Coastal Processes Investigation: Modification to the Port Kembla Outer Harbour Development

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Executive Summary

This report presents the findings of a comprehensive suite of coastal processes modelling studies undertaken by Stantec to assess the impacts of proposed modifications to the Port Kembla Outer Harbour Development. The work was conducted in response to the Secretary's Environmental Assessment Requirements (SEARs) in relation to coastal processes for the proposed Outer Harbour layout Modification.

To evaluate the effects of the proposed modified harbour layout, Stantec applied a range of numerical modelling tools. Spectral wave modelling was carried out using the SWAN module within the Delft3D system. This involved a nested grid approach to simulate offshore wave transformation and estimation of wave conditions at the harbour entrance. Design wave parameters at the entrance to the Outer Harbour were derived through Extreme Value Analysis across multiple directional sectors. Swell wave penetration was assessed using the MIKE-21 Boussinesq Wave (BW) module, which simulated wave disturbance patterns under existing and the two proposed harbour configurations: approved concept and proposed modification layouts.

The outcomes of these modelling-based investigations have been assessed in terms of changes relative to the approved harbour layout changes.

The spectral wave modelling showed that, as per the approved concept layout, the east-northeasterly offshore waves generate the highest wave heights at the harbour entrance and within the Outer Harbour.

Under the proposed modification, and compared to the approved concept layout, wave energy is predicted to reduce significantly near the proposed quay walls; swell wave disturbance coefficients were found to reduce from greater than 1 in the approved concept to 0.6 – 1.0 in the northern quay wall area of the proposed modification and to as low as 0.4 in the southern proposed quay area. Compared to the approved concept layout there is an increase in wave activity at the existing berth B201 near the northern breakwater during rare and severe storm events from the north-northeast. This increase is caused by reflection of waves from the northern proposed quay wall. This impact would only materialise if B201 still exists when the northern proposed quay wall is developed and would be small given the low utilisation of that berth. This effect is attributed to the assumption of fully reflective vertical quay walls and could be reduced if less reflective quay walls are used for a portion of the northern quay wall.

Long wave modelling was also conducted using the MIKE-21 BW system, replicating historical infra-gravity wave conditions based on previous studies. A bi-modal long wave spectrum was applied, and simulations were run for existing, approved, and proposed modified layouts. Overall long wave conditions under the proposed modification layout were found to be similar to those of the approved concept layout, suggesting that the proposed modification layout will not worsen long-wave induced vessel motions or mooring loads.

Thermal plume modelling was performed using a 3D Delft3D-FLOW model, incorporating tidal, wind, and discharge inputs. The model simulated water temperature changes under summer and winter conditions for all three harbour layouts. Discharge data included cooling water inputs from BlueScope Steel and the Squadron Energy FSRU re-gasification process. The simulations predicted only minor and localised changes in seawater temperature. For the proposal modification layout, bottom-layer

temperature decreases of up to 0.6°C were observed near the eastern breakwater during summer.

Flushing performance was assessed using conservative tracer simulations under three scenarios: tidal forcing only, tidal plus discharge, and tidal plus discharge with atmospheric forcing. The e-folding time, or the time required for tracer concentration to reduce to 37% of its initial value, was used as the key metric. The proposed modified layout slightly improves flushing compared to the approved concept layout. E-folding times at the harbour entrance were approximately seven days, while upper harbour areas exhibited longer flushing times of up to fourteen days.

Dredge siltation modelling evaluated sediment dispersion and deposition during construction activities, based on cutter suction dredging methods. The modelling predicts that sediment plumes generated during construction would remain largely confined within the port. Although modelling of sediment plumes for the approved concept layout was not undertaken during the EIS, given the area to be dredged is similar to the existing approved layout, sediment dispersion and deposition patterns during construction activities for the modified layout are likely to be similar to those for the approved layout outcomes. Outside the breakwaters, excess suspended sediment concentrations are expected to remain below 5 mg/L above background levels. Deposition was concentrated within the reclamation area due to low current speeds, minimising the risk of offsite impacts. In conclusion, the modelling studies collectively indicate that the proposed modification layout will not result in adverse impacts on coastal processes compared to the approved concept layout.

Consideration of alternative quay wall designs, such as armoured revetments, could be investigated further during the design stage of the northern reclamation area to reduce wave reflections from vertical quay walls towards the northern breakwater. It is also recommended that sediment management is considered consistent with the approved project including the use of containment bunds around reclamation of soft materials to manage sediment dispersion effectively, and the use of silt curtains around the dredging and disposal areas to minimise sediment plumes.

Abbreviations

Abbreviations	Full Name
ADCP	Acoustic Doppler Current Profiler – ocean data instrument that records currents and water levels
FSRU	Floating Storage and Regasification Unit
SI	International System of Units
UTM	Universal Transverse Mercator
UTC	Coordinated Universal Time
ARI	Average Recurrence Interval
MWD	Mean Wave Direction
PWD	Peak Wave Direction
ISO	International Organisation for Standardisation
ADI	Alternating Direction Implicit
EVA	Extreme Value Analysis
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital Elevation Model
MIKE-21 BW	MIKE-21 Boussinesq numerical wave model
PKT	Port Kembla Terminals

1 Introduction

NSW Ports is proposing to modify the Concept Approval associated with the Port Kembla Outer Harbour Development as shown below in **Figure 1-1**. The modification will simplify the staging. It will see that all reclamation and dredging works are carried out under Stage 1 rather than across three sub-stages (Stages 1a, b and c). Once Stage 1 is competed, the modified concept will create one continuous terminal footprint capable of supporting project cargo types including components for the development of offshore wind farms.

Figure 1-1. Port Kembla Outer Harbour Development Layouts

The Department of Planning, Housing and Infrastructure (DPHI) has prepared SEARs in accordance with the Secretary's Environmental Assessment Requirements issued on 27 February 2025. Included in those SEARs is a requirement to address projected climate change issues as well as coastal processes assessments of potential project impacts on shoreline conditions and changes in currents and water quality as detailed below in **Table 1-1**.

1.1 Purpose of This Report

This technical report assesses the potential impacts of the proposed modification on the hydrodynamic conditions in Port Kembla and its environs. It has been prepared to support the environmental assessment of the proposed modification to the approved project (MP08_0249), which comprises changes to both the concept proposal and the more detailed Stage 1 works.

As the concept proposal remains high-level and strategic in nature, sufficient technical assessment of all potential environmental impacts was not assessed as part of this report. This is consistent with the staged assessment approach supported under NSW planning policy, which recognises that detailed environmental assessment is more appropriately undertaken at the time that specific works are defined. Accordingly, this technical report is specifically and primarily focused on the proposed modification to the Stage 1 works, where the level of design detail is sufficient to support a robust, discipline-specific impact assessment.

Where appropriate, and to provide context or continuity, some references may be made to the modified concept proposal. However, unless otherwise stated, the term "proposed modification" throughout this report refers exclusively to the Stage 1 works.

The broader Modification Report considers the environmental implications of the modified concept at a strategic level, drawing on the findings of this and other technical reports to assess the Stage 1 works in accordance with the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Planning, Housing and Infrastructure (DPHI) on 27 February 2025 (Application number MP08_0249 Mod-2).

Table 1-1. Overall Scope of Work

Desired performance outcome	SEARs	Where addressed within this report
5. Hydrodynamics **The modification is designed, constructed, and operated to avoid or minimise adverse impacts on the hydrodynamic conditions of the harbour and its associated coastal processes, ensuring that dredging and changes to tidal flows, wave action, and sediment transport do not negatively affect marine habitats, shoreline stability, or adjacent developments.**	**1. Conduct a hydrodynamic impact assessment of the modification in relation to the Port Kembla Inner and Outer Harbours, addressing the interim and final stages of Outer Harbour configurations in the modified Concept Plan. The assessment must:**	
	a) Utilise modelling techniques to simulate the existing and post-modification hydrodynamic regime, including tidal circulation, wave climate, and sediment transport processes	Section 5, 6, 7, 8, 9, 10, 11
	b) Evaluate and quantify potential impacts of the proposed modification on coastal processes and hazards including: i. Harbour flushing characteristics ii. Tidal current velocities and patterns iii. Wave propagation and attenuation iv. Sediment erosion, transport, and deposition dynamics	Section 10 (Harbour Flushing) Section 8.1 (Tidal currents) Section 6, 7 (Wave propagation attenuation) Section 11 (Sediment Siltation, transport, deposition)
	c) Assess the potential for changes in shoreline morphology and stability resulting from altered hydrodynamic patterns, with particular focus on any	Not specifically addressed, however the shoreline within Port Kembla, once

	sensitive coastal environments or infrastructure within the study area.	developed, will be either quay wall or revetment. No changes to the hydrodynamics are predicted outside of the Port, and as such no changes to the shoreline morphology are expected.
	2. Assess the impacts of the proposed modification during construction and operation on marine and relevant terrestrial environments, including:	
	a) Evaluation of potential effects on sensitive ecosystems resulting from changes in hydrodynamic processes	Section 12 (Ecological Impacts)
	b) Analysis of dredging and spoil management impacts, including: i. Sediment dispersion and resuspension ii. Disposal options and their hydrodynamic implications iii. Potential disturbance of dinoflagellate cysts iv. Potential disturbance of contaminated seabed sediments.	Section 12 (Ecological Impacts) Section 11 (Dredge Siltation Modelling)
	3. Include a climate change hydrodynamic risk assessment for the proposed modification, addressing:	
	a) Projected sea level rise scenarios and their implications for the modification design	Section 13.1
	b) Increased frequency and intensity of storm events and associated impacts on the harbour, wave climate and coastal processes	Section 13.1
	c) Potential changes to hydrodynamic conditions under future climate scenarios and their effects on the resilience of the modified project.	Section 13.1
	4. Provide a mitigation and management strategy that:	
	a) Identifies and justifies potential mitigation measures to be applied, including but not limited to the effectiveness of learning(s) from previous projects, works, case studies and identification of good practice to manage hydrodynamic impacts relevant to the proposed modification activities	Section 14.1.1
	b) Identifies and assesses the predicted effectiveness of mitigation measures including the effect on hydrodynamic processes (both within the harbour and along adjacent coastlines), time scales of impact, and duration	Section 14.1.1
	c) Identifies potential residual hydrodynamic impacts and their significance following application of mitigation measures.	Section 14.1.2

2 Proposed Modification

NSW Ports holds existing approval to reconfigure Port Kembla's Outer Harbour for future expansion. As noted above in Chapter 1, a first modification has been approved, and a further modification (MOD 5) is now proposed to further adapt the concept design, enabling larger vessels to use the Port, while responding to evolving port needs, and supporting emerging opportunities such as offshore wind development nationally.

2.1 Modification Stages

The proposed modification includes:

- Stage 1:
    - Demolition of No.3, No. 4 Jetties (including Berth 206) and Jetty No.6
    - Reconfigure the layout of the port facility to permit greater flexibility with respect to the types of port uses that the development can accommodate. This reconfiguration aligns with the approved total reclamation area of 42 hectares. Reclamation works would now occur entirely within Stage 1
    - Slight adjustment of dredging footprint.
    - Construction of berths
    - Extension of Salty Creek and Darcy Road drain, through the reclamation area, to the Outer Harbour
    - Construction of new road link from Christy Drive
    - Execution of civil works including services
    - Construction of new navigation lead towers.
- Concept:
    - Stage 2:
        - Development and operation of a multi-use berth and terminal (including but not limited to an offshore wind and cargo terminal uses)
    - Stage 3:
        - Development and operation of container terminal
        - Construction of a rail link and siding to the container terminal.

2.2 Dredging and Reclamation Works

The proposed dredging program involves removing soft sediment using either a cutter suction dredge or a backhoe dredge, both operating 24/7 to dredge 833,675 m³. The cutter suction dredge pumps material via pipeline into a bunded reclamation area, while the backhoe dredge uses barges with overflow discharge, potentially generating more sediment plumes. Rock dredging follows, using a grab dredge to remove 383,575 m³ over six months, with material bottom-dumped into the same reclamation area. Reclamation begins post-dredging, involving temporary revetments and clean fill placement within bunds.

3 Strategic Planning and Policy Framework

This Chapter describes the strategic context for the proposed modification from a statutory and planning context.

3.1 Legislation

Coastal Management Act 2016

The *Coastal Management Act 2016* establishes the legislative framework for the sustainable use, management, and protection of the NSW coastal zone, which includes major port environments such as Port Kembla. From a statutory perspective, the Act requires decision-makers to consider how the proposed modification may affect natural coastal processes, including tides, wave action, sediment transport, and shoreline movement. In the context of Port Kembla, this directly implicates hydrodynamic conditions associated with port infrastructure, dredging activities, and coastal modifications. The Act obliges consistency with the principles of ecologically sustainable development and mandates that coastal management programs, SEPPs, and development controls consider and respond to risks from coastal hazards and alterations to hydrodynamic regimes. This Act guided the hydrodynamic modelling and sediment transport assessments presented in Chapters 5 through 11.

Water Management Act 2000

The *Water Management Act 2000* provides the statutory framework for the sustainable use and conservation of surface water, groundwater, and estuarine systems in NSW. Where development activities such as dredging, reclamation, or stormwater discharge may alter natural flow regimes, salinity gradients, or water levels, this Act requires their consideration under the proposed modification application. At Port Kembla, such works can influence estuarine hydrodynamics, with potential downstream effects on sediment transport and water quality. The Act reinforces the need to protect water-dependent ecosystems and maintain the ecological functions of estuarine environments, requiring proponents to demonstrate that hydrodynamic alterations are avoided, minimised, or appropriately mitigated. The Act informed the assessment of hydrodynamics and water quality impacts, particularly in relation to dredging and reclamation works. These are addressed in Chapters 8 (Hydrodynamic Modelling), 9 (Thermal Plume Modelling), and 11 (Dredge Siltation Modelling), which show minimal adverse effects on flow regimes, temperature, and sediment siltation.

Marine Estate Management Act 2014

The *Marine Estate Management Act 2014* governs the integrated and ecologically sustainable management of the NSW marine estate, including estuaries, coastal lakes, and nearshore waters. The Act requires that planning and development decisions consider risks to the health and function of marine ecosystems, including those arising from changes to hydrodynamic conditions. The accompanying *Marine Estate Management Strategy 2018–2028* explicitly identifies changes to natural water circulation, sedimentation, and coastal flow regimes as key pressures. In the context of Port Kembla, the Act provides a statutory mechanism to assess how proposed infrastructure, or dredging activities may alter water movement, habitat connectivity, and ecosystem resilience.

This Act underpinned the ecological impact assessment in Chapter 12. The modelling results, including wave disturbance and sediment dispersion, were used to evaluate risks to marine habitats and ecosystem resilience, with mitigation strategies proposed to manage these risks.

Ports and Maritime Administration Act 1995

The *Ports and Maritime Administration Act 1995* regulates the operation, safety, and development of commercial ports in NSW. Port Kembla, as a declared port under the Act, is subject to statutory oversight by the port authority (NSW Ports), which has responsibilities relating to navigational safety, environmental management, and port efficiency. Hydrodynamic assessments are routinely required to inform decisions about channel deepening, berth realignment, or land reclamation to ensure port activities do not compromise vessel safety or coastal processes. The Act supports the use of technical studies to understand wave climate, tidal flows, and current dynamics within port waters and adjacent coastal areas.

The Act supported the requirement for detailed hydrodynamic and wave modelling to ensure navigational safety and operational efficiency. Chapters 5 through 7 detail wave climate and penetration modelling, confirming that vessel safety and port operations are not compromised by the proposed modification.

Fisheries Management Act 1994

The *Fisheries Management Act 1994* aims to conserve fish stocks and aquatic habitats across NSW. It provides statutory protections for key fish habitats (KFH), including estuarine and marine environments such as intertidal zones. Hydrodynamic changes, whether from altered tidal flows, sedimentation, or flow velocity, can significantly impact the structure and function of these habitats. At Port Kembla, proposed works that may influence water movement must consider the implications for habitat health and fish passage. Under the Act, proposals with potential hydrodynamic impacts may require additional habitat protection or offset measures to mitigate risk to aquatic biodiversity

This Act informed the evaluation of impacts on aquatic habitats, particularly in relation to sedimentation and turbidity. Chapter 12 discusses potential effects on key fish habitats and outlines mitigation measures such as silt curtains and habitat relocation plans.

3.2 Policy and Guidelines

State Environmental Planning Policy (Resilience and Hazards) 2021

The *State Environmental Planning Policy (Resilience and Hazards) 2021* (Resilience and Hazards SEPP) establishes the planning framework for managing coastal risks, climate resilience, and natural hazards in NSW. For Port Kembla and similar coastal settings, Clause 2.4 of the SEPP requires consent authorities to consider whether development may affect coastal processes such as wave action, tides, currents, or sediment transport, core hydrodynamic parameters. The SEPP prohibits development that would significantly increase coastal hazard risk or adversely affect coastal environmental values. The SEPP also incorporates provisions relating to flooding, acid sulfate soils, and hazardous industry buffering, all of which are relevant to Port Kembla's port operations. Collectively, these clauses reinforce the statutory requirement for detailed hydrodynamic and hazard assessments to ensure port-related development is resilient, well-sited, and consistent with State planning policy.

The SEPP guided the hazard and resilience analysis throughout the report. Chapters 13 and 14 address climate change impacts and residual risks, confirming that the proposed modification does not increase coastal hazard exposure or compromise environmental values.

Coastal Engineering Guidelines for Working with the Australian Coast (Engineers Australia)

The *Coastal Engineering Guidelines for Working with the Australian Coast* provide a nationally recognised technical reference for assessing, designing, and managing coastal infrastructure and processes. While not statutory, these guidelines inform best-practice approaches and are frequently relied upon in environmental and engineering studies submitted under statutory frameworks such as the *Coastal Management Act 2016* and the *Environmental Planning and Assessment Act 1979*.

In the Port Kembla context, the guidelines are directly relevant to understanding hydrodynamic behaviour, offering detailed methods for modelling wave climates, tides, currents, and sediment transport. These parameters underpin the assessment of potential impacts from dredging, reclamation, breakwaters, and navigational changes. The guidelines also advocate for incorporating resilience and hazard risk into design, supporting the delivery of hydrodynamically sound, environmentally responsible, and approval-ready coastal infrastructure.

These guidelines informed the modelling approach and design recommendations. The use of hydrodynamic and wave models presented in this report aligns with best-practice methods for assessing hydrodynamic and sediment transport.

Coastal Management Manual

The *Coastal Management Manual* supports implementation of the *Coastal Management Act 2016* and is a mandated consideration when preparing Coastal Management Programs (CMPs). It provides technical guidance to proponents and consent authorities on identifying and assessing coastal processes and values, including hydrodynamic factors such as wave energy, current regimes, water levels, and sediment dynamics. In settings like Port Kembla, the manual helps guide the application of appropriate modelling techniques and datasets to assess the likely impacts of proposed development on local and regional coastal processes. While not a standalone statutory instrument, the manual plays a central role in interpreting and applying the Act's provisions, ensuring that hydrodynamic risks are properly identified, considered, and managed in line with the objectives of coastal sustainability and hazard mitigation.

The manual provided technical direction for identifying and assessing hydrodynamic risks. Its principles are reflected in the modelling scope and methodology described in Chapter 4, and in the mitigation, strategies outlined in Chapter 14.

NSW Wetlands Policy (DECCW)[1]

The **NSW Wetlands Policy**, updated in 2010 by the Department of Environment, Climate Change and Water, provides a strategic framework for the **conservation, sustainable management, and wise use of wetlands** across New South Wales. It builds on the original 1996 policy and reflects advancements in natural resource management and planning. The policy emphasises the ecological, cultural, and economic value of wetlands, recognising their role in biodiversity, water purification, flood mitigation, and carbon storage. It outlines guiding principles for wetland protection, encourages integrated catchment-based management, and promotes collaboration among government, community, and stakeholders. The policy also supports monitoring and evaluation to track performance and ensure adaptive management in response to environmental pressures and climate change.

[1] https://www.environment.nsw.gov.au/sites/default/files/nsw-wetlands-policy-100039.pdf

The report supports the policy's goals by assessing potential impacts on coastal and estuarine environments, including sedimentation and water quality. The modelling confirms that the proposed modification will not adversely affect wetland function. See Chapters 11 and 12 for sediment and ecological impacts.

State Significant Infrastructure Guidelines – Preparing a Modification Report. Appendix F to the State Significant Guidelines (DPIE 2021)[2]

These guidelines provide detailed instructions for preparing modification reports for State Significant Infrastructure (SSI) projects in NSW, as required under the Environmental Planning and Assessment Regulation 2021. The purpose of a modification report is to assess the economic, environmental, and social impacts of proposed changes to an approved SSI project, ensuring transparency and informed decision-making. The report must clearly describe the modifications, reflect community views, and justify the modified project in line with ecologically sustainable development principles. It should be structured into a main report and appendices, with clear presentation, logical flow, and cross-referencing to reduce repetition. The Department may require public exhibition of the report, during which submissions are invited and must be addressed in a separate submissions report. These guidelines aim to ensure consistency, clarity, and high-quality reporting to support robust public and regulatory evaluation of project modifications.

This report follows the structure and content expectations outlined in Appendix F, including clear description of the modification, assessment of environmental impacts, and justification of the proposed changes. It supports robust evaluation and public transparency. See Chapters 1–3 for project description and Chapters 4–14 for technical assessment.

4 Method

Stantec has applied numerical modelling methods to determine the differences in short and long wave conditions in the Outer Harbour arising from the proposed modification. These investigations have been undertaken to address the SEARs described in above in Table 1-1.

Table 4-1. Stantec's Scope of Work (including an ecological assessment)

SEARs	Where addressed within this report
1. Conduct a hydrodynamic impact assessment of the modification in relation to the Port Kembla Inner and Outer Harbours, addressing the interim and final stages of Outer Harbour configurations in the modified Concept Plan. The assessment must:	
(a) utilise modelling techniques to simulate the existing and post-modification hydrodynamic regime, including tidal circulation, wave climate, and sediment transport processes	From section 4 to section 11
(b) evaluate and quantify potential impacts of the proposed modification on coastal processes and hazards including:	

[2] https://www.planning.nsw.gov.au/sites/default/files/2023-03/ssi-guidelines-preparing-a-modification-report.pdf

i. ***harbour flushing characteristics***	*Section 10*
ii. ***tidal current velocities and patterns***	*Section 8.3.5*
iii. ***wave propagation and attenuation***	*Section 5 to Section 7*
iv. ***sediment erosion, transport, and deposition dynamics***	*Section 11*
(c) assess the potential for changes in shoreline morphology and stability resulting from altered hydrodynamic patterns, with particular focus on any sensitive coastal environments or infrastructure within the study area.	Not specifically addressed, however the shoreline within Port Kembla, once developed, will be either quay wall or revetment. No changes to the hydrodynamics are predicted outside of the Port, and as such no changes to the shoreline morphology are expected.
2. Assess the impacts of the proposed modification during construction and operation on marine and relevant terrestrial environments, including:	
(a) evaluation of potential effects on sensitive ecosystems resulting from changes in hydrodynamic processes	Section 12
(b) analysis of dredging and spoil management impacts, including:	Section 12
i. ***sediment dispersion and resuspension***	Section 12
ii. ***disposal options and their hydrodynamic implications***	Section 12
iii. ***potential disturbance of dinoflagellate cysts***	Section 12
iv. ***potential disturbance of contaminated seabed sediments.***	Section 12
3. Include a climate change hydrodynamic risk assessment for the proposed modification, addressing:	Section 13
(a) projected sea level rise scenarios and their implications for the modification design	Section 13
(b) increased frequency and intensity of storm events and associated impacts on the harbour, wave climate and coastal processes	Section 13
(c) potential changes to hydrodynamic conditions under future climate scenarios and their effects on the resilience of the modified project.	Section 13
4. Provide a mitigation and management strategy that:	Section 14.1.1

(a) identifies and justifies potential mitigation measures to be applied, including but not limited to the effectiveness of learning(s) from previous projects, works, case studies and identification of good practice to manage hydrodynamic impacts relevant to the proposed modification activities	Section 14.1.1
(b) identifies and assesses the predicted effectiveness of mitigation measures including the effect on hydrodynamic processes (both within the harbour and along adjacent coastlines), time scales of impact, and duration	Section 14.1.1

4.1 General Approach

The coastal processes assessment followed a structured methodology comprising five key stages: (a) data pre-processing for the model inputs and meteorological forcing inputs relevant to the Port Kembla Outer Harbour; (b) model setup and simulations based on previous validated numerical models to simulate baseline existing conditions; (c) scenario modelling to evaluate a series of proposed activities under approved concept and proposed modification layouts to investigate changes tidal currents wave attenuation, water temperature, harbour flushing ; (d) impact assessment to quantify potential impacts on sediment transport due to dredging works; and (e) development of mitigation measures to address identified impacts and ensure compliance with environmental performance objectives.

4.2 Study Area

The study area comprised the whole of Port Kembla harbour together with the region of the Tasman Sea immediately near the harbour entrance – for example, in terms of possible sediment plume occurrence beyond the harbour.

4.3 Limitations

Stantec advises that these investigations relate the proposed Stage 1 modification, likely in an early-stage form. Stantec have relied on data from ARUP, NSW Ports and various third parties, for example, offshore wave data and assumed dredging plans.

4.4 Project Datum and Conventions

4.4.1 Units

The SI System of Units has been used.

4.4.2 Coordinate System

All coordinates are in Map Grid of Australia MGA Zone 56 and are based on the Geocentric Datum of Australia 1994 (GDA94) spheroid.

4.4.3 Vertical Reference Level

All elevations are in meters and referenced to Australian Height Datum (AHD), unless otherwise noted.

4.4.4 Time Reference

All data related to time are given in Australian Eastern Standard Time (AEST), which is Coordinated Universal Time (UTC) + 10 hours.

4.4.5 Direction Convention

Wave Direction

The direction from which the wave is coming (i. e., coming from convention) and is measured clockwise from true north. A wave with a direction of 0º is coming from the north, and 90º is coming from the east etc.

Wind Direction

The direction from which the wind is blowing (i. e., coming from convention) and is measured clockwise from true north. A wind with a direction of 0º is coming from the north, and 90º is coming from the east etc.

Average Recurrence Interval

The average recurrence (or return) interval (ARI) is defined as the average interval of time, normally in years, over which the condition would be expected to be equalled or exceeded once. Design events are typically defined in this manner. For example, a 50-years ARI event is, on average, equalled or exceeded once every 50 years. It should be noted that it is possible, although not probable, that this design event could be exceeded during the first year of the life of the structure or may not be exceeded at all over the life of the structure.

5 Spectral Wave Modelling

5.1 General

Wave conditions in the Port Kembla Outer Harbour are primarily influenced by swell waves (waves formed far out at sea that travel long distances) from the Tasman Sea. Due to the absence of reliable long-term wave data inside the harbour, numerical modelling was applied to transform offshore design waves (i.e., theoretical/representative wave conditions) to the entrance to the Outer Harbour for input into a more detailed wave penetration model (i.e., a model that shows how waves from the open water travel into and behave inside the harbour).

5.2 Model Description

The overall spectral (short) wave model applied in this study is based on the SWAN wave modelling system, which is incorporated as a module into the Delft3D modelling system. This model was developed at the Delft Technical University and includes wind input (local wind sea wave generation and wave growth), combined wind sea and swell, offshore wave parameters, refraction, shoaling, non-linear wave-wave interaction, a full directional spectral description of wave propagation, bed friction, white capping, currents and wave breaking.

SWAN includes a nested grid capability that allows coarser grids in deeper water and finer grids in shallow water and the study area where better definition of seabed form and depth variation are needed. Output from the model includes significant wave height, mean and peak wave direction, spectral peak (i.e., the time between wave crests that contain the most energy in a wave spectrum) and mean periods (i.e., average time between wave crests that across all frequencies in the spectrum) and (optionally) the full directional wave spectra (i.e., how wave energy is distributed across different wave periods and directions at a specific location).

5.2.1 Model grid

Stantec maintains an established SWAN spectral wave model that encompasses Port Kembla and the surrounding regional coastline, including both the Outer Harbour and the broader port area. The model system consists of a nested grid configuration, with a 100m resolution outer regional grid and embedded 10m resolution grids focused on key areas (**Figure 5-1**). A high-resolution 4m grid—originally developed to support the design of the emplacement cell—was available and used in the current investigation. This grid was nested within one of the existing 10m grids covering Port Kembla and provides enhanced near-field resolution, particularly around the entrance to the Port Kembla Outer Harbour.

In summary, the SWAN model set-up consisted of a series of three nested rectilinear grids of increasing grid cell resolution. Cell sizes for each grid are as follow:

- Grid A: Grid cell size is 100m x 100m covering the Port Kembla region coastline.
- Grid B: Grid cell size is 10m x 10m covering Wollongong coastal waters.
- Grid C: covers the Port Kembla Outer Harbour and the grid cell size is 4m x 4m.

Figure 5-2 depicts the extent and bathymetry of the finest SWAN model grid developed for this investigation. The model was used to derive wave conditions at a location outside the port entrance for input to a detailed wave

penetration model (see Section 6). While the model bathymetry did not include the emplacement cell, this omission does not affect the accuracy of wave conditions derived outside the port.

5.2.2 Boundary Inputs

Time series of offshore wave parameters were used to calculate extreme offshore wave conditions for different ARIs and directional sectors by undertaking Extreme Value Analyses (EVA). This assessment estimates the most severe wave conditions likely to occur from different directions.

The design wave parameters (i.e., the extreme wave conditions) were then fed into the extreme offshore to nearshore wave transformation model to extract and define the extreme wave conditions at the entrance to the Port. Extreme wave events were identified using a peak over threshold method (in relevant directional bins) to select independent events. This allowed the development of a reliable statistical dataset to estimate how often severe waves are likely to occur from different directions. EVA were then undertaken considering all the independent events at the offshore location in each considered directional band. (i.e., separate extreme wave events coming from each direction out at sea). A Weibull distribution was fitted to the data for this extreme value analysis.

The EVA results, in terms of significant wave height H_s (i.e., the average height of the highest one-third of waves in a wave group) for 1, 2, 5, 10, 20, 25, 50 and 100-years Average Return Interval (ARI) for considered directional bands are presented in Table 5-1. The associated peak wave period T_p was calculated using an Hs versus T_z linear regression relationship ($T_z = 4.0 + 0.64 * H_s$) and $T_p = 1.4 * T_z$.

The EVA included ARIs up to 100 years to provide a comprehensive statistical basis for understanding the range of potential offshore wave conditions over longer planning horizons. This approach supports the environmental impact assessment by allowing consideration of rare but plausible extreme events. Port Kembla is a protected harbour and only experiences measurable wave activity during severe storm events. For this reason, only the 50-year ARI event was carried forward into the detailed wave modelling, as it represents a credible and suitably conservative design condition for assessing potential wave impacts within the harbour under severe but realistic storm scenarios.

Table 5-1: Design Wave Conditions Offshore of Port Kembla

Directional Sector	NE (45 °N)		ENE (67.5 °N)		E (90 °N)		ESE (112.5 °N)		SE (135 °N)		SSE (157.5 °N)		S (180 °N)	
ARI (years)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)
1	2.5	7.9	3.3	8.5	3.9	9.1	4.3	9.5	5.0	10.0	5.7	10.7	5.8	10.8
2	2.8	8.1	3.8	9.0	4.4	9.5	4.8	9.9	5.5	10.5	6.3	11.2	6.3	11.2
5	3.1	8.3	4.6	9.7	4.9	10.0	5.5	10.6	6.3	11.3	7.2	12.0	6.9	11.8
10	3.3	8.5	5.3	10.4	5.3	10.4	6.1	11.1	7.0	11.9	7.9	12.7	7.3	12.2
20	3.4	8.7	6.0	11.0	5.7	10.7	6.7	11.6	7.8	12.6	8.6	13.3	7.8	12.6
25	3.5	8.7	6.3	11.2	5.8	10.8	6.8	11.7	8.0	12.8	8.9	13.5	7.9	12.7
50	3.7	8.9	7.0	11.9	6.2	11.2	7.4	12.2	8.8	13.4	9.6	14.2	8.3	13.1
100	3.9	9.1	7.8	12.6	6.6	11.5	8.0	12.7	9.5	14.1	10.4	14.9	8.8	13.4

5.2.3 Model Output Location

The results of the numerical wave modelling are presented in terms of the 50-year ARI design wave parameters at the Port Kembla Harbour Entrance (**Figure 5-2**). The coordinates and water depth at the nominated output location are provided in **Table 5-2**.

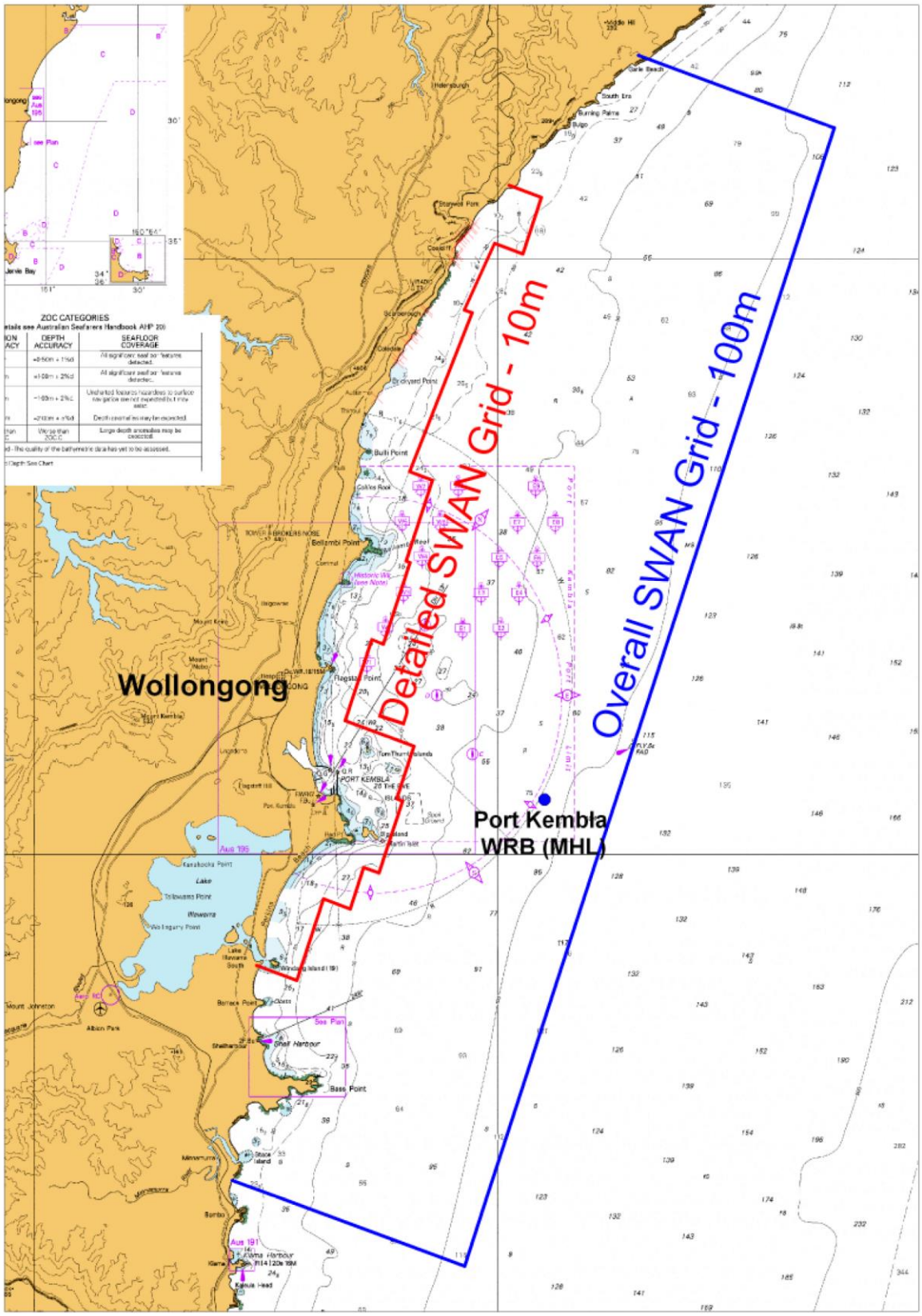

Figure 5-1. Extent of the SWAN Model Grid covering the entire Port Kembla Region Coastline

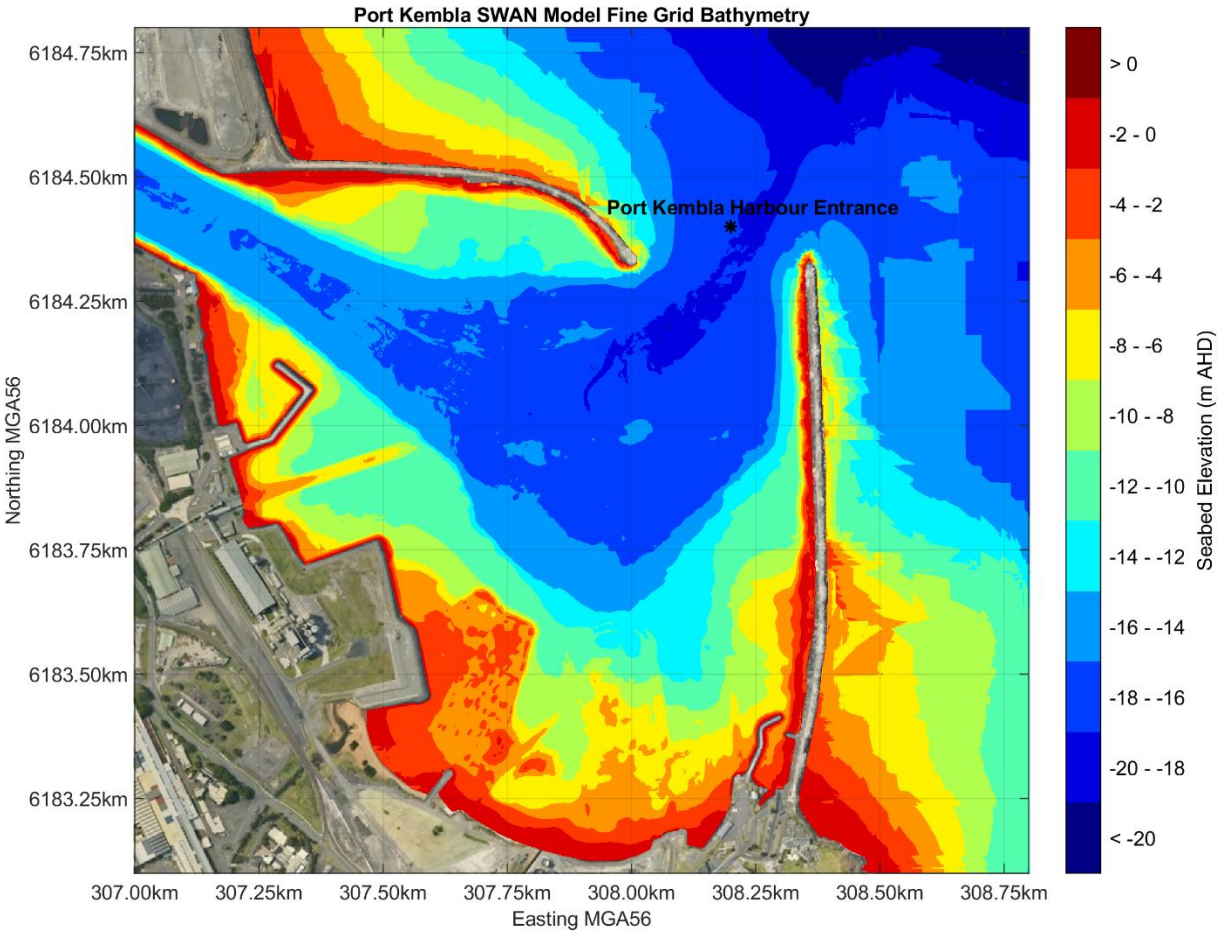

Figure 5-2. Extent and Bathymetry of the finest SWAN Model Grid applied for this Investigation

Table 5-2. The Coordinates and Seabed Level at the Nominated Output Location

Output Point	Easting	Northing	Water Depth (m AHD)
Port Kembla Harbour Entrance	308200	6184400	17.9

5.3 Results

Figure 5-3 to **Figure 5-9** present the modelled 50-year ARI significant wave height in the vicinity of the Outer Harbour. A summary of the 50-years ARI design wave parameters is also tabulated in **Table 5-3**. As can be seen, the offshore east north-easterly waves (67.5°) cause the highest wave heights at the Harbour's entrance (see red text values in **Table 5-3** below), where the significant wave height is predicted to reach up to four metres. While offshore wave heights can reach 9.6 metres (from the south, see grey cells in **Table 5-3** below) their impact at the Harbour's entrance is reduced due to sheltering and wave transformation. The analysis confirms that wave direction plays a major role in determining how much wave energy reaches the harbour.

Note that the purpose of this model is to derive wave conditions immediately offshore of the port entrance to derive input wave conditions for further models which assess wave penetration into the Port. As such, comparisons between the existing, approved concept, and proposed modification layouts have not been undertaken using this model. These assessments are presented in **Section 6**.

Table 5-3. Summary of the 50-years ARI Design Wave Parameters

Offshore Wave Parameters			Port Kembla Harbour Entrance		
Dir (°)	**H_s (m)**	**T_p (s)**	**H_s (m)**	**Dir (°)**	**T_p (s)**
45	3.7	8.9	2.1	54.8	8.3
67.5	7.0	11.9	4.0	68.5	12.1
90	6.2	11.2	3.3	77.6	10.7
112.5	7.4	12.2	3.5	85.5	12.1
135	8.8	13.4	3.2	88.5	13.8
157.5	9.6	14.2	2.8	90.8	13.8
180	8.3	13.1	1.6	91.7	13.8

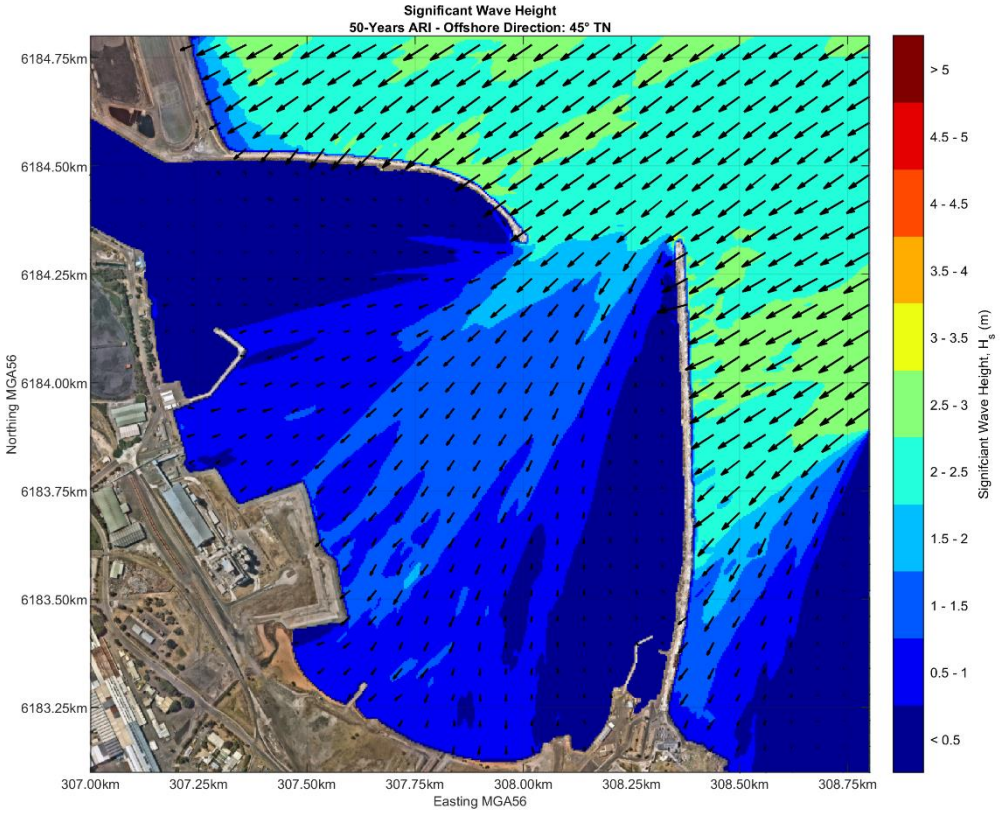

Figure 5-3: Modelled 50 Year ARI Wave Conditions from the North-East

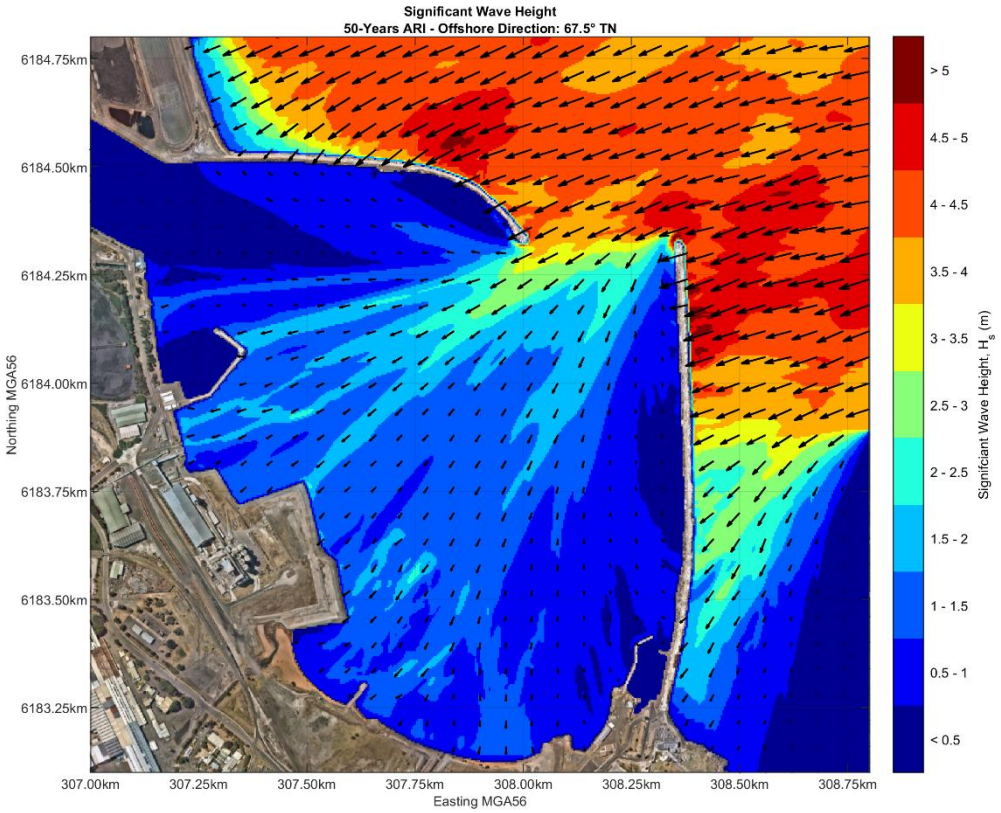

Figure 5-4: Modelled 50 Year ARI Wave Conditions from the East-Northeast

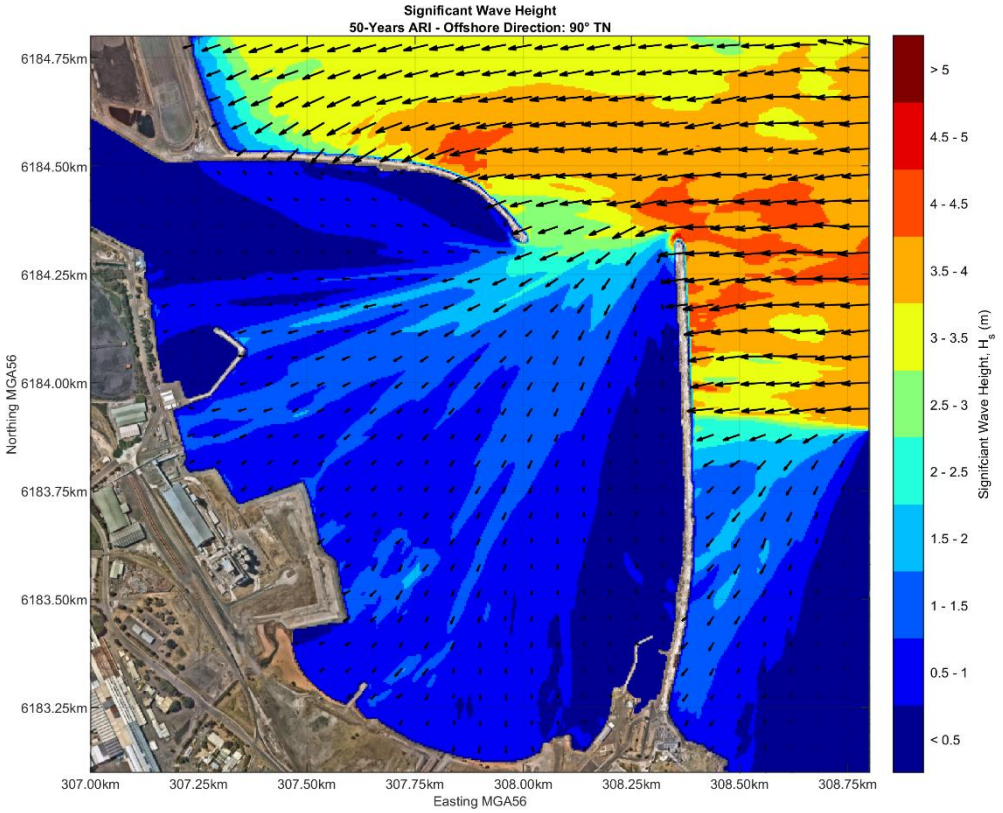

Figure 5-5: Modelled 50-years ARI Wave Conditions from the East

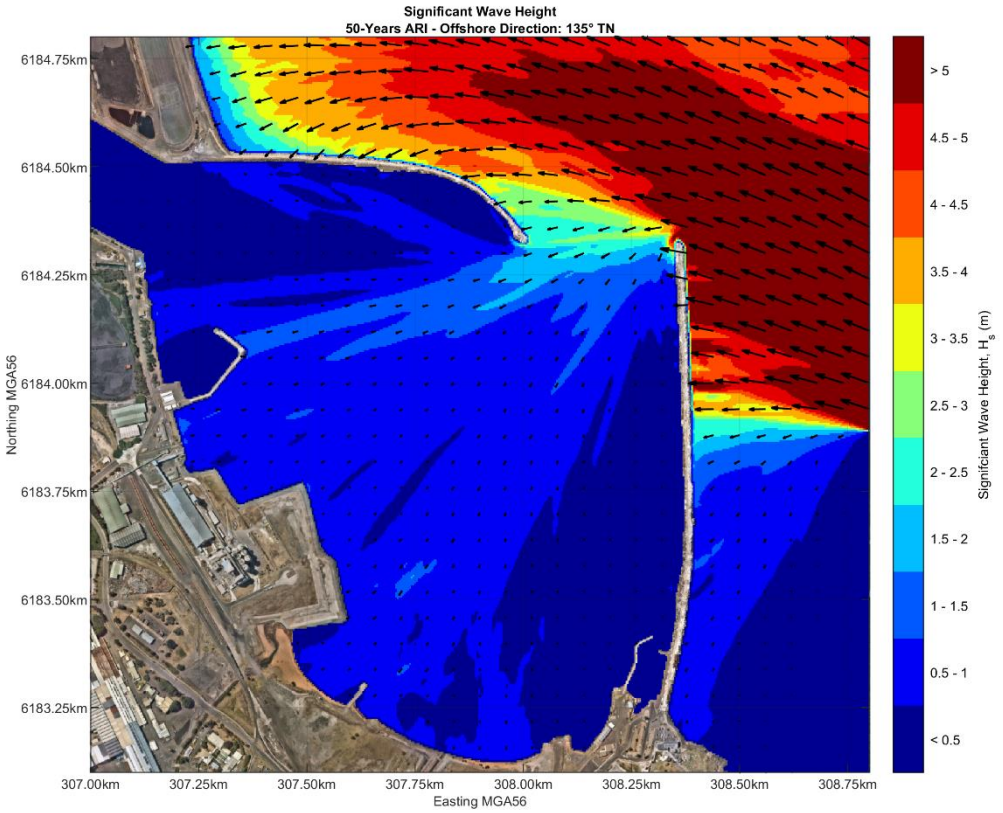

Figure 5-6: Modelled 50-years ARI Wave Conditions from the East-South-East

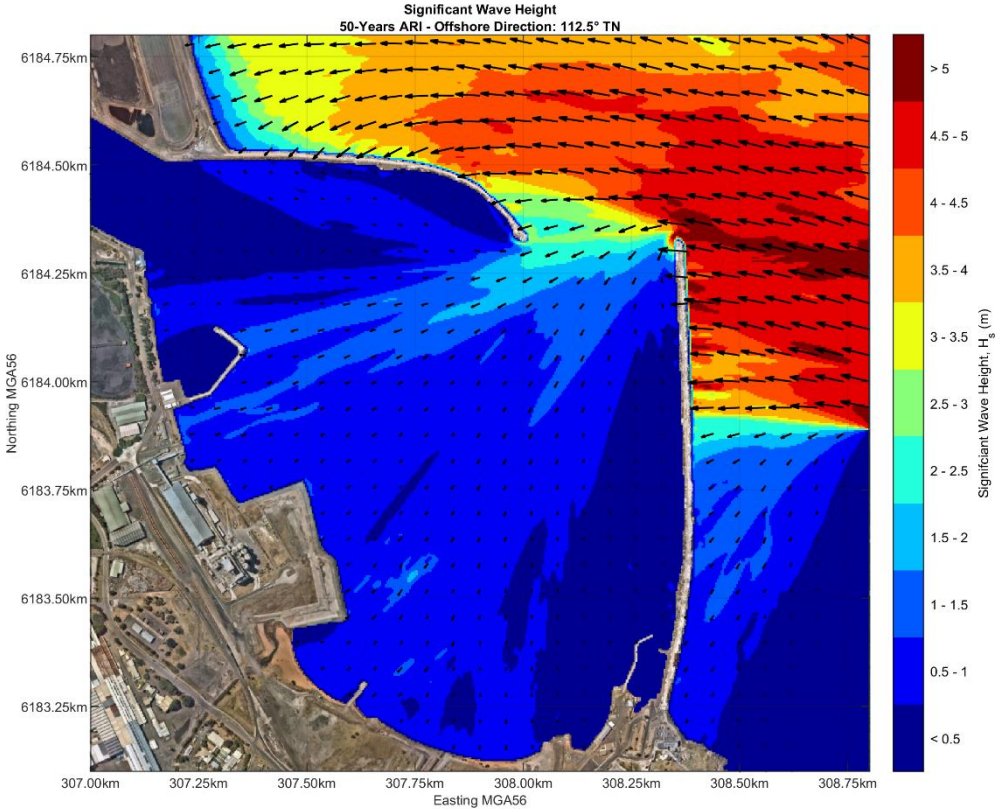

Figure 5-7: Modelled 50-years ARI Wave Conditions from the South-East

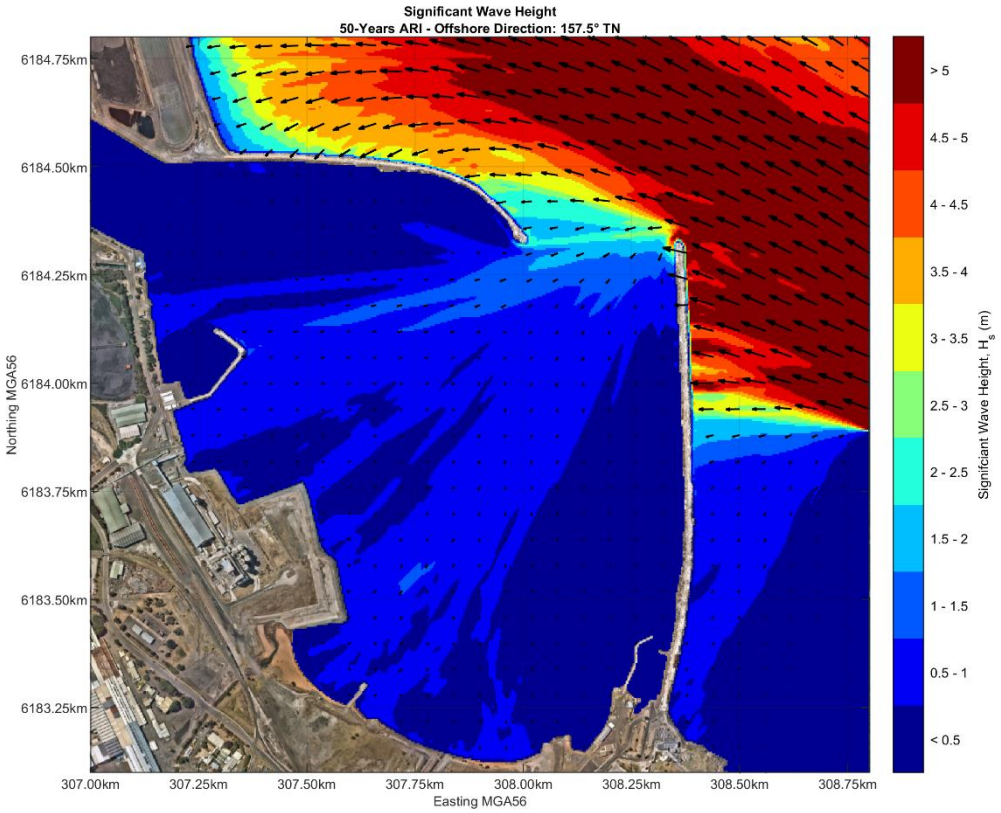

Figure 5-8: Modelled 50-years ARI Wave Conditions from the South-South-East

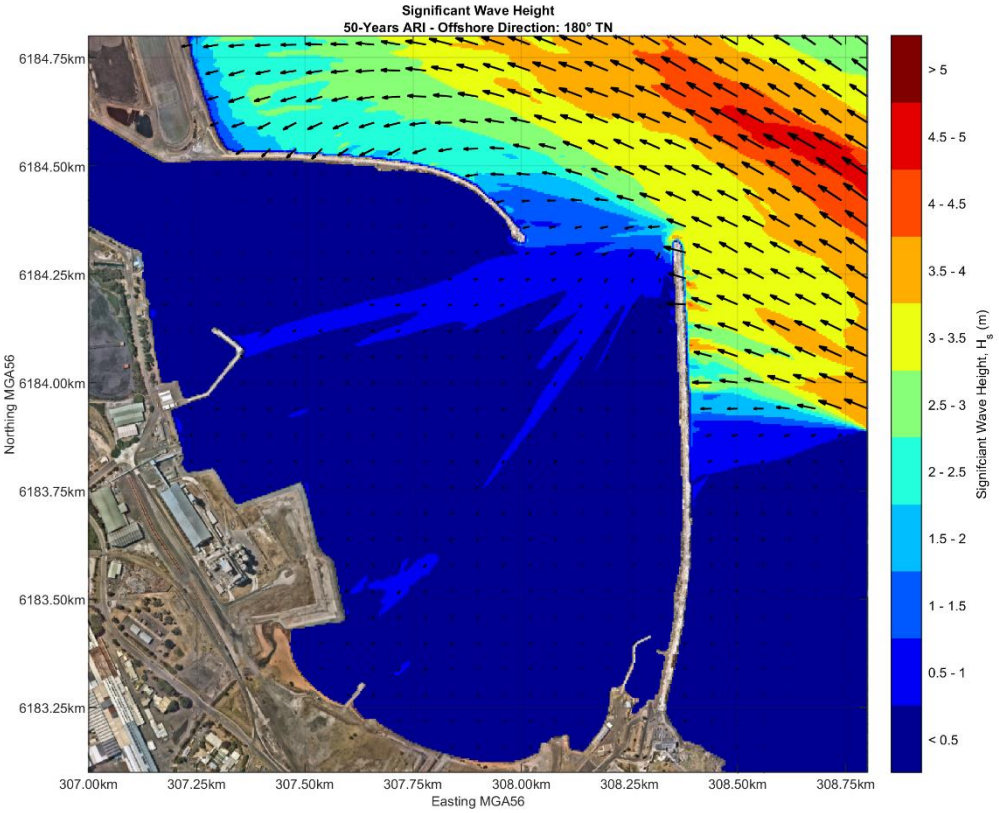

Figure 5-9: Modelled 50-years ARI Wave Conditions from the South

6 Swell Wave Penetration Modelling

6.1 Introduction

This chapter presents the methodology, configuration, and results of swell wave penetration modelling (i.e., how waves that form far out at sea enter and move through the Harbour) undertaken using the MIKE-21 Boussinesq Wave (BW) model for the proposed modification. The objective of this modelling is to assess wave disturbance patterns (i.e., study how waves behave and move around inside the Harbour) under the proposed modification, particularly in relation to the reconfiguration of the southern reclamation area and its potential impacts on wave conditions.

Previous studies undertaken by Stantec have established a robust MIKE21 BW model for the Outer Harbour. MIKE-21 BW is a general-purpose phase resolving numerical tool for simulating unsteady, non-hydrostatic, free-surface, rotational flow and transport phenomena in coastal waters (i.e., changing, complex water movement and mixing in the coastal area, including waves, currents, and how water levels and materials like sediment or pollutants move and interact over time), as driven by waves, tides, buoyancy, and wind forces. It provides a general basis for how waves transform as they move from deep water to shallower areas like beaches, ports, and harbours, in terms of changes in height, speed, and direction due to the seabed and coastal features.

MIKE-21 BW uses small grid sizes and time-steps to describe the profiles of irregular wave trains (i.e., natural, random-looking groups of waves that vary in height, period, and direction). It includes refraction, shoaling, diffraction, bed friction, wave breaking and frequency-direction spectral input (i.e., a detailed description of wave energy based on both wave frequency, and direction. It can include zero, partial and full wave reflectivity, allowing simulation of the effects of beaches, rock breakwaters, attenuators (e.g., pontoons, barges), and vertical walls.

The model has been used in various assessments, including the Squadron Energy project and the Port Kembla Gas Terminal (PKGT) emplacement cell. The current study builds upon this foundation, incorporating updated bathymetric data and incorporation of the proposed dredging and reclamation under the modification (see Section 2).

6.2 Model Setup

6.2.1 Grid and Bathymetry

The model domain (modelled area) covers the entire Outer Harbour, extending offshore of the harbour entrance. A horizontal resolution of 2 m was used, consistent with previous studies described above. Bathymetric data were sourced from recent hydrographic survey provided by NSW Ports and legacy datasets archived under the Squadron Energy project. The Emplacement Cell was also incorporated into the model based on the design drawings provided by NSW Ports.

6.2.2 Boundary Conditions

A unit wave approach was used at the offshore boundary to simulate swell wave conditions and assess the Harbour's response to incident wave energy. This allowed the model to isolate the effects of individual waves, by starting with one wave of the same size, period, and direction starting at the edge of the model and using it to determine how it behaves inshore, without mixing and other wave conditions. This allowed for a better understanding of which conditions result in the most wave disturbance inside the Harbour. It therefore involved applying a single, idealised wave spectrum with a significant wave height of 1.0m, and the peak wave period and direction based on the modelled 50-year ARI wave conditions at the Harbour's entrance. This approach was used to isolate the Harbour's wave

disturbance patterns. The unit wave was aligned with predominant swell directions observed offshore, allowing for consistent comparison between existing and proposed layout changes under the modification.

The 50-year ARI wave periods and directions with a unit wave from the east-north-east and the east, as presented in **Table 5-3,** were applied as boundary conditions to the MIKE21-BW model. These directions were selected as they represent the most critical wave approach angles for Port Kembla, based on the results of the offshore-to-nearshore wave transformation modelling. As shown in **Table 5-3**, these directions result in the highest wave energy reaching the harbour entrance due to their alignment with the port's exposure and orientation. Other directions, such as those from the south, are significantly attenuated by natural and structural sheltering and therefore do not contribute materially to wave conditions within the harbour.

6.2.3 Time Stepping and Simulation Duration

Simulations were run for 60 minutes with a 0.05 s time step (i.e., the model takes a snapshot 20 times per second to track how the waves move and change). Due to the computational effort required for the MIKE21-BW wave model, a duration of 60-minutes was chosen and is sufficiently long to capture the full evolution of the wave field under the simulated conditions. The chosen timestep of 0.05 seconds was used to ensure that the model maintains numerical stability. During post-processing, the first 15 minutes were discarded to allow for model spin-up and dynamic equilibrium establishment.

6.3 Results and Analysis

6.3.1 Wave Disturbance Coefficients

Disturbance coefficients were computed as the ratio of local Hs to the Hs at the MIKE21 BW boundary. Spatial plots of these coefficients are presented in **Figure 6-1** and **Figure 6-2**.

6.3.2 Impact of Proposed Reclamation

A comparison of the changes under the proposed modification show that the at-berth wave height is predicted to be less than the at-berth wave height of the approved concept, particularly when the offshore waves approach from the east-northeast. However, there is a clear increase in swell wave energy reflection (i.e., the amount of energy being reflected) within the Outer Harbour. The reconfiguration of the southern reclamation area under the proposed modification is predicted to generate more swell wave disturbance (i.e., increased wave activity) within the Harbour than both the existing layout and the previously approved concept, due to additional wave reflections from the newly introduced quay walls.

This will result in larger waves at the berths adjacent to the northern and eastern breakwaters, where wave disturbance coefficients (i.e., wave activity) are predicted to notably increase from less than 0.2 (mostly calm water where waves are well-blocked and absorbed) for the existing layout to up to 0.6 (much rougher water, where there is a significant amount of wave energy reaching the berths) when the swell waves arrive from the east-north-east. This will result in an increase in the significant wave height of approximately 1.6m during a 50 year ARI wave event from the east-north-east when compared to the existing layout. When compared to the approved concept, the proposed modification is predicted to increase the significant wave height at the northern breakwater by approximately 0.8m during a 50 year ARI wave event from the east-north-east.

The modelling assumes that the proposed reclamation will use fully reflective vertical walls. Reflections from the reclamation are expected to increase wave heights at nearby berths within the Outer Harbour. This effect may be lessened if the quay line is built as a suspended deck above a rock- armored revetment.

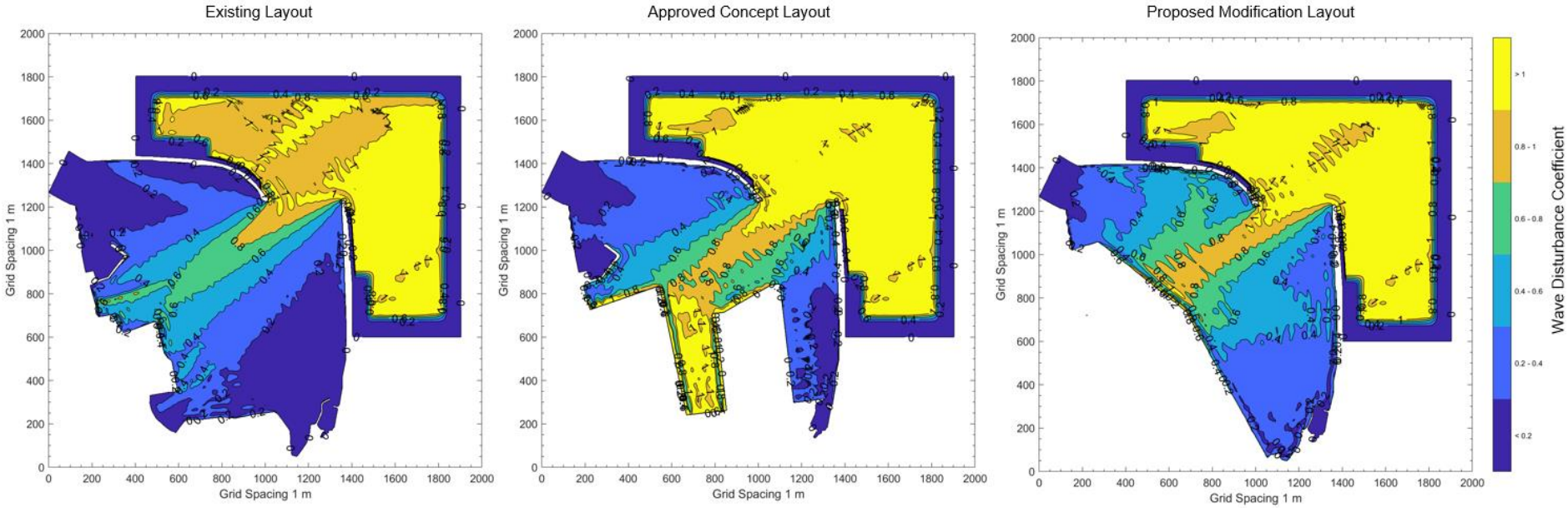

Figure 6-1: Modelled Swell Wave Disturbance Coefficient – Waves from the East-Northeast

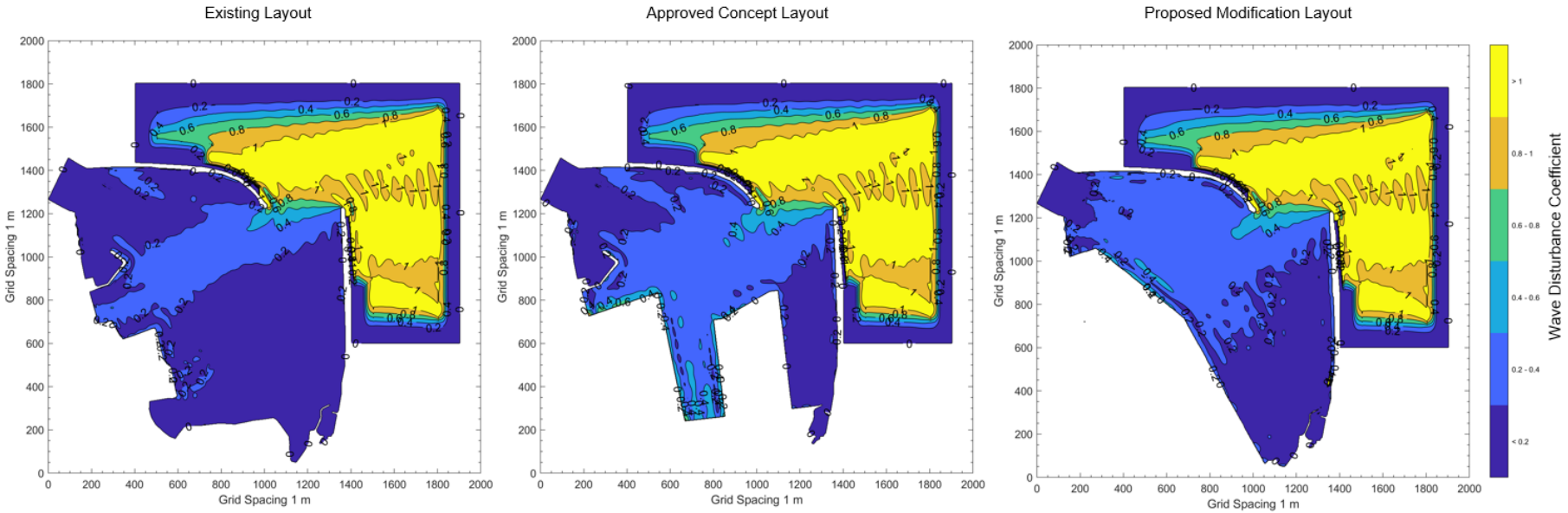

Figure 6-2: Modelled Swell Wave Disturbance Coefficient – Waves from the East

7 Long Wave Modelling

7.1 Previous Investigations

The Outer Harbour at Port Kembla has a long history of unacceptable moored vessel movements, from the aspect of the degree and type of motion experienced by a berthed vessel that exceeds safe or operational limits, caused by infra-gravity waves (i.e. very slow, rolling waves), and at some berths, high swell waves (i.e., large rolling waves) combined with long waves (i.e., long periods between each wave).

Stantec has previously undertaken data collection, analyses, and numerical wave modelling to investigate and describe long waves at berths within the Outer and Inner Harbours. In 2009, Cardno Lawson Treloar reported the results of numerical long wave modelling undertaken in the previous year that led to the adoption of the approved Outer Harbour layout. That work was undertaken using the numerical wave modelling system MIKE-21 Boussinesq Waves. In one model set-up, a bi-modal long wave spectrum with peaks at 200 and 60 seconds was developed, based on the combination of two single-peaked spectral shapes with peakedness parameters of four. The lower frequency peak at 200 seconds contained the larger part of the energy, which is in line with the measurements collected by the Port Authority of NSW approximately 600m to the north of the entrance to the Outer Harbour. A total long wave height (H_s) of 0.34m was adopted, with long wave energy propagating seaward from Coniston Beach, approximately 2,000 metres to the north of Port Kembla (H_s=0.23m) and long wave energy also propagating landward from the offshore model boundary (H_s=0.25m).

The 2008 model setup developed by Cardno Lawson Treloar has been adopted for the present investigation using archived files. This setup remains valid due to its continued relevance and proven performance in similar applications. The model was originally constructed using the MIKE-21 Boussinesq Waves (BW) system, which remains an industry-standard tool for simulating infra-gravity and long-period wave processes. The same model configuration was successfully applied in the AIE LNG Regassification Project at Port Kembla during 2019–2022, supporting environmental approvals and design assessments. For the current study, the archived setup has been re-run using the latest version of MIKE-21 BW (2023), with updated parameters including a finer grid resolution (7.5m), a reduced time-step (0.1 seconds), and updated bathymetry based on the latest available survey data. These updates ensure compatibility with current modelling standards and enable direct comparison with previous results.

7.2 Long Wave Modelling Approach

The modelling assessed whether the proposed modification to change the dredging, reclamation and port configurations will have a negative effect the behaviour of the long-period waves (e.g., infra-gravity and swell waves) within Port Kembla, potentially leading to increased wave-induced movement of moored vessels. To properly resolve complex wave processes within the Harbour, nearshore wave penetration (i.e., how much wave energy from the ocean or outer harbour makes it into the more sheltered, inner parts of the port or coastal area, particularly through or around breakwaters, channels, or entranceways) and long wave modelling was undertaken using the MIKE-21 BW wave modelling system developed by DHI.

7.3 Results

Figure 7-2 and **Figure 7-3** present the modelled long-period wave significant wave height for the existing, approved concept, and the proposed modification layouts accounting for the proposed dredging, the revised reclamation footprint, and the updated quay wall configurations associated with the proposed modification to the layout.

For the approved concept layout, the modelling results indicated that the proposed changes to the Outer Harbour reclamation footprint would increase the long period wave height in the re-entrant berth area of the approved concept in the Outer Harbour by up to approximately 0.1m compared to the existing case. The long period significant wave height at the quay line berth of the proposed modification (0.3m) is predicted to experience a similar impact as the approved concept layout].

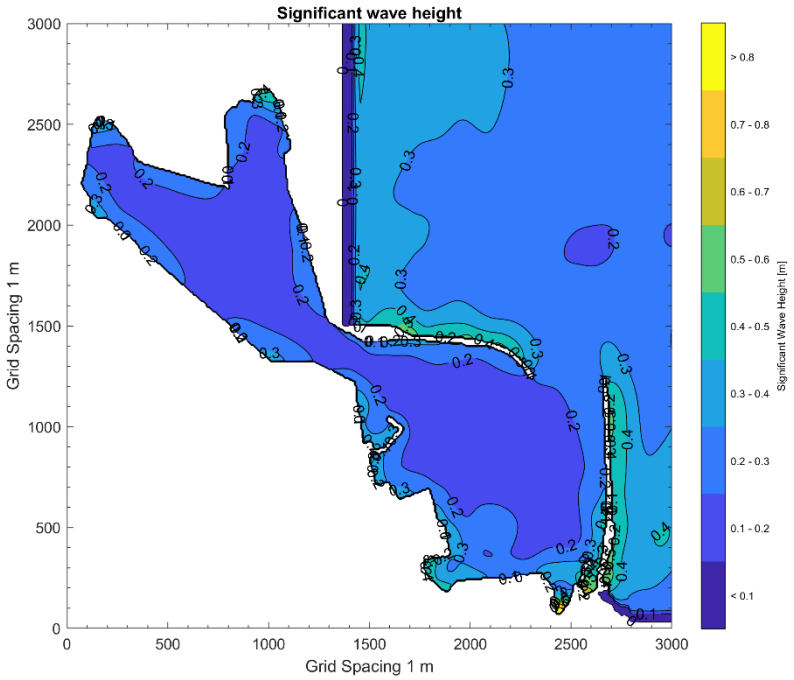

Figure 7-1 Modelled Long Wave Significant Wave Height for the Existing Layout

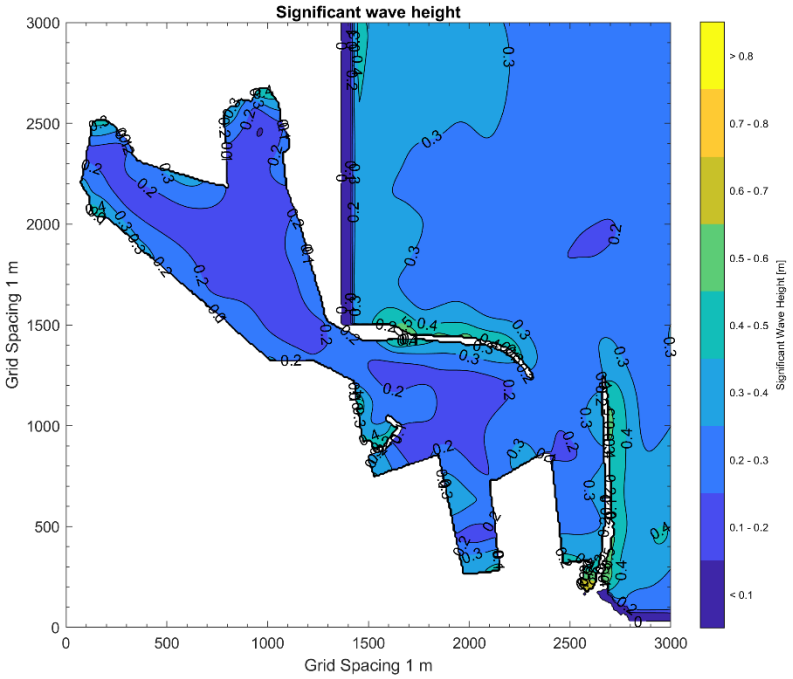

Figure 7-2. Modelled Long Wave Significant Wave Height for the Approved Concept Layout

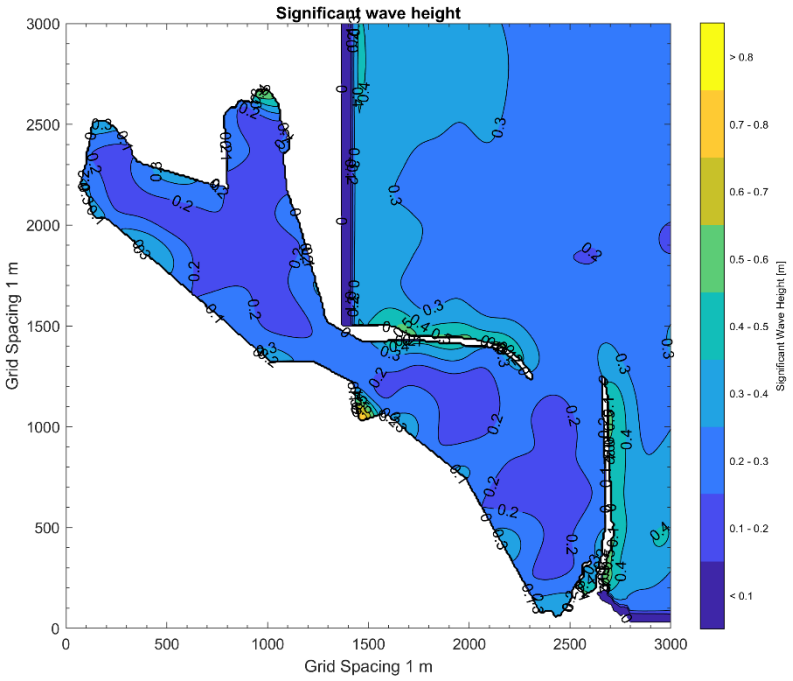

Figure 7-3. Modelled Long Wave Significant Wave Height for the Proposed Modification Layout

8 Hydrodynamic Modelling

8.1 General

Hydrodynamic modelling was used to address several SEARs in modelling the cooling water outflows associated with different discharges from intake and outfall sources within the Port Kembla area including BlueScope's power station and the Squadron Energy Floating Storage and Regassification Unit (FSRU) during operations to describe the effects of changing the impact of the proposed modification on sea water temperature through-out the Harbour.

For this study, hydrodynamic modelling was based on Stantec's existing calibrated and validated Port Kembla 3D hydrodynamic (DELFT-3D) model, which has been extended and applied for different studies within this area.

8.2 Delft3D

The Delft3D modelling system includes wind, pressure, tide and wave forcing, three dimensional current, stratification, sediment transport, cooling water and water quality descriptions and can use rectilinear or curvilinear coordinates.

Delft3D comprises several modules that provide the facility to undertake a range of studies. All studies generally begin with the Delft3D-FLOW (hydrodynamics) module. From Delft3D-FLOW, details such as velocities, water levels, density, salinity, vertical eddy viscosity (i.e., how easily it mixes) and vertical eddy diffusivity (i.e., how easily things like heat, salt, or pollutants mix) can be provided as inputs to the other modules. The wave and sediment transport modules can work interactively with the FLOW module through a common communications file.

8.2.1 Hydrodynamic Numerical Scheme

The Delft3D FLOW module is based on the robust numerical finite-difference scheme developed by G. S. Stellling (1984) of the Delft Technical University in The Netherlands. Since its inception, the Stelling Scheme has had considerable development and review by Stelling and others.

The Delft3D Stelling Scheme arranges modelled variables on a staggered Arakawa C-grid. The water level points (pressure points) are designated in the centre of a continuity cell and the velocity components are perpendicular to the grid cell faces. Finite difference staggered grids have several advantages including:

- Boundary conditions can be implemented in the scheme in a rather simple way.
- It is possible to use a smaller number of discrete state variables in comparison with the discretisation of non-staggered grids to obtain the same accuracy; and
- Staggered grids minimise spatial oscillations in the water levels.

Delft3D can be operated in 2D (vertically averaged) or 3D mode. In 3D mode, the model uses the σ-coordinate system first introduced by N Phillips in 1957 for atmospheric models. The σ-coordinate system is a variable layer-thickness modelling system, meaning that over the entire computational area, irrespective of the local water depth, the number of layers is constant. As a result, a smooth representation of the bathymetry is obtained. Also, as opposed to fixed vertical grid size 3D models, the full definition of the 3D layering system is maintained into the shallow waters and until the computational point is dried.

From a user point of view, the construction of a 3D model from a 2D model using the σ-coordinate system in Delft3D is affected by entering how many layers are required and the percentage of the depth for each layer. It is most

common to define more resolution at the surface and at the bed where the largest vertical gradients occur. Boundary conditions can also be adjusted from depth averaged to specific discharges and concentrations per layer also.

Horizontal solution is undertaken using the Alternating Direction Implicit (ADI) method of Leendertse for shallow water equations. In the vertical direction (in 3D mode) a fully implicit time integration method is also applied.

Vertical turbulence closure in Delft3D is based on the eddy viscosity concept.

This technical explanation is provided to demonstrate the scientific validity and reliability of the modelling approach used in the hydrodynamic assessment. By applying well-established and peer-reviewed numerical methods, including the Stelling Scheme, σ-coordinate system, and turbulence closure techniques, the Delft3D model is well-suited to simulate complex water movement and mixing in shallow coastal environments. This underpins confidence in the accuracy of the modelling results used to assess potential impacts associated with the proposed development.

8.2.2 Wetting and Drying of Intertidal Flats

Many estuaries and embayments contain shallow intertidal areas; consequently, Delft3D incorporates a robust and efficient wetting and drying algorithm for handling this sort of phenomenon.

Careful refinement in the intertidal areas and appropriate setting of drying depths to minimise discontinuous movement of the boundaries ensures oscillations in water levels and velocities are minimised and the characteristics of the intertidal effects are modelled accurately.

This capability is particularly relevant in the context of the current study, where accurate representation of intertidal hydrodynamics is important for assessing potential environmental impacts. For example, accurate of wetting and drying areas ensure the transition between wet and dry points realistically avoiding artificial oscillations.

8.3 Model Setup

8.3.1 Grid Resolution and Extent

To provide confidence in the reliability and spatial resolution of the hydrodynamic modelling, the following section outlines the structure and configuration of the computational grid used in the study. This detail supports the technical validity of the results and helps demonstrate that key vertical and horizontal flow processes are appropriately captured

Figure 8-1 shows the computational grid applied to this study. It is a rectilinear grid with 30m horizontal resolution with 251 by 253 grid cells in the north-south and east-west directions, respectively.

The model was run with 10 vertical sigma layers of varying thickness as described below. It included higher vertical resolution at the surface and near the seabed where vertical gradients in horizontal currents are greatest.

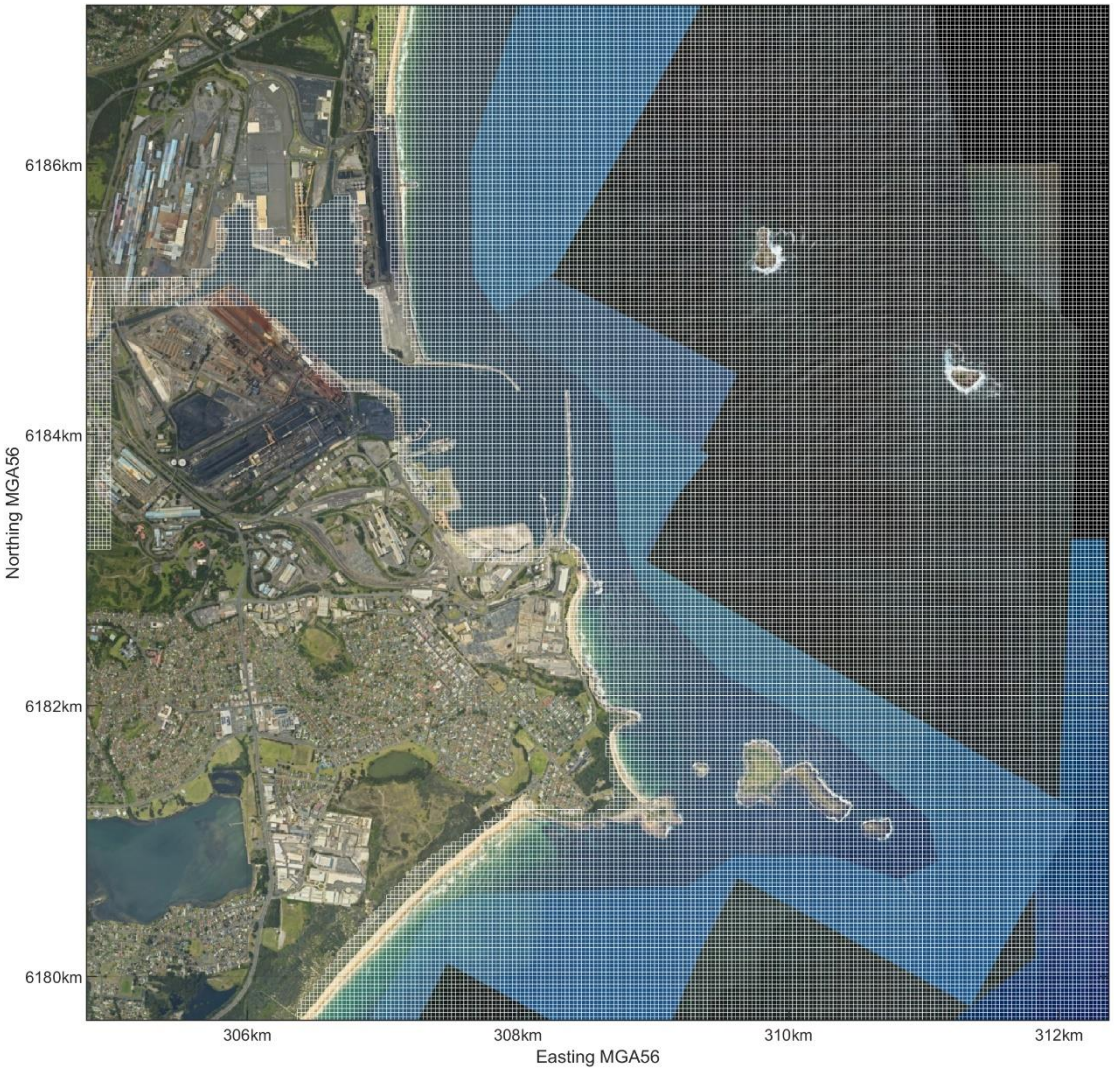

Figure 8-1. Computational Grid – Hydrodynamic Model

Table 8-1. Vertical Grid Resolution

Sigma Layer	Thickness (% of water depth)
1 (surface layer)	2
2	5
3	9
4	14
5 (mid-depth)	20
6	20
7	14
8	9
9	5
10 (bottom layer)	2

8.3.2 Model Bathymetric Data

Bathymetric data were used to describe the seabed of the harbour basins, Allans Creek and the shoreline perimeter of the waterways of Port Kembla. This detailed information was available from a range of sources including:

1. Recent bathymetric survey data provided by Arup and NSW Ports inside the Inner and Outer Harbours
2. Nautical charts offshore of Port Kembla (AUS Chart 195)
3. Survey data in Stantec's internal database from previous projects in Port Kembla.

Figure 8-2 to **Figure 8-4** depict heatmaps for different port layout options used in the present study. Before interpolating the bathymetric data onto the model grid, each dataset was transformed to common horizontal and vertical datums (MGA zone 56 and AHD). The data interpolation process was also prioritised such that where overlapping survey data is available, the more recent surveyed data is used.

This bathymetric data was used also for wave modelling but using different grid layouts and grid sizes.

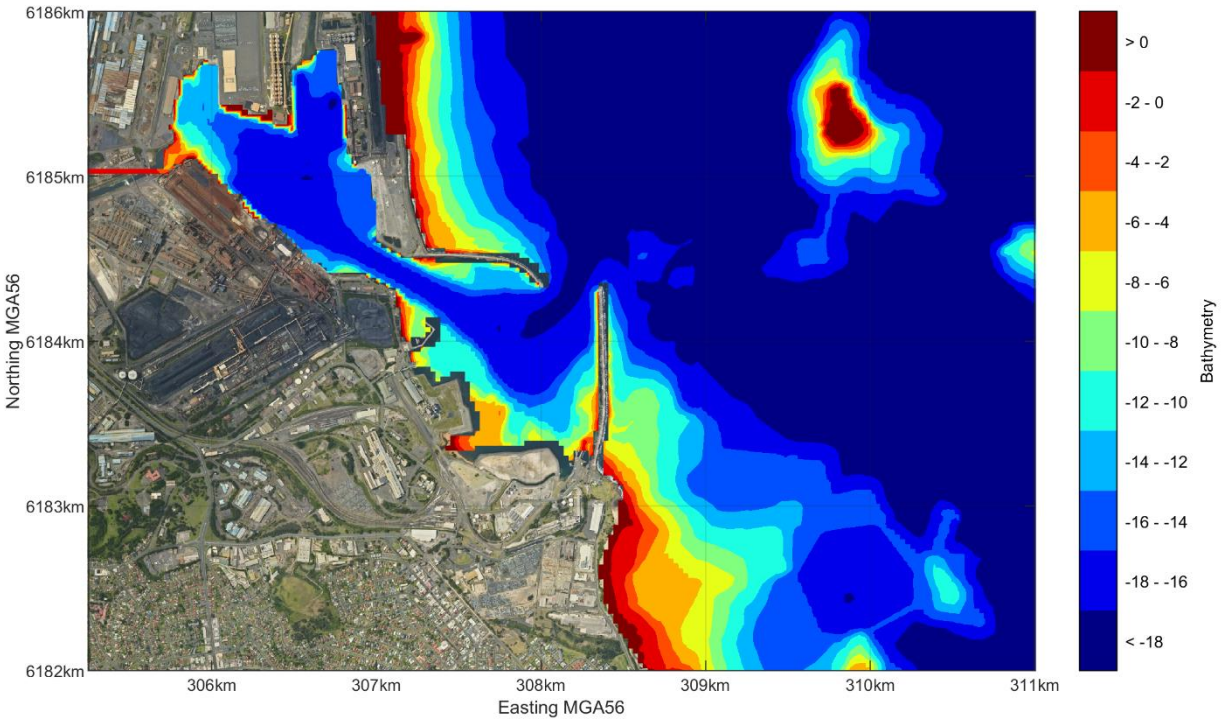

Figure 8-2. Heatmap of Bathymetry for Existing Layout

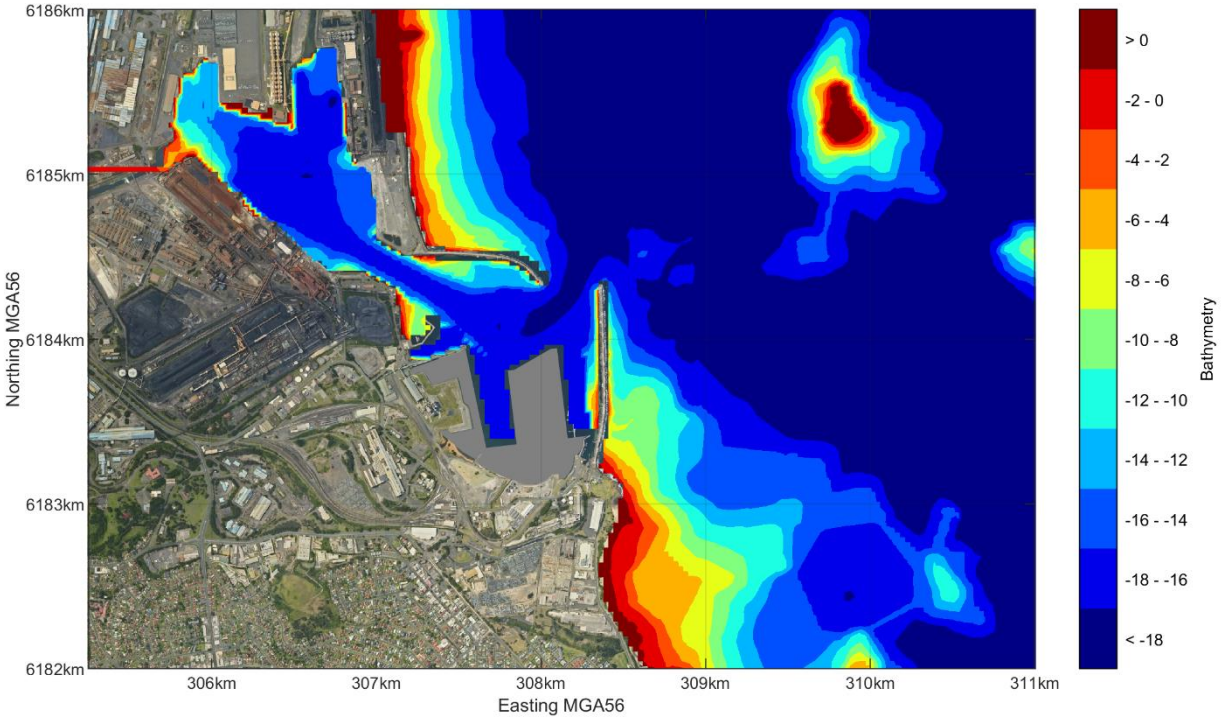

Figure 8-3. Heatmap of Bathymetry for the Approved Concept Layout

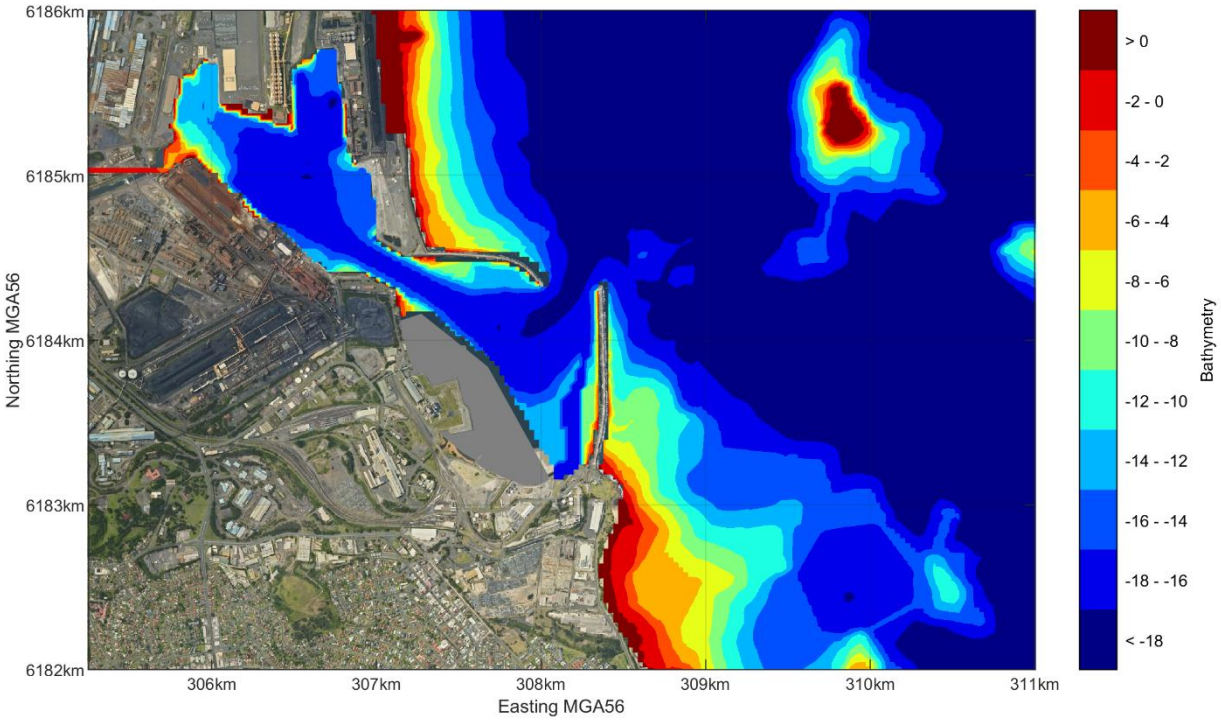

Figure 8-4. Heatmap of Bathymetry for the Proposed Modification Layout

8.3.3 Boundary Conditions

To ensure realistic simulation of water level fluctuations and current patterns at the model boundaries, offshore tidal boundary conditions were extracted from established global tidal models. Offshore tidal boundary conditions were extracted from a combination of the DTU10 (Technical University of Denmark Tidal Model), which is based on a finite element solution of the global tides with data assimilated from seventeen years of satellite altimeter readings. The methodology of the global tide models is described in Cheng and Anderson (2010). DTU10 provides up to twelve tidal constants on a 1/8-degree resolution full global grid. The tides are provided as complex amplitudes of earth-relative sea-surface elevation for ten primary (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1, S_1 and M_4) harmonic constituents. Four additional constituents (M_f, M_m, MS_4 and MN_4) were sourced from the TPx07.2 tide model, which uses along track averaged altimeter data from the TOPEX/Poseidon and Jason (on TOPEX/Poseidon tracks since 2002) satellites.

8.3.4 Time-Step

A time-step of six seconds was adopted to fulfil accuracy requirements based on the Courant Number.

8.3.5 Results

Figure 8-5 and Figure 8-6 present changes in maximum tidal currents resulting from modifications to the outer harbour configurations:

1. From the existing to the approved concept layout
2. From the existing to the proposed modification layout

Overall, changes in tidal currents are expected to be relatively minor. For example, under the approved concept layout, tidal currents at the harbour entrance are expected to decrease by up to 0.6cm/s, while currents in the outer harbour may increase up to 0.5cm/s for the approved concept layout. In comparison, the proposed modification layout results in even smaller changes, with surface currents at the entrance harbour decreasing by up to 0.4cm/s, and currents within the outer harbour increasing up to 0.1cm/s.

The reduction in tidal currents at the entrance attributed to a decrease in tidal prism (i.e. less water flowing through the harbour entrance during each tidal cycle). Conversely, the slight increase in tidal current within the outer harbour may be due to changes in the harbour configuration that constrict and redirect flow through the inner harbour area.

