Chapter 10
Hydrology

Chapter 10 Hydrology

10.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) presents the hydrological assessment of the proposed construction and operational phases of the Flood Defences West (hereafter referred to as the 'proposed development'). This chapter sets out the methodology used in the assessment (Section 10.2), details the likely significant impacts associated with the construction and operational phase of the proposed development (Section 10.4), describes measures to mitigate identified significant impacts (Section 10.5) and details residual impacts post mitigation (Section 10.6).

10.2 Methodology

10.2.1 Legislation and Guidelines

This chapter has been prepared having due regard to relevant legislation guidance documents which are listed below:

- Environmental Protection Agency (EPA 2002) Guidelines on the Information to be contained in Environmental Impact Statements;
- Environmental Protection Agency (EPA 2003) Advice Notes on Current Practice (in the preparation of Environmental Impact Statements) ;
- Draft Guidelines on the Information to be contained in Environmental Protection Agency (EPA 2017) (referred to where appropriate);
- Environmental Protection Agency (EPA 2015) Draft Advice Notes for Preparing Environmental Impact Statements;
- Transport Infrastructure Ireland (TII 2009) Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes; and
- Transport Infrastructure Ireland (TII 2008) Guidelines for the crossing of watercourses during the construction of National Road Schemes.
- DoEHLG (Nov 2009) The Planning System and Flood Risk Management – Guidelines for Planning Authorities;

10.2.2 Hydrology Assessment Methodology

The hydrological impact assessment methodology is in general agreement with the guidance outlined in Sections 5.6 and 5.7 of the TII 'Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes, 2009'. The impact category, duration and nature of impact have been assessed in this chapter, as per the guidelines. The range of criteria for assessing the importance of hydrological features within the study area (site boundary + 250m) and the criteria for quantifying the magnitude of impacts follow the TII guidelines and the EPA (2017) Draft Guidelines on the Information to be contained in Environmental Impact Assessment Reports'.

The hydrological assessment includes a review of published literature available from various sources including a web-based search for relevant material. Site specific topographical information and aerial photography has been reviewed to locate any potential features of hydrological interest, and these have been investigated on the ground by a walkover survey undertaken on the 16th May 2018, in order to assess the significance of any likely environmental impacts on them.

Available topographical and hydrometric information (field and desk based) has been used to perform hydrological impact assessments of the proposed flood defences development. All watercourses and water bodies which could be affected directly (i.e., crossed or realigned/ diverted) or indirectly (i.e., generally those that lie within 250m of the proposed development) were assessed through previous site walkover visits followed up by a detailed desk study and hydrological assessment.

10.2.3 Hydrology Impact Assessment Methodology

Types of hydrological impact for the proposed development fall into two broad categories of quantitative and qualitative impacts.

Quantitative Impacts

Hydraulic structures such as flood defences, culverts, channel diversions and outfalls can, if not appropriately designed, impact negatively on upstream water levels and downstream flows. If the conveyance area of a river is significantly reduced it may impede flow during times of floods thus causing water levels within the vicinity of the structure to be raised above what would occur in the absence of the structure and potentially increase flooding of undefended lands.

Surface water drainage from the defended lands can potentially be cut off from discharging to the receiving water body, potentially increasing surface water/pluvial flooding in relatively frequent events.

Qualitative Impacts

The nature of the proposed development as a flood defence barrier on the banks of a watercourse poses an inherent risk of surface water contamination during the construction phase. Construction works has the potential to mobilise silts and sediments in the water column. Additionally, the proposed drainage network may convey contaminants to receiving waterbodies.

10.2.4 Field Surveys

Field surveys and walkover assessments were carried out to assess the hydrological impacts of the proposed development. A detailed bathometric survey recording bed level to Malin OD (including floodplain topographical surveys, where required) were made in February 2021 at areas where hydrological impacts were likely to occur.

10.2.5 Desk Study

A desk study was completed in order to obtain information on the receiving hydrological environment using the following sources:

- Geological Survey of Ireland (GSI) – Bedrock Geology;
- Teagasc – Subsoil Map;
- Aerial Photography;
- Environmental Protection Agency (EPA) Surface Water Quality;
- EPA Viewer WFD Scores for Rivers, Transitional Water Bodies and Coastal Waters;
- OPW (Office of Public Works) Preliminary Flood Risk Assessment Mapping (pFRA);

- OPW Catchment Flood Risk Assessment and Management Mapping (CFRAMs);
- Floodmaps web mapping;
- Waterford North Quays SDZ Flood Risk Assessment 2018; and
- Geological Survey of Ireland (GSI) Web Mapping

10.3 Description of Receiving Environment

10.3.1 Regional Overview of Hydrology

The proposed development is located on the northern bank of the River Suir in Waterford City and is bound to the north by the Iarnród Éireann rail yards and R448 regional road. Plunkett Station is bounded to the north by a steep rock slope which is subject to rock stabilisation works as part of the overall Waterford City Public Infrastructure Project.

The headwaters of the Suir are located on the eastern slopes of Benduff, North West of Templemore in Co. Tipperary. The Suir becomes tidal just before reaching Carrick-on-Suir and is joined by a number of rivers between this point and Waterford city including the Lingaun, Portlaw Clodiagh, Pil, and Kilmacow Blackwater. It then makes its way to the confluence with the Nore and Barrow Rivers, downstream and east of Waterford City. The Suir estuary then turns south, flowing out to sea through Waterford Harbour between Dunmore East and Hook Head.

The River Suir is tidal at the location of the proposed development. Surface water features located in the vicinity of the proposed development are entirely within the South Eastern River Basin District. The proposed development is located within Hydrometric Area No.16 (Suir). This catchment includes the area drained by the River Suir and all streams entering tidal water between Drumdowney and Cheekpoint, Co. Waterford, draining a total area of 3,542km^2. The largest urban centre in the catchment is Waterford City.

10.3.2 Existing Drainage

The lands directly adjacent to the proposed development comprise an area of existing hard standing that drains directly into the River Suir either through the existing drainage system or overland flow.

10.3.3 Flood Risk

The Flood Risk at the site of the proposed Flood Defences West has been assessed as part of this study. Previous flood studies have been undertaken as part of the PFRAMs, CFRAMS, Waterford Flood Alleviation Scheme and Waterford North Quays SDZ Planning Scheme.

10.3.3.1 OPW Preliminary Flood Risk Assessment

To inform the Flood Risk Assessment (FRA), the OPW Preliminary Flood Risk Assessment (PFRA) mapping was consulted as an initial screening. As required by the EU Floods Directive, the OPW carried out a PFRA to identify areas where the risk of flooding may be significant. The PFRA is a broad scale assessment based on historic flooding, predictive analysis and consultation with local communities and experts. As part of the PFRA, maps of the country were produced showing the indicative fluvial, pluvial and tidal flood extents, following which, Areas for Further Assessment (AFA's) were identified.

The PFRA map at the location of proposed development indicates that the site is subject to fluvial 1 in 100 years Annual Exceedance Probability (1% AEP) and coastal 1 in 200 years Annual Exceedance Probability (0.5% AEP) flood extents. The PFRA mapping does not indicate any pluvial or groundwater flooding within or in the vicinity of the proposed development. The PFRAM mapping identified Waterford City as a probable AFA.

10.3.3.2 OPW Catchment Flood Risk Assessment and Management.

Following on from the PFRA study, the OPW commissioned The South Eastern CFRAM Study Flood Risk Review which highlighted Waterford City as an AFA for fluvial and coastal flooding. This was based on a review of historic flooding and the extents of flood risk determined during the PFRA study. The Waterford City AFA incorporates the River Suir and its associated tributaries, including the Johns River as it flows through Waterford City before joining the River Suir from the south.

The published Final CFRAM (02/08/2016) mapping (extract reproduced in figure 10.1 below) indicates that the location of the proposed development currently has the potential to flood in 1% Fluvial AEP and 0.5% Tidal AEP flood events. The CFRAM mappings shows that the southern quays are defended to the 1% AEP event. The Waterford City Flood Alleviation Scheme was constructed prior to the CFRAM publication and therefore the CFRAM mapping incorporates the benefit of the flood alleviation scheme. Calculated maximum flood depths in the 0.1%AEP event (as per the CFRAMS) for the study area are between 1-1.5m.

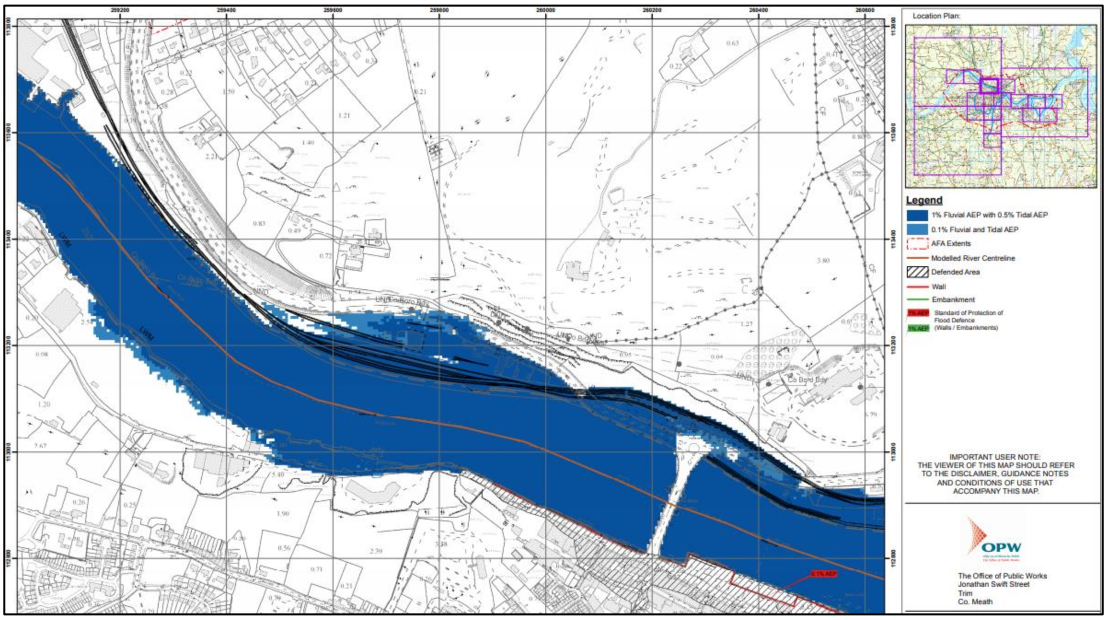

Figure 10.1 CFRAMS Flood Mapping Extract

10.3.3.3 Waterford Flood Alleviation Scheme

Waterford City and County Council and the OPW have implemented a significant flood alleviation scheme in Waterford City. Historically, Waterford City suffered recurring flooding with the River Suir and John's river experiencing out of bank flood events on multiple occasions in the latter half of the 20th Century. The flooding of the South Quays inundated the city's main thoroughfares and adjoining premises. The OPW and Waterford City Council commissioned consultants to undertake the Waterford City Flood Alleviation Scheme. The Scheme focused on containment of the watercourses within their channels. This was achieved through the construction of a series of flood defences in the form of reinforced concrete walls, glass walls, sheet piled walls, embankments, stormwater pumps, etc. The works were constructed in three separate civil works contracts and on completion is protecting the city from flooding from the rivers for events up to the 0.5% AEP in tidal areas and up to the 1% AEP in non-tidal areas. A section of flood barrier along the south quays is shown in Figure 10.2 below.

Figure 10.2 Section of Waterford Flood Relief Barrier (Carey Glass)

The flood defences devised as part of the Waterford Flood Alleviation Scheme are a maximum of 1.1 - 1.2m above ground levels to preserve river views. The design heights were increased from the modelled flood heights to accommodate the effects of climate change and uncertainty in flow estimation. A freeboard of 0.5m and 0.3m was implemented in tidal and non-tidal areas respectively. The design for Waterford South Quays flood defences features glass flood defences prominently. The implemented design height for the Waterford South Quays flood defence wall is +3.7mOD.

10.3.3.4 Waterford North Quays SDZ Planning Scheme – Strategic Flood Risk Assessment

As part of the Waterford North Quays SDZ Planning Scheme (2018) WCCC produced a flood risk assessment of the SDZ lands. A one-dimensional (1D) model was prepared to ascertain the effects of extreme tidal and combination tidal/fluvial events. A 1D model was utilised as it was determined that the Suir Estuary is dominated by tidal flows in the longitudinal flow direction.

The model was developed using surveyed topographic and channel cross-sections and OPW cross-sections. GSI / Marine Institute Infomar Sea bed survey data of the Waterford Harbour Area were also used to develop the model along with LiDAR data and a detailed hydrological assessment of the catchment. A medium range sea level rise scenario was adopted which is in keeping with the current OPW recommendations.

The findings from the hydraulic model were that critical flooding and flood levels in the estuary and at the location of the proposed development are as a consequence of the tidal storm surge conditions. Fluvial flood flows at this location contribute very little to increasing the peak flood levels in the Suir. Flood levels were derived from the hydraulic assessment conducted as part of Waterford North Quays Strategic Flood Risk Assessment. These are summarised in Table 10.1 below.

Table 10.1 Flood levels derived Waterford North Quays SFRA

Return Period – 1 in XX year	Existing Flood Level (excl. Climate Change (mOD)[Note 1]	MRFS Flood Level (mOD)[Note 2]
2	2.663	3.213
10	2.943	3.493
20	3.053	3.603
50	3.163	3.713
100	3.273	3.823
200	3.393	3.943
1000	3.633	4.183

Notes:

1. Flood Levels given above are taken from the hydraulic model based on a combined analysis of the tidal 1 in XX-year event / 1 in 2-year fluvial event at an upstream location at the confluence of the River Blackwater.
2. MRFS climate change allowance = (+0.55m which consists of +0.50m for climate change and +0.05m for isostatic tilt)

10.3.4 EPA Monitoring River Programme

The EPA carries out water quality assessments of rivers, transitional and coastal water bodies as part of a nationwide monitoring programme. Data is collected from physico-chemical and biological surveys, sampling both river water and the benthic substrate (sediment).

Water sampling is carried out throughout the year and the main parameters analysed include: conductivity, pH, colour, alkalinity, hardness, dissolved oxygen, biochemical oxygen demand (BOD), ammonia, chloride, ortho-phosphate, oxidised nitrogen and temperature.

As is the case for rivers and lakes, the impact of nutrient enrichment and the process of eutrophication is also a major concern in the tidal waters environment. The direct negative effects of excessive nutrient enrichment include increases in the frequency and duration of phytoplankton blooms and excessive growth of attached opportunistic macroalgae. The subsequent breakdown of this organic matter can lead to oxygen deficiency which in turn can result in the displacement or mortality of marine organisms. As such the effects of over enrichment can severely disrupt the normal functioning of tidal water ecosystems.

The status of individual estuarine and coastal water bodies is assessed using the EPA's Trophic Status Assessment Scheme (TSAS). This assessment is required for the Urban Waste Water Treatment Directive and Nitrates Directive. The scheme compares the compliance of individual parameters against a set of criteria indicative of trophic state (see Table 10.2). These criteria fall into three different categories which broadly capture the cause-effect relationship of the eutrophication process, namely nutrient enrichment, accelerated plant growth, and disturbance to the level of dissolved oxygen normally present.

Table 10.2 Biological River Water Quality Classification System

Trophic Status	Pollution Status	Condition
Unpolluted	Unpolluted	Unpolluted water bodies are those which do not breach any of the criteria in any category.
Intermediate	Unpolluted	Intermediate status water bodies are those which breach one or two of the criteria.
Potentially Eutrophic	Slightly polluted	Potentially Eutrophic water bodies are those in which criteria in two of the categories are breached and the third falls within 15 per cent of the relevant threshold value.
Eutrophic	Polluted	Eutrophic water bodies are those in which criteria in each of the categories are breached, i.e., where elevated nutrient concentrations, accelerated growth of plants and undesirable water quality disturbance occur simultaneously.

The River Suir at Waterford City had an EPA Transitional Surface Water Quality Status of "Eutrophic" from 2010-2012 and a Water Framework Directive (WFD) Status of "Poor" from 2013-2018. The "Poor" Status is indicated to be as a result of poor Phytoplankton Status as per the EPA Catchments website. Additionally, there appears to have been a deterioration across some parameters from the 2010-2015 to the 2013-2018 monitoring periods, these include Nutrient and Hydromorphological conditions in the River Suir.

The EPA Catchments.ie website mapping section provides details on the assessments of the water bodies / sub catchments in the study area. This data was reviewed as part of this assessment and a summary is given in Table 10.3. It should be noted that the WFD assessment considers the entire waterbody sub-catchment whereas the EPA monitoring results are point measurements at discrete locations.

Table 10.3 WFD Classification of Transitional Waters Near the Proposed Flood Defences West (2013-2018 Sampling period, EPA)

Waterbody		Code	WFD Status	Objective	Risk	Heavily Modified Status
Upper Suir Estuary	Upstream of Waterford City	IE_SE_100_0600	Poor	Restore	At Risk	No
Middle Suir Estuary	Waterford City located within Middle Suir Estuary	IE_SE_100_0550	Poor	Restore	At Risk	No
Lower Suir Estuary	Downstream of Waterford City	IE_SE_100_0500	Good	Protect	At Risk	Yes

The status of the Lower Suir Estuary as a "Heavily Modified" water body also changes the criteria for assessment, whereby the amended criteria generally have higher tolerances for pollutants etc. Water quality in the catchment is mainly "at risk" from diffuse sources of pollution such as agriculture and on-site wastewater treatment systems. Point sources of pollution in the town of Waterford City are also highlighted as "a risk" to the water quality status across the wider catchment.

10.4 Description of Potential Impacts

Flood Defence projects, given their scale and nature, have significant potential for causing impact to the hydrological environment both during their construction and operation and consequently require careful planning and detailed assessment to ensure the best solution is obtained. This section will describe the potential impacts associated with the proposed development before mitigation measures are applied. Both direct and indirect impacts will be addressed for the construction and operation of the proposed development. The nature, extent and duration of the impacts will also be assessed.

The assessment of hydrological impacts for the proposed flood defences development has been based on the analysis and interpretation of the data acquired during the site-specific investigations undertaken as part of the EIA, including the biodiversity surveys, intrusive site investigation, material assets survey, topographical survey, hydrodynamic modelling and hydrological walkover surveys. The procedure follows the guidelines set out in the publication 'Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes', TII, 2009.

Key hydrological receptors identified in the vicinity of the proposed flood defences include:

- The Lower River Suir SAC (European Designated Site);
- Ecologically sensitive surface water features and catchment systems; and,
- Flood Risk Areas.

10.4.1 Construction Phase

Construction activities pose a significant risk to watercourses, particularly works within the channel and contaminated surface water runoff from construction activities entering the watercourse.

10.4.1.1 Impact on Water Quality

Construction activities associated with flood defence construction, within and alongside surface waters, can contribute to the deterioration of water quality and can physically alter the river bed and bank morphology with the potential to alter erosion and deposition rates locally and downstream. Activities (such as sheet piling) within or close to the watercourse channels can lead to increased turbidity through re-suspension of bed sediments and release of new sediments from earthworks.

The main contaminants likely to arise from construction include:

- Elevated silt/sediment loading within watercourses from construction site runoff and sheet piling. Sheet piling will be undertaken both from the land side and primarily from a barge for river-side installation. Additionally, 3 No. temporary cofferdams will be required to construct 1 No. proposed surface water outfall structure and to upgrade 2 No. existing outfall structures. Effects on erosion and deposition processes during construction are likely to be *negative, temporary, imperceptible to slight* and highly localised to the temporary outfall cofferdams. Runoff from landside works is envisaged to be limited due to the existing high infiltration surfaces of the railway and the associated lands, the exception to this are the hardstanding areas in the vicinity of rice bridge and Plunket station. Elevated silt loading can lead to long-term damage to aquatic ecosystems by smothering spawning grounds and gravel beds and clogging the gills of fish. Increased silt load in receiving watercourses stunts aquatic plant growth, limits dissolved oxygen capacity and overall reduces the ecological quality with the most critical period associated with low flow conditions. Other pollutants in the watercourse can bind to silt which can lead to increased bioavailability of these pollutants.

- Spillage of concrete, grout and other cement-based products. These cement-based products are highly alkaline (releasing fine highly alkaline silt) and extremely corrosive and can result in significant impact to watercourses altering their pH, smothering the stream bed and physically damaging fish through burning and clogging of gills due to the fine silt.
- Accidental Spillage of hydrocarbons from construction plant and refuelling operations at storage depots / construction compounds, which can reach watercourses.
- Faecal contamination arising from inadequate treatment of on-site toilets and washing facilities.

In the absence of mitigation measures, the potential impact is *negative, temporary moderate to significant*.

10.4.1.2 Impact on Flooding

There is potential for flood events to occur during the construction phase. The construction works will increase the number of people near a known source of flooding, thus increasing the potential for flood risk related impacts on human health. This has the potential to have a *negative, temporary, imperceptible to slight* impact.

There is also potential for pollutants derived from construction materials to be mobilised by flood waters and has the potential to have a *negative, temporary, slight to moderate* impact on receiving watercourses.

The volumes displaced by the proposed flood defences during construction is extremely small relative to the volumes of the receiving waterbodies and will result in a*n imperceptible* impact on flood levels and subsequent flood risk in the vicinity of the subject site.

10.4.2 Operational Impacts

Hard flood defences, by design, cause permanent disturbance to river channels, floodplains and the flood regime. These structures can, if not appropriately designed, create an obstacle to flow, particularly under flood conditions resulting in increased flood risk and damage in the vicinity of the proposed structures. Such structures can locally alter channel morphology resulting in changes in flow velocity and water depth. These structures can also result in localised riverbed and riverbank erosion, resulting in long-term changes to the morphology of the river channel.

10.4.2.1 Impact on Water Quality

New surface water outfalls which collect surface water run-off from the railway area shall pass through a Class 1 by-pass separator prior to discharge to the River Suir. This will limit the potential for impacts to the water quality of receiving waterbody and has the potential to have a *positive, long term, slight to moderate* impact.

Additionally, operational phase maintenance works could result in accidental spillage of paint which will be used in the periodic (approximately every 10 years) repainting of the exposed sections of the new sheet pile flood defence wall. In order to control this risk, the paint specified for this purpose shall not contain lead or tributyltin (TBT) or shall be otherwise approved for use near water. This has the potential to have a *negative, temporary, imperceptible to slight* impact.

10.4.2.2 Erosion and Sediment Transport

A computational model was undertaken to assess the hydrodynamics of Suir Estuary and to assess the effects of the proposed development on the circulation patterns of the estuary (see Appendix 10.2 for further details). The hydrodynamic simulations run for both normal tidal conditions and extreme flood events show an increase in velocity magnitude along localised sections of the flood wall alignment on both ebb and flood flows and a reduction in velocity locally in the vicinity of the outfall structures. The greatest increases in velocity between existing and proposed cases occur on the spring tides and on the flooding tide with a general local increase of 0.05m/s and larger increases along the toe of the Flood wall of 0.075 to 0.1m/s. These are highly localised changes and are not significant in comparison to the computed baseline velocity magnitudes under the existing situation. There is no perceptible change in flow velocities in the main, deeper channel section or at the far bank. The predicted upstream and downstream changes to the flow velocity magnitude at the near bank is local and not very extensive.

The conclusion reached from this analysis is that the computed velocity increases from the proposed vertical sheet piled wall are relatively small and of insufficient magnitude to produce sufficient shear stresses (i.e. generally <0.7Pa) that would result in any potential significant erosion of the permanent consolidated sediments on the channel bed and banks in the vicinity of the affected area. Unconsolidated silts will be mobile under tidal ebb and flood conditions both for the proposed and existing cases and a slight reduction in silt deposition adjacent to the sheet piled wall is anticipated. This has the potential to have a *negative, long-term, imperceptible to slight* impact.

It should be noted that the post development scenario simulation represents the defence wall as bare sheet piles and not with cladding as proposed. Therefore, the aforementioned hydraulic models are inherently conservative in their estimation of erosion given that the proposed cladding will have an increased surface roughness similar to the existing quay wall.

10.4.2.3 Coastal / Fluvial Flooding

Hydraulic flood modelling was carried out to estimate the design flood level (see Appendix 10.2 for further details). In this respect, the design flow and flood levels are based on the Index Flood Estimate (Qmed) using Flood Studies Update (FSU) Estimation Method and Tidal Gauge flood level analysis.

The FSU Research Programme was implemented by the OPW and provides a substantial update of the Flood Studies Report (FSR). The FSU is an upgraded method for providing estimates at a network of hydrometric nodes throughout Ireland and has a factorial error of 1.38. The method uses a pooled growth curve of hydraulically similar catchments as the subject catchment which differs from the FSR which uses a single national growth curve.

A water level gauging station is present directly downstream (~500m) of the proposed flood defences at Adephi Quay (no. 16160). A short continuous water level record is available from 1999 to 2015 (a 17-year annual maxima series). The median water level at the Adelphi Quay hydrometric gauge was +2.58 mOD in 2018 and highest recorded water level was +2.89 mOD which occurred on the 27th October 2004.

A one-dimensional (1D) model has been prepared to ascertain the effects of extreme tidal and combination tidal/fluvial events. A 1D model was utilised as it was determined that the Suir Estuary is dominated by tidal flows in the longitudinal flow direction. The model was developed with surveyed topographic and channel cross-sections, OPW Cross-sections and GSI / Marine Institute Infomar Sea-bed survey of the Waterford Harbour Area, LiDAR data and a detailed hydrological assessment of the catchment.

The findings from the hydraulic model are that critical flooding and flood levels in the estuary and on the site are as a consequence of the tidal storm surge conditions. Fluvial flood flows at this location contribute very little to increasing the peak flood levels in the Suir. The removal of the defended lands as a tidal inundation area will have a negligible effect on the flood depths and will not have any perceivable effects on adjacent lands. Details of the modelled flood levels at the proposed flood defences are given in Table 10.4 below.

A Design Flood Level (200-year flood including Climate Change) of +4.30mOD has been calculated for the proposed Flood Defences West based on:

- 0.5% annual exceedance probability combined tidal-fluvial event (+3.45m OD);
- An additional 0.55m to allow for climate change and isostatic tilt; and,
- 0.30m freeboard, including local wave wake effects.

The proposed flood defences will have a minimum top of wall level of +4.30mOD.

The combination of the 1000-year tide and 2-year fluvial flood level including climate change is +4.240mOD. The proposed Design Flood level of +4.30mOD is above the 1000-year flood including climate change level which is a requirement for "Highly Vulnerable developments", such as the rail infrastructure as per the 2009 OPW Guidelines.

Table 10.4 Modelled Flood Levels West of Plunkett Station

Return Period – 1 in XX year	Existing Flood level (excl. climate change) (m OD) Note 1	MRFS Flood Level (m OD) Note 2
2	2.72	3.27
10	3.00	3.55
20	3.11	3.66
50	3.22	3.77
100	3.33	3.88
200	3.45	4.00
500	3.58	4.13
1000	3.69	4.24

Notes:

1. Flood Levels given above are taken from the hydraulic model based on a combined analysis of the tidal 1 in XX-year event / 1 in 2 year fluvial event at an upstream location at the confluence of the River Blackwater.
2. MRFS climate change allowance = (0.55m which consists of 0.50m for climate change and 0.05m for isostatic tilt)

The proposed flood defences will defend lands to the north from flooding including sections of the rail line, the existing Plunkett Station and Rice Bridge roundabout. The overall predicted impact is therefore *positive, significant* and *long-term*.

10.4.2.4 Surface water and Pluvial Flooding

The proposed flood defences will restrict drainage by gravity of the surface water drainage network in extreme fluvial/tidal events to the River Suir due to the proposed non-return valves and will also restrict reciprocal groundwater flows due to the cut-off sheet pile wall. Nonetheless, as part of the standard drainage design, pumping stations are incorporated to ensure the continued drainage of the subject lands during exceptional flood events within the River Suir. The potential *negative* impact is *permanent, imperceptible to slight* in magnitude.

10.4.2.5 Predicted Impact of Storm Discharge on Flooding / Morphology

The existing drainage pathways for the defended lands will be maintained as part of the development during operation. All drainage outfalls will be fitted or retrofitted with non-return valves to prevent tidal water ingress and 2 no. existing drainage outfalls in the River Suir bank will be upgraded with new headwalls and improved erosion control measures to facilitate long-term operation and maintenance of outlets. The potential impact is a *positive, slight* and *permanent*.

10.4.2.6 Predicted Impact of Storm Discharge of Pollutants

Existing drainage paths are to be maintained, including those within contributing catchments. The implementation of new filter drains and carrier drains trackside may decrease the time taken for surface water bourn pollutants to enter the River Suir imperceptibly. Nonetheless, there are no envisaged changes to sources of pollution within the drainage network catchments. The minor amendments to the existing drainage networks will be likely have a *negative, imperceptible,* and *permanent* impact.

10.5 Mitigation & Monitoring Measures

10.5.1 Construction Mitigation

As is normal practice with infrastructure projects, an Environmental Operating Plan (EOP) and Construction Environmental Management Plan will be prepared for the Flood Defences West and are included in Appendix 4.1 and Appendix 1.4 A, respectively. These will be developed by the selected contractor to suit the detailed construction methodology and allocate responsibilities to individuals in the construction team. In doing so, the measures detailed in the appended reports will be considered minimum requirements to be considered and improved upon. The level of detail provided within the current drafts of the Plans is sufficient to allow an assessment of the anticipated impacts including residual impacts.

The following will be implemented as part of this plan:

- An Incident Response Plan (see Appendix 4.1 C) will be finalised detailing the procedures to be undertaken in the event of spillage of chemical, fuel or other hazardous wastes, non-compliance with any permit or license, or other such risks that could lead to a pollution incident, including flood risks.
- All necessary permits and licenses for in stream construction work for provision of the flood defences will be obtained prior to the commencement of construction.
- Inform and consult with Inland Fisheries Ireland and Waterways Ireland.

During construction, cognisance will have to be taken of the following guidance documents for construction work on, over or near water.

- *Requirements for the Protection of Fisheries Habitat during Construction and Development Works at River Sites* (Eastern Regional Fisheries Board)

- *Central Fisheries Board Channels and Challenges – The enhancement of Salmonid Rivers.*
- *CIRIA C532 Control of Water Pollution from Construction Sites Guidance for Consultants and Contractors.*
- *CIRIA C648 Control of Water Pollution from Constructional Sites.*
- *Guidelines for the Crossing of Watercourses during the Construction of National Road Schemes (TII, 2006).*

Based on the above guidance documents concerning the control of construction impacts on the water environment, the following outlines the principal mitigation measures that will be adhered to for the construction phase, in order to protect all catchment, watercourse and ecologically protected areas from direct and indirect impacts:

General Mitigation Measures

- Site works will be limited to the minimum required to undertake the necessary elements of the project.
- Surface water flowing onto the construction area will be minimised through the provision of berms, diversion channels or cut-off ditches.
- Management of excess material stockpiles to prevent siltation of watercourse systems through runoff during rainstorms will be undertaken. This may involve allowing the establishment of vegetation on the exposed soil and bunding.
- Protection of waterbodies from silt load will be carried out through the use of gully silt/sediment filters and shallow berms in hardstanding areas to provide adequate treatment of runoff to watercourses.
- Settlement tanks, silt traps/bags and bunds will be used. Where pumping of water is to be carried out, filters will be used at intake points and discharge will be through a sediment trap.
- The anticipated site compound/storage facility will be fenced off at a minimum distance of 5m from the top of the edge of the quay wall/river edge. Any works within the 10m buffer zone will require measures to be implemented to ensure that silt laden or contaminated surface water runoff from the compound does not discharge directly to the watercourse. CEMP has been drafted and will need to be finalised by the appointed Contactor See the EOP and Construction Environmental Management Plan (CEMP) in Appendix 4.1 and 4.1 A of this EIAR for further detail.
- Protection measures will be put in place to ensure that all hydrocarbons used during the construction phase are appropriately handled, stored and disposed of in accordance with the TII document "*Guidelines for the crossing of watercourses during the construction of National Road Schemes*". All chemical and fuel filling locations will be contained within bunded areas and set back a minimum of 20m from watercourses.
- Foul drainage from all site offices and construction facilities will be contained and disposed of in an appropriate manner, off site, to prevent pollution.
- The construction discharge will be treated such that it will not reduce the environmental quality standard of the receiving watercourses.
- Water quality monitoring will be undertaken in the River Suir, with monthly samples being taken from at least 6 months prior to commencement of construction until at least 24 months post-completion. Water samples will be taken from at least two locations. The final number and location of sampling

points will be determined by the Site Environmental Manager. The results of the water quality monitoring programme will be reviewed by the Site Environmental Manager and Ecological Clerk of Works on an ongoing basis during construction. In the event of any non-compliance with regulatory limits for any of the water quality parameters monitored, an investigation will be undertaken to identify the source of this non-compliance and corrective action will be taken where the this is deemed to be associated with the proposed development.

Specific Mitigation Measures - Concrete Works

Remedial works to the existing masonry quay wall and increasing its height will require the use of in-situ concrete. The use and management of concrete in or close to watercourses must be carefully controlled to avoid spillage which has a deleterious effect on water chemistry and aquatic habitats and species. As the use of concrete cannot be avoided, the following control measures will be employed:

- Hydrophilic grout and quick-setting mixes or rapid hardener additives shall be used to promote the early set of concrete surfaces exposed to water;
- When working in or near the surface water and the application of in-situ materials cannot be avoided, the use of alternative materials such as biodegradable shutter oils shall be used;
- Any plant operating close to the water will require special consideration on the transport of concrete from the point of discharge from the mixer to final discharge into the delivery pipe (tremie). Care will be exercised when slewing concrete skips or mobile concrete pumps over or near surface waters;
- Placing of concrete in or near watercourses will be carried out only under the supervision of the Ecological Clerk of Works (ECoW);
- The weather forecast will be consulted prior to commencing concrete pours. No such works will be undertaken if inclement weather is forecast such that precipitation may make it difficult to maintain a dry working area.
- There will be no spills of concrete, cement, grout or similar materials hosed into surface water drains. Such spills shall be contained immediately and runoff prevented from entering the watercourse;
- Concrete waste and wash-down water will be contained and managed on site to prevent pollution of all surface watercourses ;
- On-site concrete batching and mixing activities will only be allowed at the identified construction compound areas;
- Washout from concrete lorries, with the exception of the chute, will not be permitted on site and will only take place at the construction compound (or other appropriate facility designated by the manufacturer);
- Chute washout will be carried out at designated locations only. These locations will be signposted. The Concrete Plant and all Delivery Drivers will be informed of their location with the order information and on arrival to site; and
- Chute washout locations will be provided with an appropriate designated, contained impermeable area and treatment facilities including adequately sized settlement tanks. The clear water from the settlement tanks shall be pH corrected prior to discharge (which shall be by means of one of the construction stage settlement facilities) or alternatively disposed of as waste in accordance with the Contractor's Waste Management Plan.

10.5.2 Flooding

The Contractor will provide method statements for weather and tide/storm surge forecasting and continuous monitoring of water levels in the River Suir and Waterford Harbour. The Contractor will also provide method statements for the removal of site materials, fuels, tools, vehicles and persons from flood zones in order to minimise the risk to persons working on the site as well as potential input of sediment or construction materials into the river during flood events.

10.5.3 Operational Phase Mitigation

There are no mitigation measures proposed for the operational phase of the proposed development.

10.6 Residual Impacts

The residual hydrological impacts associated with the Flood Defences West following the implementation of the mitigation measures outlined in section 10.5, are outlined below.

10.6.1 Construction phase

Water Quality

Following the implementation of the measures outlined in the Environmental Operation Plan in Appendix 4.1 of this EIAR, there will be a *negative, slight, temporary* residual impact on water quality during the construction of the Flood Defences West.

Flood Risk

Mitigation in place during the construction phase will limit flood risk and reduce the potential for pollution events. With the inclusion of mitigation during the construction phase, the proposed flood defences scheme will have a net *significant positive* impact.

10.7 Difficulties Encountered

There were no difficulties associated with this assessment.

10.8 References

EPA (2017a). Environmental Protection Agency Envision WFD Status

EPA (2017b) Environmental Protection Agency Envision Surface Water Quality

GSI (2017a). Geological Survey of Ireland Groundwater Data Viewer

GSI (2017b). Geological Survey of Ireland (GSI) – Bedrock Geology;
Teagasc – Subsoil Map;

OPW (2010). Irish Coastal Strategy Study Phase 2 – South East Coast – Work Packages 2, 3 & 4A – Technical Report

Appendix 10.1
Flood Defences West Site-Specific Flood Risk Assessment

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WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT

FLOOD DEFENCES WEST
Site-Specific Flood Risk Assessment | October 2021

WPIP-ROD-ENV-S1_AE-RP-CD-30001_[S4-P02]

ROD
ROUGHAN & O'DONOVAN

Waterford City Public Infrastructure Project

Flood Defences West

Site-Specific Flood Risk Assessment

TABLE OF CONTENTS

1. INTRODUCTION

As part of the preliminary design process, Roughan & O'Donovan Consulting Engineers has carried out a Flood Risk Assessment for the Waterford Flood Defences West located on the periphery of Waterford City. This report has been prepared to assess the flood risk to the subject site and adjacent lands as a result of the proposed development.

1.1 Description of Study Area

The proposed development is located on the north quays of Waterford City and is bound to the north by the Iarnród Éireann railway corridor serviced by the Plunkett Station, the Waterford railway station. The Plunkett Station is bounded to the north by a steep rock slope which is subject to rock stabilisation works as part of the overall Waterford City Public Infrastructure Project. The proposed flood defences are bounded to the south by the River Suir. The River Suir rises in South Tipperary, flowing south east for 185km before discharging into the Atlantic Ocean at Waterford Harbour. The Suir Catchment is approximately 3,600km^2. Waterford City is on lower reaches of the Suir which exhibits a tidal influence at this point due to its proximity to the sea. The R448 Dual Carriageway is located further north of the proposed development and the railway corridor (see Figure 1.1 below).

The land profile typically falls towards the River Suir, and the lands south of the railway line form a gently inclined floodplain.

