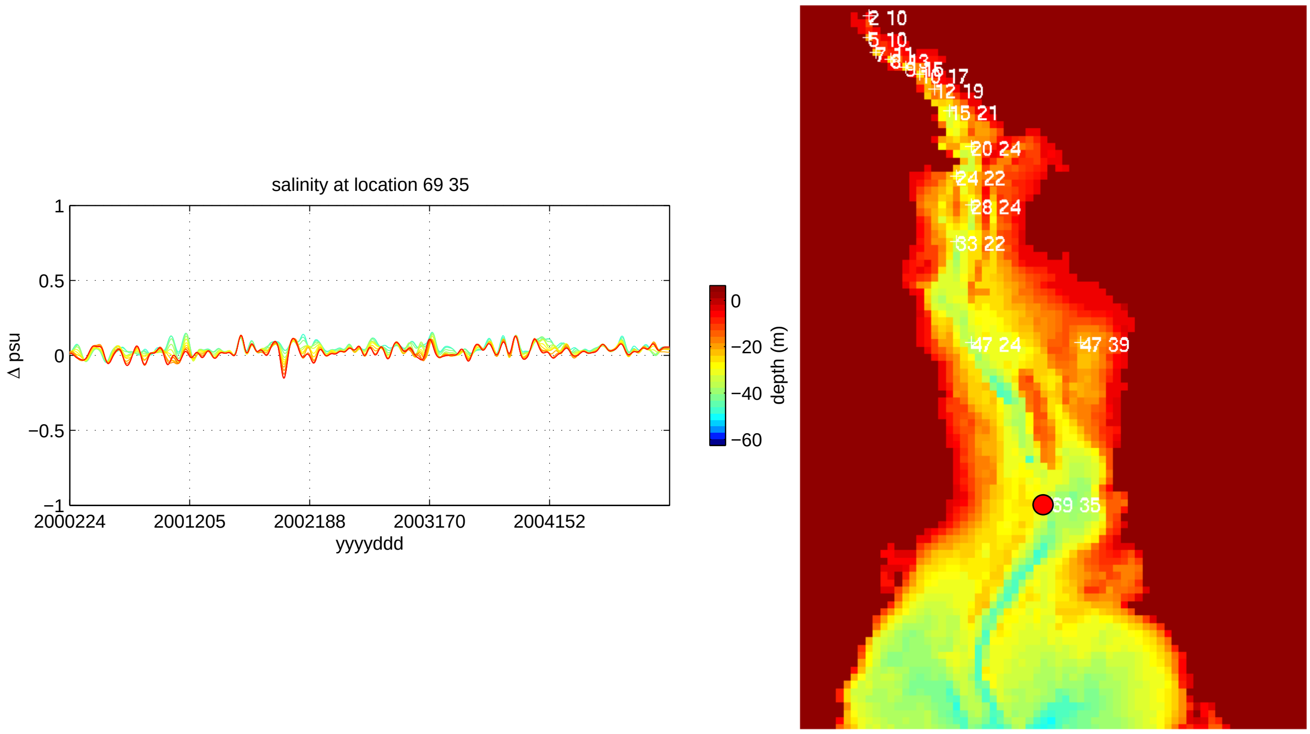


Figure 2-6 Predicted Far Field Salinity Increases – Lower Spencer Gulf, run 21

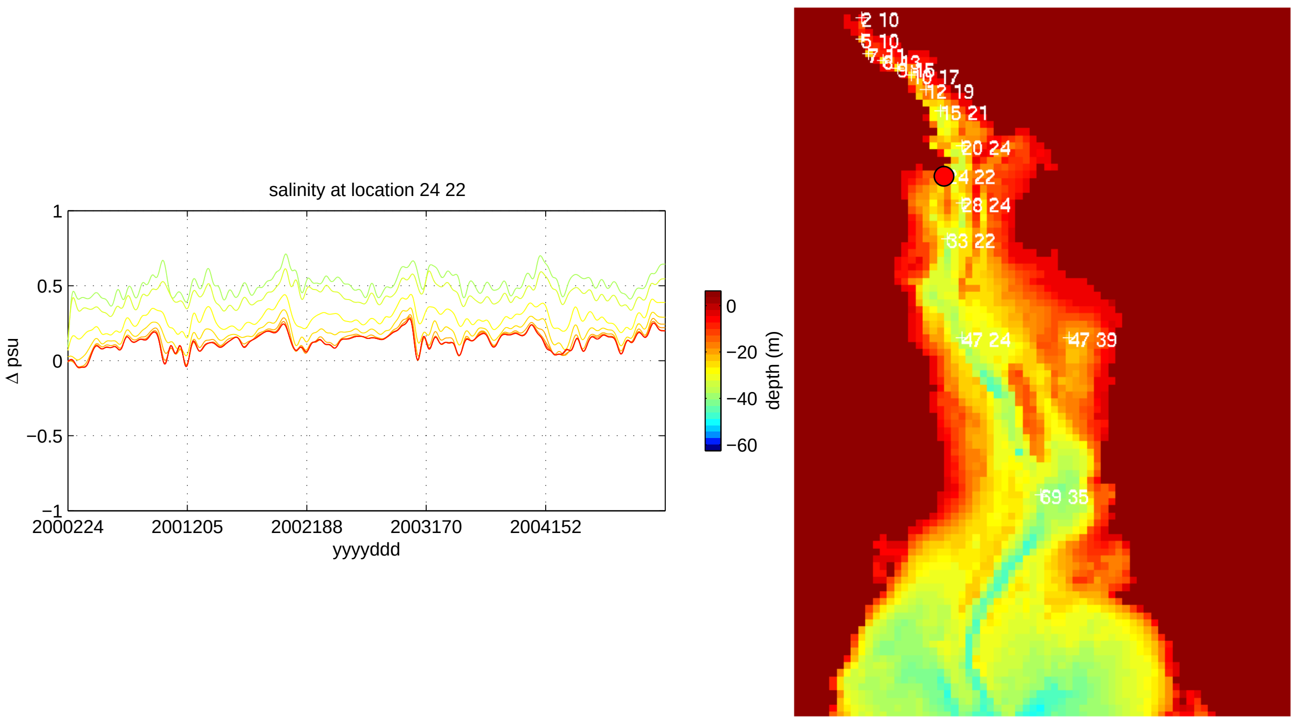


Figure 2-7 Predicted Far Field Salinity Increases – Adjacent Port Bonython, run 21

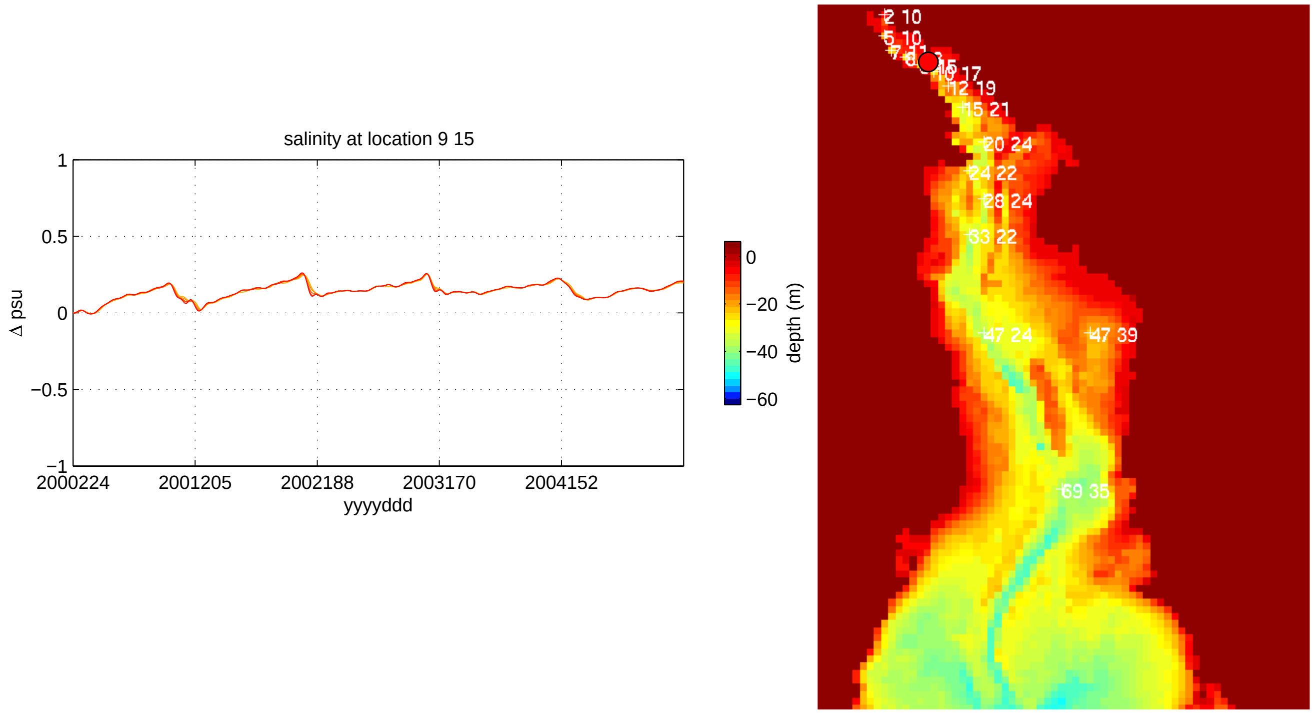


Figure 2-8 Predicted Far Field Salinity Increases – Adjacent Port Augusta, run 21

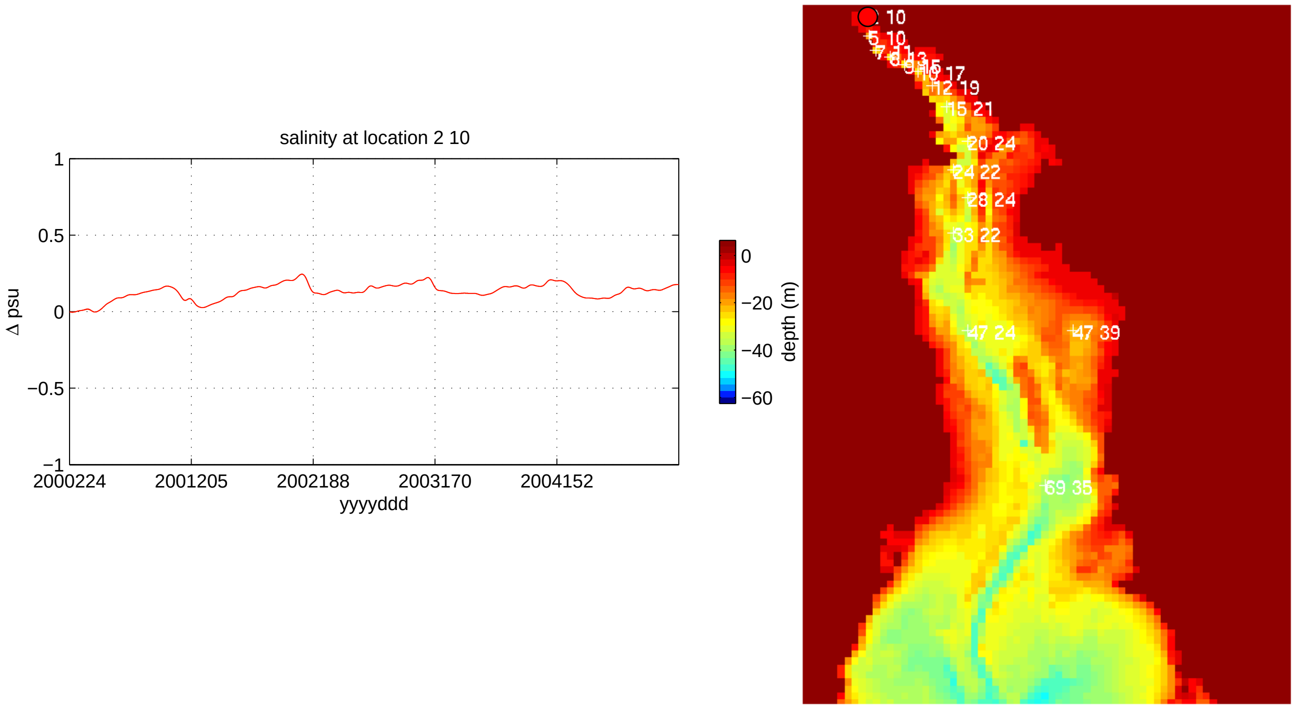


Figure 2-9 Predicted Far Field Salinity Increases – Upper Spencer Gulf, run 21

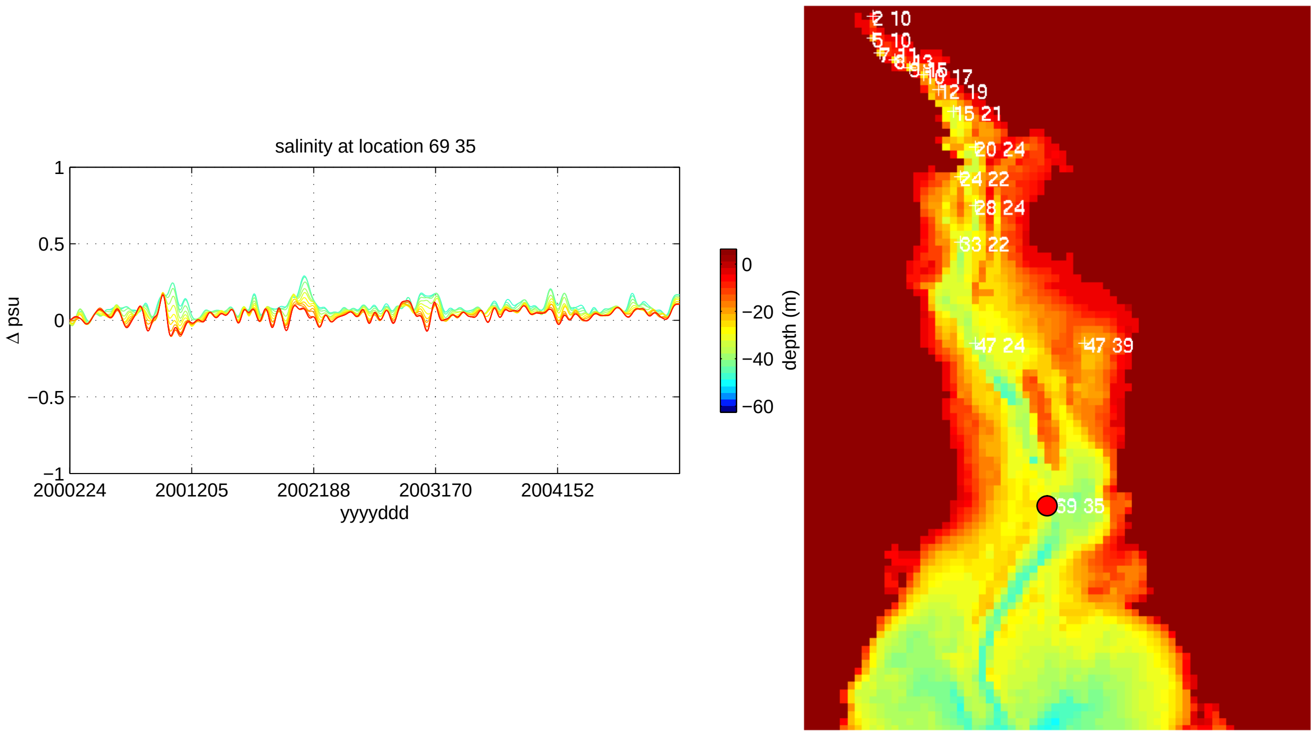


Figure 2-10 Predicted Far Field Salinity Increases – Lower Spencer Gulf, run 22

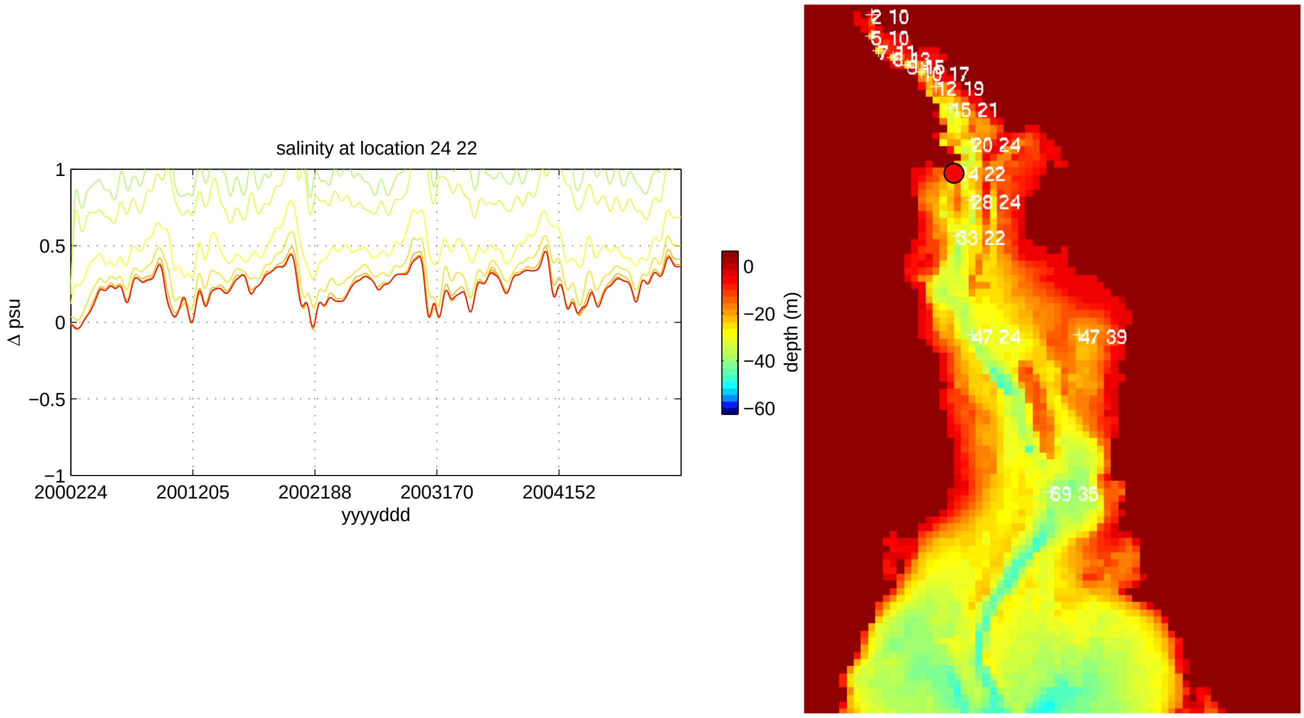


Figure 2-11 Predicted Far Field Salinity Increases – Adjacent Port Bonython, run 22

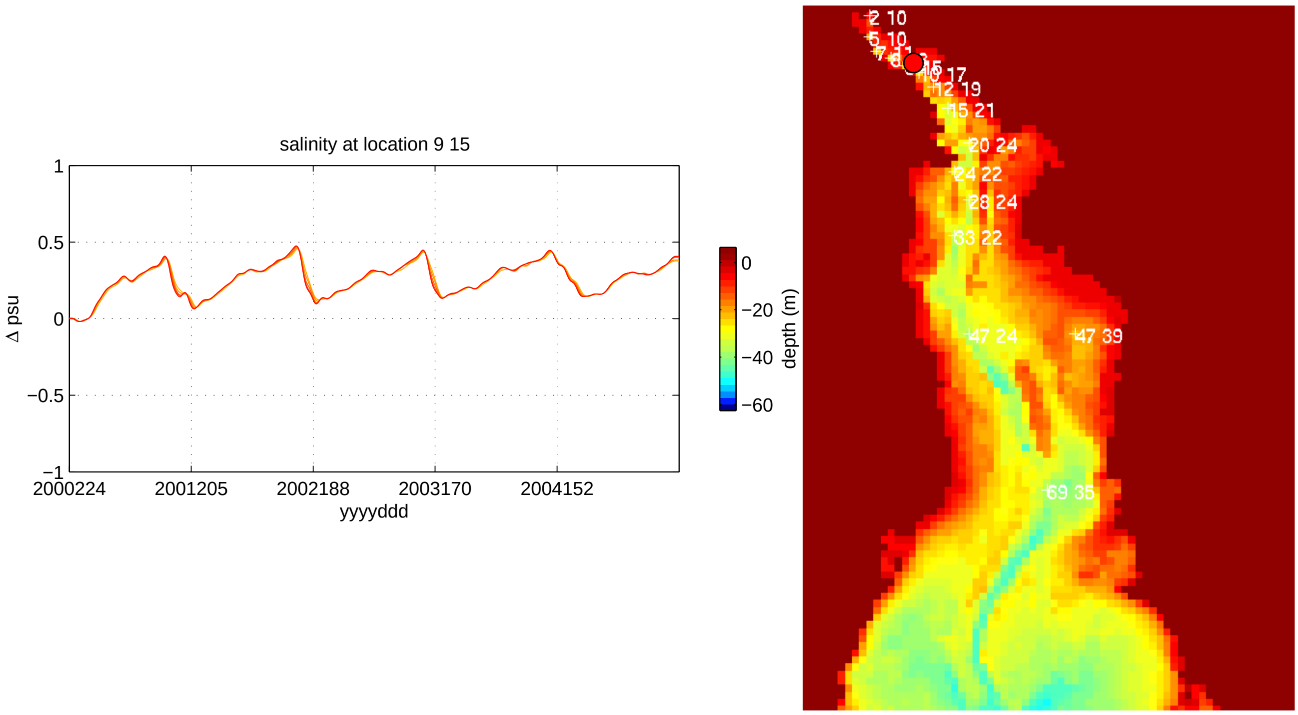


Figure 2-12 Predicted Far Field Salinity Increases – Adjacent Port Augusta, run 22

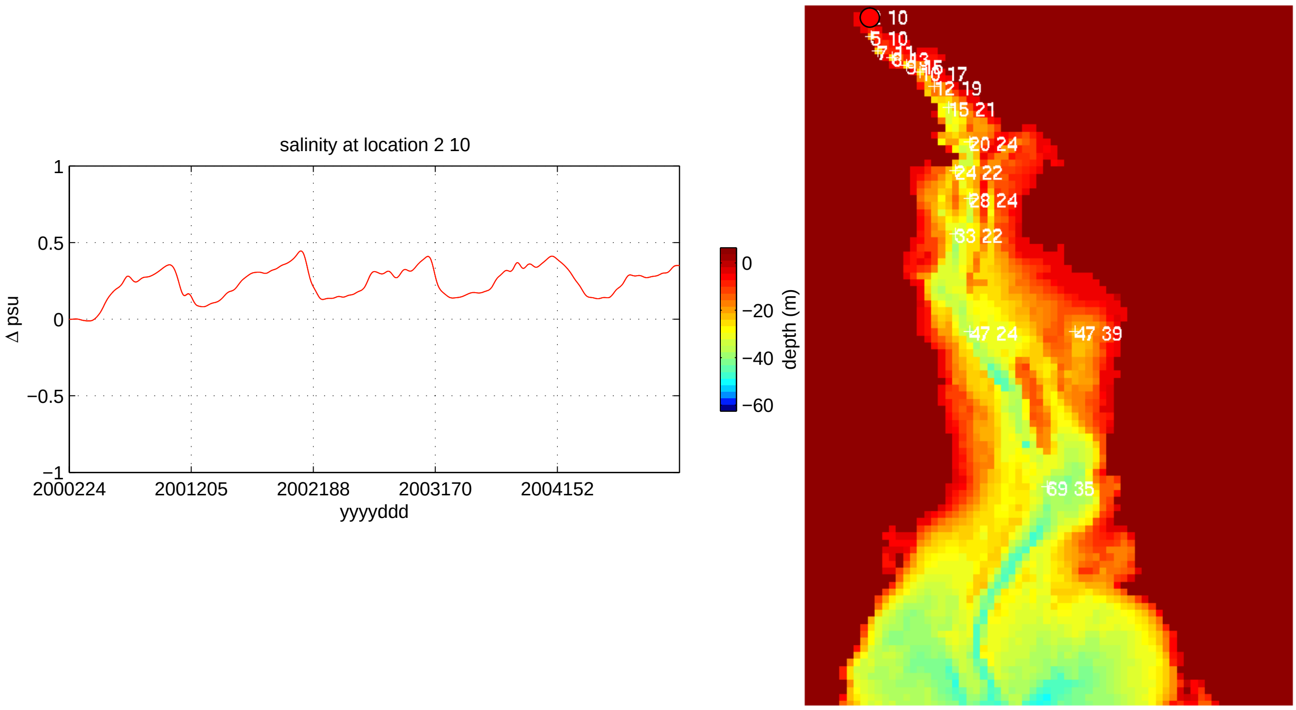


Figure 2-13 Predicted Far Field Salinity Increases – Upper Spencer Gulf, run 22

3 MID FIELD MODELLING

3.1 Simulations

The intent of the mid field modelling was to determine likely intermediate scale impacts of the proposed discharge. In particular, local effects within the modelling domain (Figure 3-1) were examined for a range of discharge locations. The specific locations are shown in Figure 3-2 (Port Bonython) and Figure 3-3 (Whyalla), the labels in which are referred to in the simulation descriptions in Table 3-1.

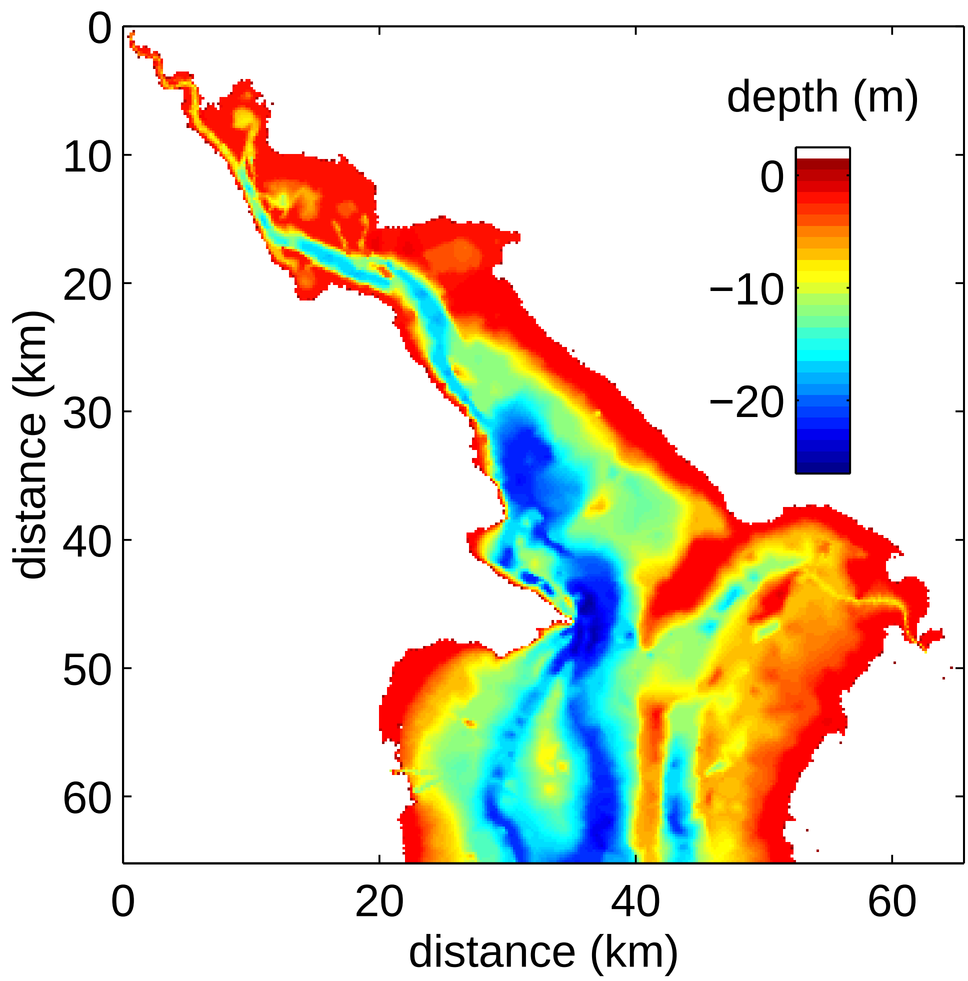


Figure 3-1 Mid Field Model Domain (Rotated 36 Degrees Anticlockwise with the pivot point at the northern model extent).

Figure 3-2 Mid Field Model Discharge Locations, Port Bonython

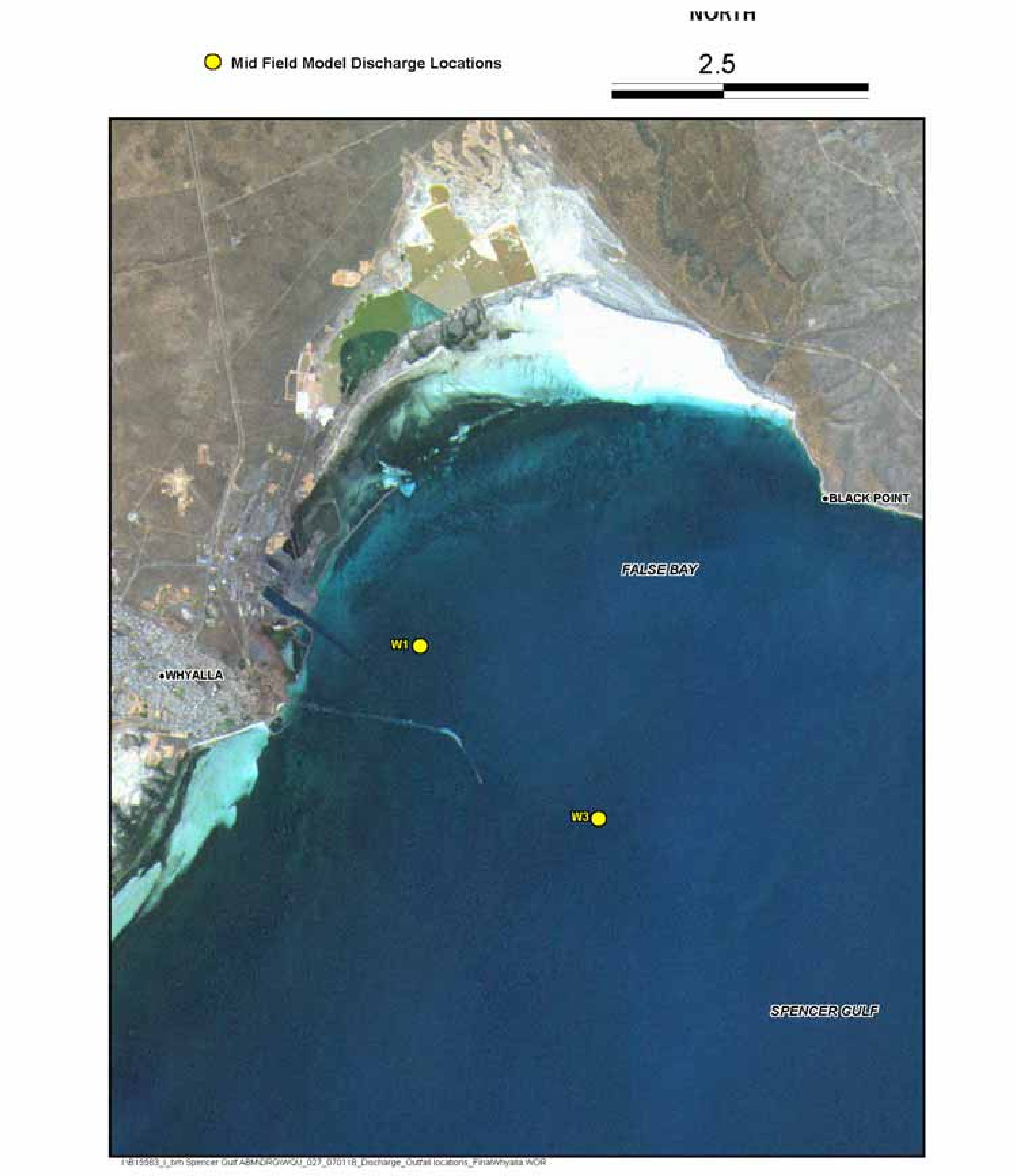


Figure 3-3 Mid Field Model Discharge Locations, Whyalla

Table 3-1 Mid Field Modelling Simulations

Run	Outlet Location	Intake Location	Plant Capacity (ML/day)	
			Seawater Intake	Brine Discharge
1	N/A base case	N/A	N/A	N/A
2	J1	J2	452	272
3	J2	J1	452	272
4	B2	B1	452	272
5	B3	J1	452	272
6	Port Augusta	Port Augusta	452	272
7	N/A base case	N/A	N/A	N/A
8	J2	J1	452	272
9	B3	J1	452	272
10	W1	Whyalla	452	272
11	B4	J1	452	272
12	B5	J1	452	272
13	W3	Whyalla	452	272
14	B6	J1	452	272
16[1]	B7	J1	452	272

[1] The outfall and intake locations were specified by BHP Billiton for this simulation as different to the preceding ones based on revised facility configurations

The simulations enumerated in Table 3-1 were executed over two distinct tidal regimes: 'typical tide' (all simulations) and 'dodge tide' (simulations 7 to 16). These tides, and associated wind conditions are described in detail in later sections. Simulation 15 is also described.

Brine composition was found to vary depending on the ambient salinity at the intake location. A time-series was constructed using ambient salinity concentrations predicted by a control case simulation performed over the period of interest. An outfall salinity time-series was then constructed using the ambient salinity time-series and altering the salinity (multiplied by 1.8) to account an increase introduced by the desalination plant. Temperature was treated in the same fashion.

In all cases, the brine was introduced into the model into the bottom cell (2m high) of each specified location and only diluted by the initial input into the full cell volume. Since the actual discharge will occur through a diffuser that will cause the brine to form a plume of greater than 2 m height, the ELCOM simulations are, to some degree, conservative in that initial dilution only occurs by mixing of the plume over the full cell volume. It is noted that the diffuser has been set at 200m long (the same as the cell size) so that the forced dilution of the effluent over once cell is only artificial in the sense of mixing perpendicular to the diffuser line. During periods of moderate ambient velocities, this assumption will most likely be satisfactory. Any further dilution is in response to the ambient flow.

Wind conditions varied over the 'typical' and 'dodge' tide conditions. Representative conditions for these periods are as follows:

- Typical
  - Mean: 4.6 m/s;
  - Maximum: 8.5 m/s

- o Minimum: 0 m/s.
- Dodge
  - o Mean: 1.5 m/s;
  - o Maximum: 8.5 m/s
  - o Minimum: 0 m/s.

3.2 Results

Results have been presented here as contour plots. Specifically, the contours are of percentile dilution at each computational cell location (in the bottom layer) over a nominated period of time. The dilutions of interest nominated by BHP Billiton were 85:1 and 180:1. These dilutions were calculated by considering the dilution of a passive and inert tracer introduced into the model with the brine stream.

The method of computation of these percentile contours was as follows. Each computational bottom cell was considered individually over each simulation's period of interest. Specifically, a timeseries of brine dilution was extracted for each cell and percentile analysis completed, reporting the 1st, 10th and 50th percentile dilution. This process was repeated for each bottom cell, and then the respective results plotted in three separate figures corresponding to each percentile. Each of these percentile maps was then contoured with a line at each of the 85:1 and 180:1 dilutions. This suite of three figures for each discharge location is presented below.

3.2.1 Typical Tidal Period

The typical tidal timeseries for simulations 1 to 6 and 7 to 16 are presented in Figure 3-4 and Figure 3-5, respectively. They were selected to be as similar as possible. Dodge tide results (also simulations 7 to 16) are presented in subsequent sections.

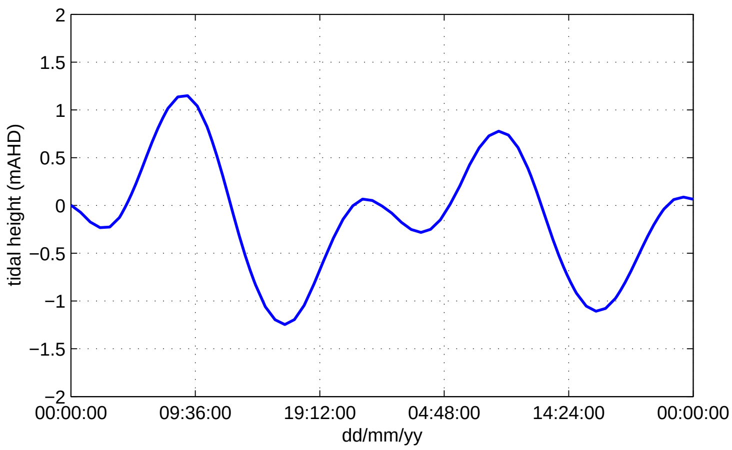


Figure 3-4 Simulations 1 to 6 'Typical Tide'

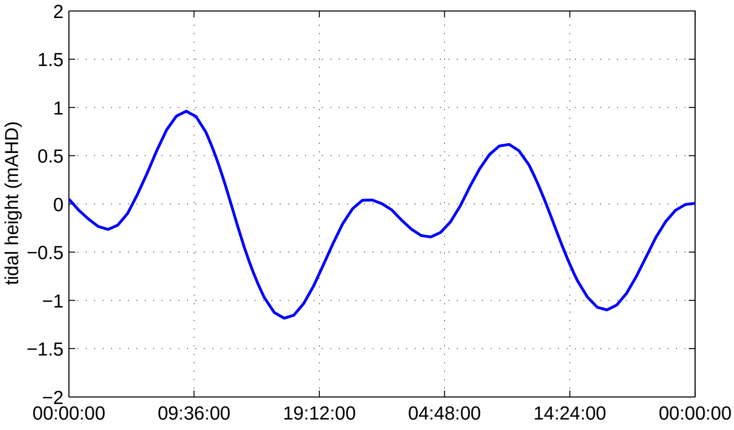


Figure 3-5 Simulations 7 to 16 'Typical Tide'

Percentile contours were computed over the simulation data throughout these periods, and the results presented below. Outfall and intake locations are marked on each figure as red and green points, respectively, and the designated names are reported in each figure caption where appropriate. Simulations 1 and 7 are not presented as these are bases cases with no outfall.

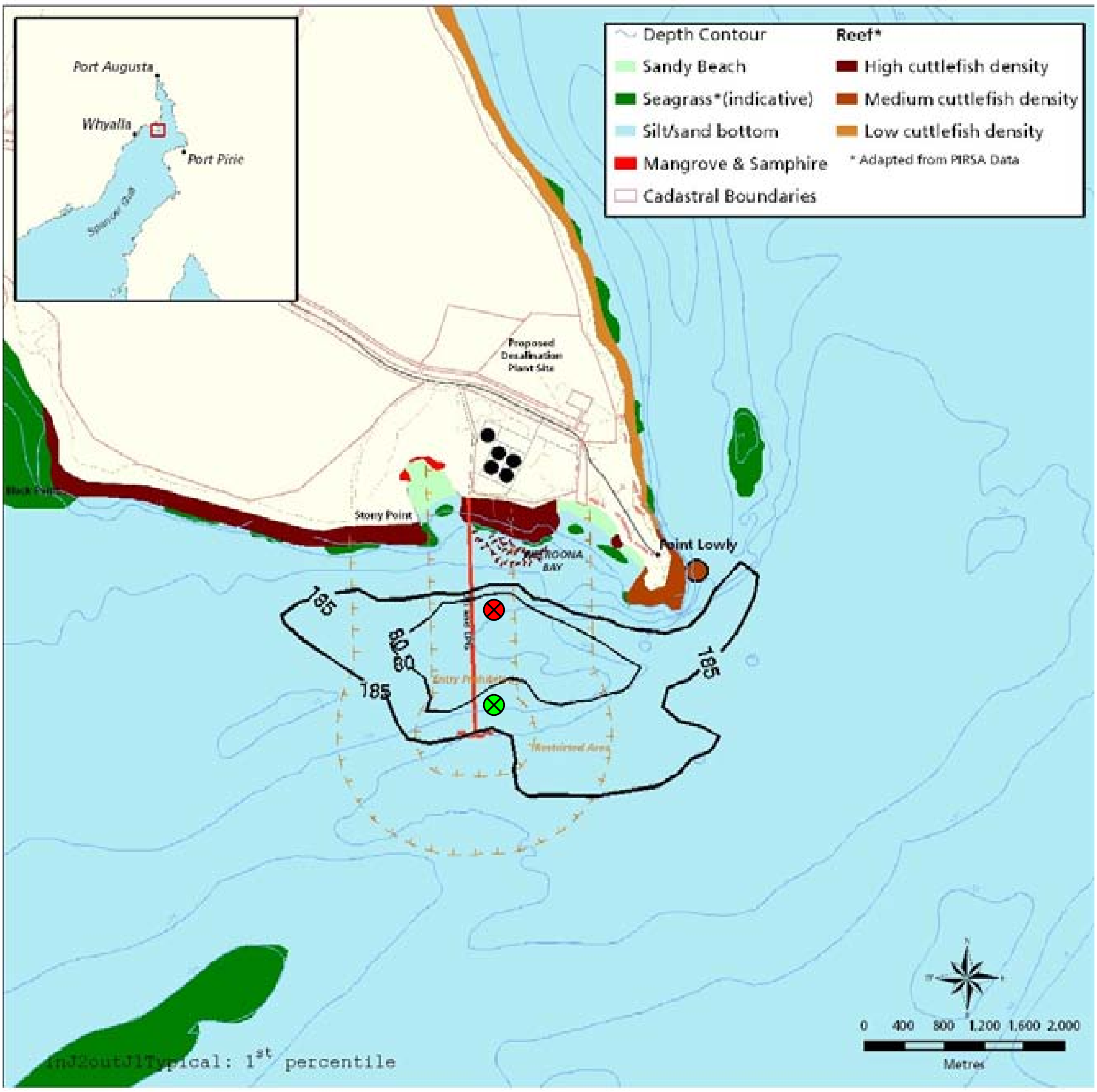


Figure 3-6 Simulation 2, 1st Percentile Contours, Typical Tide. Outlet: J1 Intake: J2

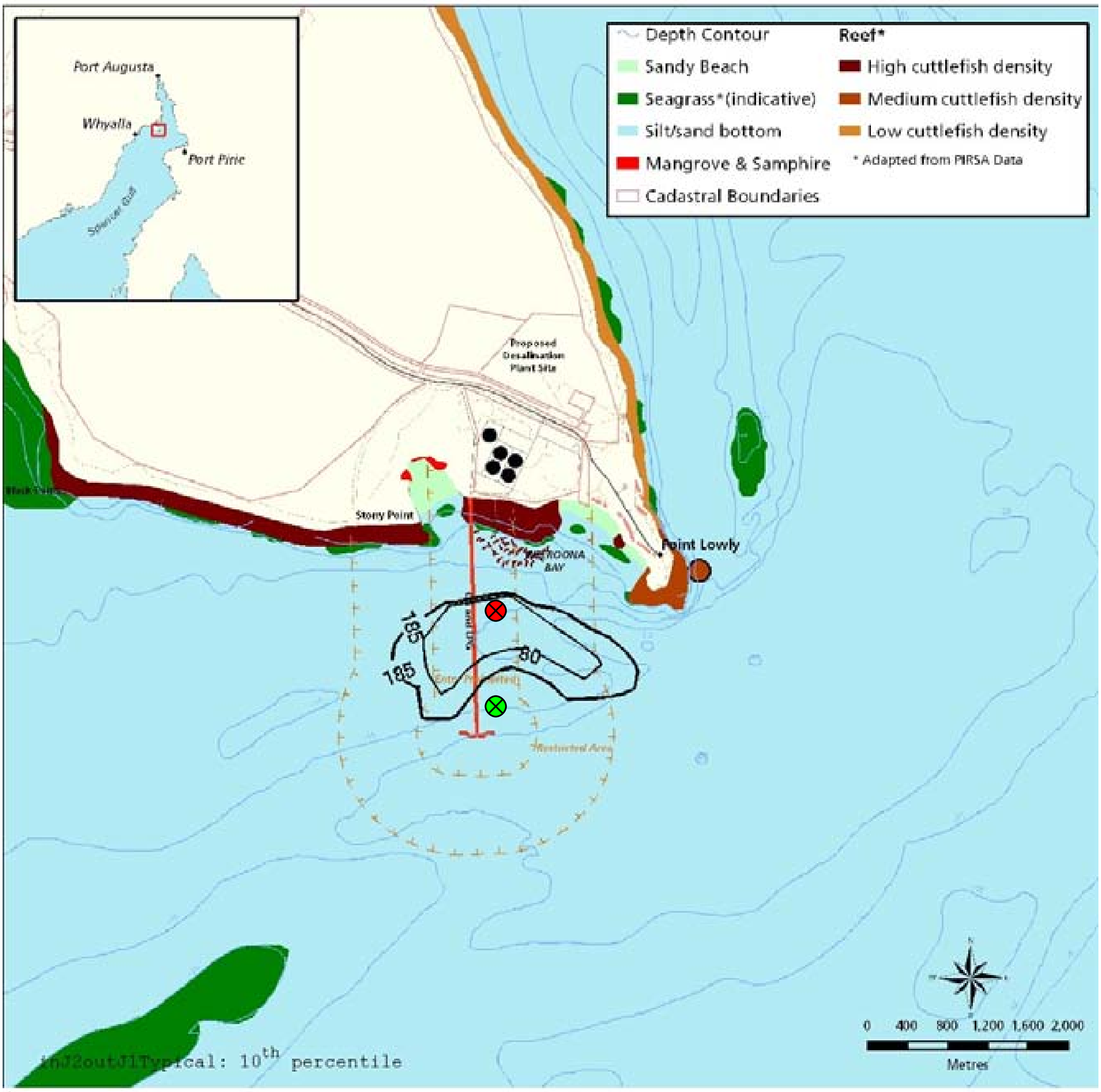


Figure 3-7 Simulation 2, 10th Percentile Contours, Typical Tide. Outlet: J1 Intake: J2

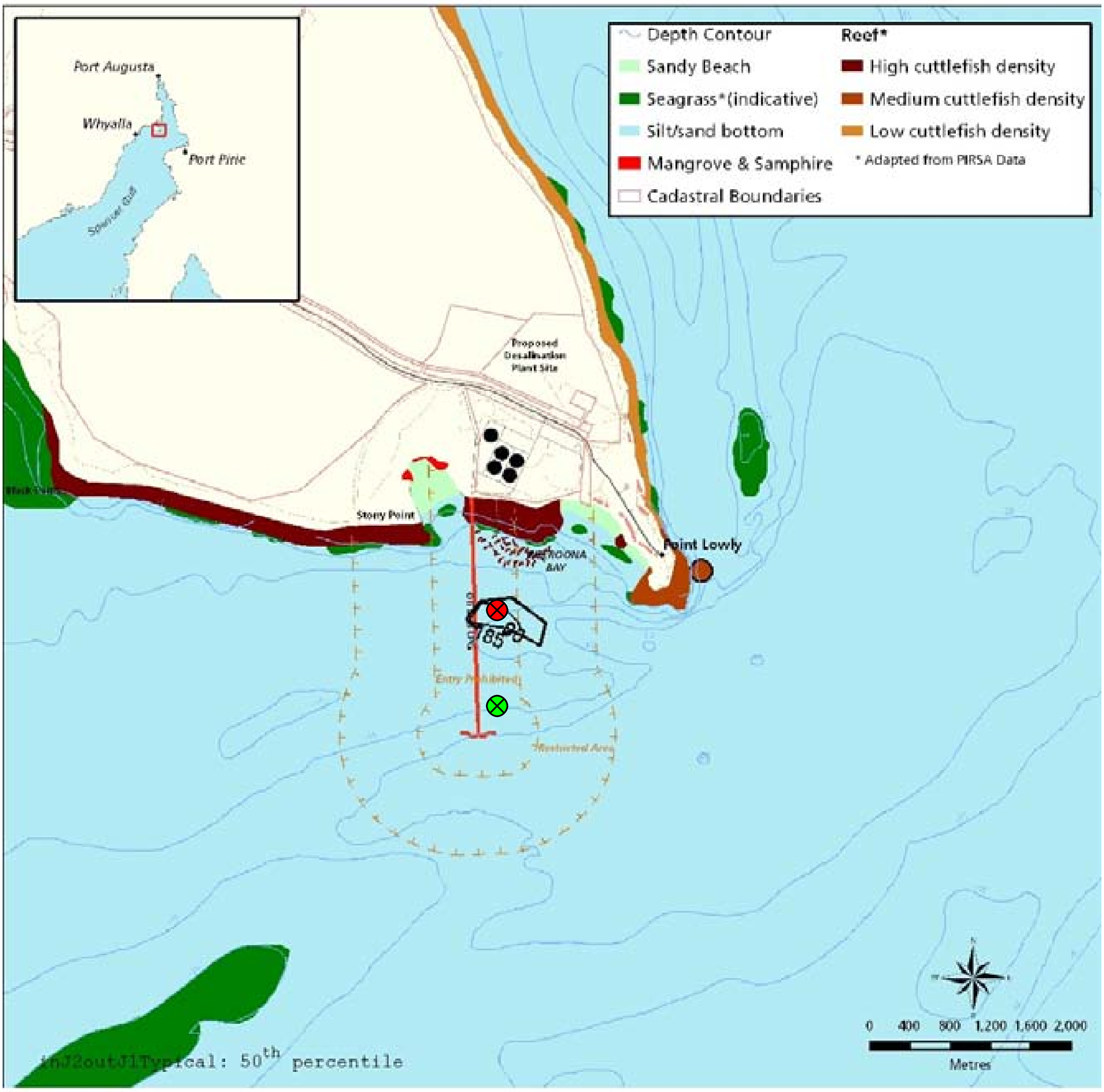


Figure 3-8 Simulation 2, 50th Percentile Contours, Typical Tide. Outlet: J1 Intake: J2

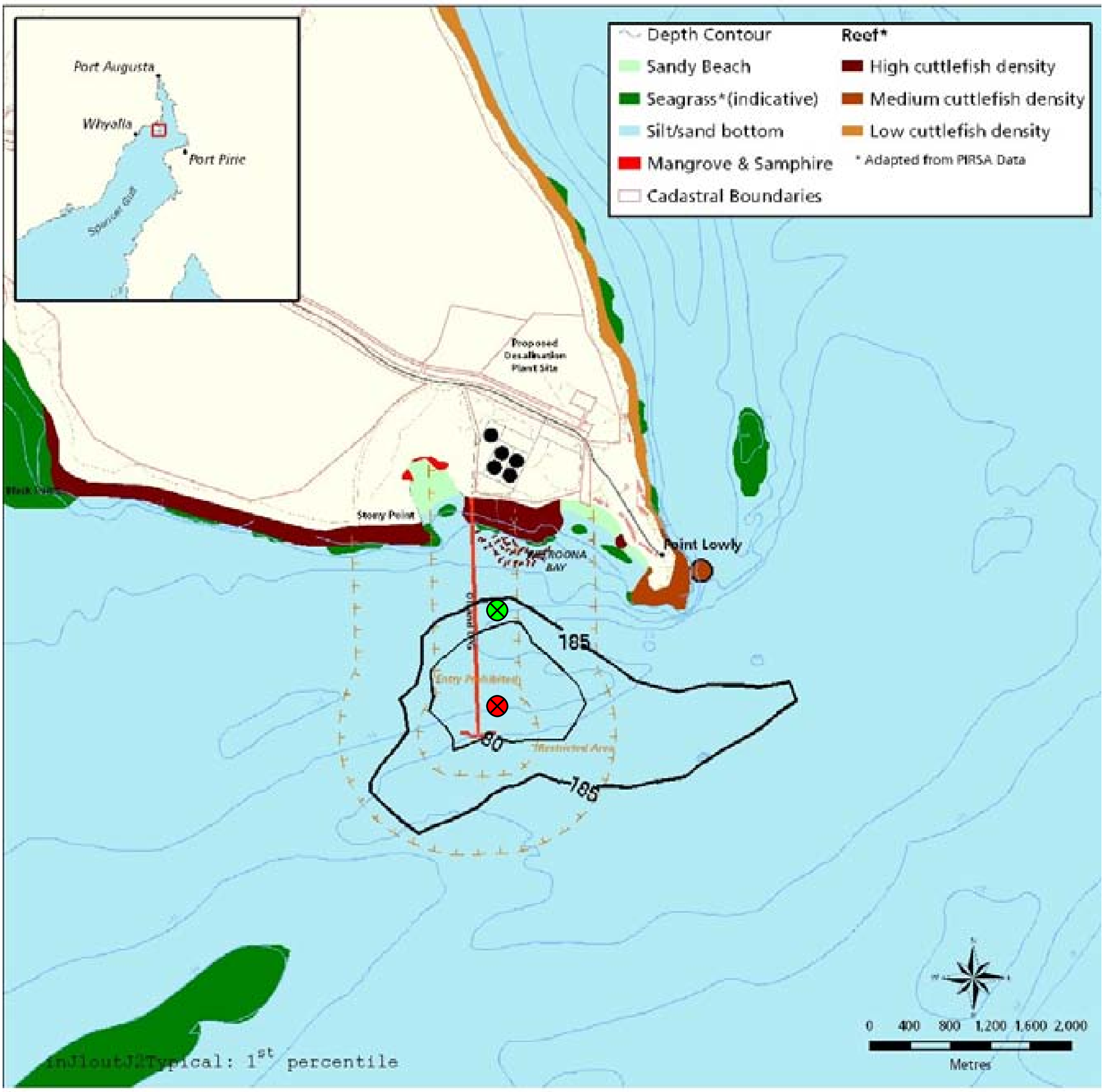


Figure 3-9 Simulation 3, 1st Percentile Contours, Typical Tide. Outlet: J2 Intake: J1