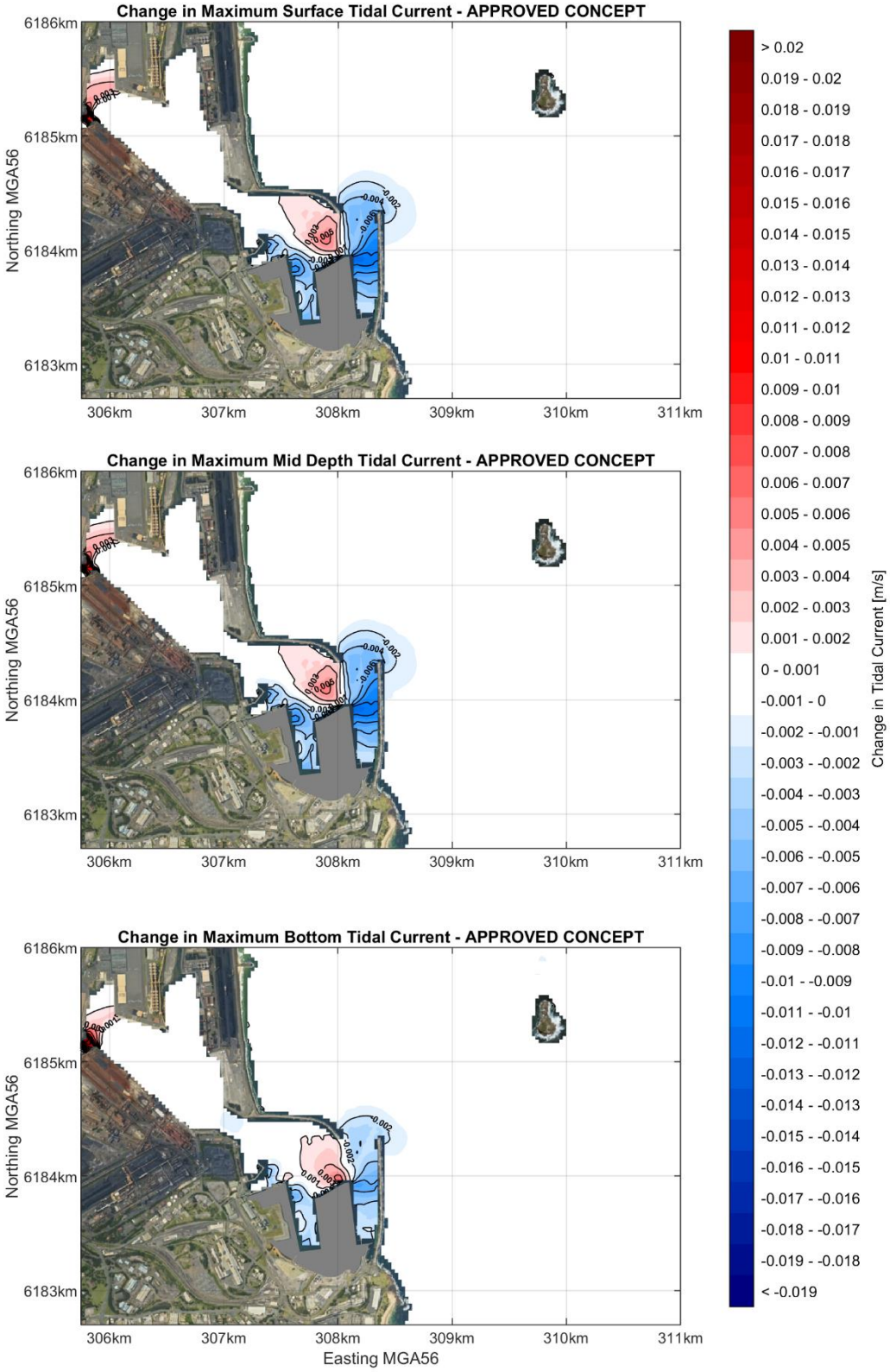

Figure 8-5. Changes in Maximum Tidal Currents - Approved Concept Layout

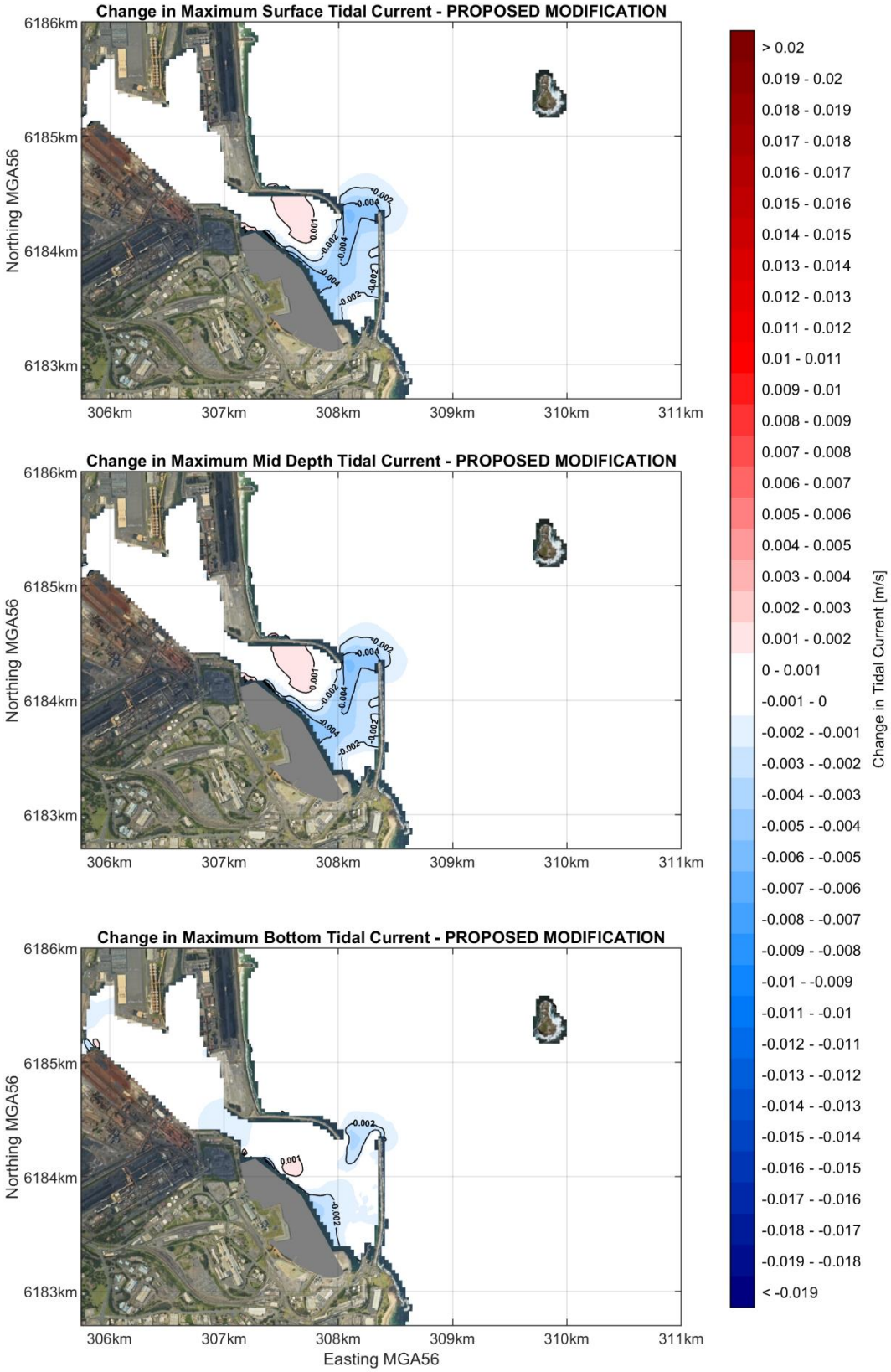

Figure 8-6. Changes in Maximum Tidal Currents – Proposed Modification Layout

9 Thermal Plume Modelling

9.1 Introduction

Within the Port Kembla area, there are several cooling water intakes and outfalls currently in operation, including those operated by BlueScope Steel and Squadron Energy. The discharge and heat load for these existing intakes/outfalls have been taken from Cardno's (now Stantec) previous cooling water investigations in Port Kembla (Cardno Lawson Treloar, 2007), Cardno (2020). Furthermore, recently Squadron Energy has recently installed a FSRU, which is moored permanently within the Port Kembla Inner Harbour (IH) at Berth 101 and would receive liquid gas periodically from a visiting LNG carrier. As part of the process, the facility would draw-in seawater from within the Inner Harbour and then discharge colder water as part of the liquid gas warming process. During this process the seawater is cooled by a maximum of 7 degrees compared to the water drawn in through the intake. This facility is under construction and has been included in the modelling.

The discharge data applied in the model are presented below in **Table 9-1**. Note that the water temperature modelling has been undertaken for typical existing summer and winter conditions to capture seasonal variations in thermal stratification, circulation, and potential mixing, which can significantly influence modelled outcomes.

Table 9-1. Cooling Water Flows

Modelled Flows					
Model Source No		Summer Conditions		Winter Conditions	
		Flow (m^3/s)	ΔT (ºC)	Flow (m^3/s)	ΔT (ºC)
1	Main Drain	1.174	7.1	1.517	6.28
2	No.2 Blower Station	7.953	6.44	8.211	7.11
3	Iron Making East	0.208	4.05	0.100	3.06
4	3500mm Plate Mill Drain	0.395	2.84	0.408	2.41
5	Slab Mill Drain	0.013	31.41*	0.016	21.37*
6	No. 1 Flat Products East Drain	0.112	4.64	0.196	4.35
7	Allans Creek Flow	0.17	22.5*	0.170	16.80*
8	North Gate Drain	0.077	28.06*	0.102	17.98*
9	Squadron Energy FSRU	2.917	-7.0	2.917	-7.0

** Presented as absolute temperature rather than excess*

9.2 Modelling Scenarios

As noted above, simulations were undertaken for summer and winter months in combination with three different layouts. This means six scenarios were modelled.

1. Existing layout during summer
2. Existing layout during winter
3. Approved concept layout during summer

4. Approved concept layout during winter
5. Proposed modification layout during summer
6. Proposed modification layout during winter

9.3 Results

Modelled water temperature results are presented in **Appendix A** to **Appendix J**. These results include water temperature contour plots including the minimum, 5th, 10th, 15th, 20th, 50th (median), 80th, 85th, 90th, 95th percentiles at each grid point and the maximum temperature for each scenario (to provide a comprehensive understanding of the spatial distribution and variability of thermal conditions, allowing assessment of both typical and extreme temperature patterns), together with the difference or change in sea water temperature due to changes in the above harbour configurations/layouts.

Under the approved concept layout,

- Surface temperature is predicted to increase by approximately 0.1°C in the summer, while temperature near the bottom is predicted to decrease by up to 0.3°C (see **Appendix G**). This change is confined to the footprint of the approved concept layout.
- In winter, there is no change in temperature near the surface, but near the bottom, the temperature is predicted to decrease by up to 0.2°C in the dock area within the approved concept footprint.

For the proposed modification layout

- No change in surface water temperature is predicted in the summer, but near the bottom, the temperature is predicted to decrease by up to 0.6°C in the area near the coastline between the proposed modification layout and the eastern breakwater (**Appendix H**).
- In the winter, there is an increase in the minimum surface temperature up to 0.1 degrees in the outer harbour, but the temperature remains unchanged for higher percentile levels

The modelling indicates that thermal impacts from both the approved concept and the proposed modification are minor, localised, and generally limited to the near-bottom water layers. Under the approved concept, a slight surface warming (+0.1°C) and bottom cooling (–0.3°C) are predicted in summer, while only a small bottom cooling (–0.2°C) occurs in winter, all within the approved footprint. Under the proposed modification, no surface warming is predicted in summer, but a slightly larger bottom cooling (–0.6°C) is expected near the eastern breakwater, indicating a minor spatial shift and slightly greater thermal effect near the seabed. There is an increase in the minimum surface temperature up to 0.1 degree in the outer harbour. Overall, the temperature changes are small and are unlikely to result in ecologically or operationally significant effects.

10 Harbour Flushing Modelling

10.1 General

Flushing modelling was undertaken for the existing, approved concept and proposed modification layouts to assess the relative tidal flushing performance (i.e., how effectively tidal movements can replace or replenish the water in the area helping disperse heat, nutrients, or pollutants and maintain water quality) of the different layout options. Initially the entire Harbour (both Inner and Outer) was filled with a conservative tracer throughout the water column with a concentration of 100. Conservative tracer testing can provide a measure of the flushing rate of a particular section of a waterbody (estuary, canal, enclosed harbour etc). This was done to determine whether any of the layout changes would reduce water exchange and potentially affect water quality or ecological conditions. A useful measure for quantification of the flushing time is to determine the e-folding time, which refers to the time taken for a tracer such as a dye to dilute to 1/e or approximately 36.8% of its initial concentration. The value 1/e is used because it represents the characteristic timescale of exponential decay, making it a standard and mathematically consistent way to compare how quickly water is replaced or flushed from a system.

10.2 Modelling Scenarios

Three different tidal forcing model scenarios were undertaken in 3D to model the influence of the tides:

- Scenario 1: Tidal forcing with intake/outfall inputs + atmospheric fields
- Scenario 2: Tidal forcing with intake/outfall options
- Scenario 3: Tidal forcing only

In general, Scenario 1 is the most realistic as it includes tide, wind and all intake and outfall sources available within the harbour area including the cooling water flow from Allan's Creek.

10.3 Results

Appendix L to **Appendix N** present the modelled flushing results for the three scenarios. As noted above, Scenario 1 is the most realistic simulation as it includes the intake/outfall inputs and is also forced with both tides and atmospheric fields. For this scenario, the approved concept and proposed modification provide slightly better flushing performance compared to the existing harbour configuration. Between the approved concept and the proposed modification layouts, the proposed modification is predicted to slightly improve tidal flushing.

At the harbour entrance, the e-folding time is approximately seven days for the proposed modification compared to 8 days under the existing scenario and 7.5 days under the approved concept layout. The e-folding time inside the harbour in the upstream of Allan's Creek is expected to be longer than seven days, but less than 14 days under the proposed modification.

These results indicate that while water exchange is slower in the more enclosed areas of the harbour, overall tidal flushing remains effective. The predicted flushing times are consistent with expectations for a semi-enclosed coastal environment and do not suggest a risk of significant water stagnation. As such, the proposed modification is not expected to result in adverse impacts to water quality or ecological conditions due to reduced tidal exchange.

The flushing time for Scenario 2 and Scenario 3 is predicted to be much longer. For example, **Figure 10-1** to **Figure 10-3** compare the concentration of the three layouts at the bottom layer seven days after introducing the conservative trace (at an initial concentration of 100). As shown in Figure 10-1, the tracer concentration inside Port Kembla under Scenario 1 remains at approximately 35 in the upper section of the Port. This is much lower than the residual tracer concentration under Scenario 2 and Scenario 3, which have a concentration of approximately 85.

The results demonstrate that Scenario 1, which includes tidal forcing, intake/outfall flows, and atmospheric fields, results in significantly more efficient flushing than Scenario 2 and Scenario 3. This indicates that the inclusion of atmospheric processes and operational flows (intake/outfall) substantially enhances water exchange and tracer dispersion. Overall, flushing times from the entrance to the proposed modification footprint range from seven to 14 days, with slower exchange observed in the more enclosed Inner Harbour to the north. These results highlight the importance of including multiple forcing mechanisms in the model to accurately reflect real-world hydrodynamics and to avoid underestimating residence times under modified layouts.

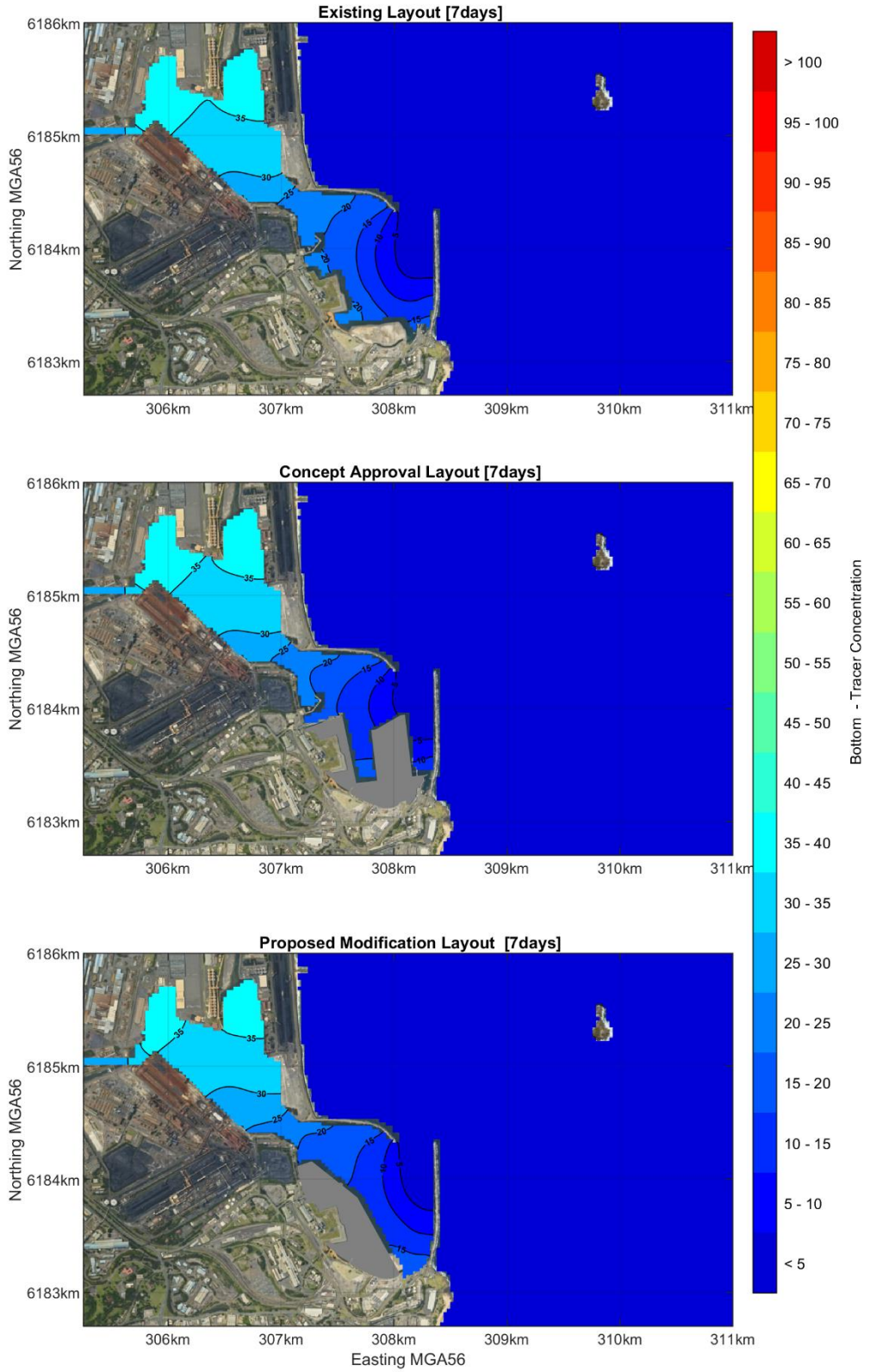

Figure 10-1. Tracer Concentration at Bottom Layer after seven days Modelled with Tidal, Atmospheric Forcing and Discharge/Outfall Inputs (Scenario 1).

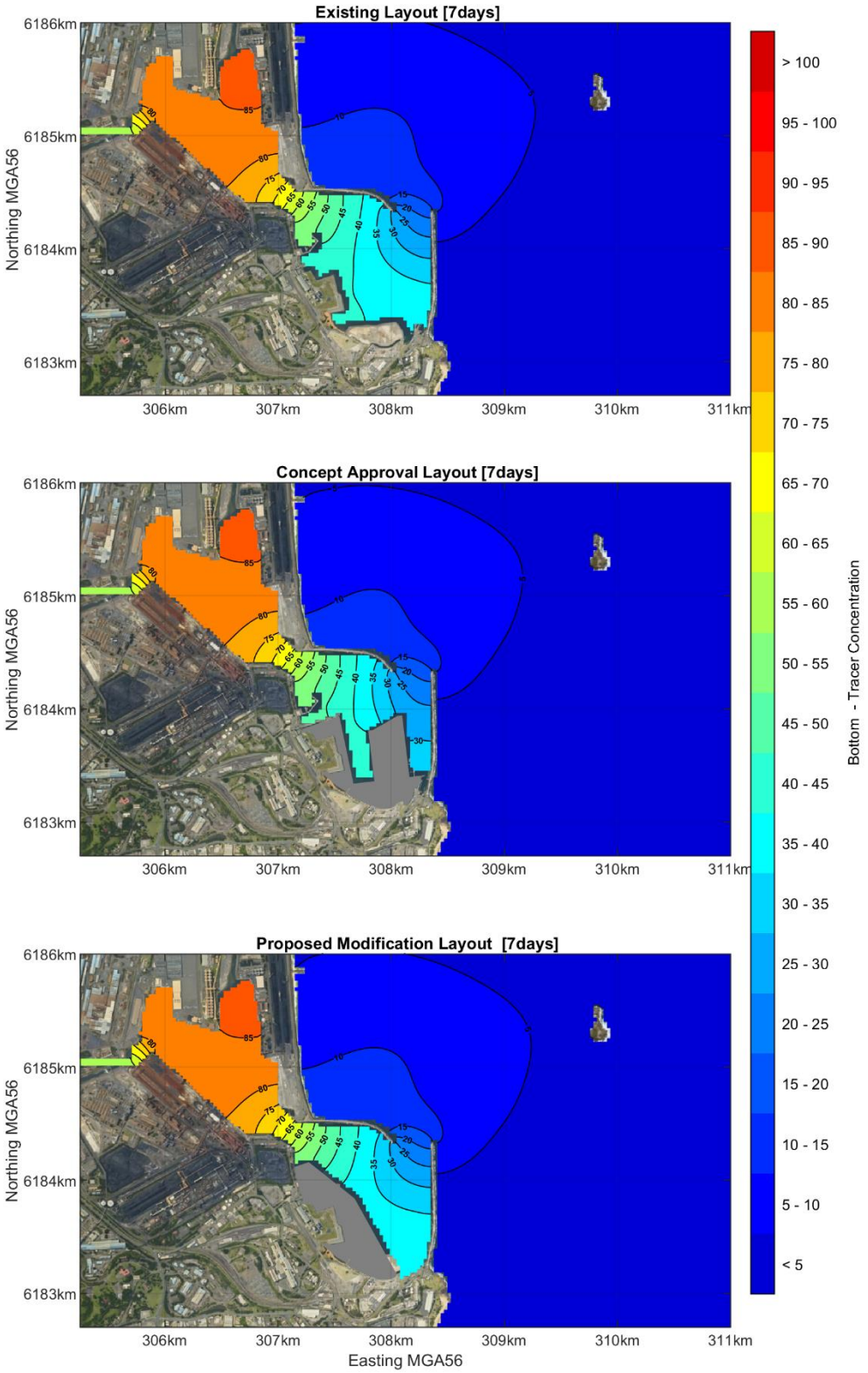

Figure 10-2. Tracer Concentration at Bottom Layer after 7 days Modelled with Tidal Forcing and Discharge/Outfall Inputs (Scenario 2).

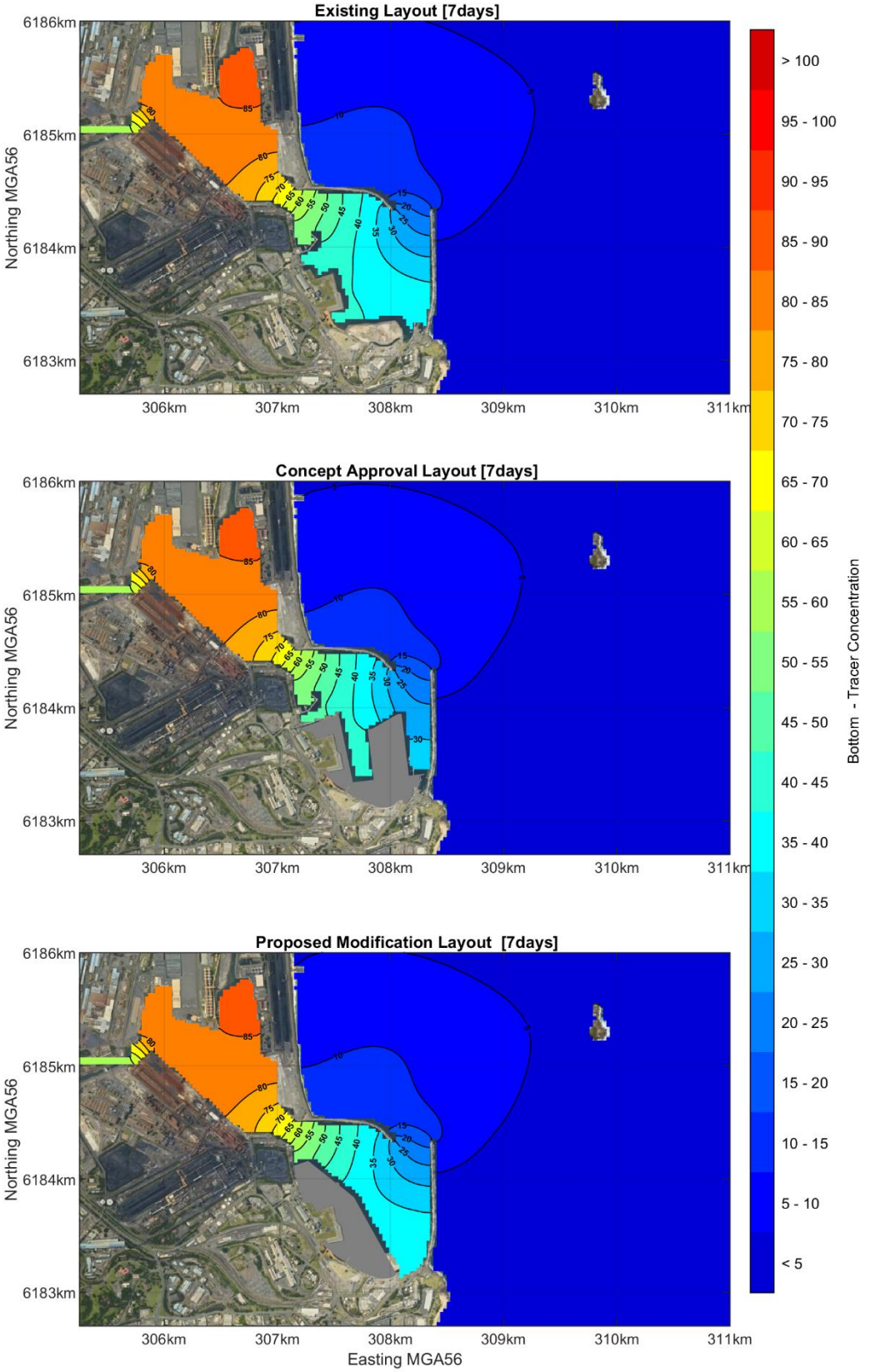

Figure 10-3. Tracer Concentration at Bottom Layer after seven days Modelled with Tidal Forcing only (Scenario 3).

11 Dredge Siltation Modelling

The proposed dredging for the construction of the new berths under the proposed modification, and concurrent reclamation within the Outer Harbour will cause some re-suspension of fine sediments. These processes are discussed below.

11.1 Dredging

11.1.1 Soft Sediment Dredging

The dredging process will involve a small cutter suction dredger (CSD) operating continuously. With a production rate of 15,000 m³/day and based on the estimated volume of soft sediment to be dredged (833,675 m³), as outlined in the approved project environmental impact statement (EIS), the dredging is expected to take approximately 55 days to complete. The CSD will cut and loosen the seabed material using a rotary cutter head. This will then mix with the surrounding seawater to form a slurry, before being pumped through a floating/submerged pipeline to the reclamation area, where it will be discharged between subsea bunds created around the perimeter. Dredging will commence on the northeastern side, near the entrance to the Port, and progress shoreward. The containment bunds will be fully constructed before dredging begins to ensure proper material management. This method avoids any overflow of sediment at the surface from using a hopper to transport the material.

Based on observations made by Barnard (1978), about 10% of the total fines within this sediment mass (the sediment load) would be released to the water column during dredging. In the Outer Harbour areas, it has been indicated that fine sediments consist of 19% clay and 45% silt, therefore providing at total fine content of 64%. Sediment fall-velocities (i.e., the speed at which sediment particles sink through the water) for clay and silt have been assumed to be 0.1 mm/s and 0.4mm/s, in the model respectively.

While the approved project EIS proposed the use of a silt curtain around the dredger as a mitigation measure, this was not included in the model scenarios. This reflects a conservative approach, ensuring that the modelling predicts the potential worst-case extent of the sediment plume without relying on mitigation performance that can vary depending on environmental conditions and operational effectiveness. As such, the results provide a robust basis for understanding and managing potential water quality impacts during dredging.

11.1.2 Rock Dredging

Rock dredging will commence after the completion of soft sediment dredging, ensuring that the two processes do not overlap. This phase will involve the use of a grab dredge operating continuously. With a production rate of 2,000 m³/day, the dredging is expected to take approximately six months to complete, based on the estimated volume of rock to be dredged (383,575 m³) as outlined in the approved project EIS. The dredged rock material will be loaded onto barges and subsequently bottom dumped into the reclamation area, on top of the previously deposited soft material, but within the confines of the underwater bunds. Due to the much lower dredging rate, and the minimal generation of fine sediment through using a grab, this phase has not been modelled.

11.2 Reclamation

Reclamation activities will follow completion of the dredging. Initially, temporary revetments will be constructed around the outer perimeter of the reclamation area. Clean fill, with minimal fines content, will then be placed within the bunded

area. Given the low fines content and confined placement of the fill, the potential sediment plumes generated during this phase of the project will be considerably less than dredging generated plumes. This has not been modelled.

11.3 Results

Appendix K presents contour plots of the simulated suspended sediment concentrations under existing layout scenario]. They are presented as percentile plots, including the 5th, 10th, 15th, 20th, 50th (median), 80th, 85th, 90th, 95th and the maximum TSS concentration. This range of percentile plots provides a comprehensive view of both typical and extreme suspended sediment concentrations across the modelled area, helping to identify zones of consistent exposure as well as areas subject to occasional higher sediment levels. These plots do not show a single point in time, but rather a summary of how far the sediment plume spreads and how concentrated it is through the whole period dredging takes place. The percentile values represent the percent of time for which the plume is predicted to be at or below the values presented in the plots. For example, the TSS values presented on the 85th percentile plots are the TSS concentrations that are exceeded for 15% of the time; and these concentrations vary spatially.

Suspended sediment concentration plots have been provided for the surface, mid-depth and bottom layers of the model to capture how sediment disperses vertically in the water column and to assess potential impacts on different parts of the marine environment.

Sediment Dispersion and Turbidity

The predicted model results show the plume to be generally confined to within the Harbour. The maximum TSS concentration at the entrance to the Port is predicted to be 5 mg/L above background**,** which is often used as the trigger value for assessing potential impacts to aquatic ecosystems under the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), particularly in slightly to moderately disturbed marine and estuarine systems. Although modelling of sediment plumes for the approved concept was not undertaken during this or the previous EIS, the extent of dredging for the proposed modification is similar to extent proposed modification.

Based on this, the spatial extent of the sediment plumes generated for the proposed modification will be very similar to the sediment plumes generated during construction of the approved concept.

Sediment Deposition

Figure 11-1 shows the predicted maximum deposition thickness developed from the start to the end of the simulation (i.e., over the course of the proposed 55 day dredging program). It shows that sediment from the dredging will sink and build up in the area designed for dropping the piped dredged material in the reclamation area. This is due to the very low current speeds within the Harbour, which minimises the spreading and travel distance of the suspended sediment, despite the high proportions of fines. No noticeable sedimentation is predicted to occur outside of the Harbour.

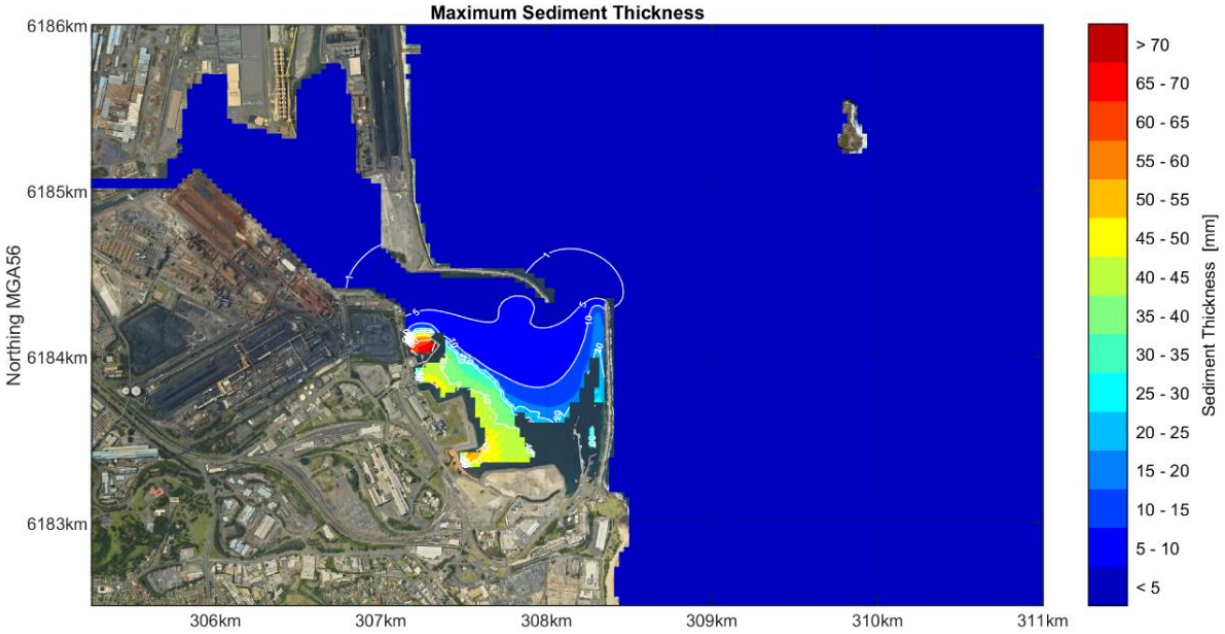

Figure 11-1. Modelled Maximum Sediment Thickness on the Seabed.

12 Ecological Impacts

This section summarises the potential ecological impacts of changes to coastal processes from the proposed modification discussed in this report.

Spectral wave modelling shows offshore waves from the east north-easterly direction cause the largest wave heights at the entrance to the Outer Harbour. The reconfiguration of the southern reclamation area under the proposed modification is predicted to generate more swell wave disturbance (from offshore waves penetrating into the harbour from the east north-easterly direction) compared to the existing layout and the previous approved concept, due to higher reflection from the newly introduced quay walls. An increase in water turbulence resulting from increased wave activity adjacent to the northern and eastern breakwaters is unlikely to have a negative impact on ecology of the Outer Harbour, particularly if less reflective structures are incorporated instead of vertical quay walls, such as a suspended deck above a rock-armored revetment.

Long wave modelling predicts overall similar conditions to those under the approved layout, with the most notable changes occurring near the northwest corner of the proposed berth (Stantec, 2025)[3]. This is not expected to introduce new ecological impacts to the Outer Harbour.

Thermal plume modelling indicates that, under the proposed modification, no surface warming is predicted in summer, but a slightly larger bottom cooling compared to that under the approved concept (–0.6°C) is expected near the eastern breakwater. This minor spatial shift and slightly greater thermal effect near the seabed is unlikely to introduce new ecological impacts to the Outer Harbour.

Precited tidal flushing times are consistent with those expected for semi-enclosed coastal environment, with a slight improvement to tidal flushing predicted under the proposed modification. There is no introduced risk of water stagnation or other changes to tidal flushing that could be expected to cause ecological impacts within the Outer Harbour.

Dredging activities are predicted to cause a temporary increase in water turbidity (increased TSS) and sediment deposition. Sediment plume modelling found that TSS concentrations would be consistently higher towards the bottom of the water column due to the nature of sediment release and settling. Maximum bottom TSS would exceed 50 mg/L in the immediate vicinity of the dredging and reclamation area for a period of approximately 55 days during dredging activities. Maximum sedimentation loads would reach up to 70 mm around the tug berth area during dredging activities. Maximum sedimentation loads in the vicinity of the remaining dredging and reclamation area would range from 10 – 60 mm. The areas most likely to experience increased sedimentation are the northern part of the eastern breakwater and the area directly north of the tug berth. Of all changes to coastal processes discussed in this report, increased TSS and sedimentation pose the most potential ecological risk within the Outer Harbour. These potential impacts and proposed mitigation measures are discussed in the Aquatic Ecology Assessment for the proposed modification (Stantec, 2025).

As little cover of macroalgae (organisms susceptible to increased TSS due to reduced light for photosynthesis) was recorded in the additional area that would be exposed to elevated TSS with the proposed modification, it is unlikely

[3] It refers to coastal processing modelling report (this report)

that dredging activities would significantly impact macroalgal assemblages, and in turn, associated aquatic fauna in the study area.

Sessile invertebrates and any associated mobile fauna that occupy the areas near the tug berth and eastern breakwater would be at risk from increases in turbidity as a result of impaired filtration, respiration, feeding capacity and settlement. Increases in turbidity can also have detrimental effects on mobile aquatic fauna that occupy the areas near the tug berth and eastern breakwater by inhibiting vision, respiration and/or mobility. Increases in TSS during proposed dredging activities would likely temporarily displace mobile fauna that occupy the tug berth and eastern breakwater, however, there would be sufficient unaffected habitat available in PKOH for fauna to temporarily relocate to. Smaller and less mobile species such as fishes in the order Syngnathiformes (seahorses, sea dragons, pipefish) would likely be at higher risk from elevated TSS as they move slowly and may be unable to escape the immediate area of the disturbance. Threatened and protected Syngnathiformes, including the White's seahorse, could occupy rock revetment and piling with macroalgal and/or sessile invertebrate coverage within the study area and may experience impaired respiration, reproduction and foraging success as a result of increased turbidity. Sedimentation (deposition of sediments) has similar impact pathways to biota to TSS, however mostly affects sessile species such as filter-feeding invertebrates and macroalgae, as well as benthic infauna which usually have limited mobility. As for TSS, sedimentation is unlikely to negatively affect macroalgae as there is little cover of these organisms present in the areas most susceptible to increase sedimentation. Sedimentation could affect infaunal and epifaunal invertebrate assemblages that occupy the areas near the tug berth and eastern breakwater by reducing filtration, feeding capacity, settlement and/or mobility. Burial of infauna in soft sediments can lead to mortality at depths over 100 mm and can cause clogging of feeding and respiration structures leading to mortality and reduce settlement success. The disturbance of sediments via dredging also has the potential to disturb and re-suspend contaminants (e.g. heavy metals) and toxic dinoflagellates, which could produce harmful algal blooms. These further impact pathways can similarly affect marine biota by interfering with their physiology and behaviour. These potential impacts and proposed mitigation measures are discussed in the Aquatic Ecology Assessment for the proposed modification (Stantec, 2025).

13 Climate Change Impacts

Stantec have considered project climate change for this region in terms of likely met-ocean changes. These parameters relate mainly to:

- Projected sea level rise
- Potential intensification and change of character of ocean storms and consequential changes to wave conditions within Port Kembla

13.1 Sea Level Rise

Watson (2022) provides recent estimates of sea level for a range of planning periods to 2100 for a range of postulated industrial scenarios based on analyses of long-term water level data at Fort Denison in Sydney Harbour, these water levels may be considered appropriate for planning in Port Kembla. Example levels in 2075 are:

100-years ARI 1.88m AHD

500-years ARI 1.92m AHD

These future levels will not have an identifiable effect on wave penetration to Port Kembla because entrance depths are relatively great. Hence there is no change in refraction or diffraction. There will unlikely be any change in breaking wave limitations on wave propagation to the harbour entrance.

However, the design of the reclamation should consider future sea level rise to set appropriate quay levels to minimise wave overtopping during severe storms, including future sea level rise. The reclamation levels also depend also on ship characteristics and connections with existing infrastructure.

13.2 Offshore Wave Climate

There is no definitive information that describes future offshore wave conditions. Stantec's experience in wave climate investigations does not indicate any present-day increases in peak event wave heights or an increase in frequency in the occurrence of east-northeast waves (the most sensitive direction for the Outer Harbour).

As part of detailed design, an analysis of a statistical measure of wave height, such as the 90^{th} percentile Hs, should be undertaken to determine any underlying trends in wave height. However, such an analysis must not overlook the very stormy period of the 1970s.

14 Discussion

This report presents the outcomes of the long-period wave, sediment and thermal plume, flushing and dredge siltation modelling studies undertaken to assess the impact of the proposed modification. The main outcomes from the modelling are:

1. Swell wave penetration modelling, undertaken to predict how waves that form far out at sea enter and move through the Harbour, indicates that the proposed modification layout would result in smaller waves at the berth compared to the approved concept. However, this layout is predicted to result in increased wave energy towards B201 and the northern breakwater in the Outer Harbour due to reflections of the proposed northern reclamation area and quay wall compared to the approved concept. The scale of the increase in wave height is approximately 0.8m during a 50 year ARI wave event from the east north-east. Therefore, to reduce internal wave disturbance, it is recommended that a less reflective structure, such as an armoured revetment, be considered for the northern reclamation quay wall in place of vertical or hard-faced structures.
2. Long wave modelling was undertaken to assess how whether changes to the dredging, reclamation and port configurations under the proposed modification will have a negative effect the behaviour of the long-period waves (e.g., infra-gravity waves which can result in resonance within the harbour and cause large mooring loads and vessel movement) within Port Kembla. The results predict that relative to the currently approved concept, the proposed modification proposed modified reclamation footprint will result in comparable long wave significant wave heights specifically resulting in an estimated long wave significant wave height of 0.3m at the proposed berths. For the proposed modification, the most notable increase in the long wave height is predicted near the northwest corner of the proposed berth, and it is recommended that a mooring analysis be undertaken during design to ensure that appropriate mooring loads are applied in the design.
3. Thermal plume modelling has been undertaken to see how water temperature would be impacted under the existing, approved concept and proposed modification layouts. The modelling predicts that only minor changes will occur to the seawater temperature caused by the changes in the proposed modification layout compared to the approved project. These minor changes are localised to the dredged areas.
4. Flushing modelling was carried out to predict how effectively tidal movements can replace or replenish the water in the harbour, helping to disperse heat, nutrients, or pollutants and maintain water quality. The modelling predicts that the proposed modification layout provides a slight improvement in the Outer Harbour in terms of flushing. Specifically, the residence time is predicted to reduce from 7.5 days to 7 days within the Outer Harbour]. In general, the proposed Outer Harbour layout is not precited to cause any substantial impacts to the overall flushing of the Harbour, compared to the approved concept.
5. Dredge siltation modelling, used to predict sediment dispersion and deposition, indicates that sediment plumes from the dredger, discharge and dumping area, will be confined within the Harbour under the proposed modification. The model predicts that the excess suspended sediment concentration outside of the port breakwaters will be up to 5 mg/L during the dredging operations. Although modelling of sediment plumes for the approved concept was not undertaken during this or the previous EIS, the extent of dredging for the proposed modification is similar to extent proposed modification. Based on this, the spatial extent of the sediment plumes generated for the proposed modification will be very similar to the sediment plumes generated during construction of the approved concept. Consistent with the approved concept EIS, the inclusion of silt curtains will minimise the extent of plumes to avoid any material impact on the surrounding water quality and aquatic ecosystems.

14.1.1 Mitigation and Management Strategy

Mitigation and management strategies have been proposed both under the approved concept and for the proposed modification to reduce potential impacts to the ecology of PKOH from changes to coastal processes (Stantec, 2025). The main impact pathways identified in this report are increased water turbidity (as TSS) and sedimentation, which are also linked to increased risk of exposure of biota to contaminants such as heavy metals and the production of harmful algal blooms. Under the approved concept, a Dredging Environment Management Plan (DEMP) is recommended to reduce the spread and associated spatial extent of impacts from the sediment plume. Further, a Water Quality Management Program (WQMP) is recommended to be implemented to monitor the effects of dredging on water quality and ensure any exceedances of those predicted effects to water quality are managed if they occur.

An Algal Bloom Contingency Plan (ABCP) is also recommended to mitigate the risk of harmful algal blooms from sediment disturbance. Discussion of these mitigation measures in the context of ecology can be found in the Aquatic Ecology Assessment (Stantec, 2025).

In addition to those measures already recommended under the approved concept, the development of a Syngnathiformes Management Plan (SMP) has been recommended (Stantec, 2025). This would involve pre-clearance relocation surveys for threatened and protected species such as White's Seahorse (Hippocampus whitei) prior to construction activities, mitigating the risks posed to such species due to their limited mobility and reduced ability to escape disturbances compared to other fishes.

These measures established, along with the construction of less reflective structures in the Outer Harbour to minimise wave energy reflection, will ensure the ecology and coastal processes of Port Kembla Outer Harbour is maintained.

14.1.2 Residual Impacts

The principal residual impact will be an increase in wave heights/energy in the Outer Harbour caused by the typical straight-line quays and the very reflective vertical walls. Generally, swell waves entering the harbour will have crests partially parallel with the modified quay lines.

These conditions might be mitigated by suspended deck quays over a rock batter – investigate during detailed design.

15 References

Barnard, W. D. (1978). Prediction and control of dredged material dispersion around dredging and open-water pipeline disposal operations. Waterways Experiment Station

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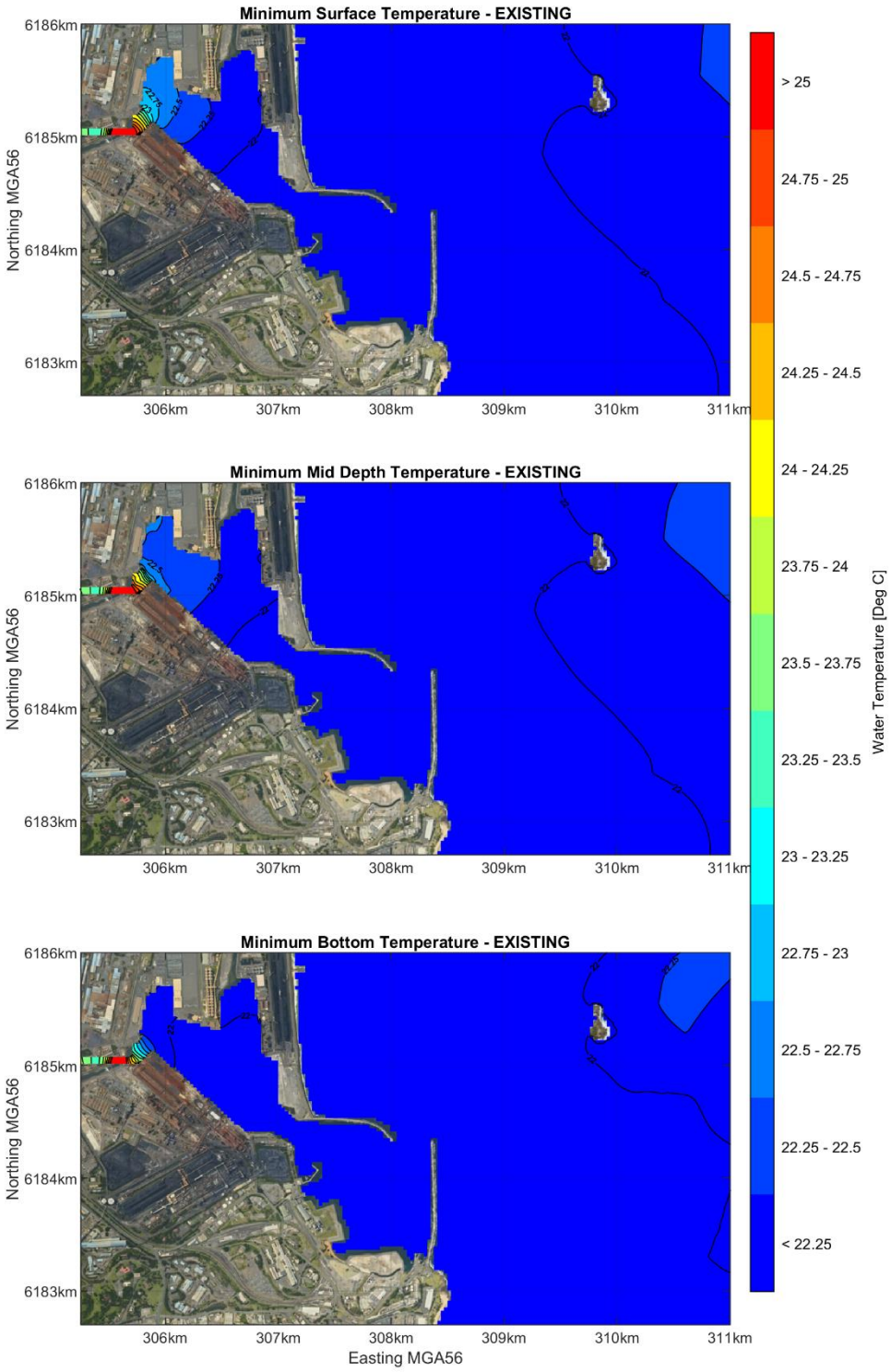
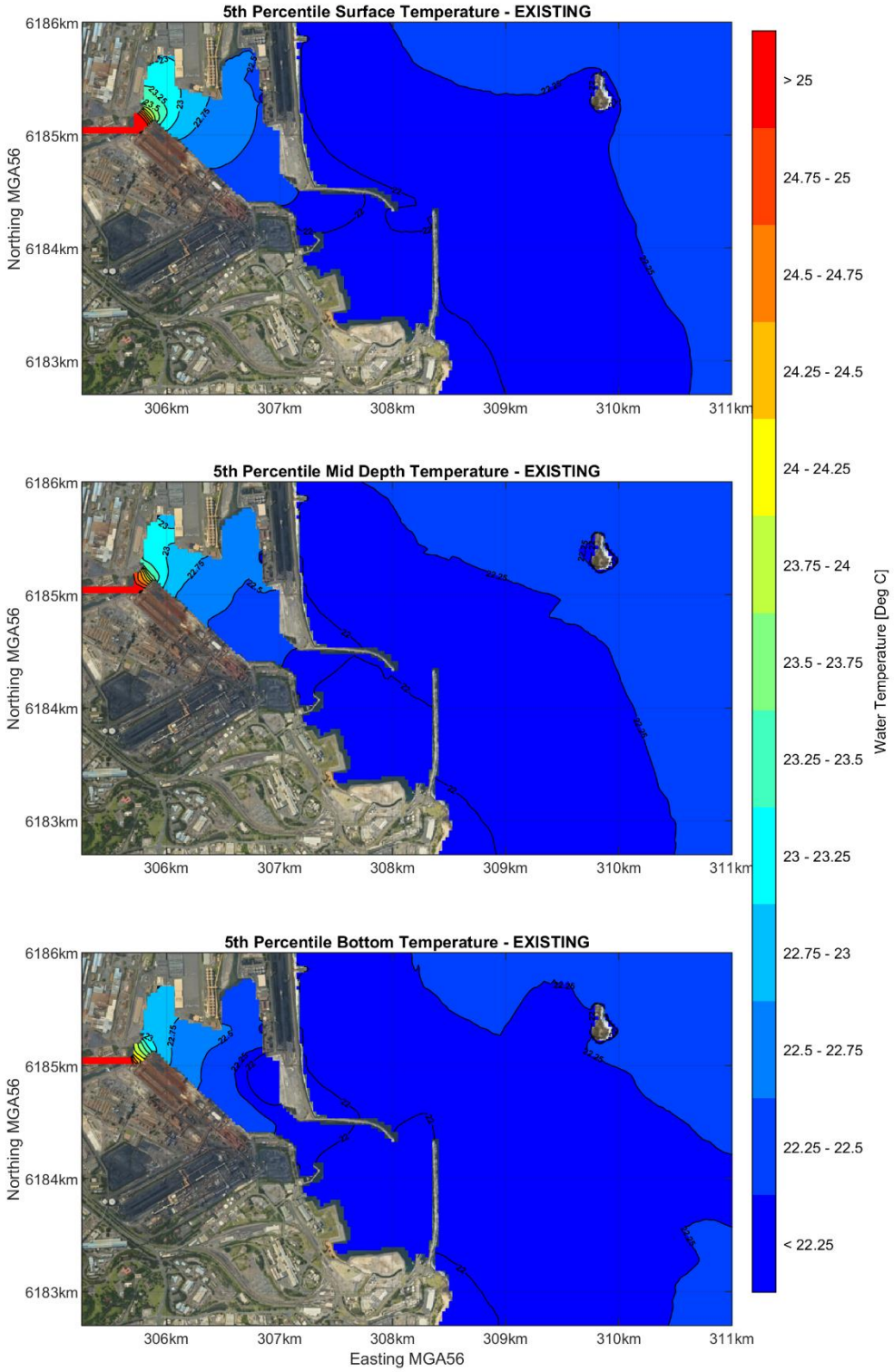
Appendices

Appendix A Summer Thermal Plume Results: Existing Layout



Modelled Minimum Summer Water Temperature – Existing Layout



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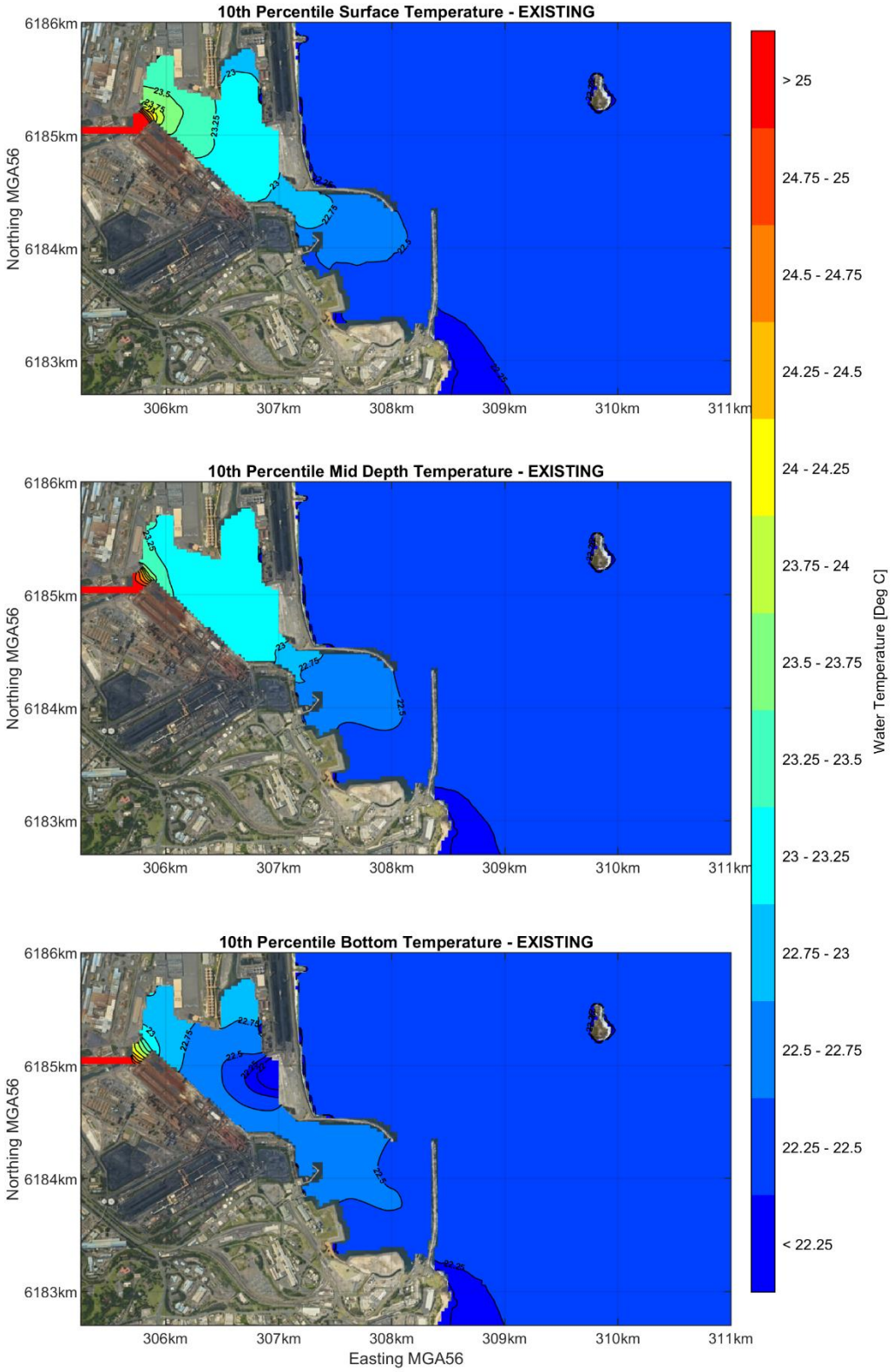

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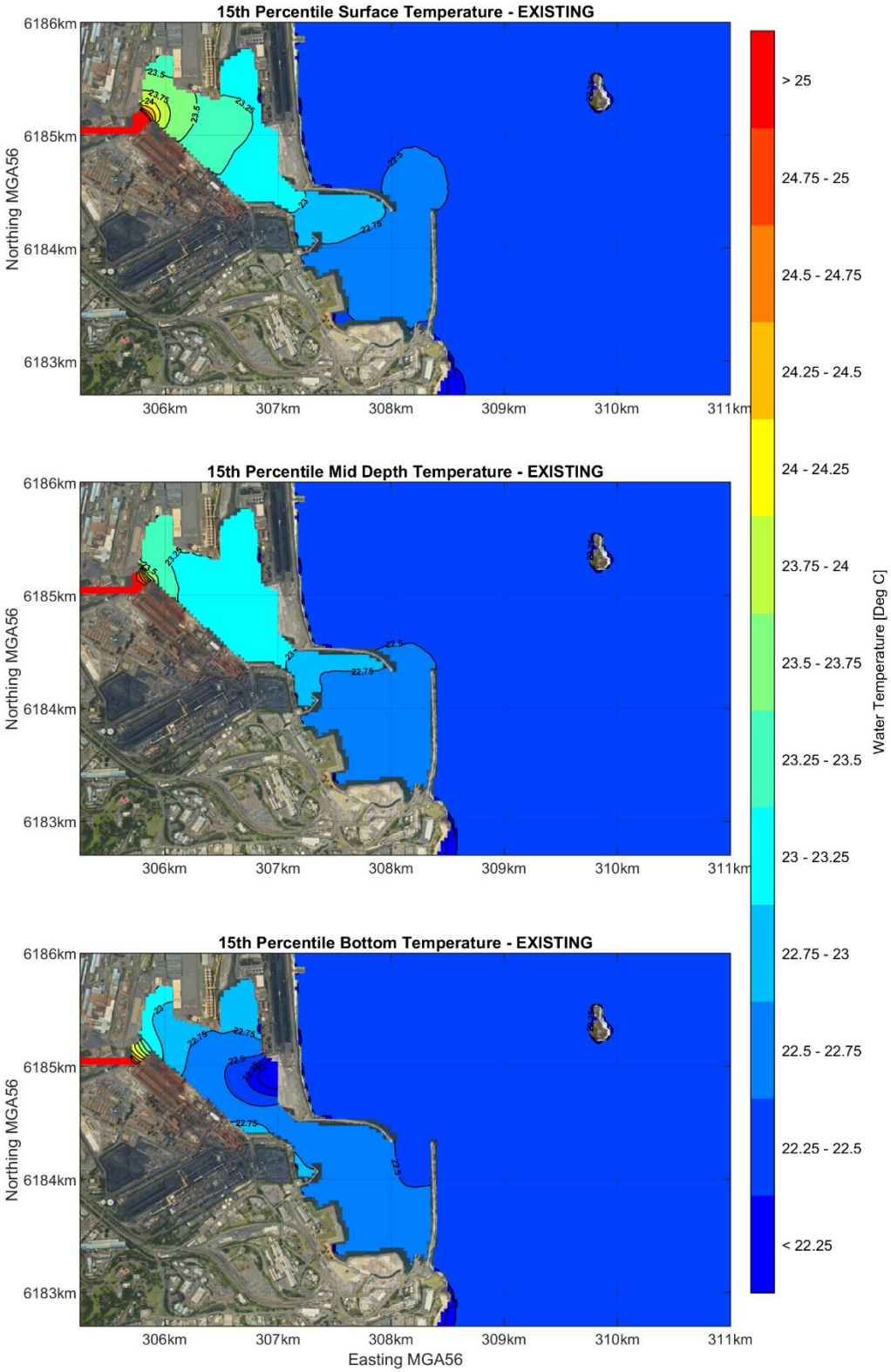

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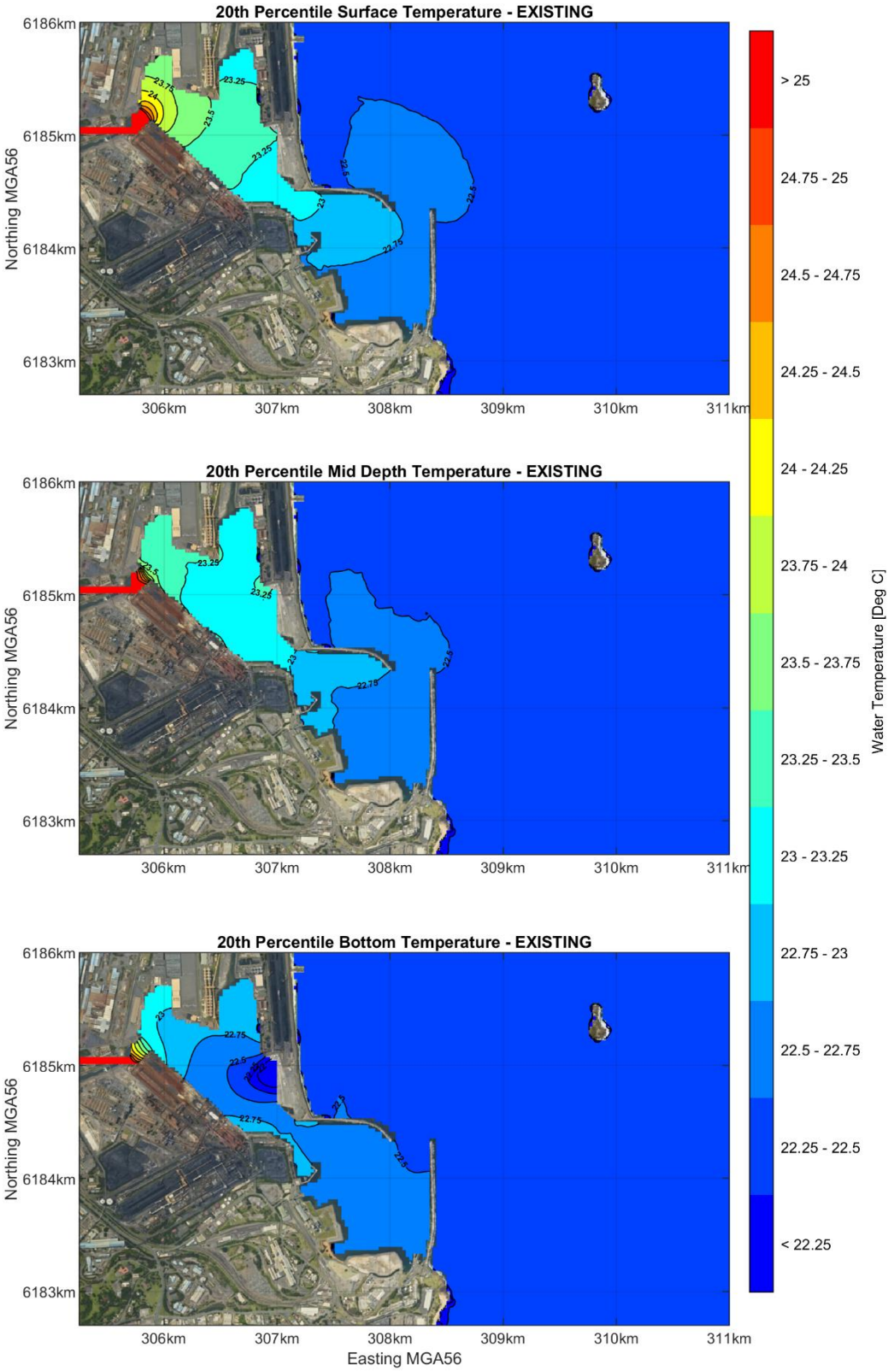

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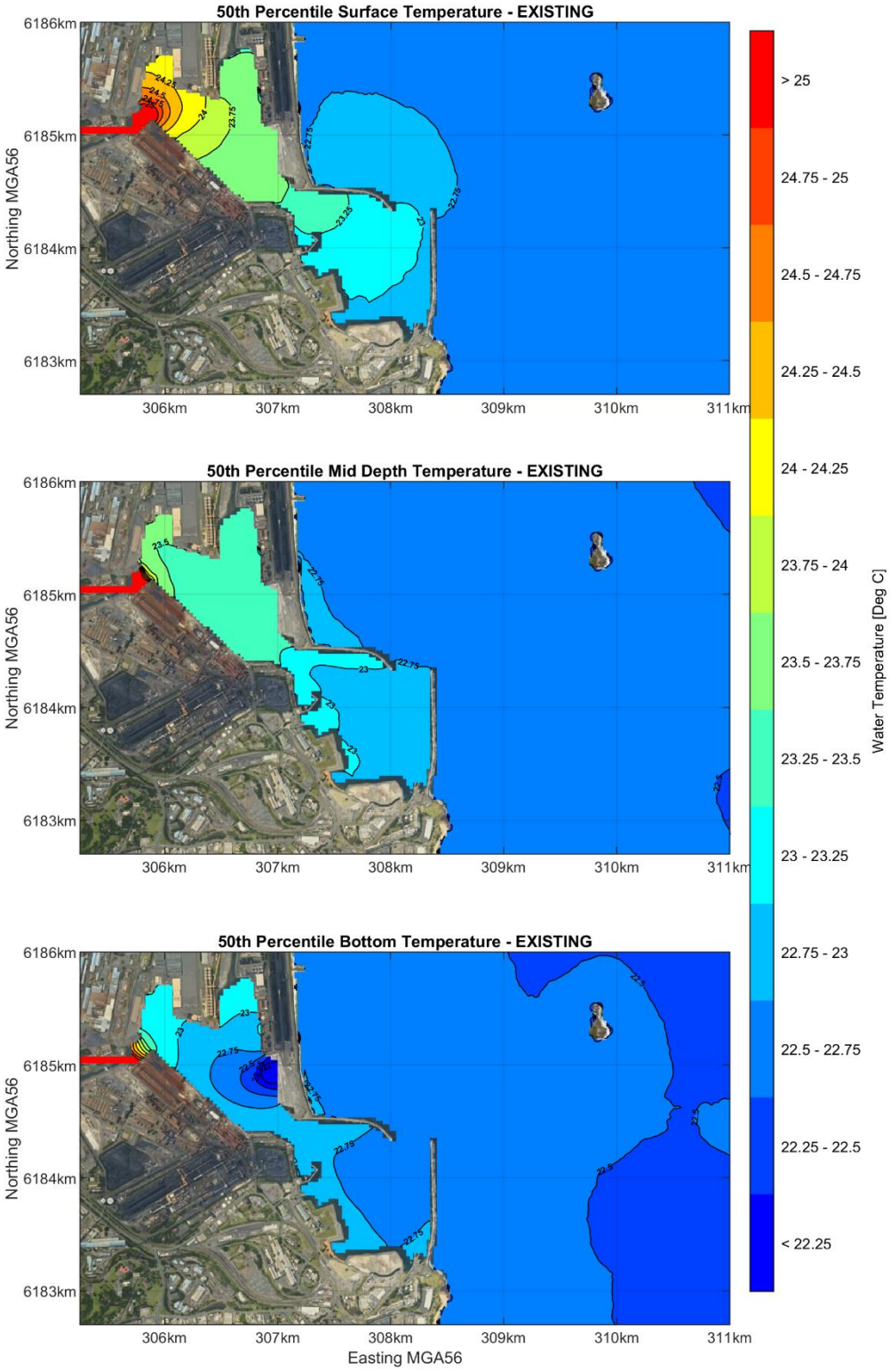

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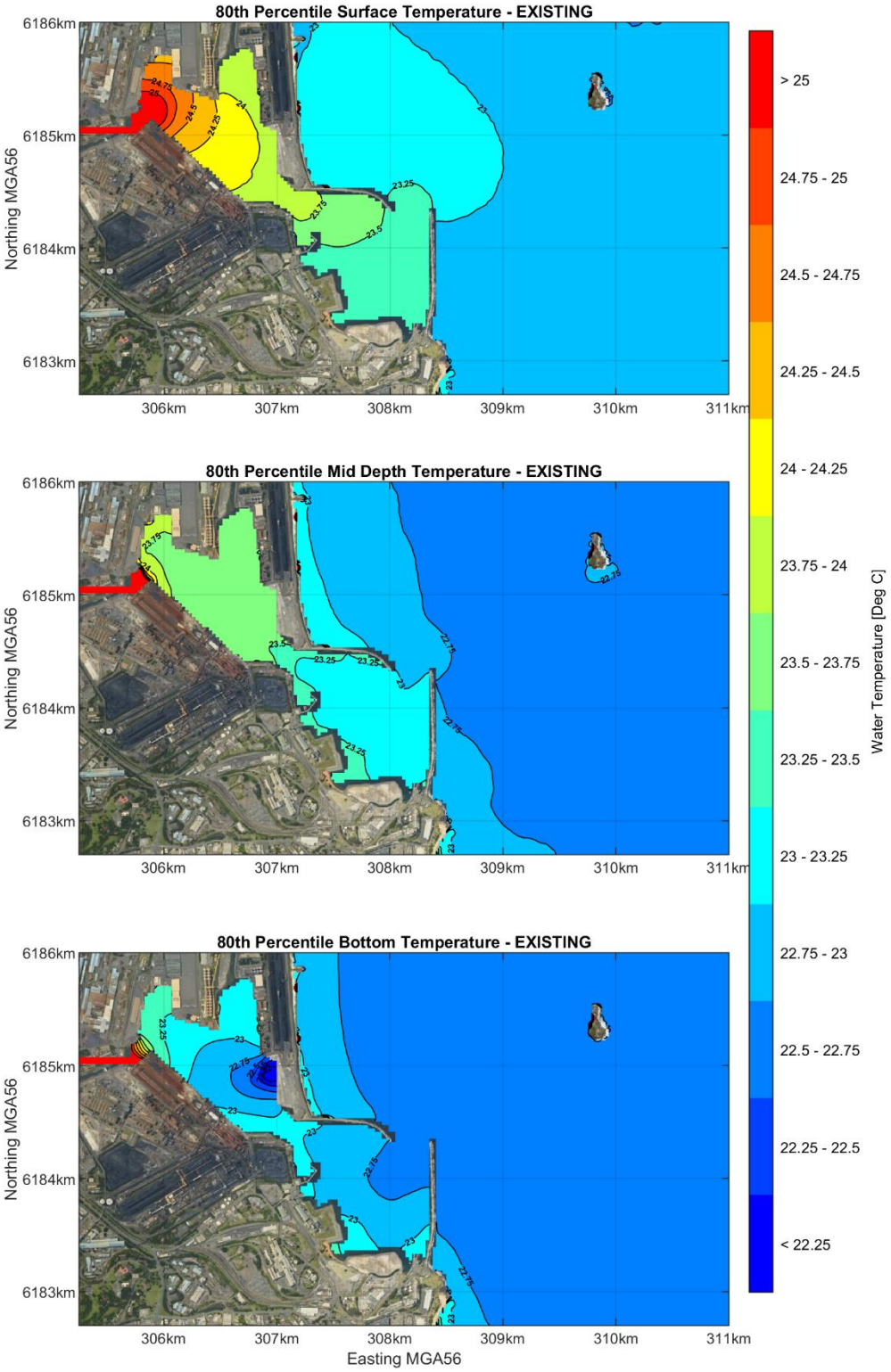

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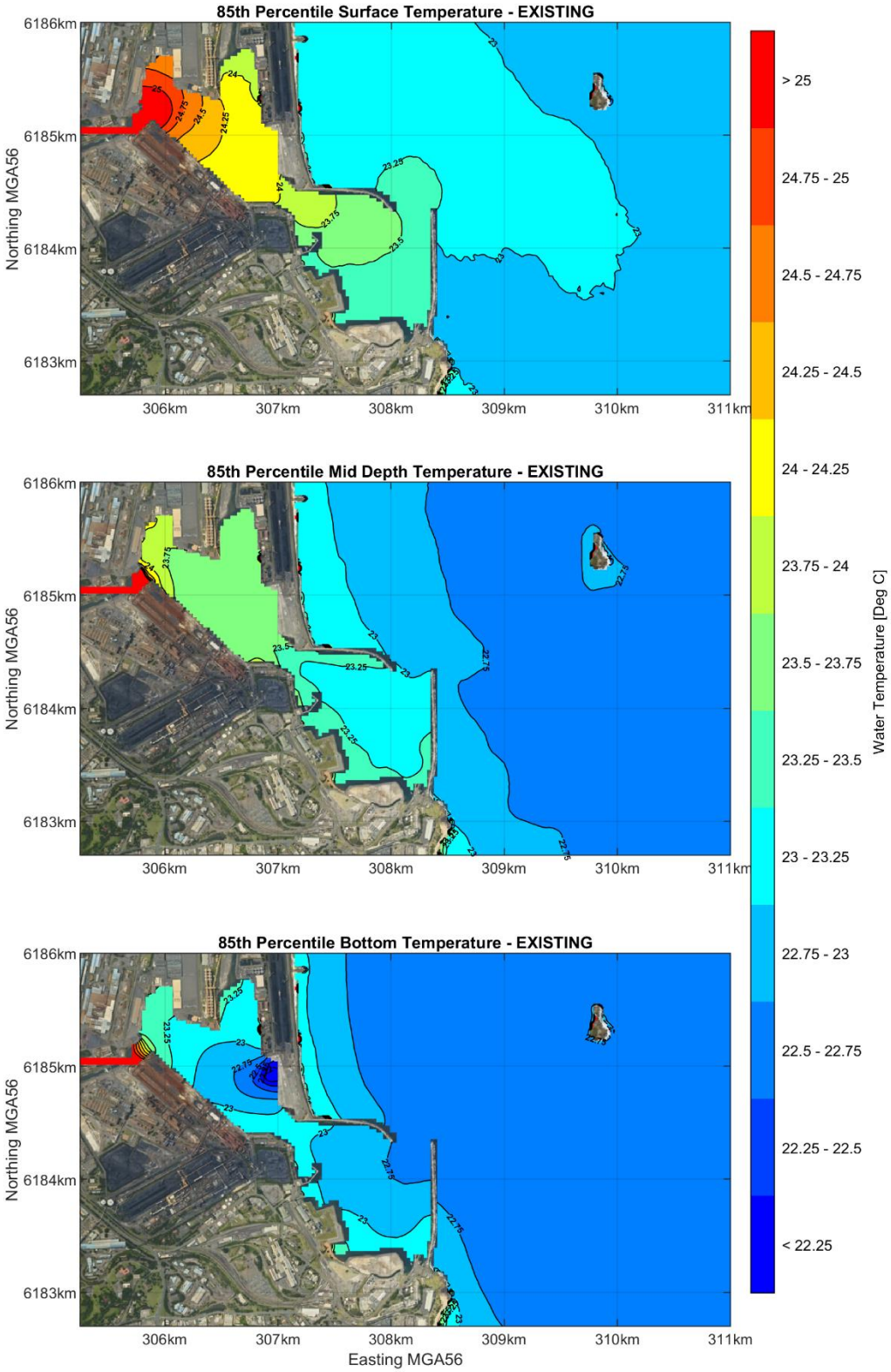

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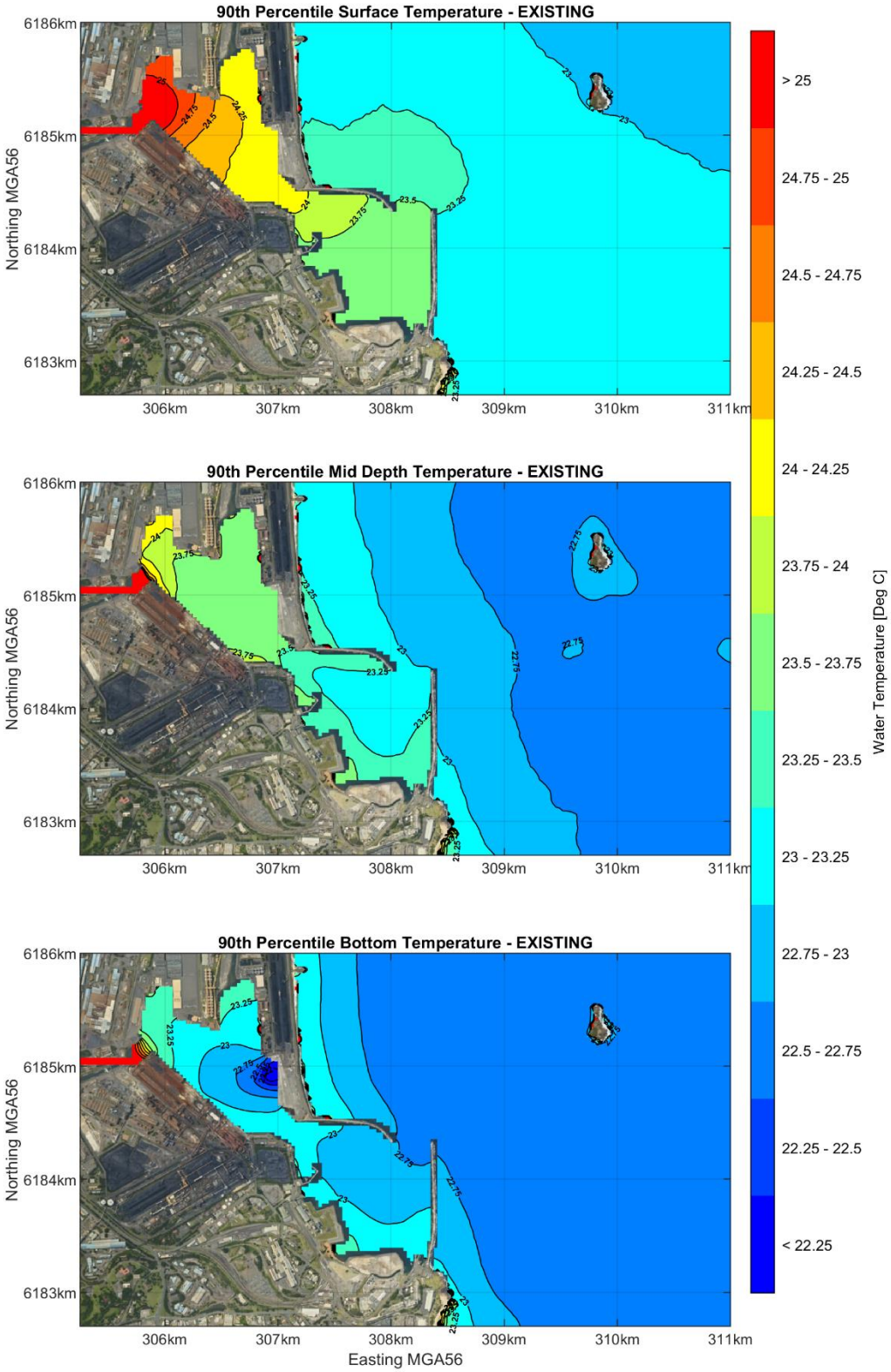

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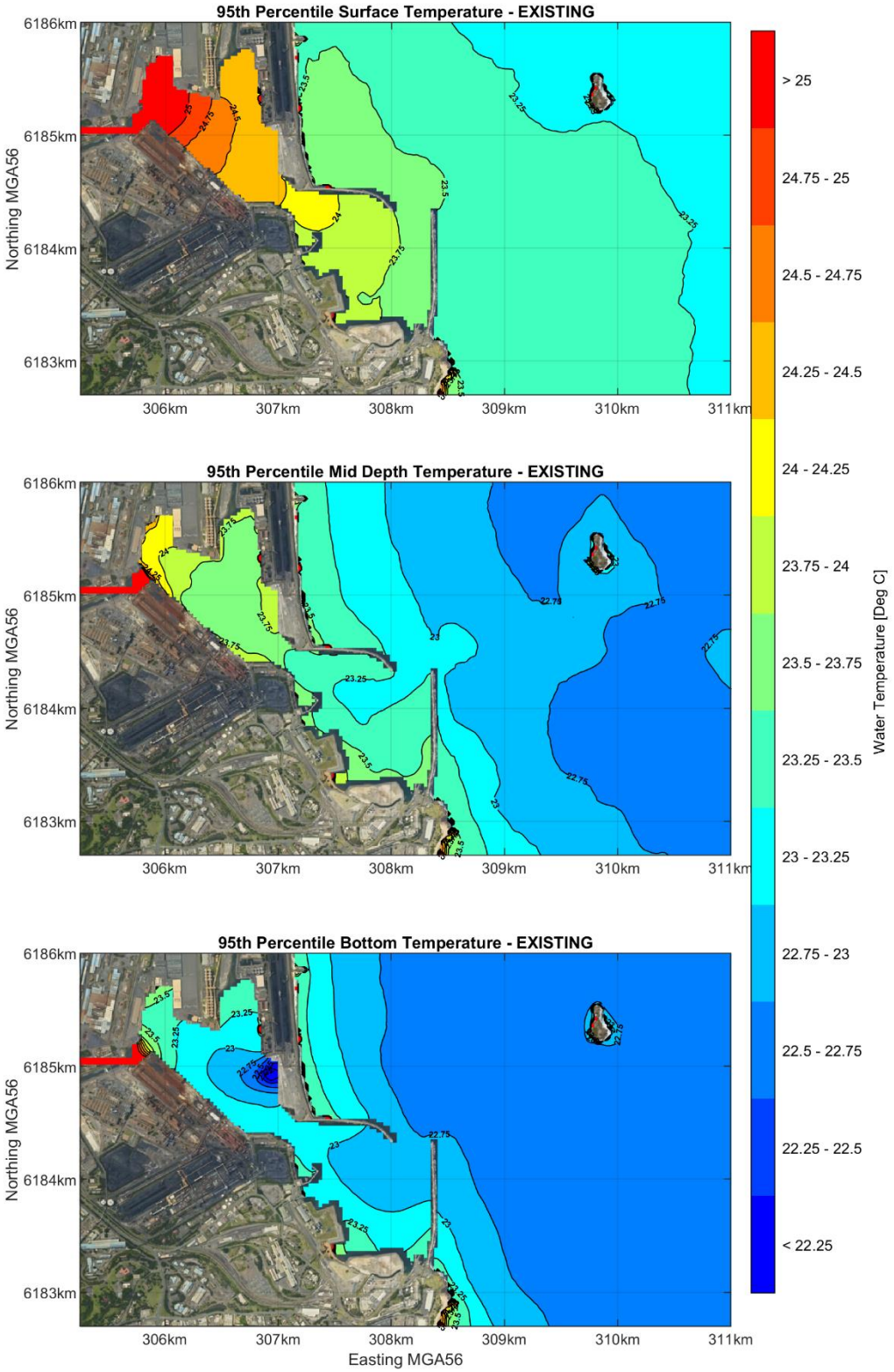

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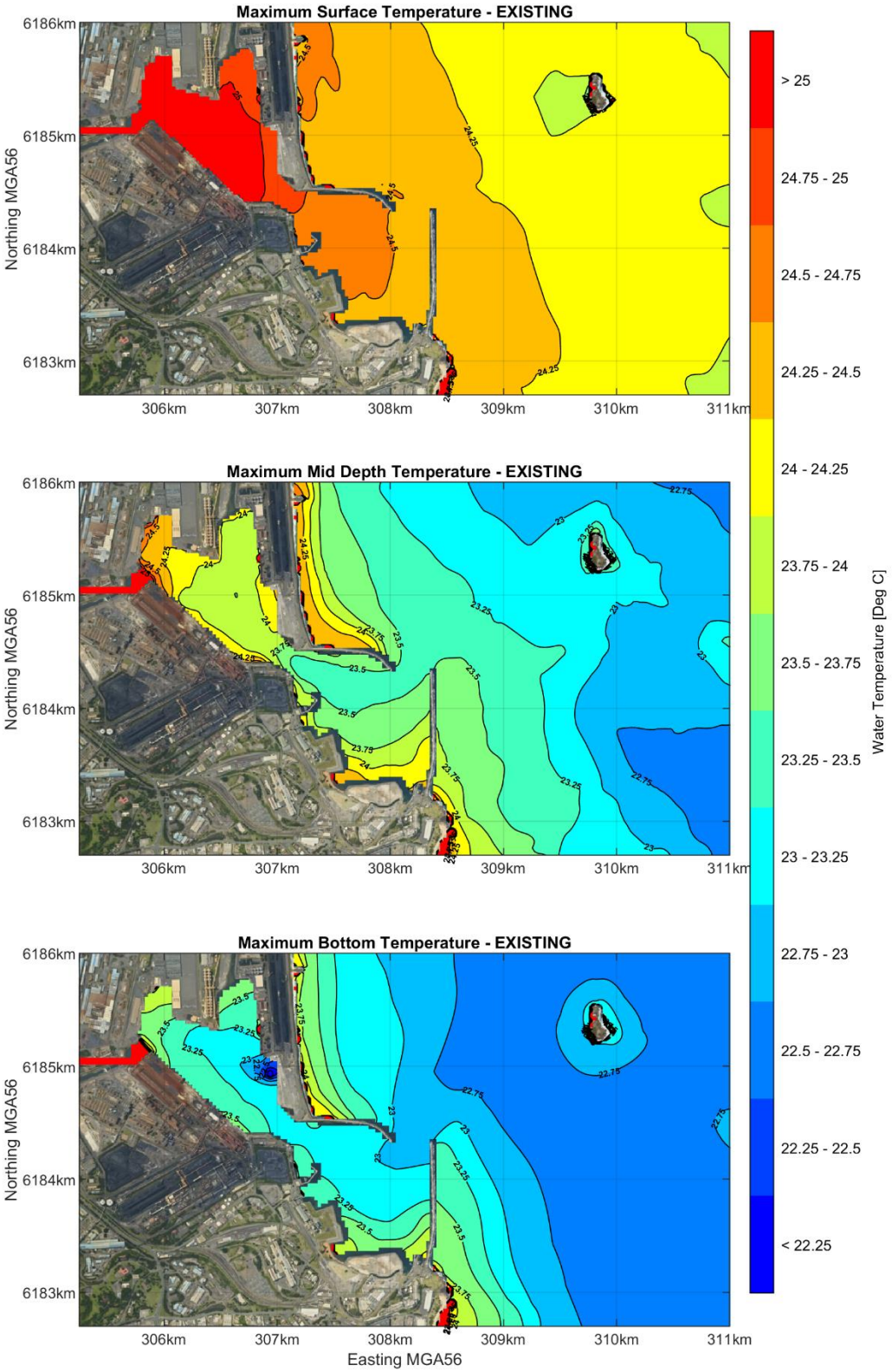
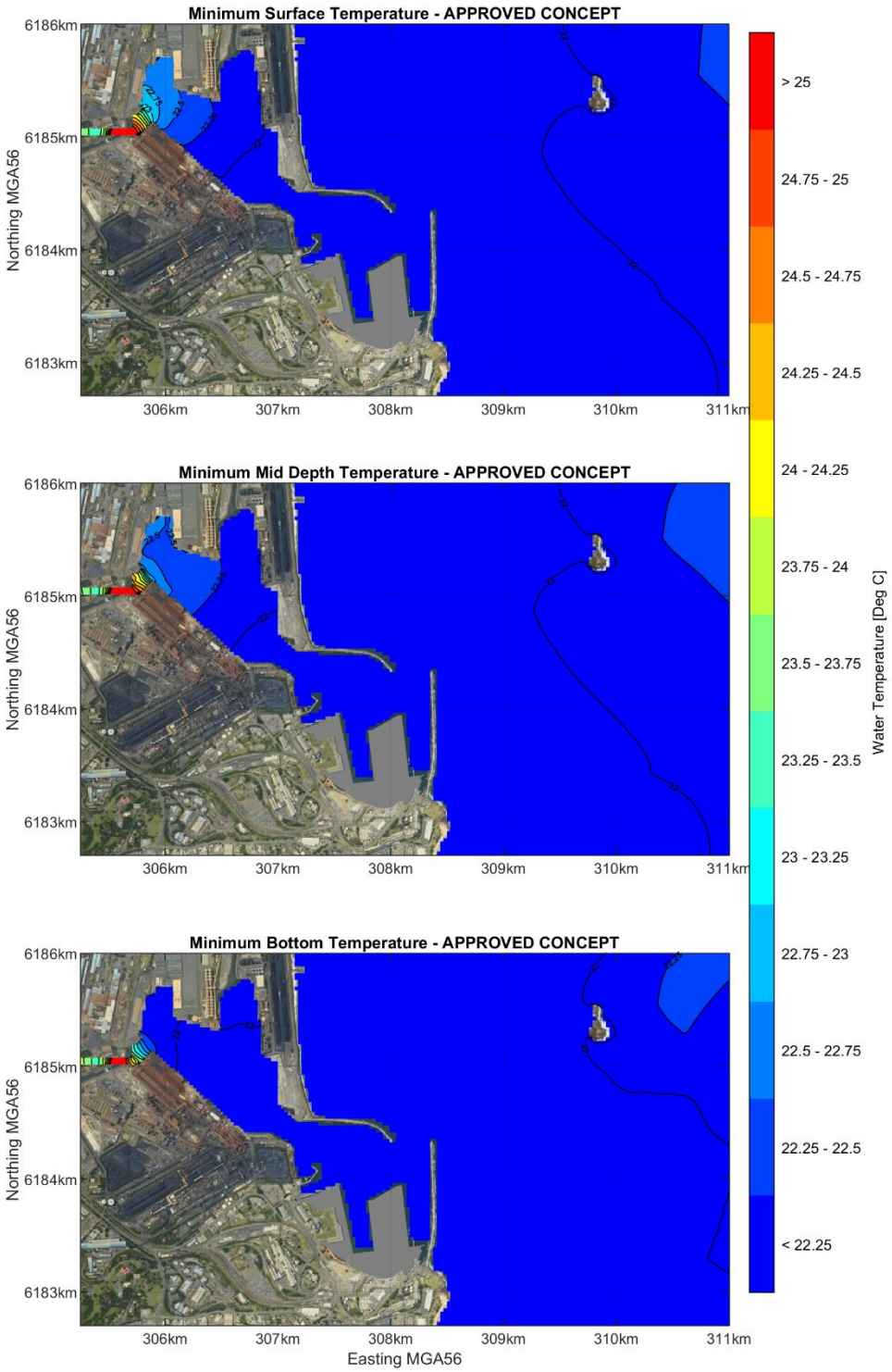
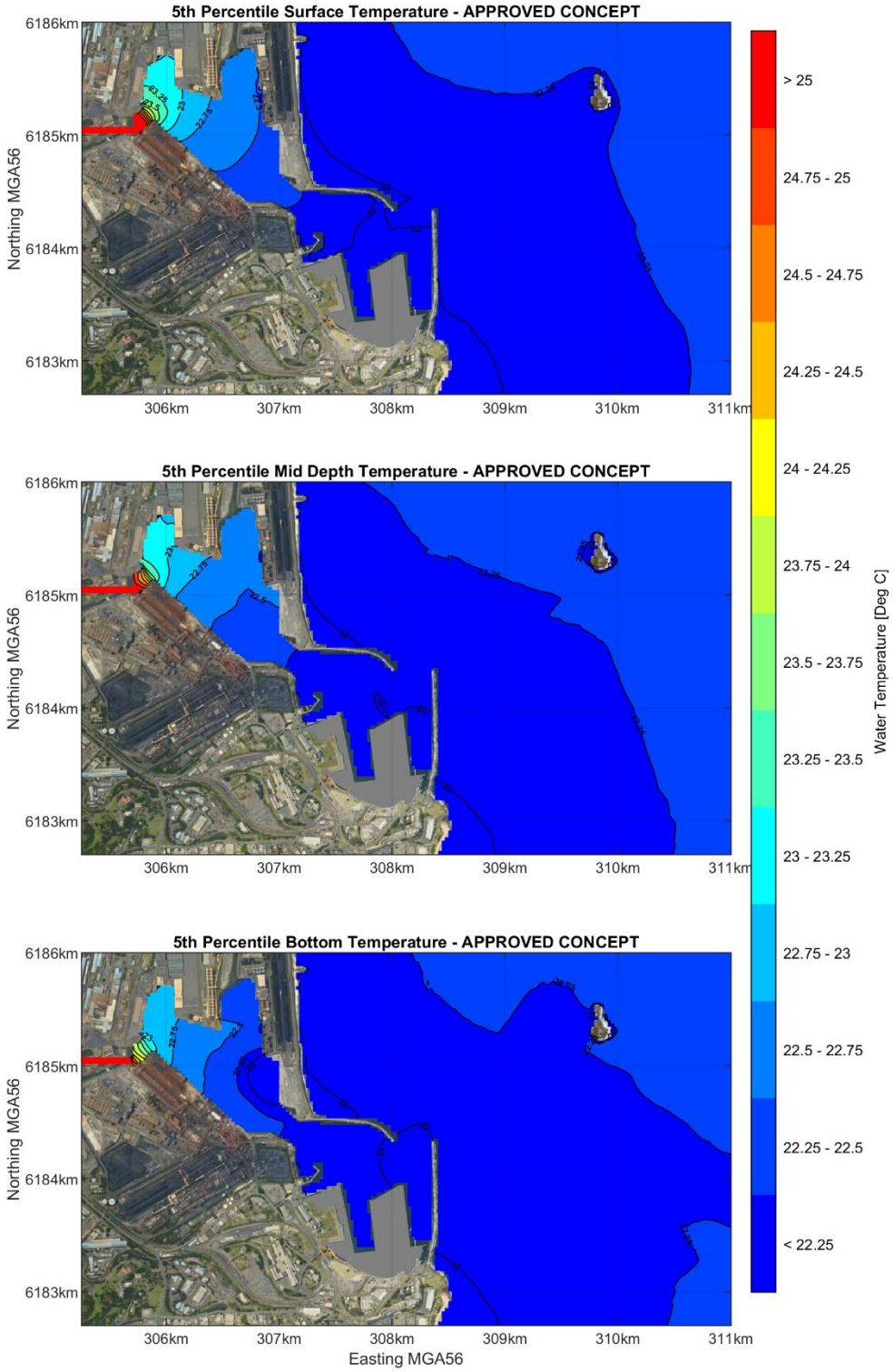


Modelled Maximum Summer Water Temperature – Existing Layout

Appendix B Summer Thermal Plume Results: Approved Concept Layout



Modelled Minimum Summer Water Temperature – Approved Concept Layout



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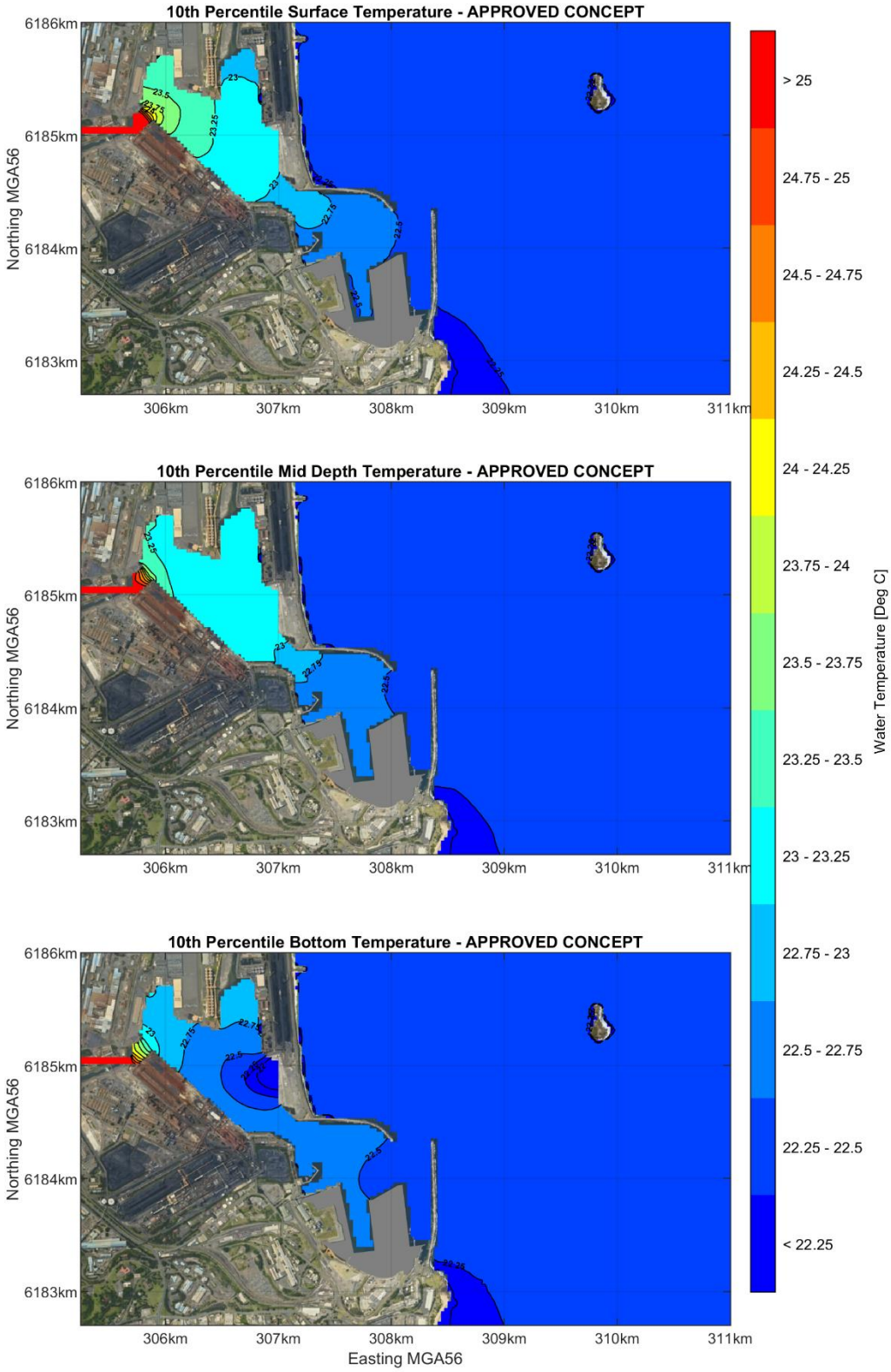

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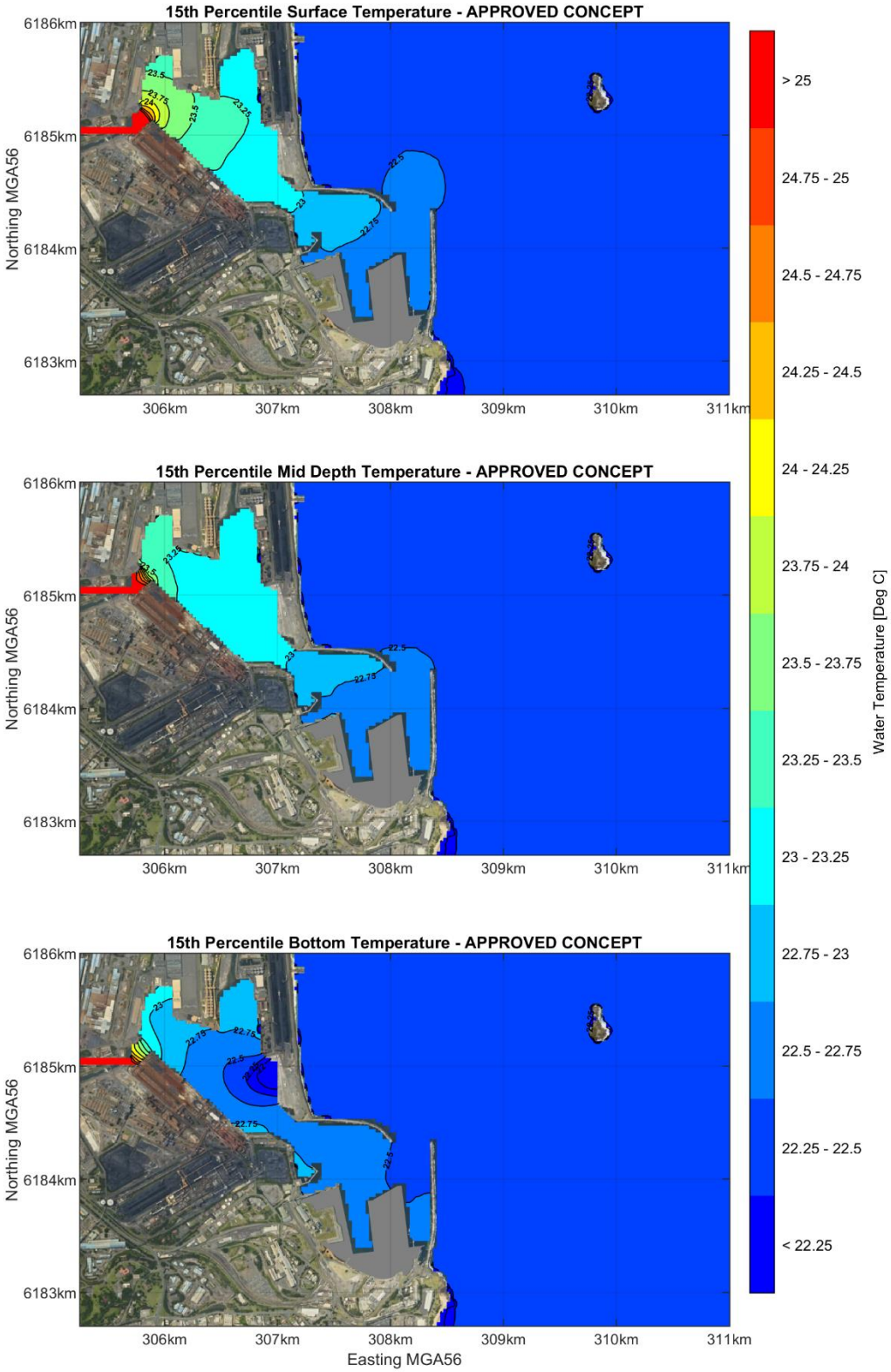