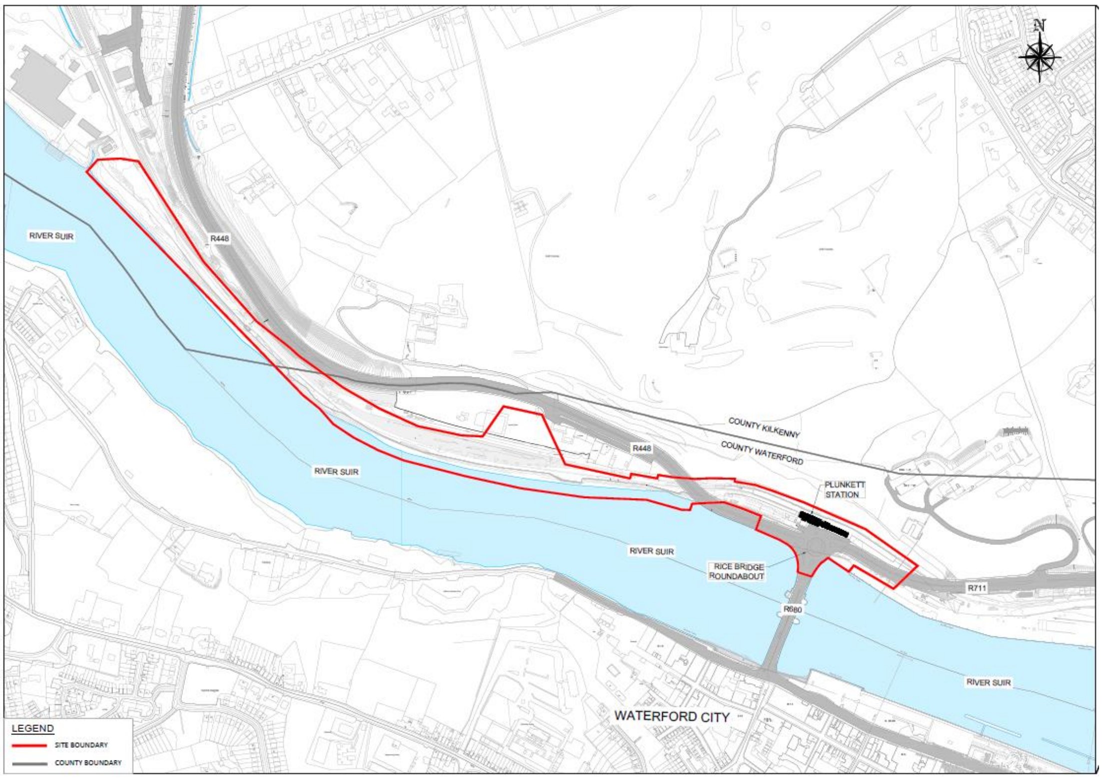


Figure 1.1 Flood Defences West Proposed Development

1.3 Description of Proposed Development

The proposed development aims to develop flood defence measures for the protection of critical infrastructure including the existing Plunkett Station, the railway line east and west of Plunkett Station and the future SDZ Transportation Hub which will provide a connection to the North Quays SDZ site via the railway line. The proposed top-of-wall level for the flood protection measures is 4.30m OD (metres above Ordnance Datum Malin). The following allowances are integrated into the proposed height of the flood defence walls:

- 0.5% annual exceedance probability combined tidal-fluvial event (+3.45m OD);
- An additional 0.55m to allow for climate change and isostatic tilt; and,
- 0.30m freeboard to the wall, including local wave wake effects.

1.3.1 Proposed Above Ground Flood Protection Measures

1.3.1.1 Remedial Works to the Existing Quay Wall

Between Ch.285 and Ch.360, the existing quay wall located in front of the car park (immediately to the west of the existing Plunkett Station) stretching c. 75m to the west under the R448 overbridge will be raised to add between 0.6m and 1.2m in height in order to attain the required height of +4.3 mOD.

Between Ch.285 and Ch.300, the works will only involve the construction of a reinforced concrete wall add-on, as the existing quay wall is reinforced concrete, and no significant defects were found in this segment of the wall during inspections. This is envisaged to be done as cast in-situ reinforced concrete, anchored into the existing wall below through post-installed chemical anchors.

A similar solution will be applied to the existing quay wall between Ch.300 and Ch.360. The wall add-on will be complemented, by an impermeable trench (possibly constructed by fill replacement, fill improvement with cement or low-pressure grouting techniques). The impermeable trench will be constructed behind the existing quay wall to prevent the seepage through the deteriorating existing quay wall that is in poor condition at this segment of the wall.

1.3.1.2 Flood Defences at Rice Roundabout

The ground levels at the Rice Bridge roundabout and the entrance to Plunkett Station (between chainages Ch.0.40 and Ch.210) are lower than the design flood level of 4.0mOD. A system of overground flood protection measures is proposed for the Rice Bridge Roundabout and along the three roundabout arms; Rice Bridge (R680), Terminus St. (R448) and Dock Rd. (R711).

The overground flood defence measures will comprise of approximately 170m of glass flood barriers, 15m of demountable flood barriers, sealing of the roundabout and approach structure roadway movement joints, and the provision of flap valves on the existing road drainage gullies.

The glass barriers will be located on the river side of the road edge vehicular parapets and will be supported off the existing concrete parapet edge beams.

1.3.2 Proposed Groundwater Flood Protection Measures

1.3.2.1 Impermeable Trench

In front of the existing Plunkett Station building and adjacent to the parking areas, starting from chainage Ch.0.0 and going westwards to approximately Ch.365, the ground conditions are such that the risk of underground seepage during flood events are expected to be comparatively lower than within the rest of the proposed development area. It is envisaged that the potential risk from groundwater flooding is reduced due to this section being dominated by shallow bedrock and an abundance of built structures that pose obstructions to water flow, such as the historical quay walls and new boundary walls. However, with climate change and the risk of rising tide levels there is a risk of increased groundwater flooding at the low points in the railway line in front of Plunkett Station in the future. To prevent groundwater seepage at this location, it is proposed to construct an impermeable shallow trench (approximately 0.35m wide and up to 3m deep trench filled with lean mix concrete); blocking of disused drainage pipes; and retrofitting the other drainage pipes with non-return valves.

It is noted that groundwater monitoring is currently ongoing as a part of the risk-based approach for this section, and it is possible that parts of these underground flood protection measures may be omitted during detailed design or may be implemented on a phased basis with ongoing monitoring of groundwater levels in the interim.

The impermeable trench's depth, width and required permeability have been designed on the basis of the local ground and groundwater model, and were determined using long-term monitoring and seepage design in accordance with IS EN 1997-1:2005 Eurocode 7: Geotechnical design General rules (Including Irish National Annex).

1.3.2.2 Underground Isolation Structure

The western end of the flood defences at Ch.1090 is set at a natural high point of the terrain and the rail track. The ground at this point is still slightly below the design flood level of +4.30mOD so an underground transverse isolation structure will be constructed in order to prevent both underground and overground flooding parallel to the rail line, i.e., it will create a cut-off return to complete the flood defences and protect from the floodwaters coming in from west to east along the rail lines. The underground isolation structure across and under the rail-line indicated at Ch.1090, will be approximately 20m in length. The underground isolation structure will consist of a sheet pile wall fully embedded in the ground, to a depth of approximately 6m below ground level. Where the sheet pile footprint is directly below rail tracks, a segment of the rail tracks will be temporarily removed to enable the piling and then reinstated back. The typical width of sheet pile profile is 450mm. The sheet pile wall proposed for the underground transverse isolation structure cannot protrude above ground at this location as its positioned directly below the existing rail tracks and would impede on the operation of the rail line. As such the sheet piles here will include a concrete capping beam finished to existing ground level. The concrete capping beam will facilitate the installation of temporary overground flood barriers (e.g. water filled inflatable flood barriers) should these be required to be implemented during a flood event. The use of demountable barriers at this location is proposed to address the long-term residual risk of flooding (when the impact of climate change on the rising tide level begins to come into effect). The use of overground flood barriers will form part of a long-term strategy to address the flood risk which will include monitoring and operation and emergency planning to be put in place. At present there is no record of flooding at this location, and the ground levels are above the current 0.5% AEP flood levels. In the shorter term (20-40 years) it is unlikely that overground flood barriers will be required to be deployed at this location. Continuing flood defences further to the west of this point would require extending them further, to a minimum distance of 1km until the next natural topographical flood cut off, hence the selection of Ch.1090 for the westernmost end of the flood defences.

1.3.3 Proposed Above and Below Ground Flood Protection Measures

1.3.3.1 Sheet - Piled Flood Defence Wall – Riverside

Between Ch.360 and Ch.900, construction of approximately 540m of new flood defence wall within the foreshore of the River Suir will be required (in-river sheet piles). This section of the driven sheet pile wall will be constructed using a piling rig on a spud-can barge situated in-stream for the duration of works.

The sheet pile wall will be constructed approximately 1m in front of the existing quay wall within the River Suir mudflats and the gap will be backfilled with clean imported granular (Class 1 or 6) earthworks fill material.

1.3.3.2 Sheet-Piled Flood Defence Wall – Landside

Between Ch.900 and Ch.1090, the works will involve the construction of a sheet piled flood defence wall on land, 1m behind the existing quay wall, but in front of the rail tracks and will meet the IÉ clearance requirements. The landside sheet piles will be installed using a piling rig. The permanent works will not encroach into the foreshore of the River Suir. The sheet piles will project above the existing ground level by between 0.7m and 2.1m in order to attain the design (top-of-wall) level of +4.3 mOD.

1.3.4 Drainage

The Flood Defence System stated above will mitigate against combination fluvial/tidal flooding. will raise the level of the quay wall and will cut off the existing flow path of over the edge surface water drainage and the existing groundwater flows.

Therefore, additional drainage pipework such as filter drains will be provided and will run linearly behind the proposed flood protection measures to accommodate the surface water and the cut-off groundwater flows.

As part of the proposed development, no significant increase in impermeable areas or changes to the overall catchment is proposed. The upgrade of the drainage networks may facilitate faster run-off of surface water from the site, however the outfall peak flows will not be increased significantly post construction.

In the vicinity of Plunkett Station from Ch.0.0 to Ch.350, a new drainage network will be provided to collect flows from the trackside drainage and also from the low point at Plunkett Station at +2.15m OD. This will reduce the risk of pluvial flooding at this location.

1.3.4.1 Outfalls to River Suir

The proposed outfalls to the River Suir at Ch.550 and Ch.900 will consist of an outfall pipe fitted flush with the proposed sheet pile wall and fitted with a flap valve or other non-return valve. Outfall levels will be above the existing mud flat levels.

At new surface water outfall locations which collect surface water run-off from the railway area, the surface water run-off shall pass through a Class 1 by-pass separator prior to discharge to the River Suir.

1.3.4.2 Outfall Structures to River Suir

A proposed new outfall structure to the River Suir will be provided at approx. Ch.390 to discharge surface water run-off from the Plunkett Station area. This new surface water outfall structure will extend between 4m and 6m into the River Suir.

At the new surface water outfall location (Ch.390) which collects surface water run-off from the railway area, the surface water run-off shall pass through a Class 1 by-pass separator prior to discharge to the River Suir.

There are 2 no. existing outfall pipes which extend past the existing quay wall into the riverbed i.e., a 750mm diameter pipe at approx. Ch.470, and a 600mm diameter pipe at approx. Ch.490. As part of the proposed works, the existing sections of these pipes which are in the riverbed will be removed and replaced in order to facilitate the construction of the proposed sheet pile wall. The new section of pipe will penetrate the new sheet pile wall and extend into the riverbed.

All three outfall structures will be provided with a headwall structure at the outfall and a flap valve or similar non-return valve at the outlet. The sections of pipe located in the river bank will be provided with a piled foundation which will be further assessed at detailed design based on localised geotechnical information. At each outfall, a pre-cast concrete wing wall will be placed in the riverbank and a stone mattress will be placed in the riverbed to prevent erosion. The stone mattress will require minor excavation works to a depth of approximately 500mm into the riverbed and will occupy an area of approximately 1.5m by 3m.The proposed new outfall structures to the River Suir will consist of a pre-cast concrete wing wall placed along the riverbank and a stone mattress which will be placed in the riverbed to prevent erosion. The existing outfall structures to be upgraded consist of a 600mm and an 900mm diameter pipe within the riverbank. The proposed new outfall will consist of a 750mm diameter pipe within the riverbank. At each outfall, a stone mattress will be provided which will require minor excavation works to a depth of approximately 500mm into the riverbed and will occupy an area of approximately 1.5m by 3m.

1.3.4.3 Surface Water Pumping Station

The 2 No. Surface Water Pumping Station Catchment area consists of surface water flows from trackside drainage.

The proposed underground surface water pumping stations at approx. Ch.380 and Ch.550, which in the event of high tide where gravity flows are not possible, will pump the flow to the River Suir via rising mains out-falling through the sheet pile wall.

The pumping station will be designed to cater for:

- Design Flood level of 4.0mOD;
- Surface water network flows for the 1 in 30 year return period, critical storm duration.

The design of the pumping stations shall be co-ordinated with IÉ to meet their requirements in relation to maintenance and access, while located close to an operational railway line.

The location of the proposed measures are presented on drawings in Appendix B.

2. FLOOD RISK

2.1 Introduction

This report has been prepared in accordance with 'The Planning System and Flood Risk Management Guidelines for Planning Authorities' herein referred to as 'The Guidelines' as published by the Office of Public Works (OPW) and Department of Environment, Heritage and Local Government (DoHLG) in 2009.

2.2 Identification of Flood Risk

Flood risk is a combination of the likelihood of a flood event occurring and the potential consequences arising from that flood event and is then normally expressed in terms of the following relationship:

Flood risk = Likelihood of flooding x Consequences of flooding.

To fully assess flood risk an understanding of where the water comes from (i.e. the source), how and where it flows (i.e. the pathways) and the people and assets affected by it (i.e. the receptors) is required. Figure 2.1 below shows a source-pathway-receptor model reproduced from 'The Guidelines' (DEHLG-OPW, 2009).

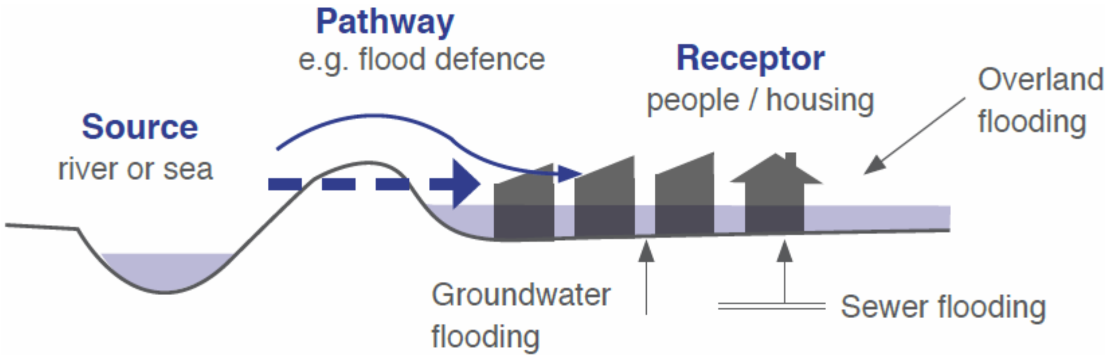


Figure 2.1 Sources, Pathways and Receptors of Flooding

The principal sources of flooding generally are rainfall or higher than normal sea levels. The principal pathways are rivers, drains, sewers, overland flow and river and coastal floodplains. The receptors can include people, their property and the environment. All three elements as well as the vulnerability and exposure of receptors must be examined to determine the potential consequences.

The Guidelines set out a staged approach to the assessment of flood risk with each stage carried out only as needed. The stages are listed below:

Stage I Flood Risk Identification – to identify whether there may be any flooding or surface water management issues.

Stage II Initial Flood Risk Assessment – to confirm sources of flooding that may affect an area or proposed development, to appraise the adequacy of existing information and to scope the extent of the risk of flooding which may involve preparing indicative flood zone maps.

Stage III Detailed Flood Risk Assessment – to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development or land to be zoned, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.

2.3 Likelihood of Flooding

The Guidelines define the likelihood of flooding as the percentage probability of a flood of a given magnitude or severity occurring or being exceeded in any given year. It is generally expressed as a return period or annual exceedance probability (AEP). A 1% AEP flood indicates a flood event that will be equalled or exceeded on average once every hundred years and has a return period of 1 in 100 years. Annual Exceedance probability is the inverse of return period as shown Table 2.1 below.

Table 2.1: Correlation Between Return Period and AEP

Return Period (years)	Annual Exceedance Probability (%)
1	100
10	10
50	2
100	1
200	0.5
1000	0.1

2.4 Definition of Flood Zones

Flood zones are geographical areas within which the likelihood of flooding is in a particular range. These are split into three categories in The Guidelines:

Flood Zone A

Flood Zone A where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal/tidal flooding).

Flood Zone B

Flood Zone B where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 or 0.5% or 1 in 200 for coastal/tidal flooding).

Flood Zone C

Flood Zone C where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal/tidal flooding. Flood Zone C covers all plan areas which are not in zones A or B.

It is important to note that when determining flood zones the presence of flood protection structures should be ignored. This is because areas protected by flood defences still carry a residual risk from overtopping or breach of defences and the fact that there is no guarantee that the defences will be maintained in perpetuity.

2.5 Sequential Approach & Justification Test

The Guidelines outline the sequential approach that is to be applied to all levels of the planning process. This approach should also be used in the design and layout of a development and the broad philosophy is shown in Figure 2.2 below. In general, development in areas with a high risk of flooding should be avoided as per the sequential approach. However, this is not always possible as many town and city centres are within flood zones and are targeted for development.

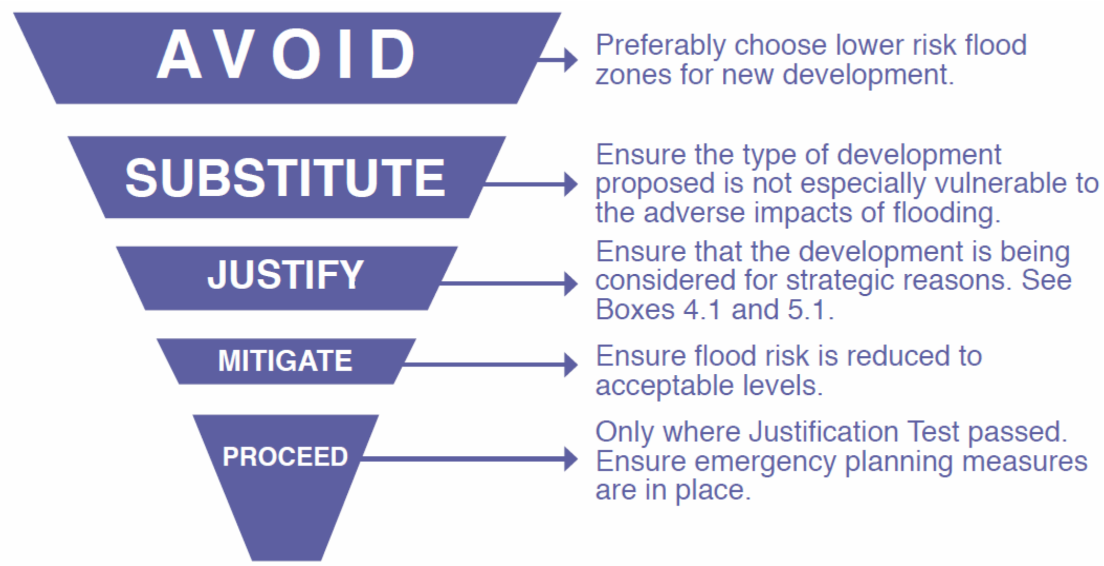


Figure 2.2 Sequential Approach (Source: The Planning System and Flood Risk Management)

The Justification Test has been designed to rigorously assess the appropriateness, or otherwise, of developments that are being considered in areas of moderate or high flood risk. The test comprises the following two processes.

The first is the Plan-making Justification Test and is used at the plan preparation and adoption stage where it is intended to zone or otherwise designate land which is at moderate or high risk of flooding.

The second is the Development Management Justification Test and is used at the planning application stage where it is intended to develop land at moderate or high risk of flooding for uses or development vulnerable to flooding that would generally be inappropriate for that land.

Table 2.2 Matrix of Vulnerability Versus Flood Zone to Illustrate Appropriate Development that is Required to Meet the Justification Test (Source: The Planning System and Flood Risk Management)

	Flood Zone A	Flood Zone B	Flood Zone C
Highly vulnerable development (including essential infrastructure)	Justification Test	Justification Test	Appropriate
Less vulnerable development	Justification Test	Appropriate	Appropriate
Water-compatible development	Appropriate	Appropriate	Appropriate

The proposed development is considered as a water compatible development as per the OPW Guidelines and as such is appropriate in all flood zones.

3. STAGE 1: FLOOD RISK IDENTIFICATION

3.1 General

This Stage 1 Flood Risk Identification includes a review of the existing information and the identification of any flooding or surface water management issues in the study area that may warrant further investigation.

3.2 Information Sources Consulted

The following information sources were consulted as part of the Stage 1 Flood Risk Identification:

Table 3.1 Information Sources Consulted

Source	Data Gathered
OPW Preliminary Flood Risk Assessment (PFRA) maps	Fluvial, Pluvial, Coastal and Groundwater flooding examined. Sourced at cfram.ie and myplan.ie
Catchment Flood Risk Assessment and Management Study (CFRAM)	Suir Fluvial & Tidal Flood Extent Mapping. Sourced at www.floodinfo.ie
Irish Coastal Protection Strategy Study	OPW Coastal flood Maps Sourced at www.floodinfo.ie
OPW National Flood Hazard Mapping	Recorded flood events. Sourced at www.floodmaps.ie
Ground Investigations	IGSL Ltd. undertook geotechnical investigations during 2019-2020.
Geological Survey of Ireland (GSI) Maps	GSI Teagasc subsoils map consulted to identify alluvial sediments
Historical Maps	OSI 25" mapping assessed. Sourced at http://map.geohive.ie/mapviewer.html
Irish Rail Technical Note	Technical Note prepared by Irish Rail staff following flood event on the 20th October 2020
News Reports	News reports published in newspapers or digital news websites.

3.3 Primary Sources of Baseline Data

(i) Preliminary Flood Risk Assessment

The PFRA is a national screening exercise, based on available and readily-derivable information, to identify areas where there may be a significant risk associated with flooding (referred to as Areas for Further Assessment, or AFA's). As part of the PFRA study, maps of the country were produced showing the indicative fluvial, coastal, pluvial and groundwater flood extents.

The PFRA map at theFlood Defences' West location indicates that the site is located within fluvial flood 1% AEP extents and within coastal flood 0.5% AEP extents. The PFRA mapping does not indicate any pluvial or groundwater flooding within or in the vicinity of the site.

The PFRA Maps for the area are reproduced in Appendix C/1-C/4.

(ii) Catchment Flood Risk Assessment and Management Study

The plan area is covered within the Suir CFRAM study areas. The CFRAM programme led by the OPW, provides a detailed assessment of flooding in areas identified as AFA's during the PFRA study. Catchment wide Flood Risk Management Plans were also developed as part of the programme.

The published Final CFRAM (02/08/2016) mapping indicates that the Flood Defences West Site has the potential to flood in the 1% Fluvial AEP flood event. The CFRAM mapping does not indicate any pluvial or groundwater flooding within or in the vicinity of the site.

The published CFRAM flood maps are reproduced in Appendix C/5.

(iii) Irish Coastal Protection Strategy Study

The Irish Coastal Protection Strategy Study (ICPSS) Phase 3, undertaken by the OPW, covers coastal flooding throughout Ireland. The aims of the ICPSS were to establish extreme coastal flood extents, produce coastal flood extent and flood depth maps and assess and quantify the hazard and potential risk associated with coastal erosion.

The ICPSS flood maps indicate that sections of the Flood Defences West Site are within the 0.5% AEP coastal flood extent.

The published ICPSS flood maps are reproduced in Appendix C/6.

(iv) OPW National Flood Hazard Mapping

The OPW National Flood Hazard Mapping Web Site (www.floodmaps.ie) was examined to identify any recorded flood events within the vicinity of the site. No Flood Event has been recorded at the Flood Defences West Site.

The OPW Flood Hazard Mapping is reproduced in Appendix C/7.

(v) Ground Investigations

Ground Investigations were undertaken by IGSL Ltd. during 2019-2020. The boreholes in the vicinity of Plunkett Station have indicated that groundwater levels in several boreholes respond rapidly to tidal levels, particularly boreholes that are closest to the riverbank and closest to the Rice Bridge northern roundabout.

(vi) Secondary Sources of Baseline data

The following sources were also examined to identify areas that may be liable to flooding:

Table 3.2 Secondary Sources of Baseline Data

Source	Data Gathered
GSI Maps	GSI Teagasc subsoils map shows the Flood Defences West Site is mainly underlain by made ground. In the most westerly section of the site there is evidence of Alluvium. No evidence of Karst features has been identified within the vicinity of the site. Refer to Appendix C/8 for GSI maps.
Historical Maps	No areas of the site have been identified as liable to flooding. Refer to Appendix C/9 for Historical Maps.
Irish Rail Technical Note	Irish Rail staff documented recent flooding on the 20/10/2020. This is summarised as follows: 1. Flooding occurred on Tuesday 20th October 2020 at Plunkett Station requiring the station to be closed. There had been 20.6mm of rainfall in the previous 24hrs and a high tide of 2.78mOD on the day of the flooding. Unusual local wind conditions emanating from the south-east on the days preceding the flood event potentially contributed to an elevated sea state. Irish Rail site staff indicate that the sea wall was over topped immediately west of Plunket station in the vicinity of a premises known as "The Paving Yard". 2. Flooding of the northern and southern rail line at Plunket station. Standing water is seen for the full length between the two road bridges over the rail line. Irish Rail staff estimate that the "Ground Level at Rail Line approx. 2.1m OD. Flood water level approx. 2.7mOD. Platform Level approx. 3.2m OD". Flood waters appear deeper along the northern line adjacent the cliff face. Water levels appear to be approximately at top of rail level on the southern line. It should be noted that following the 2013 landslide event at Plunkett Station upgrade works on the southern line were undertaken which increased track and ballast level by approximately 300mm. Records of previous flood events such as the 2012 incident indicate similar flooding at the station though at much greater depth (to platform level). 3. Flooding inside the existing sea wall immediately west of Plunket station. Water can been seen both ponding on the inside of the sea wall and draining from the flooded lands through drainage outfalls and cracks in the existing sea wall. The ponding water seems to extend no further along the sea wall than the western end of platform 5.
News Reports	An article published on www.theirishindependant.ie on the 11th March 2008 entitled "Escaping in the eye of the storm" describes that rail services at the existing Plunkett train station were affected sue to flooding resulting in bus transfers to be put in place. An article published on www.thejournal.ie on the 17th October 2012 entitled "Waterford train station is flooded… very flooded" describes how Plunkett train station was flooded following a period of heavy rain. An article published on www.theirishindependant.ie on the 5th February 2014 highlights rail services being suspended in and out of Plunkett station due to flooding at the platform. Refer to Appendix C/10-C/13 for News Reports.

3.4 Conclusion of Stage 1 SFRA

In accordance with Stage 1 of the approach outlined in the Guidelines, the possible sources of flooding associated with this development have been identified. These are summarised in Table 3.3 (taken from Appendix A of the Guidelines).

Table 3.3 Possible Sources of Flooding Associated with the Flood Defences West Site

<table>
<tr><th>Source</th><th>Pathway</th><th>Receptor</th><th>Likelihood</th><th>Consequence</th><th>Risk</th></tr>
<tr><td>Tidal</td><td>Overland flow, out of bank</td><td>Proposed Flood Defences West site</td><td>High</td><td rowspan="4">Low
(Development is classified as water compatible development as per the Guidelines)</td><td>Low</td></tr>
<tr><td>Fluvial</td><td>Overland flow, out of bank</td><td>Proposed Flood Defences West site</td><td>High</td><td>Low</td></tr>
<tr><td>Surface Water / Pluvial</td><td>Overland flow, drains</td><td>Proposed Flood Defences West site</td><td>Medium</td><td>Low</td></tr>
<tr><td>Ground Water</td><td>Rising levels</td><td>Proposed Flood Defences West site</td><td>High due to tidal /fluvial interaction</td><td>Low</td></tr>
</table>

The information provided in this section identifies that the proposed development is within an area that is liable to flooding from coastal, fluvial and groundwater sources; therefore, a Stage 2 SFRA is required to be undertaken.

4. STAGE 2 – INITIAL FLOOD RISK ASSESSMENT

4.1 General

A Stage 2 SFRA (initial flood risk assessment) was undertaken to:

- Confirm the sources of flooding that may affect the subject site;
- Appraise the adequacy of existing information as identified by the Stage 1 FRA.

4.2 Sources of Flooding

Flooding from Fluvial & Sea Level Rises / Coastal Flooding

The proposed Flood Defences West site is in close proximity to the River Suir which discharges into the Atlantic Ocean at Waterford Harbour. The character of the site is influenced by its proximity to the tidal waterbody, as such, the most prevalent flood risk to the site is from extreme tidal inundation events or tidal events in combination with extreme fluvial events. Most of the site is indicated to be within flood zones A in OPW Suir CFRAM Study, OPW Preliminary flooding assessment and the Irish Coastal Protection Strategy study. The proposed development site is considered to require a stage 3 detailed flood risk assessment with respect to flooding derived from Fluvial and Tidal Flooding.

Surface Water Flooding

Surface water flooding occurs when the local drainage system cannot convey stormwater flows from extreme rainfall events. The rainwater does not drain away through the normal drainage pathways or infiltrate into the ground but instead ponds on or flows over the ground instead. Surface water flooding is unpredictable as it depends on a number of factors including ground levels, rainfall and the local drainage network. The drainage network for the proposed development on the site will incorporate best practice in drainage design for the purpose for managing surface water in terms of both flow and quality. There is no indication of previous surface water flooding on the Flood Defences West site. The proposed site is not considered to require a detailed flood risk assessment with respect to flooding derived from surface water flooding.

Groundwater Flooding

Ground water flooding is a result of upwelling in occurrences where the water table or confined aquifers rises above the ground surface. This tends to occur after long periods of sustained rainfall and/or very high tides. High volumes of rainfall and subsequent infiltration to ground will result in a rising of the water table. Groundwater flooding tends to occur in low-lying areas, where with additional groundwater flowing towards these areas, the water table can rise to the surface causing groundwater flooding. The sources consulted such as the CFRAM mapping and GSI records show no indication that the Flood Defences West site is subject to Groundwater derived flooding. However, ground investigations indicate high permeability in the subsoils. This in combination with extreme tidal flood events may lead to groundwater flooding within the subject site. The proposed development site area is considered to require a detailed flood risk assessment with respect to groundwater flooding.

Pluvial Flood Risk

Pluvial flooding results from heavy rainfall that exceeds ground infiltration capacity or more commonly in Ireland where the ground is already saturated from previous rainfall events. This causes ponding and flooding at localised depressions. Pluvial flooding is commonly a result of changes to the natural flow regime such as the implementation of hard surfacing and improper drainage design. Sources such as the CFRAM mapping and PFRA mapping show no indication that the Flood Defences West site is subject to pluvial derived flooding. Pluvial flooding will be considered in the design of drainage systems as part of planned developments.

4.3 Conclusion of Stage 2 SFRA

The information provided in this section identifies that there is high level of coastal/fluvial and groundwater flood risk arising on the Flood Defences West site. This will be assessed further in Stage 3 Flood Risk Assessment.

5. STAGE 3 DETAILED FLOOD RISK ASSESSMENT

5.1 Introduction

Stages 1 and 2 of the flood risk assessment for the proposed Flood Defences West Development have indicated that the subject site and adjacent lands are liable to flood in medium and high probability exceedance events from tidal/fluvial and groundwater sources. The hydraulic assessment of the proposed development is summarised below.

5.2 Coastal / Fluvial Flooding

A one-dimensional (1D) model has been prepared to ascertain the effects of extreme tidal and combination tidal/fluvial events. A 1D model was utilised as it was determined that the Suir Estuary is dominated by tidal flows in the longitudinal flow direction. The model was developed with surveyed topographic and channel cross-sections, OPW Cross-sections and GSI / Marine Institute Infomar Sea-bed survey of the Waterford Harbour Area, LiDAR data and a detailed hydrological assessment of the catchment.

The findings from the hydraulic model are that critical flooding and flood levels in the estuary and on the site are as a consequence of the tidal storm surge conditions. Fluvial flood flows at this location contribute very little to increasing the peak flood levels in the Suir. Flood levels are summarised in Table 5.1 below. The removal of the defended lands as a tidal inundation area will have a negligible effect on the flood depths and will not have any perceivable effects on adjacent lands. Climate change allowances as per the OPW Climate Change Sectoral Adaptation Plan (2015) are presented in Table 5.2 for the mid-range future scenario (MRFS) and the high end future scenario (HEFS).

In accordance with *OPW The Planning System and Flood Risk Management Guidelines for Planning Authorities (2009),* the OPW MRFS climate change allowance should be adopted as the minimum for all design flood levels.

Table 5.1 Flood levels derived Waterford North Quays SFRA

Return Period 1 in XX year	Existing Flood level (excl. climate change) (m OD)[Note 1]	MRFS Flood Level (m OD)[Note 2]
2	2.72	3.27
10	3.00	3.55
20	3.11	3.66
50	3.22	3.77
100	3.33	3.88
200	3.45	4.00
500	3.58	4.13
1000	3.69	4.24

Notes:

1. Flood Levels given above are taken from the hydraulic model based on a combined analysis of the tidal 1 in XX-year event / 1 in 2 year fluvial event at an upstream location at the confluence of the River Blackwater.
2. MRFS climate change allowance = (+0.55m which consists of +0.50m for climate change and +0.05m for isostatic tilt)

Table 5.2 Extract from Climate Change sectoral Adaptation Plan (2015)

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Peak Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500 mm	+ 1000 mm
Land Movement	- 0.5 mm / year[1]	- 0.5 mm / year[1]
Urbanisation	*No General Allowance – Review on Case-by-Case Basis*	*No General Allowance – Review on Case-by-Case Basis*
Forestation	- 1/6 Tp[2]	- 1/3 Tp[2] + 10% SPR[3]

The highest recorded water level at the Adelphi Quays gauging station is 3.02mOD (03/Feb/2014). This corresponds to a 1 in 10 year present day flood event.

OPW guidelines generally include for a freeboard of 0.3m for walls and 0.5m for bunds.

5.2.1 Waterford City Flood Alleviation Scheme

Waterford City has previously implemented a significant flood alleviation scheme on the south side of the River Suir. The works were constructed in three separate civil works contracts and on completion is protecting the city from flooding from the rivers for events up to the 0.5% annual exceedance probability (1 in 200 years) in tidal areas and up to the 1% annual exceedance probability (1 in 100 years) in non tidal areas. The design heights were increased from the modelled flood heights to accommodate the effects of climate change and uncertainty in flow estimation.
The flood defences are a maximum of 1.1 - 1.2m above ground levels to preserve river views. The design heights were increased from the modelled flood heights to accommodate the effects of climate change and uncertainty in flow estimation. A freeboard of 0.5m and 0.3m was implemented in tidal and non-tidal areas respectively. The design for Waterford South Quays flood defences features glass flood defences prominently. The implemented design height for the Waterford South Quays flood defence wall is 3.7mOD.

5.3 Groundwater Flooding

Along the line of the eastern periphery of the proposed flood defences in the vicinity of the Plunkett Station, the ground layers immediately below the surface typically comprise of permeable granular made ground fills which allows relatively large groundwater seepage to take place.

The following considers groundwater flooding in this area (Ch.370 to Ch.000) and potential future groundwater flooding associated with climate change and rising sea water levels.

5.3.1 Monitoring of Groundwater Levels at Plunkett Station

Boreholes were undertaken by IGSL in late 2019. Both cable percussion (CP) and rotary coring (RC) were undertaken at each borehole location shown in figure 5.1 below. Due to issues with site access, IGSL installed the required piezometer with datalogger in BH302 on 7th May 2020 to monitor ground water levels. Ground water level readings from the 7th May to 22nd December 2020 have been analysed as part of this assessment.

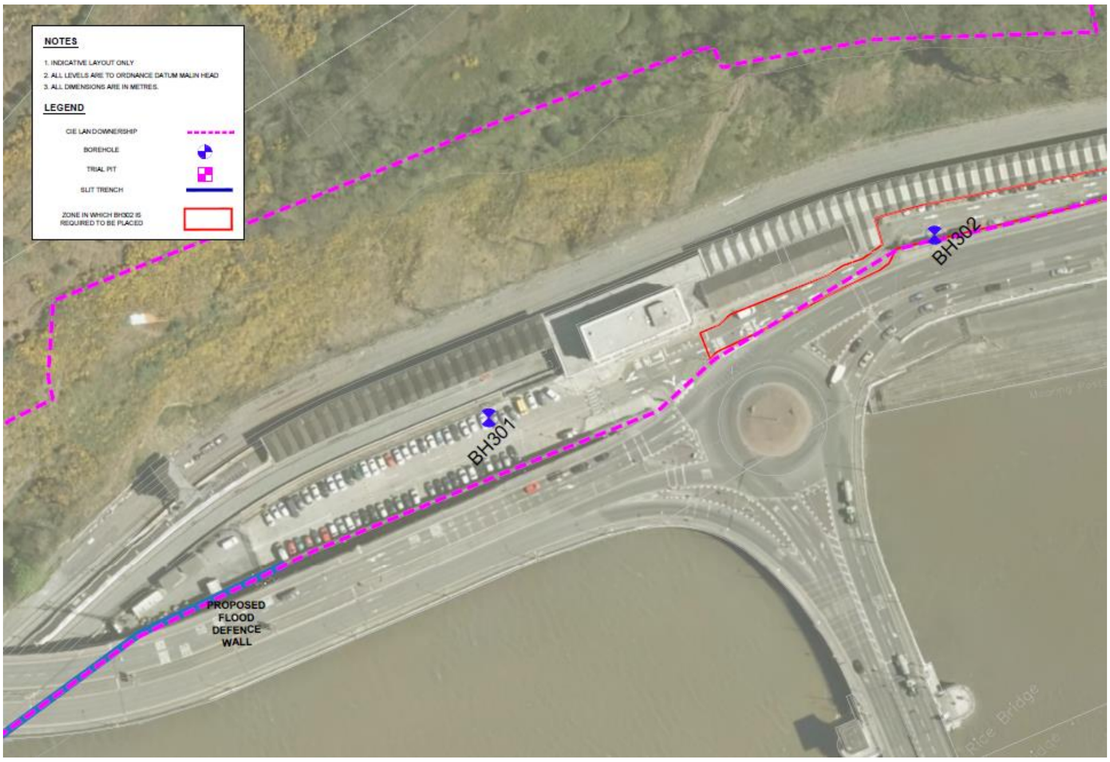


Figure 5.1 Borehole locations

The borehole records indicate bedrock very close to ground level, typically 1m to 3m below ground level (with potential local minima of 3m below ground level as suggested in some less detailed logs) with a relatively thin layer of granular overburden and made ground below existing pavement. These findings are positive from a flood protection perspective, as bedrock is typically seen as a low permeability medium, except in localised zones where it is very weathered.

