Roads of national significance

16 20 Western Ring Route – Waterview Connection

Assessment of Coastal Processes

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Executive summary

In 2009 the New Zealand Transport Agency (NZTA) confirmed its intention that the 'Waterview Connection Project' (the Project) would be lodged with the Environmental Protection Authority (EPA) as a Proposal of National Significance. The purpose of this report is to provide an assessment of effects of the proposed works on the coastal physical processes.

This assessment considers effects on coastal processes resulting from the construction and the operation of the upgraded motorway system. Effects are aligned with various categories of activities in the operative Auckland Regional Plan: Coastal i.e., structures, reclamation, disturbances of the foreshore and seabed or discharges of contaminants into the Coastal Marine Area (CMA).

The Project includes widening the existing motorway footprint of SH16 between a tidal tributary of Henderson Creek (Pixie Inlet) to the west and St Lukes Road Interchange to the east. The majority of these works are directly adjacent to, or impinge on, the CMA. The Project also includes construction of a new section of SH20 motorway from the Maioro Street Interchange to the Great North Road Interchange. These works approximately follow the route of Oakley Creek.

The assessment of coastal physical effects for the Project has been undertaken through a series of investigations commencing in December 2008 through to July 2010. These investigations comprised an evolution of approaches to assessing the effects that were commensurate with the degree of certainty about the likely level of impacts, given the existing Causeway is essentially being widened. In particular, two integrated approaches were used:

- Expert opinion approach. This approach was used to assess the environmental effects of activities in Sectors 1–4, where the works for SH16 are predominantly focused on widening the existing carriageway and footprint within the CMA. Consequently, additional effects of widening the existing footprint can be surmised to a certain extent from the effects on coastal physical processes that have occurred historically since the reclamation was constructed in the early 1950s and subsequently widened around 1959 (to separate westbound and eastbound traffic) with further bridge widening in the 1990s.

- Numerical-modelling approach. This approach was adopted to primarily assess the effects of sediment and stormwater discharges from SH20 activities (in Sectors 5–9). Modelling was also used to cross-check the conclusions from the expert opinion method for critical areas in Waterview Estuary and Oakley Inlet, focusing on the short sections of drainage channel that will require re-aligning (due to widening the Causeway), and the effect of additional piers on flows under the Whau River Bridges, (where the flow approaches the existing piers at a slight angle of 15–20°).

Experts and stakeholders from various organisations were involved in the expert opinion approach (viz. NIWA, Aurecon NZ Ltd., Green Group Ltd., the NZTA, Auckland Regional Council and Dept. of Conservation) while Tonkin & Taylor, with assistance from NIWA, carried out the numerical modelling component.

This assessment can be summarised by comparing the effects of the new works on physical coastal processes with the existing environment for three environmental areas of the Waitemata Harbour as described below.

- **The Whau River.** This is a sheltered tidal creek, currently used primarily for recreational boating and mooring. The original Whau River Bridge and associated abutments were constructed around 1952. The bed sediments are predominantly fine sand, though a high proportion of mud and silt is found where the river enters into the Central Waitemata Harbour. The river channel depth through the bridged section appears to be stable.

  New structures within the Whau River will include temporary piers (to support staging platforms for construction) and additional permanent bridge piers and widened abutments. Although the bridge pier groups are set at 15-20° to the tidal flow, the overall effect of these additional structures on hydrodynamics and general geomorphology of the river channel is expected to be no more than minor. This takes into account the effect of wakes, hydraulic backwater head differences, local scour, channel bank erosion and tidal flushing of the Whau River system. Discharges or seabed disturbances in this bridge area, using erosion and sediment control measures where feasible, are expected to have only minor effects on sediment processes and water appearance (after allowing for reasonable mixing).

  On the southern side of SH16 to the east of Rosebank Park Domain, a 125 m section of a relatively small (3-5 m wide) channel that drains into the Whau River, will be require infilling or permanent occupation of the CMA for ground treatment. The channel will be allowed to naturally migrate laterally and reform a channel on the outside of the ground-treatment works. To this end, the infilling works need to be carried out in successive stages to provide sufficient response time for the channel to migrate laterally. Also, mangroves and their rooting systems will need to be removed (excavated) on the southern side of the existing channel to allow erosion processes to operate more freely on the southern flank of the channel. With these measures in place, the effects on drainage patterns and sediment processes will be no more than minor, but the migration of the channel should be monitored regularly to ensure drainage of the intertidal flats is not impeded.

- **The Central Waitemata Harbour (north of SH16 Causeway).** Coastal fringes of the Harbour have been extensively modified as Auckland has developed, including the SH16 Causeway constructed in the early 1950s. The seabed material generally consists of sand with a higher proportion of fine grained sediments (muds and silts) typically found along the intertidal and sheltered embayment areas of the Harbour. The CMA surrounding Pollen Island on the northern (seaward) side of the Causeway is largely unmodified. The main drainage channel that services the extensive wetland behind Pollen Island plays a key hydraulic control of drainage and inundation in the wetland. The upper intertidal morphology and associated chenier (shell) ridges also appear to have been relatively stable throughout the last 60 years, although the upper-tidal beach along the Causeway to the west of the Causeway Bridges has been controlled to some extent by groynes placed during the original construction. .Chenier ridges also occur offshore (to the north of the Causeway), with the western group having migrated shorewards, but do not appear to have been directly affected by the introduction of the Causeway (based on 1959 and 2001 aerial photographs).

  No new structures will be located within this water body, with the Patiki Road Off-ramp and Rosebank Road On-ramp structures in the CMA remaining as they are. The proposed widened reclamation is not expected to change the flow regime of this environment, particularly as most of the reclamation works have either avoided the CMA (e.g., the design includes vertical retaining walls to avoid encroachment of the main Pollen Island drainage channel) or are located on upper-intertidal areas that are only inundated around high tide periods. The reclamations to widen the Causeway will cause minor adjustments to the upper-intertidal geomorphology, particularly along the wave-exposed northern toe-line, which will occur over periods of months as waves and tides re-work seabed sediments into a re-adjusted morphology. Small areas of chenier (shell) deposits would have been buried by the widened reclamation. However remediation can be achieved by excavating these shell deposits, stockpiling them and subsequently re-positioning them in the same area after the reclamation has been widened, to allow waves to re-form the chenier ridges and re-attach them to the unmodified ridge deposits.

- **The Waterview Estuary and Oakley Inlet (up to where Oakley Creek enters the CMA).** This estuarine system has been substantially modified by catchment land-use changes and the construction of the original Causeway. Catchment run-off has lead to an accumulation of muddy sediments since land clearing or urban development commenced. Decades of industrial activity and a long history of poor environmental practices have also resulted in degradation in water quality within the Estuary. The construction of the Causeway in 1952-53 also had a significant effect on the flow dynamics of the two previously separate inlet systems, including the scouring of the outlet channel under the Causeway Bridges. However the outlet from Waterview Estuary has been relatively stable since the mid to late 1970s. The existence of the Causeway will continue to exacerbate sedimentation in Waterview Estuary arising from catchment run-off and sediment inputs from Central Waitemata Harbour. Due to the short wind fetches within the Estuary and protection of the Causeway from northerly wind fetches, the Estuary is a low wave energy environment.

  Structures within this area will include temporary piers (to support staging platforms) and additional permanent bridge piers (including the cycleway bridge) and widened bridge abutments. These will cause no more than minor changes to the flow regime when compared to the existing environment. This takes into account the effect of wakes, hydraulic backwater head differences, and tidal flushing of the Waterview Estuary and Oakley Inlet system. The widened Causeway Bridge abutments to the south may cause minor erosion on the flanking banks and channel depth in the shortened confluence area, where channels from Waterview Estuary and Oakley Inlet converge. Mitigation of these effects have been incorporated into the design of the widened Causeway, by paring back the bridge abutments under the cycleway and introducing additional piers for the cycleway bridge, to provide a smoother flow transition in the confluence area.

  Discharges or seabed disturbances in along the Causeway and bridge abutment works, using erosion and sediment control measures where feasible, are expected to only have minor effects on sediment processes and water appearance (after allowing for reasonable mixing). Discharges into the CMA also include discharges of sediments sourced from works and activities in the Oakley Creek catchment. Several discharge scenarios for the Oakley Creek works were undertaken for different storm recurrence intervals and degree of erosion and sediment control. Given the model results and the existing background water quality (including turbidity within the Waterview Estuary), the potential physical effects of sediment discharges on Waterview Estuary and Oakley Inlet are assessed as no more than minor. Seabed disturbances within this area include construction works associated with widening the Causeway (including ground treatment), building new piers (Oakley Inlet) and reclamations. The managed excavation of three separate channel re-alignments have been included in the proposed works to mitigate potential hydrodynamic and geomorphological effects of the existing channels being infilled by reclamations or ground treatments to widen the Causeway. With these channel re-alignment options included, the long-term effects on coastal physical processes from temporary or permanent occupation of the CMA are also assessed as no more than minor.

In summary, the coastal marine area has been substantially modified by the construction of the original Causeway in the early 1950s and, to a much lesser extent, the protruding abutments for the original Whau River Bridge. The Causeway was widened further in 1959 and additional bridge widening took place in the 1990s. The new works proposed for SH16 between the Great North Road Interchange and Te Atatu are further lateral extensions of the existing footprint into the CMA.

As a result of the lengthy assessment process, some mitigation or avoidance measures for potentially adverse effects have already been incorporated into revisions of the engineering design and construction plans. With these measures included in the proposed design and other mitigation measures or remediation included (as outlined in this Report), the short- and long-term effects of the new works on coastal physical processes in the three coastal environment areas have been assessed as either **minor** or **no more than minor**.

1. Introduction

In 2009 the New Zealand Transport Agency (NZTA) confirmed its intention that the 'Waterview Connection Project' (the Project) would be lodged with the Environmental Protection Authority (EPA) as a Proposal of National Significance. The key elements of the Project are:

- Completing the Western Ring Route (WRR) (which extends from Manukau to Albany via Waitakere)
- Improving resilience of the SH16 Causeway between the Great North Road and Rosebank Road Interchanges to correct historic subsidence and "future proof" it against sea level rise
- Providing increased capacity on the SH16 corridor (between the St Lukes and Te Atatu Interchanges);
- Providing a new section of SH20 (through a combination of surface and tunnelled road) between the Great North Road and Maioro Street Interchanges
- Providing a cycleway throughout the surface road elements of the Project corridor.

1.1 Report purpose

The purpose of this report is to provide an assessment of the effects the Project may have on existing coastal physical processes within the Coastal Marine Area (CMA). Of primary consideration in this report are:

- Hydrodynamic processes e.g., flows, water levels, drainage patterns, navigation
- Sediment transport and deposition processes e.g., sediment pathways, sedimentation, erosion/scour, suspended-sediment plumes
- Geomorphology — changes in characteristic features and morphology of the seabed in the coastal zone, which are the product of hydrodynamic and sediment processes e.g. changes in the form of intertidal banks and channels.

Where this assessment identifies potential adverse effects that are more than minor, the report suggests various measures that have already, or could be, implemented to avoid, remedy or mitigate these effects. As a result of the assessment process, some avoidance measures have already been incorporated into the final engineering design. The report also identifies where remediation or mitigation measures should be monitored to ensure the effects are no more than minor.

1.2 Description of Project

The Project includes widening the existing motorway footprint of SH16 between a tidal tributary of Henderson Creek (Pixie Inlet) to the west and Great North Road Interchange to the east. The majority of these SH16 works are directly adjacent to the CMA. In particular, this section of the CMA also includes the Motu Manawa (Pollen Island) Marine Reserve. Figure 1.1 illustrates the parts of the coastal environment relevant to the Project.

The Project also includes construction of a new section of SH20, from the Maioro Street Interchange to the Great North Road Interchange (see Figure 1.2). These works approximately follow the route of Oakley Creek. The works have potential to discharge sediment and contaminants into Oakley Creek, which would then discharge into the CMA through the Oakley Inlet.

1.3 Description of report

This Assessment of Coastal Processes report documents the environmental assessment of potential physical effects on the coastal environment associated with the proposed construction activities and the long term operation of the Project. An overall description of the Project is provided in the AEE report.

This report also cross references other assessments contained within Part G of the AEE. The main assessment reports referred to are:

- Assessment of Marine Ecological Effects (G.11).
- Assessment of Stormwater and Streamworks Effects (G.15)
- Erosion and Sediment Control Plan (ESCP) (G.22)
- Coastal Works Report (G.23)
- Associated Sediment and Contaminant Calculation Report (G. 30)

This report documents the investigations undertaken to ascertain the range of potential effects on the coastal environment (Section 2, Methodology). Section 3 then assesses the existing coastal environment, including the existing Causeway and SH16 footprint. The assessment of potential effects of the Project on coastal physical processes is then discussed in Section 4 for various activities in each of three environment areas (see Figure 1.3). These potential effects are separated into construction activities and long-term operational effects. Mitigation or remedial options, where appropriate, are also presented in Section 4. Section 5 covers the conclusions.

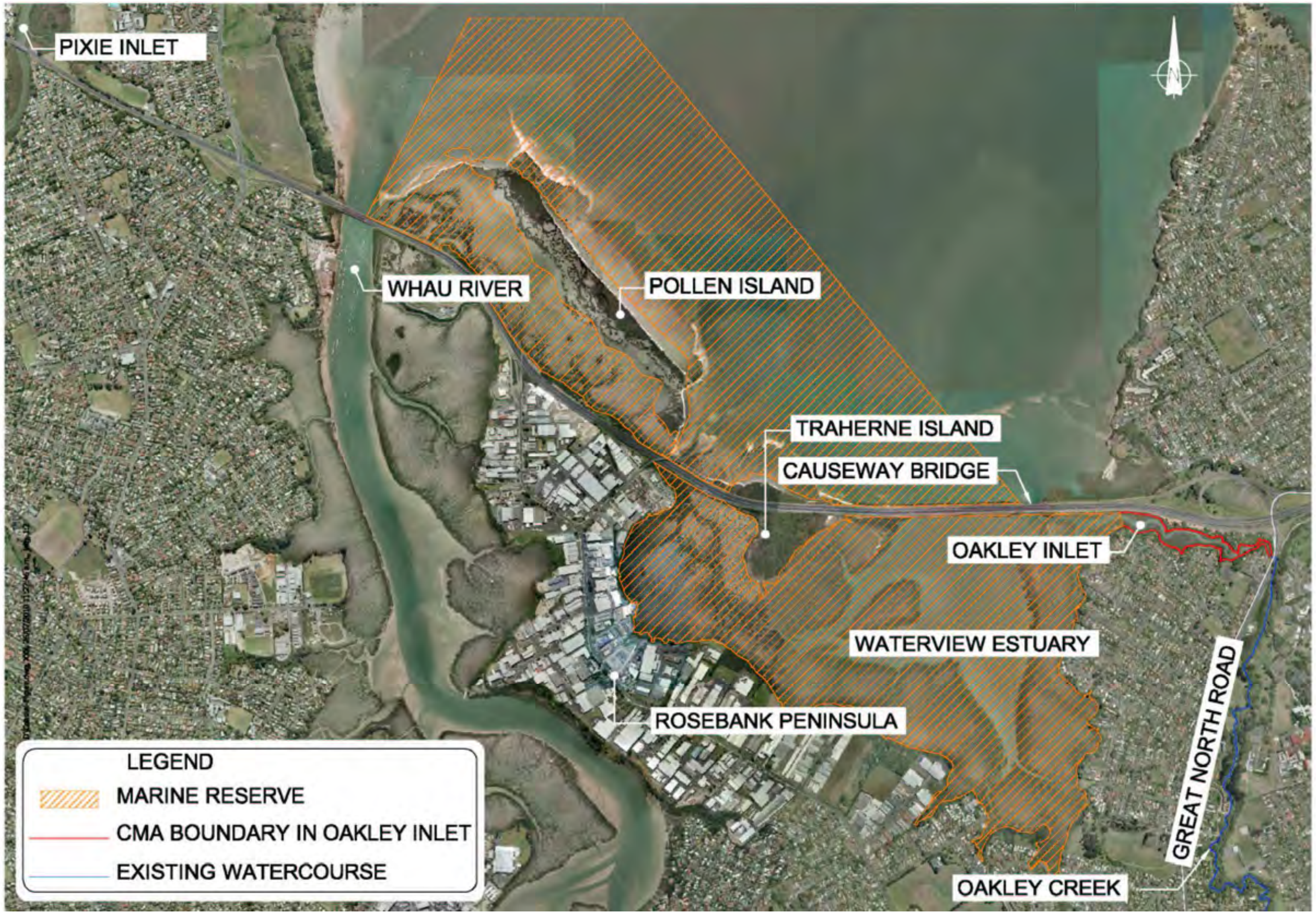

Figure 1.1: The coastal environment relevant to the Project. The hatched area shows the Motu Manawa Marine Reserve

Figure 1.2: Sectors making up the Waterview Connection Project

Figure 1.3: Environmental areas used in this Report

1.4 Project sectors relevant to coastal processes

The Project has been divided into Sectors for consistency across the technical and engineering reports. These Project Sectors are shown in Figure 1.2. Proposed works in the following Project Sectors may result in potential changes to coastal processes within the Waterview Estuary, Oakley Inlet, Whau River and Central Waitemata Harbour:

- Sector 1: Te Atatu Interchange
- Sector 2: Whau River
- Sector 3: Rosebank - Terrestrial
- Sector 4: Reclamation
- Sector 5: Great North Road Interchange.

In addition to the Project Sectors, the coastal environment relevant to the Project can be conveniently divided into three separate environment areas (Figure 1.3). These are:

- Whau River (including Pixie Inlet, which is a side inlet of Henderson Creek)
- Central Waitemata Harbour
- Waterview Estuary (which includes Oakley Inlet).

Proposed land-based works within Project Sectors 1 and 3 could lead to sediment and stormwater discharges to the Whau River area. In Sectors 2, 4 and parts of 3 and 5, a wider range of activities could affect the CMA in the Whau River area, the Central Waitemata Harbour and the Waterview Estuary. These include physical disturbances, reclamation, structures (temporary and permanent), and sediment and stormwater discharges arising from widening existing reclamations, abutments, bridges and off/on-ramps. In Sector 5, freshwater from Oakley Creek enters the CMA through Oakley Inlet, which is thus the discharge point of sediment and contaminants from terrestrial-based SH20 works within Sectors 7, 8 and 9.

2. Methodology

The assessment of coastal effects for the Project has been undertaken through a series of investigations commencing in December 2008 through to May 2010. These investigations used a range of approaches that were commensurate with the degree of certainty about the likely level of impacts. In particular the two main approaches used were:

- Expert opinion approach. This included an appraisal of existing data and aerial photography, hydrographic surveys, a field reconnaissance with stakeholders, a workshop, conservative calculations for worst-case situations and applying intuitive professional judgements by a team of experienced coastal scientists and engineers. This phase of the investigations was undertaken by NIWA between December 2008 and November 2009 working closely with the engineering team from Aurecon NZ Ltd. through various design iterations. The expert opinion assessment involving NIWA and stakeholders was originally accepted by the ARC (before the SH20 sectors were added) as an appropriate approach for the SH16 upgrade from Great North Road Interchange to Whau River Bridges, given most of the works involved widening the existing footprint.

- Numerical-modelling approach. Numerical modelling was undertaken by Tonkin & Taylor to simulate discharges from Oakley Creek resulting from SH20 works (Sector 5 and beyond) using a computer model. The same model was also used to cross-check assessments from the expert opinion approach for critical works relating to the encroachment of the wider SH16 footprint into adjacent drainage channels and flow through bridge piers.

Experts and stakeholders from various organisations were involved in the expert opinion approach to SH16 effects (viz. NIWA, Aurecon NZ Ltd., Green Group Ltd., the NZTA, ARC and DoC). Tonkin & Taylor, with model set-up assistance from NIWA, carried out the numerical modelling component.

2.1 Coordinate system and vertical datum

Within this Technical Report, all geographical coordinates are given in New Zealand Transverse Mercator 2000 (NZTM) projection and reduced-level (RL) vertical elevations are relative to Auckland Vertical Datum–1946 (AVD-46). The Port of Auckland Chart Datum is 1.743 m below AVD–46 and the current mean level of the sea is ~0.13 m above AVD–46. The Mean High Water Spring (MHWS) elevation for Sectors 2-5 is taken to be 1.63 m above AVD–46 (compared with 1.56 m above AVD–46 at the Port of Auckland[1]) and was used to define the landward edge of the CMA.

[1] Based on the 18.6–year MHWS for cadastral purposes at URL: http://www.linz.govt.nz/geodetic/datums-projections-heights/vertical-datums/tidal-level-information-for-surveyors/index.aspx

2.2 Categorising assessment of effects

The assessment of effects on coastal physical processes is examined as a consequence of:

- specific **construction** activities within the proposed works
- **long-term** effects arising from the new or widened footprint or structures and / or **operational** aspects of the Project.

The proposed construction activities or ongoing effects from operations are reported in Sector sequence, starting from Project Sector 1 (Te Atatu Interchange) and moving east to Sector 5 (Great North Road Interchange).

The effects of the various activities may not be limited to the sector in which the work activity is undertaken. In general the effects on coastal processes were identified as potentially affecting the three environment areas shown in Figure 1.3.

Activities that potentially affect the CMA have been broadly categorised into:

- **Structures** (both temporary and permanent) focusing on the effects on geomorphology, alteration of water-flow patterns and consideration of the effects of extreme water levels and climate change
- **Reclamations** (both temporary and permanent) focusing on the effects on geomorphology (including long-term erosion or sedimentation) and water-flow patterns
- **Disturbances** of the seabed or foreshore during construction activities and the effects of sediment discharges and seabed excavations
- **Discharges** directly or indirectly to the CMA from foreshore disturbances, terrestrial earthworks activities and storm run-off during construction and the physical effects of operational stormwater discharges.

2.3 Risk assessment study

In November 2009, the SH16 and SH20 projects were combined into the current Project. A risk assessment study was undertaken in late 2009 to determine the type and scale of assessment required for the combined project. This was used to describe potential effects on coastal physical processes and to support the assessment of ecological effects. This risk scoping exercise was lead by T&T with input from Beca, Green Group Ltd, NIWA, Aurecon NZ Ltd., Boffa Miskell and the NZTA.

As part of the risk assessment study, estimates were made of sediment and contaminant loads that may potentially be released into the Oakley Inlet, Waterview Estuary and Central Waitemata Harbour from Oakley Creek. These loads were calculated for the existing situation and both the construction and operational phases of the Project. The following data sources were used in the risk scoping exercise:

- ARC marine sediment monitoring programme (Reed & Gadd, 2009)
- ARC stormwater contaminant monitoring programme (Kelly, 2007)
- Contaminant accumulation in the Central Waitemata Harbour (Swales et al., 2008)
- G.11 Assessment of Marine Ecological Effects report
- Datasets and findings on ecological effects from earlier Bioresearches investigations on SH16 from Great North Road Interchange to the Whau River Bridges (2008–2009)
- Datasets and findings on environmental physical effects from an earlier NIWA investigation on SH16 from Great North Road Interchange to the Whau River Bridges (2008–2009).

The risk assessment study culminated in a Project team workshop held on 9 December 2009 to address the question:

> *"Are the proposed works likely to make a significant change to the amount of sediment/contaminants entering the CMA through Oakley Creek?"*

The outcome of the workshop was:

> "*The Waterview Estuary is currently 'highly contaminated', with high proportions of fine sediments and a low ecological biodiversity over most of the region of interest. However, the proposed works do have the potential to increase the amount of sediments and contaminants entering the CMA and thus a coastal model should be used to assess potential sediment transport*".

Thus it was decided to construct a computation model of the Central Waitemata Harbour and Waterview Estuary. The primary purpose of this model was to determine potential sediment deposition within the Waterview Estuary for contaminated sediment entering the CMA from Oakley Creek. Having established the model, it was also considered prudent to use this model to cross-check some of the assessments of the SH16 effects undertaken by NIWA and also to provide some input to the final engineering designs.

2.4 Assessment of wider SH16 footprint and associated works

A expert opinion assessment of potential physical effects of the wider SH16 footprint was conducted by NIWA. The chronological sequencing of each stage of the assessment is outlined below, followed by further details on the information and data that was used in the assessment.

Stages for SH16 assessment of effects

The assessment of potential physical effects for the Sectors 1–4 was carried out in several stages as follows:

- Field surveys in December 2008 and January 2009 to measure the seabed bathymetry in the main channels of Waterview Estuary and the Whau River in and around the Whau River Bridges[2]. Surficial sediment samples (5) were also collected from both areas to determine grain size distributions.

- An appraisal of existing data, information and photographs (oblique and aerial), drawing on the extensive experience on the estuarine sedimentary systems within Waitemata Harbour that NIWA scientists and coastal engineers have accumulated over the last 20-30 years.

- A field reconnaissance of Sectors 2–4 with key stakeholders and practitioners. This was undertaken between 1030 and 1530 h (NZDT) on Friday 27 February 2009, with representatives from Aurecon NZ Ltd., NIWA, Green Group Ltd., the NZTA, DoC and the ARC (represented by their consultant, Dr Shane Kelly).

- A workshop involving NIWA and Aurecon NZ Ltd. to isolate potential effects of the upgraded and wider motorway footprint, and to discuss potential mitigation options, including design changes. This was held at Aurecon offices on Monday 1 March 2009.

- A follow-up meeting with the ARC and the NZTA where preliminary findings from the field reconnaissance and workshop were discussed.

- A project teleconference between Aurecon and NIWA staff to discuss potential physical effects and mitigation options in preparation for the next ARC consultation meeting.

- Subsequent consultation meetings (March/April 2009) between ARC, Aurecon and the Green Group Ltd to discuss the preliminary findings from the NIWA assessment of effects.

- Channel encroachments from the widened Causeway at particular pinch-points were extensively discussed between Aurecon, Green Group and NIWA. Consequently, Aurecon surveyors conducted channel cross-section surveys of the main encroachments in Oakley Inlet (that drains Oakley Creek) and the northern drainage channel of Waterview Estuary along the southern side of the Causeway. This field work was undertaken in late May 2009, and various causeway widening options and revetment and retaining-wall designs were analysed and assessed through to September 2009.

- A synthesis of the likely effects and their significance from these steps is reported in Section 4 of this report.

[2] Further bathymetry data was collected in Waterview Estuary and Inlet to construct the computational model. A description of all the available bathymetric data currently available is presented in Section 2.5.

Existing data and information used

Existing data used included results from:

- Published papers (Hume, 1991; Hume & Herdendorf, 1993)
- Heavy metal analyses for sediments in Waterview Estuary from a 2003 field programme (NIWA research database) and routine sediment monitoring of a network of Waitemata Harbour sites by the ARC (e.g. Reed & Webster, 2004 and Reed & Gadd, 2009)
- Sedimentation and sediment characteristics of the Central Waitemata Harbour from a study by NIWA commissioned by ARC (Swales et al., 2008)
- Engineering drawings for the previous widening of the Whau Bridge (Ministry of Works and Development, 1987, 1989 obtained from Aurecon NZ Ltd.)
- Aerial photography flown in February 2006 (obtained from Aurecon NZ Ltd.) and historic aerial photography flown in 1940 (prior to SH16), 1959 and 2001, used with permission from the ARC.

Extensive field notes and photographs were collected during the field reconnaissance and synthesized in a project workshop. Bathymetric contour maps and channel transects near the existing bridge sites (Whau River and Causeway Bridges) were derived from the 2008/09 hydrographic surveys, and in the case of the Causeway Bridges compared with available historic cross sections. The sequence of historic aerial photographs was used to determine any macro changes in the geomorphology since the Causeway was constructed.

Expert knowledge and local experience of the Harbour environment were then used to identify potential issues and physical effects of the proposed works in Sectors 2 to 4. This expert opinion process formed the basis for determining the potential physical effects on the CMA, their significance, and if more than minor, appropriate mitigation options for Sectors 2 and 4. These options are discussed under various types of activities for both construction and operational phases of the Project in Section 4 of this report.

For activities which may have a significant effect, or the effect could only be assessed with a large degree of uncertainty, the numerical model approach was used to cross-check the findings from the expert opinion approach. Specifically, this included the effects of seabed disturbance and sediment discharges arising from channel re-alignment works, where the widened footprint would encroach on an adjacent section of a major drainage channel, and sediment/stormwater discharges from earthworks associated with the Causeway widening.

2.5 Coastal model-based assessment

A computational model of the Whau River, Central Waitemata Harbour and Waterview Estuary was constructed using the MIKE 21 FM coastal model. This computational model suite is commercially available through DHI

Water & Environment Ltd.[3] and is an industry accepted model for simulating coastal and inland flows. It has previously been successfully applied to several coastal areas of New Zealand, including the Waitemata Harbour.

The computational model covers the three Environmental Areas relevant to the Project. These are the Whau River, the Central Waitemata Harbour (from the Auckland Harbour Bridge in the east to the Upper Harbour Bridge in the north) and the Waterview Estuary including Oakley Inlet. The model bathymetry was obtained from the existing calibrated MIKE 21 ‘Regional Harbour Model’ (RHM) of the complete Waitemata Harbour and inner Hauraki Gulf. In the Waterview Estuary, Oakley Inlet and Whau River areas, the RHM bathymetry was supplemented by additional boat surveys, LiDAR and aerial photographs. These data sources were combined to generate the computational grid shown in Figure 2.1and Figure 2.2.

A hydrodynamic module was used simulate the flow currents and water levels throughout the model. In order to assess the potential movement of sediments released into the CMA from either the construction or operational phases of the Project, a sediment transport module was used. Both the hydrodynamic module and the sediment transport module are described in detail in **Appendix A**.

An additional fine-scale hydrodynamic model was also generated for the local region of the Whau River Bridges. This model used small rectangular grid cells (0.3 m x 0.3 m) and was used solely to analyse the flow patterns and hydraulic head differences through proposed bridge piers.

2.5.1 Sediment released into the CMA via Oakley Creek

The objective of these simulations was to predict suspended sediment concentrations and sediment deposition resulting from a sediment-discharge source emanating from Oakley Creek into Oakley Inlet and beyond (see Figure 1.1). The sediment source, placed adjacent to Great North Road, represents the combined sediment (and contaminant) inputs from along the Oakley Creek catchment due to proposed works over the length of SH20 in Sectors 7–9. During construction, disturbed sediment from the works will pass through sediment treatment according to ARC TP90 guidelines before entering Oakley Creek. During the operational phase, stormwater will be treated according to ARC TP10 (ARC 2003) guidelines before entering Oakley Creek. Details on this can be found in G.15 Assessment of Stormwater and Streamworks Effects. The remaining sediment is transported by freshwater and tidal flows within the Creek and the narrow Oakley Inlet. The sediment will then be dispersed within the Waterview Estuary, some leaving through the channel under the Causeway Bridges to enter the Central Waitemata Harbour (and possibly return on the next flood tide). Eventually all sediment particles will sink to the seabed, and in some cases remain on the seabed, particularly in low energy areas.