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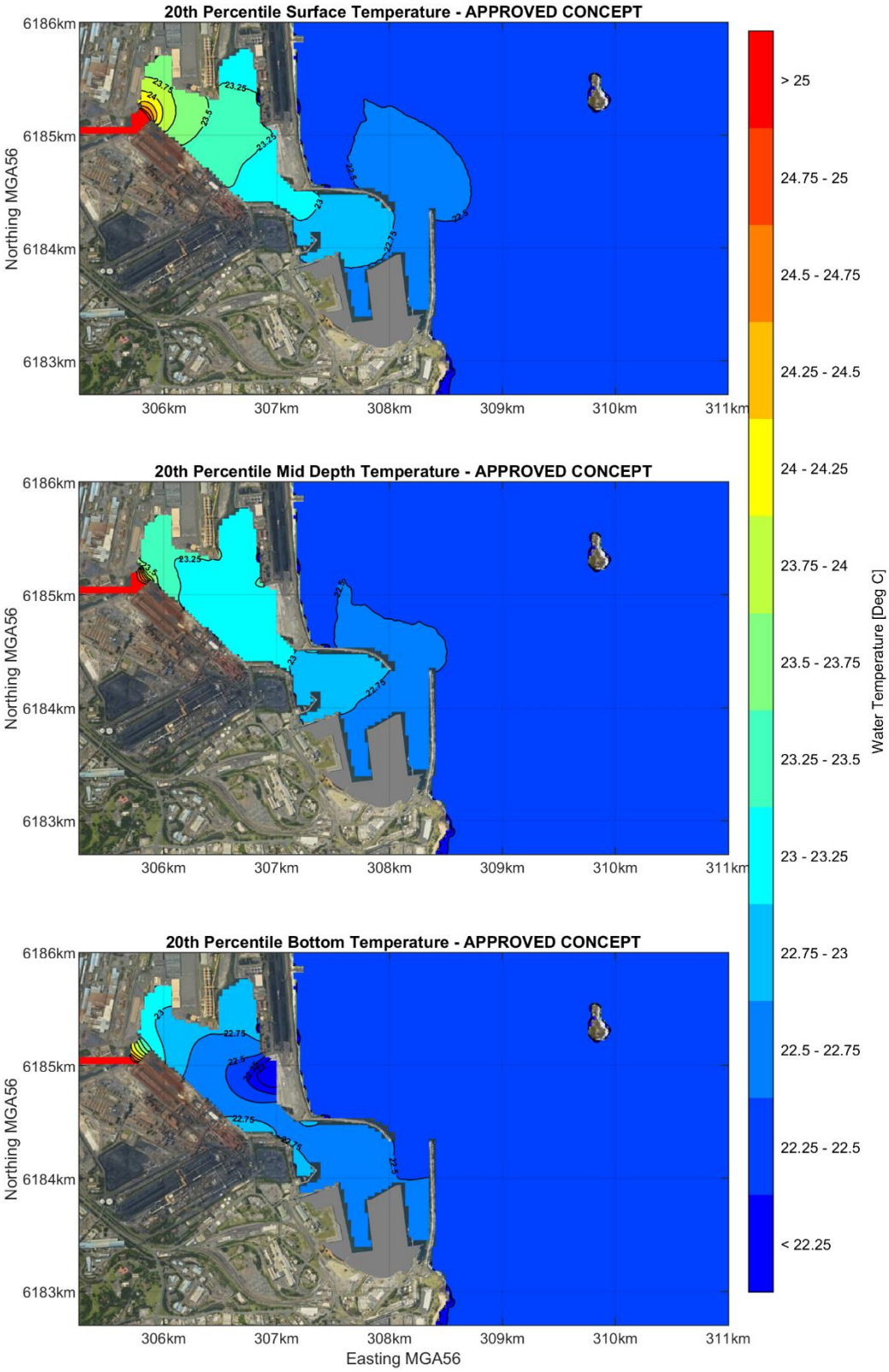

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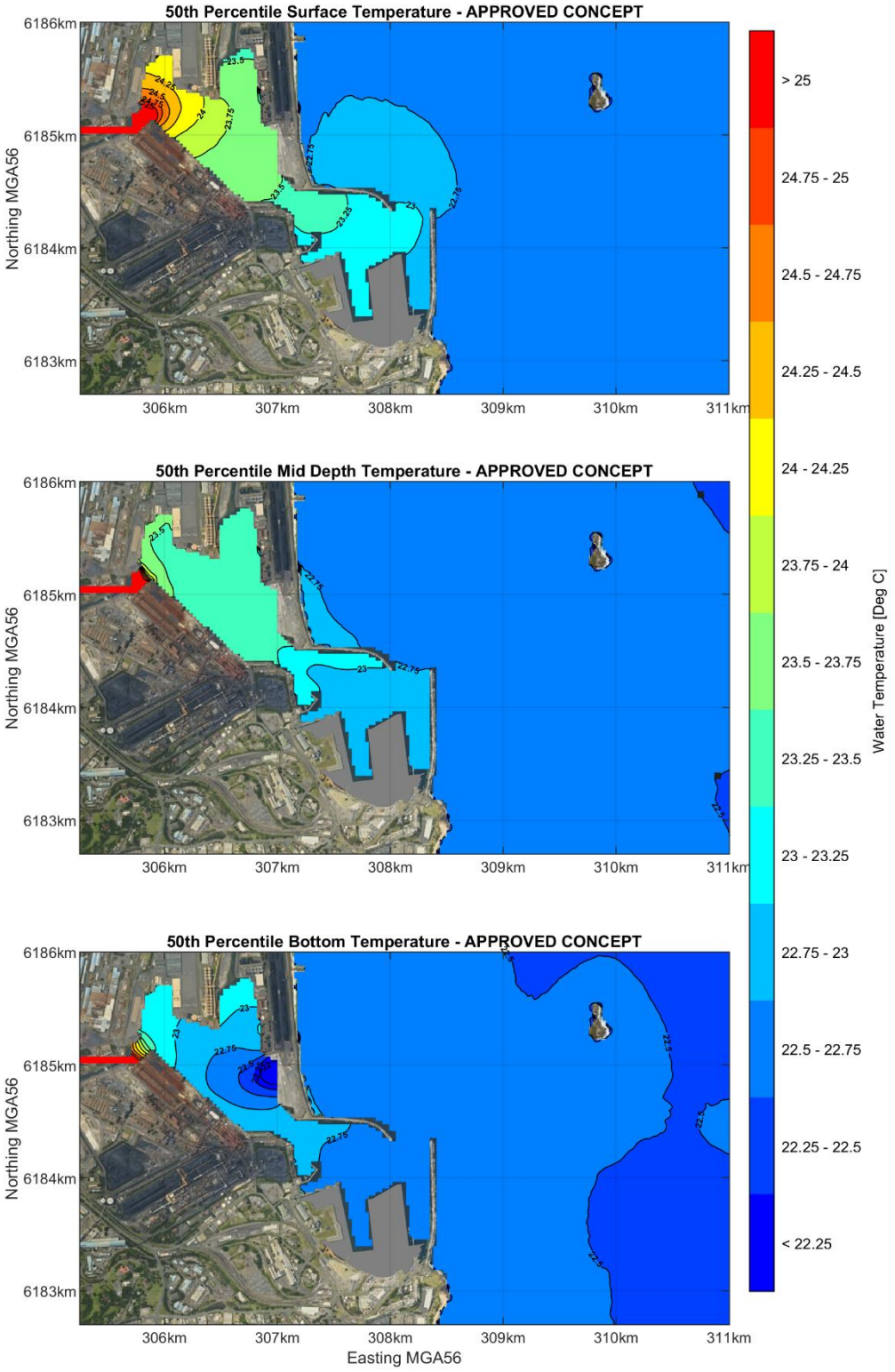

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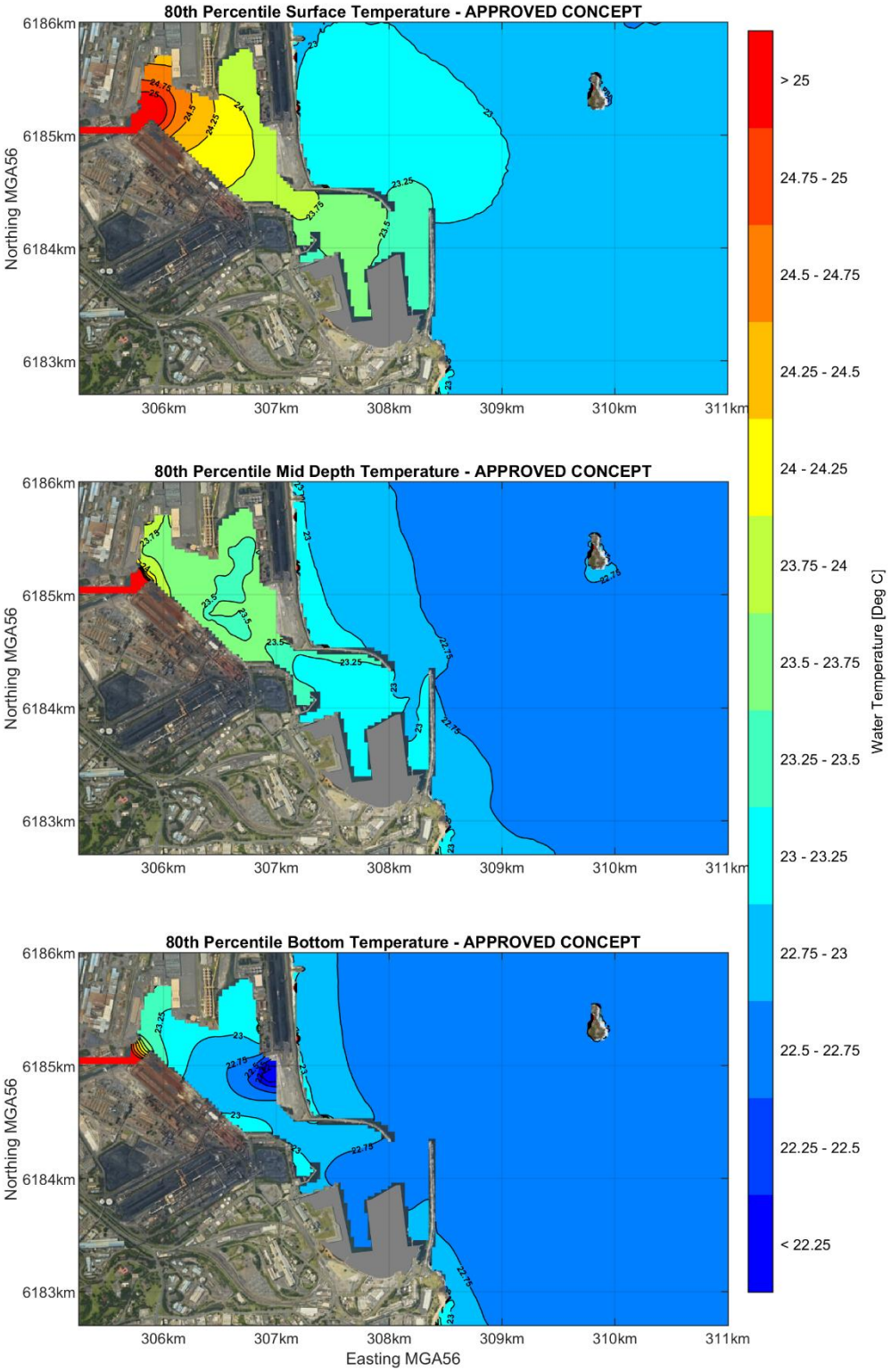

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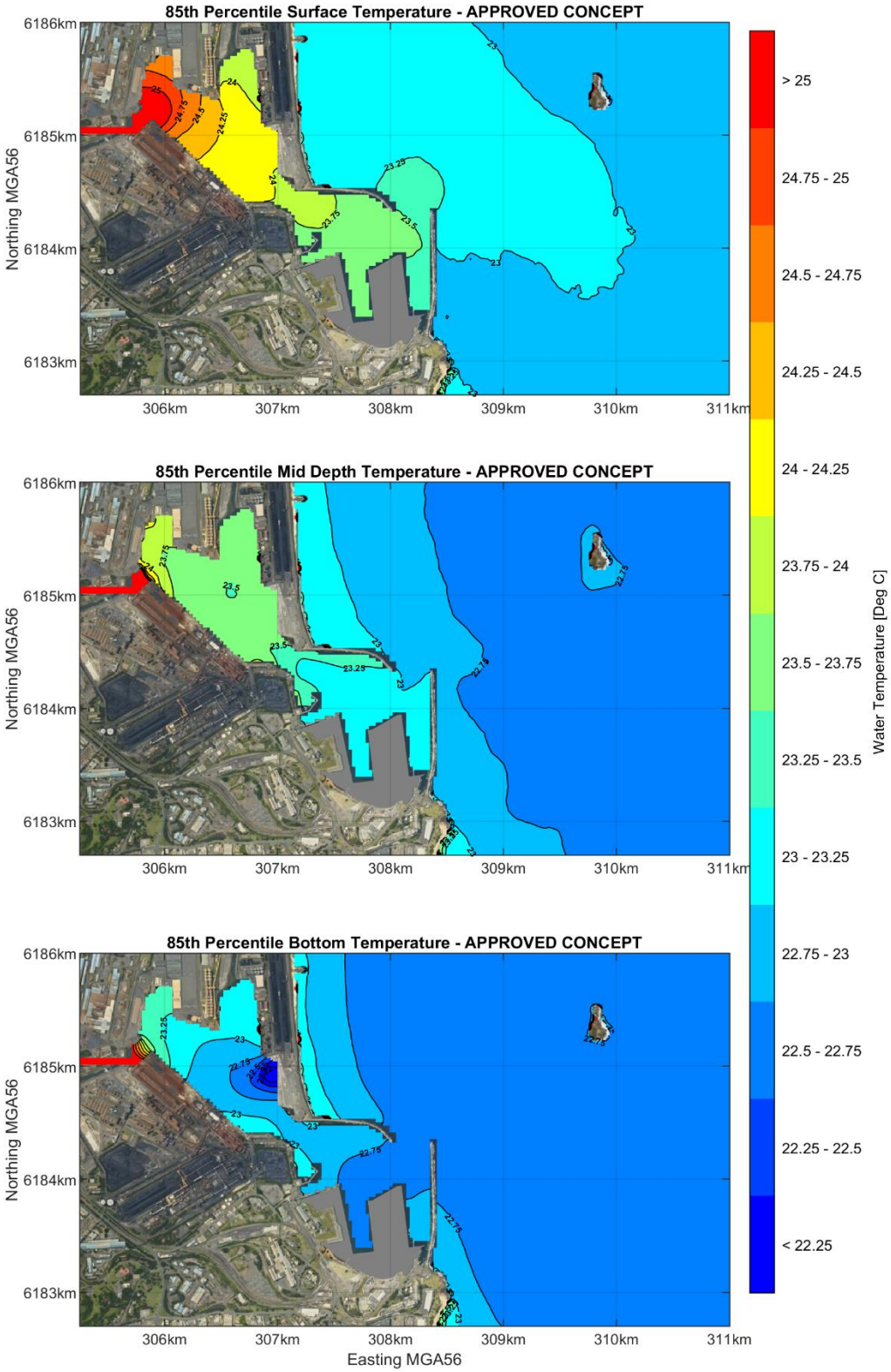

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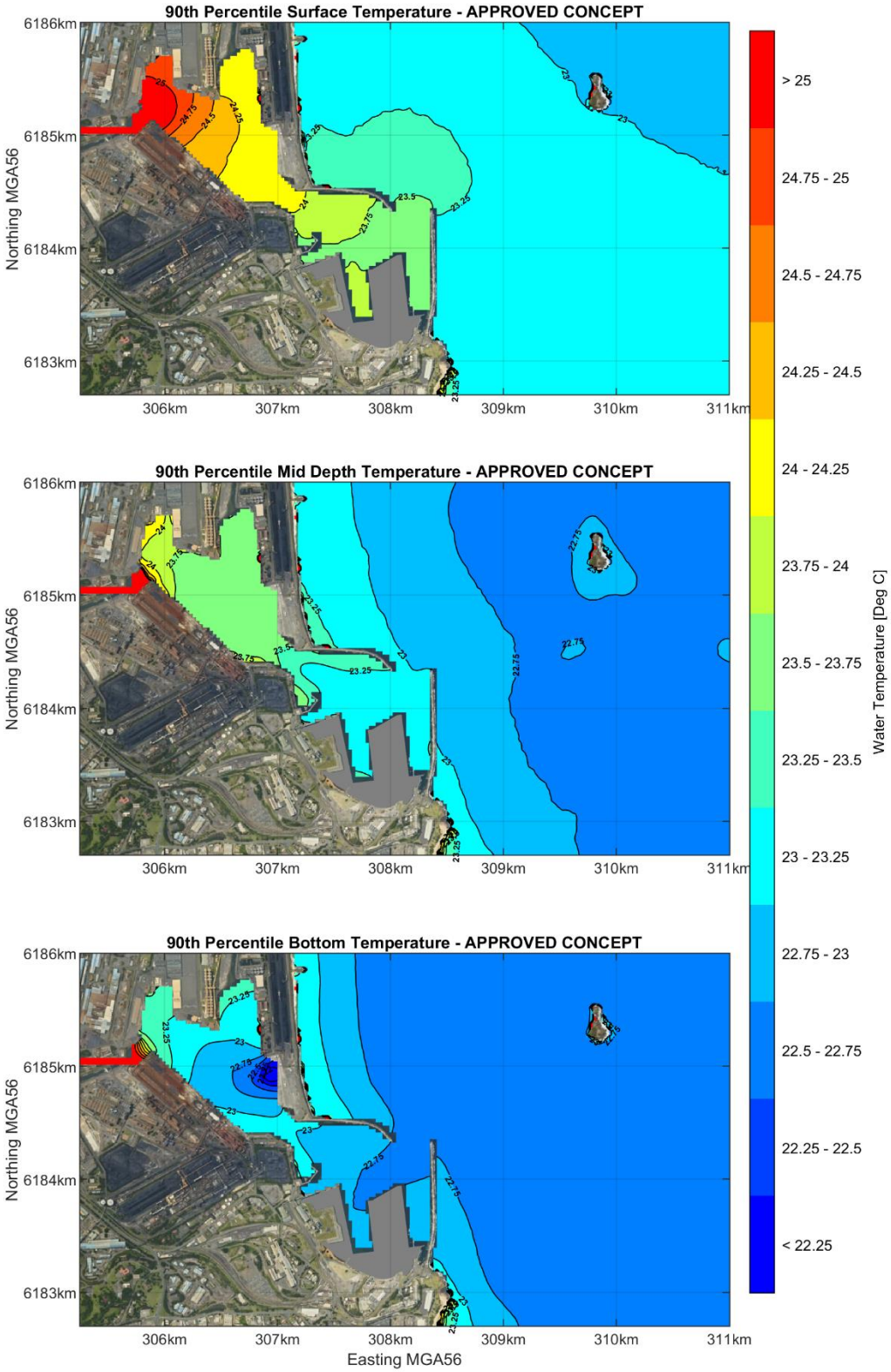

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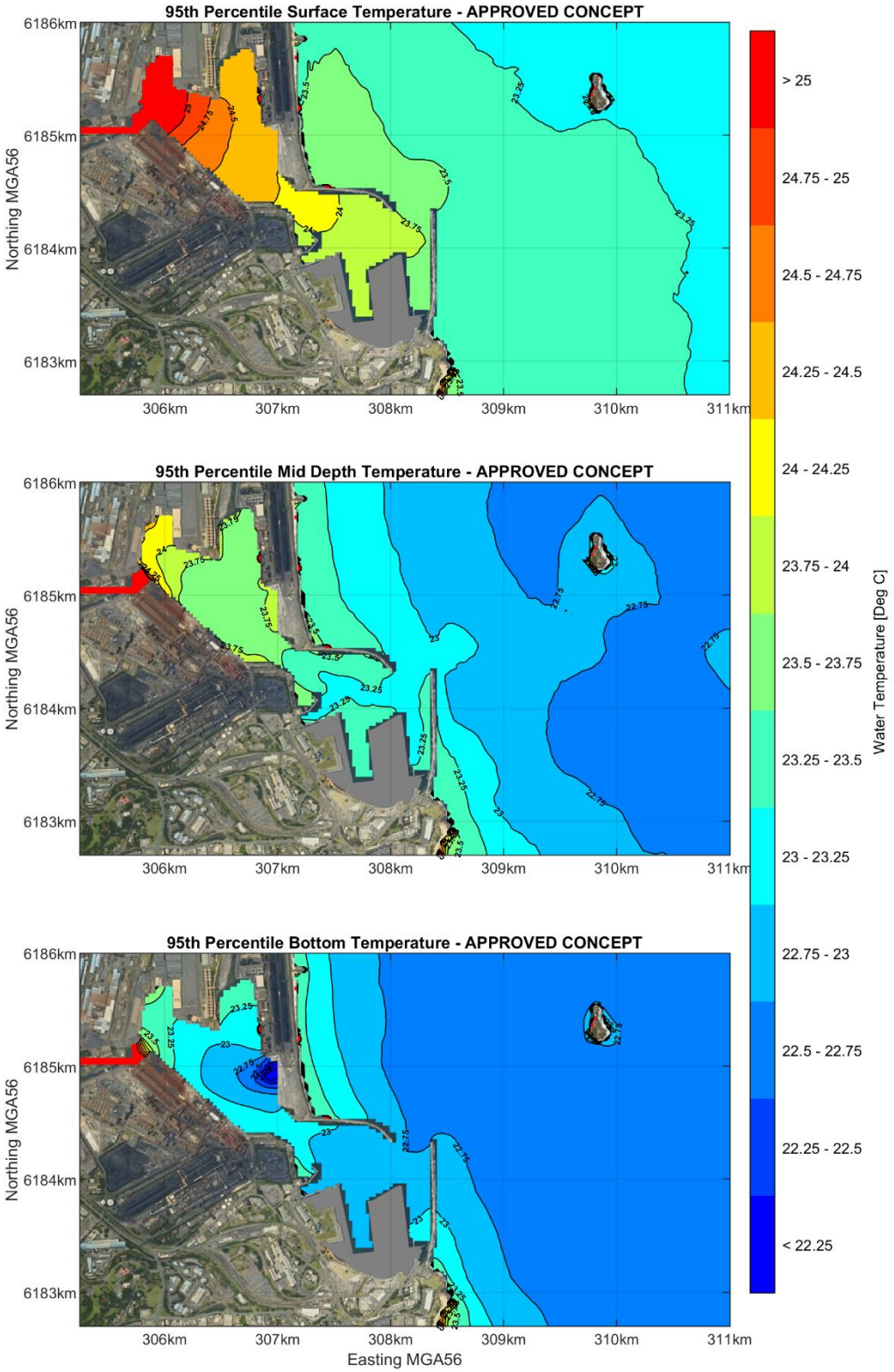

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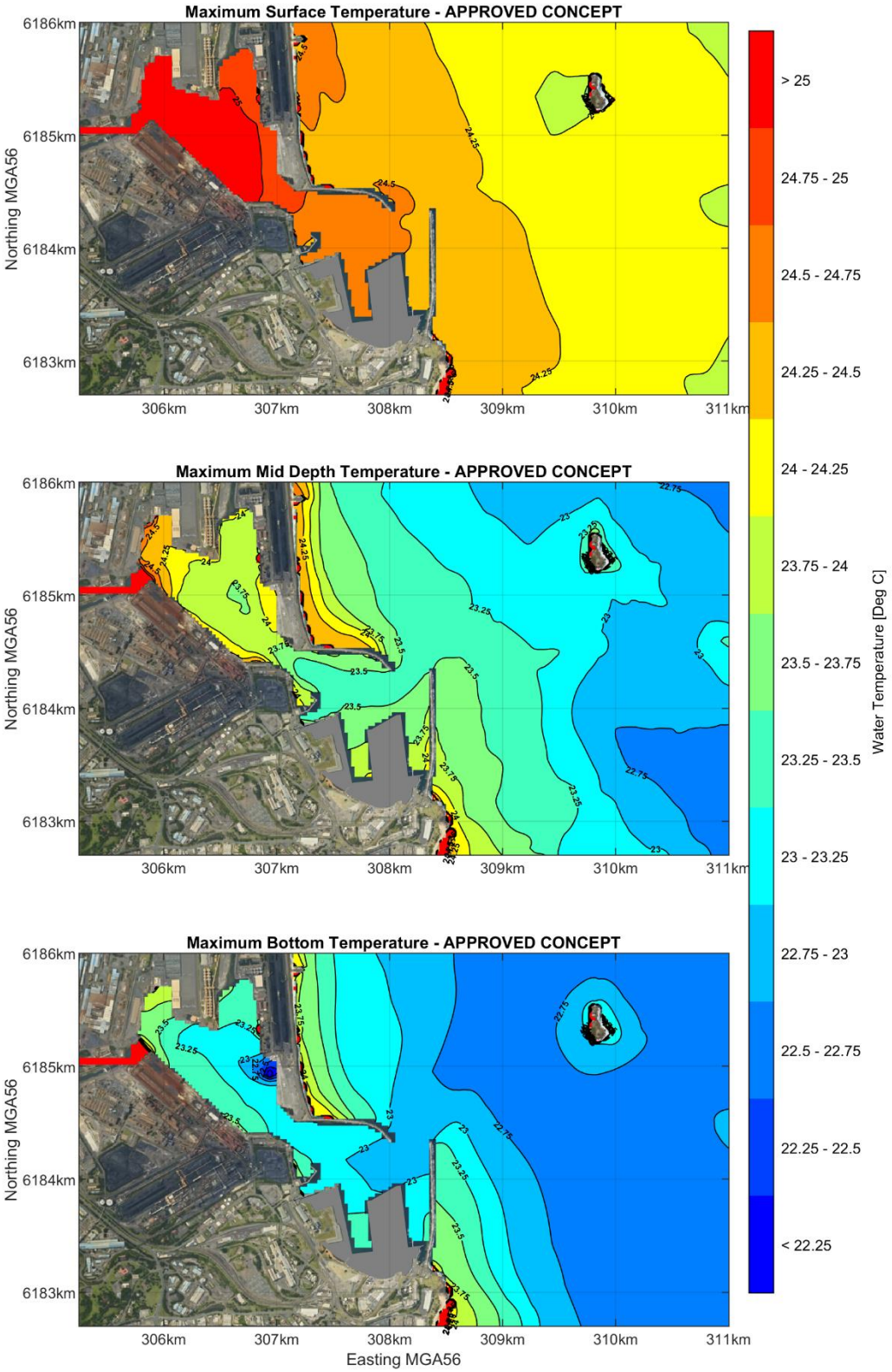
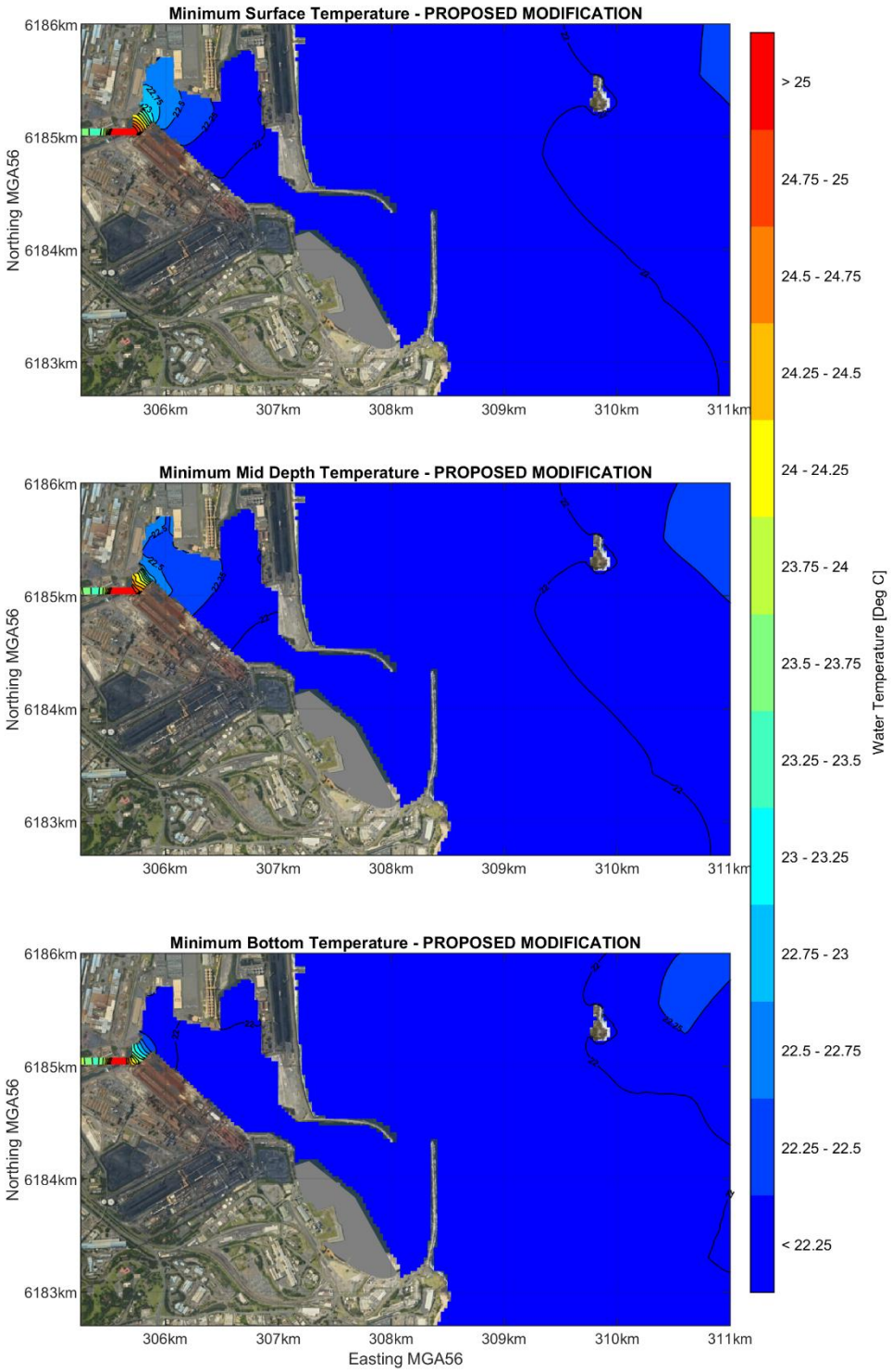


Modelled Maximum Summer Water Temperature – Approved Concept Layout

Appendix C Summer Thermal Plume Results: Proposed Modification Layout



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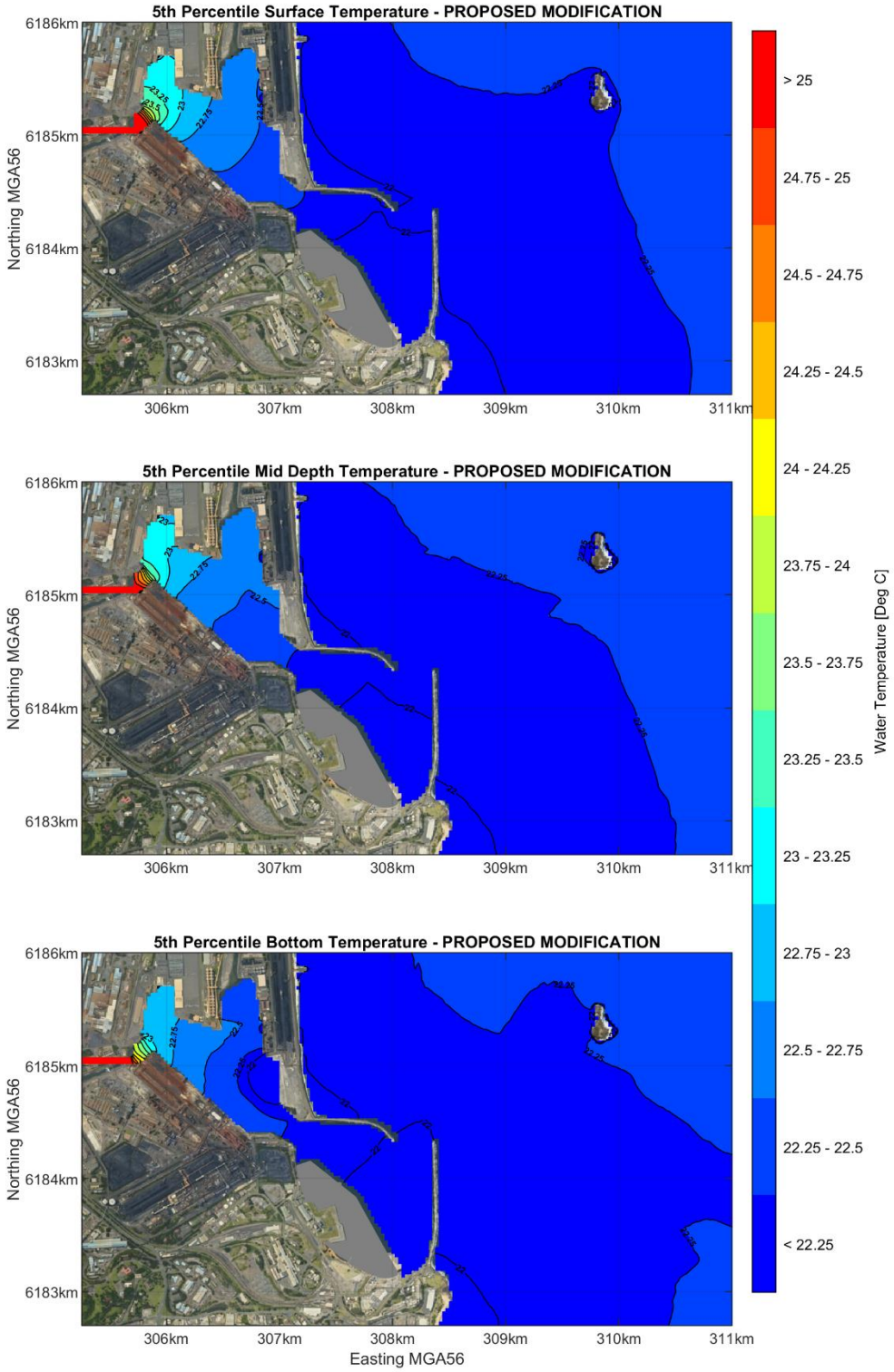

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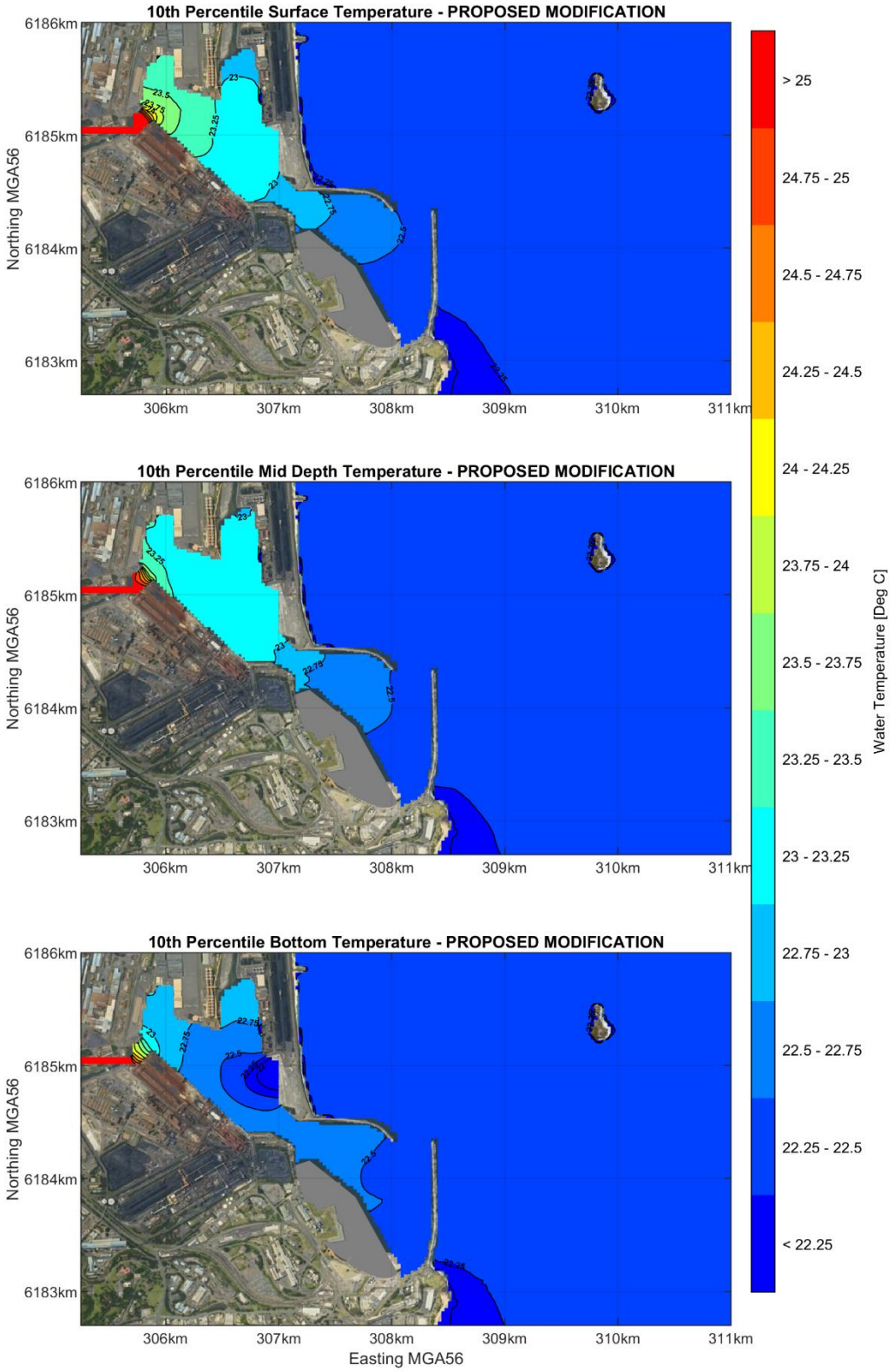

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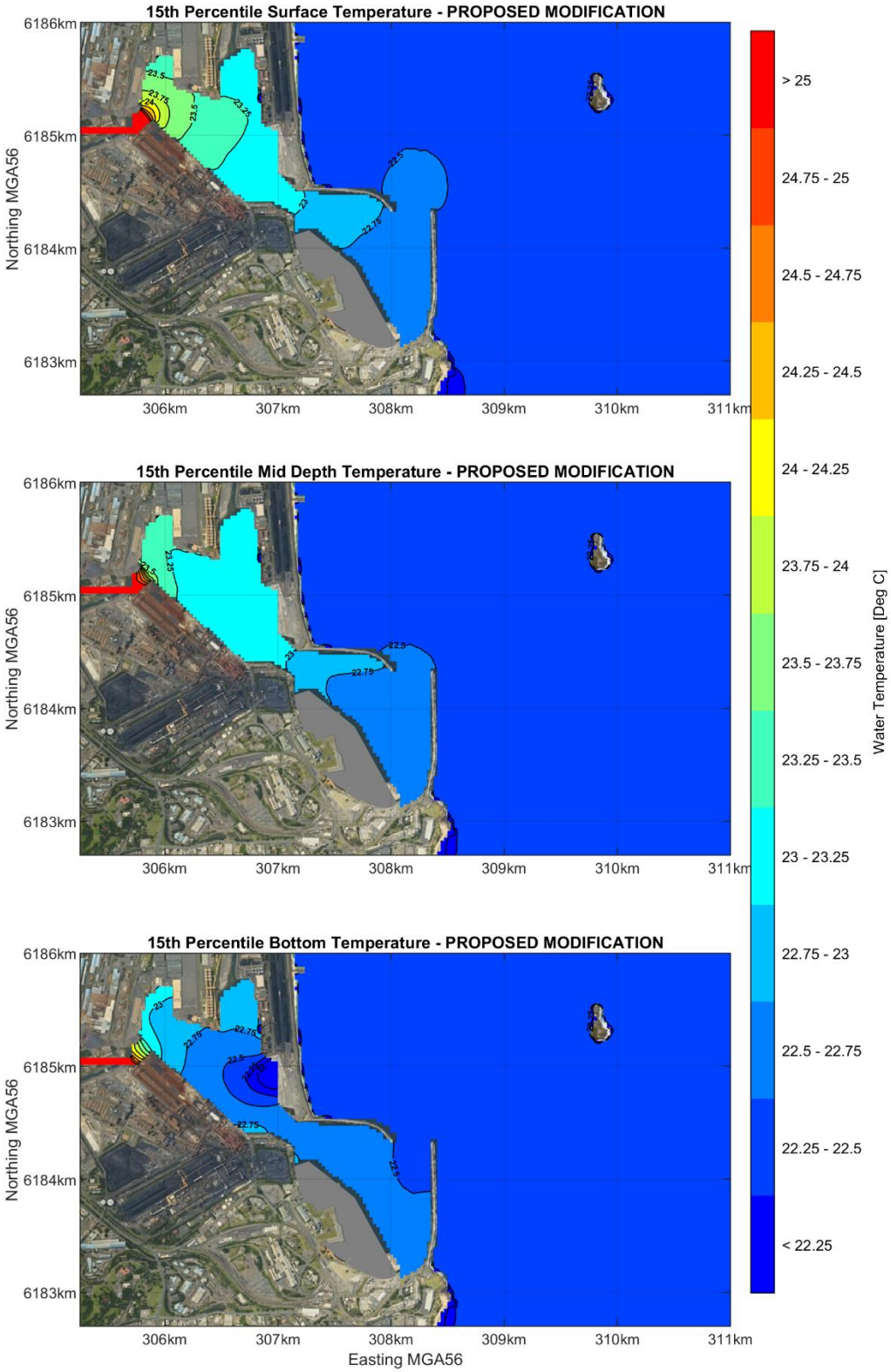

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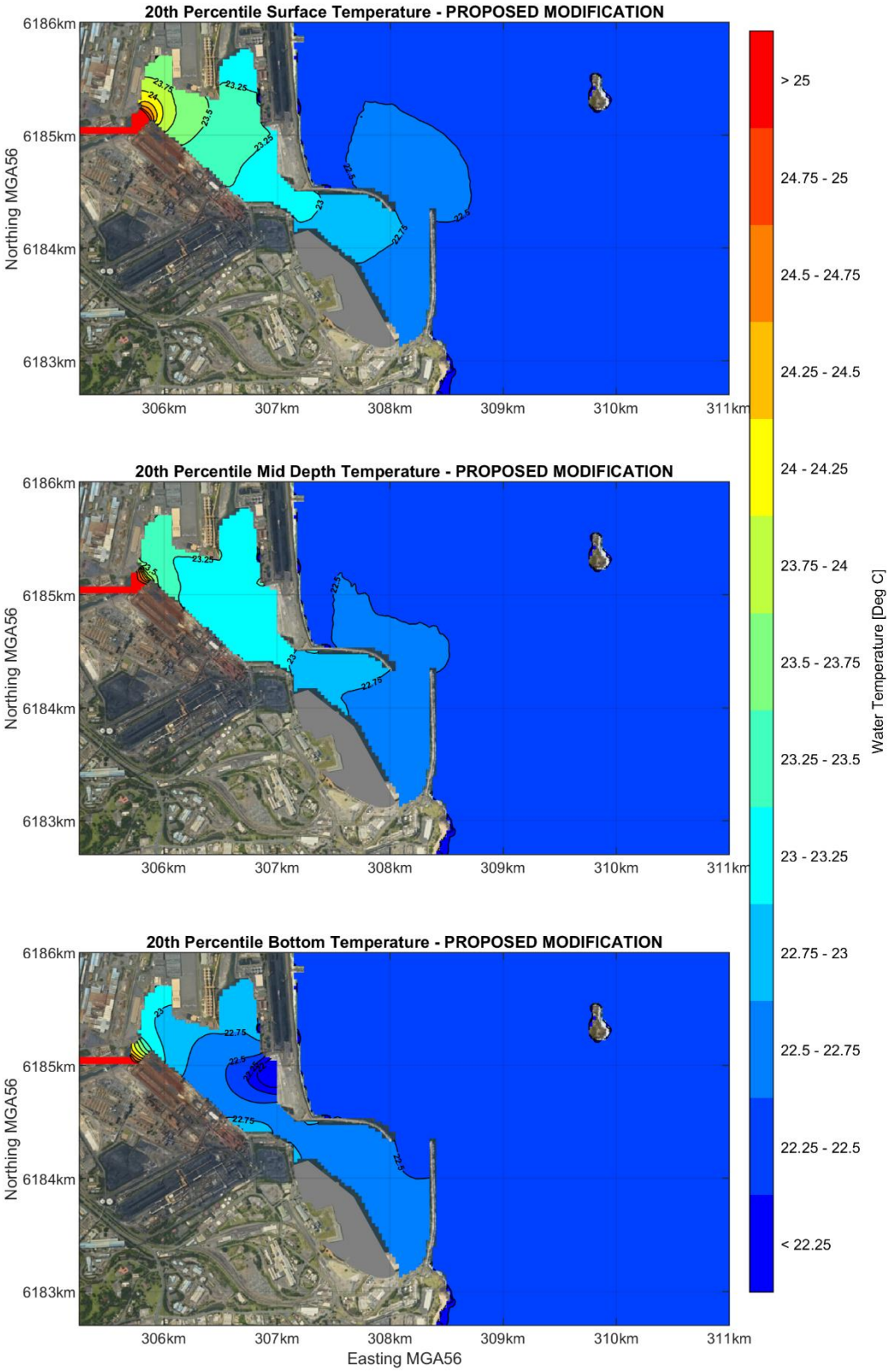

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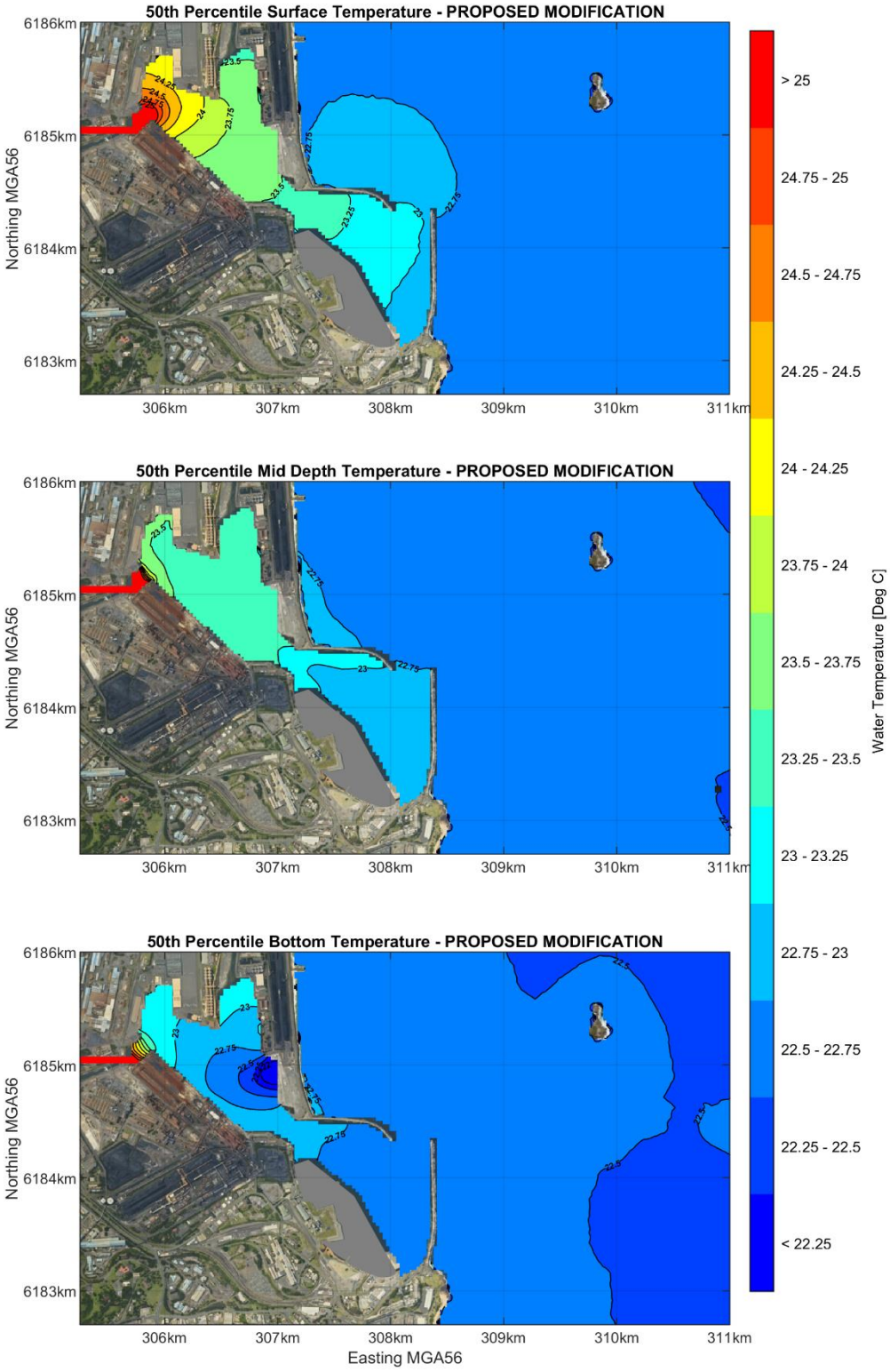
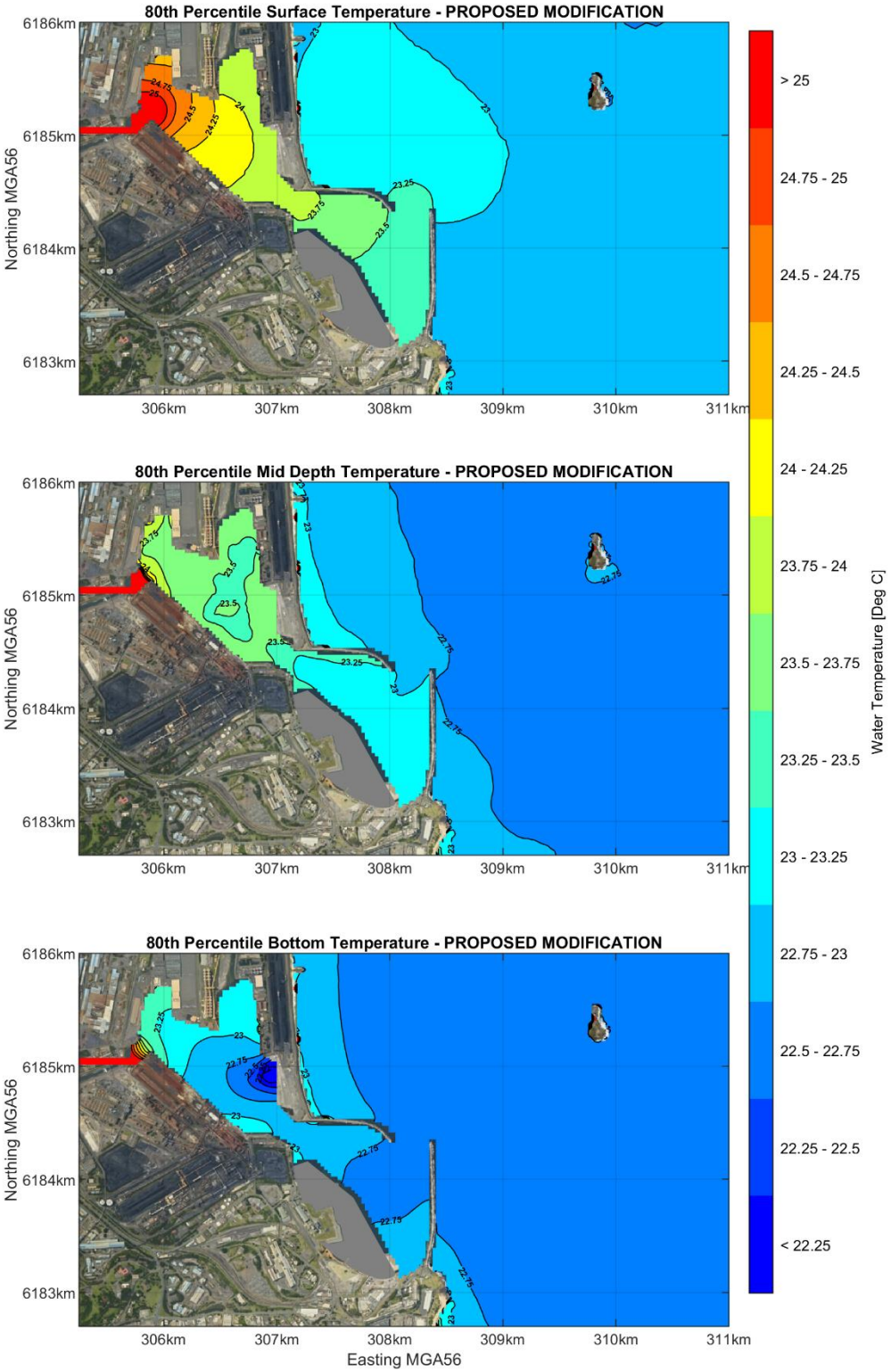


Modelled 50th Percentile Summer Water Temperature – Proposed Modification Layout



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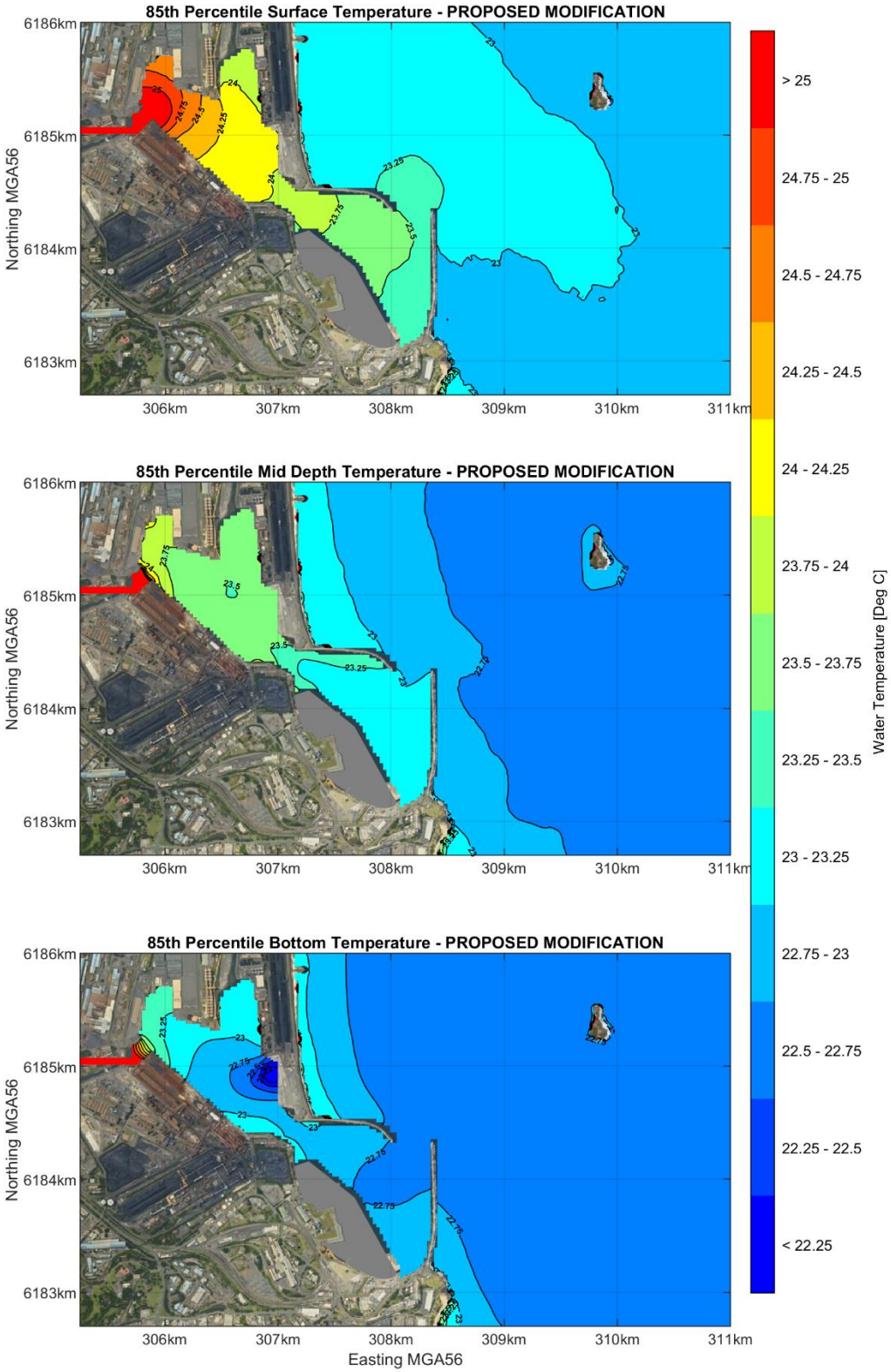

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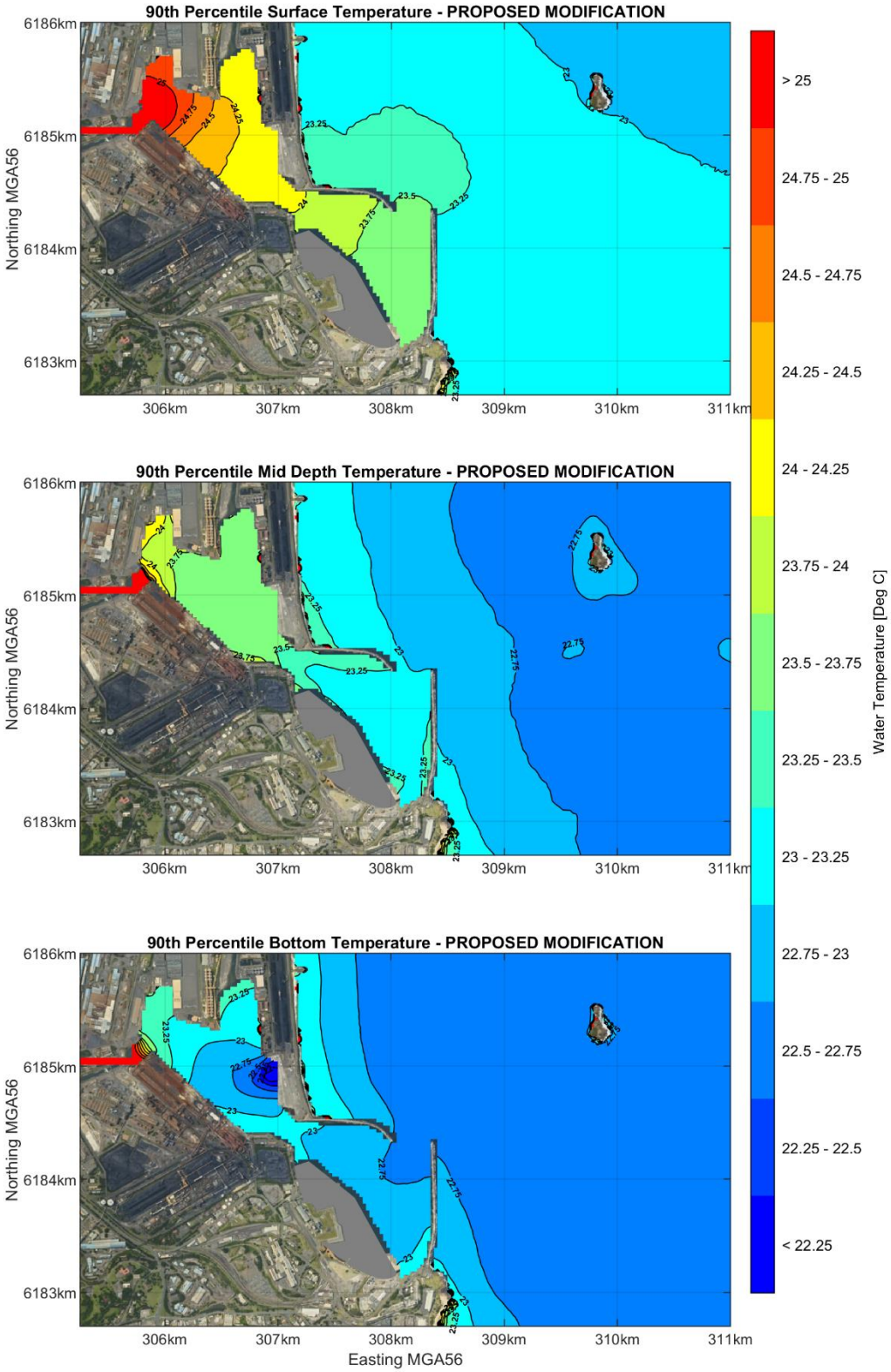
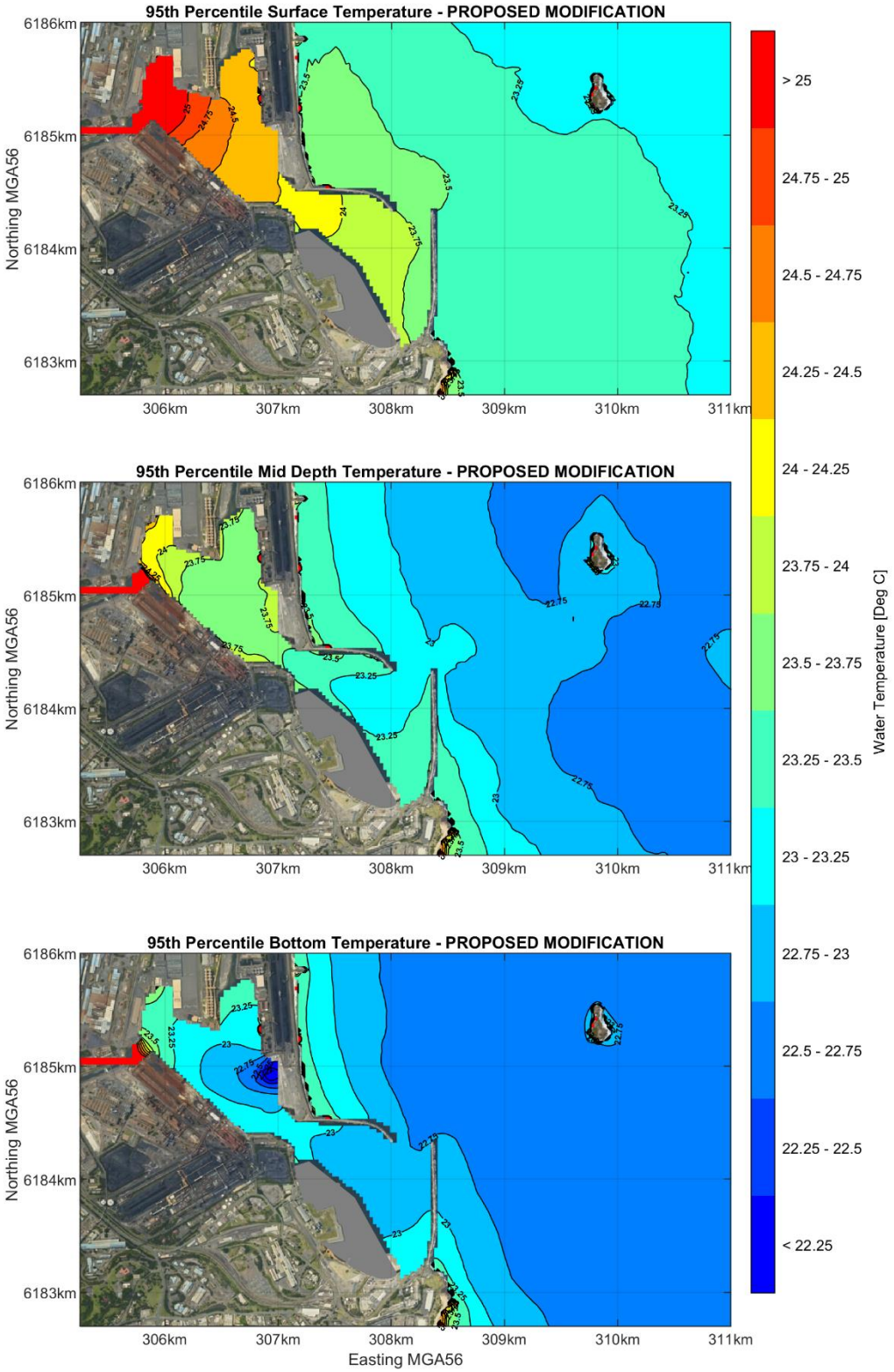


Modelled 90th Percentile Summer Water Temperature – Proposed Modification Layout



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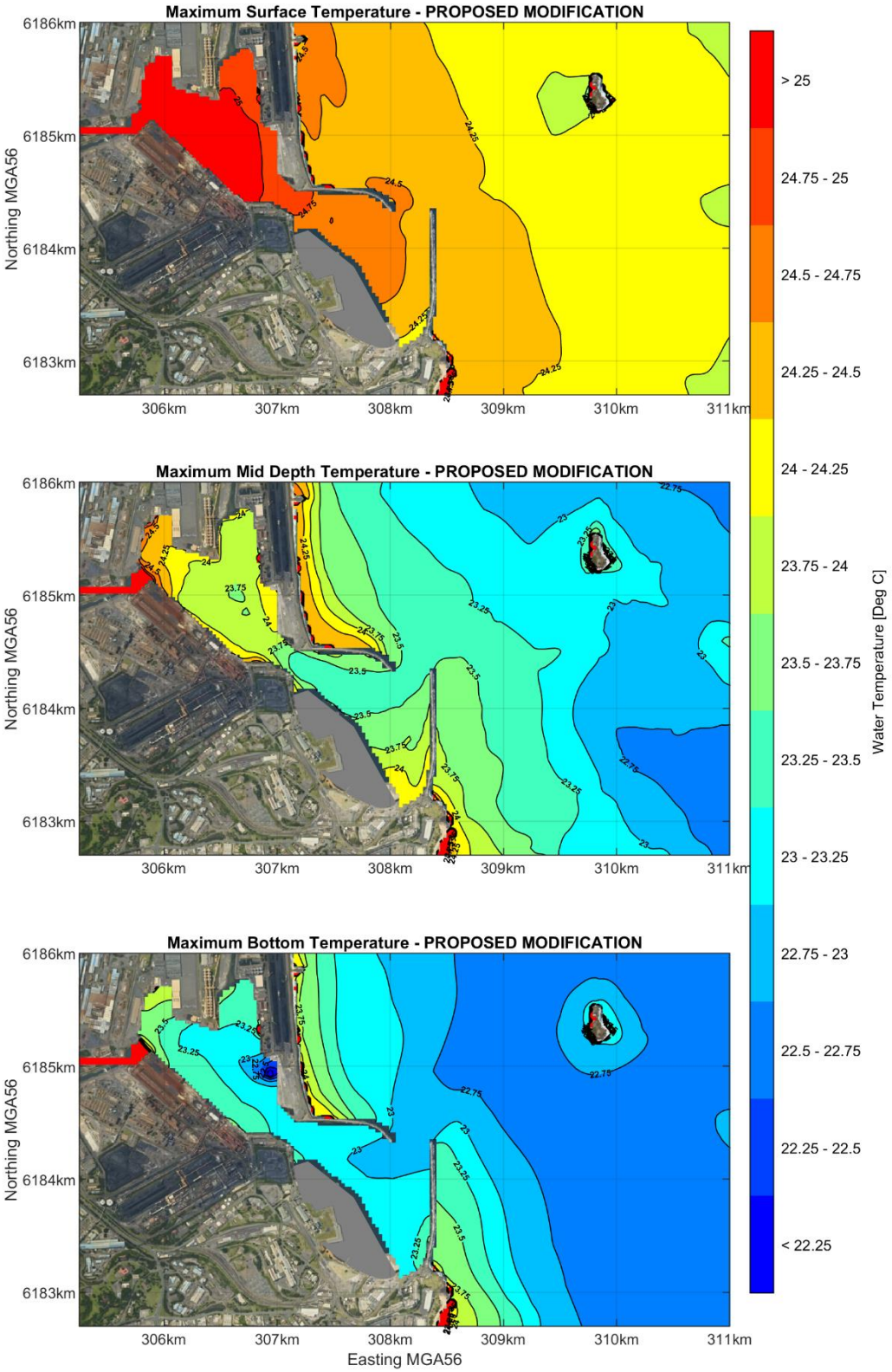
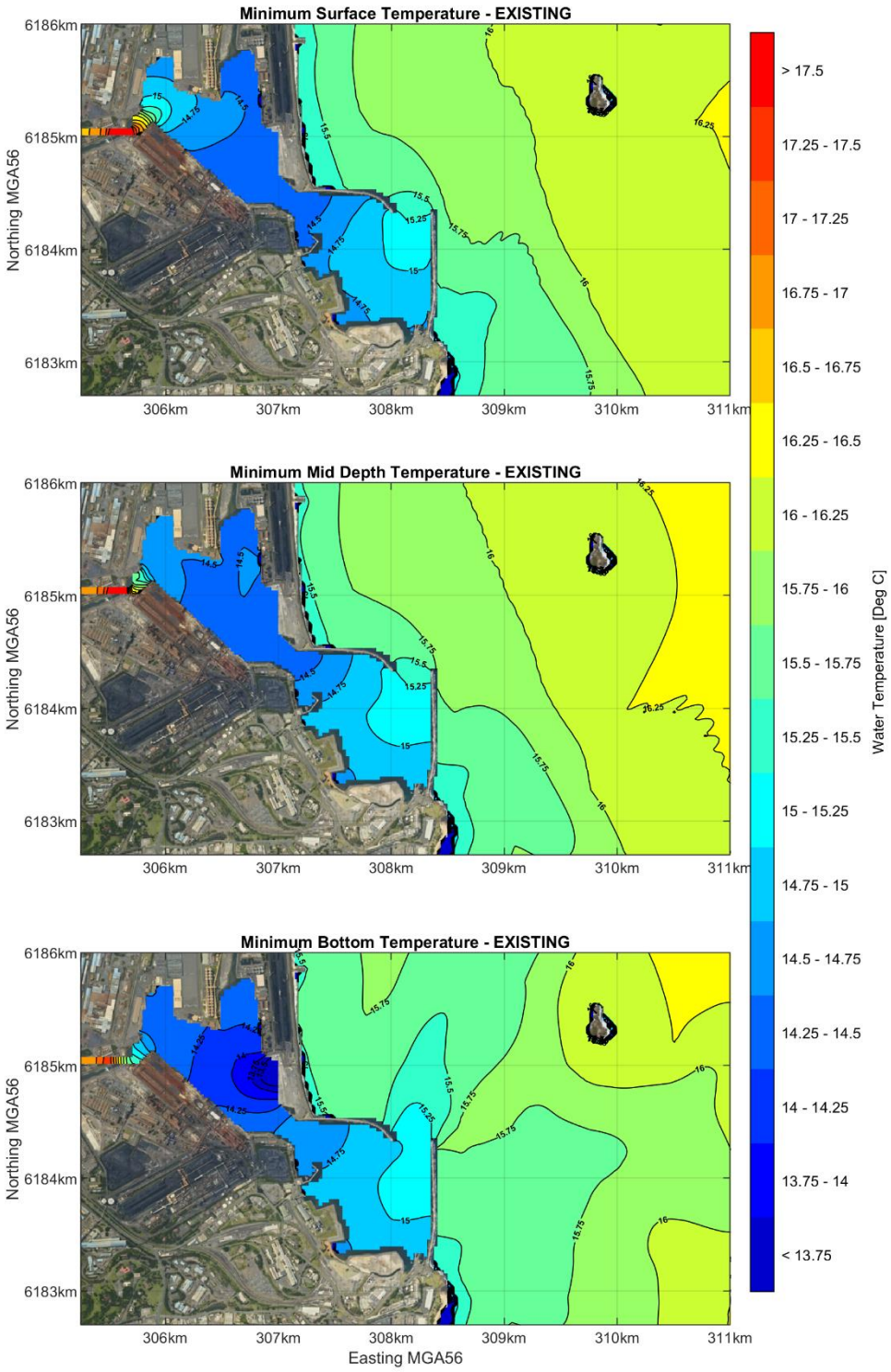
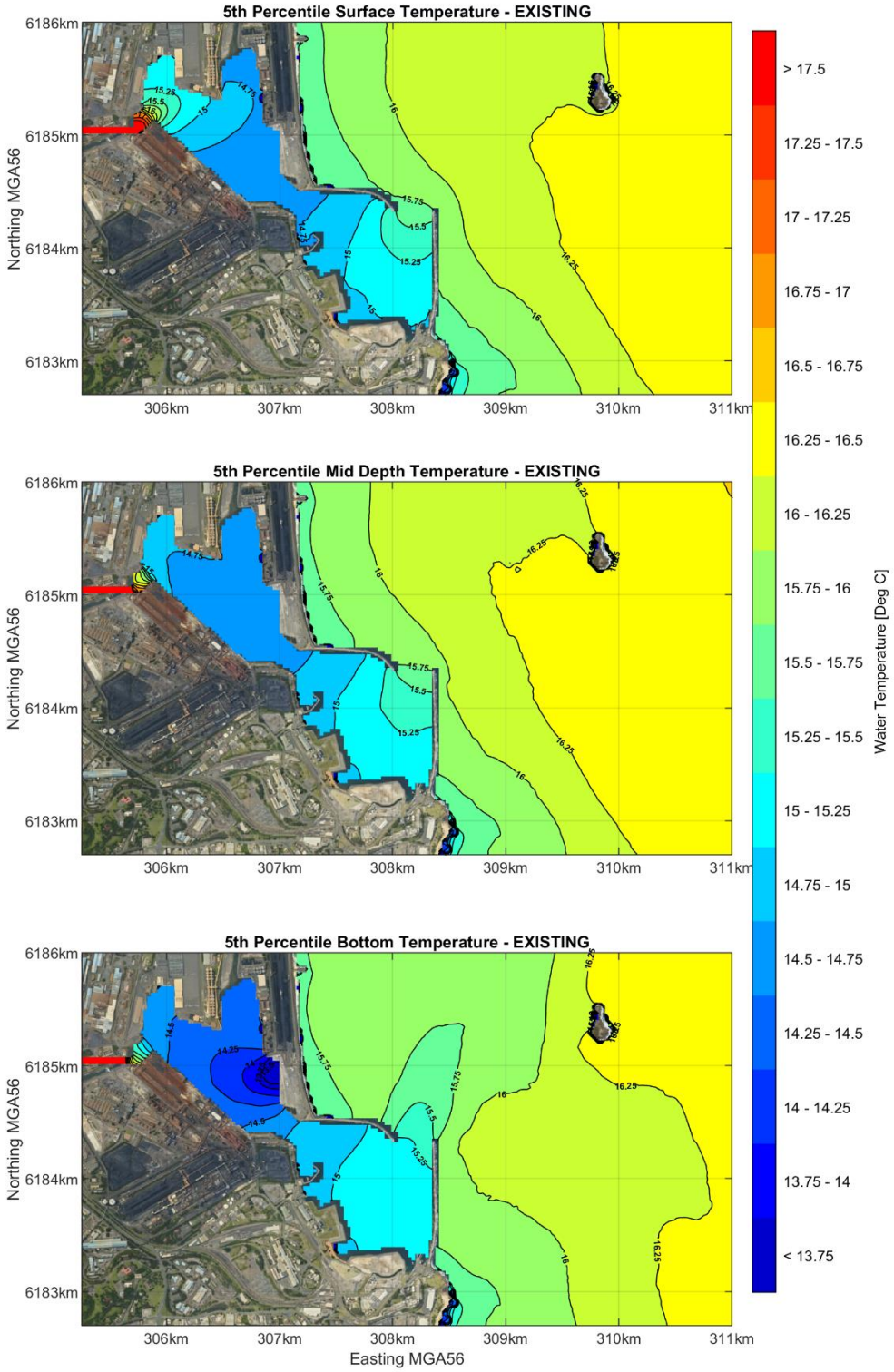


Modelled Maximum Summer Water Temperature – Proposed Modification Layout

Appendix D Winter Thermal Plume Results: Existing Layout



Modelled Minimum Winter Water Temperature – Existing Layout



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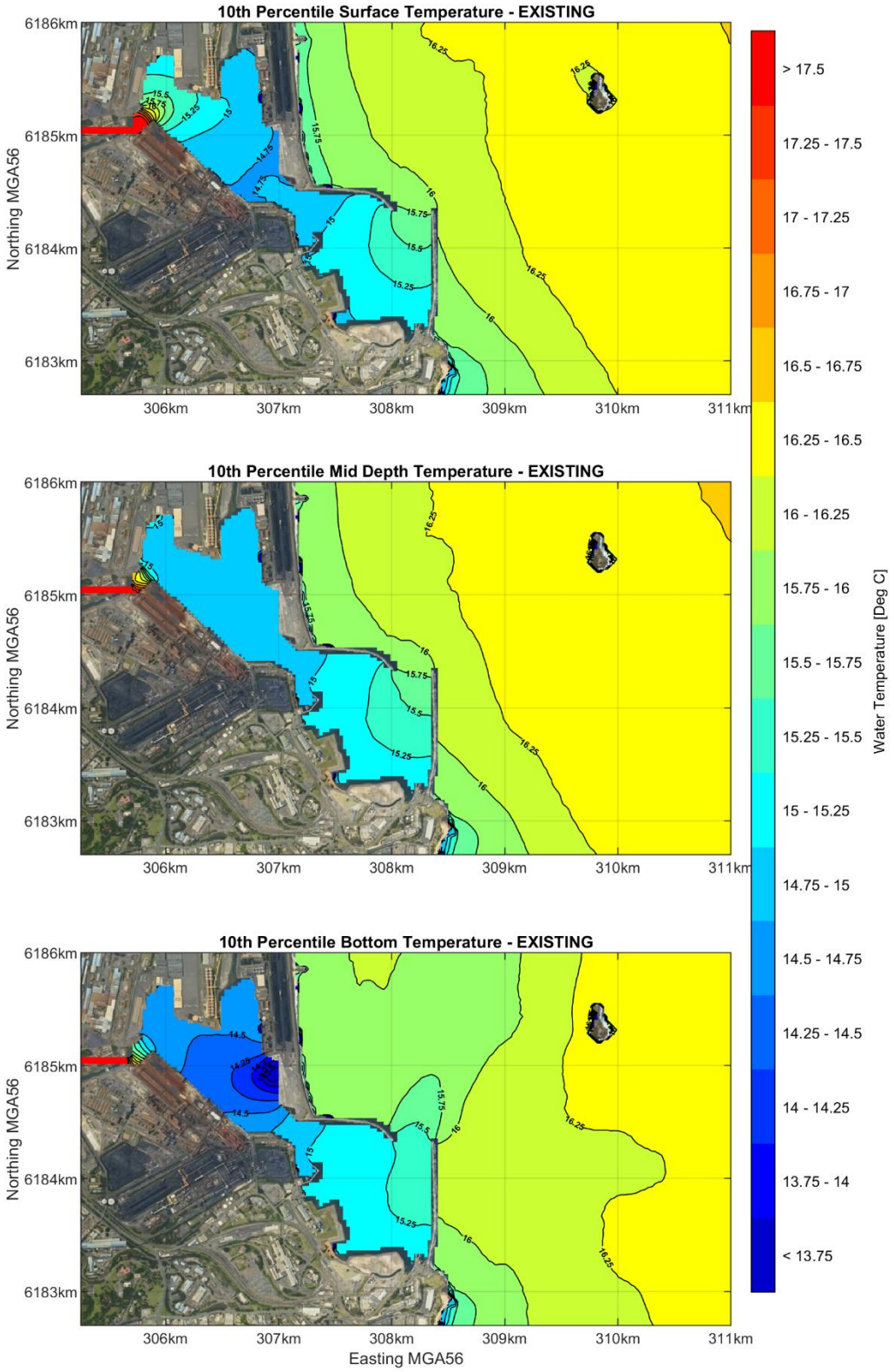
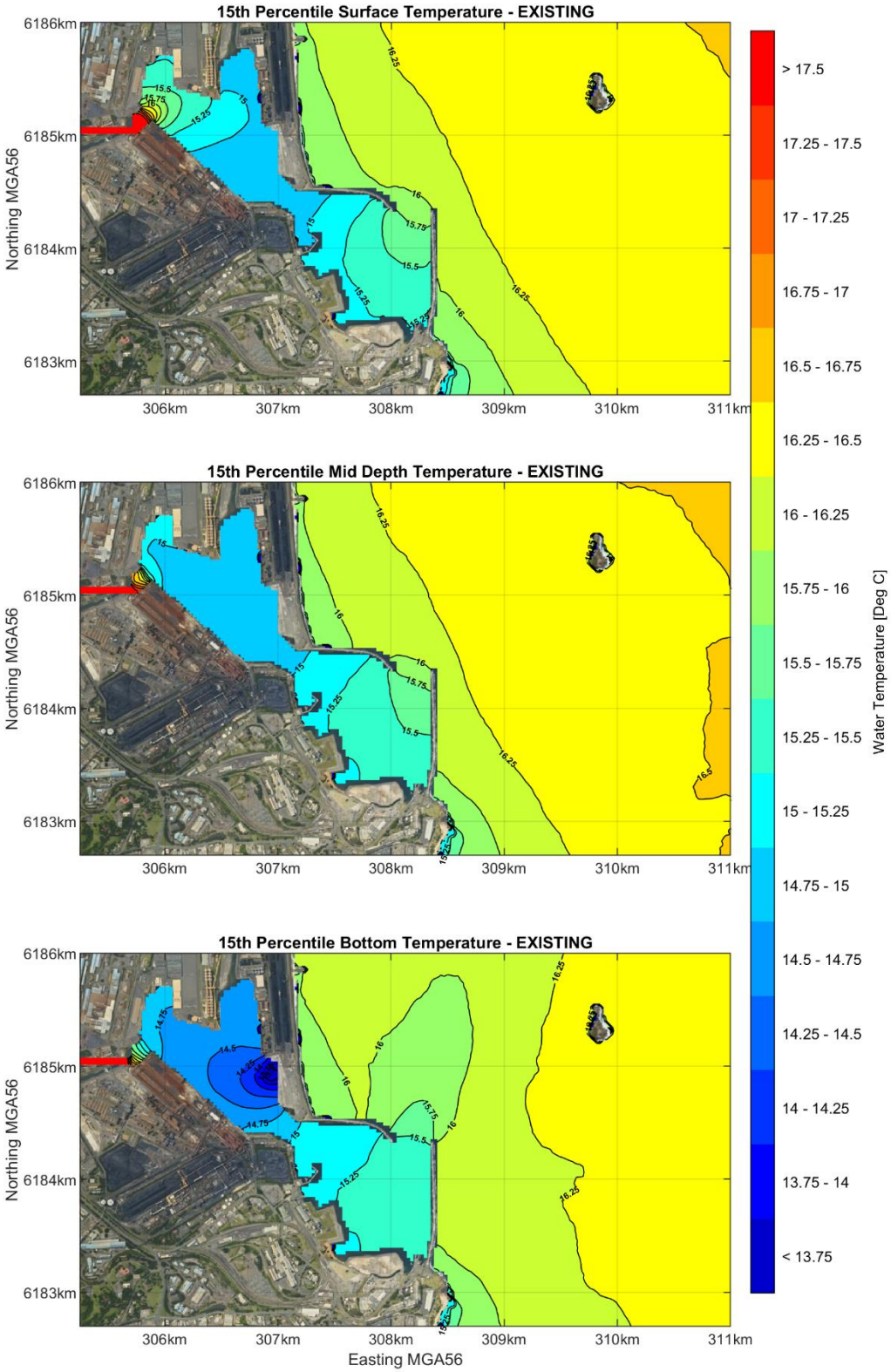
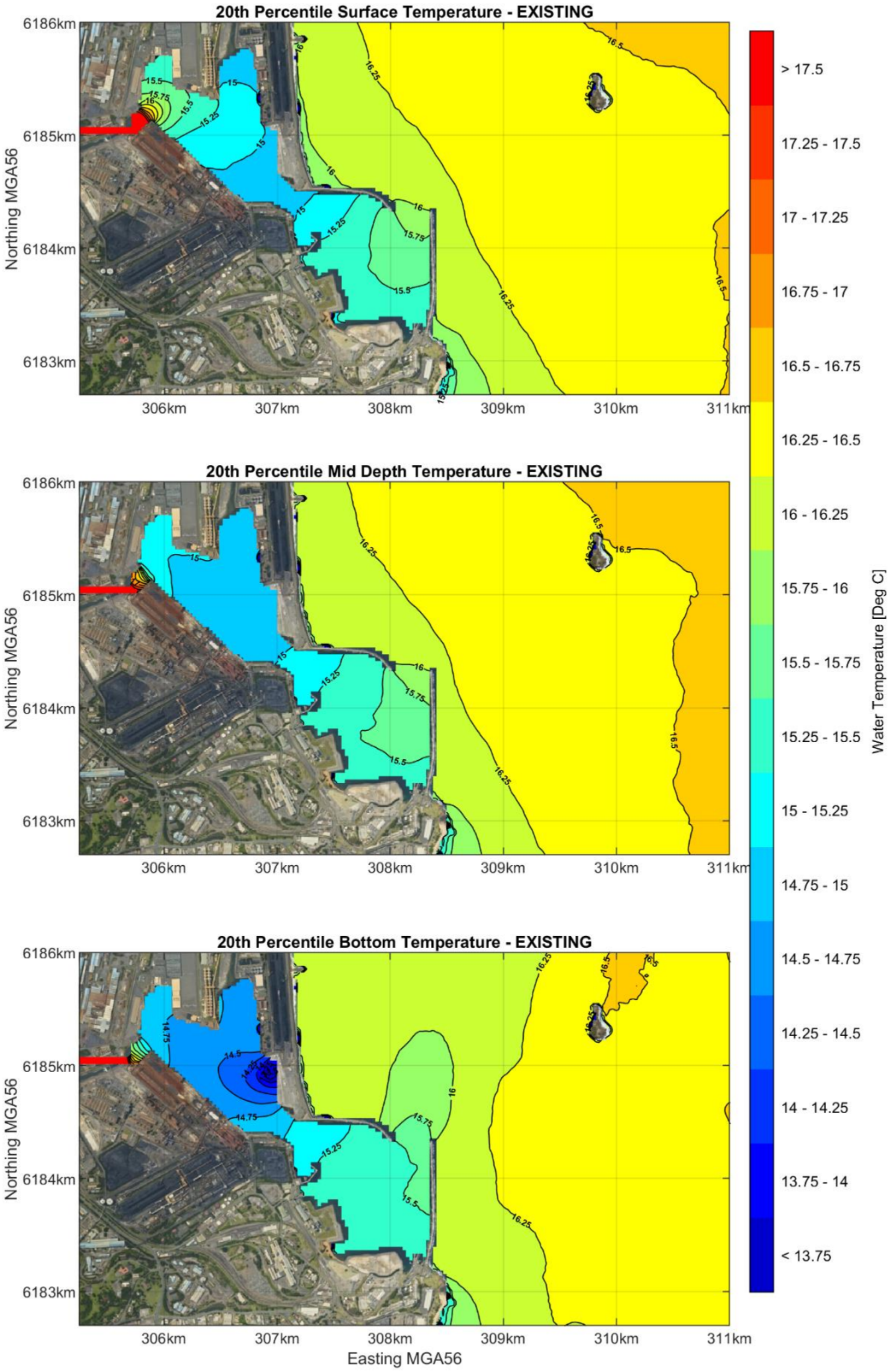


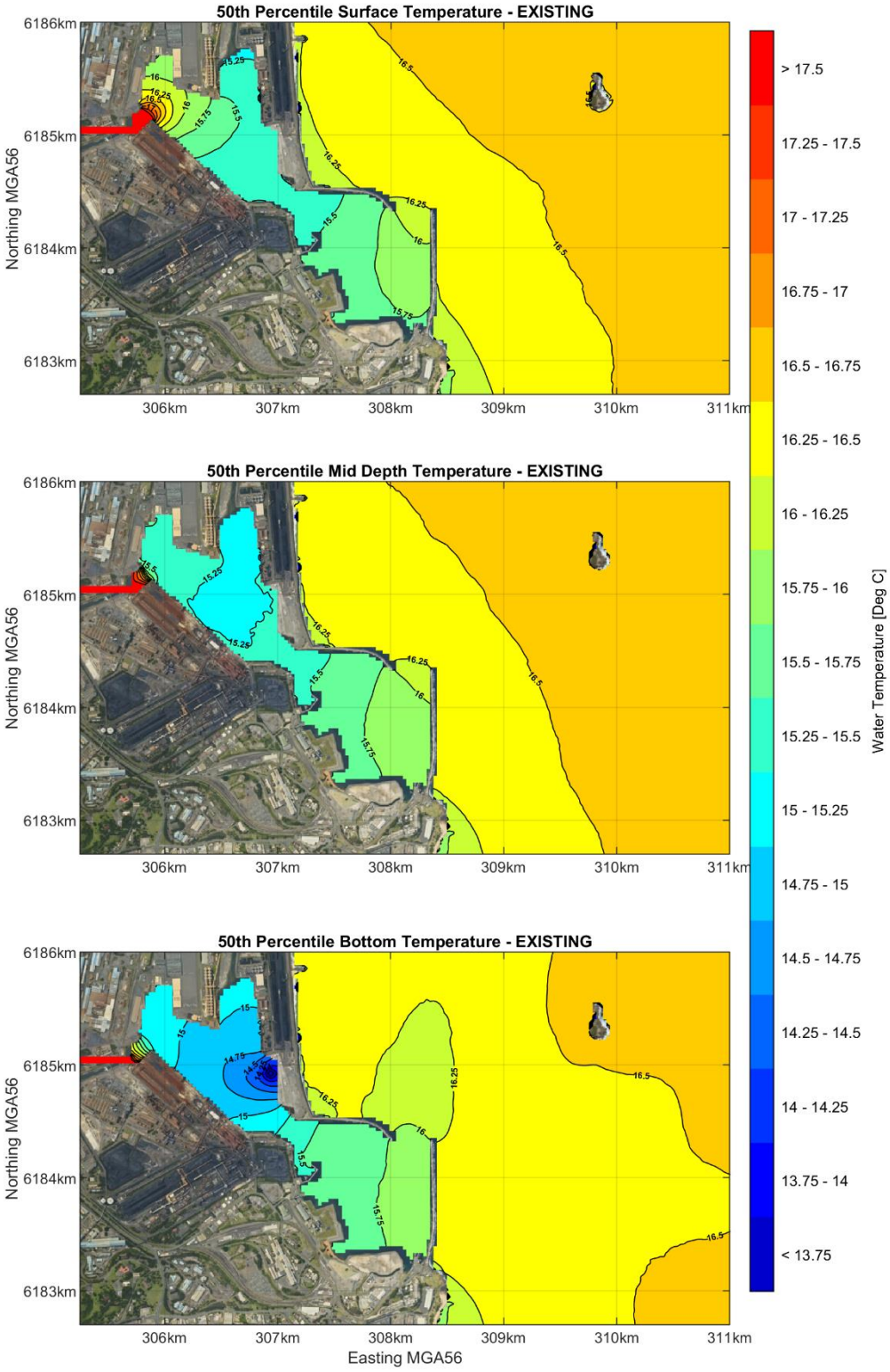
Modelled 10th Percentile Winter Water Temperature – Existing Layout



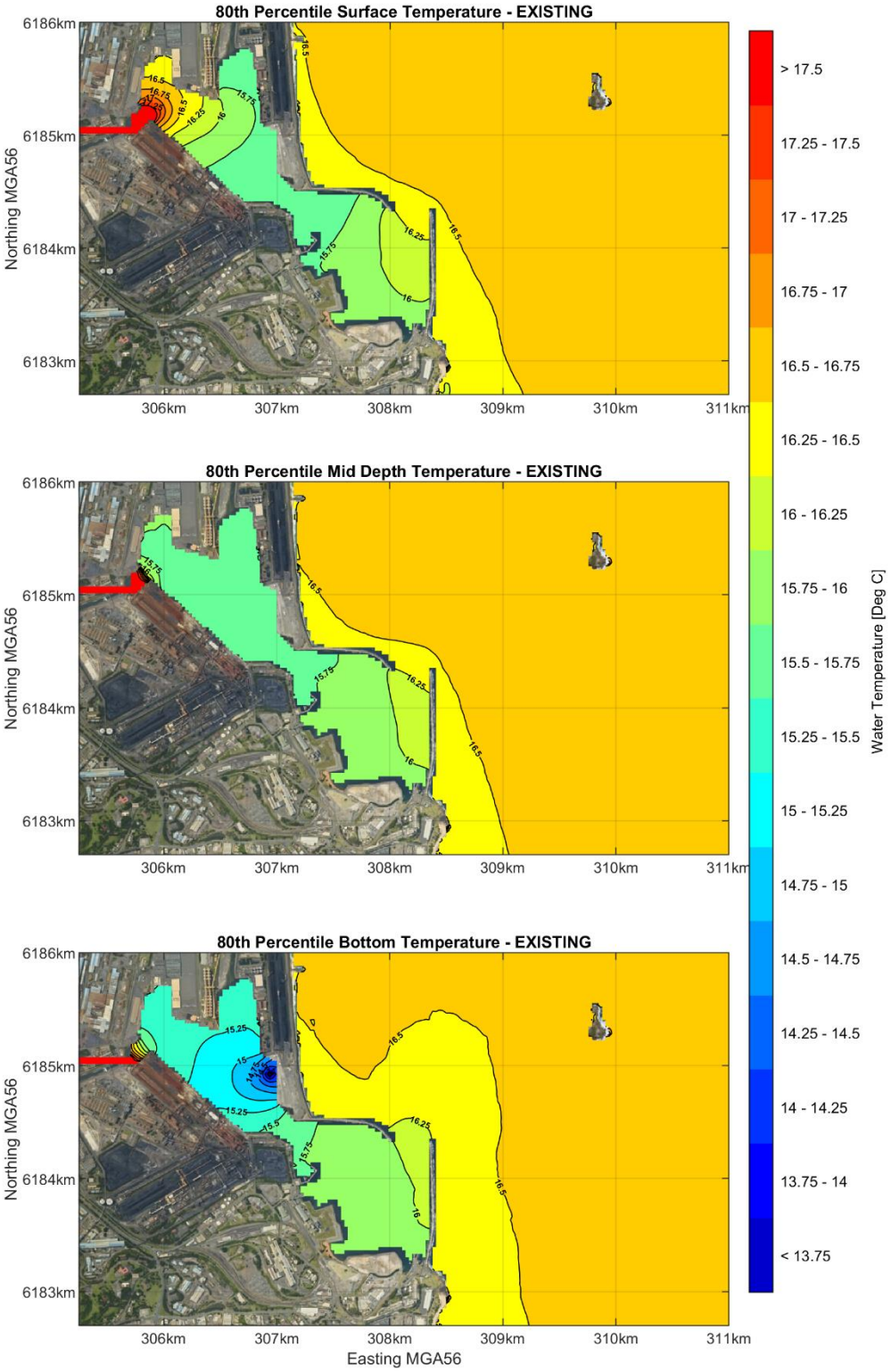
Modelled 15th Percentile Winter Water Temperature – Existing Layout



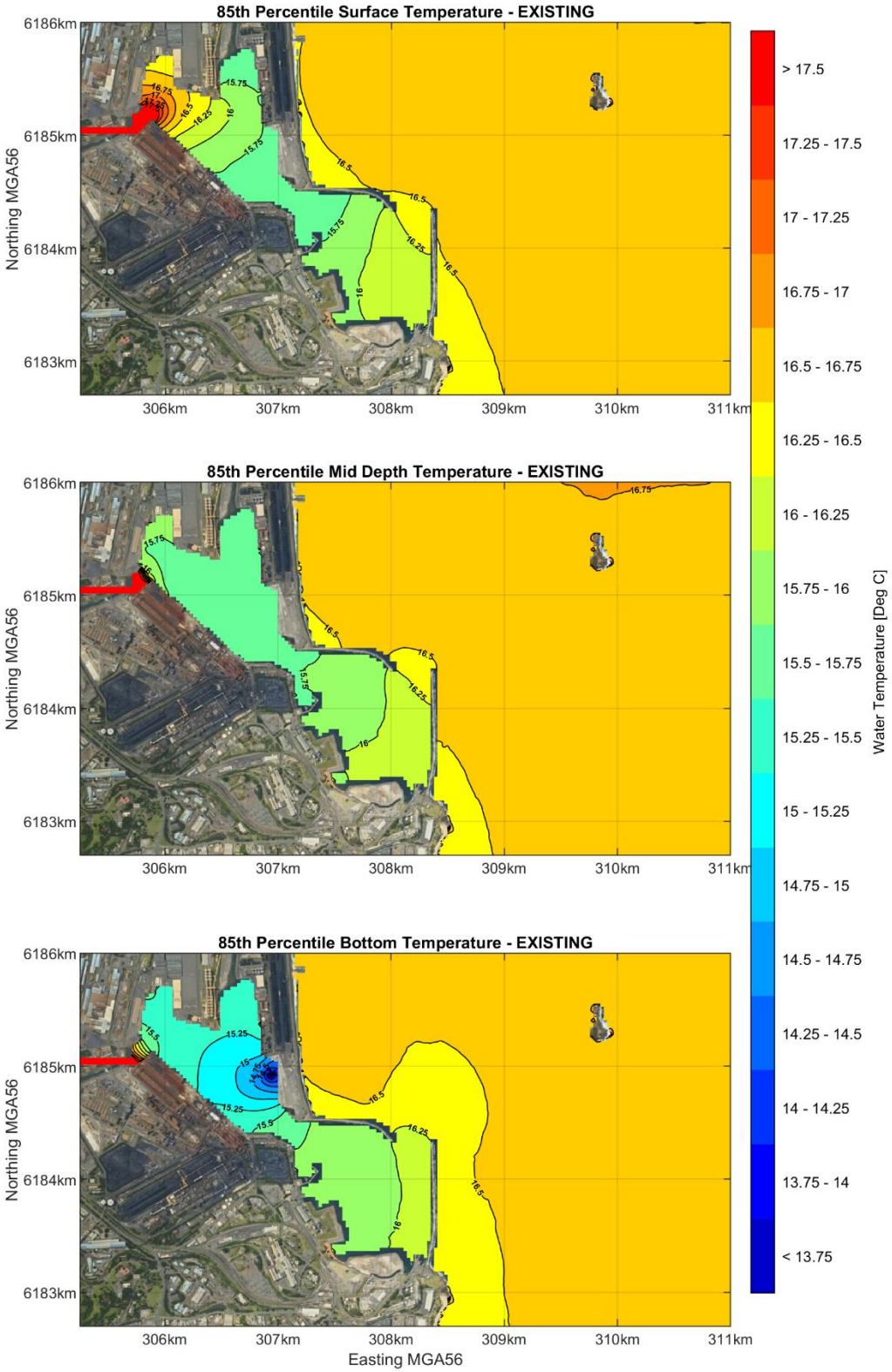
Modelled 20th Percentile Winter Water Temperature – Existing Layout