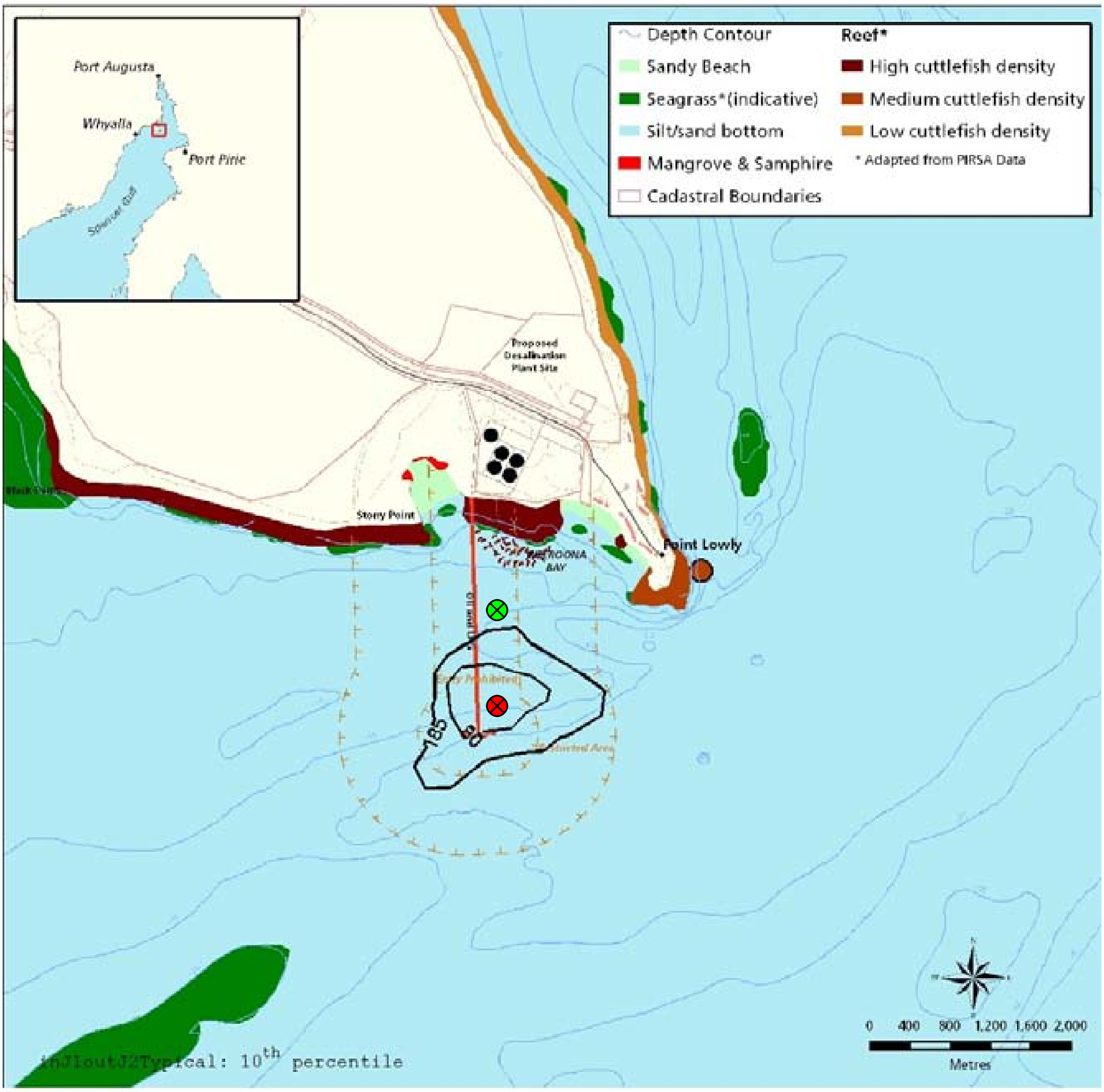


Figure 3-10 Simulation 3, 10th Percentile Contours, Typical Tide. Outlet: J2 Intake: J1

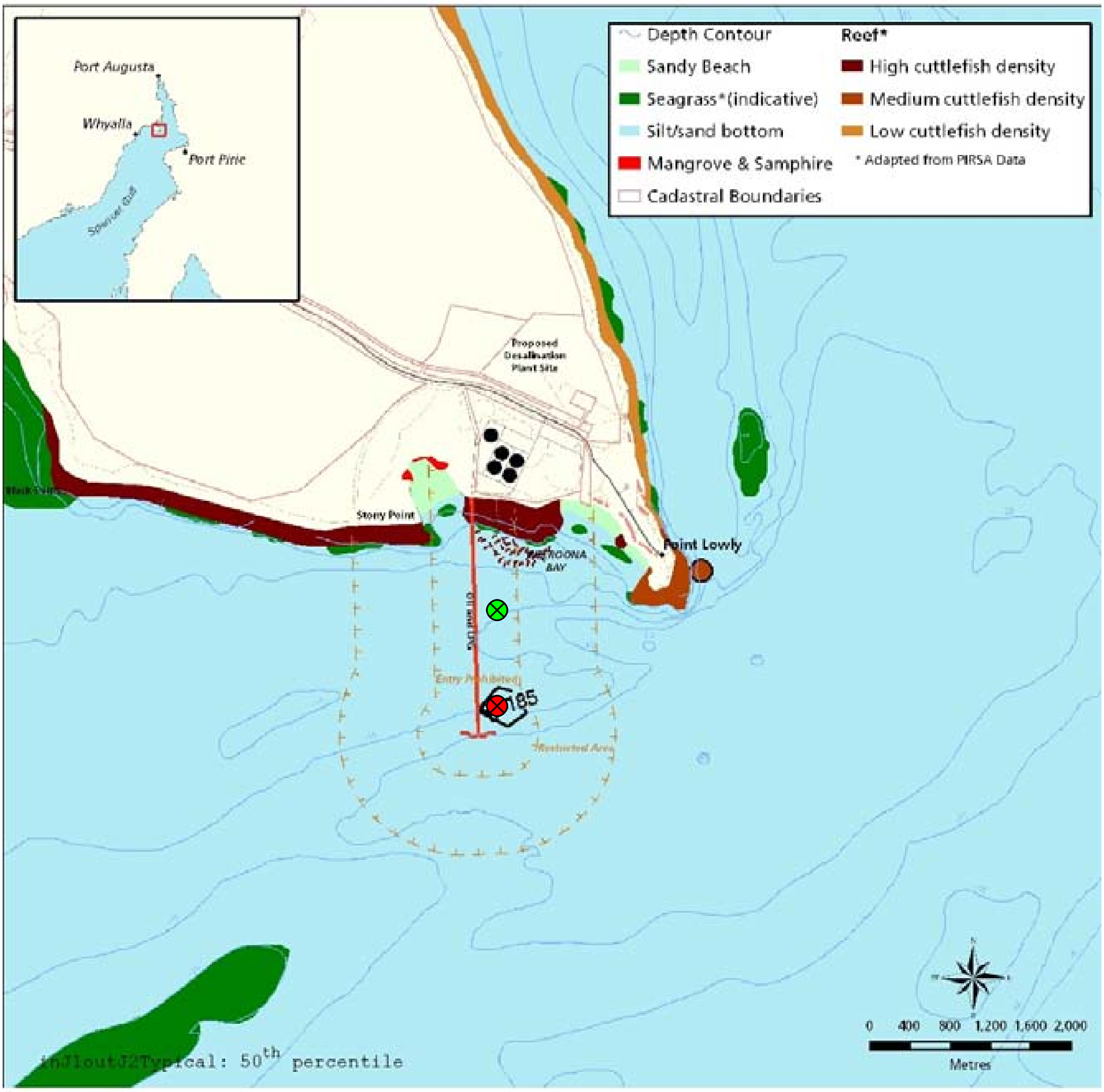


Figure 3-11 Simulation 3, 50th Percentile Contours, Typical Tide. Outlet: J2 Intake: J1

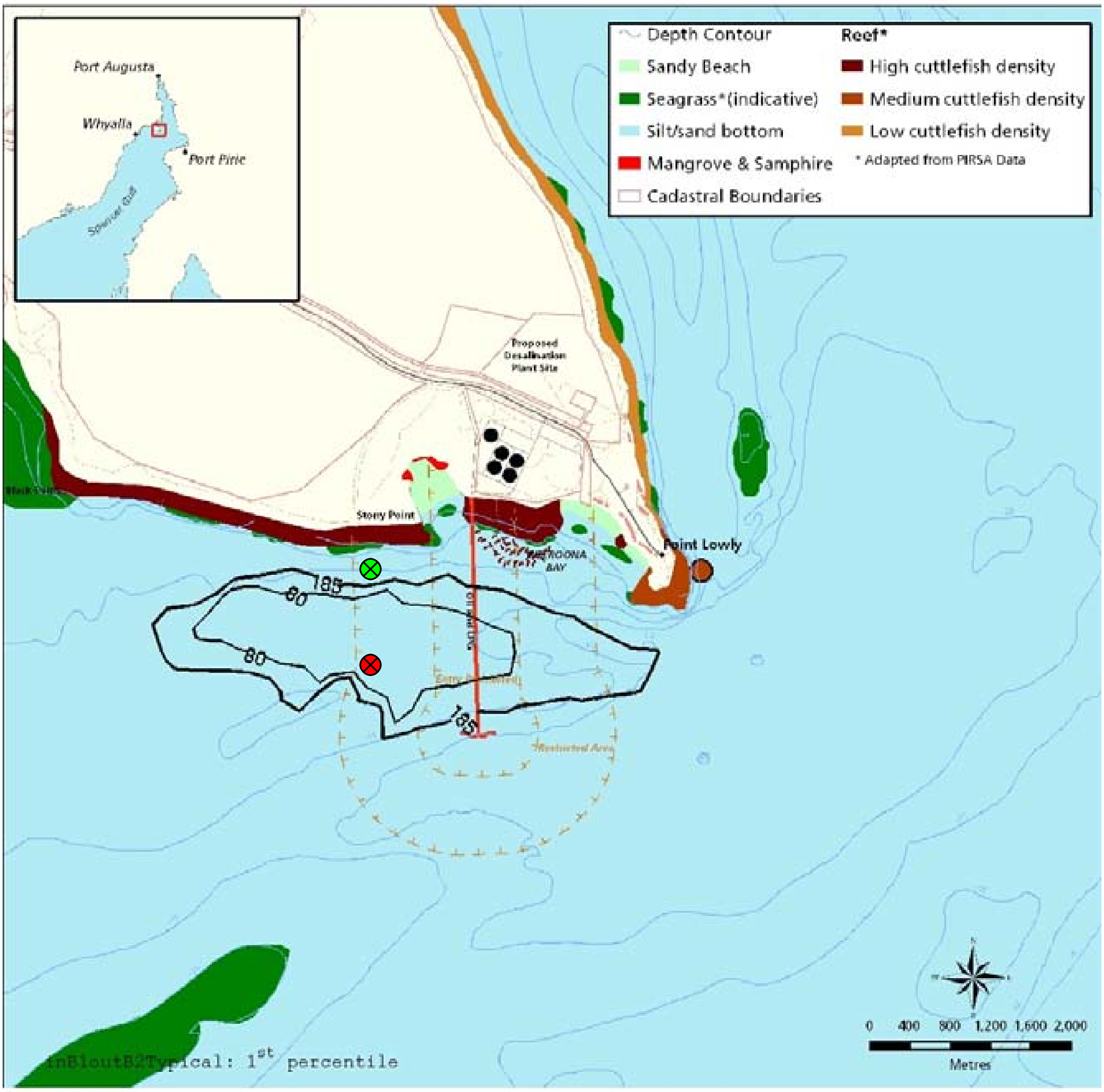


Figure 3-12 Simulation 4, 1st Percentile Contours, Typical Tide. Outlet: B2 Intake: B1

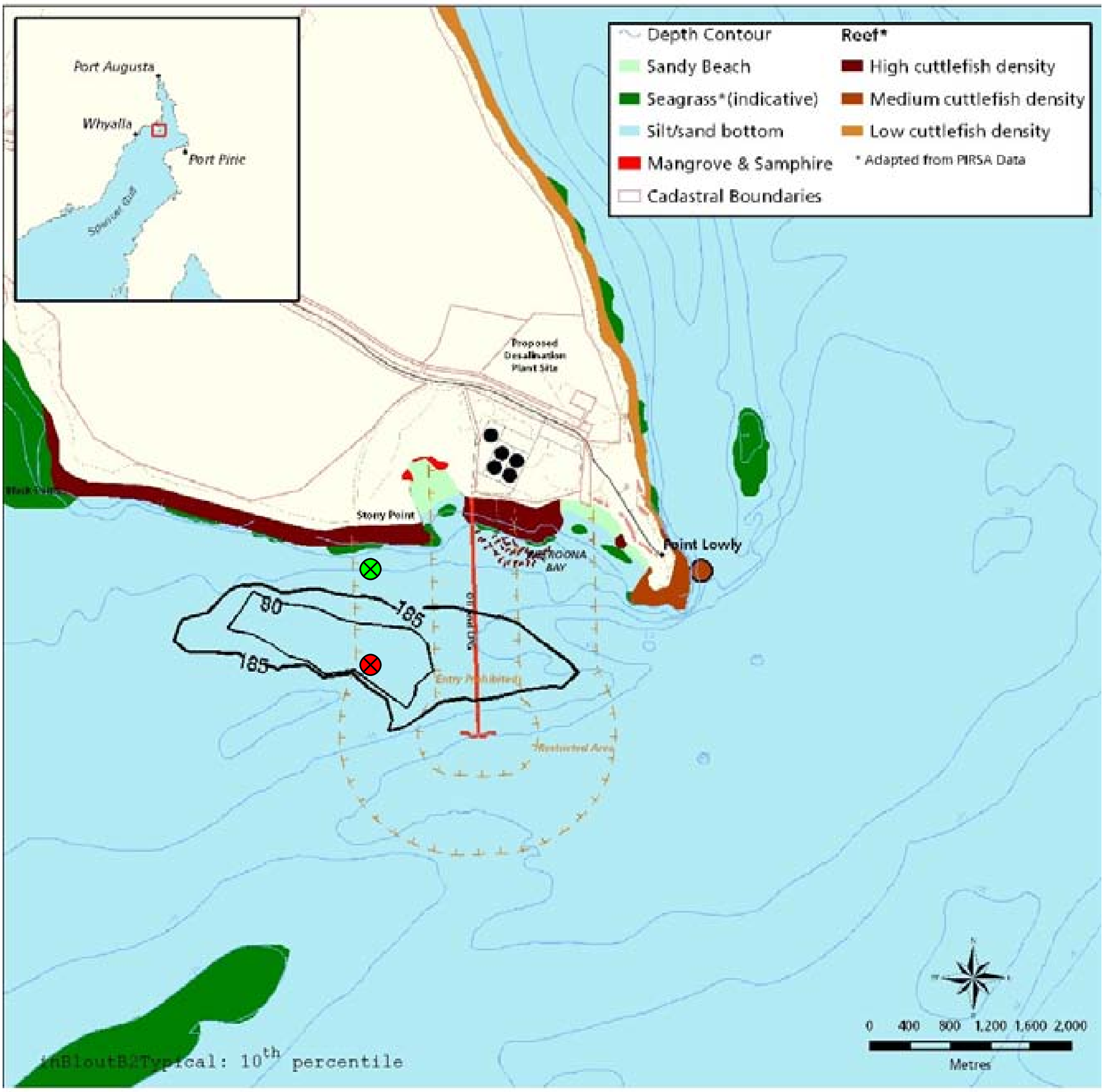


Figure 3-13 Simulation 4, 10th Percentile Contours, Typical Tide. Outlet: B2 Intake: B1

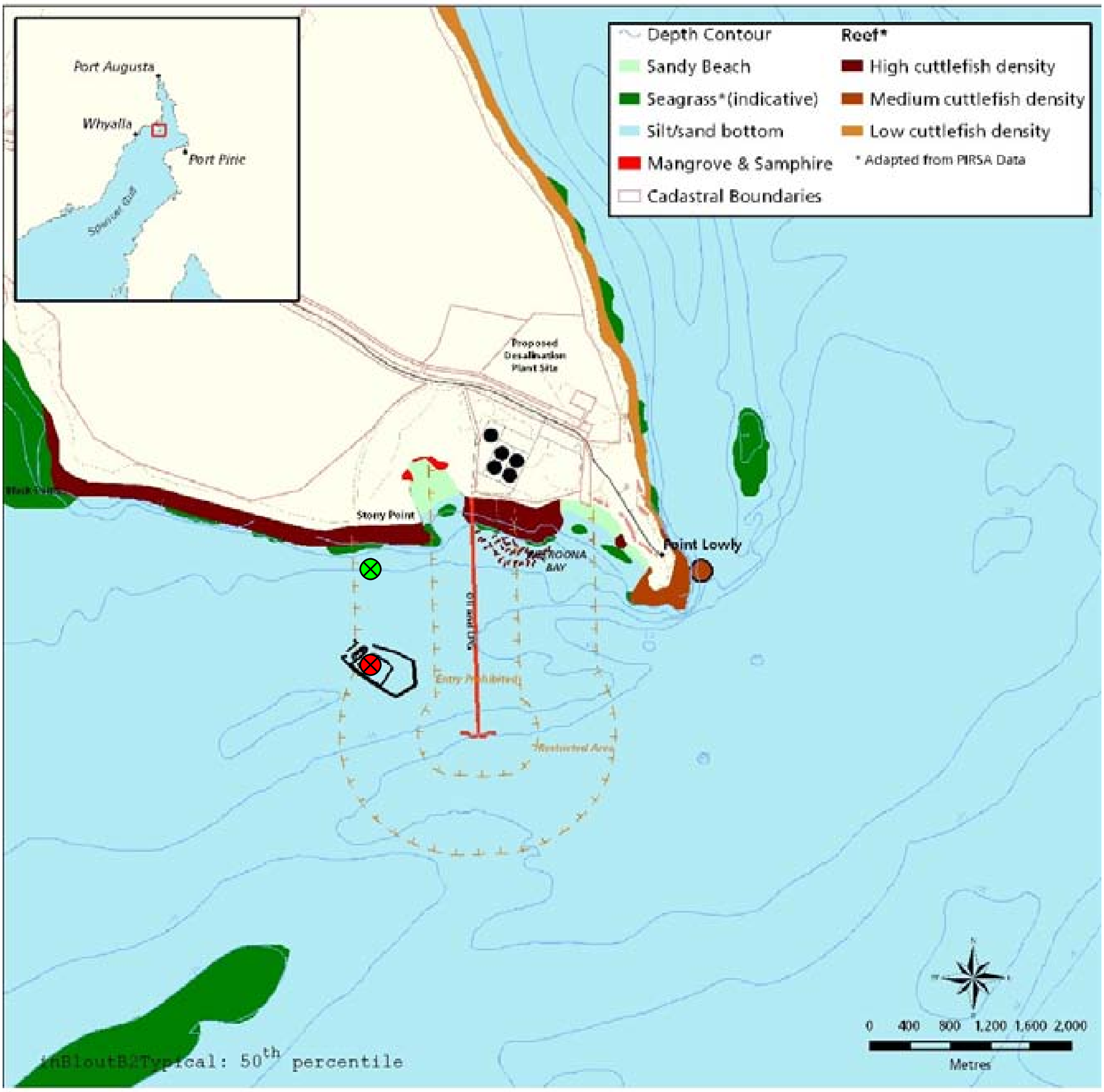


Figure 3-14 Simulation 4, 50th Percentile Contours, Typical Tide. Outlet: B2 Intake: B1

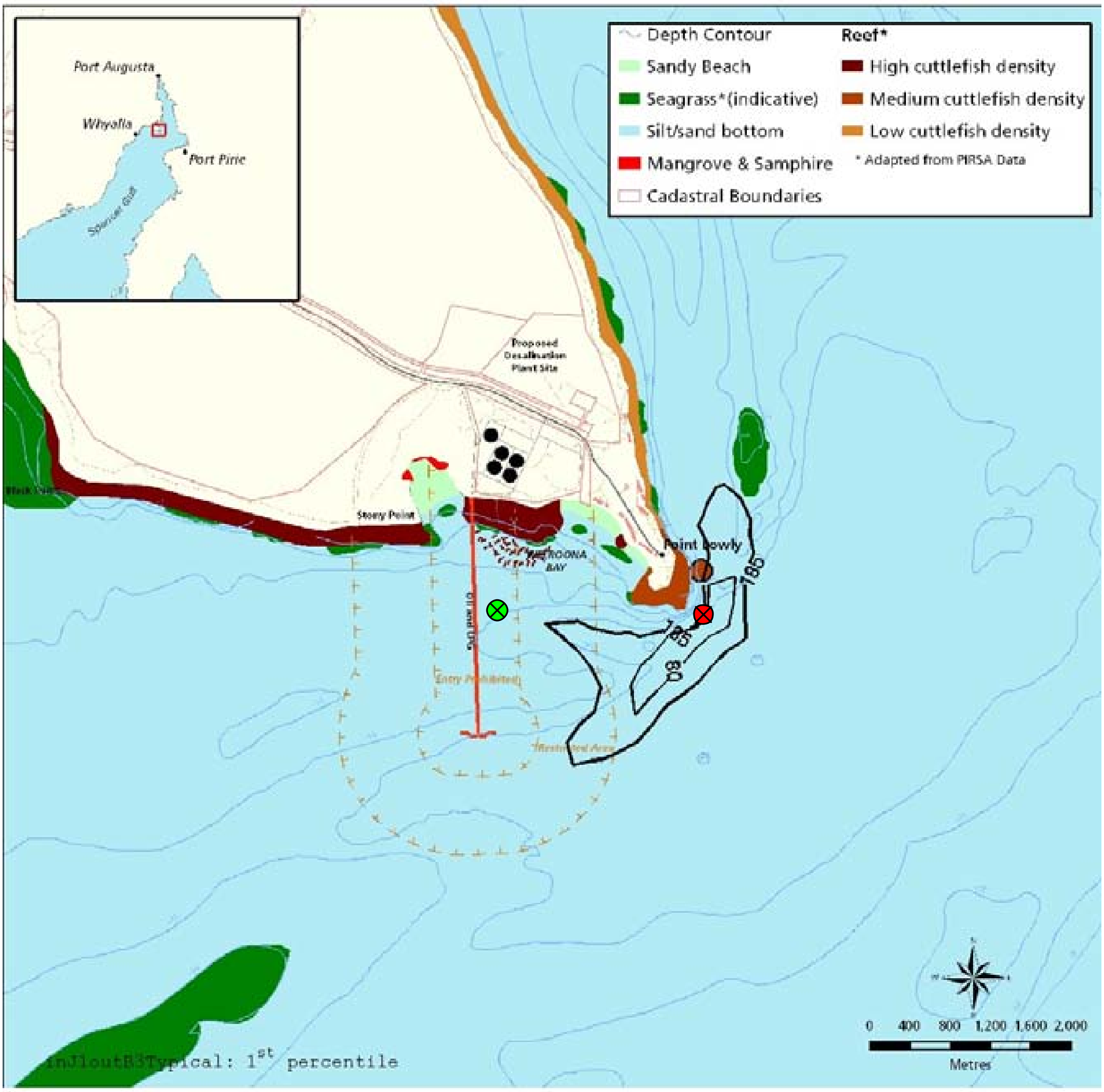


Figure 3-15 Simulation 5, 1st Percentile Contours, Typical Tide. Outlet: B3 Intake: J1

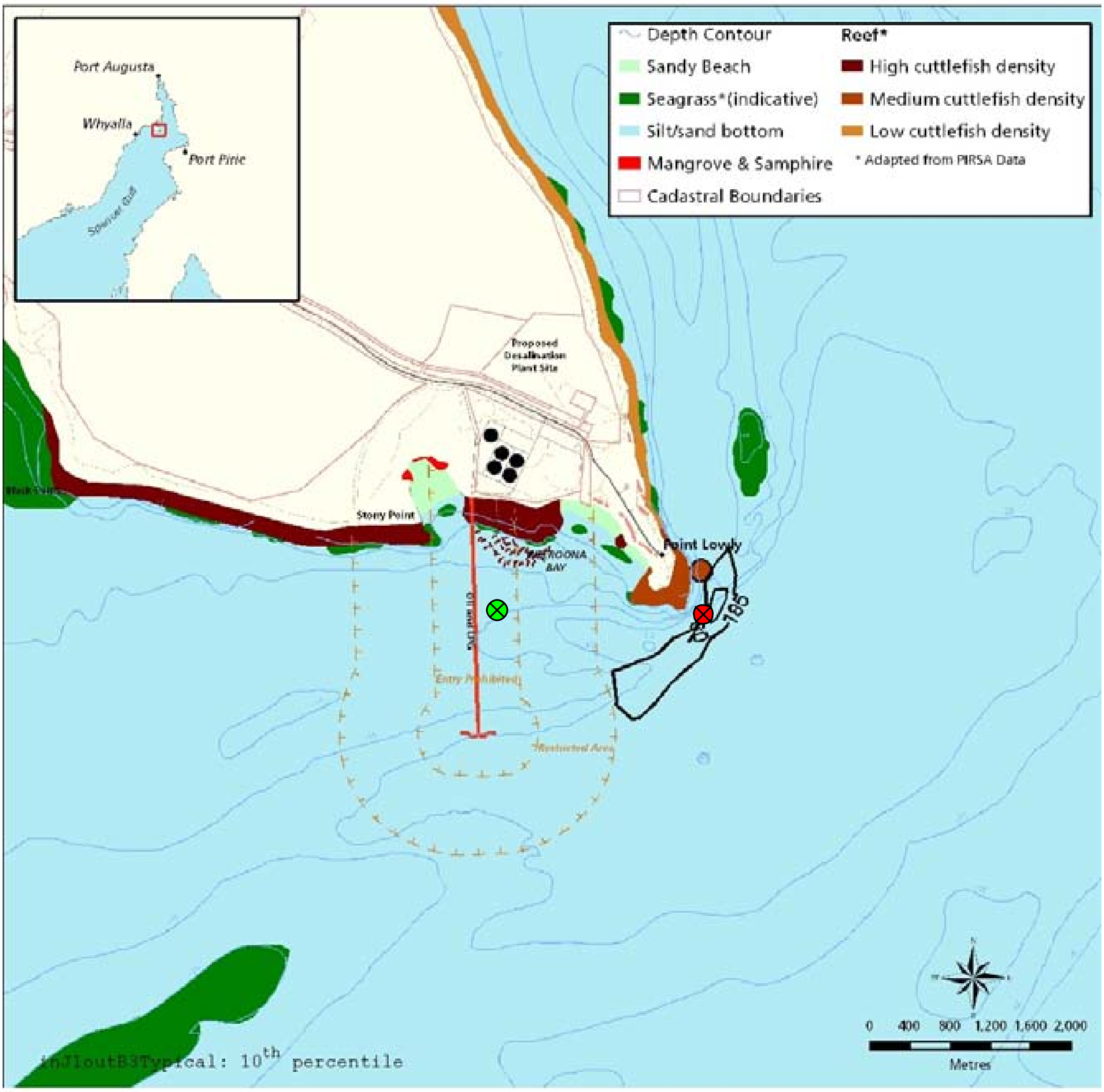


Figure 3-16 Simulation 5, 10th Percentile Contours, Typical Tide. Outlet: B3 Intake: J1

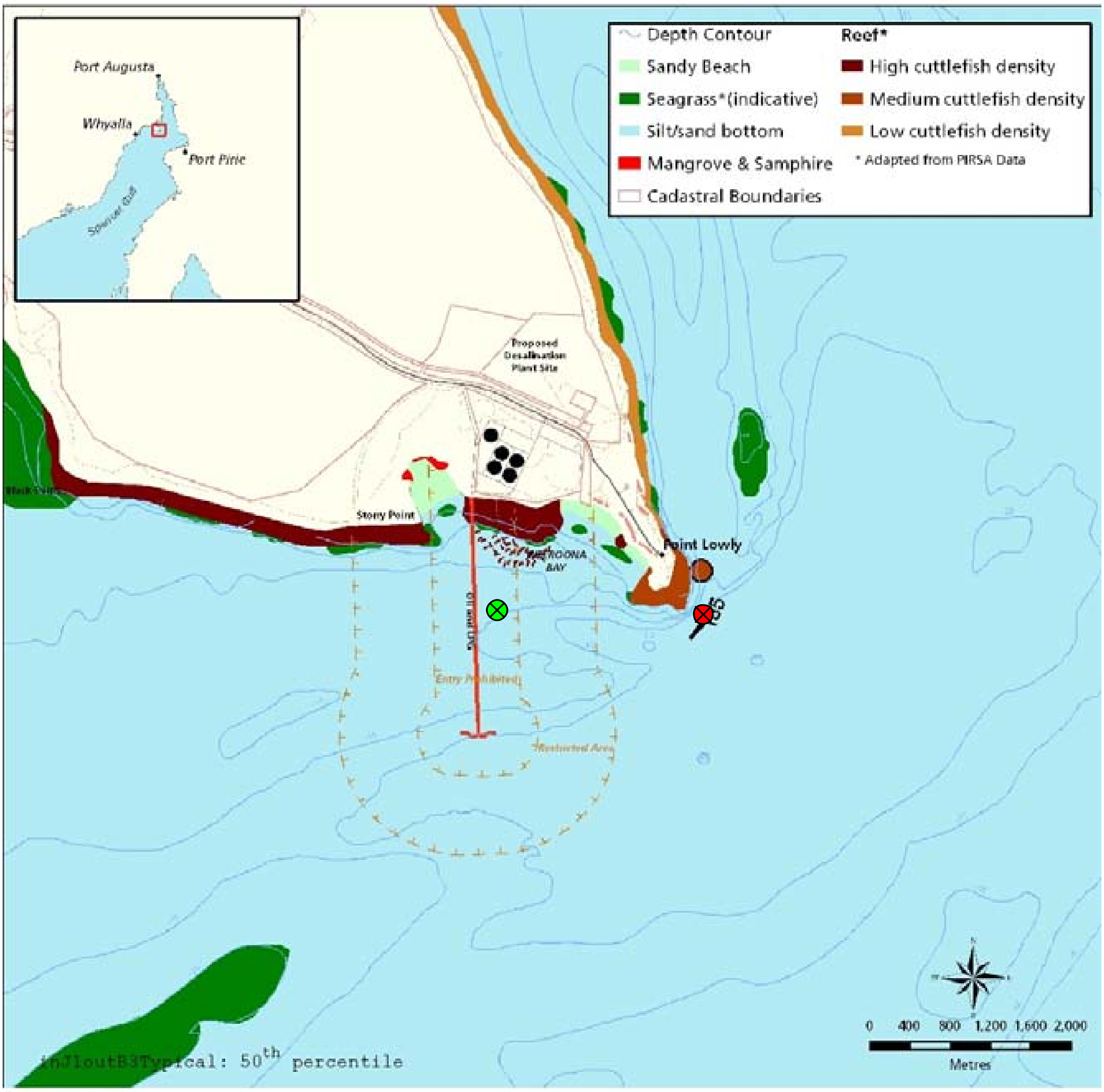


Figure 3-17 Simulation 5, 50th Percentile Contours, Typical Tide. Outlet: B3 Intake: J1

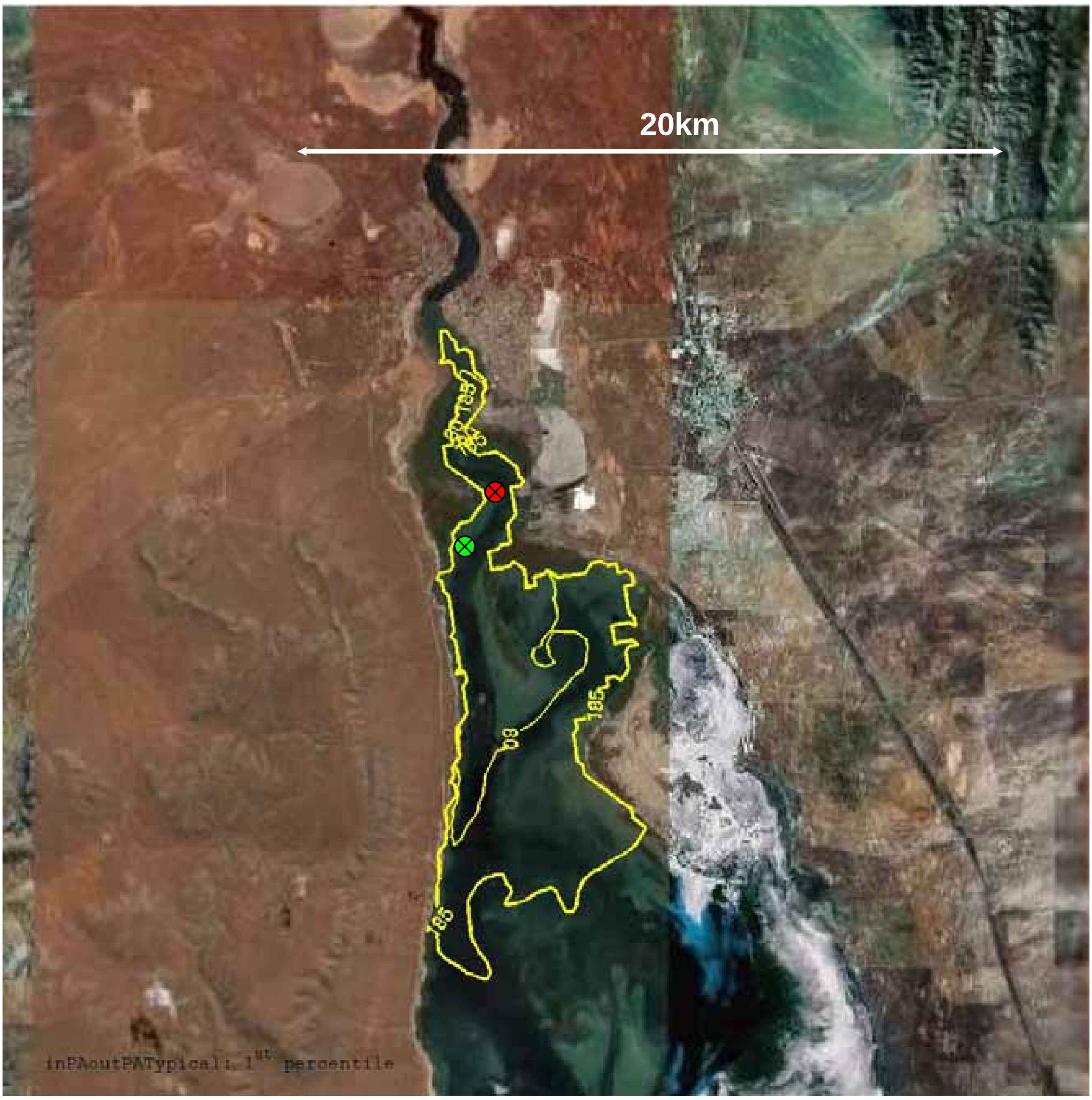


Figure 3-18 Simulation 6, 1st Percentile Contours, Typical Tide Conditions

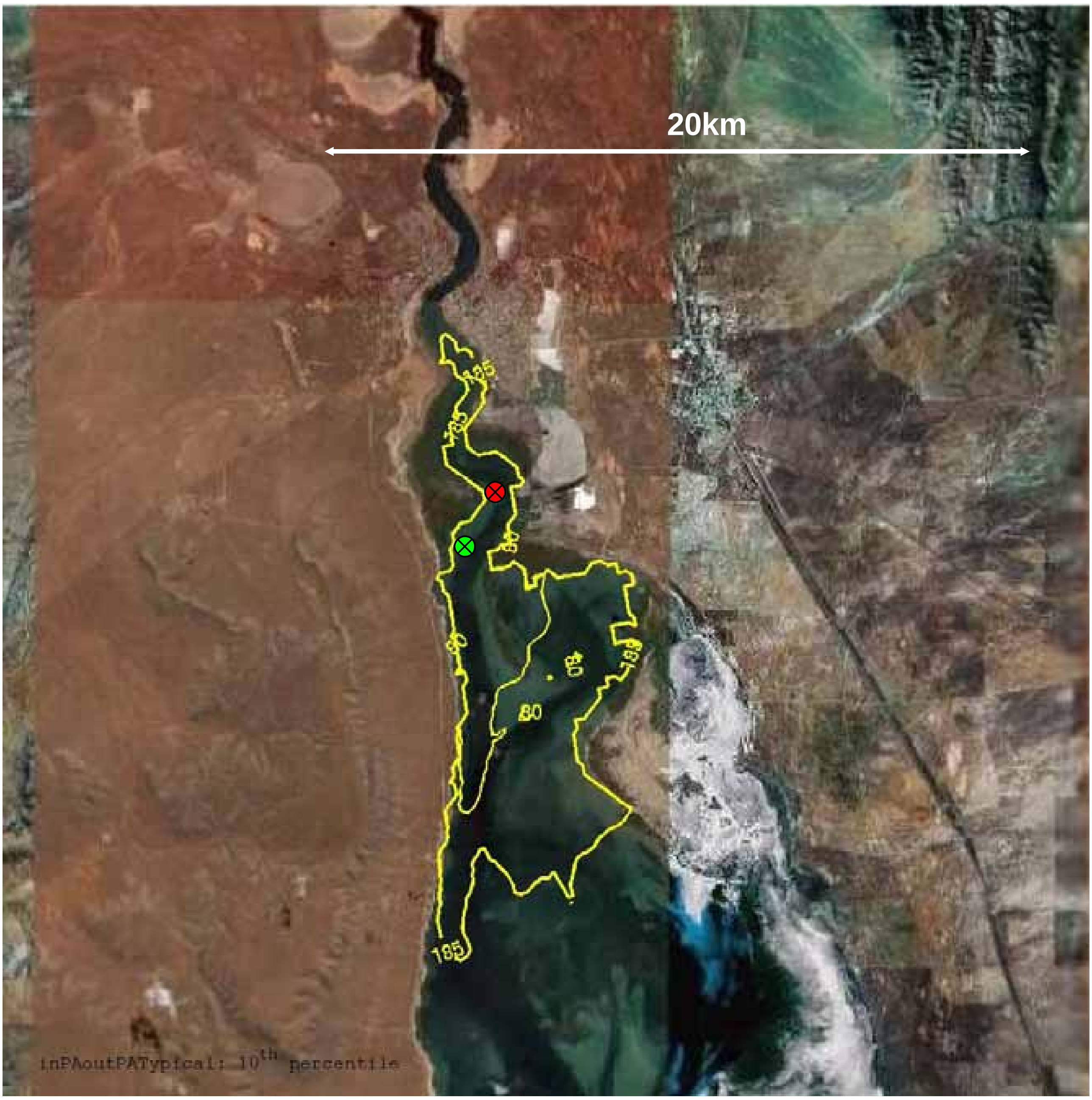


Figure 3-19 Simulation 6, 10th Percentile Contours, Typical Tide Conditions

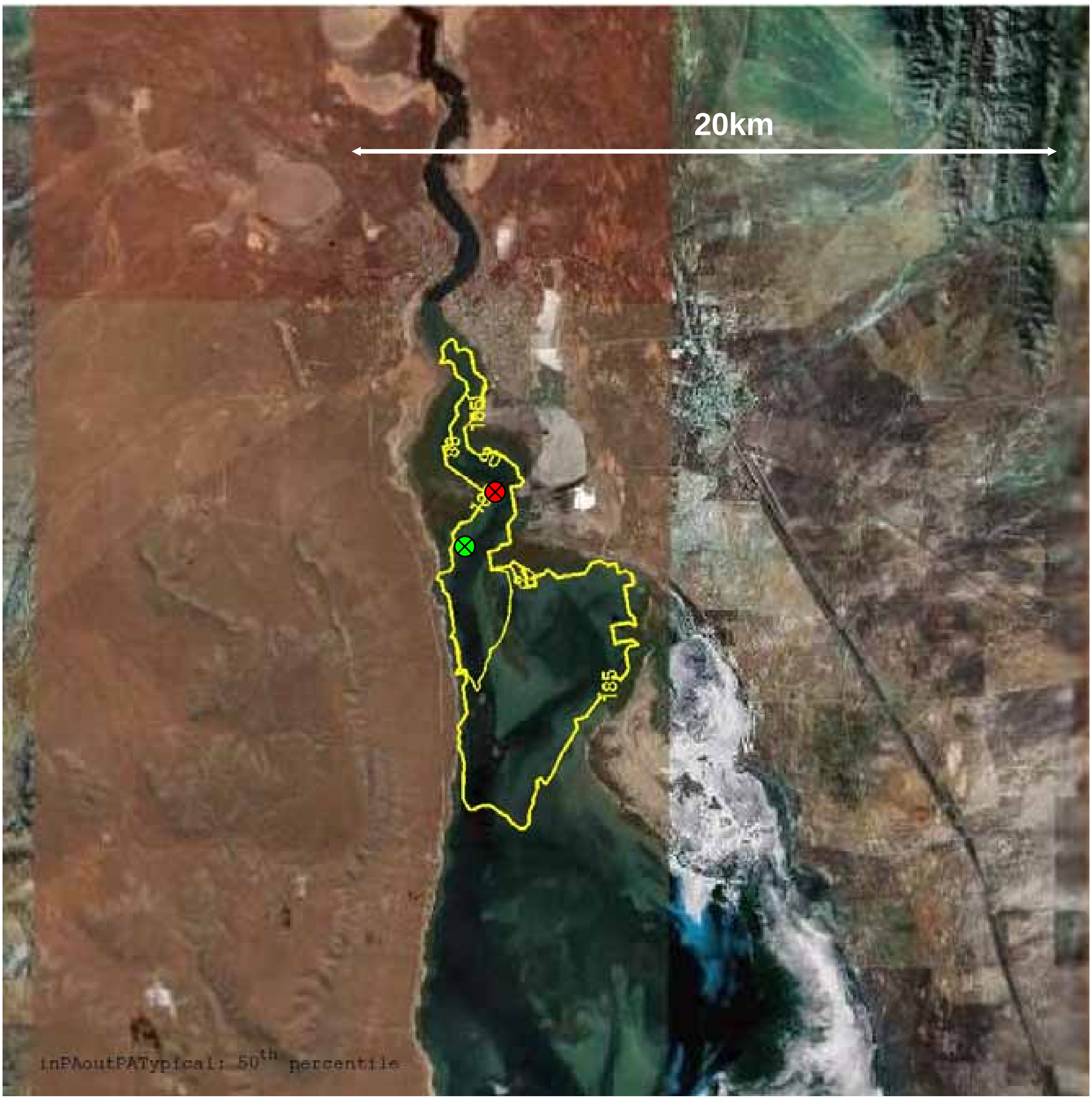


Figure 3-20 Simulation 6, 50th Percentile Contours, Typical Tide Conditions

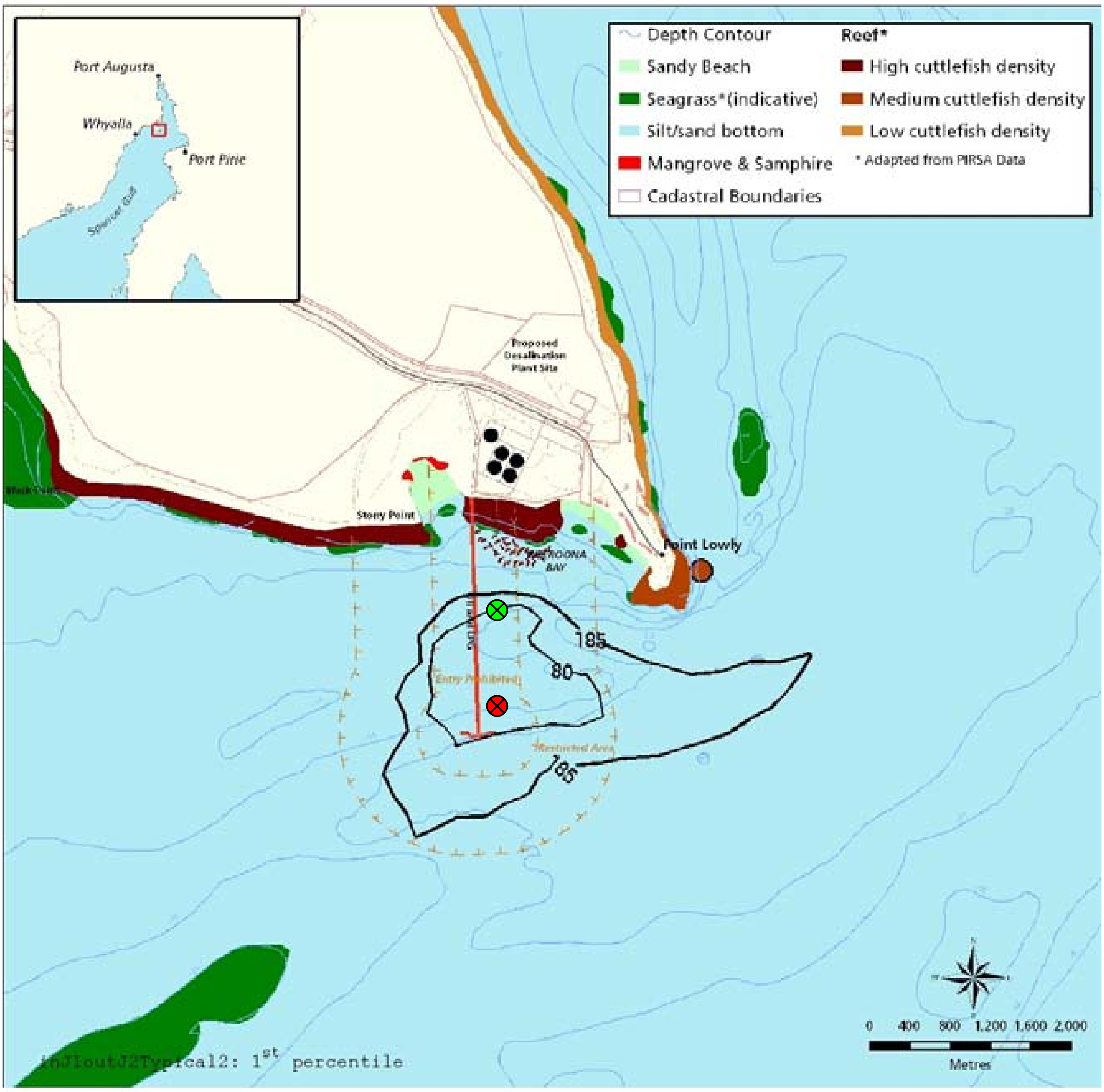


Figure 3-21 Simulation 8, 1st Percentile Contours, Typical Tide. Outlet: J2 Intake: J1

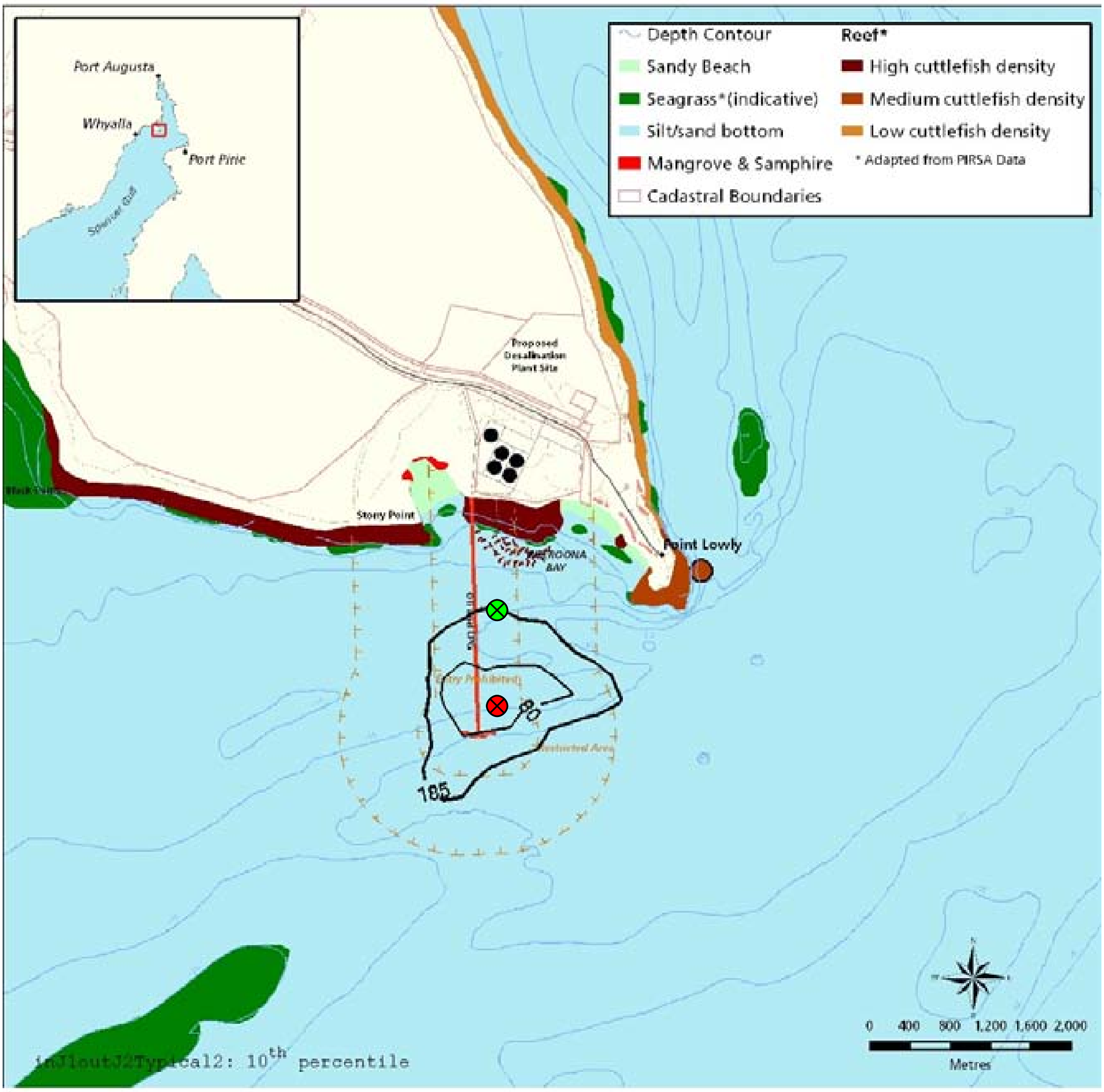


Figure 3-22 Simulation 8, 10th Percentile Contours, Typical Tide. Outlet: J2 Intake: J1