Sediment loads used as input to the sediment transport module were obtained from the method detailed in **Appendix B**. This methodology uses outputs from catchment models as reported in G.30 Associated Sediment and Contaminant Calculation Report, for the ‘existing’, ‘construction’ and ‘operational’ scenarios. Details of the computational simulations and results are presented in **Appendix B**. The results are utilized in Section 4 to assess the effects of the Project on coastal processes. The results are also used in G 11 Assessment of Marine Ecological Effects report.

[3] See http://www.mikebydhi.com/Products/CoastAndSea/MIKE21.aspx

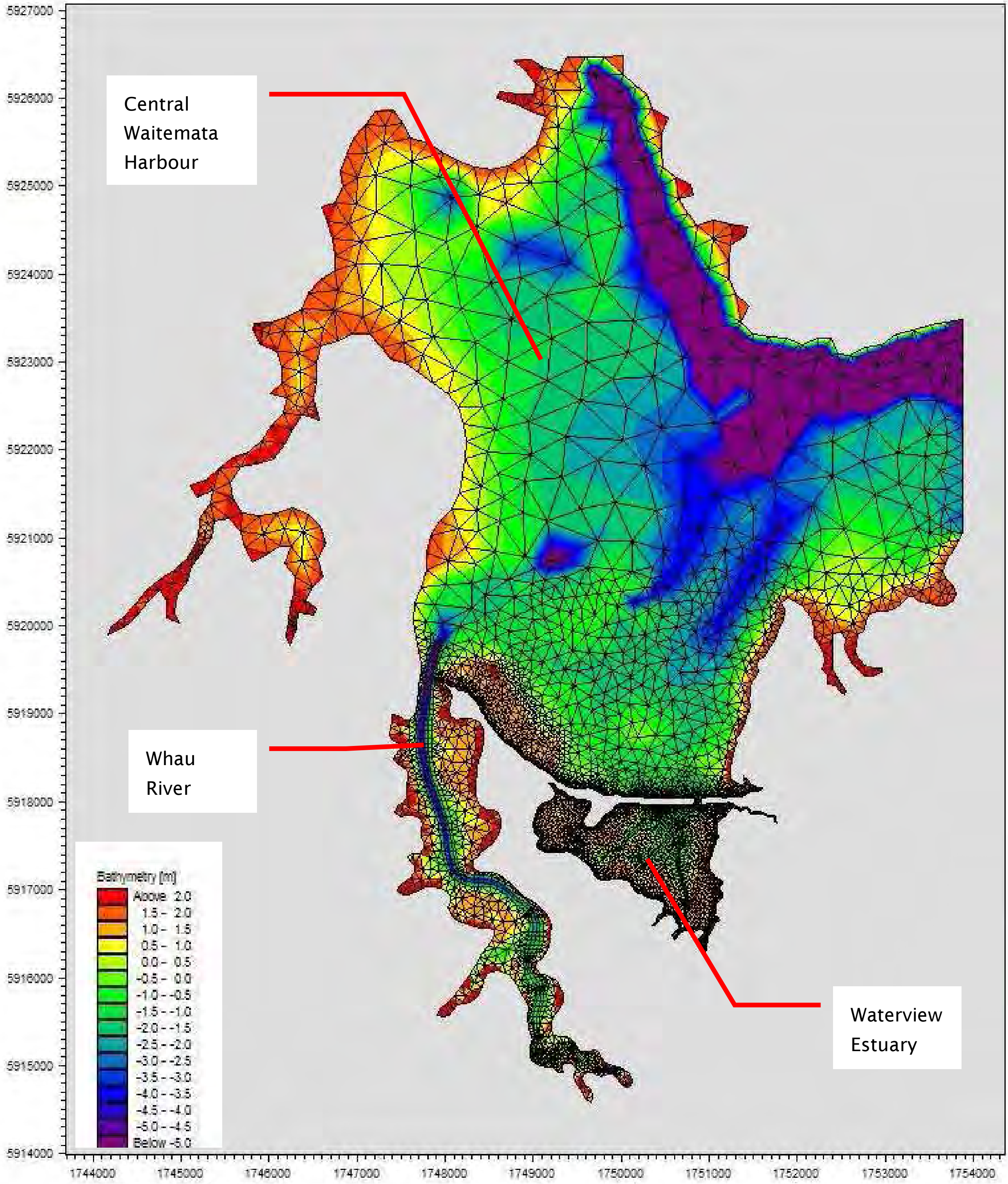

Figure 2.1: Model bathymetry (AVD-46) and computational grid of Central Waitemata Harbour

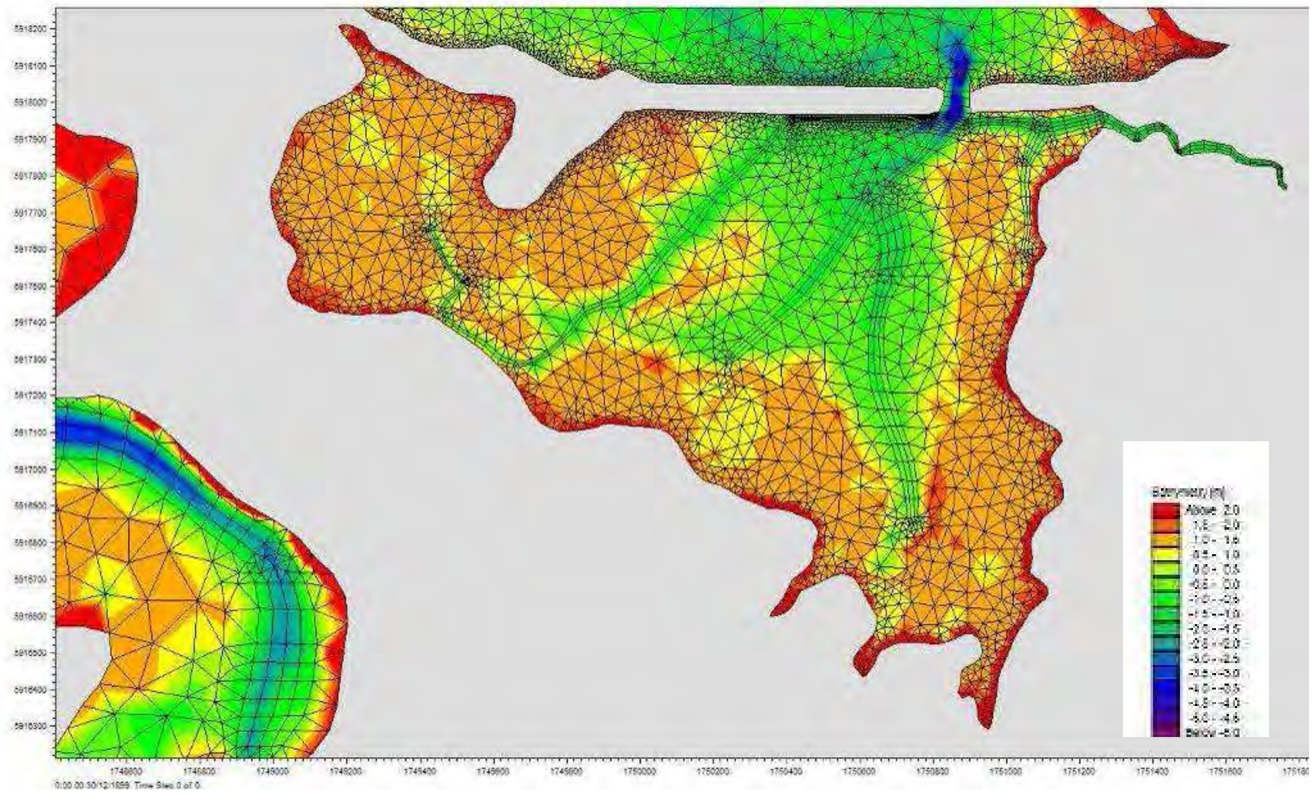

Figure 2.2: Magnified view of bathymetry (m; AVD-46) and model grid for Waterview Estuary, Oakley Inlet (to right) and Whau River (to left).

2.5.2 Sediment-disturbance discharges from channel re-alignments

The objective of these simulations was to cross-check conservative expert opinion assessments made by NIWA. Specifically, the potential suspended sediment concentration and sediment deposition arising from excavation of sections of re-aligned drainage channels (adjacent to the Causeway), was assessed using the mud-transport model of MIKE21. These sections of channel occur where the widened Causeway will intersect with the channel where it pinches in close to the toe of the existing Causeway (Figure 2.3). The three sites where local re-alignment of the drainage channel will be required are: a) in Waterview Estuary around the mid section of the Causeway (location XC), and b) two channel meander bends in Oakley Inlet (locations XA and XB).

The details of this modelling and results are presented **in Appendix C**. These results are used in Section 4 to assess the effects of the channel re-alignment works. The model results are also used within the AEE report G.11 (Assessment of Marine Ecological Effects).

Figure 2.3: Locations of suspended sediment sources arising from channel re-alignment works that were used in the computational model simulations. [*Image source: ARC*]

3. Existing environment

As discussed above in Section 1.4, the existing coastal environment assessed in this document is described in terms of three environment areas of the Waitemata Harbour CMA (Figure 1.3):

1. Whau River including Pixie Inlet (sheltered tidal creek).

2. Central Waitemata Harbour (exposed northern side of SH16 Causeway)

3. Waterview Estuary and Oakley Inlet up to where Oakley Creek enters the CMA (sheltered estuarine environment)

Much of these areas are within a Coastal Protection Area (CPA) 1 (the Motu Manawa Marine Reserve, see Figure 1.1) described as a significant area of saltmarsh, mangroves, shellbanks, and estuarine and harbour mud flats that supports significant wading bird roosts. The Whau River upstream of the Whau River Bridges is within a CPA 2, also due to its saline vegetation and wading bird habitat.

Part of the Project in Sector 1 also borders a side inlet to Henderson Creek (Pixie Inlet), where a stormwater treatment pond is to be located adjacent to the CMA. Henderson Creek is classified as CPA 2.

The implications of the CPA classifications are discussed in the Assessment of Marine Ecological Effects report (G.11).

3.1 Whau River

3.1.1 Built environment

The original embankments and first Whau River Bridge were constructed around 1952 with a combined span of 183 m across the Whau River. In 1959–60, a second bridge was added to the south side of the original bridge, separating the eastbound and westbound traffic[4]. The Whau River Bridges were widened on both sides in 1990–91 (as evident from design drawings and as-built drawings by the Ministry of Works and Development).

The existing pier groups on the southern side of the bridges are oriented at around 20° to the channel thalweg (defined as the line of maximum depth) while on the northern side of the bridges, the alignment is closer (~15°) to the flow orientation as the channel curves eastward under the Bridges. The ends of the abutments are also at the same orientation as the pier groups.

[4] Personal communication with Andrew Hale, Senior Engineer, Aurecon NZ Ltd., 2 March, 2009

3.1.2 Geomorphology and hydrodynamics

A bathymetric survey of the Whau River channel in the vicinity of the bridges was undertaken on 21 January 2009 by NIWA. Contoured soundings for the channel south of the Whau River Bridges are shown in Figure 3.1. In the channel thalweg, depths below the datum exceed 5 m. A cross-section of the channel adjacent to the southern side of the Whau River Bridges is shown in Figure 3.2 relative to an assumed origin on the west side. The maximum depth below AVD-46 datum is 5.84 m. There is a bias of the deepest section of the channel being more towards the western side, with more of a shoal on the eastern side (Figure 3.2). Hume (1991) gives a maximum depth of 6.7 m below mean-tide-level, which is approximately 6.6 m below the AVD–46 datum. This probably was measured on the northern side of the bridges, indicating the channel is marginally deeper on the northern side.

The cross-sectional area of the flow under the Whau River Bridges reported by Hume (1991) was 625 m^2 below mean-tide level (which is ~ 0.1 m above AVD-46). Based on the recent surveyed transect in Figure 3.2, the calculated flow area on the south side of the Bridge is 600 m^2 below mean-tide level. After allowing for a slightly deeper channel on the north side, this comparison of cross-sectional areas indicates the channel cross-section has remained reasonably stable over the last 20 years.

Based on previous flow gaugings, Hume (1991) determined the peak spring-tide velocity, averaged over the cross-section in the Whau channel adjacent to the bridges, to be around 0.87 m/s (1.7 knots).

Figure 3.1: Bathymetry of the Whau River section south of the present SH16 Whau River Bridge (in metres relative to AVD-46) gridded from hydrographic survey data measured on 21 Jan 2009. [Source: bathymetry (NIWA), aerial photography from 2002 (LINZ, MapToaster)]

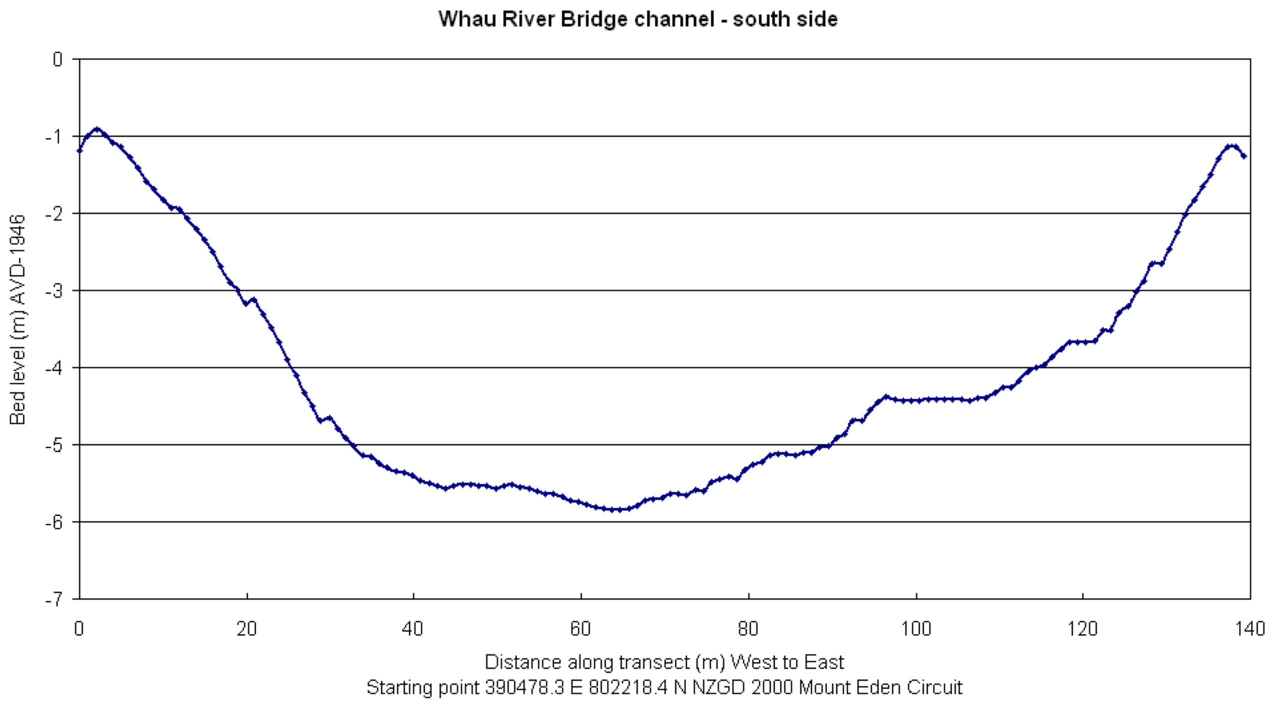

Figure 3.2: West-to-east cross-section of Whau River channel on the south side of the existing Whau River Bridges, relative to an assumed horizontal origin. [Source: NIWA]

From comparing historical aerial photographs (Figure 3.3 to Figure 3.6), there appears to be two observable geomorphology changes since the original bridge was built. Comparison of Figure 3.4 (1959) and Figure 3.5 (2001) shows siltation has occurred behind and in front of the Whau River Bridge abutments, and mangroves have become established in the accreted sediments. Also, the accreted channel bank on the north-eastern side of the Whau River Bridges is somewhat indented at the confluence of the side channel from the east that drains the wetland behind Pollen Island. This localised indentation may have been influenced by ebb-tide flows on the eastern side of the Whau River being re-aligned more towards the shore by the pier-group alignment at 15–20° to the main channel axis. Note that this series of photographs were taken at different stages of the tide and this needs to be taken into account when considering the position of the shoreline.

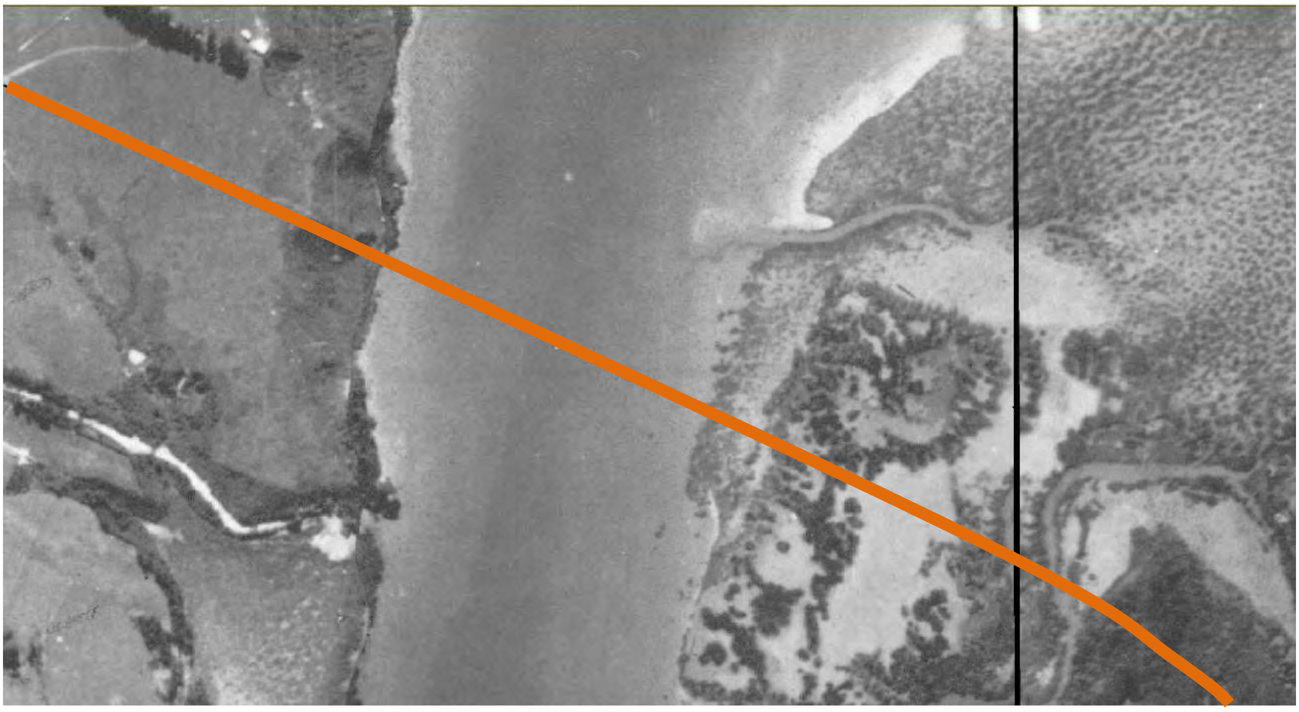

Figure 3.3: 1940 aerial photograph of Whau River entrance. Overlaid is the route of the present day road. The vertical black line is the stitch-line between two adjacent photographs and can be ignored. [Source: ARC]

Figure 3.4: 1959 aerial photograph of Whau River entrance. The original single Whau River Bridge is shown. Note: protrusion of the west and east abutments. [Source: ARC]

Figure 3.5: 2001 aerial photograph of Whau River entrance. [Source: ARC]

Figure 3.6 : 2009 aerial photograph of Whau River entrance. [Source: ARC]

3.1.3 Sediments

Sediment characteristics in the Whau River system have been measured by Swales et al. (2008) (see Figure 3.8) and at sites routinely sampled as part of the ARC Marine Sediment Monitoring Programme (see Figure 3.7). At the entrance to the Whau River, Swales et al. (2008) reported 32% and 64% mud content. A similar mud content was found further upstream ("Whau Lower"), with increasing grain sizes found in the upper reaches of the Whau River (see Table 3.1).

The high mud contents in the lower reaches and the mouth of the Whau River suggest these intertidal banks are a low-energy environment and an area of ultimate deposition for fine sediments. The sub-tidal channel however appears to be stable.

Table 3.1: Percent contributions of each particle size fraction by % volume (0 – 300 μm) from ARC Marine Sediment Monitoring Programme[5]

	Clay	Very Fine Silt	Fine Silt	Medium Silt	Coarse Silt	Very Fine Sand	Fine Sand	Median Sand	Mud < 63 μm (%)
Size Range (μm)	0 – 3.9	3.9–7.8	7.8–15.6	15.6–31.3	31.3–62.5	62.5–125	125–250	250–300	
Whau Lower									
2005	1.5	2.2	5.3	11.9	40.3	37.8	0.9	0.0	**61**
2007	3	3	5	6	15	45	24	0	**31**
Whau Wairau									
2005	0.4	0.6	1.4	2.3	9.7	39.5	46.3	0.0	**14**
2007	2	1	3	5	15	38	37	0	**25**
Whau Upper									
2005	0.3	0.4	1.25	1.8	8.3	42.6	45.5	0.0	**12**
2007	1	1	1	2	9	40	46	0	**14**

Note 1: Data given as mean values of three replicates

Note 2: No data obtained for the Whau Entrance sampling as shown in Figure 3.7.

[5] 2005 values are from McHugh & Reed (2006) and 2007 values are from Reed & Gadd (2009)

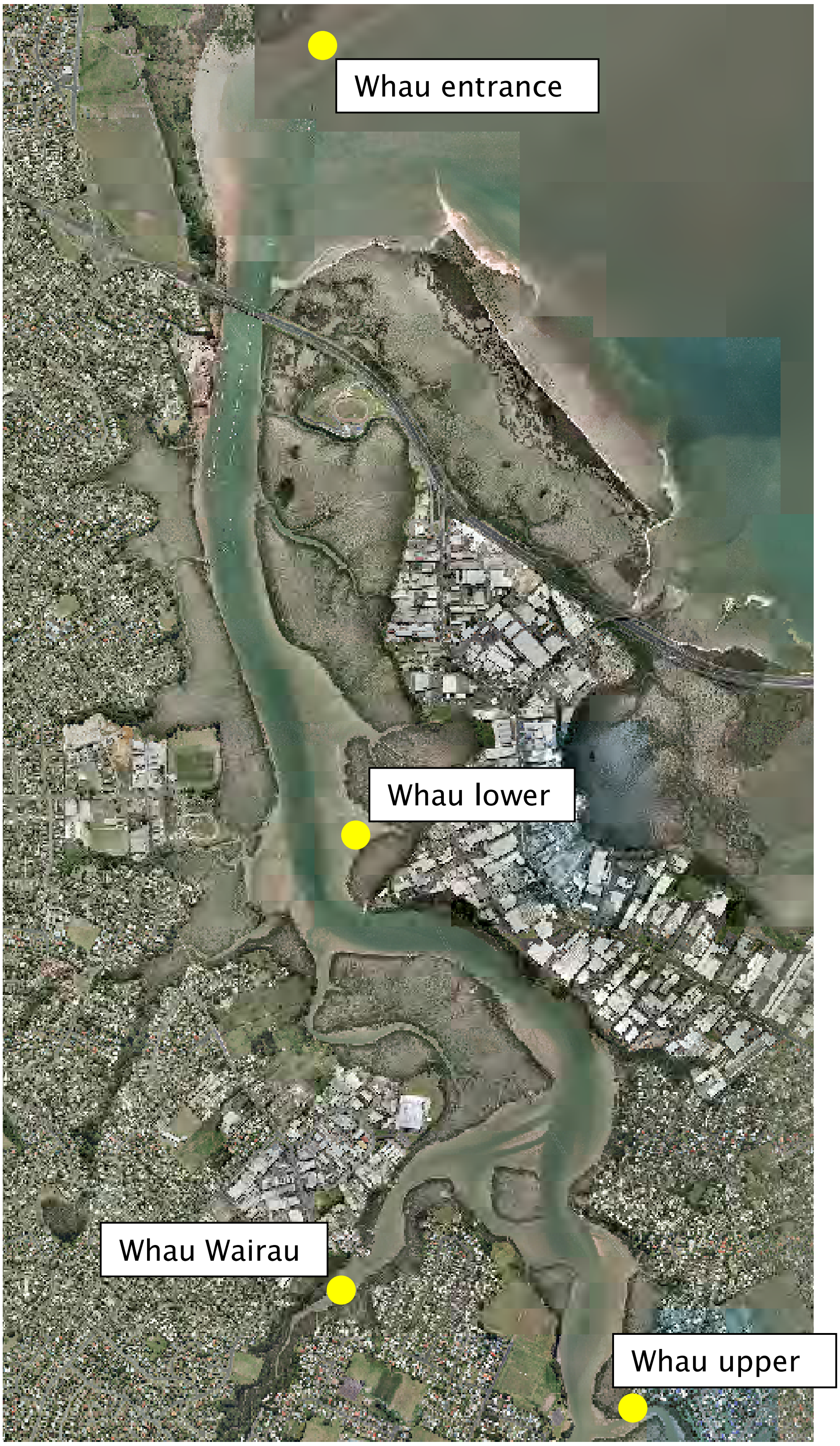

Figure 3.7: ARC Marine Sediment Monitoring Programme sites (Whau River)

3.2 Central Waitemata Harbour

This sub-section covers the broad hydrodynamic and sediment characteristics of the Central Waitemata Harbour. Descriptions of the built environment and geomorphological features are covered in Section 3.3.

3.2.1 Hydrodynamics

The Waitemata Harbour is the largest estuary on Auckland's east coast, and has been an integral part of the history and development of Auckland City. It is a drowned valley system that remains mostly sub-tidal. The Central Waitemata Harbour, being the area between the Auckland Harbour Bridge and the Upper Harbour Bridge, receives runoff from a 205 km^2 land catchment area. The largest catchment is Henderson Creek, which accounts for 50% of the discharge into the Central Waitemata Harbour (Swales et al., 2008).

The nearest tide gauge is at the Port of Auckland, where Auckland Vertical Datum-1946 (AVD-46) is set at 1.743 m above Chart Datum. The tidal properties for the Port of Auckland relative to AVD-46 are (adapted from LINZ cadastral tide survey information)[6]:

Mean High Water Springs (MHWS)	1.56 m
Mean High Water Neaps (MHWN)	1.04 m
Mean Sea Level (MSL)[7]	0.12 m
Mean Low Water Neaps (MLWN)	-0.79 m
Mean Low Water Springs (MLWS)	-1.33 m

Thus Port of Auckland has a spring tidal range of approximately 2.9 m. Numerical modelling studies by NIWA for the SH16 coastal engineering design (Ramsay et al., 2009) indicate that a tidal amplification factor of ~1.04 applies to the SH16 Causeway area in the southern Central Waitemata Harbour. This gives a MHWS of 1.63 m AVD-46.

3.2.2 Sediments

Figure 3.8 shows the spatial distribution of percentage of muddy sediments on the seabed of the Central Waitemata Harbour (Swales et al., 2008). Muddy sediments are clays and silts with a grain size of less than 63 μm. Over most of the Central Waitemata Harbour the mud content is typically less than 16% by volume of the surface seabed composition. From this we can infer that most of the seabed material consists of sand or larger grain sizes (or base rock). A higher proportion of mud is typically found along the intertidal and

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[6] See: http://www.linz.govt.nz/geodetic/datums-projections-heights/vertical-datums/tidal-level-information-for-surveyors/index.aspx

[7] See: http://www.linz.govt.nz/hydro/tidal-info/tide-tables/tidal-levels/index.aspx

sheltered embayment areas of the Central Waitemata Harbour. In particular, over the southern region, the proportion of muddy sediments increases substantially. At the mouth of the Whau River the mud content is between 32 and 64%.

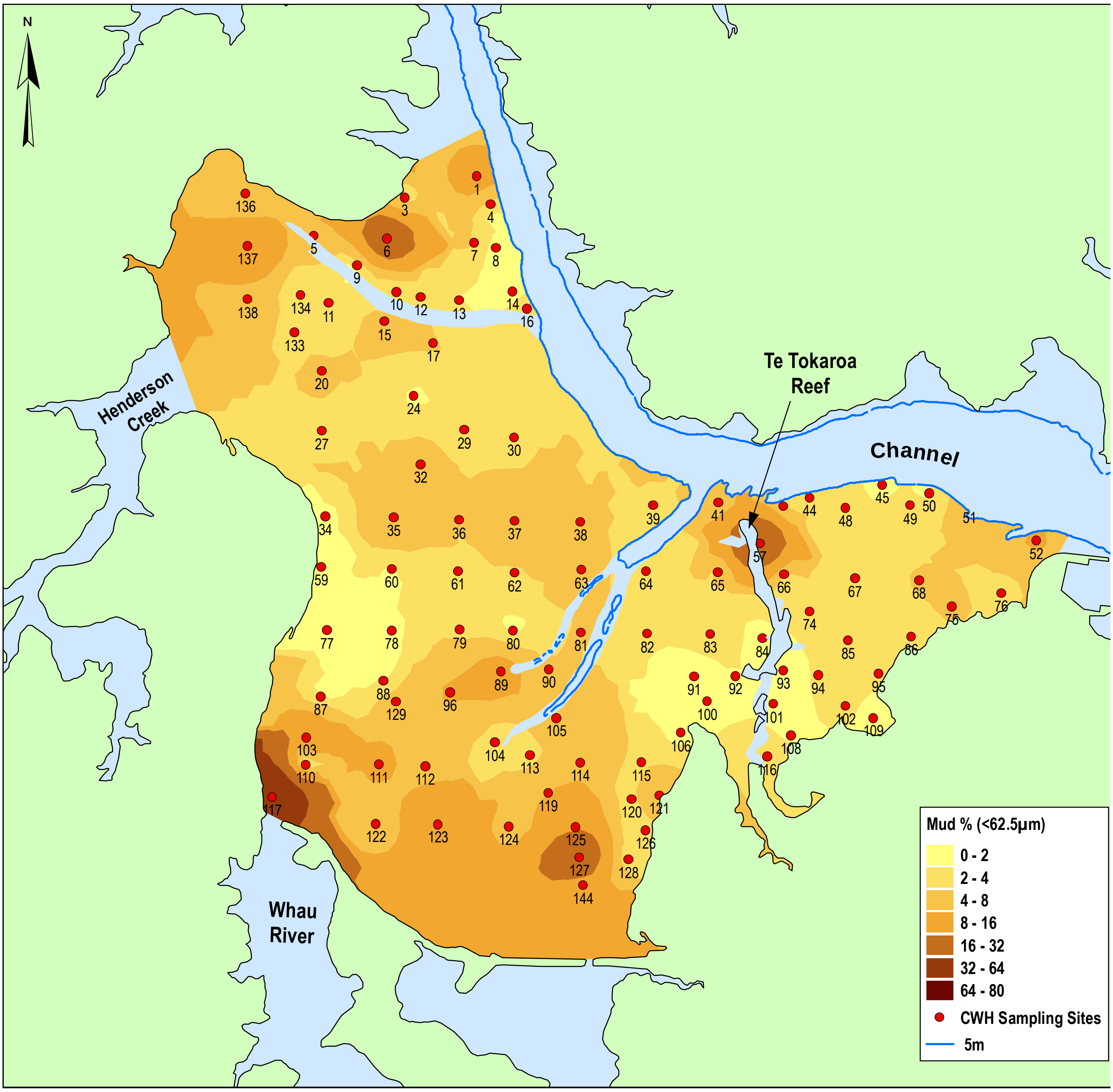


Figure 3.8: Mud content (< 62.5 µm) with the Central Waitemata Harbour by % volume (Source: ARC, NIWA)

3.3 Waterview Estuary

The Waterview Estuary area comprises two inter-connected hydrodynamic compartments:

1. Waterview Estuary

2. Oakley Inlet, being the tidal reach between Oakley Creek (at the culvert under Great North Road) and the Causeway Bridges.