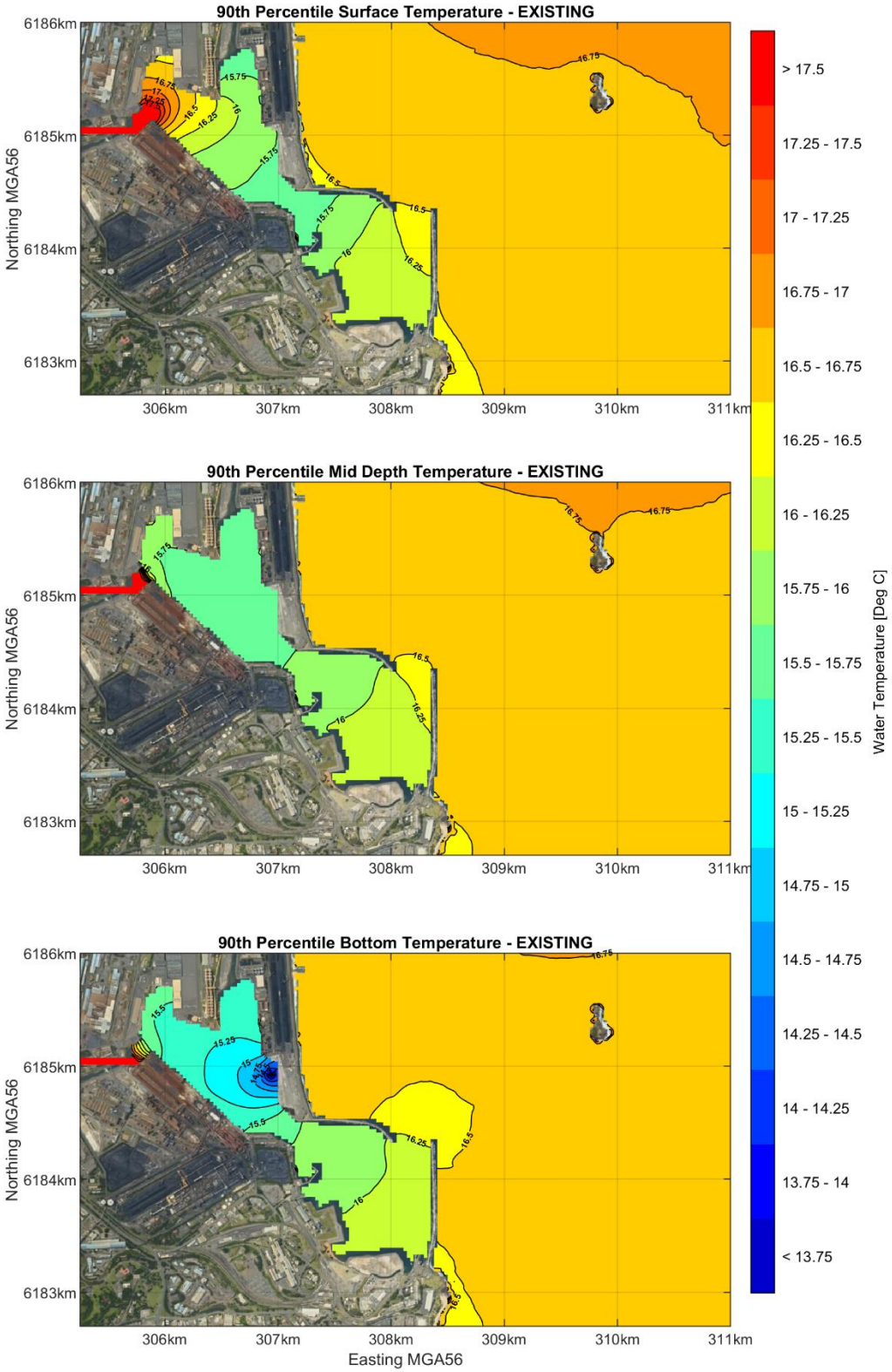
Modelled 50th Percentile Winter Water Temperature – Existing Layout



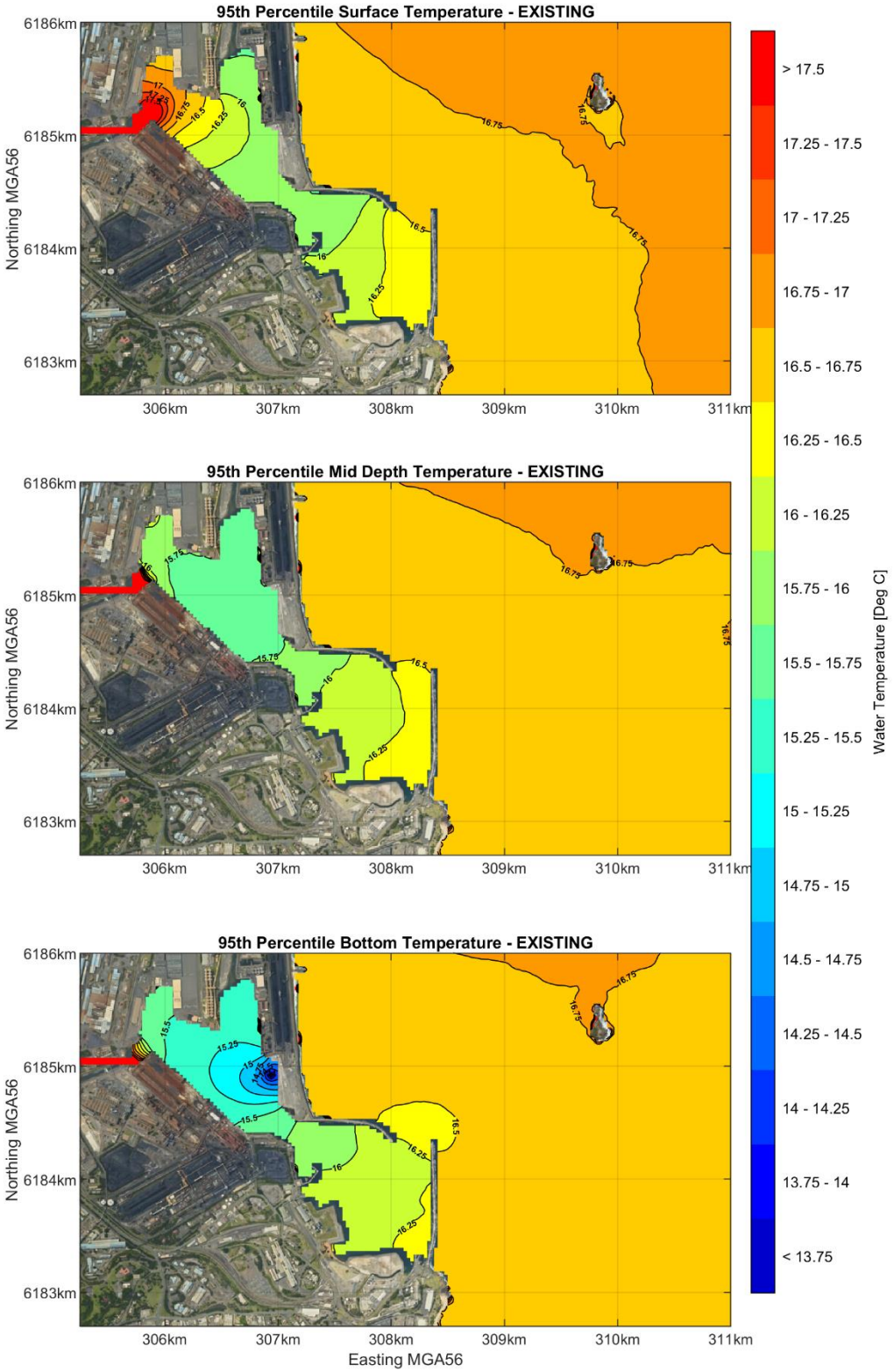
Modelled 80th Percentile Winter Water Temperature – Existing Layout



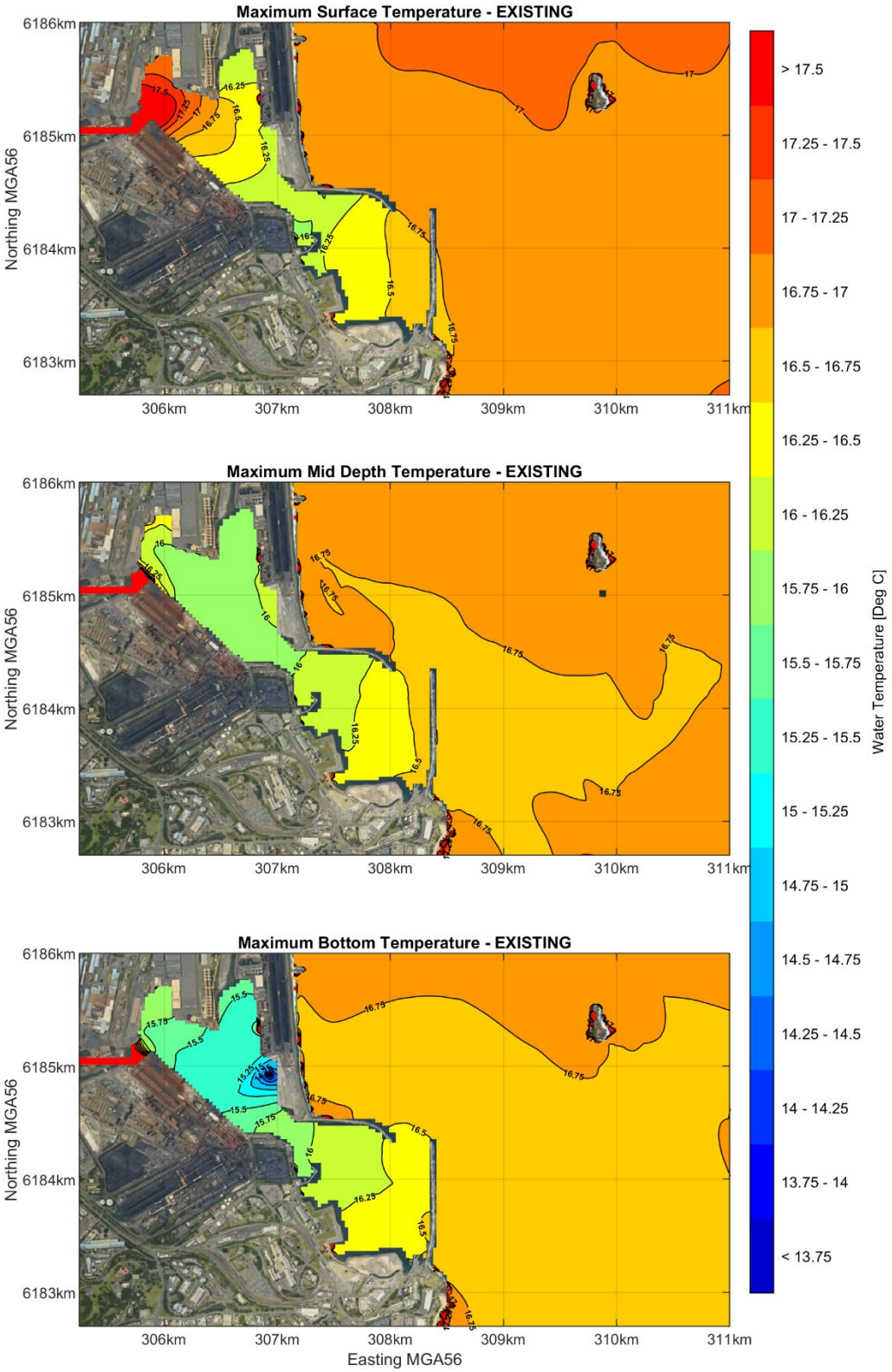
Modelled 85th Percentile Winter Water Temperature – Existing Layout



Modelled 90th Percentile Winter Water Temperature – Existing Layout

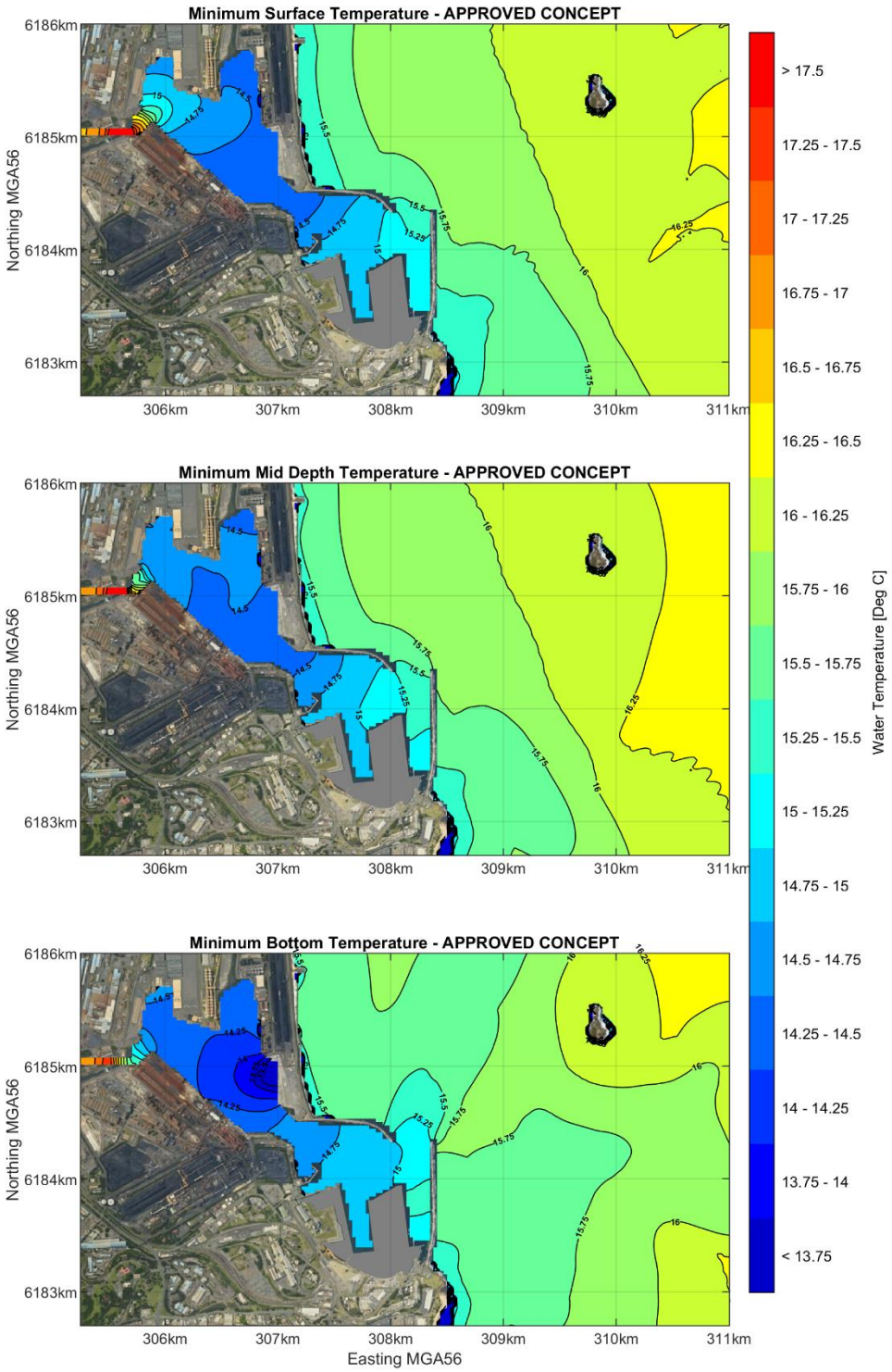


Modelled 95th Percentile Winter Water Temperature – Existing Layout

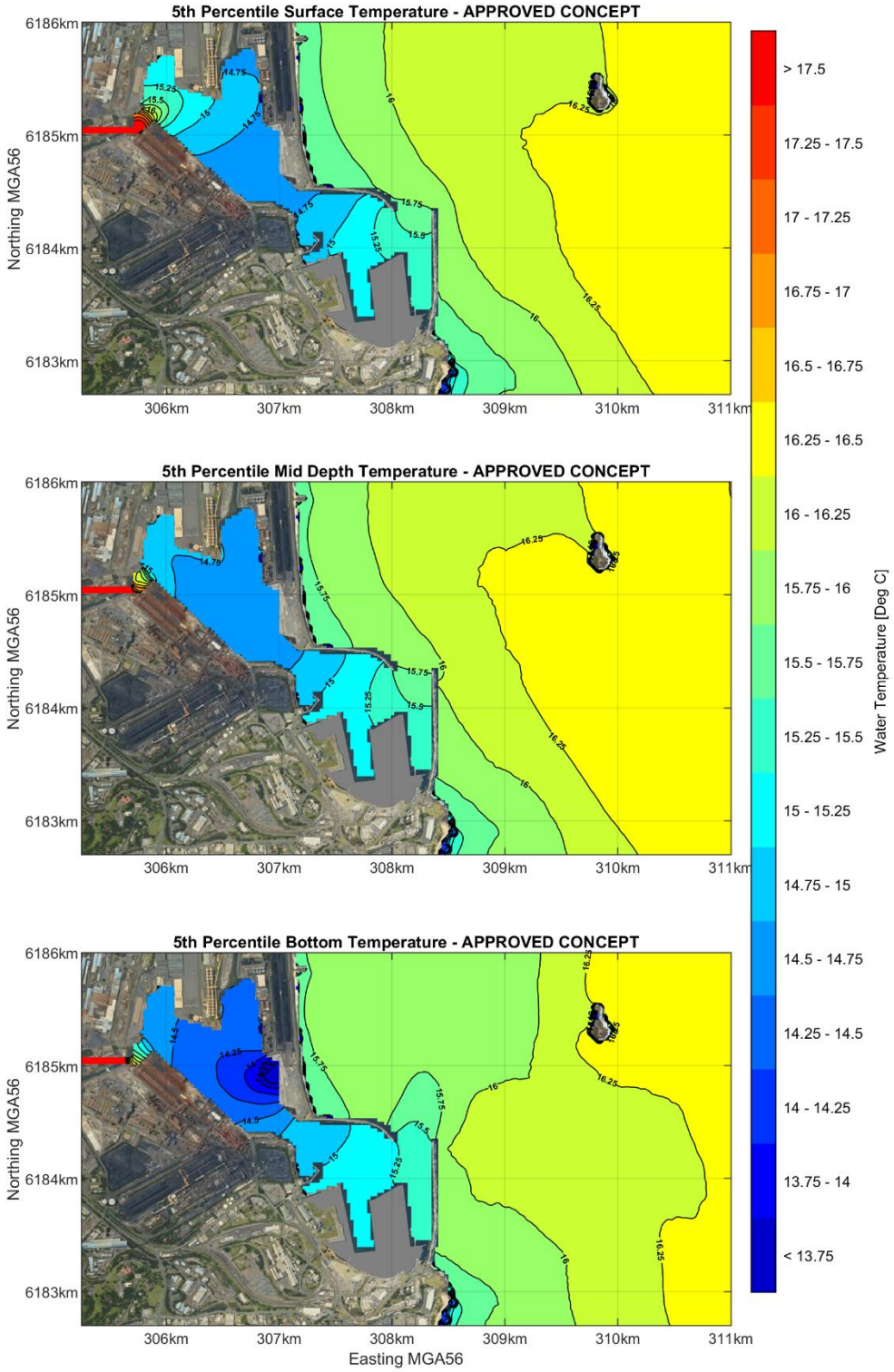


Modelled Maximum Winter Water Temperature – Existing Layout

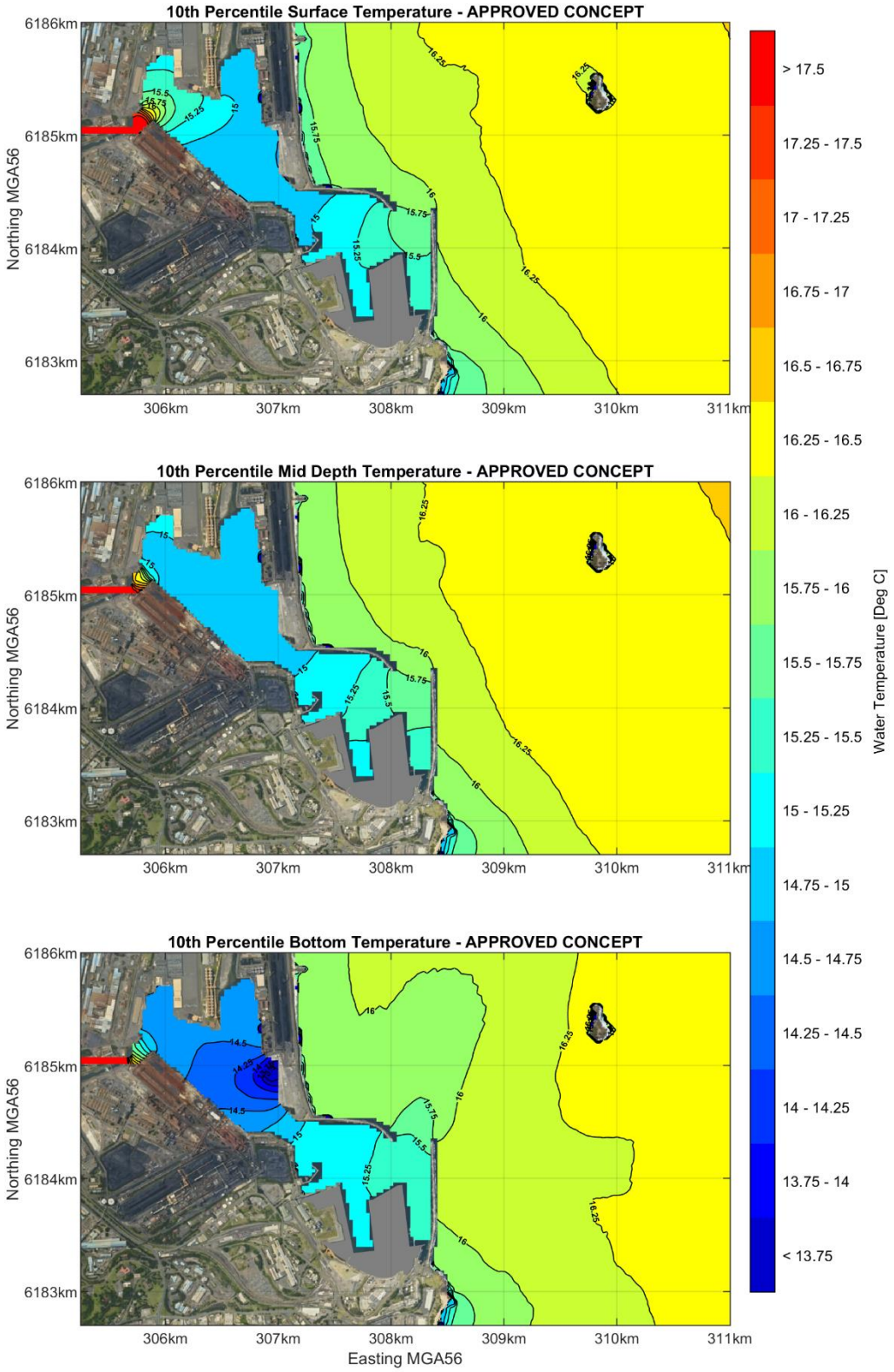
Appendix E Winter Thermal Plume Results: Approved Concept Layout



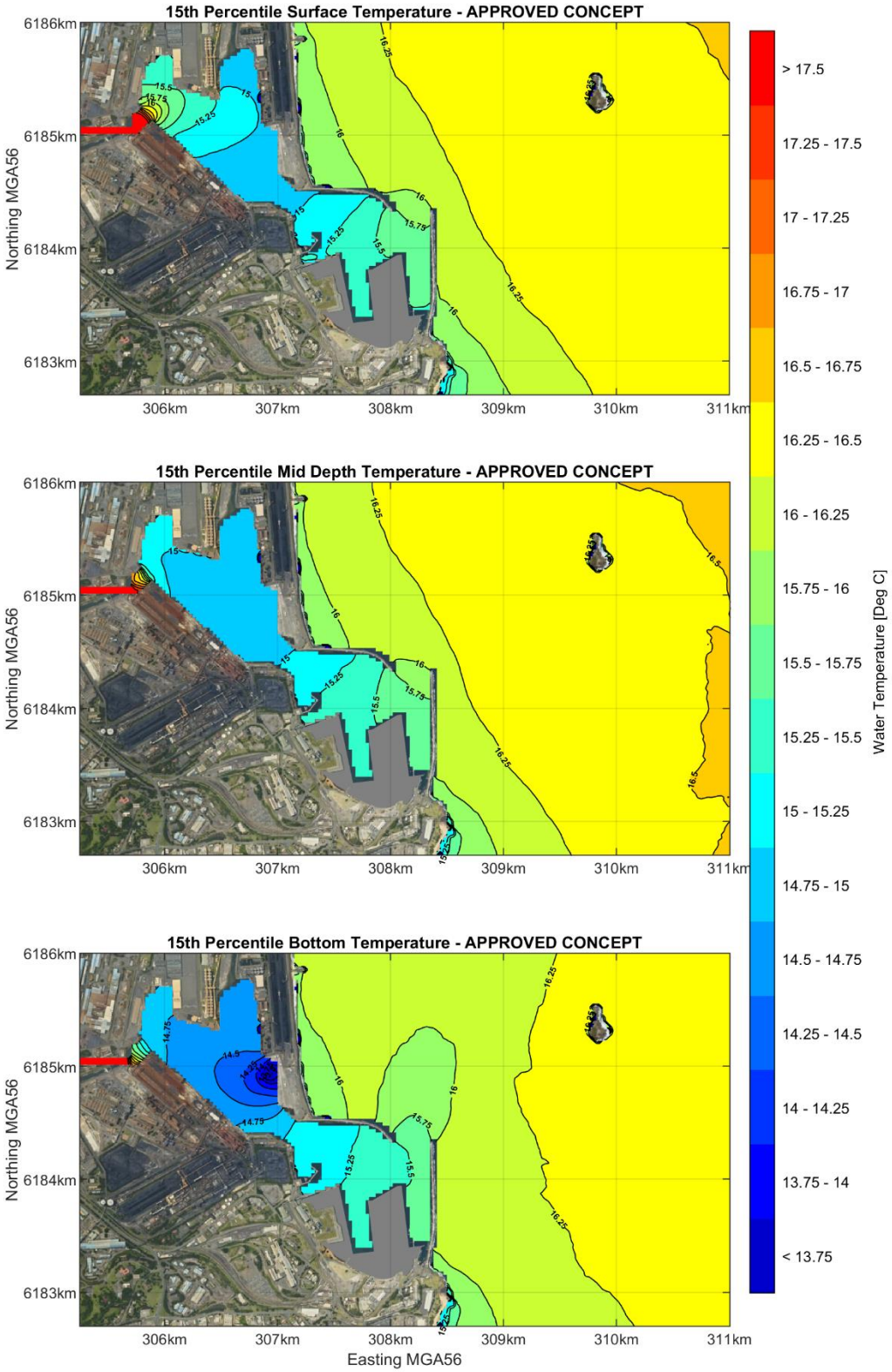
Modelled Minimum Winter Water Temperature – Approved Concept Layout



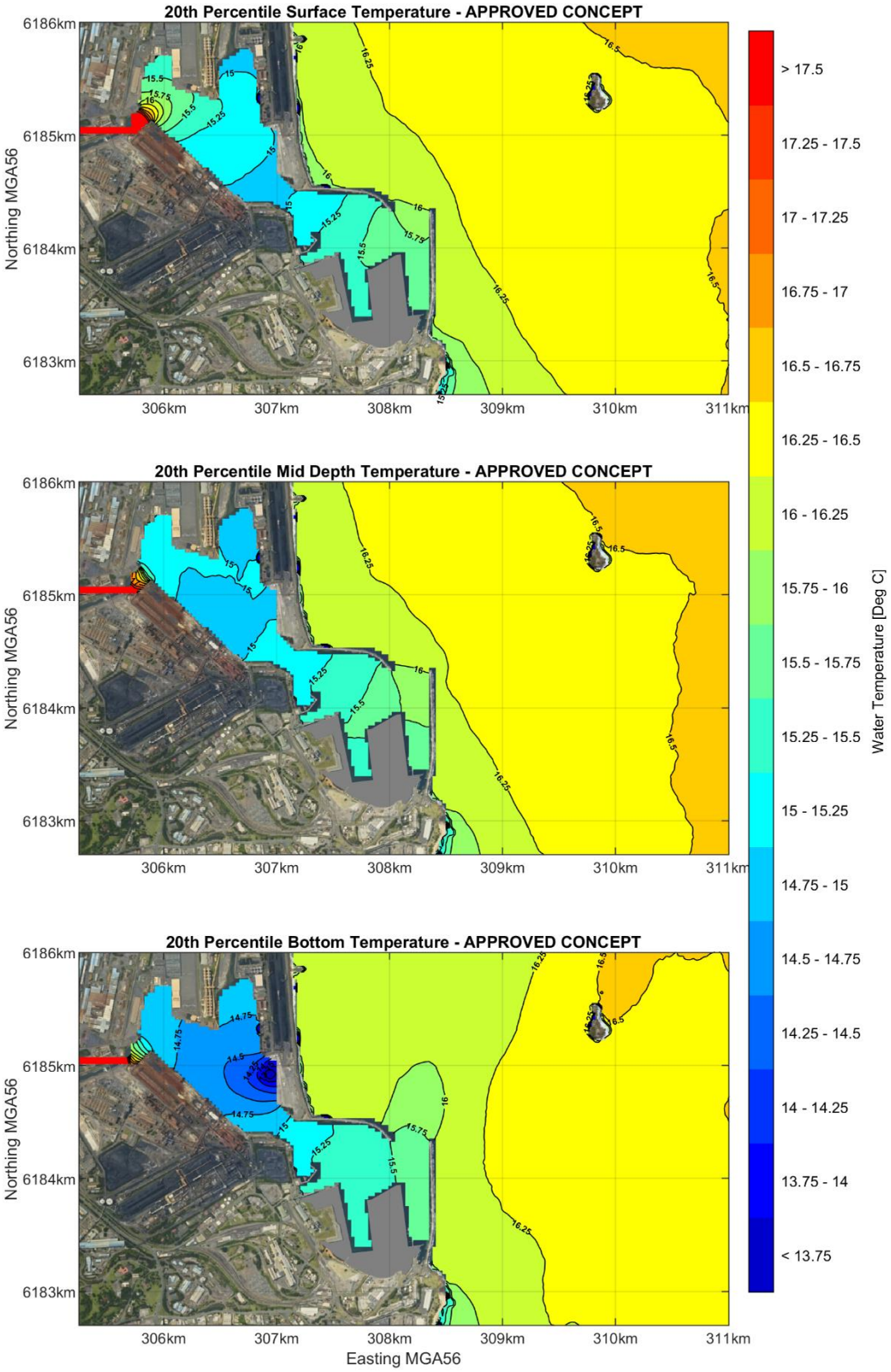
Modelled 5th Percentile Winter Water Temperature – Approved Concept Layout



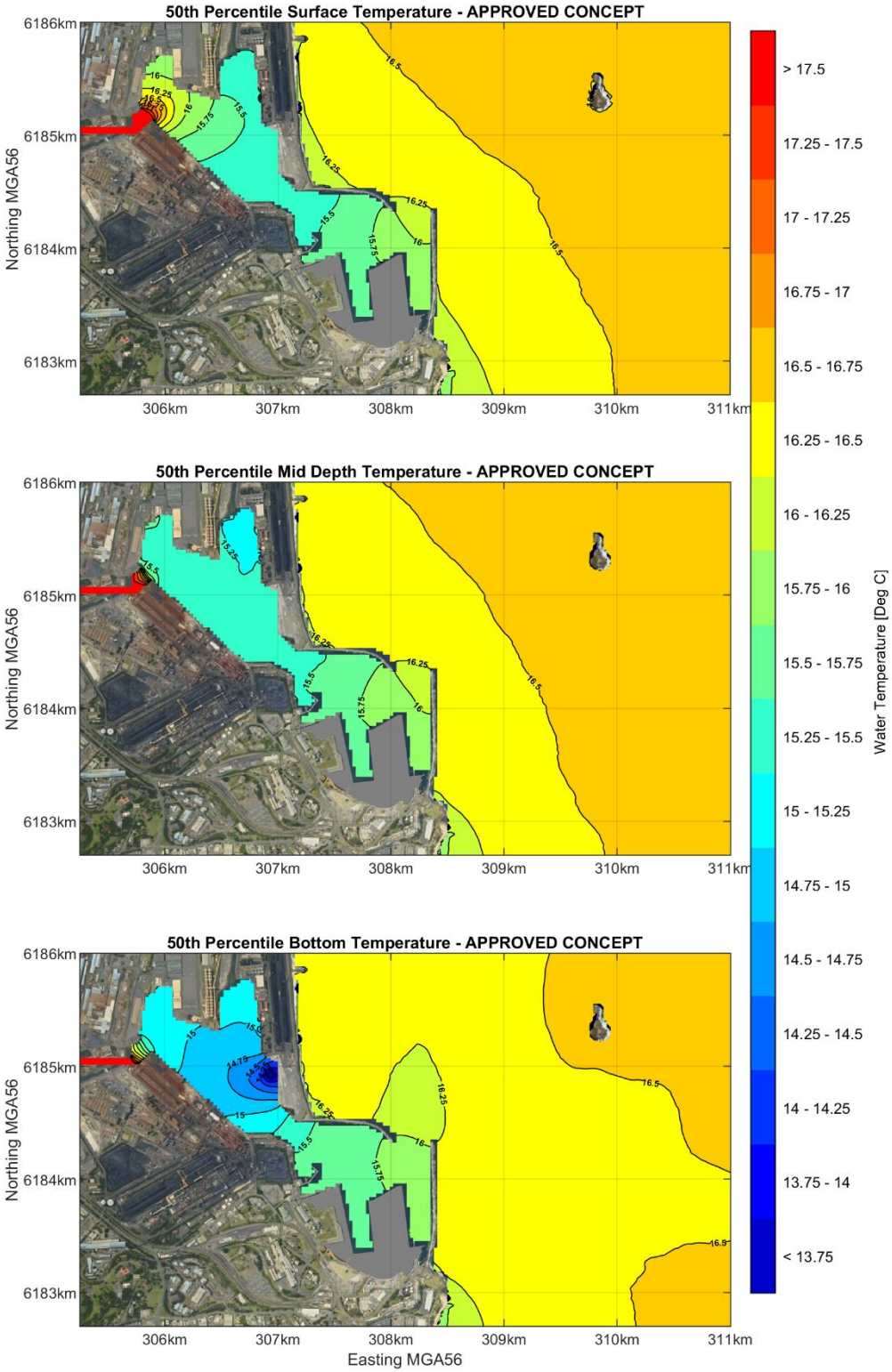
Modelled 10th Percentile Winter Water Temperature – Approved Concept Layout



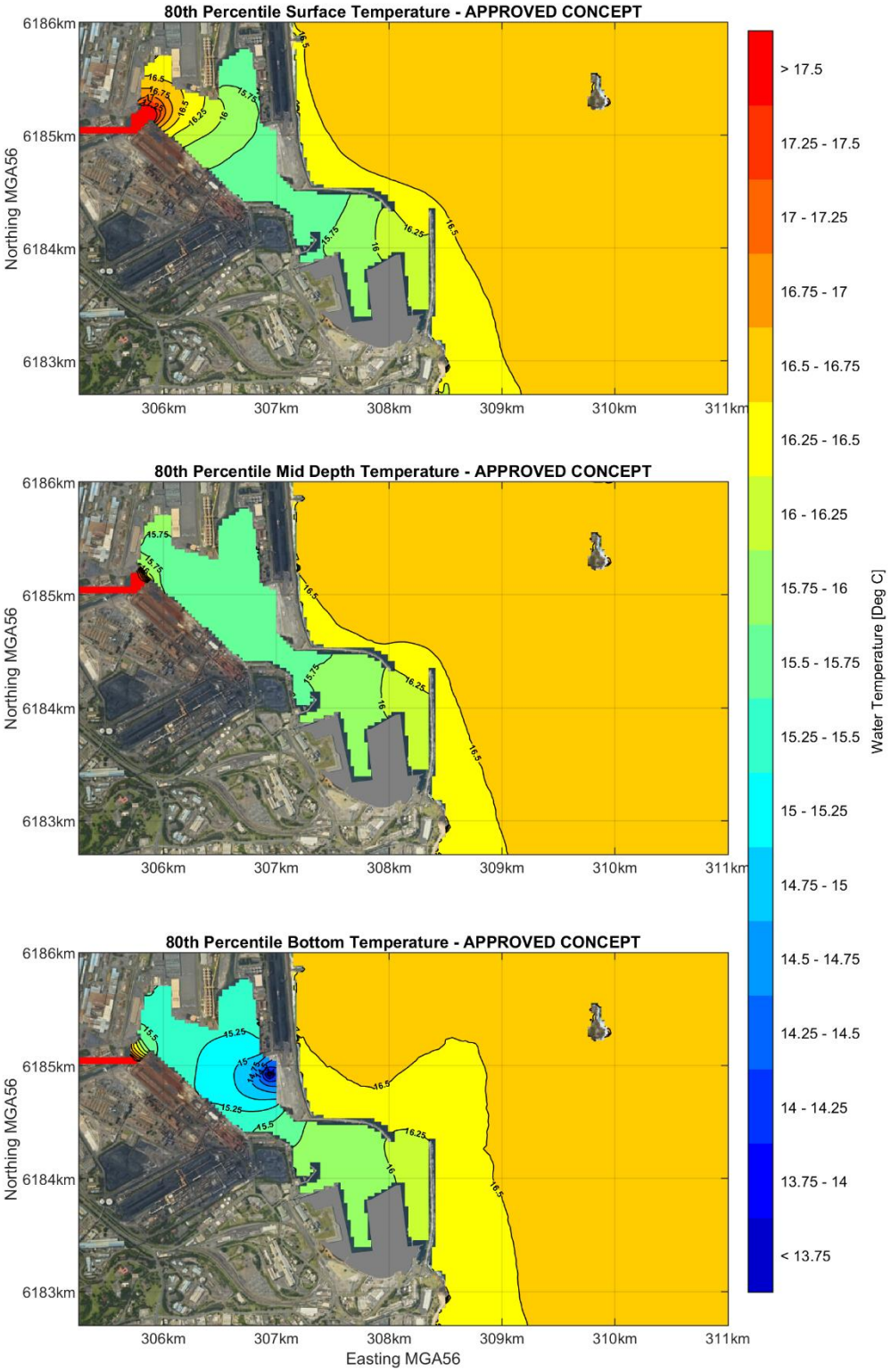
Modelled 15th Percentile Winter Water Temperature – Approved Concept Layout



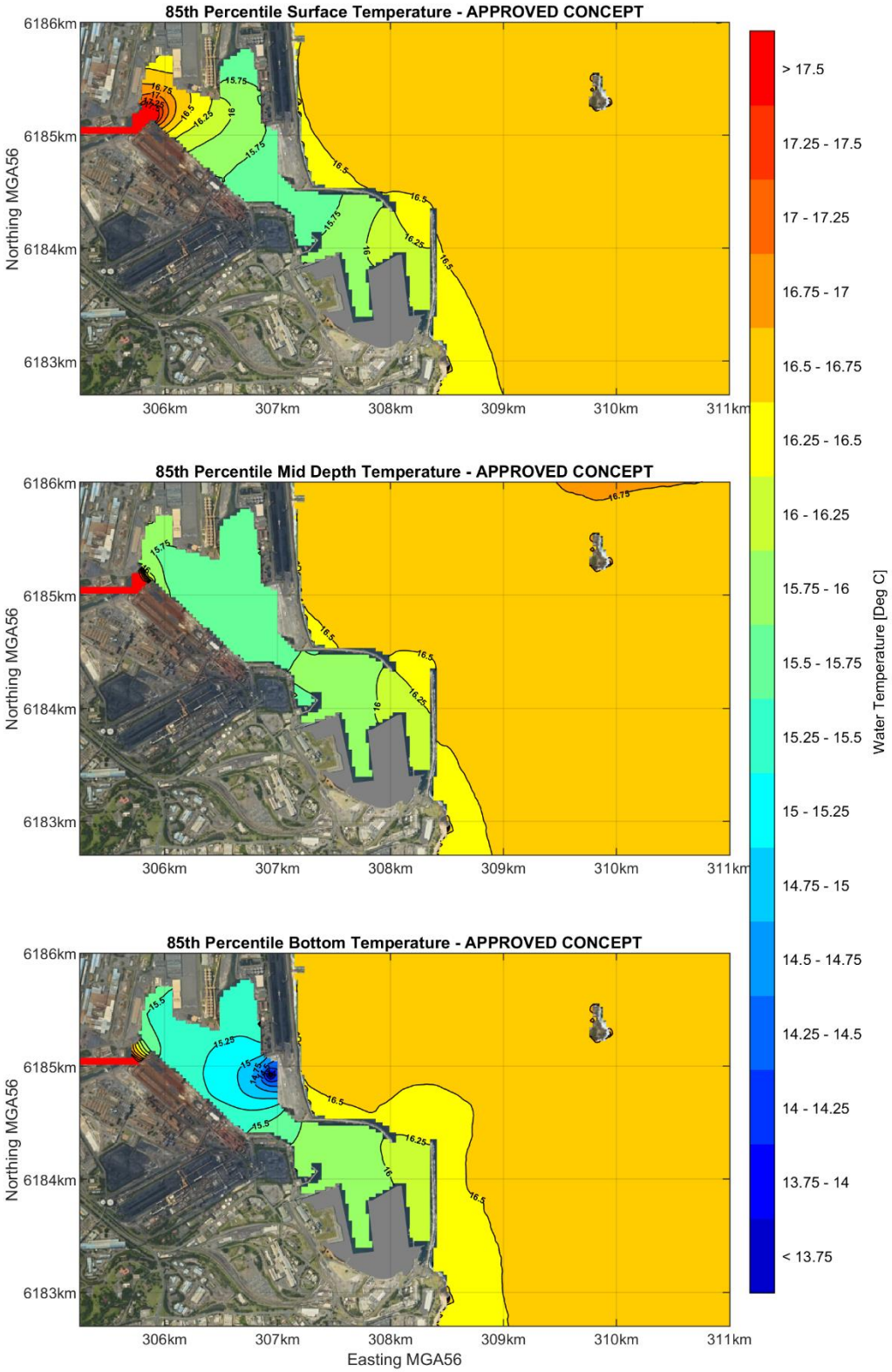
Modelled 20th Percentile Winter Water Temperature – Approved Concept Layout



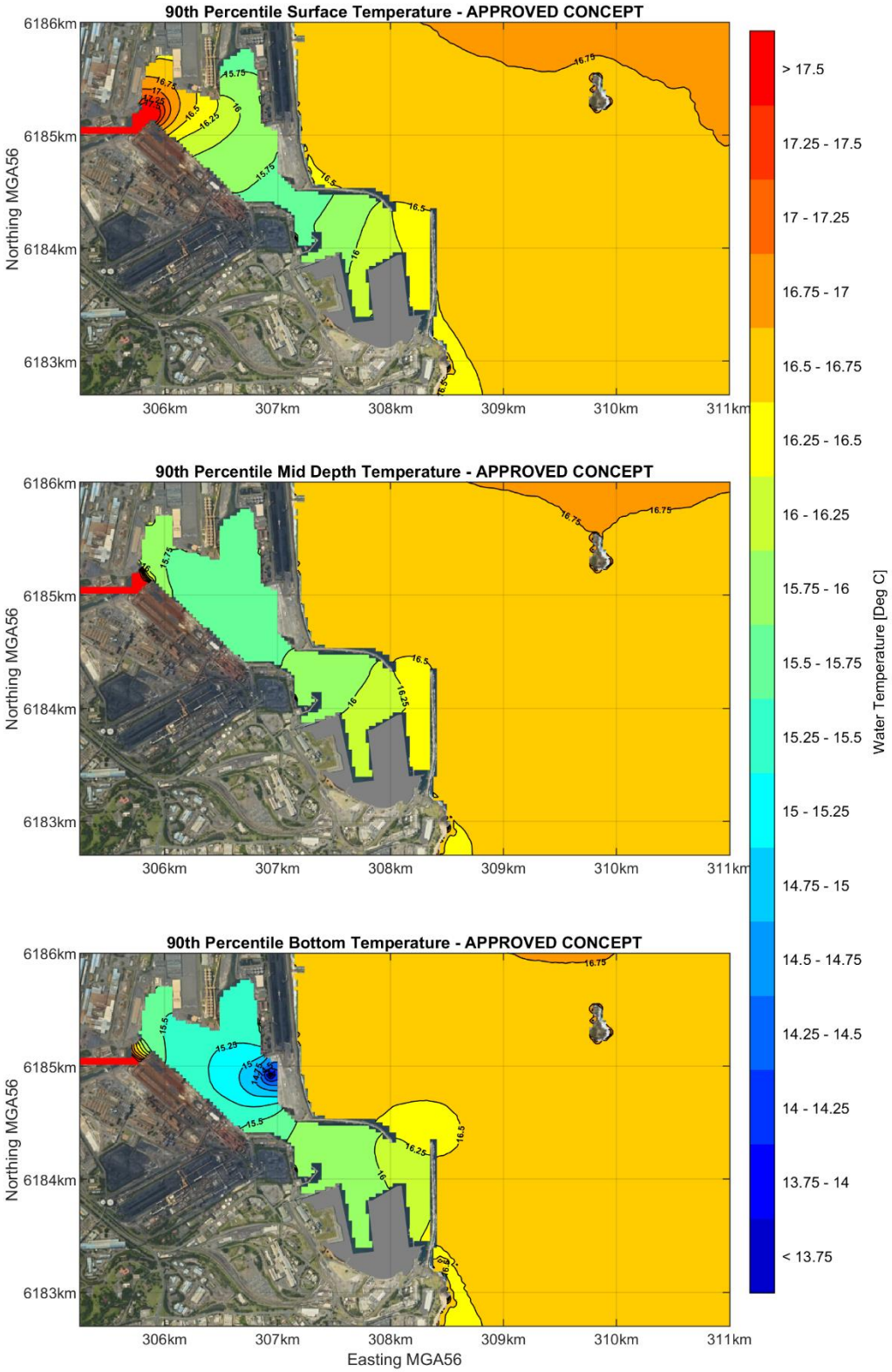
Modelled 50th Percentile Winter Water Temperature – Approved Concept Layout



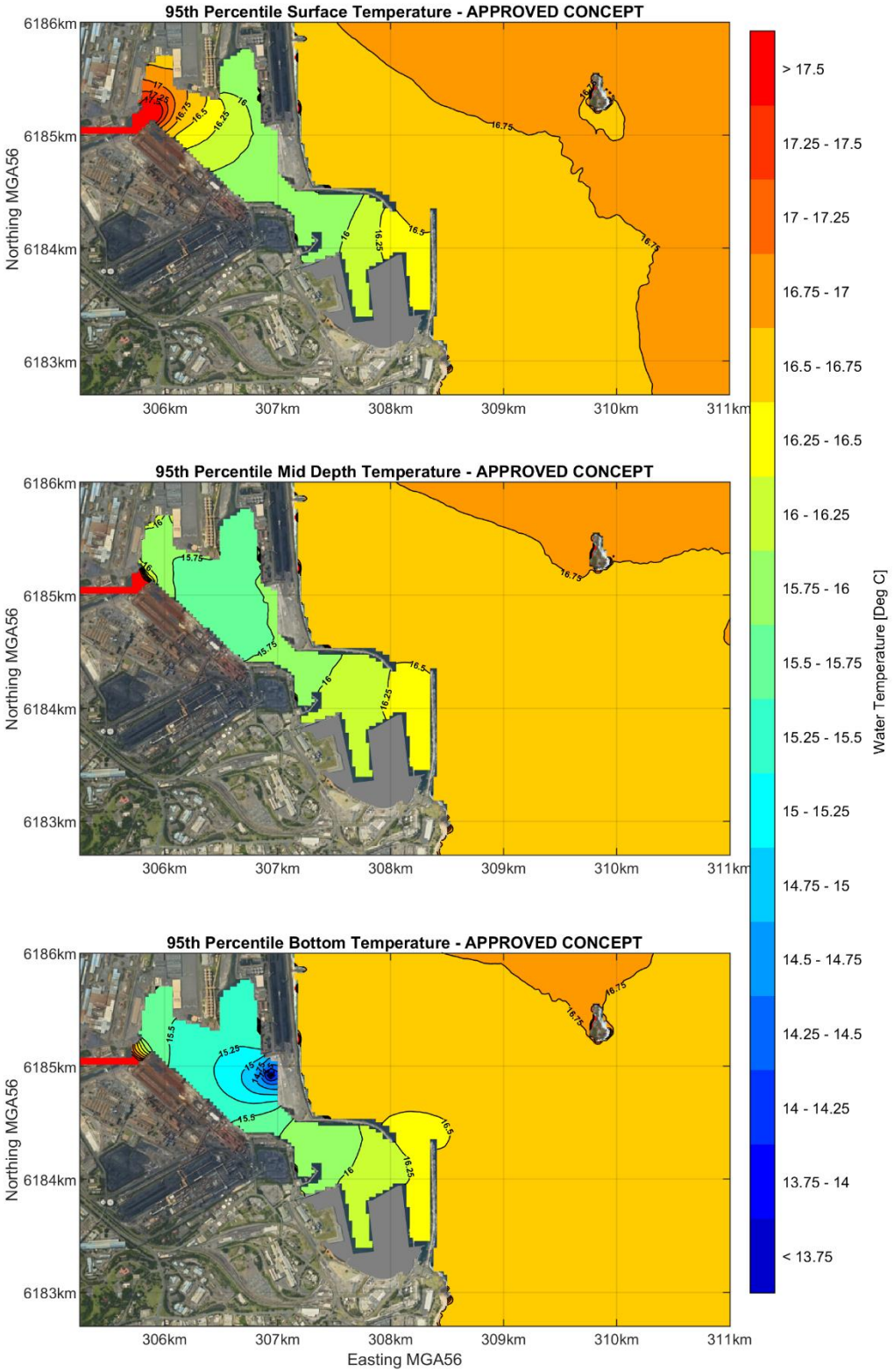
Modelled 80th Percentile Winter Water Temperature – Approved Concept Layout



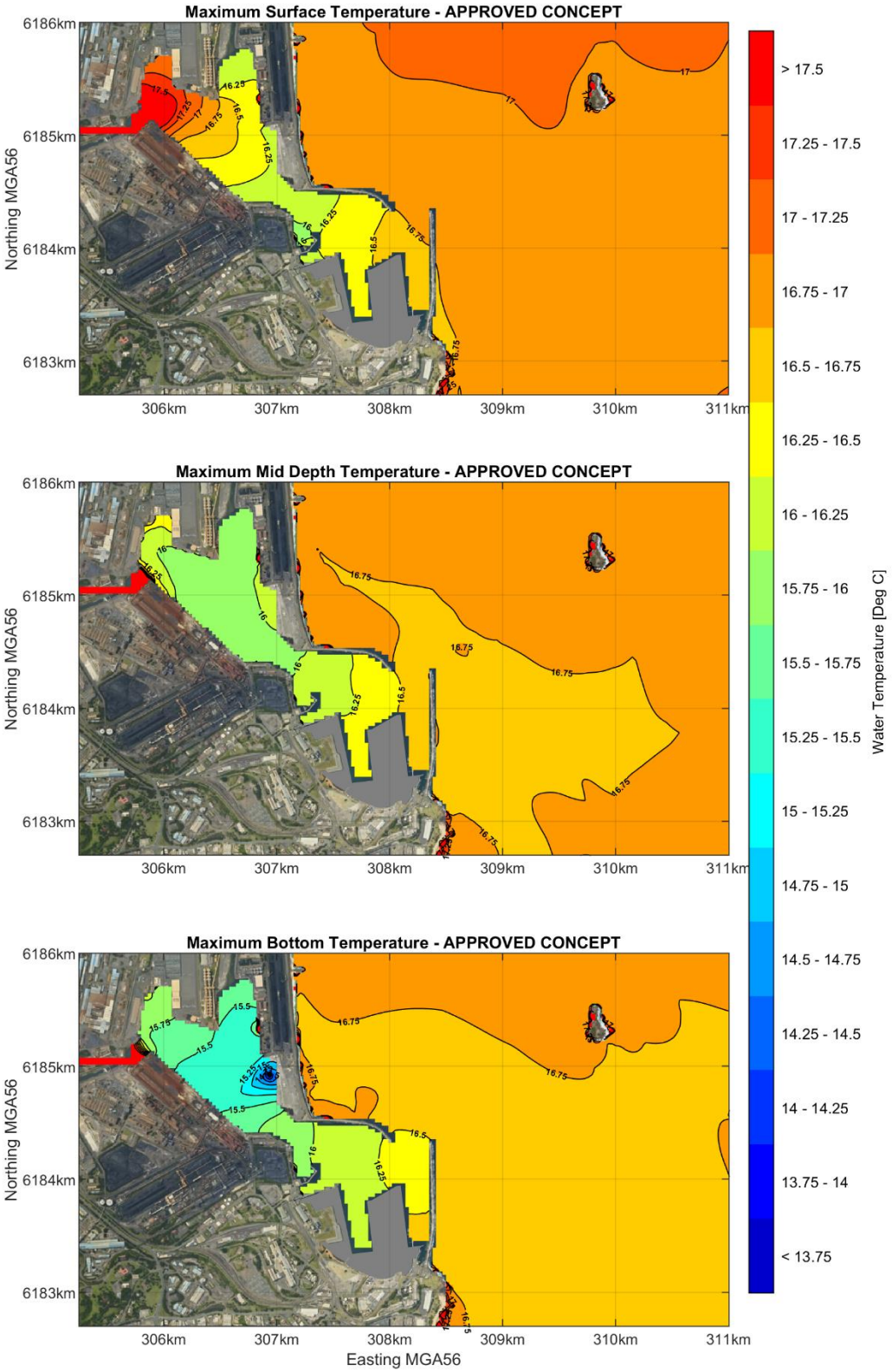
Modelled 85th Percentile Winter Water Temperature – Approved Concept Layout



Modelled 90th Percentile Winter Water Temperature – Approved Concept Layout

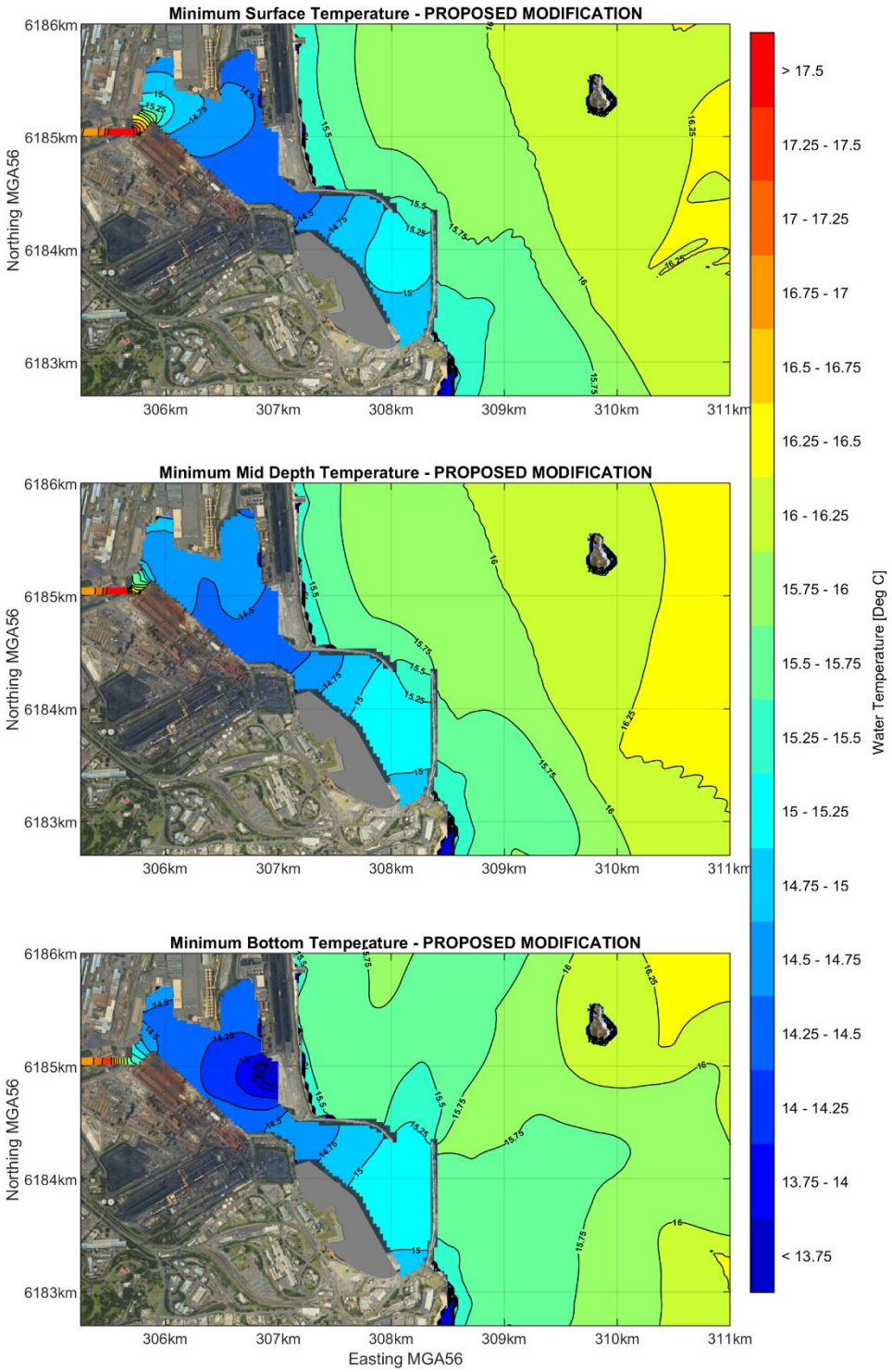


Modelled 95th Percentile Winter Water Temperature – Approved Concept Layout

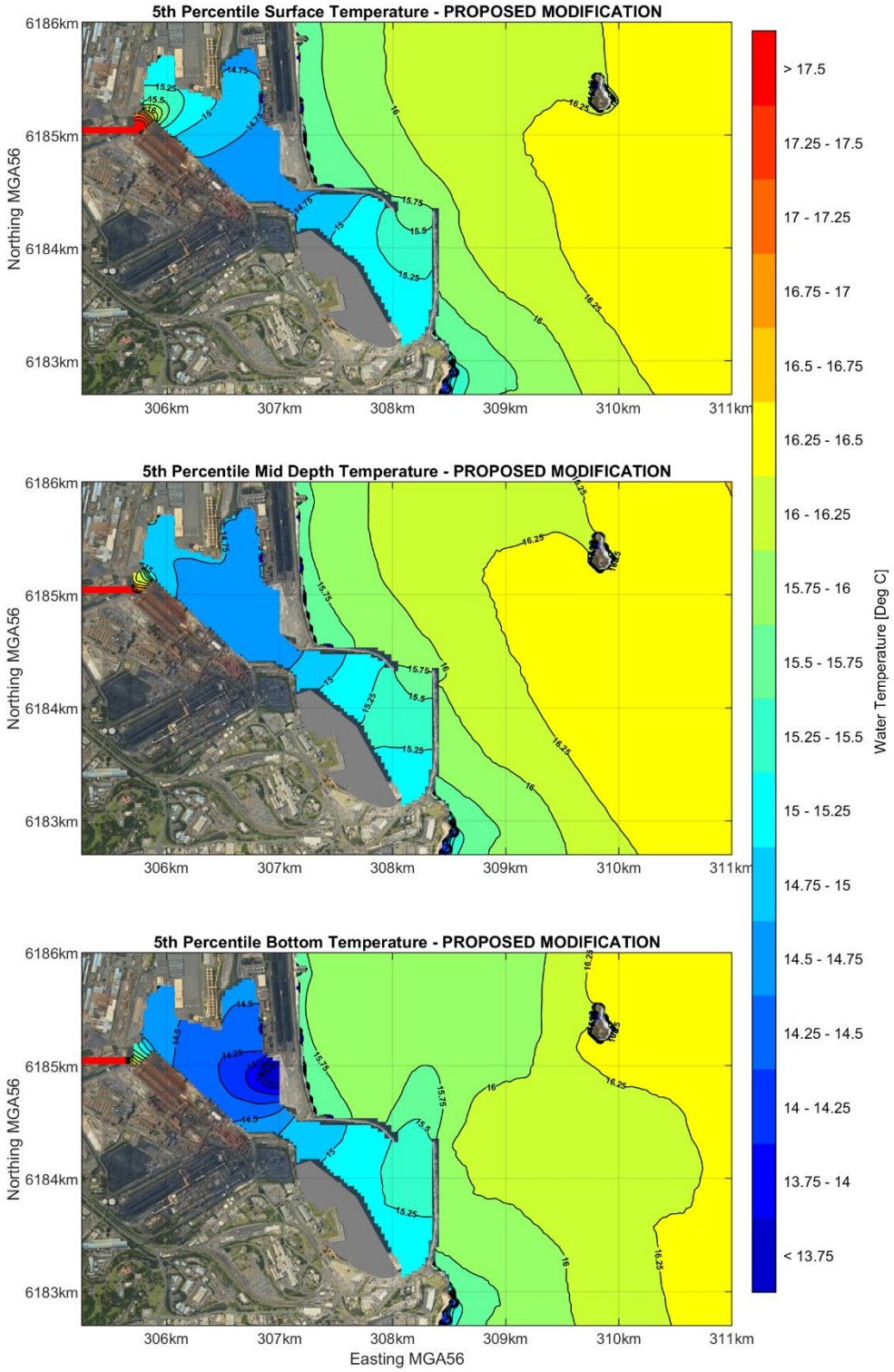


Modelled Maximum Winter Water Temperature – Approved Concept Layout

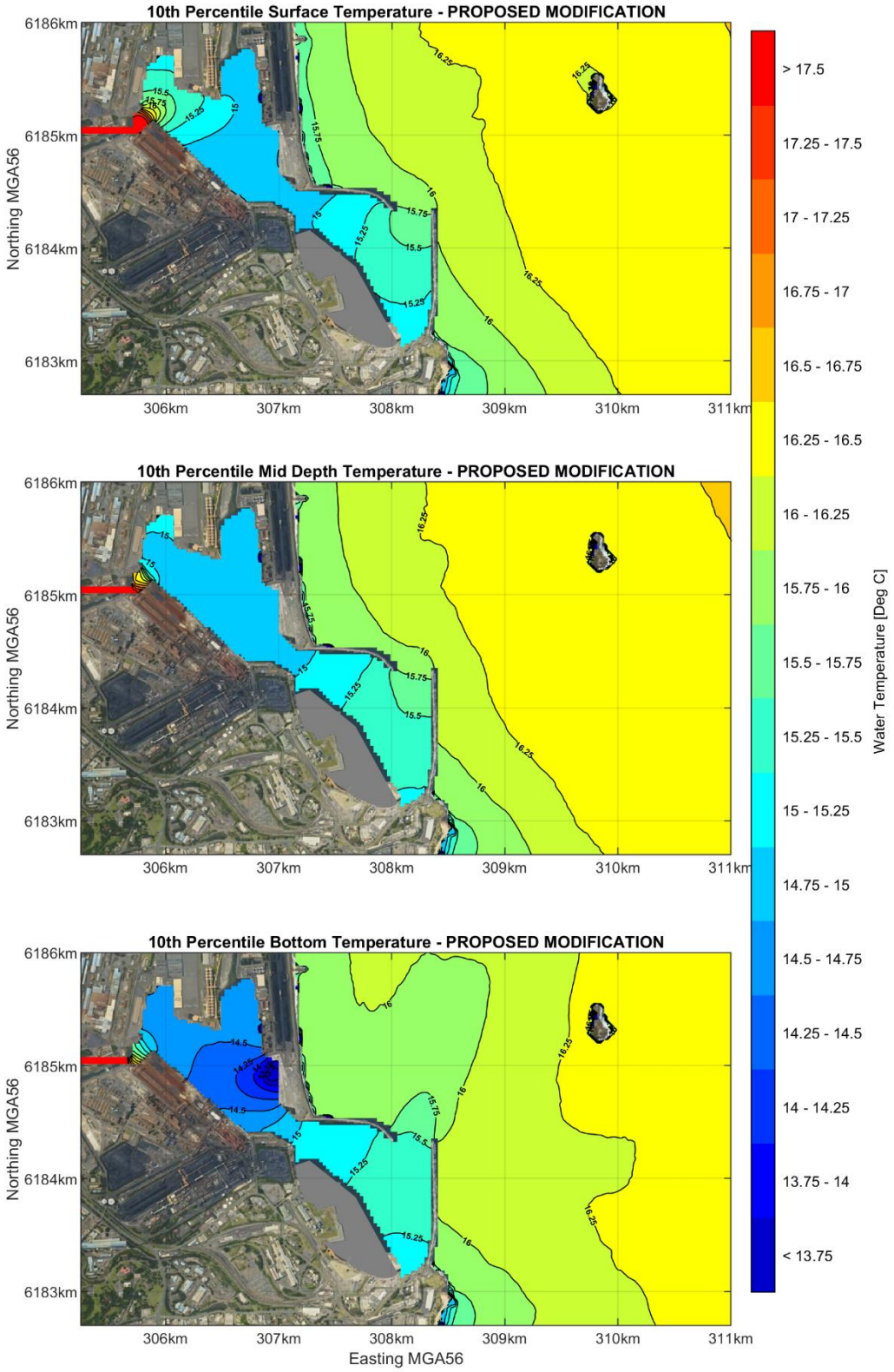
Appendix F Winter Thermal Plume Results: Proposed Modification Layout



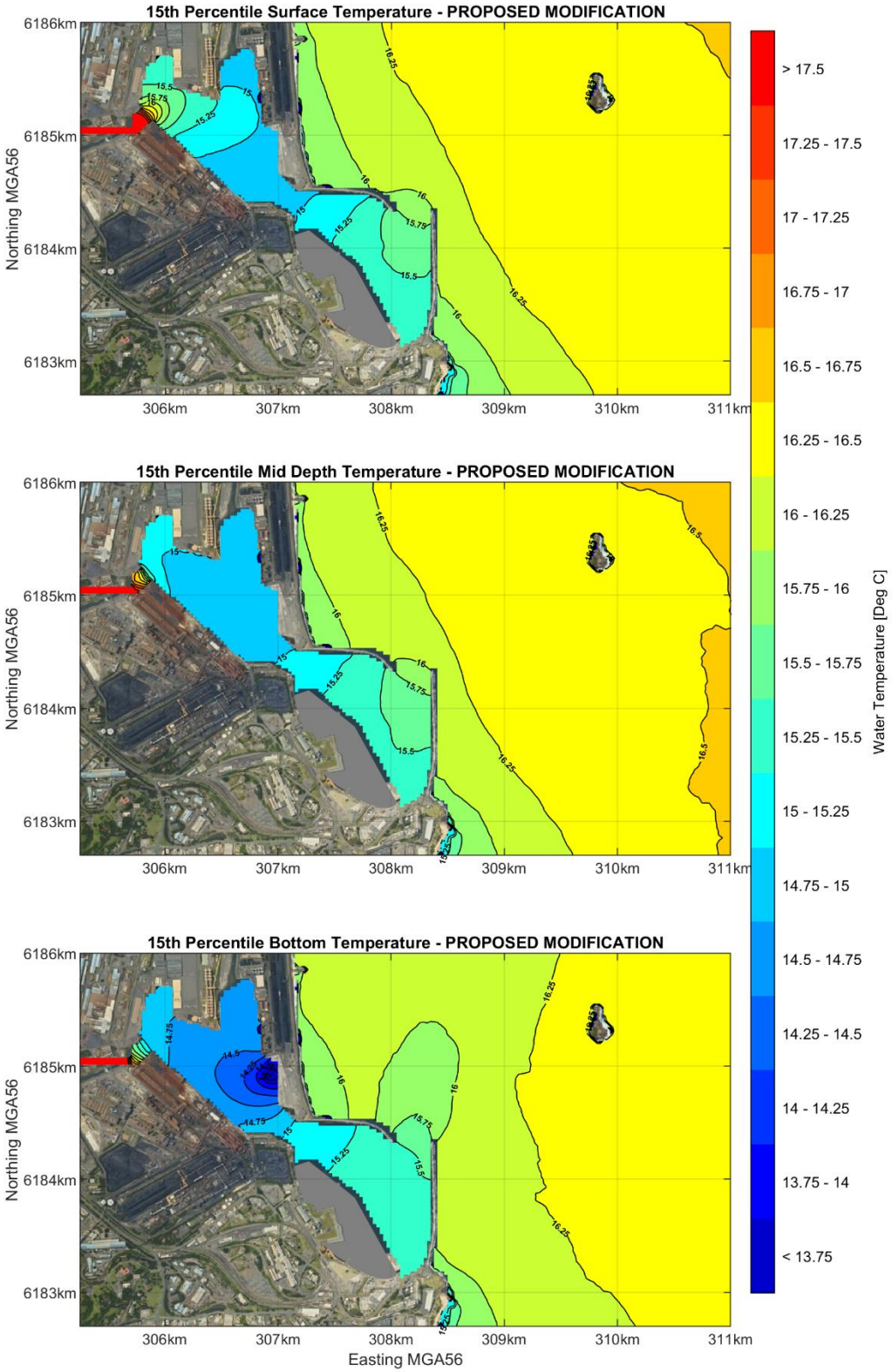
Modelled Minimum Winter Water Temperature – Proposed Modification Layout



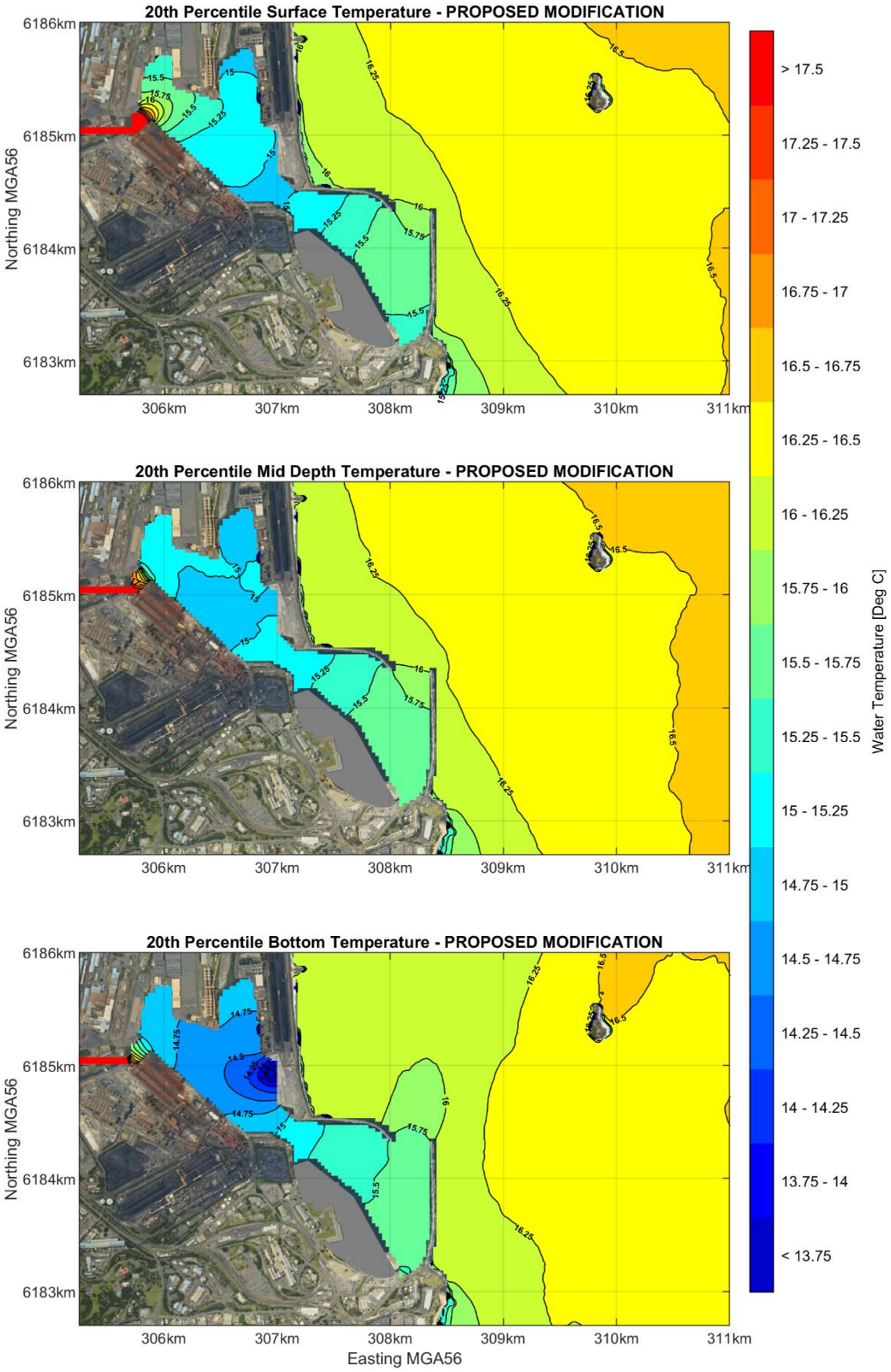
Modelled 5th Percentile Winter Water Temperature – Proposed Modification Layout



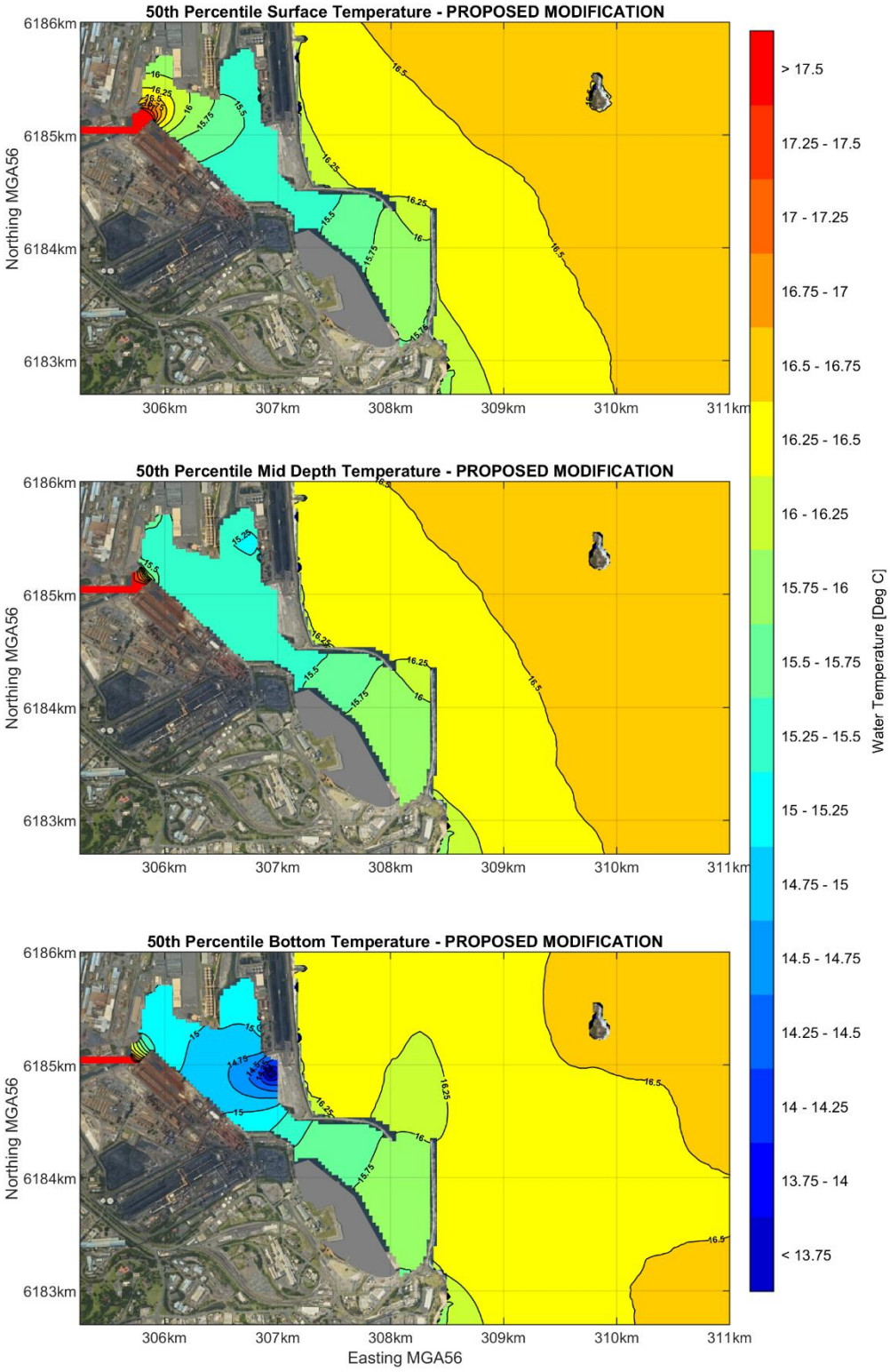
Modelled 10th Percentile Winter Water Temperature – Proposed Modification Layout



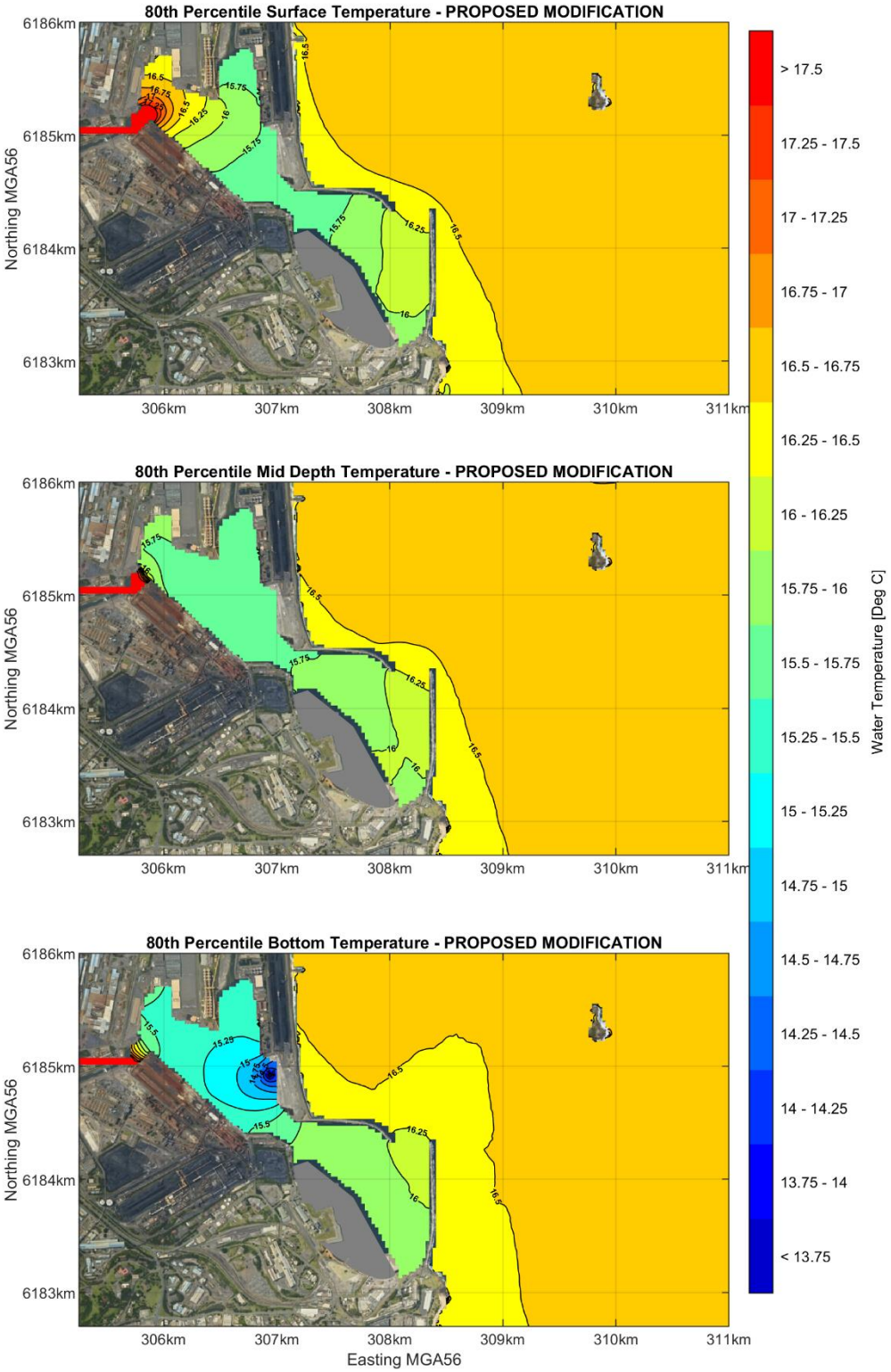
Modelled 15th Percentile Winter Water Temperature – Proposed Modification Layout



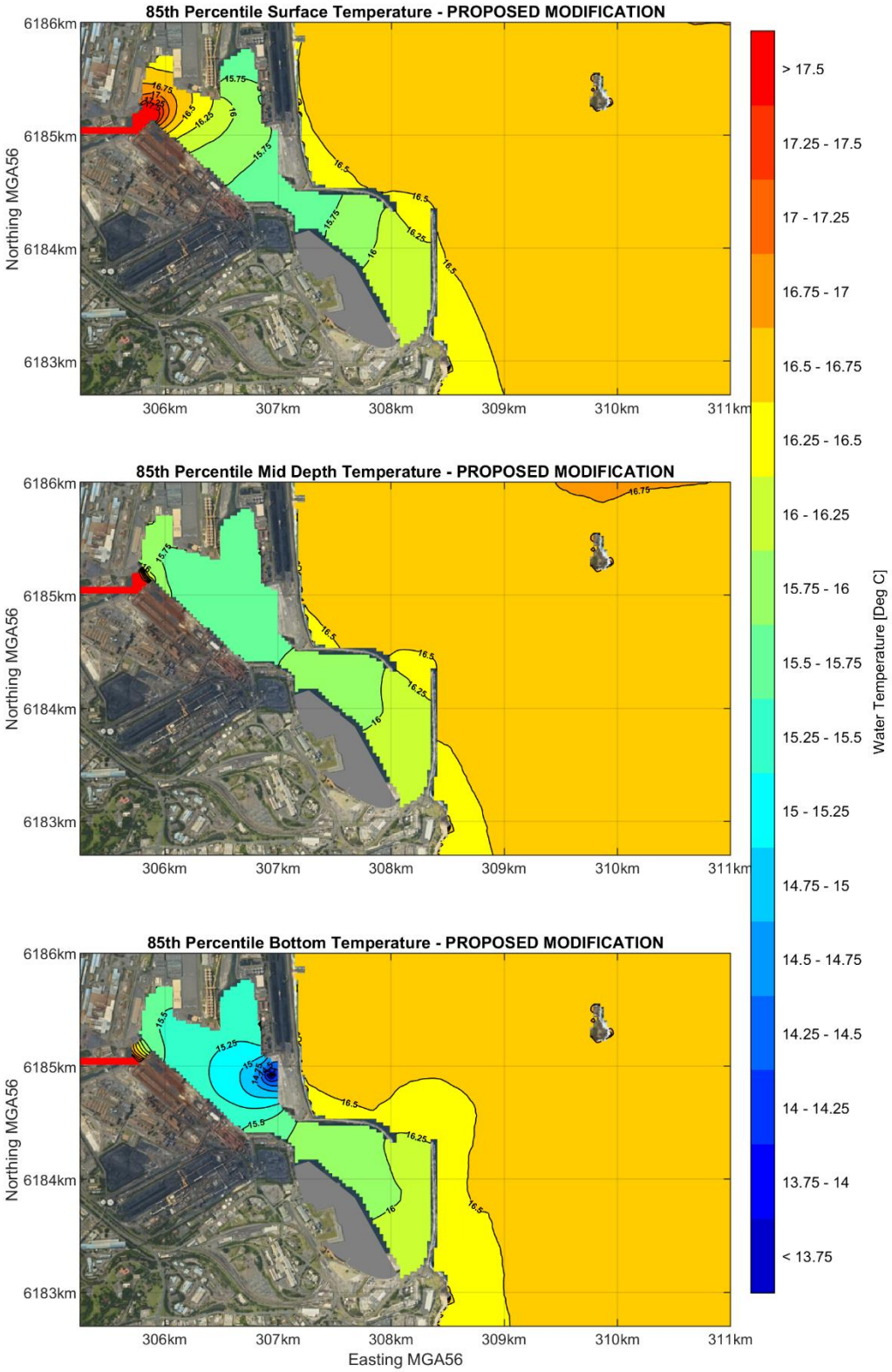
Modelled 20th Percentile Winter Water Temperature – Proposed Modification Layout



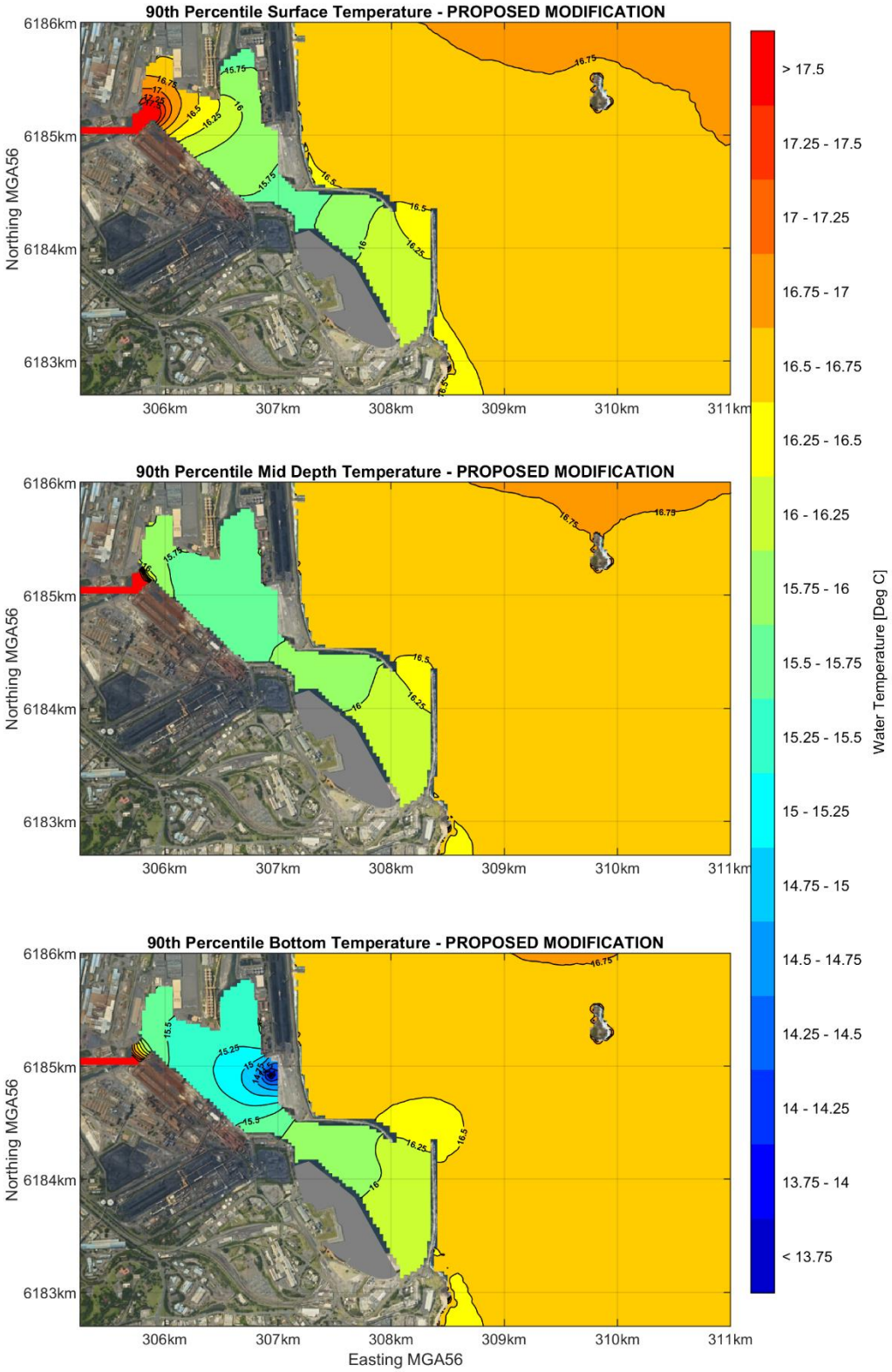
Modelled 50th Percentile Winter Water Temperature – Proposed Modification Layout



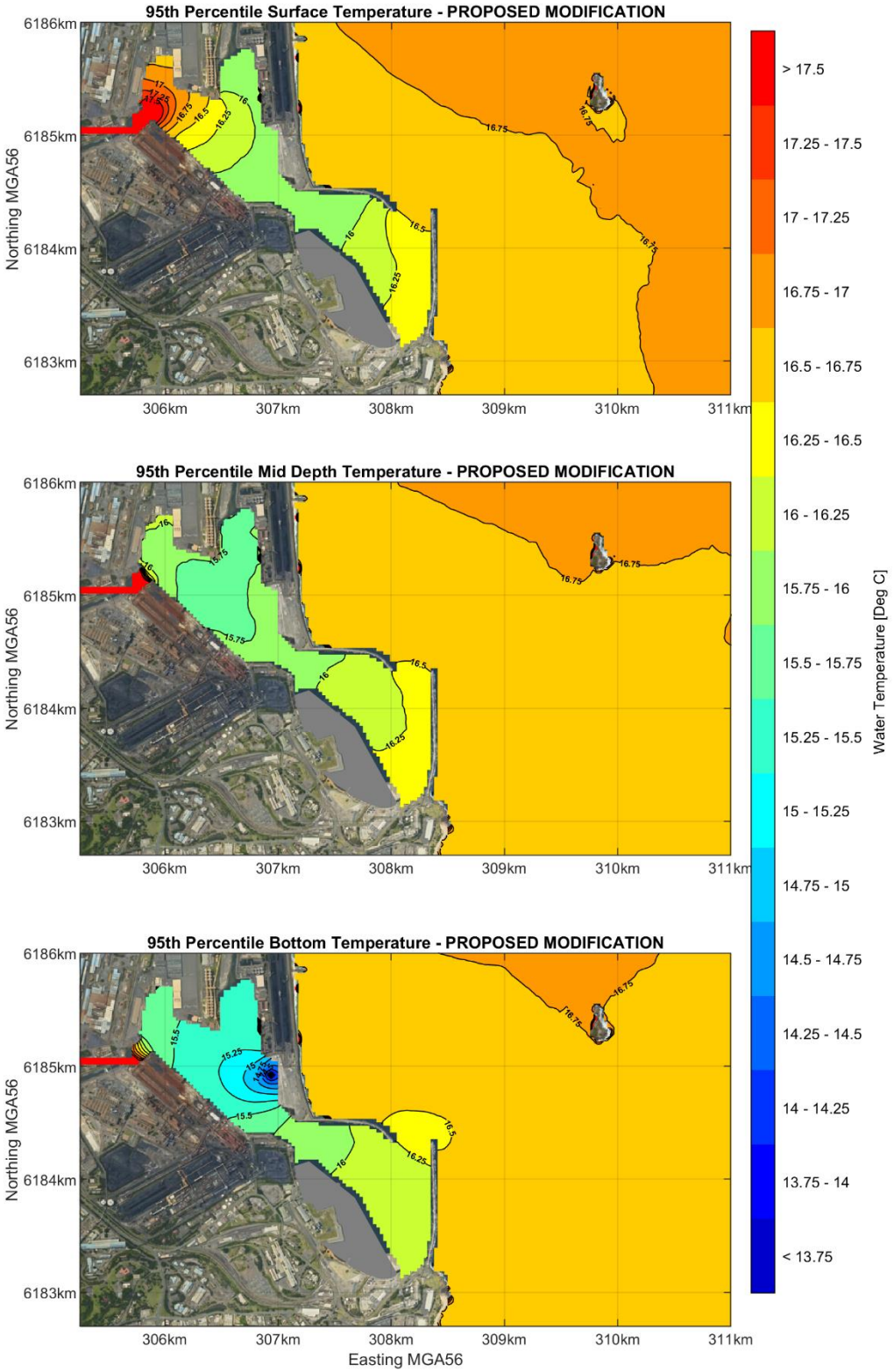
Modelled 80th Percentile Winter Water Temperature – Proposed Modification Layout



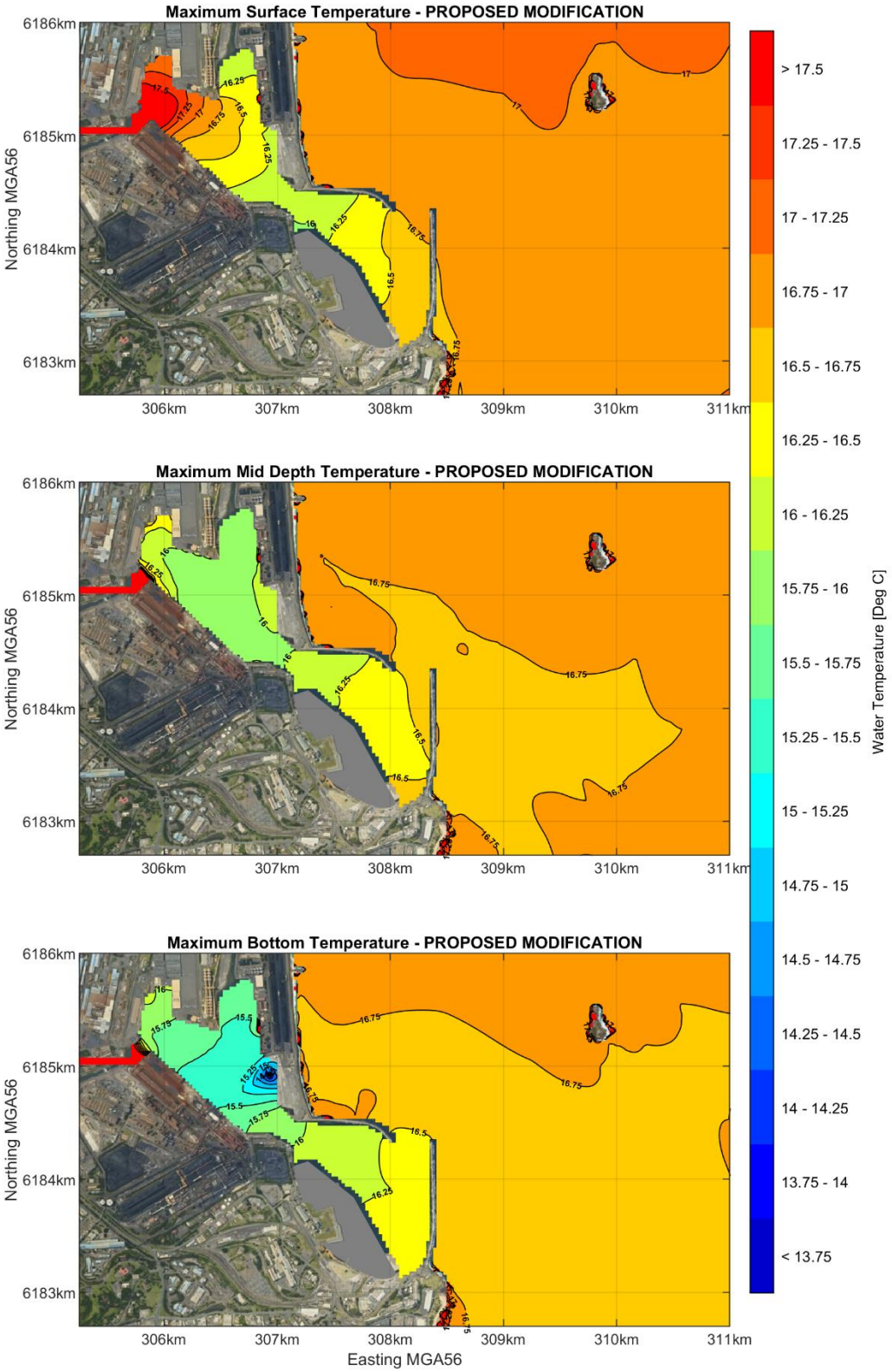
Modelled 85th Percentile Winter Water Temperature – Proposed Modification Layout



Modelled 90th Percentile Winter Water Temperature – Proposed Modification Layout

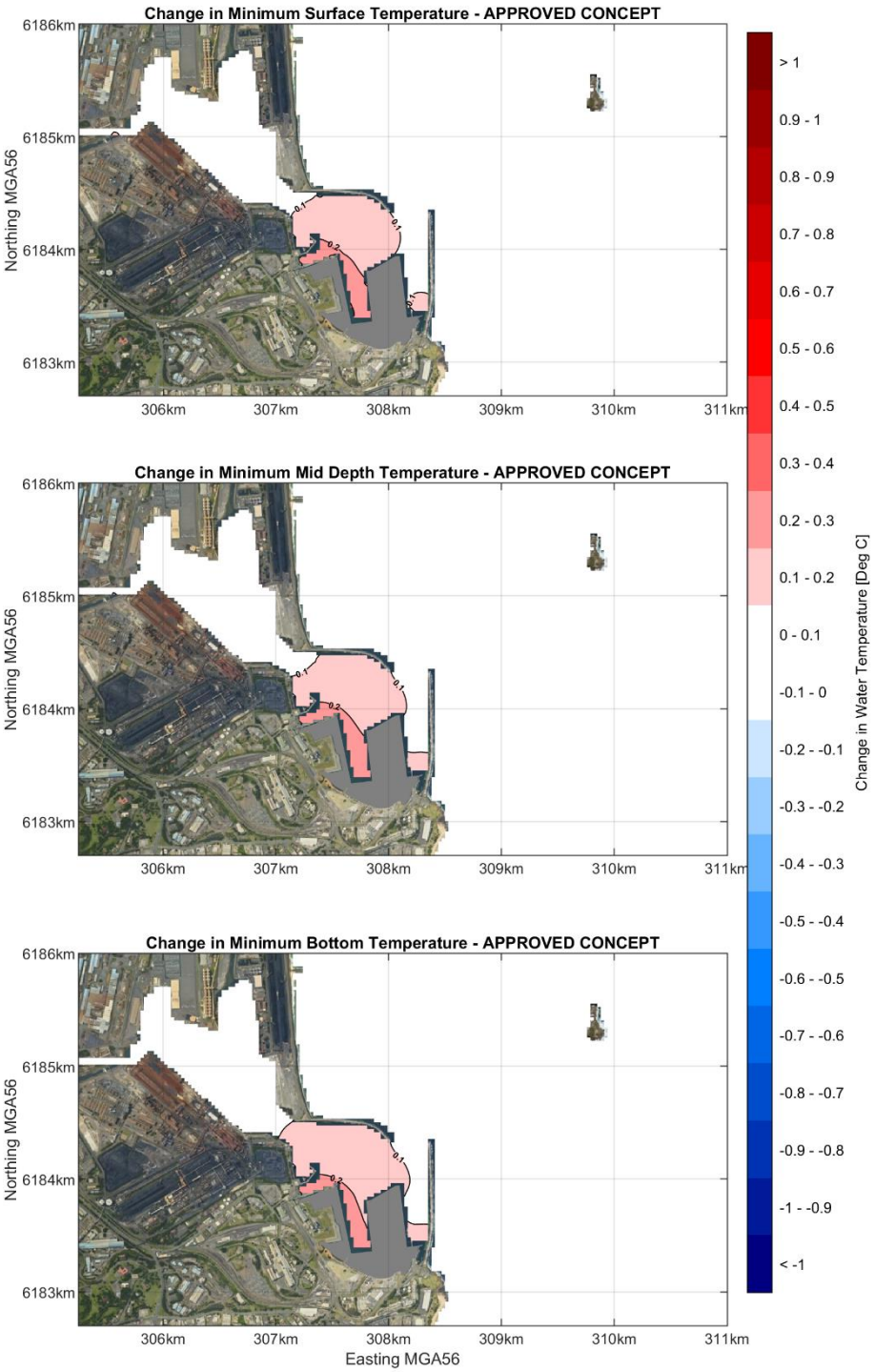


Modelled 95th Percentile Winter Water Temperature – Proposed Modification Layout

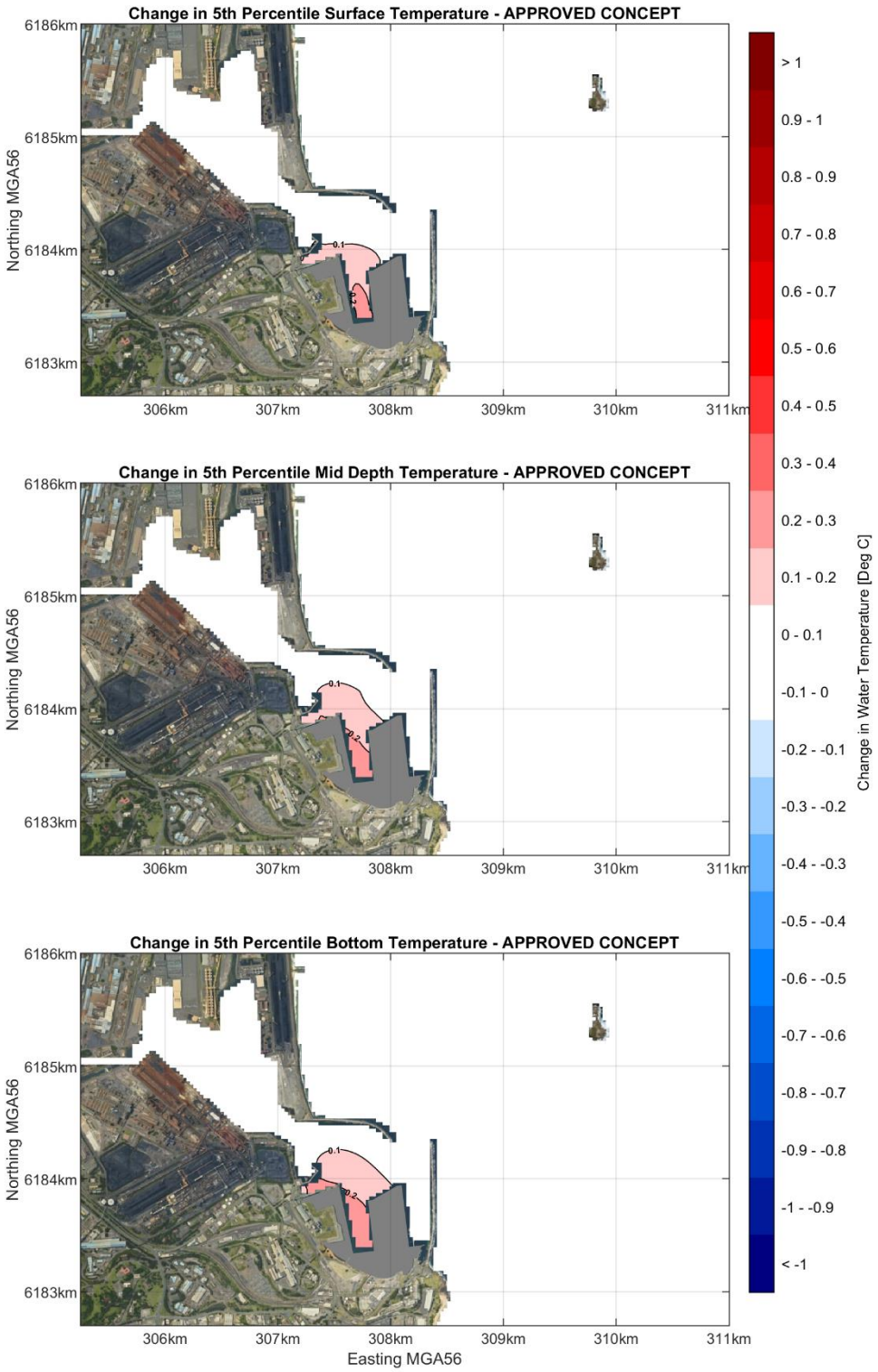


Modelled Maximum Winter Water Temperature – Proposed Modification Layout

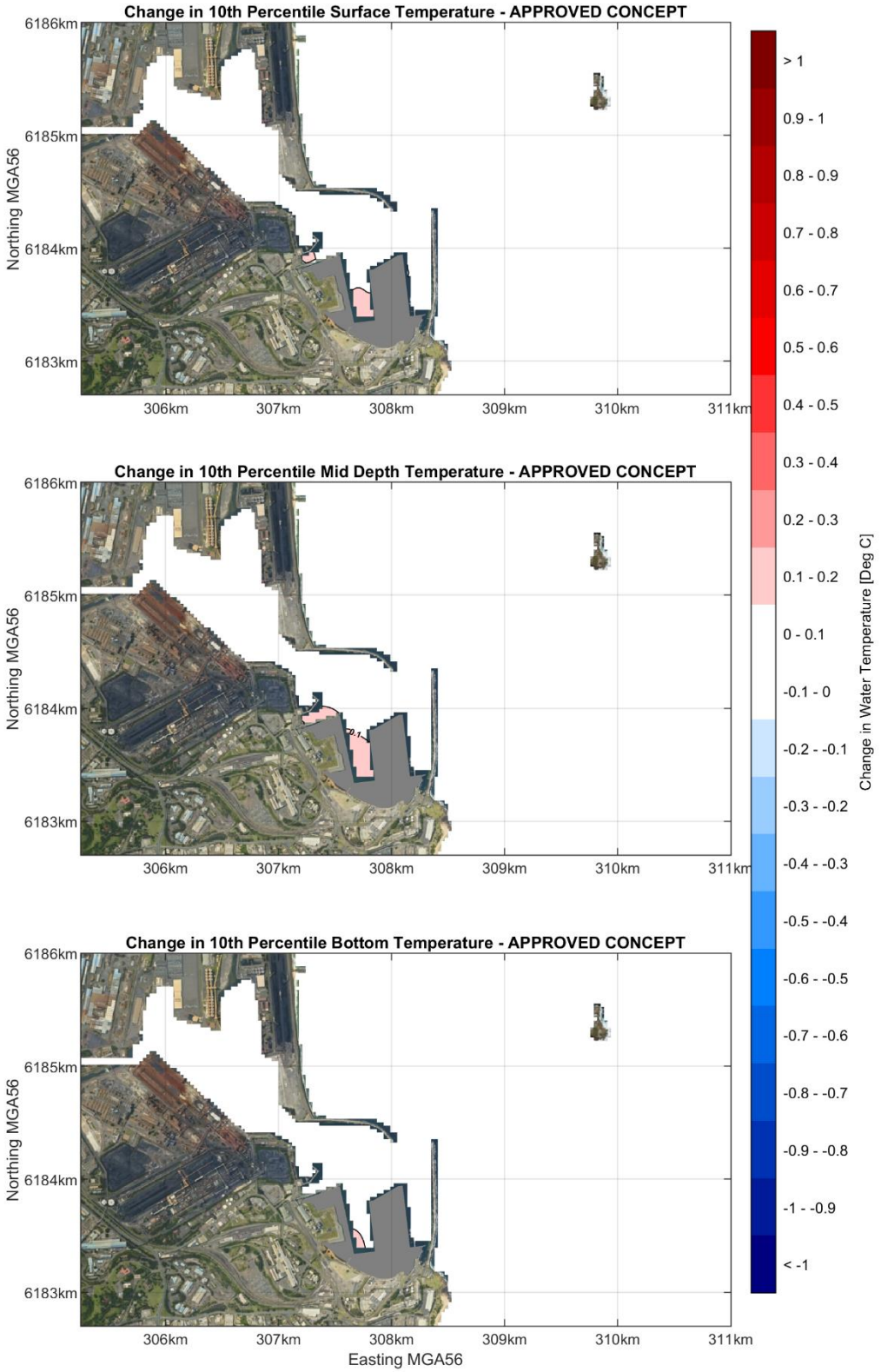
Appendix G Summer Thermal Impacts: Approved Concept Layout