The BH 302 piezometer (with datalogger) was installed with a response zone in the granular overburden material in order to track the change of groundwater levels in this material. A groundwater level observation graph was produced using the datalogger readings. This graph was superimposed onto a graph of the River Suir levels for the same period to investigate if there was a correlation between the dataset (Appendix D).

Based on the analysis of the available datasets it would appear that:

i. the tidal fluctuations in the River Suir during the normal conditions (high tide up to 2.0m OD) have a near-negligible impact on the groundwater levels in BH302, which seem stable at around +1.00m OD.

ii. Tidal maxima during high water (above 2.0m OD) induces the rise in BH302 to the level of approximately 0.9-1.0m below the tidal maxima. The maximum reading in BH302 also lags the tidal maximum for approximately 3 hours.

5.3.2 Record of Flood Event at Plunkett Station (20th October 2020)

During the flood event of 20th October 2020 when the tracks at Plunkett station were flooded by overtopping for the existing sea wall (high tide at +2.78m OD). There was significant flooding on the railway line (approx. 0.6m of standing water). The recorded groundwater level rose to +1.87m OD. BH302 is approximately 20m closer to River Suir than the railway tracks. It was observed during this flood event that there was evidence of groundwater ingress to the west of Plunkett station in the vicinity of the Road Over Bridge prior to the overtopping of the wall.

5.3.3 Risk of Groundwater Flooding

From the obtained data it would appear that there is a significant risk of ground water flooding at the following locations:

- Ch.370 to Ch.310 (i.e., large groundwater inflows through the overburden towards the rail infrastructure during flood events under present day conditions);
- Ch.310 to Ch.000 (i.e., some groundwater inflows through the overburden towards the rail infrastructure during flood events under present day conditions which is likely to increase with future climate change and rising tide levels);

5.4 Flood Defences West Proposed Standard of Protection

5.4.1 Design Flood Level

A Design Flood Level (200 year flood including Climate Change) of 4.30mOD has been calculated for the Flood Defences West based on:

- 0.5% annual exceedance probability combined tidal-fluvial event (3.45 m OD);
- An additional 0.55 m to allow for climate change and isostatic tilt; and,
- 0.30 m freeboard, including local wave wake effects.

The proposed flood defences will have a minimum top of wall level of 4.30mOD.

The combination 1000 year tide and 2 year fluvial flood level including climate change is 4.240mOD. The proposed Design Flood level of 4.30mOD is above the 1000 year flood including climate change level which is a requirement for “Highly Vulnerable developments” as per the OPW Guidelines 2009.
The proposed standard of protection will be achieved by undertaking works as described below. The location of the proposed measures (as described in Section 1 of this report) are presented on scheme drawings within Appendix B.

6. RESIDUAL FLOOD RISK

As discussed above, the Design Height for flood protection measures along the proposed Flood Defences West is 4.30mOD. Residual risk will be managed through the use flood resilient design throughout the development. The proposed development will be subject to a maintenance plan, the maintenance will be undertaken by the relevant competent authority. Due to the nature of the flooding (tidally dominated), extreme events will be forecasted multiple days in advance.

7. FLOOD RISK ASSESSMENT CONCLUSIONS

The Proposed Flood Defences West development has been assessed for existing and future sources of flood risk. The primary sources of flood risk identified for the site are from combination of tidal/fluvial events emanating from the River Suir.

A hydraulic assessment of the potential impact of the proposed development has been completed using best practice hydraulic modelling techniques. This has concluded that there will be an imperceptible effect on extreme flood levels upstream or downstream of the proposed development and will therefore not increase flood risk within the locality. The proposed flood defences shall defend to a minimum level of 4.30mOD. This will defend the Irish Rail lands in a combination 1 in 1000 year coastal + 1 in 2 year fluvial (+ climate change factor) extreme flood event.

The proposed development has been designed with regard to flood resilient construction measures and materials. The proposed development will be subject to a maintenance plan, the maintenance will be undertaken by the relevant competent authority. The proposed development will serve existing and future development within Waterford City and environs. The proposed project shall reinforce the transportation network, which will assist in achieving strategic planning objectives in the immediate vicinity and County Waterford as a whole.

The proposed development is considered to a water compatible development as per the OPW Guidelines. The proposed development is therefore appropriate for the associated flood risk as per the OPW Guidelines.

APPENDIX A

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Catchment: The area that is drained by a river or artificial drainage system.

Catchment Flood Risk Assessment and Management Studies (CFRAMS): A catchment-based study involving an assessment of the risk of flooding in a catchment and the development of a strategy for managing that risk in order to reduce adverse effects on people, property and the environment. CFRAMS precede the preparation of Flood Risk Management Plans (see entry for FRMP).

Climate change: Long-term variations in global temperature and weather patterns, which occur both naturally and as a result of human activity, primarily through greenhouse gas emissions.

Core of an urban settlement: The core area of a city, town or village which acts as a centre for a broad range of employment, retail, community, residential and transport functions.

Detailed flood risk assessment: A methodology to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of flood hazard and potential risk to an existing or proposed development, of its potential impact on flood elsewhere and of the effectiveness of any proposed measures.

Estuarial (or tidal) flooding: Flooding from an estuary, where water level may be influenced by both river flows and tidal conditions, with the latter usually being dominant.

Flooding (or inundation): Flooding is the overflowing of water onto land that is normally dry. It may be caused by overtopping or breach of banks or defences, inadequate or slow drainage of rainfall, underlying groundwater levels or blocked drains and sewers. It presents a risk only when people, human assets and ecosystems are present in the areas that flood.

Flood Relief Schemes (FRS): A scheme designed to reduce the risk of flooding at a specific location.

Flood Defence: A man-made structure (e.g. embankment, bund, sluice gate, reservoir or barrier) designed to prevent flooding of areas adjacent to the defence.

Flood Risk Assessment (FRA): FRA can be undertaken at any scale from the national down to the individual site and comprises 3 stages: Flood risk identification, initial flood risk assessment and detailed flood risk assessment.

Flood Risk Identification: A desk- based study to identify whether there may be any flooding or surface water management issues related to a plan area or proposed development site that may warrant further investigation.

Flood Hazard: The features of flooding which have harmful impacts on people, property or the environment (such as the depth of water, speed of flow, rate of onset, duration, water quality, etc.).

Floodplain: A flood plain is any low-lying area of land next to a river or stream, which is susceptible to partial or complete inundation by water during a flood event.

Flood Risk: An expression of the combination of the flood probability, or likelihood and the magnitude of the potential consequences of the flood event.

Flood Storage: The temporary storage of excess run-off, or river flow in ponds, basins, reservoirs or on the flood plain.

Flood Zones: A geographic area for which the probability of flooding from rivers, estuaries or the sea is within a particular range.

Fluvial flooding: Flooding from a river or other watercourse.

Groundwater flooding: Flooding caused by groundwater escaping from the ground when the water table rises to or above ground level.

Initial flood risk assessment: A qualitative or semi-quantitative study to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information, to provide a qualitative appraisal of the risk of flooding to development, including the scope of possible mitigation measures, and the potential impact of development on flooding elsewhere, and to determine the need for further detailed assessment.

Freeboard: Factor of safety applied for water surfaces. Defines the distance between normal water level and the top of a structure, such as a dam, that impounds or restrains water.

Justification Test: An assessment of whether a development proposal within an area at risk of flooding meets specific criteria for proper planning and sustainable development and demonstrates that it will not be subject to unacceptable risk nor increase flood risk elsewhere. The justification test should be applied only where development is within flood risk areas that would be defined as inappropriate under the screening test of the sequential risk-based approach adopted by this guidance.

Likelihood (probability) of flooding: A general concept relating to the chance of an event occurring. Likelihood is generally expressed as a probability or a frequency of a flood of a given magnitude or severity occurring or being exceeded in any given year. It is based on the average frequency estimated, measured or extrapolated from records over a large number of years and is usually expressed as the chance of a particular flood level being exceeded in any one year. For example, a 1-in-100 or 1% flood is that which would, on average, be expected to occur once in 100 years, though it could happen at any time.

Ordnance Datum (or OD) Malin: is a vertical datum used by an ordnance survey as the basis for deriving altitudes on maps. A spot height may be expressed as AOD for “above ordnance datum”. Usually mean sea level (MSL) is used for the datum. In the Republic of Ireland, OD for the Ordnance Survey of Ireland is Malin Ordnance Datum: the MSL at Portmoor Pier, Malin Head, County Donegal, between 1960 and 1969. Prior to 1970, Poolbeg Ordnance Datum was used: the low water of spring tide at Poolbeg lighthouse, Dublin, on 8 April 1837. Poolbeg OD was about 2.7 metres lower than Malin OD.

Management Train/Treatment Train: the sequence of drainage components that collect, convey, store and treat runoff as it drains through the site.

Mitigation: The term is used to describe an action that helps to lessen the impacts of a process or development on the receiving environment. It is used most often in association with measures that would seek to reduce negative impacts of a process or development.

Pathways: These provide the connection between a particular source (e.g. high river or tide level) and the receptor that may be harmed (e.g. property). In flood risk management, pathways are often ‘blocked’ by barriers, such as flood defence structures, or otherwise modified to reduce the incidence of flooding.

Pluvial flooding: Usually associated with convective summer thunderstorms or high intensity rainfall cells within longer duration events, pluvial flooding is a result of rainfall-generated overland flows which arise before run-off enters any watercourse or sewer. The intensity of rainfall can be such that the run-off totally overwhelms surface water and underground drainage systems.

Regional Planning Guidelines (RPG): These provide the regional context and priorities for applying national planning strategy to each NUTS III region and encourage greater co-ordination of planning policies at the city/county level. RPGs are an important part of the flood policy hierarchy as they can assist in co-ordinating flood risk management policies at the regional level.

Resilience: Sometimes known as “wet-proofing”, resilience relates to how a building is constructed in such a way that, although flood water may enter the building, its impact is minimised, structural integrity is maintained, and repair, drying and cleaning and subsequent reoccupation are facilitated.

Receptors: Things that may be harmed by flooding (e.g. people, houses, buildings or the environment).

Residual risk: The risk which remains after all risk avoidance, substitution and mitigation measures have been implemented, on the basis that such measures can only reduce risk, not eliminate it.

Sequential Approach: The sequential approach is a risk-based method to guide development away from areas that have been identified through a flood risk assessment as being at risk from flooding. Sequential approaches are already established and working effectively in the plan-making and development management processes.

Sustainable Drainage System (SuDS): Drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental impact.

Site-specific Flood Risk Assessment: An examination of the risks from all sources of flooding of the risks to and potentially arising from development on a specific site, including an examination of the effectiveness and impacts of any control or mitigation measures to be incorporated in that development.

Source: Refers to a source of hazard (e.g. the sea, heavy rainfall).

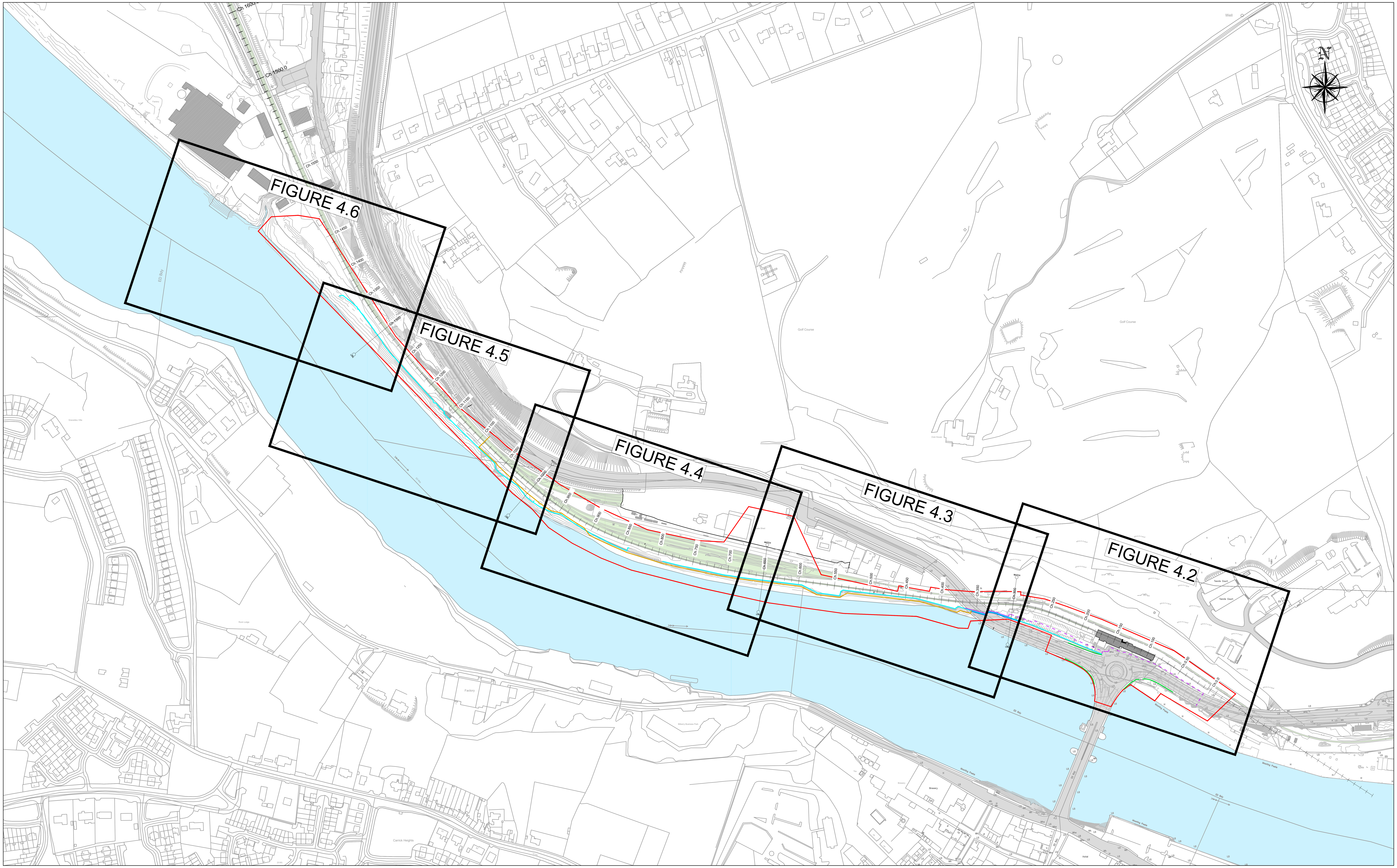
Strategic Flood Risk Assessment: The assessment of flood risk on a wide geographical area against which to assess development proposed in an area (Region, County, Town).

Vulnerability: The resilience of a particular group of people or types of property or habitats, ecosystems or species to flood risk, and their ability to respond to a hazardous condition and the damage or degree of impact they are likely to suffer in the event of a flood. For example, elderly people may be more likely to suffer injury, and be less able to evacuate, in the event of a rapid flood than younger people.

Source: *The definitions above are sourced from the DoEHLG Guidelines for Planning Authorities on ‘The Planning System and Flood Risk Management, 2009’ and Ciria 753 “the SuDS Manual”.*

APPENDIX B

SCHEME DRAWINGS



Project Ireland 2040 — Building Ireland's Future

Comhairle Cathrach & Contae Phort Láirge — Waterford City & County Council

NTA — Údarás Náisiúnta Iompair — National Transport Authority

Iarnród Éireann — Irish Rail

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

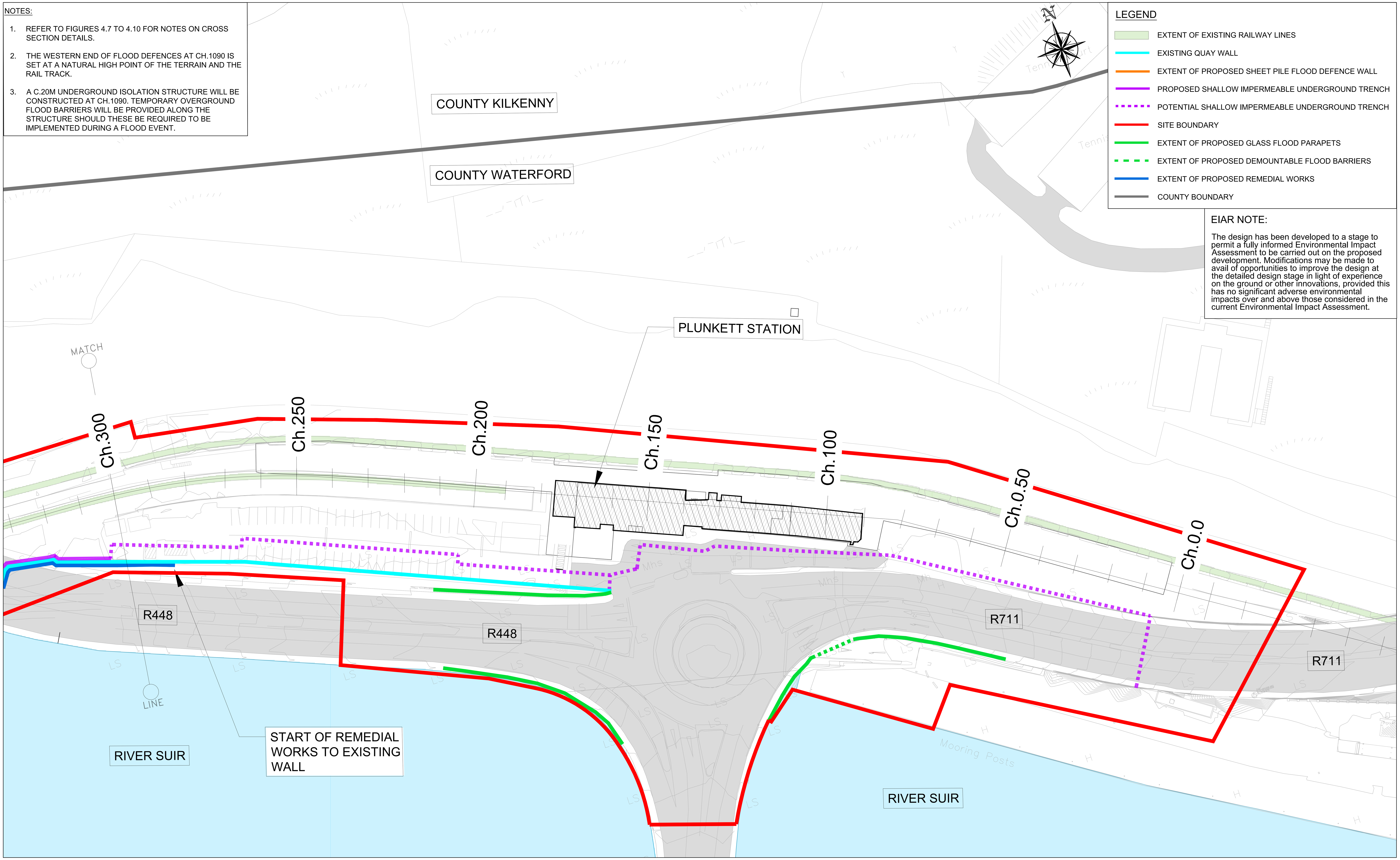
Drawing Title: Proposed Extents of Structural Works Sheet - Key Plan

Designed: YB	File:	Status: E.I.A.R.	
Drawn: IM	Job No: 18.141		
Checked: BC	Scale: 1:2500 (@ A3)	Drawing No: FIG 4.1	Rev: -
Approved: TD	Date: OCTOBER 2021		

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

NOTES:

1. REFER TO FIGURES 4.7 TO 4.10 FOR NOTES ON CROSS SECTION DETAILS.
2. THE WESTERN END OF FLOOD DEFENCES AT CH.1090 IS SET AT A NATURAL HIGH POINT OF THE TERRAIN AND THE RAIL TRACK.
3. A C.20M UNDERGROUND ISOLATION STRUCTURE WILL BE CONSTRUCTED AT CH.1090. TEMPORARY OVERGROUND FLOOD BARRIERS WILL BE PROVIDED ALONG THE STRUCTURE SHOULD THESE BE REQUIRED TO BE IMPLEMENTED DURING A FLOOD EVENT.



LEGEND

- EXTENT OF EXISTING RAILWAY LINES
- EXISTING QUAY WALL
- EXTENT OF PROPOSED SHEET PILE FLOOD DEFENCE WALL
- PROPOSED SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- POTENTIAL SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- SITE BOUNDARY
- EXTENT OF PROPOSED GLASS FLOOD PARAPETS
- EXTENT OF PROPOSED DEMOUNTABLE FLOOD BARRIERS
- EXTENT OF PROPOSED REMEDIAL WORKS
- COUNTY BOUNDARY

EIAR NOTE:

The design has been developed to a stage to permit a fully informed Environmental Impact Assessment to be carried out on the proposed development. Modifications may be made to avail of opportunities to improve the design at the detailed design stage in light of experience on the ground or other innovations, provided this has no significant adverse environmental impacts over and above those considered in the current Environmental Impact Assessment.

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Proposed Extents of Structural Work Sheet 1 of 5

Designed:	YB	File:		Status:	E.I.A.R.
Drawn:	IM	Job No:	18.141		
Checked:	BC	Scale:	1:500 (@ A3)	Drawing No:	FIG 4.2
Approved:	TD	Date:	OCTOBER 2021	Rev:	-

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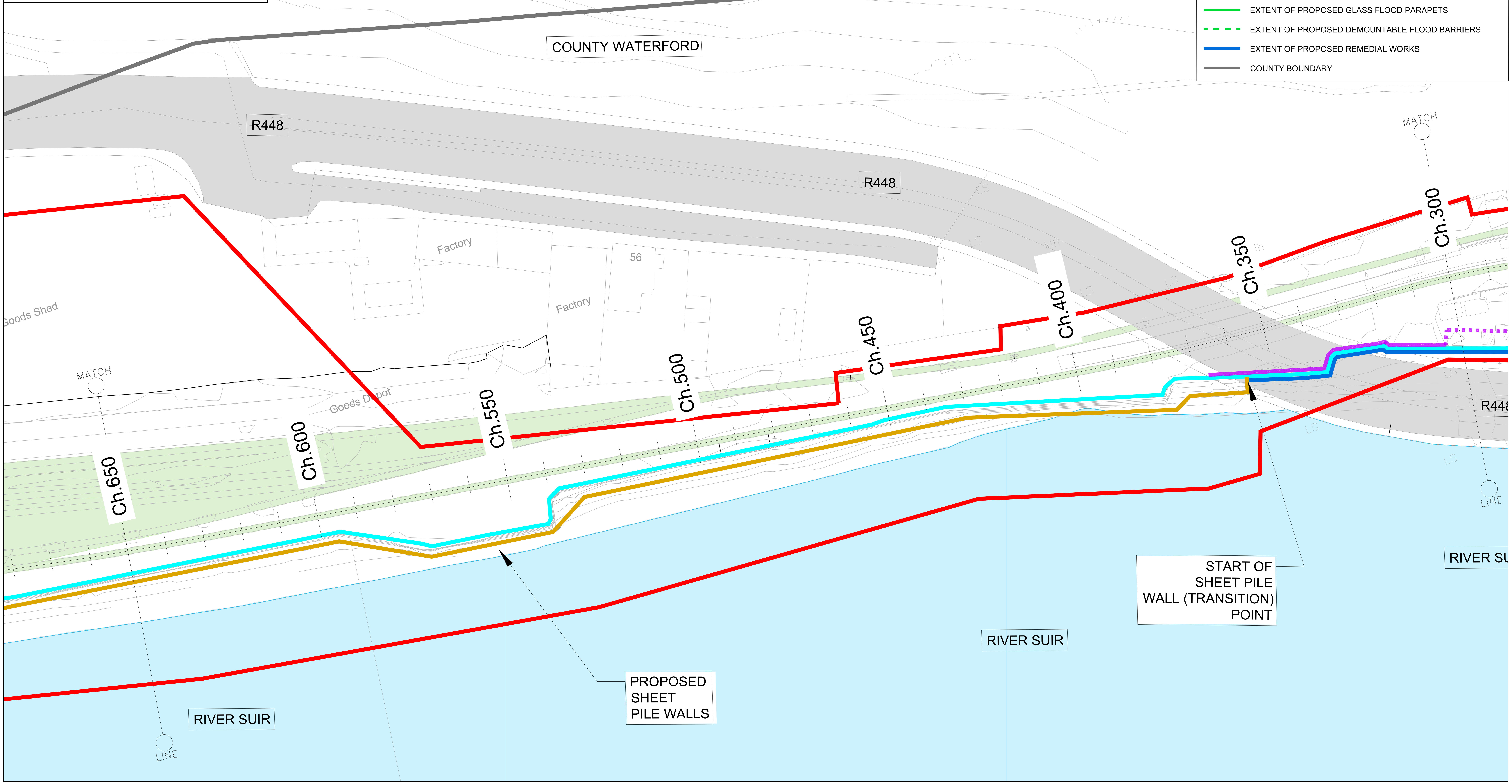

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ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Proposed Extents of Structural Works Sheet 2 of 5

Designed:	YB	File:		Status: E.I.A.R.	
Drawn:	IM	Job No:	18.141		
Checked:	BC	Scale:	1:500 (@ A3)	Drawing No: FIG 4.3	Rev: -
Approved:	TD	Date:	OCTOBER 2021		

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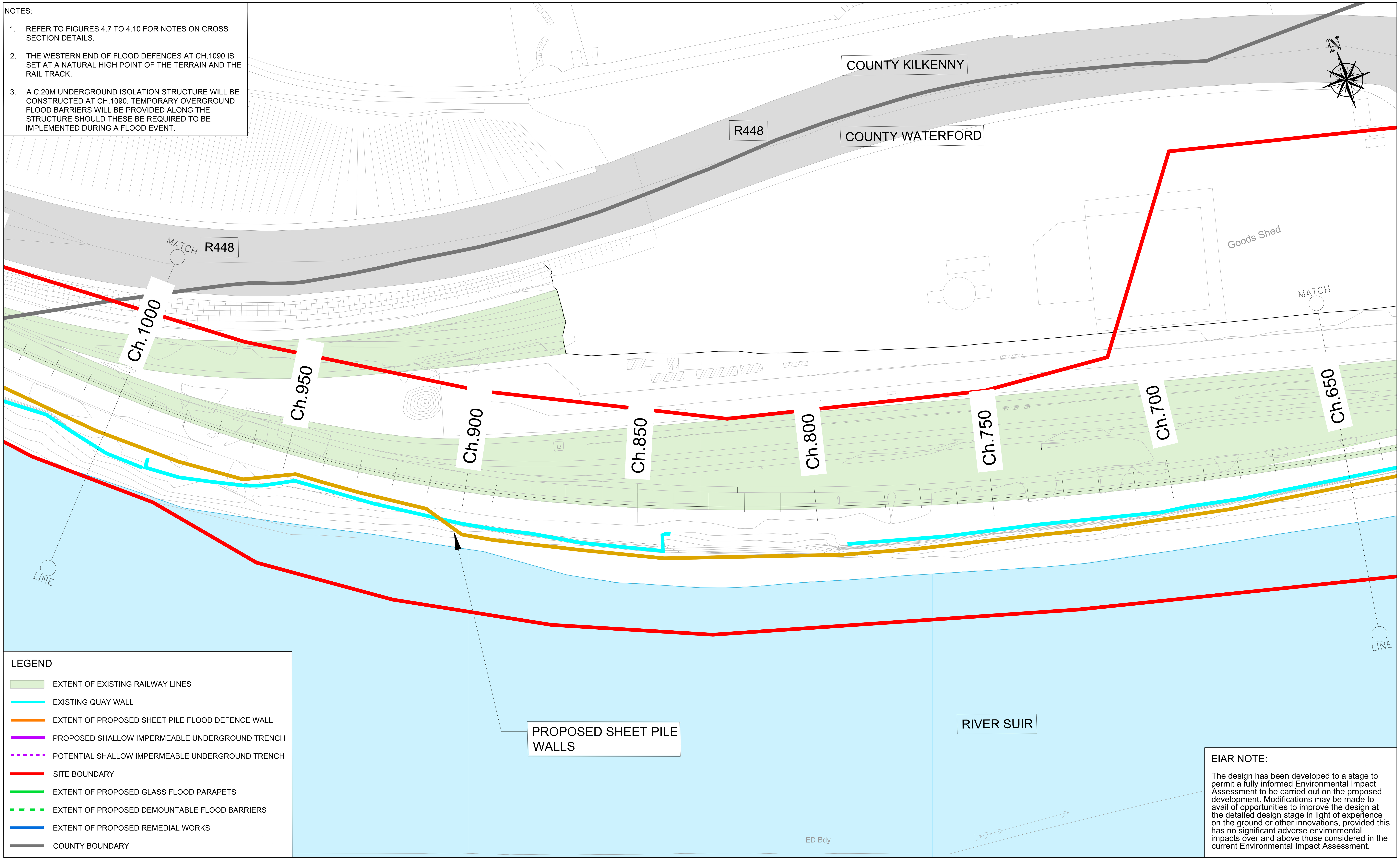

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Proposed Extents of Structural Works Sheet 3 of 5

Designed: YB	File:	Status: E.I.A.R.	
Drawn: IM	Job No: 18.141		
Checked: BC	Scale: 1:500 (@ A3)	Drawing No: FIG 4.4	Rev: -
Approved: TD	Date: OCTOBER 2021		

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

EIAR NOTE:

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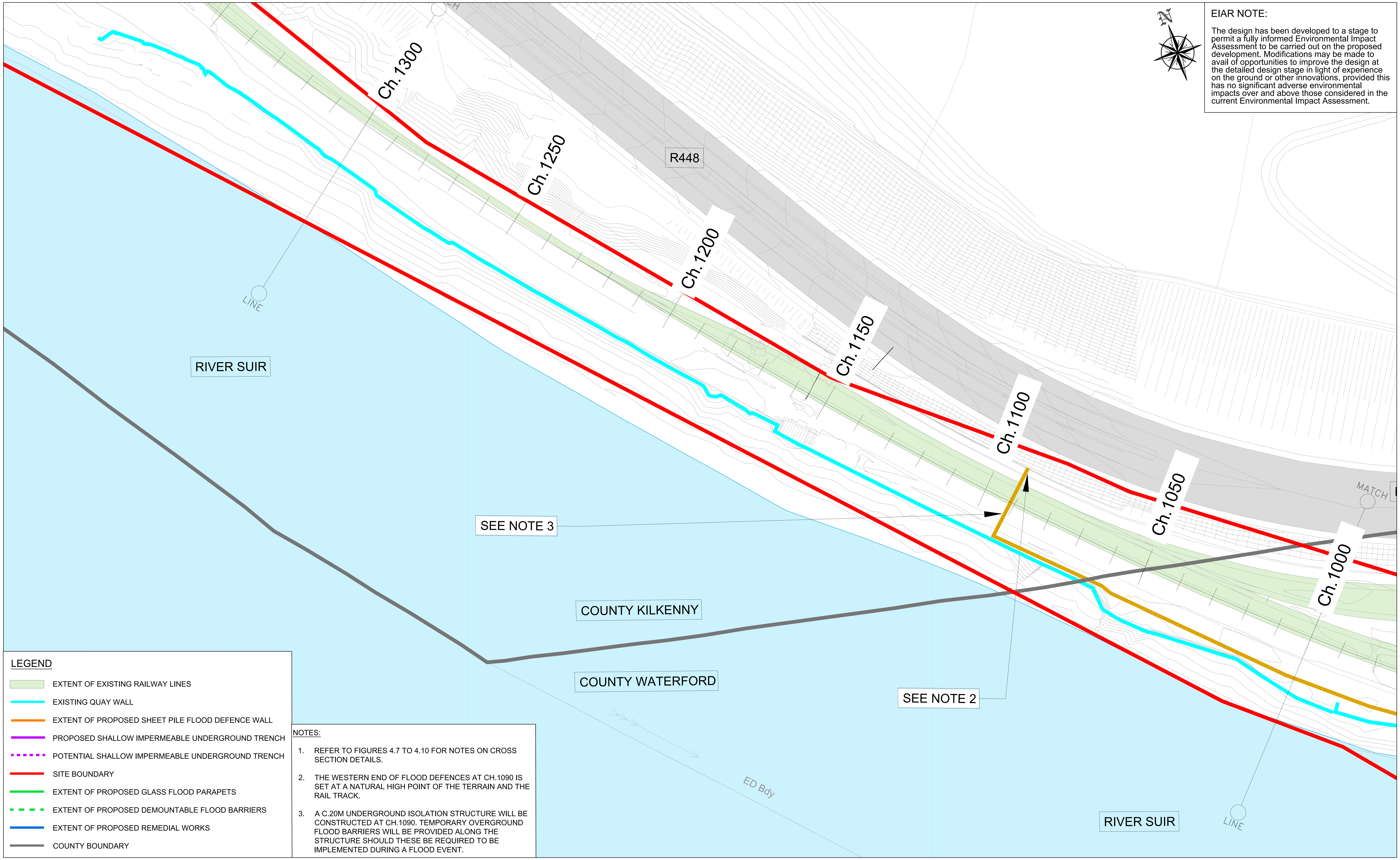

LEGEND

- EXTENT OF EXISTING RAILWAY LINES
- EXISTING QUAY WALL
- EXTENT OF PROPOSED SHEET PILE FLOOD DEFENCE WALL
- PROPOSED SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- POTENTIAL SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- SITE BOUNDARY
- EXTENT OF PROPOSED GLASS FLOOD PARAPETS
- EXTENT OF PROPOSED DEMOUNTABLE FLOOD BARRIERS
- EXTENT OF PROPOSED REMEDIAL WORKS
- COUNTY BOUNDARY

NOTES:

1. REFER TO FIGURES 4.7 TO 4.10 FOR NOTES ON CROSS SECTION DETAILS.
2. THE WESTERN END OF FLOOD DEFENCES AT CH.1090 IS SET AT A NATURAL HIGH POINT OF THE TERRAIN AND THE RAIL TRACK.
3. A C.20M UNDERGROUND ISOLATION STRUCTURE WILL BE CONSTRUCTED AT CH.1090. TEMPORARY OVERGROUND FLOOD BARRIERS WILL BE PROVIDED ALONG THE STRUCTURE SHOULD THESE BE REQUIRED TO BE IMPLEMENTED DURING A FLOOD EVENT.

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Comhairle Cathrach & Contae Phort Láirge Waterford City & County Council
NTA Údarás Náisiúnta Iompair National Transport Authority
Iarnród Éireann Irish Rail

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Proposed Extents of Structural Works Sheet 4 of 5

Designed:	YB	File:		Status:	E.I.A.R.
Drawn:	IM	Job No:	18.141		
Checked:	BC	Scale:	1:500 (@ A3)	Drawing No: FIG 4.5	Rev: -
Approved:	TD	Date:	OCTOBER 2021		

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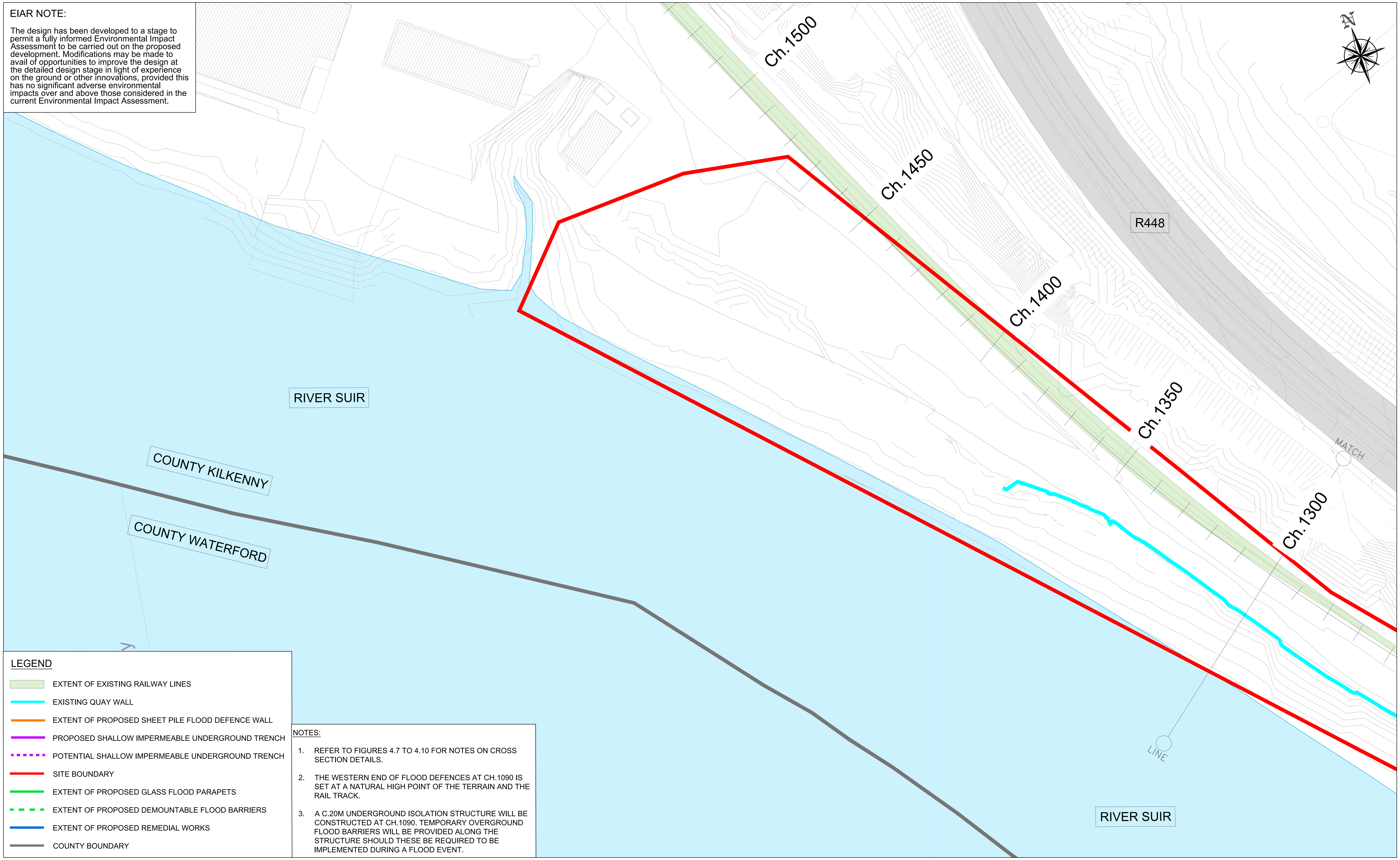

LEGEND

- EXTENT OF EXISTING RAILWAY LINES
- EXISTING QUAY WALL
- EXTENT OF PROPOSED SHEET PILE FLOOD DEFENCE WALL
- PROPOSED SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- POTENTIAL SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- SITE BOUNDARY
- EXTENT OF PROPOSED GLASS FLOOD PARAPETS
- EXTENT OF PROPOSED DEMOUNTABLE FLOOD BARRIERS
- EXTENT OF PROPOSED REMEDIAL WORKS
- COUNTY BOUNDARY

NOTES:

1. REFER TO FIGURES 4.7 TO 4.10 FOR NOTES ON CROSS SECTION DETAILS.
2. THE WESTERN END OF FLOOD DEFENCES AT CH.1090 IS SET AT A NATURAL HIGH POINT OF THE TERRAIN AND THE RAIL TRACK.
3. A C.20M UNDERGROUND ISOLATION STRUCTURE WILL BE CONSTRUCTED AT CH.1090. TEMPORARY OVERGROUND FLOOD BARRIERS WILL BE PROVIDED ALONG THE STRUCTURE SHOULD THESE BE REQUIRED TO BE IMPLEMENTED DURING A FLOOD EVENT.