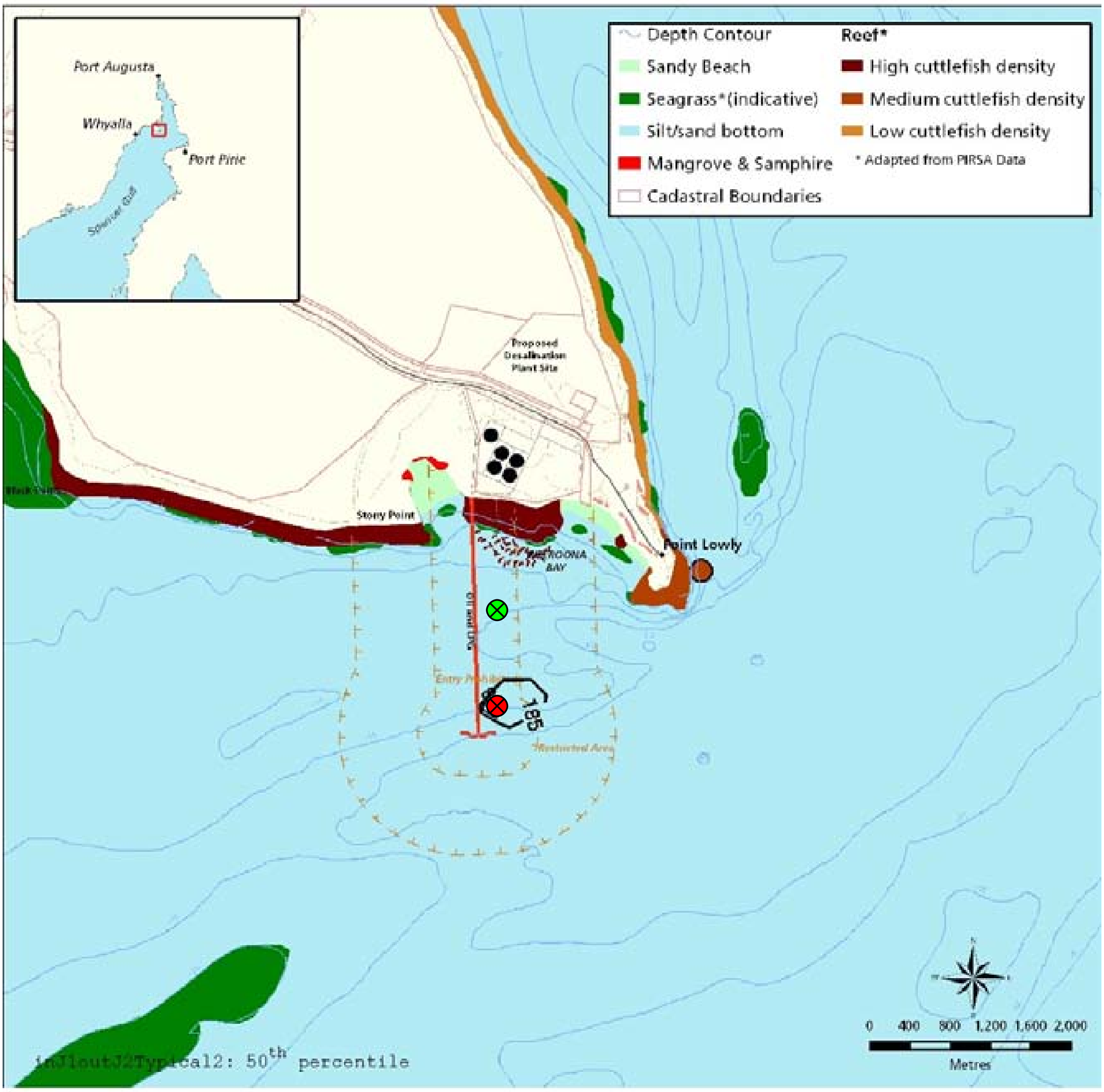


Figure 3-23 Simulation 8, 50th Percentile Contours, Typical Tide. Outlet: J2 Intake: J1

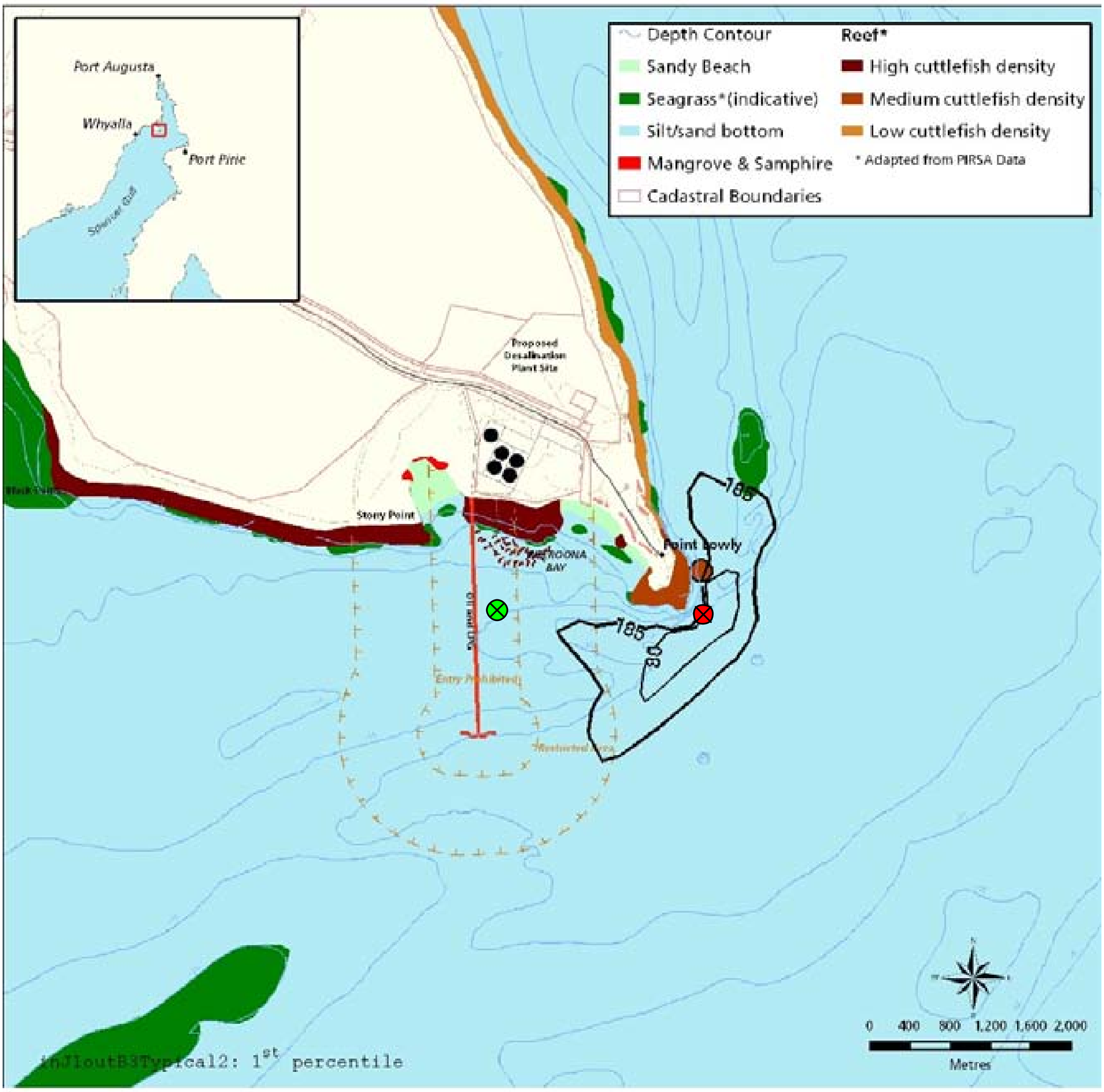


Figure 3-24 Simulation 9, 1st Percentile Contours, Typical Tide. Outlet: B3 Intake: J1

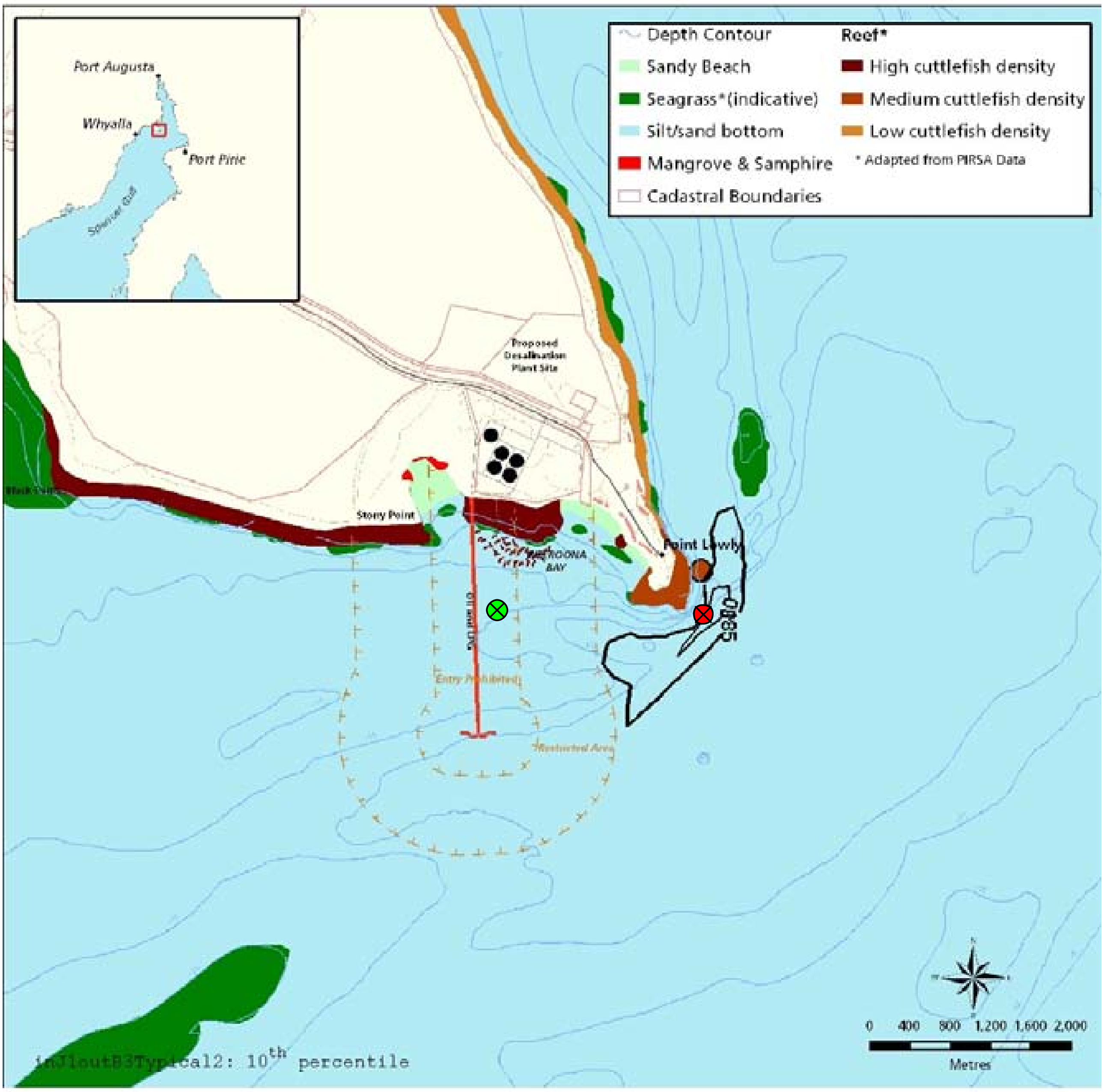


Figure 3-25 Simulation 9, 10th Percentile Contours, Typical Tide. Outlet: B3 Intake: J1

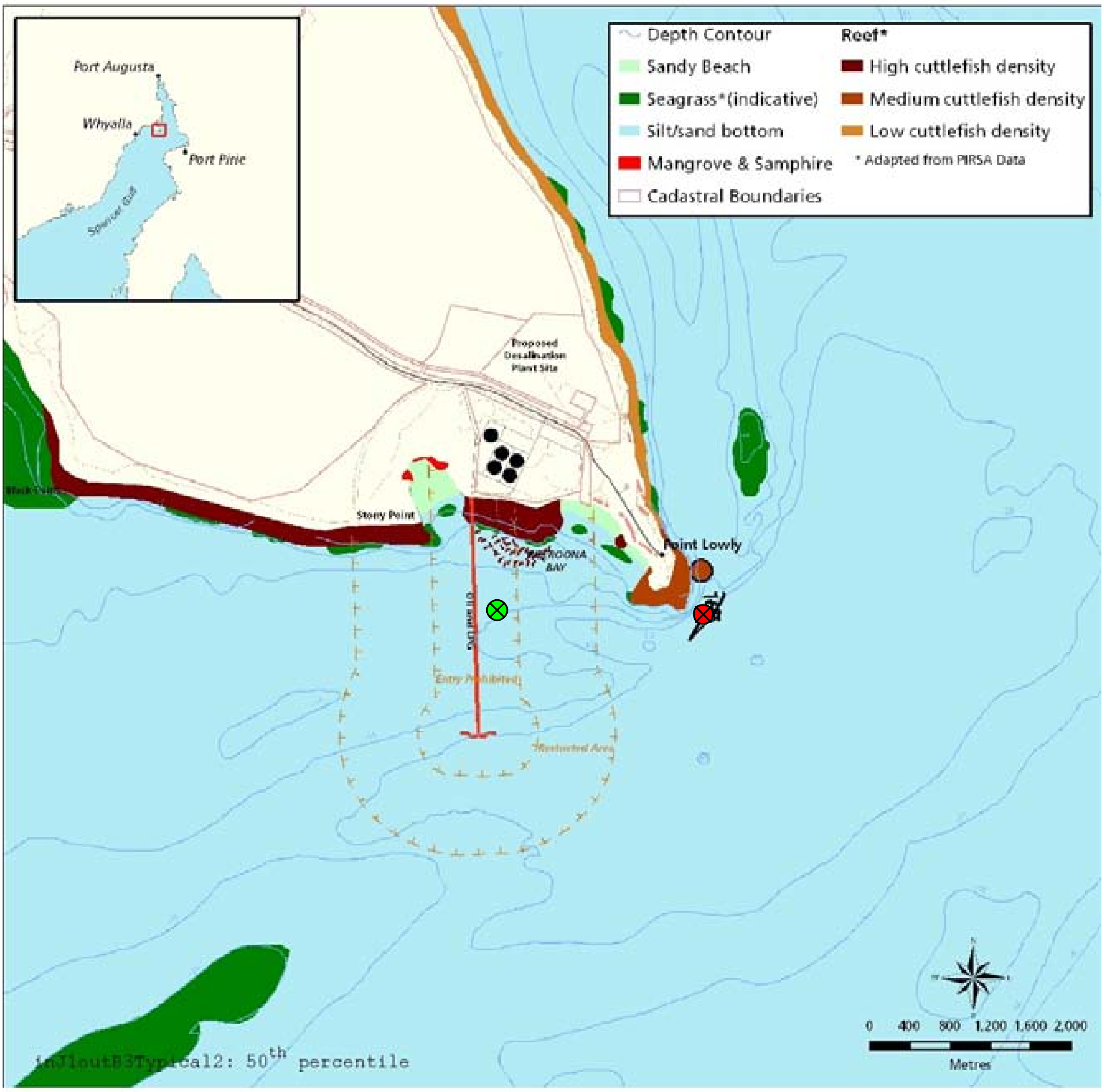


Figure 3-26 Simulation 9, 50th Percentile Contours, Typical Tide. Outlet: B3 Intake: J1

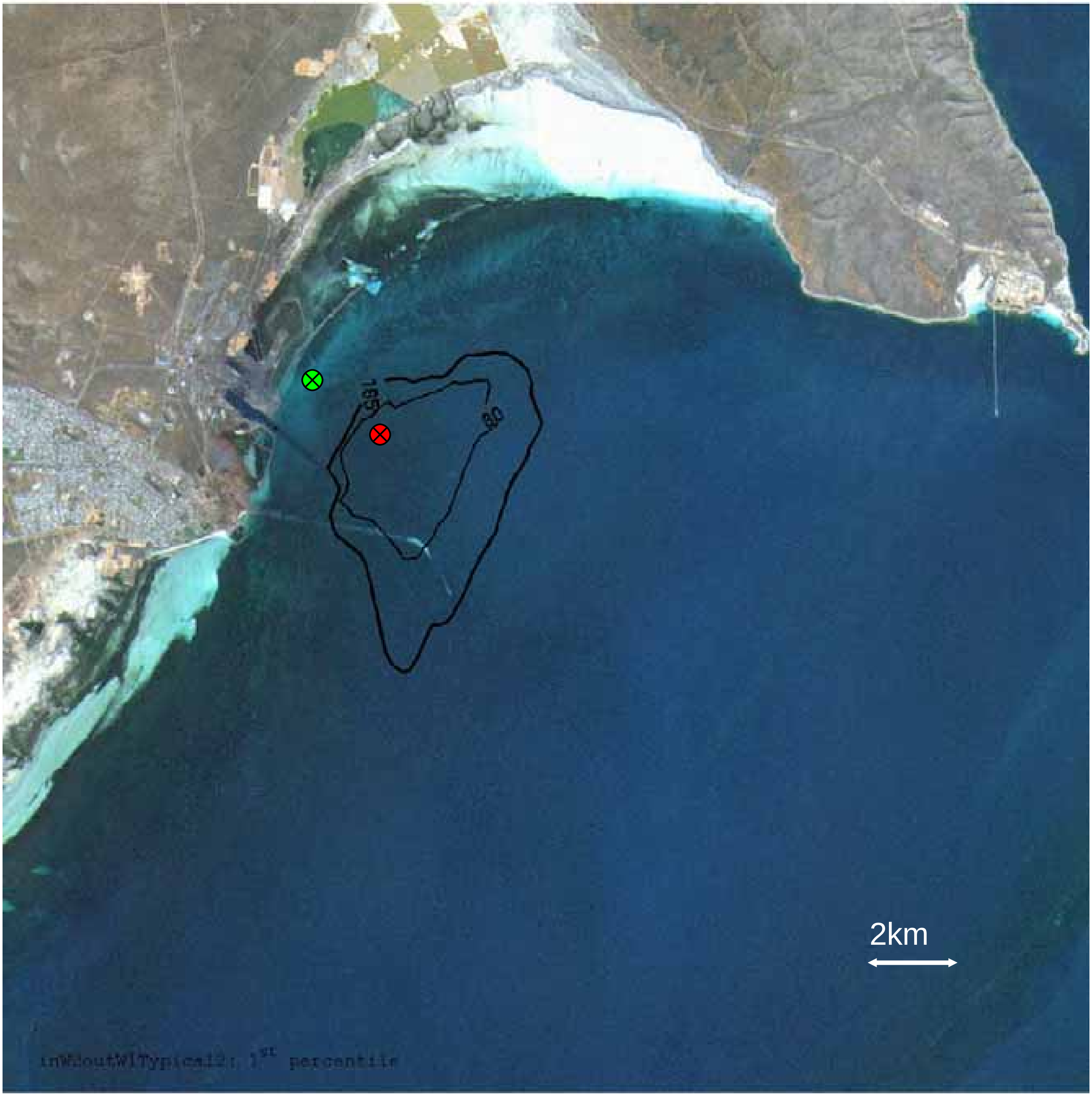


Figure 3-27 Simulation 10, 1st Percentile Contours, Typical Tide. Outlet: W1

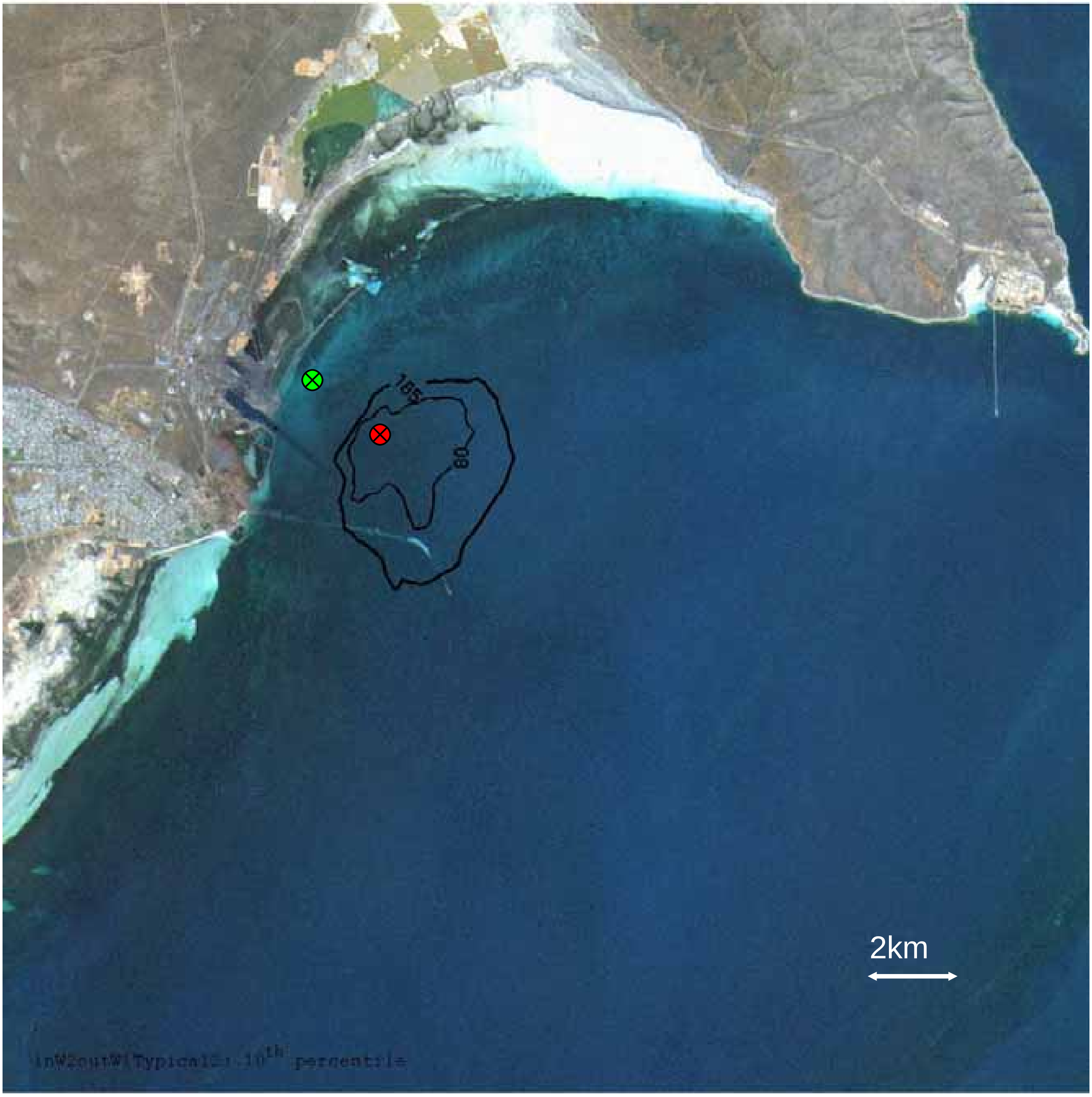


Figure 3-28 Simulation 10, 10th Percentile Contours, Typical Tide. Outlet: W1

Figure 3-29 Simulation 10, 50th Percentile Contours, Typical Tide. Outlet: W1

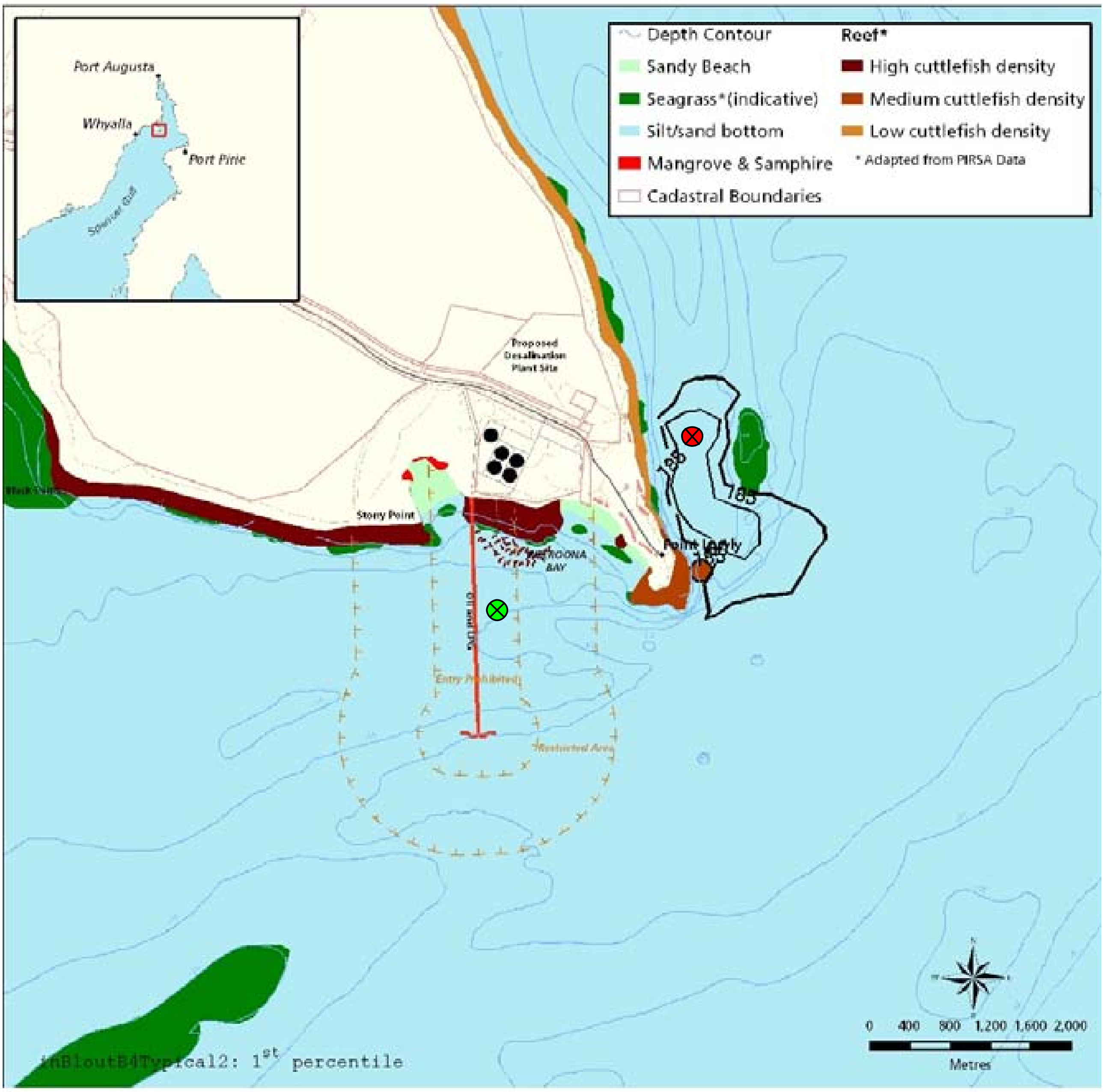


Figure 3-30 Simulation 11, 1st Percentile Contours, Typical Tide. Outlet: B4 Intake: J1

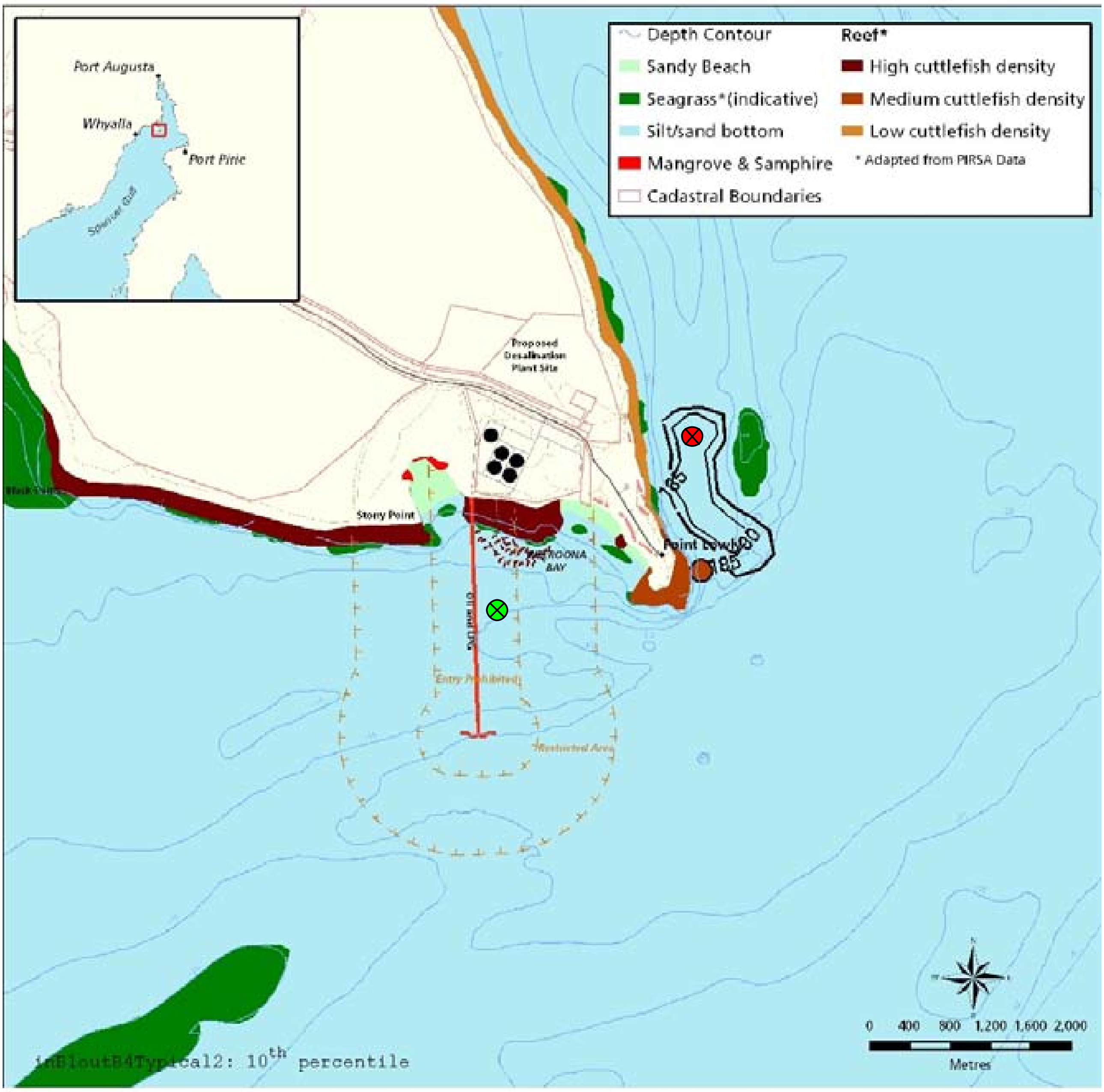


Figure 3-31 Simulation 11, 10th Percentile Contours, Typical Tide. Outlet: B4 Intake: J1

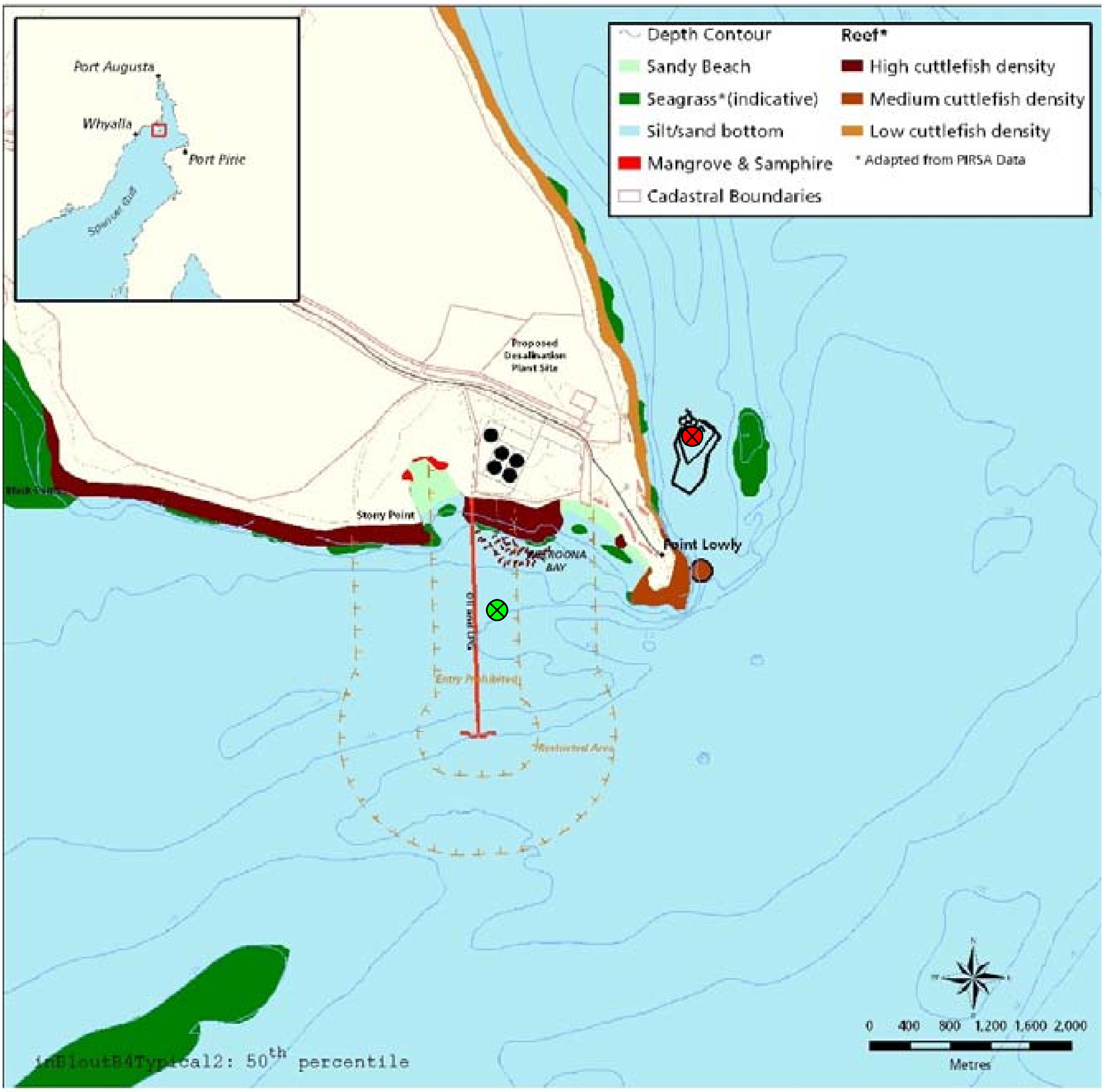


Figure 3-32 Simulation 11, 50th Percentile Contours, Typical Tide. Outlet: B4 Intake: J1

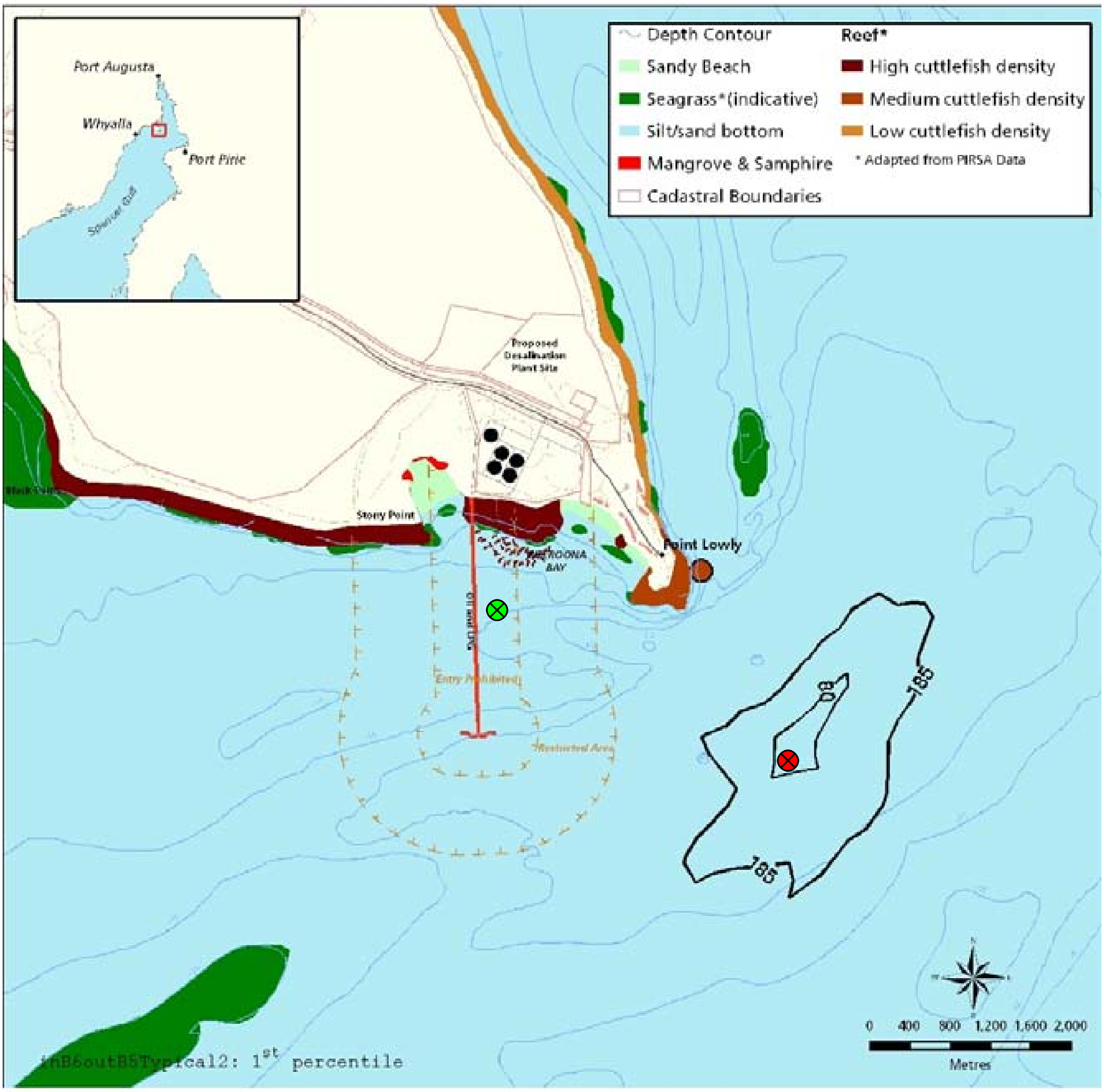


Figure 3-33 Simulation 12, 1st Percentile Contours, Typical Tide. Outlet: B5 Intake: J1

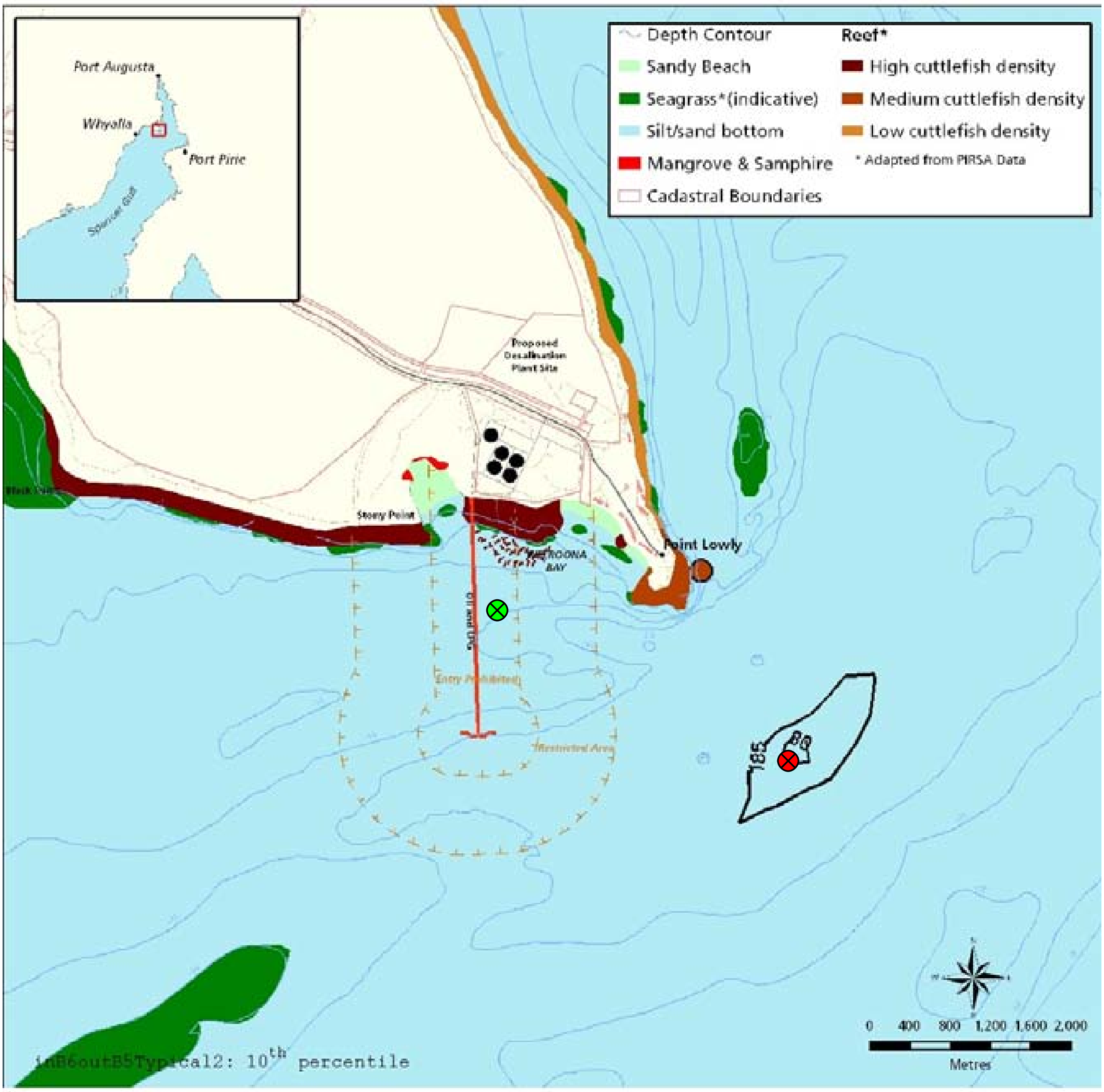


Figure 3-34 Simulation 12, 10th Percentile Contours, Typical Tide. Outlet: B5 Intake: J1

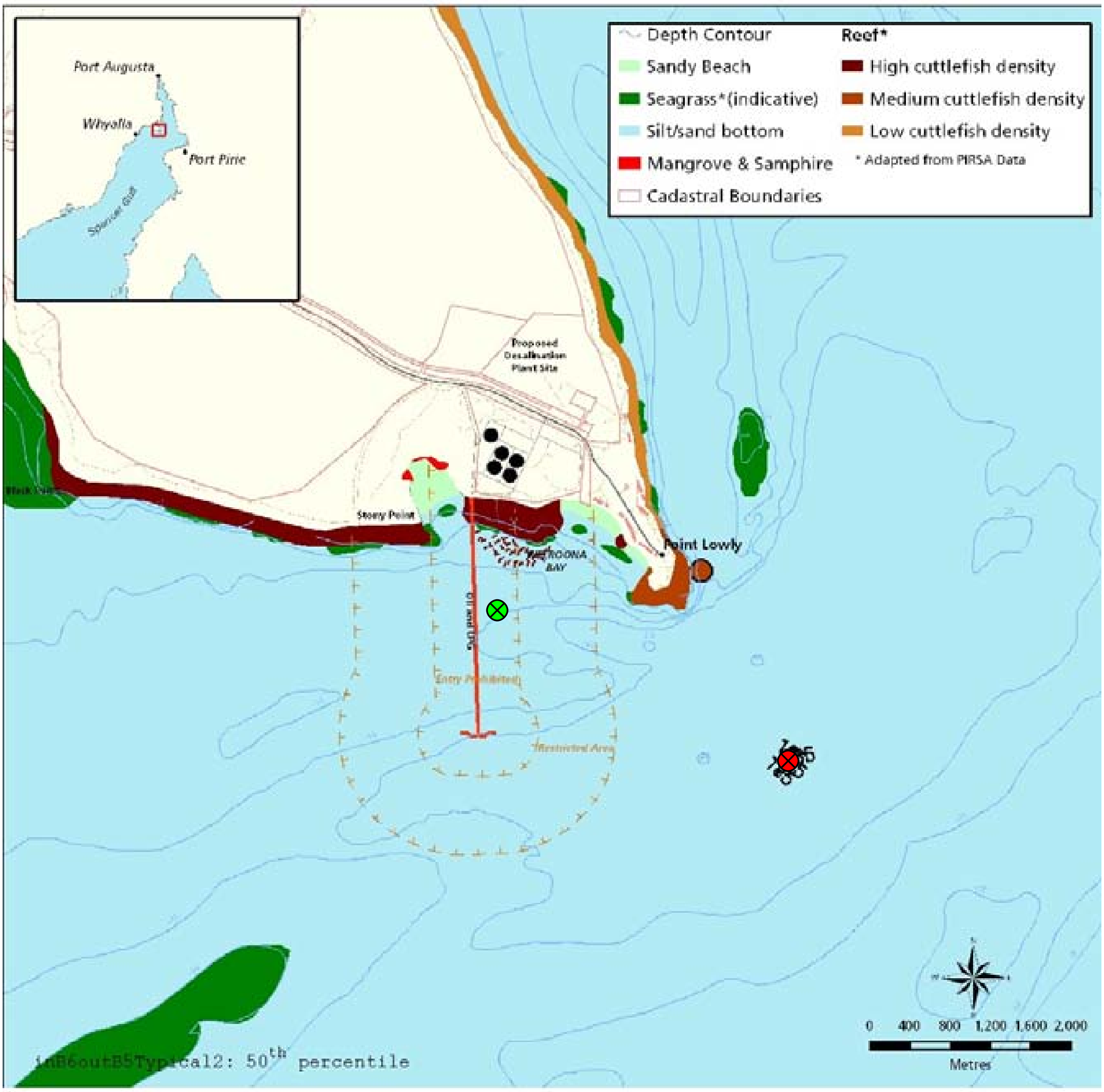


Figure 3-35 Simulation 12, 50th Percentile Contours, Typical Tide. Outlet: B5 Intake: J1