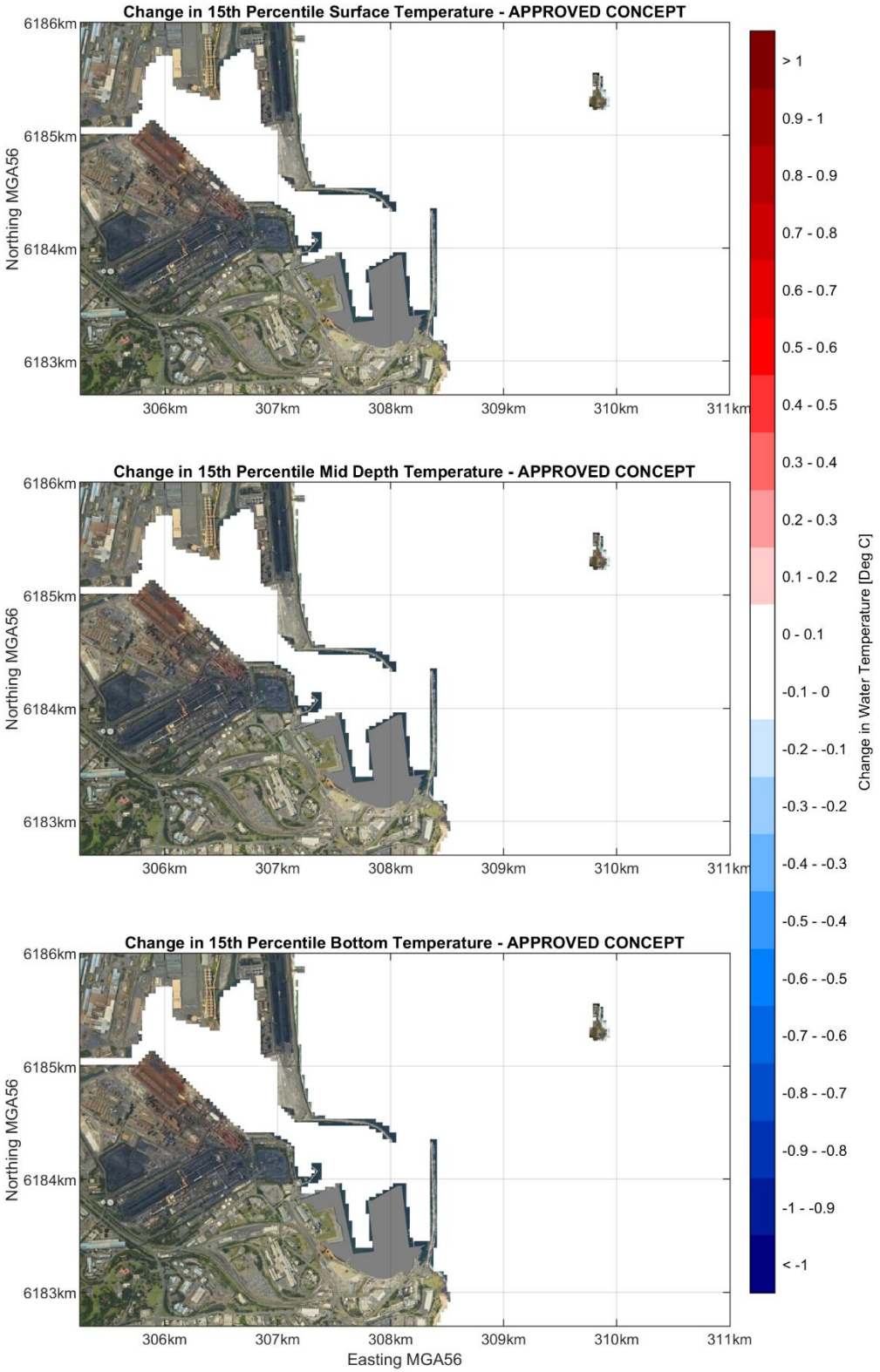
Modelled Changes in Minimum Summer Water Temperature – Approved Concept Layout



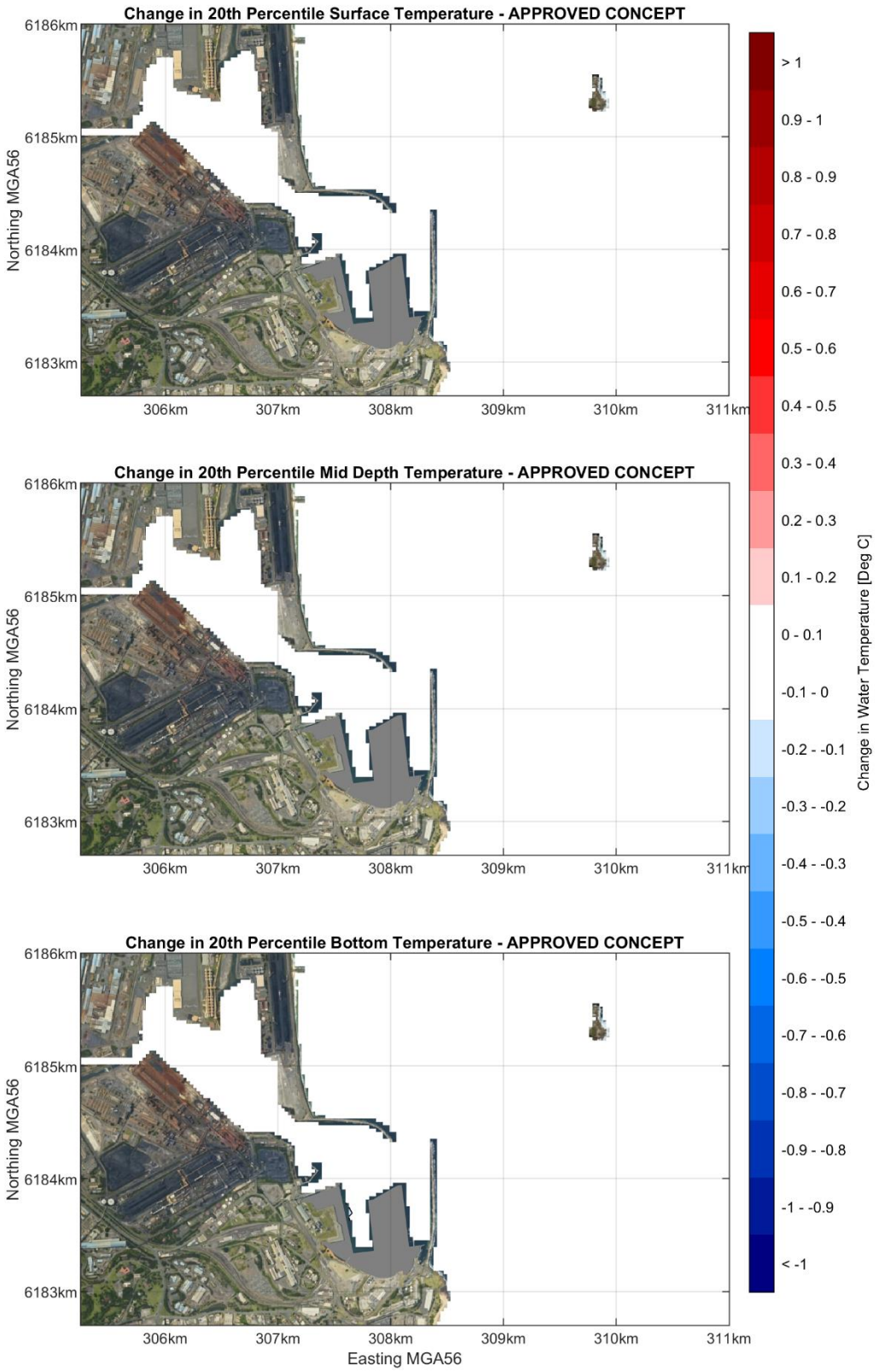
Modelled Changes in 5th Percentile Summer Water Temperature – Approved Concept Layout



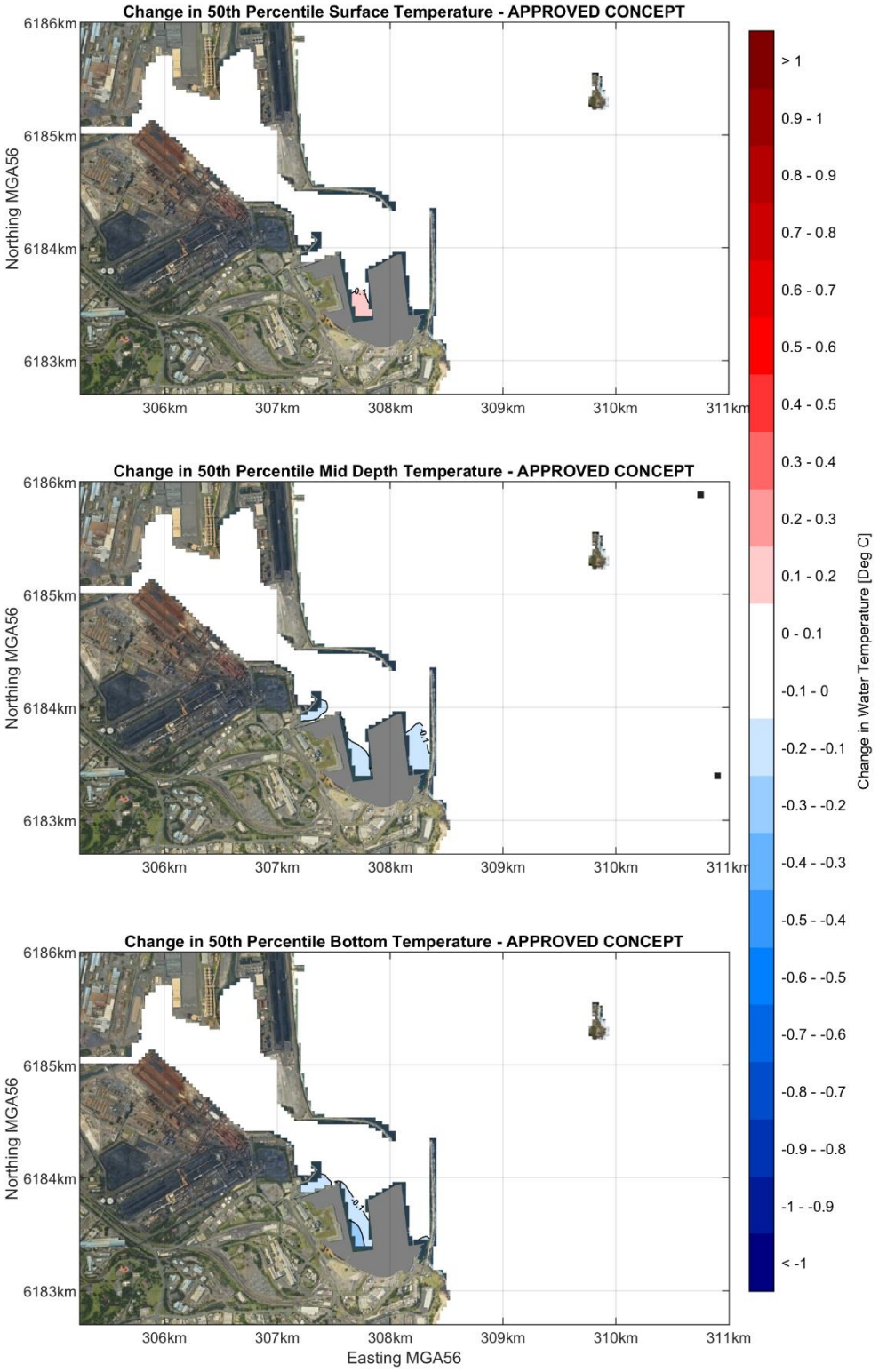
Modelled Changes in 10th Percentile Summer Water Temperature – Approved Concept Layout



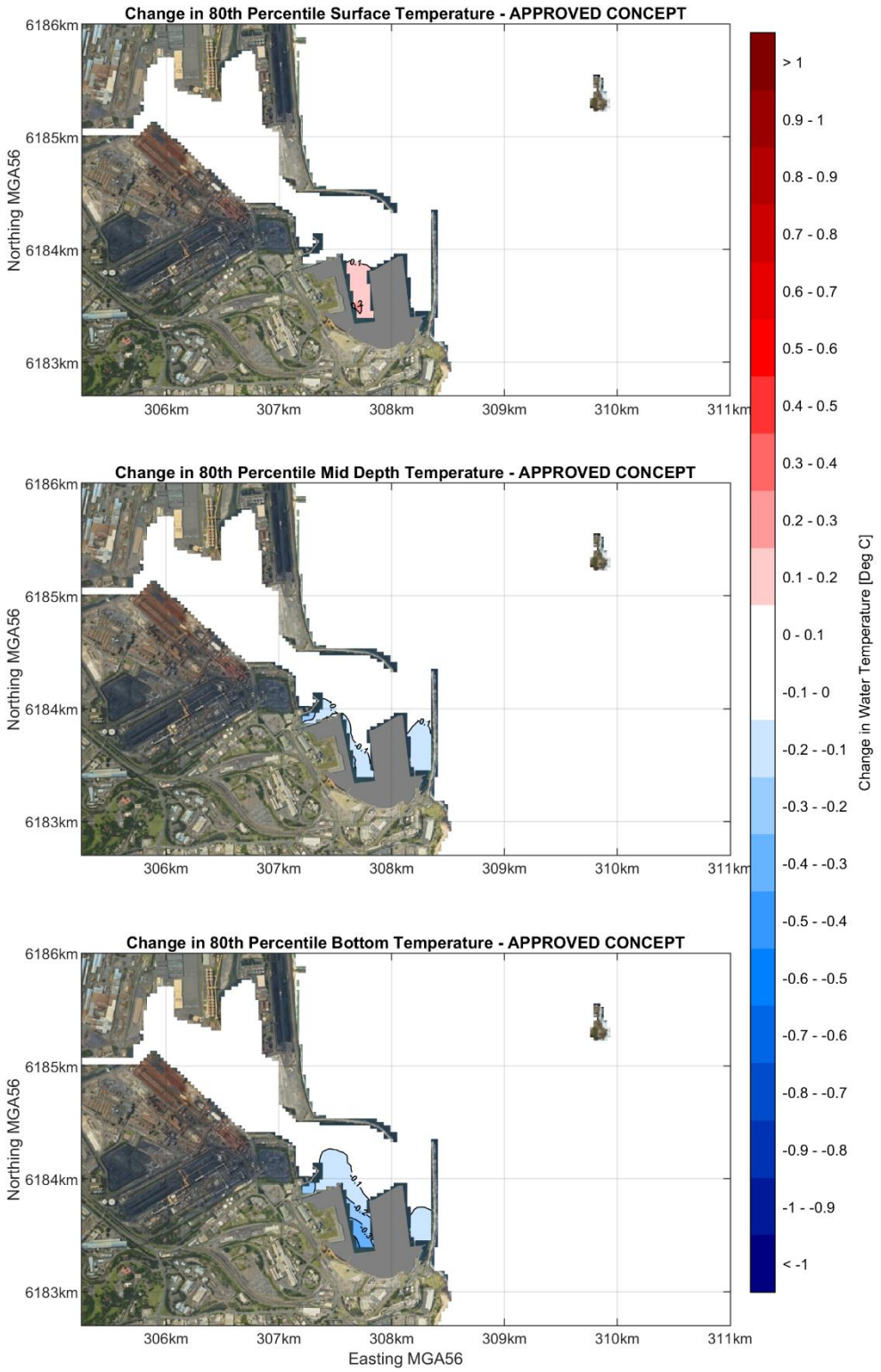
Modelled Changes in 15th Percentile Summer Water Temperature – Approved Concept Layout



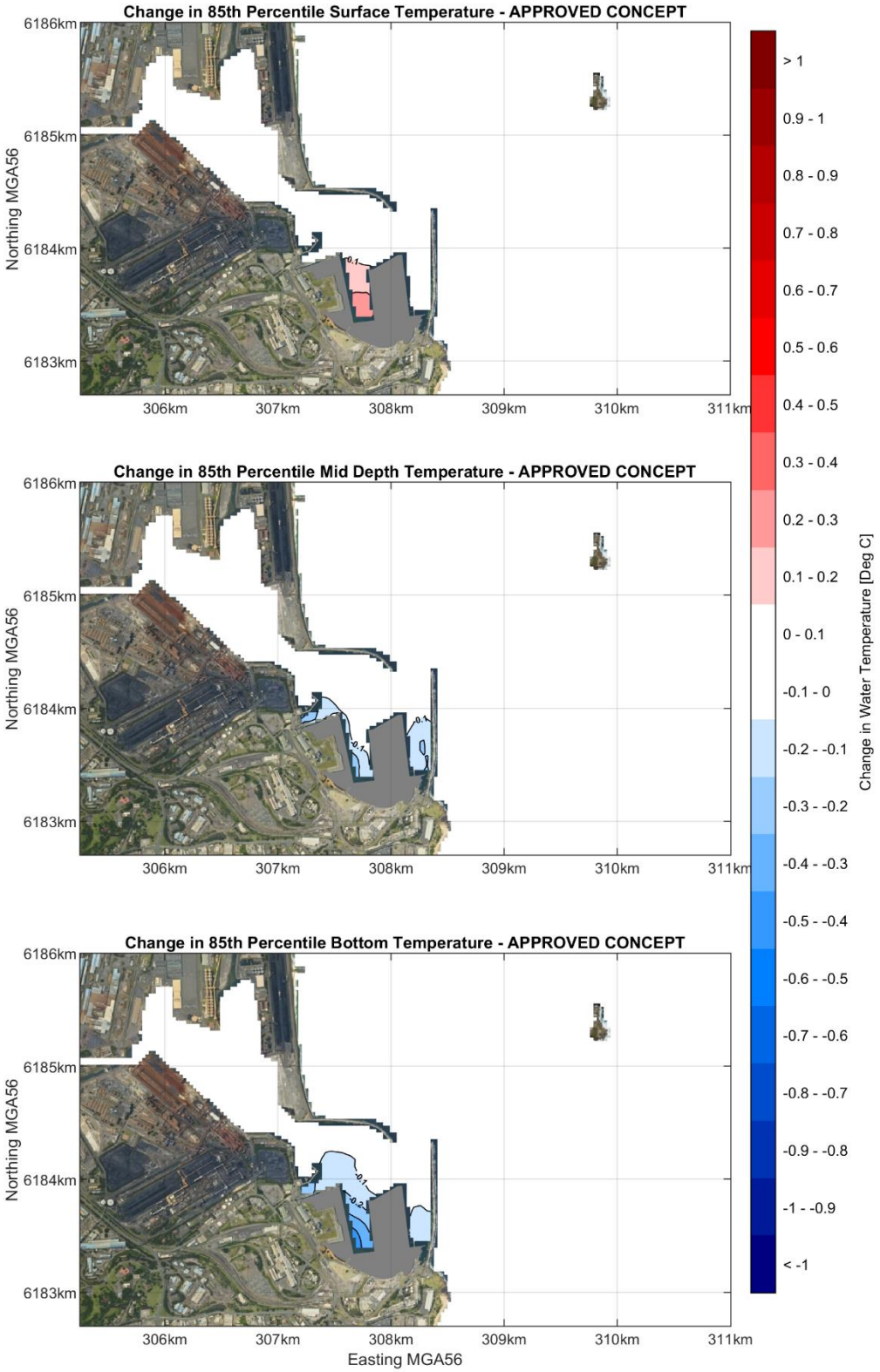
Modelled Changes in 20th Percentile Summer Water Temperature – Approved Concept Layout



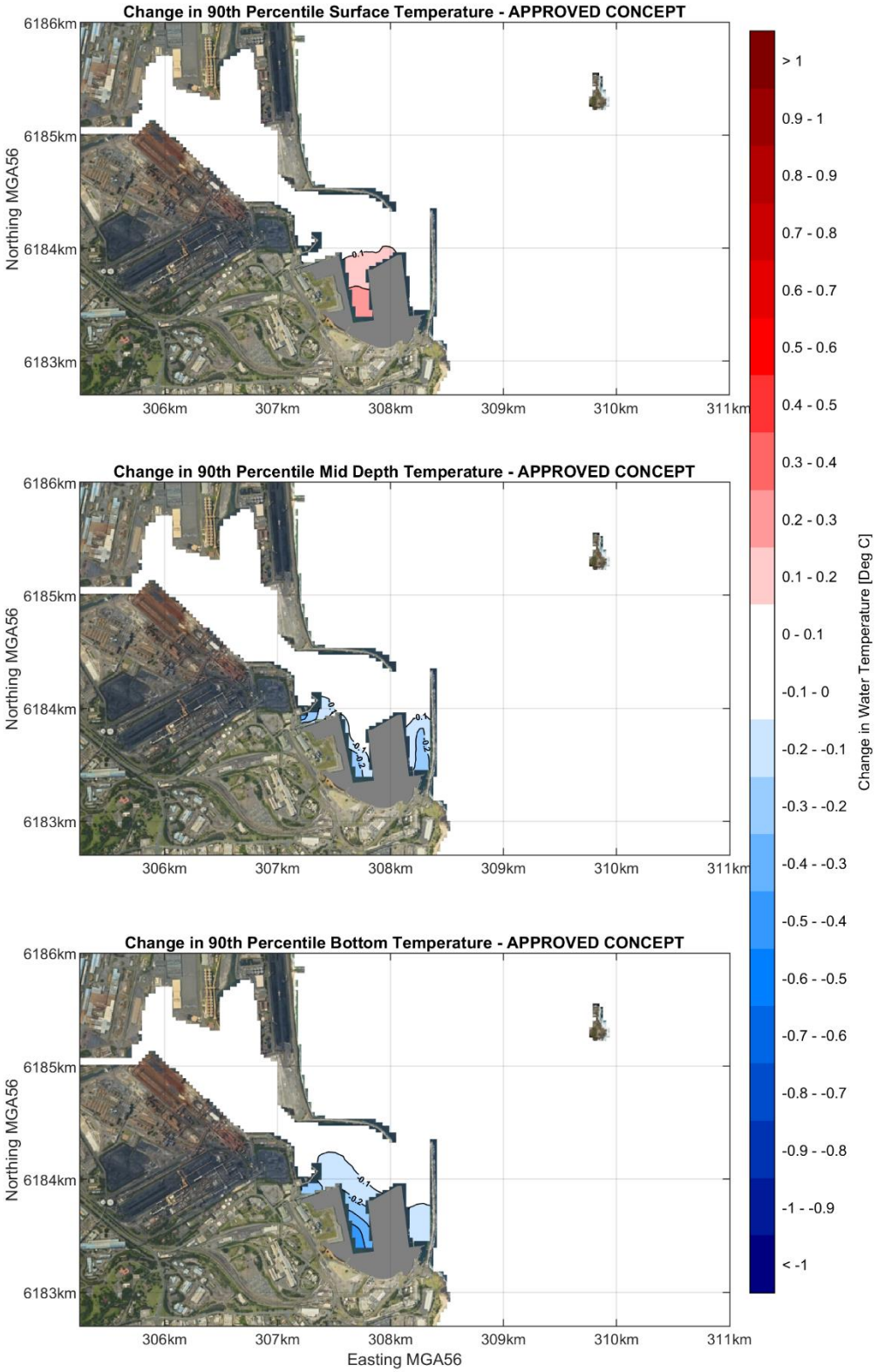
Modelled Changes in 50th Percentile Summer Water Temperature – Approved Concept Layout



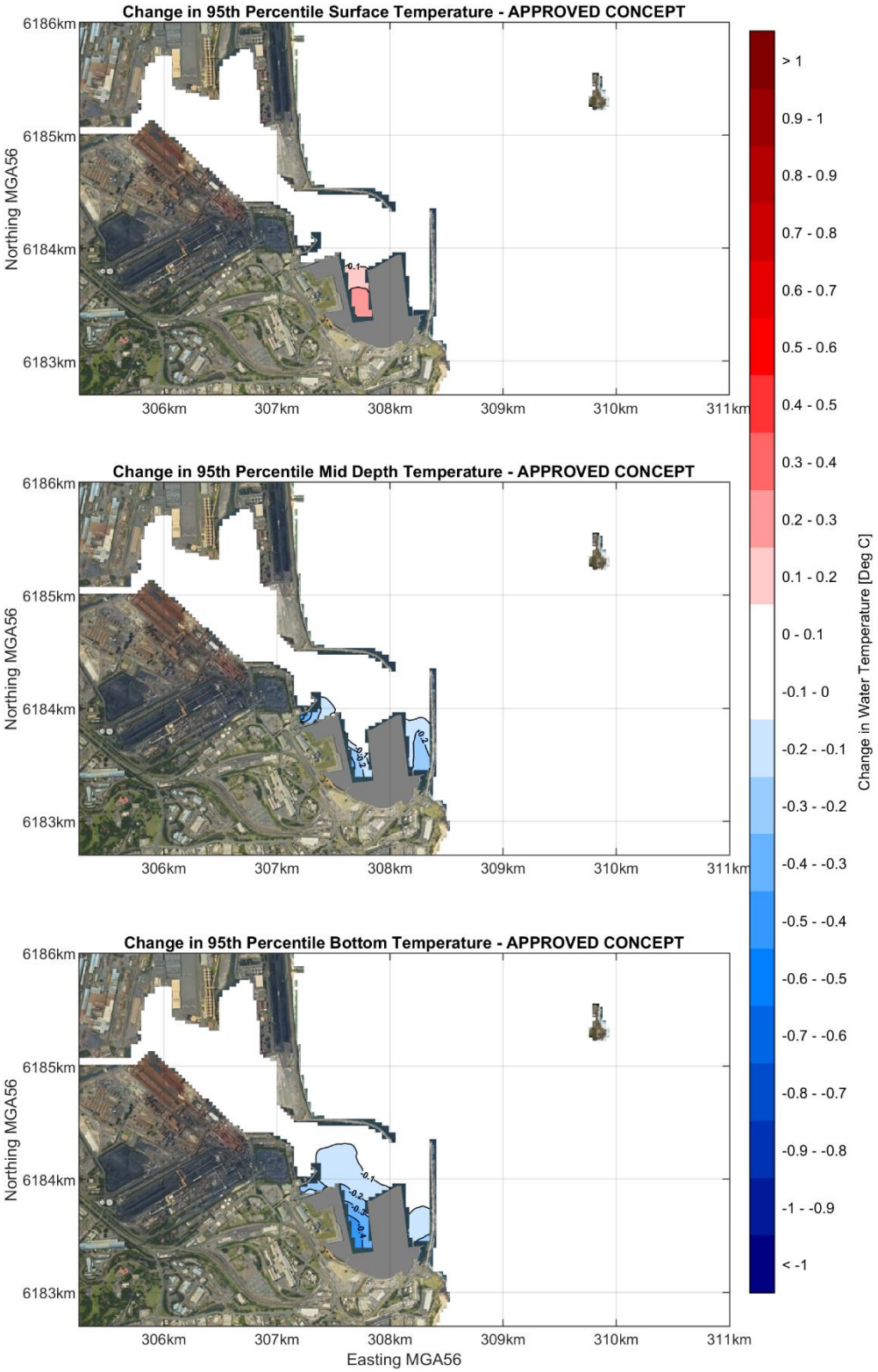
Modelled Changes in 80th Percentile Summer Water Temperature – Approved Concept Layout



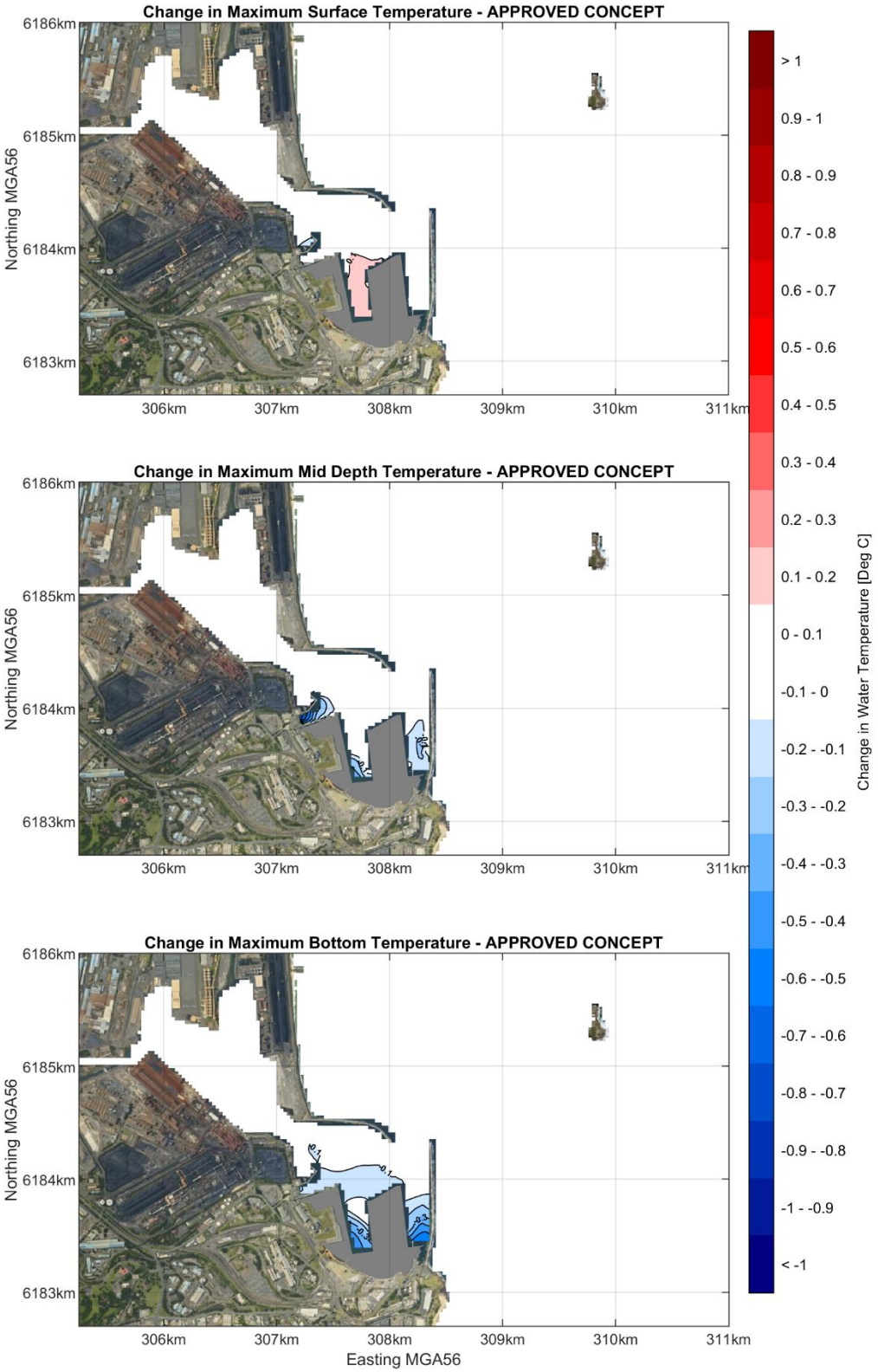
Modelled Changes in 85th Percentile Summer Water Temperature – Approved Concept Layout



Modelled Changes in 90th Percentile Summer Water Temperature – Approved Concept Layout

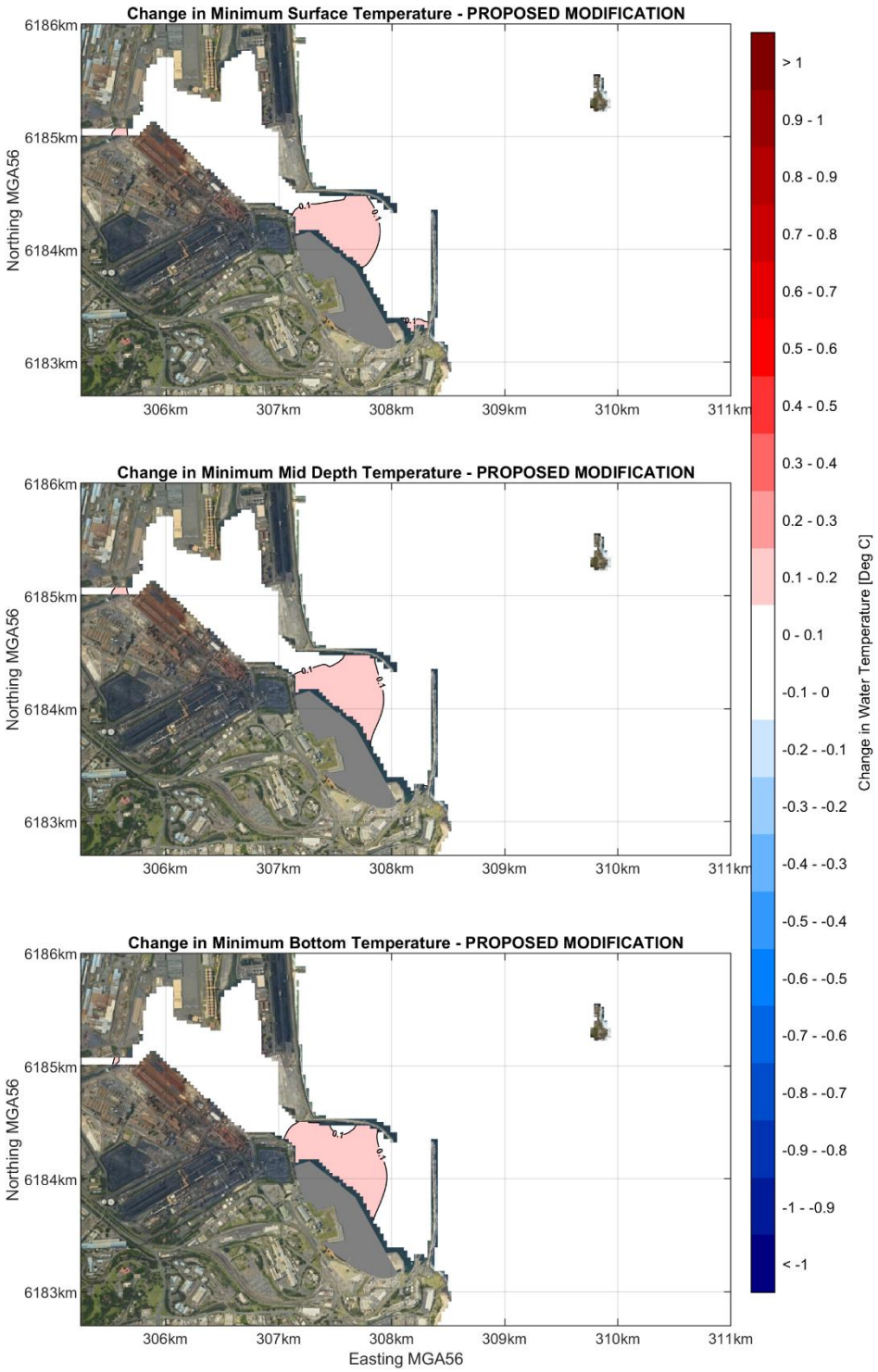


Modelled Changes in 95th Percentile Summer Water Temperature – Approved Concept Layout

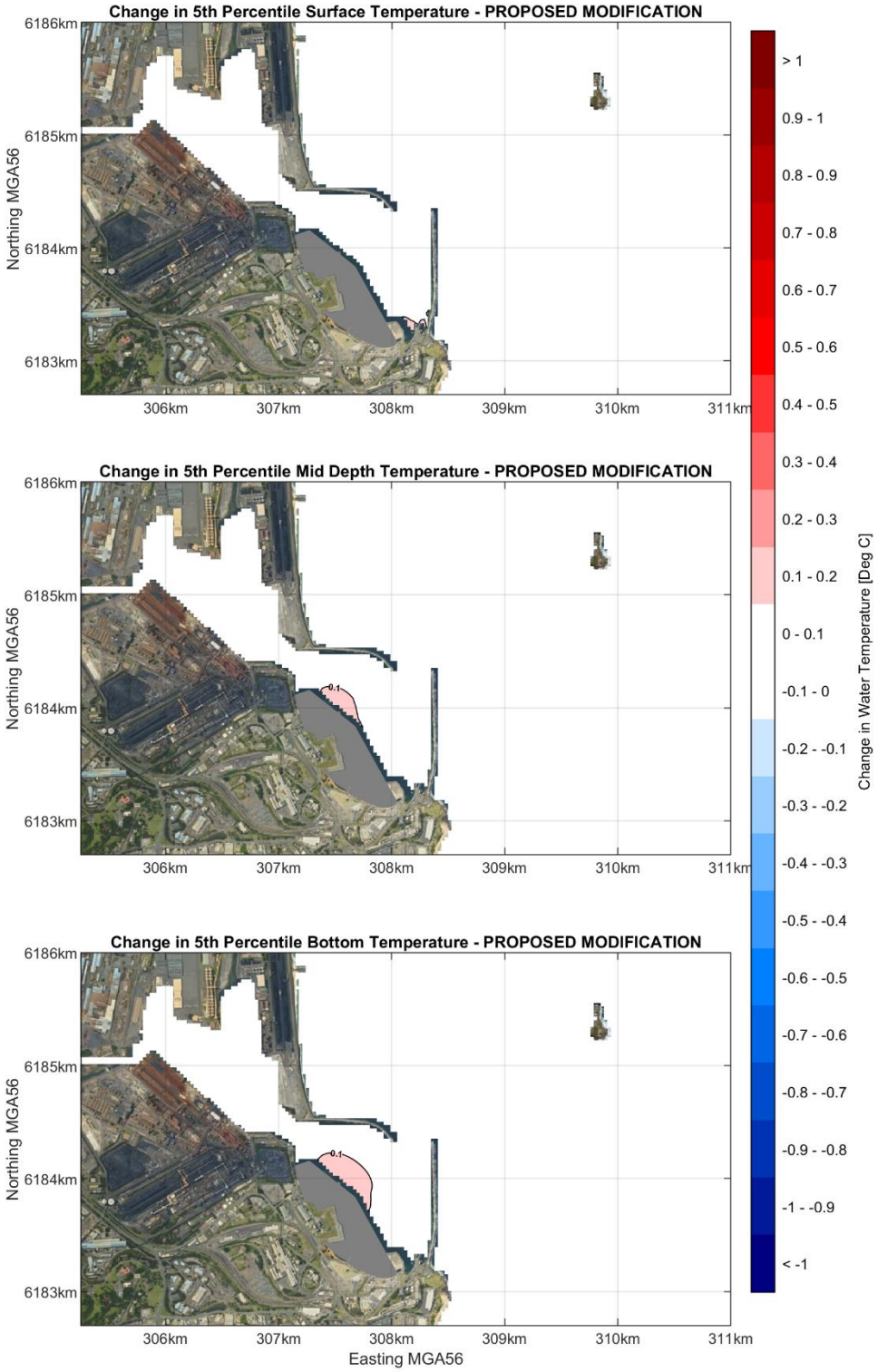


Modelled Changes in Maximum Summer Water Temperature – Approved Concept Layout

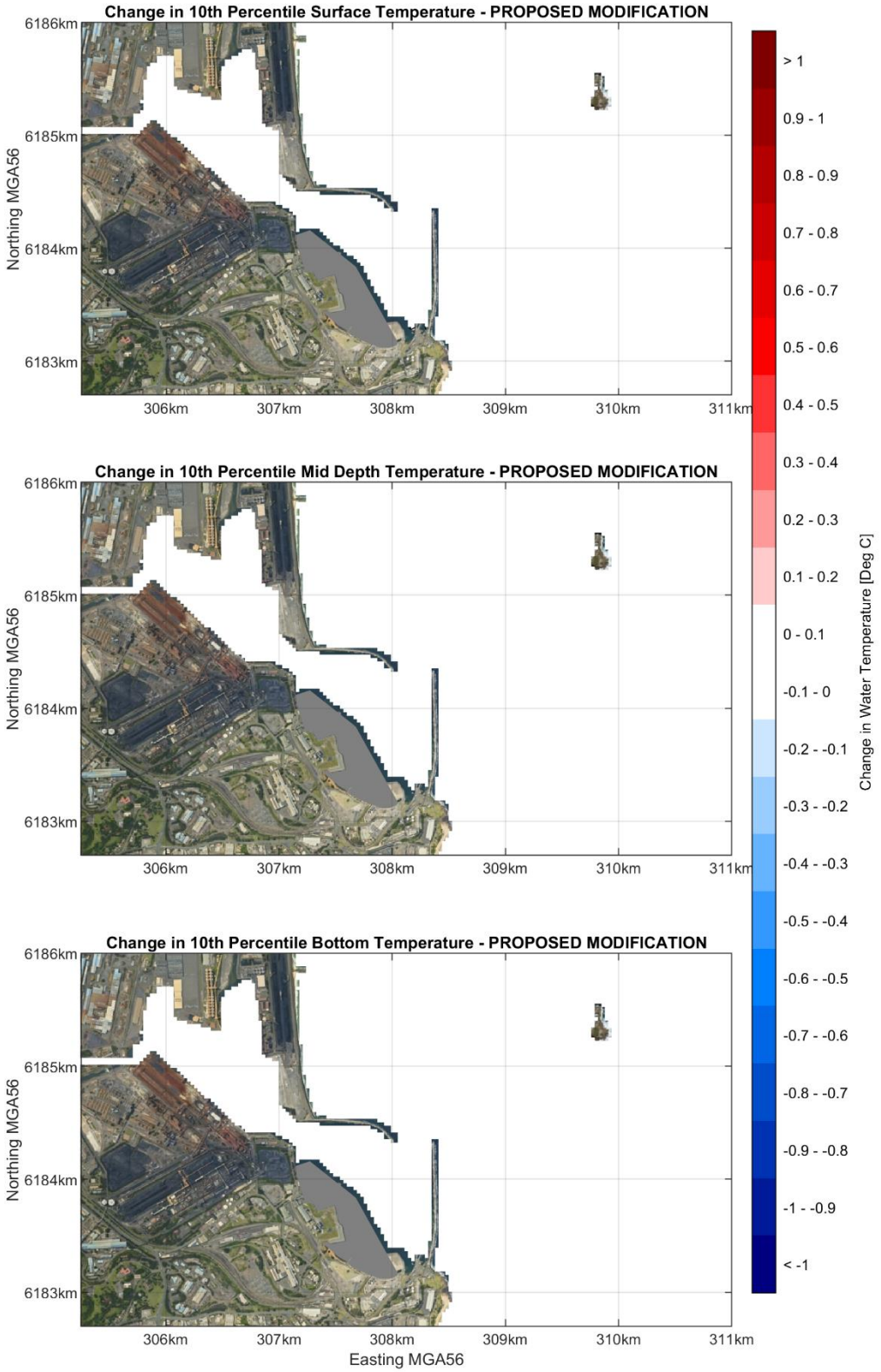
Appendix H Summer Thermal Impacts: Proposed Modification Layout



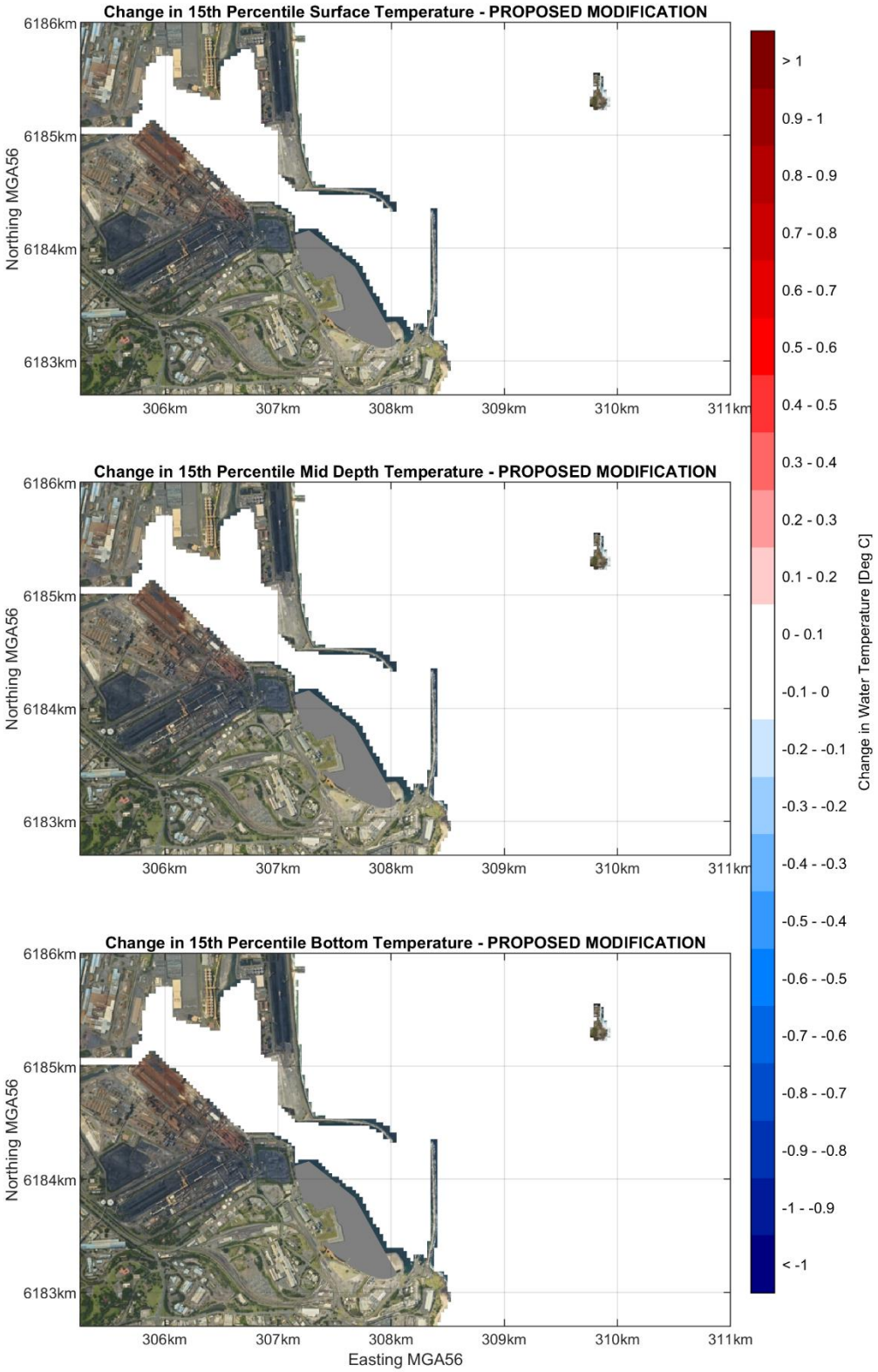
Modelled Changes in Minimum Summer Water Temperature – Proposed Modification Layout



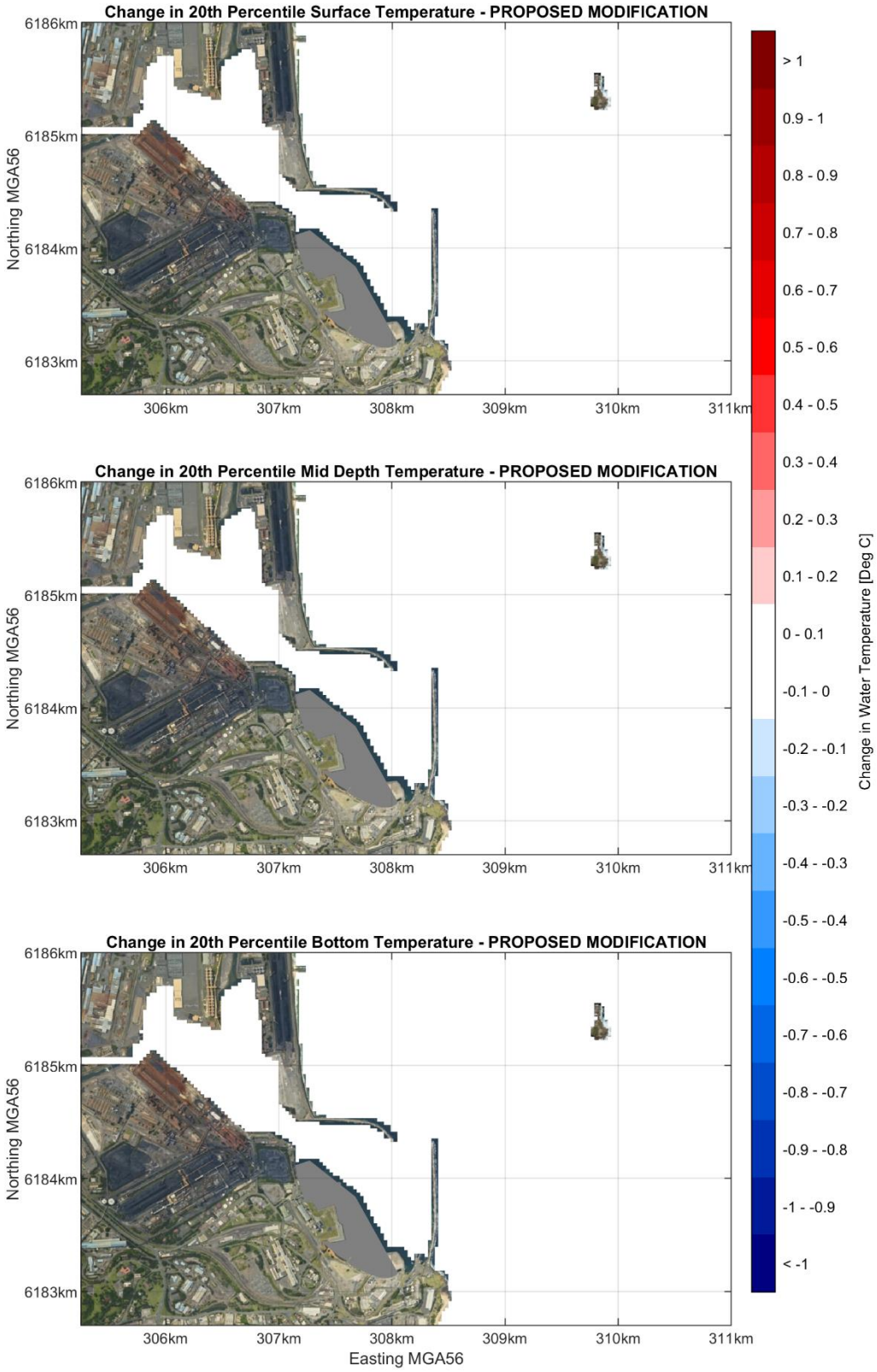
Modelled Changes in 5th Percentile Summer Water Temperature – Proposed Modification Layout



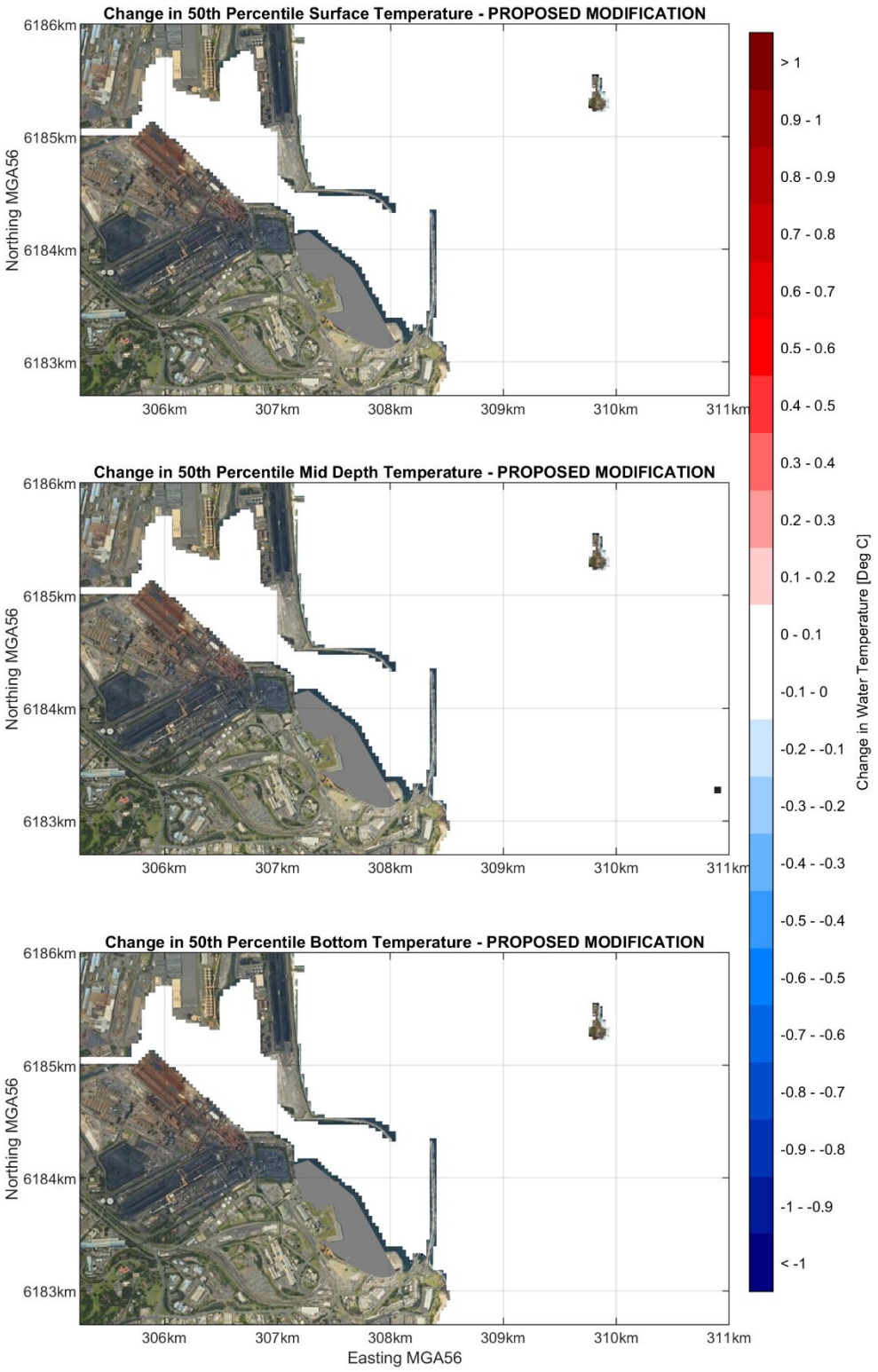
Modelled Changes in 10th Percentile Summer Water Temperature – Proposed Modification Layout



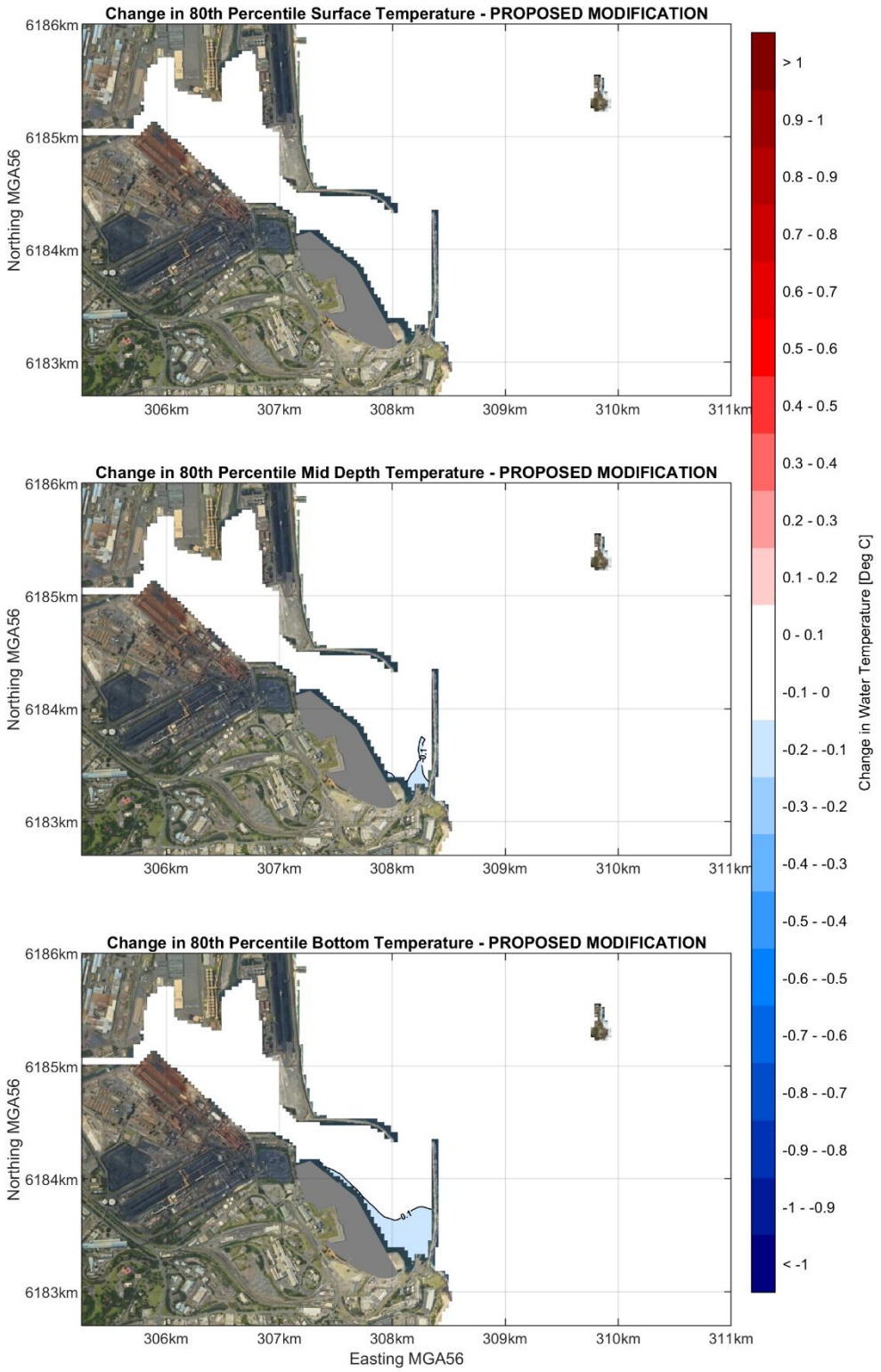
Modelled Changes in 15th Percentile Summer Water Temperature – Proposed Modification Layout



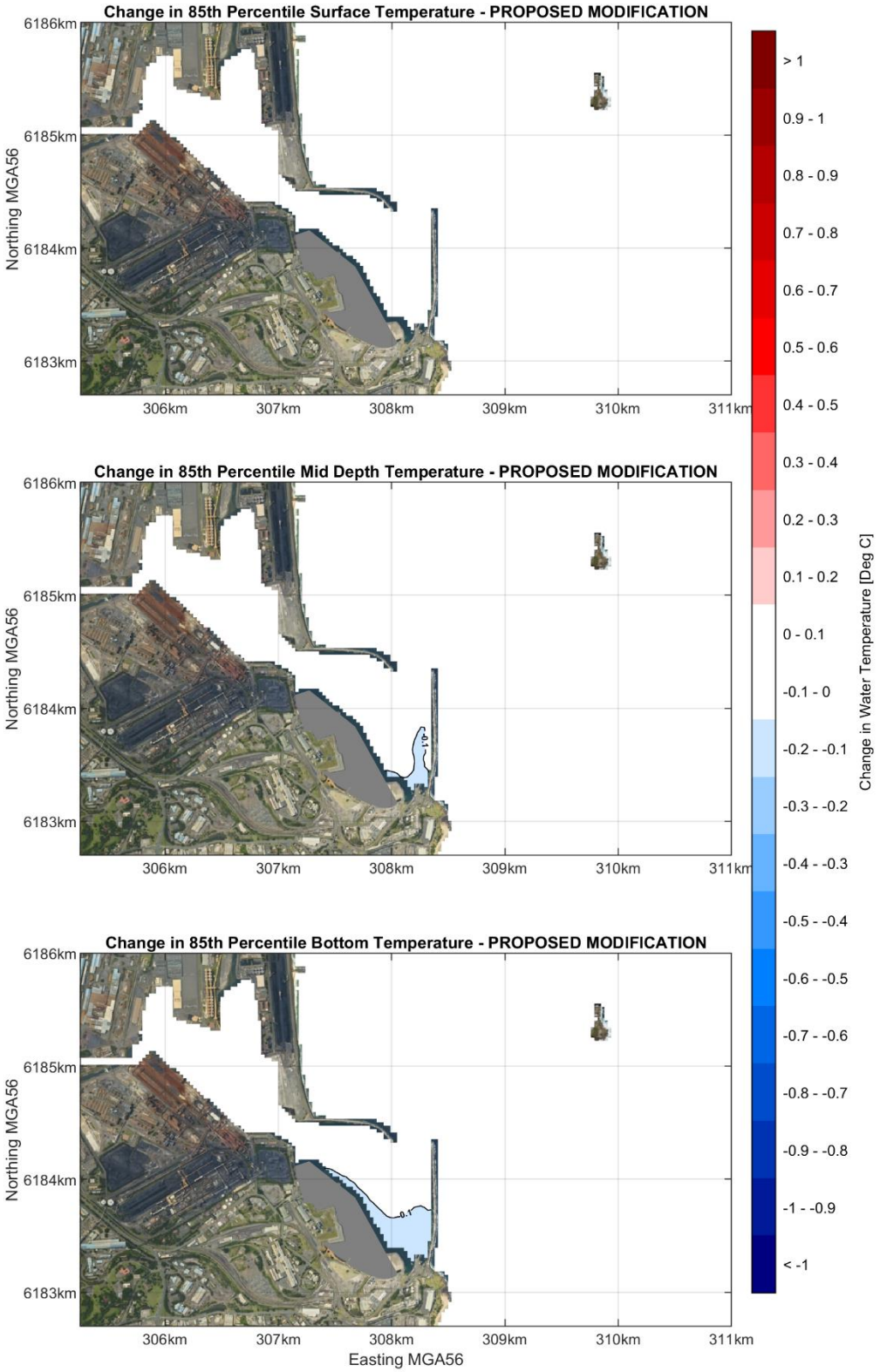
Modelled Changes in 20th Percentile Summer Water Temperature – Proposed Modification Layout



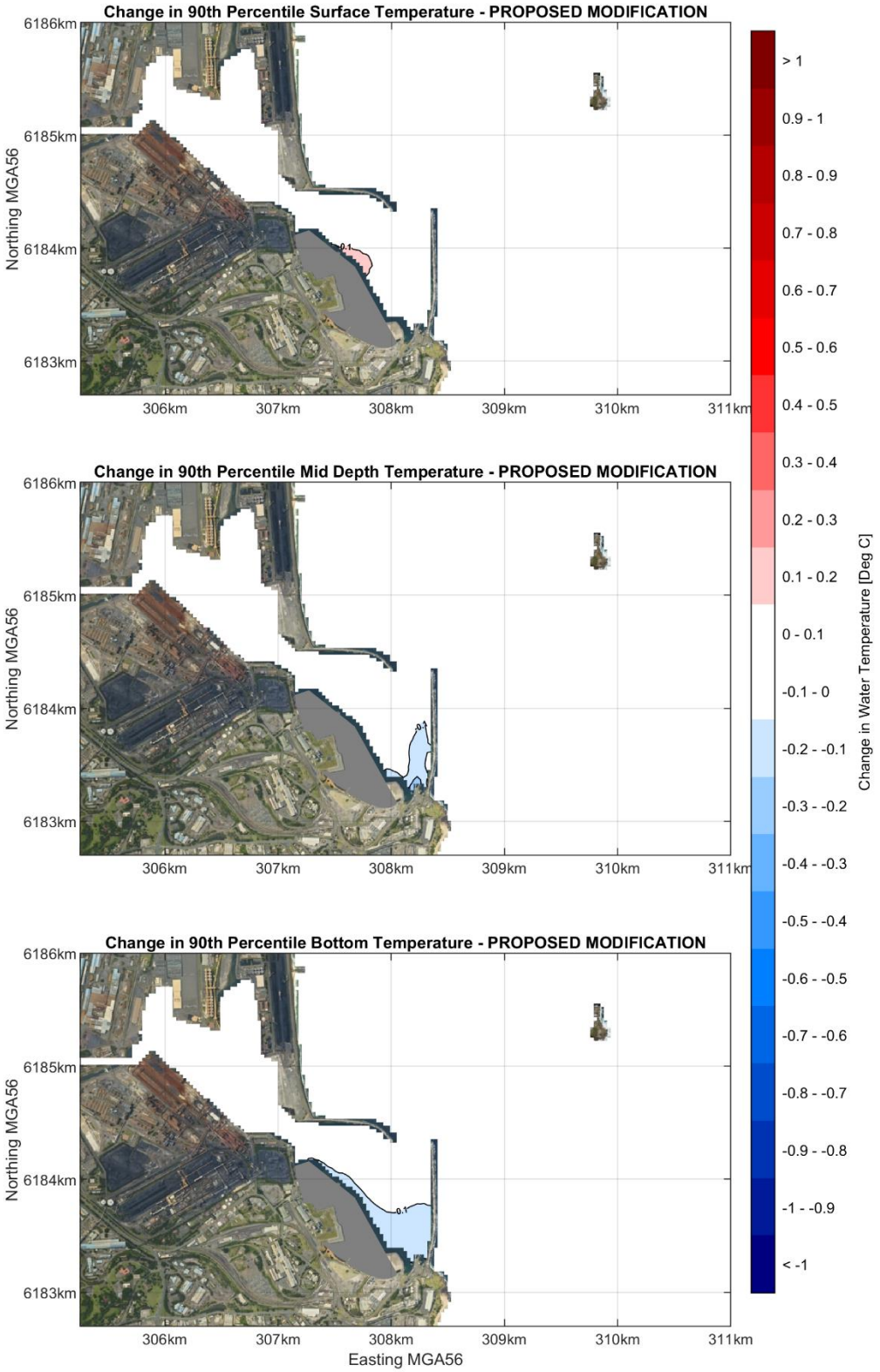
Modelled Changes in 50th Percentile Summer Water Temperature – Proposed Modification Layout



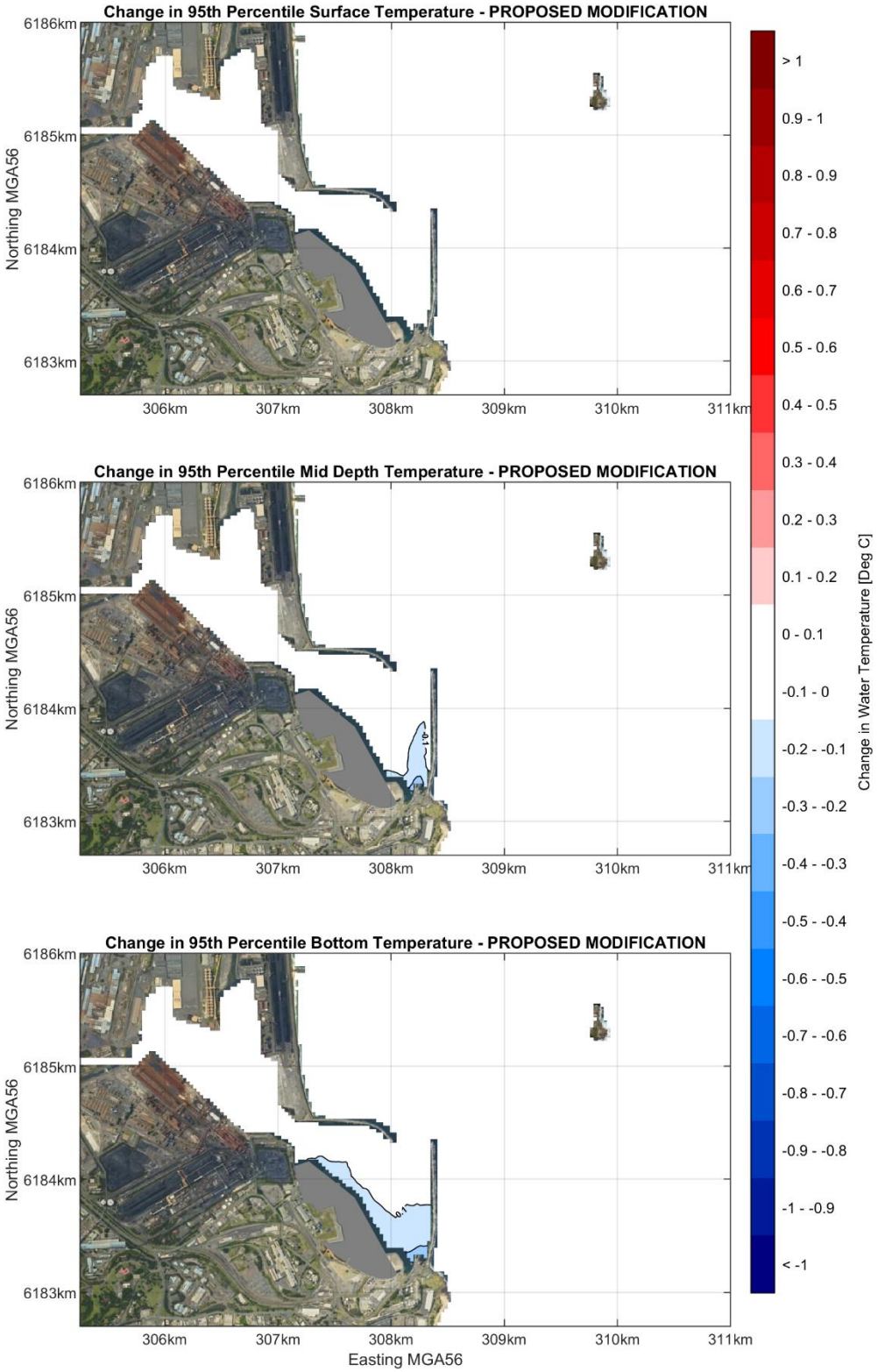
Modelled Changes in 80th Percentile Summer Water Temperature – Proposed Modification Layout



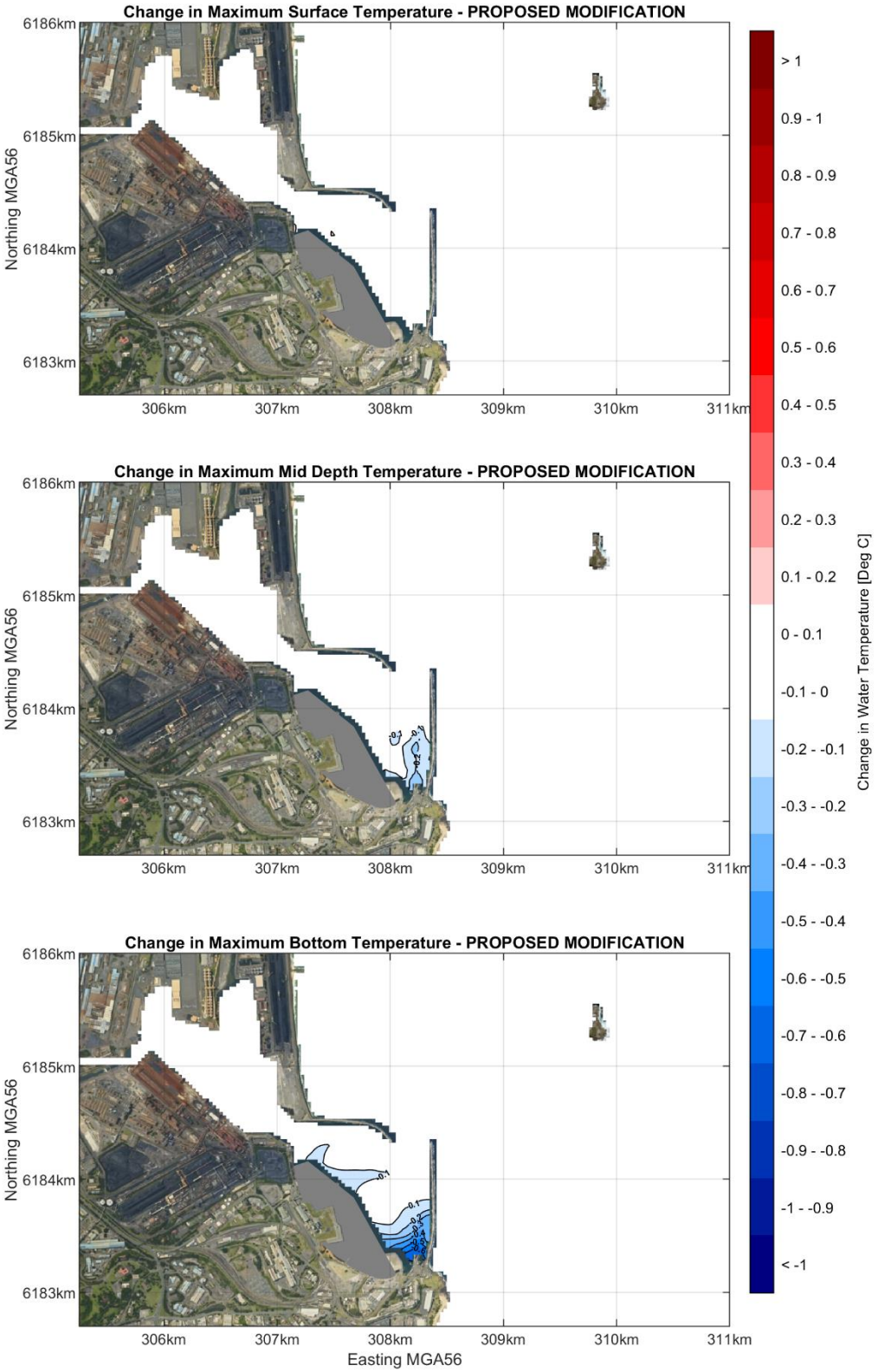
Modelled Changes in 85th Percentile Summer Water Temperature – Proposed Modification Layout



Modelled Changes in 90th Percentile Summer Water Temperature – Proposed Modification Layout

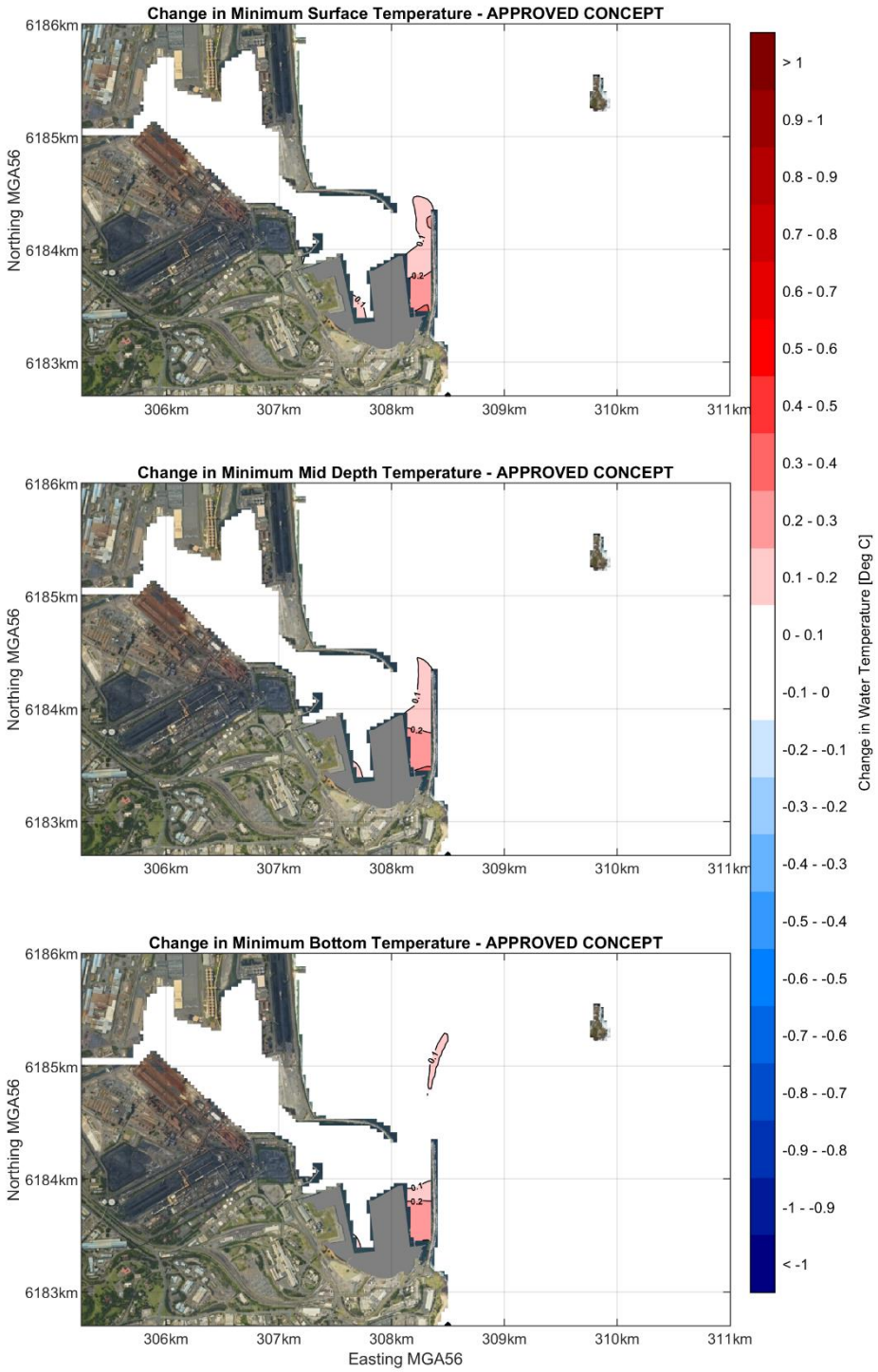


Modelled Changes in 95th Percentile Summer Water Temperature – Proposed Modification Layout

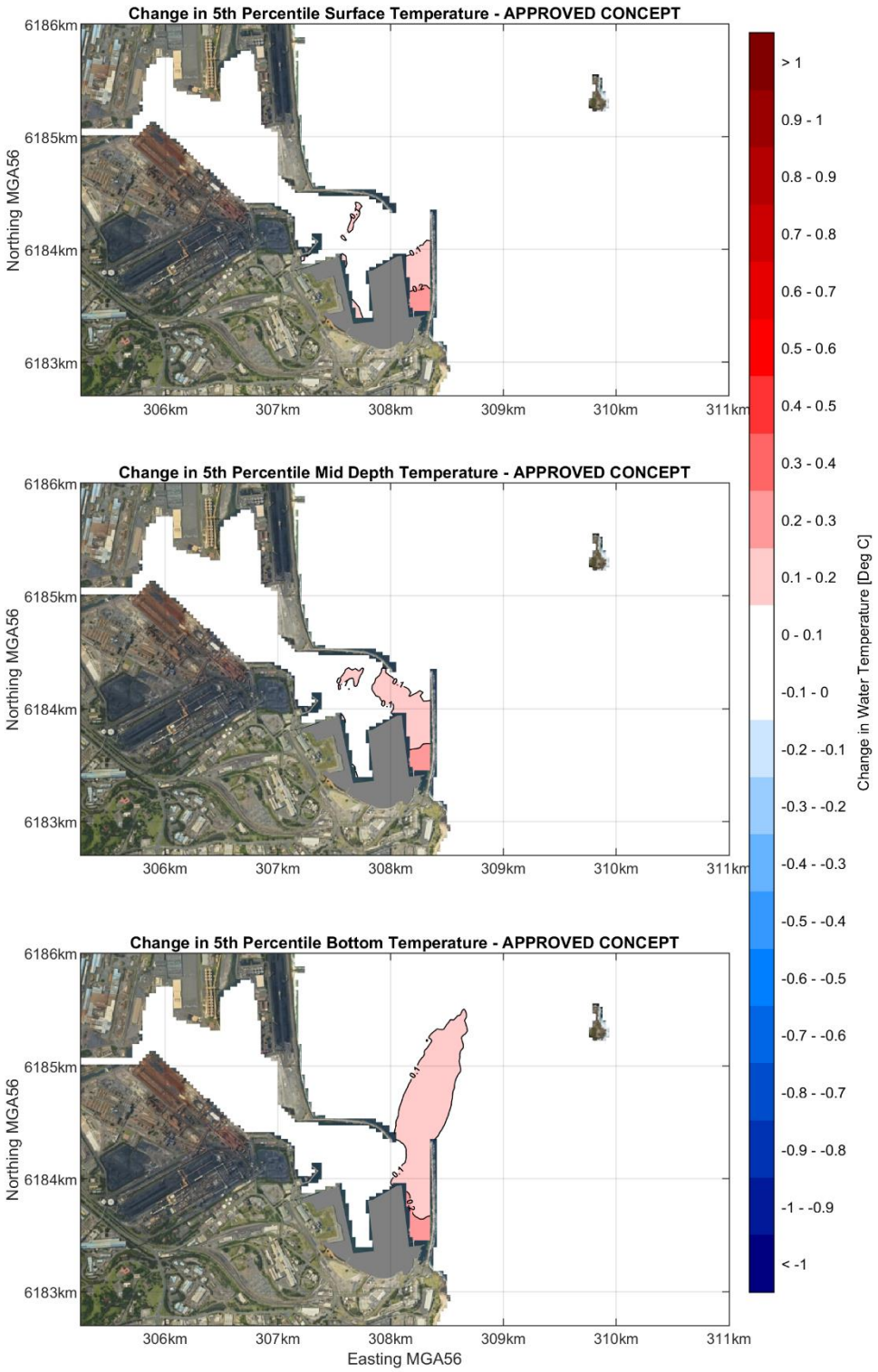


Modelled Changes in Maximum Summer Water Temperature – Proposed Modification Layout

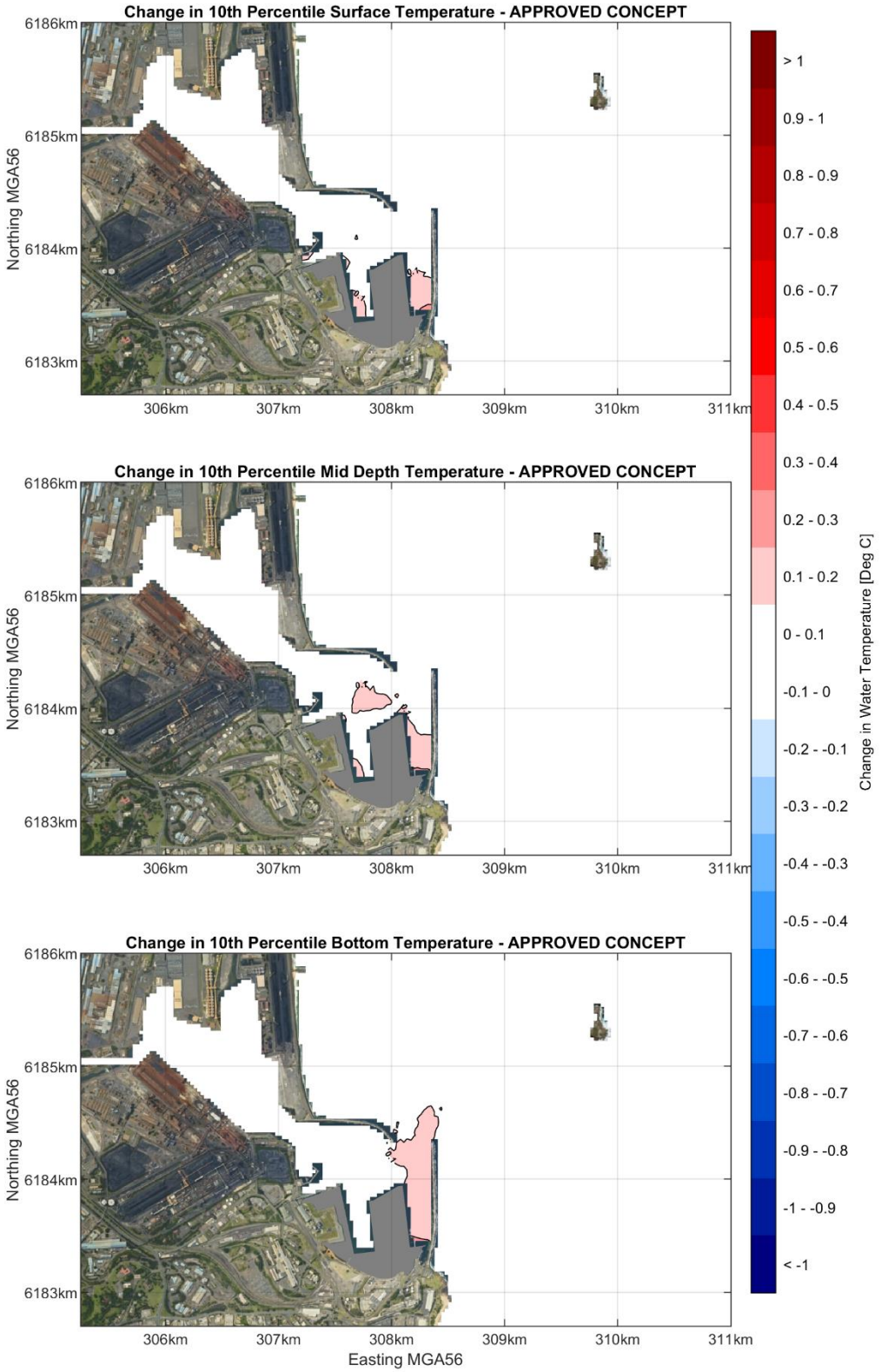
Appendix I Winter Thermal Impacts: Approved Concept Layout



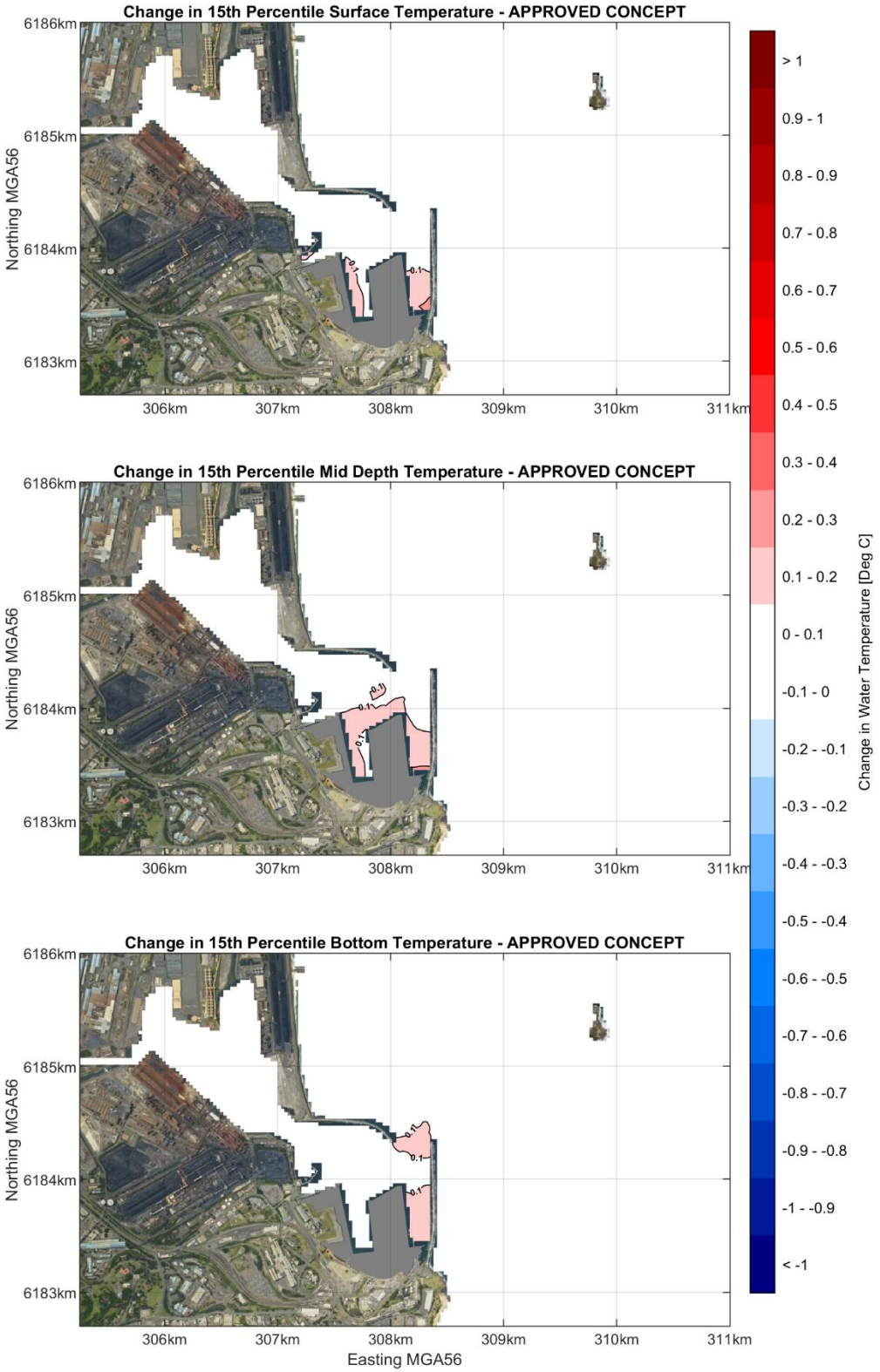
Modelled Changes in Minimum Winter Water Temperature – Approved Concept Layout



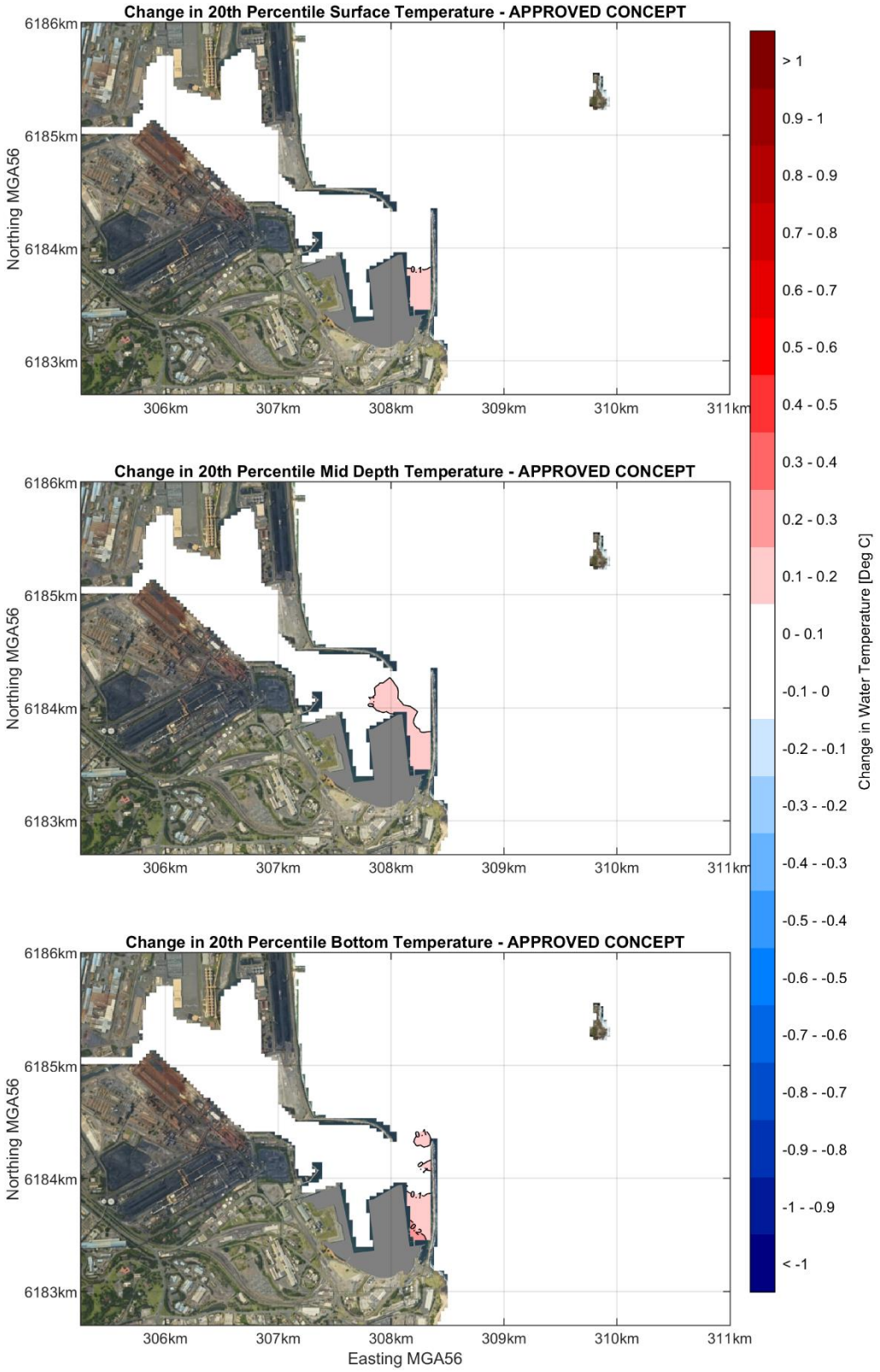
Modelled Changes in 5th Percentile Winter Water Temperature – Approved Concept Layout



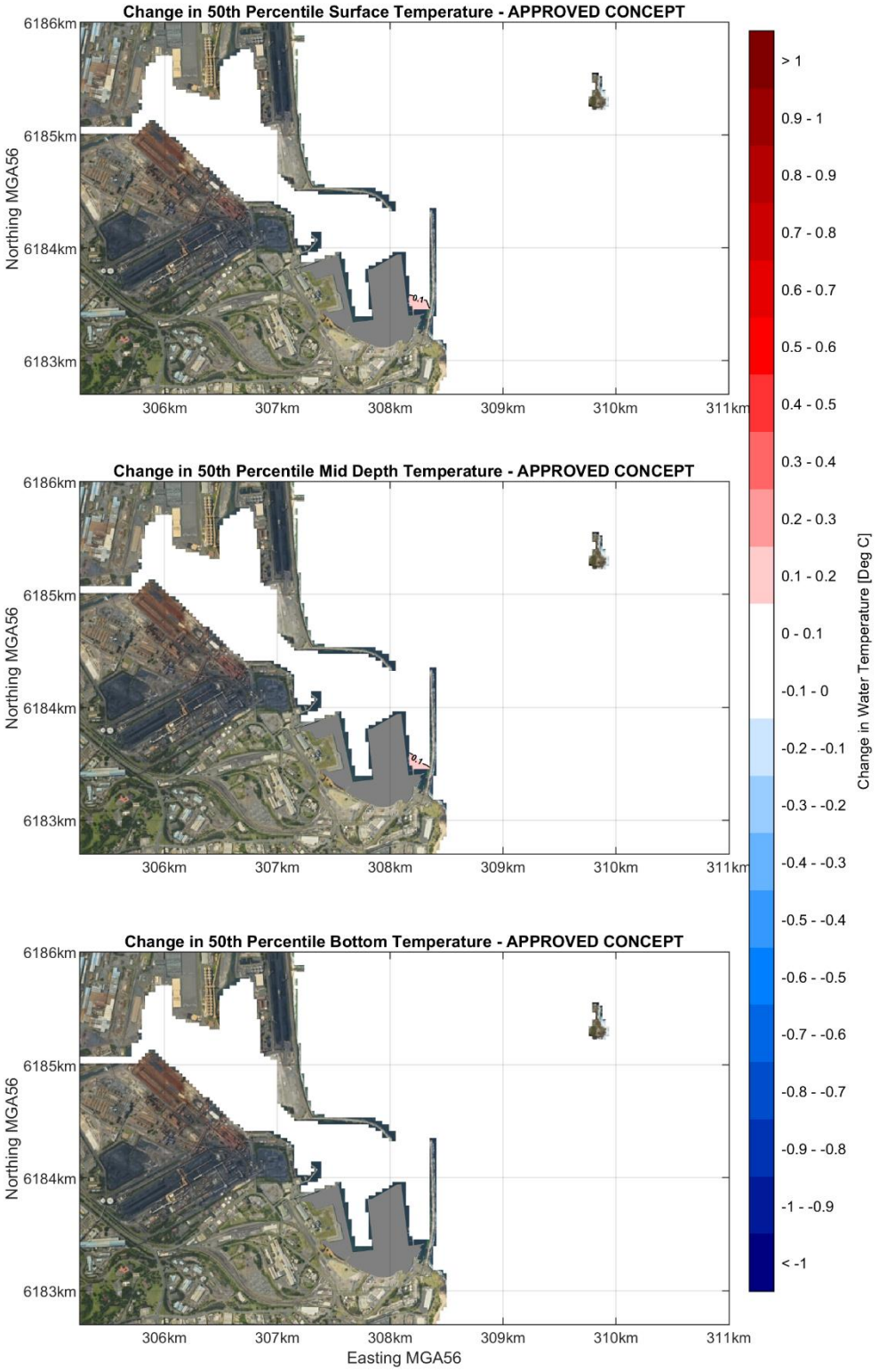
Modelled Changes in 10th Percentile Winter Water Temperature – Approved Concept Layout