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Proposed Extents of Structural Works Sheet 5 of 5

Designed:	YB	File:		Status:	E.I.A.R.
Drawn:	IM	Job No:	18.141		
Checked:	BC	Scale:	1:500 (@ A3)	Drawing No: FIG 4.6	Rev: -
Approved:	TD	Date:	OCTOBER 2021		

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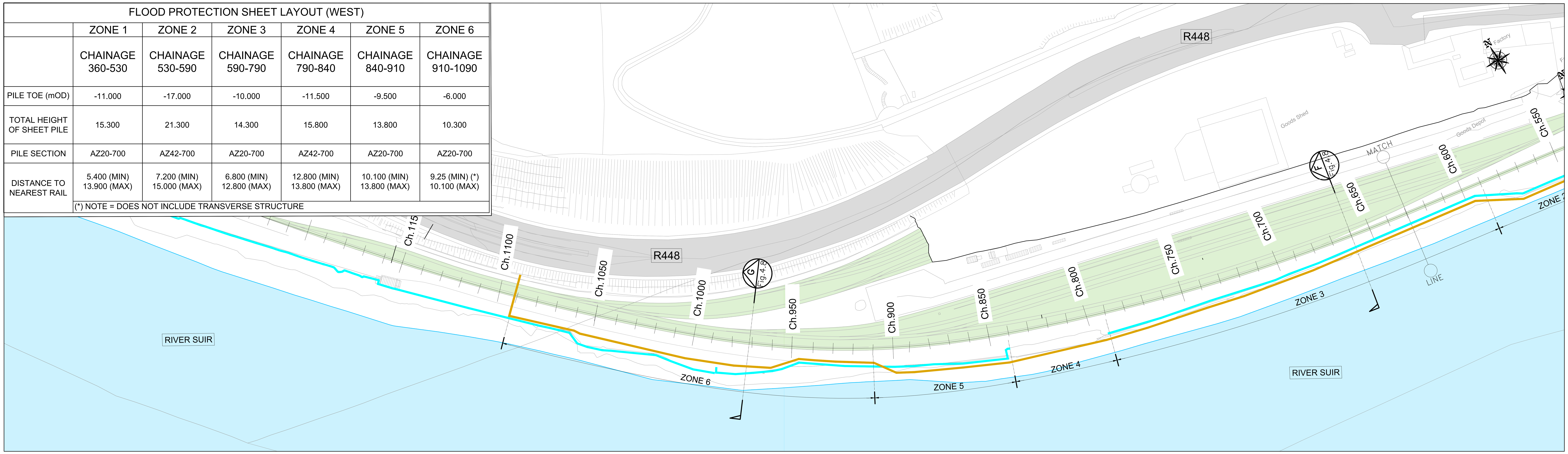
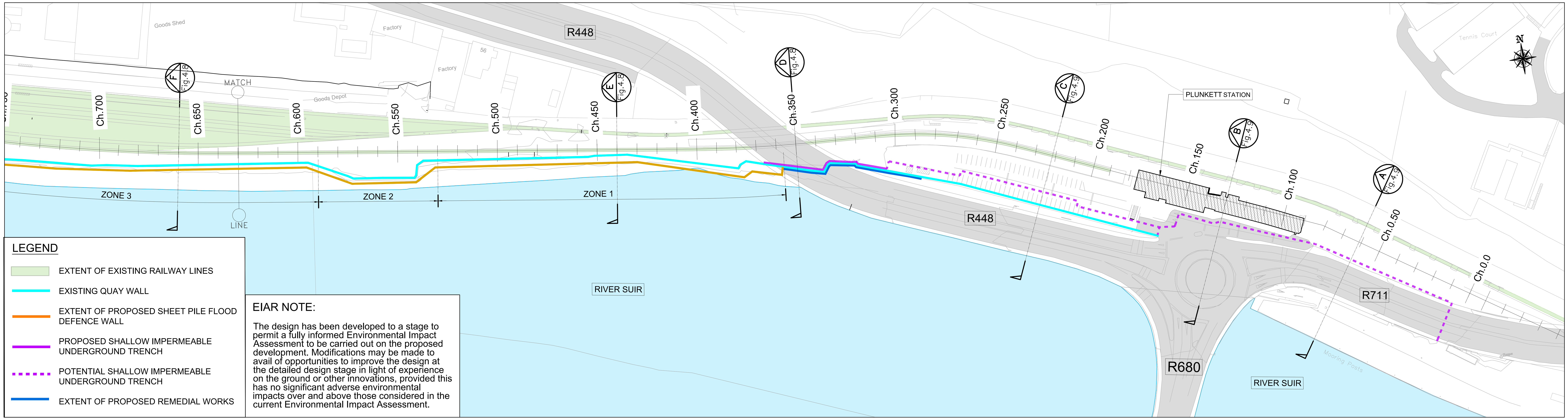
FLOOD PROTECTION SHEET LAYOUT (WEST)

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
	CHAINAGE 360-530	CHAINAGE 530-590	CHAINAGE 590-790	CHAINAGE 790-840	CHAINAGE 840-910	CHAINAGE 910-1090
PILE TOE (mOD)	-11.000	-17.000	-10.000	-11.500	-9.500	-6.000
TOTAL HEIGHT OF SHEET PILE	15.300	21.300	14.300	15.800	13.800	10.300
PILE SECTION	AZ20-700	AZ42-700	AZ20-700	AZ42-700	AZ20-700	AZ20-700
DISTANCE TO NEAREST RAIL	5.400 (MIN) 13.900 (MAX)	7.200 (MIN) 15.000 (MAX)	6.800 (MIN) 12.800 (MAX)	12.800 (MIN) 13.800 (MAX)	10.100 (MIN) 13.800 (MAX)	9.25 (MIN) (*) 10.100 (MAX)

(*) NOTE = DOES NOT INCLUDE TRANSVERSE STRUCTURE





LEGEND

- EXTENT OF EXISTING RAILWAY LINES
- EXISTING QUAY WALL
- EXTENT OF PROPOSED SHEET PILE FLOOD DEFENCE WALL
- PROPOSED SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- POTENTIAL SHALLOW IMPERMEABLE UNDERGROUND TRENCH
- EXTENT OF PROPOSED REMEDIAL WORKS

EIAR NOTE:

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

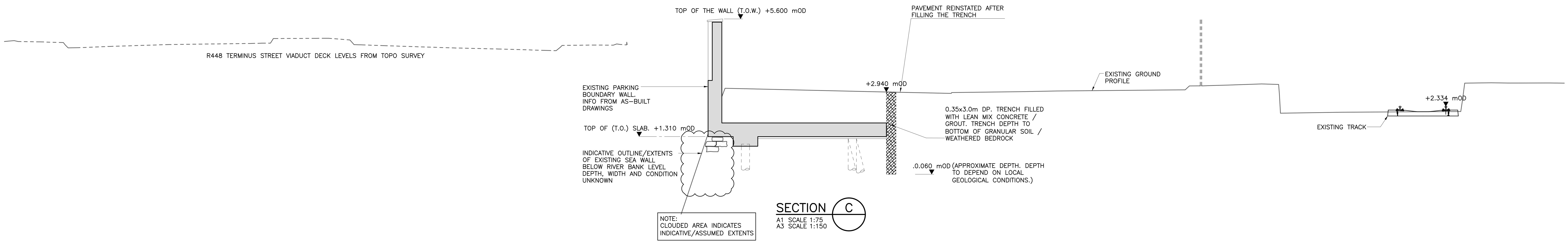
Drawing Title: Indicative Cross Sections of Structural Works - Key Plan

Designed:	YB	File:		Status:	E.I.A.R.
Drawn:	IM	Job No:	18.141		
Checked:	BC	Scale:	1:2000 (@ A3)	Drawing No: FIG 4.7	Rev: -
Approved:	TD	Date:	OCTOBER 2021		

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

NOTES:

1. HAND DIGGING TO BE EMPLOYED AROUND UTILITIES TO ADEQUATELY PROTECT SERVICES AND UTILITIES.
2. TRENCH TO BE CONSTRUCTED IN SHORT SECTIONS TO MINIMISE THE TIME TRENCH IS LEFT OPEN.

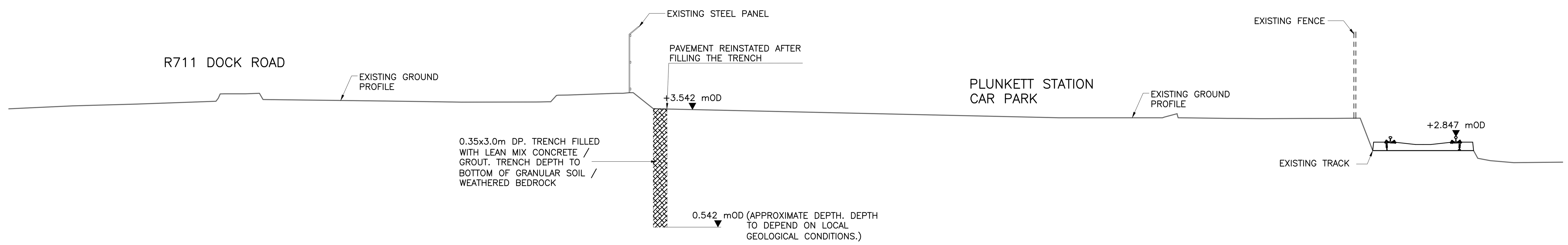


SECTION C
A1 SCALE 1:75
A3 SCALE 1:150

CROSS SECTION TAKEN AT CH:220 FACING WESTWARDS

SECTION B
A1 SCALE 1:75
A3 SCALE 1:150

CROSS SECTION TAKEN AT CH:130 FACING WESTWARDS



SECTION A
A1 SCALE 1:75
A3 SCALE 1:150

CROSS SECTION TAKEN AT CH:060 FACING WESTWARDS

EIAR NOTE:

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Indicative Cross Sections of Structural Works - Sheet 1 of 2

Designed: YB	File:	Status: E.I.A.R.	
Drawn: IM	Job No: 18.141		
Checked: BC	Scale: AS SHOWN	Drawing No: FIG 4.8	Rev: -
Approved: TD	Date: OCTOBER 2021		

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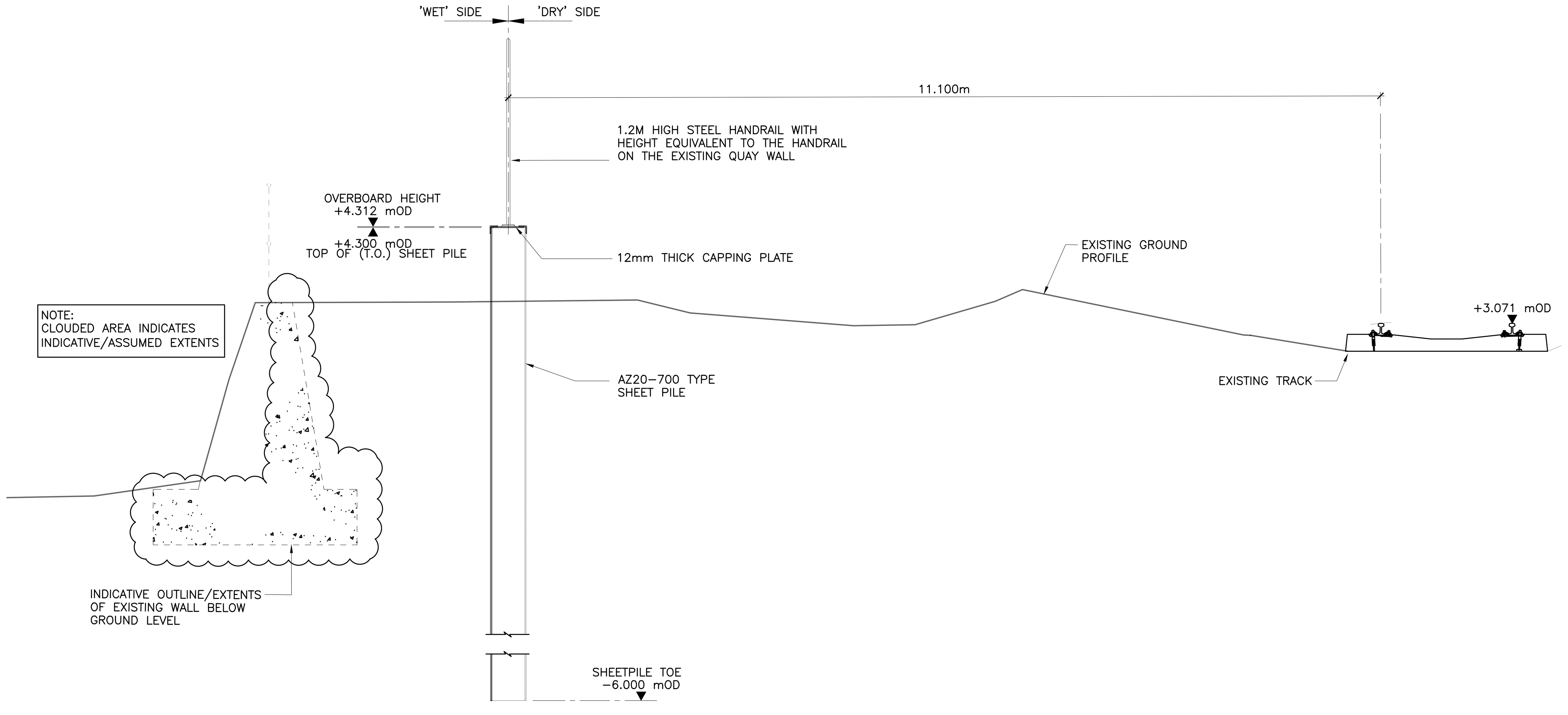
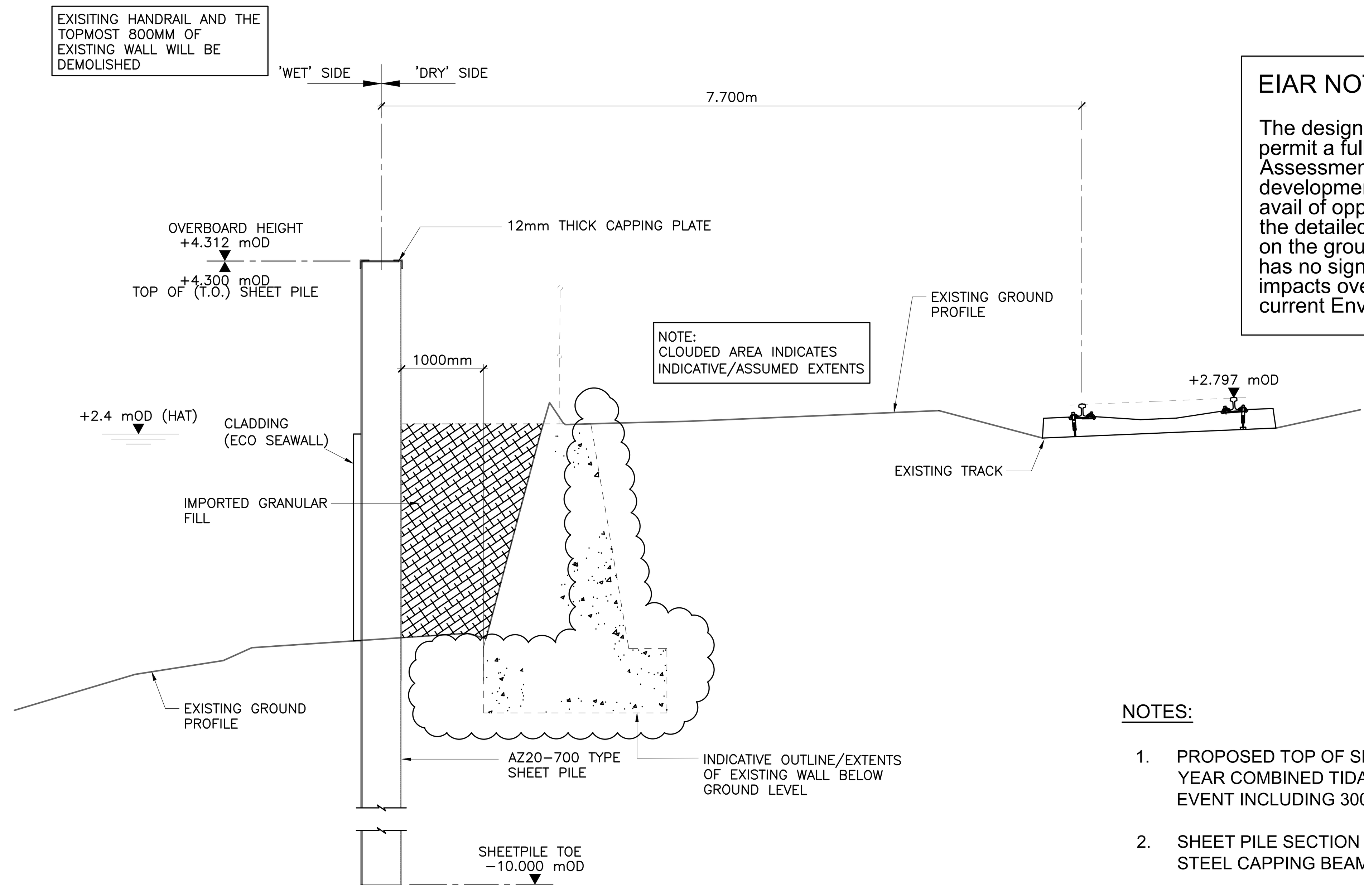


SECTION G
A1 SCALE 1:50
A3 SCALE 1:100

SECTION TAKEN AT CH:970 FACING WESTWARDS



SECTION F
A1 SCALE 1:50
A3 SCALE 1:100

SECTION TAKEN AT CH:660 FACING WESTWARDS

EIAR NOTE:

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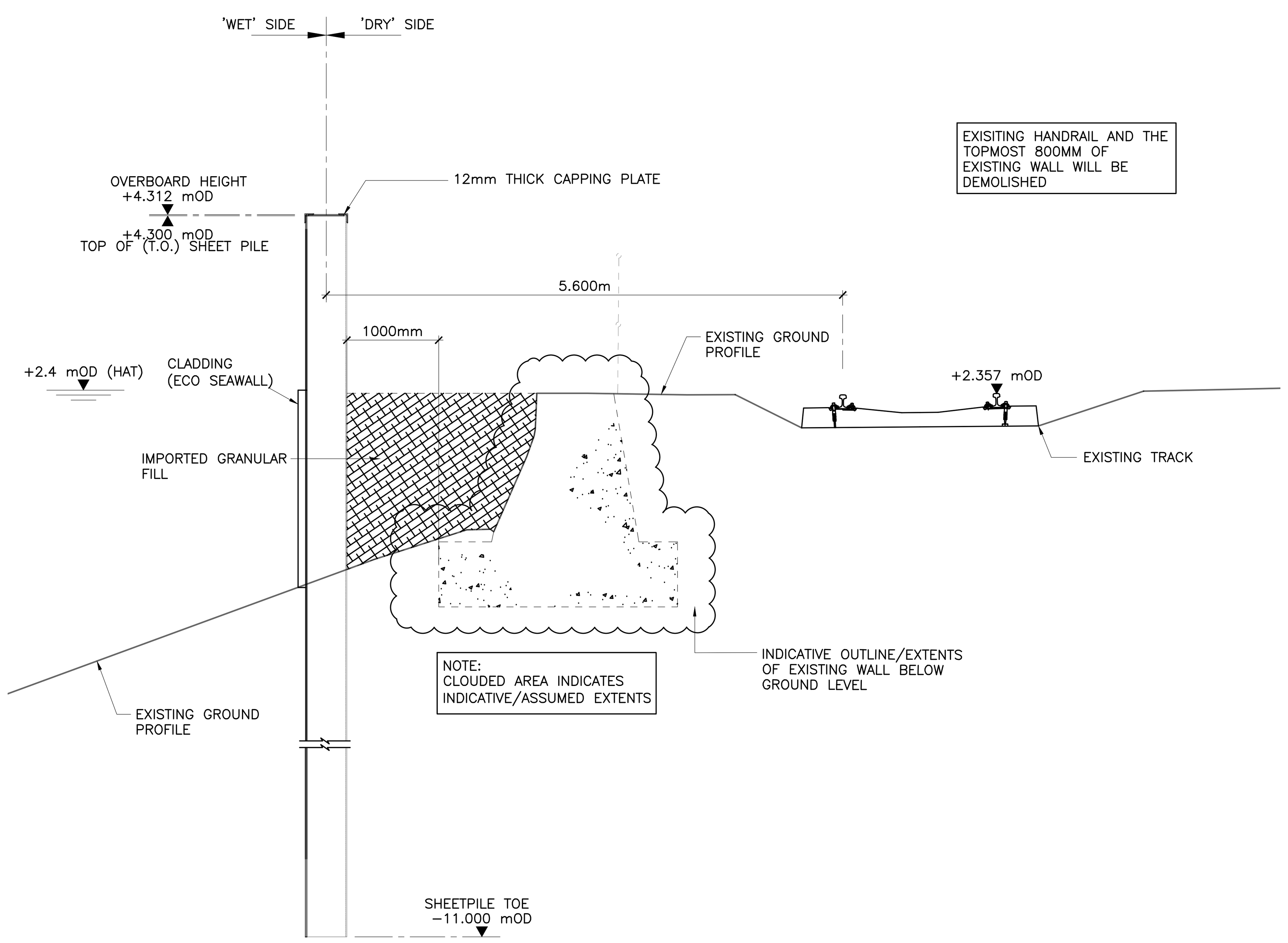
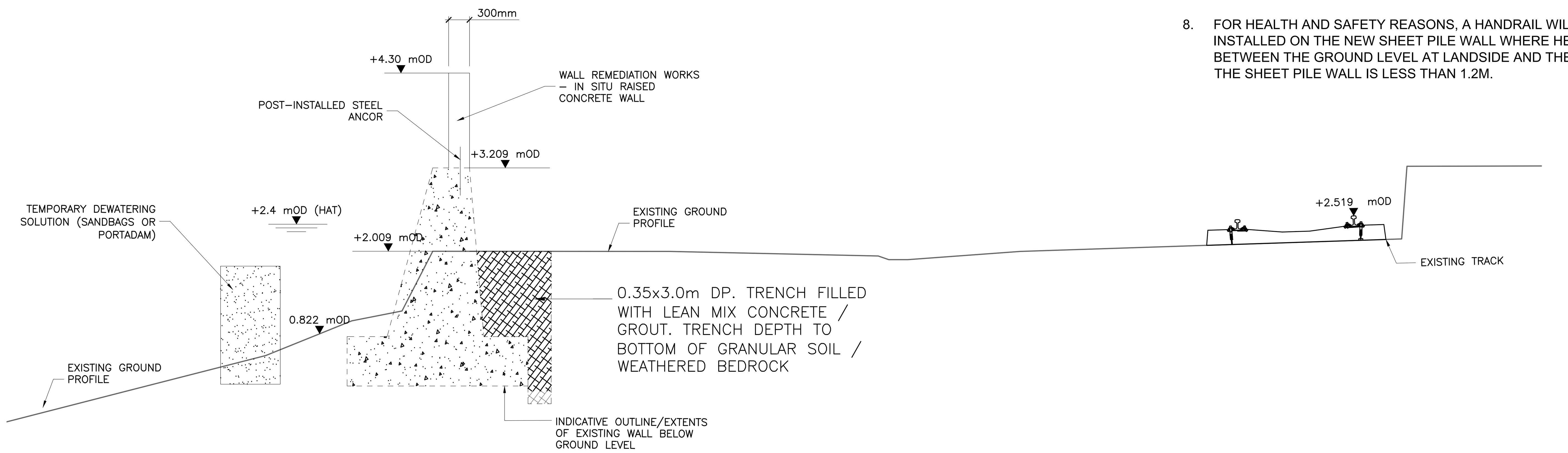
NOTES:

1. PROPOSED TOP OF SHEET PILE (+4.300MOD) TO PROVIDE 1:200 YEAR COMBINED TIDAL/ FLUVIAL PROTECTION DURING FLOOD EVENT INCLUDING 300MM FREEBOARD ALLOWANCE.
2. SHEET PILE SECTION DEPTH OF 450mm ASSUMED. PRESSED STEEL CAPPING BEAM PROPOSED.
3. A MINIMUM WIDTH 1000mm SHALL BE PROVIDED, WHERE FEASIBLE, BETWEEN THE FRONT AND BACK OF EXISTING QUAY WALL AND THE NEAREST FACE OF THE PROPOSED SHEET PILE TO MINIMIZE RISK OF CLASHES WITH THE EXISTING WALL.
4. THE PROPOSED SHEET PILE WALL WILL NOT BE DESIGNED TO RESIST NOTIONAL IMPACT FORCES ARISING FROM A DERAILMENT.
5. RIVERSIDE SHEET PILE WALL INSTALLATION WILL BE UNDERTAKEN FROM BARGE. BARGE IS EXPECTED TO BE SET-UP A MINIMUM OF 6M FROM THE FRONT OF FACE OF EXISTING MASONRY QUAY WALL.
6. PRE-CAST CONCRETE CLADDING ("ECO-SEAWALL") WILL BE INSTALLED TO THE INTERTIDAL ZONE OF THE RIVERSIDE SHEET PILE WALL TO ENHANCE MARINE BIODIVERSITY.
7. NO DRAINAGE WORKS ARE SHOWN ON THESE CROSS SECTIONS. REFER TO FIG. 4.11. TO 4.20 FOR DRAINAGE WORKS FIGURES.
8. FOR HEALTH AND SAFETY REASONS, A HANDRAIL WILL BE INSTALLED ON THE NEW SHEET PILE WALL WHERE HEIGHT BETWEEN THE GROUND LEVEL AT LANDSIDE AND THE TOP OF THE SHEET PILE WALL IS LESS THAN 1.2M.



SECTION E
A1 SCALE 1:50
A3 SCALE 1:100

SECTION TAKEN AT CH:440 FACING WESTWARDS



SECTION D
A1 SCALE 1:50
A3 SCALE 1:100

SECTION TAKEN AT CH:350 FACING WESTWARDS

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Project Title: WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Indicative Cross Sections of Structural Works - Sheet 2 of 2

Designed:	YB	File:		Status:	E.I.A.R.
Drawn:	IM	Job No:	18.141		
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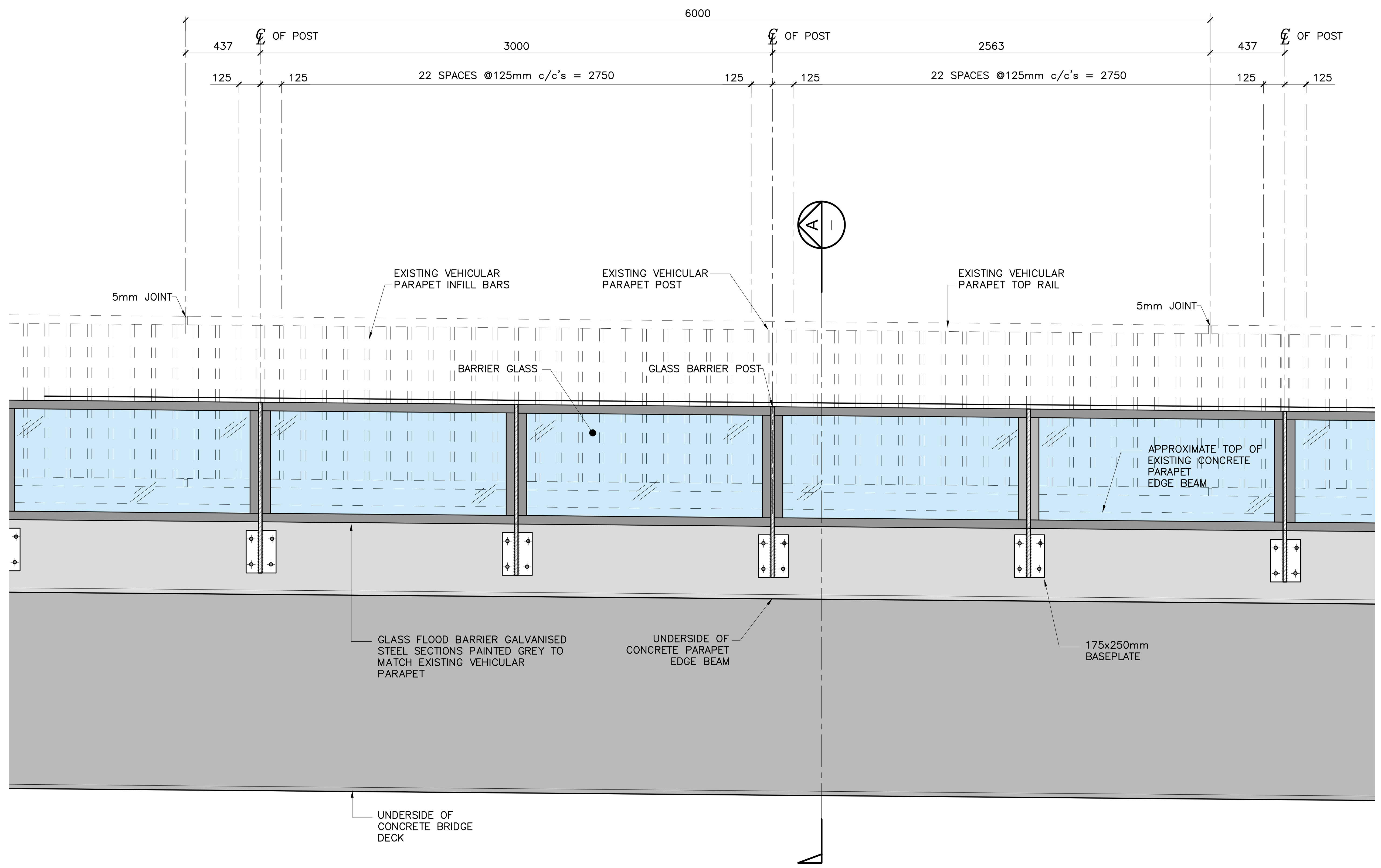
Approved:	TD	Date:	OCTOBER 2021	Rev:	-

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

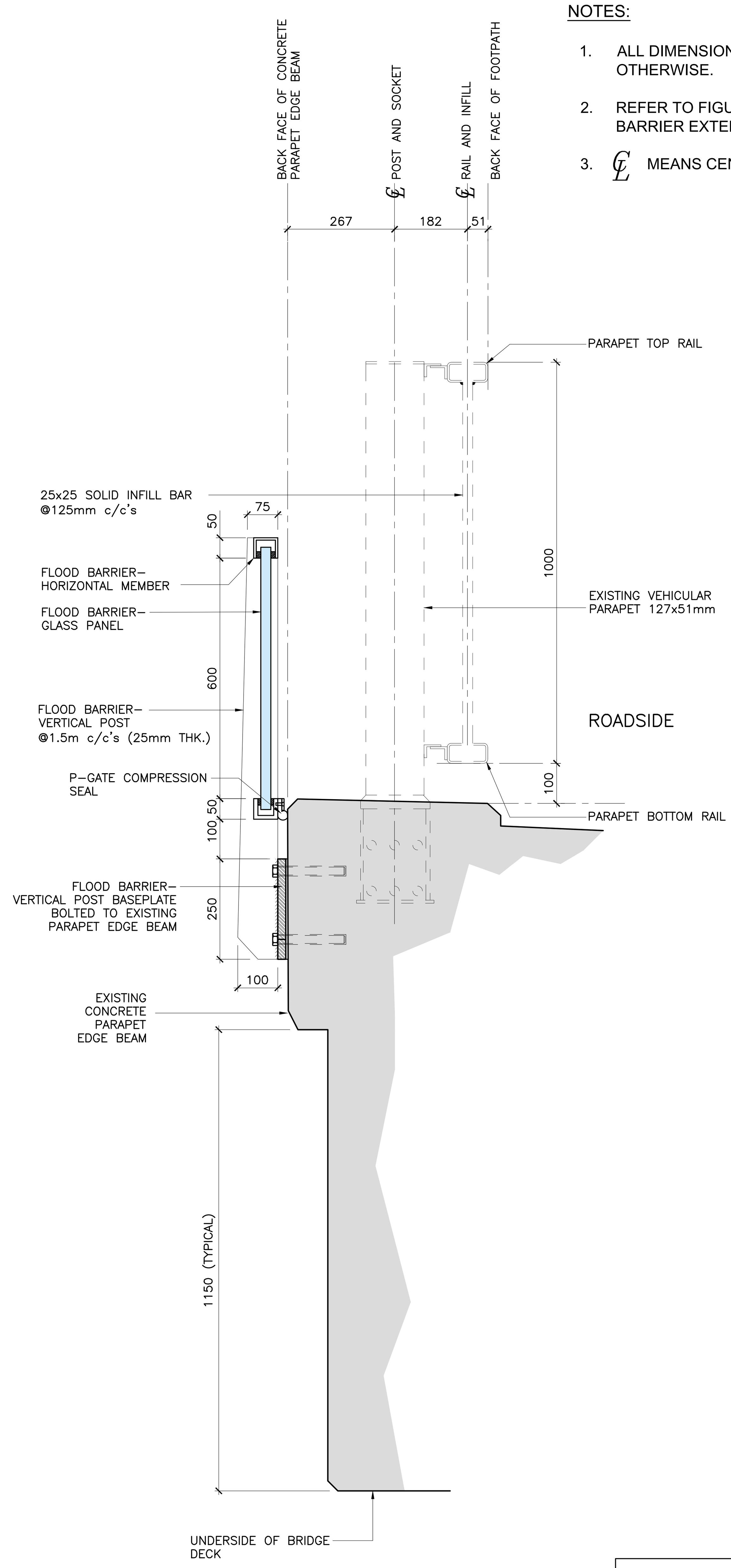
NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. REFER TO FIGURES 4.1 & 4.2 FOR PROPOSED GLASS FLOOD BARRIER EXTENTS.
3. ℄ MEANS CENTRE LINE



ELEVATION–TYPICAL GLASS FLOOD BARRIER ARRANGEMENT

A1 SCALE 1:20
A3 SCALE 1:40



SECTION A –

A1 SCALE 1:10
A3 SCALE 1:20

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Project Title: **WATERFORD CITY PUBLIC INFRASTRUCTURE PROJECT FLOOD DEFENCES WEST**

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Drawing Title: Indicative Elevation & Section of Glass Flood Barriers

Designed:	CS	File:		Status:	E.I.A.R.
Drawn:	AR	Job No:	18.141		
Checked:	BC	Scale:	AS SHOWN	Drawing No:	FIG 4.10
Approved:	TD	Date:	OCTOBER 2021	Rev:	