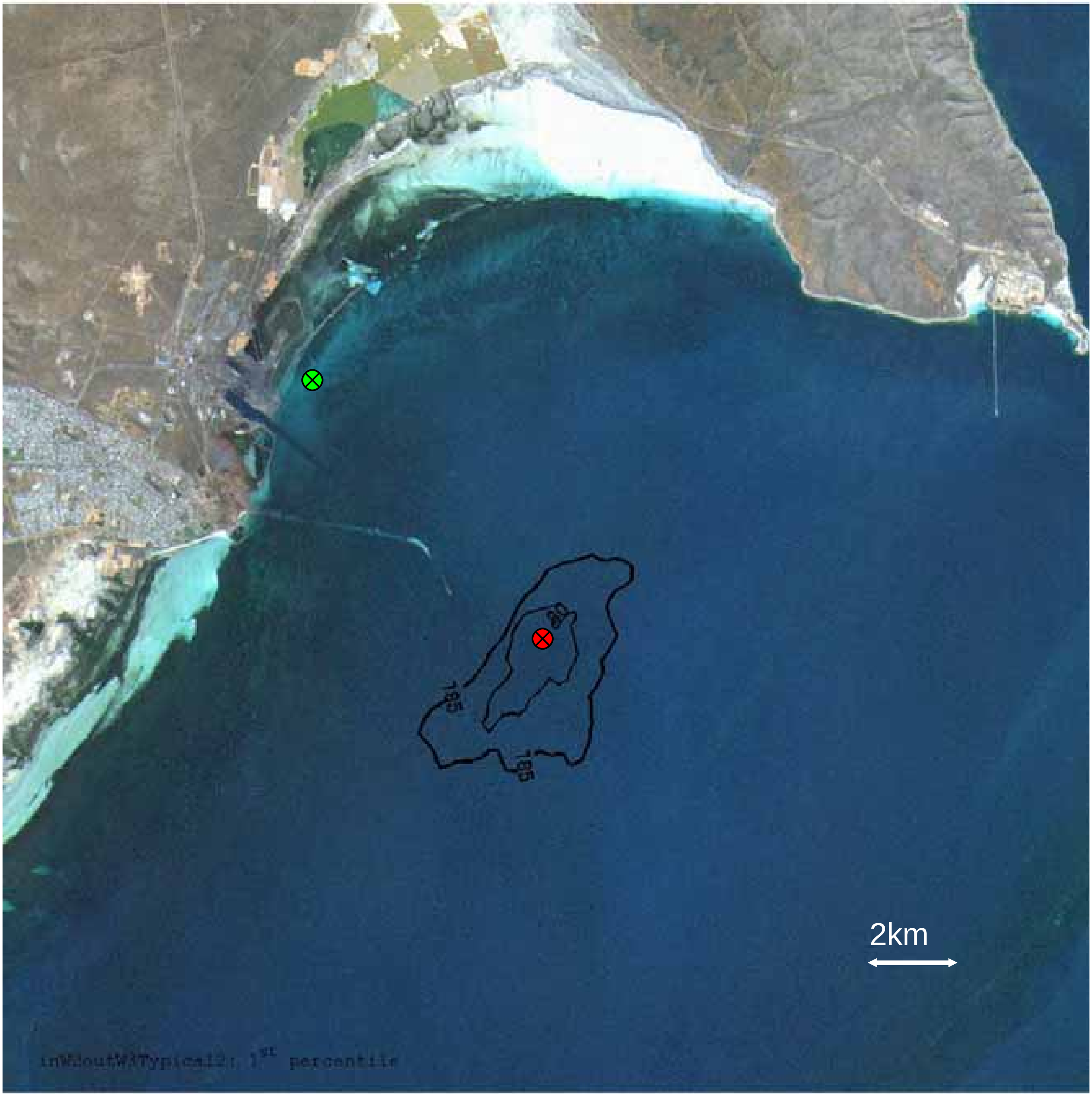


Figure 3-36 Simulation 13, 1st Percentile Contours, Typical Tide. Outlet: W3

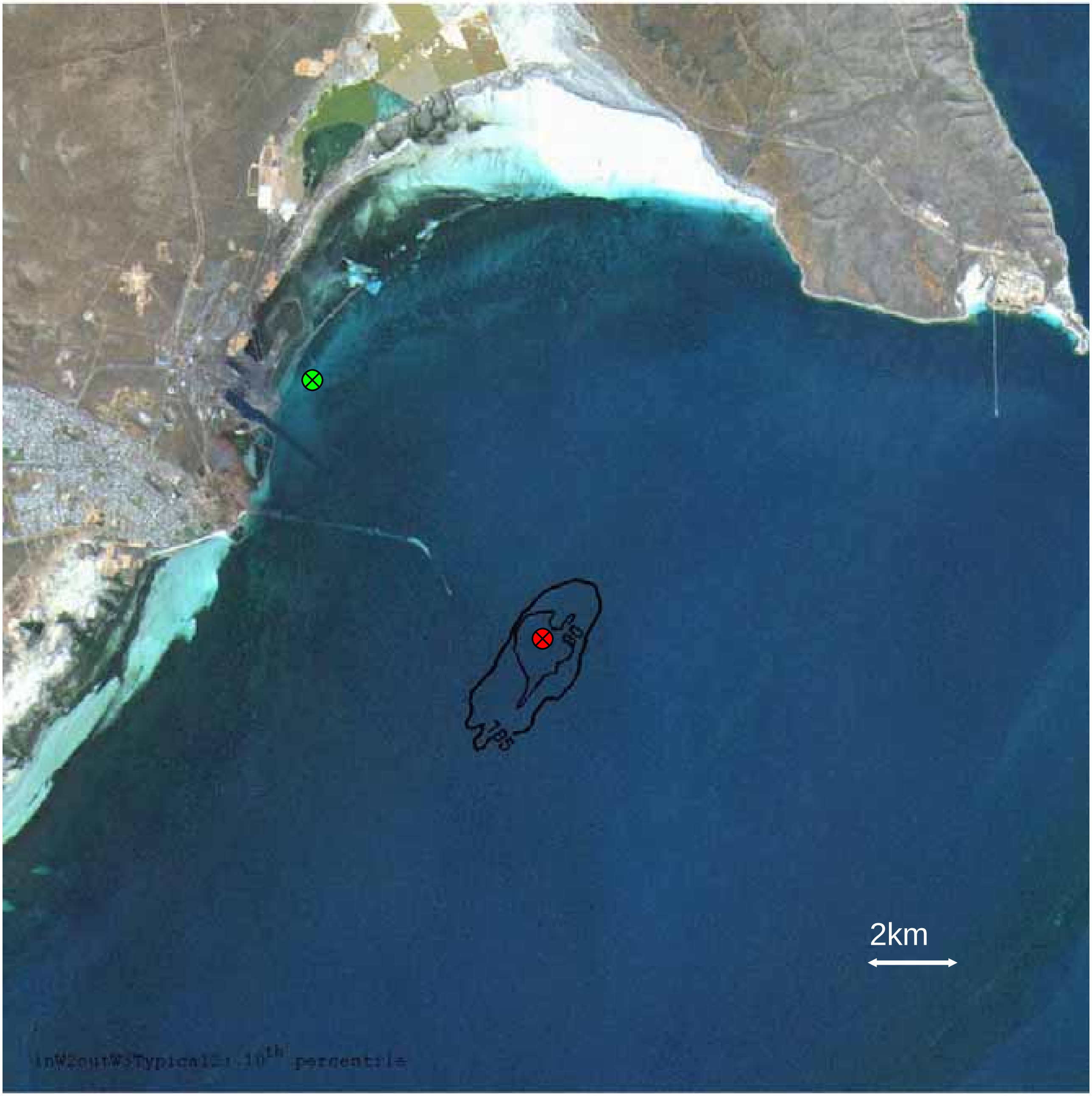


Figure 3-37 Simulation 13, 10th Percentile Contours, Typical Tide. Outlet: W3

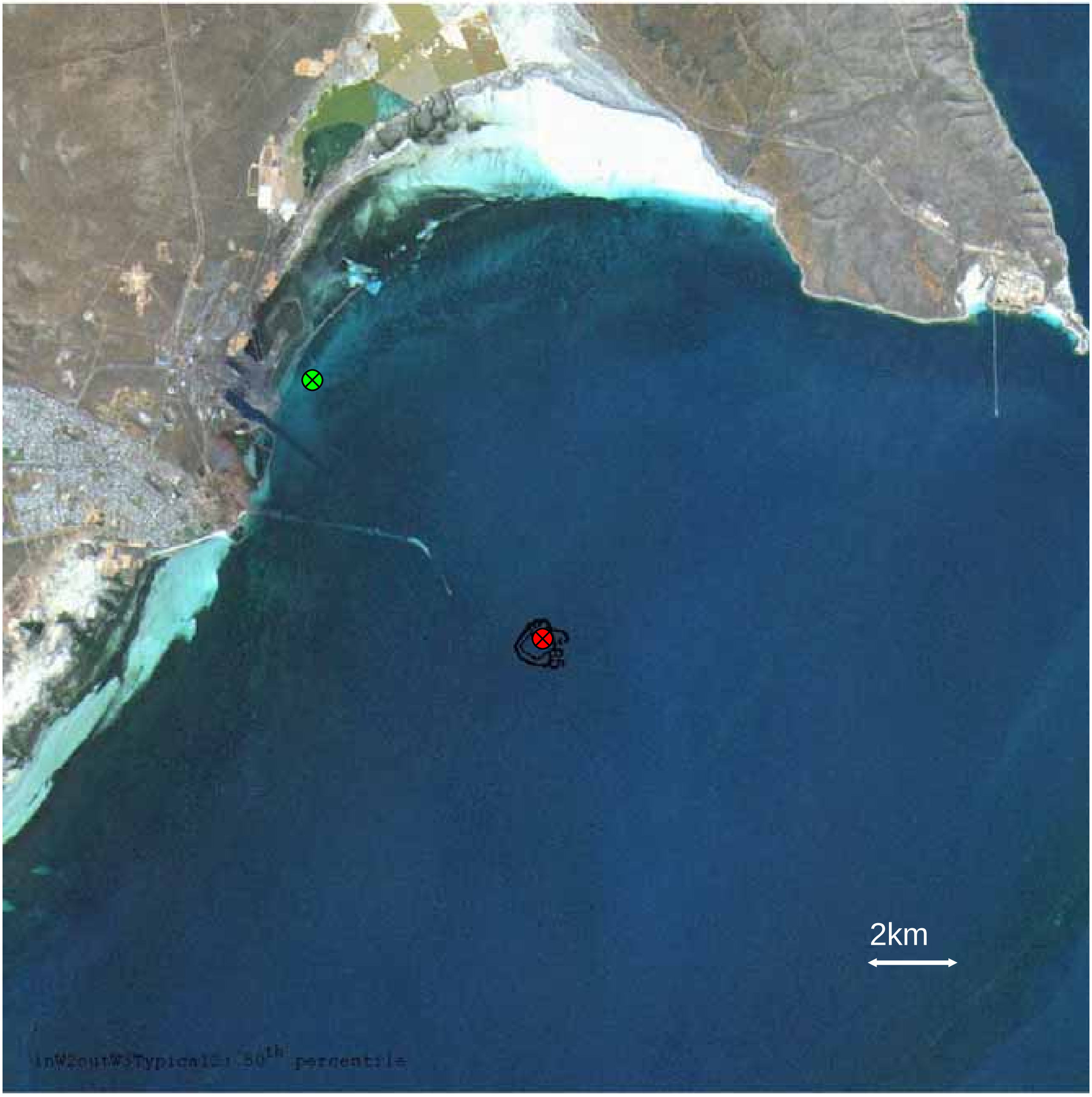


Figure 3-38 Simulation 13, 50th Percentile Contours, Typical Tide. Outlet: W3

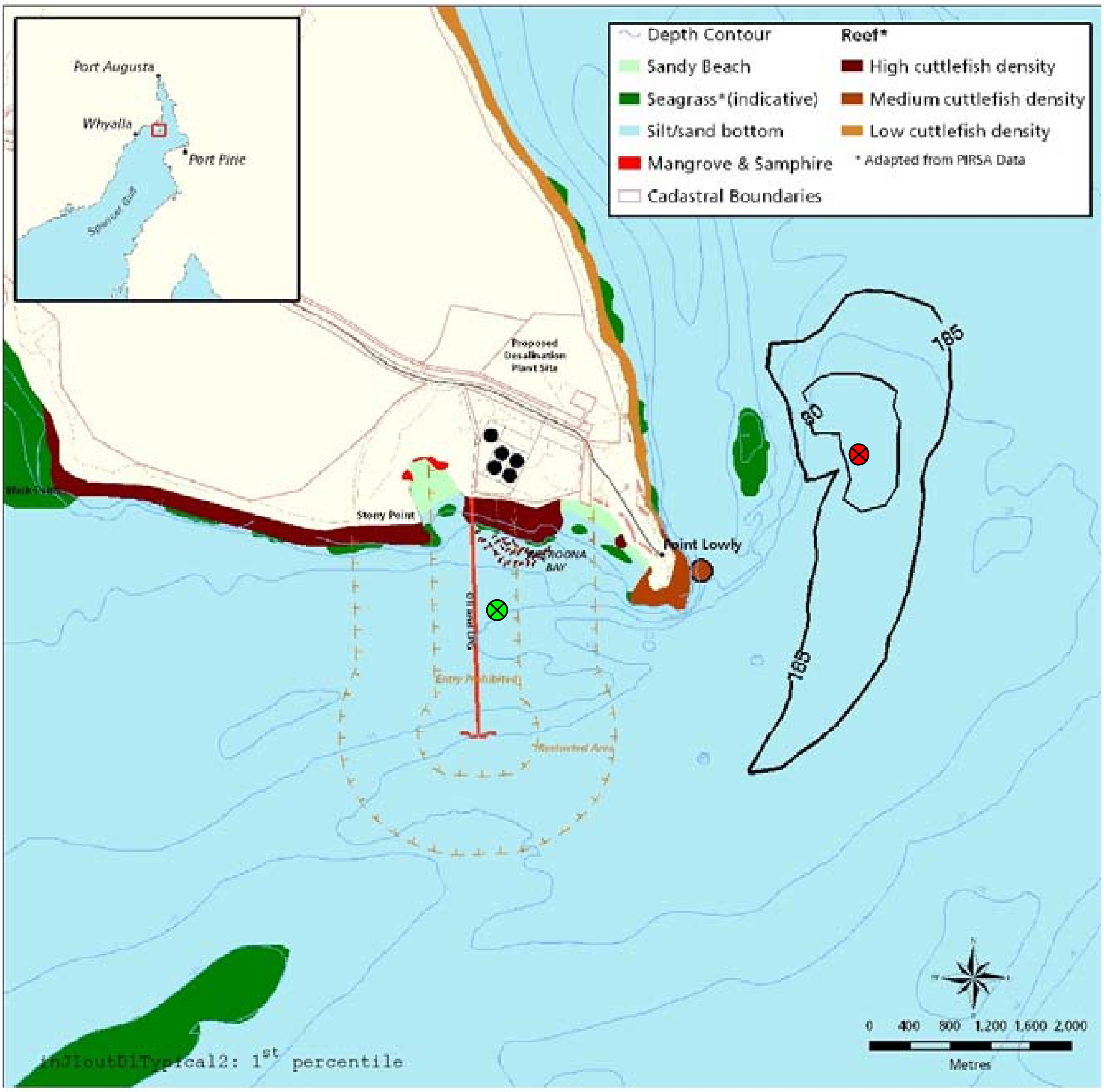


Figure 3-39 Simulation 14, 1st Percentile Contours, Typical Tide. Outlet: B6 Intake: J1

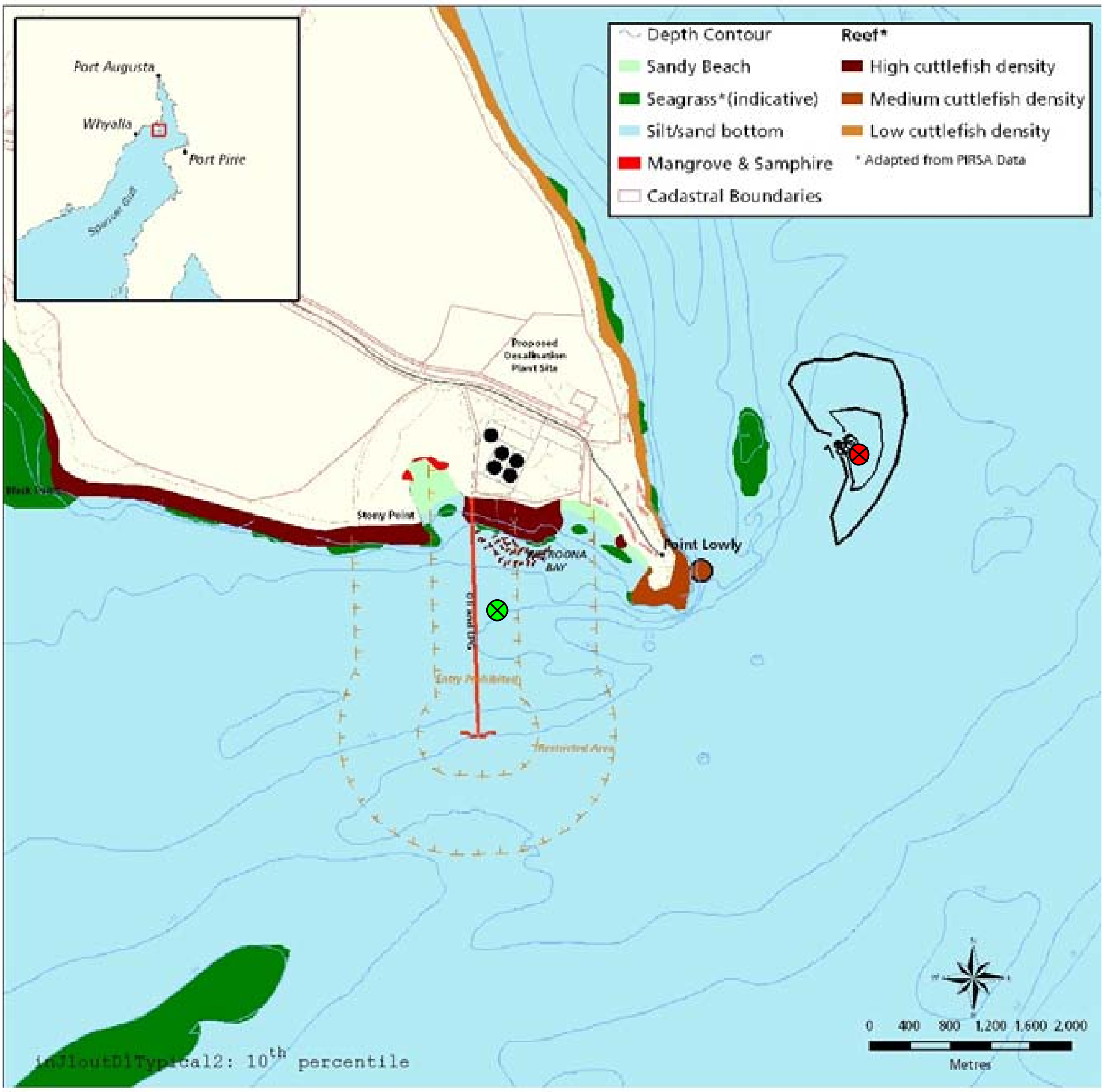


Figure 3-40 Simulation 14, 10th Percentile Contours, Typical Tide. Outlet: B6 Intake: J1

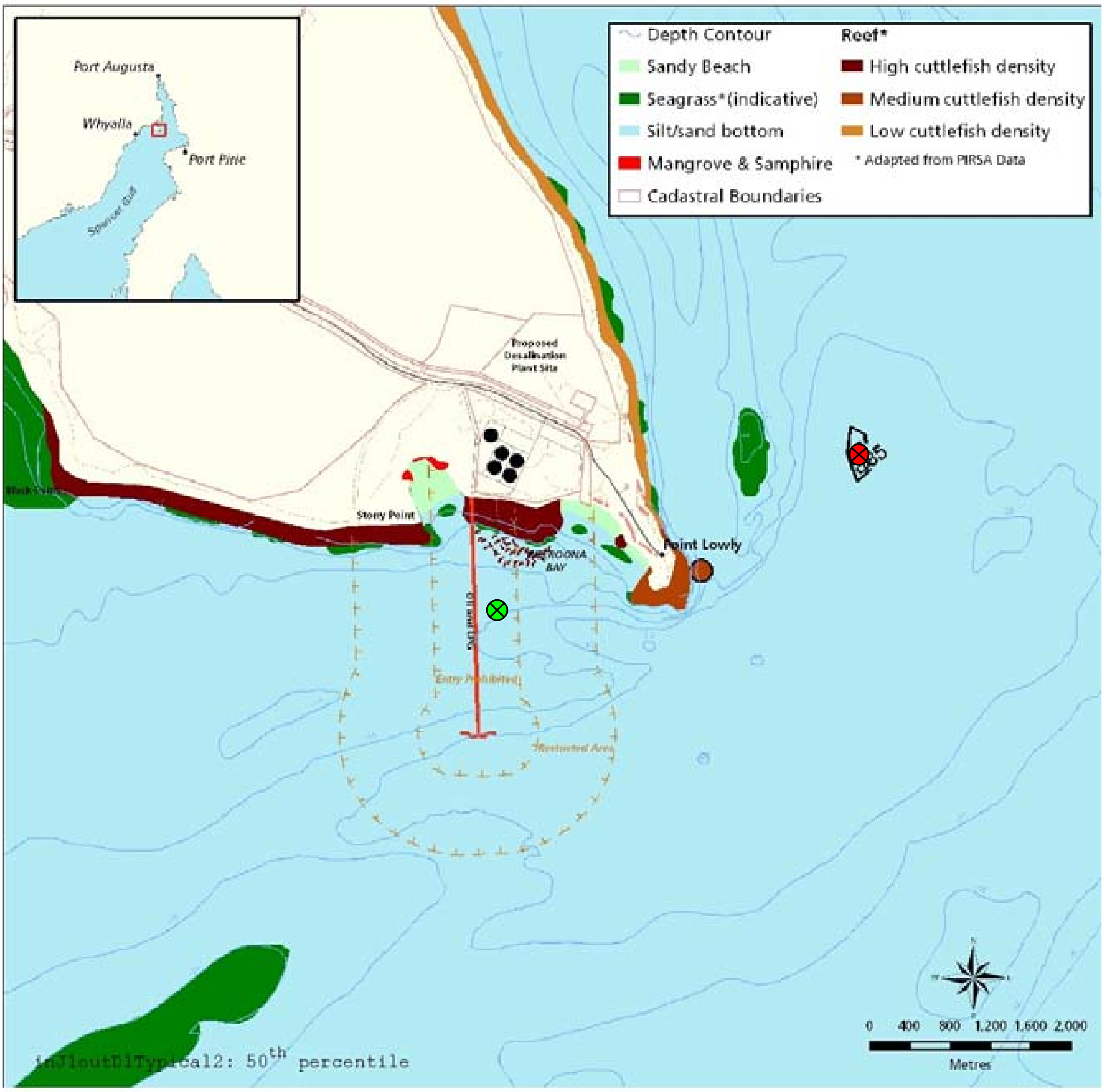


Figure 3-41 Simulation 14, 50th Percentile Contours, Typical Tide. Outlet: B6 Intake: J1

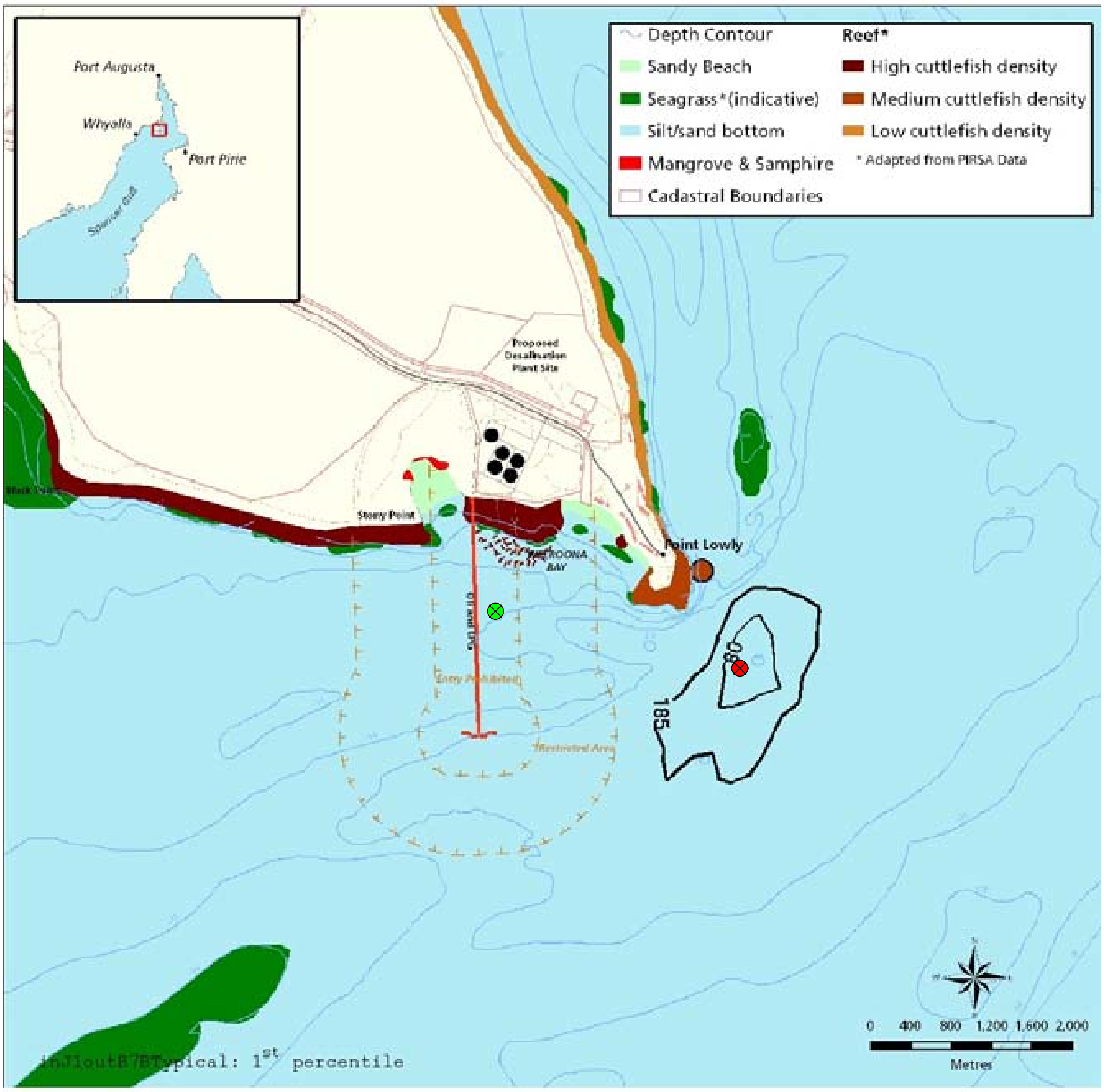


Figure 3-42 Simulation 16, 1st Percentile Contours, Typical Tide. Outlet: B7 Intake: J1

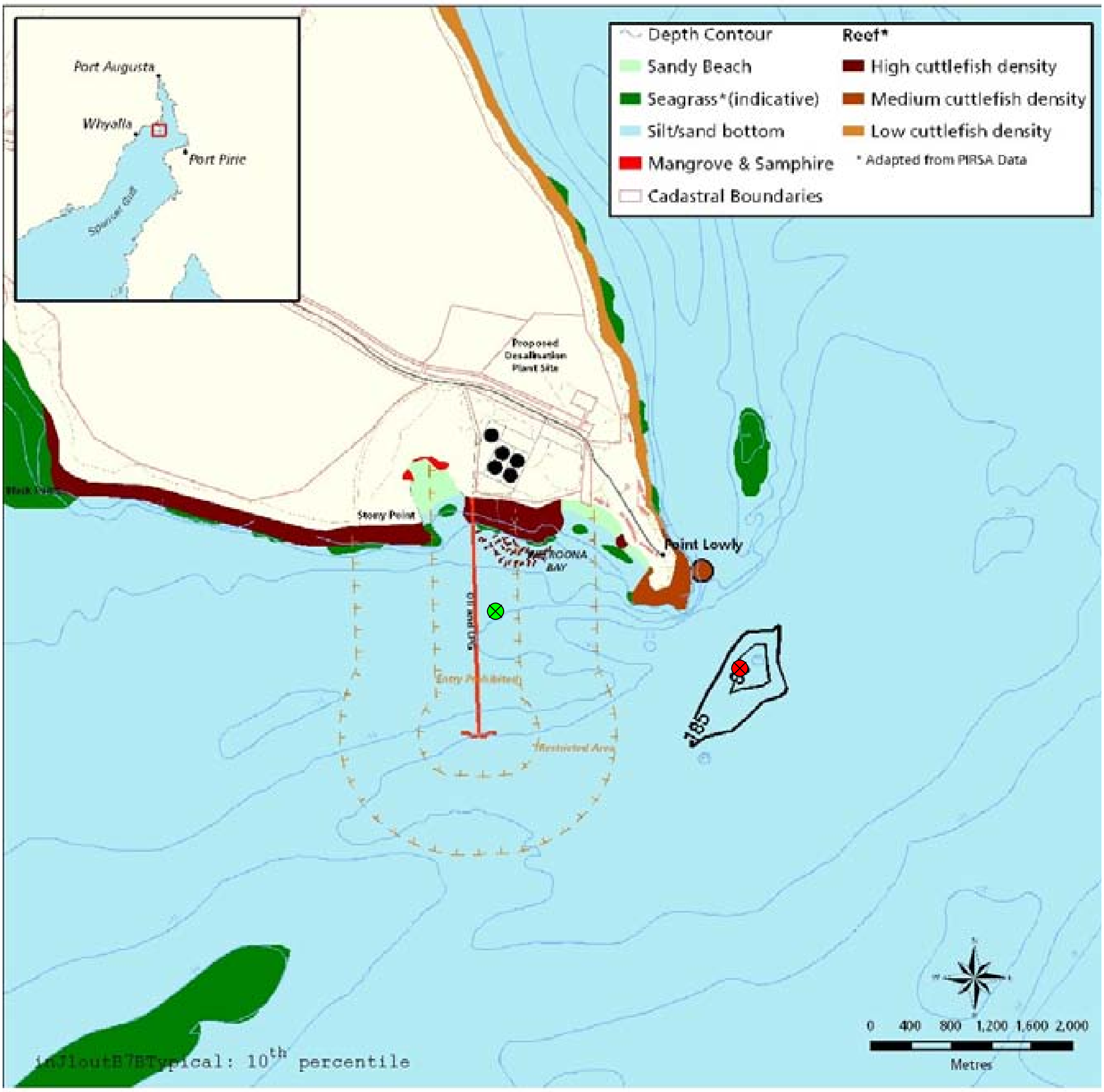


Figure 3-43 Simulation 16, 10th Percentile Contours, Typical Tide. Outlet: B7 Intake: J1

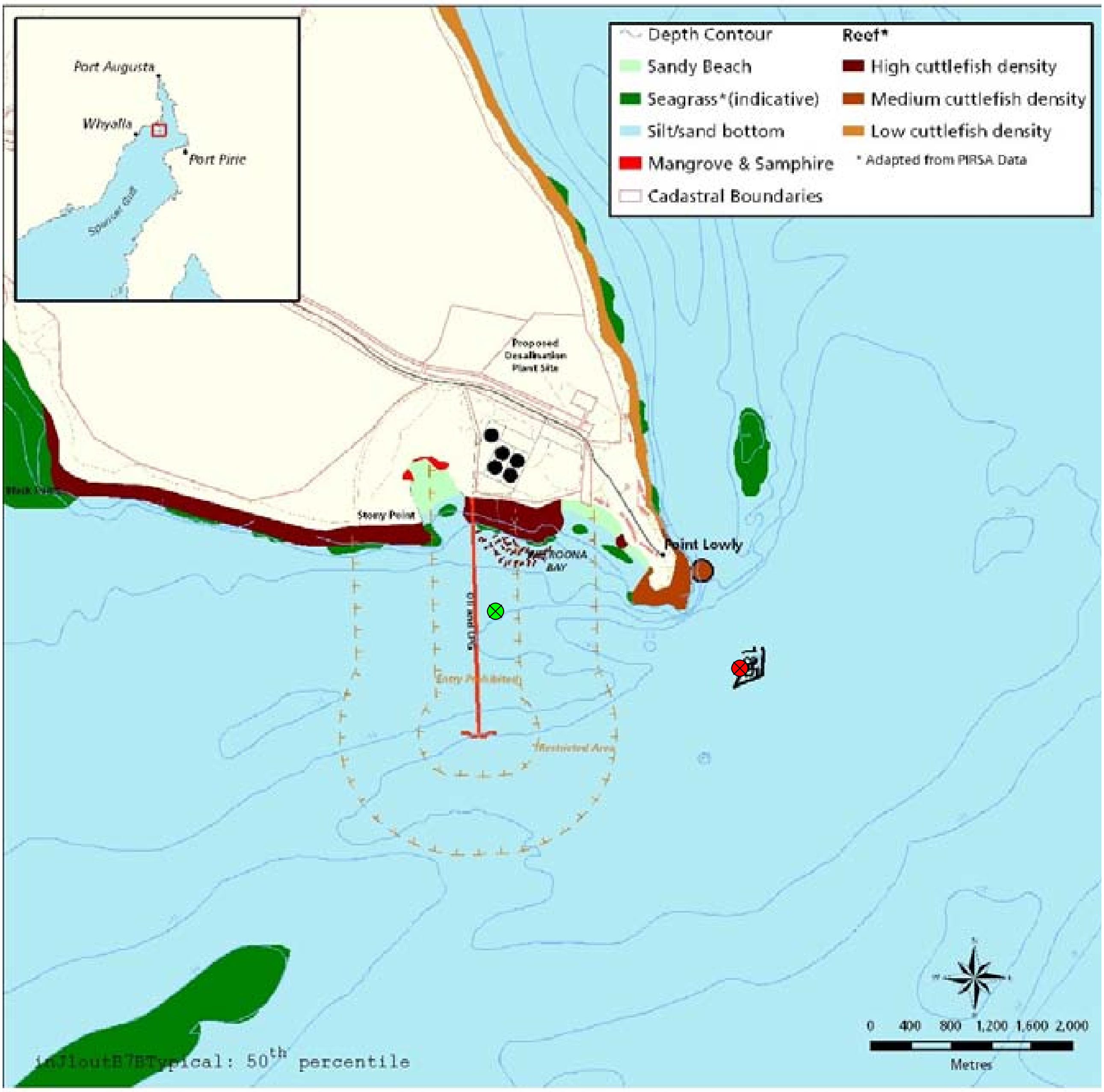


Figure 3-44 Simulation 16, 50th Percentile Contours, Typical Tide. Outlet: B7 Intake: J1

3.2.2 Dodge Tidal Period

The dodge tidal timeseries for simulations 8 to 16 is presented in Figure 3-45.

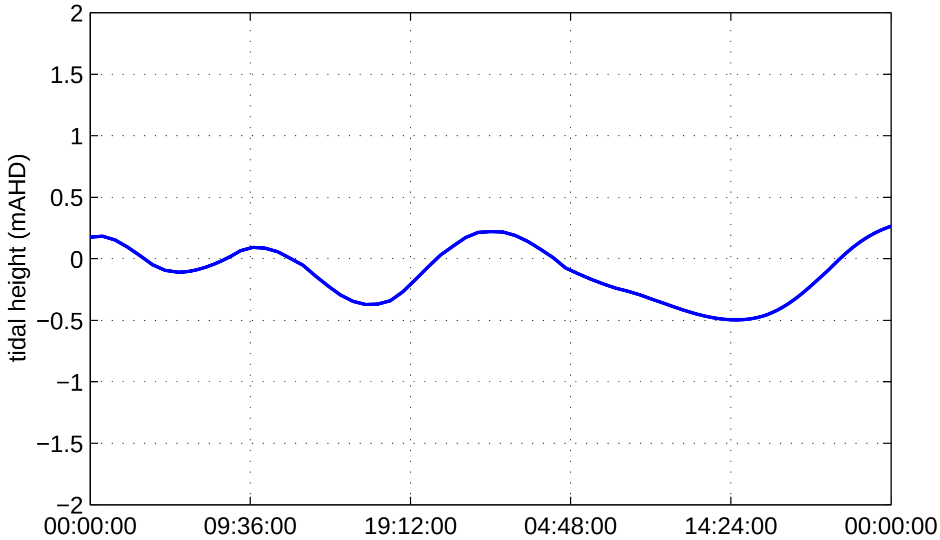


Figure 3-45 Simulations 8 to 16 'Dodge Tide'

Included in this period were a no wind condition and high daily temperatures. The intent of this was to simulate a 'worst case' scenario for each discharge condition. An analysis of the likelihood of recurrence of these conditions (and a detailed definition of a dodge tide as applied to this study) is presented in Appendix A. The analysis presented is approximate based on a brief assessment of the data at hand. A more thorough analysis should be executed to assess the likelihood of occurrence, but this is considered unnecessary at this stage.

Percentile contours were computed over the simulation data throughout this worst case scenario period, and the results presented below. Simulation 7 is not presented as it is a base case with no outfall.

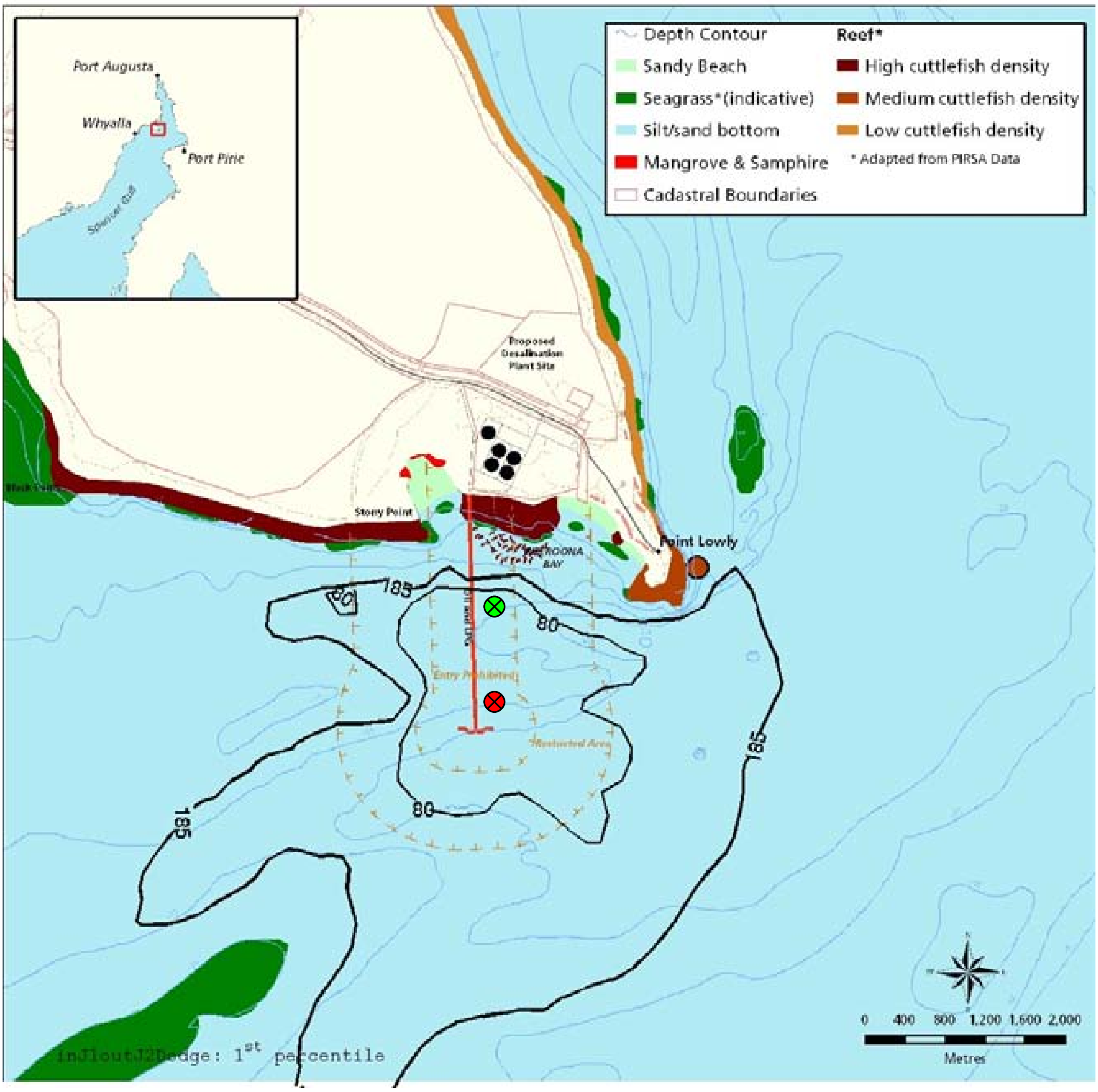


Figure 3-46 Simulation 8, 1st Percentile Contours, Dodge Tide. Outlet: J2 Intake: J1

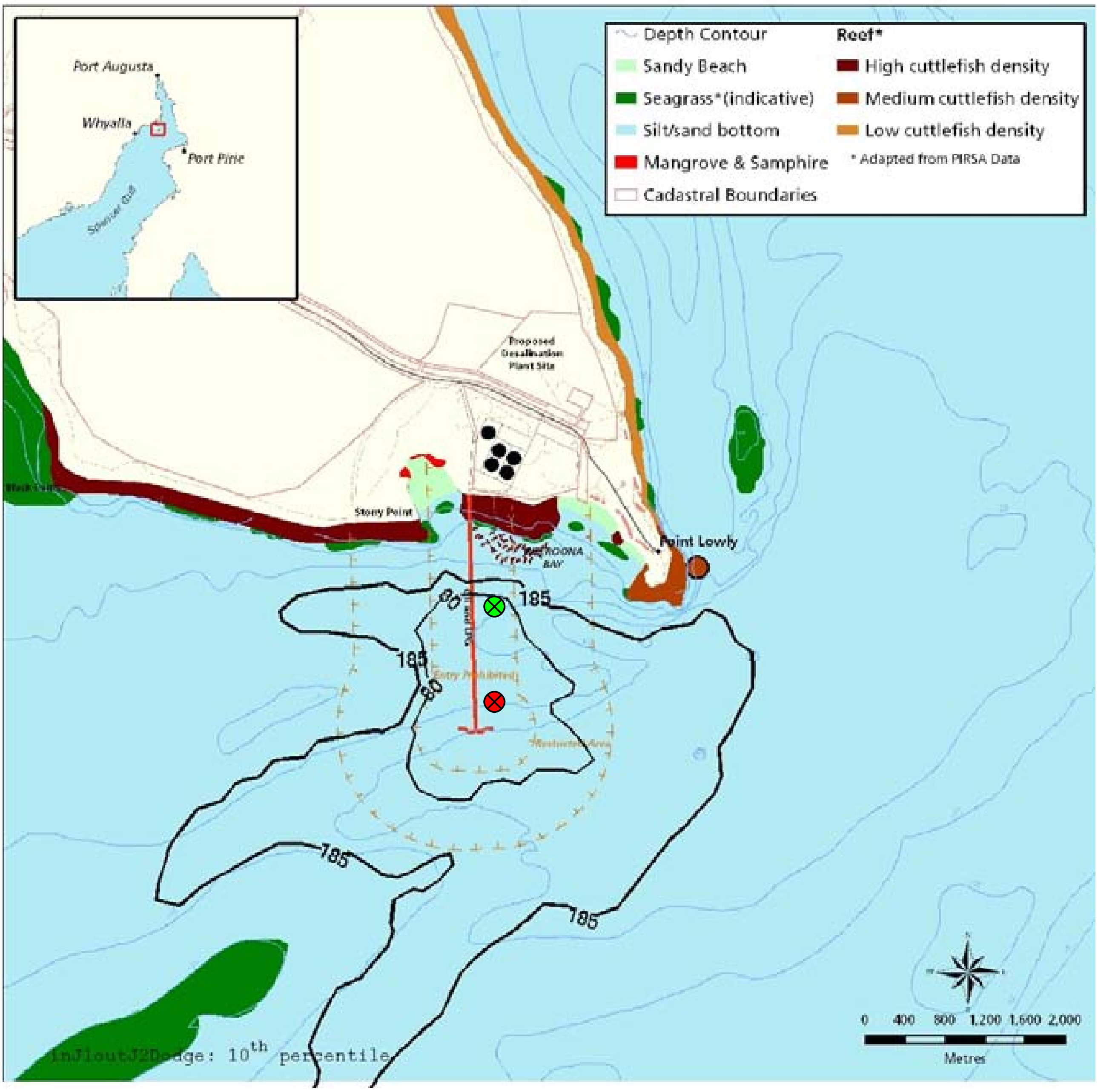


Figure 3-47 Simulation 8, 10th Percentile Contours, Dodge Tide. Outlet: J2 Intake: J1

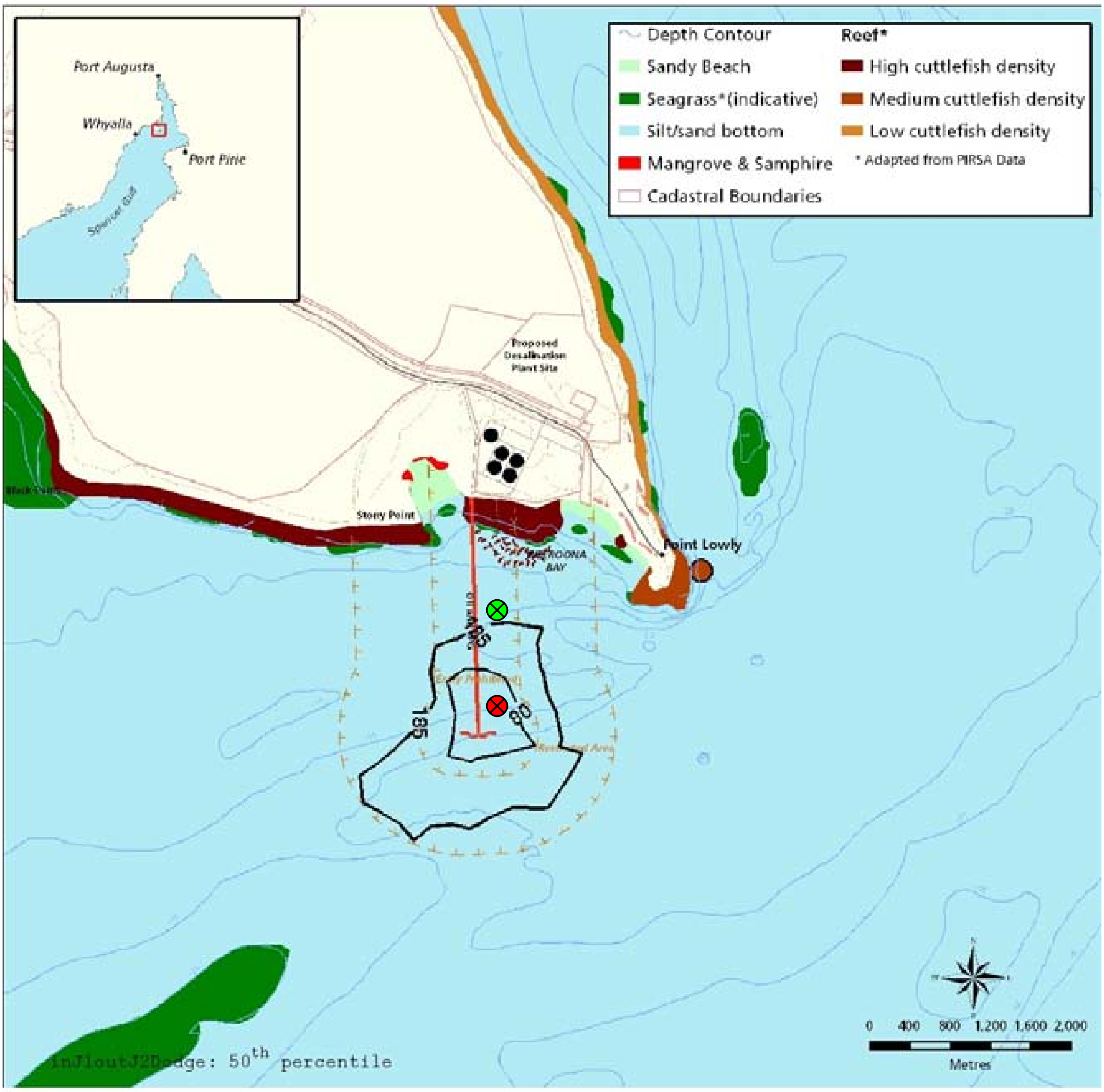


Figure 3-48 Simulation 8, 50th Percentile Contours, Dodge Tide. Outlet: J2 Intake: J1

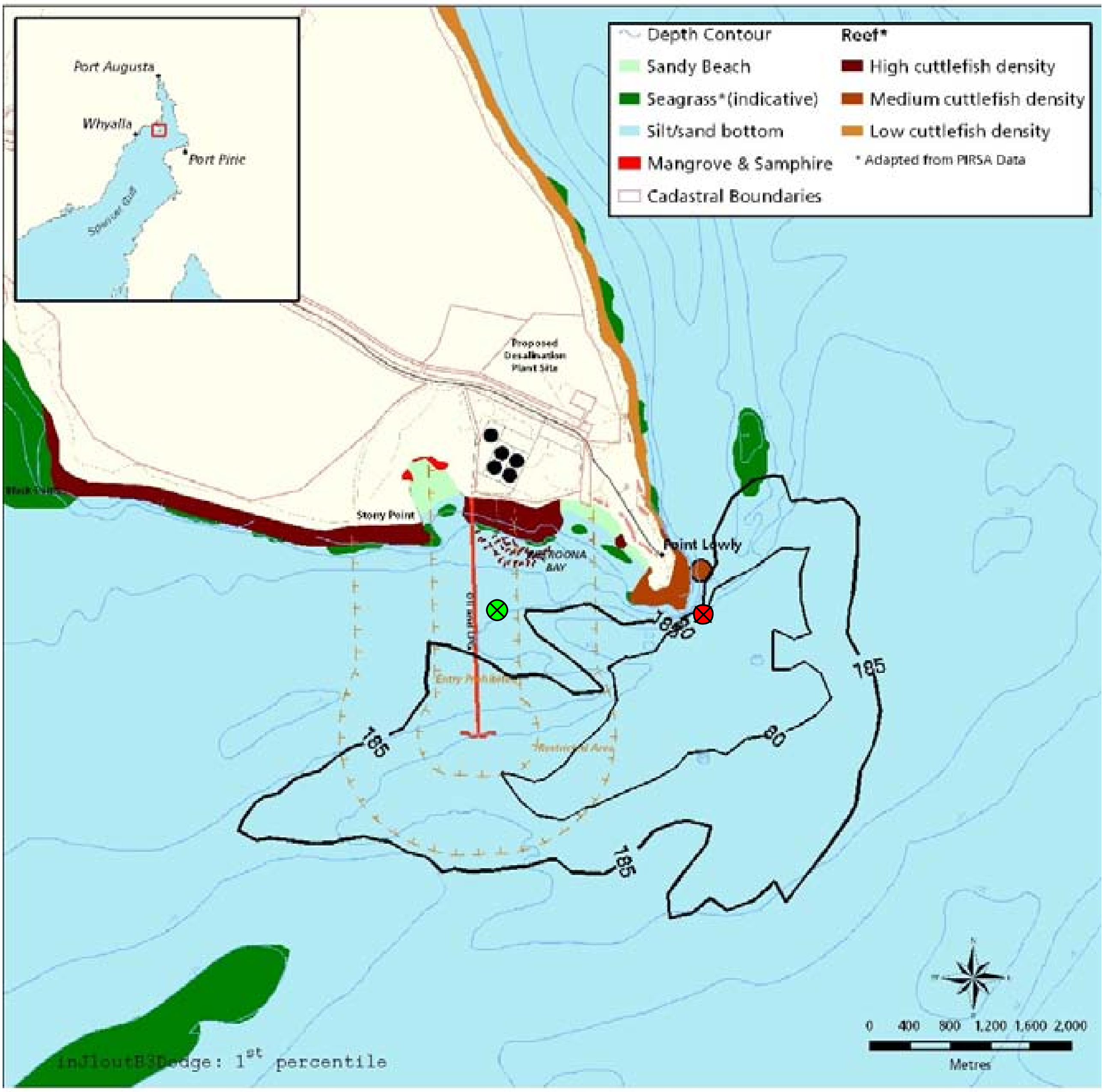


Figure 3-49 Simulation 9, 1st Percentile Contours, Dodge Tide. Outlet: B3 Intake: J1

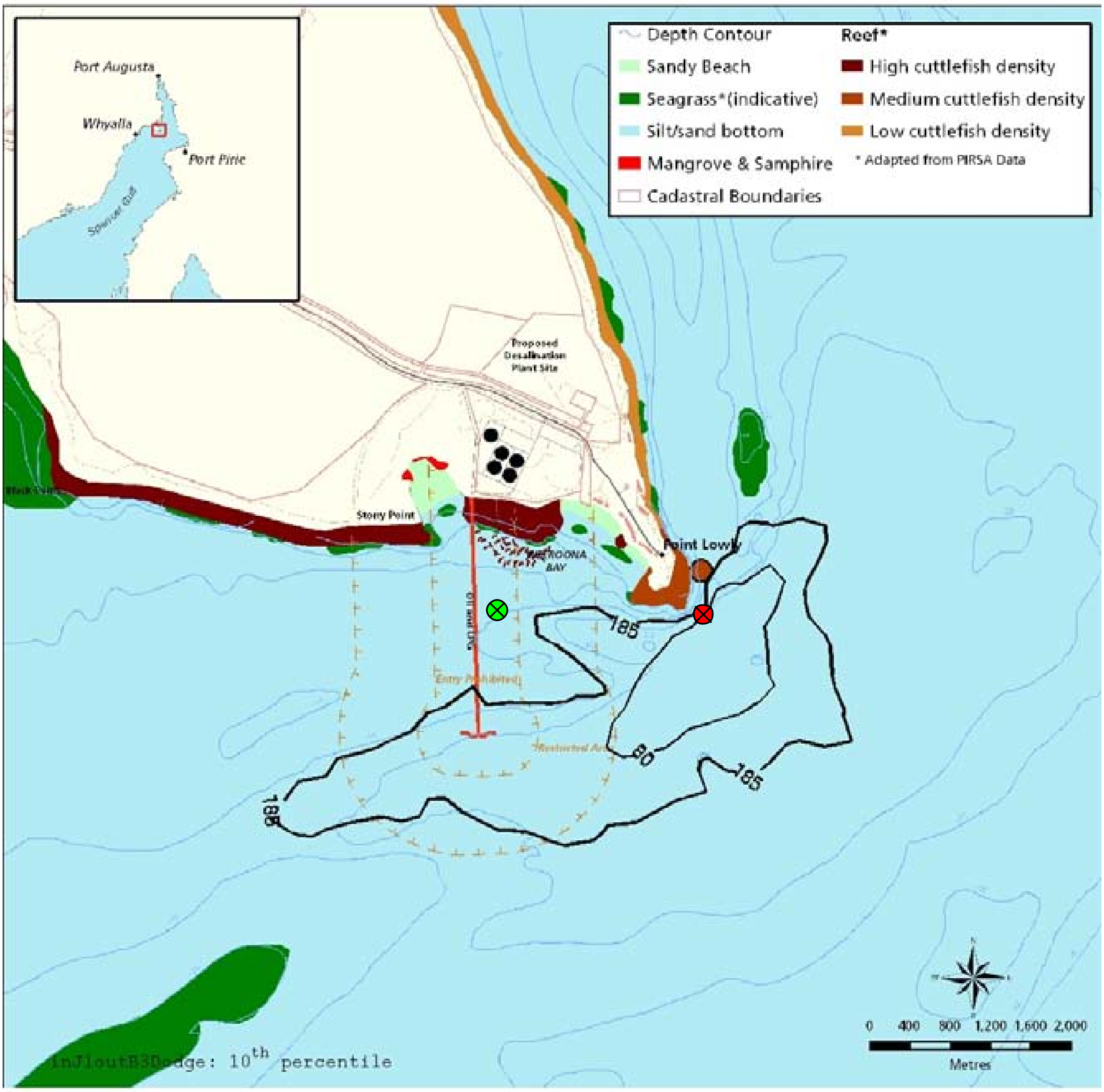


Figure 3-50 Simulation 9, 10th Percentile Contours, Dodge Tide. Outlet: B3 Intake: J1

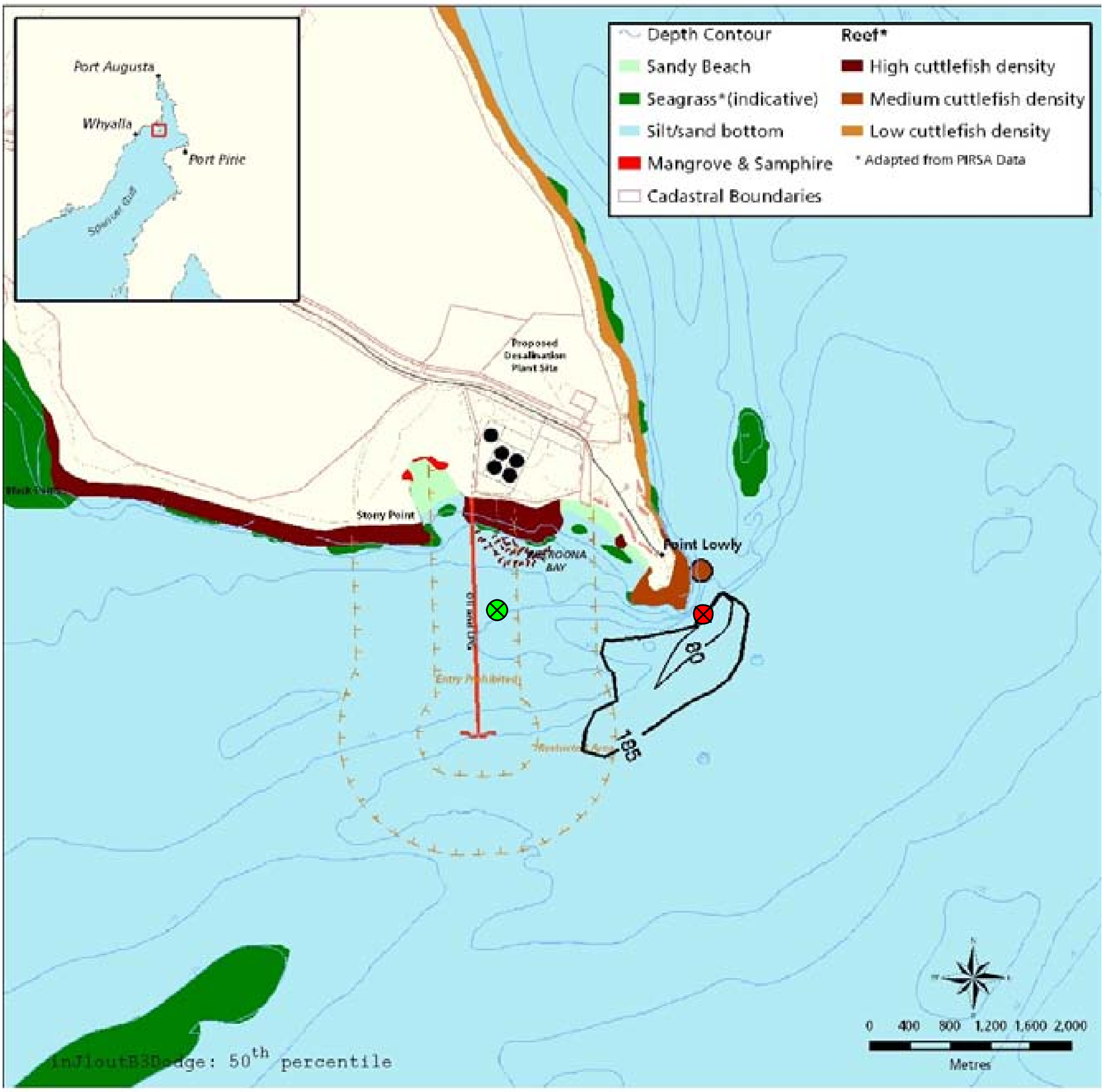


Figure 3-51 Simulation 9, 50th Percentile Contours, Dodge Tide. Outlet: B3 Intake: J1