For convenience, the northern side of the Causeway (southern shore of the Central Waitemata Harbour), is also described in this Section.

3.3.1 Built environment

The SH16 Causeway across Waterview Estuary and the associated Causeway Bridge (No. 1) were constructed around 1952–53 (Hume, 1991; Aurecon[8]). Prior to the Causeway, the Oakley Inlet and the Waterview Estuary would have performed as two separate inlet systems (see Figure 3.14). Construction of the Causeway would have had significant effect on the flow dynamics and geomorphology of these two systems and would have reduced the tidal flushing considerably. Groynes comprising rubble material were constructed in the 1950s to encourage sedimentation in front of the revetment, or in the case of the southern side, to deflect the channel away from the Causeway revetment (

Figure 3.9). Groynes on the northern side contributed to the shoal that has developed around the groyne on the north-west abutment of the Bridges, and the localised sedimentation within the western triplet of groynes. On the south side, the Waterview Estuary channel has been deflected away from the Causeway in that section, with sedimentation between the groynes. The eastern groyne near the Bridges appears to be slightly longer than needed to provide a smooth transition to the outlet channel. The channel has meandered close into the Causeway further west where no groynes were placed.

A second Causeway Bridge (No. 2) was constructed to the south of the No. 1 Bridge around 1959-1960 to separate westbound from eastbound traffic. Further widening of both bridges occurred in the 1990s, and a third narrow bridge was erected to provide a crossing for the cycle track south of the existing two bridges. The development of SH16 has significantly modified the Waterview Estuary and Oakley Inlet systems. They have been subject to an increased accumulation of fine-grain sediments throughout the estuary that are primarily derived from the Oakley catchment. In addition to the reduced tidal flushing of the estuarine system, decades of industrial activity and a long history of poor environmental practices have resulted in a degradation of water quality within the estuary (see Assessment of Marine Ecological Effects report). In contrast, the CMA surrounding Pollen Island is largely unmodified and as such supports a diverse range of plant and animal communities including some threatened species (see Assessment of Marine Ecological Effects report).

[8] Personal communication with Andrew Hale, Senior Engineer, Aurecon NZ Ltd., 2 March, 2009

Figure 3.9: Groynes constructed in 1950s to protect the Causeway: (top) 1959; (bottom) 2006 at a low tide. [Source: (top) ARC; (bottom) ©2010, DigitalGlobe, Google Earth, 28 March 2009]

3.3.2 Geomorphology and hydrodynamics

Much of the Project is to be located in the Oakley Creek Catchment, for which the major watercourse is the approximately 12 km long Oakley Creek. The creek passes through a series of open and vegetated reserves, and light industrial, residential and commercial land use from its headwaters at Molly Green Reserve to discharge into the Oakley Inlet. Oakley Creek is significantly degraded as a result of historical channel modifications and water quality effects arising from urbanisation. Due to the short wind fetches within Waterview Estuary (even at high tide) and protection of the Causeway from northerly wind fetches, the Estuary is a low wave energy environment, which is conducive to sediment deposition.

A hydrographic survey of the Waterview Estuary near the Causeway Bridges and part of the Oakley Inlet was undertaken on 10 December 2008 by NIWA. A further hydrographic survey of Oakley Inlet (tidal zone) was arranged by Tonkin & Taylor and conducted by Discovery Marine Ltd. (DML) in December 2009. The average seabed elevation of the sub-tidal channel in Oakley Inlet is approximately 1.5 m below AVD-46. Intertidal elevations were obtained from previous LiDAR surveys undertaken by the Auckland Local Government

Geospatial information agency (ALG*i*). This data was purchased as 'bare-earth' spot elevations every 0.5 m. The combined bathymetry for Waterview Estuary and Oakley Inlet is shown in Figure 2.1.

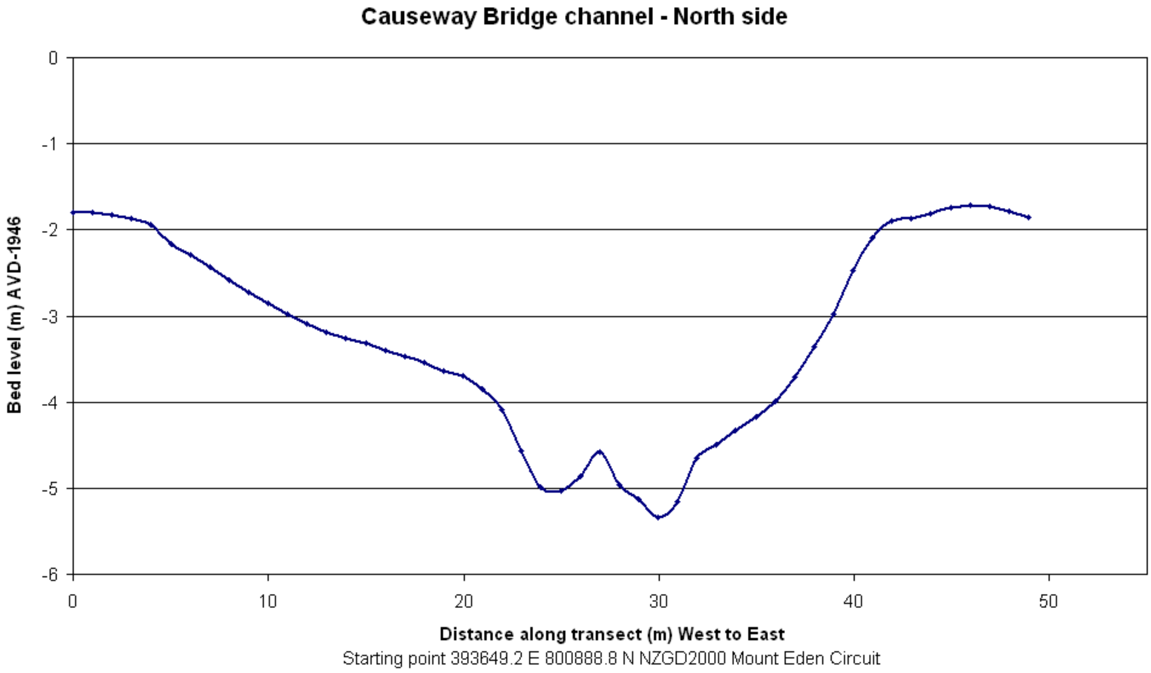
Generally, seabed elevations are higher than 2 m below AVD–46 (or less than 0.3 m deep at Lowest Astronomical Tide). The only exception is within the Waterview Estuary under the Causeway Bridges, where the channel bed reaches elevations of 5–6 m below AVD-46. Spot sounding depths along the western channel of the Waterview Estuary are shown in Figure 3.10. This channel drains the upper western reaches of the Waterview Estuary, then flows past the southern side of SH16 Causeway. In the section of the channel immediately adjacent to the southern-side of the Causeway, the seabed elevations are around 1.8 m below AVD-46.

Cross-sections of the channel adjacent to the Causeway Bridges, on both the southern and northern sides, are shown in Figure 3.11 relative to separate assumed origins on the west side. The maximum channel depth is approximately 5.35 m below AVD-46. The channel cross-section is larger on the south side, which means the velocities will be highest on the northern side.

Figure 3.12 and Figure 3.13 (from Hume, 1991) show how the channel scoured following the Causeway construction in 1952 through to 1983. The 1952 profile (Figure 3.12) is the dredged channel design for the original Causeway Bridge waterway. Figure 3.13 shows that following initial rapid scour of the outlet channel in the first two decades or so, the scouring slowed and the channel moved towards a state of equilibrium. The deepest part of the channel is presently 5.35 m below AVD-46, which is similar to the maximum channel depth in 1983 indicating little scour has occurred since then. The cross-sectional area of the flow under the Causeway Bridges reported by Hume (1991) was 180 m^2 at mean-tide level (~ 0.1 m above AVD-46), which was measured prior to widening of the two bridges. Based on the recent surveyed transects in Figure 3.11, the calculated mean-tide-level cross-sectional areas on the south and north sides of the present Causeway Bridges are 200 m^2 and 164 m^2 respectively. Hume (1991) reports a cross-section of 180 m^2 in 1983, although it is not clear where the section was measured relative to the Causeway No. 1 or 2 Bridge. Nevertheless, the comparison of cross-sectional areas and maximum depths indicates that the channel has remained reasonably stable since the mid-1970s (within ±10%) despite the widening of the two bridges in the 1990s and the addition of the cycleway bridge.

Based on flow-gauging surveys in 1983, Hume (1991) determined the peak spring-tide velocity, in the Waterview Estuary outlet channel under the Causeway Bridges, to be around 1.84 m/s (3.6 knots), which is approximately twice as fast as the Whau River velocity described earlier.

Figure 3.10: Spot seabed sounding levels in the western drainage channel of Waterview Estuary in metres relative to AVD-46. [Source: Soundings (NIWA), background aerial photography from 2002 (LINZ, MapToaster)]



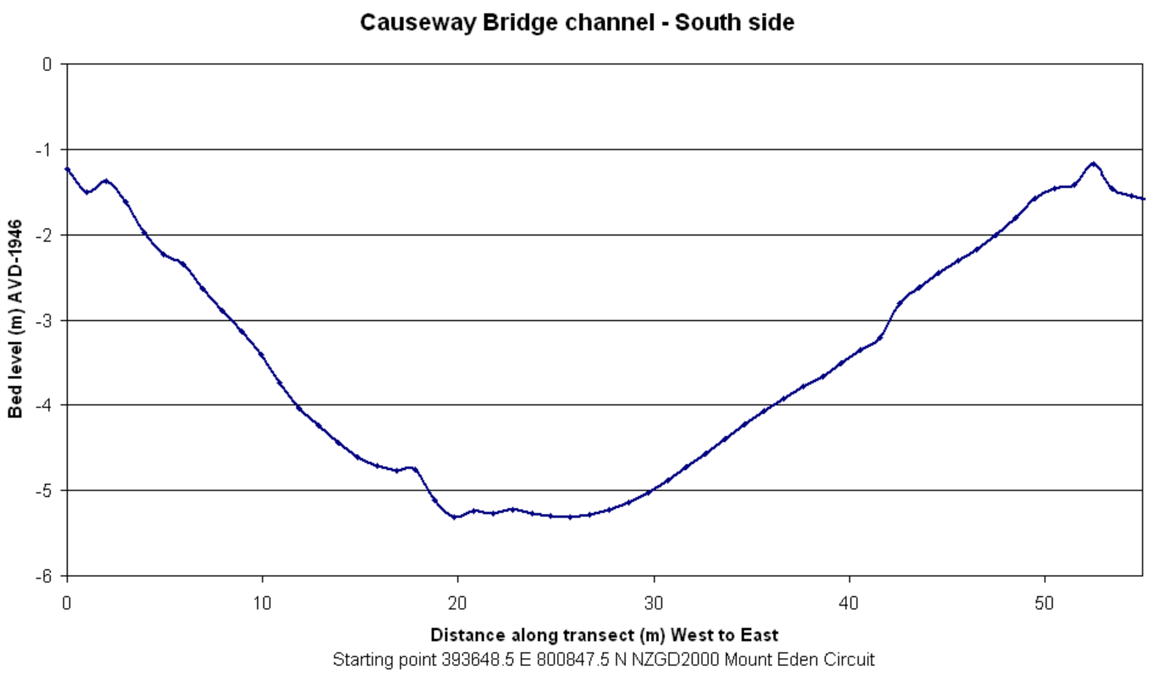


Figure 3.11: West-to-east cross-sections of the channel on the north side (top) and south side (bottom) of the existing Causeway Bridges relative to an assumed horizontal origin, with bed levels relative to AVD–46 surveyed on 10 Dec 2008. [Source: NIWA].

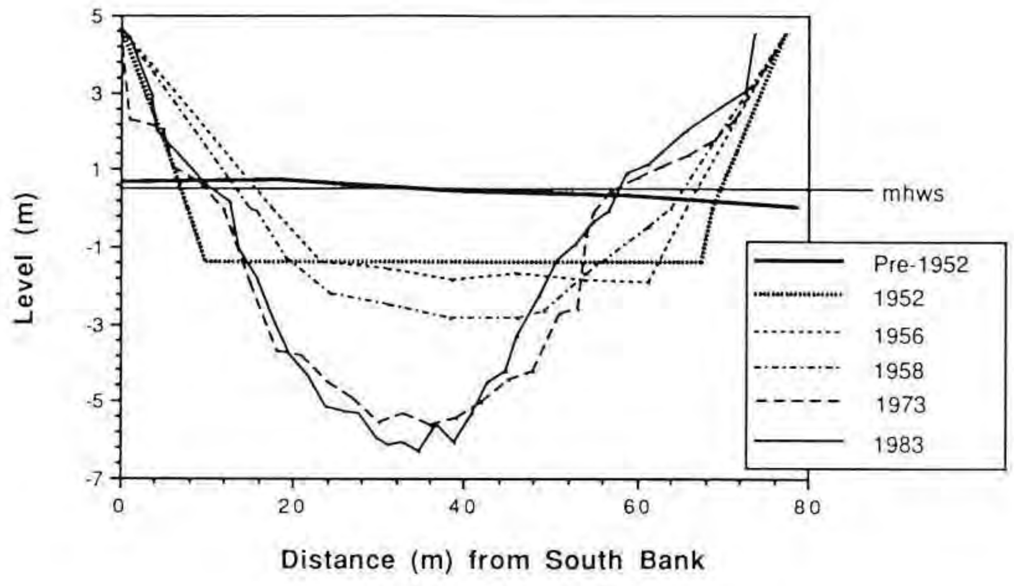


Figure 3.12: Progression of channel scouring below mean tide level from before the Causeway construction through to 1983 (extracted from Hume, 1991). The 1952 profile is the dredged channel design for the original Causeway Bridge. Note: The deepest part of the channel is presently (2009) about 5.35 m below AVD–46 (which is similar to the maximum channel depth in 1983, indicating little change since then)

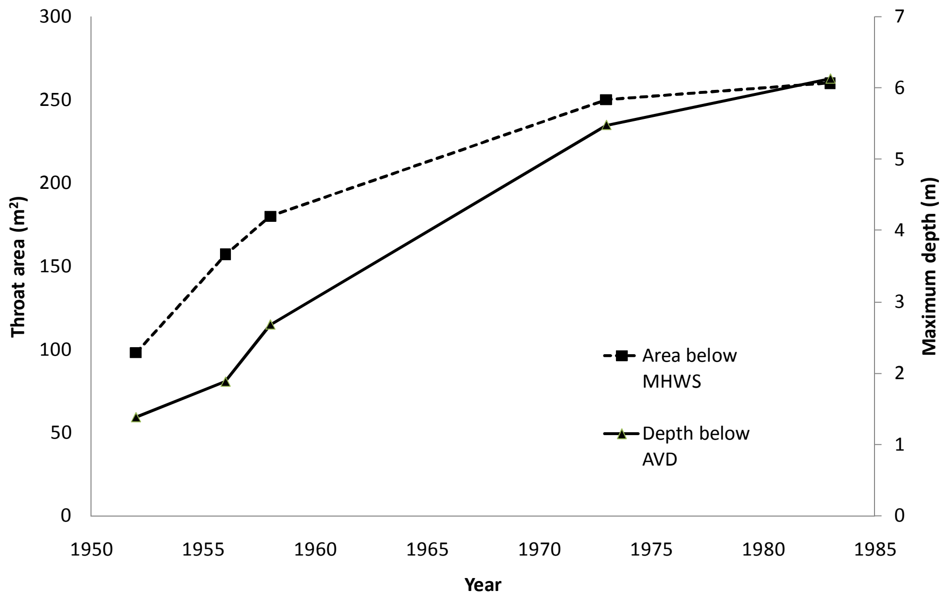


Figure 3.13: Progression of channel scouring exhibited by the channel throat area below MHWS and the maximum depth below AVD-46 from 1952 (before the Causeway construction) through to 1983 (figure reconstructed from Hume, 1991)

Aerial photographs of Waterview Estuary and Oakley Inlets from 1959 and 2001 respectively are shown in Figure 3.14 and Figure 3.15. In 1959, only the single Causeway Bridge (No. 1) was in place as originally built. Figure 3.14 shows clearly that Waterview Estuary and Oakley Inlet were two separate inlet systems prior to construction of the Causeway. Sedimentation has occurred since 1959 adjacent to the Causeway section that blocked off the old Oakley Inlet outlet (arrow B in Figure 3.14 compared with the same area in Figure 3.15), and the dredged channel (arrow A on Figure 3.14), to divert Oakley Inlet flows across to Waterview Estuary and under the Causeway Bridge, has widened over time.

The chenier shell ridges to the north of the Causeway off Traherne Island (arrow C on Figure 3.14) exhibit a similar pattern to that in 1959 (comparing Figure 3.14 and Figure 3.15). Superimposing these two photographs however shows the western group of offshore chenier banks (north of Traherne Island) have migrated shoreward by 50-100 m between 1959 and 2001. With the main wave fetch to the north, these chenier systems can migrate slowly south by way of progressive wave overwash of the shell material. This can be influenced by subtle changes in wind-wave patterns, surrounding sedimentation and sea-level changes. The northern shoreline of Traherne Island has also receded by about 10-20 m in the intervening time, but the shell deposits are still present on the intertidal foreshore. This onshore migration of chenier ridges is likely to be a natural occurrence, given the dominant wave fetch is towards the shoreline. Therefore the presence of the Causeway is unlikely to have influenced this migration, apart from the section directly off the Causeway between Traherne Island and Rosebank Peninsula.

The eastern group of chenier ridges (to west of Point Chevalier) have largely remained in a similar position since 1959, but have coalesced from two ridges into a single ridge (see Figure 3.14 and Figure 3.15).

South of the Causeway to the east of Traherne Island, the triangular wedge area (arrow D in Figure 3.14) has since accreted and been colonised by mangroves. Similar accretion has occurred between Rosebank Peninsula and the Causeway to the west of Traherne Island (extreme left of Figure 3.14)

The Causeway has settled from the gravitational loading since construction. This is reported in detail in G.23 Coastal Works Report.

In summary, the historical aerial photograph comparisons in Figure 3.14 and Figure 3.15 show:

- The existing Causeway has exacerbated long-term sedimentation on the south side within the Waterview Estuary in tandem with increased sediment run-off from the Oakley catchment.

- The artificially-narrowed outlet from Waterview Estuary created by the bridged section of the Causeway in 1952-53 caused a deep channel to scour but it has been relatively stable since the mid to late 1970s.

- The upper-intertidal morphology and associated chenier ridges on the northern (seaward) side of the Causeway to the west of the Causeway Bridges appears to have been relatively stable over the same time frame. However, the western group of offshore chenier banks (north of Traherne Island) have migrated shoreward by 50-100 m between 1959 and 2001, while the two eastern chenier ridges off Point Chevalier have merged but are have not migrated from the area.

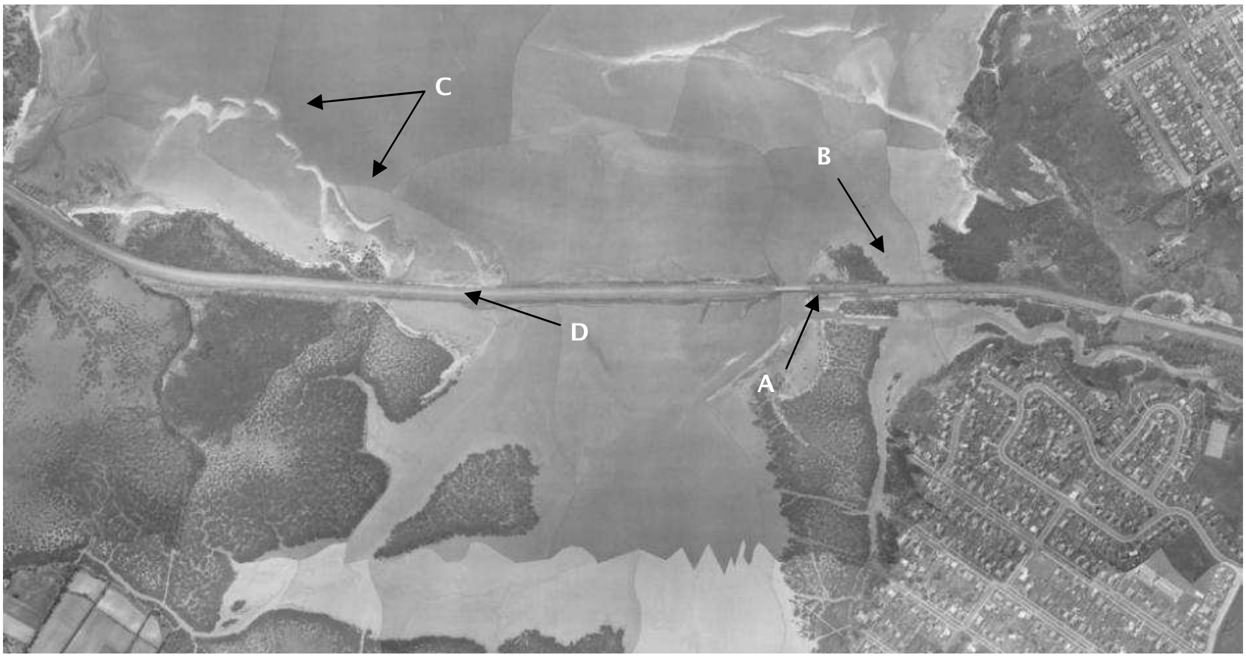


Figure 3.14: Aerial photograph from 1959 of the Waterview Estuary and the original Causeway Bridge No. 1. A channel has obviously been dredged through the eastern mudbank in Oakley Inlet (arrow A) to divert Oakley Inlet to drain through the Causeway Bridge outlet (rather than the previous eastern Oakley outlet, B). Other sites (C and D) are referred to in the text. [Source: ARC]

Figure 3.15: Aerial photograph from 2001 of the Waterview Estuary, Oakley Inlet and the present SH16 Causeway [Source: ARC]

3.3.3 Sediments

Sediment grain sizes within Waterview Estuary and Oakley Inlet have been measured as part of the ARC's Marine Sediment Monitoring Programme (Reed & Gadd, 2009), and also by NIWA and Boffa Miskell (see G.11 Assessment of Marine Ecological Effects report) as part of these AEE investigations. Data from these sources are summarised in Figure 3.16 by plotting the proportion of mud (<63 µm). In locations where the grain size has been suitably analysed, the proportion of fine, medium and coarse silt is presented in Figure 3.17. In this figure, fine silt is where the grain size is less than 6 µm, and coarse silt is any grain size greater than 20 µm. Medium silt is between 6 and 20 µm.

The results show clear patterns of sediment type within the region. North of the Causeway, the proportion of mud is low (also see Figure 3.8), with more fine sand and sand sediment fractions. Within Waterview Estuary and Oakley Inlet the proportion of fine sediment is higher, with the highest mud content being found round the upper, intertidal, fringes of the Estuary and throughout Oakley Inlet. Within the sub-tidal channels, a higher proportion of larger grain sizes are found. This sediment pattern is typical of estuaries within New Zealand. More specific to Waterview Estuary however is the effect of the Causeway, which has reduced the tidal flushing currents (except around the Causeway Bridges) and considerably reduced the wave energy inside the estuary (which was formerly open to a longer wave fetch from the north). This has lead to an increased build up of muds within the estuary distributed as shown in Figure 3.16. Thus the Waterview Estuary and Oakley Inlets are depositional environments for muds, and have become increasingly so after construction of SH16 in the early 1950s. Just to the north of the Causeway, any fine grained sediments which do deposit are more likely to be subsequently resuspended and transported to other areas by wave and tidal currents.

Figure 3.16: Proportion of mud content (<63 µm grain size) from surface sediment samples within the Waterview Estuary [Source: based on data from ARC, NIWA and Boffa Miskell]

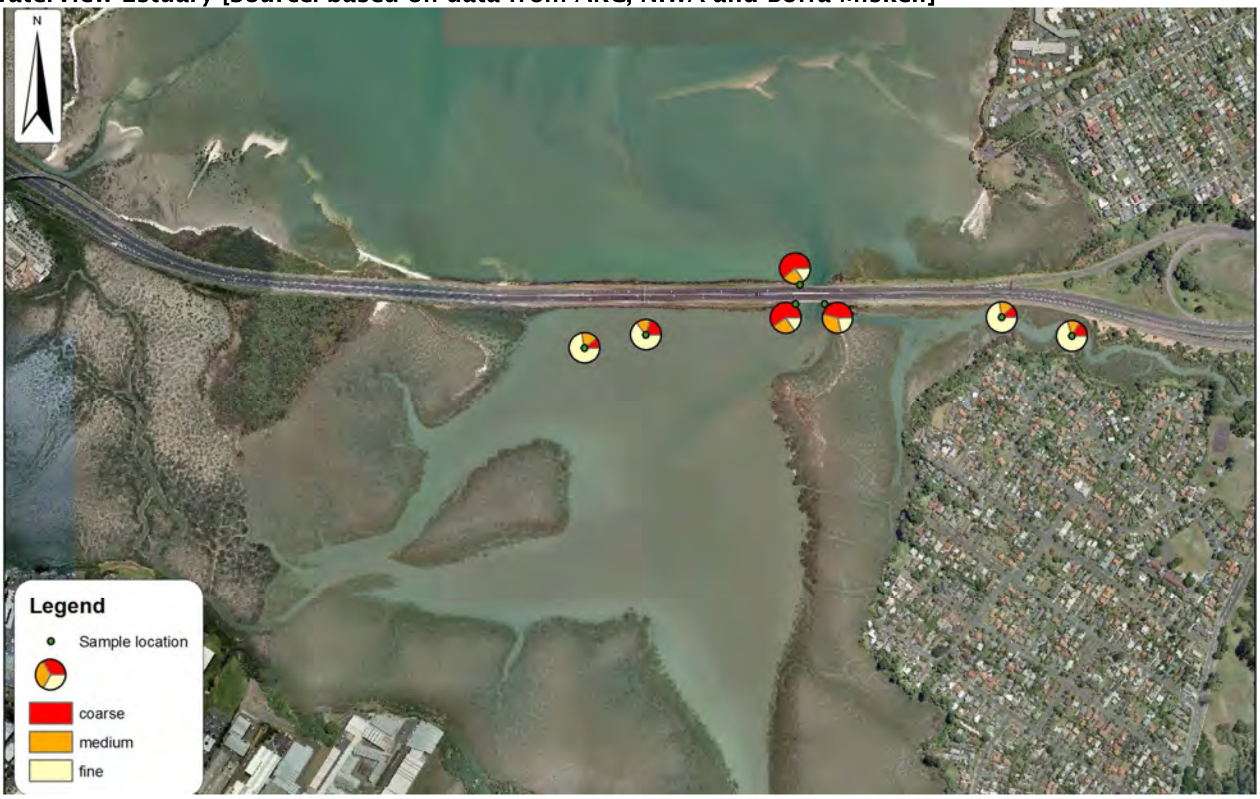


Figure 3.17: Proportion of fine, medium and coarse silt grain sizes

4. Potential effects on the coastal physical processes and mitigation, avoidance or remediation options

Assessment of the Project's effects on coastal physical processes in the CMA has been split into two phases: construction (Section 4.1) and operational (Section 4.2). The coastal physical processes considered in this Assessment are the effects of activities and works on:

- Hydrodynamic processes:
  - water levels including backwater effects
  - changes in current velocities
  - alteration of drainage patterns
  - changes in wave patterns
  - impacts on navigation through bridge waterways
  - future effect of works on flows through bridge waterways due to sea-level rise

- Sediment processes:
  - distribution of sediment characteristics
  - sediment transport pathways
  - sedimentation and erosion or scour
  - suspended-sediment plumes from sediment run-off into the CMA or sea-bed disturbances

- Geomorphology:
  - changes in characteristic features and morphology of the seabed in the coastal zone e.g., intertidal banks and channels.

The direct effects of the Project on these physical coastal processes are evaluated and assessed in this Report. Some coastal physical processes may be affected, but also have "downstream" effects on water quality, water appearance or the marine ecology. These latter effects on the CMA are assessed in companion Reports listed below, but some ecological effects (e.g., effect of deposition on the benthic ecology from sediment run-off) are based on computational modelling or field observations that are described in this Report.

- Assessment of Marine Ecological Effects (G.11).

- Assessment of Stormwater and Streamworks Effects (G.15)

- Erosion and Sediment Control Plan (ESCP) (G.22)

- Coastal Works Report (G.23)

As discussed in Section 3, since the Causeway was constructed in 1952-53 there have been substantial effects on coastal physical processes, particularly in Waterview Estuary and Oakley Inlet. In this current assessment of the upgraded works for SH16, the existing SH16 footprint has been deemed to be part of the coastal environment, albeit a built environment. Consequently, only the effects of the new additional works and associated activities are assessed as to whether they are minor or not. Where relevant, mitigation or remedial measures are proposed or in some cases effects have been avoided by modifications to the engineering design.

Table 4.1 provides a summary and index to the various Project activities and where they are located e.g., Sectors (see Figure 1.2), specific chainage and relevant engineering drawings. The assessments of effects are discussed in detail in Sections 4.1 and 4.2, followed by a summary in Table 4.2 at the end of Section 4.

Table 3.1: Index of activities that are assessed for effects on coastal physical processes and their location and relevant engineering drawing.

#	Sector	Summary of activity	Chainage (CH) (m from Great North Rd Interchange)	Drawing No.
Construction Effects				
A: Structures				
1	1	Occupation of the CMA in Pixie Inlet (Henderson Creek) for a temporary rock-toe silt fence	CH6250-6350N	20.1.11-3-D-C-942-101 (Temp. Occ.)
2	2	Occupation of the CMA by temporary piers to support temporary construction platforms, Whau River Bridges and cycleway bridge	CH4890-4690	20.1.11-3-D-C-942-103 (Temp. Occ.)
3	1—4	Occupation of the CMA by temporary silt fences or cofferdams along the periphery of Causeway and bridge abutments to facilitate construction	CH600 - 4930	20.1.11-3-D-C-942-103 *to* -108 (Temp. Occ.)
4	4	Occupation of the CMA by temporary piers to support temporary staging platforms to construct widened Causeway Bridges and cycleway bridge	CH1180-1315	20.1.11-3-D-C-942-108 (Temp. Occ.)
5	5	Occupation of the CMA in Oakley Inlet for temporary piers to support temporary staging platforms to construct on/off-ramps for the SH16/SH20 interchange.	Interchange Ramps 1,2,3,4	20.1.11-3-D-S-610-500 *to* –501 (rev A)
B: Reclamation				
6	4	Extending the width of SH16 adjacent to the main channel that drains the Pollen Island wetland system	CH2950–3150N & CH3320-3410N	20.1.11-3-D-C-942-105 (Temp. Occ.)
7	4	Extending the width of SH16 carriageway on the south side adjacent to a side drainage channel that flows around Rosebank Park Domain into the Whau River	CH3990–4100S	20.1.11-3-D-C-942-104 (Temp. Occ.)