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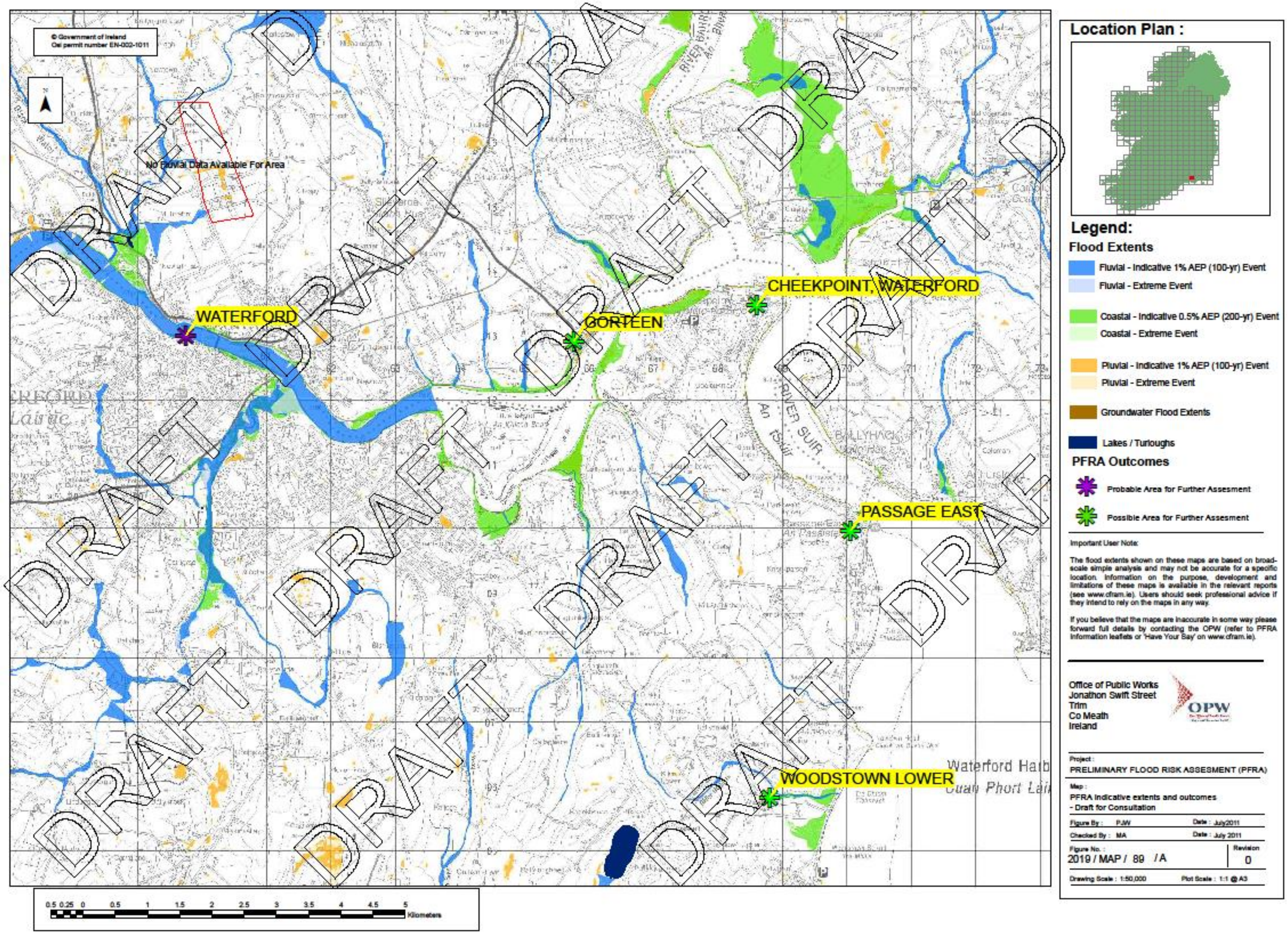
APPENDIX C

INDICATIVE FLOOD SOURCES

Preliminary Flood Risk Assessment



Myplan Web Map

January 28, 2019

- Coastal - Indicative 0.5% AEP (200-yr) Event
- Coastal - Extreme Event

1:25,000

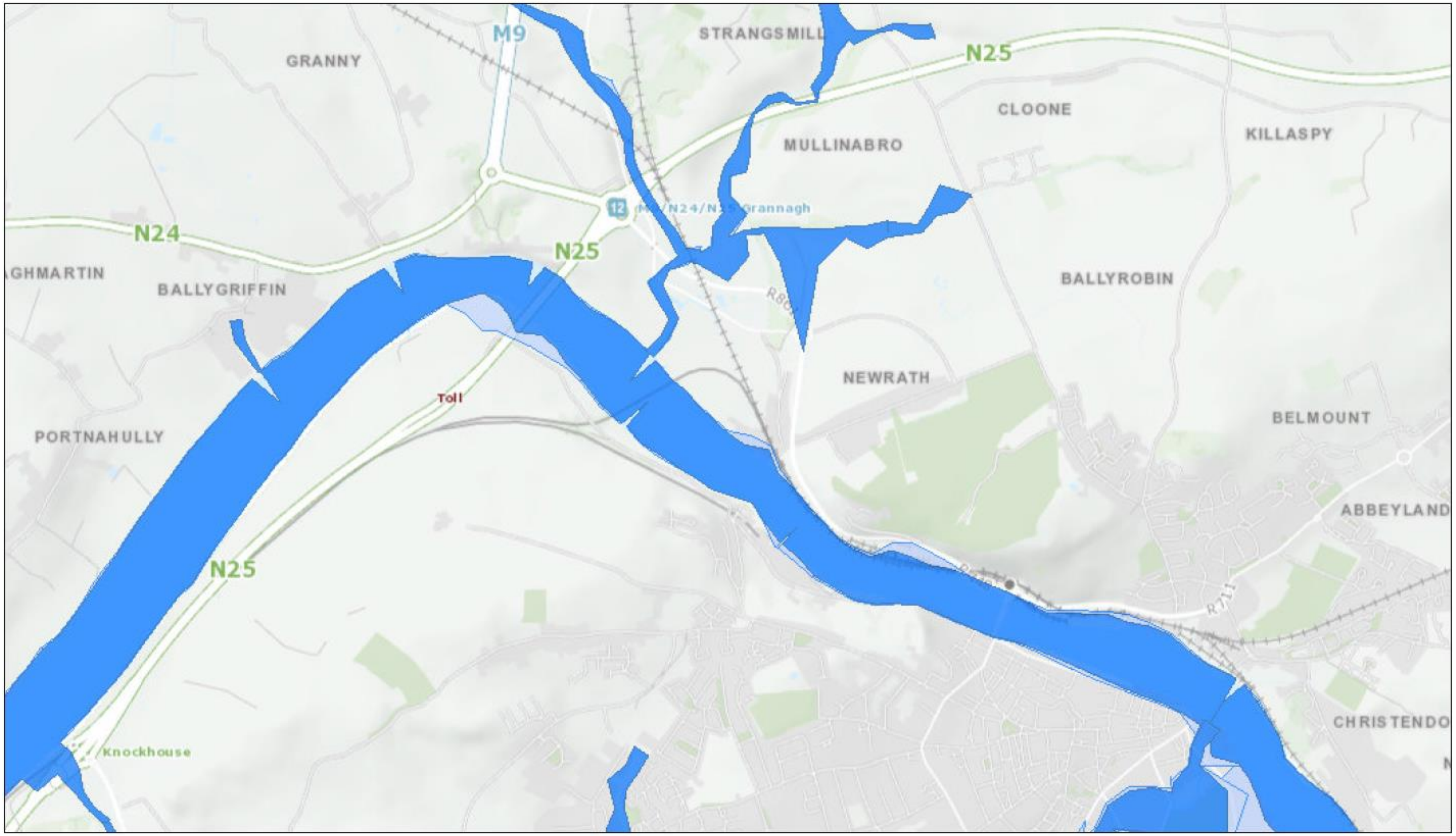
0 0.2 0.4 0.8 mi

0 0.325 0.65 1.3 km

© Ordnance Survey Ireland

Myplan
DHPCLG

Myplan Web Map Fluvial



January 28, 2019

- Fluvial - Indicative 1% AEP (100-yr) Event
- Fluvial - Extreme Event

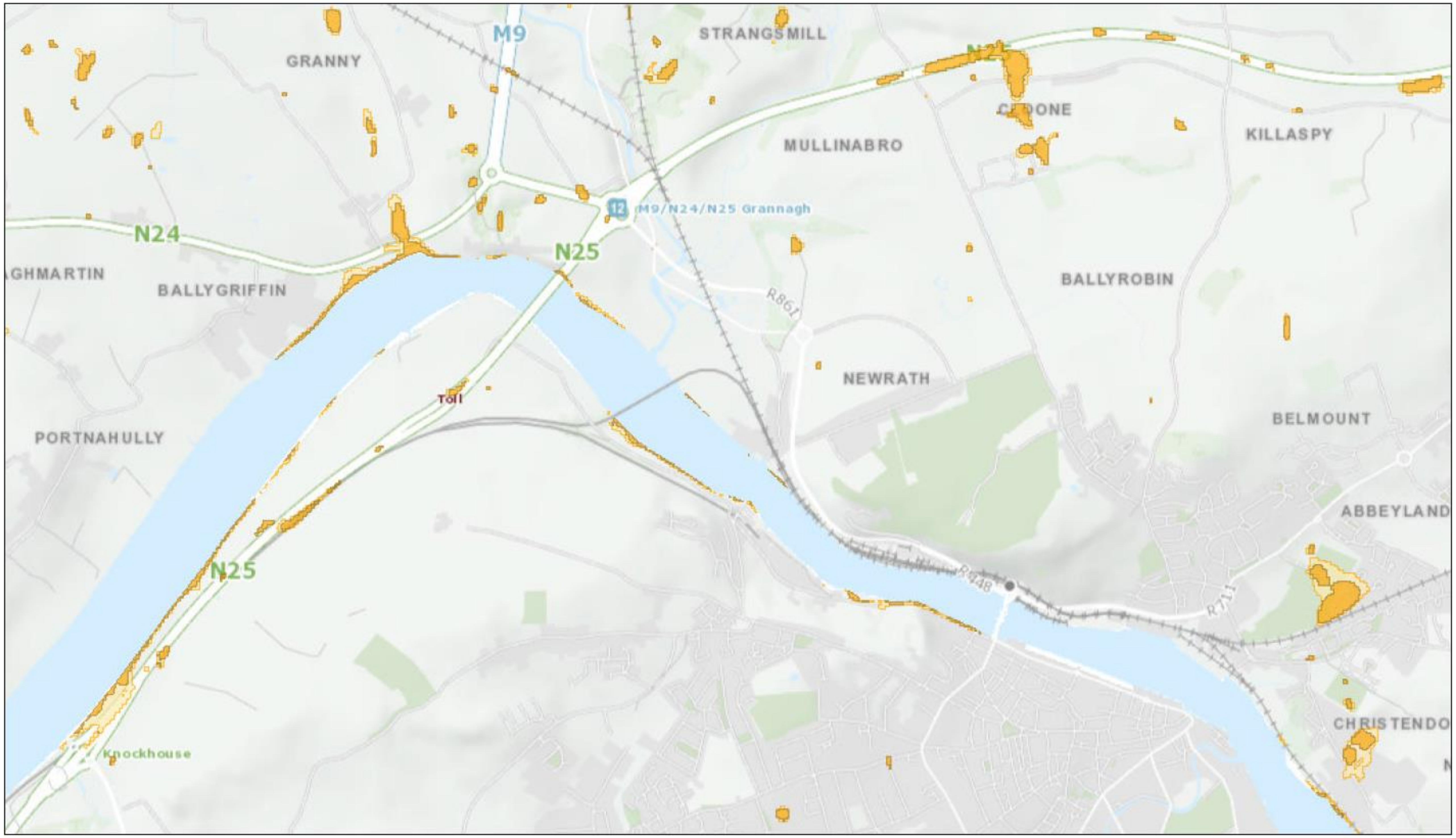
1:25,000

0 0.2 0.4 0.8 mi

0 0.325 0.65 1.3 km

Myplan
DHPCLG

Myplan Web Map Pluvial



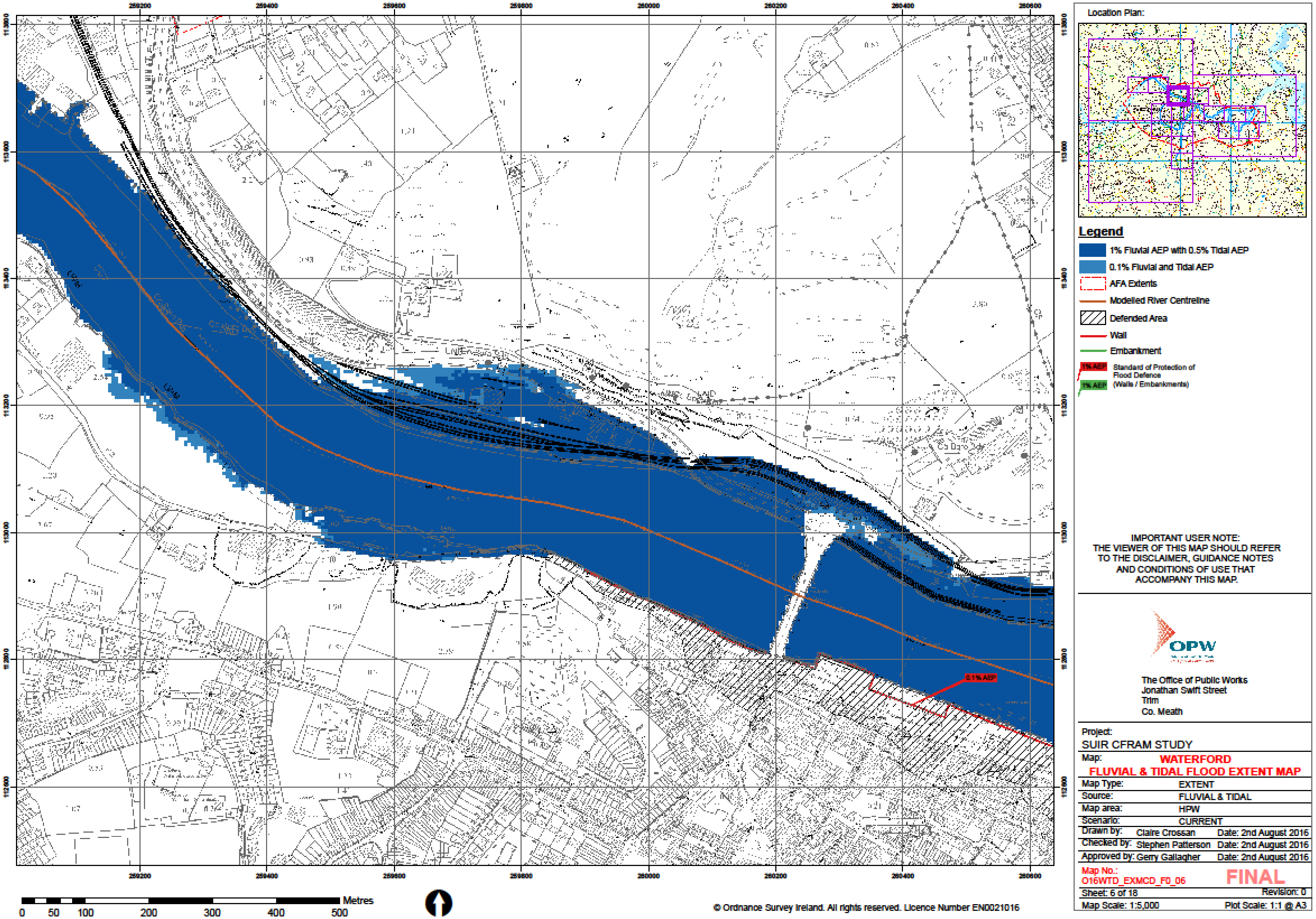
January 28, 2019

- Pluvial - Indicative 1% AEP (100-yr) Event
- Pluvial - Extreme Event

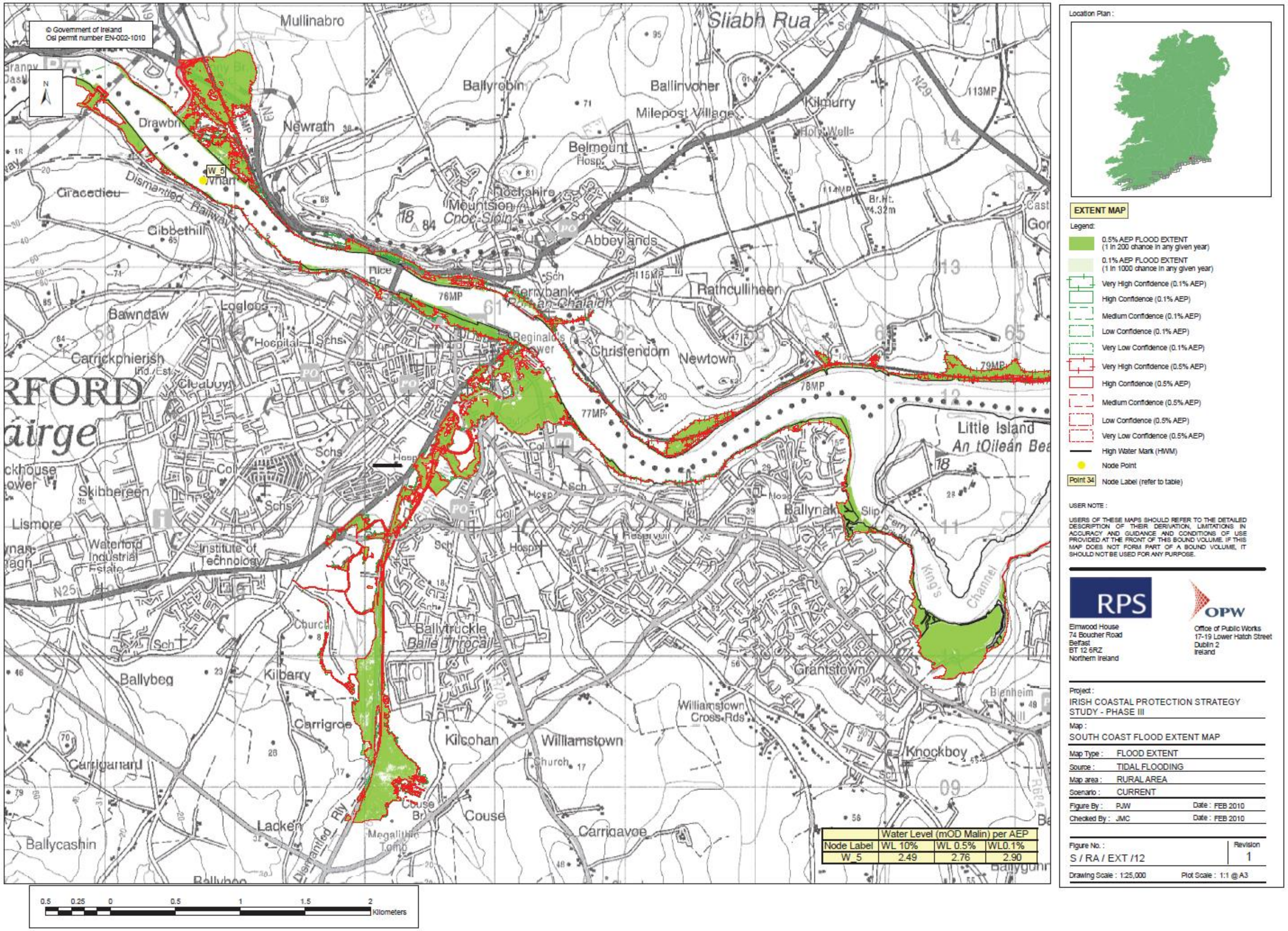
1:25,000
0 0.2 0.4 0.8 mi
0 0.325 0.65 1.3 km
© Ordnance Survey Ireland

Myplan
DHPCLG

Catchment Flood Risk Assessment and Management Study



Irish Coastal Protection Strategy Study



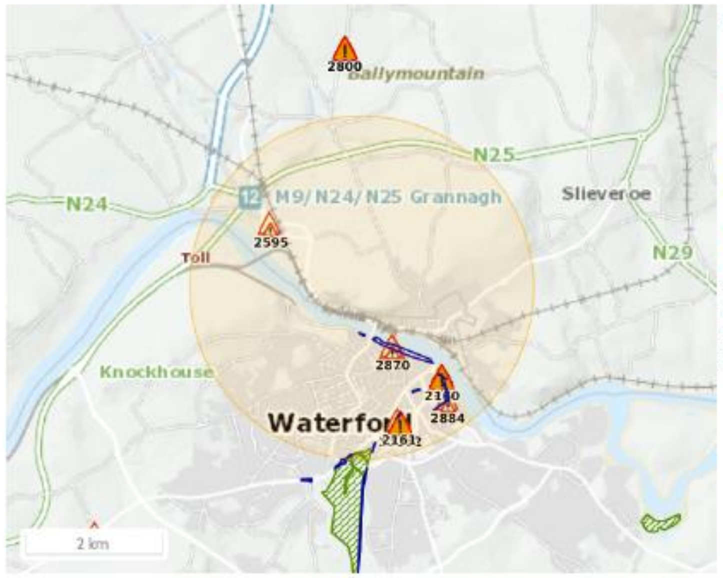
OPW Flood Hazard Mapping

Past Flood Event Local Area Summary Report

OPW Oifig na nOibreacha Poiblí Office of Public Works

Report Produced: 17/2/2021 11:14

This Past Flood Event Summary Report summarises all past flood events within 2.5 kilometres of the map centre.



Map Legend

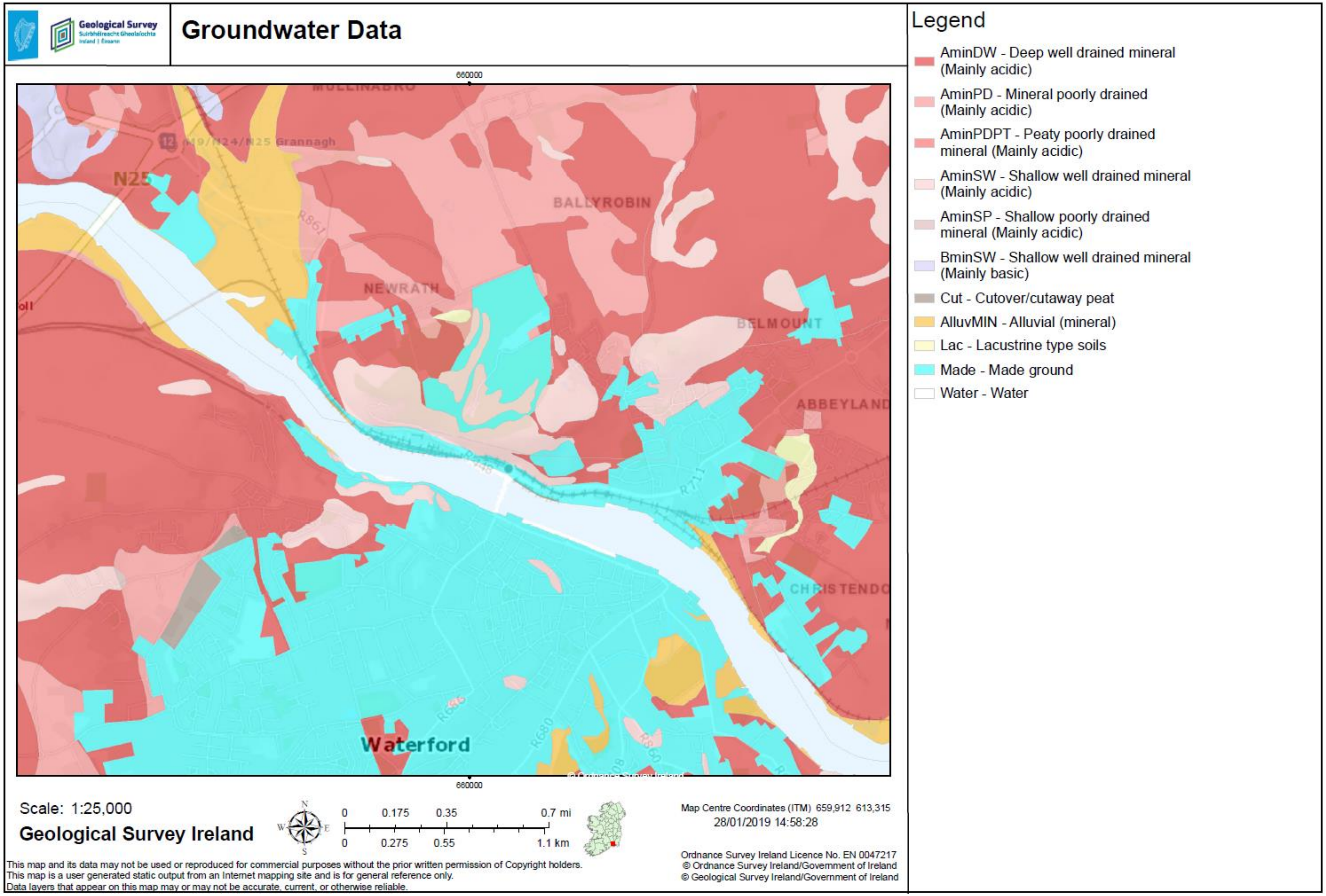
- Single Flood Event
- Recurring Flood Event
- Past Flood Event Extents
- Drainage Districts Benefited Lands*
- Land Commission Benefited Lands*
- Arterial Drainage Schemes Benefited Lands*

* Important: These maps do not indicate flood hazard or flood extent. Their purpose and scope is explained on Floodinfo.ie

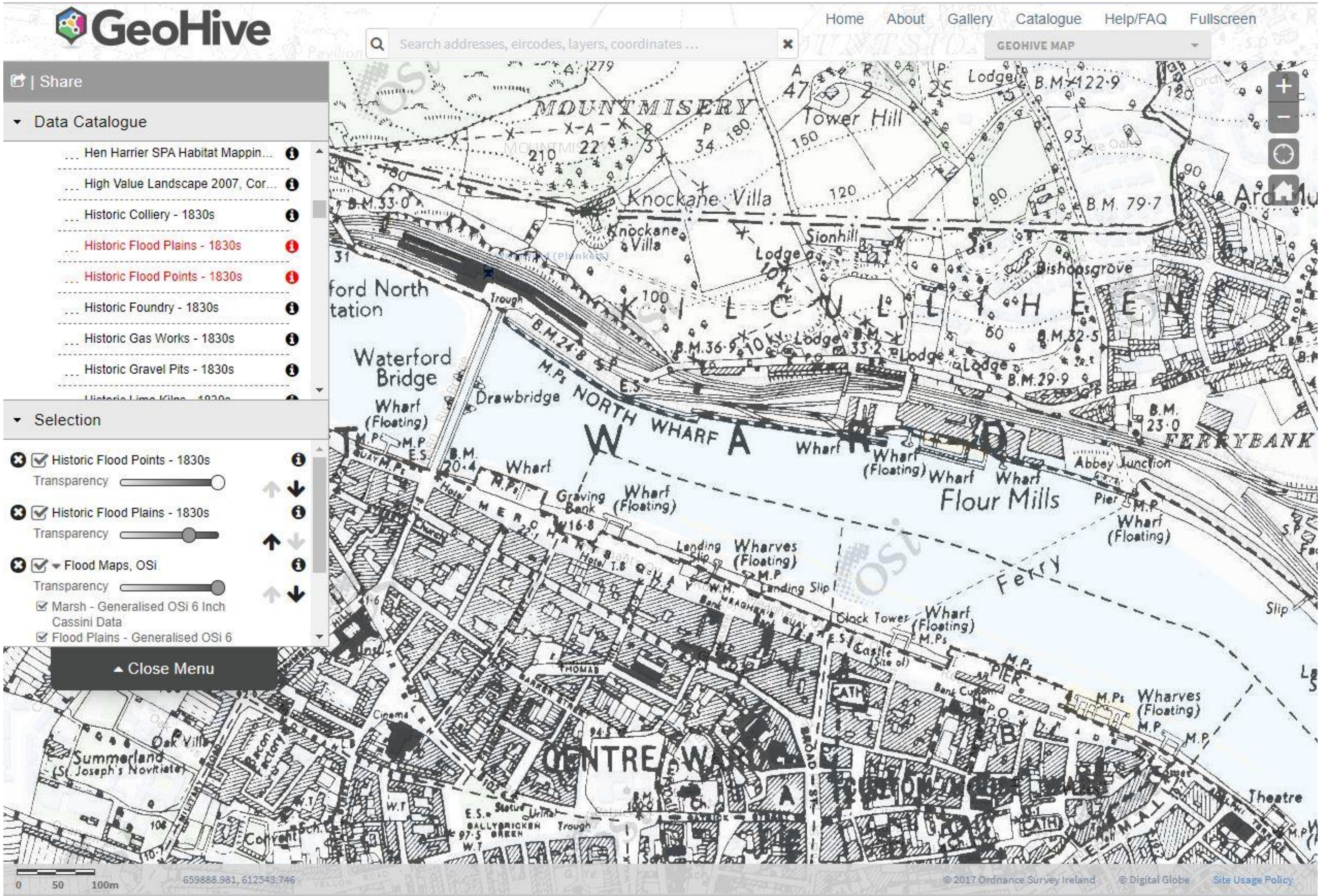
14 Results

	Name (Flood_ID)	Start Date	Event Location
1.	Scotch Quay Area Waterford Recurring (ID-2160)	n/a	Approximate Point
	Additional Information: Reports (11) Press Archive (0)		
2.	Poleberry Bath St Waterford Recurring (ID-2161)	n/a	Approximate Point
	Additional Information: Reports (6) Press Archive (0)		
3.	Scotch Quay Newtown Park Road Oct 2004 (ID-2876)	27/10/2004	Area
	Additional Information: Reports (5) Press Archive (0)		
4.	Flooding at Poleberry, Co. Waterford (ID-12162)	03/02/2014	Exact Point
	Additional Information: Reports (1) Press Archive (0)		
5.	Suir Newrath at Redbridge recurring. (ID-2595)	n/a	Exact Point
	Additional Information: Reports (4) Press Archive (0)		
6.	Suir Waterford City Quay Feb 1994 (ID-2870)	28/02/1994	Approximate Point
	Additional Information: Reports (5) Press Archive (0)		
7.	Suir Waterford City Quay recurring (ID-2880)	n/a	Approximate Point
	Additional Information: Reports (12) Press Archive (73)		
8.	Suir Newtown Road/Park Road recurring (ID-2884)	n/a	Approximate Point
	Additional Information: Reports (4) Press Archive (5)		
9.	Suir Scotch Quay William St area Feb 1994 (ID-2885)	28/02/1994	Approximate Point
	Additional Information: Reports (6) Press Archive (2)		
10.	St John's River Poleberry Oct 2004 (ID-2875)	27/10/2004	Area
	Additional Information: Reports (5) Press Archive (0)		
11.	Suir Waterford City Quay Oct 2004 (ID-2873)	27/10/2004	Area
	Additional Information: Reports (5) Press Archive (0)		
12.	St John's River Tramore Road Oct 2004 (ID-2874)	27/10/2004	Area
	Additional Information: Reports (5) Press Archive (0)		
13.	Kingsmeadow Roundabout Waterford Oct 2004 (ID-2878)	27/10/2004	Area
	Additional Information: Reports (5) Press Archive (0)		
14.	St John's River Waterside Oct 2004 (ID-2877)	27/10/2004	Area
	Additional Information: Reports (5) Press Archive (0)		

Geological Survey of Ireland: Teagasc Subsoil Mapping



Historical Maps: 6” Cassini



News Reports

thejournal.ie

Waterford train station is flooded... very flooded

Last night's heavy rain led to this happening to the station.

BY AOIFE BARRY | WEDNESDAY 17 OCT 2012, 10:32 AM | HTTP://JRNL.IE/638505

LAST NIGHT'S HEAVY rain **led to flooding** around parts of Ireland – and Waterford train station got hit particularly badly.

This image, which was **tweeted by Irish Rail**, shows the full extent of the flooding caused by the downpour.

Bus transfers are in place from Waterford to Kilkenny while Irish Rail works to get the station back up and running.

Read: Heavy overnight rain leads to flooding, delays>

1/31/2019 Waterford train station is flooded... very flooded · TheJournal.ie

ABOUT THE AUTHOR
Aoife Barry | **@sweetoblivion26** | **aoife@thejournal.ie**

Residents face health alert as flood nightmare strikes again

8

A man with two children make their way through flood water in Cork city.

Ralph Riegel Twitter Email

February 5 2014 2:30 AM

-
- Email

A MAJOR health alert was issued over the dangers posed by bacteria-laden flood waters as Cork suffered its fourth flooding nightmare in just four weeks.

The River Lee broke its banks for a second time in 24 hours and the fourth time since early January due to high tides, torrential rain and a one-metre high storm surge.

But Limerick residents and traders breathed a sigh of relief as the city escaped a second round of flooding from the River Shannon.

Both Limerick County and City councils confirmed no further flooding with high tides over the next 36 hours predicted to be up to two metres lower than on Saturday when the worst floods in living memory hit the city.

Saturday's flooding hit 200 acres of the city, impacting 300 houses and over 3,000 people.

However, while Limerick residents began the clean-up, homeowners in Athlone were being given sandbags as water levels on the River Shannon threaten low-lying properties.

Cork Flooding time lapse

00:00 00:35 480p

Athlone Town Council activated its flood emergency plan on Monday due to the rising water levels with 2,000 sandbags ready for distribution. A further 2,000 have been in place since January when flooding also threatened the town.

In Cork, pressure has mounted on the Office of Public Works (OPW) to fast-track a long-delayed flood defence plan for Ireland's lowest lying city.

While parts of the city centre were left under flood waters last night, the damage was limited due to a major emergency plan by Cork City Council, Cork Fire Brigade and trader groups.

Stores on Oliver Plunkett Street, Patrick Street and other vulnerable areas had moved stock out of the reach of flood waters after a 24-hour advance warning.

Both Cork Chamber of Commerce and Cork Business Association warned that the clean-up costs will still be disastrous for some retailers.

Parts of the city centre were effectively evacuated as a precautionary measure given the scale of the feared storm surge.

Cork School of Music and Cork College of Commerce were both ordered to close by 7pm because of their location in a high-risk flood zone.

A number of businesses also closed early to allow flood gates and sand-bags to be installed.

Gardai and traffic wardens warned motorists not to leave vehicles parked in flood zones including Union Quay, Morrisson's Quay, Fr Mathew Quay, Oliver Plunkett Street, Lavitt's Quay, Proby's Quay and Sharman-Crawford Street.

City Manager Tim Lucey had appealed to all householders and traders to be on their premises from 6pm to aid in the flood protection campaign.

"We have done everything we possibly can. We are dealing with quite an extensive area and we needed property owners to be on their premises to check flood defences," he said.

But while Cork city took the brunt of the flooding, deluges also hit county towns including Mallow, Fermoy, Youghal, Bandon, Cobh, Clonakilty, Carrigaline and Bantry. Access to Cobh on Great Island was again restricted because of flooding near Belvelly Bridge.

Train passengers using the services into and out of Waterford city were transferred on buses yesterday after Plunkett Station was closed at 9.30am because of flooding at the platforms. And train services between Limerick and Ennis were suspended because the rail line is flooded in two places.

SEWERS

Concern over the risks posed by the flooding prompted the HSE to issue a health warning for flooded areas including Cork, Limerick and Waterford.

In some areas, the flood waters have resulted in sewers and septic tanks overflowing with the sludge flowing into homes, streets and gardens.

The HSE urged parents not to allow children to play in flood waters given the potentially high bacteria levels present.

People were also urged to wash their hands carefully if they come in contact with floods and not to expose any cuts or grazes to such water.

Anyone who feels unwell after they have come in contact with flood waters is urged to seek urgent medical advice.

Irish Independent

Follow @Independent_ie

Escaping in eye of the storm

Fiach Kelly
March 11 2008 12:00 AM

"The eye of the storm was so large that it killed off most of the winds," Met Eireann's Pat Clarke told the Irish Independent. He added that there were some tidal swells caused by low pressure and winds.

"Pressure was so low and allied to that, there were onshore winds that caused swelling of one third to two thirds. The spring tides were already high to start off with."

Flooding yesterday affected Waterford city, where the River Suir burst its banks and flooded Scotch Quay and Williams Street. Flooding also affected the Waterford-Wexford road in New Ross.

Waterford rail services were also hit by flooding on the line at Plunkett Station and bus transfers were used to complete passengers' journeys until the service was restored just before two o'clock.