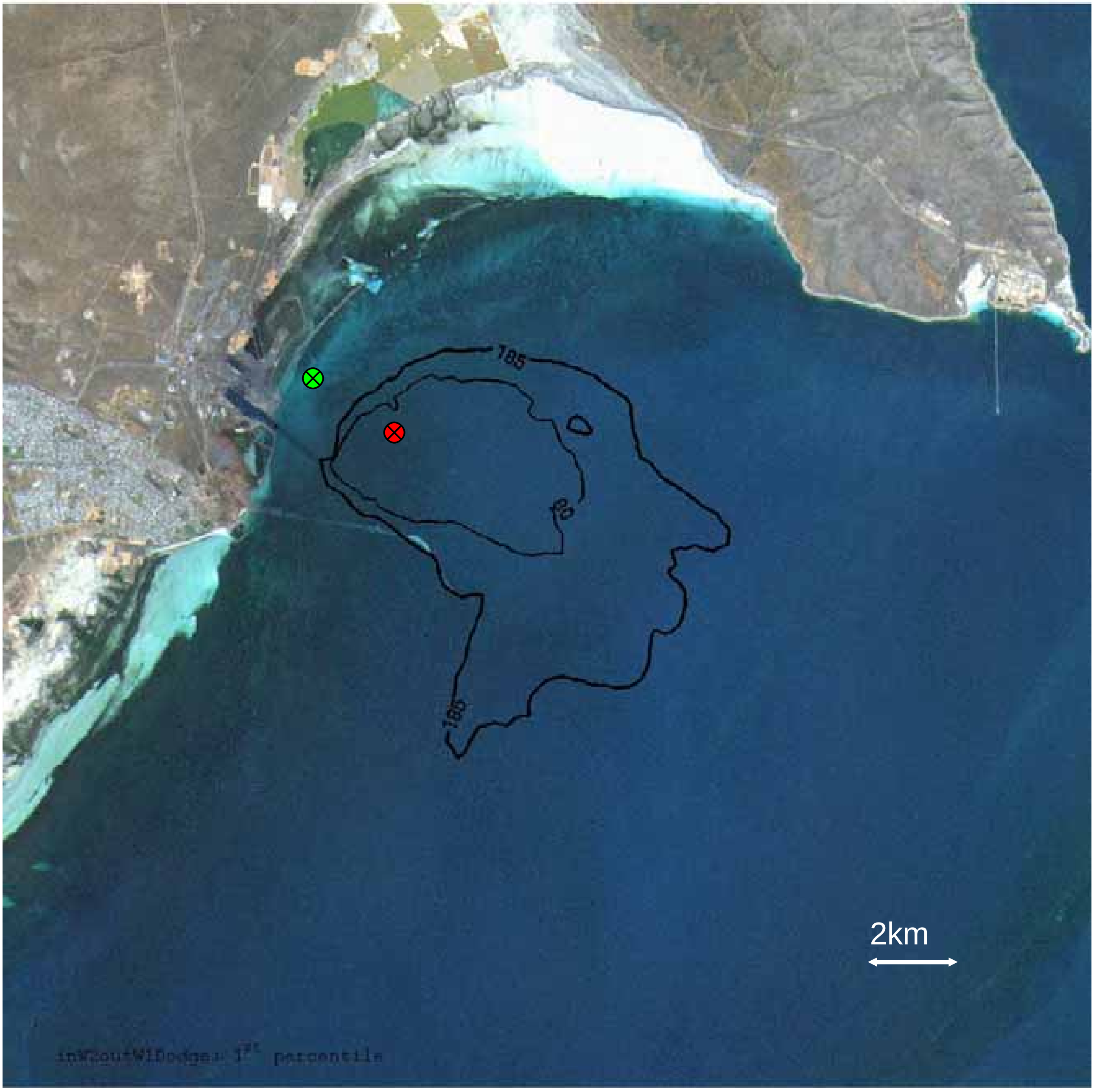


Figure 3-52 Simulation 10, 1st Percentile Contours, Dodge Tide. Outlet: W1

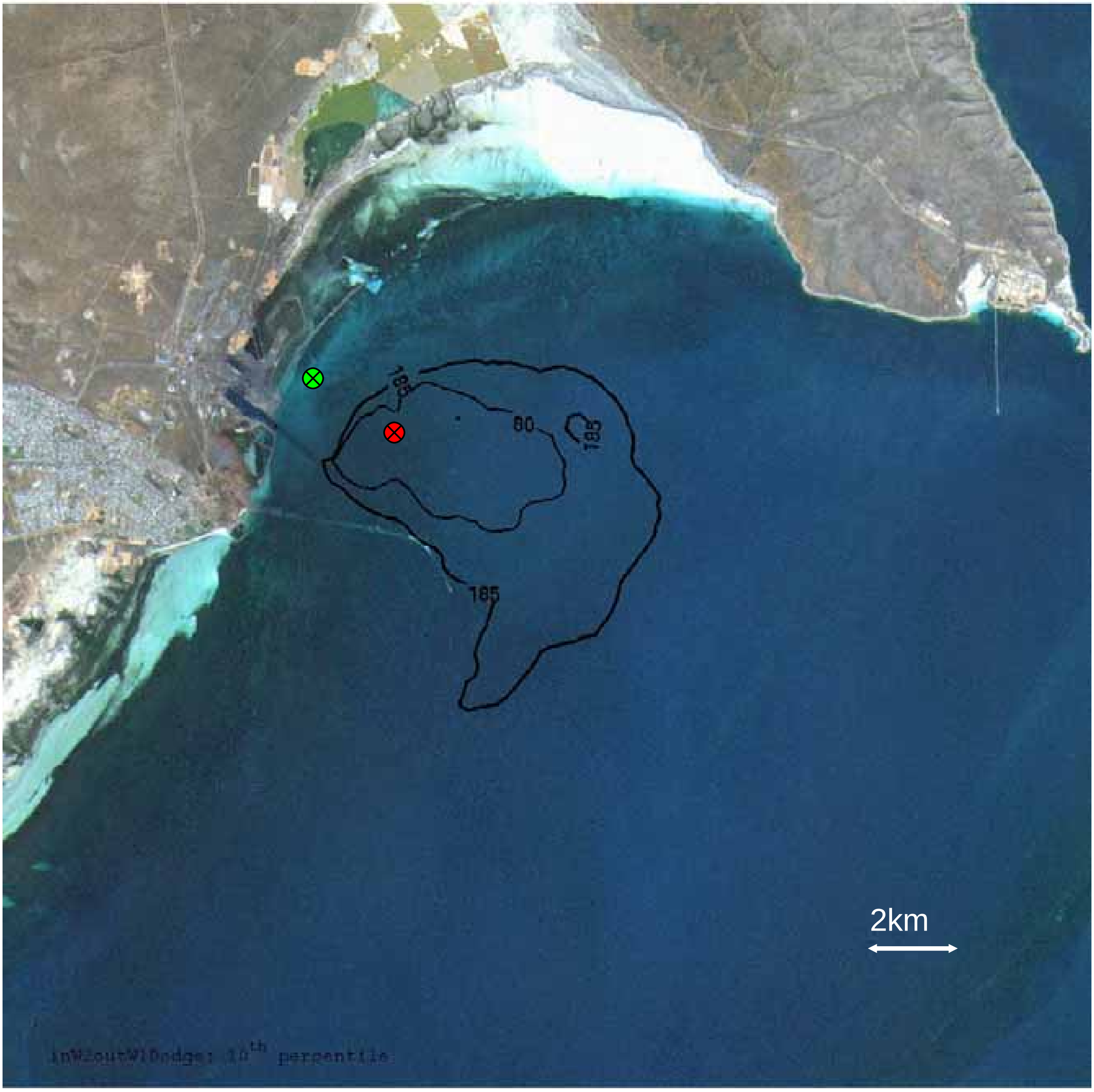


Figure 3-53 Simulation 10, 10th Percentile Contours, Dodge Tide. Outlet: W1

Figure 3-54 Simulation 10, 50th Percentile Contours, Dodge Tide. Outlet: W1

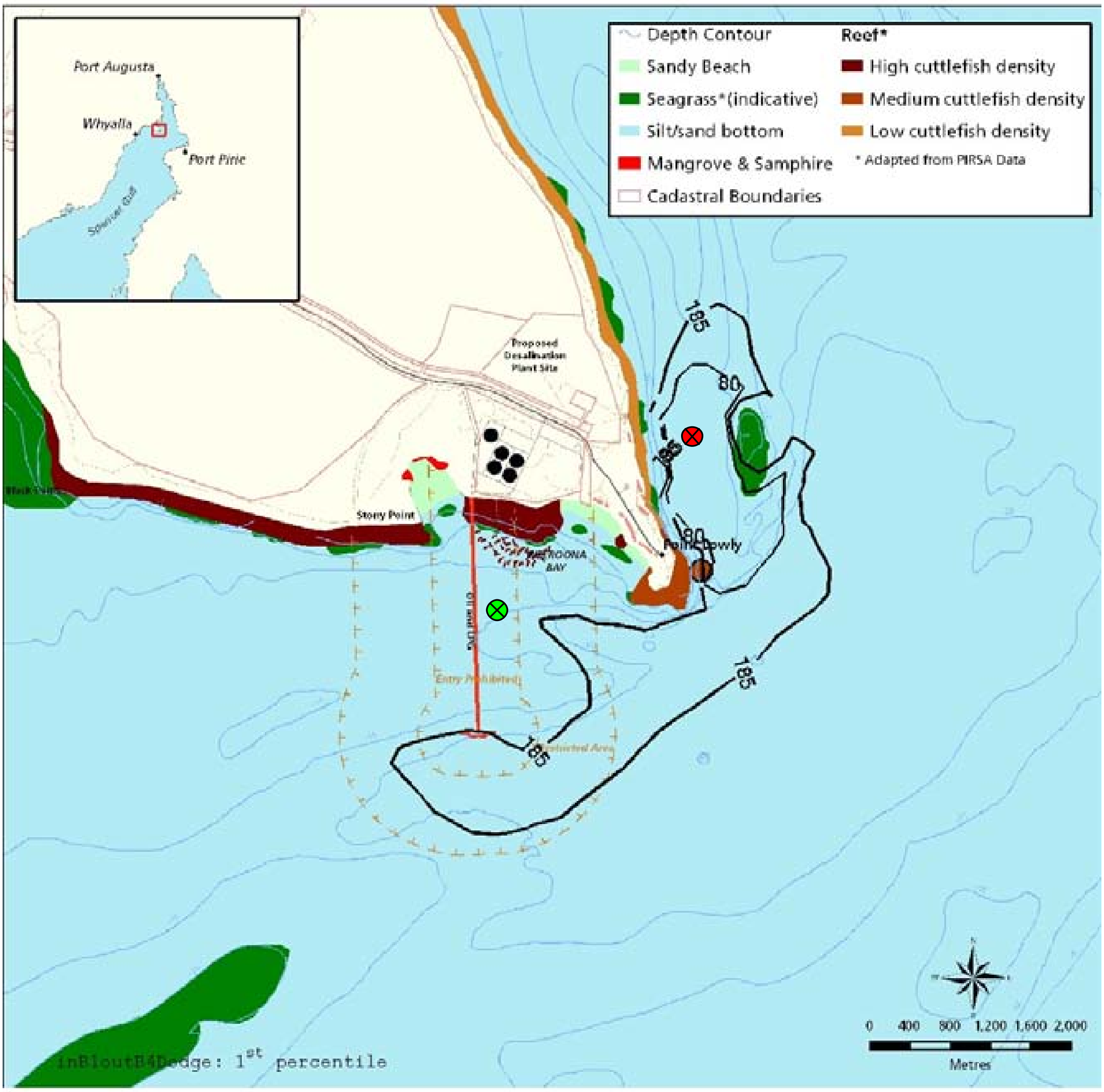


Figure 3-55 Simulation 11, 1st Percentile Contours, Dodge Tide. Outlet: B4 Intake: J1

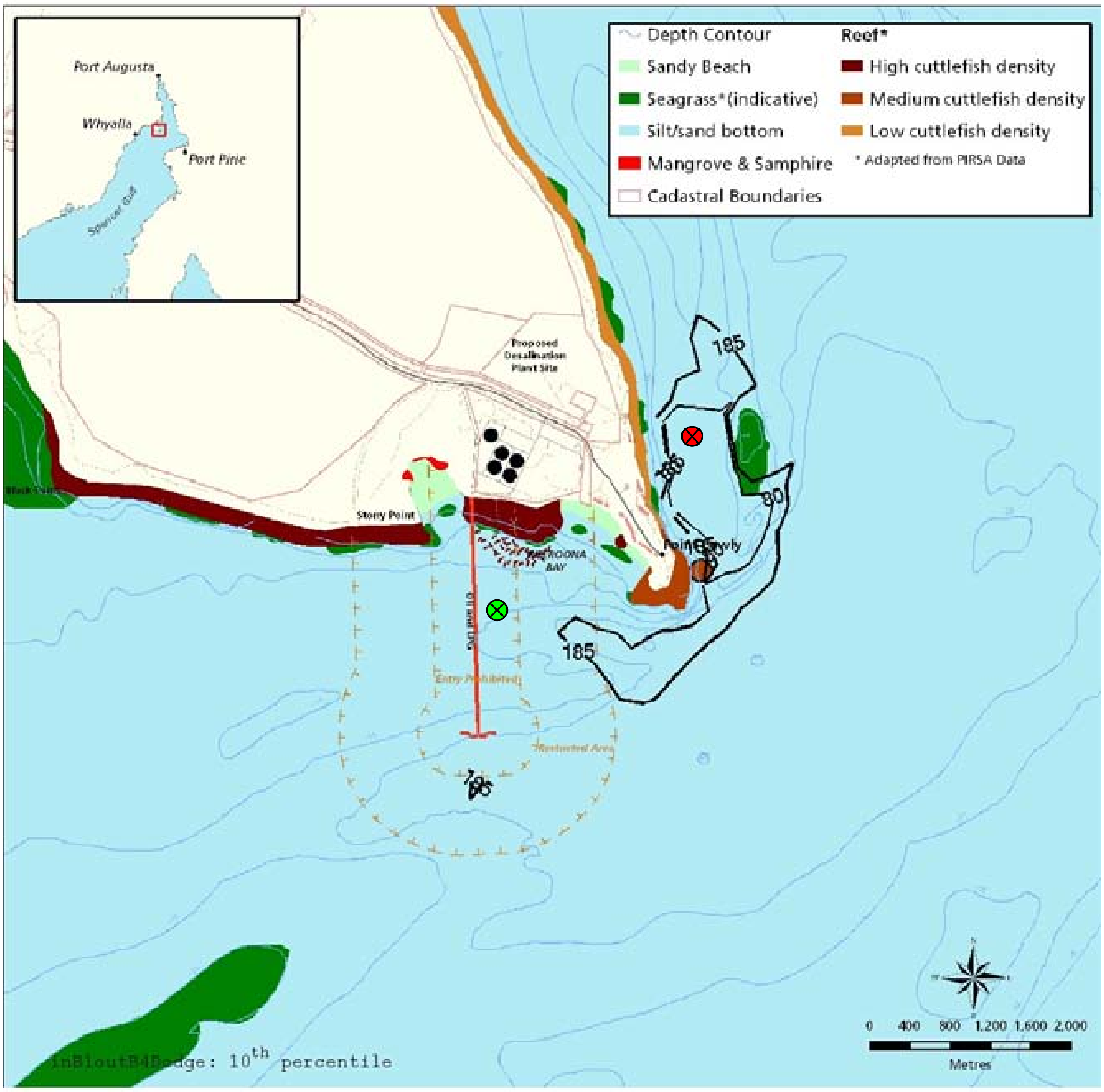


Figure 3-56 Simulation 11, 10th Percentile Contours, Dodge Tide. Outlet: B4 Intake: J1

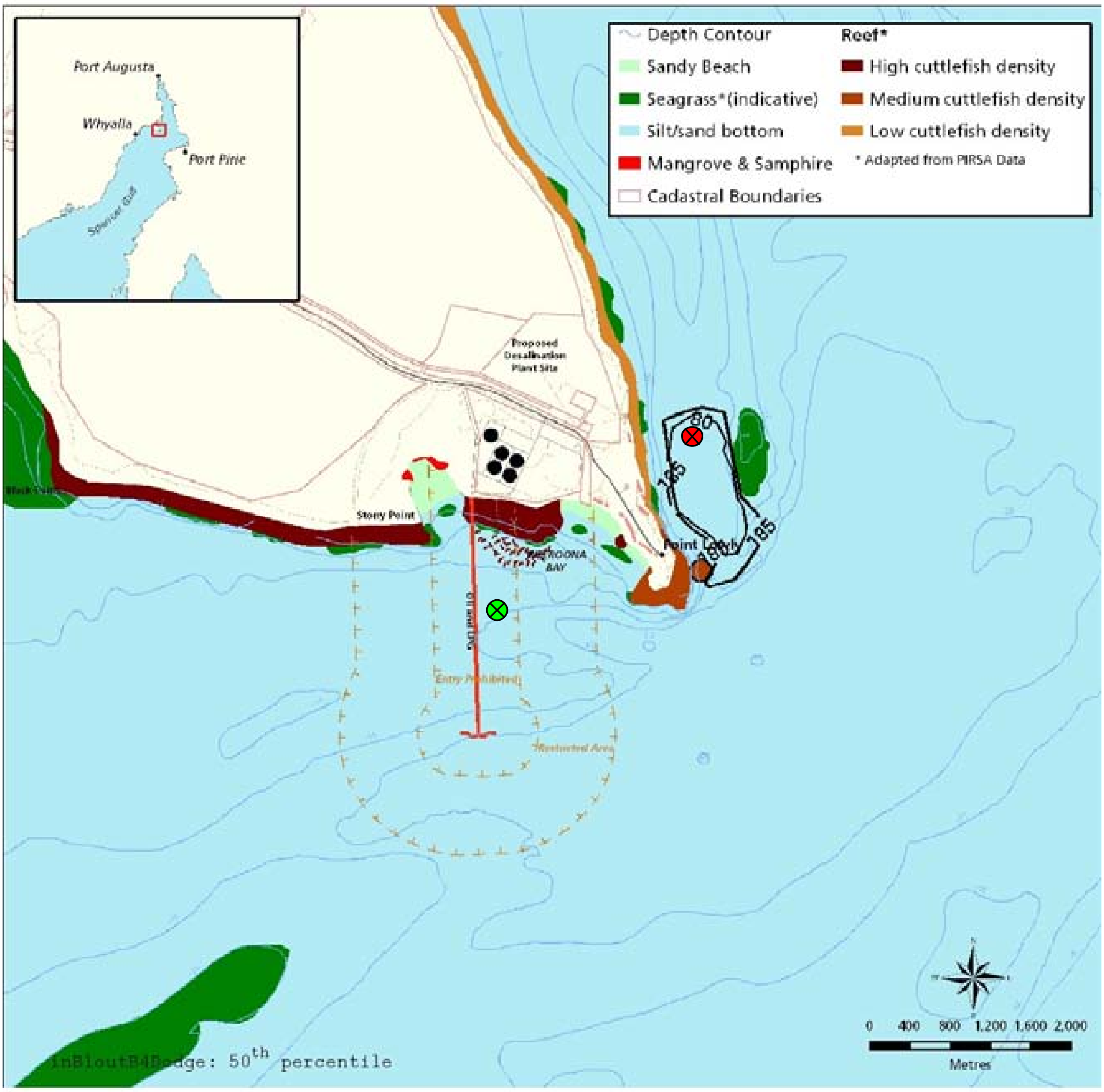


Figure 3-57 Simulation 11, 50th Percentile Contours, Dodge Tide. Outlet: B4 Intake: J1

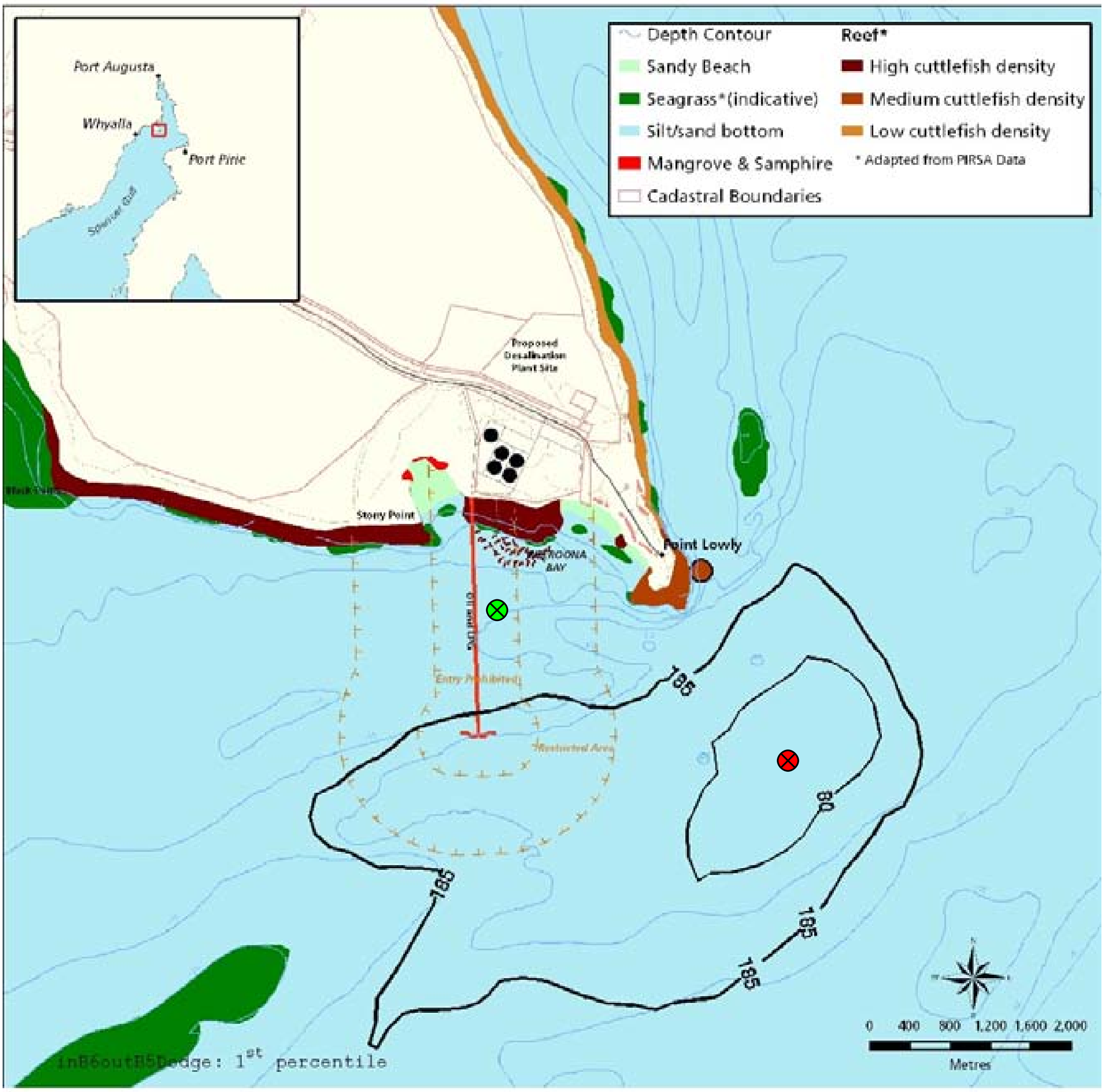


Figure 3-58 Simulation 12, 1st Percentile Contours, Dodge Tide. Outlet: B5 Intake: J1

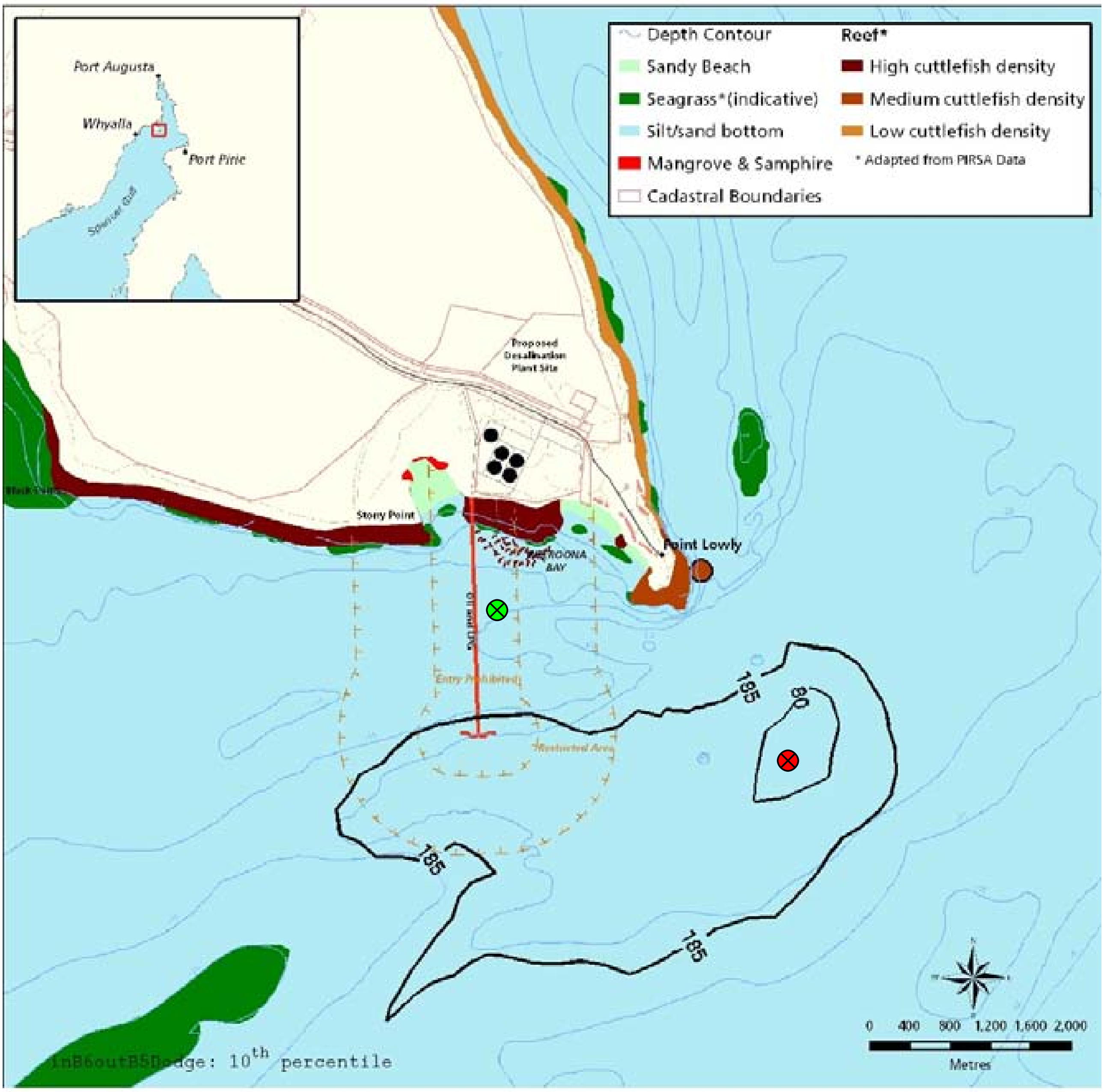


Figure 3-59 Simulation 12, 10th Percentile Contours, Dodge Tide. Outlet: B5 Intake: J1

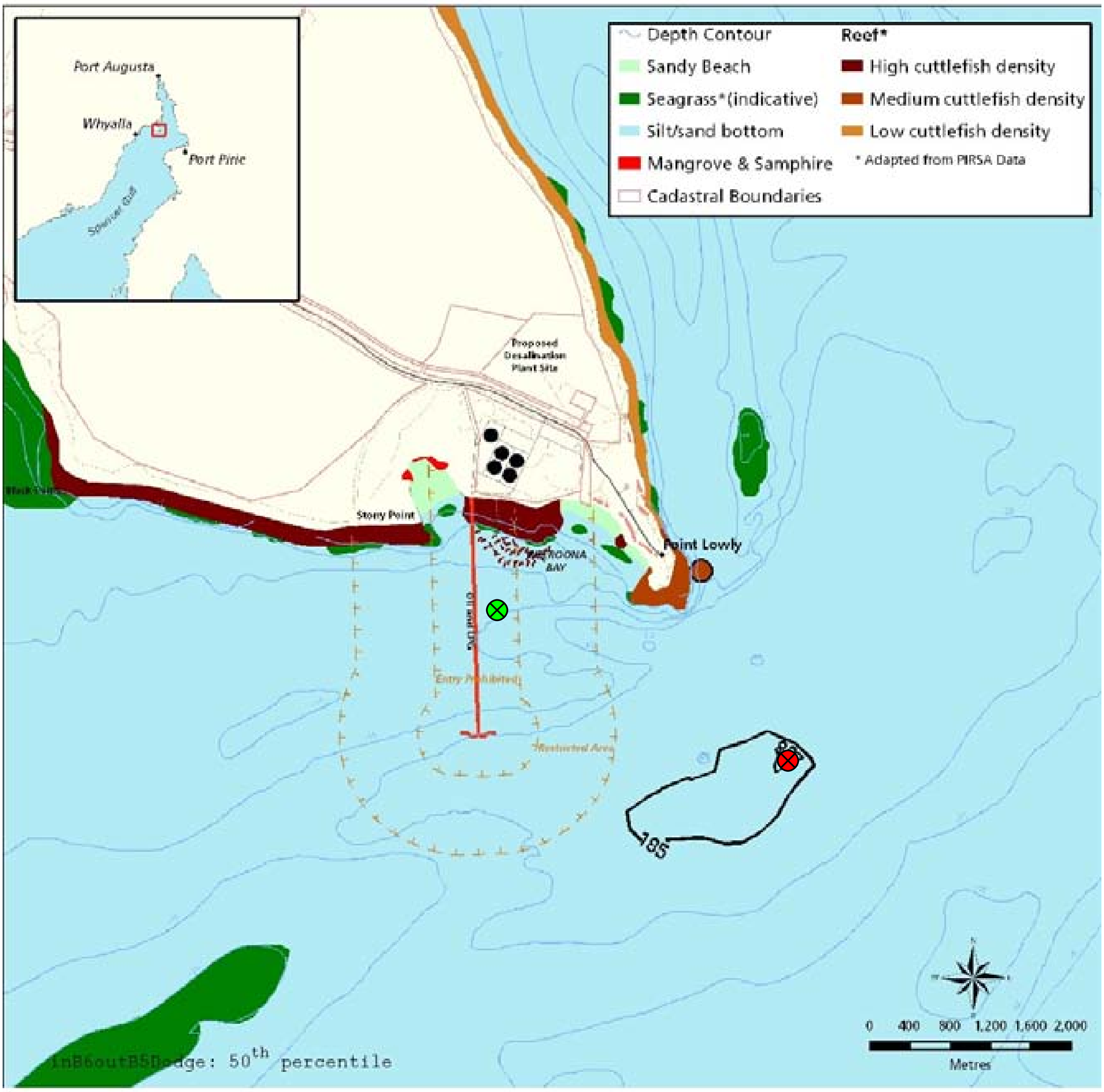


Figure 3-60 Simulation 12, 50th Percentile Contours, Dodge Tide. Outlet: B5 Intake: J1

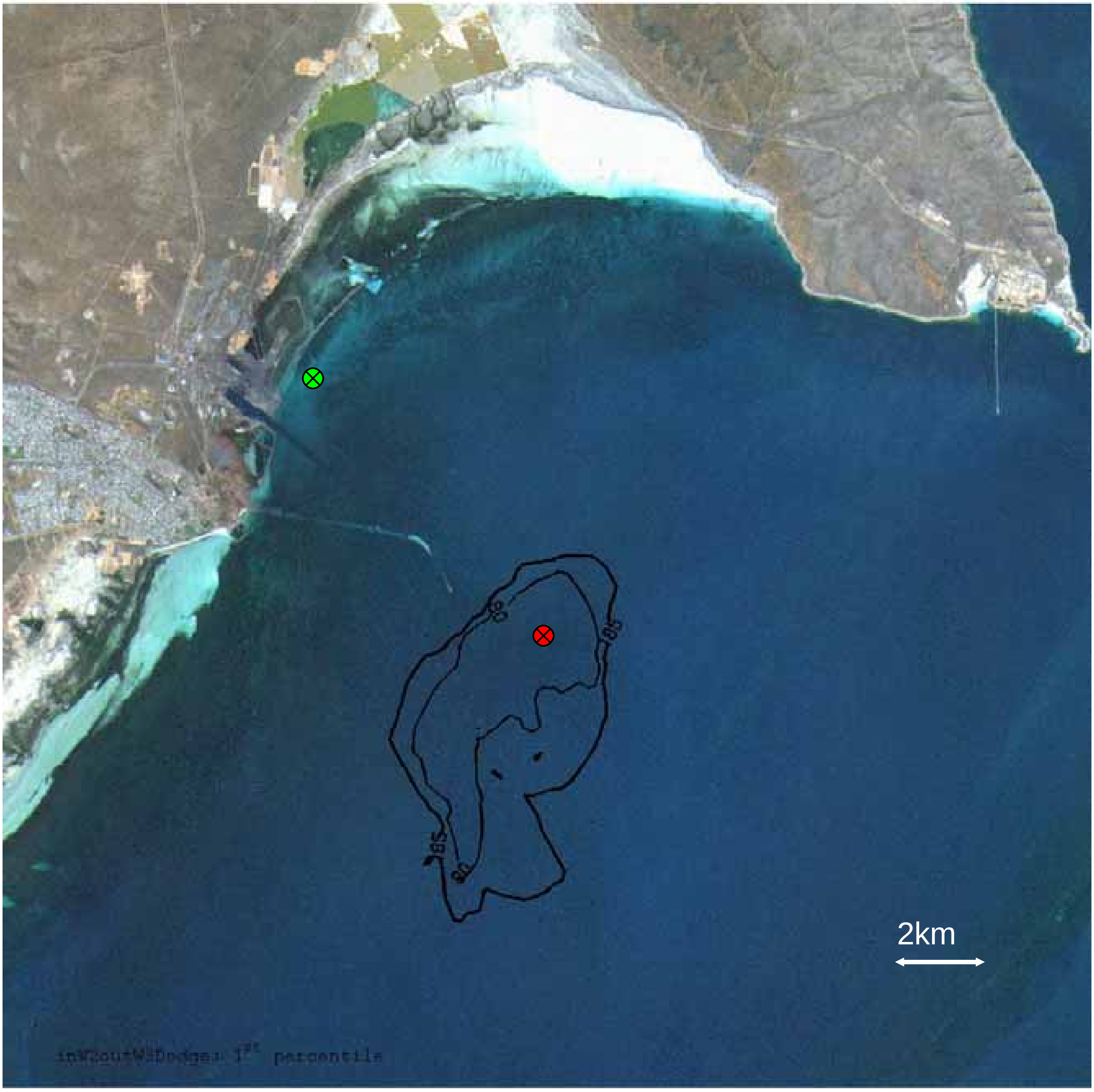


Figure 3-61 Simulation 13, 1st Percentile Contours, Dodge Tide. Outlet: W3

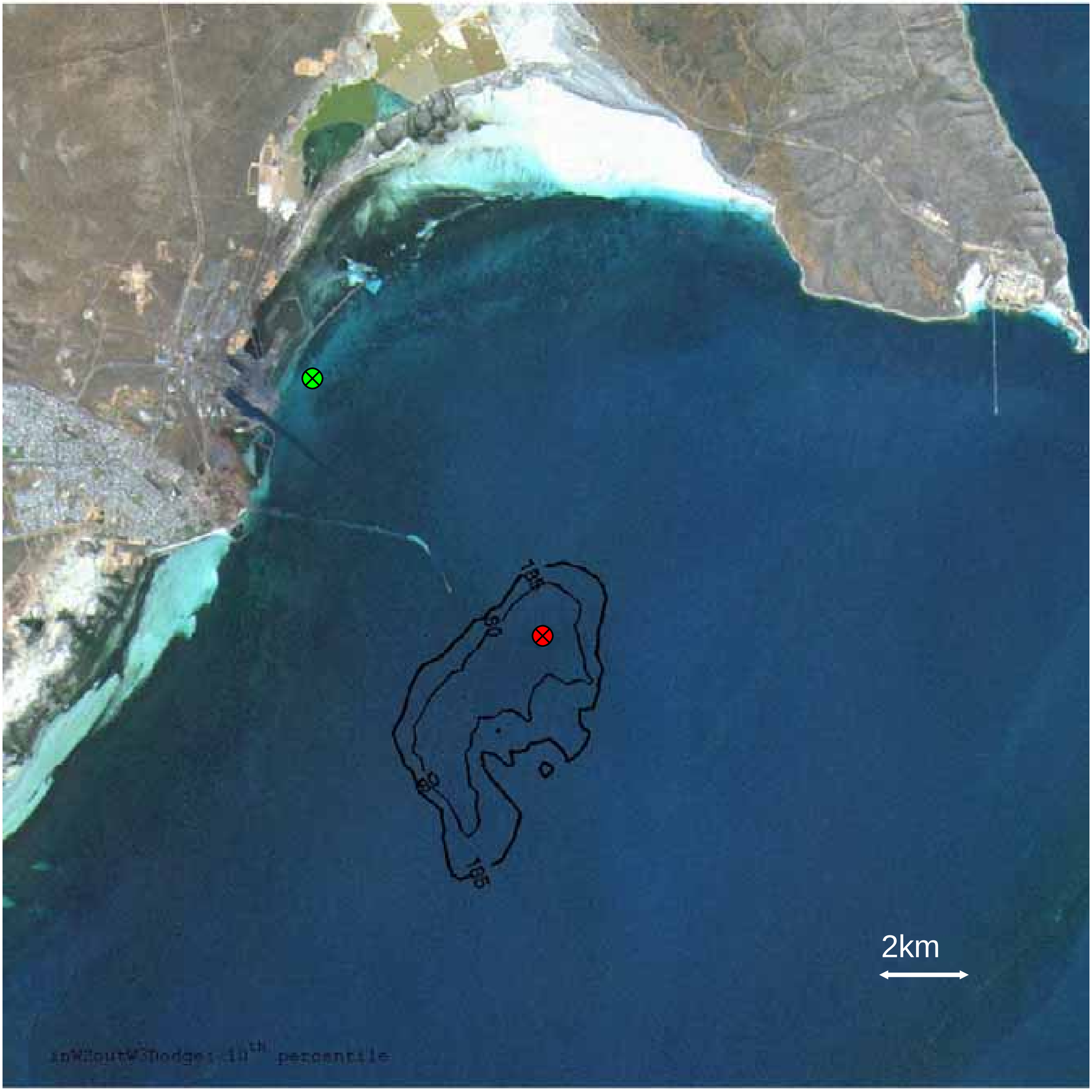


Figure 3-62 Simulation 13, 10th Percentile Contours, Dodge Tide. Outlet: W3

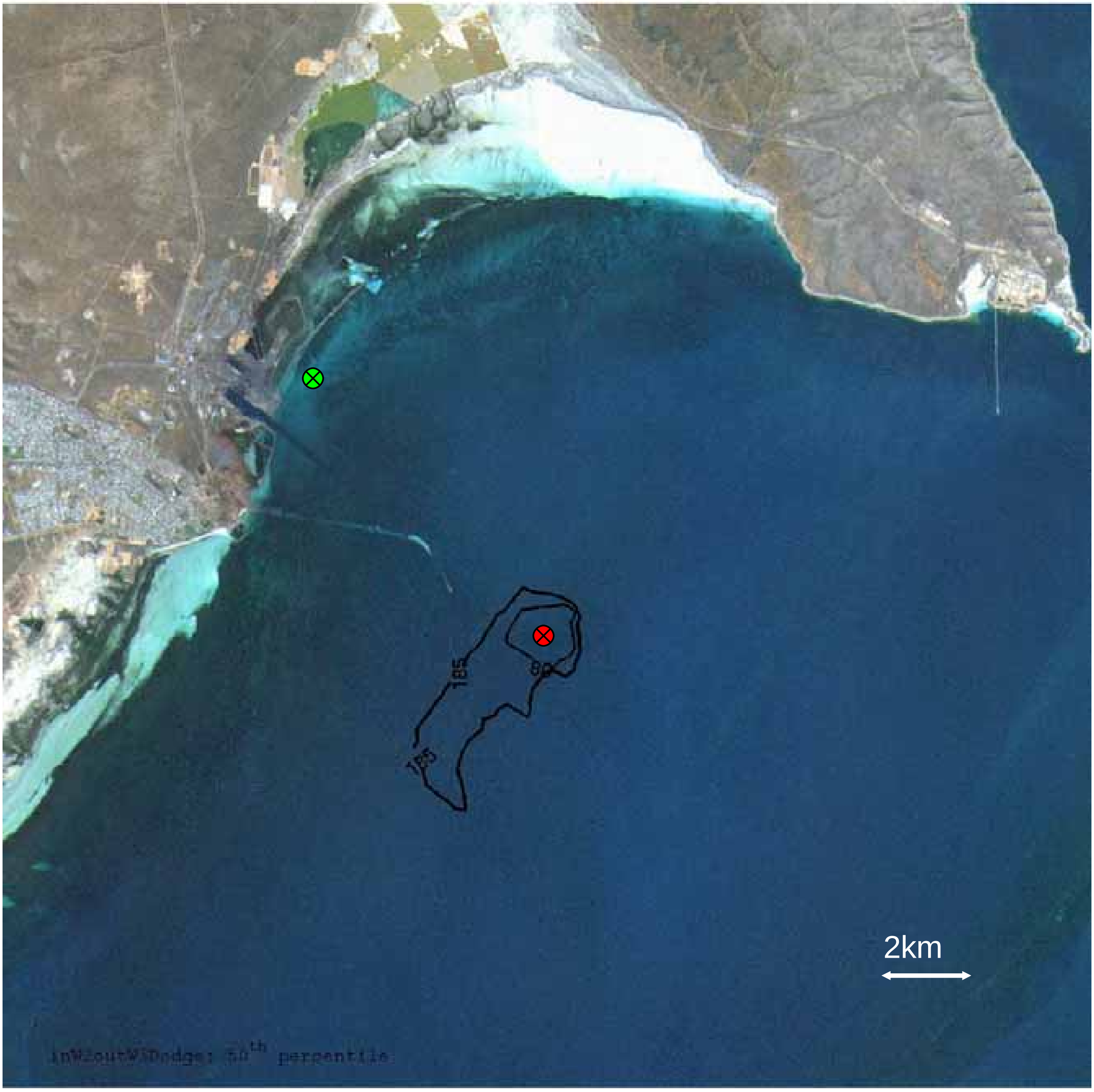


Figure 3-63 Simulation 13, 50th Percentile Contours, Dodge Tide. Outlet: W3

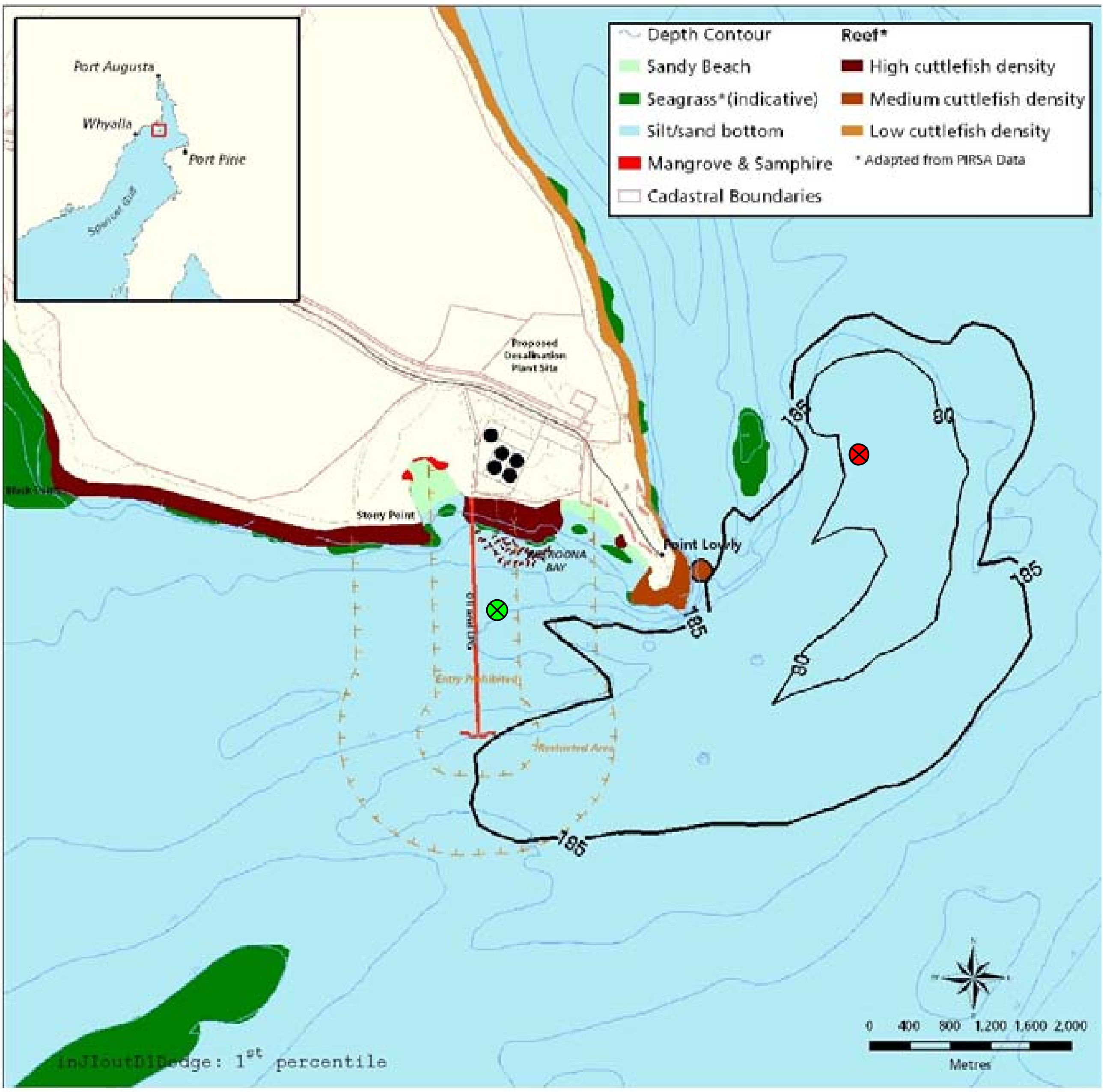


Figure 3-64 Simulation 14, 1st Percentile Contours, Dodge Tide. Outlet: B6 Intake: J1

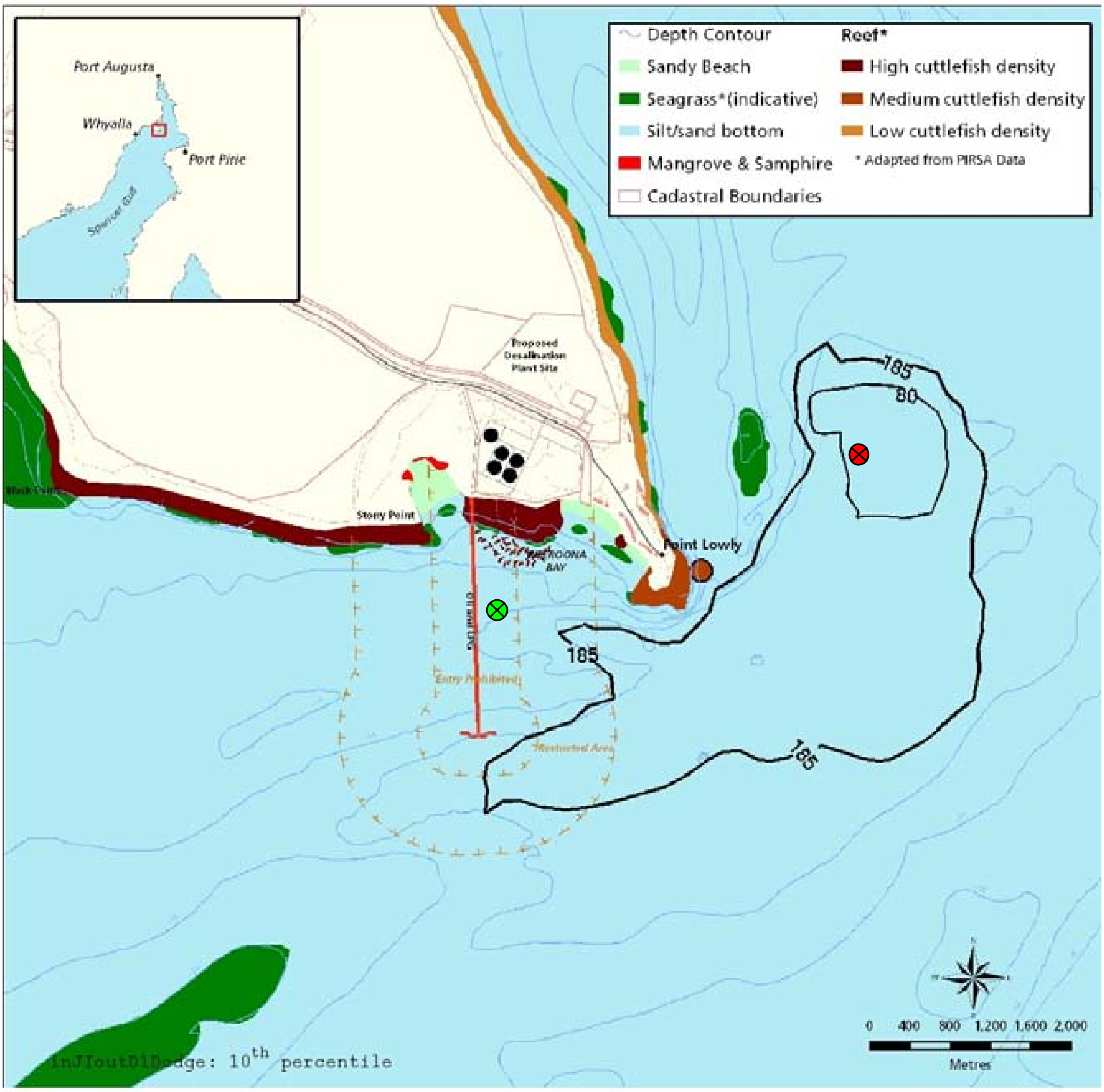


Figure 3-65 Simulation 14, 10th Percentile Contours, Dodge Tide. Outlet: B6 Intake: J1

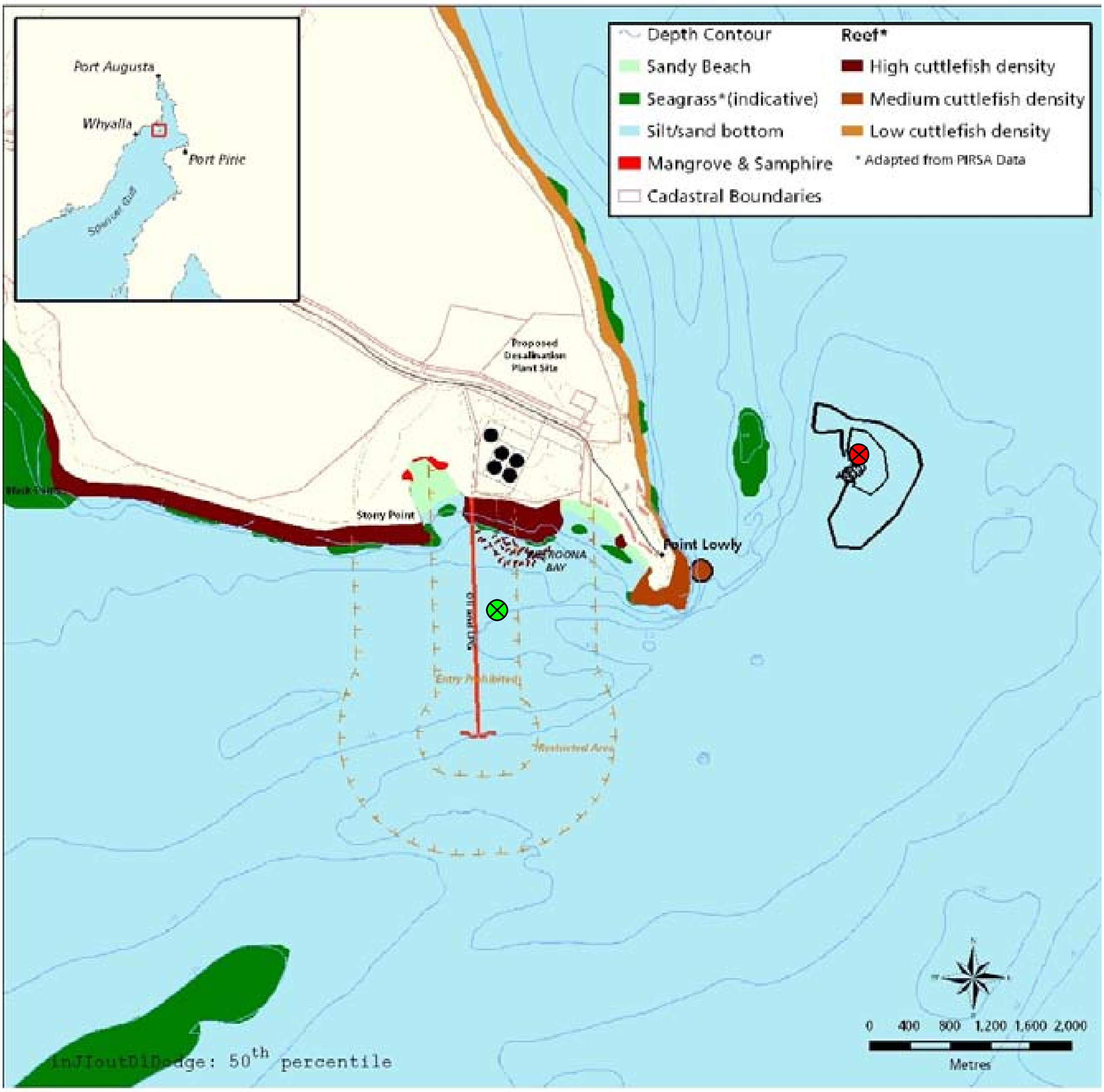


Figure 3-66 Simulation 14, 50th Percentile Contours, Dodge Tide. Outlet: B6 Intake: J1