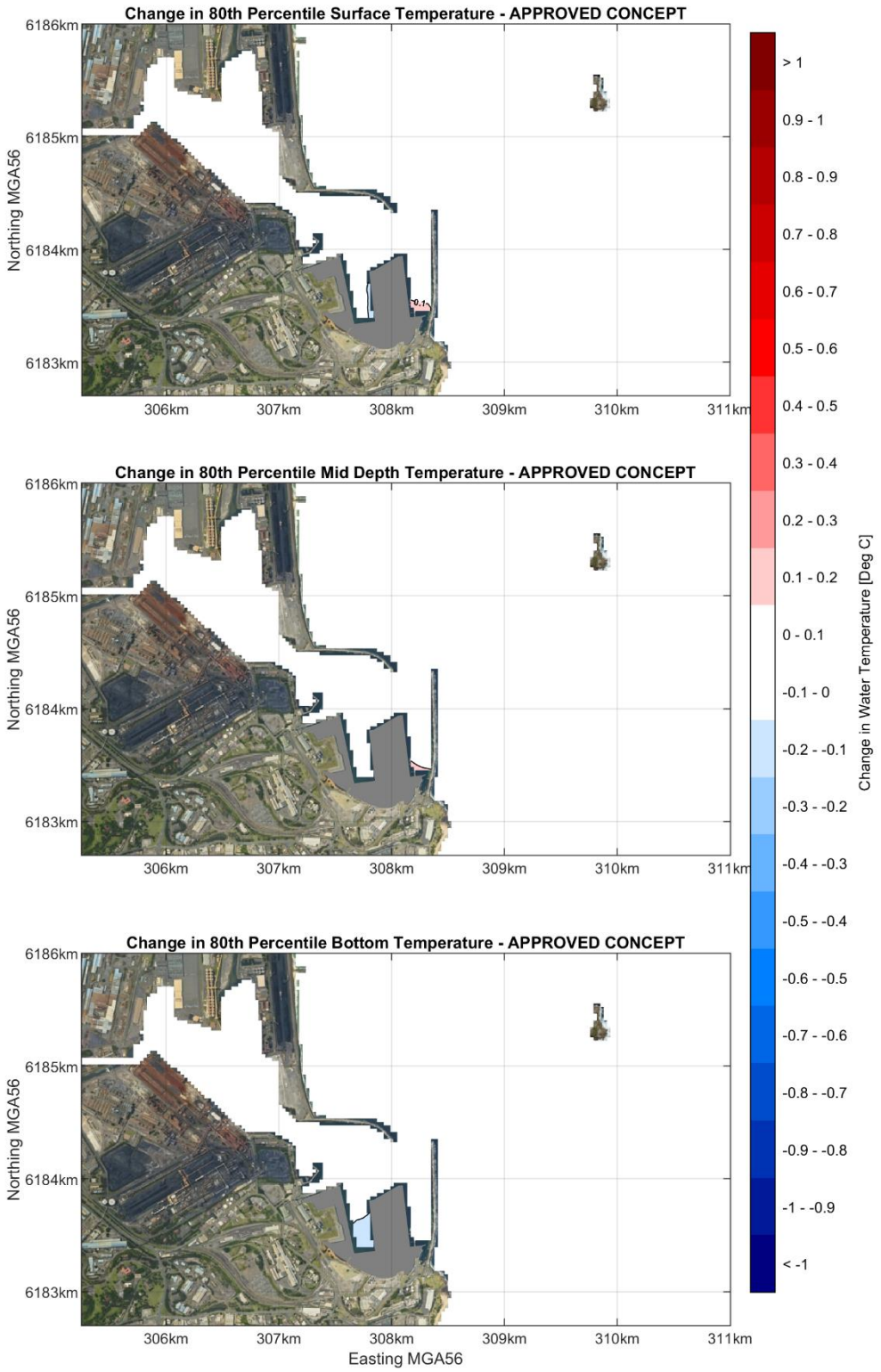
Modelled Changes in 15th Percentile Winter Water Temperature – Approved Concept Layout



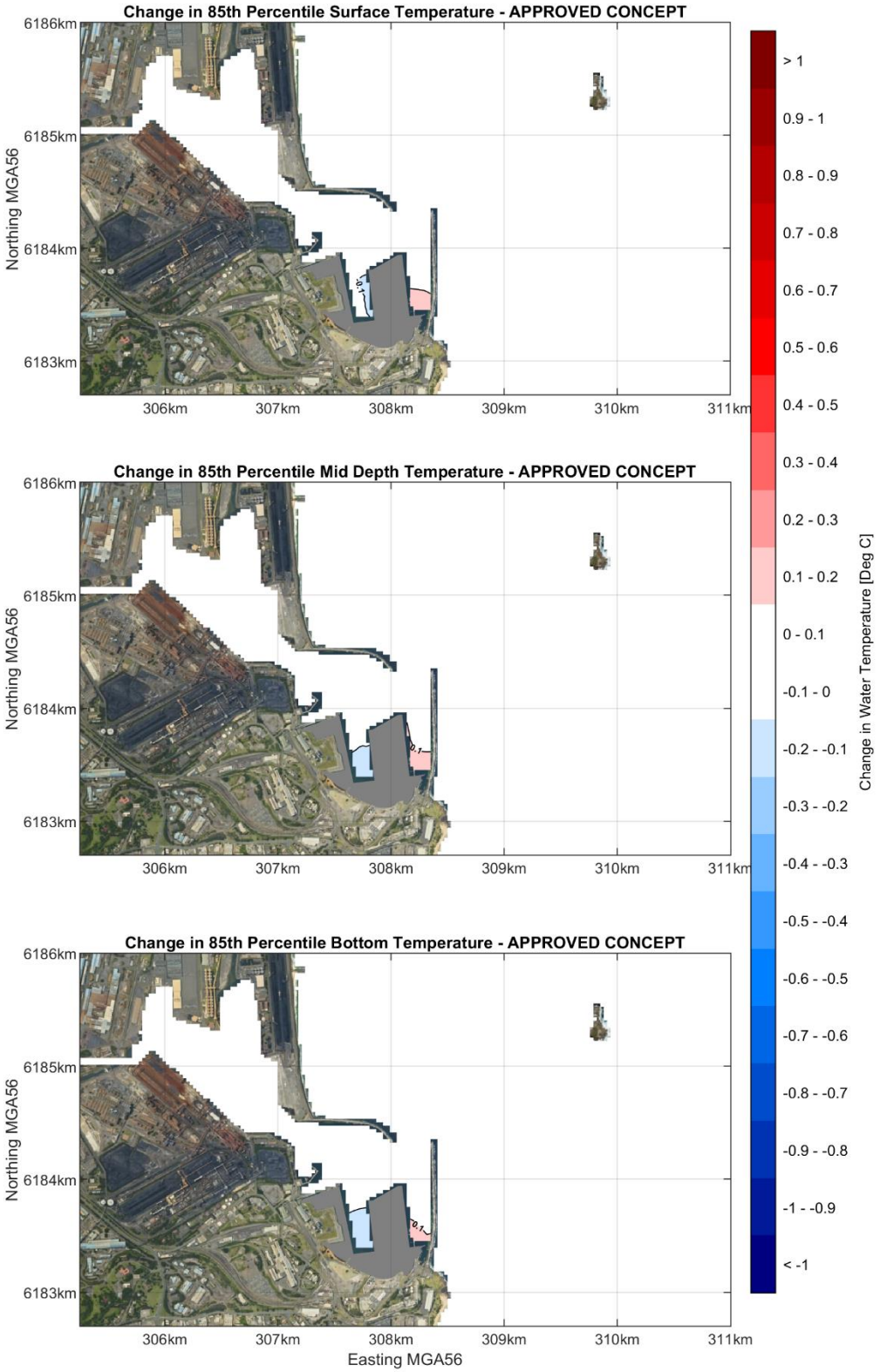
Modelled Changes in 20th Percentile Winter Water Temperature – Approved Concept Layout



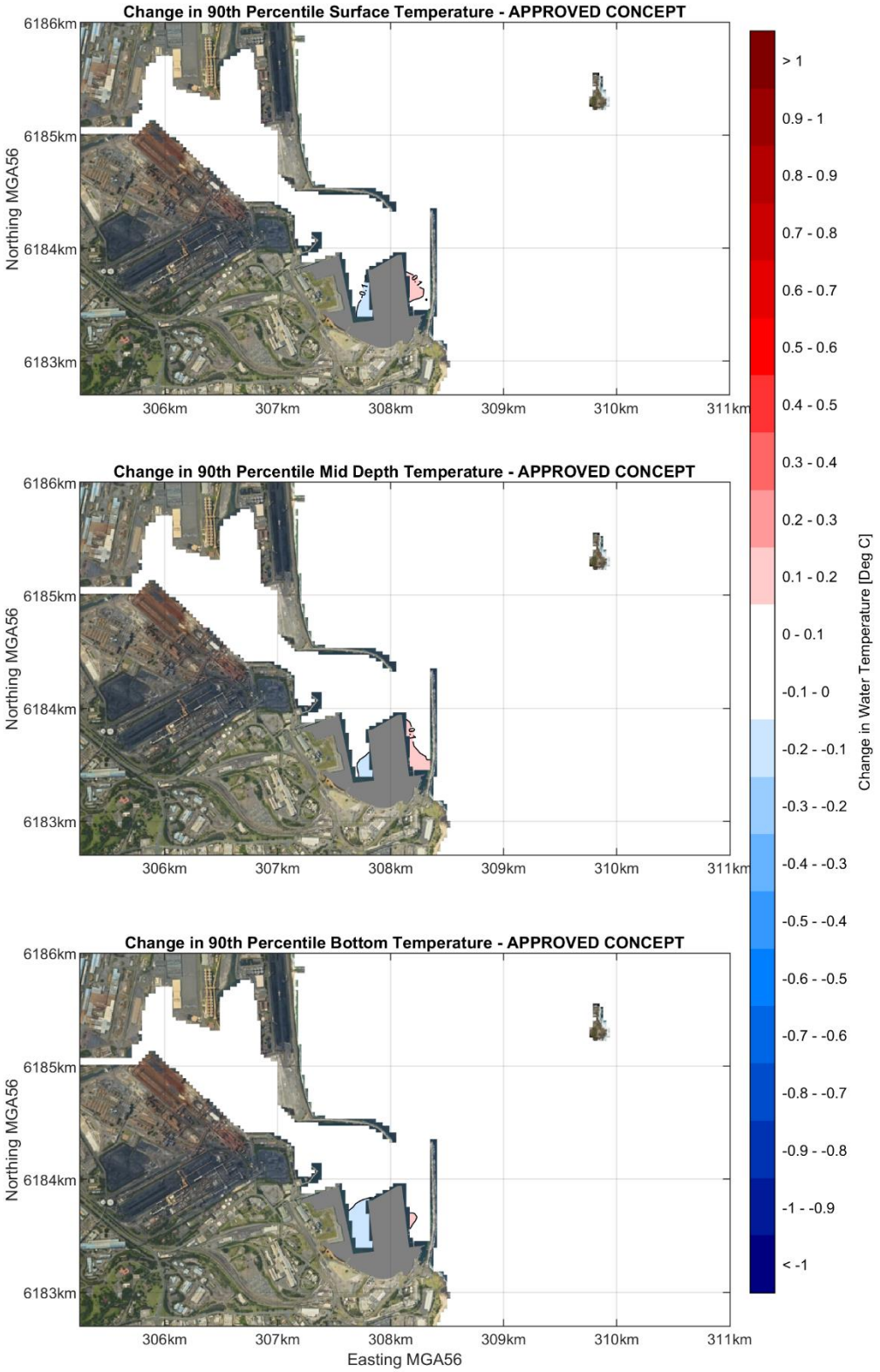
Modelled Changes in 50th Percentile Winter Water Temperature – Approved Concept Layout



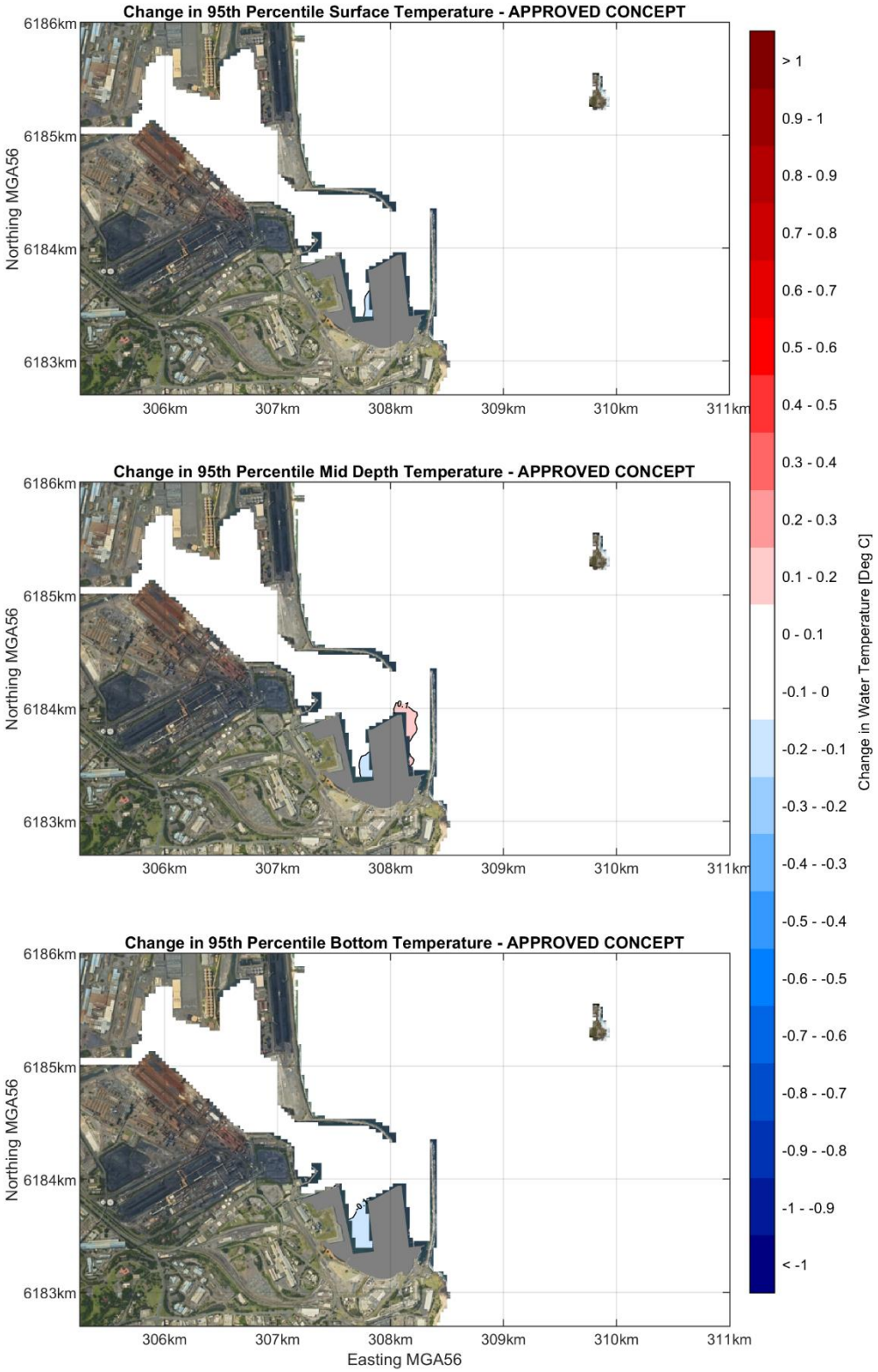
Modelled Changes in 80th Percentile Winter Water Temperature – Approved Concept Layout



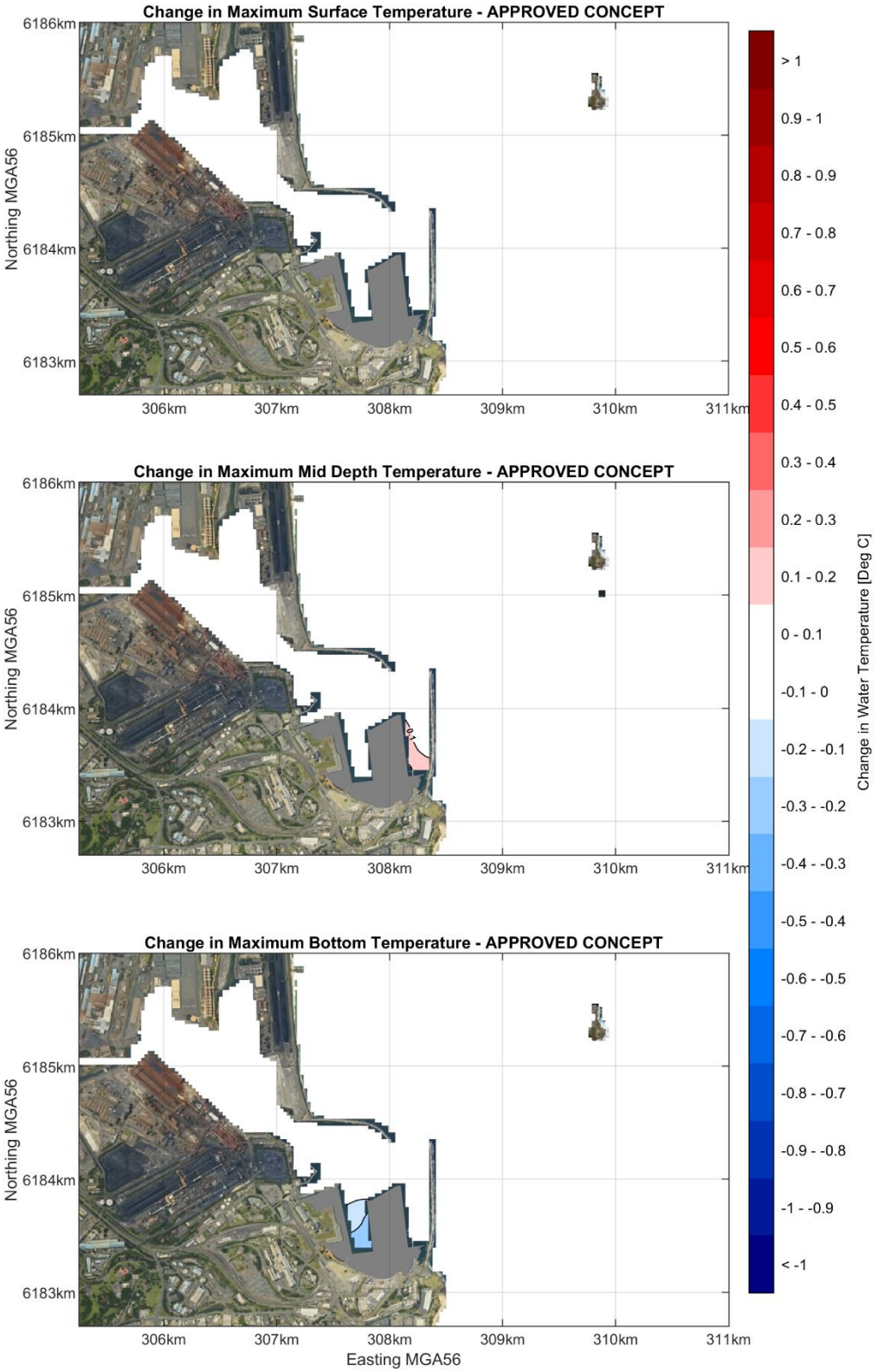
Modelled Changes in 85th Percentile Winter Water Temperature – Approved Concept Layout



Modelled Changes in 90th Percentile Winter Water Temperature – Approved Concept Layout

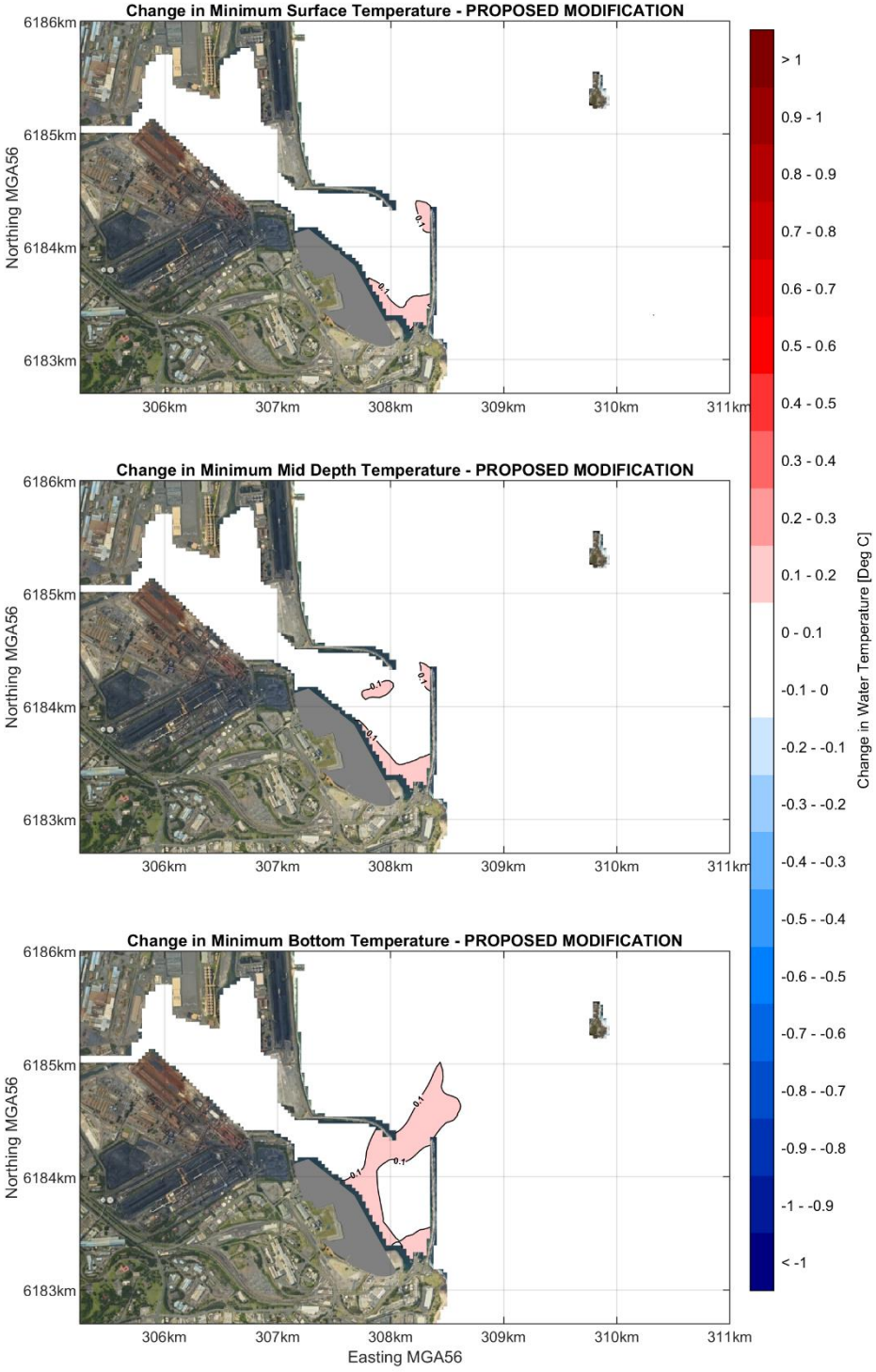


Modelled Changes in 95th Percentile Winter Water Temperature – Approved Concept Layout

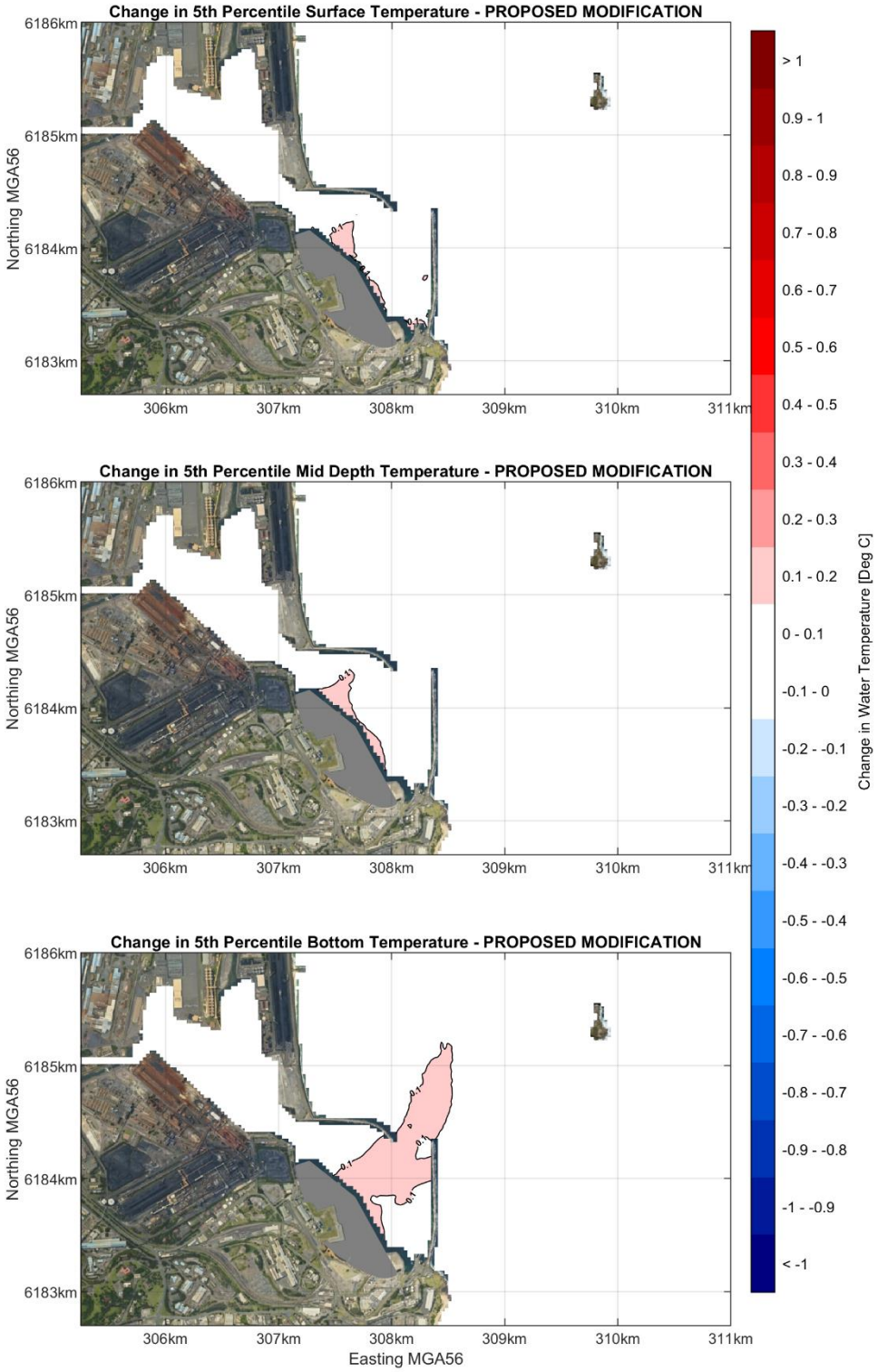


Modelled Changes in Maximum Winter Water Temperature – Approved Concept Layout

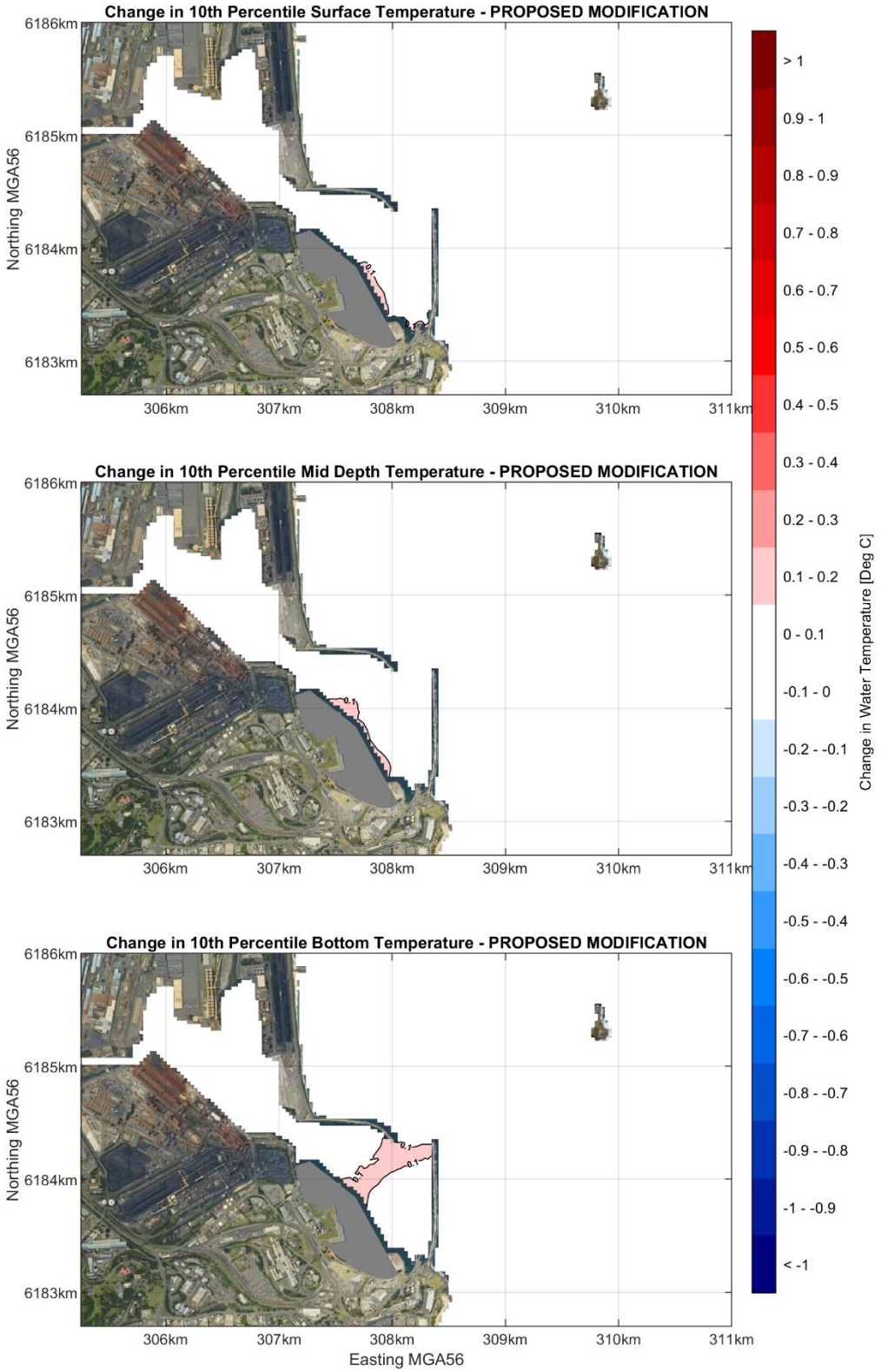
Appendix J Winter Thermal Impacts: Proposed Modification Layout



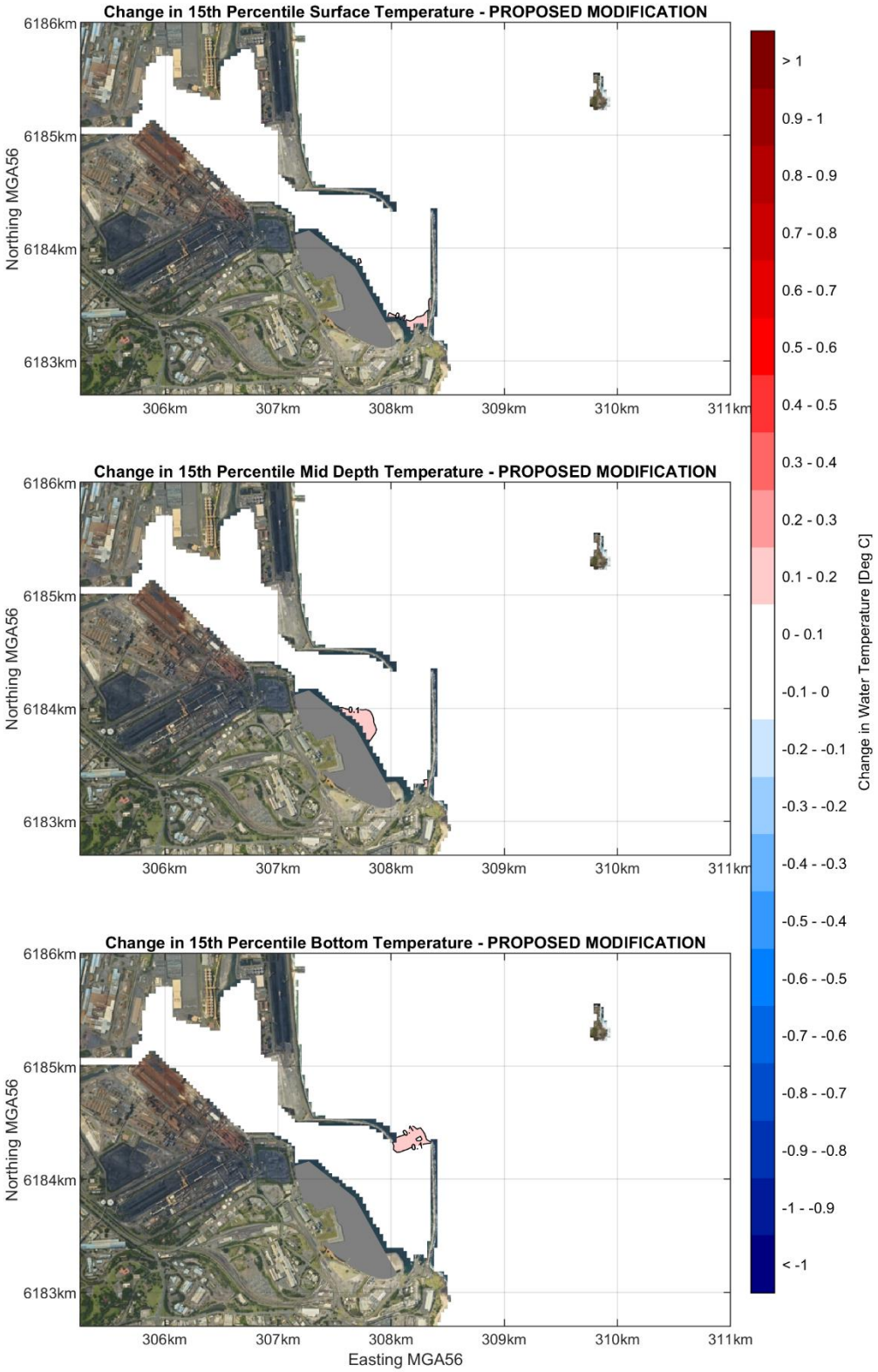
Modelled Changes in Minimum Winter Water Temperature – Proposed Modification Layout



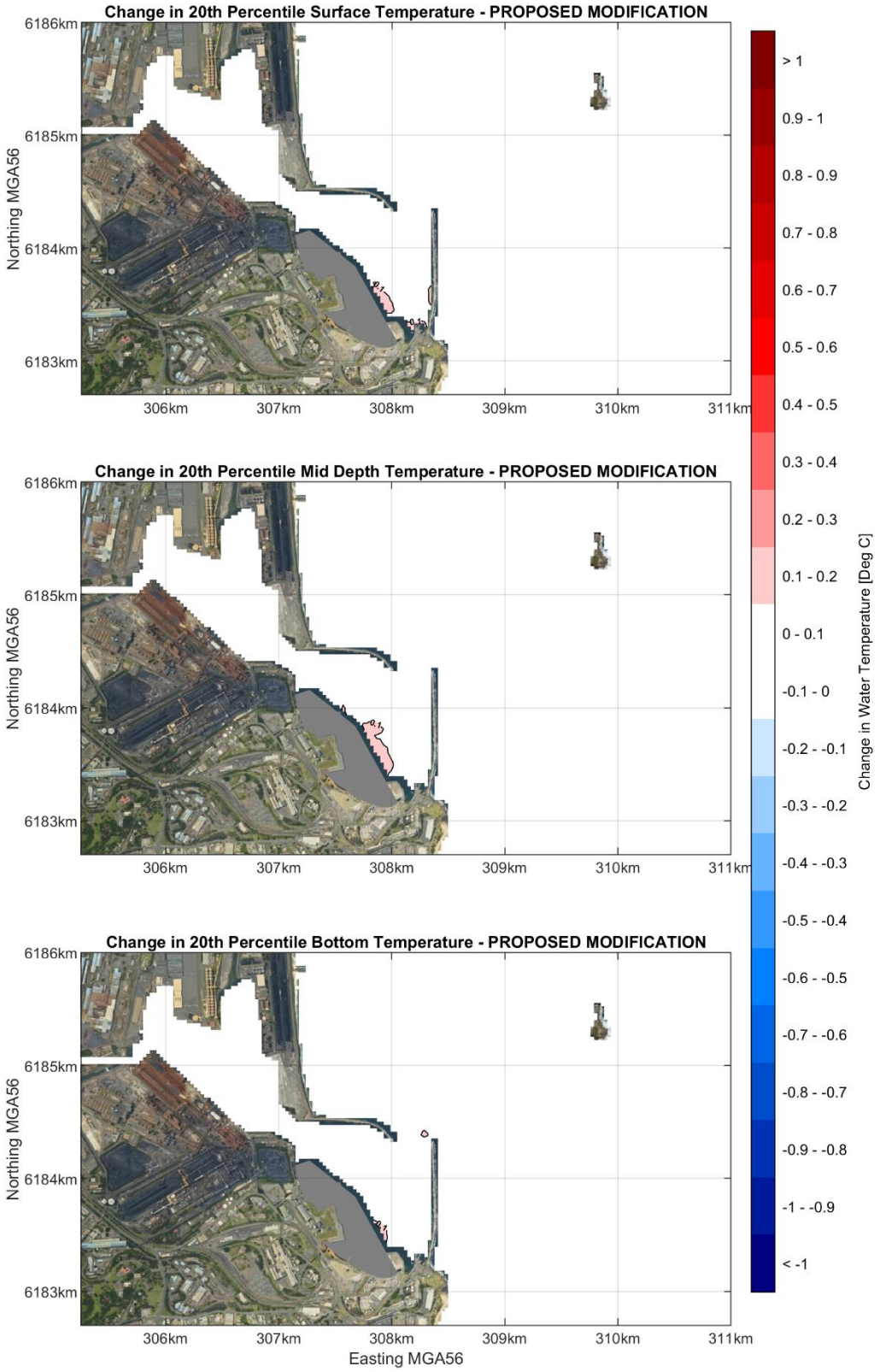
Modelled Changes in 5th Percentile Winter Water Temperature – Proposed Modification Layout



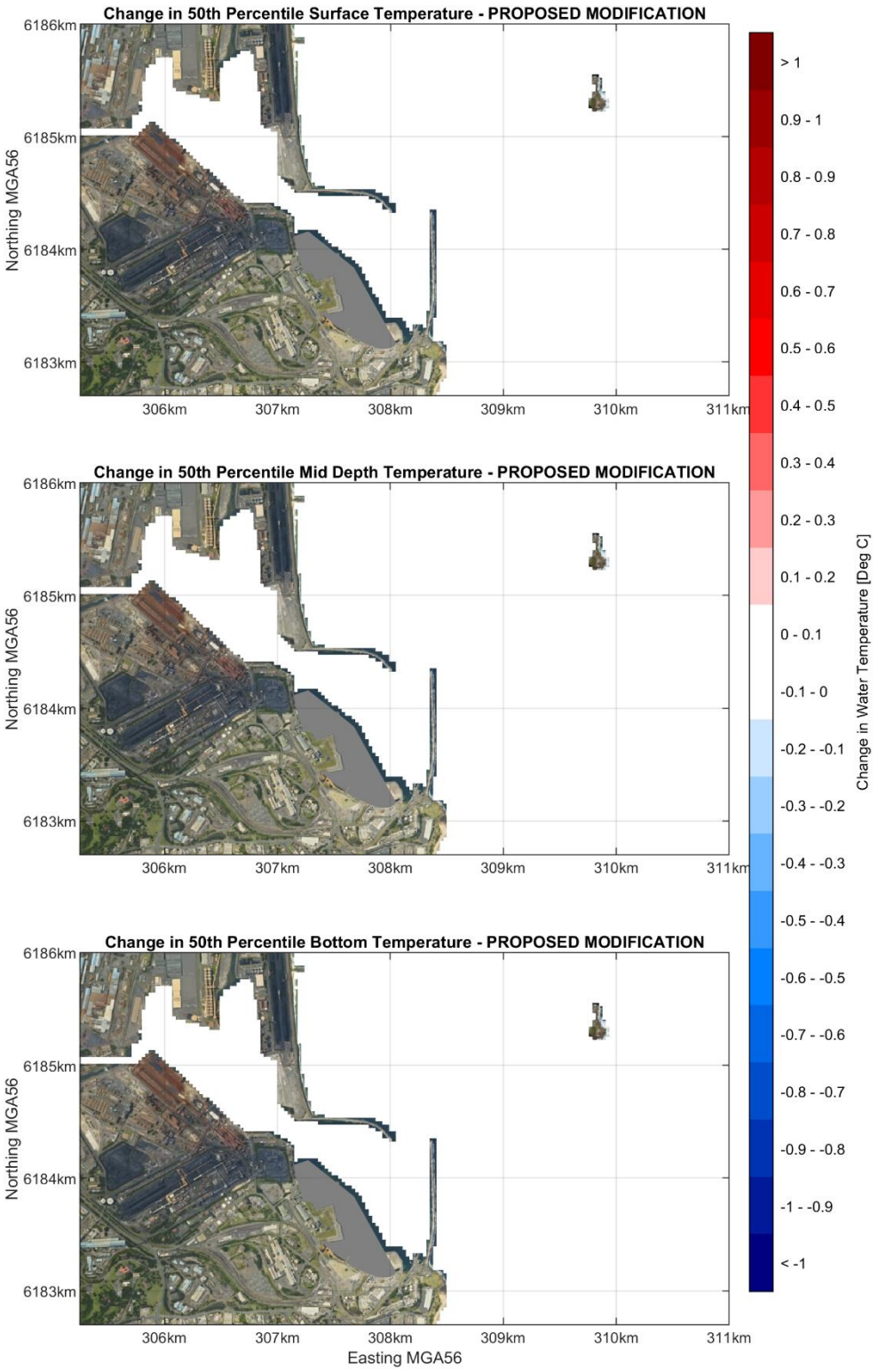
Modelled Changes in 10th Percentile Winter Water Temperature – Proposed Modification Layout



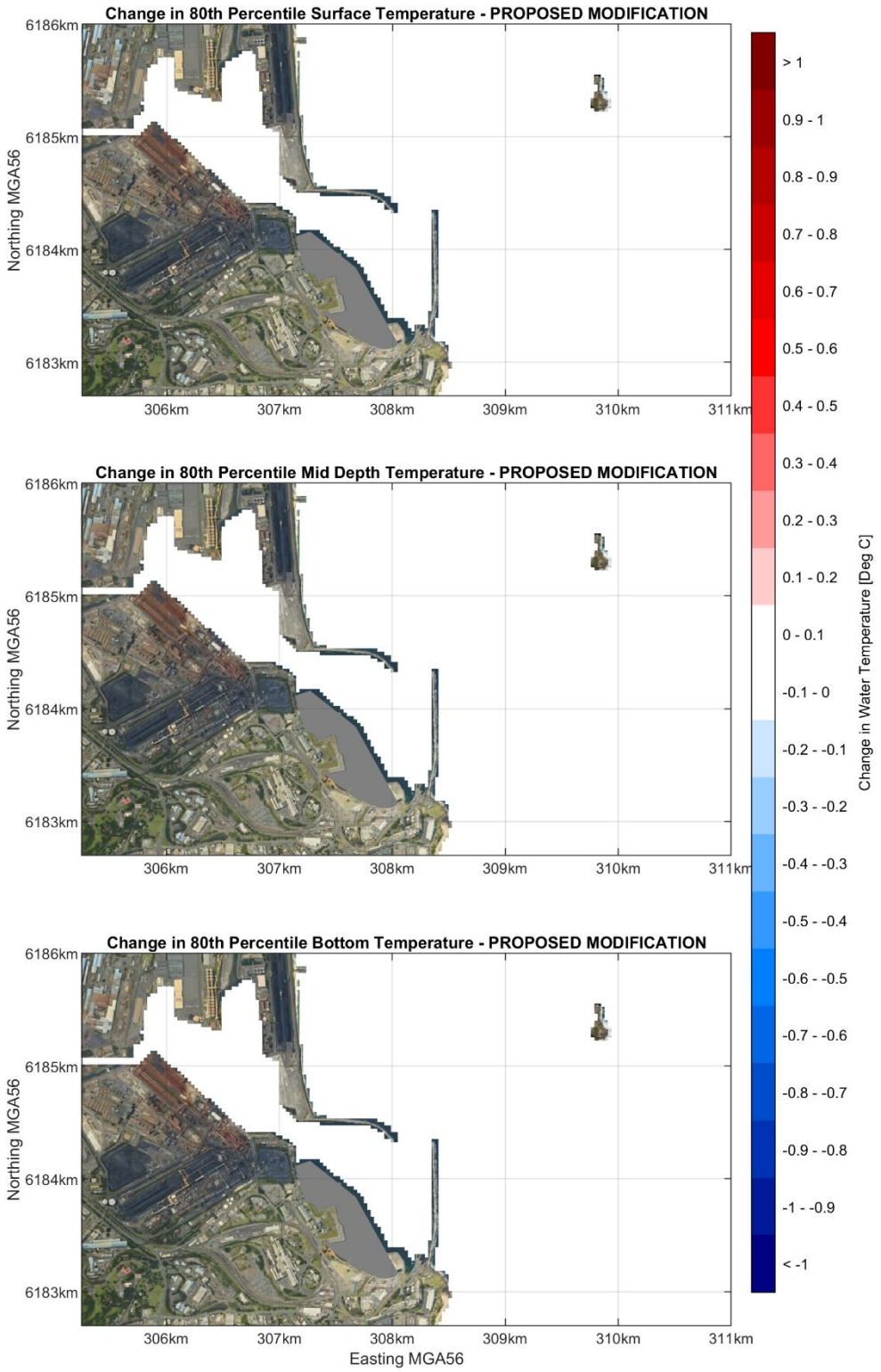
Modelled Changes in 15th Percentile Winter Water Temperature – Proposed Modification Layout



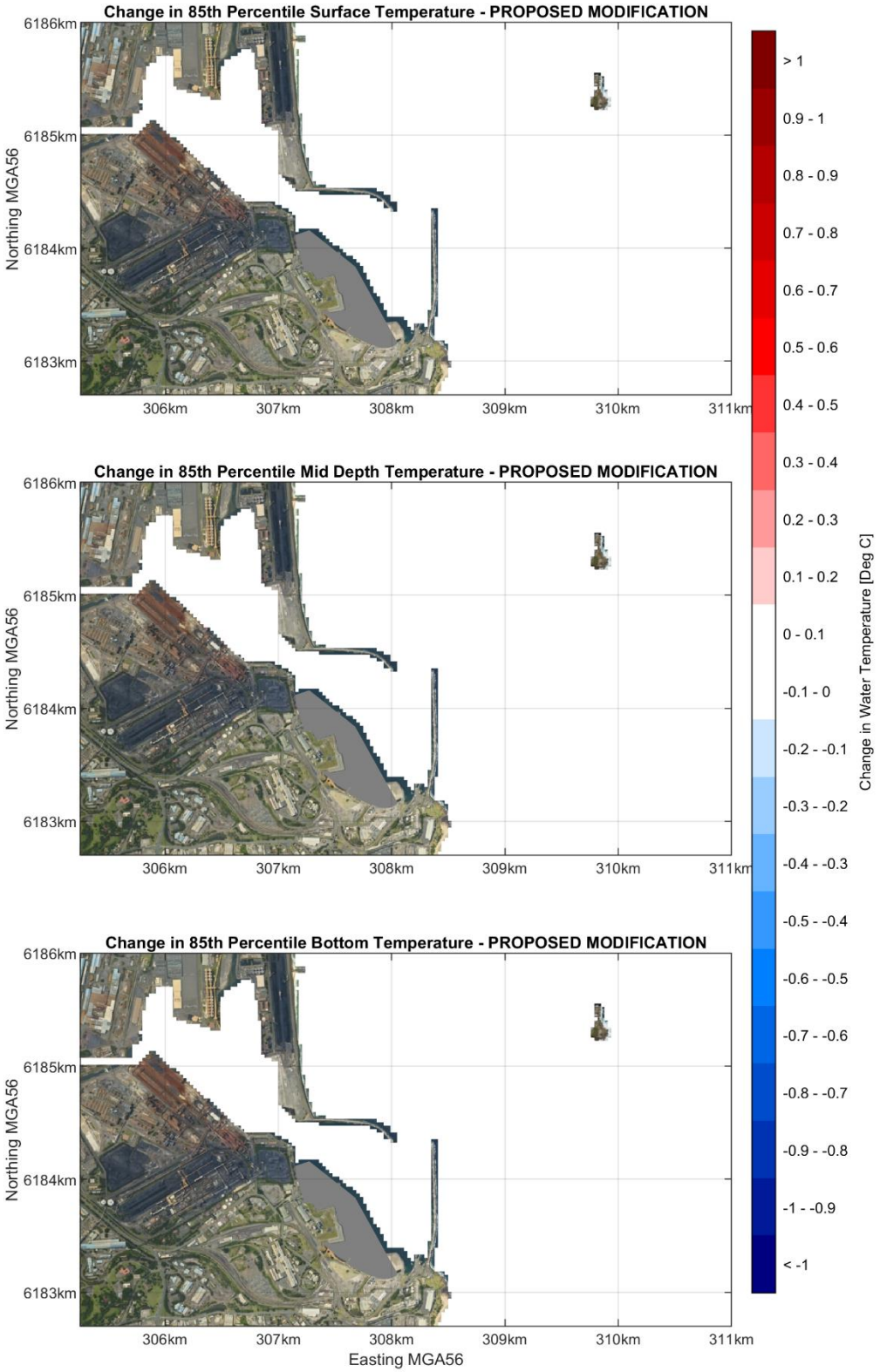
Modelled Changes in 20th Percentile Winter Water Temperature – Proposed Modification Layout



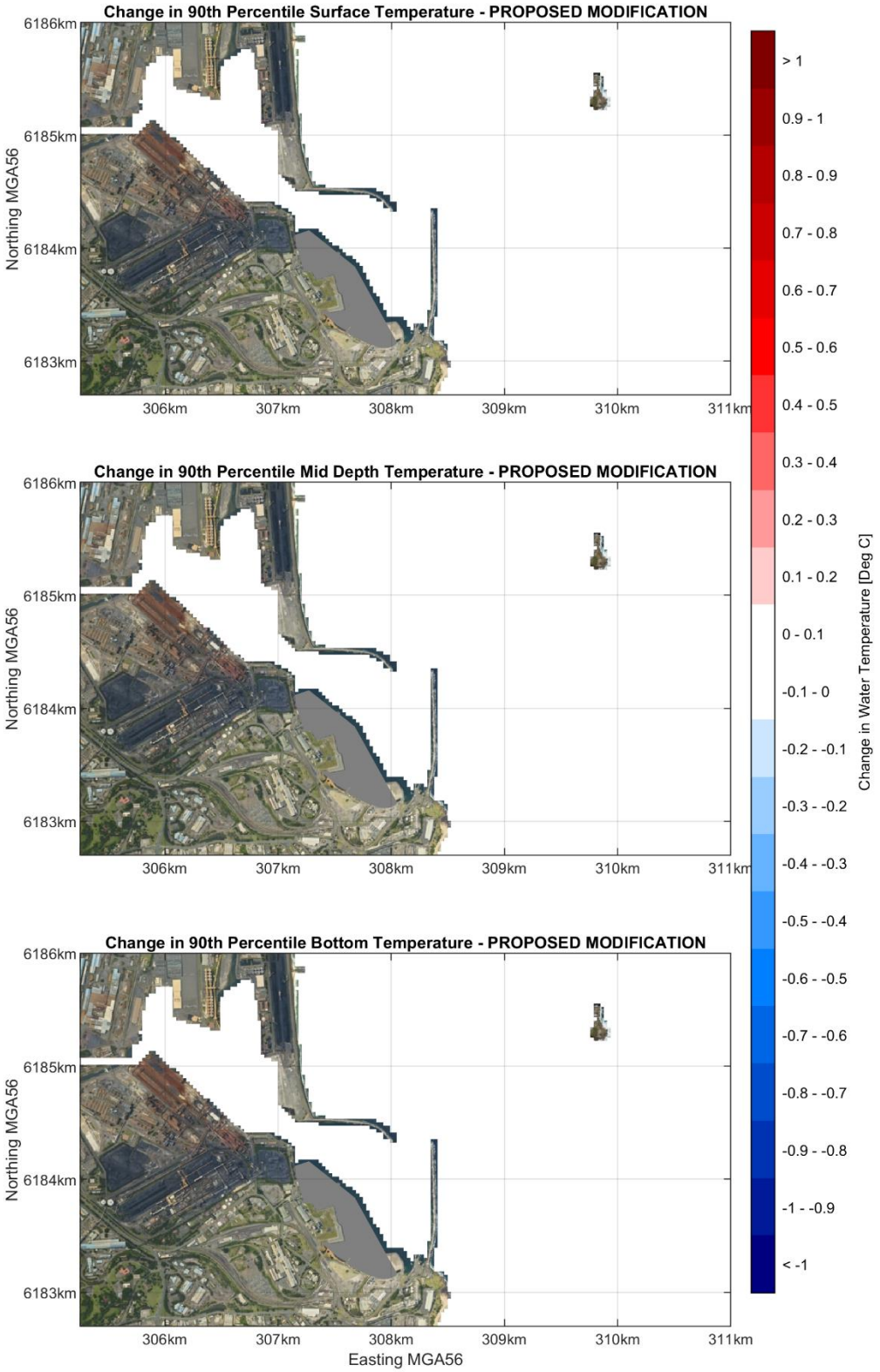
Modelled Changes in 50th Percentile Winter Water Temperature – Proposed Modification Layout



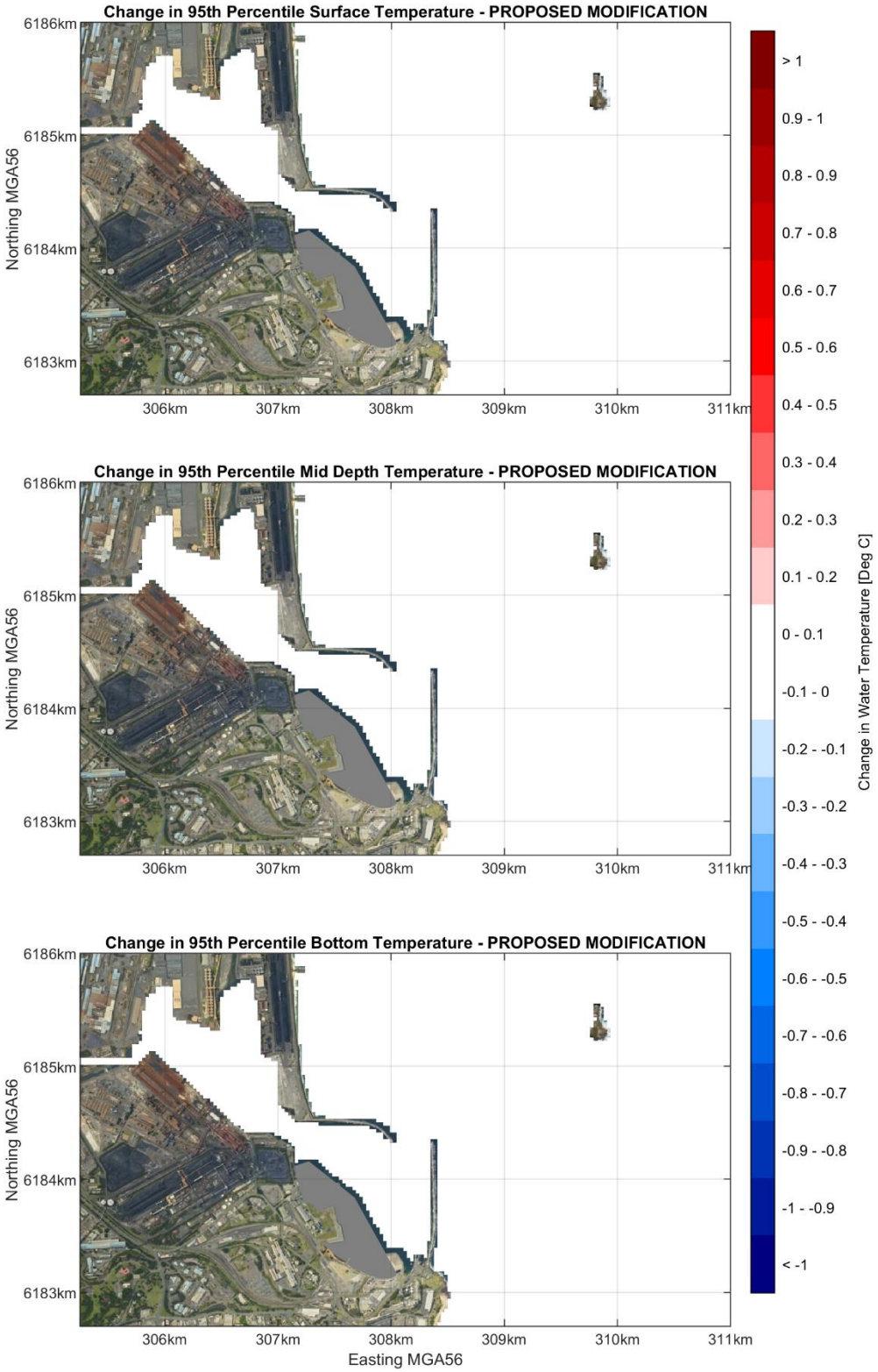
Modelled Changes in 80th Percentile Winter Water Temperature – Proposed Modification Layout



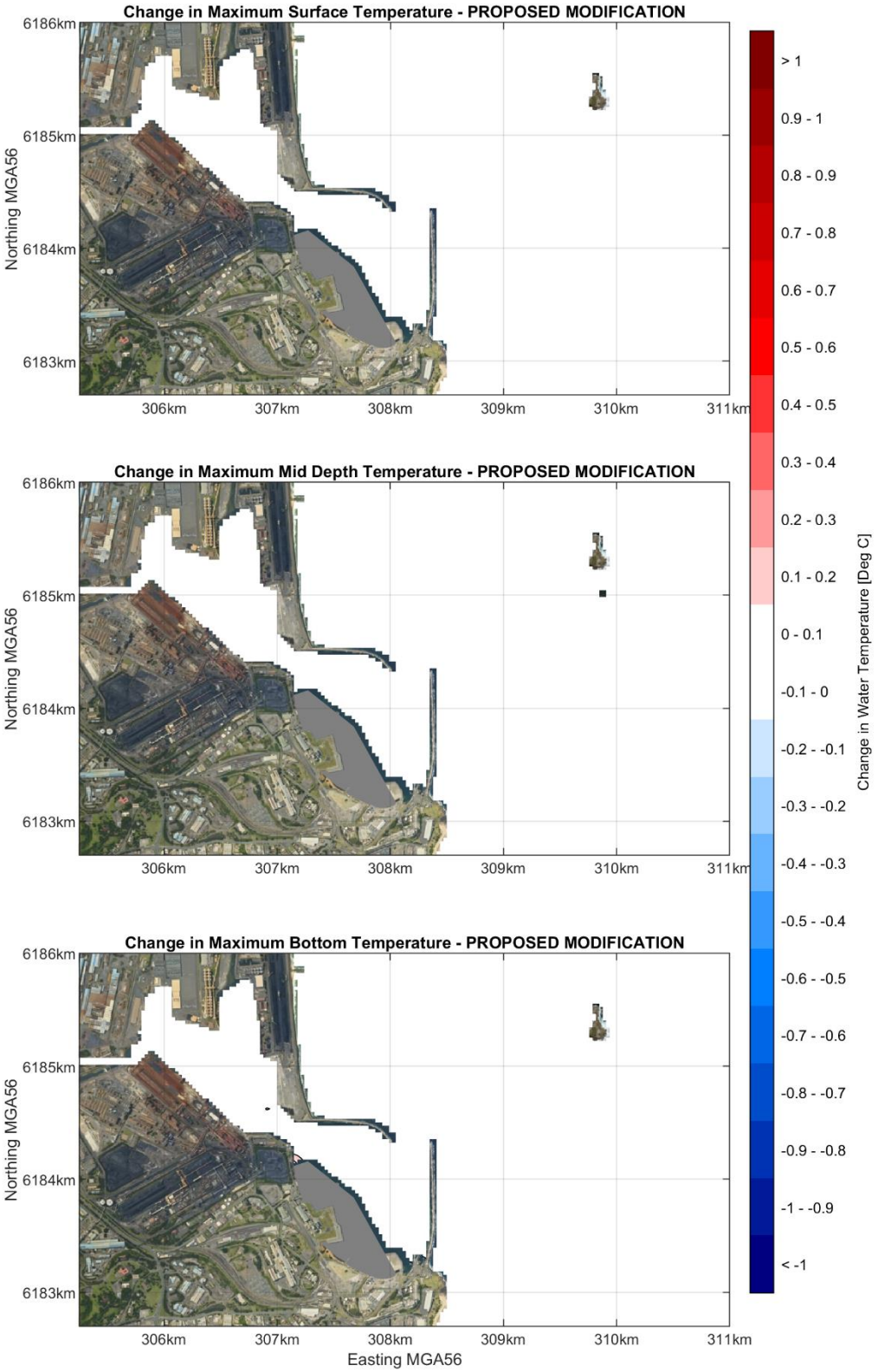
Modelled Changes in 85th Percentile Winter Water Temperature – Proposed Modification Layout



Modelled Changes in 90th Percentile Winter Water Temperature – Proposed Modification Layout

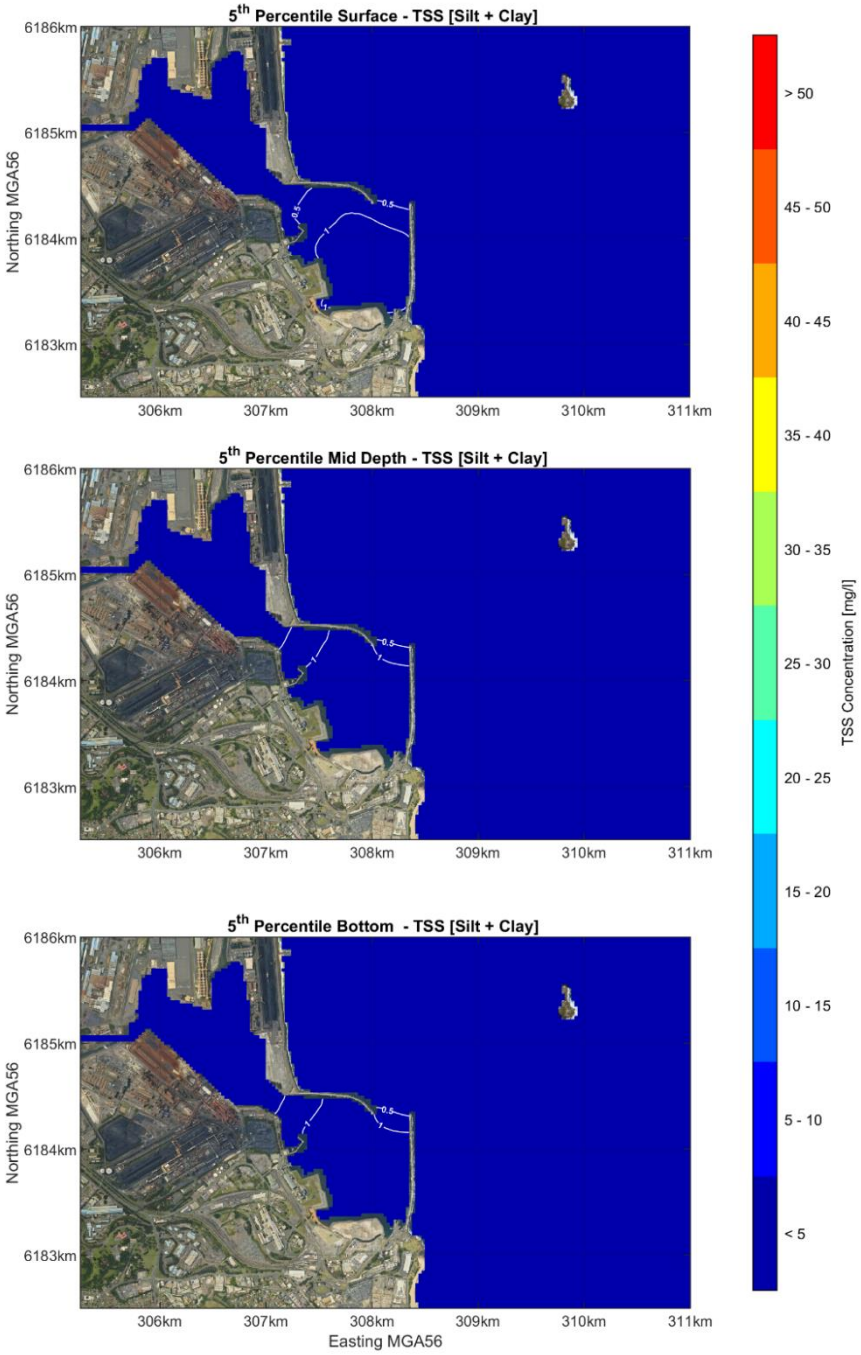


Modelled Changes in 95th Percentile Winter Water Temperature – Proposed Modification Layout

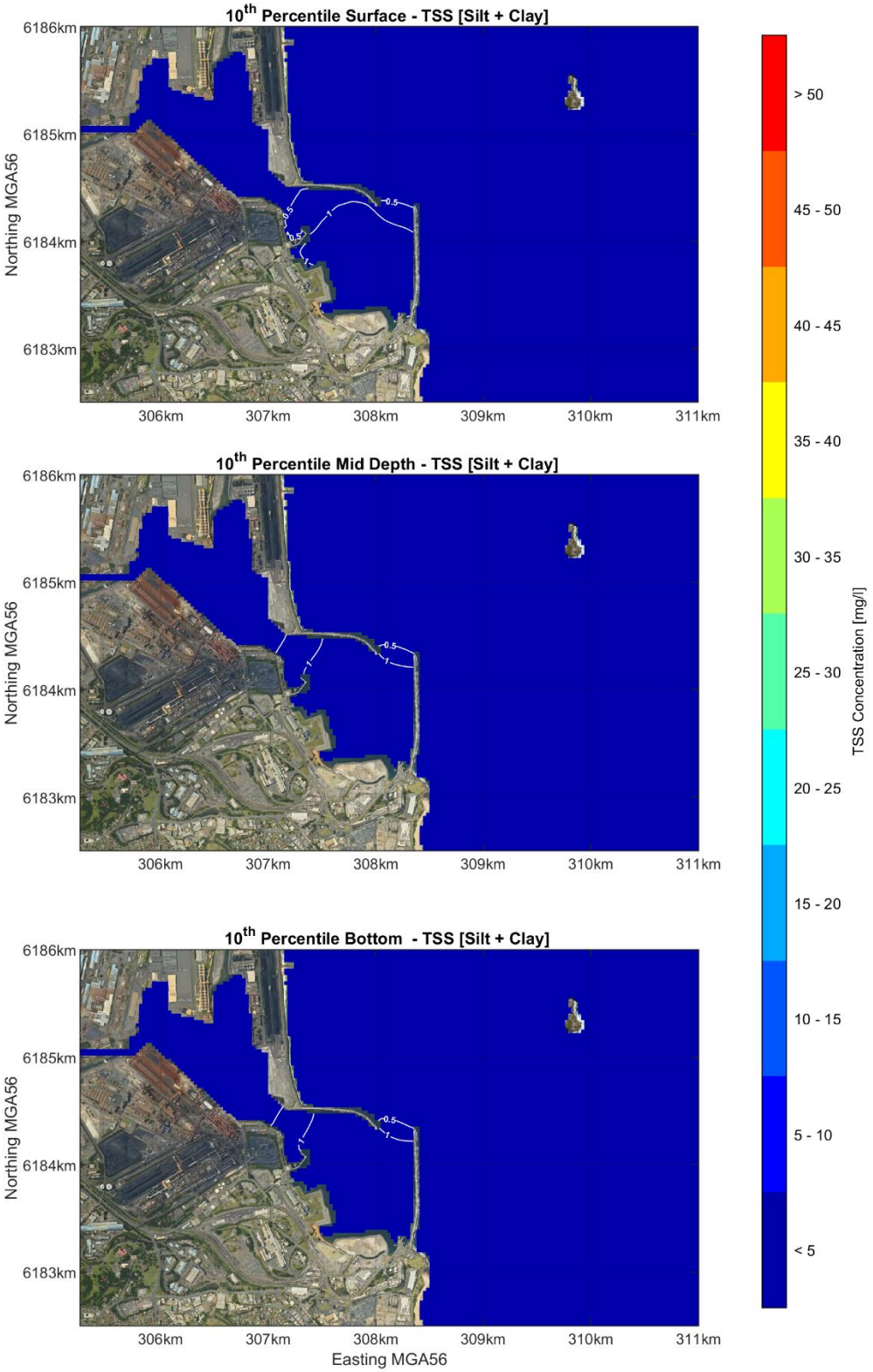


Modelled Changes in Maximum Winter Water Temperature – Proposed Modification Layout

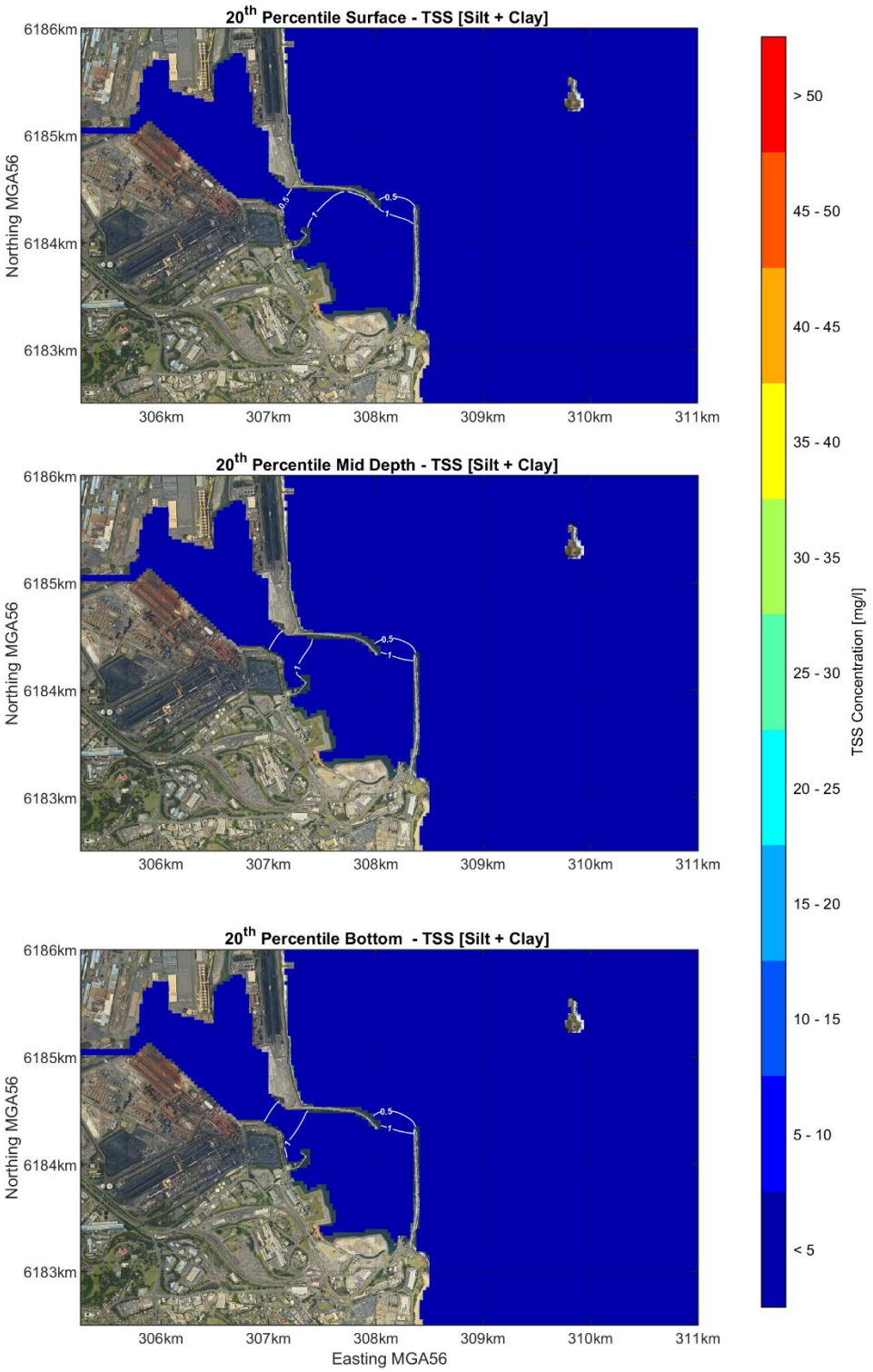
Appendix K Siltation Modelling Results - Sediment Concentration



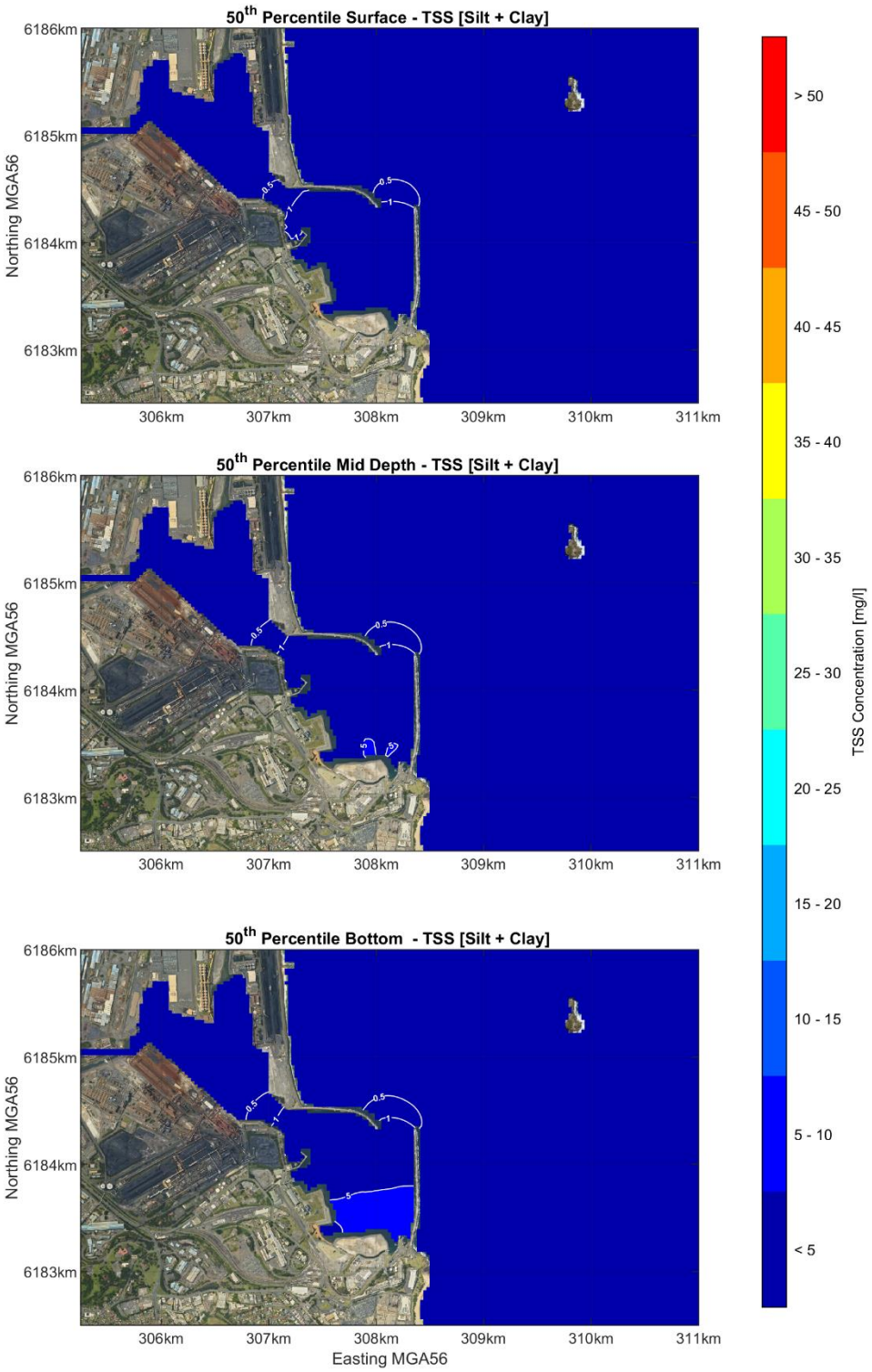
Modelled 5th Total Suspended Sediment Concentration (TSS)



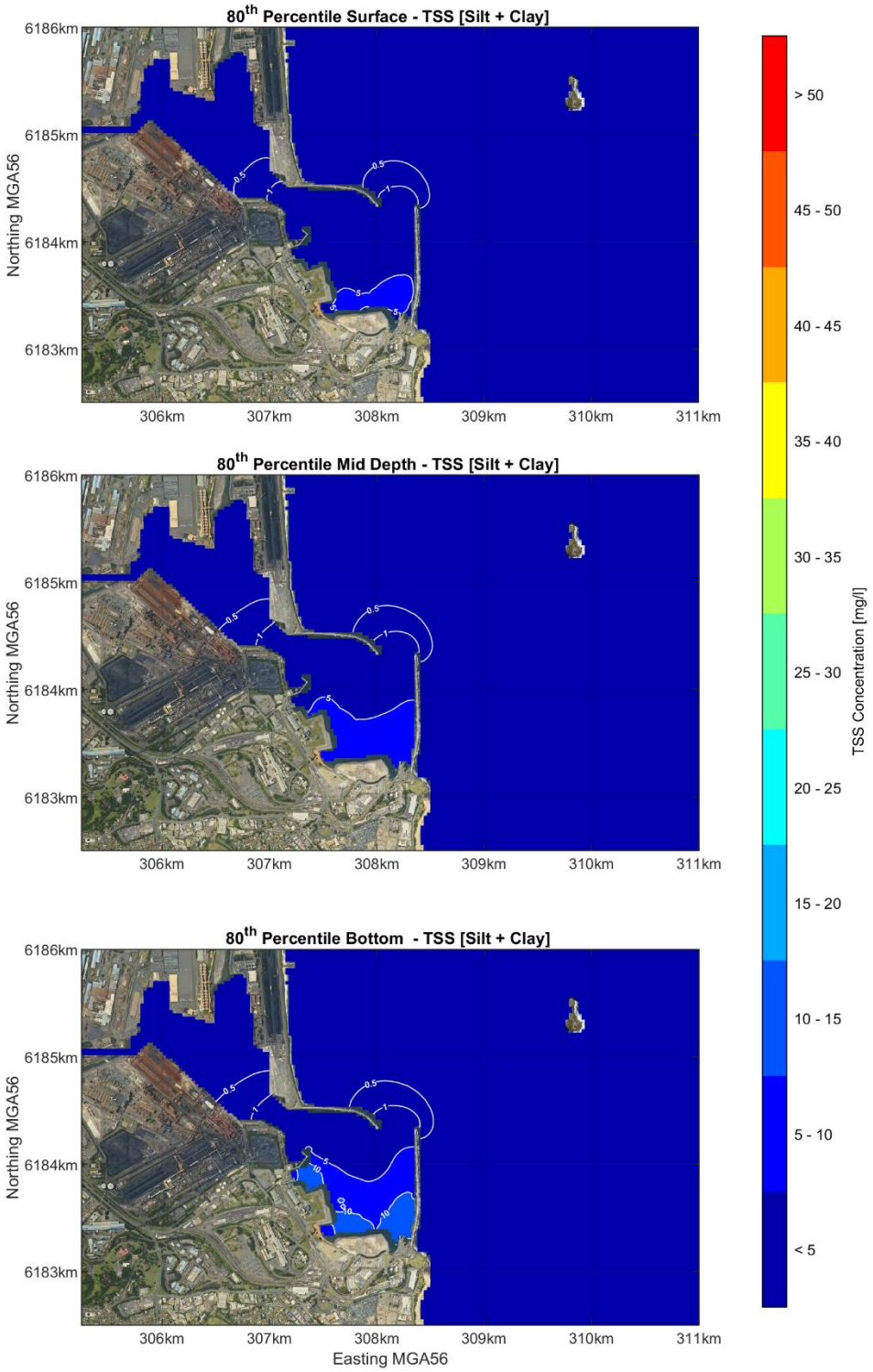
Modelled 10th Total Suspended Sediment Concentration (TSS)



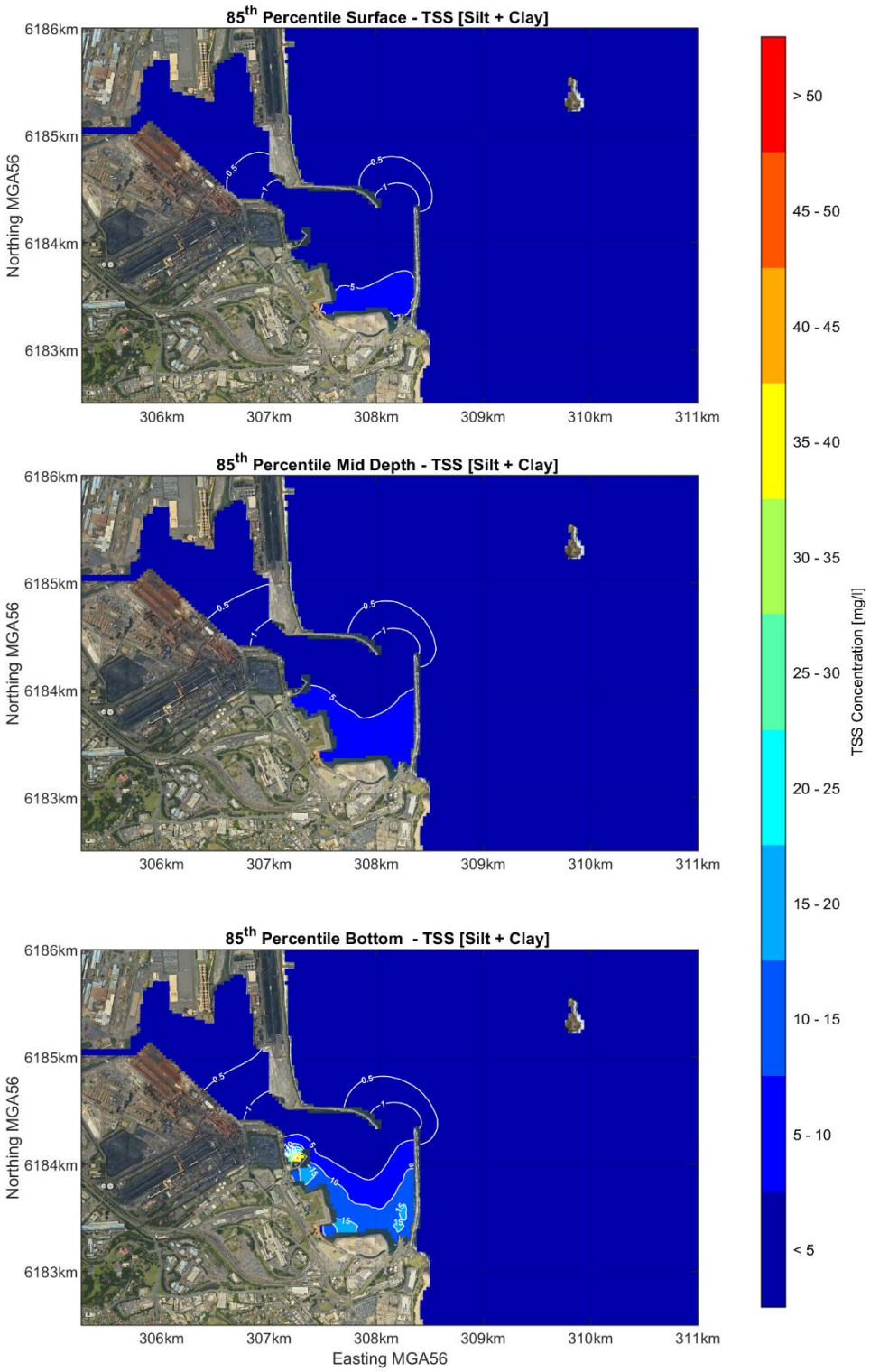
Modelled 20th Total Suspended Sediment Concentration (TSS)



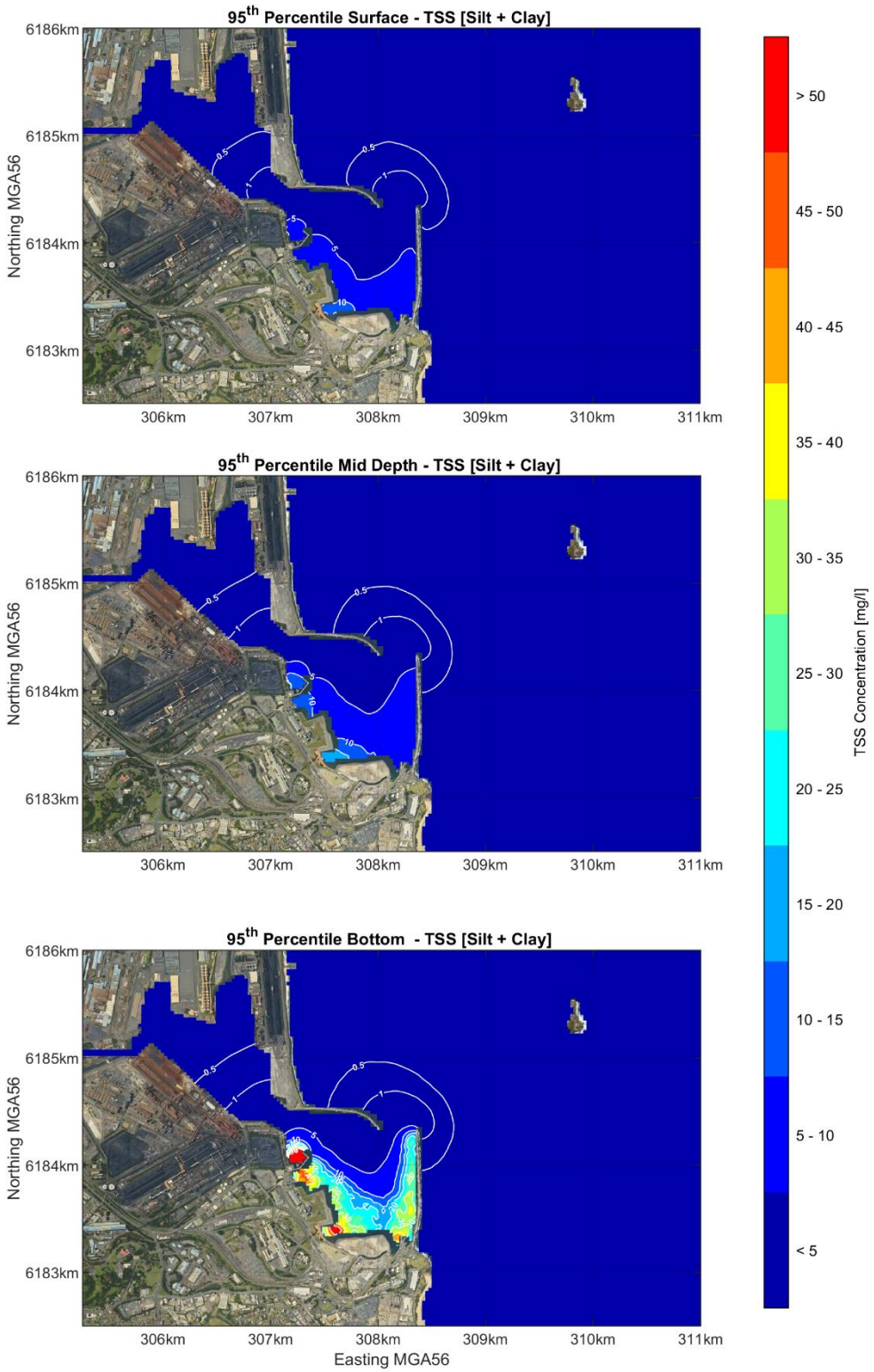
Modelled 50th Total Suspended Sediment Concentration (TSS)



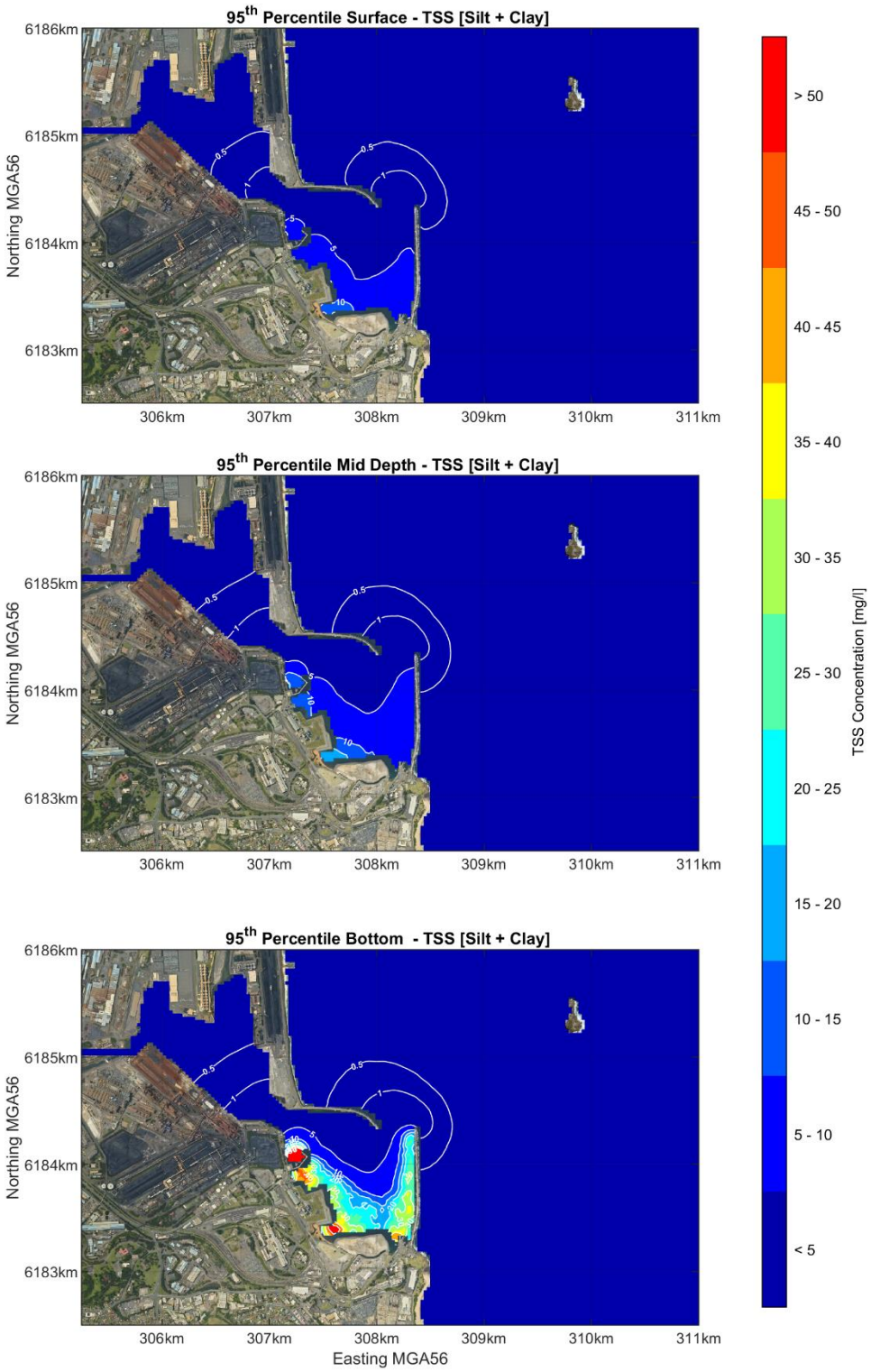
Modelled 80th Total Suspended Sediment Concentration (TSS)



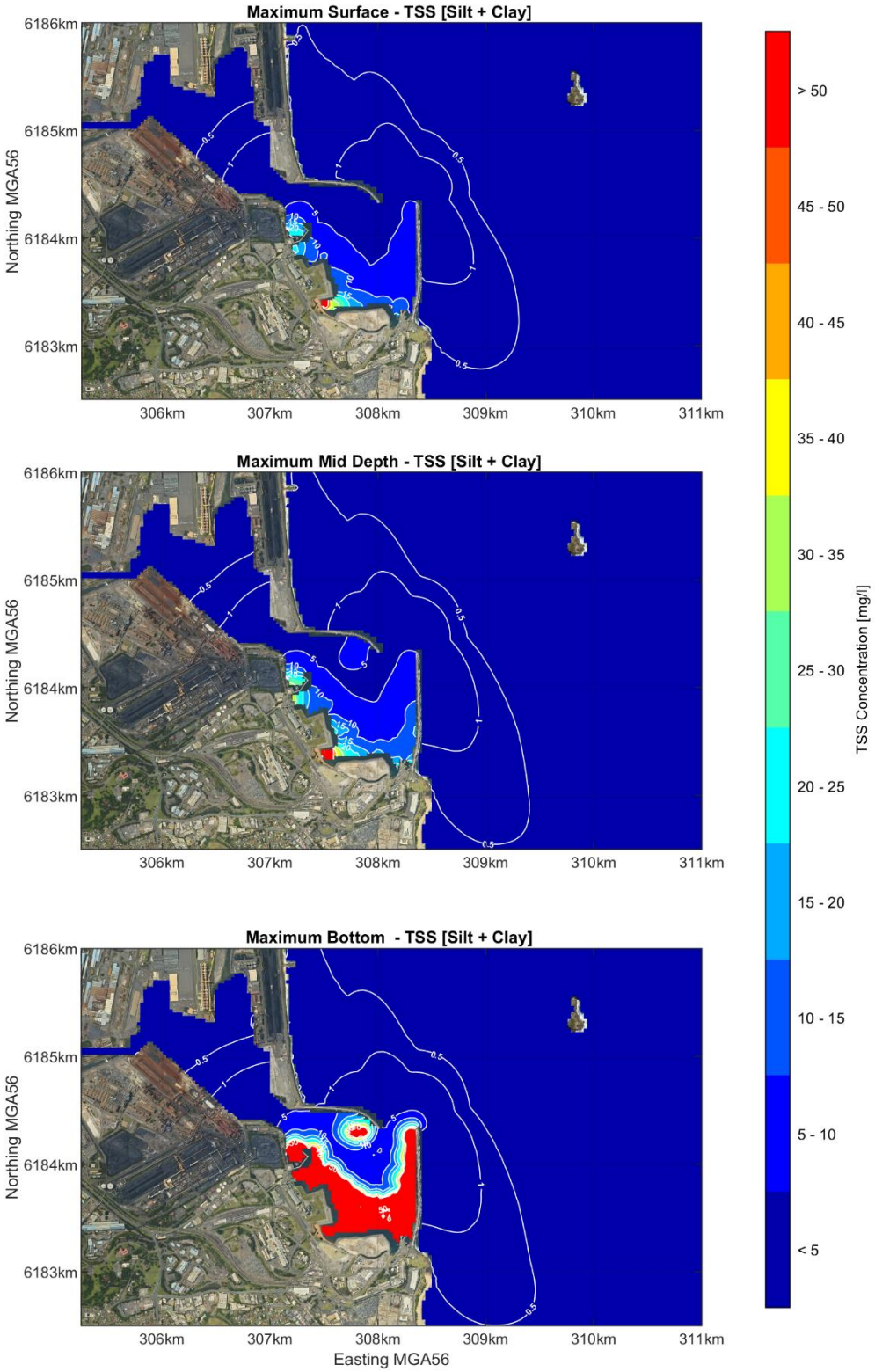
Modelled 85th Total Suspended Sediment Concentration (TSS)



Modelled 90th Total Suspended Sediment Concentration (TSS)

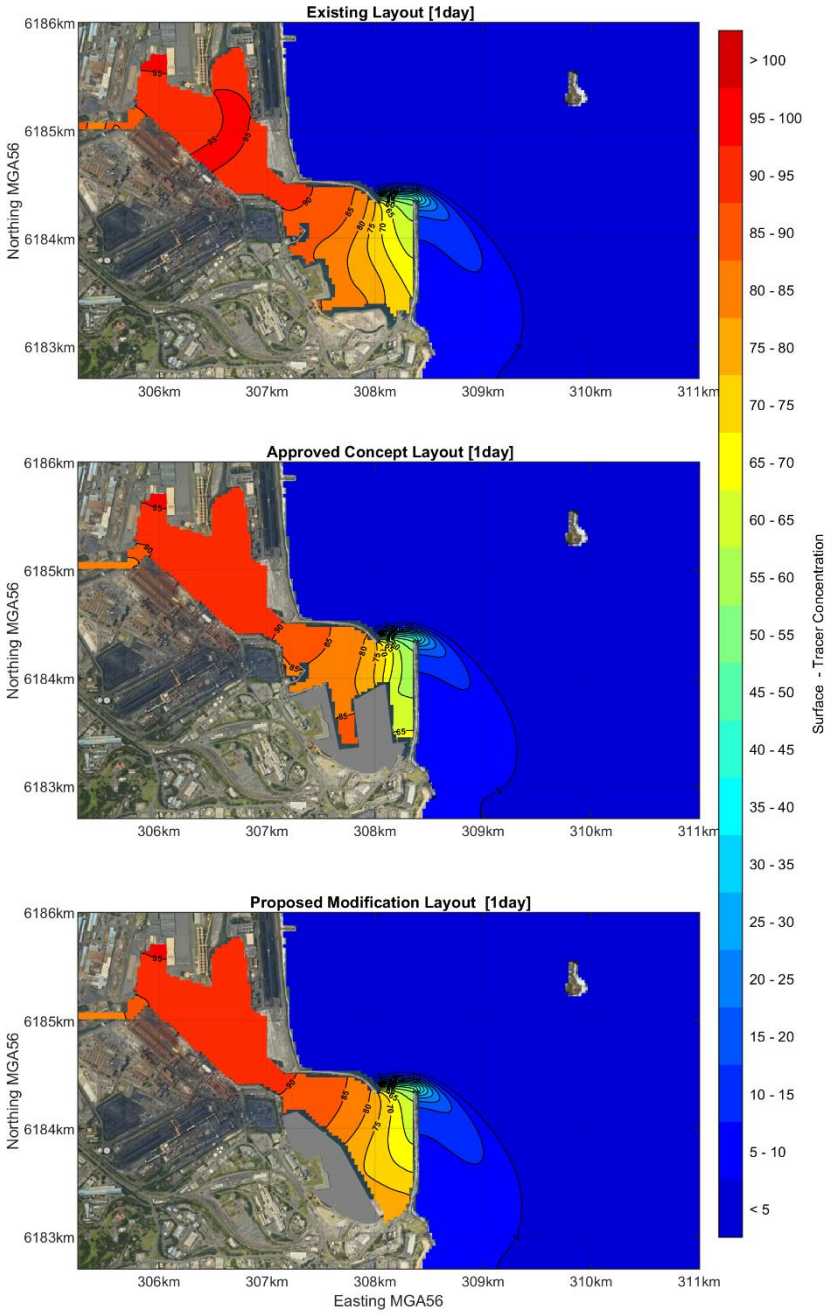


Modelled 95th Total Suspended Sediment Concentration (TSS)