APPENDIX D

GROUNDWATER ANALYSIS

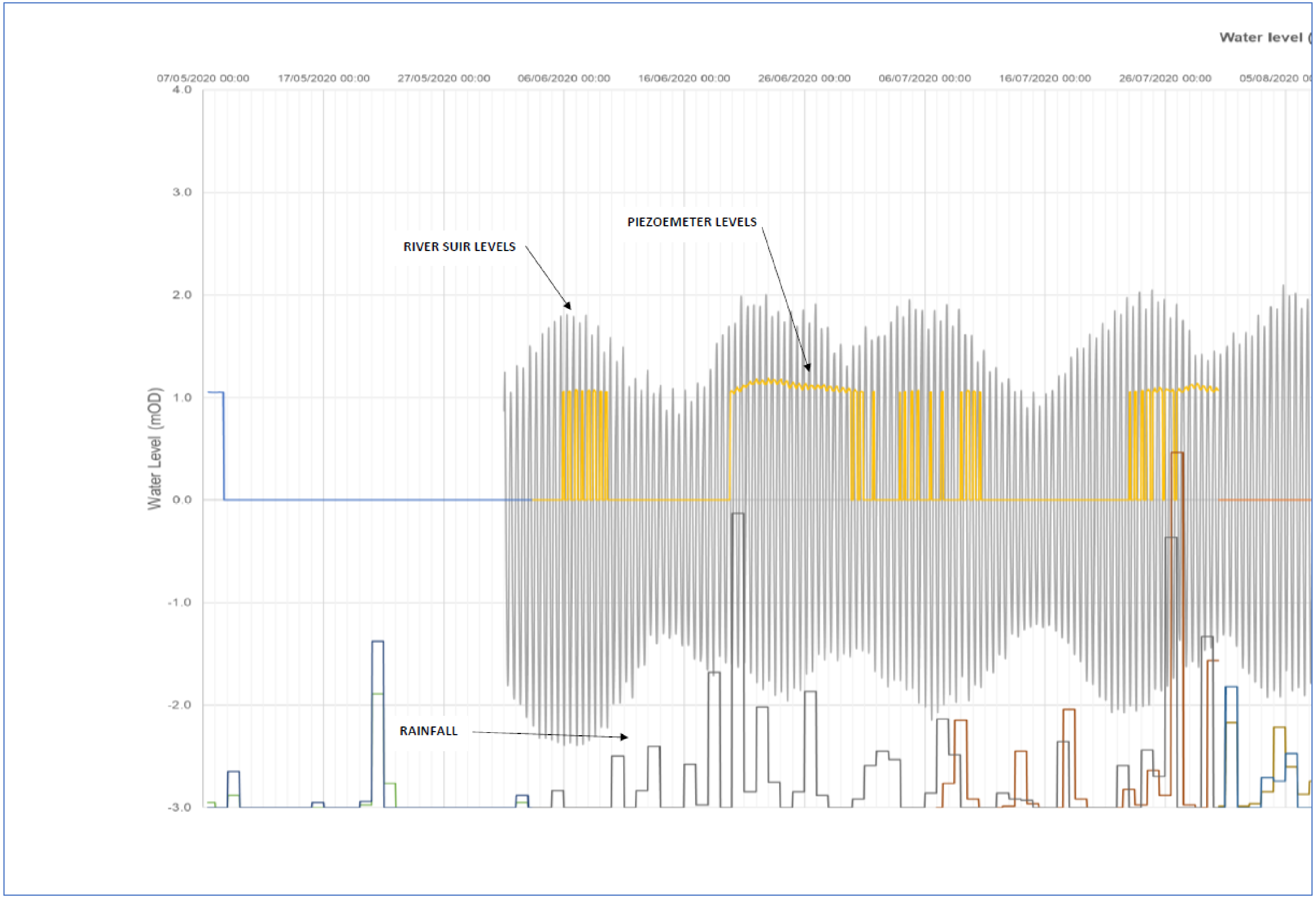


Figure 3 **(Part 1) Groundwater levels in BH302.** *Note that where dry conditions (no groundwater in response zone) were encountered, the reading defaults to +0.0mOD. Note: When the piezometer groundwater levels fall below 0.0 mOD the readings are set to 0 (indicating that ground water levels drop below the 0.0m level- this is notable during periods of neap\ moderate tides)*

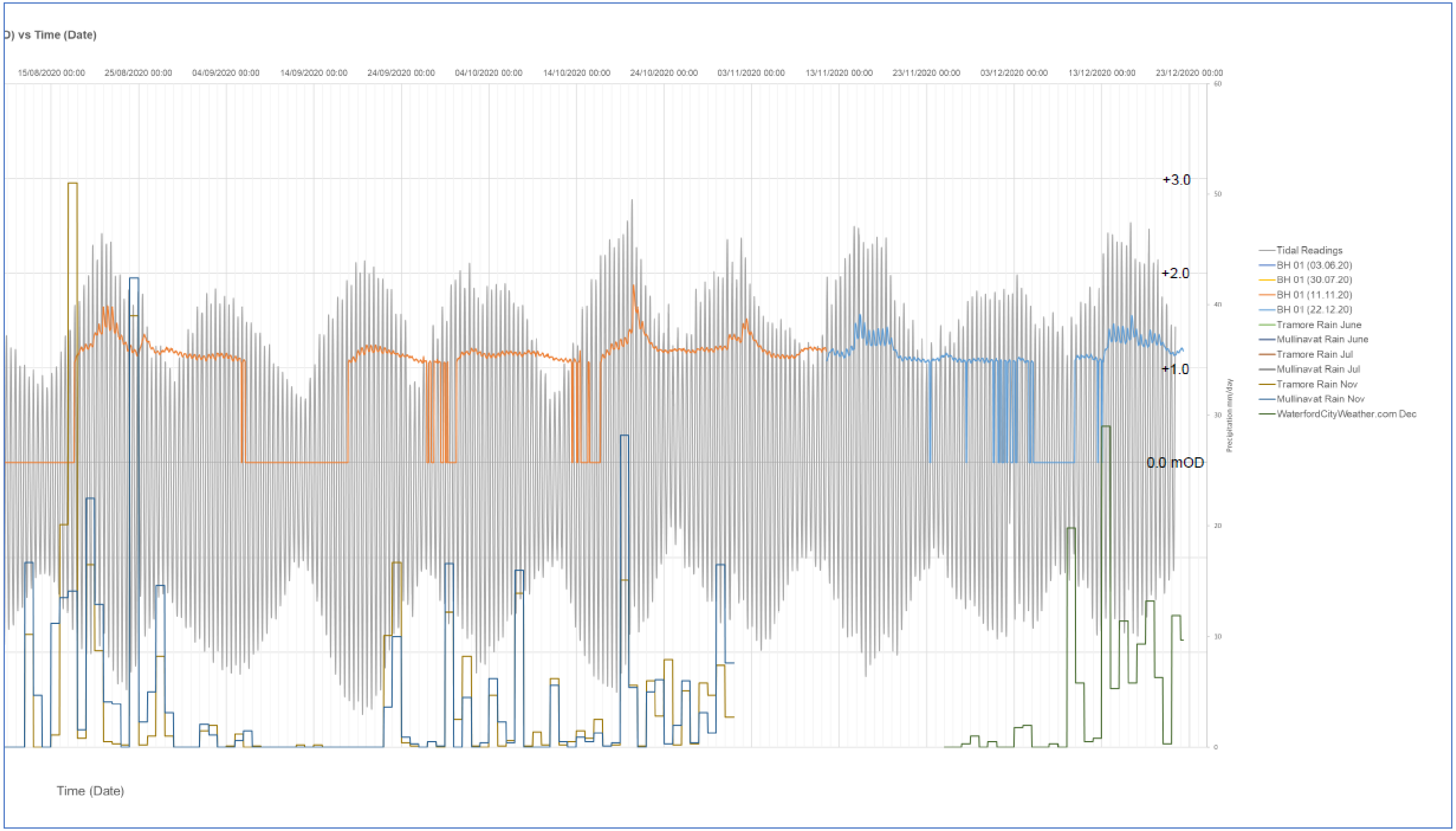


Figure 3 **(Part 2) Groundwater levels in BH302**. *Note that where dry conditions (no groundwater in response zone) were encountered, the reading defaults to +0.0mOD.*

Appendix 10.2
Hydraulic Modelling of the Flood Defences West Scheme River Suir Flood Wall

ROD ROUGHAN & O'DONOVAN

Comhairle Cathrach & Contae Phort Láirge Waterford City & County Council

Údarás Náisiúnta Iompair National Transport Authority

Iarnród Éireann Irish Rail

Rialtas na hÉireann Government of Ireland

Tionscadal Éireann Project Ireland 2040

Report No. HEL212204 v1.2

Hydraulic Modelling of the Flood Defences West Scheme River Suir Flood Wall

Prepared for

Roughan O'Donovan Consulting Engineers

April 2021

FINAL

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Hydraulic Modelling of the Flood Defences West Scheme River Suir Flood Wall

Job No.:	212204
Report No.:	HEL212204 v1.2
Prepared by:	Anthony Cawley BE, MEngSc, CEng MIEI
Date:	30th April 2021
Issue	**Final**

DISCLAIMER

This hydraulic modelling report has been prepared for Roughan O'Donovan Consulting Engineers as input to the Flood Defences West Scheme Project. Hydro Environmental Ltd. accept no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned.

Contents

1. INTRODUCTION

1.1 Background

Hydro Environmental Ltd., was commissioned by Roughan O'Donovan Consulting Engineers to carry out hydrodynamic modelling study of a proposed Flood Defence Wall a long a 730m Section of the north bank of the River Suir northwest of the Waterford Plunkett Rail Station. This hydrodynamic model study supports the Hydrology chapter of the Environmental Impact Assessment Report (EIAR) and the Natura Impact Statement (NIS). The purpose of this study is to predict the potential local change in flow velocities within the Suir Estuary and to assess the impact of the proposed flood wall on bed morphology as a result of changes to the hydrodynamic regime.

1.2 Description of Proposed development

The proposed development comprises c.1.1km of flood protection measures in the townlands of Mountmisery and Newrath in Co. Waterford, the townland of Newrath in Co. Kilkenny located along the north bank and within the foreshore of the River Suir in Waterford City. The development extends for approximately 1km to the west and 100m to the east of the Waterford (Plunkett) Station, following the alignment of the existing quay wall and the Iarnród Éireann (IÉ) railway corridor located to the north of the proposed development.

The proposed flood defence measures are for the protection of critical infrastructure including the existing Plunkett Station, the railway line east and west of Plunkett Station and the Rice Bridge roundabout. The proposed development will also form a continuation of the flood protection measures, Flood Defences East proposed along the North Quays Strategic Development Zone (SDZ) as part of the Transport Hub Part 8 planning approval, eliminating the risk of flooding to the Transport Hub.

A design flood level of +4.0m OD (metres above Ordnance Datum Malin) is proposed for this development. The design flood level has been based on a flood with an annual exceedance probability of 0.5% and allowances for climate change and isostatic tilt as noted below.

The design (top-of-wall) level for the proposed flood protection measures is +4.30m OD (metres above Ordnance Datum Malin). The following allowances are integrated into the proposed height of the flood defence walls:

- 0.5% annual exceedance probability combined tidal-fluvial event (+3.45 m OD)
- An additional 0.55m to allow for climate change and isostatic tilt; and,
- 0.30m freeboard to the wall, including local wave wake effects.

The proposed flood protection measures will consist of:

- Construction of c.365m of impermeable shallow underground trench (0.35m wide and up to 3m deep) within Iarnród Éireann's Plunkett Station car park.

- Total of c.185m of overground flood defence measures consisting of:
  - c.170m of glass flood barriers (each parapet is approx. 1.5m in length and 0.7m in height) fitted on the river side of the road edge vehicular parapets on R680 Rice Bridge roundabout and along the 3 roundabout arms; R448 Terminus St., R711 Dock Rd., and R680 Rice Bridge.
  - c.15m of demountable flood barriers on the R680 Rice Bridge (leading to the North Quays Strategic Development Zone);
- Remedial works to c.75m section of existing quay wall in front of the Plunkett Station car parking area by raising its height to between 0.6m and 1.2m to conform with the top-of-wall flood protection measures of +4.30m OD.
- Construction of c.730m of sheet pile flood defence wall with the top-of-the wall level at +4.30mOD consisting of:
  - c.540m of sheet pile wall within the foreshore from the riverside, 1m from the front face of the existing quay wall. The space between the sheet pile wall and the front face of the existing quay wall will be filled with clean imported granular fill. The intertidal zone of the sheet pile wall within the foreshore will be fitted with pre-cast concrete cladding material (“eco-seawall”).
  - c.190m of sheet pile wall will be installed on Iarnród Eireann land, 1m behind the existing quay wall. Construction of c.20m underground isolation structure comprising of a sheet pile cut-off wall and a concrete capping beam. The concrete capping beam will facilitate the installation of temporary overground flood barriers to the structure should these be required to be implemented during a flood event.
  - Demolition of up to 3m of existing quay wall at transition point between the landside and riverside sheet pile wall.
- Drainage works will consist of:
  - Remedial works to the existing drainage outfalls to the River Suir by extending them to reach an outlet within the new sheet pile wall and/or be retrofitted to pass through the new sheet pile wall, and installation of non-return valves.
  - Construction of new trackside drainage and groundwater drains to include 2 no. pumping stations and surface water outfalls to the River Suir.
  - Demolition of c. 540m of existing quay wall south of the railway corridor to approximately 800mm below the existing ground level.
  - Demolition of the existing quay wall to approximately 800mm below the existing ground level. The demolition of approx. 25m of the existing quay wall to a level of between 2 to 4m below existing ground level to facilitate the construction of a surface water pumping station.
- And all ancillary works.

The location of the proposed 730m length of sheet piled food defence wall upgrade located along the Suir channel bank within the North Quays area is presented here in Figure 1-1.

Figure 1-1 Location and Extent of the proposed Flood Defence Wall at the North Quays area

Figure 1-2 Location of storm drainage outfalls associated with the proposed Flood Defence Wall at the North Quays area

1.3 Existing Flood Defences on the North Quays

The existing flood protection measures along this section of north quays area consist of a quay wall along the banks of the River Suir. These existing flood protection measures are no longer effective in protecting the infrastructure on the North Quays from flood events. The existing quay wall is a masonry structure over most of its length built in the late 19th century and has been subject to numerous upgrades / repairs since including sections of mass concrete. Sections of this existing Quay Wall structure are damaged with structural cracks and damage to both foundations and wall and loss of masonry from the wall.

There has been a series of recent tidal flood events in the vicinity of Plunkett Station over the past two decades in which the estuary overtopped of sections of the existing flood wall at Ch 370, Ch 540, Ch 590 and between Ch. 900 and Ch.1050. The OPW CFRAM Flood inundation mapping of this area shows the lands behind the proposed floodwall to be inundated at both 200 (0.5% AEP) and 1000year (0.1% AEP) return period coastal flood events.

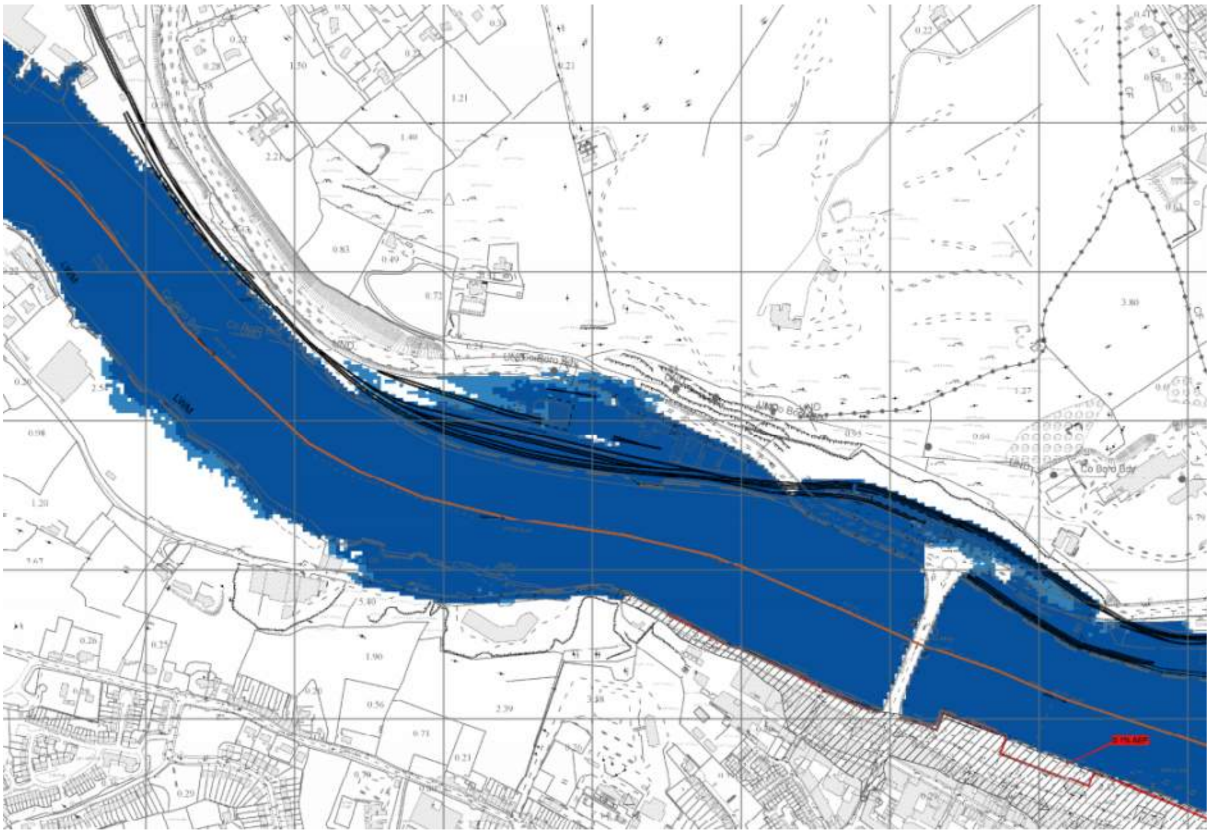

Figure 1-3 Extract from OPW River Suir CFRAM Map of 200year and 1000year coastal flooding

1.3 Sediment Sampling of channel bed

Aquafact Ltd. was commissioned to take a series of bed surface grab sediment samples for sediment distribution analysis across the width of the estuary channel and banks. They were unable to obtain any grab samples towards the middle of the River channel as no loose sediment was present with the bed sediment likely to be a compacted cohesive sandy Silt. The location where grab samples were obtained are shown in Figure 1-4 and the sediment distribution results are presented in Table 1.1.

The results show that where fresh unconsolidated sediment was captured it generally represented a silt and fine sand with little or no coarser sediments. It is likely given the generally high fines content that the sediment acts as a cohesive sediment that is consolidated over time and provides good resistance to erosion. With only the freshly laid silts mobile in the tidal flows.

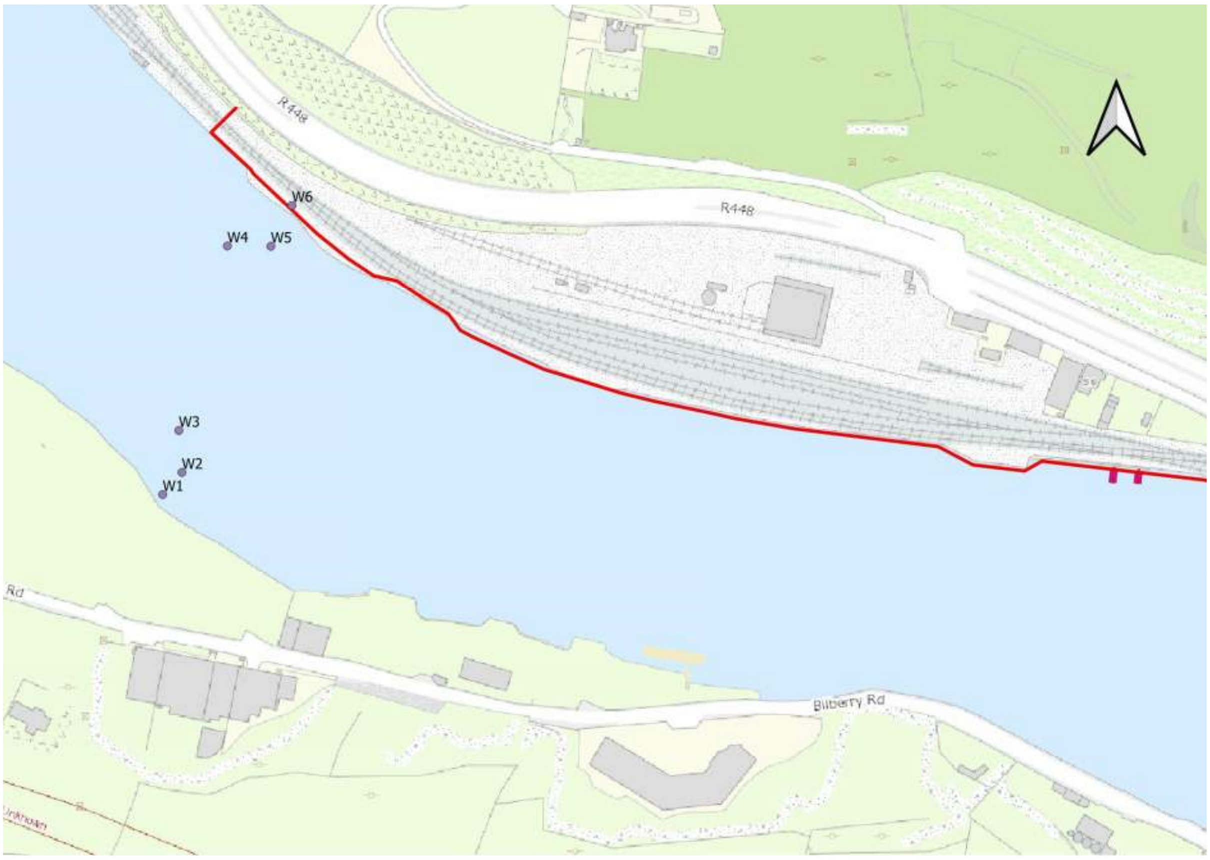

Figure 1-4 Bed Sediment sampling Locations

Table 1.1 Results from Sediment Sampling

Fraction Size (mm)	Description	W1 (%)	W2 (%)	W3 (%)	W4 (%)	W5 (%)	W6 (%)
< 0.063	Silt/clay	42.3	6.5	38.4	38.9	33.3	34.5
0.063 - 0.125	silt / v. fine Sand	30.6	40.9	32.6	36.5	34.6	38.2
0.125 - 0.250	fine Sand	7.9	27.7	9.5	8.9	14.4	8.7
0.250 - 0.500	medium sand	7.7	8.5	8	6.7	6.5	7.7
0.500 - 1.000	Coarse Sand	6.8	8.9	7.2	5.6	5.9	6.9
1.000 - 2.000	Very Coarse Sand	3.9	5.7	3.4	2.9	4	3.6
2.000 - 4.000	fine gravel	0.8	1.3	0.7	0.3	0.8	0.3
> 4.000	medium gravel	0.2	0.6	0.1	0.2	0.5	0.1

2. HYDRAULIC MODEL DESCRIPTION

2.1 General

In order to assess accurately the potential impact of the proposed 740m length of sheet piled flood wall on the hydrodynamics of the River Suir adjacent to the development a high resolution 2-D hydrodynamic model of the local reach was developed. Two-dimensional modelling was chosen in preference to 1-d modelling so as to evaluate spatially the tidal circulation and flood inundation of the estuary banks. To efficiently drive the high resolution 2-D model a 1D node-link river estuary model was developed, which extended from southern open sea upstream to the tidal extents on the Suir, Nore and Barrow Rivers, as presented in Figure 3. This enabled the large tidal flows generated within each of the estuaries to be computed under varying tides and fluvial inflow conditions and the relevant output from this model in terms of flow and water level hydrographs was specified as boundary conditions to drive the local 2-D model.

2.2 HEC-RAS 1-D model

A 1D river model using HEC-RAS hydraulic software system developed by the U.S. Army Corps of Engineers was used to model Waterford Harbour and its full estuarine reaches of the Suir, Barrow and Nore Rivers. HEC-RAS is the industry standard used internationally for hydraulic modelling of river and estuarine systems. HEC-RAS implements a 1-dimensional model of longitudinal channel flow (depth and width averaged) and solves for water elevation and average cross-sectional velocity under unsteady flows solving the full St. Venant equations that include the momentum and mass equations. HEC-RAS 1-D is ideal for modelling narrow elongated estuaries where the dominant flow is longitudinal with little variation in the energy slope in the transverse direction.

The unsteady model allows for tidal varying flow and elevation boundary conditions to be specified at the downstream Open Sea boundary and inflow hydrographs at the upstream fluvial boundaries. It also facilitates internal inflows at various nodes to allow for inclusion of lateral tributary inflows. The HEC-RAS model requires cross section survey data of bed and overbank levels versus Station distance from left overbank to right overbank and facilitates different channel roughness's and various structure types including bridges, culverts spillways and weirs.

2.3 TELEMAC Hydraulic Software System

The TELEMAC system is the software of choice for modelling the complicated hydrodynamics of the Suir Estuary at the bridge crossing, particularly given the very high computation refinement required to model the individual slender piles for the proposed bridge structure and the collision fender system. TELEMAC is a software system designed to study environmental processes in free surface transient flows. It is therefore applicable to seas and coastal domains, estuaries, rivers and lakes. Its main fields of application are in hydrodynamics, water quality, sedimentology and water waves.

TELEMAC is an integrated, user friendly software system for free surface waters. TELEMAC was originally developed by Laboratoire National d'Hydraulique of the French Electricity Board (EDF-LNHE), Paris. It is now under the directorship of a consortium of organisations including EDF-LNHE, HR Wallingford, SOGREAH, BAW and CETMEF. It is regarded as one of the leading software packages for free surface water hydraulic applications and with more than 1000 Telemac Installations Worldwide.

The TELEMAC system is a powerful integrated modelling tool for use in the field of free-surface flows. Having been used in the context of very many studies throughout the world (several thousand to date), it has become one of the major standards in its field. The various simulation modules use high-capacity algorithms based on the finite-element method. Space is discretised in the form of an unstructured grid of triangular elements, which means that it can be refined particularly in areas of special interest. This avoids the need for systematic use of embedded models, as is the case with the finite-difference method. Telemac-2D is a two-dimensional computational code describing the horizontal velocities, water depth and free surface over space and time. In addition it solves the transport of several tracers which can be grouped into two categories, active and passive, with salinity and temperature being the active tracers which alter density and thus the hydrodynamics.

The TELEMAC System is a set of finite element programs designed to solve free water surface problems. A series of modules are available for solution of hydrodynamics, transport and dispersion of pollutants, sediment transport and wave dynamics. These are:

- TELEMAC-2D: 2-dimensional depth averaged hydrodynamics and transport and dispersion of tracers
- TELEMAC-3D: 3-dimensional hydrodynamics, transport and dispersion and sediment movement

- TOMAWAC: A third generation spectral wave model representing the generation of waves due to winds or offshore climates and propagation into shallow waters.

- ARTEMIS: A harbor wave model that solves the mild slope equation in elliptical form and includes the processes of refraction by bed shoaling, wave breaking, diffraction and reflection of waves due to structures.

- SISYPHE: Sediment transport module solving bed and suspended load of cohesive and non-cohesive sediments and can be coupled with TELEMAC-2D, -3D and TOMAWAC for the hydrodynamic transport and bed shear stress calculations

Each TELEMAC Module uses a completely flexible unstructured mesh of triangular elements allowing it to efficiently model complex geometry problems such as harbours and estuaries.

2.4 Data Sources

A range of survey information was utilised in constructing the 1D and 2D models which are described below:

- OPW CFRAM river cross-section survey of the Suir, Nore and Barrow river channels
- Apex cross-sections River Survey of the Suir at Waterford
- Infomar Sea bed Survey of Waterford Harbour
- Admiralty Chart of Waterford Harbour
- Apex Topographical Survey of the SDZ site and adjacent lands
- 2m Lidar Survey of Waterford City
- High resolution bathymetric Survey of the river reach by Murphy Surveys in 2021.
- Bed sediment sampling by Aquafact at the bridge crossing
- ADCP (Acoustic Doppler Current Profiler) current metering over a 24day period at 1m vertical Bin depths by Aquafact.

2.5 1-D Model Development

River channel and overbanks were defined for approximately 115km of river reach along the main river/estuarine channels of the Suir, Nore and Barrow. The complete estuarine reaches which extend many kilometres upstream along the Suir, Barrow and Nore were included in the model so that the simulations accurately accounted for the large tidal exchange volume that generate significant ebbing and flooding flows at

Waterford Harbour. The model domain is presented in Figure 2-1 and the HEC-RAS model schematic in Figure 2-2.

The model domain extends from the open sea off Dunmore to 1km upstream of Carrick-On-Suir on the Suir, to 3km north of St. Mullin's Village on the River Barrow and to Inistoige on the Nore. A total of 249 river sections were included from the various surveys. Survey information was not available for a 19km upstream middle section of the Suir Estuary from Woodstown, Waterford to Piltown, southeast of Carrick-on-Suir. This unavailable (un-surveyed) reach was represented by simple liner interpolation between the nearest available upstream and downstream surveyed section so as to account for the tidal exchange volume.

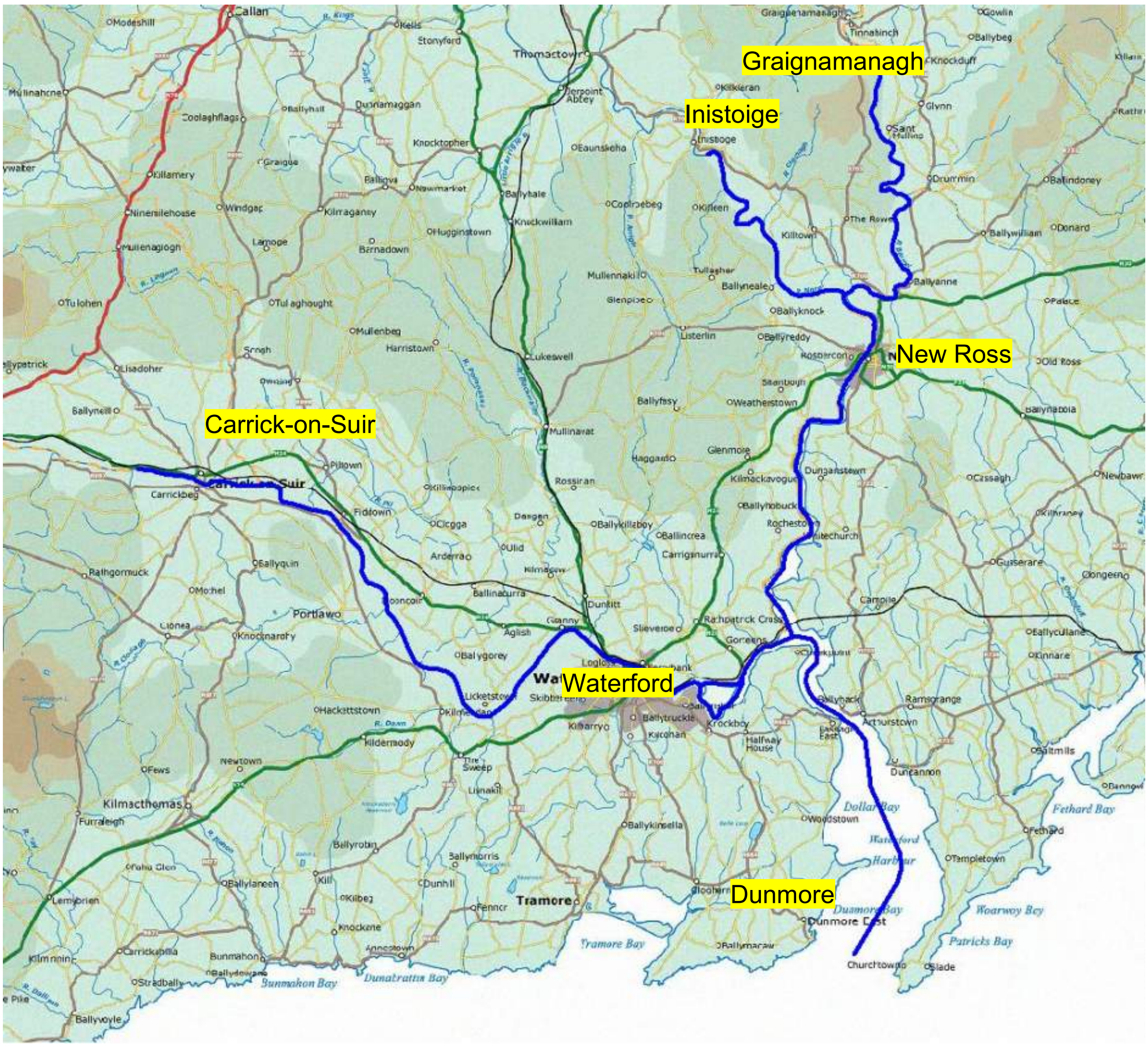

Figure 2-1 Extent of one-dimensional tidal model for the Waterford Flood Defences Project

A Manning's roughness coefficient (n) of 0.028 was used for the various estuarine reaches and a lower roughness coefficient of 0.024 for the wider and deeper Waterford Harbour reach. These roughness coefficients are considered to be appropriate for the wide deep estuarine reaches through Waterford. The HEC-RAS 1-D model set-up included the loop configuration around King's island in Waterford Harbour.

Figure 2-2 ***HEC-RAS Model Schematic***

2.6 2-D Model Development

The 2-D model domain area is presented in Figure 2-3 which represents the local estuarine reach at Waterford City, some 4km in length and 90ha in area. The existing model has a variable mesh set with a general mesh spacing of 10m remote from the flood wall reach section and a more refined mesh within the flood wall reach section of 5m and local refinement in the vicinity of the flood wall of 2m. The total number of computational nodes in the finite element model is 20,652 and 40,168 triangular finite elements. Tidal Flat wetting and drying option was included in the model to facilitate out of channel flow and the wetting and drying of the channel banks with the rising and falling of the tide. Computationally this can lead to some numerical oscillation in water surface elevation and computed flows in the vicinity of the drying element. The Mesh structure in the vicinity of the proposed flood wall is presented in Figure 2-7.

Figure 2-3 2-D Model Reach of Suir Estuary at Waterford City

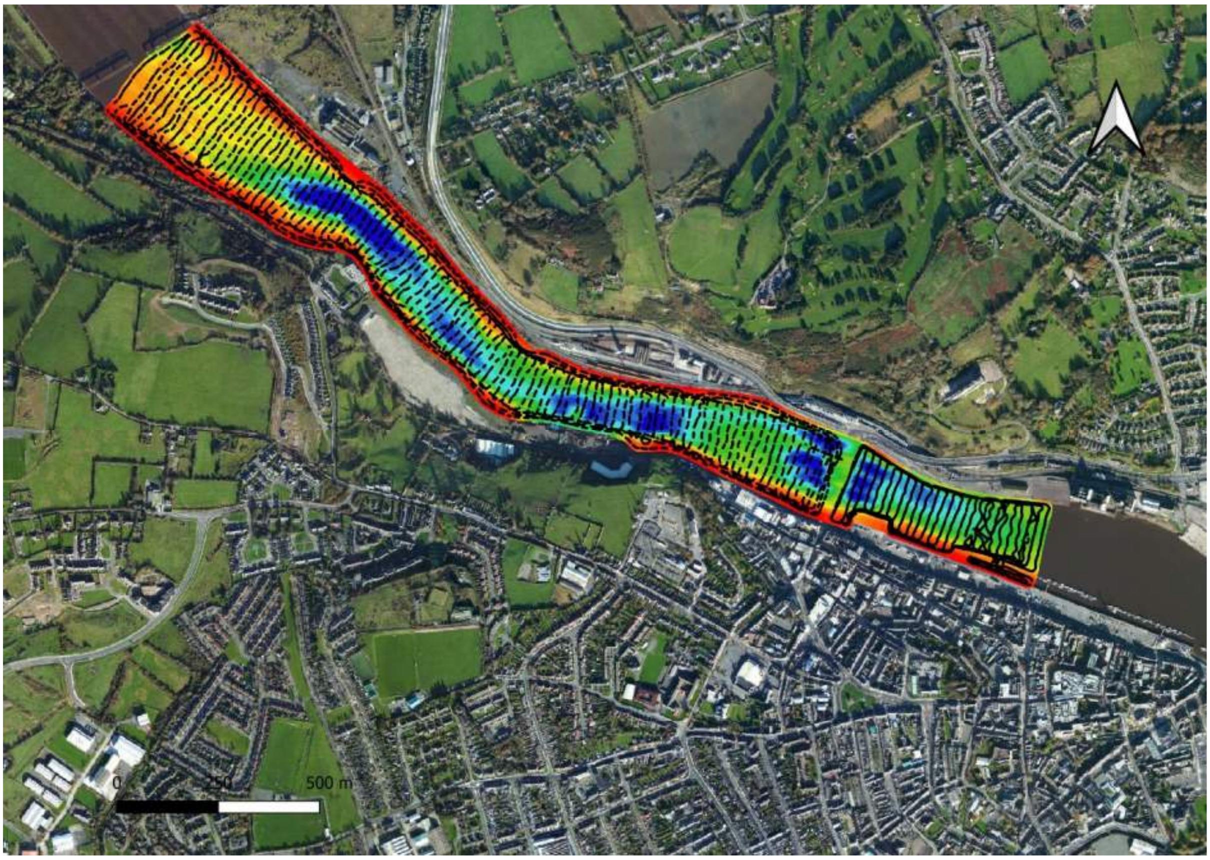

Figure 2-4 2-D Recent 2021 Murphy Survey's bathymetric coverage

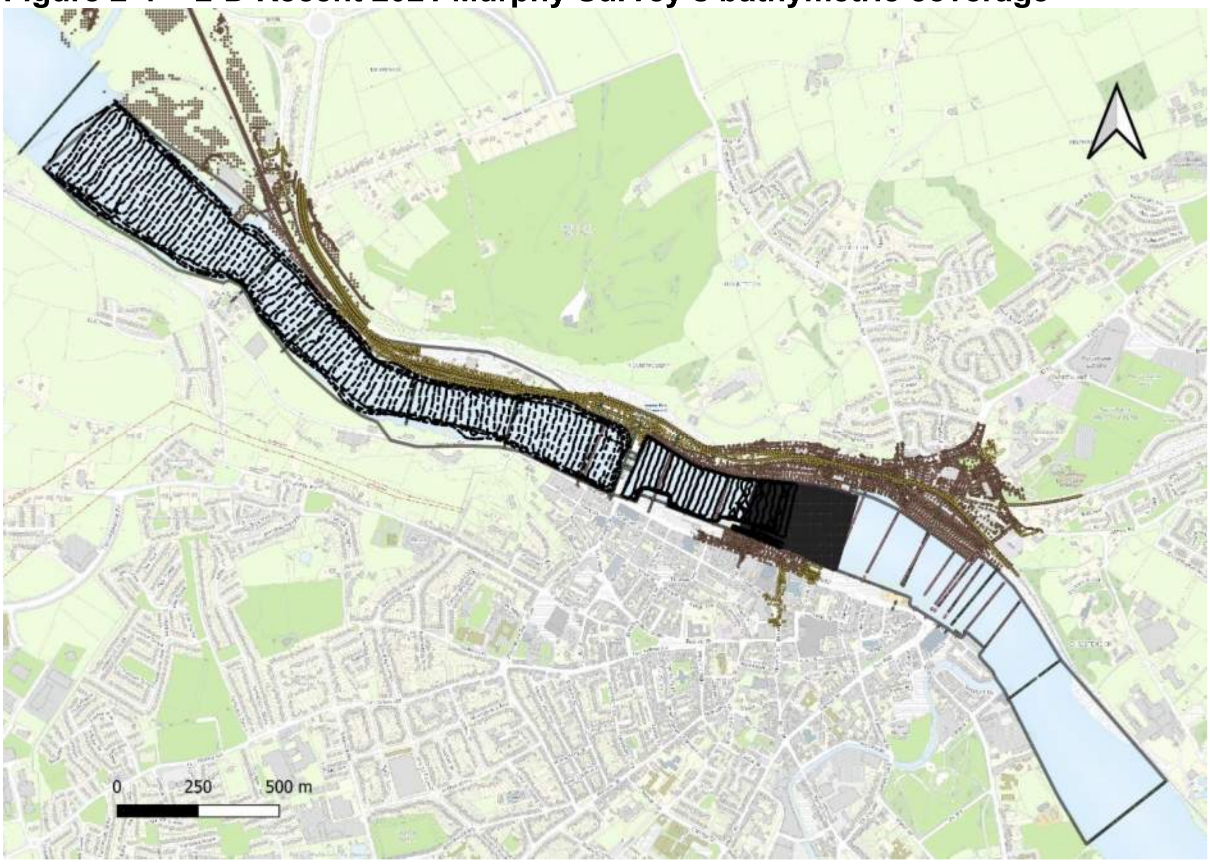

Figure 2-5 combined Bathymetric and topographic surveys including OPW CFRAM cross-section survey data (lidar data not included in figure)