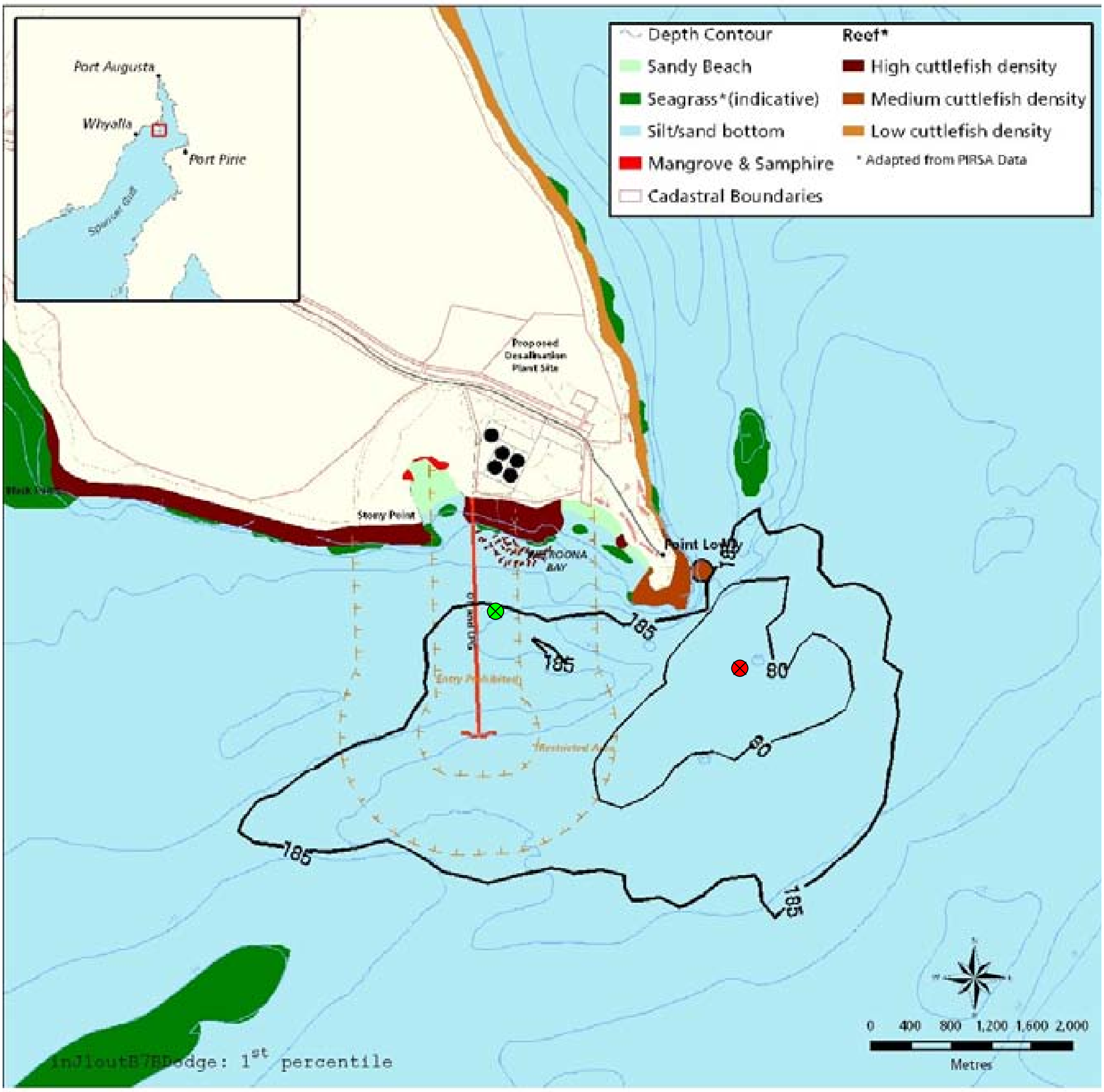


Figure 3-67 Simulation 16, 1st Percentile Contours, Dodge Tide. Outlet: B7 Intake: J1

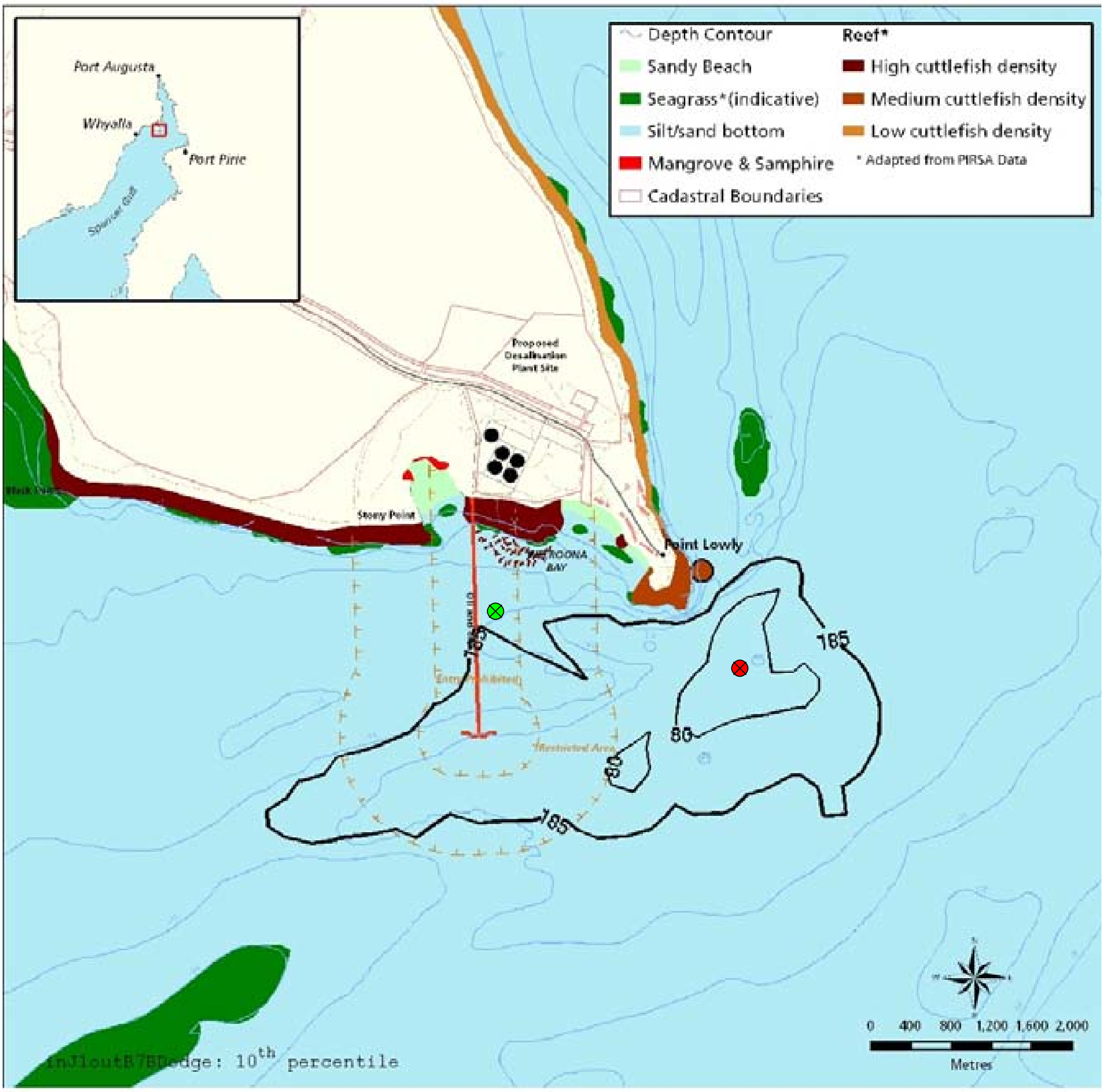


Figure 3-68 Simulation 16, 10th Percentile Contours, Dodge Tide. Outlet: B7 Intake: J1

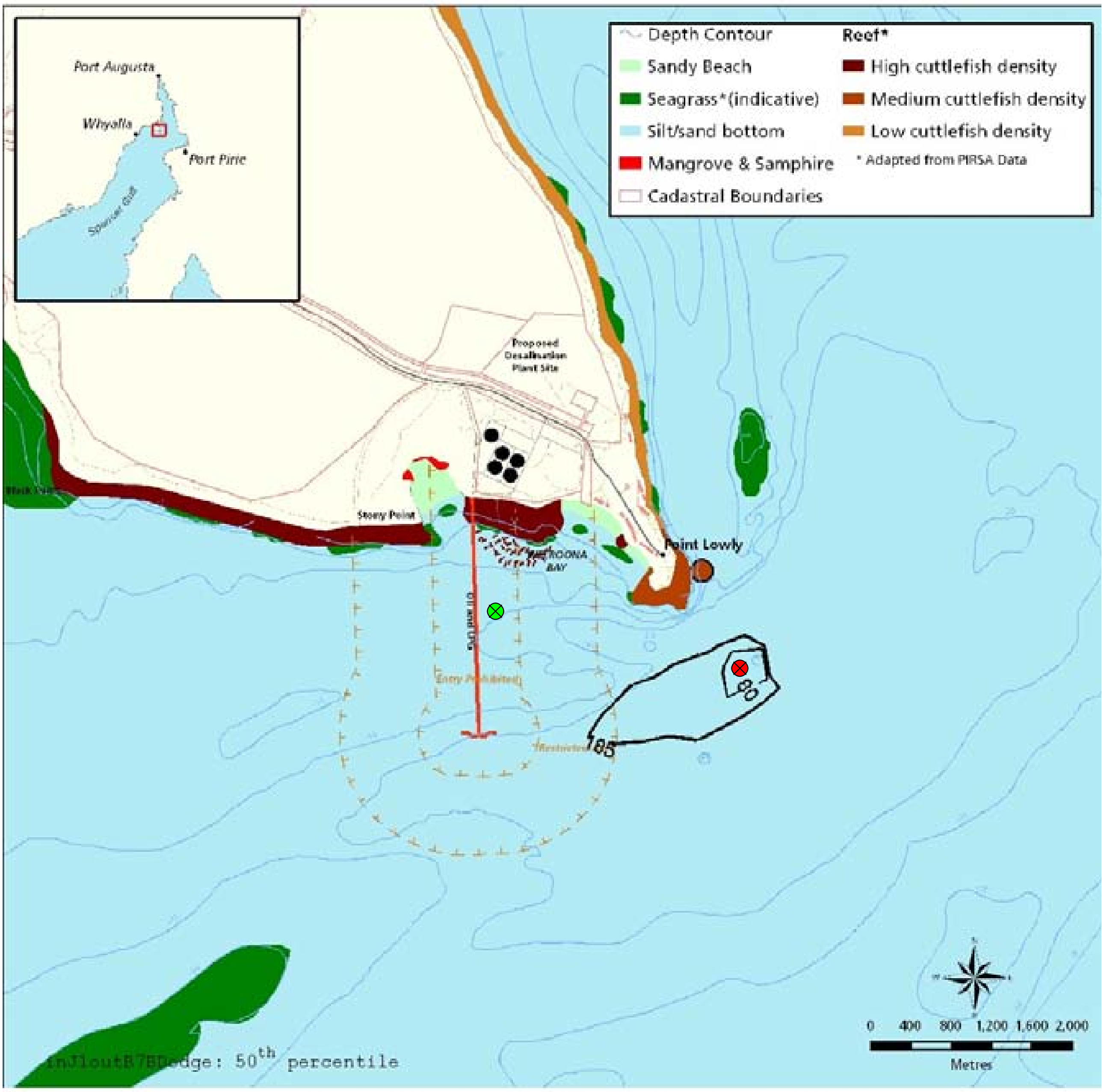


Figure 3-69 Simulation 16, 50th Percentile Contours, Dodge Tide. Outlet: B7 Intake: J1

3.2.3 Acceptable Discharge Location

After considering the above results, it is evident that simulation 16 shows small spatial extents of the typical and dodge tide contours, compared to the other simulation configurations. The discharge site (B7) is also located in deep, typically fast flowing water, with conditions as such being generally conducive to enhanced mixing and dispersion.

Typical and dodge tide period percentile analyses have been presented in previous sections. These, however, are not temporal figures: they do not convey the dynamic nature of the discharge and its interaction with the ambient flows. As such, presented here are timeseries of salinity at selected locations across the model domain bottom cells. These locations are shown in Figure 3-70. Key receptor locations including cuttlefish habitats and prawning areas have been selected, together with an array of points surrounding the outfall itself.

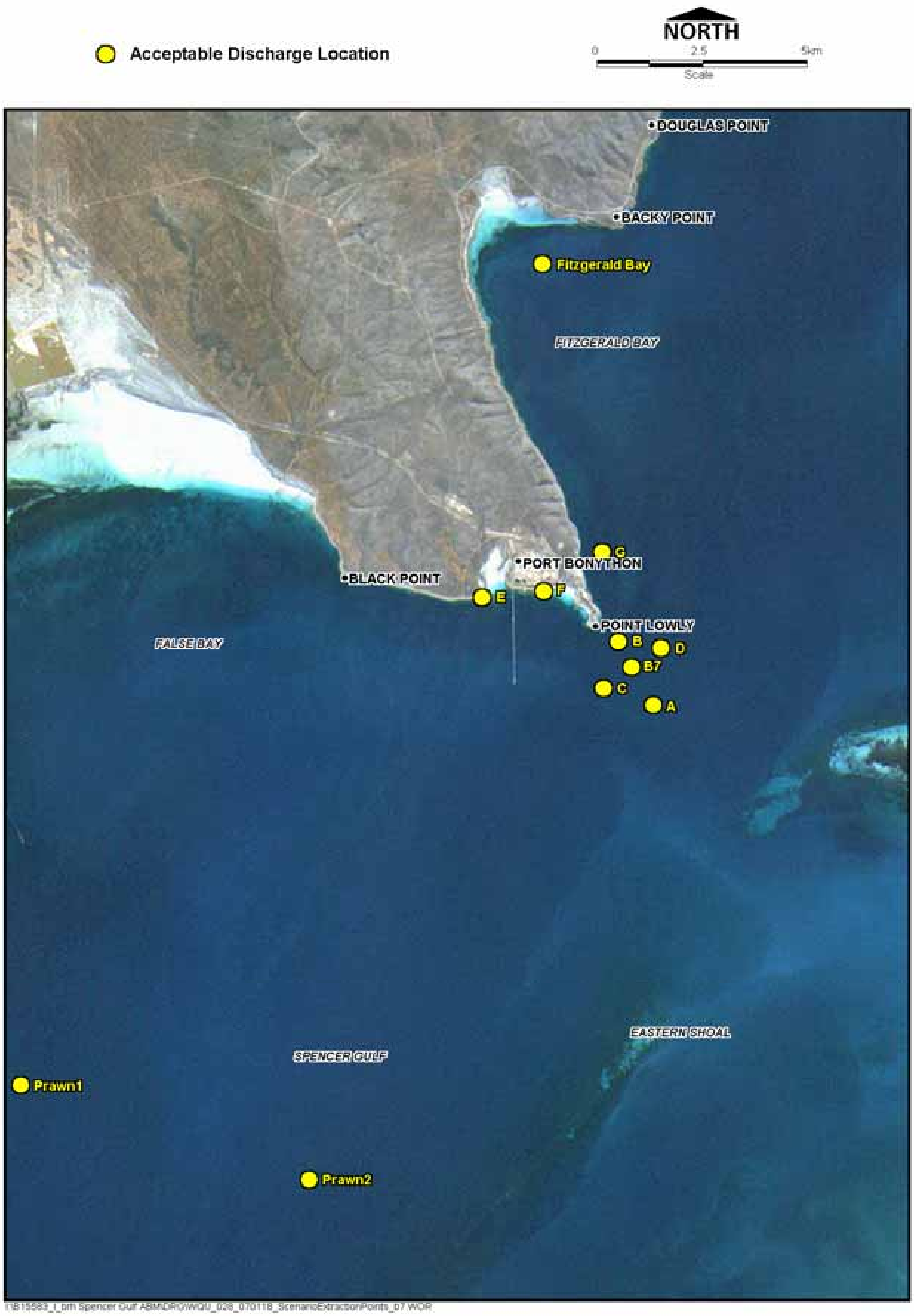


Figure 3-70 Interrogation Locations: Acceptable Discharge Location

Figure 3-71 presents the salinity timeseries at these locations over the consecutive (and continuous) spring-neap and dodge period. The upper panel presents the tidal water level and the lower panels display the salinity timeseries data. Both base case (blue line) and outfall (red line) cases are presented.

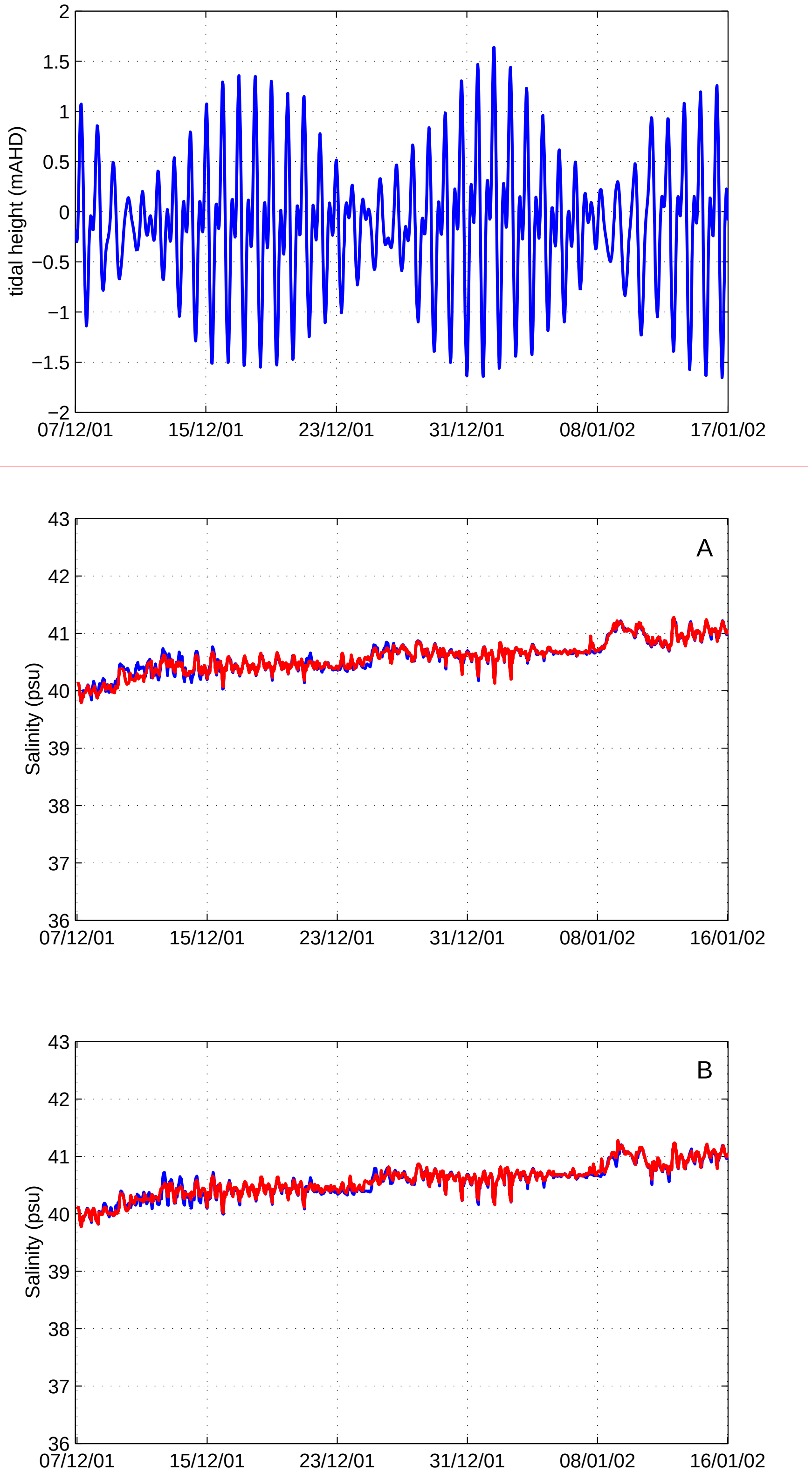


Figure 3-71 Salinity Timeseries (Bottom Layer)

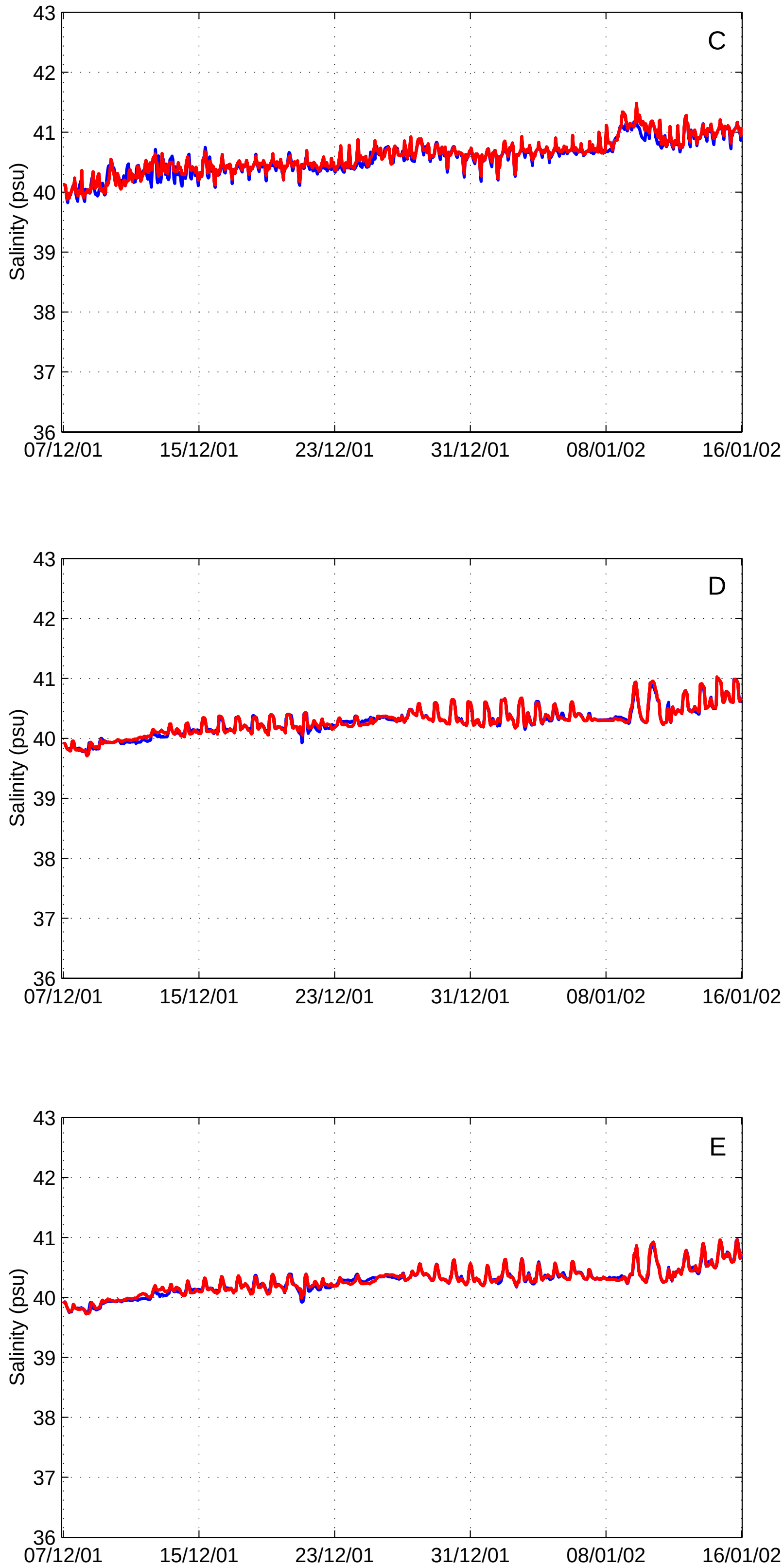


Figure 3 71 Salinity Timeseries (Bottom Layer) – Continued

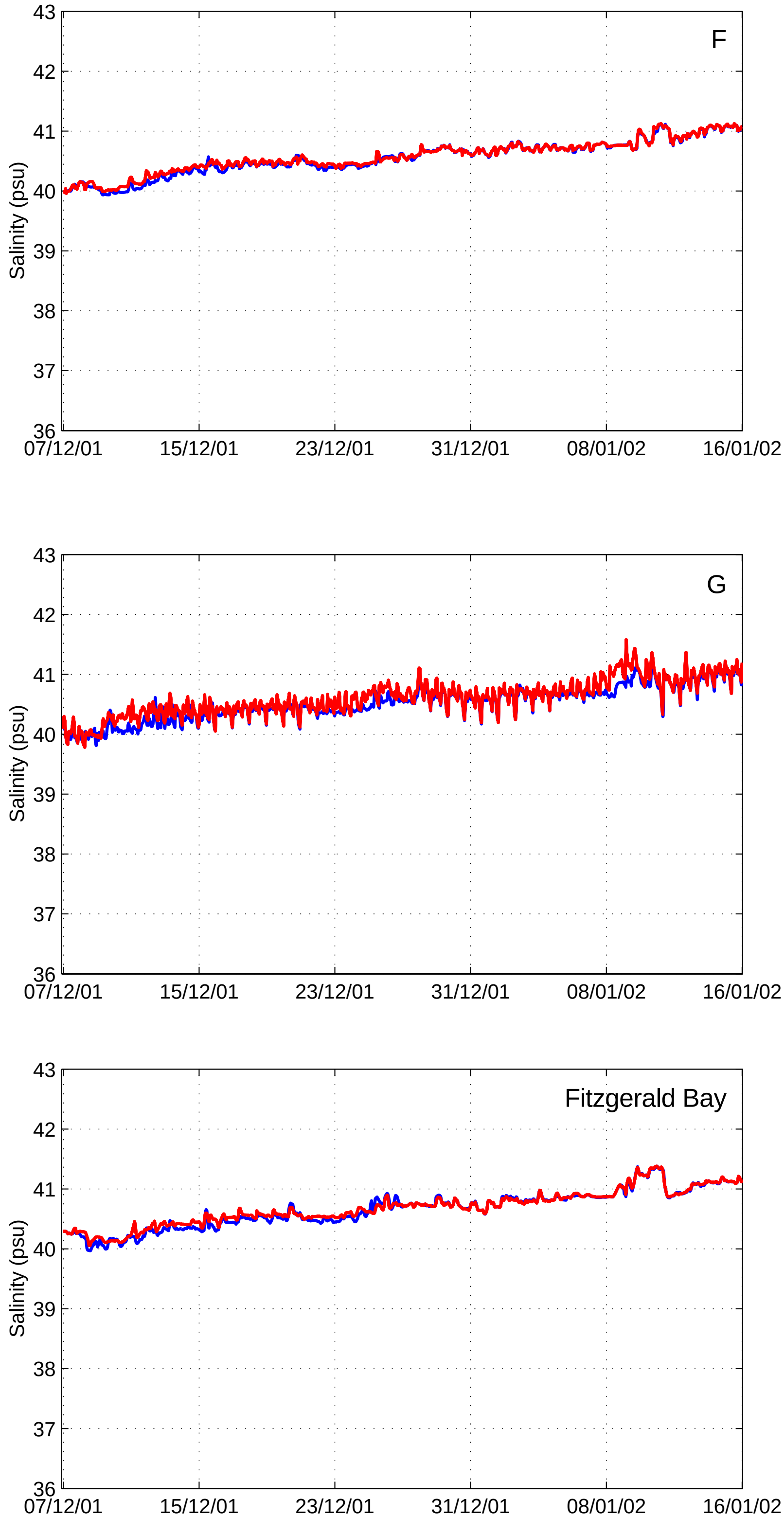


Figure 3 71 Salinity Timeseries (Bottom Layer) – Continued

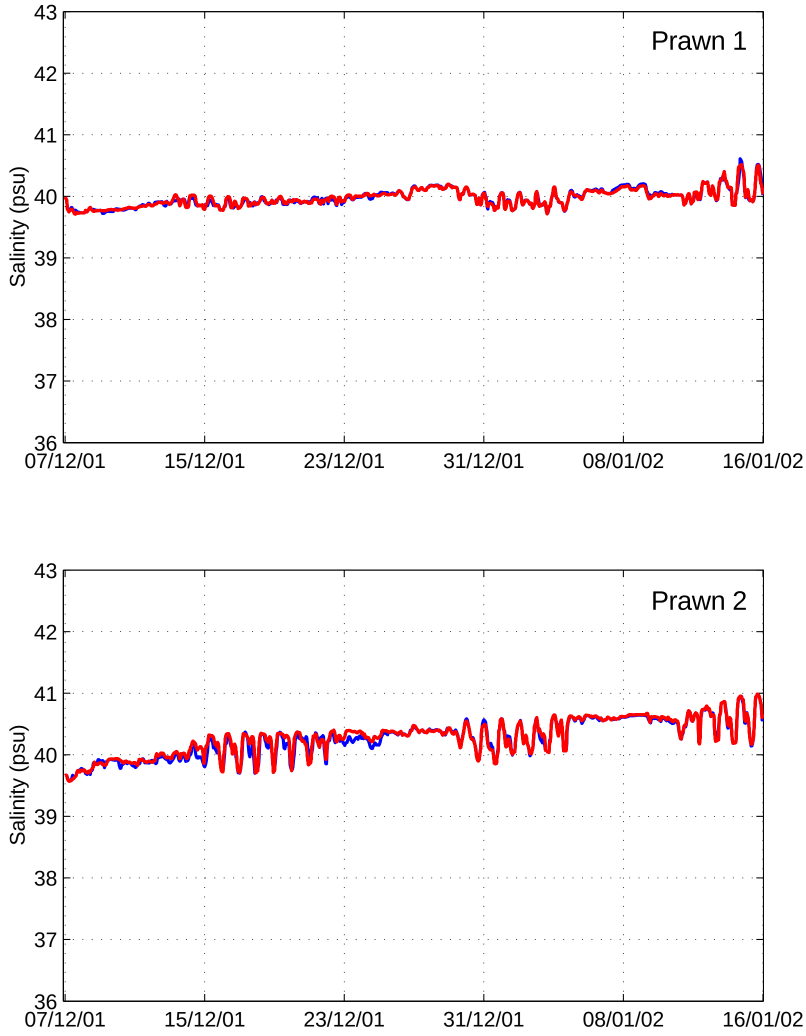


Figure 3-72 Salinity Timeseries (Bottom Layer) – Continued.

An additional execution of these same discharge conditions (referred to as simulation 15) was performed, but for an annual period, with seasonally varying potable delivery, to an average of 160 ML/day. The seasonally varying discharge is shown in Figure 3-73.

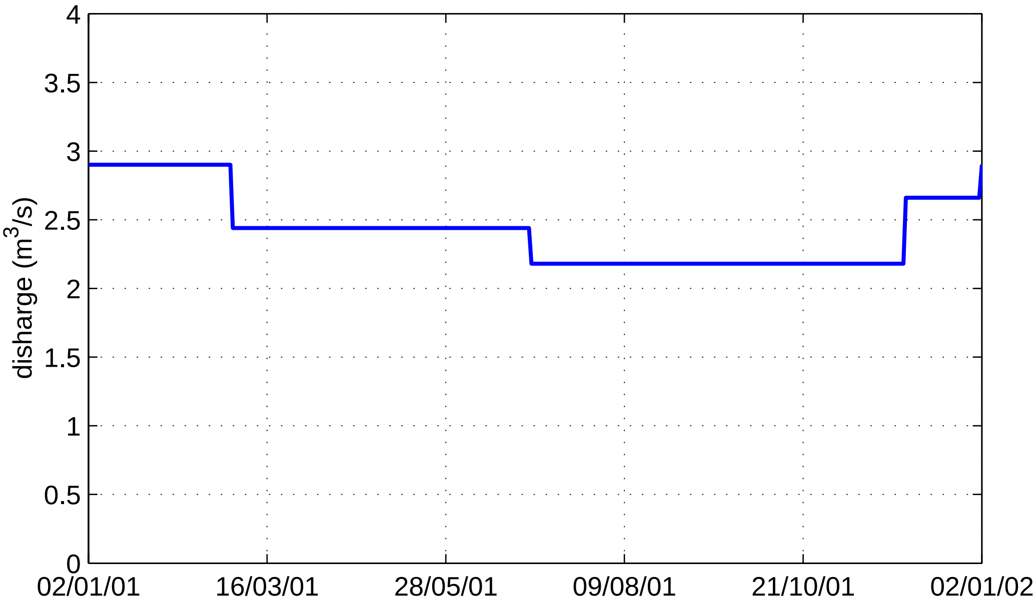


Figure 3-73 Seasonally Varying Discharge (Simulation 15)

The corresponding contour plots over that annual period (as opposed to the typical tide period) are presented below.

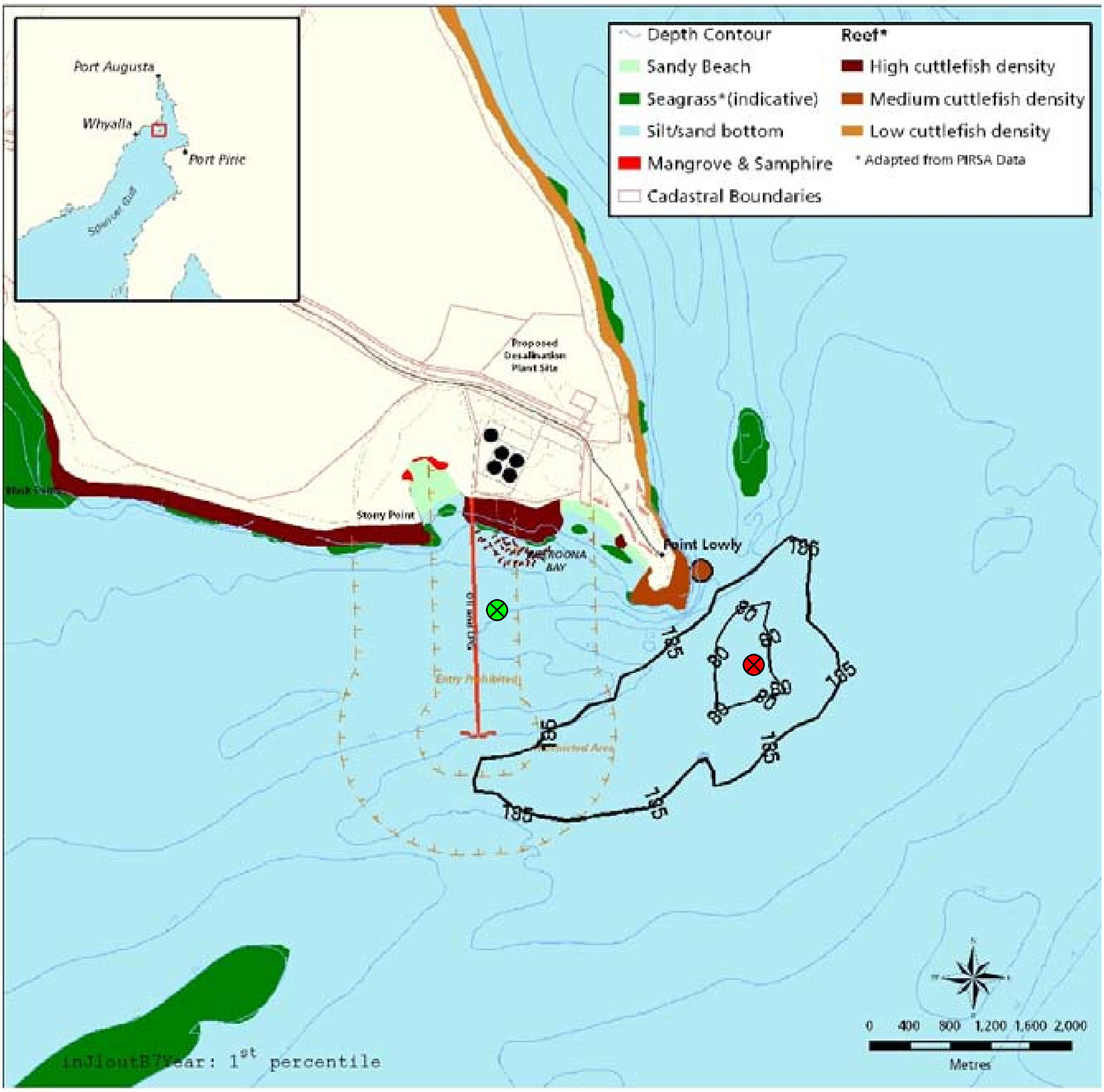


Figure 3-74 Simulation 15, 1st Percentile Contours, Annual Period. Outlet: B7 Intake: J1

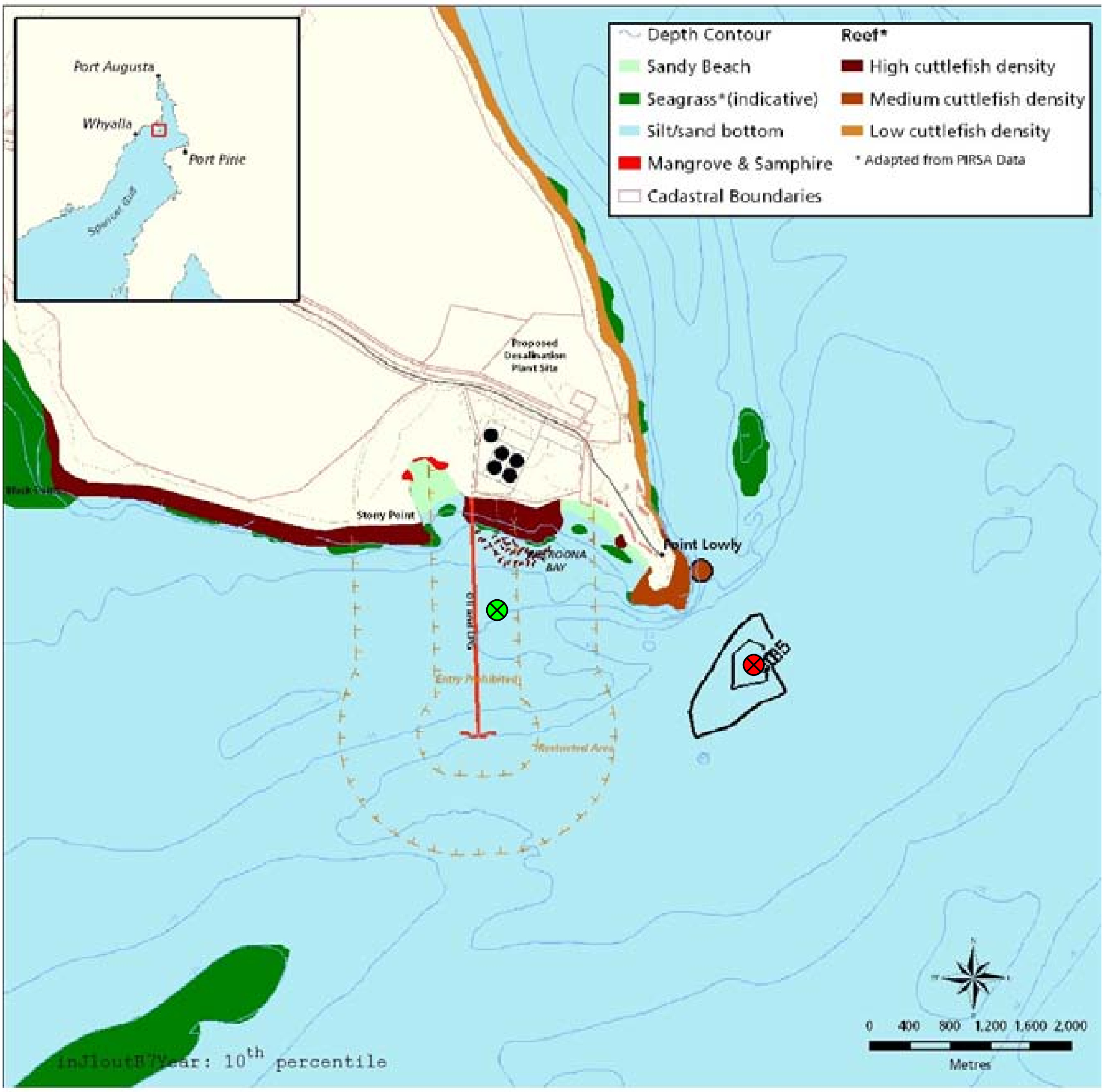


Figure 3-75 Simulation 15, 10th Percentile Contours, Annual Period. Outlet: B7 Intake: J1

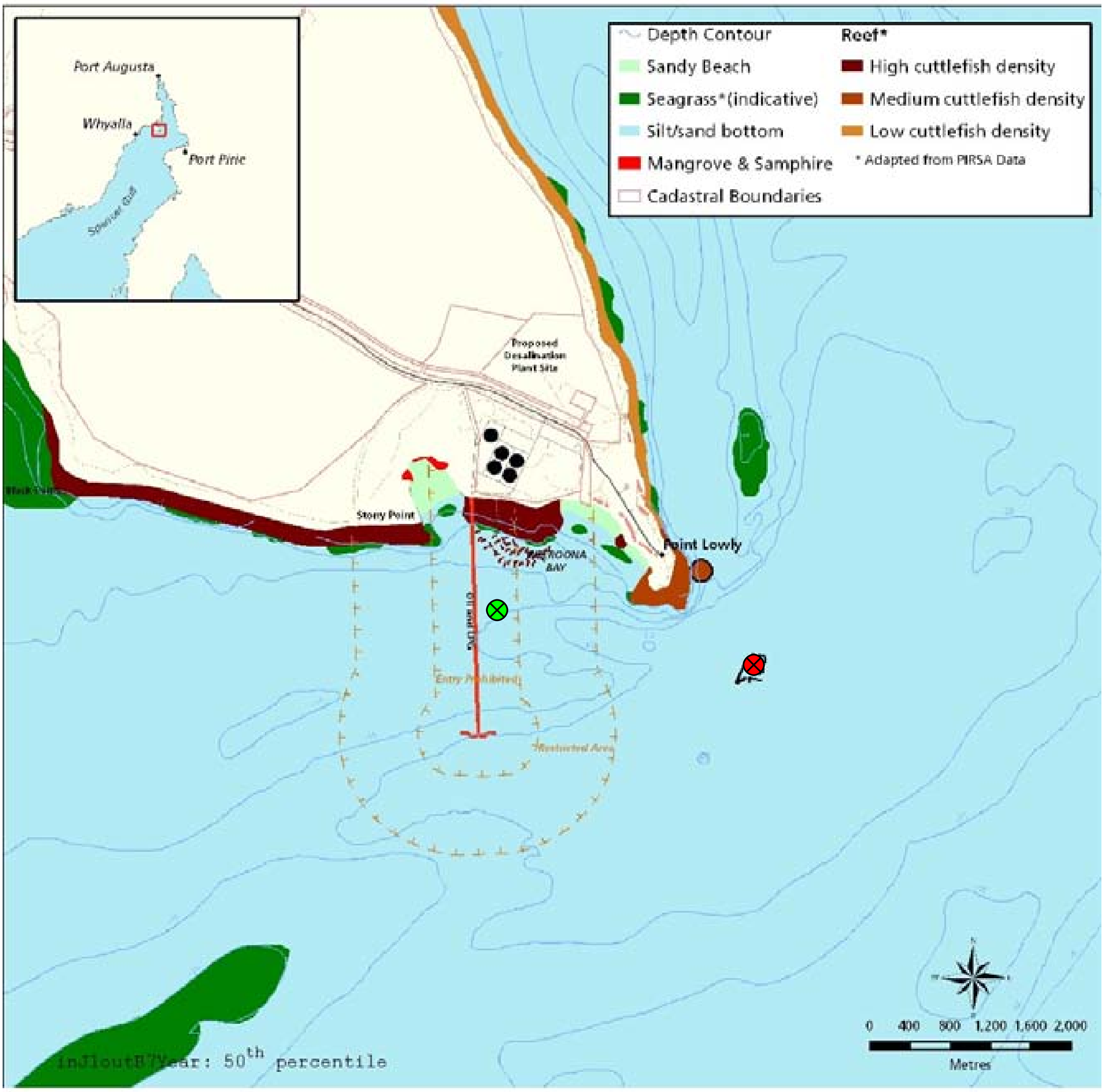


Figure 3-76 Simulation 15, 50th Percentile Contours, Annual Period. Outlet: B7 Intake: J1

4 NEAR FIELD MODELLING

4.1 Simulations

The intent of the near field modelling was to examine the impacts of the proposed discharge on the immediate surroundings of the outfall. The conditions of the outfall were selected as those of the acceptable discharge location, B7. Additional (prior) near field modelling was also conducted to inform preliminary investigations, and the corresponding results are described in Appendix B.

For all near field assessments, the CORMIX modelling package was used.

CORMIX is a USEPA-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. The system emphasizes the role of boundary interaction to predict steady-state mixing behavior and plume geometry.

The CORMIX methodology contains systems to model single-port, multiport diffuser discharges and surface discharge sources. Effluents considered may be conservative, non-conservative, heated, brine discharges or contain suspended sediments. Advanced information systems provide documented water quality modelling, NPDES regulatory decision support, visualization of regulatory mixing zones, and tools for outfall specification and design. MixZon Inc. is the primary contact for CORMIX information and technical support.

This model is an accepted industry standard for such investigations. CORMIX is a steady state model, which assesses plume behaviour for a fixed water depth and velocity case. As such, the velocity predictions of the mid field hydrodynamic (ELCOM) modelling at the B7 discharge site were interrogated and a range of relevant velocity percentiles extracted. A timeseries of velocity magnitude near B7 is shown below, for information only.

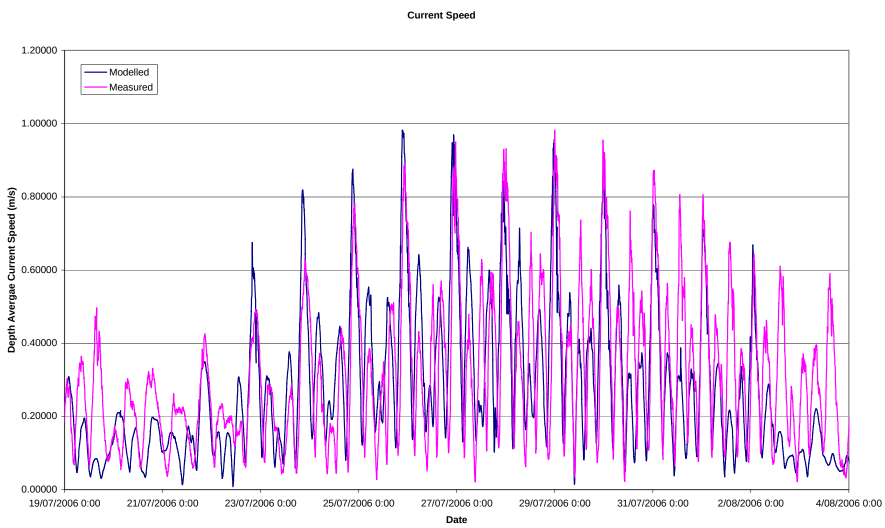


Figure 4-1 Indicative Velocity Magnitudes, Predicted and Measured

For each velocity percentile case, a CORMIX model run was performed. For each of these runs, the following salient model predictions were extracted:

- the dilution at the end of the near field zone, this being defined as the zone wherein the outfall plume contacts a seabed for the first time; and
- the distance down current from the outfall centreline to the edge of the near field zone.

A schematic of the interrogation point is shown below.

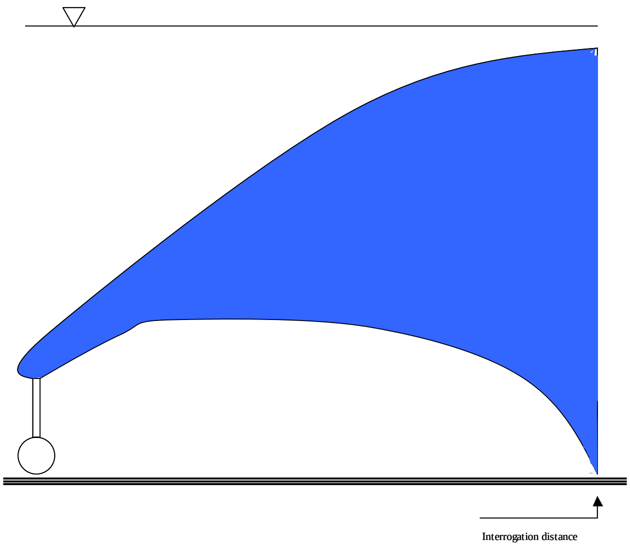


Figure 4-2 Schematic of CORMIX Interrogation Point – Conceptual Only

4.2 Input Data

Key input parameters and assumptions are provided below.

- Advice from Arup was that the outfall pipeline would be located on the seabed, with the effective height above the seabed of the outfall ports being two metres;
- The outfall structure was set to be 200 metres long;
- The outfall ports were set at one metre spacings (i.e. 200 ports);
- The outfall ports were set to discharge vertically upwards;
- The outfall axis was directed perpendicular to the prevailing current direction;
- Outfall port diameter: 0.1. More detailed engineering and pump capacity/head loss calculations will be required to confirm the feasibility of these respective diameters;
- Density of discharge: 1052 kg/m^3;
- Flow through each discharge port: 0.01575m^3/s;
- Velocity through each discharge port: 2m/s, 0.5m/s;
- Wind speed: 0m/s;
- Water depth at discharge point: 20m;
- Ambient water density: 1030 kg/m^3; and

- Manning's n: 0.022

4.3 Results

The results of the CORMIX modelling are summarised in Table 4-1, Figure 4-3 and Figure 4-4.