#	Sector	Summary of activity	Chainage (CH) (m from Great North Rd Interchange)	Drawing No.
B: Reclamation (cont.)				
8	4	Extending the width of SH16 Causeway into the adjacent meander of the drainage channel that services the western side of Waterview Estuary	CH1550–1710S	20.1.11-3-D-C-942-107 (Temp. Occ.)
9	4	Extending the width of SH16 Causeway, including the transition from the Westbound On-ramp from SH20 and cycleway, into two meanders of the sub-tidal channel in Oakley Inlet	CH800–880S & CH650–700S	20.1.11-3-D-C-942-108 (Temp. Occ.)
C: Disturbance				
10	2,3, 4	Ground (seabed) treatment works in the CMA required to support widened reclamations	CH600 - 4930	20.1.11-3-D-C-942-103 *to* -108 (Temp. Occ.)
11	1-5	Mobilisation, installation and removal of sediment-control and containment measures	CH600 – 5000+ and upper Oakley Inlet	20.1.11-3-D-C-942-101 *to* –108 *and* 20.1.11-3-D-S-610-500 *to* -501
12	1-4	Excavation and ground-treatment works in the CMA for outlet structures for permanent storm water outlets	various	(see Stormwater Assessment and Erosion & Sediment Control reports)
13	2	Excavation for widened bridge abutments and ground-treatment works in the CMA, Whau River Bridges and cycleway bridge	CH4600 - 4930	20.1.11-3-D-C-942-103 (Temp. Occ.)
14	2	Installation and removal of temporary piers to support the temporary staging platforms for construction of Whau River Bridges and cycleway bridge	CH4690 - 4890	20.1.11-3-D-C-942-103 (Temp. Occ.)
15	2	Construction of permanent piers to support widened Whau River Bridges and cycleway bridge	CH4720 - 4880	20.1.11-3-D-C-941-103 (Perm. Occ.)
16	4	Blocking off redundant culvert under the Causeway (adjacent to west side of Rosebank Peninsula)	CH2900	20.1.11-3-D-C-942-105 (Temp. Occ.)
17	4	Ground (seabed) treatment works between Traherne Island and Rosebank Peninsula on northern side will disturb or bury shoreline chenier (shell) beach deposits	CH2720 – 2780N & CH2050-2130N	20.1.11-3-D-C-942-106 *to* –107 (Temp. Occ.)
18	4,5	Excavate a by-pass channel further south of western drainage channel in Waterview Estuary to re-align the meander in the channel that would otherwise be occupied or reclaimed by the widened Causeway.	CH1550 – 1720S	20.1.11-3-D-C-942-107 (Temp. Occ.)

#	Sector	Summary of activity	Chainage (CH) (m from Great North Rd Interchange)	Drawing No.
C: Disturbance (cont.)				
19	4	Excavations for widened bridge abutments and ground treatment works, Causeway Bridges and cycleway bridge	CH1200-1270	20.1.11-3-D-C-942-108 (Temp. Occ.)
20	4	Installation and removal of temporary piers to support the temporary staging platforms, Causeway Bridges and cycleway bridge	CH1200-1270	20.1.11-3-D-C-942-108 (Temp. Occ.)
21	4	Construction of permanent piers to support widened Causeway Bridges and cycleway bridge	CH1200-1270	20.1.11-3-D-C-941-108 (Perm. Occ.)
22	4	Ground treatment works and construction of widened causeway revetments adjacent to Oakley Inlet. Excavate two by-pass channels further south of the main sub-tidal channel in Oakley Inlet to re-align the meanders in the channel that would otherwise be occupied or reclaimed by the widened Causeway.	CH800 – 870S & CH650 – 700S	20.1.11-3-D-C-942-108 (Temp. Occ.)
23	5	Installation and removal of piers to support temporary construction platforms, SH16/SH20 on/off-ramps	Interchange Ramps 1,2,3,4	20.1.11-3-D-S-610-500 *to* –501 (rev A)
D: Discharges				
24	5	Earthworks and construction relating to the construction of SH20, Sectors 7-9 discharging into Oakley Creek before discharge to CMA in Oakley Inlet	Head of Oakley Inlet (Great North Rd.)	See Erosion & Sediment Control Plan
Operational effects				
A: Structures				
25	2	Permanent occupation within the CMA of additional bridge piers to support the widened Whau River Bridges and cycleway bridge	CH4720 - 4880	20.1.11-3-D-C-941-103 (Perm. Occ.)
26	4	Permanent occupation within the CMA of additional bridge piers to support the widened Causeway Bridges and cycleway bridge over the outlet channel from Waterview Estuary	CH1200-1270	20.1.11-3-D-C-941-108 (Perm. Occ.)
27	5	Permanent occupation within the CMA in Oakley Inlet of bridge piers to support new SH16/SH20 on/off-ramps	Interchange Ramps 1,2,3,4	20.1.11-3-D-S-610-500 *to* –501 (rev A)
B: Reclamation				
28	1	Reclamation in Pixie Inlet (Henderson Creek) to support a permanent stormwater treatment pond	CH6250-6350N	20.1.11-3-D-C-941-101 (Perm. Occ.)

#	Sector	Summary of activity	Chainage (CH) (m from Great North Rd Interchange)	Drawing No.
B: Reclamation (cont.)				
29	2	Reclamation for widened abutments to support the widened Whau River Bridges and cycleway bridge	CH4875–4920 (west abutment) & CH4600–4720 (east abutment)	20.1.11-3-D-C-941-103 (Perm. Occ.)
30	2,4	Reclamation to widen the existing SH16 carriageway on either or both the north and south sides from the Whau River to the eastern side of Rosebank Peninsula	CH2950–4580	20.1.11-3-D-C-941-103 *to* -105 (Perm. Occ.)
31	4	Reclamation to widen the existing SH16 Causeway on both the north and south sides from the eastern side of Rosebank Peninsula through to the Great North Road Interchange	CH630–2950	20.1.11-3-D-C-941-105 *to* -108 (Perm. Occ.)
32	4	Reclamation to widen the existing eastern and western abutments for the Causeway Bridges and cycleway bridge	CH1170 to 1290	20.1.11-3-D-C-941-108 (Perm. Occ.)

Note: Chainage (CH) is measured in metres along the centreline of the SH16 carriageway and is marked on the engineering drawings. Chainage suffix N = North side, S = South side

4.1 Construction effects and mitigation options

The general layout of temporary CMA occupation for construction purposes is shown in F13. The permanent CMA reclamations and permanent occupation are respectively in drawing F18 and F12. Temporary staging to facilitate construction of piers in the CMA (Oakley Inlet) for new on- and off-ramps is proposed. These drawings can be found in the AEE Part F.

The following sections provide an assessment of the main physical effects on the CMA from different Project activities that could arise from construction of the permanent works and also mobilisation, installation and de-mobilisation of temporary ancillary structures to protect the works and minimise discharges to the CMA. Location of sites or zones over which an activity is envisaged along SH16 together with the relevant engineering drawing(s) are listed in Table 4.1.

4.1.1 Structures

Activity 1: Occupation of the CMA in Pixie Inlet (Henderson Creek) for a temporary rock-toe silt fence.

Sector: 1 **Environment area:** Whau River area

Potential effects: Slightly restricted flow around high tides when currents are slower; minimal effects on inlet sediment processes.

Assessment:

The temporary rock-toe silt fence is a component of the Erosion & Sediment Control Plan (G.22). This will be used to reduce sediment run-off from the stormwater pond construction site from entering into Pixie Inlet (a side arm of Henderson Creek). The rock-toe is located well above the mean tide level and out of the main sub-tidal channel of this small side inlet of Henderson Creek. Therefore there will be minimal effect on retarding water flows, especially as flow velocities diminish to small magnitudes around the high tide period when the tide level reaches the rock-toe. Given these minimal effects on flows and the temporary nature of the structure, the effects on sediment processes are likely to be less than minor.

Mitigation options: Not required.

Degree of potential effects: Less than minor.

<u>**Activity 2:**</u> Occupation of the CMA by temporary piers to support temporary construction platforms, Whau River Bridges and cycleway bridge.

Sector: 2 **Environment area:** Whau River area
Potential effects: Change to hydrodynamic flow patterns through the bridge section; backwater effects from higher flow retardation; local and general scour from temporary piers; erosion of adjacent channel banks; reduced tidal flushing of Whau River.

Assessment:

During the construction, the widening of the existing Whau River Bridges and new cycleway bridge will be built by installing temporary platforms supported by driven 0.6 m diameter piers. The layout of the temporary platforms and supporting piers adjacent to, and on either side of, the existing Whau River Bridges is shown in the relevant engineering drawing (Table 4.1).

Each pair of piers (in the north-south direction) will be spaced at 9 m apart across the channel, with a wider 18 m gap at approximate chainage 4835 m in order to maintain navigation under the higher bridge span towards the western bank. Thus the temporary building platform will consist of 4 structures, built out from the left and right banks and adjacent to the north and south sides of the existing bridges. A total of 88 temporary piers will be located in the CMA, though not all of these are placed within the main sub-tidal channel. In total, the temporary piers will occupy approximately 25 m^2 of sea floor area within the CMA which is only ~0.2% of the total area underneath the widened bridges and cycleway bridge within the CMA. It is likely that all these temporary piers will be in place concurrently for a period of 18–24 months to facilitate the widening on the east-bound bridge (north side) and the cycleway bridge (south side) at the same time. The northern temporary staging will then be removed but the southern temporary staging will be left in place for the construction of the west-bound carriageway, estimated at another 18 months.

The width of the Whau River channel at the bridge site is approximately 150–160 m at high tide, but the existing bridges, of around 185 m length, span the River at a slightly skewed angle. The bridge pier groups are currently aligned at approximately 20º to the main flow direction on the southern side, reducing to 15º on the northern side, as the channel curves around more to the east. Thus the river flow will 'see' most of the 88 temporary platform piers rather than just the outer nearest outside pier (if the flow was parallel). However, the flow will be able to weave between the downstream gap between the pairs of piers and the larger 48 m gap between the northern and southern staging platforms (notwithstanding the presence of existing, and progressively constructed, permanent bridge piers).

Of the 88 temporary piers, 56 will be in the main channel flow across a width of 135 m and will only result in a ~13% contraction in effective flow area, allowing for a 50% reduction in the full projected cross-sectional area of all 56 piers at an 18° flow angle due to flow weaving in between individual piers and some flow alignment with existing bridge-pier groups.

The presence of these slightly skewed pier groups in the channel will increase the resistance to flow of the channel. To convey the same volume of water through the bridge section, the streamwise water surface gradient in the region of the bridge will increase somewhat. Flow velocities in the cross-stream gaps between the piers will also increase. However, in the wake zone of each pier velocities will be lower.

The MIKE 21 hydrodynamic model was used to simulate a steady flow in the vicinity of the Whau River Bridges to quantify the magnitude of these hydrodynamic effects and confirm that the magnitude of these effects is less than minor. A rectangular mesh of cells 0.3 x 0.3 m was used, so that the temporary piers were explicitly, but approximately, represented as a block of 2 x 2 cells. A steady-state simulation at peak flow during an incoming spring tide was modelled. The seaward boundary was defined as a volume flow rate of 590 m^3/s estimated from Hume (1991). The local downstream water level was fixed at a constant level of 0.7 m AVD-46.

A 'baseline simulation' was undertaken with the existing pier groups. The effect of including the temporary piers for the staging platforms was then simulated. The result is that the temporary piers will increase the difference in water surface upstream and downstream of the bridges (the water-level head) by a modest 12 mm. However, for some period during the construction, some of the new permanent piers will be in place at the same time as the temporary piers. As a 'worse case' scenario, a simulation was undertaken with the existing piers, plus the temporary piers and the new permanent piers. The resulting increase in water-level head is 20 mm. Figure 3. shows water surface elevation up the centre of the Whau River for these three simulations. The effect of the bridge and temporary piers is clearly seen as a small but rapid increase in water level.

Figure 3.18 to Figure 3.20 shows the depth-averaged velocity in the vicinity of the bridge piers. The wake zones are clearly identified. Between the wake zones, the streamwise velocity may locally increase by up to 0.2 m/s in places, for the simulation with both the temporary and permanent piers in place. This increase in velocity may be reduced with time by a compensatory increase in flow area through a small degree of general channel bed scour at the bridge site. Also due to the skewed flow orientation, the temporary 0.6 m diameter piers will generate additional wake shedding during both flood and ebb tide flows, but the wakes formed will be lower in both strength and length in comparison to those generated currently from the existing larger bridge piers (see Figure 3.19).

Mitigation options: The smallest pier diameters possible (0.6 m), relative to the span, have been used for safe load-bearing capacity of the temporary staging platforms. The smaller the diameter, the smaller the overall flow resistance. It is not possible to align the temporary pile groups with the flow, as structurally they must be perpendicular across the staging platform. A wider 18 m gap between pile groups has been provided towards the western side of the channel (Figure 3.19) to retain navigational passage, which will also slightly reduce flow contraction.

Degree of potential effects: Effects of temporary piers on hydrodynamic flows and navigation passage are likely to be minor. All other effects on coastal physical processes will be less than minor.

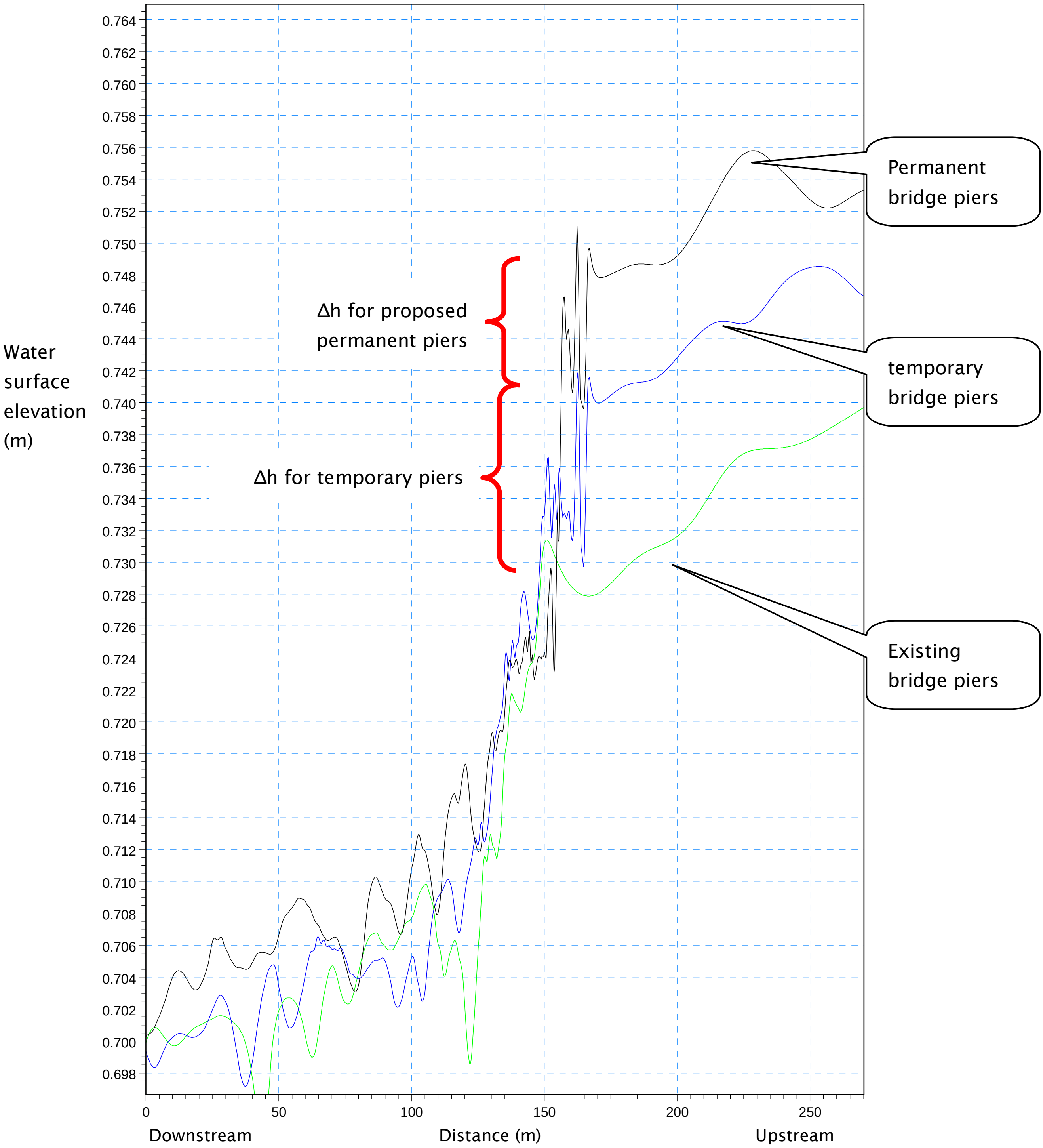


Figure 3.1: Computer model predictions of water surface elevations with distance up the middle of the Whau River (zero at seaward boundary) through the section where Whau River Bridges are located (at ~150 m mark). The comparison of water-level head (Δh in m) is shown between the proposed temporary platform piers and the existing bridge piers. For completeness, the effect of the additional permanent bridge piers is also shown on this plot (Section 4.2.1).

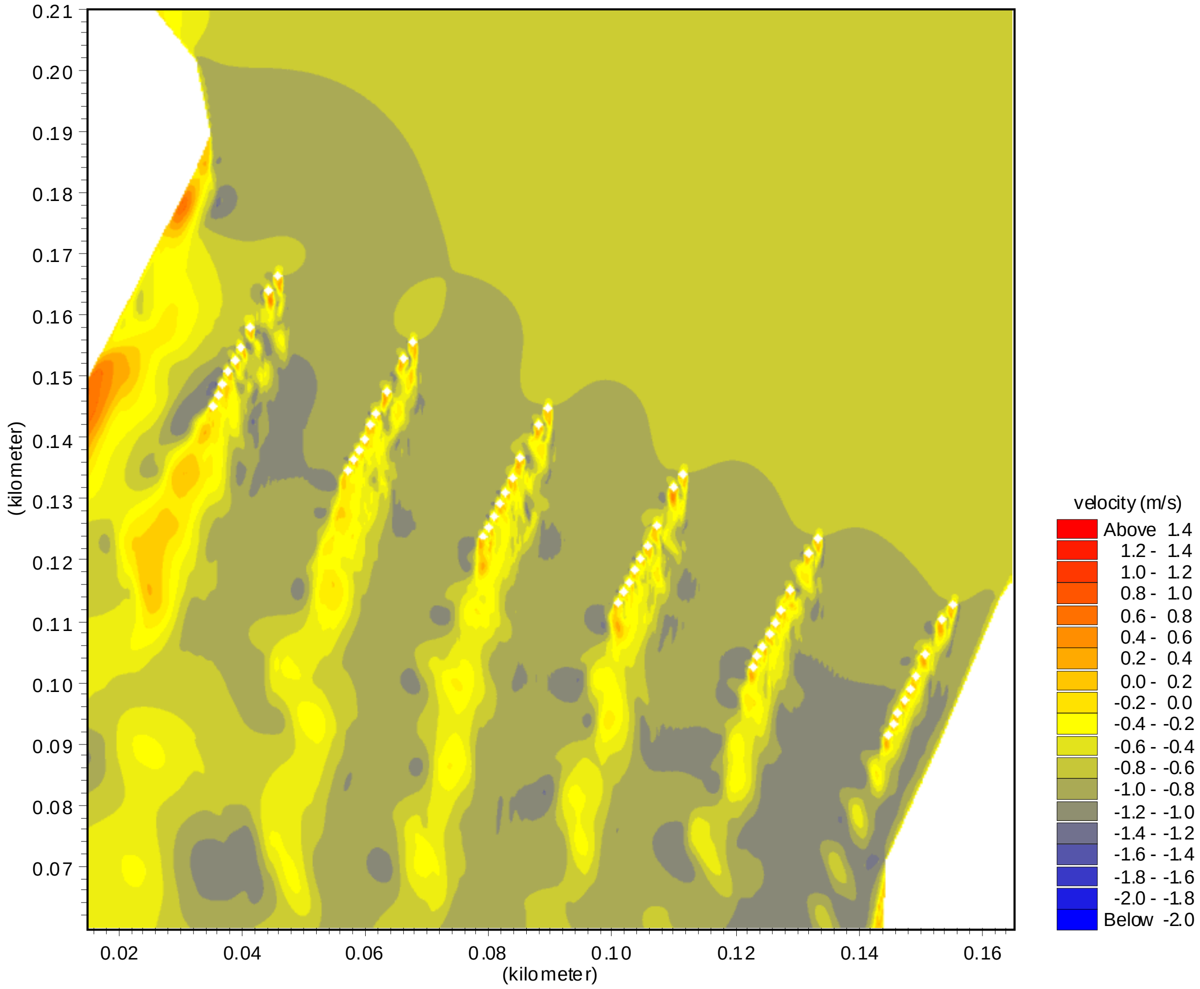


Figure 3.18: Computer model simulations of a spring flood-tide flow through Whau River Bridges channel with existing bridge piers. North is towards the top.

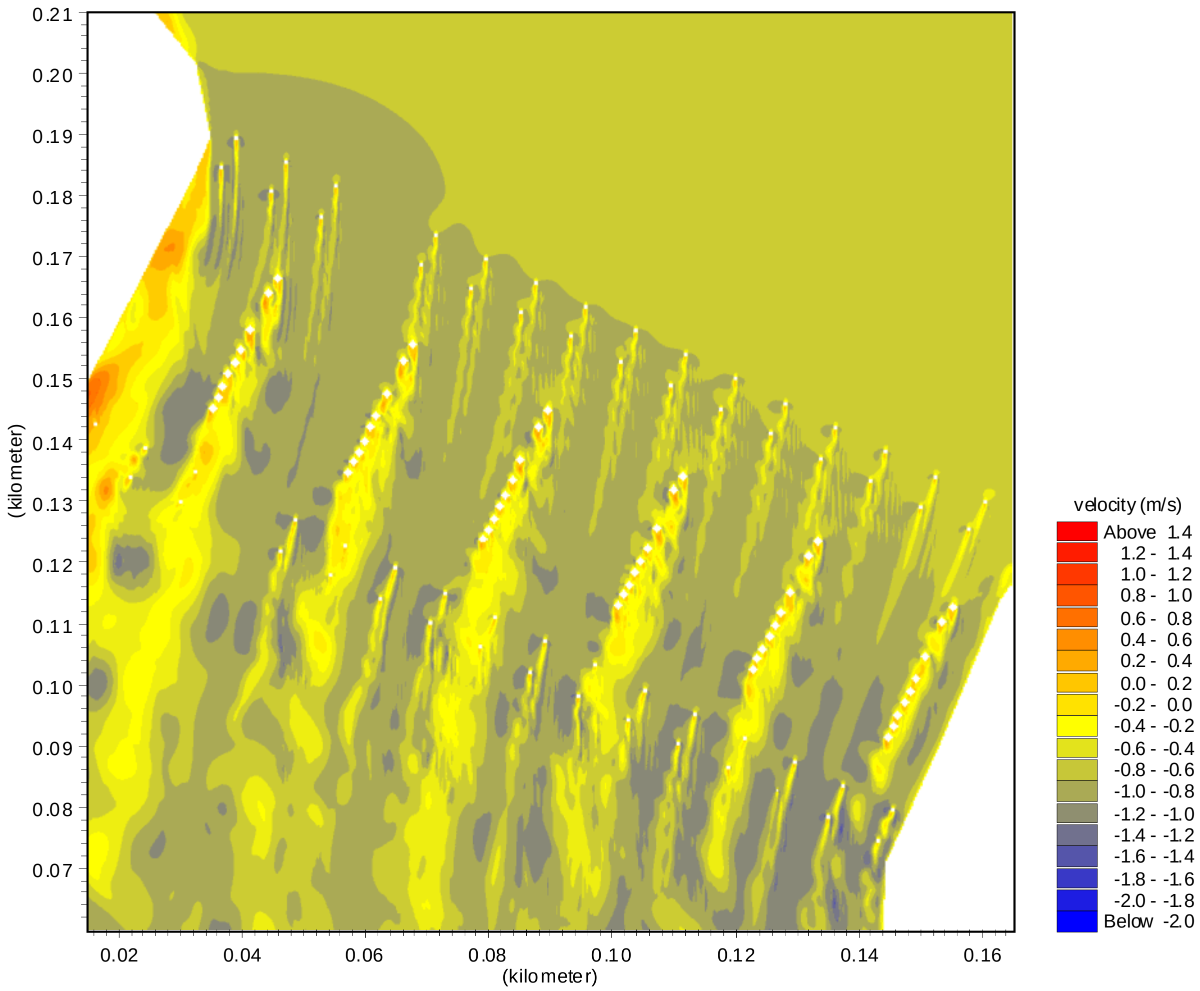


Figure 3.19: Computer model simulations of a spring flood-tide flow through Whau River Bridges channel with existing piers and temporary platform piers used during construction. North is towards the top.

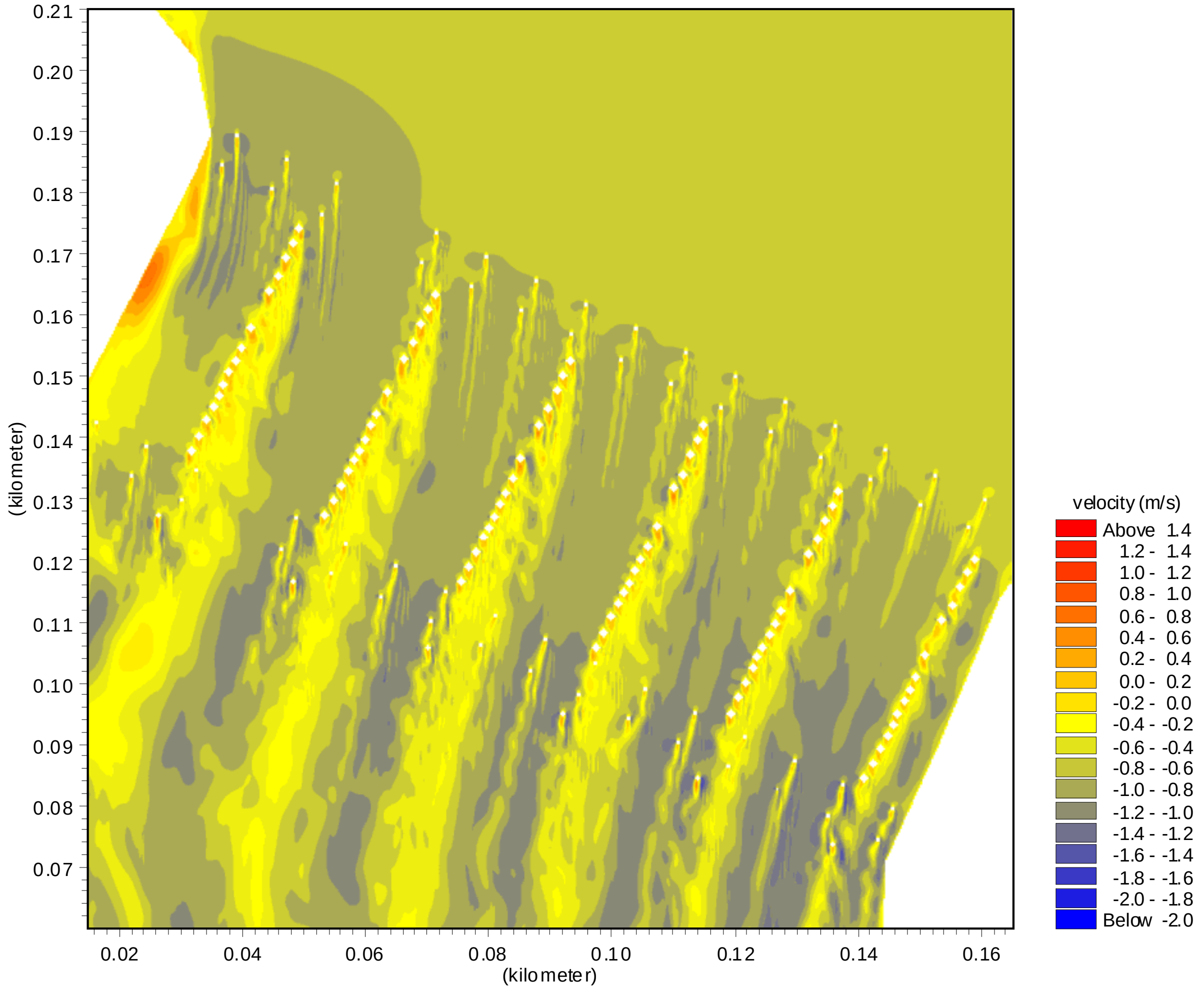


Figure 3.20: Computer model simulations of a spring flood-tide flow through Whau River Bridges channel with the full combination of existing bridge piers, temporary platform piers and new permanent bridge piers. North is towards the top.

<u>**Activity 3:**</u> Occupation of the CMA by temporary silt fences or cofferdams.

Sector: 1—4 **Environment area:** Whau River area; Central Waitemata Harbour; Waterview Estuary

Potential effects: Alteration of tidal flows; changes to sediment-transport processes and morphology.

Assessment:

Cofferdams will be used to create dry working areas and minimise sediment discharges into CMA—see Coastal Works Report (G.23). Silt fences are components of the Erosion & Sediment Control Plan (G.22). These temporary structures will be used to minimise the sediment run-off from construction sites from entering the CMA. Details of the deployment and specific areas where cofferdams and silt-fences are to be located are provided in the above two Reports.

Generally because these temporary containment structures or silt fences will be adjacent and parallel to the existing causeway revetments or bridge abutments and in most cases located on the upper levels of intertidal zones in the CMA, the effects of these structures on hydrodynamic processes and hence sediment processes is likely to be minimal. However there will be localised areas where the effects will be no more than minor such as: i) the exposed northern side of the main Causeway where wave reflection from the cofferdam may induce erosion of the upper intertidal beach in front of the structure during northerly wind storms and high tides, but is likely to naturally recover with favourable beach-building wave activity in following weeks (Note: this process is likely to occur now in front of the present revetment); and ii) where channel meanders pinch in close to the existing Causeway (Waterview Estuary and Oakley Inlet). For the latter, specific engineering approaches working in with the cofferdams will be adopted (see Coastal Works Report) and mitigation measures undertaken to re-align the channels (see Activities 8, 9, 18, 22).