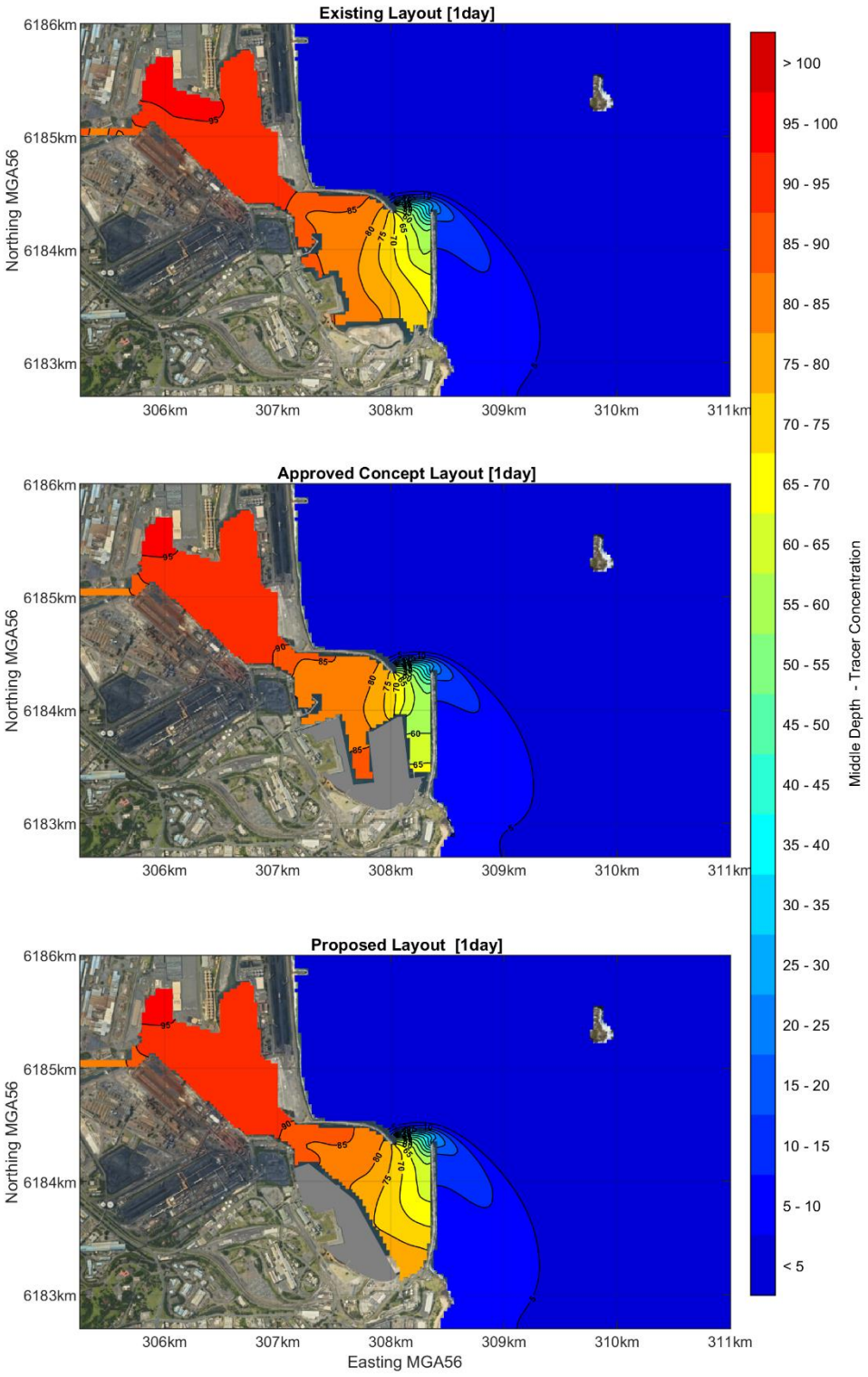


Modelled Maximum Total Suspended Sediment Concentration (TSS)

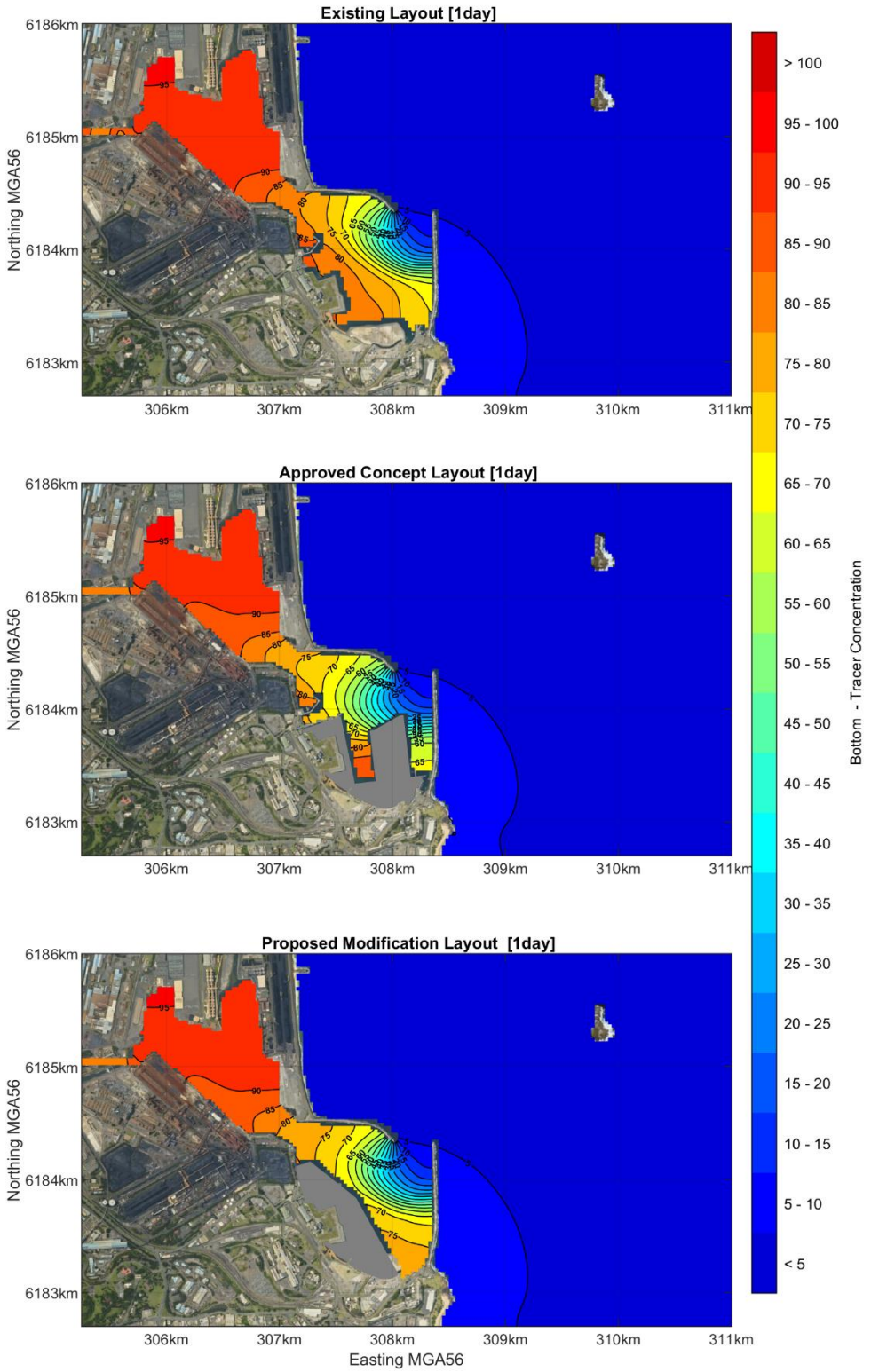
Appendix L Flushing Modelling Results: (Wind, Tide, Temperature, Intake/Outfall)



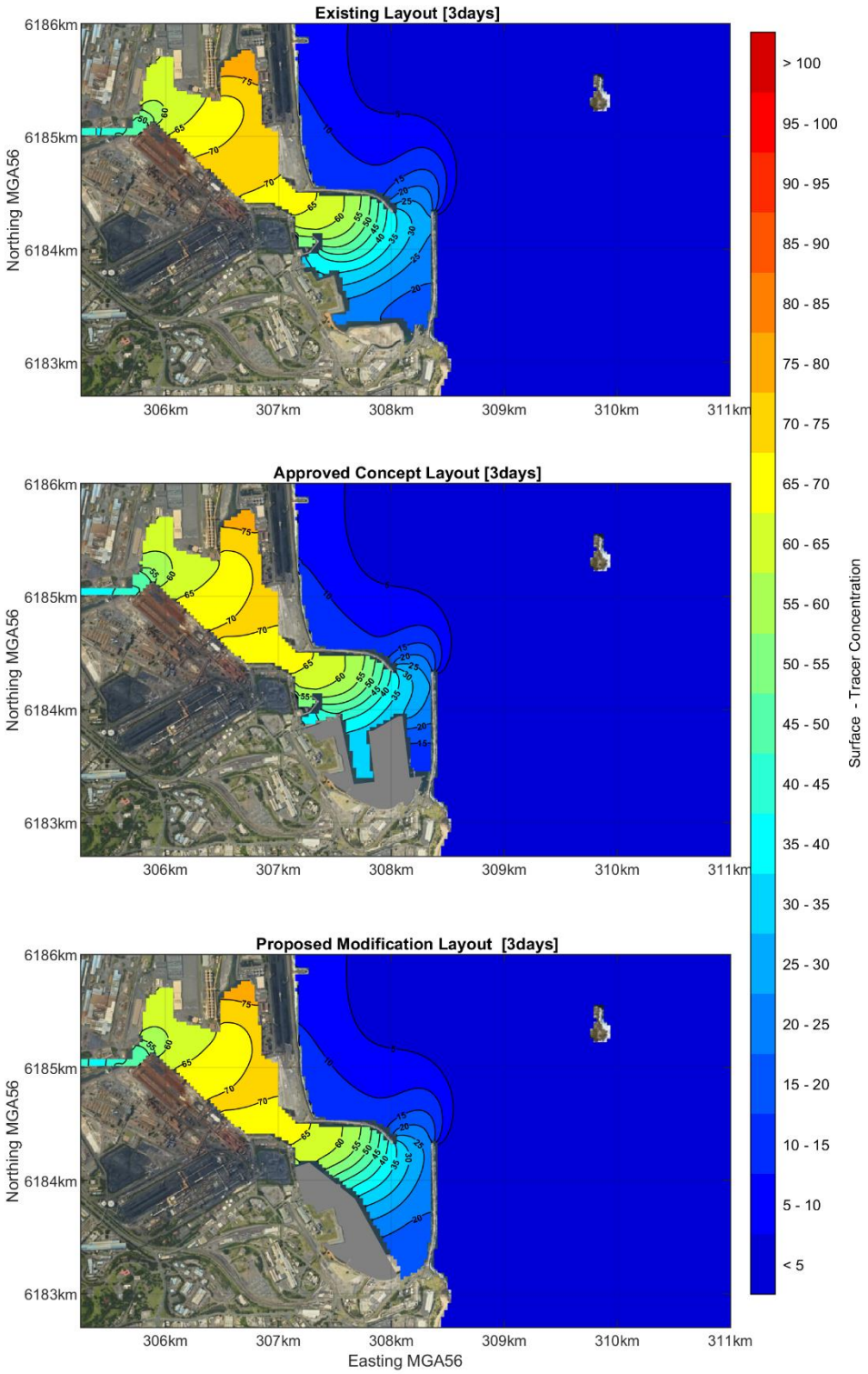
Modelled Flushing Tracer Concentration at the Surface Layer after 1 day from the Initial Concentration of 100



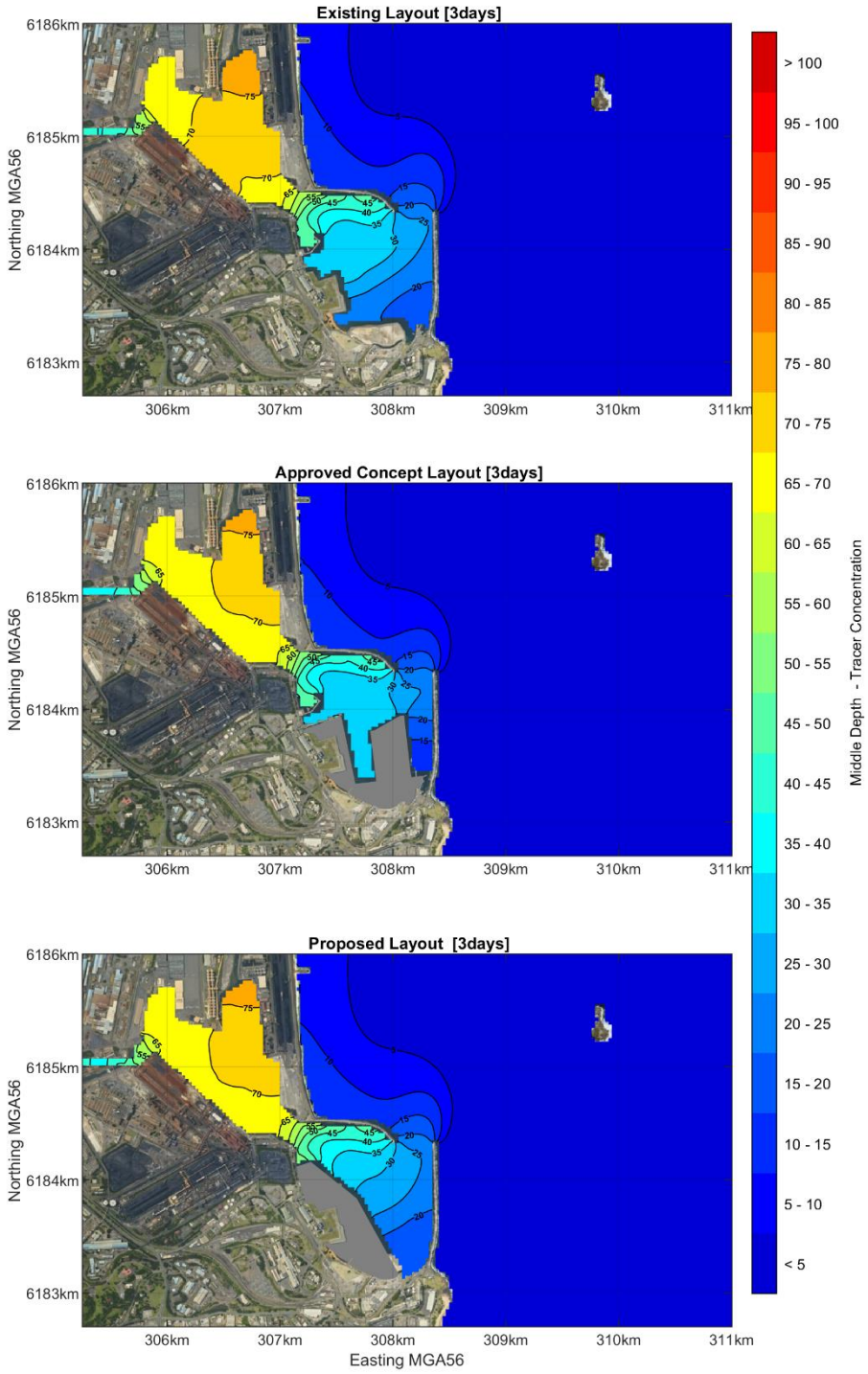
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 1 day from the Initial Concentration of 100



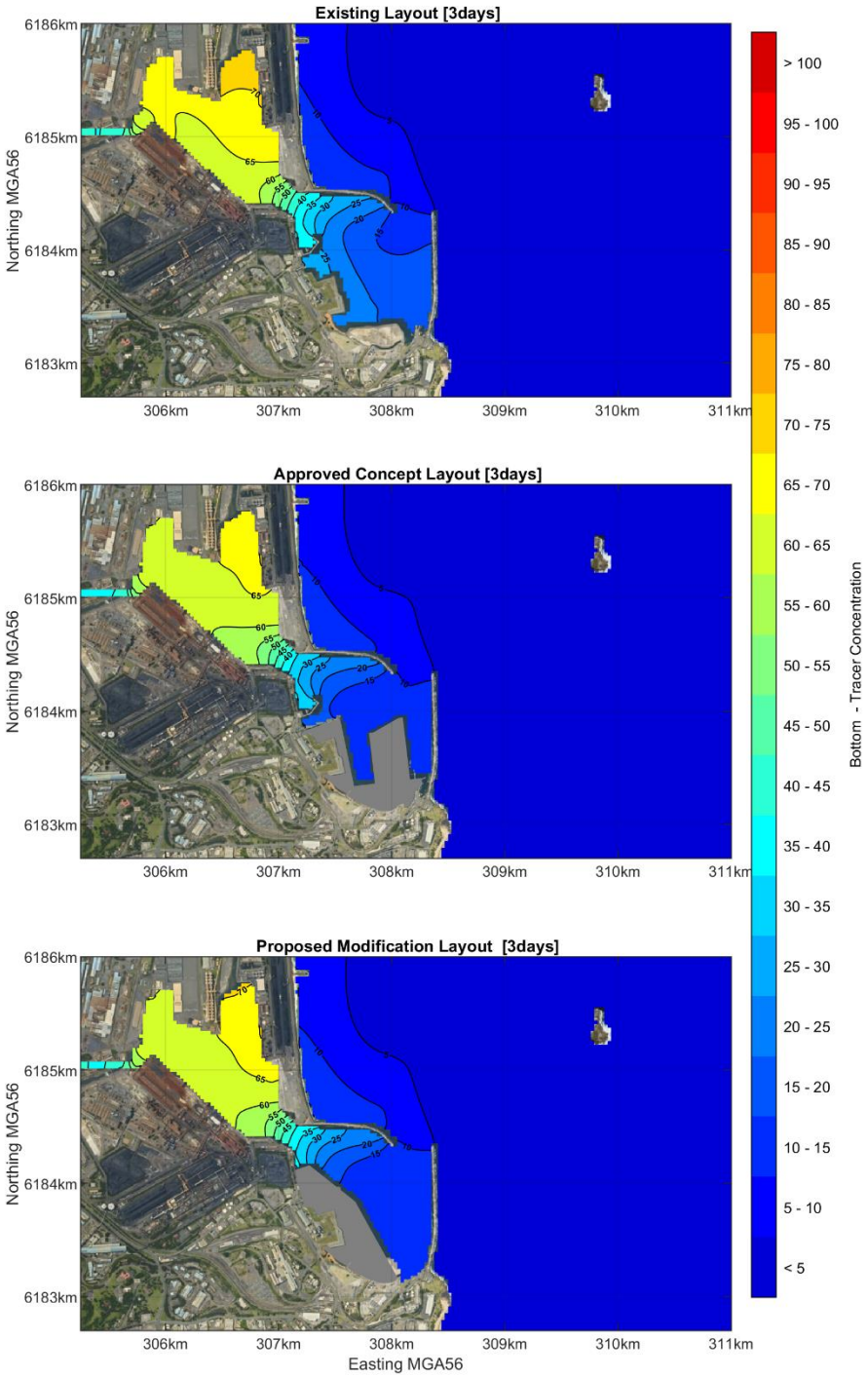
Modelled Flushing Tracer Concentration at the Bottom Layer after 1 day from the Initial Concentration of 100



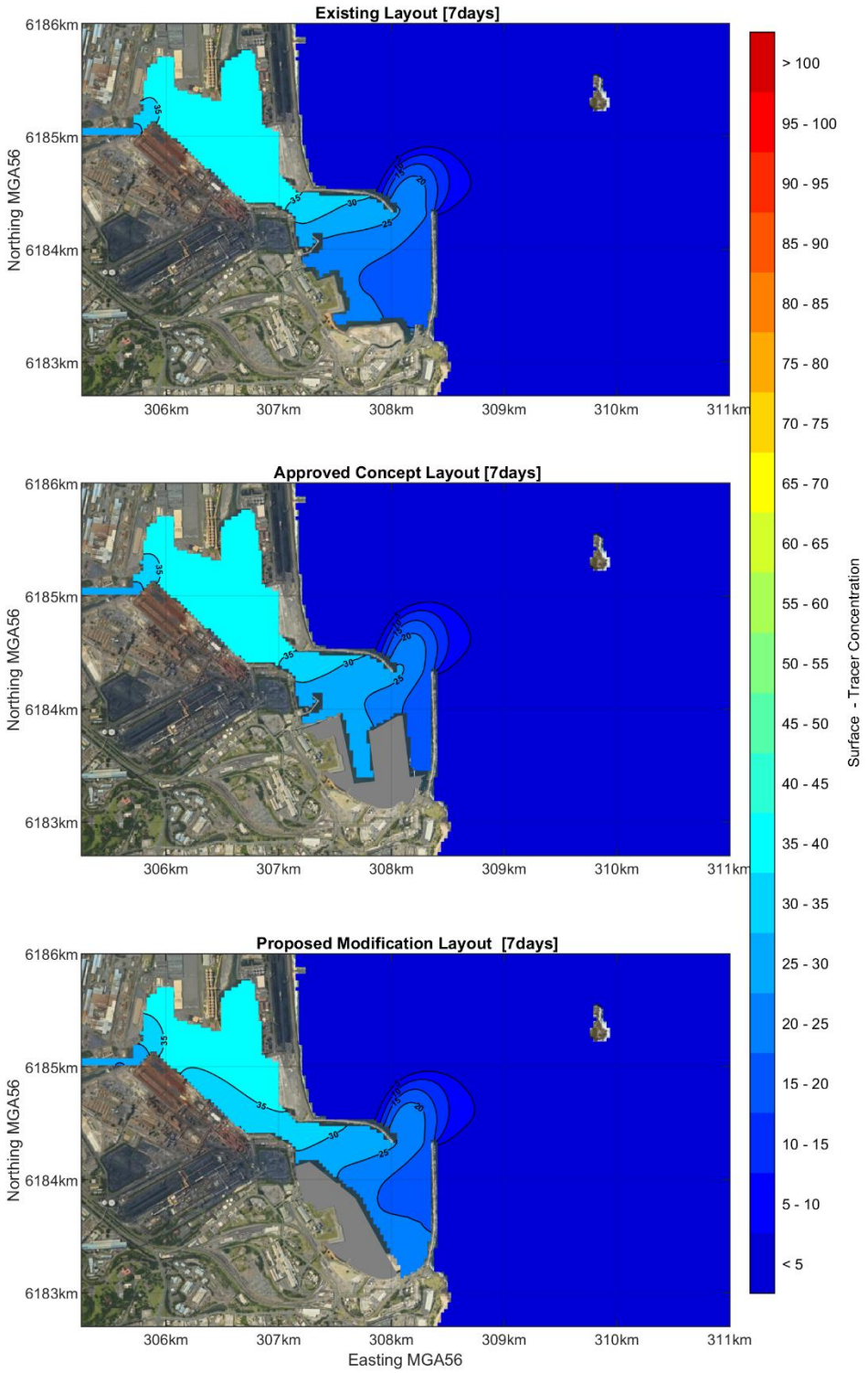
Modelled Flushing Tracer Concentration at the Surface Layer after 3 days from the Initial Concentration of 100



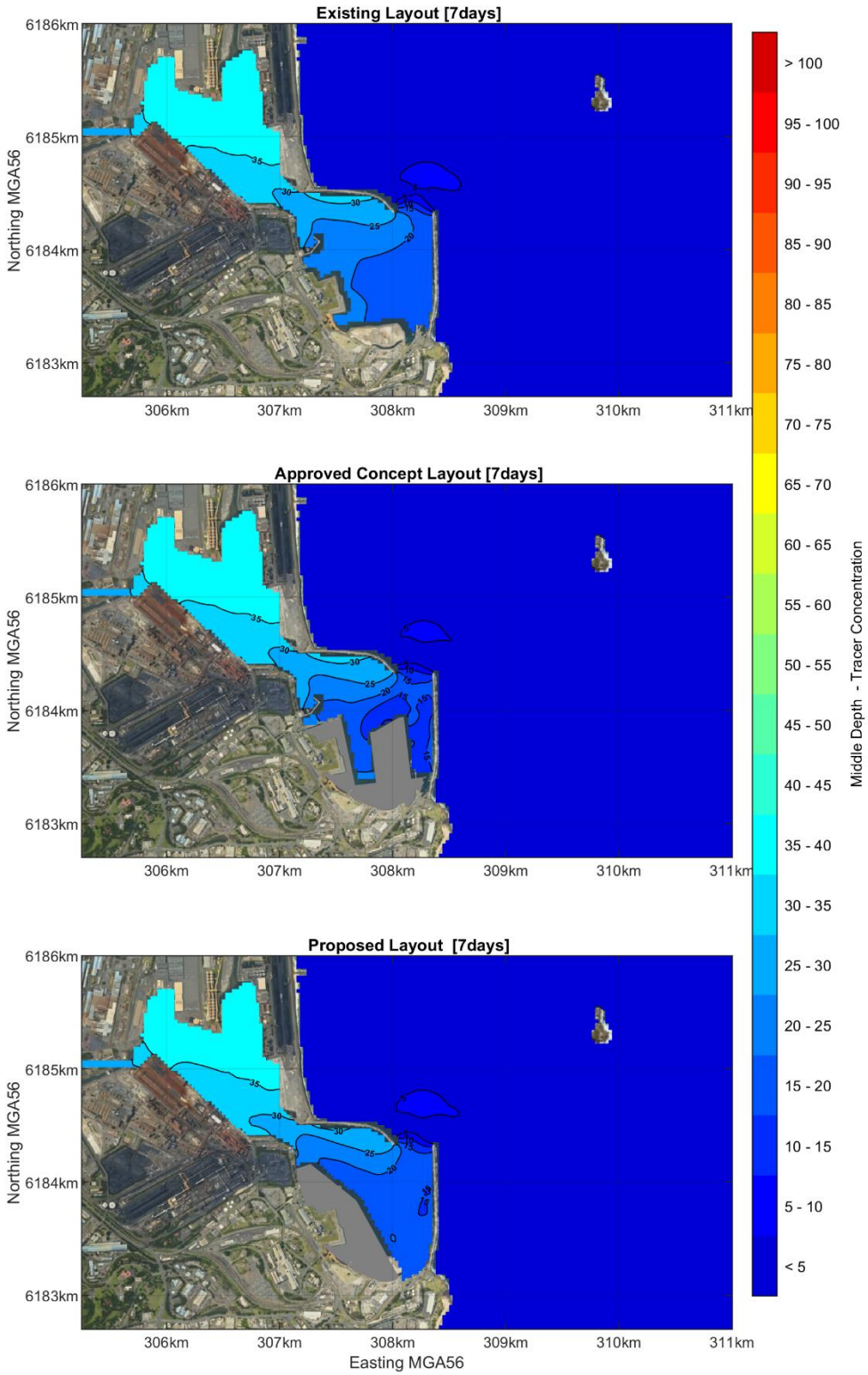
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 3 days from the Initial Concentration of 100



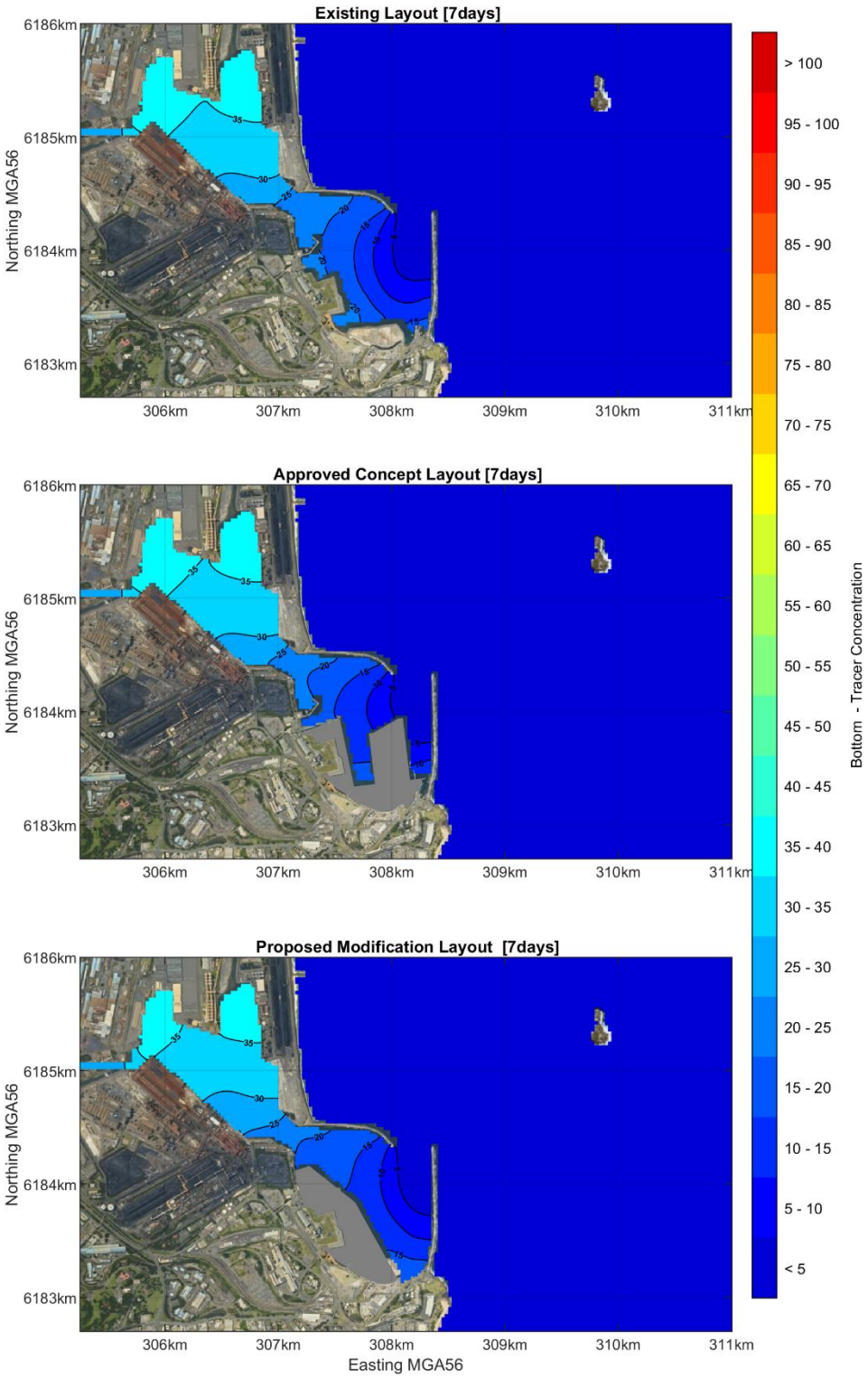
Modelled Flushing Tracer Concentration at the Bottom Layer after 3 days from the Initial Concentration of 100



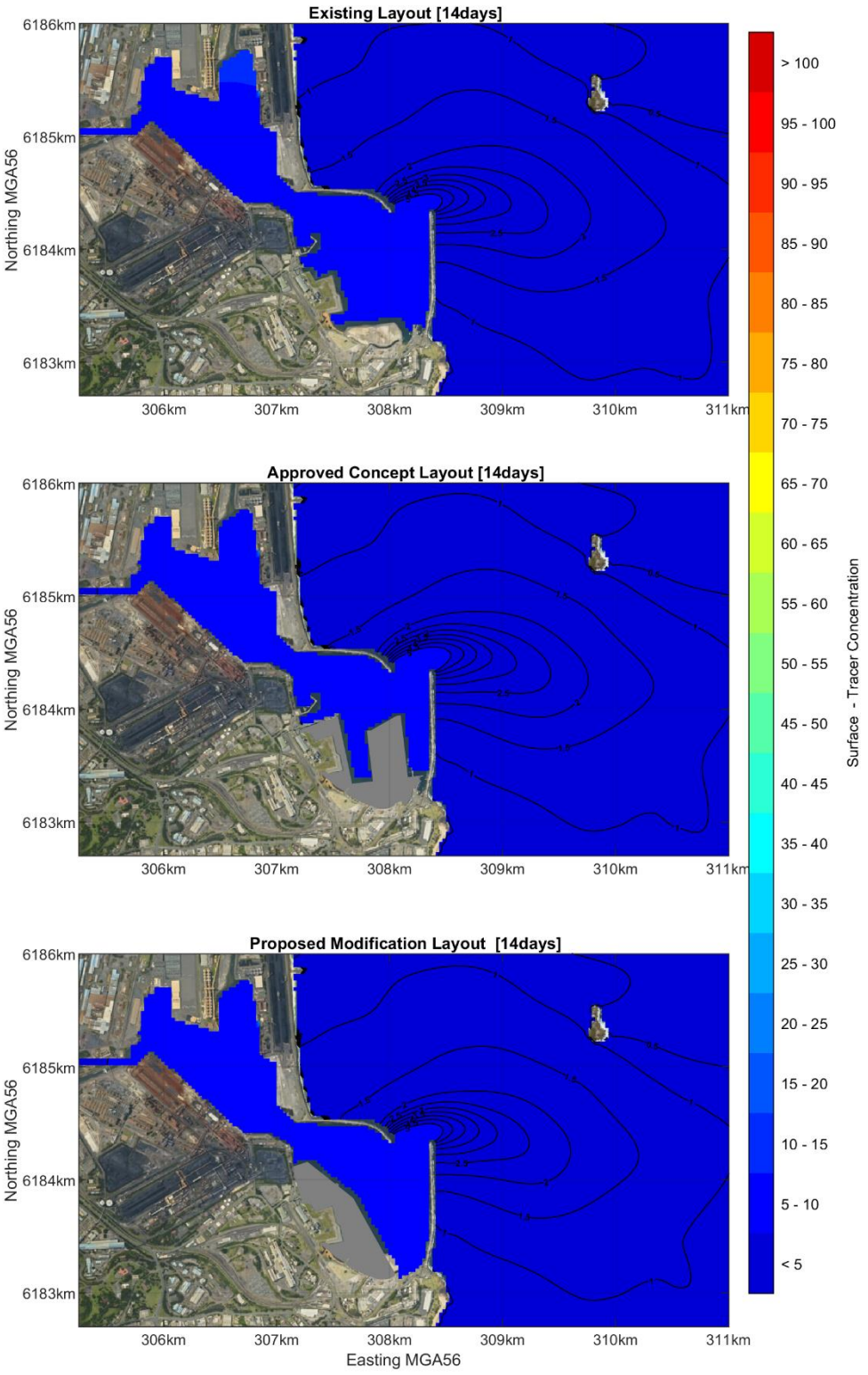
Modelled Flushing Tracer Concentration at the Surface Layer after 7 days from the Initial Concentration of 100



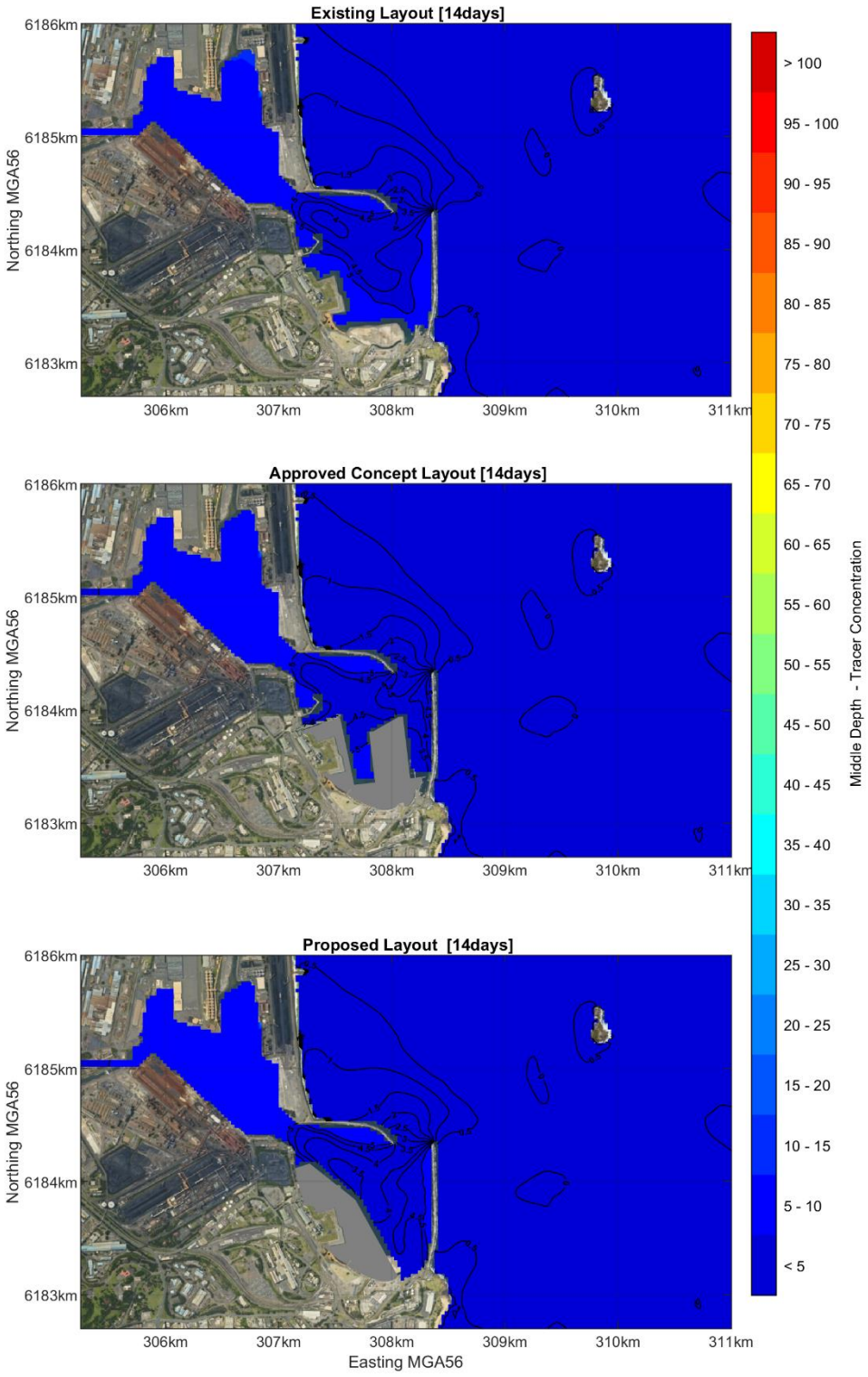
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 7 days from the Initial Concentration of 100



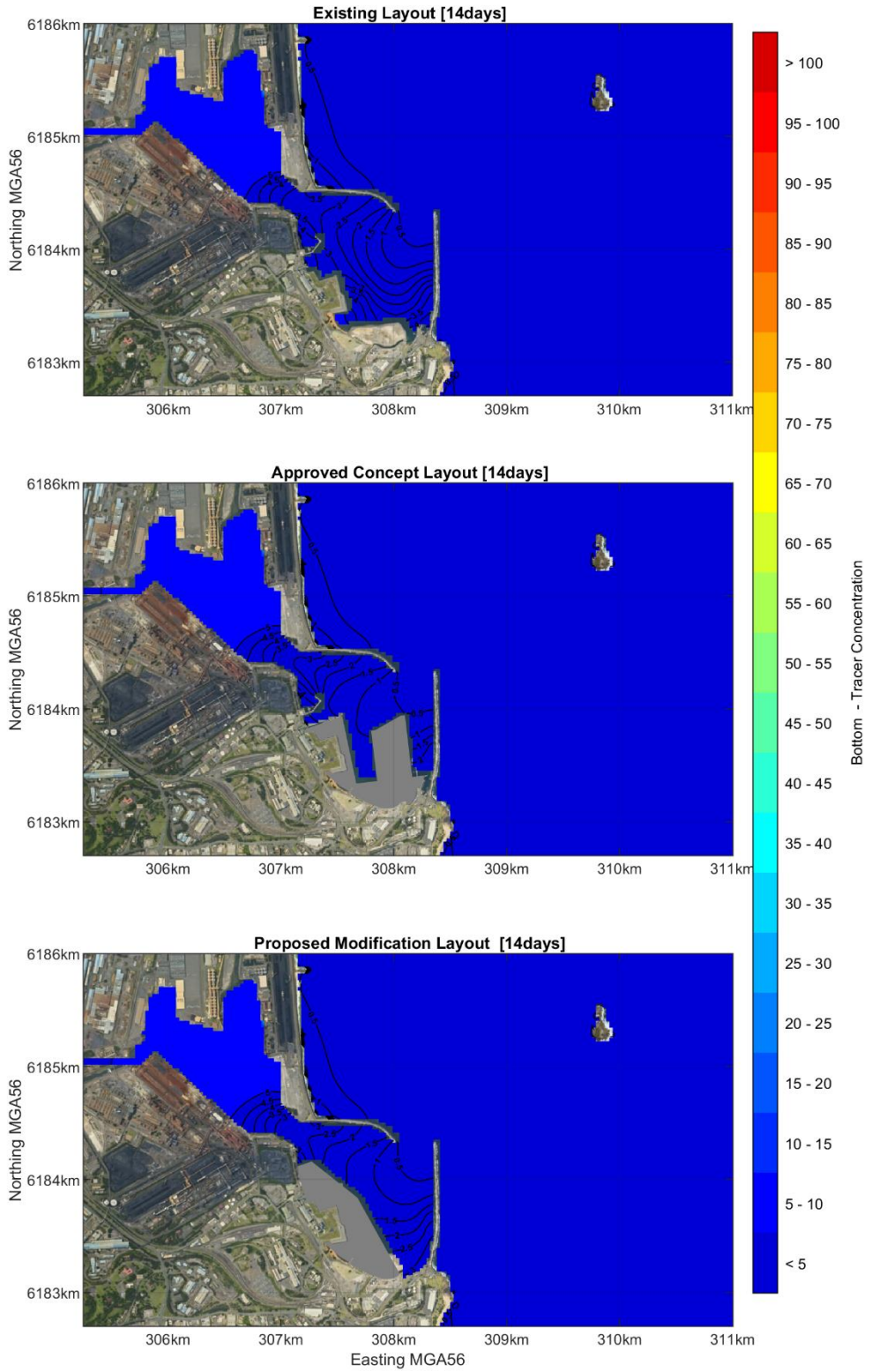
Modelled Flushing Tracer Concentration at the Bottom Layer after 7 days from the Initial Concentration of 100



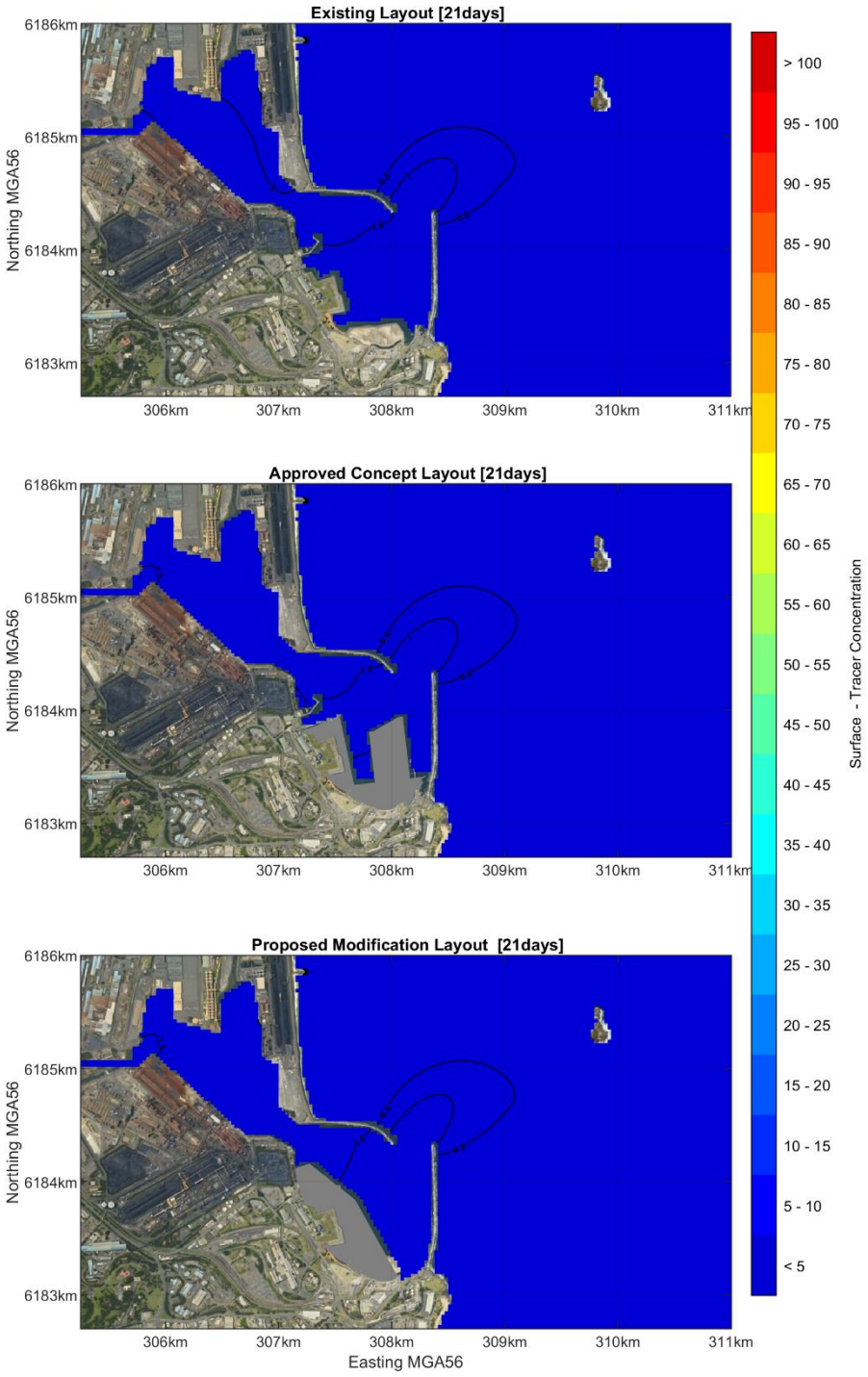
Modelled Flushing Tracer Concentration at the Surface Layer after 14 days from the Initial Concentration of 100



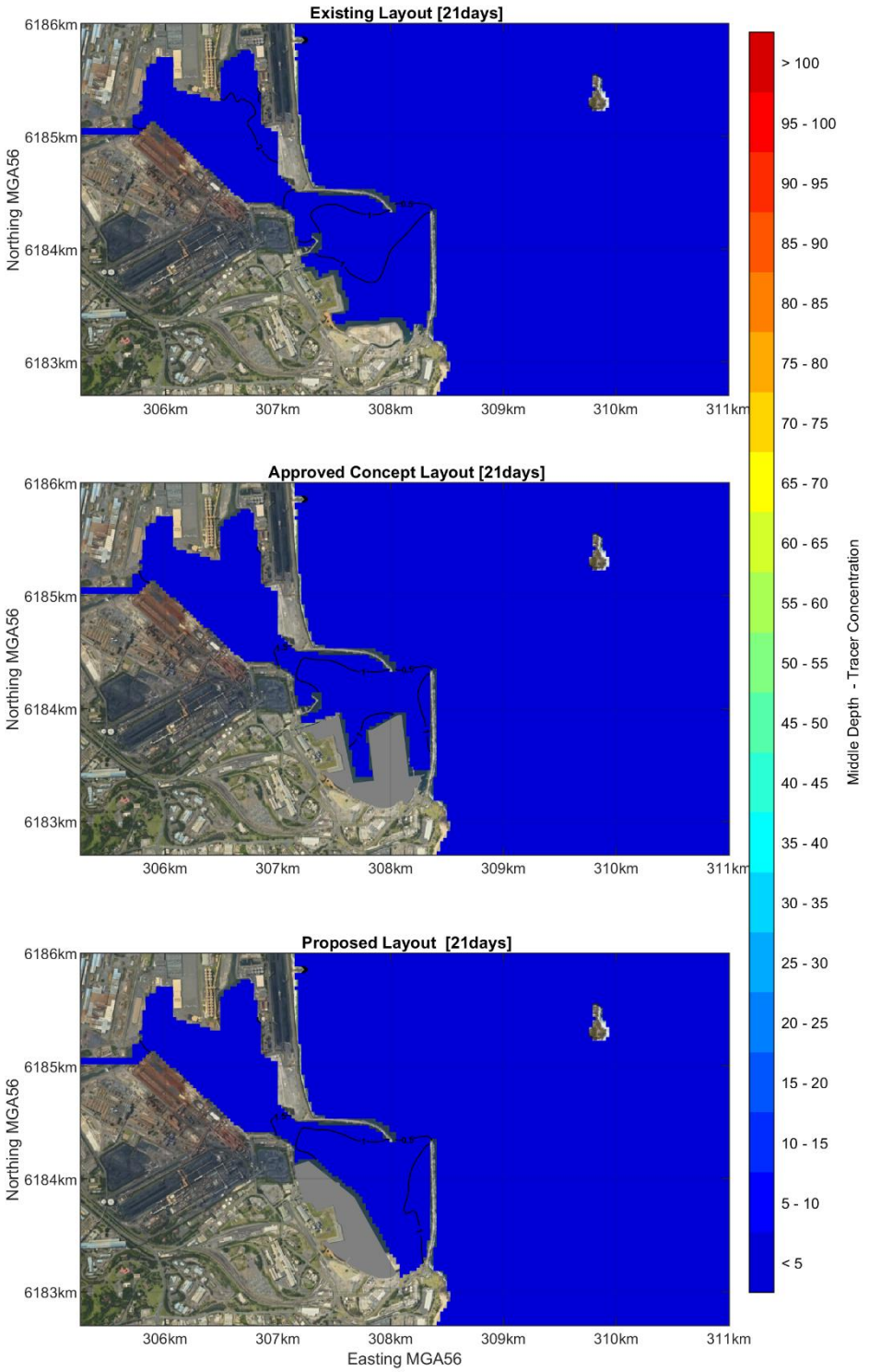
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 14 days from the Initial Concentration of 100



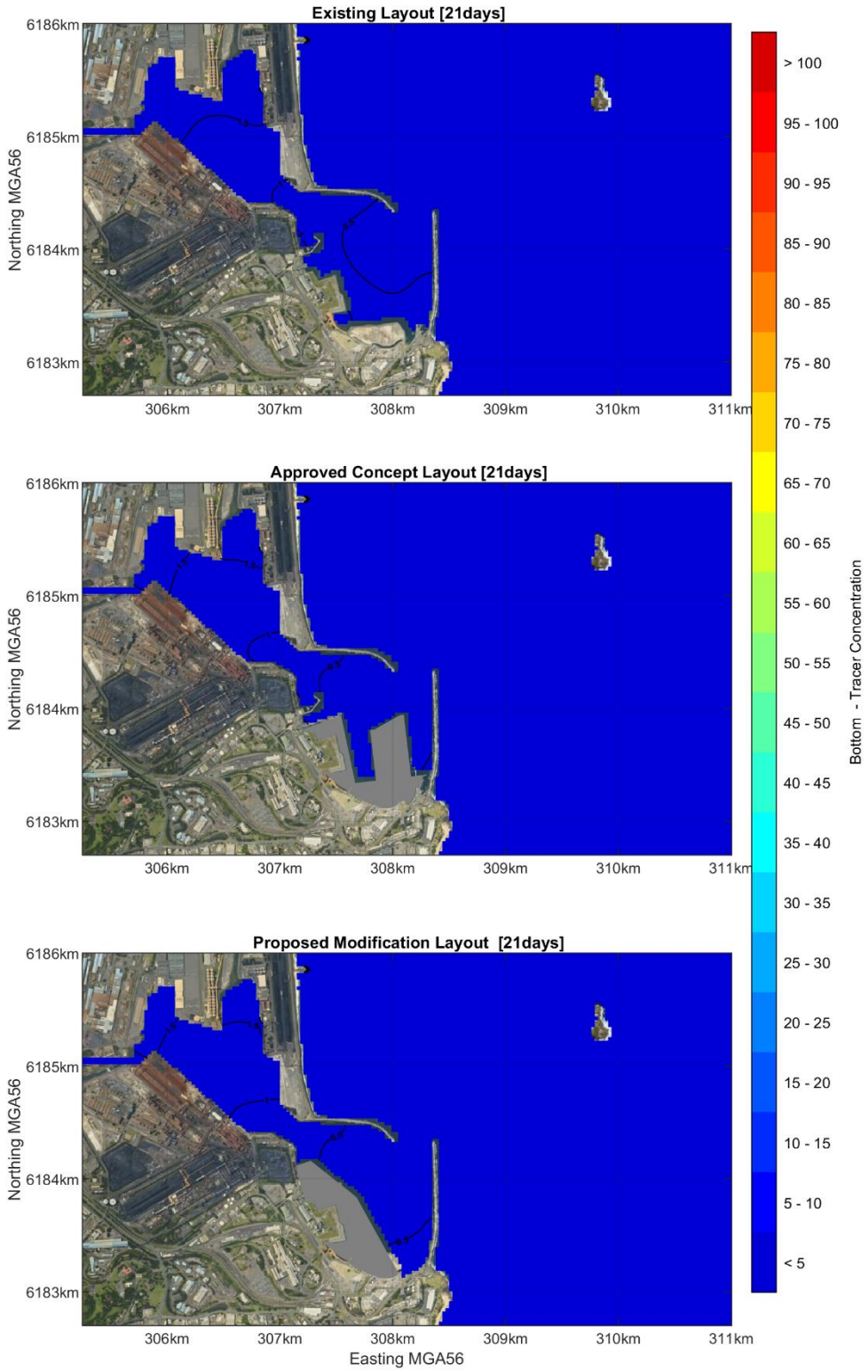
Modelled Flushing Tracer Concentration at the Bottom Layer after 14 days from the Initial Concentration of 100



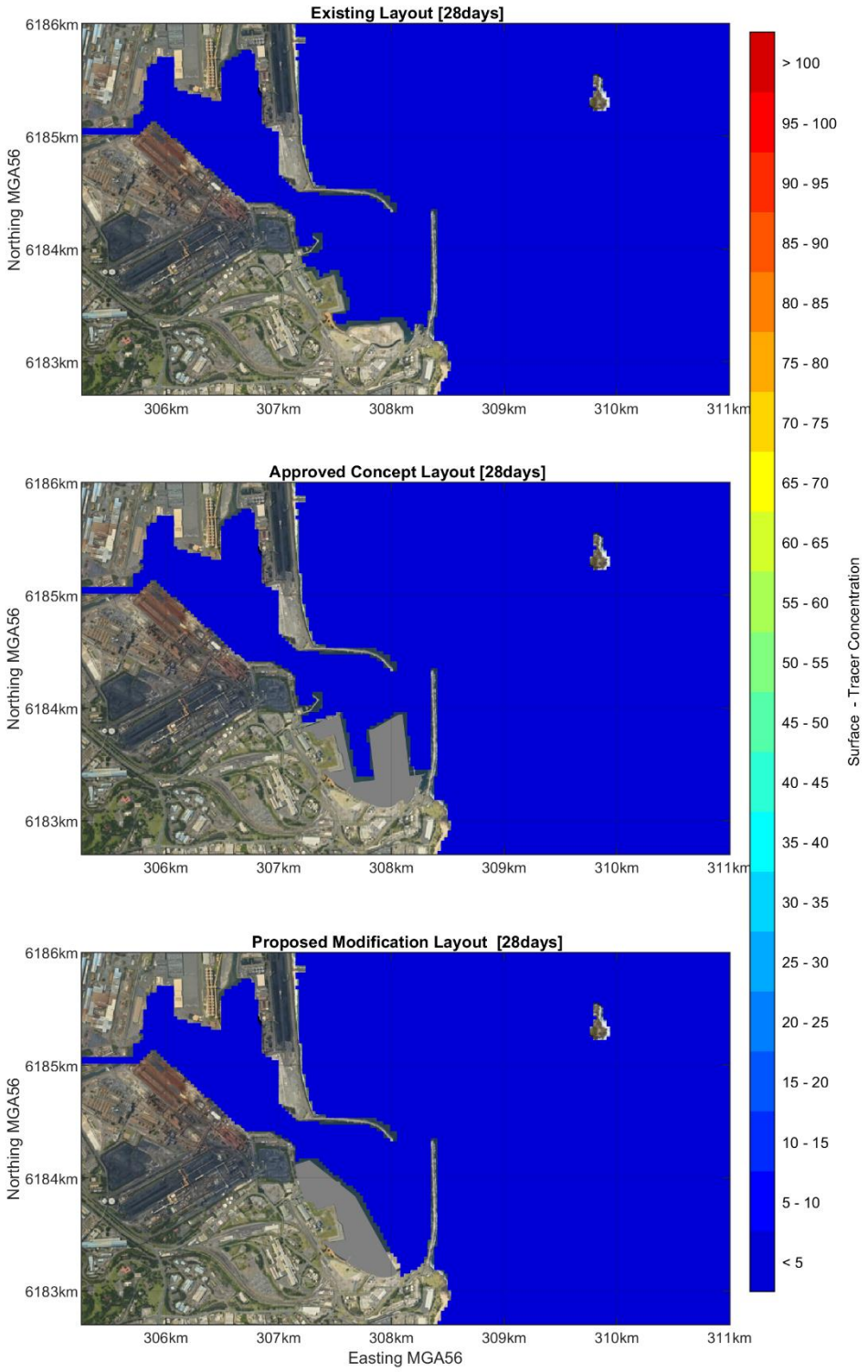
Modelled Flushing Tracer Concentration at the Surface Layer after 21 days from the Initial Concentration of 100



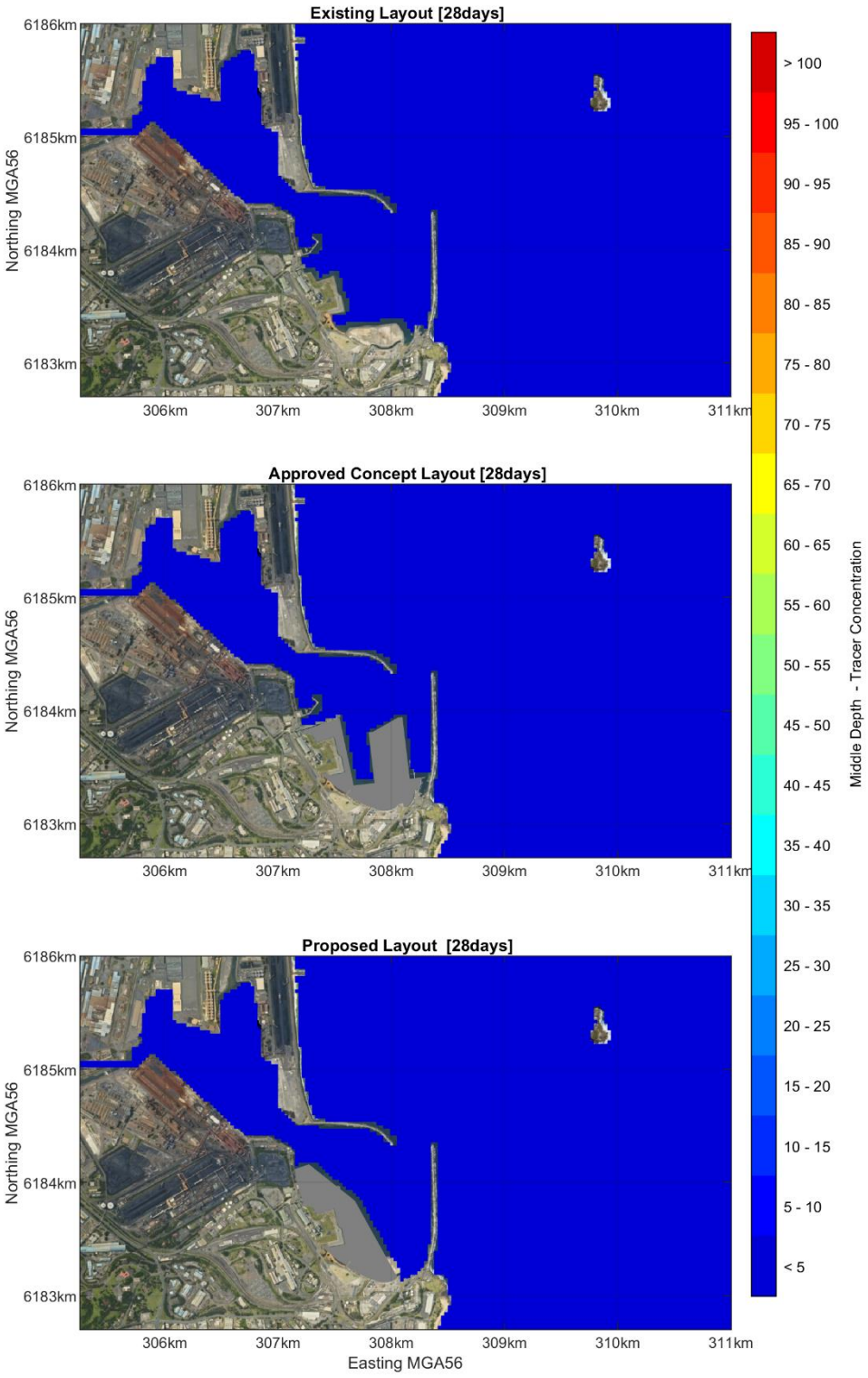
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 21 days from the Initial Concentration of 100



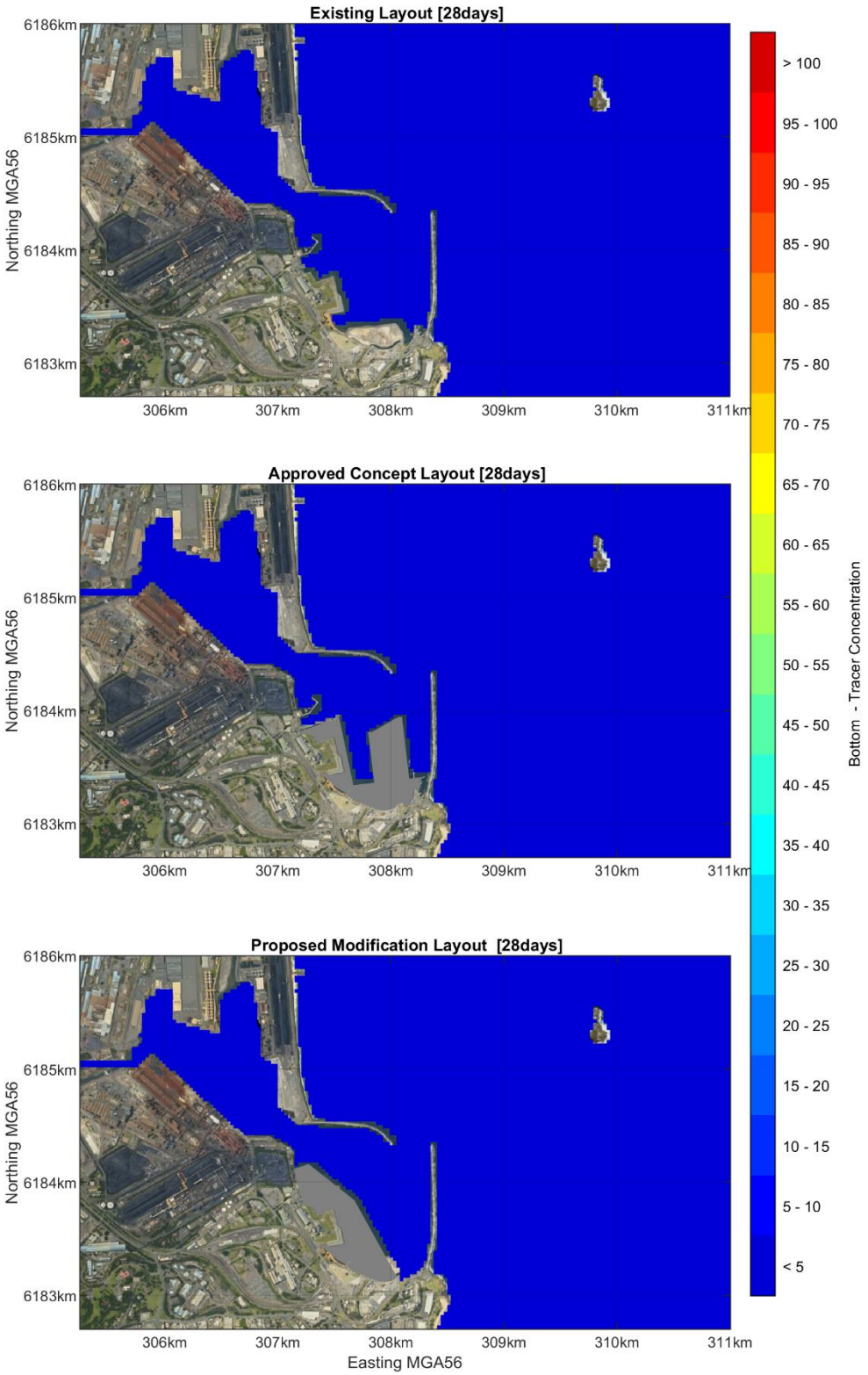
Modelled Flushing Tracer Concentration at the Bottom Layer after 21 days from the Initial Concentration of 100



Modelled Flushing Tracer Concentration at the Surface Layer after 28 days from the Initial Concentration of 100

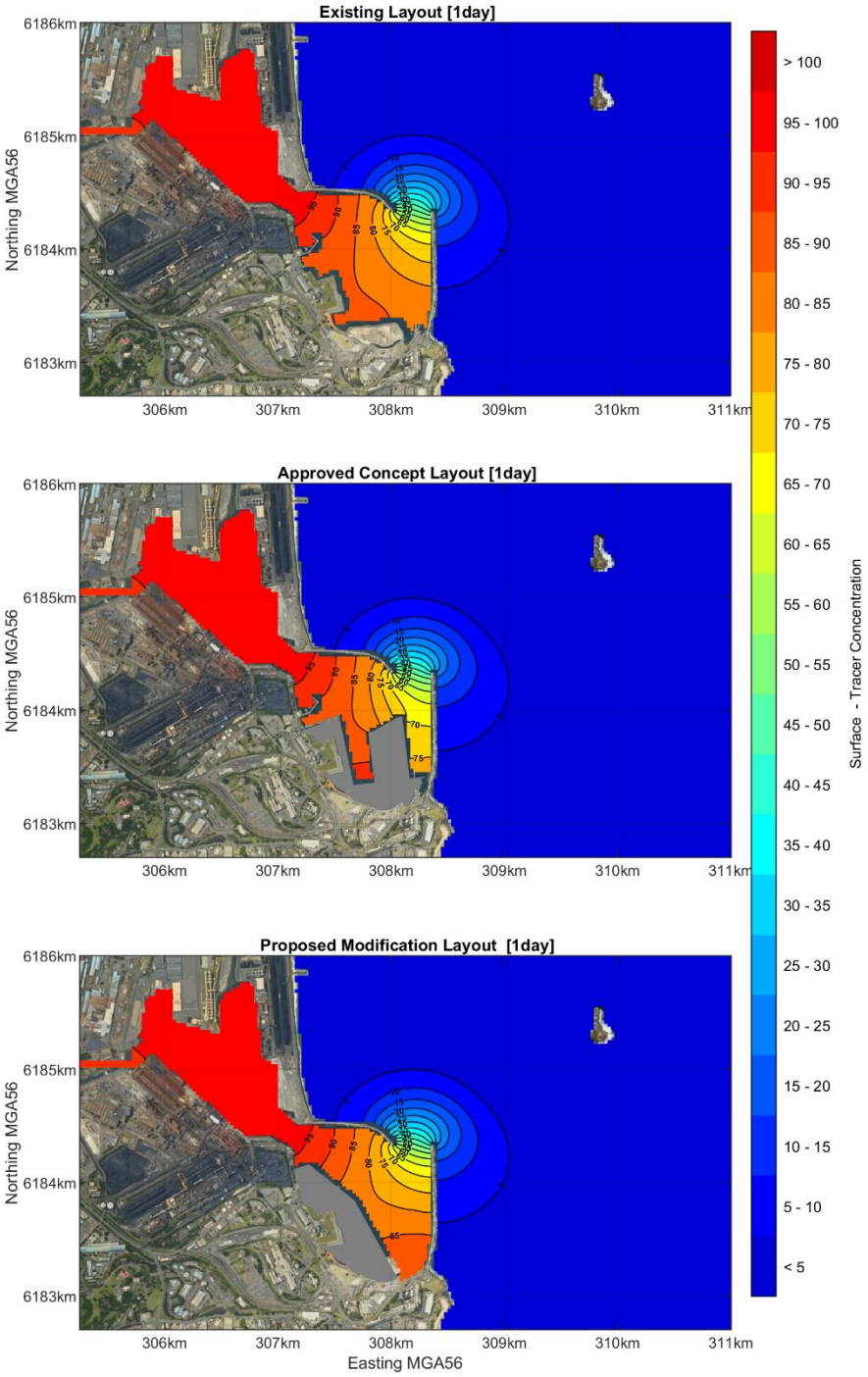


Modelled Flushing Tracer Concentration at the Middle Depth Layer after 28 days from the Initial Concentration of 100

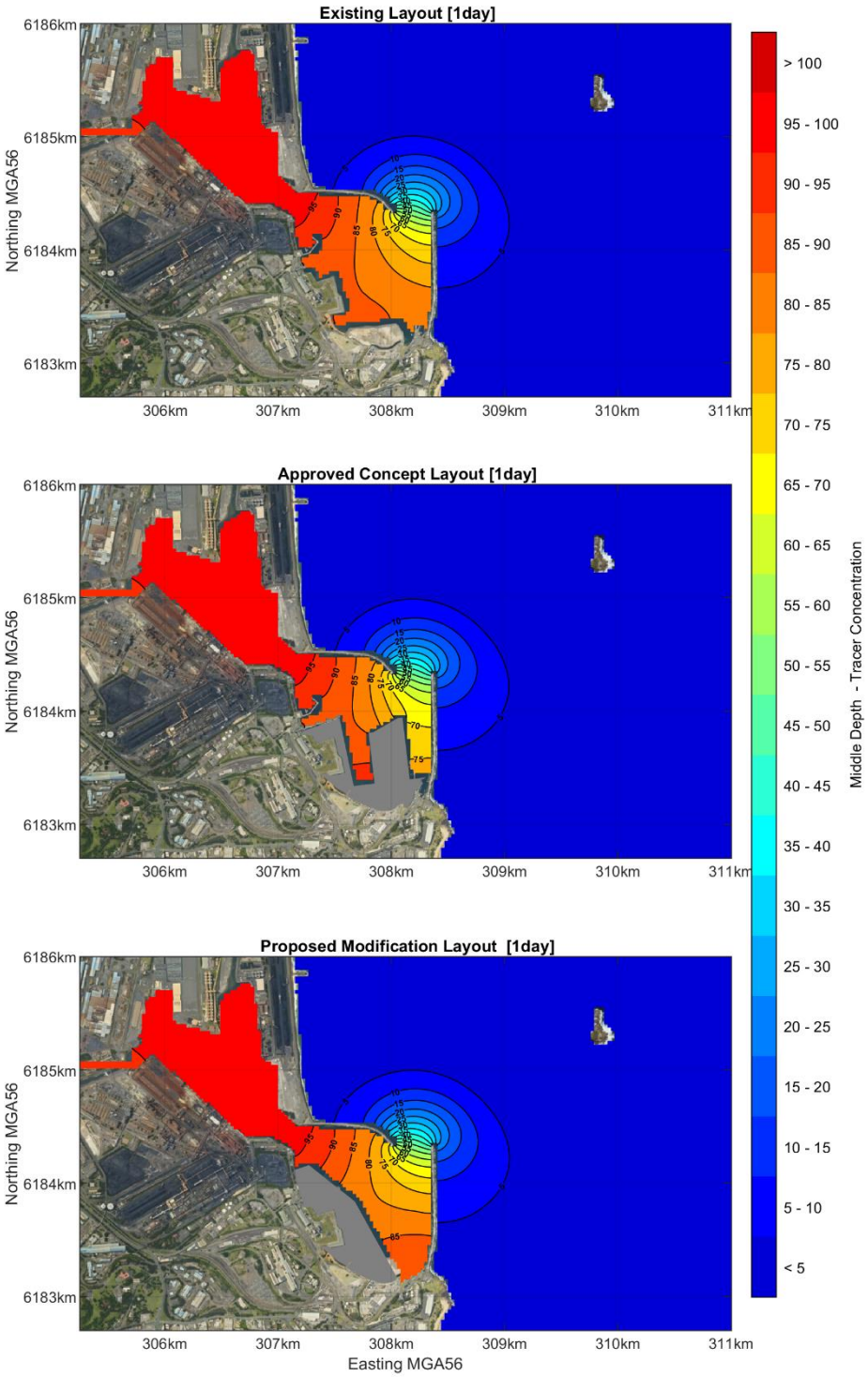


Modelled Flushing Tracer Concentration at the Bottom Layer after 28 days from the Initial Concentration of 100

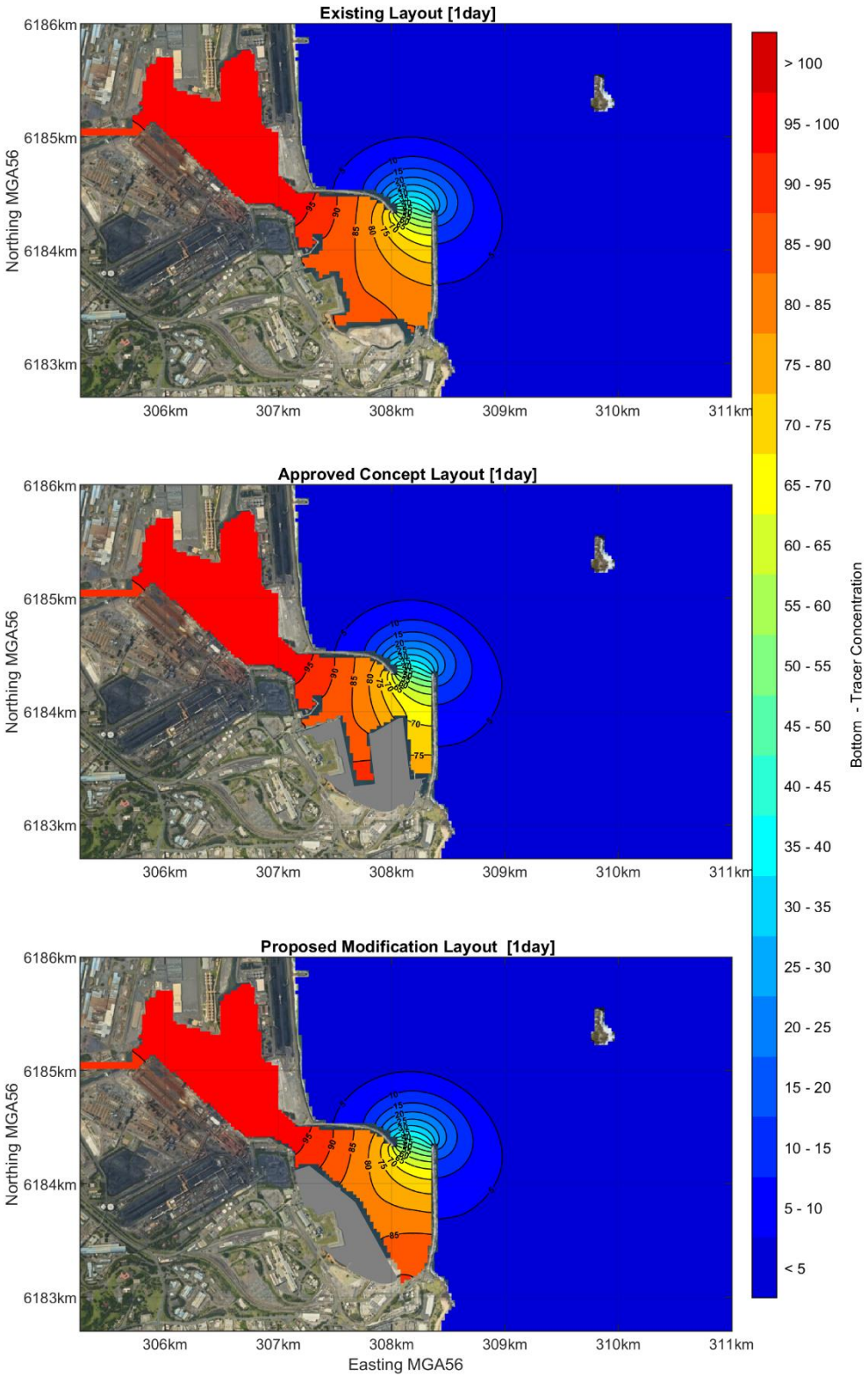
Appendix M Flushing Modelling Results: (Tides + Intake/Outfall)



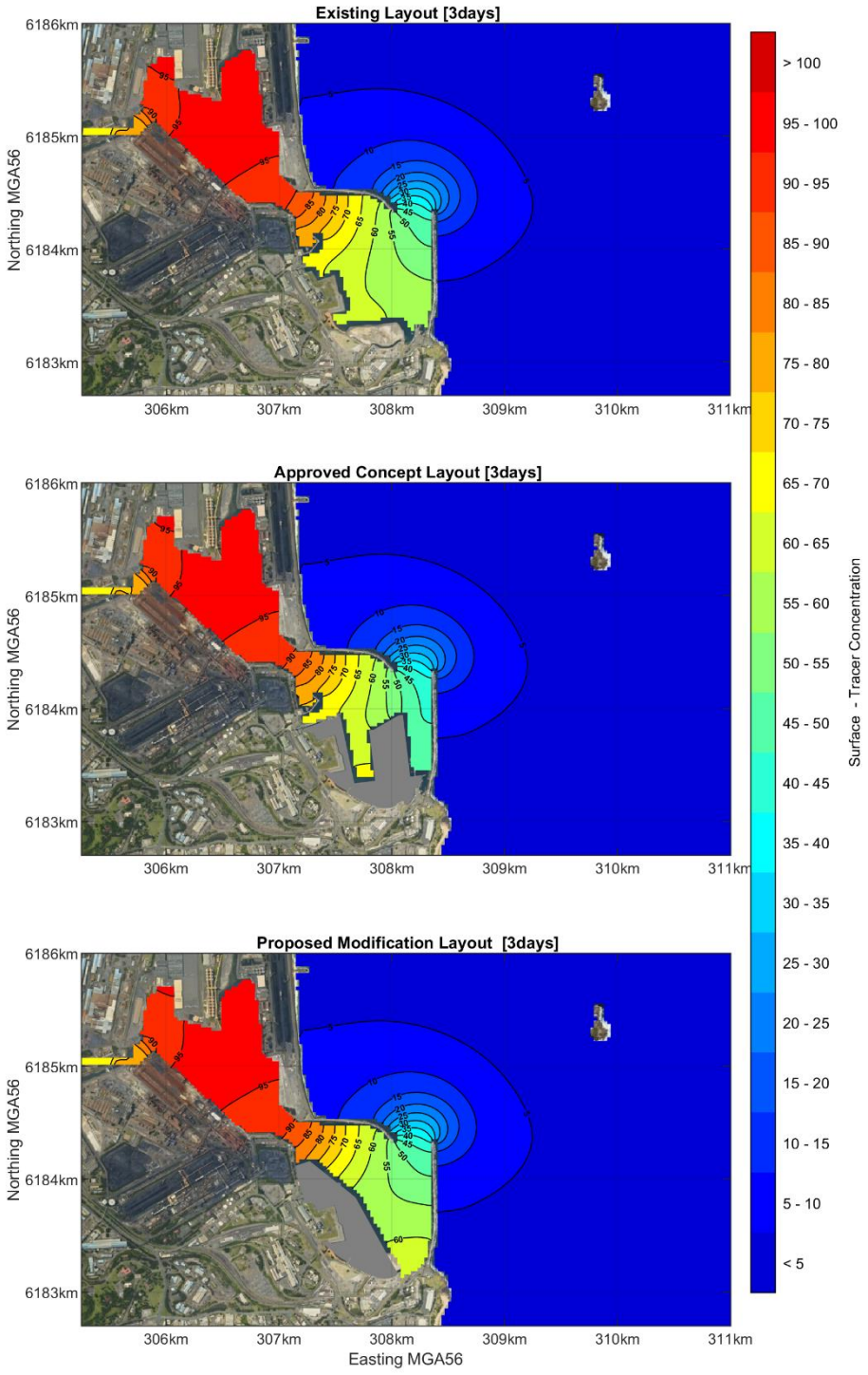
Modelled Flushing Tracer Concentration at the Surface Layer after 1 day from the Initial Concentration of 100



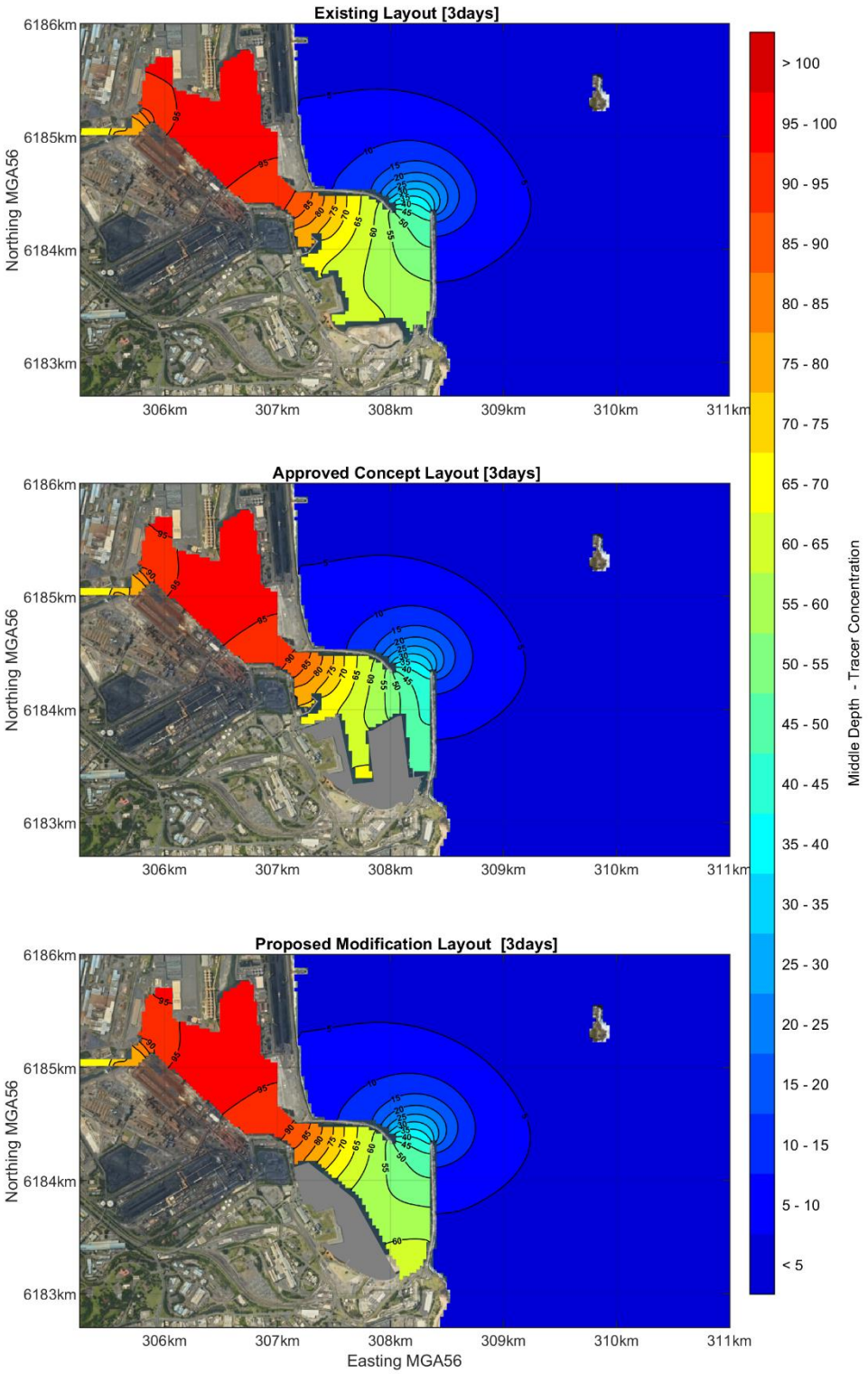
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 1 day from the Initial Concentration of 100



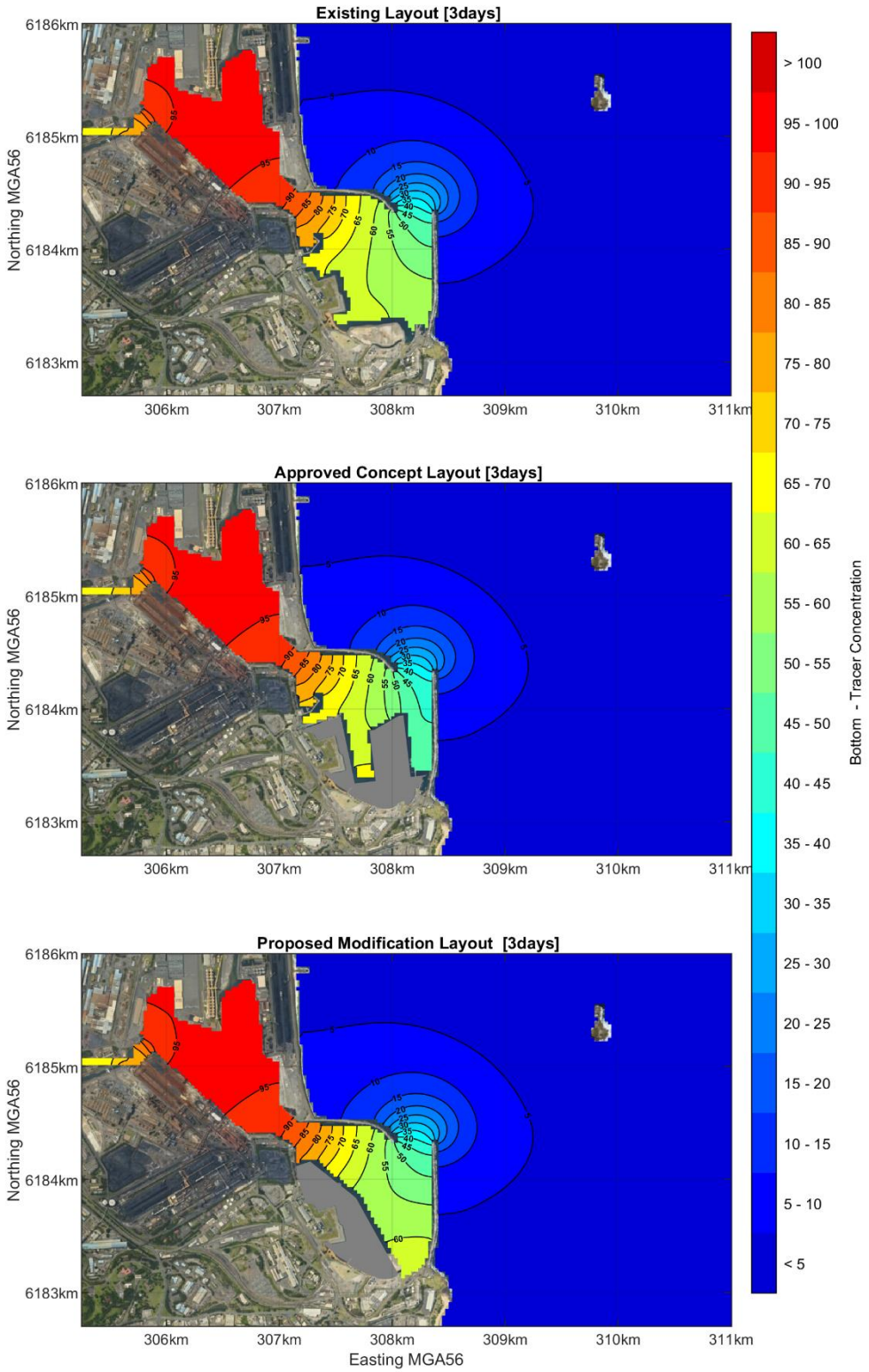
Modelled Flushing Tracer Concentration at the Bottom Layer after 1 day from the Initial Concentration of 100



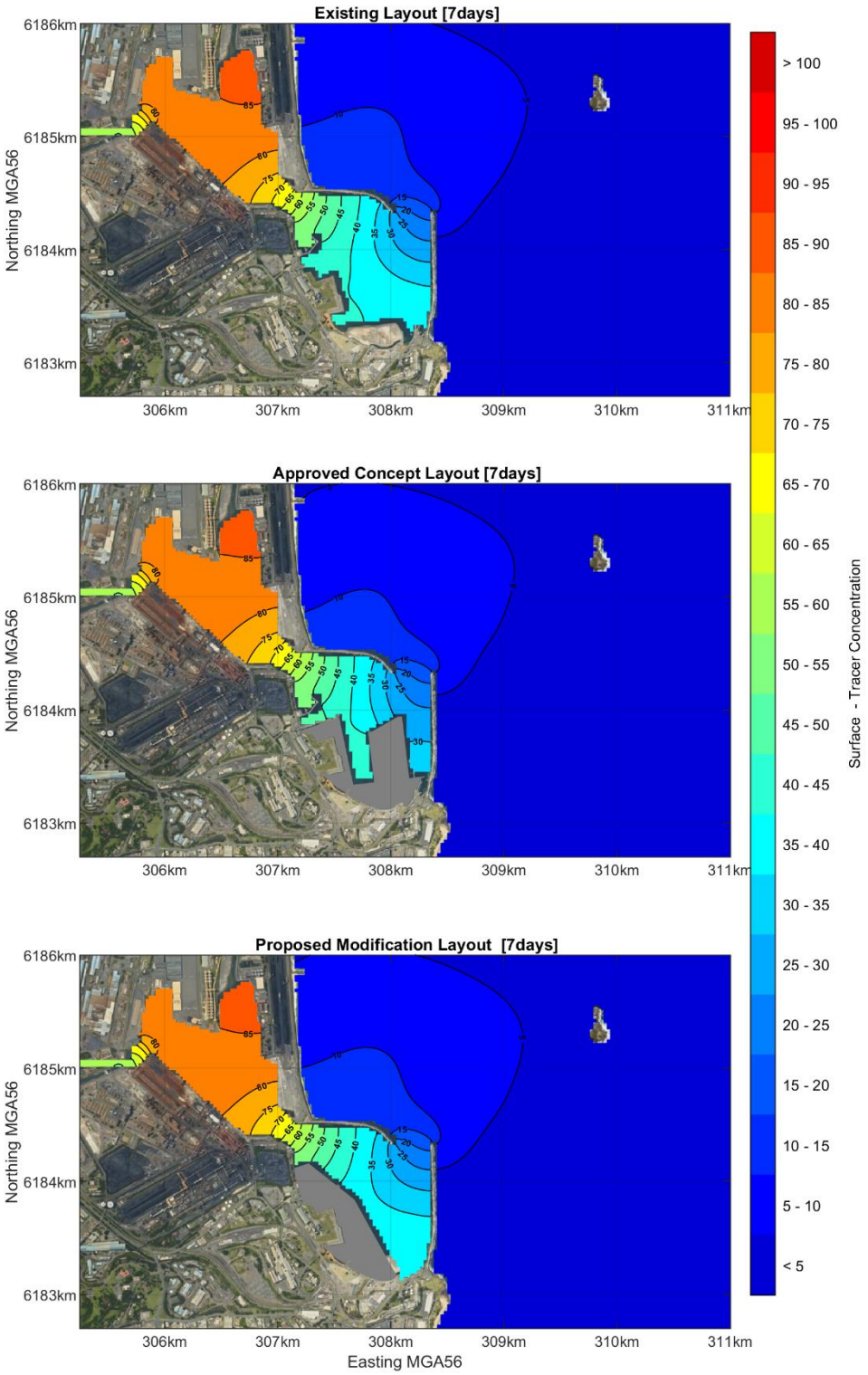
Modelled Flushing Tracer Concentration at the Surface Layer after 3 days from the Initial Concentration of 100



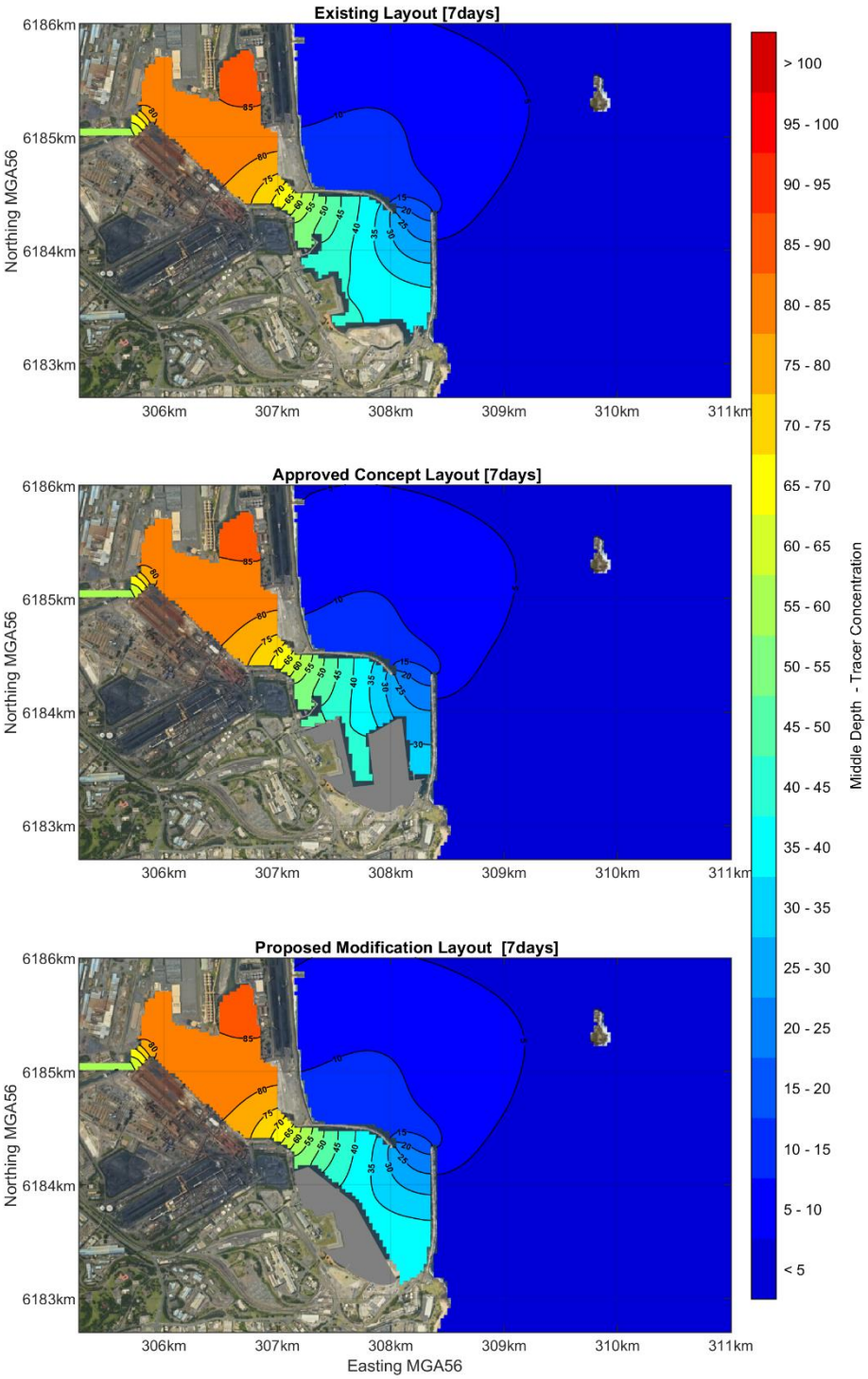
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 3 days from the Initial Concentration of 100



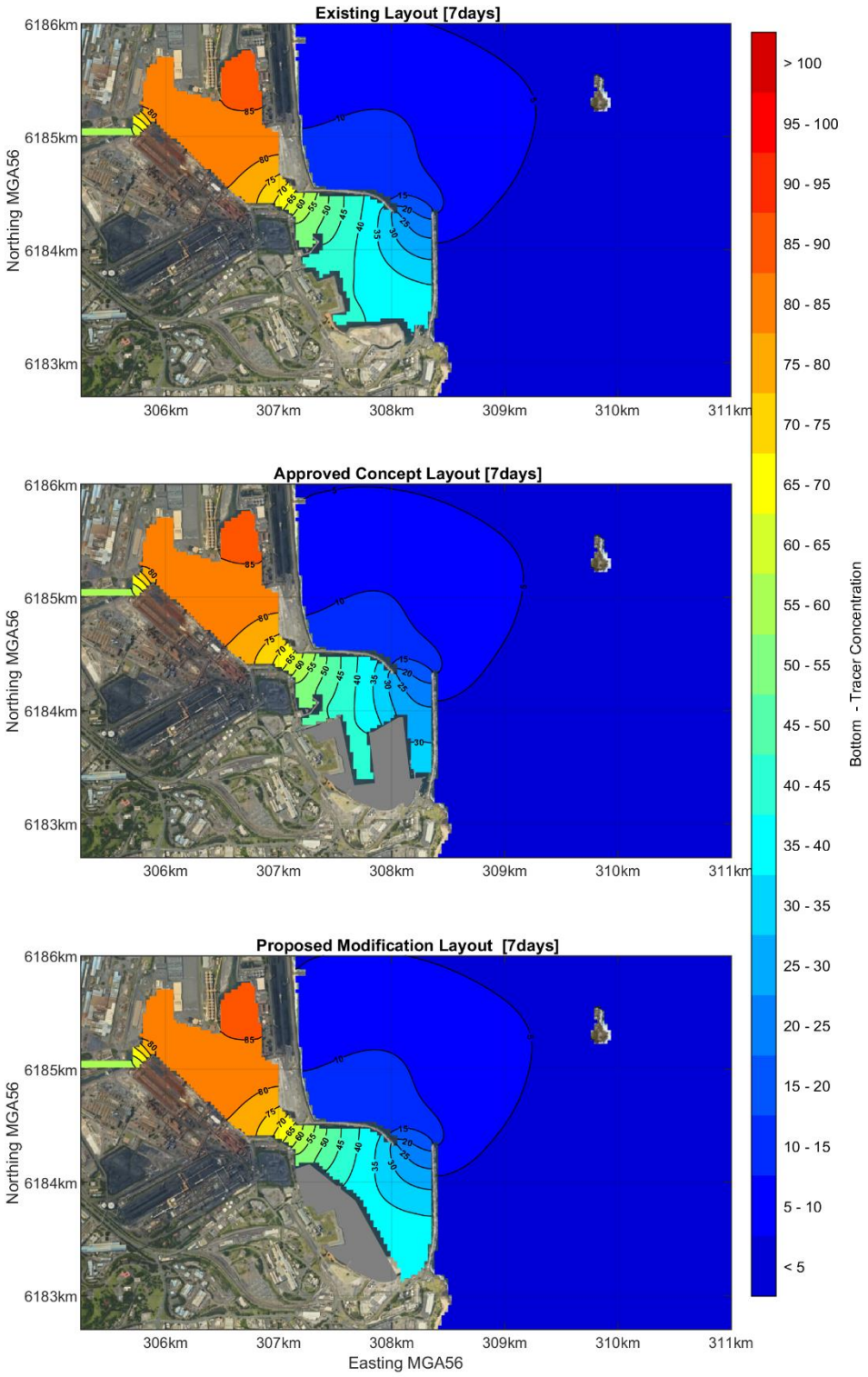
Modelled Flushing Tracer Concentration at the Bottom Layer after 3 days from the Initial Concentration of 100



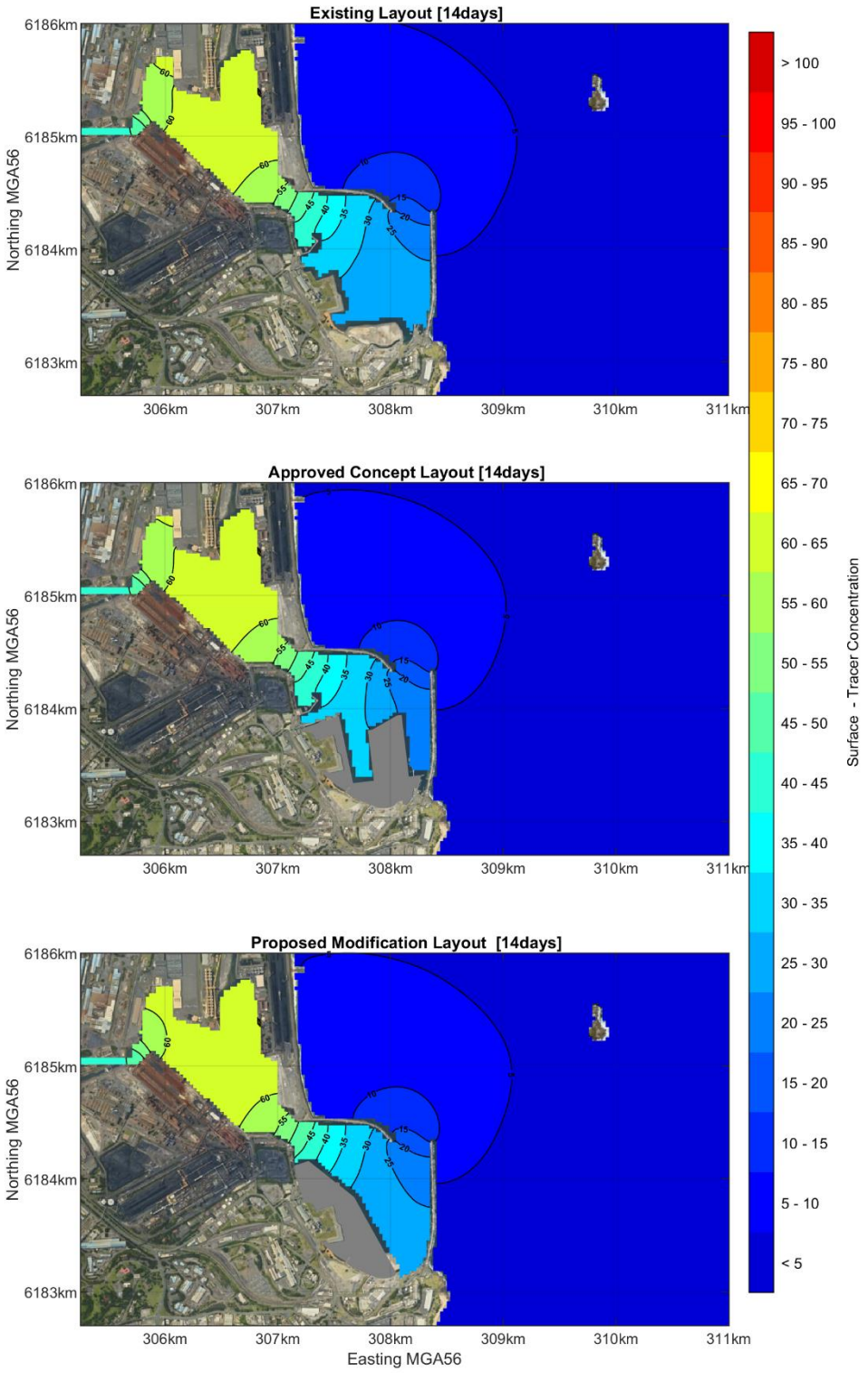
Modelled Flushing Tracer Concentration at the Surface Layer after 7 days from the Initial Concentration of 100