Table 4-1 Near Field Modelling Results

Velocity percentile	Velocity (m/s)	Near Field Dilution	Near Field Extent (m)	Dilution at 100m
1	0.042	20:1	5	
5	0.082	39.3:1	13	48.3:1
10	0.111	43.5:1	17	50.1:1
25	0.177	53.3:1	25.5	53.3:1[1]
50	0.326	72.3:1	43.1	72.3:1[1]
75	0.591	98.2:1	68.6	98.2:1[1]
90	0.807	119.2:1	85.2	119.2:1[1]
95	0.901	128.3:1	90.3	128.3:1[1]
99	0.990	137:1	93.1	137:1[1]

[1] These dilutions were estimated from the model, which did not output at exactly 100m. They are conservative estimates

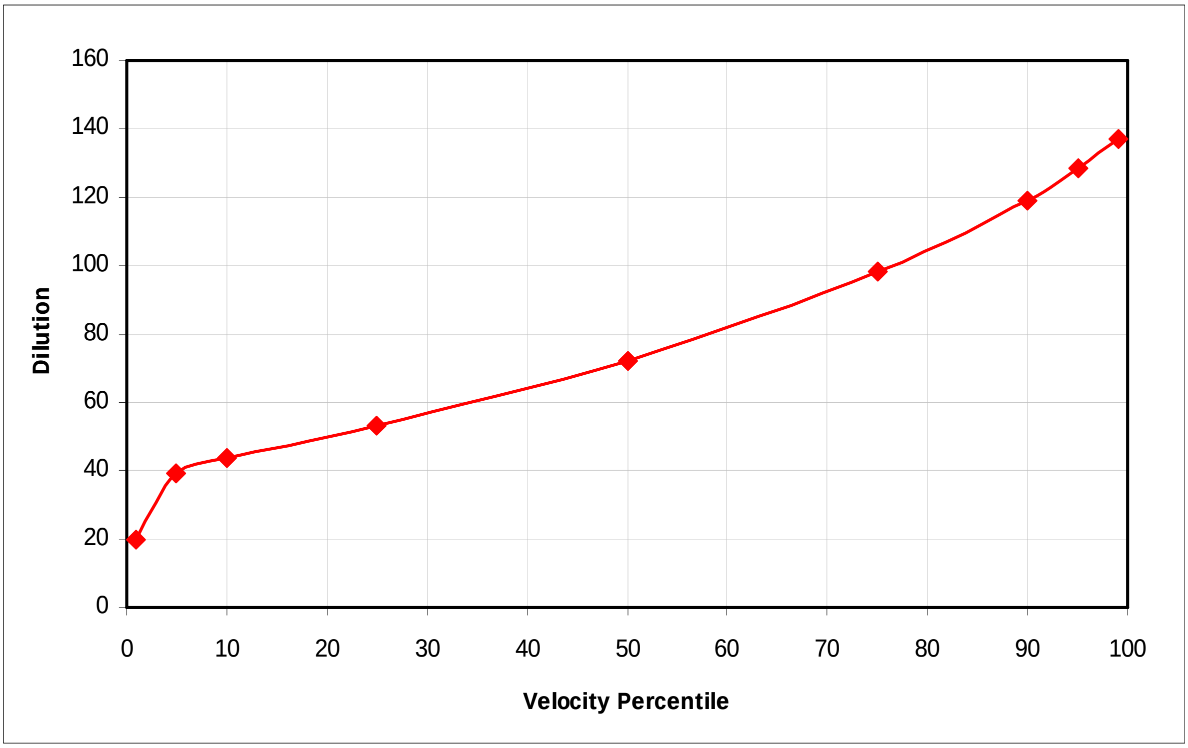


Figure 4-3 Near Field Dilutions

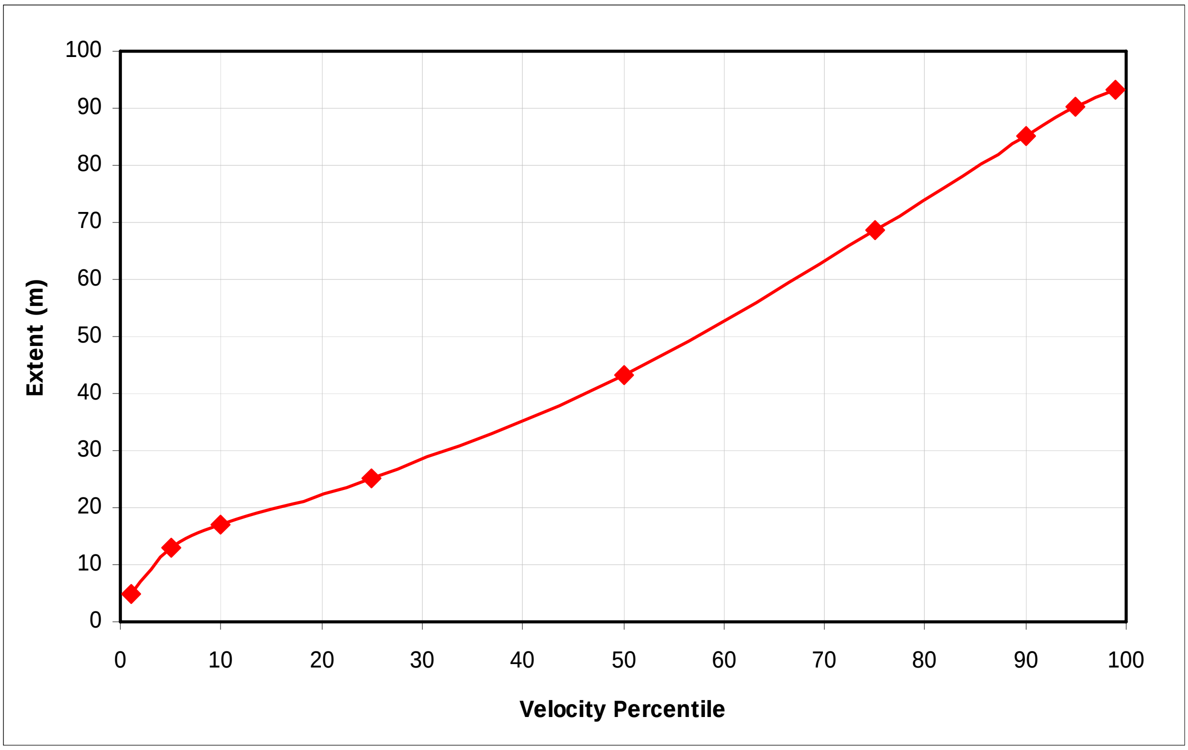


Figure 4-4 Near Field Extents

5 CONCLUSION

This report has presented the results of near, mid and far field modelling. By way of a conclusion to the report, we feel it is cogent to highlight the spatial and temporal scales at which the results of these different models can (and should) be 'combined'. Specifically:

- Near Mid and Far field model predictions can be combined additively only in the immediate vicinity of the outfall itself (+/- 200m). Such additive effects, especially for the extremely low velocities which see the maximum near field impacts, would occur for no more approximately a few hours at a time;
- Mid and Far field model predictions can be combined additively only in the general vicinity of Port Bonython (say +/- 2-4km from the outfall). Such additive effects, especially for the low water movements associated with neap/dodge tides, would occur for no more than approximately several hours to a few days at a time; and
- Far field model predictions apply in isolation for sites more than 2-4km from the outfall. The temporal scale of such model predictions is of the order of weeks to months.

APPENDIX A: DODGE TIDE FREQUENCY ASSESSMENT

Definition of Dodge Tide

As the ocean tides travel up into Spencer Gulf the relative strengths of the major semi-diurnal components, the M_2 and S_2, change and this results in a cross over point where their amplitudes coincide (Grzechnik, 2000). The importance of this crossover is the similarity (and sometimes equality) of the amplitudes of the two constituents. This has a periodic effect on the observed tides. The S_2 tide has a period of exactly 12 hours and the M_2 has a period of 12 hours, 25 minutes, so that every 14.77 days the two tides are in opposition and cancel each other out. This is when neap tides are produced and the absence of the semi diurnal component produces relatively stationary waters for a day or two, which can produce stratification (Nunes and Lennon, 1986 and Lennon, 1982). It is noted that there is some ambiguity in the definition of dodge, and that the above has been adopted for the purposes of this study.

Definition of Worst Case

The worst-case tidal sequence that was employed for the numerical modelling consisted of a period containing 'dodge' tides, which can be predicted. Based on the above, the occurrence of dodge tides, coincides with neap tides, and will occur twice monthly.

The likelihood of a worst-case scenario occurring, which includes a concurrent 'dodge' tide and nil wind.

If we assume a dodge tide will last for approximately 2 days (worst case) during every neap tide, then the probability of a dodge tide occurring is approximately 6.6% per year. If we assume a period of nil wind can be defined as winds 0 – 12 km/hr then Riedel and Byrne (1981) estimate that 15.6% of the time there will be little to no wind. Further analysis of wind data from the Bureau of Meteorology provided by Arup, estimates the same magnitudes of wind will occur 21.71% of the time.

These values produce a probability of the dodge tide and nil wind occurring, to be 2-3%, which accounts for approximately 7-10 days of the year. The chances of nil wind coinciding with the full two day period of dodge tides are clearly lower than this. While this is a relatively infrequent event it is not inconceivable that such events will occur a few times in the lifetime of the facility.

The probability of the worst-case scenario occurring during the winter months of May – September when the cuttlefish eggs are present will be related to the variation in the wind climate, given that the 'dodge' tides can occur unconditionally throughout the year.

The probability of the worst-case scenario (dodge tides and nil wind), at 2-3% occurring during summer is lower than for the entire year, but it is not expected to be significantly lower.

There may be seasonal and diurnal variations in the wind climate that will add bias to the probabilities. The wind analysis by Riedel and Byrne (1981) (Table 1) suggests that there are greater periods of calm during the winter months as opposed to the summer months, which may suggest greater probability of the scenario occurring in winter. However even if the probability is 100% it still cannot exceed the 2-3% defined by the other conditions. The diurnal variations in wind may also affect the bias, potentially decreasing the probability due to the low percentage of calm winds that may persist for 1 - 2 days.

Table 1 Percentage of Winds that are Calm (0-12 km/hr) for a Designated Summer and Winter Period (Riedel and Byrne, 1981)

Time	Percentage (%) of calm winds in Summer	Percentage (%) of calm winds in Winter
3am	24.8	28.1
9am	9	28
3pm	0.7	6.5
9pm	6.7	21.5

It should be noted that the presence and absence of stratification (which can be directly linked to the occurrence of dodge tides and air temperatures) should also be included when considering the impacts of the worst-case scenario on cuttlefish eggs. The presence of stratification will directly affect the advection and dispersion of salinity, resulting in higher localised concentrations of salinity and this is more likely to occur in the summer months. During the winter months, of May to September, when the cuttlefish eggs are present, the cooler air temperatures are not as conducive to stratification of the water column.

APPENDIX B: ADDITIONAL NEAR FIELD MODELLING

Prior to the near field modelling at location B7, surface plume modelling was also executed at a series of locations through Spencer Gulf. These sites were J1, J2, B2, B3 and Port Augusta, with the locations of these sites provided in the main body of the report.

As per site B7 in the report document, the modelling conducted assumed steady state conditions at the outfall. As such, the mid field model hydrodynamic results over a period encompassing spring and neap tides were interrogated for each possible outfall site to define a suite of such steady state conditions to model. Key forcing data are as follows:

- Advice from Arup was that the outfall pipeline would be located two metres below the lowest tidal water level in each case;
- The outfall structure was set to be 200 metres long;
- The outfall ports were set at one metre spacings (i.e. 200 ports);
- The outfall ports were set to discharge vertically upwards;
- The outfall axis was directed perpendicular to the prevailing current direction;
- The outfall diameter was 0.1 metres in all cases;
- Density of Port Bonython and Port Augusta discharges: 75.6 g/L and 84.6 g/L, respectively;
- Flow through each discharge port: 0.01575m^3/s;
- Velocity through each discharge port: 2m/s;
- Wind speed: 0m/s;
- Water depth at discharge point: 20m;
- Ambient water density: 42 and 47 g/L for Port Bonython and Port Augusta, respectively; and
- Manning's n: 0.022

The results of these assessments are presented below.

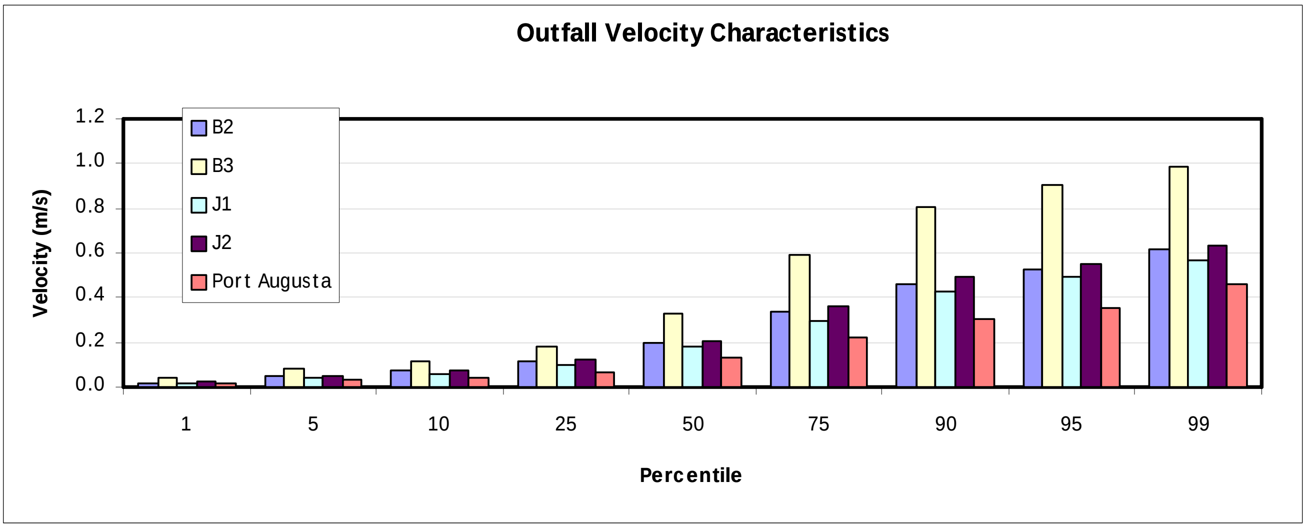


Figure 1 Velocity Percentiles at Simulated Locations

This graph shows that:

- Of all sites, the Port Augusta outfall has the lowest ambient tidal velocities:
- Of the Port Bonython outfall options, sites B2, J1 and J2 have comparable velocity patterns; and
- Outfall site B3 has greater incident velocities than all other sites.

We subsequently used these velocity data, and the depth data for each outfall site, to develop and run a series of near field model runs. For each of these runs, plume dilution results were extracted from the model at the time/location when the outfall plume impacted on/contacted with the seafloor. The results of these model runs are presented below.

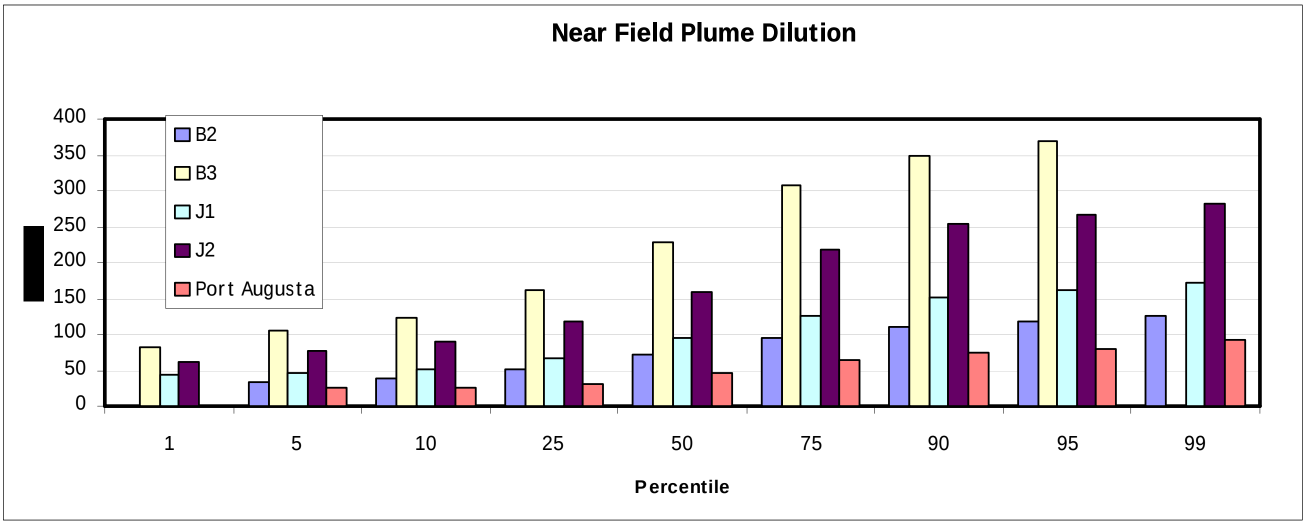


Figure 2 Dilution Percentiles at Simulated Locations

Having defined plume dilutions, we then defined commensurate brine/salinity concentrations associated with these scenarios. In this case, we adopted the following upper limit salinities in ambient water at the intake/outfall sites, and assumed that the SWRO process would increase salinities between the intake and outfall by a factor of 1.8 (we assumed this to be slightly higher than the factor of 1.7 we were advised by Arup in order to allow for some local recirculation and accumulation of brine).

- Bonython 42 g/L
- Port Augusta47 g/L

The results of these assessments are presented below.

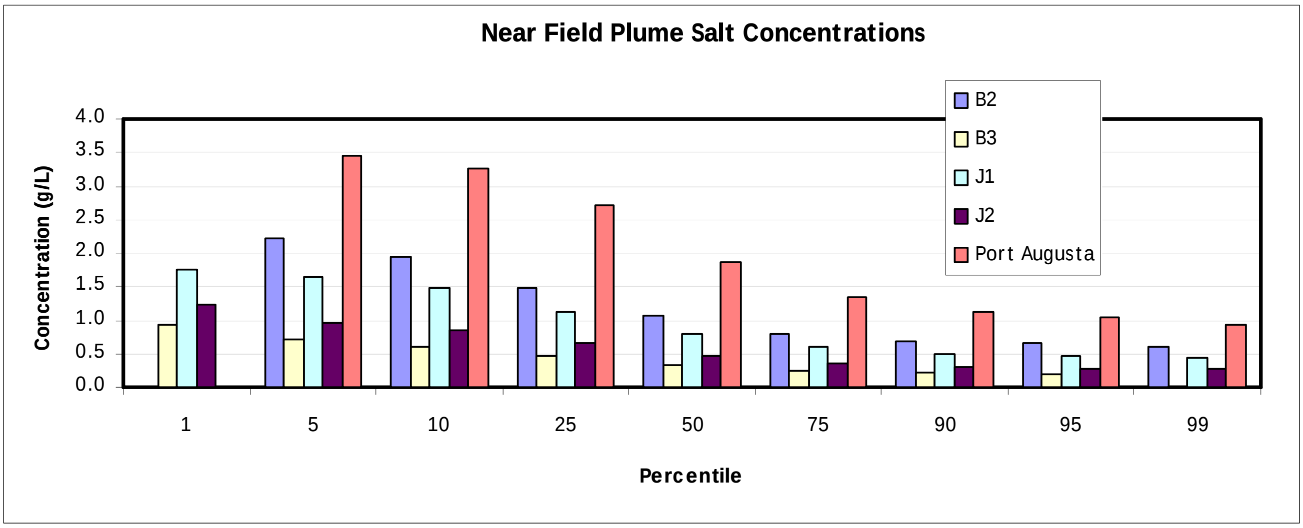


Figure 3 Salinity Percentiles at Simulated Locations

In regard to Figures 2 and 3, we note that for the scenarios where data are 'missing' (e.g. B2 and Port Augusta 1% velocity cases and B3 99th percentile velocity case), scenario parameters were either outside acceptable model domain limits and the model could not be run, or there was massive mixing. This indicates either extremely low rates of potential mixing (for the B2 and Port Augusta 1% velocity cases) or extremely high rates of mixing that results in no detectable bottom contact of the plume within the model domain (in the case of B3 for the 99th percentile velocity).

APPENDIX C: ADDITIONAL MEMORANDA

MEMORANDUM

TO: Arup/BHP Billiton

FROM: Tony McAlister

DATE: 10 October, 2006

SUBJECT: **Preferred Outfall Location**

1.0 Introduction

In association with ongoing assessments being conducted in regard to the proposed Olympic Dam project, specifically with respect to the environmental assessments of brine discharge to Spencer Gulf from a proposed desalination plant, WBM has been requested to prepare this briefing note on the relative merits of potential outfalls at Port Augusta and Port Bonython. We have, in preparing this advice, applied rigorous mathematical models to compare these two outfall locations and have supported this modelling with skilled analysis and interpretation. We summarise below the methodology followed, the results of the various modelling tools which were applied and conclude with a discussion of the findings and recommended outfall location. This briefing note should be read in conjunction with WBMs main report which includes further details.

2.0 Methodology

To compare the relative merits of the two preferred outfall locales, we have combined the results of far, mid and near field modelling. This approach is necessary in order to accommodate the various spatial and temporal scales at which impacts may occur on the receiving waters of Spencer Gulf and is summarised below.

2.1 Far Field Modelling

These assessments used a calibrated model of the whole of Spencer Gulf (Figure 1), which was run for a 5-year period. This model has a 2 km grid and is intended to quantify the long-term accumulation of brine associated with each outfall option. Given the 2km grid and long model run time, this model represents impacts on salinity levels over several kilometre spatial scales and temporal impacts of monthly to annual time scales.

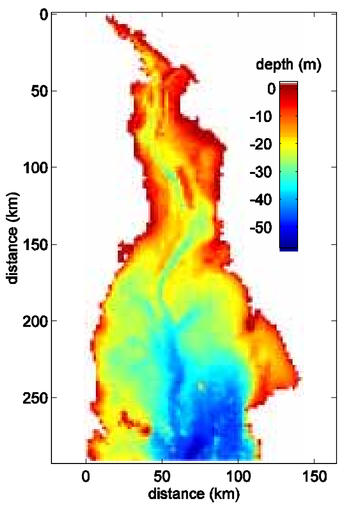


Figure 1 Far Field (2000m) Model Grid

2.2 Mid Field Modelling

These assessments used a calibrated model of the upper reaches of Spencer Gulf (Figure 2), which was run for a 15-day period. This model has a 200m grid size and is intended to quantify the more medium term accumulation of brine associated with each outfall option. Given the 200m grid and model run duration, this model represents impacts on salinity levels over several hundred metre spatial scales and temporal impacts of hourly-daily scales.

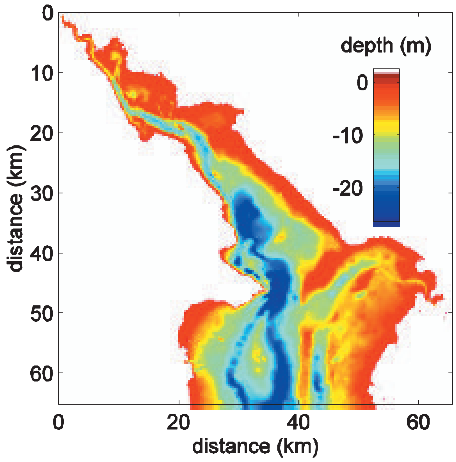


Figure 2 Mid Field (200m) Model Grid

For this modelling, we note that the impacts associated with several outfall options (see Figure 3 and Table 1) in the vicinity of Port Bonython were assessed. Given the 2km grid of the far field modelling, any differential effects between these options at this scale would have been undetectable and their joint far field effects were represented by one common (far field) model simulation.

Table 1 Port Bonython Scenario Intake and Outlet Configurations

Scenario	Outlet location	Intake location
Base	-	-
1	J1	J2
2	J2	J1
3	B2	B1
4	B3	J1

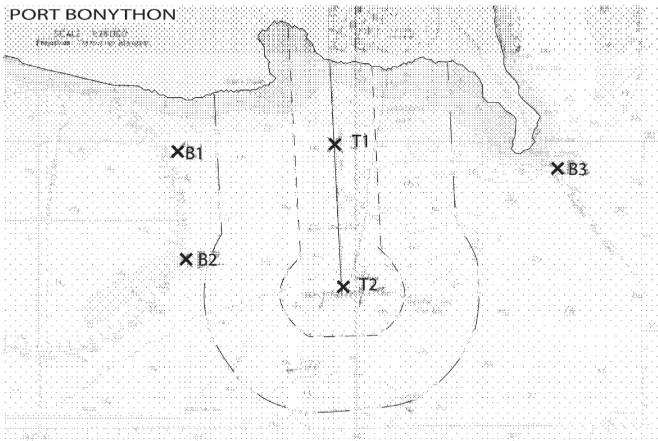


Figure 3 Mid Field Model Outfall Options

2.3 Near Field Modelling

These assessments used appropriate modelling techniques to define the initial mixing zone from the potential outfall sites, that is the zone wherein there is considerable initial dilution and vertical movement of brine after it discharges from the diffuser structure that will be associated with the outfall. In all our assessments, we have assumed a 200m long diffuser structure, located at a level equivalent to 1m below the Lowest Astronomical Tide (LAT) at the outfall site and configured perpendicular to the major current direction. This configuration will maximise the initial mixing of brine and minimise commensurate brine concentrations when the plume interacts with the sea floor.

This modelling represents impacts over 10's to 100's of metre spatial scales and temporal impacts over sub hourly timescales.

2.4 Combined Impacts

The far, mid and near field modelling results have been combined additively to assess the potential impacts of the various outfall options on Spencer Gulf salinity levels. We have combined the maximum far and mid field results (which will occur over respective timeframes of monthly to annual and hourly to daily) with the 10^{th} percentile dilution near field concentrations (which will occur for a time scale of the order of sub hourly) as we feel that combining all three as maxima is both overconservative and unrealistic. We note that the adopted near field dilution will be exceeded (and concentrations will be lower) for more than 90 percent of the time and hence this is still quite an extreme case.

3.0 Far Field Modelling

The far field modelling has been presented in previous reporting by WBM. In summary, the far field modelling showed the following long term increases in salinity (for time periods of the order of 1 month in duration within the 5 year model period) for the respective Port Bonython and Port Augusta discharges:

- Port Bonython 0.04 g/L
- Port Augusta 0.27 g/L

4.0 Mid Field Modelling

Separate mid field modelling exercises were carried out for the various outfall options at Port Bonython and for the Port Augusta outfall. The results of these assessments are presented below. A typical 20 day spring neap cycle period was selected for the simulations, and it should be noted that this is not necessarily representative of long term conditions. All simulations were executed over the same period so are, nonetheless, directly comparable.

4.1 Port Augusta

For the Port Augusta outfall, model runs for a suitable period encompassing spring and neap tides were performed. Model results were extracted as depth averages, surface and bottom readings from the 3D model at the outfall site (noting the 200m grid size) and for locations ranging up to several kilometres upstream and downstream of the outfall. The results of these assessments are presented in Figure 5, Figure 6 and Figure 7 respectively for depth average, top and bottom layer salinity levels. Box and whisker plots are shown, with the following characteristics:

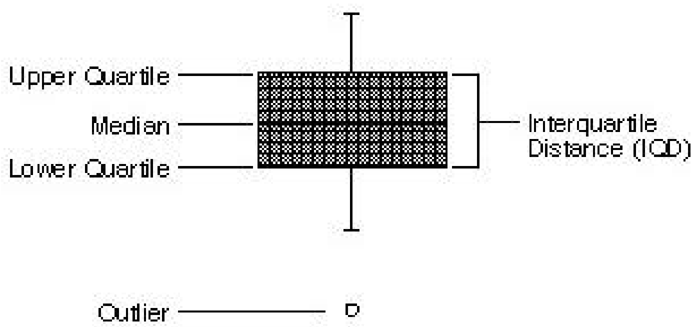
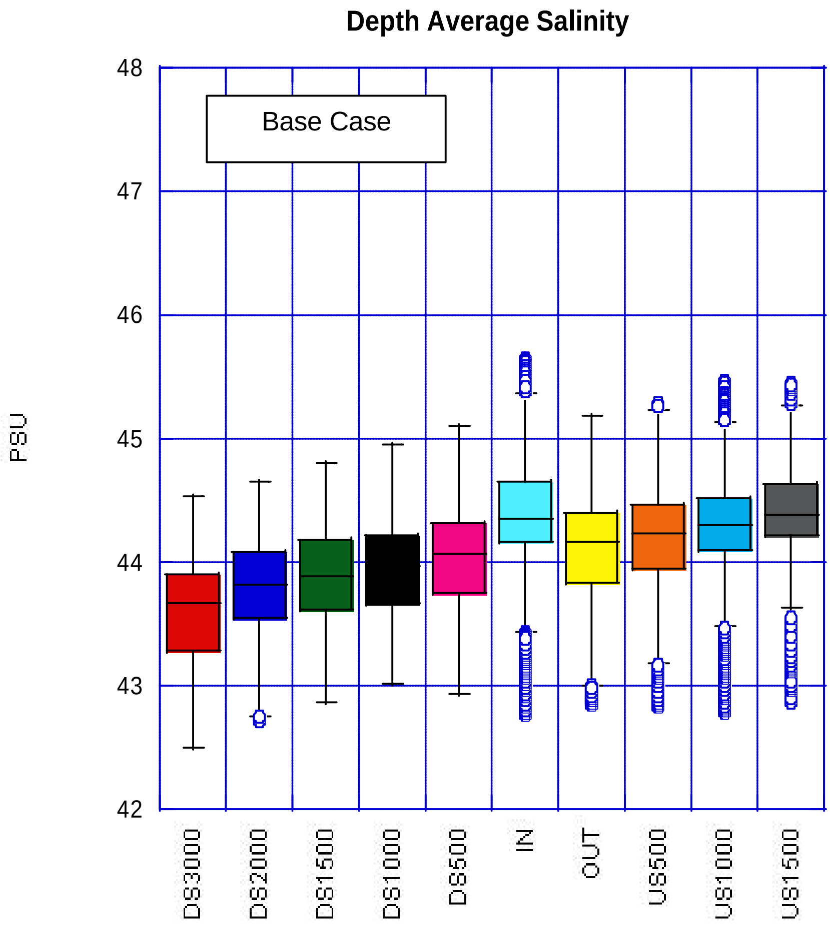


Figure 4 Box and Whisker Plot Characteristics

The horizontal axis of each box and whisker has a label corresponding to an interrogation point. These are labelled either US or DS for upstream and downstream of the outfall, respectively. The digits after US or DS refer to the distance in metres from the outfall. IN and OUT refer to the intake and outfall locations, respectively.



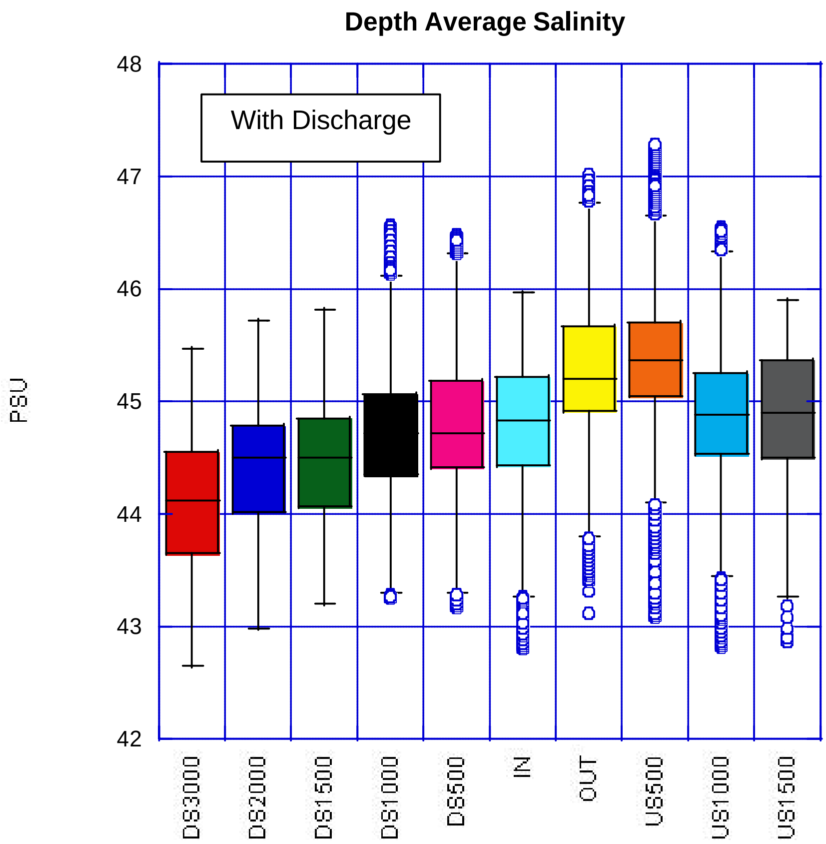
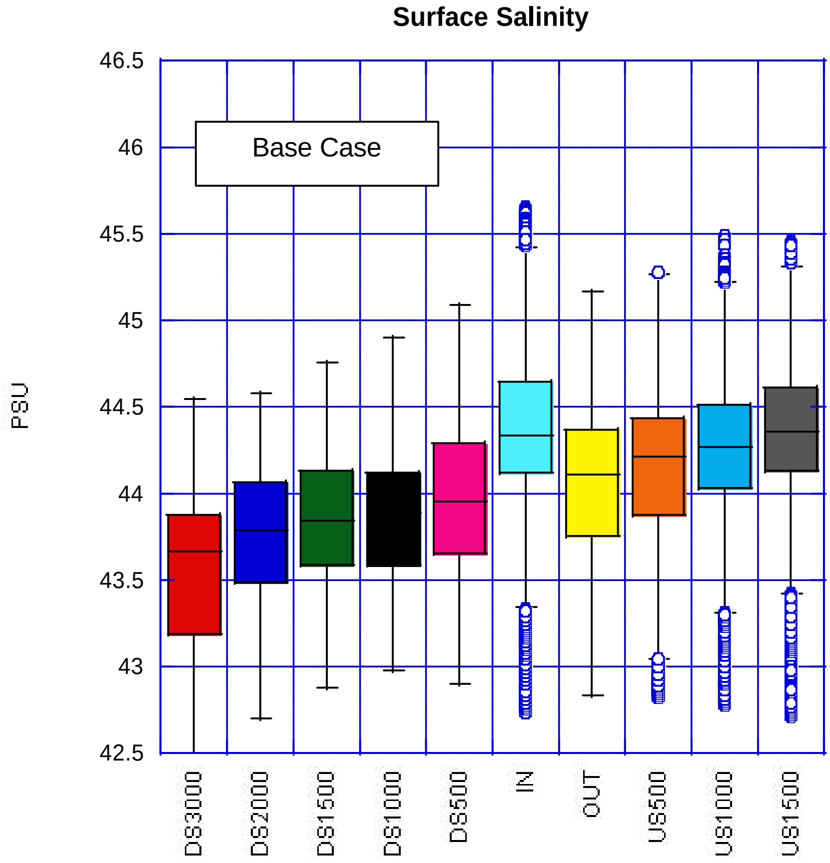


Figure 5 Port Augusta Outfall Mid Field Model Depth Average Salinity Results



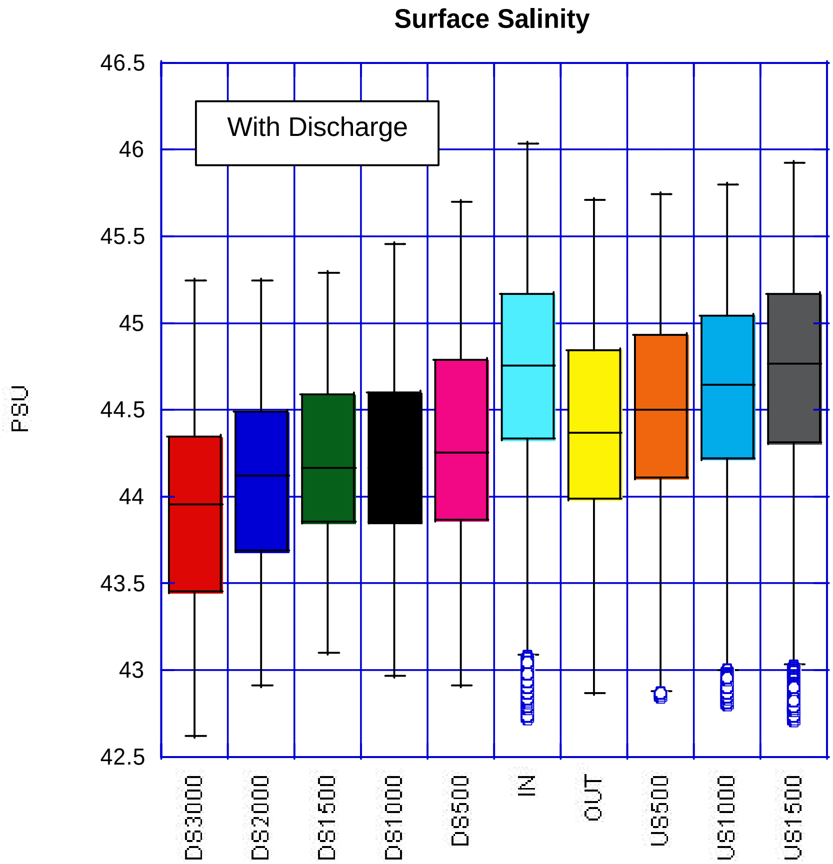
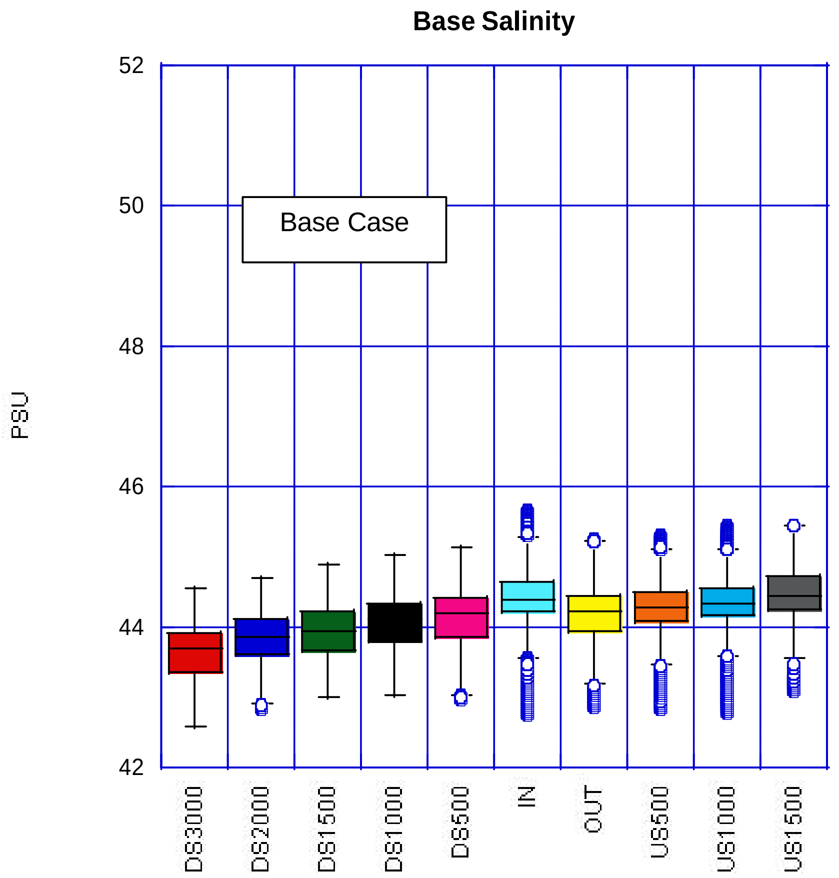


Figure 6 Port Augusta Outfall Mid Field Model Surface Salinity Results



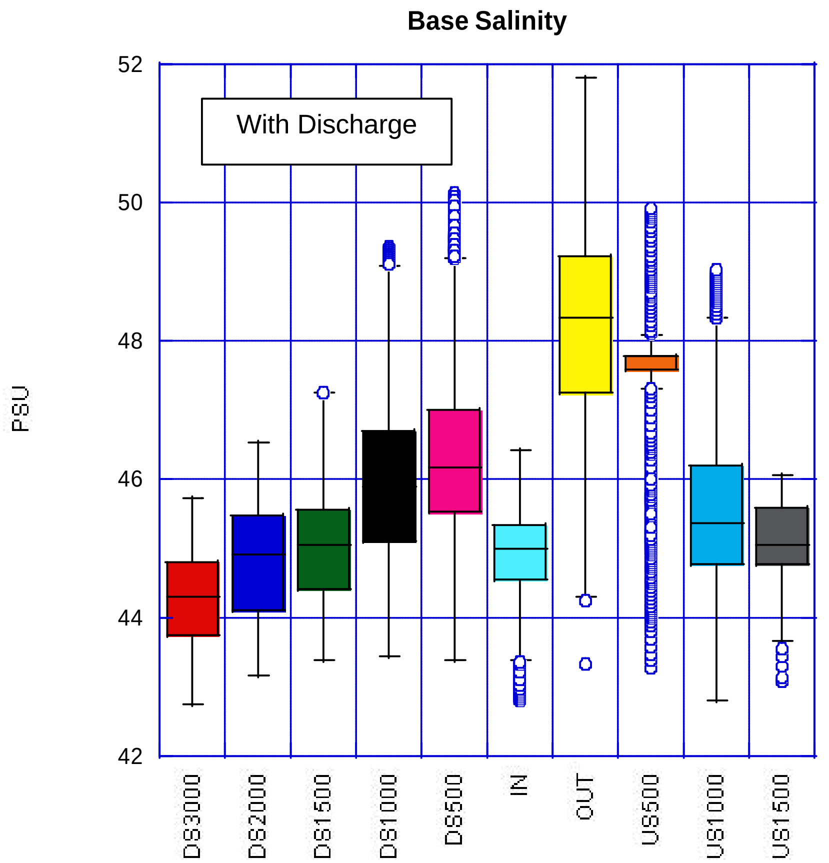


Figure 7 **Port Augusta Outfall Mid Field Model Bottom Salinity Results**

In regard to these assessments, we note as follows:

- Median depth averaged mid field salinity increases at the outfall site are of the order of 1 g/L;
- Maximum depth averaged mid field salinity increases at the outfall site are of the order of 2 g/L;
- Median surface mid field salinity increases at the outfall site are of the order of 0.2 g/L;
- Maximum surface mid field salinity increases at the outfall site are of the order of 0.5 g/L;
- Median bottom mid field salinity increases at the outfall site are of the order of 4 g/L;
- Maximum bottom mid field salinity increases at the outfall site are of the order of 7 g/L; and
- There are noticeable mid field impacts (bottom salinity increases of the order of 0.4-0.5 g/L) up to 3 km upstream and downstream of the outfall.

4.2 Port Bonython

The mid field model was run for the four (4) potential outfall locations and data extracted from the model at a site 500m from each outfall (just outside the near field mixing zone). These data were analysed and the following median and maximum depth averaged, surface and bottom salinity increases were obtained.

Table 2 Increase in Median Mid Field Salinity 500m from Outfall Sites

Outlet	Median Mid Field Salinity Increase (g/L)		
	Depth Averaged	Surface	Bottom
J1	0.01	0.01	0.02
J2	0.03	0.01	0.02
B2	0	0	0.1
B3	0	0.02	0.04

Table 3 Increase in Maximum Mid Field Salinity 500m from Outfall Sites

Outlet	Maximum Mid Field Salinity Increase (g/L)		
	Depth Averaged	Surface	Bottom
J1	0	0.01	0.02
J2	0.03	0.02	0.02
B2	0.02	0.06	0.16
B3	0.08	0.1	0.11

5.0 Near Field Modelling

The near field modelling conducted by this study assumed steady state conditions at the outfall. As such, the mid field model hydrodynamic results over a period encompassing spring and neap tides were interrogated for each possible outfall site to define a suite of such steady state conditions to model. The results of these assessments are presented in the first graph in Figure 9. This graph shows that:

- Of all sites, the Port Augusta outfall has the lowest incident (tidal) velocities:
- Of the Port Bonython outfall options, sites B2, J1 and J2 have comparable velocity patterns; and
- Outfall site B3 has greater incident velocities than all other sites.

We subsequently used these velocity data, and the depth data for each outfall site, to develop and run a series of near field model runs. For each of these runs, plume dilution results were extracted from the model at the time/location when the outfall plume impacted on/contacted with the seafloor, as illustrated in Figure 8. The results of these model runs are presented in the second graph in Figure 9.

Having defined plume dilutions, we could now define commensurate brine/salinity concentrations associated with these scenarios. In this case, we adopted the following upper limit salinities in ambient water at the intake/outfall sites, and assumed that the SWRO process would increase salinities between the intake and outfall by a factor of 1.8 (we assumed this to be slightly higher than the factor of 1.7 we were advised by Arup in order to allow for some local recirculation and accumulation of brine).

- Bonython 42 g/L
- Port Augusta 47 g/L

The results of these assessments are presented in the third graph in Figure 9.

In regard to the second and third graph in Figure 9, we note that for the scenarios where data are 'missing' (*e.g. B2 and Port Augusta 1% velocity cases and B3 99th percentile velocity case*), scenario parameters were either outside acceptable model domain limits and the model could not be run, or there was massive mixing. This indicates either extremely low rates of potential mixing (*for the B2 and Port Augusta 1% velocity cases*) or extremely high rates of mixing that results in no detectable bottom contact of the plume within the model domain (*in the case of B3 for the 99th percentile velocity*).

From these data, we conclude as follows:

- The Port Augusta outfall is by far the worst performing of all options. Even at the 95th percentile velocity case (*i.e. velocities are greater than this level only 5 % of the time*), bottom concentrations in the near field domain would increase by more than 1 g/L (*in addition to mid and far field effects*);
- The B2 outfall is better than the Port Augusta case, though bottom concentrations in the near field would still increase by more than 1 g/L (*in addition to mid and far field effects*) at the 50th percentile level (*i.e. half of the time*);
- The J1 outfall is the next best performing option, with bottom salinity impacts of the order of 1 g/L occurring at the 25th percentile level (*i.e. a quarter of the time*); and
- The J2 and B3 outfalls are by far the best of all options in the near field domain. For B3, bottom salinity impacts never exceed 1 g/L and for most cases are less than 0.5 g/L, while for J2 some impacts of the order of 1 g/L are evident for the 1st and 5th percentile cases.

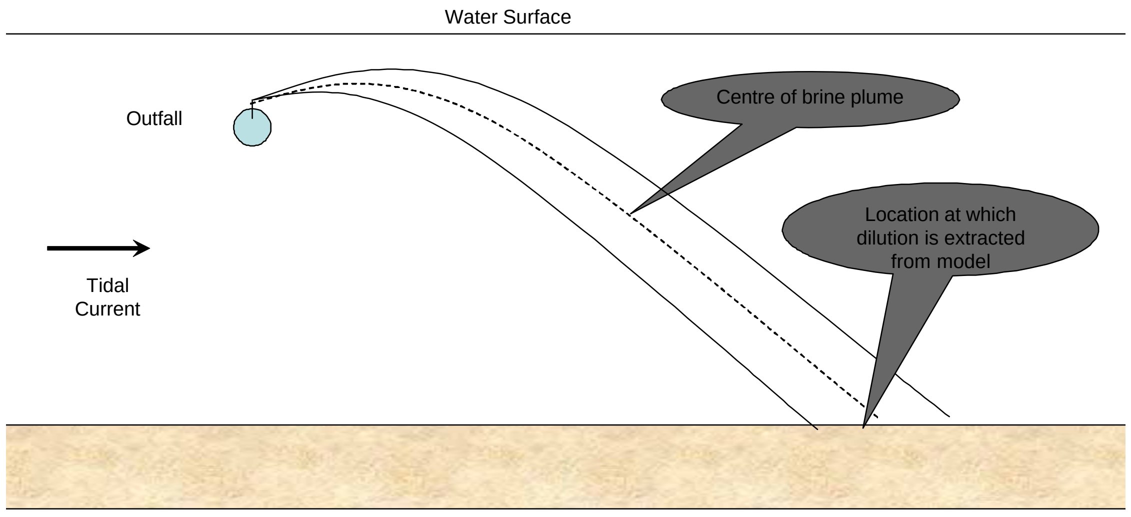


Figure 8 Illustration of Near Field Model Interrogation Location

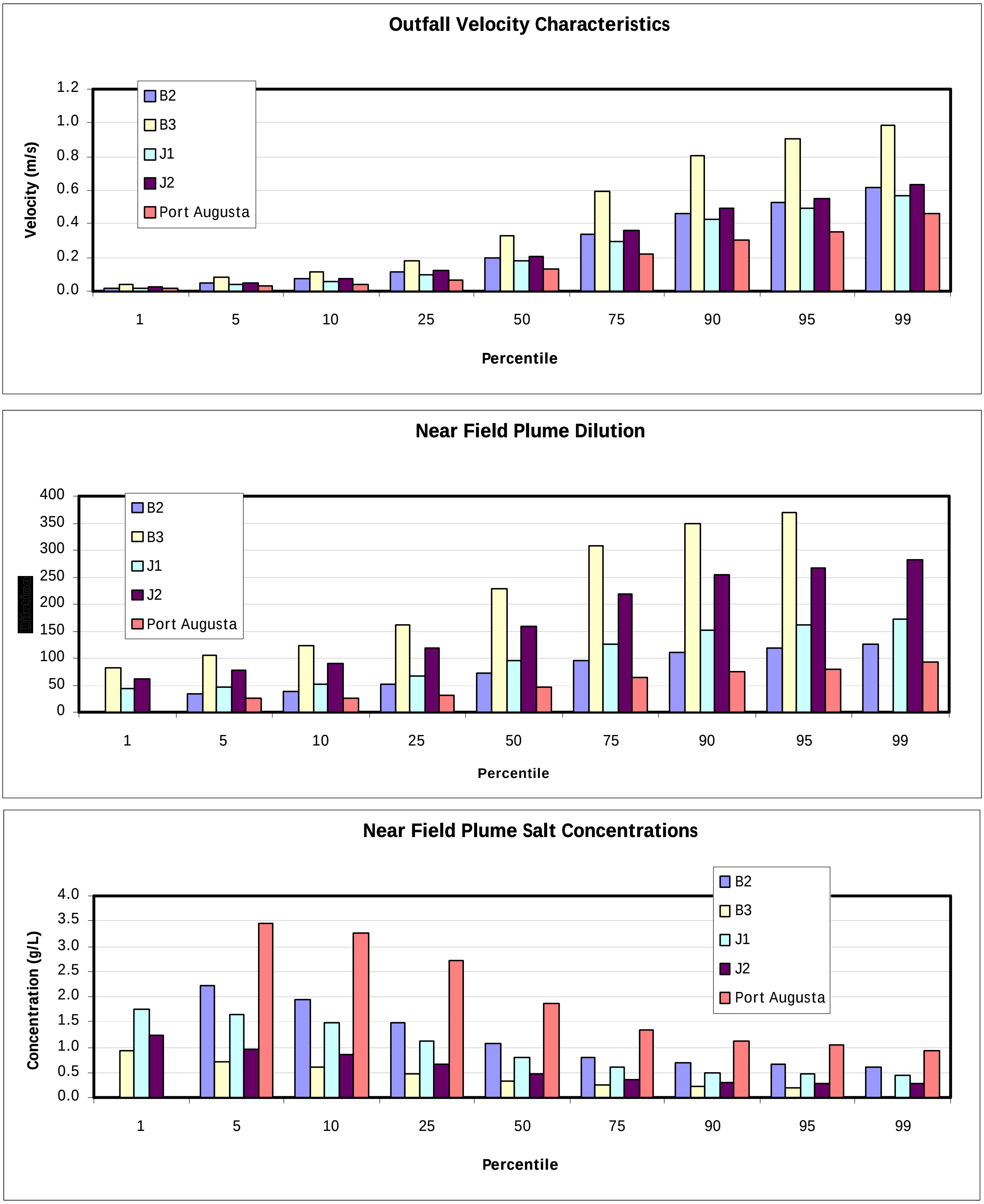


Figure 9 Near Field Modelling Results

6.0 Combined Assessments

In combining the results of the above assessments, we reiterate at this point the spatial and temporal scales at which the various near, mid and far field model outputs will apply, as follows.

- In the zone immediately proximate to the outfall, within 1-200m either side of the outfall, far, mid and near field results will have a combined impact over temporal scales of the order of sub-hourly;
- For the zone more distant from the outfall, within 1-2 km either side of the outfall, mid and far field results will have a combined effect over temporal scales of the order of several hours-daily; and
- For sites which are distant from the outfall, greater than 1-2km either side of the outfalls, far field effects will apply in isolation, at a temporal scale of days to weeks.

Given the above, we have appropriately combined model results for each outfall site. In this regard, we note that we have adopted the 10th percentile **near field** results for interrogation as we feel that using the 1st percentile to be overly conservative. For the mid and near field cases however, we have adopted the analysed **maximum bottom** salinity levels for reporting as the time frame of such occurrences will be of the order of days to weeks rather than sub-hourly as will be the near field case. For the Port Bonython options, we have selected an extraction point from the model within 500m to 1km of the discharge location scenarios at the edge of the near field zone of influence.

Table 4 Cumulative Salinity Impacts

Outfall	Individual Model Salinity Increase (g/L)			Combined Model Salinity Increase (g/L)		
	Far Field (maximum)	Mid Field (maximum)	Near Field (10th %ile dilution or 90th %ile concentration)	Far Field (>1-2km from outfall)	Mid Field (within 1-2km of outfall)	Near Field (within 1-200m of outfall)
Port Augusta	0.27	5	3.3	0.35	5.27	8.57
Port Bonython J1	0.04	0.02	1.49	0.05	0.06	1.55
Port Bonython J2	0.04	0.02	0.85	0.05	0.06	0.91
Port Bonython B2	0.04	0.16	1.95	0.05	0.2	2.15
Port Bonython B3	0.04	0.11	0.61	0.05	0.15	0.76

7.0 Discussion and Recommendations

From the results in the above table, it is apparent that an outfall at Port Augusta would have major impacts on the salinity regime and associated ecological values of the upper reaches of Spencer Gulf. Worst case combined near field salinity increases are expected to regularly be of the order of 18% of background values and worst case combined mid field salinity increases are also expected to be of the order of 11% of background values.