Mitigation options: An AquaDam is one of the options for use as a cofferdam in the Coastal Works Report (**G.23**) along with some construction areas in the CMA where the traditional sheet-piling cofferdam is more suited (especially where construction space is limited). AquaDams are easier to deploy and sustain in deep estuarine muds and have distinct environmental advantages over traditional sediment control measures. These include minimal seabed disturbance (other than initial vegetation clearance), improved containment of any seabed mud slumps that eventuate (see Coastal Works Report), minimal noise and no ground shaking. However they do require a larger area of the CMA for temporary occupation and suit areas that only have minimal mangrove cover (as vegetation will need to be removed to provide a smooth base for the AquaDams). AquaDams may be used predominantly to support construction of the main Causeway, where there is more open space. Areas where there is limited or constricted CMA space e.g., prolific mangrove cover, near bridge abutments and in the narrow Oakley Inlet, sheet piling will be the preferred cofferdam structure used to temporarily maintain dry working areas. Silt-fence deployment areas and design are covered in the Erosion & Sediment Control Plan (**G.22**)

Degree of potential effects: The effects of temporary containment structures or silt fences are likely to have only minimal effects on hydrodynamic and sediment processes because largely they will be located well up on the intertidal zone. Minor localised effects could occur on sediment processes in front of the cofferdam when storms coincide with higher tides (especially the exposed northern side) or where the widened Causeway will encroach on adjacent channels, which requires mitigation via a by-pass channel.

<u>**Activity 4:**</u> Occupation of the CMA by temporary piers to support temporary staging platforms to construct the widened Causeway Bridges and cycleway bridge.

Sector: 4 **Environment area:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Change to hydrodynamic flow patterns through the bridge section; backwater effects from higher flow retardation; local and general scour from temporary piers; erosion of adjacent channel banks; reduced tidal flushing of Waterview Estuary; backwater effects from Oakley Creek flooding.

Assessment:

During construction of the widened Causeway Bridges and the new cycleway bridge, temporary staging on piers will be erected on both the north and south sides of the Causeway Bridges to facilitate construction. This staging will be very similar to that described above for the Whau River Bridges (Activity 2). The piers will be 0.6

m diameter at a spacing of 9 m. There is no navigable access for vessels into the Waterview Estuary, due to the low clearance height of the existing bridge decking. Therefore the temporary piers to support the staging platforms can be located across the full width of the bridge and abutment works without affecting navigation of powered vessels. There will be 22 temporary piers (11 pairs) to support the northern staging platform and 30 piers (15 pairs) to support the longer southern platform. These temporary piers will occupy approximately 15 m^2 of sea floor area within the CMA. This is only ~0.3% of the total CMA area underneath the widened bridges and cycleway bridge.

The flow under the Causeway Bridges is essentially parallel to the orientation of the pairs of temporary piers, apart from the converging flows on the sides of the main channel through the piers adjacent to the abutments. Approximately 6 pairs of piers from the southern staging platform are located in the channel and 7 pairs of piers for the northern platform. The reduction in flow area will be 4.2 m^2 per m water depth. This is no more than a 7% reduction over the 60 m width of the channel under the bridges. The additional resistance to flow will be naturally compensated by a combination of a slight water level rise “upstream” of the pile groups (depending on ebb or flood tide) of less than a centimetre (comparing the result for the more skewed flow under the Whau River Bridges) and a slight increase in velocity through the reduced flow area to balance the energy head and hence maintain flow volumes.

Overall, the flow volumes passing through the channel on ebb and flood tides will be much the same as present, and any changes to tidal flushing of the Waterview Estuary and Oakley Inlet will be negligible. The additional pairs of temporary piers on either side of the bridges will generate additional wake shedding during both flood and ebb tide flows, but the effects will be less than minor given there are already 17 piers of 0.5 m diameter in a line that support the existing bridges, and the faster flows in the central portion of the channel are parallel with the pile or pier groups. Most of the shoreline in the immediate vicinity of the bridges is hardened bridge abutments or causeway revetments, so no additional bank erosion from installation of the temporary staging is expected. However, there may be some minor scouring of the “natural” intertidal mud banks to the south of the bridge abutments from the end groups of piers where the channels converge towards the outlet channel from Waterview Estuary (south west corner) and Oakley Inlet (south east corner). This is only expected to be minor because flow velocities decrease towards the edges of the channels and around high tide. Some localised seabed scour of up to 0.5 m could occur adjacent to the piers at the interface with the existing seabed, but will not lead to any larger-scale channel scour and will not present any issues with the structural integrity of the temporary staging platforms. Flow resistance from the temporary piers will also add an additional small backwater effect to Oakley River floods emanating from Oakley Inlet (in the order of a few centimetres) combined with an ebbing tide, but mostly the increased through-flow will be achieved by increasing current velocities through the bridged outlet channel.

Mitigation options: The smallest temporary pier diameters possible (0.6 m) have been used relative to a reasonable pier spacing (9 m) for safe load-bearing capacity of the temporary staging platforms.

Degree of potential effects: All effects of temporary piers on physical coastal processes will be minor. Minor effect on navigation as mainly small watercraft e.g., kayaks.

<u>**Activity 5:**</u> Occupation of the CMA in Oakley Inlet for temporary piers to support temporary staging platforms to construct on/off-ramps for the SH16/SH20 interchange.

Sector: 5 **Environment area:** Waterview Estuary

Potential effects: Change to hydrodynamic flow patterns; backwater effects from higher flow retardation; local and general scour from temporary piers; erosion of adjacent channel banks; reduced tidal flushing of Oakley Inlet.

Assessment:

For the new westbound on-ramp to SH16 (Ramp No. 2), six of the new on-ramp piers (Nos. 2–7) will require temporary staging platforms located partially or wholly in the CMA of Oakley Inlet, although only four of the permanent piers will be located directly within the CMA. Ramp No. 2 will require a total of 44 piers of 0.6 m diameter to support the temporary staging platforms. Only 3 of these piers (between Piers 4 & 5) will be located in the central portion of the main channel, and will be positioned to be near parallel with the flow direction to minimise flow resistance.

The new eastbound off-ramp from SH16 to SH20 (Ramp No. 3) will require two temporary staging platforms in the CMA supported by a total of 14 piers in the CMA, which avoid the central portion of the main channel. The new eastbound on-ramp to SH16 (Ramp No. 4) requires two staging platforms in the CMA supported by a total of 9 piers. Finally, the new westbound off-ramp from SH16 to SH20 (Ramp No. 1) requires one staging platform supported by 4 piers in the CMA.

The overall total will be 71 temporary piers of 0.6 m diameter to be temporarily installed within the CMA to support staging platforms used for the construction of the on/off-ramps for the Great North Road Interchange. The spacing between the piers varies from 5 m to 10 m. Only 3 piers are located within the central portion of the main sub-tidal channel, with another 4-5 piers near the sides of the main channel and the remainder positioned higher up on the intertidal banks within the mangroves. Consequently, the actual temporary loss of mid-tide channel flow area, when velocities are highest, will be small. Some disturbance of the upper-tidal vegetation will be required to drive the temporary piers.

Mitigation options: The layout of the piers to support the temporary staging platforms has been designed to minimise the number of piers within the main sub-tidal channel of Oakley Inlet and hence minimise the effects of piers on flow resistance and current flows and hence by inference sediment processes (other than minimal local scour around the temporary piers).

Degree of potential effects: Less than minor effects on flows and geomorphology (mostly piers are outside the main sub-tidal channel).

4.1.2 Reclamation

The physical effects on the CMA of construction of new reclamation works are mainly associated with discharges of sediment into the CMA (which are discussed in Section 4.1.4) and the effects on sediment processes and local geomorphology of the adjacent channel systems during the transition phase of construction.

<u>**Activity 6:**</u> Extending the width of SH16 adjacent to the main channel that drains the Pollen Island wetland system**.**

Sector: 4 **Environment area:** Central Waitemata Harbour

Potential effects: Erosion of channel banks; northward migration of the drainage channel; release of sediment into the water column; change in upstream drainage patterns in the Pollen Island wetland system.

Assessment:

In this Sector across the northern tip of Rosebank Peninsula, where the Pollen Island drainage channel pinches in close to the embankment (Figure 3.21) extending the embankment using the same fill and revetment approach as the Causeway would have partially encroached on the channel. This main channel drains the tidal wetland to the south of Pollen Island (Figure 3.22). Sheet-piling would also have been required to contain the reclamation works to avoid accidental run-out of fill material. Field observations demonstrated that current velocities around mid-tide can be quite high (~1 m/s) in this 2-3 m deep tidal channel, which is indicative of the substantial flow volumes that are exchanged between the mangrove and saltmarsh wetland system and the Central Waitemata Harbour. If the channel was to be constricted (even partially) it could cause two potential impacts: a) local migration of the channel further to the north to maintain the channel cross-sectional area (by way of erosion and bank failure of the opposite bank), and b) physical changes to the drainage patterns in the wetland catchment.

Figure 3.21: Aerial photograph of the section of SH16 in the vicinity of Rosebank Rd. on-ramp. The main drainage channel draining the Pollen Island wetland is shown adjacent to the existing revetment and approximate sections where retaining walls will be used to avoid encroachment of the channel are indicated. [*Source*: Aurecon NZ Ltd.].

Mitigation or avoidance options: Given the importance of tidal-drainage channels for wetlands such as the Pollen Island Marine Reserve, it was decided early on in the engineering design process to <u>avoid any encroachments</u> of this drainage channel and reclamation in the CMA by adopting vertical retaining walls to support the widened embankment, given the ground conditions (on Peninsula itself) are conducive to this type of structure. These two sections, totalling 290 m in length, are largely in a zone screened from wind waves compared with the much more exposed Causeway, so a sloping rock revetment for coastal-hazard protection is not required.

Degree of potential effects: Less than minor by avoiding encroachment of the CMA in these two sections through changes to the engineering design (using vertical retaining walls instead of sloped rock revetments). The effect of even partial channel encroachment may cause more than minor changes in the drainage patterns of the wetland and geomorphological changes in the tidal drainage channel if sloped revetments were to be used.

Figure 3.22: View of the main Pollen Island drainage channel looking upstream (to the west) from the SH16 embankment across Rosebank Peninsula and beyond towards the substantial tidal wetland behind Pollen Island at 1216 h (NZDT) on 27 February 2009. [*Photo source*: T. Hume, NIWA]

Activity 7: Extending the width of SH16 carriageway on the south side adjacent to a side drainage channel that flows around Rosebank Park Domain into the Whau River.

Sector[9]**:** 4 **Environment area:** Whau River area

Potential effects: Encroachment on a small channel that drains the intertidal areas to the west of Rosebank Peninsula; effects on drainage patterns upstream; effects on sediment processes locally.

Assessment:

On the southern side of SH16 on Rosebank Peninsula, there is a small drainage channel (in comparison with the other drainage channels considered in this sub-section) that drains the intertidal area to the west of Rosebank Peninsula, conveying intertidal waters to the Whau River near Rosebank Park Domain (Figure 3.23). The channel is only about 3-5 m in width and extends about 400 m further upstream from the construction site before petering out. Due to the smaller scale of the channel and its upstream catchment (compared to the

[9] Figure 1.2 shows this geographical location to be in 'Sector 3: Rosebank – Terrestrial'. However, this activity is designated to be in 'Sector 4: Reclamation' as the works correspond to reclamation of the CMA due to extending the width of the existing carriageway through the narrow isthmus.

other channel encroachments considered), the 125 m section of channel will be allowed to naturally migrate laterally and reform a channel on the outside of the ground-treatment works protected by super silt fences.

However, to facilitate the natural migration of the drainage channel, the widening of the reclamation and associated ground treatment works needs to proceed slowly in stages out into the existing drainage channel. This is to provide sufficient time for the channel to migrate laterally to avoid upstream ponding as the tide level drops. Also, mangroves and their rooting systems will need to be removed on the southern side of the drainage channel to allow erosion processes from weak current velocities to operate more freely on the southern flank of the channel. Current velocities in the drainage channel are modest as seawater only covers the extensive intertidal flats around high tide and become negligible when the flats have been drained. Therefore, there is a low risk of channel bank instabilities or slumping occurring as the channel migrates and reforms.

Mitigation options: The speed and staging of the reclamation and ground treatment works that will infill the 125 m section of drainage channel, should be matched with the response of the channel to naturally migrate to maintain a similar flow conveyance area.

Degree of potential effects: The effect of the reclamation works encroaching on the small drainage channel will be no more than minor if a new channel is allowed time to form to the south of the ground improvement and super silt fence as the reclamation works proceed. Some mangrove removal may be needed to allow the channel more freedom to migrate southwards. With these measures in place, the effects on drainage patterns and sediment processes will be no more than minor, but the migration of the channel should be monitored regularly to ensure drainage is not impeded.

Figure 3.23: Aerial view of the subsidiary drainage channel that services the intertidal banks to the west of Rosebank Peninsula (bottom RHS). The section of channel where the encroachment will occur is highlighted by arrows. [*Image source: ©MapData Sciences Pty Ltd., PSMA and Google Earth*]

<u>**Activity 8:**</u> Extending the width of the SH16 Causeway into the adjacent meander of the drainage channel that services the western side of Waterview Estuary.

Sector: 4 **Environment area:** Waterview Estuary

Potential effects: In this section of Waterview Estuary, a major drainage channel has formed hard in against the existing revetment, but the widened reclamation will necessitate complete infilling of this section of channel. Allowing the channel to naturally migrate laterally and reform could lead to upstream and downstream instabilities, or slumping on the flanks of the sub-tidal channel and associated backwater effects, besides potentially undermining the ground treatment works or the cofferdam. Another issue is the dispersal of contaminated sediments buried in the surface layer as the channel is forced to migrate by eroding the opposite intertidal banks,

Assessment:

In this section of Waterview Estuary, the main western drainage channel has formed a meander hard in against the existing revetment (Figure 3.24 and Figure 3.25) following construction of the Causeway in the early 1950s. This section of channel is somewhat deeper than the channel either end of the meander (up to –1.8 m AVD-46; 2008 NIWA hydrographic survey, Figure 3.10).

These characteristics stem from the historic drainage pattern for the Estuary, where this specific area was part of a former outlet channel from the Estuary before the Causeway was built (Figure 3.14). If no intervention was employed after the existing channel meander is infilled, the muddy flanks of the channel on the opposite side (southern) of the channel will quickly erode to maintain a drainage channel of similar cross-sectional area. This will erode a substantial volume of sediments (of the order of 2,000 m^3), some of which will be contaminated (~0.25 m top layer) and most of the fine sediment will be suspended into the flow by strong but shallow sheet-flow as the channel develops.

Surface sediments are moderately contaminated by heavy metals (see G.11 Assessment of Marine Ecological Effects report for details). The contaminated portion of eroded in-situ sediment will then get dispersed throughout Waterview Estuary and out into the Central Waitemata Harbour. This volume of eroded sediment will have the potential to generate a visual turbid plume and increased sedimentation of fine-grained sediments in preferential deposition areas. Both the thickness of deposition and the transport of contaminants may result in ecological effects. These are discussed further in the Assessment of Marine Ecological Effects report.

Consequently, the encroachment of the channel in this section of Waterview Estuary is best dealt with by re-aligning the affected section by excavating a by-pass channel prior to the reclamation widening to avert:

a) potential erosional instabilities from rapid scouring especially during spring tides;
b) dispersal of contaminated and/or fine sediment through Waterview Estuary and out into the Central Waitemata Harbour; and
c) the likelihood of the channel to scour deeper at the cofferdam interface if left to re-align naturally.

Mitigation options: The advantages of undertaking a managed excavation of a by-pass channel (same cross-sectional area) and controlled infilling of the present channel (to be occupied by the widened reclamation) outweigh the uncertainties and avoidable environmental contamination that could arise from allowing the channel to naturally migrate and re-establish itself. While a controlled excavation of a new by-pass channel will cause seabed disturbance and some sediment discharges, these will be much smaller and contained than the alternative of leaving natural erosion processes to form a new channel, generating substantial sediment discharges in the transition period. More details of the effects of excavating a by-pass channel are provided in the next section covering disturbance activities and effects. Further mitigation options were considered early in the engineering design phase to reduce the reclamation footprint in this section, such as steeper revetment slopes (e.g., 1:1) or sheet-piling, but were discounted due to the poor geotechnical properties of the deep estuarine muds (see Coastal Works Report).

Degree of potential effects: Minor, if mitigation options are used. Infilling one of the main estuary channels in its deepest section without mitigation measures or remedial works is likely to lead to potential upstream and downstream instabilities or slumping on the flanks of the sub-tidal channel and the release and dispersal of contaminated sediments (especially from the top 0.25 m layer of modern sediments) that may result in more than minor effects.

Figure 3.24: Aerial view (February 2006) of the main drainage channel that services the intertidal banks on the western side of Waterview Estuary. The channel meander that cuts in close to the south side of the existing Causeway is clearly shown and is the section which will require complete infilling by the widened reclamation and associated ground treatment to approximately the dotted line. North is top of the photograph. [*Photograph source:* Aurecon NZ Ltd.]

Figure 3.25: Oblique view looking west along the Waterview Estuary drainage channel where the widened Causeway to the south will necessitate infilling of the adjacent channel out to the opposite flank. Taken at 1449 h (NZDT) on 27 February 2009. [*Photo*: T. Hume, NIWA]

<u>Activity 9:</u> Extending the width of SH16 Causeway, including the transition from the Westbound On-ramp from SH20 and cycleway, into two meanders of the sub-tidal channel in Oakley Inlet.

Sector: 4 **Environment area:** Waterview Estuary

Potential effects: In these two sections of Oakley Inlet (see Table 4.1 for locations and drawing No.), the sub-tidal channel currently meanders in close to the existing revetment (Figure 3.26), particularly the western meander. The widened reclamation will necessitate complete infilling of the western meander and substantial infilling of the eastern meander. Allowing the channel to naturally migrate laterally and reform could lead to upstream and downstream instabilities or slumping on the flanks of the sub-tidal channel and associated backwater effects during spring tide and flood events, besides potentially undermining the ground treatment works or the temporary sheet-piling. Another issue is the dispersal of contaminated sediments in the surface layer as the channel erodes the intertidal banks and reforms.

Assessment:

In a similar approach to the Waterview Estuary channel (see Activity 8 assessment), the two meander sections will need to be re-aligned by excavating a by-pass channel to avert:

a) potential erosional instabilities from rapid scouring especially during spring tides and Oakley Creek floods;

b) dispersal of contaminated sediments through the Estuary and out into the Central Waitemata Harbour, and;

c) the tendency for the channel to scour deeper at the sheet-piling interface if allowed to re-align naturally.

Mitigation options: The advantages of undertaking a managed excavation of a by-pass channel (same cross-sectional area) and controlled infilling of the present channel (to be occupied by the widened reclamation) outweigh the un-predictabilities and avoidable environmental contamination that could arise from allowing the channel to naturally migrate and re-establish itself. While a controlled excavation of the new by-pass channels will cause seabed disturbances and some sediment discharges, these will be much smaller and contained than allowing natural erosion processes to form a new channel, generating substantial sediment discharges in the process.

More details of the effects of excavating a by-pass channel are provided in the next section covering disturbance activities and effects. Further mitigation options were considered early in the engineering design phase to reduce the reclamation footprint in this section, such as steeper revetment slopes (e.g. 1:1) or permanent sheet-piling, but were discounted due to the poor geotechnical properties of the estuarine muds.

Degree of potential effects: Minor, if mitigation options used. Infilling these meander channels in the narrow confines of Oakley Inlet without mitigation measures is likely to lead to potential geomorphological instabilities of the channel banks and release and dispersal of contaminated sediments (especially from the top 0.25 m layer of modern sediments) as the channel re-aligns itself. This may result in more than minor effects—therefore a controlled excavation of two by-pass channels is proposed.

Figure 3.26: Aerial view (February 2006) of the two meanders in the Oakley Inlet channel that will require complete or substantial infilling by the widened reclamation and ground treatment. North is top of the photograph. [*Photograph source:* Aurecon NZ Ltd.]

4.1.3 Disturbance

__Activity 10:__ Ground (seabed) treatment works in the CMA required to support widened reclamations.

Sector: 2,3,4 **Environment areas:** Whau River area; Central Waitemata Harbour; Waterview Estuary

Potential effects: Seabed sediments and any associated contaminants disturbed down to approximately 2–3.5 m during construction and out to 4 m beyond the toe-line of the widened reclamations. In areas where mudcrete is proposed, sediments will be returned to the seabed in a strengthened bound form. In other areas the excavated sediments will be replaced with either lightweight buoyant fill or engineered fill material. Other effects are removal of vegetation within the disturbed areas, sediment discharges into receiving waters of the CMA, possible visual plume and reduced water clarity from sediment discharges, cement mix (for mudcrete) entering receiving waters and increasing pH.

Assessment:

Details of construction techniques are provided in the Coastal Works Report (G.23). Over the majority of the length of the Causeway and other reclamation sites (see Permanent Occupation drawings), the widened reclamation will be founded on mudcrete formed by injecting and mixing cement in situ into the existing fine sediment substrate of the CMA. This method avoids excavation of the contaminated sediment and reduces potential for adverse environmental effects from discharges. Any contaminants within the sediment fabric are also 'locked up' within the mudcrete. There is however potential for some disturbance of sediment due to vehicle and plant movement and general works. This method requires a relatively dry working area, such as working during low tide periods or enclosing the area off from the seawater. In the transition between the existing and widened reclamations, foundation undercut will be used to remove seabed sediments under the edge of the existing reclamations and replace with engineered fill material. This will also be executed under the same dry conditions as for mudcrete. A third ground improvement technique that will be applied is in the transition areas either side of the Causeway Bridges, where seabed sediments will be excavated and replaced with lightweight buoyant fill to match the similar fill used in the Bridge widening works in the early 1990s. This approach is needed to reduce the long-term subsidence on the approaches to the firmly-founded bridge structures.

From all of these ground treatment disturbances, the main effects to mitigate are the release of sediments into the receiving waters of the CMA and therefore downstream issues of sediment deposition and aesthetic impacts on water quality.

Mitigation, monitoring and remediation options: Construction methodologies (see Coastal Works Report) will require the use of a temporary cofferdam to allow construction at all states of the tide, or in some less critical areas, use of super-silt fences enclosing the seabed disturbance works that can be done high up on intertidal banks where tidal inundation only occurs for short periods. The cofferdam forms a dry working area and also serves as a sediment-control measure. The cofferdam will be either temporary sheet-piling, or a temporary water-filled tubular bund such as the AquaDam™. Sheet-piling will be used within intertidal mangrove areas, where other systems would require the removal of substantial tracts of mangrove vegetation or where temporary working areas within the CMA are limited e.g., Oakley Inlet. Tubular systems will be used over both intertidal and sub-tidal sections. The water-filled chambers will be used in short sections, approximately 100 m long. On completion of each 100 m section of construction activity, the temporary bund is removed and relocated slightly further along the causeway. The construction area will be continually pumped dry and the slurry disposed of as contaminated waste material. Monitoring of pH and suspended sediment concentration on the seaward side of the bund during construction will confirm the effectiveness of the bund. Works will cease if monitoring shows values of suspended sediment and pH in excess of agreed thresholds. Monitoring will also be undertaken on the removal and relocation of each temporary bund, and remediation undertaken to restore the portion of disturbed areas to be returned to the CMA after temporary occupation is no longer needed.

Degree of potential effects: Minor with mitigation and monitoring measures in place and remediation of the areas on completion to be suitable marine habitats (see Assessment of Marine Ecological Effects report).

<u>Activity 11:</u> Mobilisation, installation and removal of sediment-control and containment measures.

Sector: 1,2,3,4,5 **Environment areas:** Whau River area; Central Waitemata Harbour; Waterview Estuary

Potential effects: Disturbances of CMA sediments due to any ground (seabed) preparation, installation and removal of temporary structures or bunds; discharge of sediments if tidal inundation is present during installation or removal, removal of vegetation to facilitate installation of AquaDam or sheet-piling .

Assessment:

Construction activities include installation and removal of sheet-pilling, clearance of seabed vegetation for AquaDam, installation and dismantling of silt fences and super-silt fences. These activities may cause localised and temporary releases of sediment or minor scouring on installation of removal but if largely done at lower stages of the tide, there should only be minor localised effects on sediment processes.

Mitigation options: Sheet-piling, rather than the AquaDam, will be used for creating dry working space in areas where there a substantial tracts of mangroves. Installation and dismantling will be done outside tidal inundation windows to minimise suspended-sediment discharges to the receiving waters.

Degree of potential effects: Minor, particularly if undertaken during dry tidal windows.

<u>Activity 12:</u> Excavation and ground-treatment works in the CMA for outlet structures for permanent storm water outlets.

Sector: 1-4 **Environment areas:** Whau River area; Central Waitemata Harbour; Waterview Estuary

Potential effects: Disturbance of in-situ sediments and/or vegetation in the CMA; discharges of suspended sediments.

Assessment:

The treated stormwater outlets from settling ponds or cartridge treatment pods will be located at various locations as per Figure 3.27. Details of these stormwater outlets and assessment of construction effects are given in the Stormwater Assessment Report (**G.15**). Works within the CMA will be enclosed by erosion and sediment control methods designed in accordance with ARC TP90. Works can be done outside tidal inundation periods (which high on the intertidal banks only excludes a relatively short period). The disturbance of in-situ sediments and discharges of suspended sediments during construction of these outlets is therefore likely to lead to less than minor effects.

Mitigation options: None required.

Degree of potential effects: Less than minor due to the small scale and temporary nature of the works within the CMA and with the use of erosion & sediment control measures.

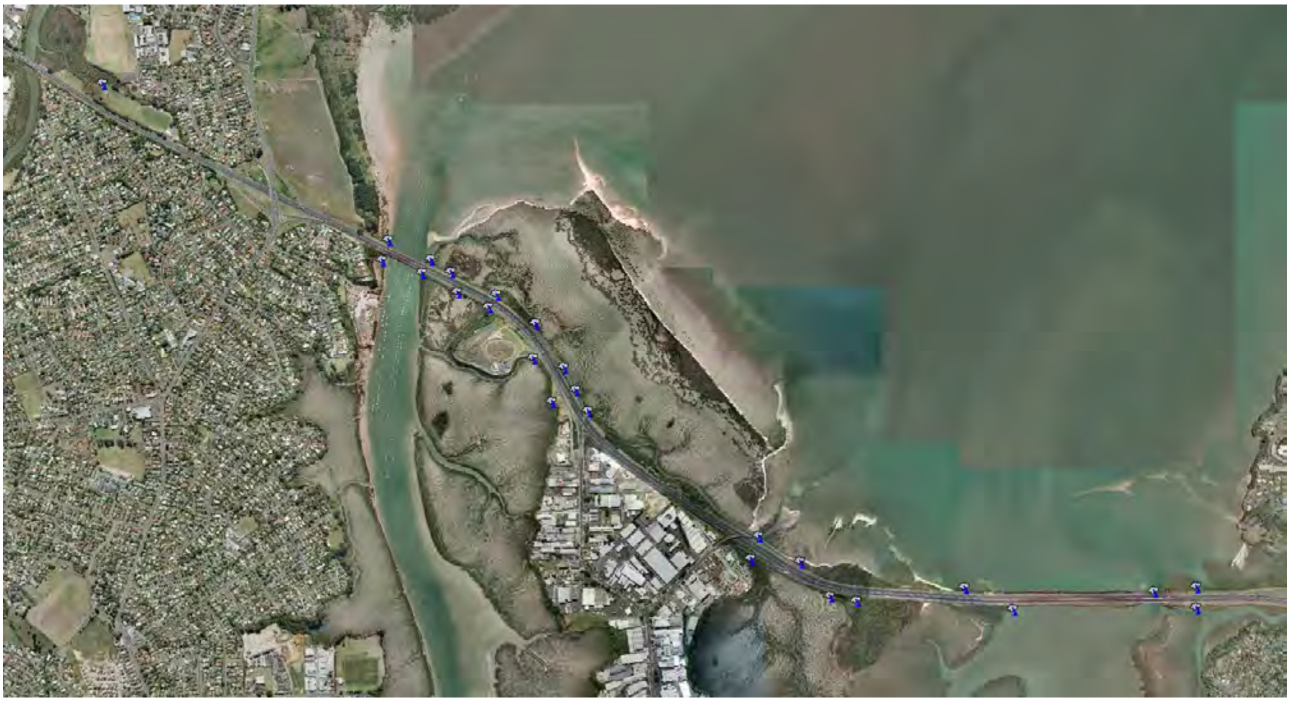


Figure 3.27: Discharge locations for stormwater outlets.

__Activity 13:__ Excavation for widened bridge abutments and ground-treatment works in the CMA, Whau River Bridges and cycleway bridge.

Sector: 2 **Environment areas:** Whau River area

Potential effects: Seabed sediments and any associated contaminants will be disturbed during construction out to the toe-line of the widened western and eastern abutments. In areas where mudcrete ground treatment is proposed, sediments will be returned to the seabed in a strengthened bound form. In other areas the excavated sediments will be replaced with engineered fill material. Other effects include:

i) the removal of any vegetation within the disturbed areas (mainly the lateral sides of the existing abutments)
ii) sediment discharges into receiving waters of the CMA including wave stirring of disturbed sediments
iii) possible visual plume and reduced water clarity from sediment discharges
iv) cement mix (for mudcrete) entering receiving waters and increasing pH.

Assessment:

These potentially adverse activities, while localised in most cases, except for the longer sections of widened reclamation either side of the eastern abutment, will require work practices and erosion and sediment control methods that minimise the effects of disturbances of the seabed in the CMA and minimise suspended-sediment discharges into the adjacent receiving waters. The design of erosion and sediment control methods for these abutments are discussed in the Erosion and Sediment Control Plan (**G.22**). Given these mitigation measures and allowing for reasonable mixing of any residual discharges of like sediment (i.e., similar sediments that already contribute to the background Whau River turbidity) with River waters, the physical effects and aesthetic effects of discharges from disturbance activities should be minor. Greater control on discharges using erosion and sediment control methods can be achieved higher up on the intertidal areas adjacent to the sides of the abutments, where the tidal inundation window is shorter and current velocities are much slower.

Mitigation options: Appropriate erosion and sediment control methods, with particular design features required to withstand stronger channel flows for the sections along the terminus of both abutments and to contend with a higher wave exposure on the western abutment, compared with the eastern abutment which is more sheltered behind Pollen Island.

Degree of potential effects: Minor with erosion and sediment control mitigation measures in place.

<u>Activity 14:</u> Installation and removal of temporary piers to support the temporary staging platforms for construction of Whau River Bridges and cycleway bridge.