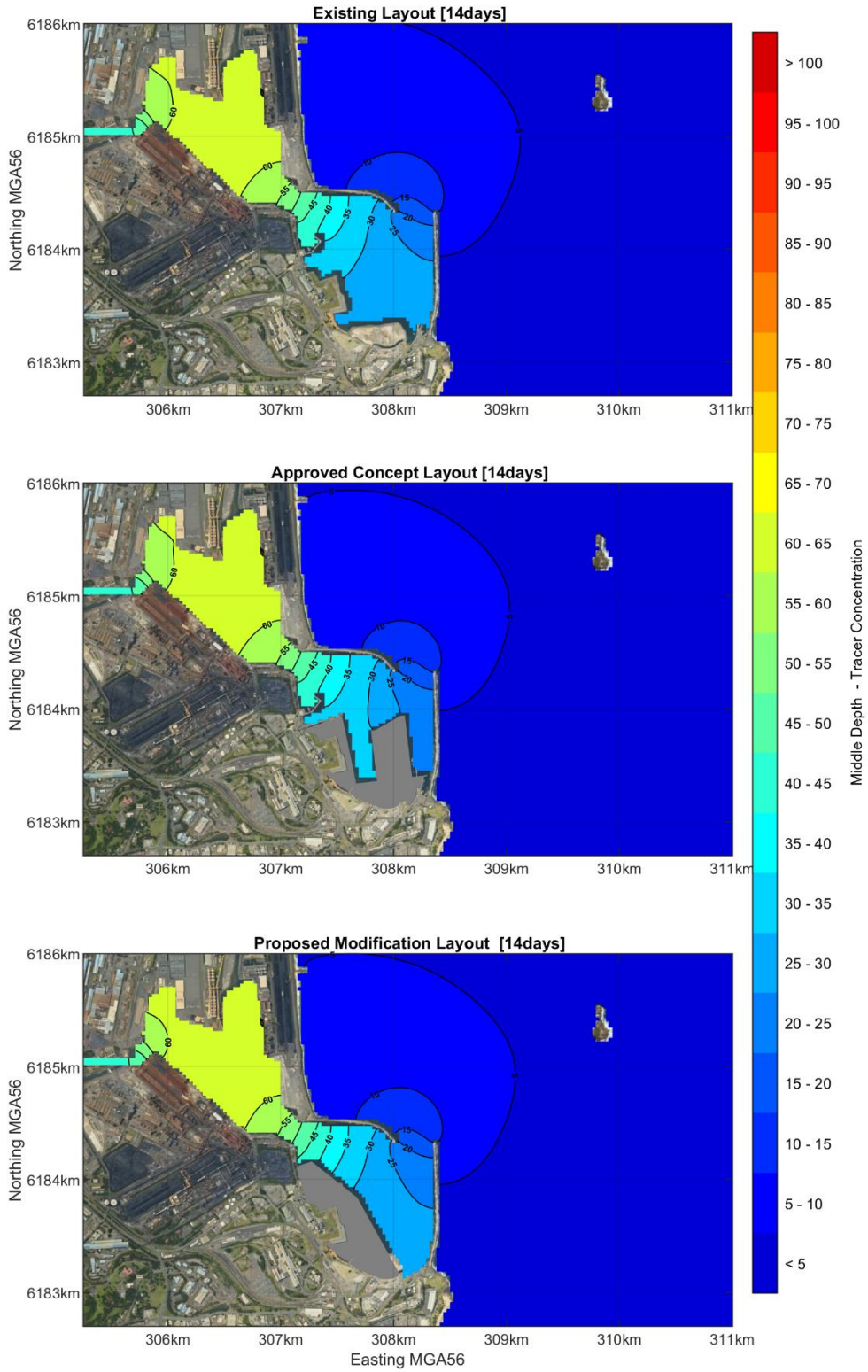
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 7 days from the Initial Concentration of 100



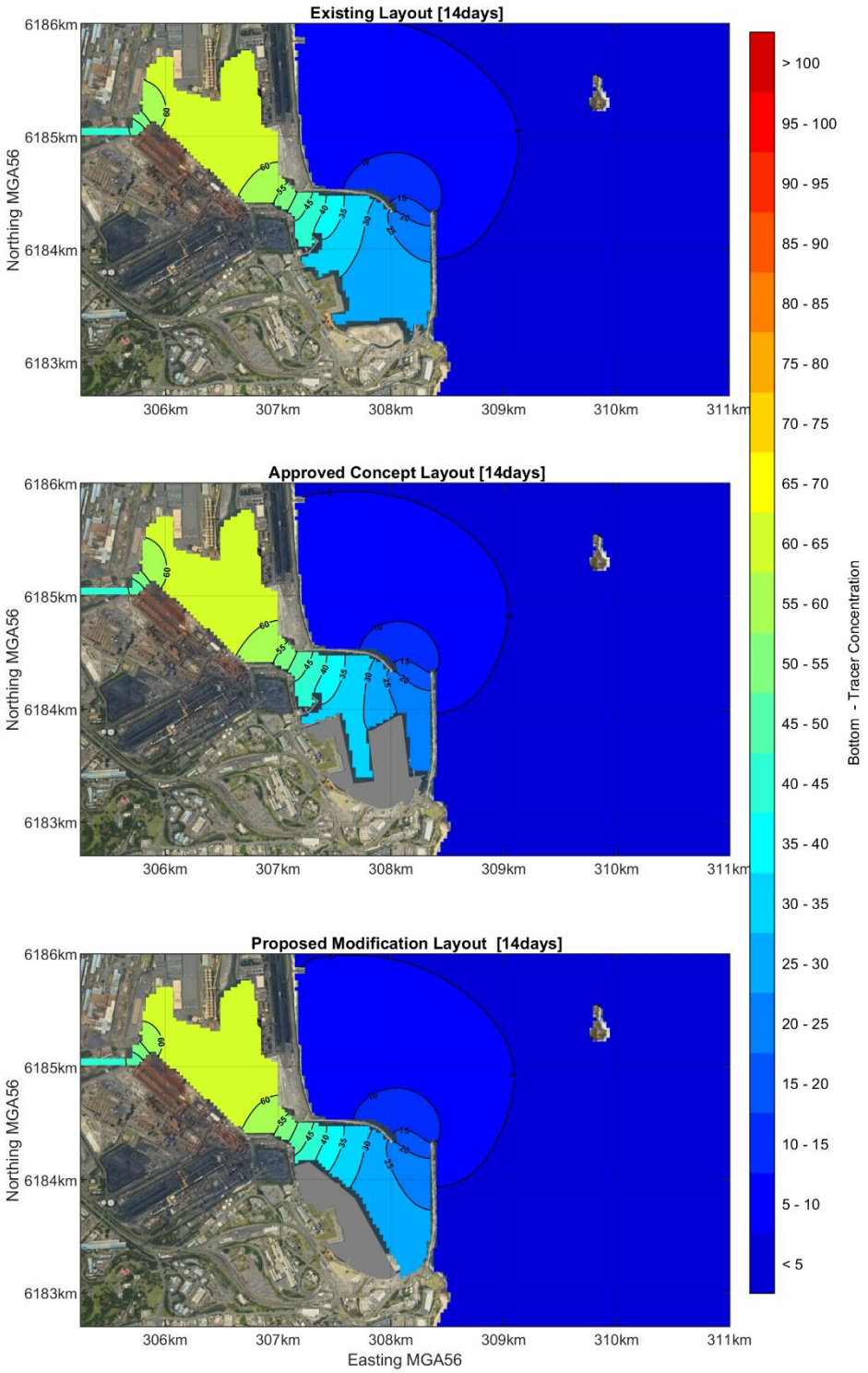
Modelled Flushing Tracer Concentration at the Bottom Layer after 7 days from the Initial Concentration of 100



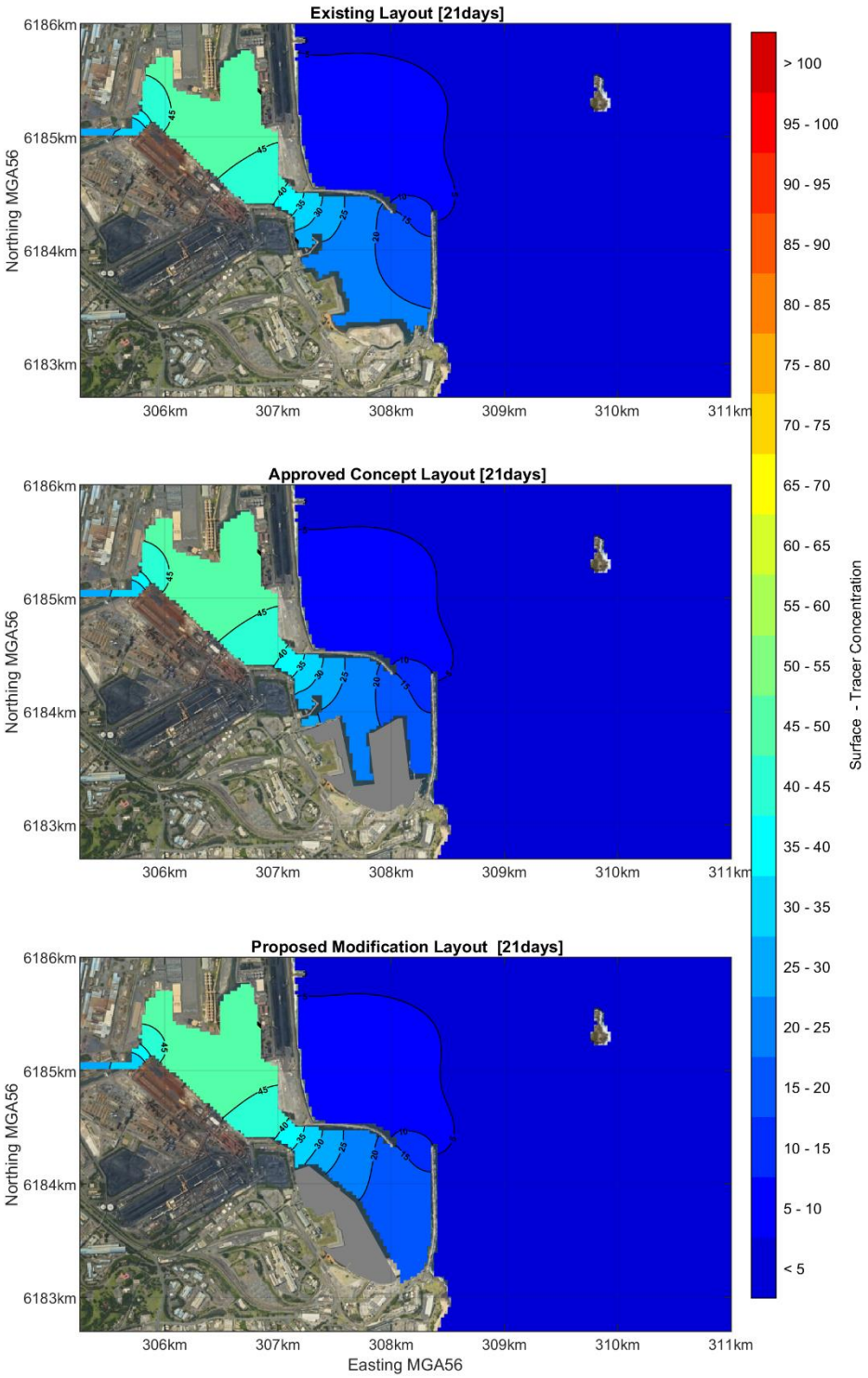
Modelled Flushing Tracer Concentration at the Surface Layer after 14 days from the Initial Concentration of 100



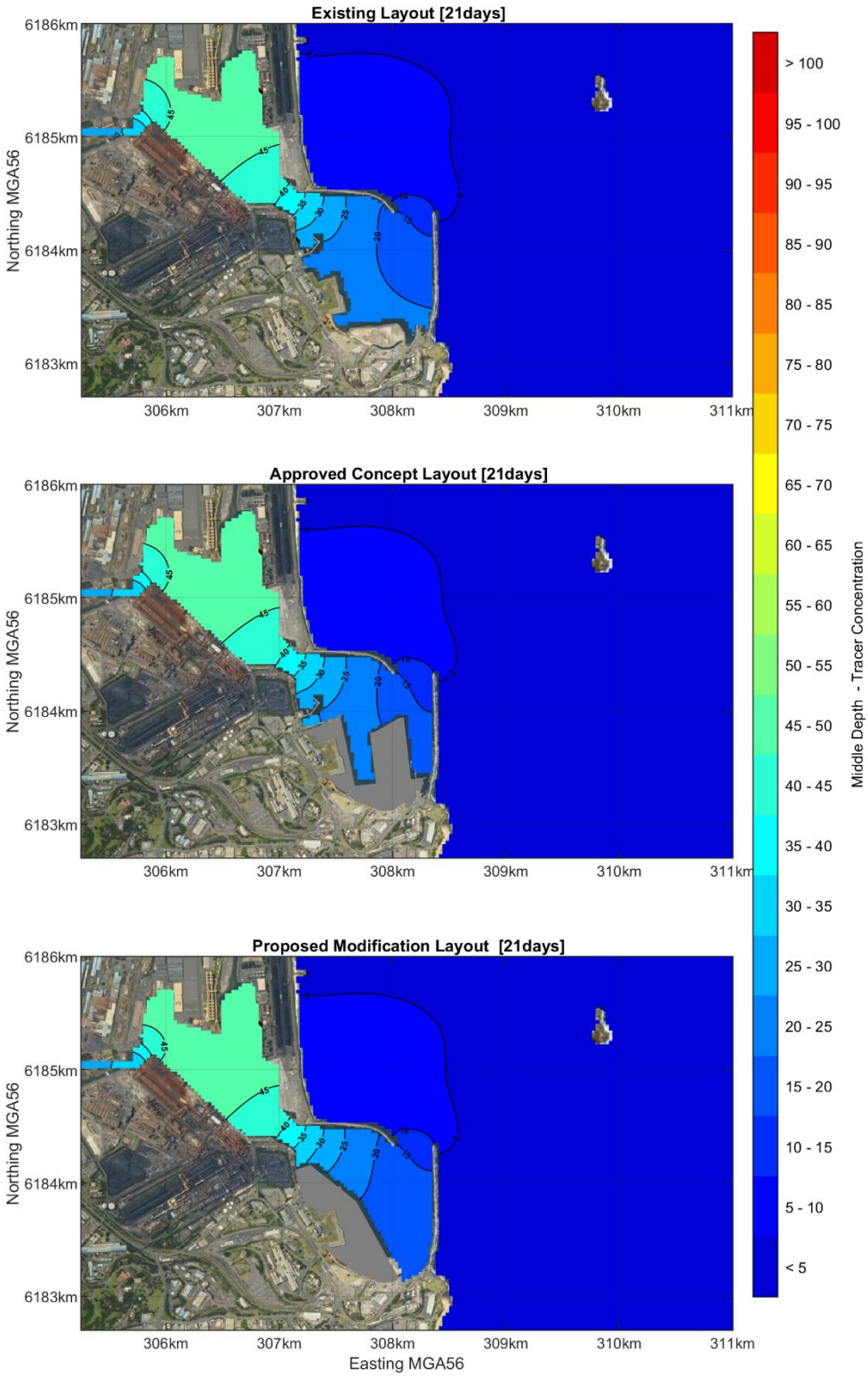
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 14 days from the Initial Concentration of 100



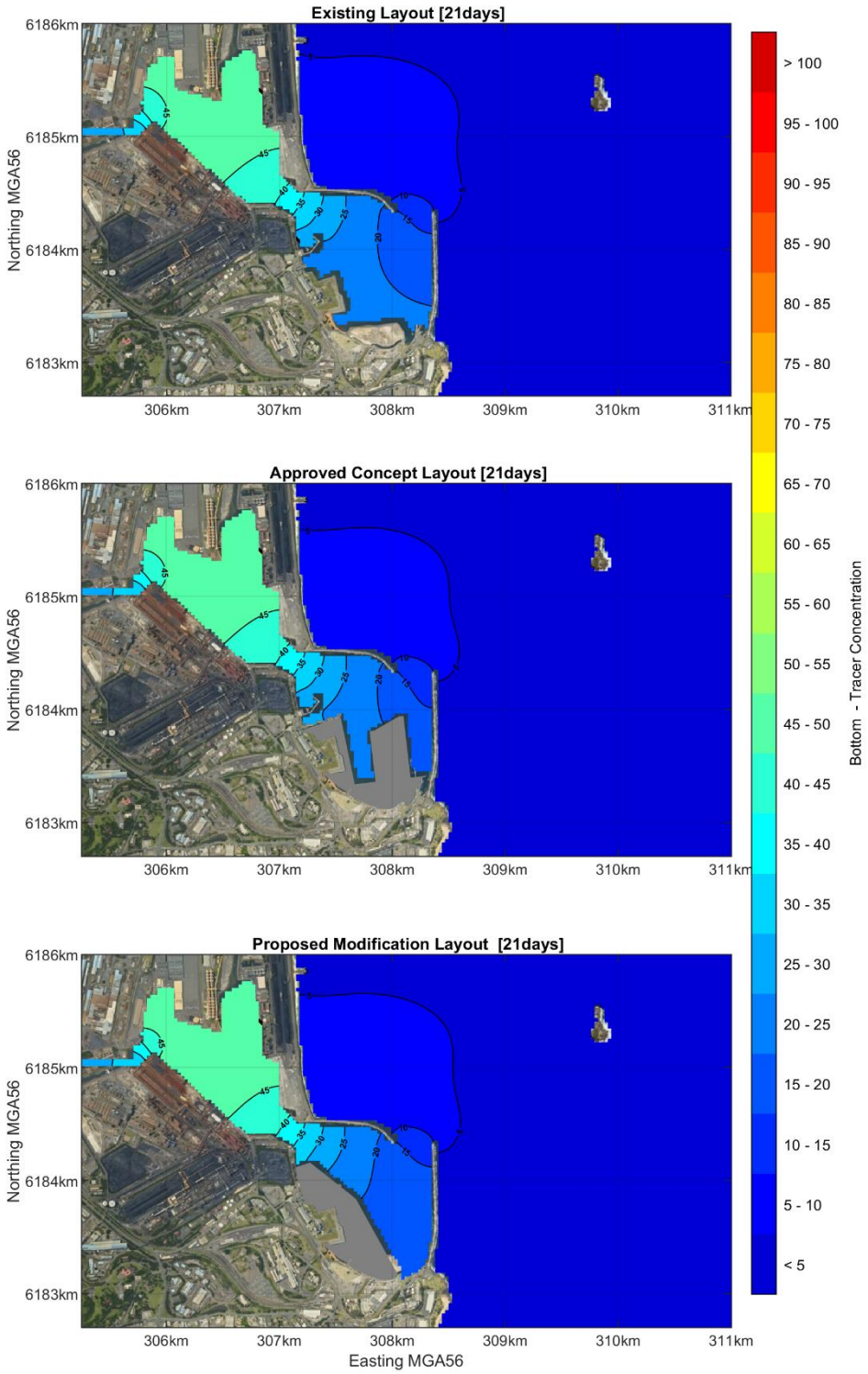
Modelled Flushing Tracer Concentration at the Bottom Layer after 14 days from the Initial Concentration of 100



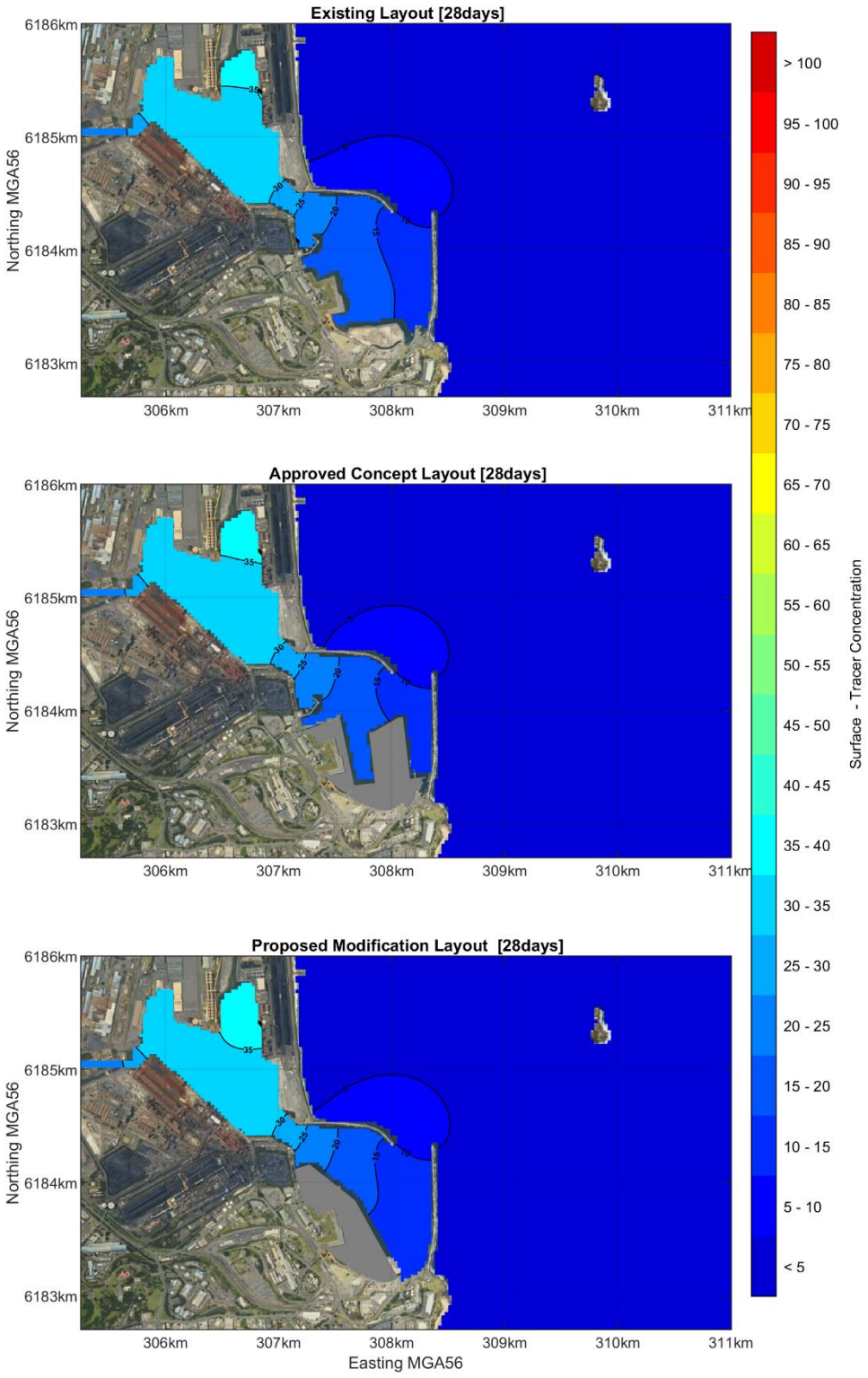
Modelled Flushing Tracer Concentration at the Surface Layer after 21 days from the Initial Concentration of 100



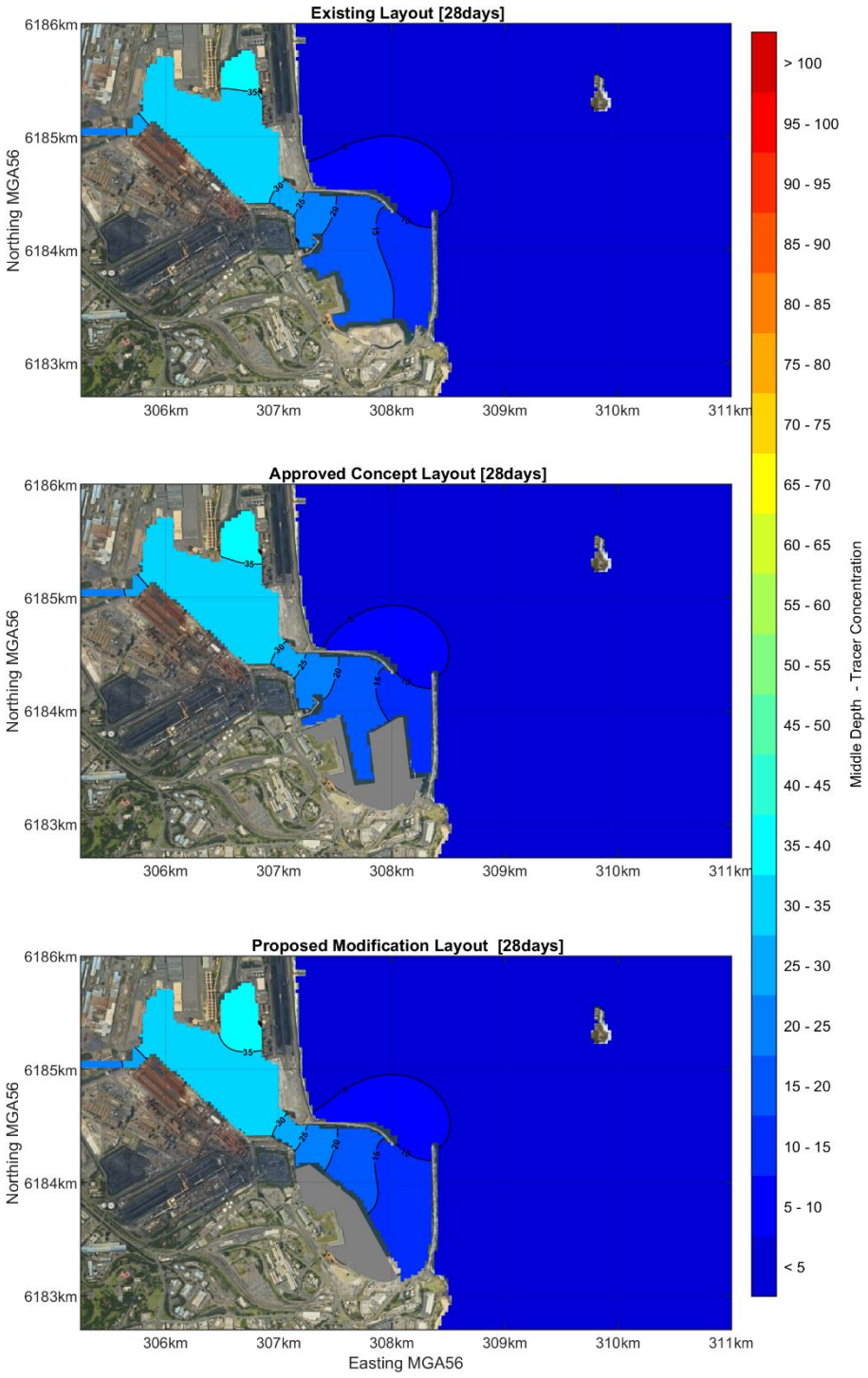
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 21 days from the Initial Concentration of 100



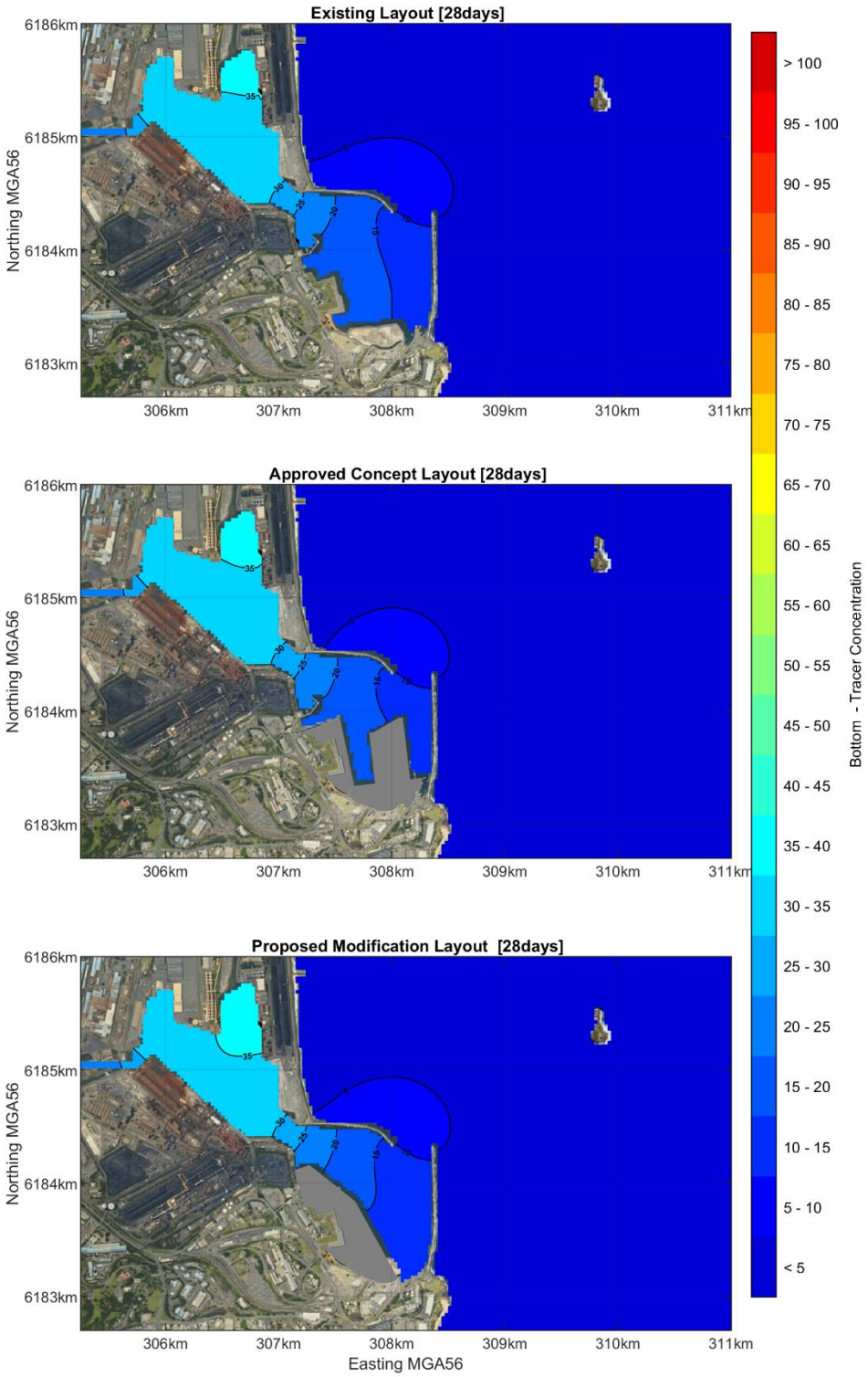
Modelled Flushing Tracer Concentration at the Bottom Layer after 21 days from the Initial Concentration of 100



Modelled Flushing Tracer Concentration at the Surface Layer after 28 days from the Initial Concentration of 100

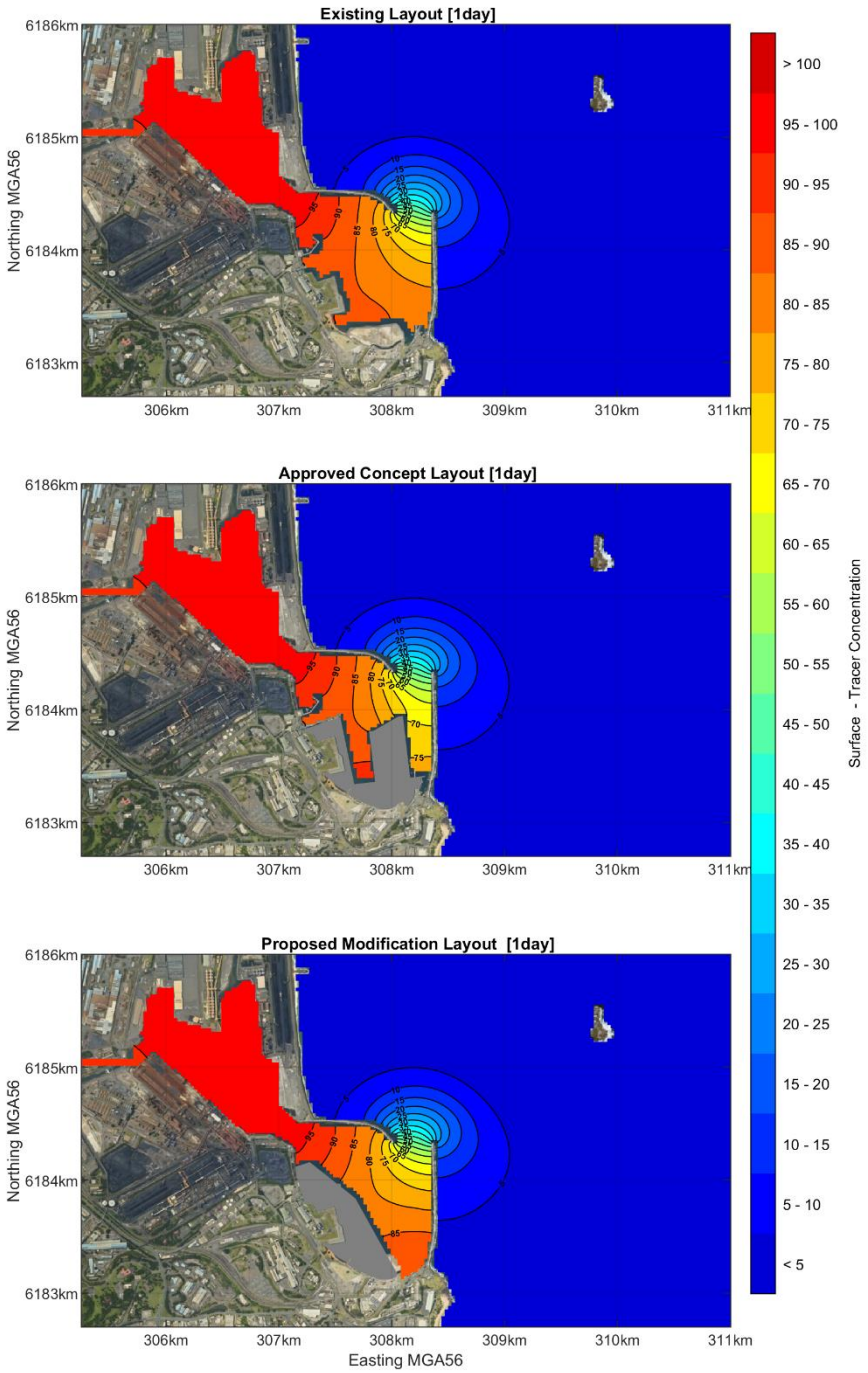


Modelled Flushing Tracer Concentration at the Middle Depth Layer after 28 days from the Initial Concentration of 100

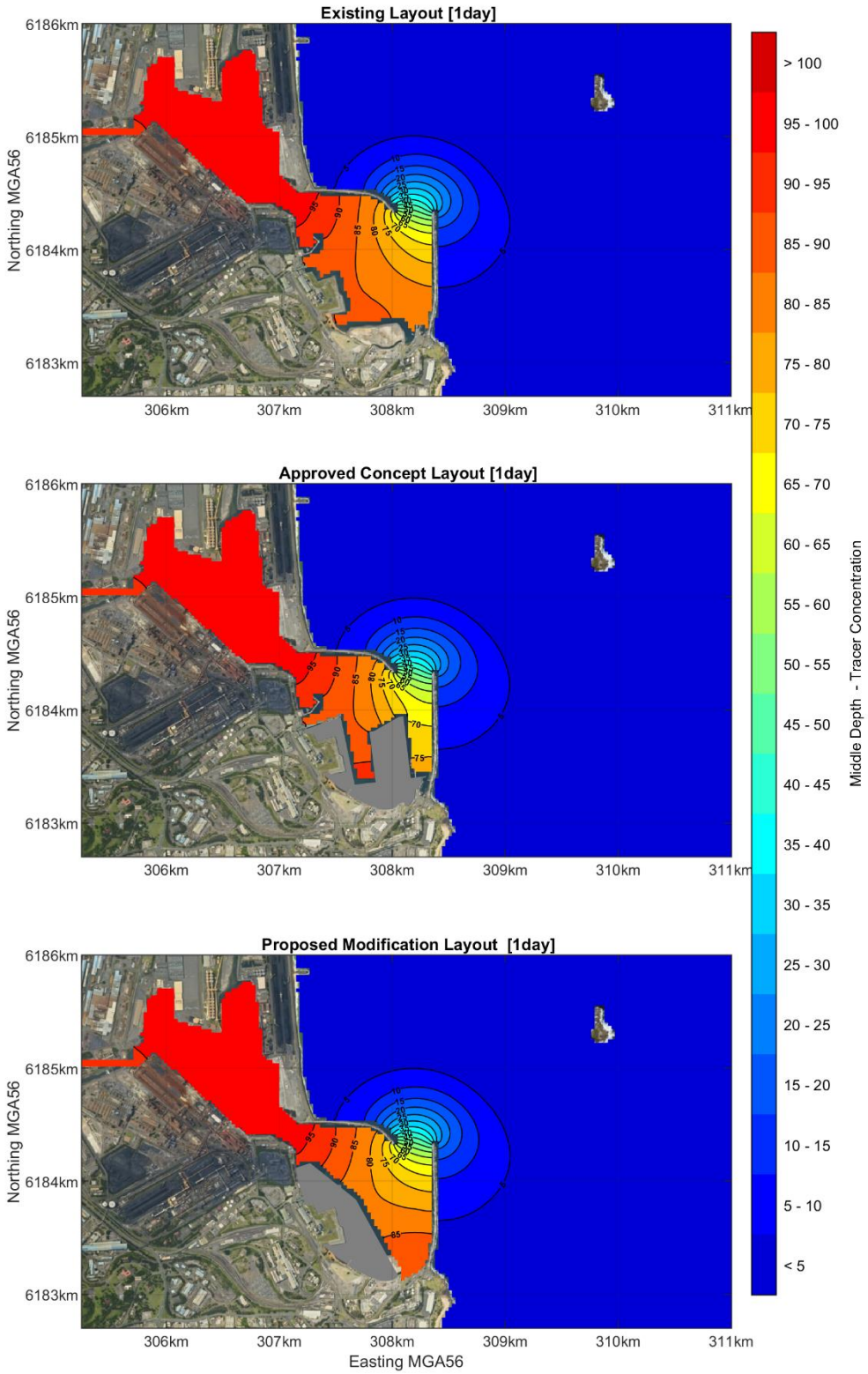


Modelled Flushing Tracer Concentration at the Bottom Layer after 28 days from the Initial Concentration of 100

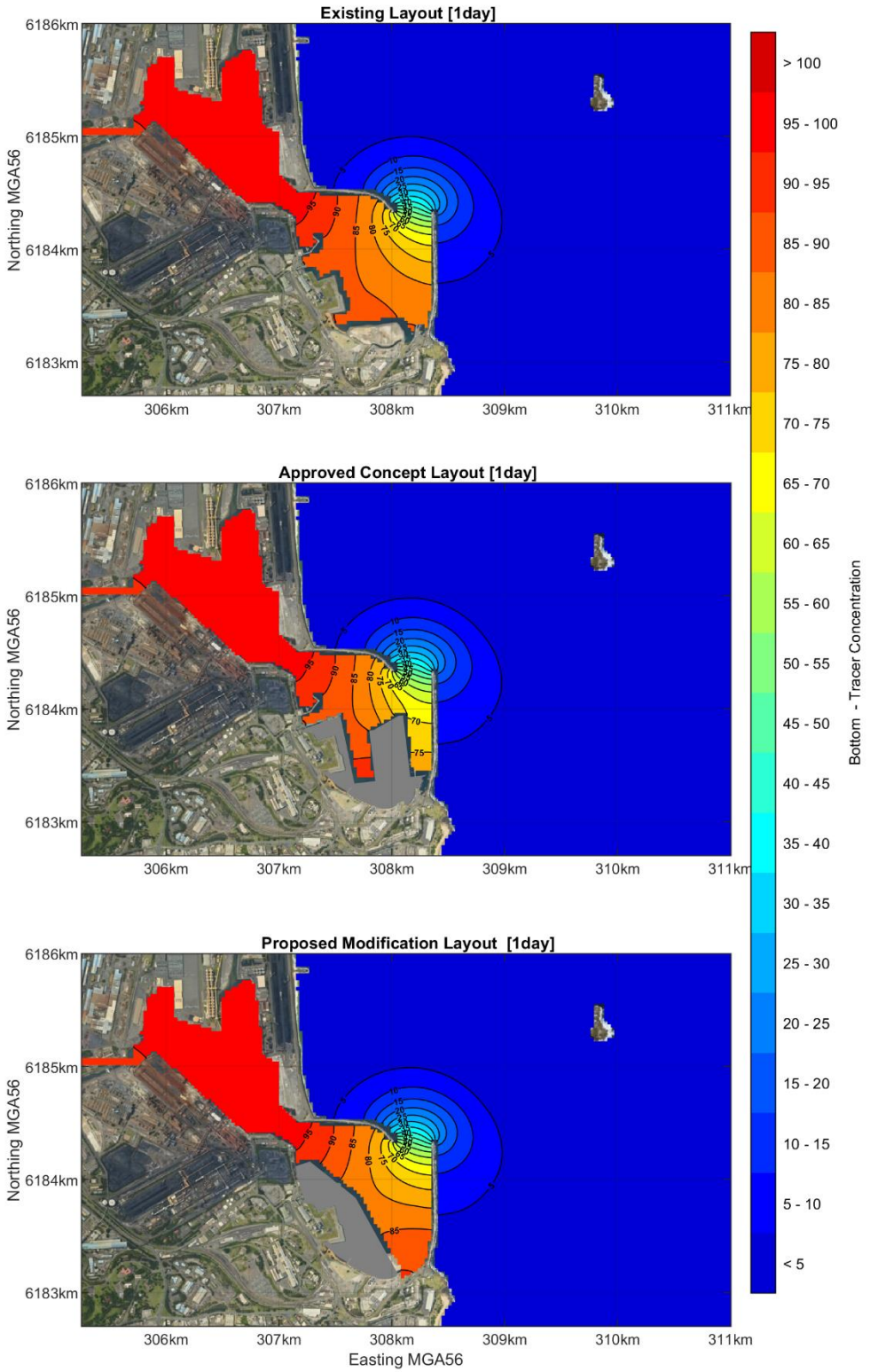
Appendix N Flushing Modelling Results: (Tide only)



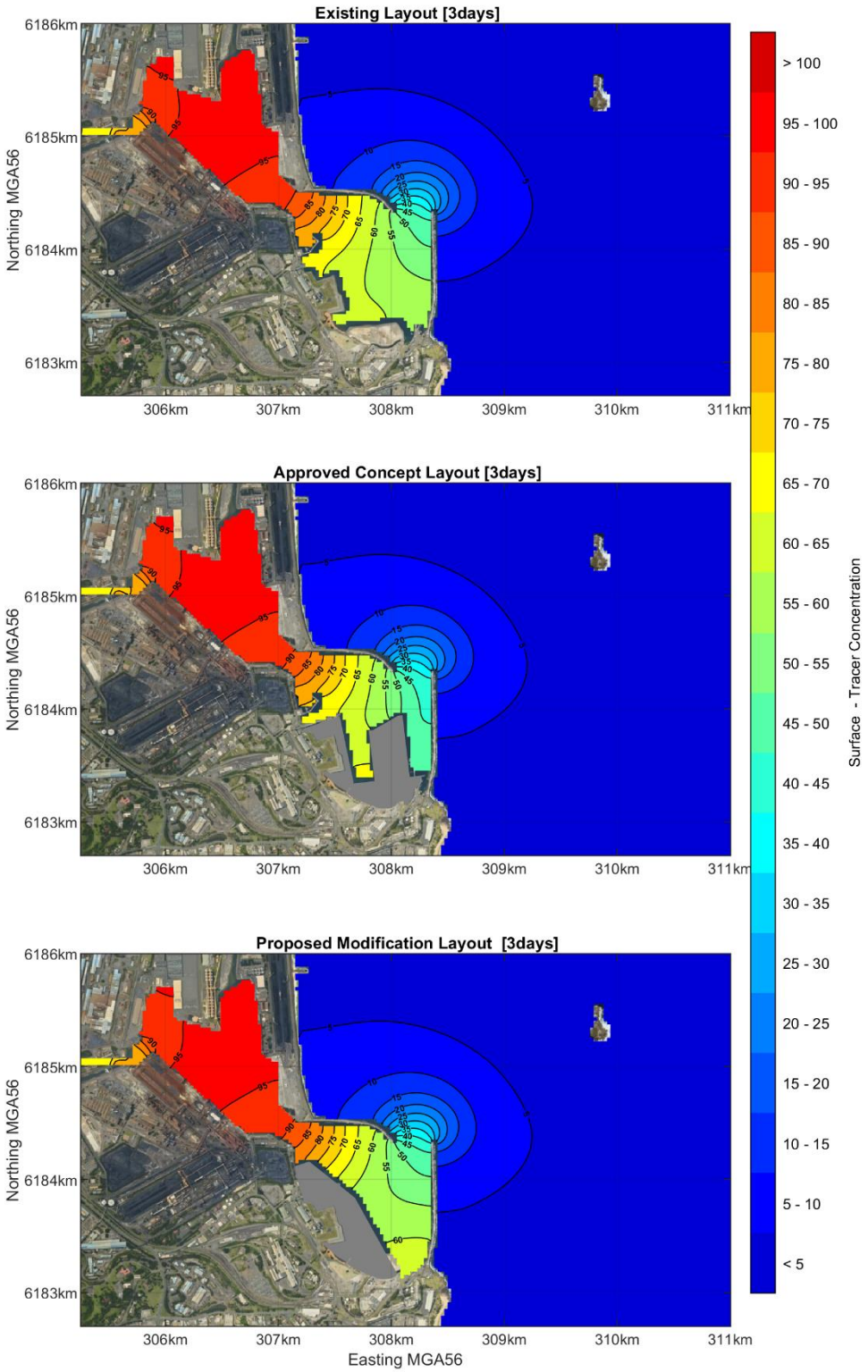
Modelled Flushing Tracer Concentration at the Surface Layer after 1 day from the Initial Concentration of 100



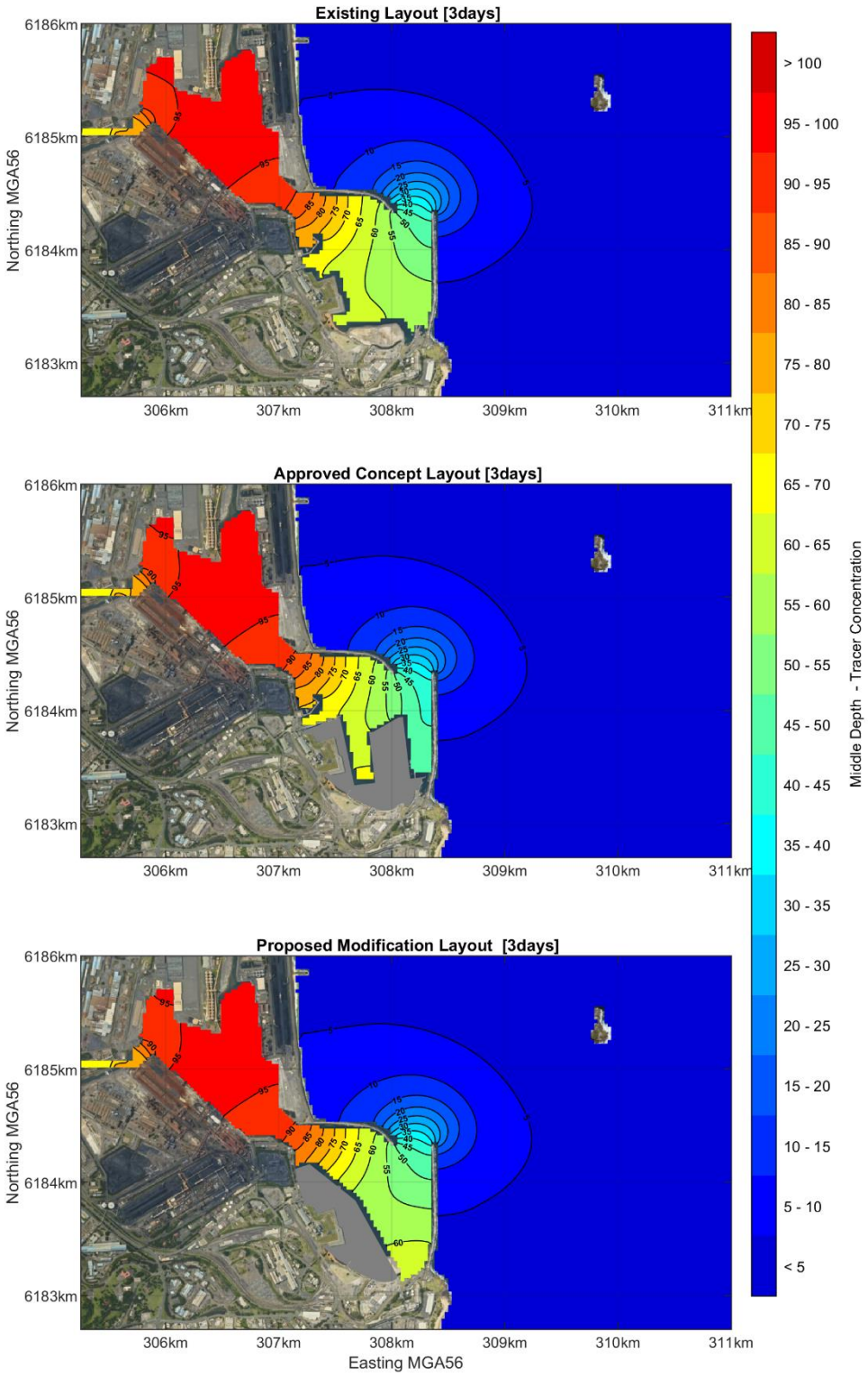
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 1 day from the Initial Concentration of 100



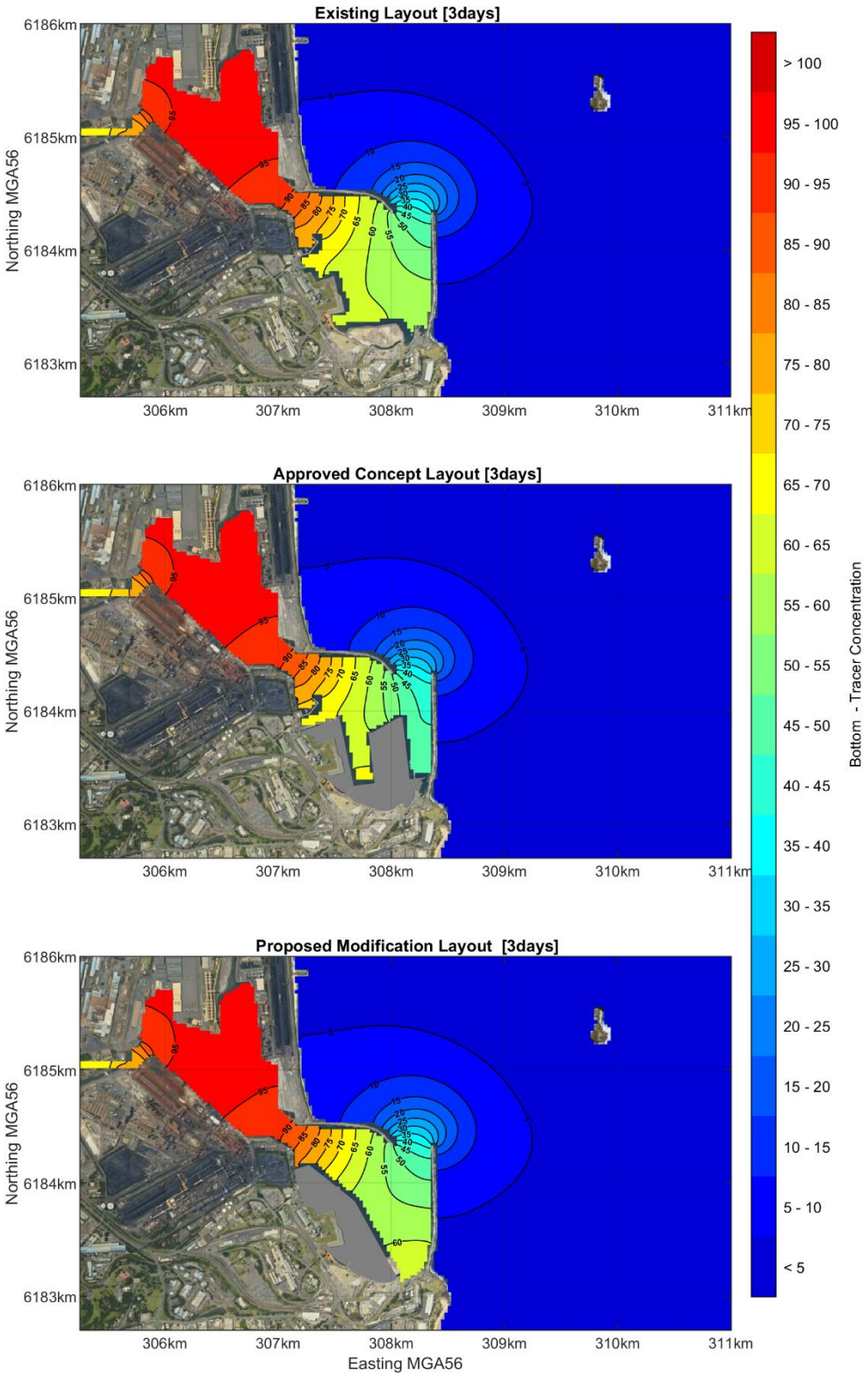
Modelled Flushing Tracer Concentration at the Bottom Layer after 1 day from the Initial Concentration of 100



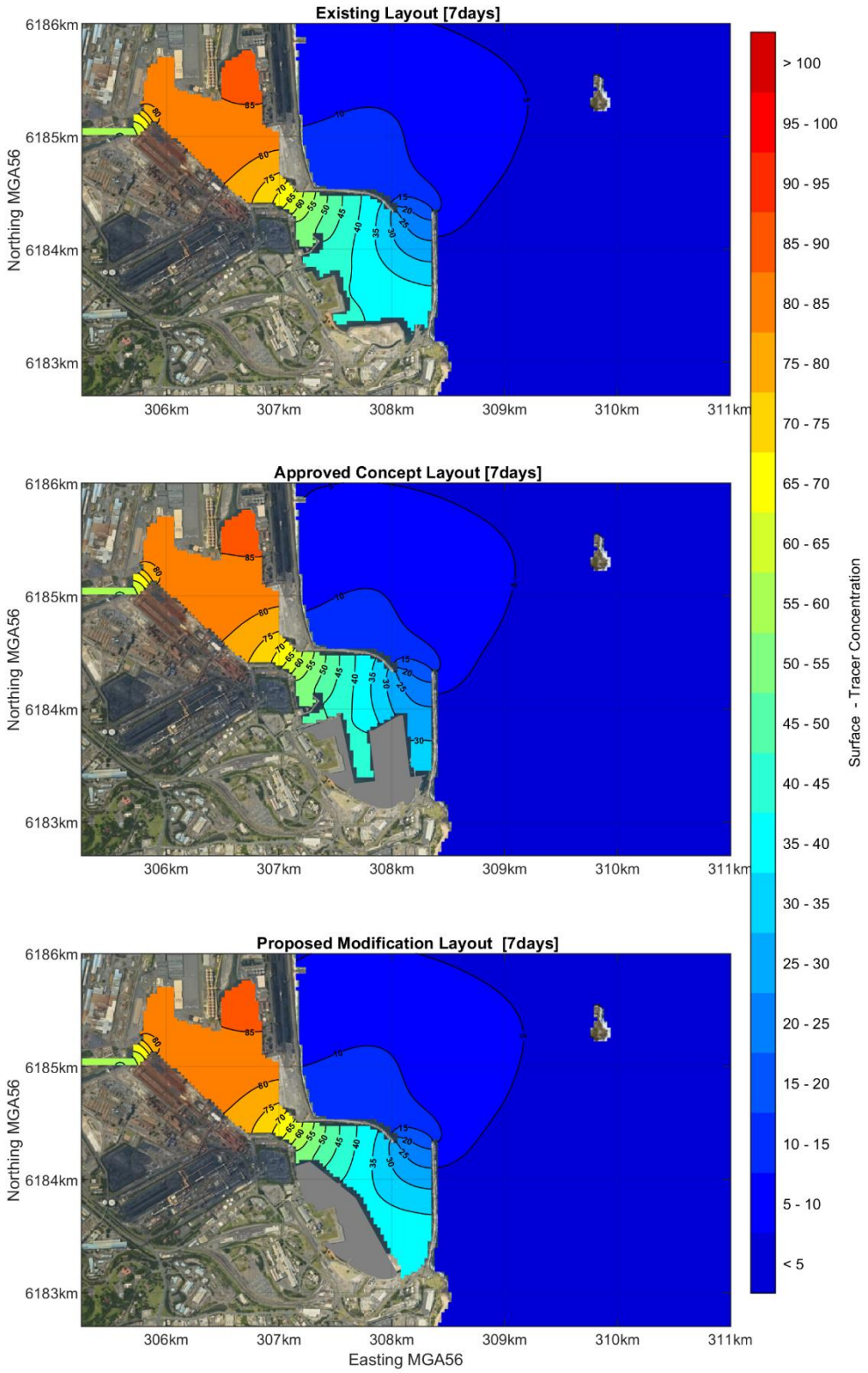
Modelled Flushing Tracer Concentration at the Surface Layer after 3 days from the Initial Concentration of 100



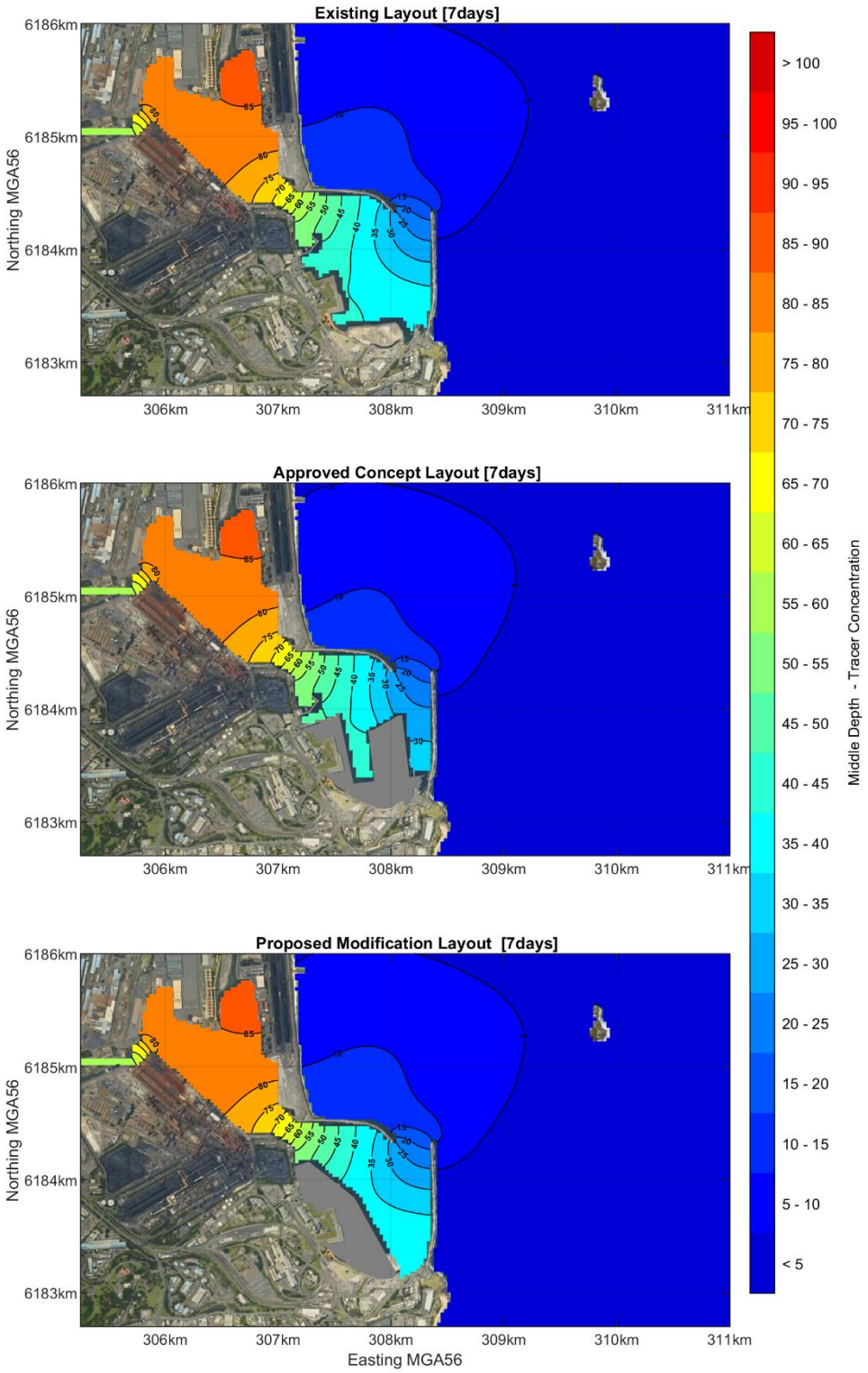
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 3 days from the Initial Concentration of 100



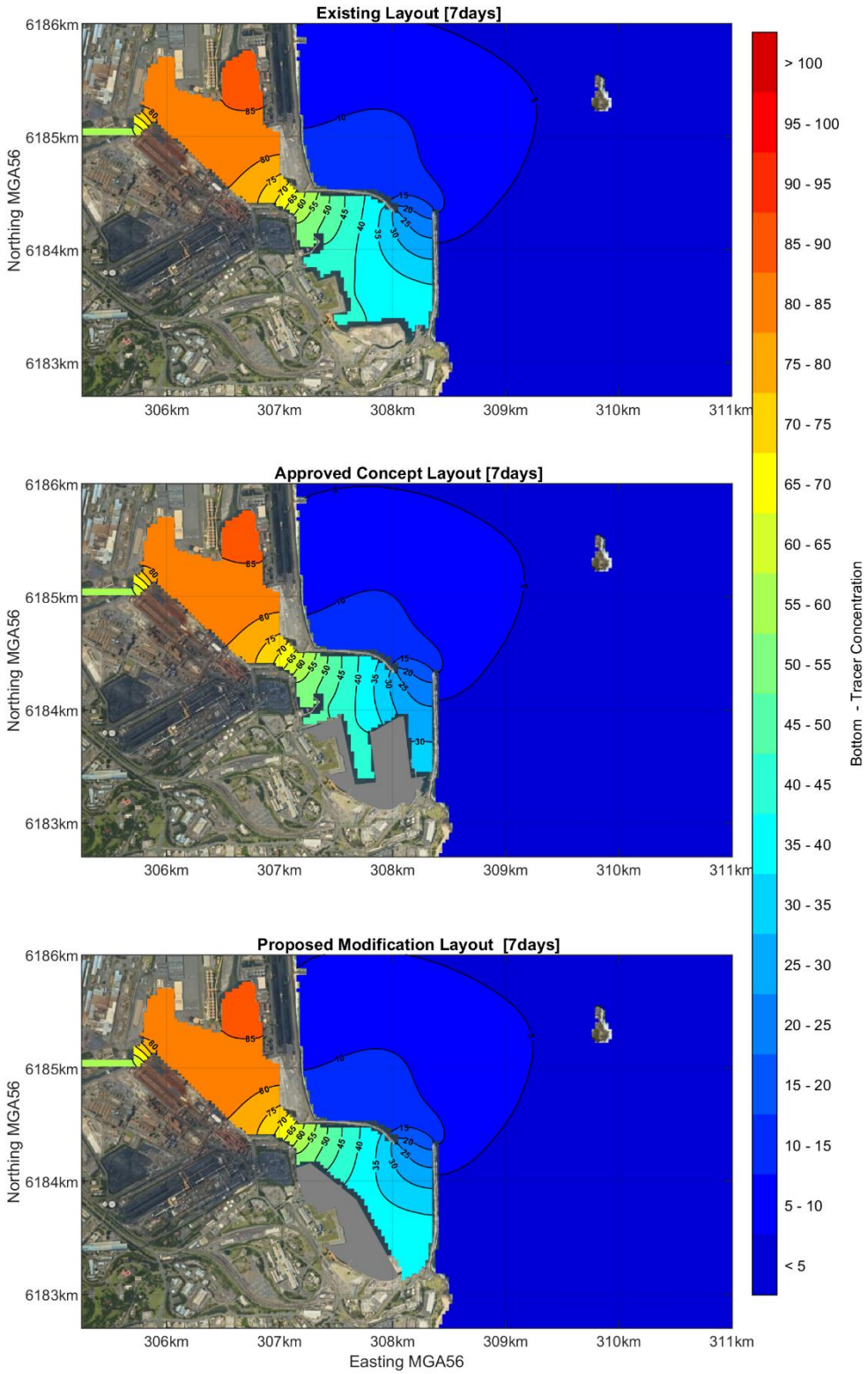
Modelled Flushing Tracer Concentration at the Bottom Layer after 3 days from the Initial Concentration of 100



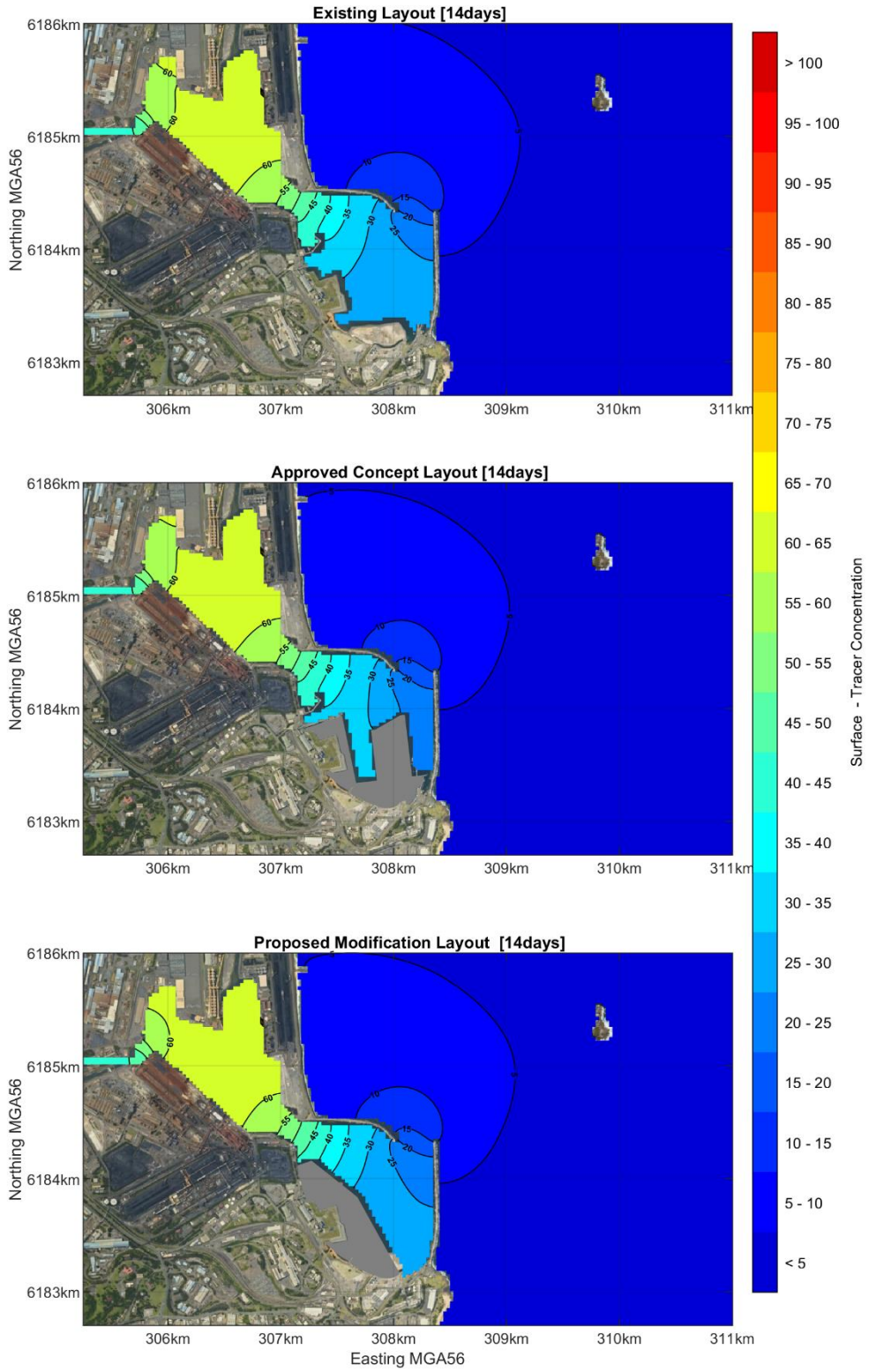
Modelled Flushing Tracer Concentration at the Surface Layer after 7 days from the Initial Concentration of 100



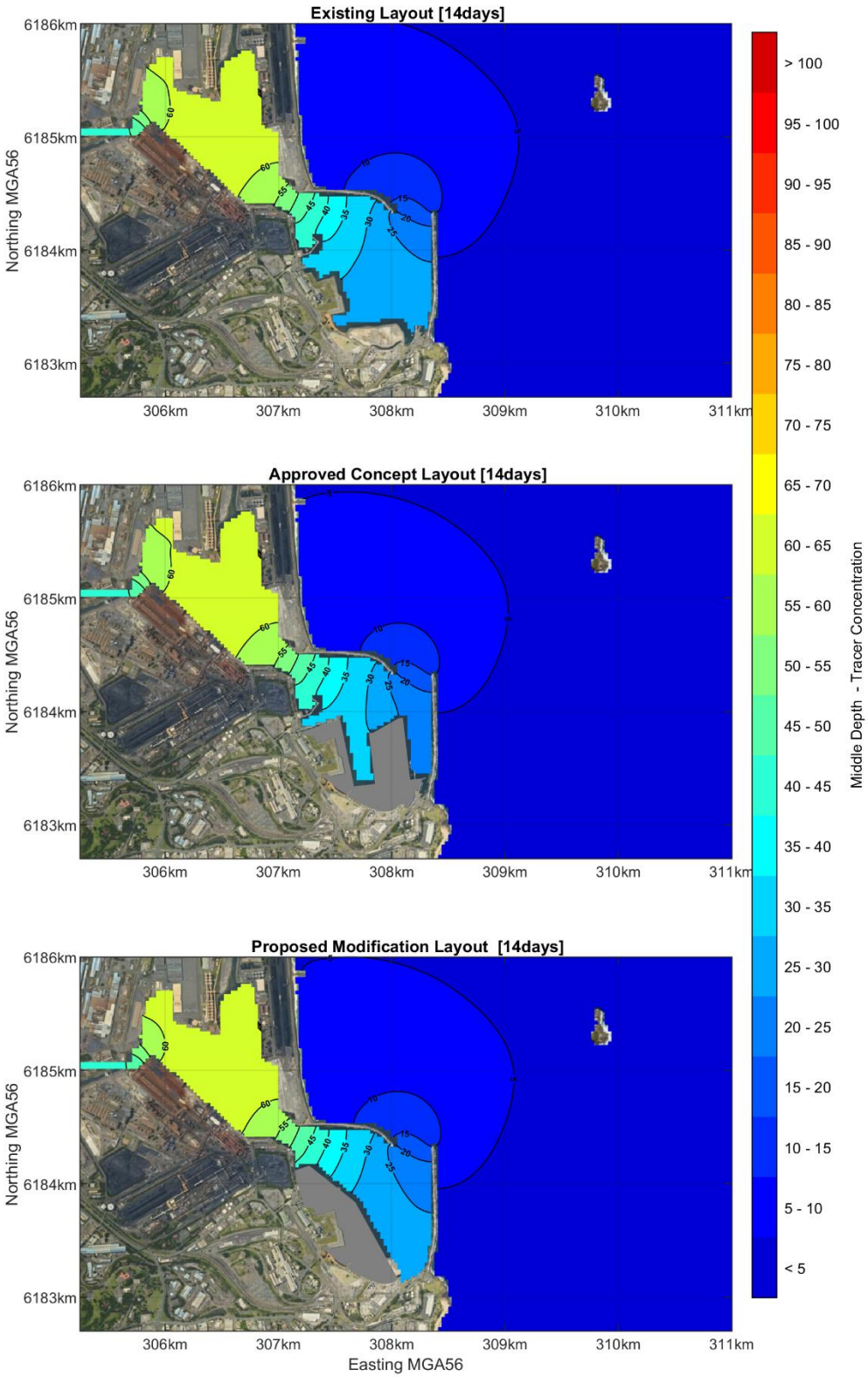
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 7 days from the Initial Concentration of 100



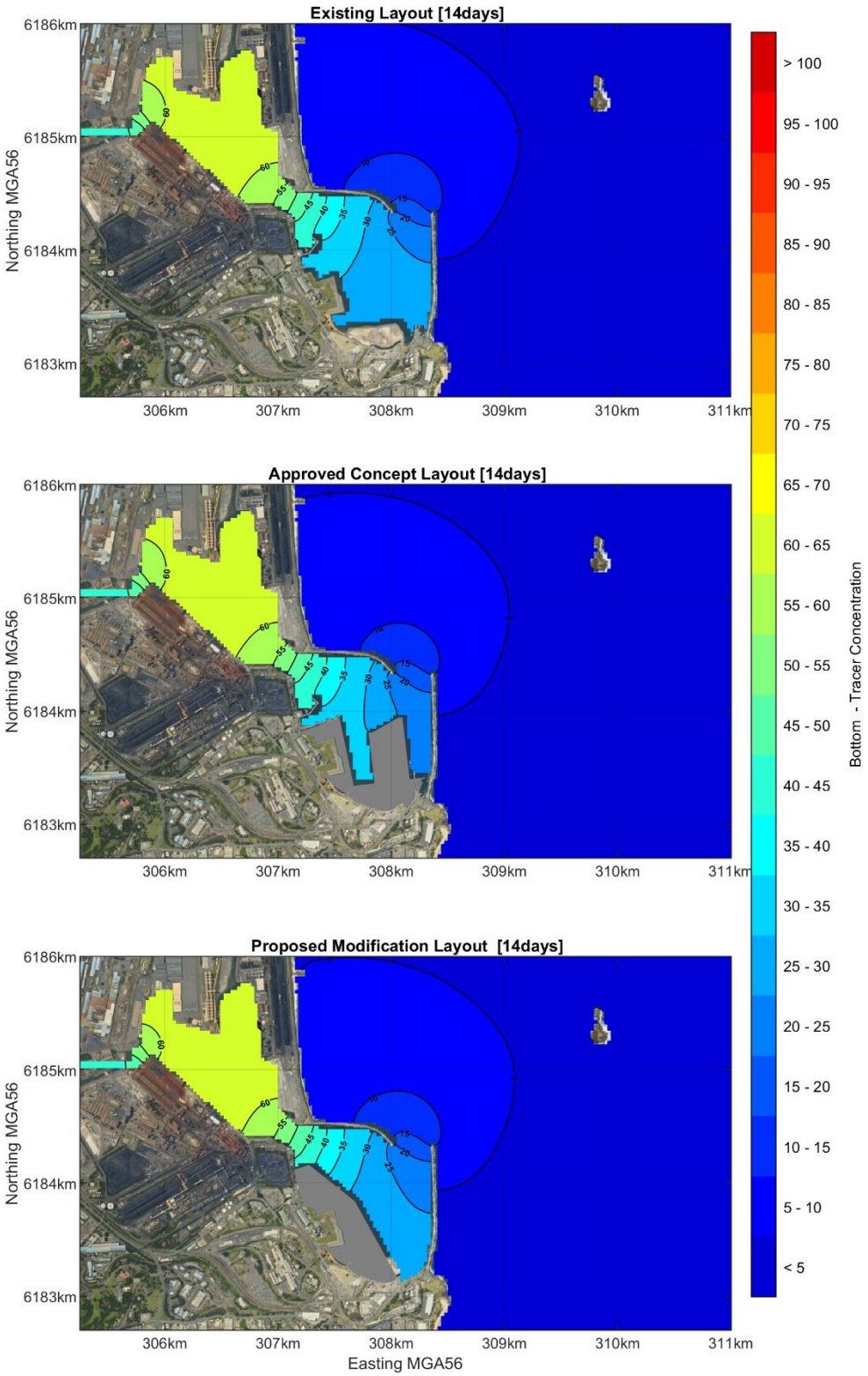
Modelled Flushing Tracer Concentration at the Bottom Layer after 7 days from the Initial Concentration of 100



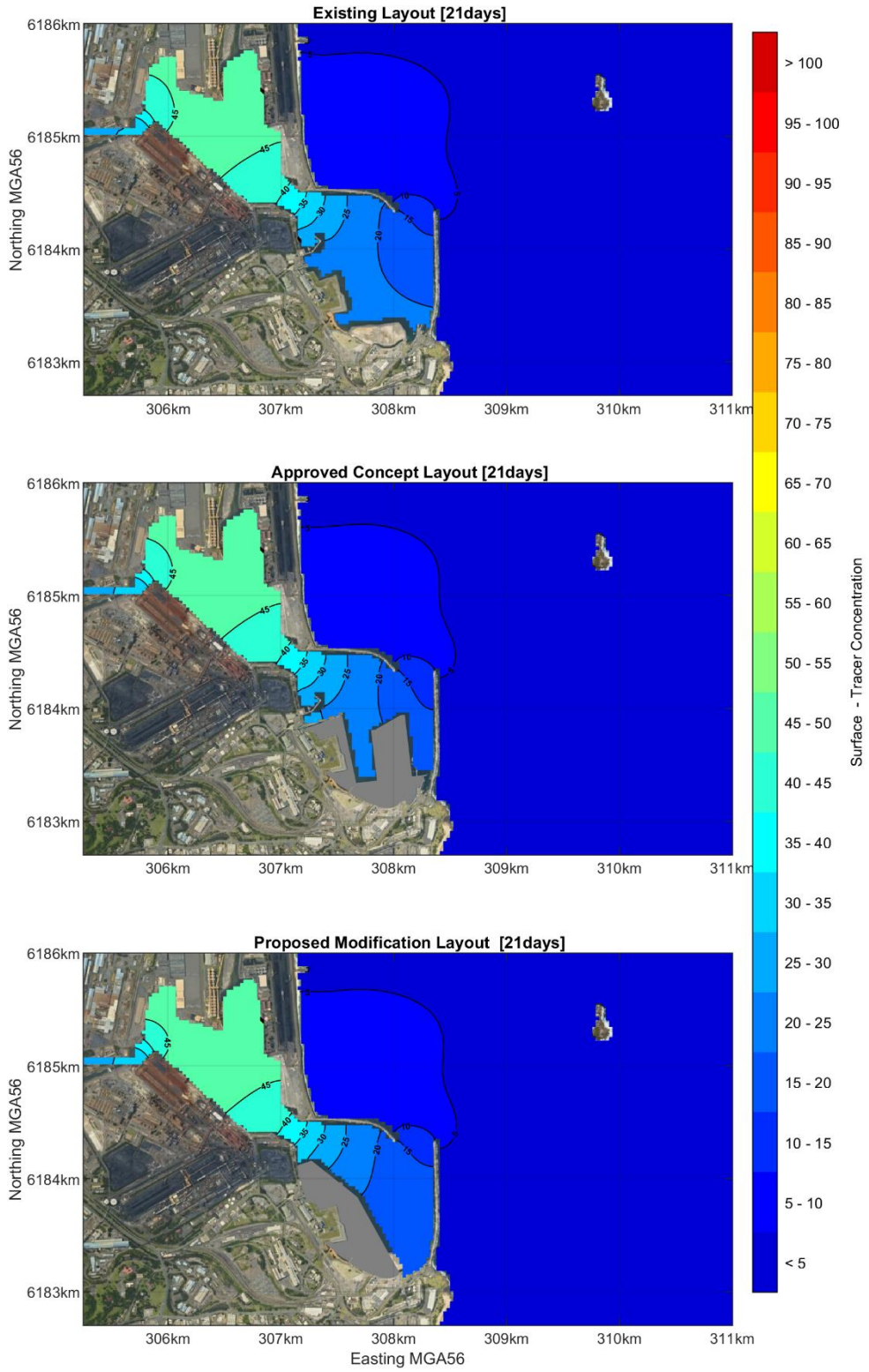
Modelled Flushing Tracer Concentration at the Surface Layer after 14 days from the Initial Concentration of 100



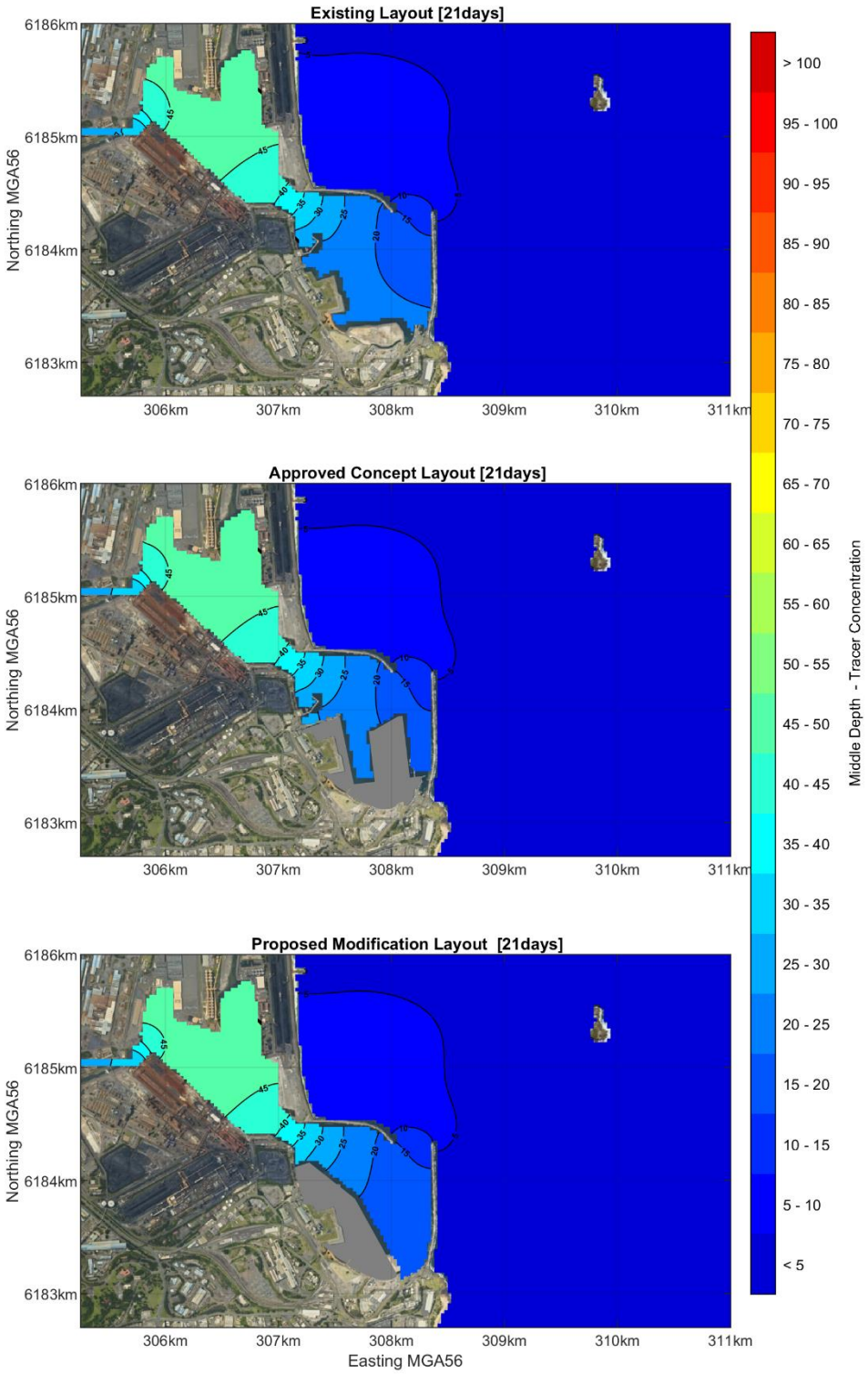
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 14 days from the Initial Concentration of 100



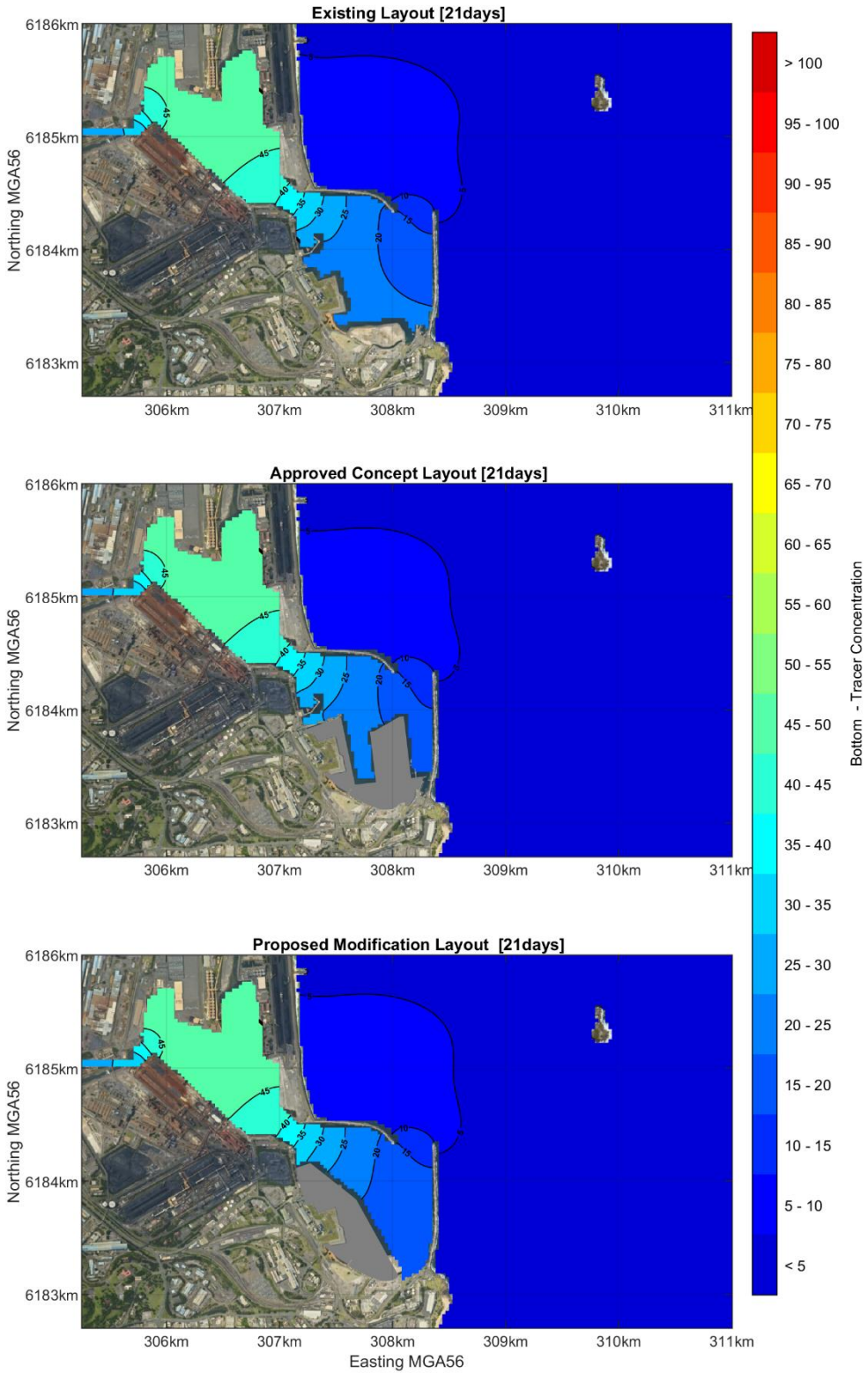
Modelled Flushing Tracer Concentration at the Bottom Layer after 14 days from the Initial Concentration of 100



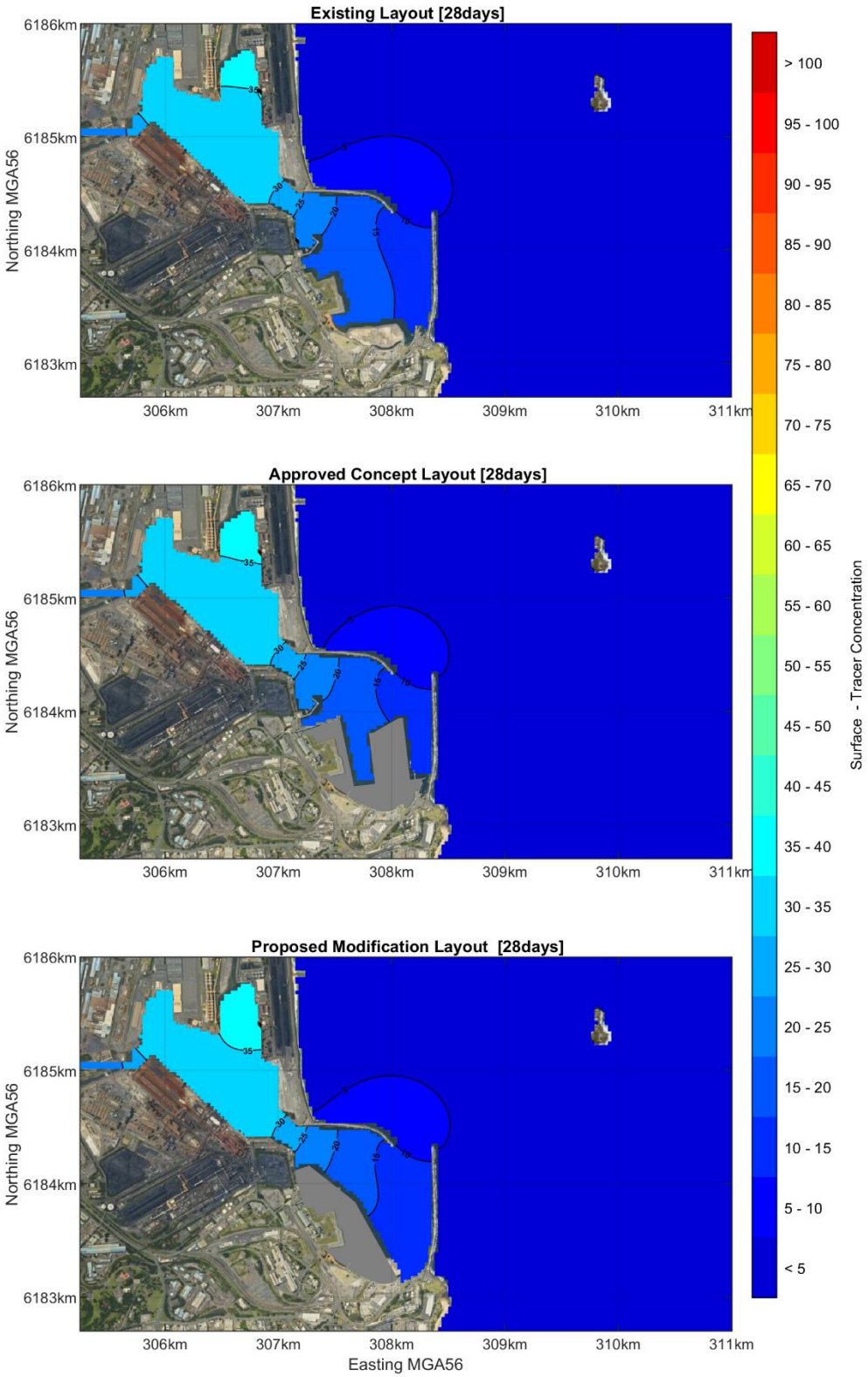
Modelled Flushing Tracer Concentration at the Surface Layer after 21 days from the Initial Concentration of 100



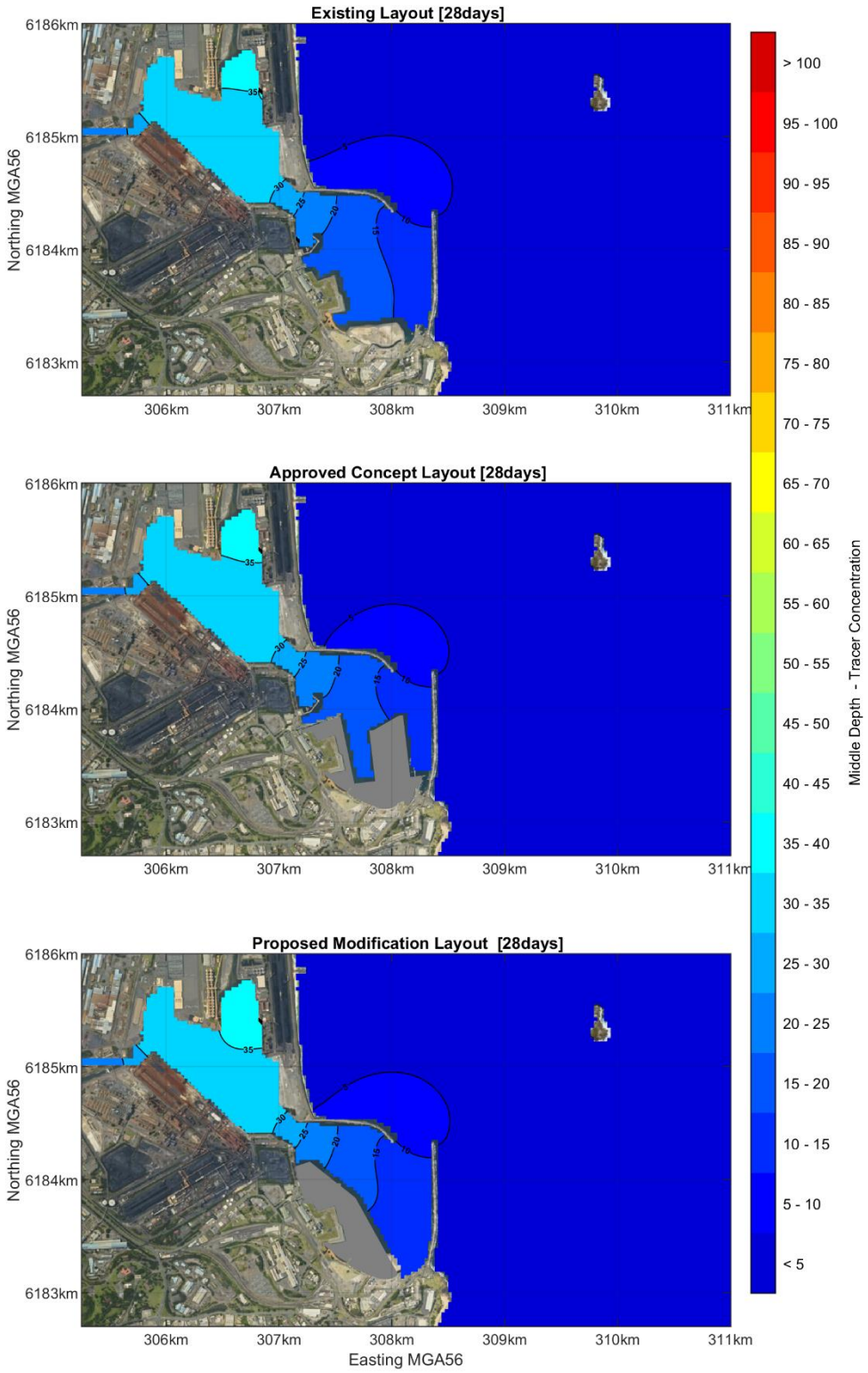
Modelled Flushing Tracer Concentration at the Middle Depth Layer after 21 days from the Initial Concentration of 100



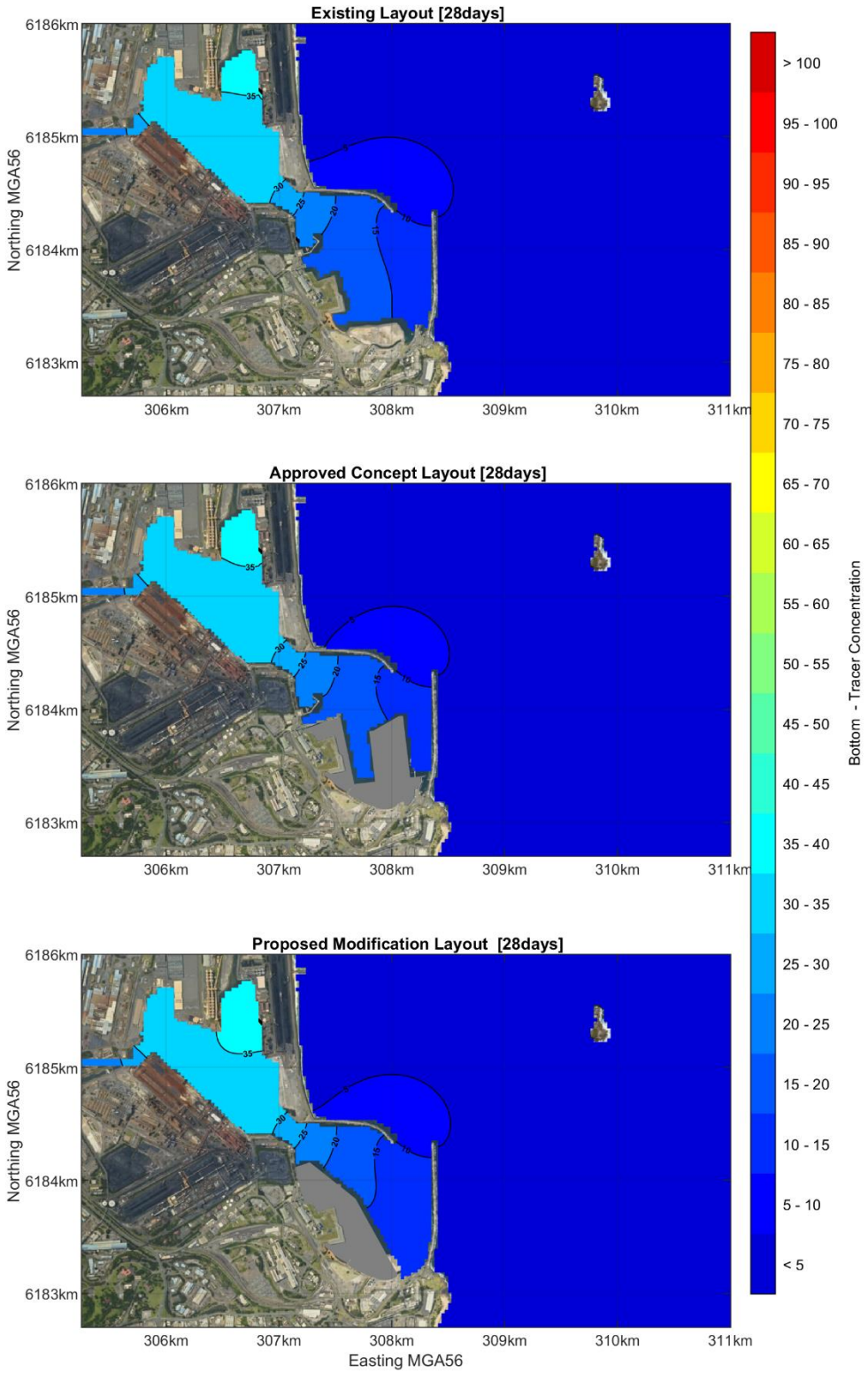
Modelled Flushing Tracer Concentration at the Bottom Layer after 21 days from the Initial Concentration of 100



Modelled Flushing Tracer Concentration at the Surface Layer after 28 days from the Initial Concentration of 100



Modelled Flushing Tracer Concentration at the Middle Depth Layer after 28 days from the Initial Concentration of 100



Modelled Flushing Tracer Concentration at the Bottom Layer after 28 days from the Initial Concentration of 100

Stantec

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