For the Port Bonython outfall options, far smaller impacts are predicted. Combined near field salinities are expected to exceed background levels by between 1.8% (B3, best case) and 5% (B2, worst case), with this later value being of potential concern as it is approaching the EPA guideline initial mixing zone value of 10% of background. Combined mid field salinities are predicted to change by between 0.15% (J1, J2) and 0.5% (B2). It is noted that these estimates are based on closest site analysis and that this introduces some variability to the statistics.

Given the above, we recommend that no further consideration be given to Port Augusta as a potential outfall site. Of the Port Bonython outfall options, B3 performs best of those tested in terms of its dispersion characteristics. If an opportunity exists for this site (B3) to be extended out from Point Lowly into deeper water, then the associated salinity increases presented above are likely to reduce even further.

MEMORANDUM

TO: Arup - Attention Iain Gunn

FROM: Tony McAlister

DATE: 18 October, 2006

SUBJECT: **Worst Case Modelling - Spencer Gulf J2 and B3 Outfalls**

This memo reports on the investigation of 'worst case' impacts resulting from two of the four previously determined discharge scenarios. Based on the modelling undertaken previously, these outfalls were selected to be Scenarios 2 and 4 (outfall from site J2 and B3 respectively).

Methodology

The key investigation tool for this worst case modelling was the calibrated mid field ELCOM model. In order to support this phase of work, the number of model interrogation points was increased beyond that previously adopted. Specifically, the following points were added:

- 4 points approximately 500m from each outfall;
- 1 point in Fitzgerald Bay; and
- 2 points in commercial prawning grounds to the south of Port Bonython.

These locations, together with those previously adopted, are shown in Figure 1 below. Point labels shown are used to refer to locations in subsequent tables.

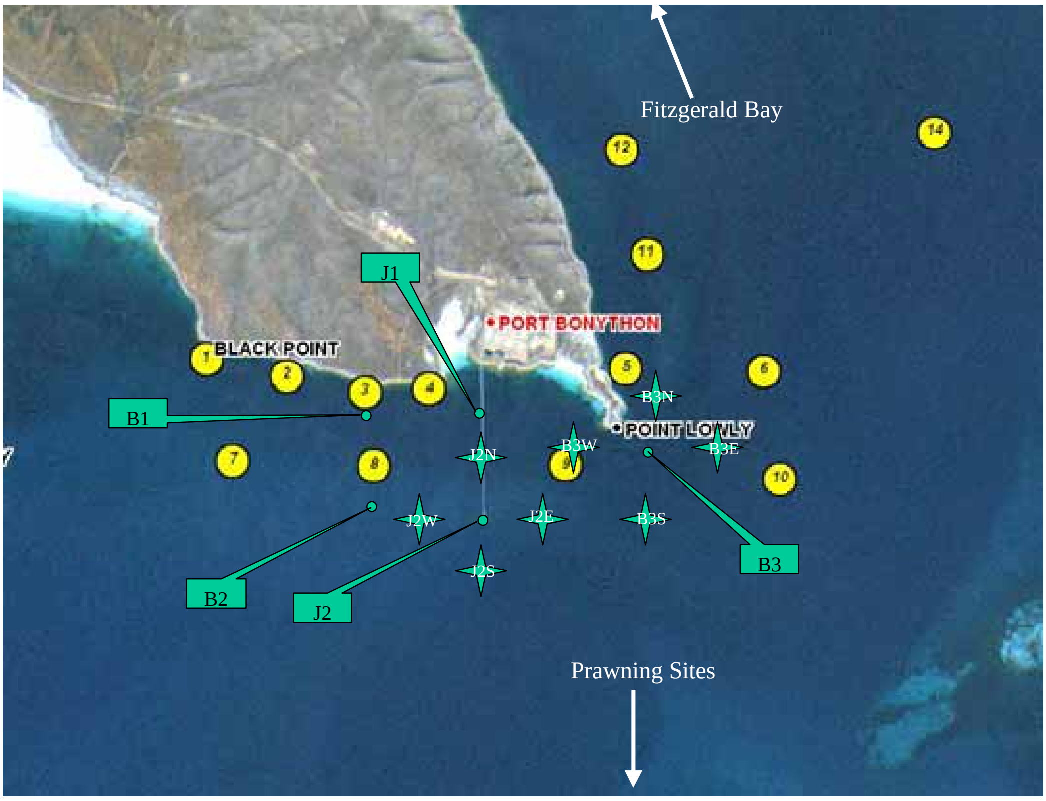


Figure 1 Model Output Extraction Locations

Data at all surface and bed cells across the entire model domain was also retained during simulations.

A dodge tide period in mid to late summer was selected for this detailed modelling. Such a period was chosen to facilitate a 'worst case' analysis, as dodge tides are known to be characterised by small tidal ranges and generally slow flowing currents. In addition, late summer periods are characterised by high surface temperatures and the potential for additional thermally induced stratification. It is under these conditions that the greatest impacts of the discharge will occur.

Investigation of tidal records for the area revealed an appropriate dodge tide period immediately following the period chosen for the mid field simulations described above. The detailed simulations were 'hot started' using initial conditions from the termination of the previous mid field simulations. This provided the additional benefit that the mid field initial conditions in the dodge tide simulations reflected the signature of a previously operational saline discharge, rather than starting from an unimpacted state. In total, these and previous mid field simulations continually spanned approximately 40 days, with the dodge tides occurring approximately three quarters of the way through that period. To ensure that true worst case conditions were simulated over this period, wind forcing was set to zero during the dodge tide. The dodge and preceding spring tide water levels at Port Bonython are shown in Figure 2 below.

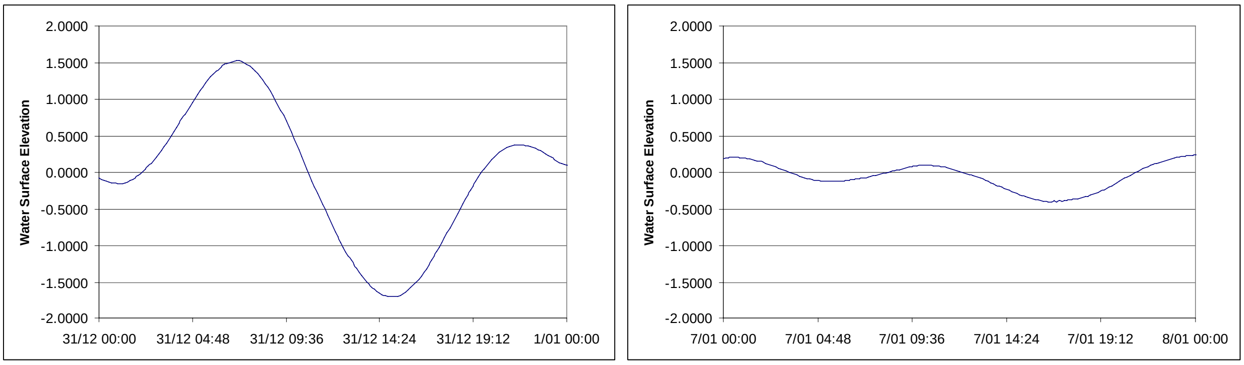


Figure 2 Modelled Tides

Results

1 Temperature Stratification

Anecdotal evidence is that thermal stratification develops during low wind and dodge tide periods. The model was interrogated to assess its ability to reproduce this effect. Figure 3 below shows simulated temperature contours with depth and time at location J2 (note that this simulation has no outfall and represents 'base' conditions). Clear and strong temperature stratification by up to 3-4 deg C is evident during the dodge tide period, consistent with anecdotal evidence.

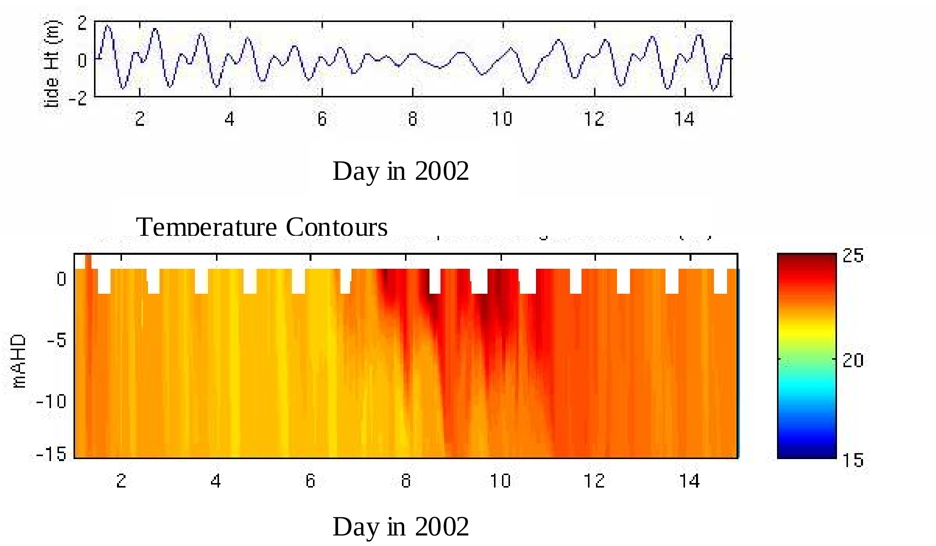


Figure 3 Worst Case Temperature Results (no discharge)

2 Dilution: Statistical Analysis

Having examined temperature stratification in the model, attention was turned to investigation of dilution coefficients (in a mid field model sense) associated with the outfall of each scenario. To do so, a dynamically passive tracer was introduced into the saline outfall waste stream in each simulation to act as a tracker of salinity. The tracer was introduced at a concentration of 1 arbitrary unit at the same volumetric flow rate as the saline discharge. Timeseries data were extracted from the bottom cell of the model at each of the interrogation points shown in Figure 1. Statistical analysis was then performed on these timeseries.

The EIS team had previously advised WBM that the limiting (i.e. minimum) brine dilution factor to ensure no adverse impacts on local flora and fauna should be of the order of 160:1. Analyses focused on this critical dilution rate, and the results of these analyses are presented in the following tables. Table 1 is for a discharge at site J2 (scenario 2) while Table 2 is for a discharge at site B3 (scenario 4). Bolded numbers are dilutions less than 160, and statistics are for the entire simulation period.

The tables show that the outfall at J2 results in lower than acceptable minimum dilutions over the course of the entire simulation at some 13 sites. The average percentage of time within the 2-day extreme case summer dodge tide and no wind period across these sites where this condition holds is 17%, with a maximum of 32% at site J2W (excluding the outfall location J2).

Conversely, the discharge at B3 results in lower than acceptable minimum dilutions over the course of the entire simulation at only 9 sites. The average percentage of time within the 2-day extreme case summer dodge tide and no wind period across these sites where this condition holds is 5%, with a maximum of 13% at site B3W (excluding the outfall location B3). This favourable comparison with discharge from J2 is consistent with B3 being at a deeper location affected by stronger and more prevalent tidal currents.

It is noted that the analysis shows both prawn harvesting areas and Fitzgerald Bay to be unaffected by the discharge to any detectable degree over the simulated period.

3 Dilution: Contour Analysis

In order to provide a more complete spatial analysis of the dilution factors associated with each scenario, the data retained from the bed cells in each simulation were analysed. In particular, average and minimum dilution factors for every bed cell in the model were computed for three separate 2 day periods: spring tides, the dodge tide and tidal recovery following the dodge tides. These are presented in Figure 4 and Figure 5 below. Colour contours are from dilutions of zero (blue) to 160 (red).

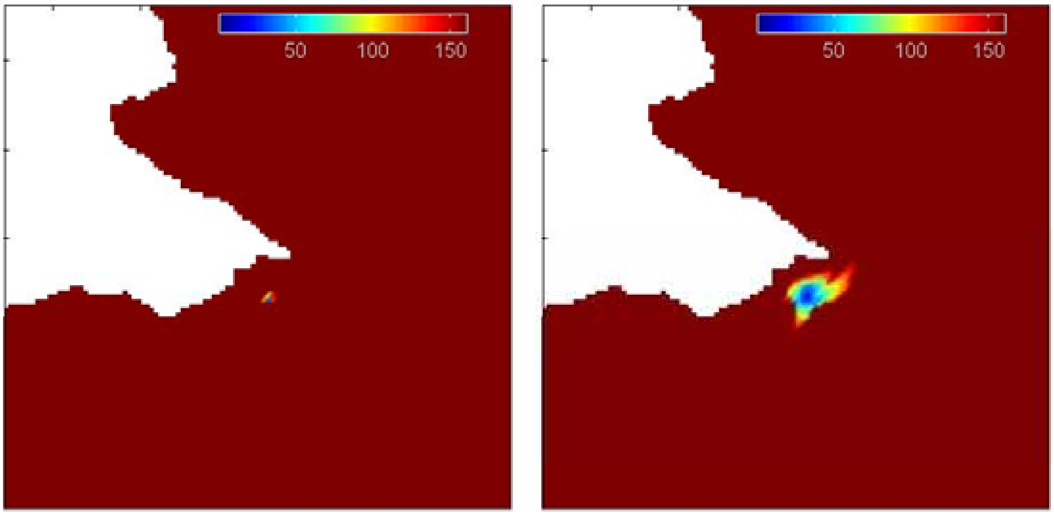
The figures show that in all cases and tidal regimes, there are at least some locations that have minimum dilutions less than 160. The areal extent of these locations is most extensive in the case of the J2 discharge for the dodge tides. Conversely, the highest dilutions and smallest areas of impact occur during the spring tide and post-dodge tide periods for scenario 4 (B3 discharge).

Table 1 Statistical Analysis of Dilutions for Scenario 2 (J2 discharge), Entire Period

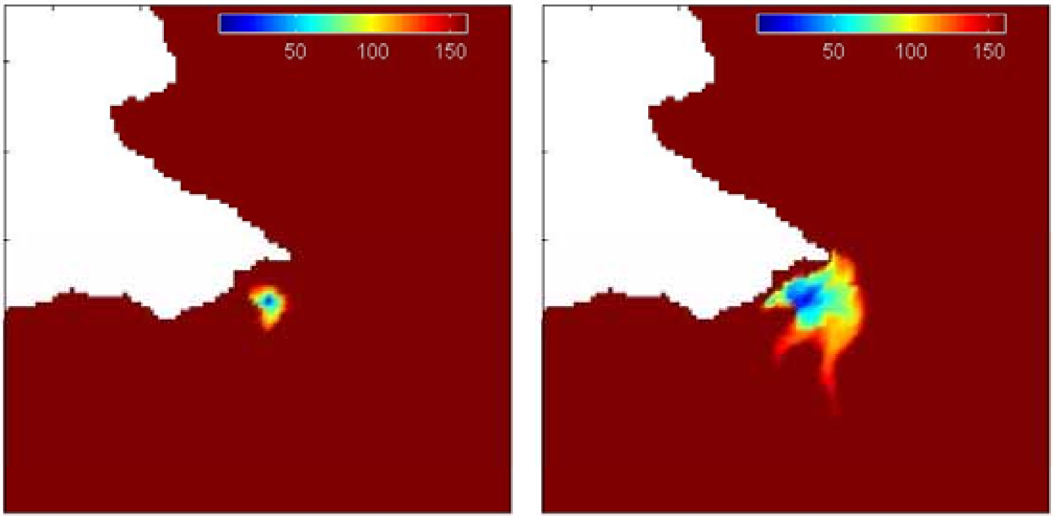
Site	Percentile							Min	Count <160	Percent < 160
	5	10	25	50	75	90	95			
1	1892	2761	3878	6708	18809	33434	43650	210	0	0
2	501	846	2100	3259	6026	20661	27252	167	0	0
3	294	639	1178	2444	3580	8529	18816	**110**	77	2
4	359	641	1216	2268	3155	5435	10776	168	0	0
5	621	913	1216	1444	1622	1783	1857	216	0	0
6	590	763	966	1239	1852	2351	2831	213	0	0
7	543	848	1518	2770	5304	11675	20310	196	0	0
8	402	576	956	1418	2306	4056	6045	167	0	0
9	**89**	**113**	213	596	1160	1487	1722	**56**	750	18
10	715	857	1059	1364	1955	2570	3030	206	0	0
11	1057	1136	1261	1479	1638	1869	1966	437	0	0
12	1252	1295	1426	1592	1798	1975	2141	930	0	0
13	1008	1156	1697	2849	4467	6394	7739	579	0	0
14	1338	1491	1794	2086	2827	3809	3966	1088	0	0
J1 (intake)	102	155	401	1080	1715	2435	3438	**46**	431	10
J2 (outfall)	**17**	**18**	**20**	**25**	**37**	**53**	**61**	**14**	4188	100
B1	262	389	976	1885	2733	4387	9569	**85**	74	2
B2	264	348	776	1226	1852	2971	4331	**92**	62	1
B3	222	385	898	1254	1514	1731	1852	**99**	74	2
B3E	519	691	960	1241	1701	2102	2492	203	0	0
B3N	275	403	745	1084	1410	1722	1961	**140**	30	1
B3S	162	276	749	1118	1419	1749	1957	**86**	201	5
B3W	**149**	198	574	1052	1382	1708	2057	**72**	247	6
J2E	**95**	**117**	184	345	970	1398	1526	**53**	828	20
J2N	**68**	**88**	209	1001	1444	2096	2986	**40**	828	20
J2S	**103**	**131**	252	956	1331	1591	1806	**61**	609	15
J2W	**40**	**48**	**86**	642	1193	1552	1940	**25**	1341	32
Fitz	1343	1368	1473	1737	1955	2246	2373	1254	0	0
Pr1	2671	3332	4676	7247	11427	19749	28994	1380	0	0
Pr2	734	852	1010	1249	1584	3057	7431	250	0	0

Table 2 Statistical Analysis of Dilutions for Scenario 4 (B3 discharge), Entire Period

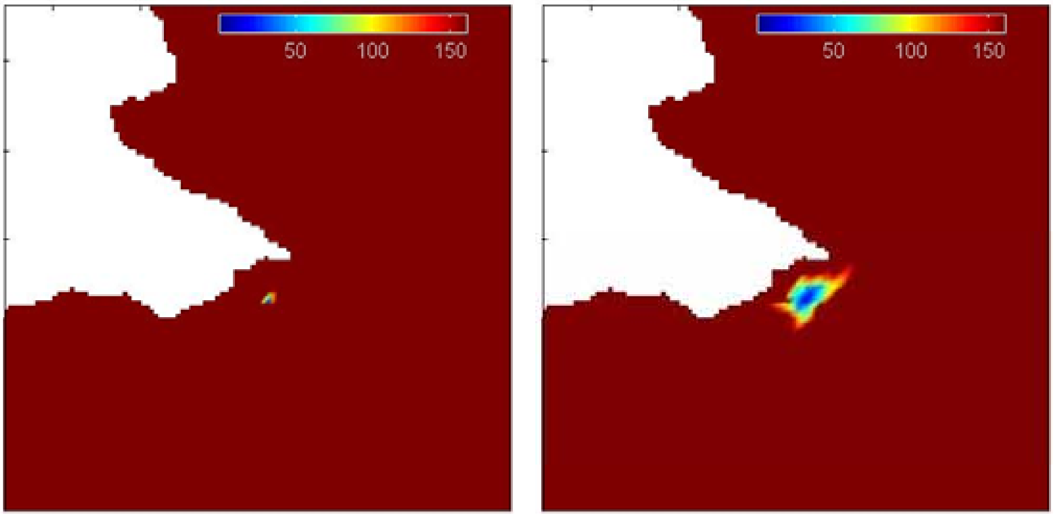
Site	Percentile							Min	Count <160	Percent < 160
	5	**10**	**25**	**50**	**75**	**90**	**95**			
1	3099	3503	4515	7432	23683	37161	46531	2440	0	0
2	1308	1902	2798	3819	7581	24935	30912	837	0	0
3	1004	1176	2135	3128	4445	11143	21570	256	0	0
4	1031	1210	2014	2997	4216	7377	12447	258	0	0
5	**138**	193	561	1234	1500	1721	1925	**77**	300	7
6	696	814	1076	1373	1769	2303	2772	297	0	0
7	1075	1240	1987	3133	5567	14592	24116	740	0	0
8	826	990	1282	1953	3182	5714	9939	154	8	0
9	270	323	496	943	1371	1979	2590	140	17	0
10	595	753	1074	1372	1877	2596	2980	267	0	0
11	661	951	1196	1427	1652	1882	2015	262	0	0
12	1202	1243	1392	1570	1792	2069	2185	987	0	0
13	1303	1444	2358	3805	5789	8108	10226	979	0	0
14	1147	1320	1595	2006	3028	3423	3748	768	0	0
J1 (intake)	560	748	1058	1738	2518	3602	6967	**127**	21	1
J2	340	525	822	1203	1520	2485	3717	**130**	45	1
B1	880	1026	1624	2724	3577	6785	12666	223	0	0
B2	738	916	1229	1740	2952	4860	8139	180	0	0
B3 (outfall)	**11**	**13**	**21**	**37**	**66**	**102**	**129**	**7**	4146	99
B3E	432	638	1007	1306	1609	2128	2584	**88**	41	1
B3N	**92**	199	654	1113	1396	1636	1807	**22**	338	8
B3S	193	291	722	1191	1437	1688	1965	**48**	171	4
B3W	**114**	**141**	249	688	1354	1977	2587	**70**	535	13
J2E	235	339	513	875	1344	1760	2380	**128**	55	1
J2N	439	561	870	1402	1937	2945	4014	166	0	0
J2S	**147**	228	771	1132	1397	1675	2128	**61**	250	6
J2W	385	629	940	1252	1584	2670	3837	**125**	52	1
Fitz	1308	1331	1516	1765	2024	2188	2359	1235	0	0
Pr1	3826	4474	6396	10361	20543	102614	987485	3361	0	0
Pr2	901	984	1130	1401	1874	3694	7934	568	0	0



Spring Tides, average and minimum dilution factors

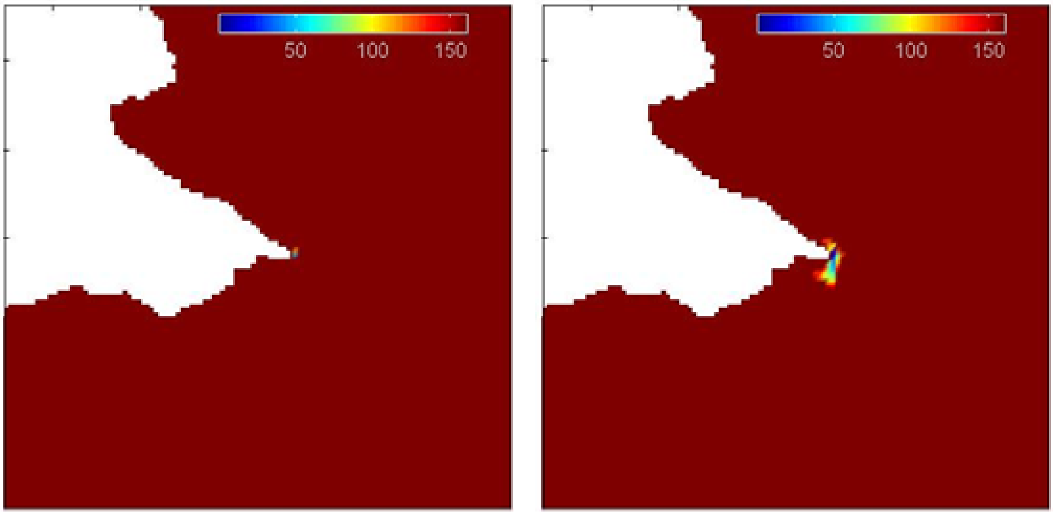


Dodge Tides, average and minimum dilution factors

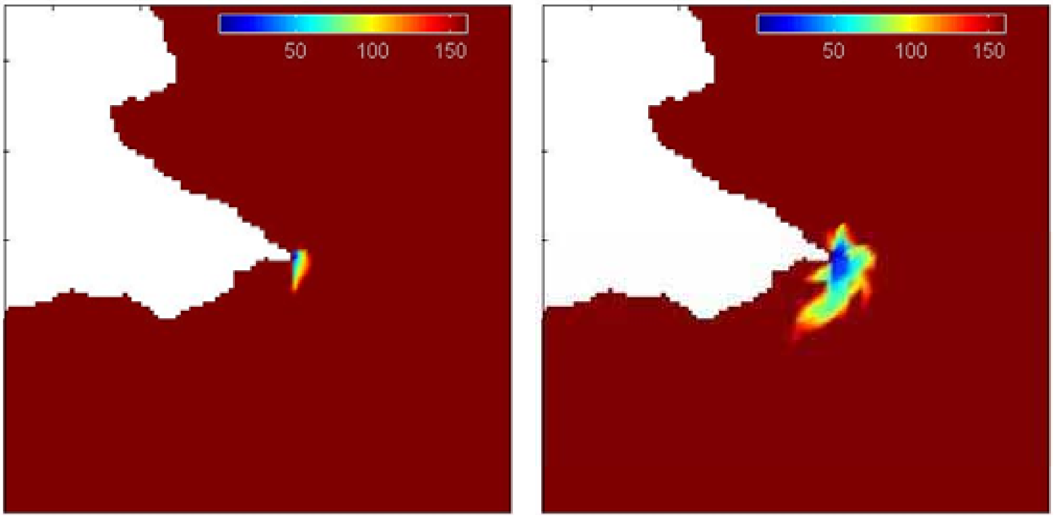


Post Dodge Tides, average and minimum dilution factors

Figure 4 Scenario 2 (J2 outfall) – Average and Minimum Dilution Factors



Spring Tides, average and minimum dilution factors



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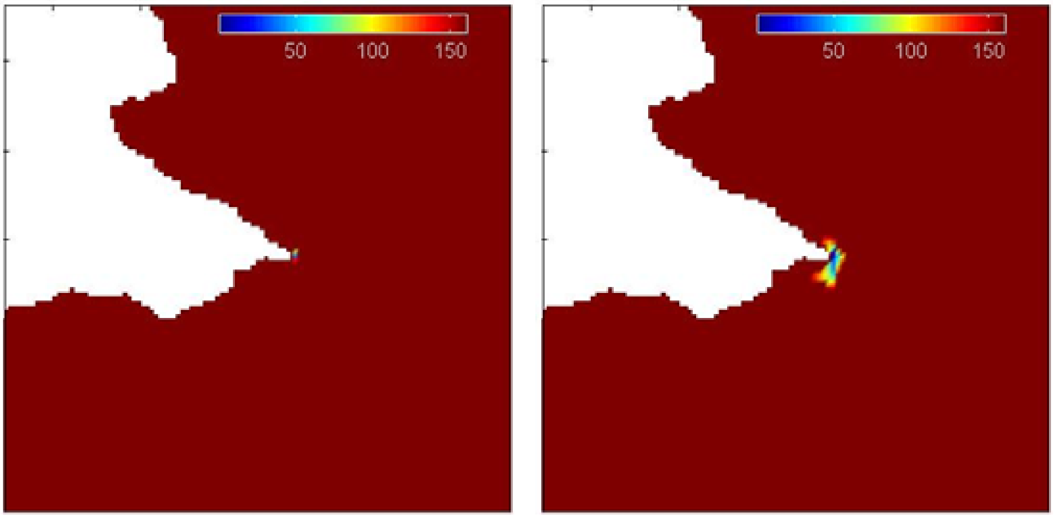


Post Dodge Tides, average and minimum dilution factors

Figure 5 **Scenario 4 (B3 outfall) – Average and Minimum Dilution Factors**

WBM

MEMORANDUM

BMT

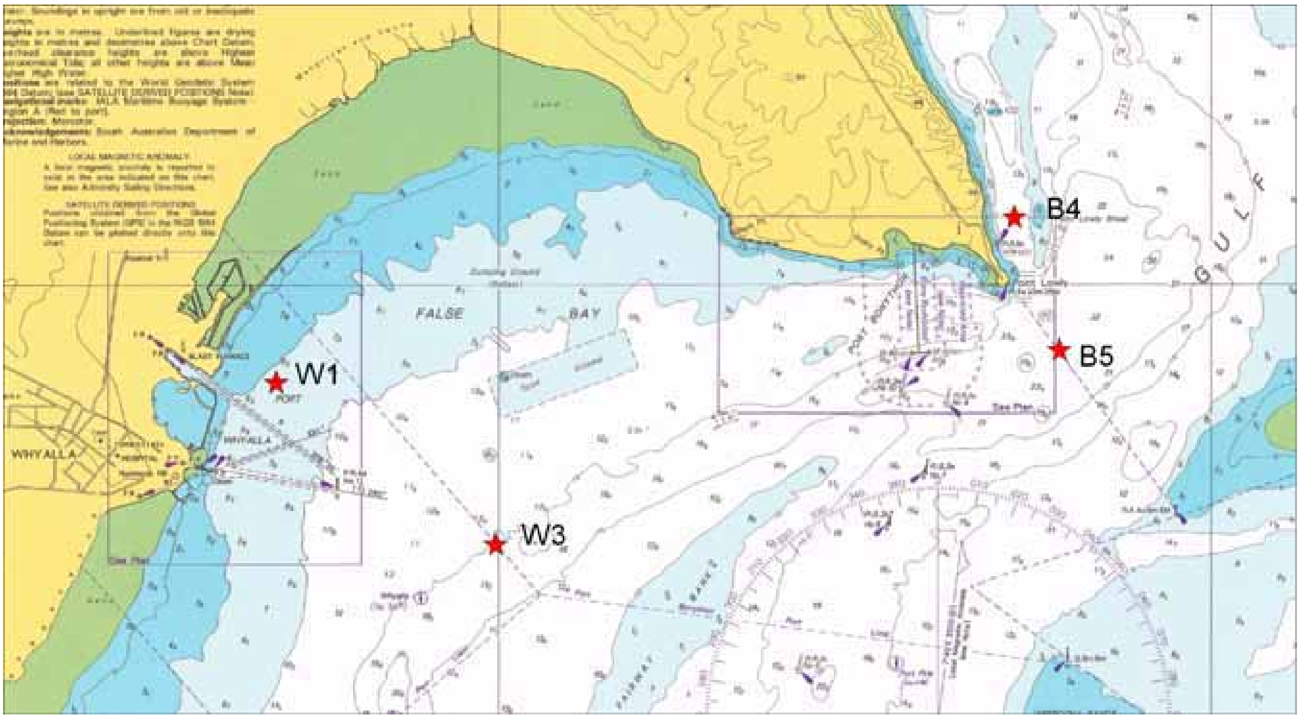
TO: Arup

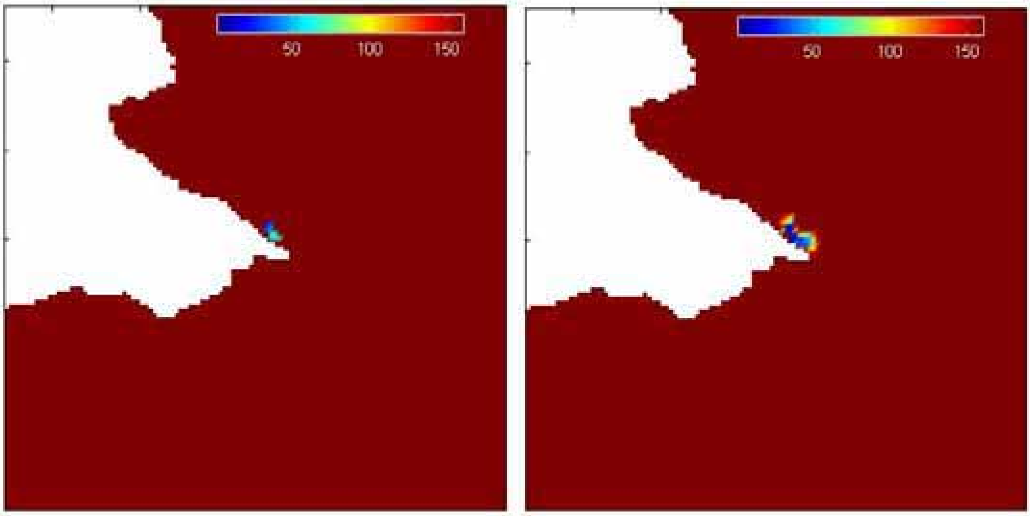
FROM: Michael Barry

DATE: 30 November, 2006

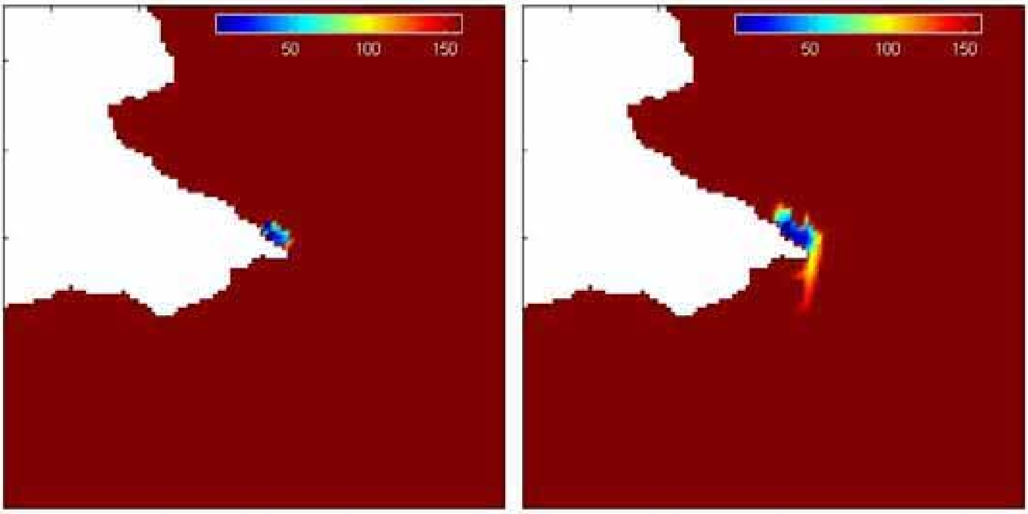
SUBJECT: **Additional Worst Case Modelling - Spencer Gulf B5 and W3 Outfalls**

This memo reports data already presented to Arup and BHP regarding further analysis of four potential discharge locations for the proposal desalination plant outfall, and their behaviour during 'dodge tides'. All methodologies were the same as described in M.B15583.006.doc, and as such only contour plots of results are presented here. The approximate locations of the sites are shown below, with referencing labels.

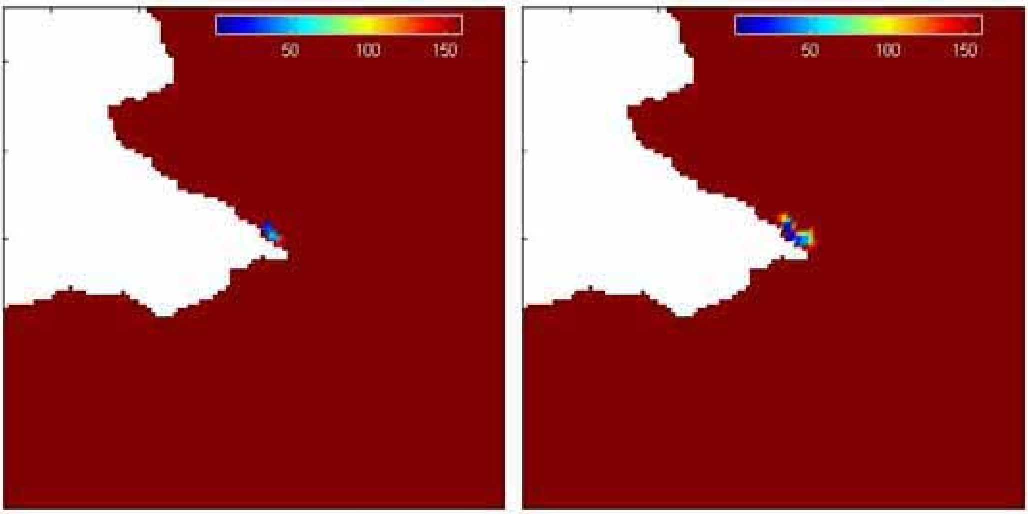




Spring Tides, average and minimum dilution factors

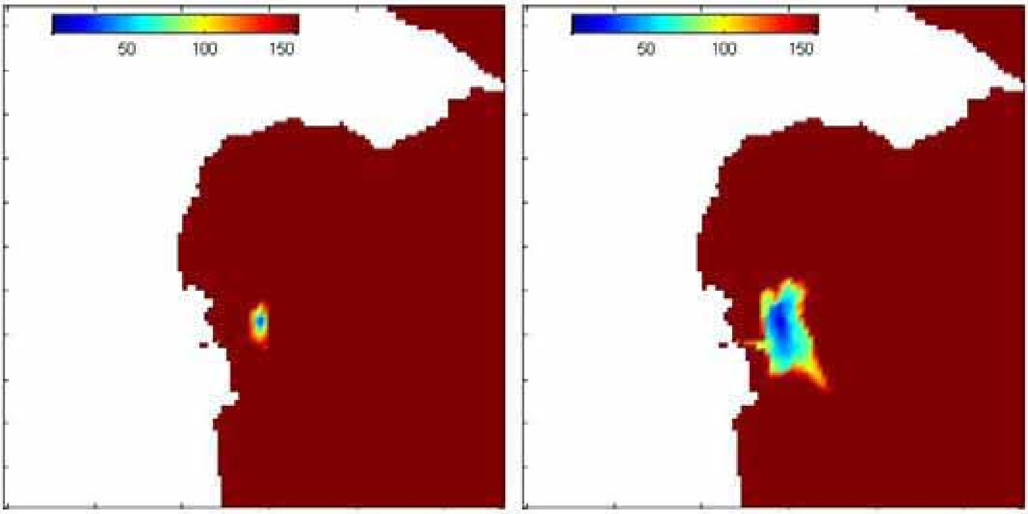


Dodge Tides, average and minimum dilution factors

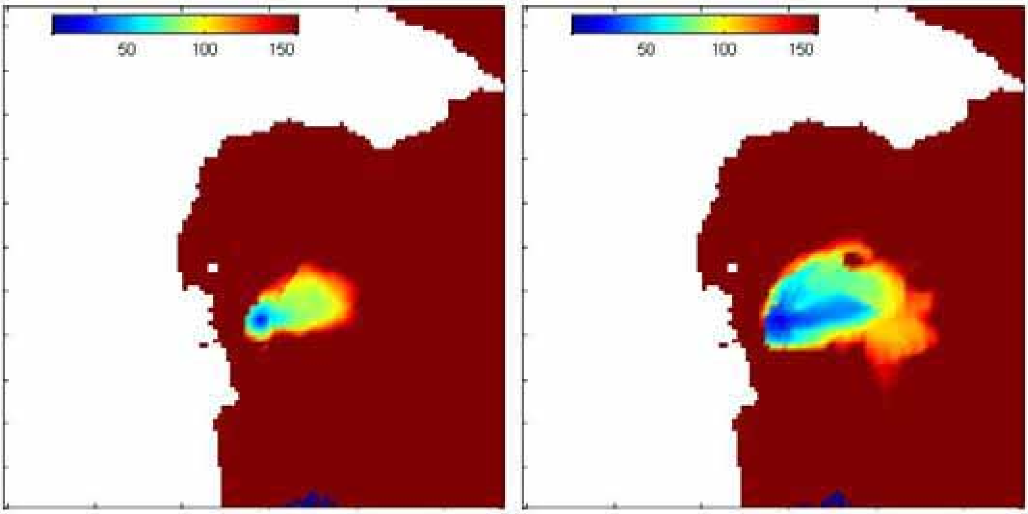


Post Dodge Tides, average and minimum dilution factors

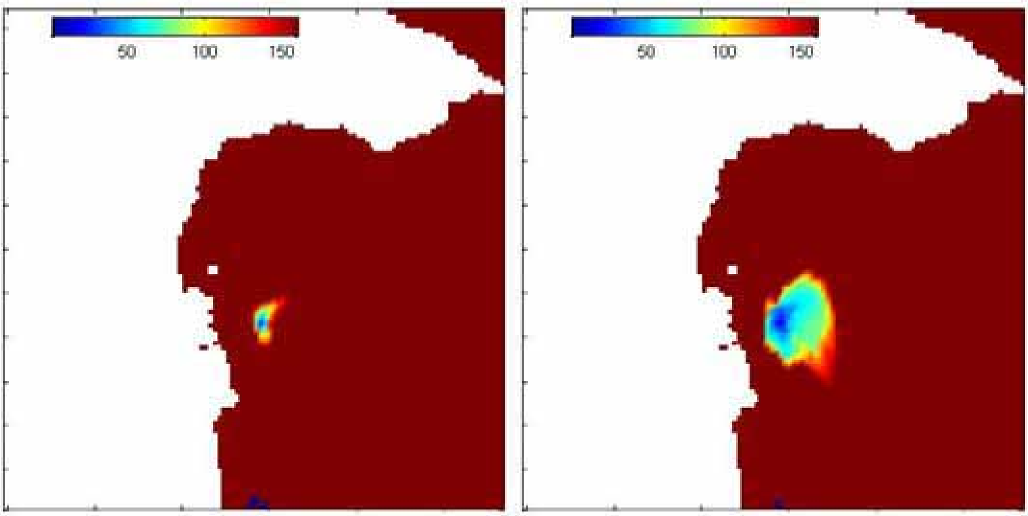
Figure 1 B4 outfall – Average and Minimum Dilution Factors



Spring Tides, average and minimum dilution factors

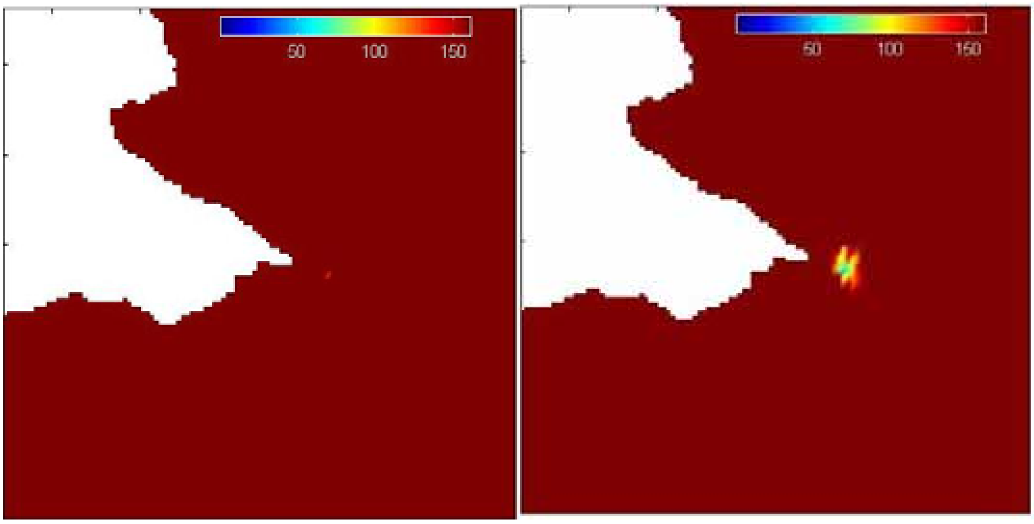


Dodge Tides, average and minimum dilution factors

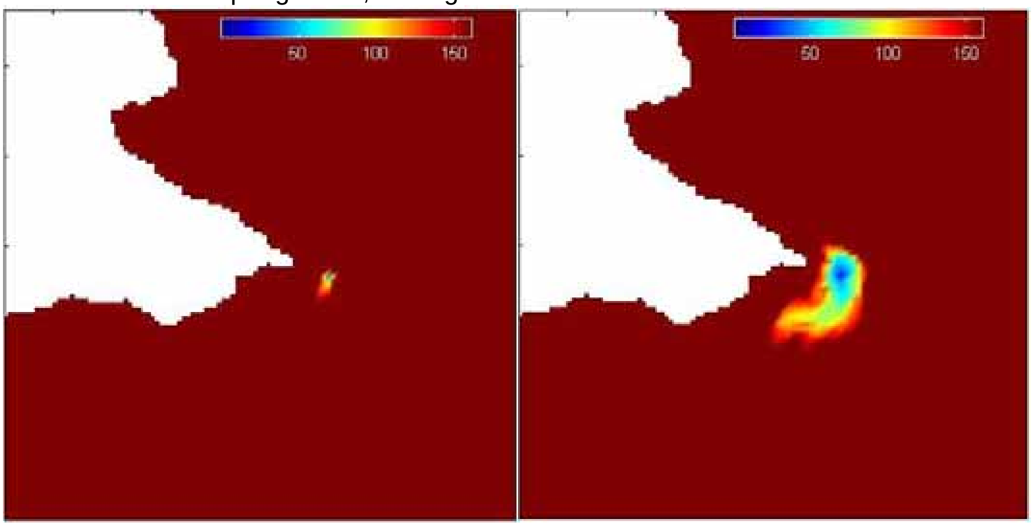


Post Dodge Tides, average and minimum dilution factors

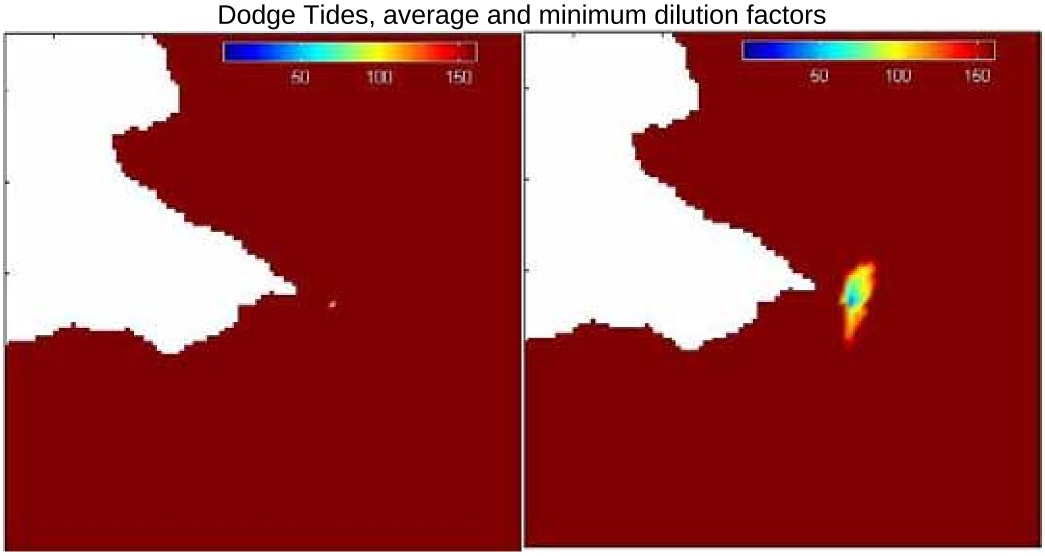
Figure 2 W1 outfall – Average and Minimum Dilution Factors



Spring Tides, average and minimum dilution factors

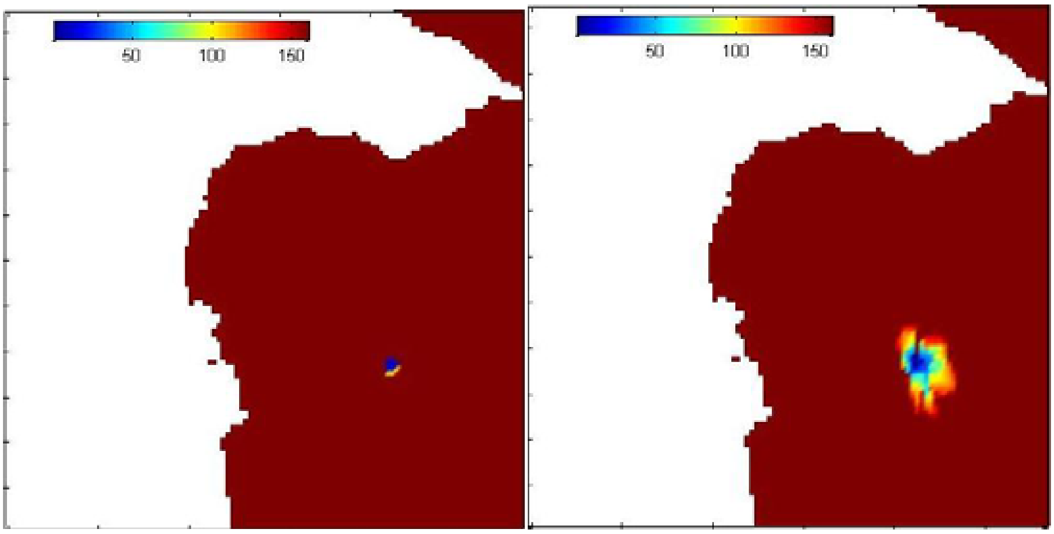


Dodge Tides, average and minimum dilution factors

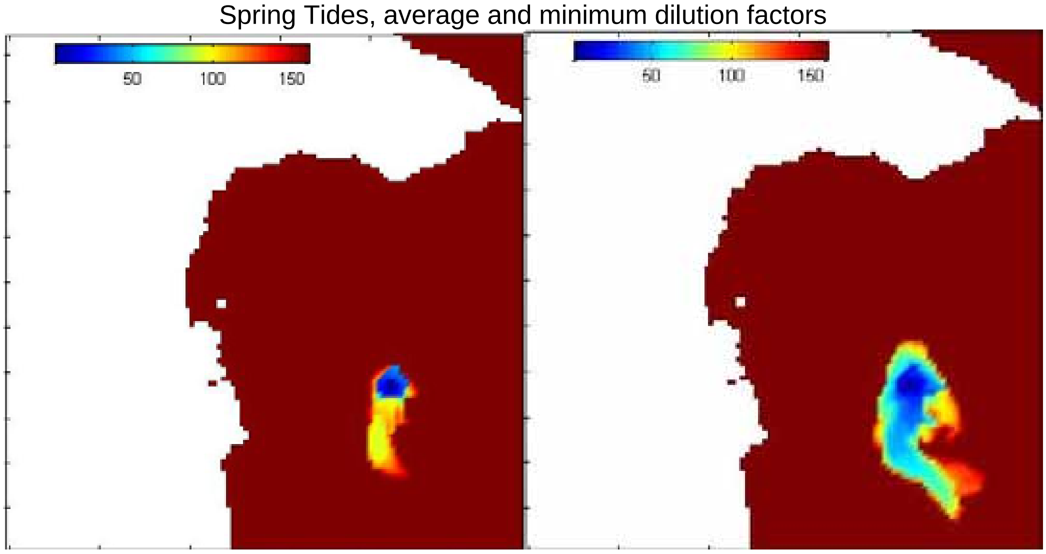


Post Dodge Tides, average and minimum dilution factors

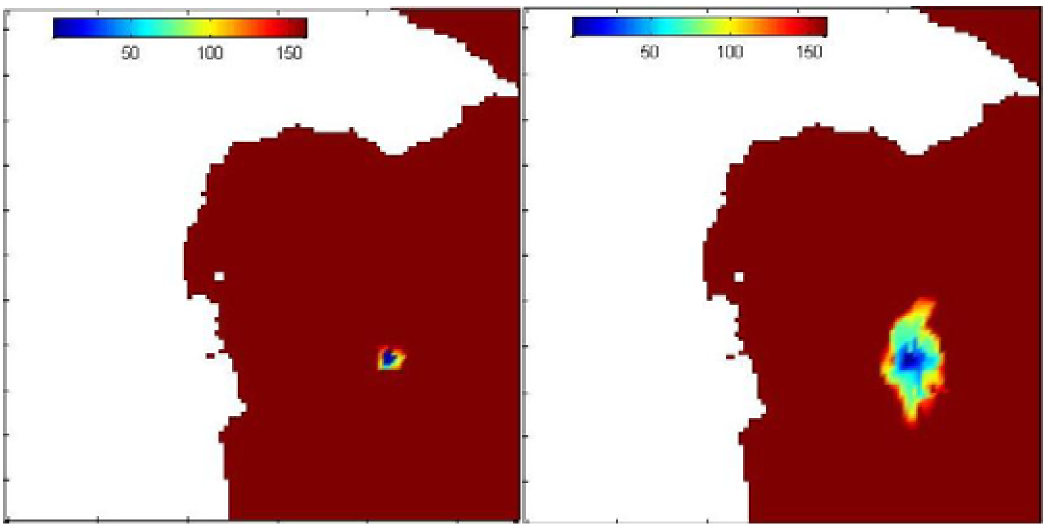
Figure 3 B5 outfall – Average and Minimum Dilution Factors



Spring Tides, average and minimum dilution factors



Dodge Tides, average and minimum dilution factors



Post Dodge Tides, average and minimum dilution factors

Figure 4 **W3 outfall – Average and Minimum Dilution Factors**

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