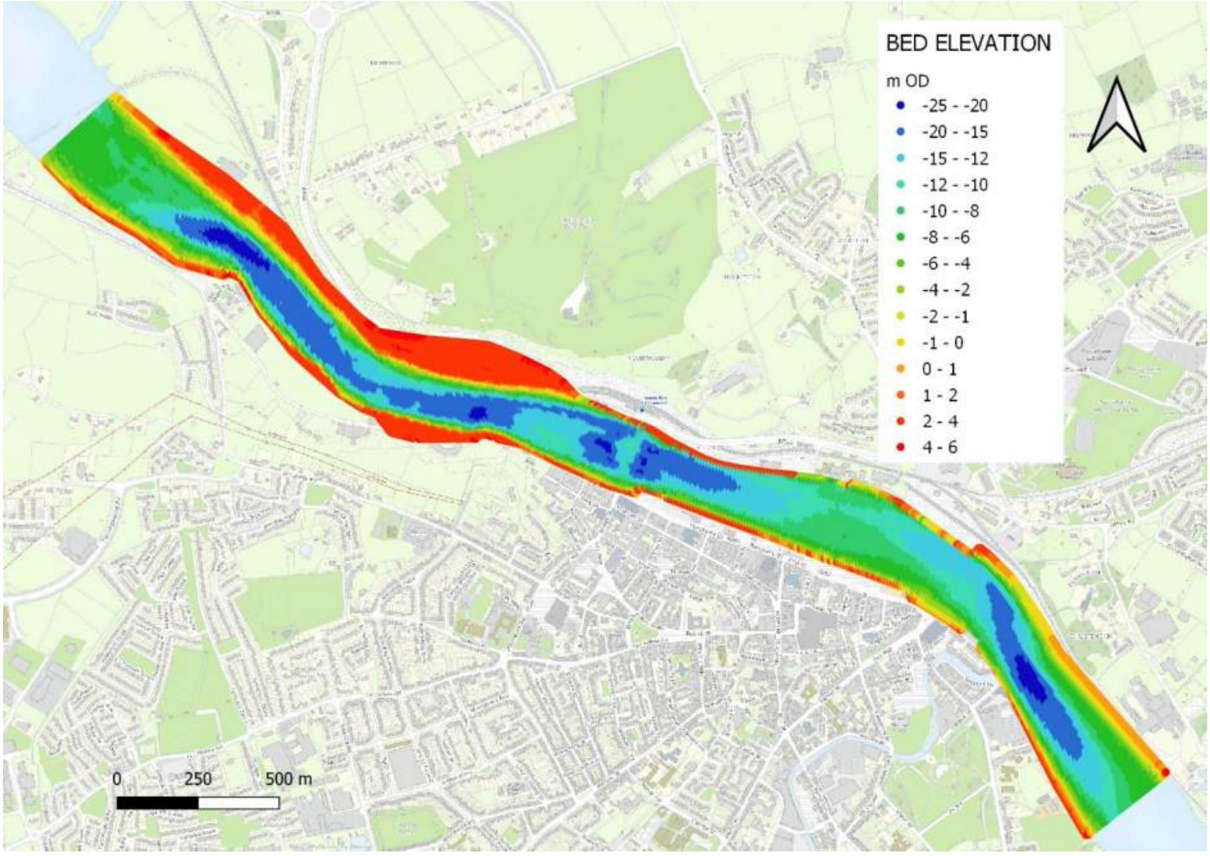

Figure 2-6 Modelled Bathymetry

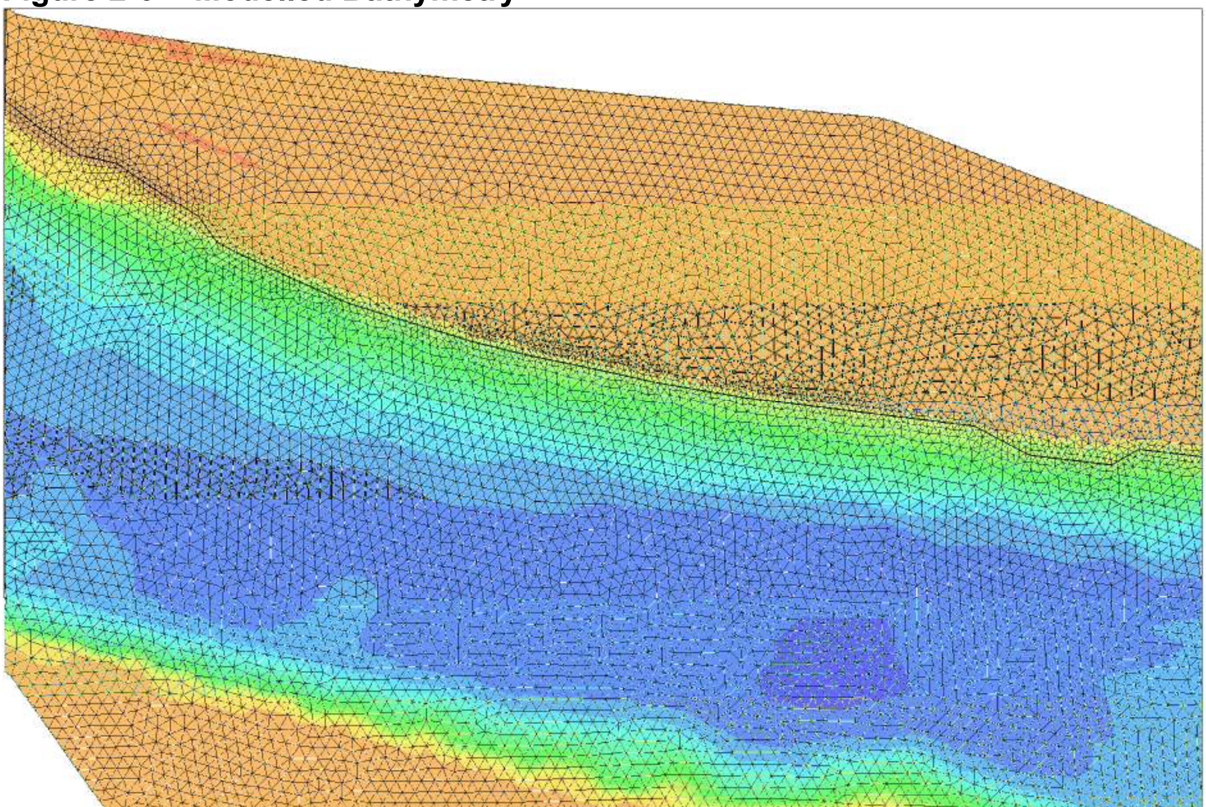

Figure 2-7 Finite Element Mesh for existing case in vicinity of the proposed Flood Wall alignment

2.7 Model Calibration

The hydrodynamic model was calibrated against the tidal velocity and elevation measurements obtained from a previous survey that was carried out in support of the hydrodynamic modelling for the Sustainable Transport Bridge planning application. This hydrographic survey was performed by Aquafact (2018) using an Acoustic Doppler Current meter for the period 25th June 2018 to 19th July 2018. The ADCP was deployed for 24 days near the proposed pedestrian bridge crossing section, located 42m out from the North Quay at National Grid Reference 260782, 112796 (refer to Figure 2-8).

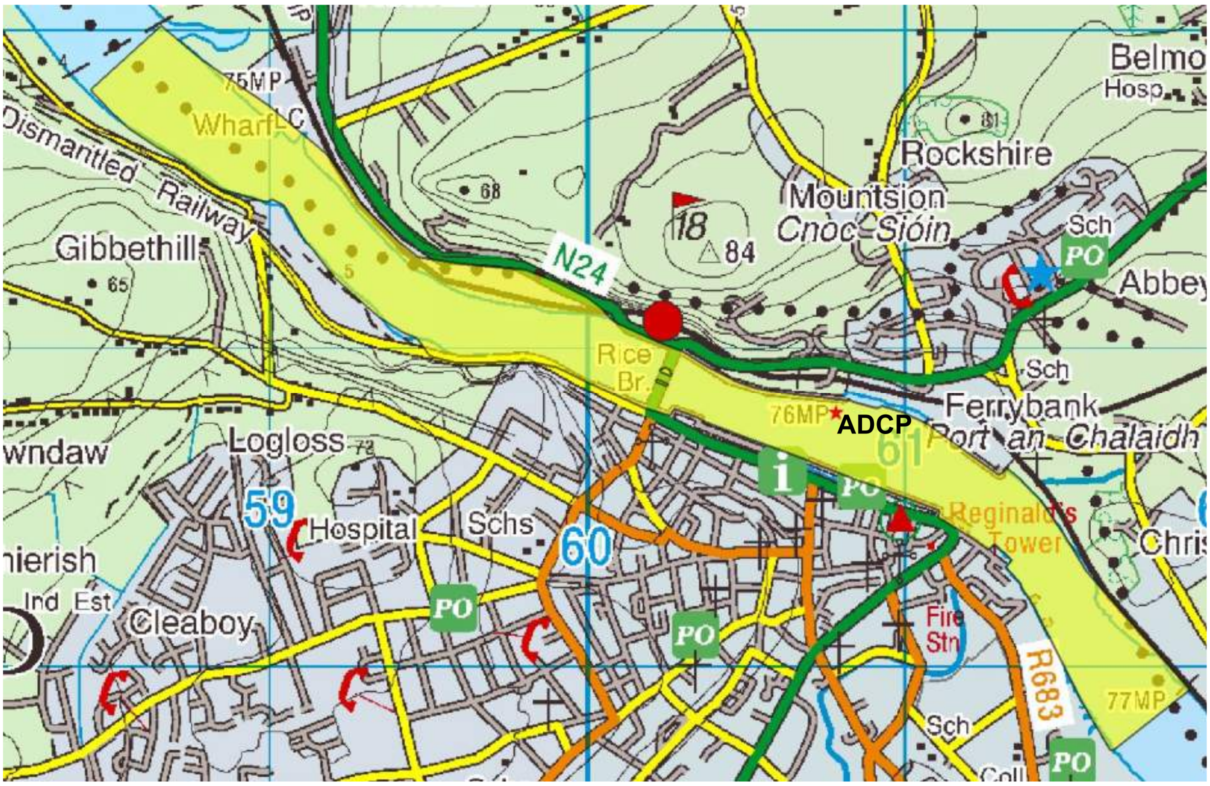

Figure 2-8 ***Location of ADCP current meter for model calibration.***

The tide elevation recorded at Dunmore East tidal gauge was input to the 1D HEC-RAS model and the model was run for the 24day simulation period so as to produce flow and elevation hydrographs at the upstream and downstream locations.

The hydrodynamic model was run for a start date of 25/06/2018 14:00 to the 19/07/2018 12:00 for a computational time step of 1second and simulation results were output every 10 minutes for the complete model domain and stored in a binary results database. Time series of tide elevation and depth averaged velocities were generated for the measurement point from this results database. A final calibrated

Manning's roughness of 0.028 was used with a full k-ε turbulence model to simulate eddy viscosity / turbulence and accurately produce the observed hydrodynamics.

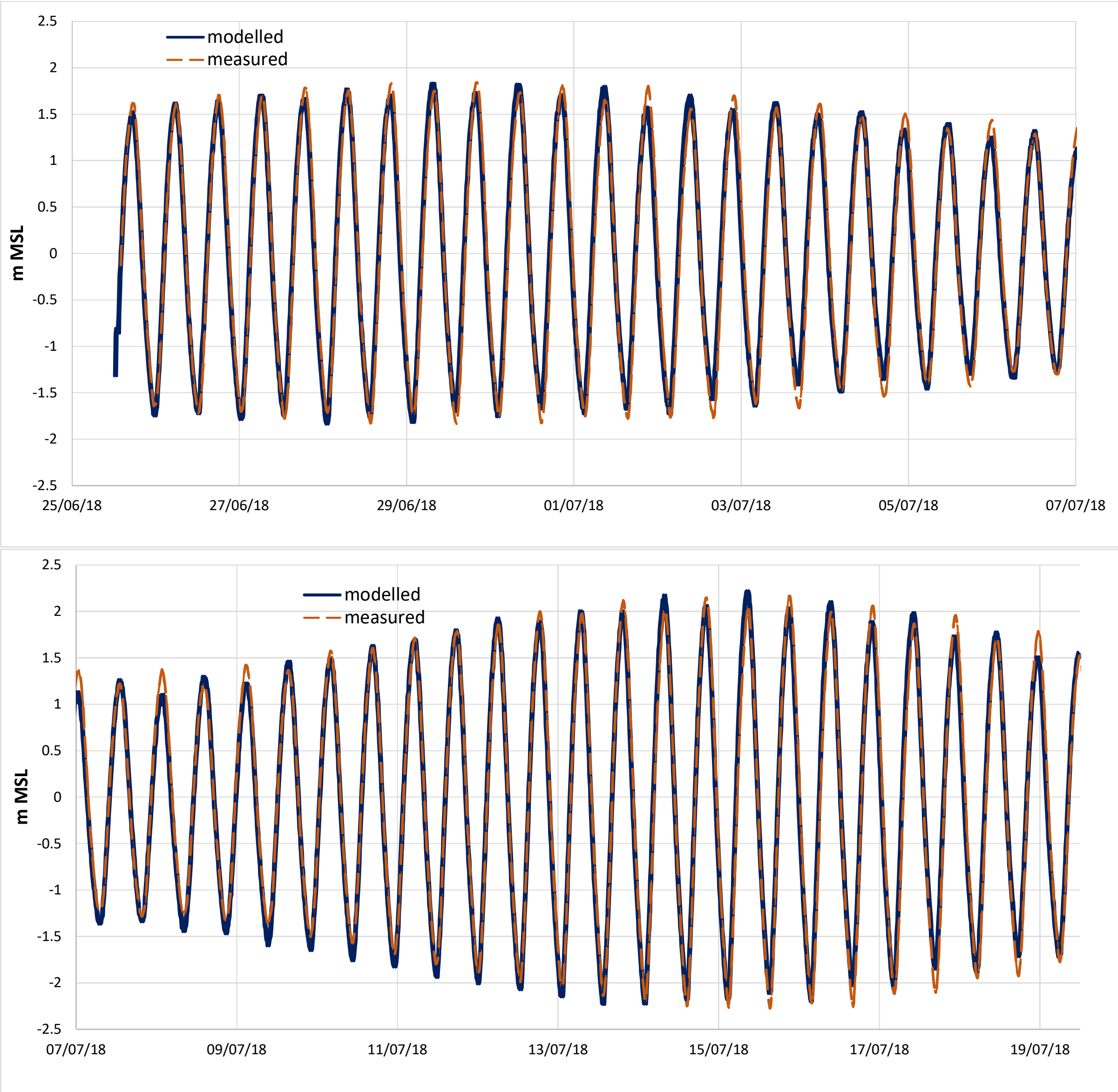

Figure 2-9 Measured and Predicted Tidal Elevation 25 June 2018 to 19 Jul 2018

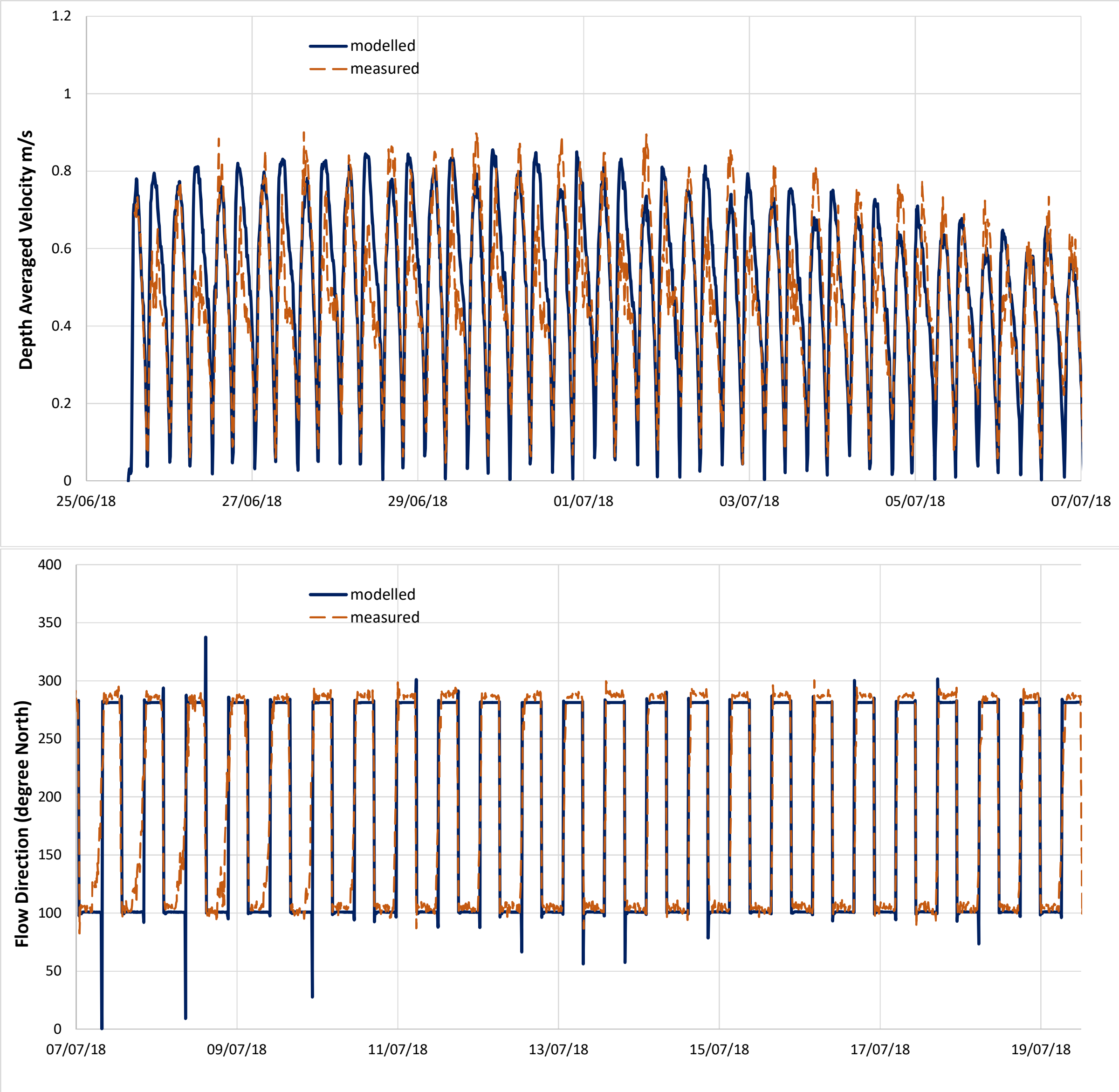

Figure 2-10 Measured and Modelled Depth Averaged Velocity Magnitude and Direction 26 June 2018 to 7 July 2018

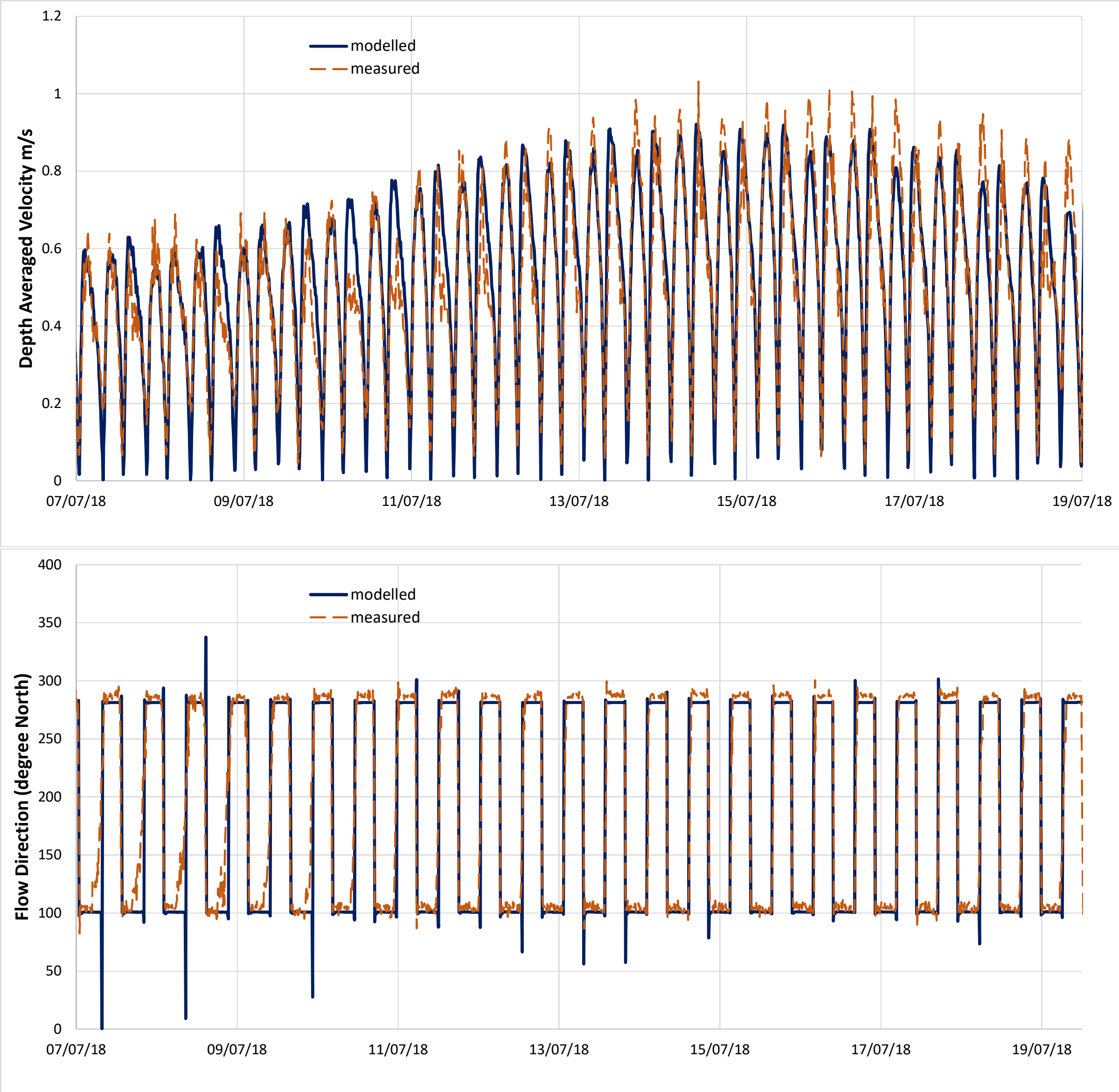

Figure 2-11 Measured and Modelled Depth Averaged Velocity Magnitude and Direction 7 July 2018 to 19 July 2018

2.8 Proposed Flood Wall Finite Element Model

The proposed case which includes the proposed 740m long sheet piled flood Wall and three no. proposed drainage outfalls was modelled using the same mesh structure as the existing case model but with the defended land behind the flood wall removed and a lateral model boundary included along the proposed flood wall alignment, refer Figure 2-12. This is the preferred method for modelling a vertical structure such as a flood wall. The avoidance of remeshing for the proposed case eliminates potential for additional numerical noise associated with the performance of two different finite element meshes which can generate differences that mask the impact of the physical changes being modelled.

An alternate to this approach is to raise the ground levels defended behind the flood wall to the defended level but this would model the flood wall as a sloped wall structure as opposed to a vertical wall which for 2m meshing represents a significant difference and likely to cause additional artificial roughening on the flow field in the vicinity of these elements. A regular vertical sheet piled wall is expected to produce a smoother effect with less resistance on the flow passing along the face of the wall.

The effect of the three proposed outfalls were modelled by locally rising the bathymetry at the model nodal points in the vicinity of the outfalls to the proposed top of outfall elevation.

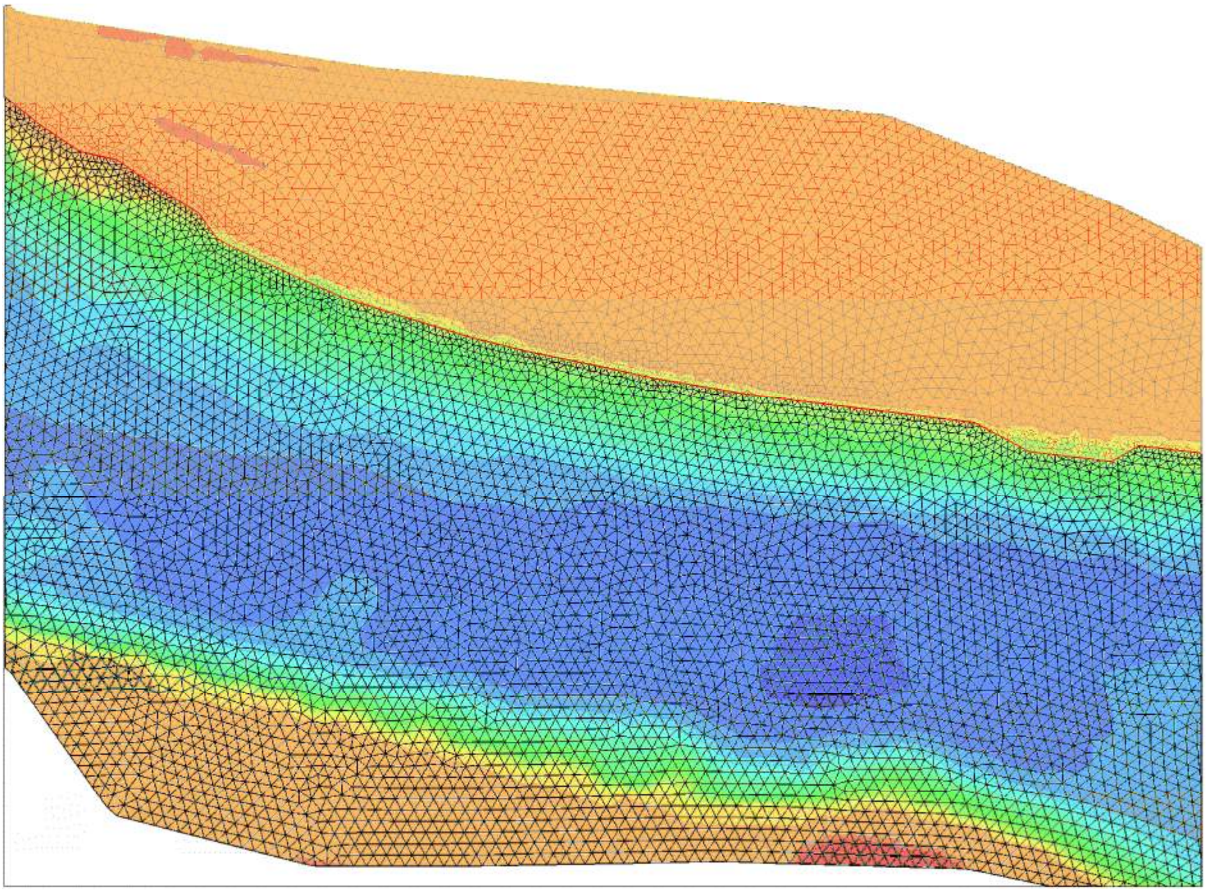

Figure 2-12 Proposed Case Model with model boundary set along the proposed flood wall alignment

3. HYDRODYNAMIC SIMULATIONS

3.1 Introduction

A 24day spring – neap – spring tide using the tidal observations recorded from the 25th June to the 19th July 2018 was simulated so as to assess the potential change in tidal velocities and bed shear stresses within the study reach under existing and proposed cases.

In addition to the normal lunar tide simulations a number of extreme flood simulations were also performed that included both tidal storm surge and fluvial flood events.

3.2 Predicted Hydrodynamic change

The computed neap and spring tide ebb and flood velocities for the existing (do nothing scenario) case are presented in Figure 3-1 to Figure 3-4. These simulation results show the strongest currents located in the middle of the channel where water depths are the largest. The plots show significant reduction in flow velocities in the shallow depths along the channel banks. The velocity plots show locally increased velocities around the existing piers at Edmund Rice Bridge. The flows are generally rectilinear with the longitudinal channel access and maximum flow velocities reaching 0.6 to 0.7m/s on the neap tides and 0.9 to 1.0m/s on spring tides towards the centre of the channel adjacent to the proposed Flood Defence Wall. Along the alignment of the Flood Wall the stronger currents along the bank and toe of the Flood Wall occur on the Flooding Tide whereas on the Ebbing tide the flow velocities slightly pull away from the bank as it navigates the slight NW to ESE bend in the river channel.

Velocity difference plots between proposed and existing cases are presented in Figure 3-5 to Figure 3-8 for neap and spring tides at mid-ebb and mid-flood respectively, These figures show the extent of the estuary area hydraulically impacted by the sheet pilled flood defence wall and associated storm outfalls. The simulations show an increase in velocity along the middle section of the flood wall alignment on both ebb and flood tidal flows and a reduction in velocity locally in the vicinity of the outfall structures with their slightly raised profile. The higher increases in velocity between existing and proposed cases occur on the spring tides and on the flooding tide with a general local increase of 0.05m/s and larger increases along the toe of the Flood wall of 0.075 to 0.1m/s. These local changes and are not significant in comparison to the computed baseline velocity magnitudes under the present existing situation. There is no perceptible change in flow velocities in the main, deeper channel section or at the far bank. The predicted upstream and downstream changes to the flow velocity magnitude at the near bank is local and not very extensive.

To demonstrate the effect of the proposed flood defence wall on tidal velocities a series of 10 output reference locations were chosen, refer to Figure 3-9. The time series plots of existing velocity magnitude under the spring and neap tidal conditions for a 24day simulation period and computed change in velocity magnitude is presented in Figure 3-10 to Figure 3-19. Location 1 to 6 show generally an increase in velocity magnitude over the existing and sites 7 and 8 near the outfalls show a reduction. These changes in velocity magnitude is small relative to the existing velocities and will not represent a significant change to the hydrodynamics of the flow regime of the bed morphology and sediment transport within the reach. Reference site 1 upstream and 9 and 10 further off shore show minimal effect on velocity magnitudes. Only local changes to velocity along this northern bank are predicted with no impacts to flows in the main channel of on the adjacent riverbank.

3.3 Predicted Channel erosion

In order to access the potential impact on bed sediments the bed shear stress is computed using the Chezy equation for bed shear. This is then compared to the critical bed shear of a given sediment particle size for initiation of mobilisation. The Mobility Factor M is defined as the ratio of bed shear to critical bed shear, such that factors exceeding 1 represent mobilisation of the fresh unconsolidated silt/sediment and less than 1 represents immobility with the deposited sediment remaining in place on the bed.

$$\theta_{cr} = \frac{0.3}{1+1.2\mathrm{D}_{gr}} + 0.055\left[1 - e^{-0.02\mathrm{D}_{gr}}\right] \qquad (1)$$

$$D_{gr} = \mathrm{D}\sqrt[3]{\frac{g(s-1)}{\vartheta^2}} \qquad (2)$$

$$\theta_{cr} = \frac{\tau_{cr}}{\rho(s-1)gD} \qquad (3)$$

$$\tau_{cr} = \theta_{cr}\rho(s-1)gD \qquad (4)$$

Where g = 9.81m/s2, s= 2.65 (specific density), D_{gr}= dimensionless grain size, θ_{cr} critical Shield's parameter, ϑ viscosity = 1.2 x $10^{-6}$$m^2$/s, ρ water density kg/m3, D is the sediment diameter and τ_{cr} is the critical shear stress for mobilisation.

Bed Shear Stress is calculated as follows

$$\tau = \frac{U^2\rho}{C'^2} \qquad (5)$$

Where

$$C' = \frac{H^{\frac{1}{6}}}{ng} \qquad (6)$$

U depth averaged velocity, H is water depth, n is manning roughness.

The mobility Factor is expressed as

$$\mathrm{M} = \frac{\tau}{\tau_{cr}} \qquad (7)$$

M=1	At some point, the fluid shear will just be in balance with the critical shear stress for erosion (M=1). As flow increases past this point, the grain will start to move along the bed: at first by 'saltating' or jumping along the bed (bed load). These jumps are caused by turbulence in the flow.
$1<M<8$	In this range, the size and mass of the grain is sufficient that it falls back to the bed quite quickly after each jump. As the amount of bed load increases, bedforms such as ripples and/or dunes develop. Bedform length of ripples is mainly a function of grain-size while the height of the bedform is dependent on flow intensity. For dunes, bedform length is mainly a function of flow depth.
$8<M<14$	As flow intensity increases, the bedforms start to reduce in height, the 'hang time' of the particles increases.
$14<M<65$	Sediment is now being swept higher into the flow field. The lift forces in this increasingly turbulent flow field are sufficient to keep the grain in suspension. The onset and characterisation of suspended load is, in large part, controlled by the ratio of sediment fall velocity to the total shear velocity, (w/u_*).

The sediment sampling indicates a silty sediment. This sediment forms over time a cohesive consolidated sediment which provides strong resistant to erosion. Only in the slacker waters towards the channel banks was unconsolidated silt encountered and retrieved by the grab sampling, which is likely to have been freshly laid and the underlying sediment is likely to be a consolidated cohesive clayey silt. Such consolidated cohesive material provides good resistance to erosion and can have a critical shear stresses that exceed a coarse sand in respect to bed erosion.

The computed maximum Bed Shear Stresses for the existing and proposed flood wall case is presented in Figure 3-20 to Figure 3-27 for neap and spring, flood and ebb flows respectively. These generally show relatively low shear stress magnitudes along the riverbank of less than 0.7Pa and typically below 0.5 Pa, which would be of insufficient shear force to erode a consolidated cohesive sediment but sufficient both under the existing and proposed cases, particularly on spring tides (ebb and flood) to mobilise unconsolidated silt and fine sand primarily on the flooding tide but also to a lesser extent on the ebbing tide. The computed mobility factors for fine silt is presented in Figure 3-28 to Figure 3-35 for the neap and spring tides and existing and proposed cases and shows local increases in the silt mobility factor in the vicinity of the bank area immediately adjacent to the flood wall encroachment into the riverbank from Chainage Ch.540 to Ch.900.

The conclusion reached from this analysis is that the computed velocity increases from the proposed vertical sheet piled wall are relatively small and of insufficient magnitude to produce shear stresses (i.e., generally <0.7Pa) that would result in any potential significant erosion of the permanent consolidated sediments on the channel bed and banks in the vicinity of the affected area. Fresher unconsolidated silts will be mobile under ebb and flood conditions both for the proposed and existing cases.

3.4 Extreme Flood Conditions

The impact of the proposed flood defence wall on the hydrodynamics was also assessed under worse case scenarios in respect to a combined fluvial and coastal storm surge event. The extreme flood simulations considered were

- A 200year storm Surge Tide (over two highwater cycles coinciding with a 2year fluvial flood event in the Rivers
- A 100year Fluvial Flood event in the rivers coinciding with a high spring tide event.

The predicted impact on flow velocity magnitudes for these extreme flood events are presented in Figure 3-36 to Figure 3-39. These show the fluvial 100year flooding event to generate lower velocities and velocity change than the 200year tidal storm surge event. The 200 year storm surge event which limited to a very short period of a 12.5 hour tidal cycle produces slightly higher velocities and velocity change over the normal range of tidal events considered earlier in section 3.2 as to be a local impact with the maximum change occurring along the toe of the Sheet pile and no effect to the deeper channel sections. The conclusion reached given the low probability of such an event and the limited duration of the mid-flood and mid-ebb flows that insignificant morphological change is likely to occur along the impacted section adjacent to the sheet piled wall.