Sector: 2 **Environment area:** Whau River area

Potential effects: Disturbance of the seabed of the CMA; release of sediment into water column

Assessment:

The disturbance of seabed sediments and release into the water column will diminish as the piers are driven and local scour around the pile has removed the surface layer of sediments. Extraction of piers after the construction phase will also lead to disturbance of the seabed around each pier with release of localised quantities of sediment into the water column. These sediment releases for each pier will only occur for short durations. In assessing effects on water appearance, given: a) the relatively high background suspended-sediment concentrations (normally 4-20 mg/L up to 40 mg/L at the ARC monitoring station 1 km north of the Whau River Bridges in Central Waitemata Harbour—and likely to be higher in the Whau River; and b) the sediments disturbed from the seabed of the channel are similar to the type and colour of sediments causing background turbidity in the Whau River, the effects on water appearance are likely to be minor after allowing for reasonable mixing (s. 107(1)(d) RMA) and will be short-lived.

Mitigation options: Not feasible to contain the disturbed sediment in the sub-tidal channel

Degree of potential effects: Minor effects including suspended-sediment plumes after allowing for reasonable mixing.

<u>Activity 15:</u> Construction of permanent piers to support widened Whau River Bridges and cycleway bridge.

Sector: 2 **Environment area:** Whau River area

Potential effects: Disturbance of the seabed of CMA; release of sediment into water column.

Assessment:

42 concrete cast in-situ piers of 1.5 m diameter will support the widened Whau River bridges continuing in the same orientation as the existing pier groups, and 7 cast in-situ piers of 1 m diameter will support the cycleway bridge. These piers will be cast inside a driven steel casing after sediments are extracted from inside the casing. The casing itself will release smaller quantities of disturbed sediments to the water column as it is driven into position (similar to previous assessment for temporary piers).

Mitigation options: Not required as the steel casings will minimise discharges of sediment during excavation of the seabed sediment prior to in-situ casting.

Degree of potential effects: Minor effects on sediment processes (sediment discharges after allowing for reasonable mixing and local scour).

<u>Activity 16:</u> Blocking off redundant culvert under the Causeway (adjacent to west side of Rosebank Peninsula).

Sector: 4 **Environment area:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Localised seabed sediment disturbance; sediment discharges.

Assessment:

An existing culvert under SH16 was originally included through the Causeway to connect the western reach of the Waterview Estuary (adjacent to Rosebank Peninsula) to the main tidal channel that drains the wetland south of Pollen Island. However, this culvert no longer operates due to siltation and mangrove growth at the entrance to the culvert and the general accretion of this north-western section of Waterview Estuary, even though the invert level is at approximately 0.25m AVD-46 at either end (i.e. about 0.13 m above mean tide level).

In widening the Causeway, this culvert can be either permanently closed off, or extended to the width of the new Causeway. The high elevation of the invert level of the culvert will always limit the flow exchange through the culvert and will require substantial works to lower the culvert. The area to the south of the culvert, i.e. the upper reaches of the Waterview Estuary adjacent to Rosebank Peninsula is an intertidal area with a relatively high seabed elevation (from extensive sedimentation) and degraded water and sediment quality with elevated contaminant concentrations. If a lowered culvert was able to provide a more efficient flow exchange, there could be adverse environmental effects if these contaminated sediments were discharged into the wetland drainage channel behind Pollen Island. In any case, given the high sediment accumulation and mangrove colonisation that has occurred at the western end of Waterview Estuary since the Causeway was built in the 1950s, it is unlikely that a lowered culvert will provide any additional flushing and recirculation for Waterview Estuary. Overall, it is the recommended that works are undertaken to permanently block off this culvert under SH16 (see also Coastal Works Report).

Mitigation options: Placement of erosion and sediment controls around the periphery of the site works which are designed according to ARC TP90 guidelines.

Degree of potential effects: Negligible effects if works mainly undertaken during lower tide levels.

<u>Activity 17</u>: Ground (seabed) treatment works between Traherne Island and Rosebank Peninsula on the northern side will disturb or bury shoreline chenier (shell) beach deposits.

Sector: 4 **Environment area:** Central Waitemata Harbour

Potential effects: Disturbance or burial of parts of chenier (shell) beach deposits

Assessment:

The beach and offshore shell deposits are features of geological significance (called a chenier ridge). Shell ridges also prevent erosion of the shore by protecting underlying finer grain sized sediments.

Mitigation and remediation options: Where burial of the shell deposits will occur under the widened reclamations or where construction works will potentially disturb or damage the shell material, it is recommended that the vulnerable shell layers are excavated and stockpiled. After completion of the revetment works, this shell material will be replaced on the beach in front of the new reclamation at the same geographical locations (chainage). Waves during high spring tides will eventually sort the shells back towards an equilibrium beach profile and re-build the chenier ridge.

Degree of potential effects: Minor effects on the intrinsic value of these geomorphological features of this area if the recommended remediation measures are undertaken.

<u>Activity 18:</u> Excavate a by-pass channel further south of western drainage channel in Waterview Estuary to re-align the meander in the channel that would otherwise be occupied or reclaimed by the widened Causeway.

Sector: 4 **Environment area:** Waterview Estuary

Potential effects: Complete infilling of the meander in the present drainage channel, disturbance of seabed sediments by excavation, release of sediments and associated contaminants into the water column; re-diversion of estuarine flows.

Assessment:

The widened Causeway revetment and associated ground treatment will completely infill the meander of the main tidal drainage channel for western Waterview Estuary which currently runs in close along the southern side of the Causeway (Figure 3.24 and Figure 3.25). The channel is completely within the widened Causeway footprint for approximately 170 m. Reasons why the channel should not be left to naturally migrate southwards by erosion of the southern banks of the meander were provided in the previous section on reclamation activities (see Activity 8).

The advantages of undertaking a managed excavation of a by-pass channel (with the same cross-sectional area) and controlled infilling of the present channel (to be occupied by the widened reclamation) outweigh the potential for channel slumping and instabilities, environmental contamination and deposition of fine-grained sediment that could arise from allowing the channel to naturally migrate and re-establish itself. The recommended mitigation option is to excavate a new by-pass channel under controlled conditions. While a controlled excavation of a new by-pass channel will cause seabed disturbance and some sediment discharges, these will be much smaller and contained than the alternative of leaving natural erosion processes to form a new channel, generating substantial sediment discharges in the transition period. The new section of channel will be located immediately to the south of the existing drainage channel, by-passing the existing channel meander. This mitigation option has been incorporated into the constructability design (see Coastal Works Report). To maintain a similar flow capacity, the design specifies a similar cross-sectional shape. Smooth flow transitions will be created at the upstream and downstream confluences with the existing channel, while the thalweg of the new channel section will be curved, rather than straight, to accommodate secondary flow process around bends. This is illustrated in Figure 3.28 and is detailed in drawing 20.1.11-3-D-C-150-225. Material excavated to form the new channel will be mixed with cement to form mudcrete and then used to infill the existing channel meander. The use of mudcrete will safely lock-in any contaminants within the sediment and keep the sediment within the estuarine system.

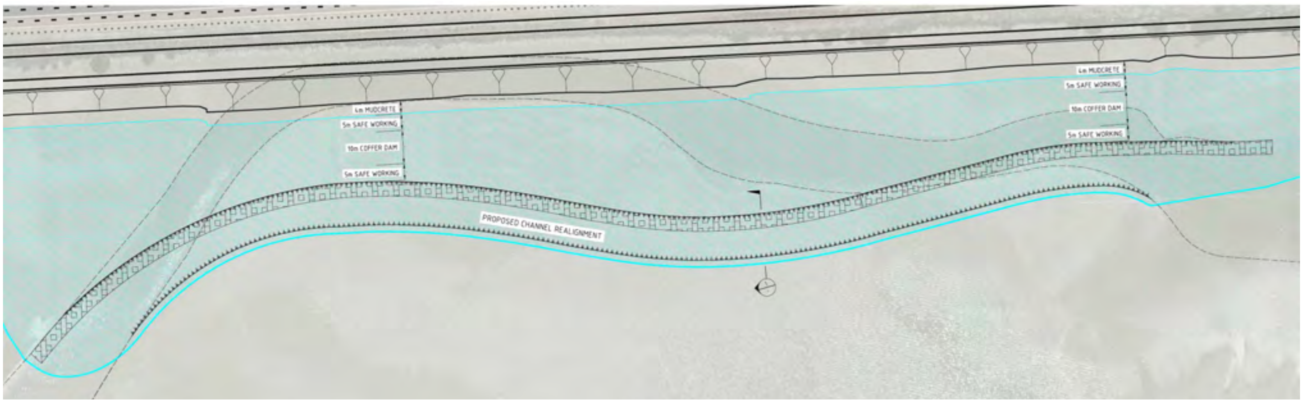


Figure 3.28: Realignment of western drainage channel south of the Causeway. (Extracted from drawing 20.1.11-3-D-C-150-225).

The infilled volume to be excavated adjacent to the existing channel meander will be ~1700 m3 plus an allowance of approximately 100–200 m3 for shaping the up and downstream and opposite-bank transitions. This means a total of about 2000 m3 of bed sediments will need to be excavated.

The methodology for construction of this channel is detailed in the Coastal Works Report (**G.23**). A computational model was used to predict the potential dispersal of disturbed sediments that could enter the receiving waters (without assuming any mitigation measures and excavation occurring during the entire tide cycle). Assuming a conservative 3% loss of sediment from an excavator bucket (based on conservative rates of resuspended sediment mass per m^3 of material excavated by a backhoe dredger with smaller bucket sizes dredging in water (CIRIA, 2000), the predicted suspended sediment concentrations and depth of deposition will only result in minor effects in terms of physical coastal process. The ecological effects of this sediment dispersal and deposition are reported in the Assessment of Marine Ecological Effects report (**G.11**). The details of the computation modelling simulations for the by-pass excavation are given in Appendix C, with a summary of the results discussed below.

During the period of these channel re-alignment works, the sediment released into the water column will be dispersed throughout the Waterview Estuary. Simulations (Appendix C) show that up to 84% of the released sediment will get exported from the Waterview Estuary (for medium silt sediment under a Water Quality storm event). The maximum suspended sediment concentration predicted to occur at any time over the construction period is shown in Figure 3.29 (medium silt, base flow). The relatively high suspended-sediment concentrations shown within the western section of the drainage channel results from the high turbid 'front' on the flooding tide entering progressively shallower water depths. These sediment concentrations occur for a relatively short period of time, as can be seen by a time series plot taken from a point in the upper reaches of this drainage channel (Figure 3.30).

The total amount of sediment deposited within the Waterview Estuary by the end of the model simulation is approximately 15% of that potentially discharged (assuming a 3% loss from excavator bucket) which is ~10 m^3. For both medium and coarse silts, most of the sediment deposits very close to the excavation location and within the construction zone footprint. This is essentially from sediment lost from the bucket falling quickly to the seabed. The depth of deposited sediment will depend on the grain size of the disturbed sediment. Detailed laboratory analysis of sediment samples from this location are currently in progress. Simulations were undertaken from both medium and coarse sediment grain sizes, and provide an envelope for potential deposition. Outside of the construction area, deposition of greater than 7 mm may occur over an area of 250 m^2, for the coarse sediment (Figure 3.32). For the medium silt simulations, the maximum deposition thickness outside the construction zone is 3 mm (Figure 3.31). The actual deposition will lie between these two predictions. Further away from the construction zone, sediment deposits as a very thin layer, less than 1 mm thick, spread over the Waterview Estuary. The mass of contaminants, attached to the deposited sediment, will also be correspondingly low.

Mitigation options: Erosion and sediment control methods will largely focus on undertaking excavations during low-tide windows when the new channel site is not inundated by the tide. Release of suspended sediments to the adjacent receiving waters will be minimised by excavating the middle section of the by-pass channel first before breaking through the eastern and western ends that transition to the existing channel. Excavation will be undertaken from a barge to minimise seabed disturbance by machinery adjacent to the new channel.

Degree of potential effects: Minor effects on sediment and hydrodynamic flow processes after undertaking a managed excavation of a bypass channel section followed by infilling of the existing channel meander with mudcrete using the excavated material.

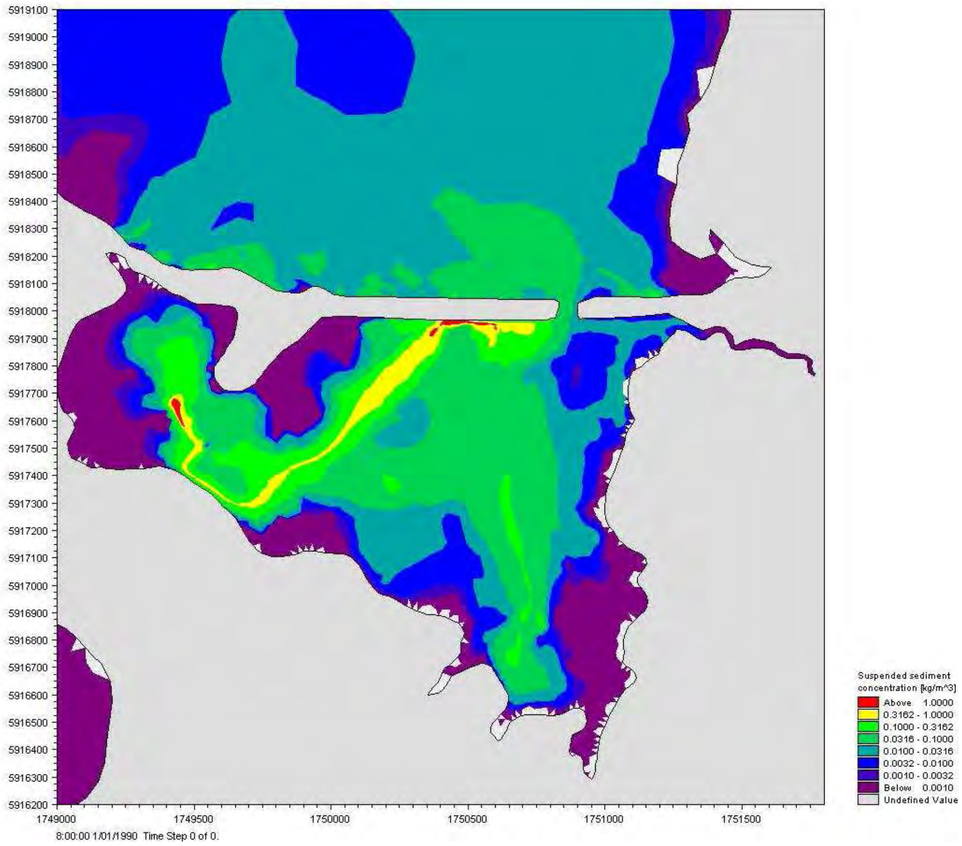


Figure 3.29: Envelope of maximum suspended sediment concentration at any time during the simulation for a discharge of medium silt (6 – 20 μm) from a source adjacent to the Causeway, with concentrations in kg/m³ Note: multiply by 1000 to get mg/L e.g. 0.1 kg/m³ is 100 mg/L.

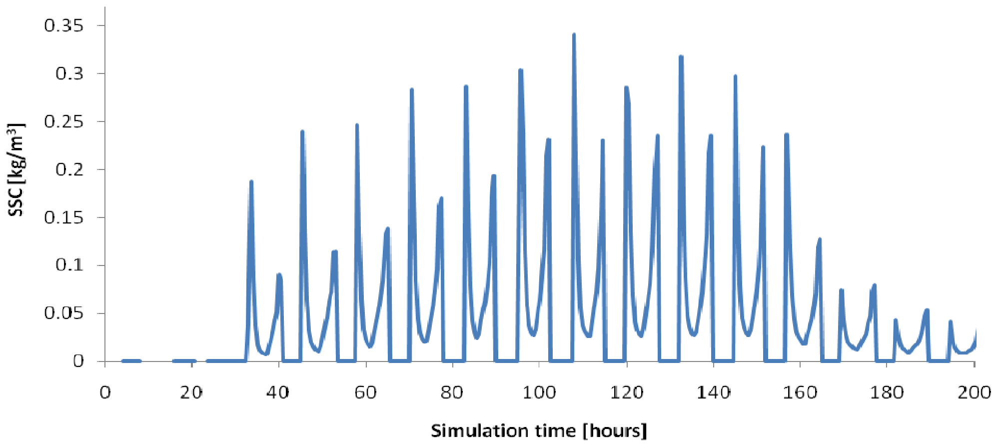


Figure 3.30: Time series of suspended sediment concentration in upper western reaches of Waterview Estuary drainage channel (NZTM location 1749903, 5917444). The higher peaks coincide with the flood tide and the lower peaks, the ebb tide.

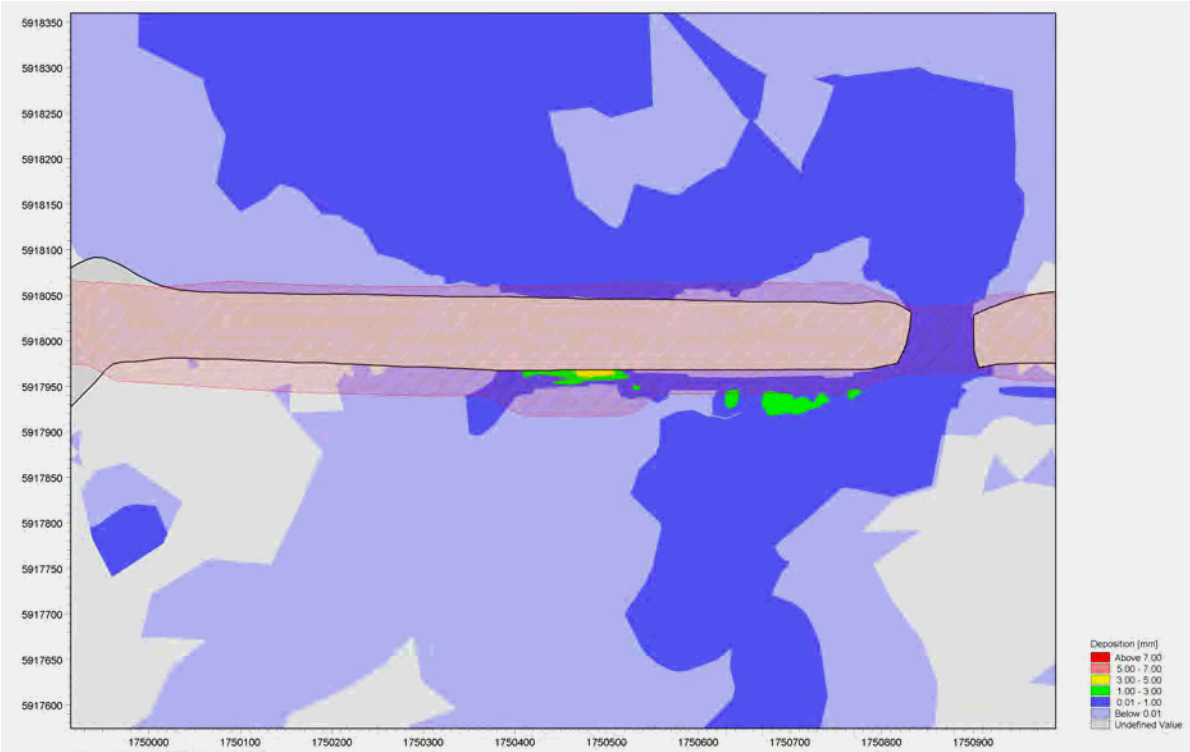


Figure 3.31: Accumulated sediment deposition for a discharge of medium silt (6 – 20 μm) from the channel excavation site in Waterview Estuary. Also shown is the CMA temporary occupation footprint to facilitate construction or as part of the widened Causeway footprint.

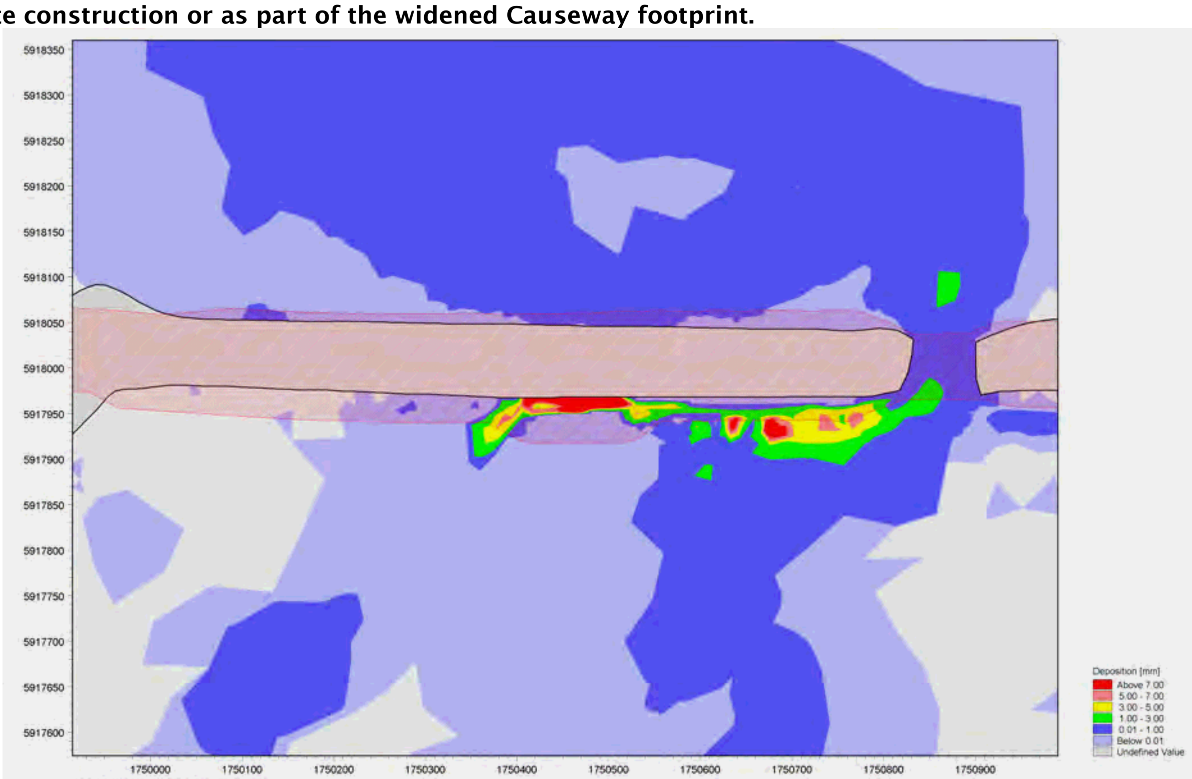


Figure 3.32: Accumulated sediment deposition for a discharge of coarse silt (20 - 63 μm) from the channel excavation site in Waterview Estuary.

Activity 19: Excavations for widened bridge abutments and ground treatment works, Causeway Bridges and cycleway bridge.

Sector: 4 **Environment areas:** Central Waitemata Harbour; Waterview Estuary

Potential effects: i) Seabed sediments and any associated contaminants disturbed during construction out to the toe-line of the widened western and eastern abutments. In areas where mudcrete ground treatment is proposed, sediments will be returned to the seabed in a strengthened bound form. In other areas the excavated sediments will be replaced with engineered fill material; ii) removal of any vegetation within the disturbed areas (mainly the lateral sides of the existing abutments); iii) sediment discharges into receiving waters of the CMA including wave stirring of disturbed sediments; iv) possible visual plume and reduced water clarity from sediment discharges; v) cement mix (for mudcrete) entering receiving waters and increasing pH.

Assessment:

These potentially adverse activities, while localised in most cases, will require work practices and erosion and sediment control measures that minimise disturbances of the seabed in the CMA and suspended-sediment discharges into the adjacent receiving waters. The design of erosion and sediment control methods for these abutments are discussed in the Erosion and Sediment Control Plan (**G.22**). Given these mitigation measures and allowing for reasonable mixing of any residual discharges of like sediment (i.e., similar sediments that already contribute to the background Waterview Estuary turbidity) with receiving waters, the physical and aesthetic effects of discharges from disturbance activities will be minor. Greater control on discharges using erosion and sediment control methods can be achieved higher up on the intertidal areas adjacent to the sides of the abutments, where the tidal inundation window is shorter and current velocities are much slower.

Mitigation options: Appropriate erosion and sediment control methods, with particular design features required to withstand stronger channel flows for the sections along the terminus of both abutments and can contend with a higher wave exposure on the northern side of both abutments.

Degree of potential effects: Minor with erosion and sediment control mitigation measures in place.

Activity 20: Installation and removal of temporary piers to support the temporary staging platforms, Causeway Bridges and cycleway bridge.

Sector: 4 **Environment areas:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Disturbance of the seabed within the CMA; release of sediment into water column.

Assessment:

As the piers are driven deeper into the sea floor, the disturbance of seabed sediments and the subsequent release of sediment into the water column will diminish. Local scour from locally-accelerated currents around the piers will also remove the surface layer of seabed sediments in the vicinity of the piers during and after the installation of the piers. Extraction of piers after the construction phase will also lead to disturbance of the seabed around each pier with release of localised quantities of sediment into the water column. These sediment releases for each pier will only occur for short durations. In assessing effects on water appearance, given: i) the relatively high background suspended-sediment concentrations (normally 2-10 mg/L and up to 38 mg/L at the Oakley Carrington ARC monitoring station in lower Oakley Creek), and ii) the sediments disturbed from the seabed of the channel are similar to the type and colour of sediments causing turbidity in the Waterview Estuary, the effects on receiving-water appearance are likely to be minor after allowing for reasonable mixing (s. 107(1)(d) RMA) and short-lived.

Mitigation options: No further measures apart from erosion & sediment control measures outlined in the Erosion and Sediment Control Plan (G.22).

Degree of potential effects: Minor effects on sediment processes (discharges of sediment and local scour around the piers).

<u>Activity 21</u>: Construction of permanent piers to support widened Causeway Bridges and cycleway bridge.

Sector: 4 **Environment areas:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Disturbance of the seabed within the CMA during installation of pier casings and subsequent local scour around the casing; localised release of disturbed seabed sediments into the water column during driving operations.

Assessment:

To support the widened motorway bridge, there will be 52 piers located within the CMA, and a further 26 piers outside the CMA (supporting the two concrete reinforced abutments). These piers will be cast concrete within a 1.5 m diameter metal casing installed by bottom driving into the bed sediment. To support the cycleway bridge, four piers of 1.0 m diameter are proposed. These will also be cast in-situ.

As the pier casings are driven deeper into the sea floor, the disturbance of seabed sediments and the subsequent release of sediment into the water column will diminish. Local scour from locally-accelerated currents around the piers will also remove the surface layer of seabed sediments in the vicinity of the pier during and after the installation of the casing.

Mitigation options: No further mitigation required as the steel casings will minimise discharges during excavation of the seabed sediment prior to in-situ casting.

Degree of potential effects: Minor effects on sediment processes (sediment discharges after allowing for reasonable mixing and local scour).

Activity 22: Ground treatment works and construction of widened causeway revetments adjacent to Oakley Inlet. Excavate two by-pass channels further south of the main sub-tidal channel in Oakley Inlet to re-align the meanders in the channel that would otherwise be occupied or reclaimed by the widened Causeway.

Sector: 4 **Environment area:** Waterview Estuary

Potential effects: Substantial encroachment of the sub-tidal channel in Oakley Inlet at two meander sections; reduced flow capacity of the sub-tidal channel; potential uncontrolled channel bed erosion and intertidal bank instabilities and significant release of contaminants from the surface layer of seabed sediments.

Assessment:

Widening of motorway will require substantial infilling of the channel at two meander bends of Oakley Inlet channel (see Figure 3.26). Any blockage of this channel will significantly change the flow capacity of the channel with potentially significant short-term effects to the hydrodynamics of Oakley Inlet and lower Oakley Creek. Over time, or possibly quickly during river floods or spring tides, the channel will migrate into the existing mangrove area to the south of the existing blocked channel. During this period there could be erosional instabilities, upper-tidal bank slumping and potential for deeper scouring than exists presently in the channel bend. While this would naturally return the flow capacity of the creek and tidal flushing to the current state, a significant volume of contaminated sediment would have been released into the Waterview Estuary and on into the Central Waitemata Harbour.

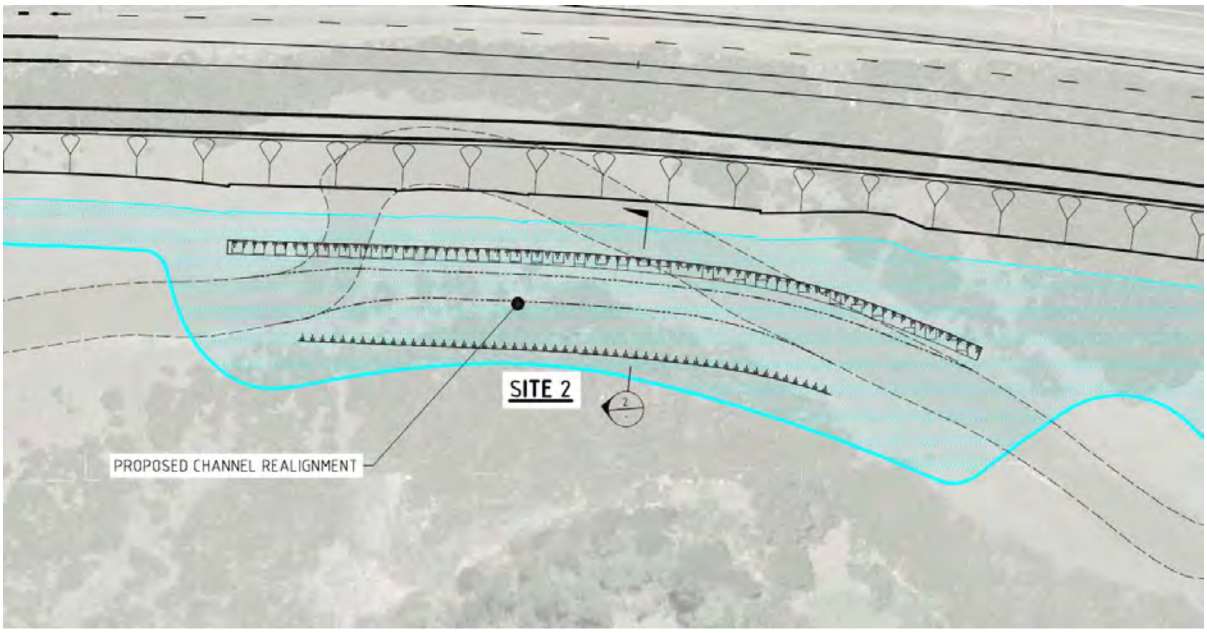


Figure 3.33: Realignment of western meander in Oakley Inlet channel. (Extracted from drawing 20.1.11-3-D-C-150-226).

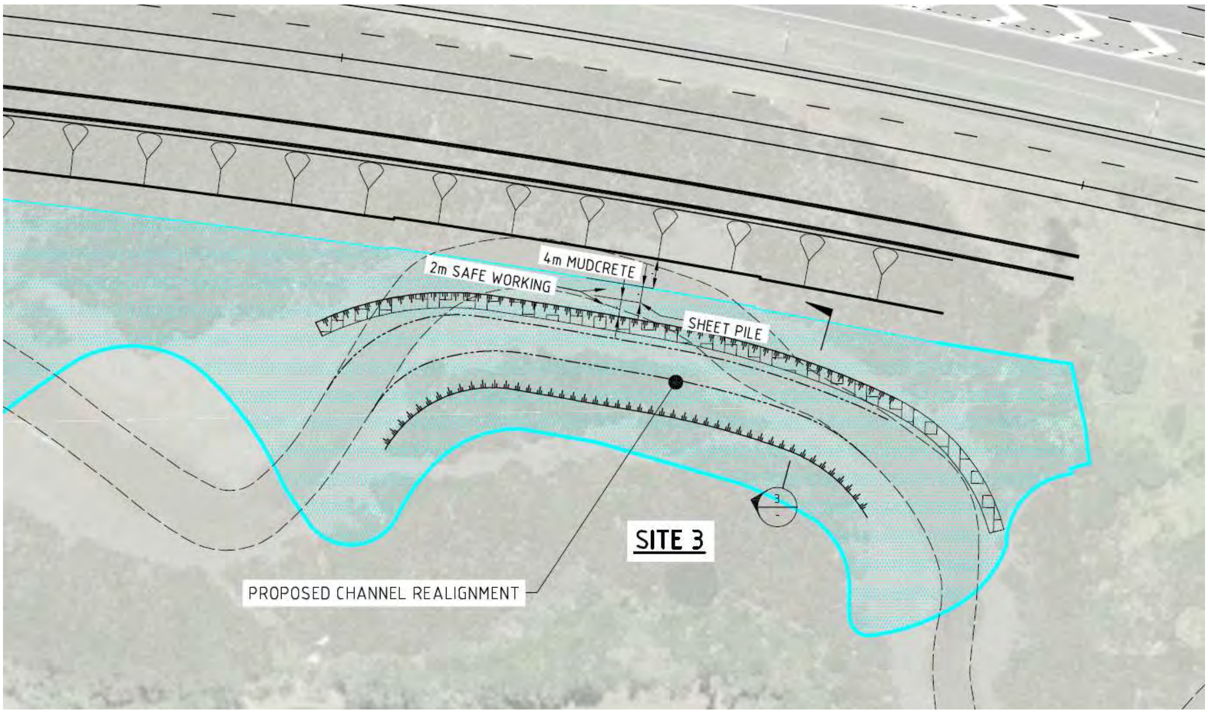


Figure 3.34: Realignment of eastern meander in Oakley Inlet channel. (Extracted from drawing 20.1.11-3-D-C-150-225).

Oakley Inlet at the western sections is approximately 25 m wide and 3.3 m deep at MHWS tide. For the eastern section, the channel is approximately 15 m wide and 3.0 m deep. The widened Causeway will affect two lengths of the Inlet, each of approximately 40 m in length. At the apex of each of the two bends in the channel, the reclamation encroaches across the total width of the channel. If the channels were allowed to migrate naturally, based on cross sections of the channel, the potential volume which may be eroded from the southern bank for each meander is about 400 m^3 below +0.13 m AVD-46 (approximately the present mean level of the sea). Including an additional factor of the flow compartment above mean sea level and the potential for up and downstream erosion on the opposite flank of the channel, the volume of eroded sediment for each of the two bends is 500–600 m^3 (a total of 1000-1200 m^3 for both meanders). Based on the plan view for Oakley Inlet (Figure 3.26), if it was left to naturally erode a new channel, the opposite bank will move by up to 12-14 m sideways (southward) at each of the two bends to compensate for the infilling.

Mitigation options: The recommended mitigation option is to mechanically excavate a by-pass channel under controlled conditions. The two by-pass sections will effectively straighten the channel by removing two meanders (Figure 3.33 and Figure 3.34). The new by-pass channels will have similar cross-sectional shapes and depths to the existing channel sections they replace. Smooth flow transitions will be created at the upstream and downstream confluences with the existing channel. Material excavated from the by-pass channels will be mixed with cement to form a mudcrete and then used to infill the existing channel. The use of mudcrete will safely lock-in any contaminants within the sediment. The methodology for construction of these two channel re-alignments is detailed in the Coastal Works Report.

The volume of sediment to be transferred from the by-pass channels to infill the present meanders will be ~1,000 m^3 for each of the two bends. This includes an allowance of approximately 100–200 m^3 for shaping upstream and downstream and opposite-bank transitions, meaning a total of about 2,000 m^3 of bed sediments will need to be excavated.

A numerical model was used to predict the potential dispersal of disturbed sediment released into the water column. Assuming a 3% loss from the excavator bucket (see Activity 18 for further background), the predicted suspended sediment concentration and depth of deposition is predicted to result in less than minor effects in terms of coastal physical processes. The effect of sediment released from these controlled excavations on marine ecology is reported in the Assessment of Marine Ecological Effects report (**G.11**). The numerical modelling simulations are presented in detail in Appendix C, with the results summarized below:

In general, the sediment is predicted to settle out of suspension close to the point of disturbance, and within the construction zone. The remainder of the sediment gets transported throughout both the Waterview Estuary and into the Central Waitemata Harbour. Any sediment which deposits within the Waterview Estuary outside of the construction zone results in only a thin layer of accumulated sediment (generally less than 1 mm).

Coarser sediments will tend to settle out closer to the point of disturbance than the fine silt and less of the coarser sediment will get exported out of Waterview Estuary through the outlet channel under the Causeway Bridges. For example, approximately 70% of coarse silt disturbed in channel re-alignment works in Oakley Inlet will get deposited within Waterview Estuary, compared to only 14% for an equivalent simulation with medium silt. As a consequence, higher levels of deposition are predicted both within, and surrounding, the construction zone for the coarse silts. The model predicts that the sediment accumulation may reach approximately 7 mm at the edge of the construction zone for coarse silt sizes (see Figure C22). For medium silt, the maximum predicted deposition is less than 3 mm (Figure C4). In practice this thickness of sedimentation will be between these two values. Locally these high areas of deposition are likely to be short lived, getting resuspended by high spring tides or high freshwater flows down Oakley Creek. This is shown by the Water Quality storm simulations (e.g., Figure C27).

During periods of higher freshwater flows (small storm events) the increased flow velocities within Oakley Inlet and more turbulent mixing prevent sediment deposition within Oakley Inlet. Thus the deposition thickness for even the coarse silt is less that 1 mm outside of the construction zone. For this small-storm scenario, sediment will be more dispersed within Waterview Estuary.

The level of sedimentation predicted from these works will only have a minor effect on physical coastal processes. Some areas just outside the construction zone may experience increased levels of deposition of medium silt, however these are likely to be short lived. Over time the sediment will be redistributed by currents and wind waves to settle in more sheltered areas of the Waterview Estuary—typically those that already have a high proportion of fine sediments. During the by-pass excavation works, the disturbed sediment will generate a suspended-sediment plume that will disperse around the Estuary and into Central Waitemata Harbour. The visibility of the sediment plume will depend on the suspended-sediment concentration relative to the background turbidity, as well as other factors such as grain colour (mostly will be like sediments that already contribute to the background turbidity). The modelled suspended sediment concentrations indicate that the sediment plume will be no more visible than may be expected during naturally occurring events such as wind-wave activity or higher flows from Oakley Creek.

Finally, these model scenarios assume that excavation takes place at all times of the tide, even while the site is inundated. The effects will be considerable smaller if excavation is largely carried out during lower tide levels. Erosion and sediment control methods will largely focus on undertaking excavations during low-tide windows when the new channel site is not inundated by the tide. Release of suspended sediments to the adjacent receiving waters will be further minimised by excavating the middle section of the by-pass channel first before breaking through the eastern and western ends that transition to the existing channel. Excavation will be undertaken from a barge to minimise seabed disturbance by machinery adjacent to the new channel.

Degree of potential effects: Minor effects on sediment and hydrodynamic flow processes after undertaking a managed excavation of two bypass channel sections followed by infilling of the existing channel meanders with mudcrete using the excavated material.

Activity 23: Installation and removal of piers to support temporary construction platforms, SH16/SH20 on/off-ramps

Sector: 5 **Environment area:** Waterview Estuary

Potential effects: Disturbance of seabed and vegetation within the CMA; release of sediment into water column.

Assessment:

Metal piers of 0.6 m diameter will be driven into the seabed in the upper reaches of Oakley Inlet, in order to support temporary staging to construct the permanent piers. Most of these piers (see Activity 5, Section 4.1.1) are within the upper intertidal vegetated areas and will require removal of vegetation within the immediate surroundings of the piers. The total area of vegetation removal will be small in comparison to the total area of CMA in these upper reaches of Oakley Inlet. Where piers are driven into the main channel, sediment displaced from the upper bed sediments will be eroded from adjacent to the piers (local scour), though this volume of sediment will be very small due to the low number of piers within the channel and low tidal flow velocities. Given: a) the relatively high background suspended-sediment concentrations (normally 2-10 mg/L and up to 38 mg/L at the Oakley Carrington ARC monitoring station in lower Oakley Creek) and b) the sediments disturbed from the seabed of the channel are similar to the type and colour of sediments causing turbidity in the Oakley Inlet, the effects on colour, visual water clarity and aesthetics of the water appearance will be less than minor after allowing for reasonable mixing.

Mitigation options: The number of temporary piers located within the main sub-tidal channel have been minimised.

Degree of potential effects: Less than minor effects on flows and sediment processes.

4.1.4 Discharges

<u>**Activity 24:**</u> Earthworks and construction relating to the construction of SH20, Sectors 7-9 discharging into Oakley Creek before discharge to the CMA in Oakley Inlet.

Sector: 5 **Environment area:** Waterview Estuary

Potential effects: Release of fine-grained sediments and contaminants into Oakley Inlet, Waterview Estuary and Central Waitemata Harbour; potential increase of suspended sediment concentration, sediment deposition and associated contaminant accumulation.

Assessment:

Much of the entirely new construction work relates to connecting the existing end of SH20 from Maioro Street Interchange to Great North Road Interchange (Sector 5). The majority of this route runs close to the course of Oakley Creek. Although sediment control measures will be used along the proposed works where sediment may enter the Oakley Creek, there is still potential for some sediment to be released into the Creek, and thereby discharged into the CMA. A series of numerical models was used to predict:

a) the sediment and contaminant load released from the catchment area during the period of works;

b) retention of sediments and contaminants using sediment control measures; and

c) dispersal of the resulting discharged sediments and contaminants throughout Oakley Inlet, Waterview Estuary and the Central Waitemata Harbour by tidal processes.

The set-up of the model and inputs to the simulations are given in Section 2.5 and the results are presented in Appendix B. These results are summarised below:

The series of numerical model predictions show that:

a) after passing through the sediment control measures, the construction loads entering Oakley Creek are relatively low in comparison to base loads from the overall catchment; and

b) any sediment that is released into the CMA through Oakley Inlet gets rapidly dispersed throughout Waterview Estuary, and much of it gets released into the Central Waitemata Harbour.

The resulting levels of suspended-sediment concentration, sediment deposition thickness and associated particulate contaminant accumulation, are therefore low.

The proposed works include sediment control measures to reduce the sediment being discharged into Oakley Creek. Under a water quality storm event (approximately a 1-month average recurrence interval), any sediment discharged into Oakley Inlet will get transported and dispersed throughout Waterview Estuary, with some of the suspended sediment exported into Central Waitemata Harbour. The maximum predicted suspended sediment concentration above background will be around 0.3 kg/m^3 (300 mg/L), but the majority of Waterview

Estuary will experience suspended-sediment concentrations of less than 0.01 kg/m^3 (10 mg/L) above background concentrations. The maximum accumulated sediment deposition at the end of the water quality storm event will be less than 1 mm.

For an upper-bound scenario, where sediment control measures are not used, or fail completely, the maximum suspended-sediment concentration increases to approximately 1 kg/m^3 (1000 mg/L). The accumulated sediment thickness at the head of Oakley Inlet may reach 7 mm, though this is likely to be resuspended by the high flow velocities in ensuing days or weeks. Downstream of Oakley Inlet, the sediment deposition within Waterview Estuary and Central Waitemata Harbour will still be less than 1 mm.

The resulting environmental effects in terms of coastal physical processes will be minor and of short duration during rainstorm events. The ecological consequences of released sediment and associated contaminant dispersal is detailed further and assessed in the Assessment of Marine Ecological Effects report (**G.11**).

Mitigation options: The mitigation options involve use of erosion and sediment control measures near the point of works designed according to ARC TP90 guidelines to minimise the release of sediment into Oakley Creek. The details of erosion and sediment control measures are discussed in the Sediment and Erosion Control Plan (**G.22**).

Degree of potential effects: Only minor effects on sediment processes (particularly sedimentation) of the CMA after rainstorm events when sediment control measures are employed within the construction zones.

4.2 Operational effects and mitigation options

This section provides an assessment of potential physical effects on the CMA that could arise from the long-term operation of the upgraded motorway after construction is complete.

4.2.1 Structures

Activity 25: Permanent occupation within the CMA of additional bridge piers to support the widened Whau River Bridges and cycleway bridge.

Sector: 2 **Environment area:** Whau River area

Potential effects: Change to hydrodynamic flow patterns; local and general scour from additional piers; erosion of adjacent channel flanks; reduced tidal flushing of Whau River; backwater effects from additional piers.

Assessment:

Additional bridge piers will be required to support the widened Whau River Bridges and the separate cycleway bridge. The new bridge piers to support the widened bridge structures will comprise 14 sets of 3 piers, each 1.5 m diameter (cylindrical) and in line with the existing bridge pier groups. These pier groups are aligned at ~15-20 degrees to the flow. These additional piers will occupy 74 m2 of seafloor area within CMA. The cycleway bridge will be a separate structure supported on 7 piers of 1 m diameter, occupying 5.5 m2 of seabed area.

The additional piers to the north and south will be in line with existing pier groups, but due to the skewed flow orientation of 15-20° to the pier group orientation, the additional piers will somewhat reduce the effective flow area and widen the zone of wakes that are shed behind each pier (see Figure 3.20).

The channel thalweg under the widened bridge may swing slightly to the right (facing North) due to an extension of piers along the present alignment and associated wakes, but is not expected to be noticeable. The effect of extended pier groups on generating additional wakes is unlikely to hinder vessel navigation when the tide is running strongly (e.g., peak ebb and flood), as such wakes are already present from the existing piers (Figure 3.18), and passage is generally parallel to the pier group alignment. Average peak spring-tide currents are around 1.7 knots (Hume, 1991).

Additional general scour associated with the longer pier groups is unlikely to result in any substantial deposition or shoaling further downstream (northwards on ebb tides, southwards for flood tides) as the cross-section is relatively deep (Figure 3.1 and Figure 3.2). Local scouring around pier groups generally reach equilibrium relatively quickly in regular ebb and flood spring tidal streams. The substantial channel depth and the peak mid-tide current velocities will hinder the formation of any shoals immediately upstream or downstream of the pier groups from any scoured sediments. Local scour will occur around the base of the new piers (potentially up to 1–1.5 m deeper in the immediate vicinity of the piers of 1.5 m diameter), but this will not affect bridge stability as piers will be founded below the overlying estuarine muds, and bridge scour is taken into account in any bridge design using the NZTA Bridge Manual (2005)—see Coastal Works Report. The local scour will also be altered by changes in eddies around the existing piers shedding off the additional new piers. These flow effects from the additional piers on the local scour patterns around the earlier-designed existing piers are difficult to predict, but because of the sizeable depth of marine muds and Holocene sediments at the site, it is likely that the existing piers have sufficient founding depth to be unaffected by changes in local scour around the piers.

Any channel-bank erosion from the skewed pier alignment will be localised and constrained in two areas:

a) the northern extension of eastern-most pier group will create a slightly longer pathway for the initial ebb flow to be more directed to the north-east and could increase the downstream extent of a localised channel-bank indentation that currently exists on the north-eastern flanks of the channel (Figure 3.35); and

b) the southern extension of western-most pier group may cause a minor indentation in the channel bank on south-west side of the widened westbound bridge for incoming tide flows in the lead up to high tide.

In both cases, this additional constraining of channel flow direction and associated additional wakes from the extended pier-groups along the channel flanks will be slight, given tidal flows are slower across the high tide period when these flanks are inundated and additional piers will not affect wave penetration from the north. Also, any localised erosion of the channel flanks will occur in the context of the substantial accretion that has already occurred either side of the protruding bridge causeway abutments since construction of the original bridge (contrast 1959 and 2001 situations in Figure 3.4 and Figure 3.5).

The 42 new piers at a skewed flow angle of between 15-20˚ will add 60% more pier resistance elements into the flow than at present. However, this will only result in a ~16% contraction in effective flow area, allowing for a 40% reduction in the full projected cross-sectional area of all new piers at an 18˚ flow angle due to flow weaving in between individual cylindrical piers, and some flow alignment with pier groups. This is unlikely to cause any detrimental effect on upstream channel flushing and backwater effect during tidal flows. This is because the local hydraulic response through the bridge waterway to a slightly contracted cross-sectional flow area will be for the current velocity to increase slightly (with a slight increase in water-level head upstream).

Computational model simulations with both the temporary and permanent piers (shown in Figure 3. and Figure 3.20, Section 4.1.1) shows the increase in water-level head across the bridge section will only be around 10 mm for the new permanent piers (taking out the contribution from the temporary staging piers). The flow direction will also turn to be more in alignment with the pier-group orientation to compensate for a reduction in geometrically-projected flow area. The channel bed will naturally adjust by a small amount of bed scour to increase its cross-section to compensate (as well as the slight increase in velocity). The single piers of 1 m diameter to support the separate cycleway to the south will not cause any further environmental effects to those discussed, other than lengthening the section for more restricted navigation that is bounded by piers, and the occurrence of local scour around the immediate vicinity of cycleway bridge piers (which is factored into pier foundation design). Consequently, no mitigation measures are necessary, as there will not be any perceptible change in the existing upstream tidal-flushing capacity or flow patterns through the bridged waterway.

In relation to waterway clearance under the Whau River Bridges for higher sea levels, an analysis was undertaken using soffit levels of the widened Whau Bridges at the lower eastern end (as the bridges have an incline towards the west). At the eastern end, the minimum soffit level is 3.8 m AVD-46 (0.9 m higher than the minimum soffit level at the Causeway Bridges), while the minimum bridge deck level is 5.4 m AVD-46. A combined 100-year average recurrence interval (ARI) storm-tide event with a 0.8 m sea-level rise will reach a water level of 3.11 m AVD-46 (Ramsay et al., 2009), which will still leave ~0.7 m to cover additional water level increases from any joint-combination extreme event involving a Whau River flood. Therefore, the waterway under the existing and upgraded Whau Bridges is more than adequate to accommodate future combined storm tides and sea-level rise to at least the year 2100.

Overall, the effects on physical coastal processes are likely to be localised and no more than minor, with no threat to the stability of the shorelines due to the general accretion that has already occurred either side of the original bridge causeway abutments following their construction. Also, similar-sized cylindrical piers (1.5 m diameter) have been used in the engineering design—the same as most of the existing piers (although some piers under the original bridge are supported on 2.4 m diameter piers up to the low tide level)—to minimise the effects on additional wake generation behind piers.

Mitigation options: One mitigation option that was considered early on in the engineering design was to configure the arrangement of additional piers to be more in line with the flow direction. However, this is structurally not possible as the proposed works require widening the existing bridges to the north and south, rather than construction of new bridge structures. There is also a need to maintain navigational passage by continuing to align new piers in same line as existing pier group. However, the new piers are spaced further apart along the pier group than the existing 1.5 m diameter piers, which will allow the skewed flow to more freely weave between the new piers. Final construction design of the bridges will need to assess the lateral bridge loading and hydraulic heads from the passage of Whau River floods in combination with tides and the effect of sea-level rise, based on the NZTA Bridge Manual (2005).

Degree of potential effects: Considering both hydrodynamic and sediment processes (e.g., erosion of adjacent channel flanks), the effects will be no more than minor.

Figure 3.35: Aerial photograph at a lower tide of the north-eastern side of the existing Whau River Bridges and the western end of the wetland behind Pollen Island flown in February 2006. Arrow shows localised erosion where the flank of the channel at the confluence of the western channel draining the wetland is somewhat indented. This may be influenced by the alignment (~15–20°) of the eastern-most pier groups relative to the flow. Generally though, there has been accretion of the intertidal area towards the main channel as a result of the protruding bridge causeways (see Figure 3.4 and 3.5) [*Photograph Source*: Aurecon NZ Ltd.]

Activity 26: Permanent occupation within the CMA of additional bridge piers to support the widened Causeway Bridges and cycleway bridge over the outlet channel from Waterview Estuary.

Sector: 4 **Environment areas:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Change to hydrodynamic flow patterns; local and general scour from additional piers; erosion of adjacent channel flanks; reduced tidal flushing of Waterview Estuary; increased backwater effects.

Assessment:

The pier groups supporting the existing Causeway Bridges are closely aligned with the flow direction because the channel in the causeway gap has developed perpendicular to the Causeway since the reclamation in the early 1950s. With no skewed flows, there will be little change in the wake zone, effective flow area and peak velocities other than the small increase in resistance to flow as the outlet channel is extended north and south by the additional bridge piers and widened abutments. Latest bathymetry surveys (2008) and past work by Hume (1991) show the outlet channel under the existing bridges reached a stable maximum seabed depth of –5.5 m AVD-46 about two decades ago (Figure 3.12 and Figure 3.13). The peak mean-spring tidal velocity reaches 1.8 m/s (3.5 knots), which is twice that measured for the same tidal conditions in the channel under the Whau River Bridges.

Because the flow is parallel with the existing pier groups, the widening of the Causeway Bridges and associated piers will only produce a small increase in the backwater (or choking) effect for normal tidal flows or storm-tide events. The increase in backwater effect will certainly be no more than that computed for the Whau Bridges for a skewed-flow situation (see Activity 25).

An assessment was made for the effects of the new widened bridge structure on future conveyance of flows through the outlet channel arising from sea-level rise. The minimum bridge soffit elevation of the widened bridges will be 2.87 m and 3.17 m AVD-46 on the extremities of the wider westbound and eastbound bridges respectively, after allowing for a 2.5% lateral slope for road-surface drainage. This soffit level provides sufficient clearance for flows with water levels (excluding waves) comprising a 100-year ARI storm-tide event and a 0.6 m sea-level rise (2.92 m AVD-46) as determined by Ramsay et al. (2009). While the underside of the bridge decking on the extreme southern side of the westbound bridge will be slightly underwater at this water level, the rest of the bridge soffits will be clear, including a gap of 0.25 m on the more wave-exposed northern extremity of the eastbound bridge. These high storm-tide levels will only occur for short periods coinciding with a predicted high tide, when flow velocities will be quite slow, including a brief period of slack water during the tide reversal. The minimum bridge-deck elevation at the southern side of the westbound bridge will be around 4.1 m AVD-46, which will only be inundated by a 100-year ARI storm-tide when sea-level rise had reached 1.8 m, or some allowance for wave set-up or an Oakley Creek flood component for lower sea-level rises.

The effects of the new piers and longer outlet channel on pleasure boating (e.g., kayaking) will be less than minor, as the flows are parallel with the pier groups. Because of the low soffit levels under the existing bridges, passage by powered vessels is already limited. At MHWS, the minimum clearance of the widened westbound bridge will be 1.24 m (using MHWS from Section 3.1), so kayakers will still have sufficient clearance at spring high tides, but this high tide clearance will gradually diminish as sea level rises this century.

Mitigation options: Not required

Degree of potential effects: Mostly minor effects on hydrodynamic and sediment processes (given the ebb and flood tidal flows through the outlet channel under the bridges are parallel with the existing pier groups). Also only minor effects of the widened bridge decks on future hydrodynamic flows from low underside bridge clearance (southern side) for extreme high-tide water levels for sea-level rises of up to 0.6-0.8 m.

<u>Activity 27:</u> Permanent occupation within the CMA in Oakley Inlet of bridge piers to support new SH16/SH20 on/off-ramps.

Sector: 5 **Environment area**: Waterview Estuary

Potential effects: Change to hydrodynamic flow patterns; local and general scour from piers; erosion of adjacent channel flanks; reduced tidal flushing of Oakley Inlet; backwater effects.

Assessment:

The four on- and off-ramps to service the Great North Road Interchange will be supported on single 1.8 m cast in-situ piers. Four of the piers supporting Ramp 2 (Westbound SH16 On-ramp) will be located within the CMA (Pier 2 and 4–6) and one pier further upstream near Great North Road supporting Ramp 1 (Westbound SH20 on-ramp) will be within the CMA (Pier 7). All 5 permanent piers have been located outside the main sub-tidal channel of Oakley Inlet. Apart from Pier 5 (Ramp 2), which is located on the flank of the channel, all the other piers are located well up intertidal areas towards the edge of the CMA boundary within mangrove areas.

Therefore given the position of piers outside the main sub-tidal channel, the effects on hydrodynamic flows, general scour and geomorphology of Oakley Inlet are likely to be minimal. Similarly, the presence of the piers, in mostly the upper elevations of the intertidal zone, will have only minor effects on backwater effects upstream during floods in Oakley Creek. Local scour immediately around the piers could occur under Oakley Creek flood events, particularly for Pier 5 (Ramp 2) on the side of the sub-tidal channel, although the amount of scour will be tempered by flow retardation provided by the surrounding mangroves. Even if local scour were to occur, ongoing sedimentation processes in the Inlet will re-fill these localised scour depressions within weeks, particularly during spring high tides.

Mitigation options: Spacing of piers within the CMA during the design process has ameliorated any potential effects on physical coastal processes in Oakley Inlet.

Degree of potential effects: Effect of permanent on/off-ramp piers on coastal physical processes will be minor.

4.2.2 Reclamation

<u>**Activity 28:**</u> Reclamation in Pixie Inlet (Henderson Creek) to support a permanent stormwater treatment pond.

Sector: 1 **Environment area:** Whau River area

Potential effects: Changes to flows on intertidal banks and local geomorphology.

Assessment:

The reclamation of a portion of the intertidal area of Pixie Inlet (a side inlet of Henderson Creek) is required to develop an operational stormwater settling basin of sufficient storage capacity to meet ARC TP10 guidelines (see Stormwater Assessment Report for details). As the small reclamation is at the upper elevation of the intertidal area, out of the sub-tidal channel, the effects of hydrodynamic flows, flushing (in terms of lost tidal prism volume) and geomorphology of the stream will be minor, given the area is also populated by mangroves. The catchment area of Pixie Stream serviced by the inlet is small, which together with the considerable widening of Pixie Inlet where the small reclamation (0.11 ha) will occur, means the backwater effects or retardation of stream flood waters will be negligible.

Mitigation options: Not required, other than having minimised the area of CMA reclamation required in the design of the stormwater treatment pond, including maximising the use of available land.

Degree of potential effects: Only minor effects on coastal physical processes from the small intertidal reclamation.

<u>**Activity 29:**</u> Reclamation for widened abutments to support the widened Whau River Bridges and cycleway bridge.

Sector: 2 **Environment area:** Whau River area

Potential effects: Changes in hydrodynamic flow regime; local deposition or scour of river banks; reduction in Whau River flushing capacity.

Assessment:

A total of 1,570 m^2 (0.16 ha) will be needed for reclamation from the CMA to construct a widened western abutment (drawing 20.1.11-3-D-C-941-103). The longer 115 m existing eastern abutment, back to a relic island west of Rosebank Peninsula (Figure 3.4) will require an additional reclamation of 2,497 m^2 (0.25 ha). End effects from the wake shedding off the end of the extended abutments, including the longer flow-alignment pathway parallel to the abutments, could occur at high spring tides, or high tides elevated by storm surges or river floods. This could potentially cause more localised erosion adjacent to the ends of the lengthened abutments as the flows converge (flowing into the bridge waterway) or diverge on the other side, flowing out of the waterway as it emerges from the extended abutments. However, there is little geomorphological evidence from aerial photographs that this has occurred up to present with the abutments that have been progressively widened since initial construction in the early 1950s. These areas adjacent to the abutment corners instead show a more gradual transition and establishment of mangroves (see Figure 3.6 and 4.20).

This is probably because at higher spring tide elevations, ebb and flood tide flows are slow, including the slack tide period as the tide reverses. Therefore there are limited opportunities for strong wakes to develop at the abutment corners (apart from during episodic high Whau River floods or high storm-tide events). The exception would seem to be the indentation in the flanks of the sub-tidal channel on the north of the eastern abutment (Figure 3.35), but this is probably due more to the slightly skewed alignment of the pier groups rather than just wake effects from the abutment.

Since the initial abutments were constructed in 1952, the intertidal areas to the north and south of the abutments have accreted, mangroves have become established and the channel flanks have built out towards the terminus of each abutment (see situation with protruding abutments in 1959 in Figure 3.4 compared to 2001 in Figure 3.5). By widening the abutments yet again, there will be minor effects on the geomorphology of the channel flanks adjacent to the wider abutments as they respond to the converging and diverging of high-tide flows. As the past evidence has shown, it is likely that a smoothed-transition will occur in the geomorphology of the channel flanks at the corners of the widened abutments, rather than any adverse upstream or downstream erosion. Also, the existing abutments are largely being widened laterally, rather than being extended significantly into the sub-tidal channel, although the southeast abutment supporting the new cycleway may lead to some localised erosion at the corner during higher tide levels (see drawing 20.1.11-3-D-C-941-103).

Overall, these additional reclaimed areas will add laterally to historic abutment reclamations, rather than extend out into the main tidal waterway. Therefore the additional reclamations will have little additional effect on the overall geomorphology, flow paths and flushing of Whau River through the bridged cross-section. Locally, the southeast corner of the extended eastern abutment to support the cycleway bridge may lead to minor localised erosion.

Mitigation options: An early option was investigated to align the extended bridge abutment extensions to the north and south so that they are aligned more with the existing channel flow, rather than flush with the present abutment alignment. However, besides being difficult structurally, the benefits will be minimal given there is no evidence for any substantial erosion around the corners of the existing abutments that have now been widened three times. Therefore the present alignment of the ends of the abutments should be maintained for construction and structural design purposes, in conjunction with keyed-in foundations to support the toe of the revetment and apron treatments to protect the abutment revetments at the corners.

Degree of potential effects: Only minor localised effects on coastal physical processes from the widened bridge abutment reclamations.

Figure 3.36: Aerial photograph of the western abutment of the Whau River Bridges. North vertically up the page. [*Photograph source*: Aurecon NZ Ltd. flown in Feb. 2006].

__Activity 30:__ Reclamation to widen the existing SH16 carriageway on either or both the north and south sides from the Whau River abutment to the eastern side of Rosebank Peninsula.

Sector[10]: 2, 4 **Environment areas:** Whau River area; Central Waitemata Harbour

Potential effects: Changes to tidal flows; drainage patterns and geomorphological features.

Assessment:

Reclamation along SH16 over various sections of the carriageway will be necessary where the widening requires extension to the north or south into the CMA. The effects of the main Causeway reclamations are separately considered below.

Commencing at the western end, the Whau intertidal section between the Whau River Bridges and western side of Rosebank Park Domain (chainage 4400–4580), will require three strips of reclamation on the northern side (combined area of 1456 m^2 or 0.15 ha), and on the southern side, two strips with a similar combined area of

[10] Figure 1.2 shows this part of this activity to be geographically located in 'Sector 3: Rosebank – Terrestrial'. However, this activity is designated to be in 'Sector 4: Reclamation' as the works correspond to reclamation of the CMA due to extending the width of the Causeway.

1519 m^2 (0.15 ha). Figure 3.37 shows the overall stretches where the five reclamations are required (see engineering drawing 20.1.11-3-D-C-941-103). The aerial photograph clearly shows that all these reclamations are well up on the intertidal banks of the Whau River system, well clear of the sub-tidal channel. Consequently, the widening of these existing reclamations will have a negligible effect on flows and drainage along the intertidal area, and little effect on the overall geomorphology of the banks, given the historic reclamations for SH16 and that the proposed reclamations are only to provide additional width.

Proposed reclamations for the next section of SH16, from the eastern side of Rosebank Park Domain to the Patiki Road off-ramp flyover bridge, comprise two stretches on the northern side of the Causeway behind Pollen Island (totalling 4787 m^2 (0.5 ha), and one stretch on the southern side of the Whau River intertidal zone of 1208 m^2 (or 0.12 ha). The indicative stretches where these reclamations are required is shown in Figure 3.38. The northern section comprises an extensive mangrove tidal wetland behind Pollen Island, with slow drainage flows and no major arterial drainage channels in close to the existing embankment (see Figure 3.38, Figure 3.39 and Figure 3.40). Therefore on the northern side for this stretch, these additional reclamations will have little effect on flows and drainage across the extensive intertidal wetland and on the overall geomorphology of the banks, given the historic reclamations for SH16 and the presence of existing piers in the CMA for the Patiki Road fly-over bridge.

On the southern side of the Causeway, the extended reclamation will encroach entirely on a small drainage channel (see left side of Figure 3.38), as discussed in more detail for Activity 7 in Section 4.1.2. The existing channel is only about 3-5 m in width and extends only about 400 m further upstream to its terminus. Due to the relatively small scale of the channel and its upstream catchment, the 125 m section of affected channel should be allowed to naturally migrate laterally. However, reclamation works will need to extend progressively to allow the channel sufficient time to slowly re-align and erode itself to a more southerly position adjacent to the new toe-line of the extended revetment. Also mangroves and their rooting systems may need to be removed along the southern flanks of the existing channel to allow erosive processes to operate. In the transition period, there may be some areas of the upstream intertidal "catchment" that are not inundated as soon during the rising tide as at present and conversely may be subject to shallow ponding for longer after spring high tides when the tide drops below the elevation of the scouring channel. Eventually, as the flow velocities decrease in the initially contracted stretch of drainage channel, the affected section of will reach a depth and cross-section that is in equilibrium with the intertidal flows it needs to convey downstream. Given the relatively small scale of the drainage channel, and the extensive intertidal areas well above mean sea level (which are only inundated at higher tides), the risk of channel bank instabilities or slumping occurring as the channel migrates and reforms is very low. Overall the effects on coastal physical processes in the long-term will be minor.

In the longer section across Rosebank Peninsula (chainage 2950 to 3800), no additional reclamations of the CMA are envisaged. However, two sections of potential CMA reclamations on the northern side (chainage 2950–3150N and 3320-3410N) were eliminated in an earlier design revision to avoid potential adverse effects on the main drainage channel servicing the Pollen Island wetland system. The reasoning was discussed in Section 4.1.2 (Activity 6). The proposed design includes vertical retaining walls to support the wider embankment for SH16, which avoids the need for reclamations in the CMA.

Figure 3.37: Aerial photograph of section of SH16 to the east of the Whau River Bridges through to the Rosebank Park Domain (tip of the Rosebank Peninsula) indicating stretches where reclamation of the CMA will be required. [*Source*: Aurecon NZ Ltd.; flown Feb 2006].

Figure 3.38: Aerial photograph of section of SH16 from east of Rosebank Park Domain to Patiki Road Eastbound Off-ramp flyover indicating stretches where reclamation of the CMA will be required. [*Source*: Aurecon NZ Ltd.; flown Feb 2006].

Figure 3.39: View of wetland behind Pollen Island looking south-east from the existing embankment for the start of the Patiki Road Off-ramp at approximate chainage 4180N. [*Source*: T. Hume; 1.7 hours after high tide, 27 Feb 2009].

Figure 3.40: View of wetland between the Patiki Road Off-ramp piers and the main SH16 carriageway in the background at approximate chainage 3900N. [*Source*: T. Hume; 1.7 hours after high tide, 27 Feb 2009].

Mitigation options: Not required apart from careful monitoring the progress of natural re-alignment of the Whau drainage channel adjacent to the south-side reclamation between 3990–4120S. Potential contraction of the main drainage channel (that services the Pollen Island wetland system) has been avoided by changes in the engineering design.

Degree of potential effects: Effects on drainage flows and geomorphology will be minor in the long term – where they may have been potential adverse long-term effects on coastal physical processes, these have been avoided through changes to the engineering design.

<u>**Activity 31:**</u> Reclamation to widen the existing SH16 Causeway on both the north and south sides from the eastern side of Rosebank Peninsula through to the Great North Road Interchange.

Sector[11]: 3 (eastern end), 4 **Environment areas:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Changes to tidal flows; drainage patterns and geomorphological features (banks, chenier deposits).

Assessment:

Reclamation of the CMA will be required along most of the existing Causeway (apart from the terrestrial section across Traherne Island) to support the widened carriageway for SH16. For the shorter 500 m section of Causeway to the west of Traherne Island (engineering drawing 20.1.11-3-D-C-941-106), the northern side will require three separate reclamations covering a total of 2443 m^2 (0.24 ha). The larger reclamation between Chainage 2600 to 2825N will cover part of a chenier deposit as outlined in Section 4.1.2 (Activity 17) and shown in Figure 3.25. Once the reclamation has been completed, the previously stockpiled shell material should be re-positioned off the toe of the widened revetment along the relevant section to allow waves at higher tides to re-distribute shell material, and therefore re-attach and re-form the chenier ridge.

On the southern side, reclamation of the CMA in the north-western part of Waterview Estuary will be required over most of most of the 500 m section of existing Causeway, covering 5748 m^2 (0.6 ha). This area of Waterview Estuary (Figure 3.25) is either an elevated intertidal area (Chainage 2450–2850S) or a relic channel (Chainage 2850–2950S) that has since infilled as a result of the original Causeway construction (Figure 3.25). Given this historic infilling or high-elevation intertidal mudflats, the long-term effects of widening the existing Causeway on tidal flows, drainage patterns and geomorphological features will be minor and confined to gradual geomorphological adjustments to the intertidal areas immediately adjacent to the new reclamations . In other words, the effects of widening the Causeway in this section west of Traherne Island will not worsen the long-term effects on overall flows and geomorphology that have already been caused by the existing Causeway.

[11] Figure 1.2 shows this part of this activity to be geographically located in 'Sector 3: Rosebank – Terrestrial'. However, this activity is designated to be in 'Sector 4: Reclamation' as the works correspond to reclamation of the CMA due to extending the width of the Causeway.

The 1.65 km main Causeway east of Traherne Island (Chainage 630–2290) will require reclamations to widen the Causeway over most of its length (see engineering drawings 20.1.11-3-D-C-941-107 to –108. On the north-east end of Traherne Island, two smaller pockets of reclamation covering 1525 m^2 (0.15 ha) will be required in an area that straddles chenier ridge deposits (Figure 3.41). As discussed above, remediation should be undertaken to re-position the stockpiled shell deposits in the general area they were retrieved from.

The reclamation required to widened the main Causeway through to the Causeway Bridges will be about 30,682 m^2 or 3.1 ha on both sides of the existing Causeway. For most of this length, the additional reclamation will be on elevated intertidal areas apart from the 160-m section on the south side that will encroach on the main western drainage channel in Waterview Estuary (chainage 1550–1710S). The need to re-align this section of channel and excavate a by-pass channel has been discussed previously in Section 4.1.2 (Activities 8 & 18).

On the northern side of the Causeway, the high tide extends to the existing basalt revetment, with an intertidal beach appearing around mid tide (Figure 3.42) and also shown around low tide in

Figure 3.9. This is also the section of the Causeway that is most exposed to waves generated from the wind fetch across Central Waitemata Harbour. In the long-term, over periods of months, an intertidal beach will gradually re-establish in front of the widened embankment using the present beach and groyne system as an analogue for how the geomorphology responded when the original Causeway was built. Overall, the effects on the long-term intertidal geomorphology of widening the Causeway by approximately 7–10 m seawards will be minor. The existing groynes on the northern side (

Figure 3.9) have had only a limited effect on building an intertidal beach between the groynes, so lengthening these groynes for a widened Causeway is not warranted, but they should be left as they are to minimise any further changes to the intertidal geomorphology.

On the southern side of the Causeway, apart from the section adjacent to the drainage channel, the effects of widening the Causeway over the intertidal areas will be minor as currents around high tide are generally slow and will have only minor effects on sediment processes, particularly as there will be a transition from the higher strength mudcrete to the in-situ sediments. The wave fetch inside the Estuary will not be affected significantly and as the extended reclamations will be parallel to the existing Causeway, the orientation of the new shoreline to waves will remain the same

On the eastern section of the Causeway (east of the bridges), the area that will be required for reclamation is 19,631 m^2 or 1.9 ha covering both sides of the existing Causeway. Mostly this additional reclamation will only occupy higher intertidal areas of Oakley Inlet or Central Waitemata Harbour, apart from two sections on the south side that will encroach on bends in the Oakley Inlet channel (chainage 800–880S and 650–700S). The need to re-align these sections of channel and excavate by-pass channels has been discussed previously in Section 4.1.2 (see Activities 9 & 22). Other than these channel encroachments, the effects of the widened Causeway on tidal and flood flows and geomorphology of the intertidal area adjacent both the south and north side are likely to be minor given the existing Causeway configuration and the reclamation is mostly on elevated intertidal areas where high-tide currents and drainage volumes are small.

Mitigation, remediation and monitoring options: No further mitigation is required, apart from: a) remediation of the chenier shell deposits at the toe of relevant sections of the widened revetments; and b) excavation of by-pass channels as discussed in Section 4.1.2. These re-aligned channels in Waterview Estuary and Oakley Inlet will need to be monitored to ensure they are not affecting overall flow and drainage patterns and that they have reached an equilibrium depth and cross-section that is commensurate with the regular tidal flows. The affected chenier deposits should also be monitored to ensure they have been able to reform naturally and re-attach back into the unmodified chenier ridges.

Degree of potential effects: Effects on tidal flows and drainage patterns and upper intertidal geomorphology will be minor – where there could have been short- or long-term adverse effects from reclamation, such as encroachment on major tidal channels, consents are sought to excavate by-pass channels to re-align affected sections of channel (given that vertical retaining walls are not an option in the deep estuarine muds along the Causeway as they are on Rosebank Peninsula).

Figure 3.25: Aerial photograph of section of SH16 Causeway to the west of Traherne Island (on the right). The chenier deposits are the white fringe areas shown to the north of SH16. The section affected by reclamation is indicated by bracket. The area of Waterview Estuary to the south of SH16 comprises relatively high intertidal mud flats and a portion of the old relic drainage channel is shown by the arrow (largely infilled since the Causeway construction). [*Source*: Aurecon NZ Ltd.; flown Feb 2006].

Figure 3.41: Aerial photograph of section of SH16 Causeway on the north-east of Traherne Island (to the left). The chenier deposits are the white fringe areas shown to the north of SH16. The sections affected by reclamation are indicated by brackets. The area of Waterview Estuary to the south of SH16 is relatively high intertidal mud flats (above 0.5 m AVD-46). [*Source*: Aurecon NZ Ltd.; flown Feb 2006].

Figure 3.42: View of northern side of the SH16 Causeway looking towards Pt. Chevalier. [*Source*: T. Hume; 3 hours after high tide, 27 Feb 2009].

<u>Activity 32:</u> Reclamation to widen the existing eastern and western abutments for the Causeway Bridges and cycleway bridge.

Sector: 4 **Environment areas:** Central Waitemata Harbour; Waterview Estuary

Potential effects: Localised scour of adjacent banks; geomorphological changes in channel confluences; increased backwater effects in Oakley Inlet and Waterview Estuary.

Assessment:

Widened abutments for the Causeway Bridges will not further constrict flows through the outlet channel under the bridges as the same cross-sectional flow area will be maintained, given the flow velocity is parallel to the pier groups. However, by widening the abutments to the south, there is potential for end-erosion of the banks adjacent to the new widened abutments. There is also the potential for re-adjustment of the local geomorphology, due to the southern extension of the bridged outlet channel that will shorten the confluence between that channel, Oakley Inlet channel and the Waterview Estuary drainage channels (Figure 3.43). Consequently, there will be a transitional period of slightly higher backwater effect (a few cm's) associated with merging channel flows while the geomorphology (intertidal banks and channel) of the three-way channel confluence re-adjusts to the outlet channel being closer. The groyne that currently anchors the confluence of the Waterview Estuary channels and the outlet channel should remain as is, but the partial infilling of the depression to the east of the groyne (Figure 3.43) should not cause any more than minor effects on the morphology – and will also smooth out the low-tide shoreline in that stretch.

General scour of the cross-section profile will occur to the north of the outlet channel under the extended bridge and abutments to the north, but it will be minor as the channel there is already relatively deep (Figure 3.11).

Mitigation options: Early changes to the engineering design of the southern abutments, especially that supporting the cycleway bridge, have reduced the potential geomorphological changes in the confluence area by smoothing the revetment shoreline transitions into and out of the confluence. A key part of the design revision was the inclusion of an additional pier at the eastern and western ends of the cycleway bridge which enabled the southern abutments to be pared back considerably (rather than supporting that section of the cycleway) as shown in engineering drawing 20.1.11-3-D-C-941-108 The south-west and south-east abutments and adjoining Causeway revetment design now have curved transitions into Waterview Estuary and Oakley Inlet channels respectively that are much closer to the natural curvature of the existing upper intertidal banks (see mangrove line in Figure 3.43).

Degree of potential effects: Effects of widened abutments will cause minor re-adjustments of the geomorphology (channel depths and flanking intertidal banks) in the confluence area where channels merge or diverge to flow in and out through the bridged outlet channel.

Figure 3.43 : Aerial photograph of the existing Causeway Bridges and the confluence of channels from Oakley Inlet (bottom right), Waterview Estuary (bottom left) and the outlet channel to Central Waitemata Harbour. White arrows indicate intertidal banks that may erode from widened bridge abutments and yellow dashed arrows, bank corners which may experience erosion and re-alignment. The black arrow indicates a depression beside the groyne that will be partially infilled by the widened abutment revetment. [*Source*: Aurecon NZ Ltd., flown Feb 2006].

4.2.3 Disturbance

Not applicable during the operational phase of the Project.

4.2.4 Discharges

Operational stormwater treatment systems for SH16 and SH20 will discharge to the CMA through various outlets located in Sectors 1-5 (Figure 3.27). Mitigation, through stormwater treatment, of the stormwater run-off from both the existing and upgraded impervious road surfaces and the effects on the receiving waters of the CMA after reasonable mixing [RMA s. 107 (1) (a-e)] are covered in the Assessment of Stormwater and Streamworks Effects (**G.15**).

The effects of contaminants from treated stormwater systems on aquatic life [RMA s. 107 (1) (g)] are covered in the Assessment of Marine Ecological Effects report (**G.11**).

However, to provide a basis for these two reports to assess the effects of operational stormwater discharges on the CMA, model simulations were undertaken for potential sediment and contaminant loads from SH20 outlets into Oakley Creek, and flowing on into the CMA via Oakley Inlet.

Although stormwater treatment and control measures will be used along the proposed SH20 motorway to capture the majority of sediment and contaminant load from entering Oakley Creek, there will be a residual load of sediments and contaminants released into the Creek and ultimately discharged into the CMA. A series of numerical models was used to predict: i) the sediment and contaminant load released from the new road area; ii) the retention of sediments and contaminants using sediment-treatment measures; and iii) the dispersal of the discharged sediments and contaminants throughout Oakley Inlet, Waterview Estuary and the Central Waitemata Harbour by tidal processes. The computational modelling is described in Appendix A and results are presented in Appendix B.

The series of numerical models predict that:

a) after passing through the stormwater treatment measures, the operational loads entering into Oakley Creek are only a modest increase over the existing base loads from the overall catchment; and
b) any sediment that is released into the CMA through Oakley Inlet gets rapidly dispersed throughout Waterview Estuary and the Central Waitemata Harbour.

The simulations and results of the numerical modelling of stormwater loads are summarised further below.

The proposed works include stormwater-treatment measures to reduce sediment and contaminants being discharged into Oakley Creek from the motorway surface during storm events (see Assessment of Stormwater and Streamworks Effects (**G.15**)). In a storm event (approximately a 1 month return period), any sediment discharged into Oakley Inlet will get transported throughout Waterview Estuary, with some of the sediment getting exported into the Central Waitemata Harbour. The maximum predicted suspended-sediment concentration was for localised patches at 0.065 kg/m^3 (65 mg/L) above background concentrations with the majority of the Waterview Estuary having excess suspended-sediment concentrations of less than 0.0022 kg/m^3 (~2 mg/L). The accumulated sediment deposition at the end of the storm event has a maximum thickness in the upper reaches of Oakley Inlet of less than 0.22 mm.

For larger storm events (20 and 100 year return periods) the residual amount of sediment released into the Waterview Estuary increases. However, the maximum suspended-sediment concentration and maximum thickness of deposition remain approximately the same as the above water quality event due to the higher flow rates in Oakley Creek from catchment run-off. However, the aerial extent of the suspended-sediment plume and seabed deposition increase, rather than the peak magnitudes of suspended-sediment concentration and sediment deposition.

The resulting peak levels of suspended sediment concentration, sediment deposition depths and contaminant accumulation, are therefore relatively low. The resulting environmental effect of the discharged suspended sediments in terms of coastal physical processes (e.g., sedimentation) is minimal for the CMA overall, or localised and of short duration in Oakley Inlet and its confluence with Waterview Estuary. Overall the effects on sediment processes are minor. The ecological consequences of this sediment and contaminant dispersal are detailed in the Assessment of Marine Ecological Effects report (**G.11**).

4.3 Summary of effects on coastal physical processes

An overall summary of the effects on coastal physical processes for each activity assessed in previous sections 4.1 and 4.2 is provided in Table 4.2. Where potential effects on coastal physical processes may be more than minor, mitigation or remediation measures or avoiding the effect on the CMA have been put forward.

Table 3.2: Summary of activities and an assessment of their effects on coastal physical processes.

#	Sector	Summary of activity	Maximum degree of potential effects	Avoidance, mitigation or remediation
Construction Effects				
A: Structures				
1	1	Occupation of the CMA in Pixie Inlet (Henderson Creek) for a temporary rock-toe silt fence	Less than minor	None
2	2	Occupation of the CMA by temporary piers to support temporary construction platforms, Whau River Bridges and cycleway bridge	Effects of temporary piers on flows and navigation passage likely to be minor. All other effects less than minor.	Effects on navigation mitigated by providing a wider section with a longer span between piers. Optimally small pier diameters used.
3	1-4	Occupation of the CMA by temporary silt fences or cofferdams along the periphery of Causeway and bridge abutments to facilitate construction	Minor localised effects on sediment processes and geomorphology in front of cofferdams and on flows adjacent to channels	Erosion and Sediment Control Plan
4	4	Occupation of the CMA by temporary piers to support temporary staging platforms to construct widened Causeway Bridges and cycleway bridge	Minor effects on flows. Minor effect on navigation as mainly small watercraft e.g., kayaks.	Optimally small pier diameters to be used.
5	5	Occupation of the CMA in Oakley Inlet for temporary piers to support temporary staging platforms to construct on/off-ramps for the SH16/SH20 interchange.	Less than minor effects on flows and geomorphology (mostly outside the main sub-tidal channel).	Location of permanent piers (and hence staging platforms) has avoided the sub-tidal channel where possible.
B: Reclamation				
6	4	Extending the width of SH16 adjacent to the main channel that drains the Pollen Island wetland system	Less than minor after avoiding any encroachment of the adjacent channel draining the Pollen Island wetland.	Vertical retaining walls (rather than rock revetments) adopted in the design for these sections to avoid encroachment.
#	**Sector**	**Summary of activity**	**Maximum degree of potential effects**	**Avoidance, mitigation or remediation**
B: Reclamation (cont.)				
7	3	Extending the width of SH16 carriageway on the south side adjacent to a side drainage channel	Minor effects on drainage patterns and geomorphology with	Speed of the reclamation works to be matched with the response of the

		that flows around Rosebank Park Domain into the Whau River	mitigation measures and removal of some mangroves on south side of channel.	channel to naturally migrate to maintain a similar flow area.
8	4	Extending width of SH16 Causeway into the adjacent meander of the drainage channel that services the western side of Waterview Estuary	Minor, if mitigated by re-aligning the channel to prevent scour and slumping instabilities.	Undertake excavation of a by-pass channel under controlled tidal conditions and techniques.
9	4	Extending width of SH16 Causeway, including the transition from the Westbound On-ramp from SH20 and cycleway, into two meanders of the sub-tidal channel in Oakley Inlet	Minor, if mitigated by re-aligning the channel to prevent scour and slumping instabilities.	Undertake excavation of two by-pass channels under controlled tidal conditions and techniques.
C: Disturbance				
10	2, 3, 4	Ground (seabed) treatment works in the CMA required to support widened reclamations	Minor effects on sediment processes with mitigation and monitoring measures in place.	Temporary cofferdam or super-silt fences (Erosion and Sediment Control Plan and Coastal Works Report).
11	1-5	Mobilisation, installation and removal of sediment-control and containment measures	Minor, particularly if undertaken during dry tidal windows.	Use of sheet-piling rather than Aquadam in mangrove areas. Installation and dismantling undertaken around low tide.
12	1-4	Excavation and ground-treatment works in CMA for outlet structures for permanent storm water outlets	Less than minor due to the small scale and temporary nature of the work.	Erosion and Sediment Control Plan
13	2	Excavation for widened bridge abutments and ground-treatment works in the CMA, Whau River Bridges and cycleway bridge	Minor with mitigation measures.	Erosion and Sediment Control Plan
14	2	Installation and removal of temporary piers to support the temporary staging platforms for construction of Whau River Bridges and cycleway bridge	Minor effects from disturbed sediments incl. suspended-sediment plumes after allowing for reasonable mixing.	None
#	**Sector**	**Summary of activity**	**Maximum degree of potential effects**	**Avoidance, mitigation or remediation**
C: Disburbance (cont.)				
15	2	Construction of permanent piers to support widened Whau River Bridges and cycleway bridge	Minor effects on sediment processes with best-practice construction techniques.	Not required: steel casings will reduce sediment discharges during seabed excavation.
16	4	Blocking off redundant culvert under the Causeway (adjacent to west side	Negligible effects if works mainly undertaken during	Erosion and Sediment Control Plan

		of Rosebank Peninsula)	lower tide levels.	
17	4	Ground (seabed) treatment works between Traherne Island and Rosebank Peninsula on northern side will disturb or bury shoreline chenier (shell) beach deposits	Minor effects on erosion and intrinsic value of the chenier deposits with remediation.	Remedying will entail excavation of affected shell layers, stockpiling and replacing after completion of the works.
18	4, 5	Excavate a by-pass channel further south of western drainage channel in Waterview Estuary to re-align the meander in the channel that would otherwise be occupied or reclaimed by the widened Causeway.	Minor sedimentation effects from sediment releases by undertaking managed excavations of by-pass channel.	a) Excavations during low-tide windows; b) excavating the middle section of the by-pass channel first; c) excavation from a barge to minimise seabed disturbance from machinery.
19	4	Excavations for widened bridge abutments and ground treatment works, Causeway Bridges and cycleway bridge	Minor effects with mitigation measures.	Erosion and Sediment Control Plan.
20	4	Installation and removal of temporary piers to support the temporary staging platforms, Causeway Bridges and cycleway bridge	Minor effects from disturbed sediments incl. suspended-sediment plumes after allowing for reasonable mixing.	None
21	4	Construction of permanent piers to support widened Causeway Bridges and cycleway bridge	Minor effects with best-practice construction techniques.	Not required as steel casings will reduce sediment discharges during seabed excavations.
22	4	Ground treatment works and construction of widened causeway revetments adjacent to Oakley Inlet. Excavate two by-pass channels further south of the main sub-tidal channel in Oakley Inlet to re-align the meanders in the channel that would otherwise be occupied or reclaimed by the widened Causeway.	Minor sedimentation effects from sediment releases by undertaking managed excavations of two by-pass channels.	Mechanically excavate by-pass channels under controlled conditions (see Activity #18).
#	**Sector**	**Summary of activity**	**Maximum degree of potential effects**	**Avoidance, mitigation or remediation**
C: Disturbance (cont.)				
23	5	Installation and removal of piers to support temporary construction platforms, SH16/SH20 on/off-ramps	Less than minor effects on flows and sediment processes.	None
D: Discharges				
24	5	Earthworks and construction relating	Minor effects on sediment	Erosion & Sediment Control

#	Sector	Summary of activity	Maximum degree of potential effects	Avoidance, mitigation or remediation
		to the construction of SH20, Sectors 7-9 discharging into Oakley Creek before discharge to CMA in Oakley Inlet	processes (particularly sedimentation) of the CMA after rainstorm events with sediment control measures in the construction zones.	Plan
Operational effects				
A: Structures				
25	2	Permanent occupation within the CMA of additional bridge piers to support the widened Whau River Bridges and cycleway bridge	Minor effects on hydrodynamic flows and sediment processes.	Considered but nothing feasible.
26	4	Permanent occupation within the CMA of additional bridge piers to support the widened Causeway Bridges and cycleway bridge over the outlet channel from Waterview Estuary	Less than minor as flow is parallel to pier groups. Minor effects for extreme water levels at sea-level rises of 0.6-0.8 m.	None
27	5	Permanent occupation within the CMA in Oakley Inlet of bridge piers to support new SH16/SH20 on/off-ramps	Minor effect of piers on flows (as mostly located on intertidal areas).	Avoided more than minor flow effects by locating piers outside sub-tidal channel.
B: Reclamation				
28	1	Reclamation in Pixie Inlet (Henderson Creek) to support a permanent stormwater treatment pond	Minor effects on flows and geomorphology.	None
29	2	Reclamation for widened abutments to support the widened Whau River Bridges and cycleway bridge	Minor localised effects on coastal physical processes.	None
30	2, 3, 4	Reclamation of CMA to widen the existing SH16 carriageway on either or both the north and south sides from the Whau River to the eastern side of Rosebank Peninsula	Effects on drainage flows and geomorphology will be minor in the long term.	Design avoids encroachment of Pollen Island channel. Monitoring of channel migration next to Rosebank Park Domain.
#	**Sector**	**Summary of activity**	**Maximum degree of potential effects**	**Avoidance, mitigation or remediation**
31	3, 4	Reclamation to widen the existing SH16 Causeway on both the north and south sides from the eastern side of Rosebank Peninsula through to the Great North Road Interchange	Effects on tidal flows, drainage patterns and upper intertidal geomorphology will be minor. For channel encroachments on south side of Causeway (3 sites), excavation will be used to re-align channels rather than risk leaving to natural	Monitoring of channel re-alignments and the remediation of the chenier deposits on the northern side.

			processes.	
32	4	Reclamation to widen the existing eastern and western abutments for the Causeway Bridges and cycleway bridge	Widened abutments to the south will cause minor effects on the geomorphology (channel depths and flanking intertidal banks) in the confluence area where channels merge.	These effects mitigated in the design by paring back the southern abutments and having additional cycleway. bridge piers.

5. Conclusions

This assessment considers effects on coastal processes resulting from the construction and operation of the upgraded motorway system. Effects are measured against the baseline of the existing coastal environment including the present SH16 footprint. Effects are aligned with various categories of activities in the operative Auckland Regional Plan: Coastal i.e., structures, reclamation, disturbances of the foreshore and seabed or discharges of contaminants into the Coastal Marine Area (CMA).

The assessment of coastal physical effects for the Project has been undertaken through a series of investigations commencing in December 2008 through to July 2010. These investigations comprised an evolution of approaches to assessing the effects that were commensurate with the degree of certainty about the likely level of impacts, given the existing Causeway is essentially being widened.

This assessment compared the effects of the new works on physical coastal processes with the existing environment for three environmental areas of the Waitemata Harbour, mainly the Whau River, the Central Waitemata Harbour (to the north of the Causeway) and the Waterview Estuary (including Oakley Inlet).

In summary, the coastal marine area has already been substantially modified by the construction of the original Causeway in the early 1950s and to a much lesser extent, the protruding abutments for the original Whau River Bridge. The Causeway was widened further in 1959 and additional bridge widening took place in the 1990s. The new works proposed for SH16 between the Great North Road Interchange and Te Atatu are further lateral extensions of the existing footprint into the CMA.

As a result of the lengthy assessment process, some mitigation or avoidance measures for potentially adverse effects have already been incorporated into revisions of the engineering design and construction plans. With these measures included in the proposed design and other mitigation measures or remediation included (as outlined in this Report), the short- and long-term effects of the new works on coastal physical processes in the three coastal environment areas have been assessed as either **minor** or **no more than minor**.

6. Glossary

AVD-46. Refers to the regional vertical datum called Auckland Vertical Datum–1946.

Average recurrence interval (ARI). The average, or expected, value of the period in years between exceedances of a given water level or flow discharge (also known as the return period).

Bathymetry. The water depth to the seabed below a known vertical datum.

Bioturbation. The mixing of sediment by living organisms.

Chenier ridge. A geological formation being a ridge on beach or offshore intertidal banks, composed of shell material resting on underlying sediments.

Cofferdam. An enclosure within a water environment constructed to allow water to be pumped out and replaced by air for the purpose of creating a dry work environment.

Embayment. An indentation in a shoreline forming an open bay.

Geomorphology. The study of landforms

Groyne. A rigid hydraulic structure built perpendicular or at an angle out from a shoreline to limit the along shore movement of sediment.

Intertidal. The region of terrain which gets inundated between low tide and high tide cycles.

LiDAR. (**Li**ght **D**etection **A**nd **R**anging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. Used from an aeroplane to collect bathymetry data for intertidal areas.

MHWS. Mean High Water Spring level to a known vertical datum.

Mudcrete. A structural material made from a mixture of concrete and marine sediment (muds).

Surficial. From the surface e.g., *Surficial sediment* is sediment from the surface of the sea bed.

Thalweg. The deepest continuous line along a water course or channel.

Water Quality Storm Event. A storm event defined as having a magnitude of 1/3rd of the 2 year return period storm. It is used in Water Quality analysis as being the design storm which transports 80% of the annual sediment.

7. References

7.1 Project technical reports

Technical Report No. G.11 Assessment of Marine Ecological Effects

Technical Report no. G.15 Assessment of Stormwater and Streamworks Effects

Technical Report No. G.22 Erosion and Sediment Control Plan (ESCP)

Technical Report No. G.23 Coastal Works Report

Technical Report No. G.30 Associated Sediment and Contaminant Calculation Report

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7.2 Other references

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