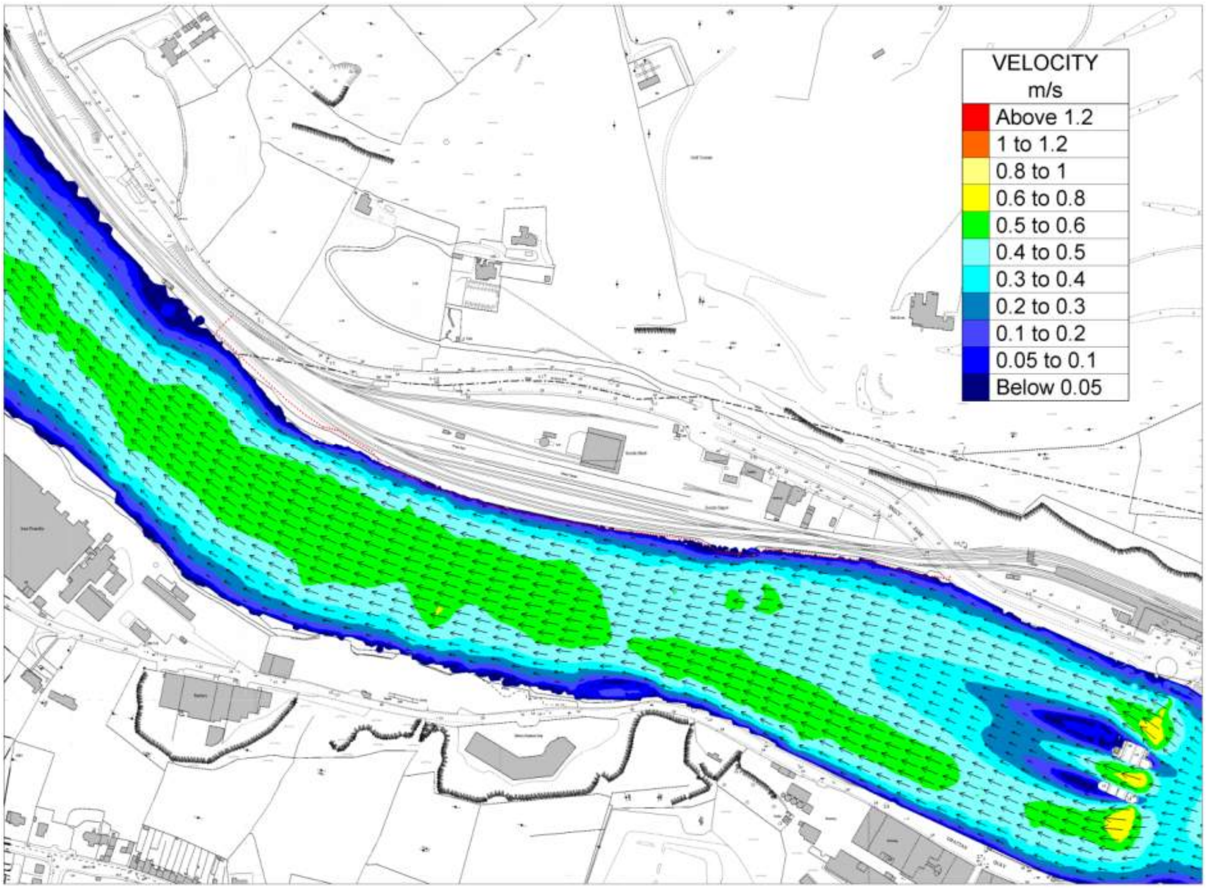

Figure 3-1 Mid-Flood velocities under existing conditions - Neap Tide

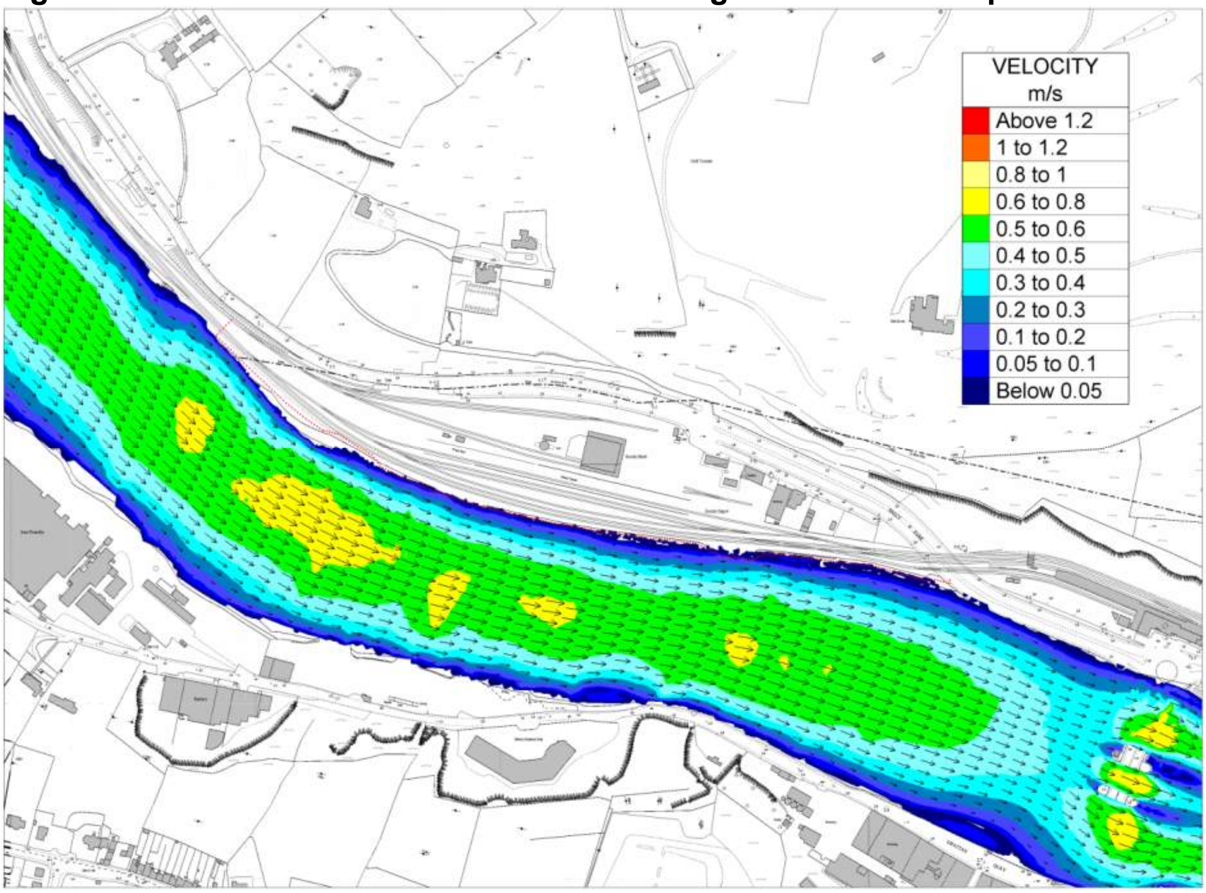

Figure 3-2 Mid-Ebb velocities under existing conditions - Neap Tide

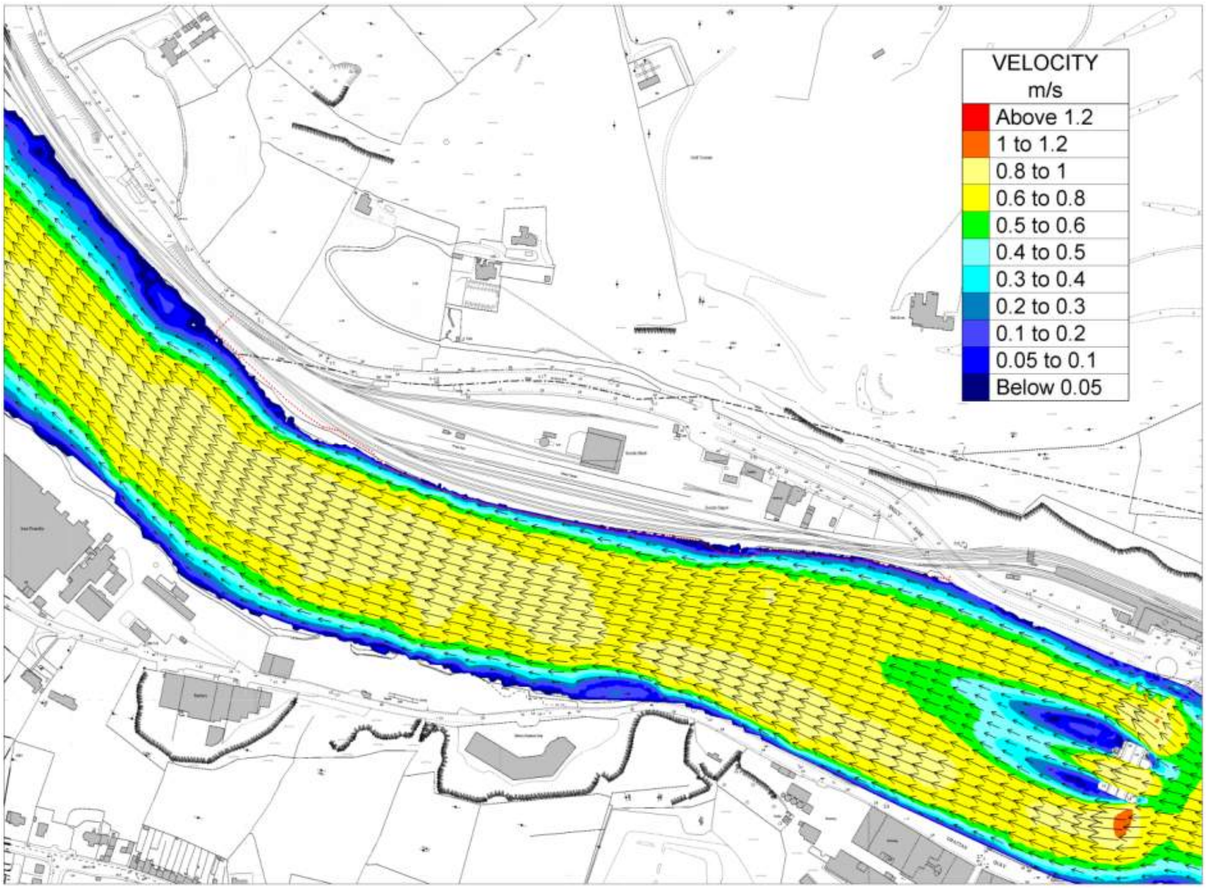

Figure 3-3 Mid-Flood velocities under existing conditions - Spring Tide

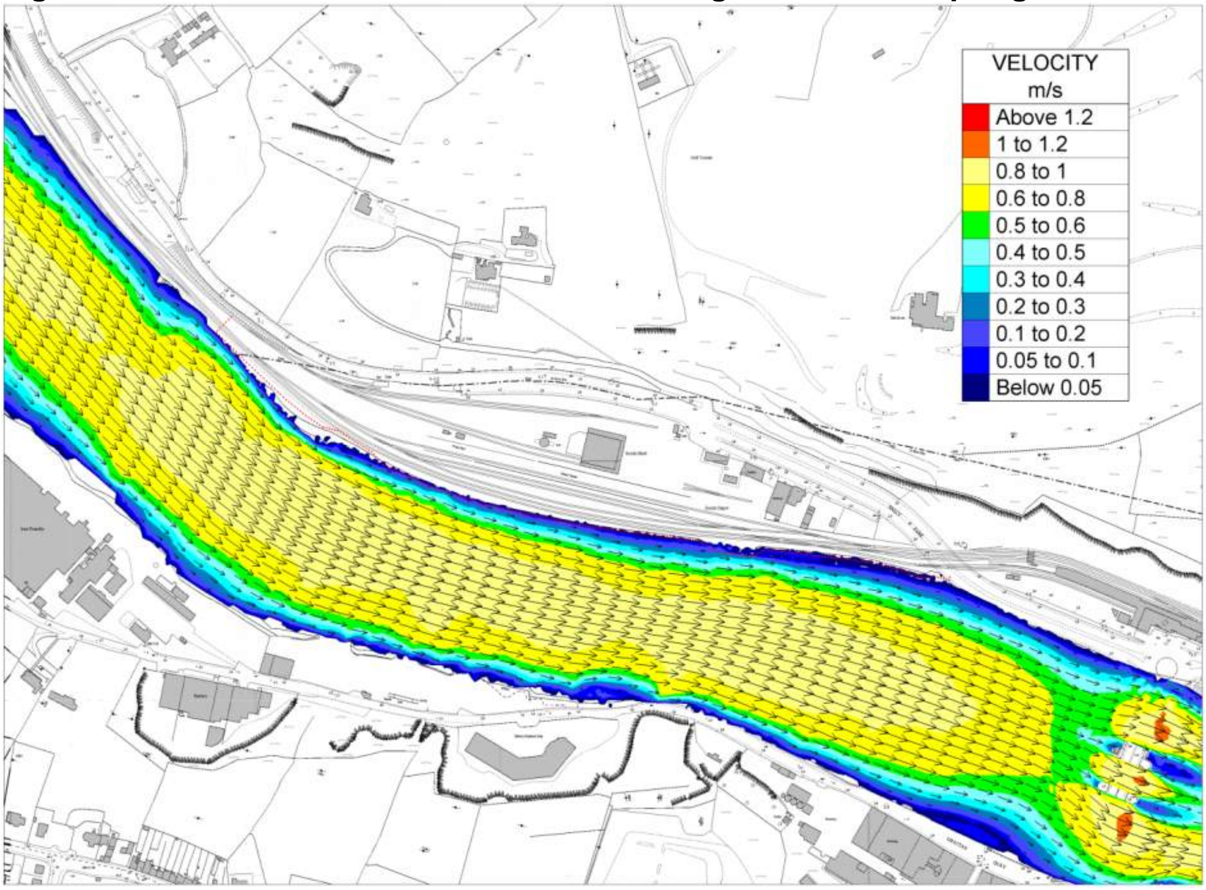

Figure 3-4 Mid-Ebb velocities under existing conditions - Spring Tide

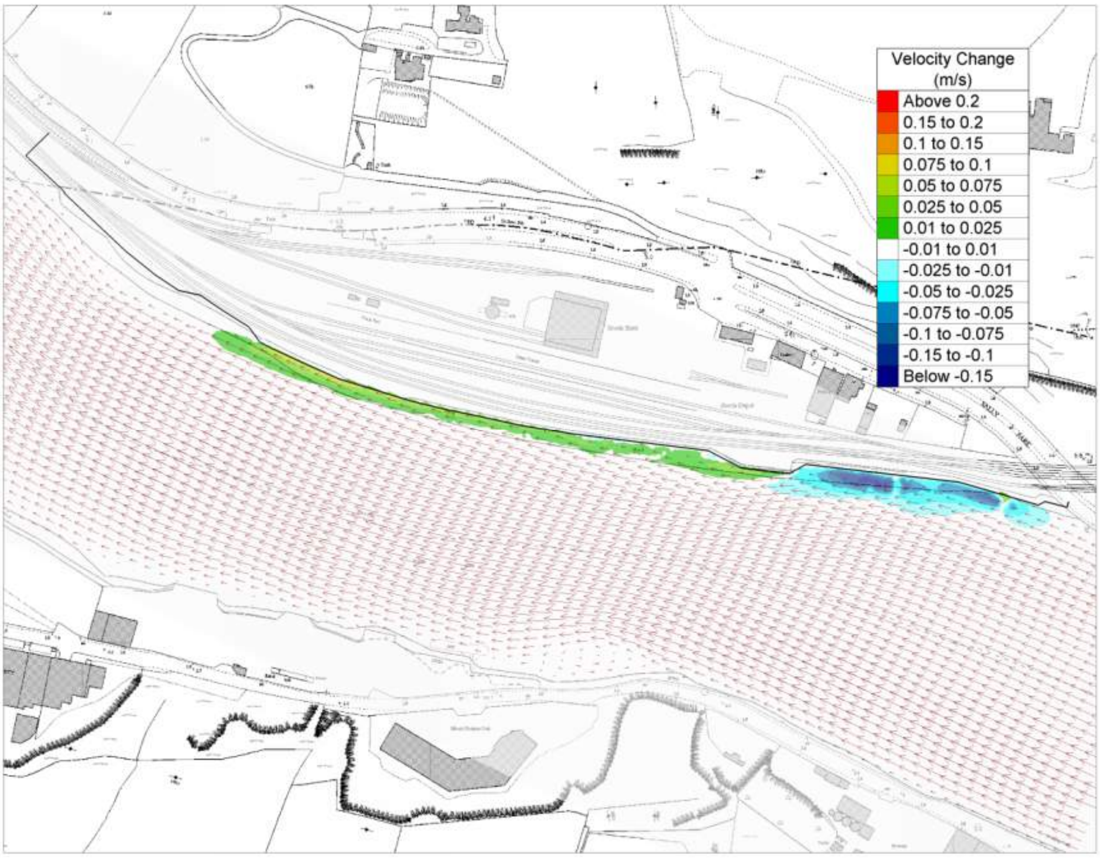

Figure 3-5 Computed change in velocity magnitude Neap Tide Mid-Flood

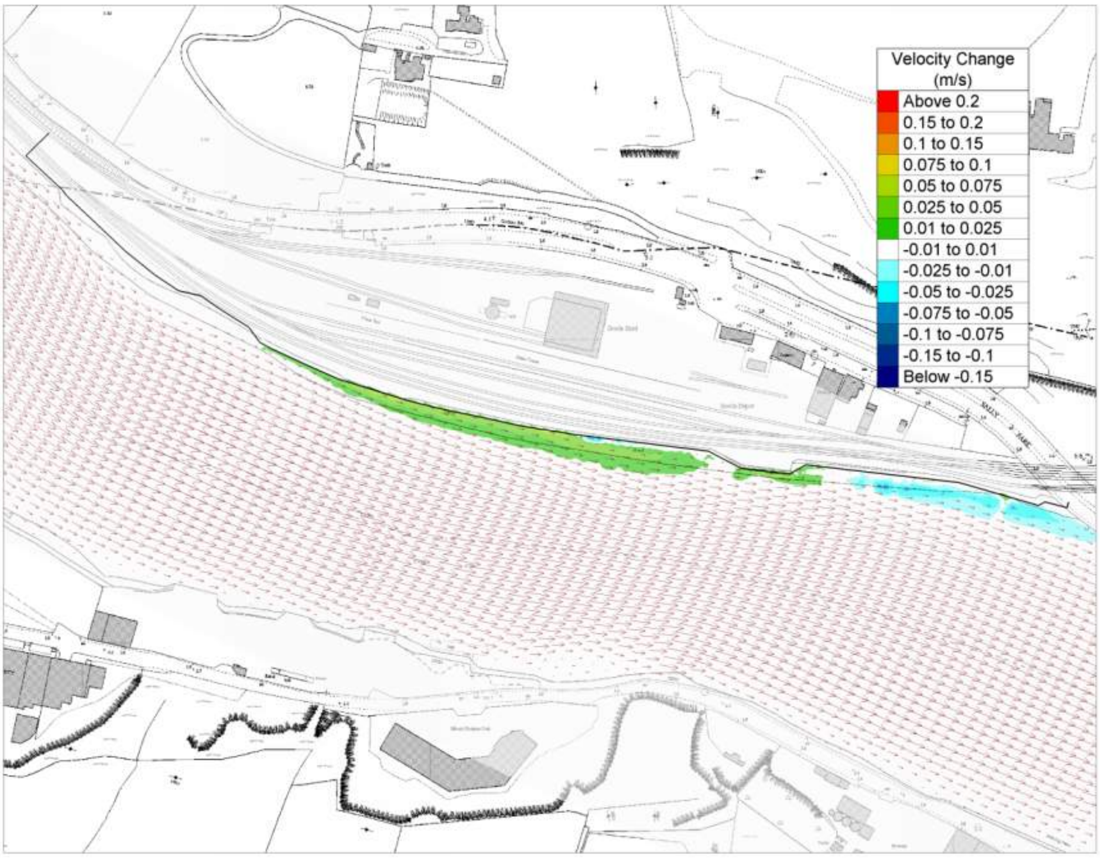

Figure 3-6 Computed change in velocity magnitude– Neap Tide Mid-Ebb

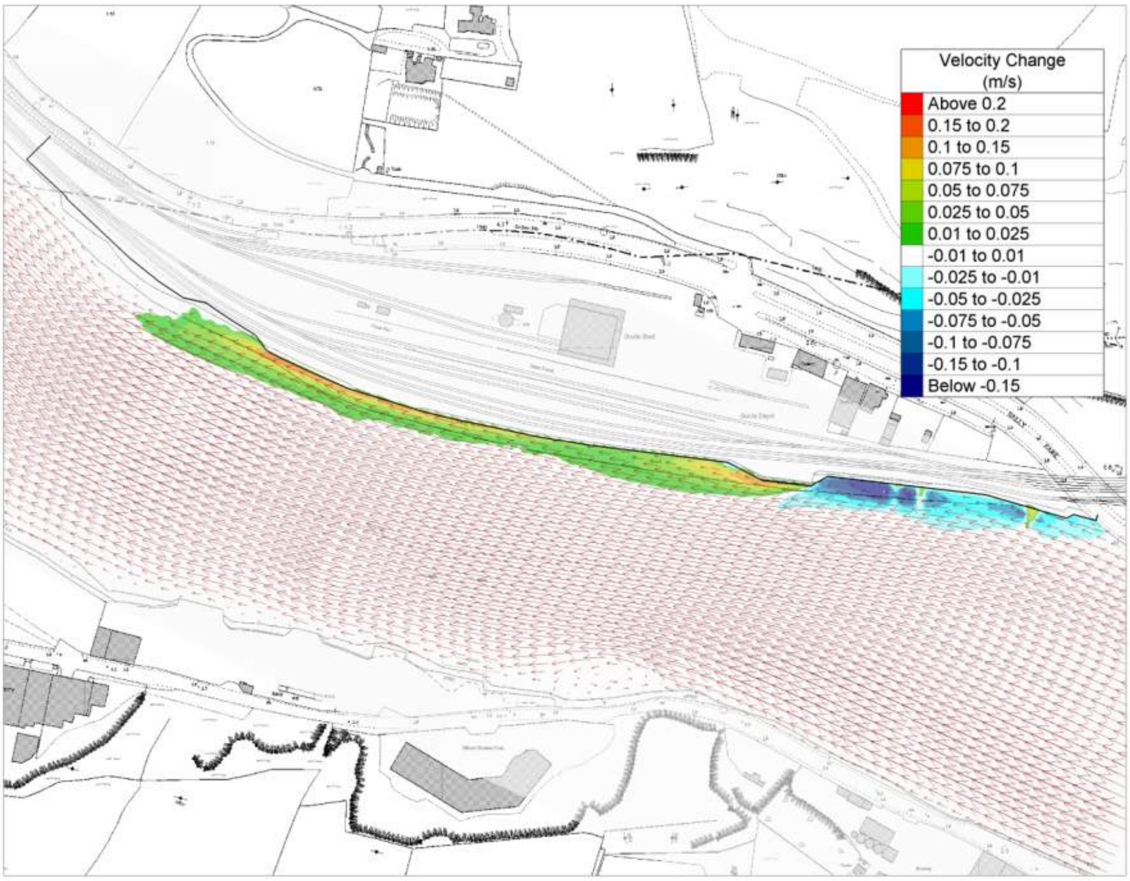

Figure 3-7 Computed change in velocity magnitude – Spring Tide Mid-Flood

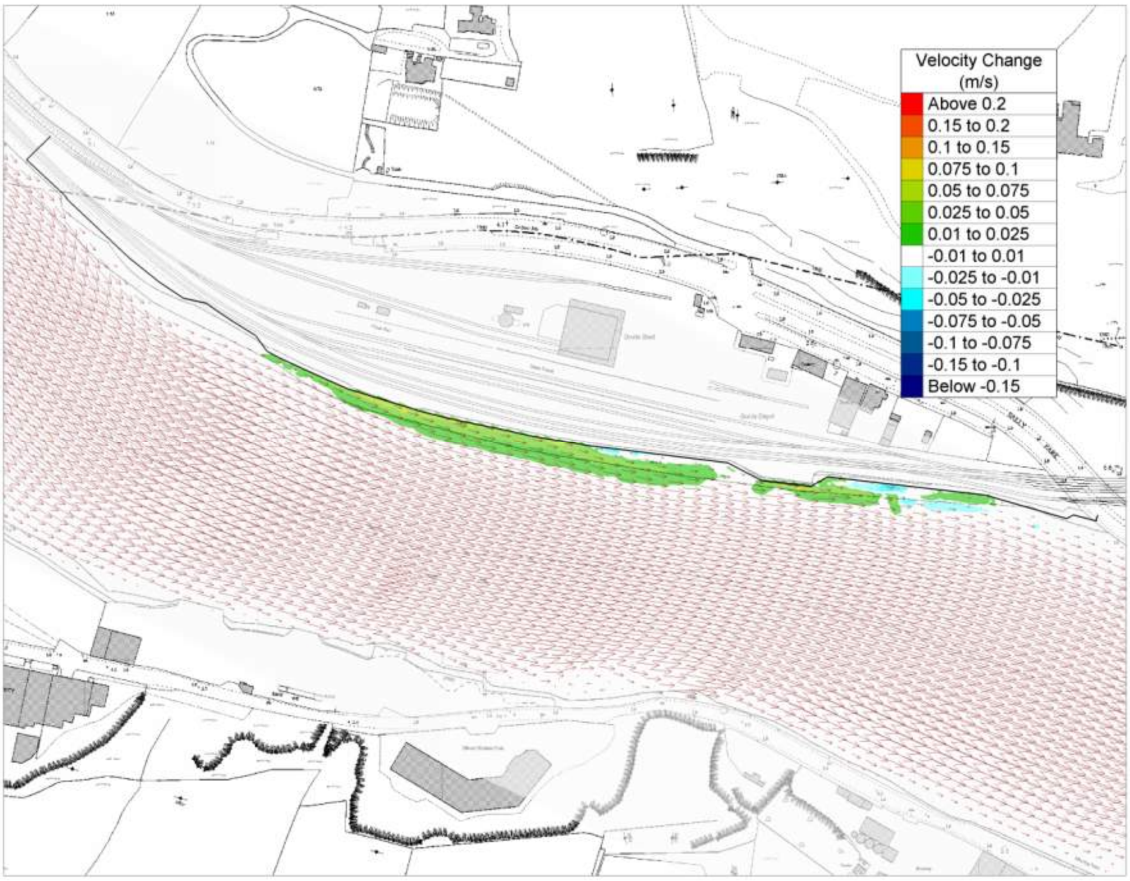

Figure 3-8 Computed change in velocity magnitude – Spring Tide Mid-Ebb

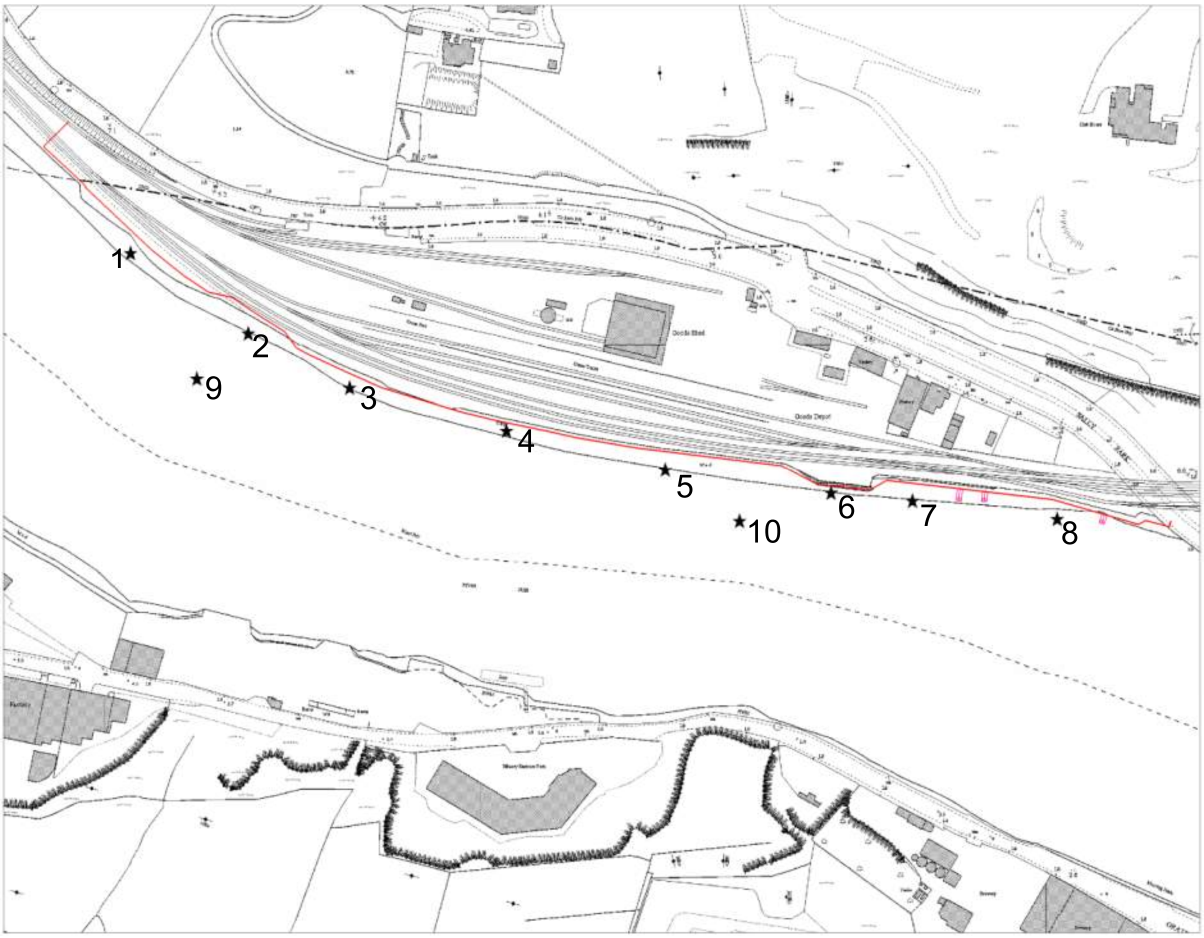

Figure 3-9 Reference Points for Time series output of existing Velocity and change in Velocity

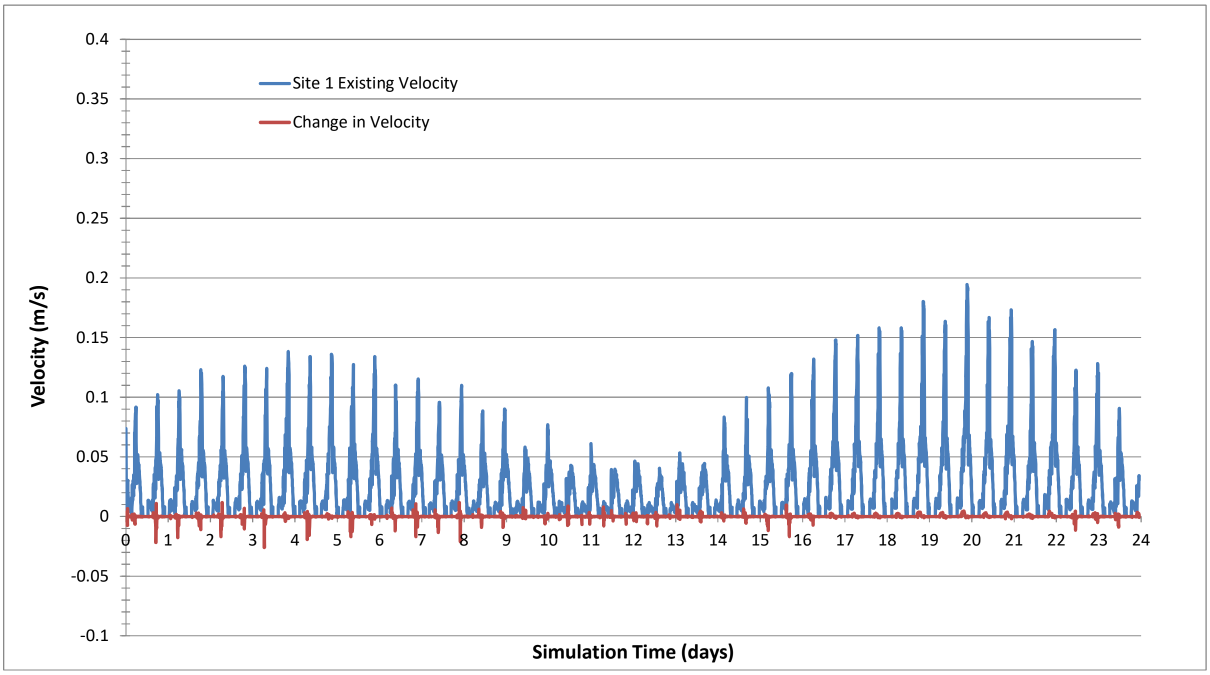

Figure 3-10 Time Series of existing velocity magnitude and computed change at Site 1

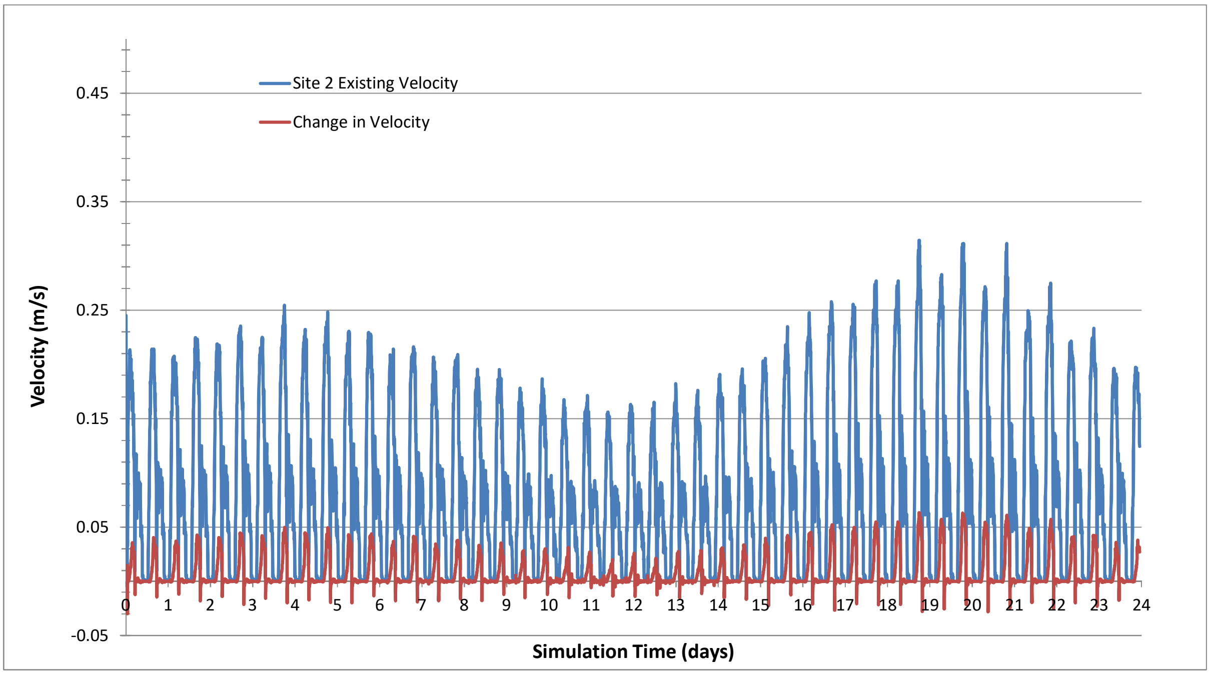

Figure 3-11 Time Series of existing velocity magnitude and computed change at Site 2

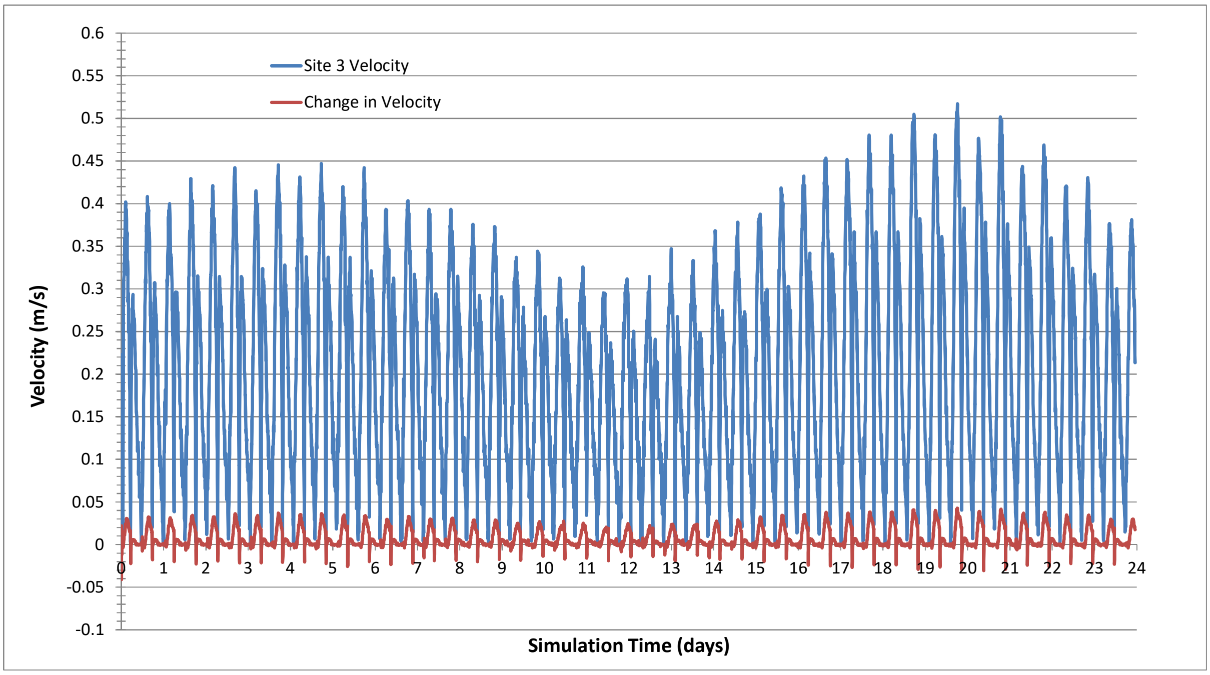

Figure 3-12 Time Series of existing velocity magnitude and computed change at Site 3

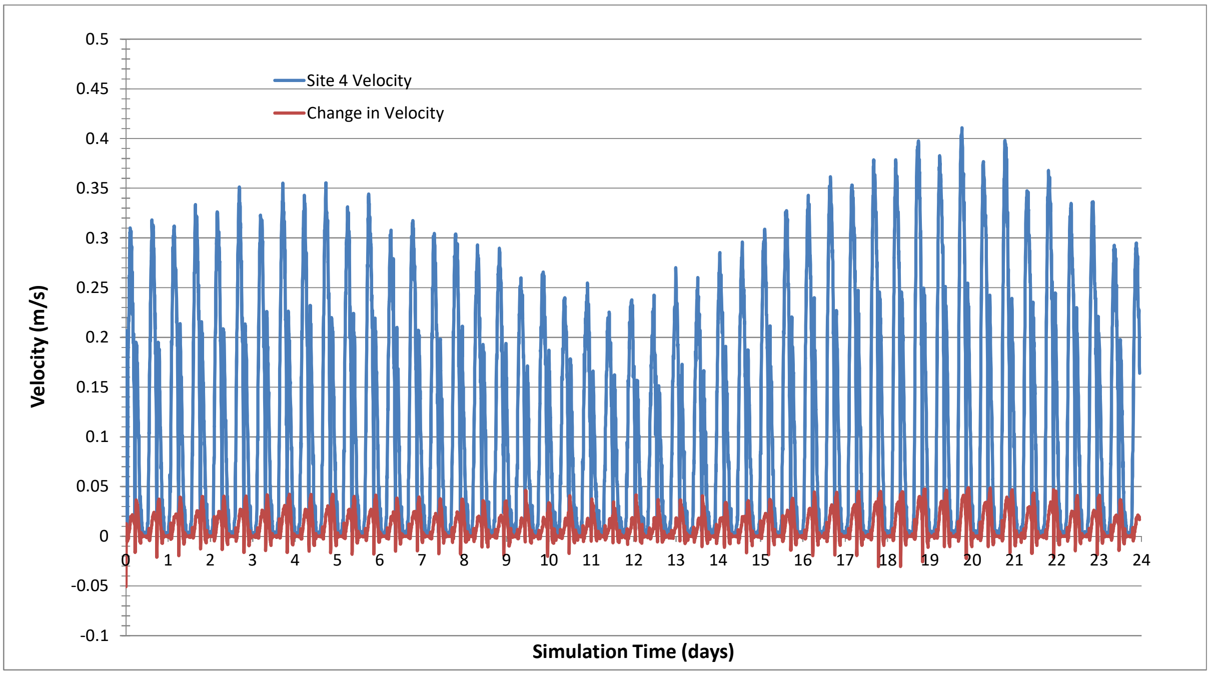

Figure 3-13 Time Series of existing velocity magnitude and computed change at Site 4

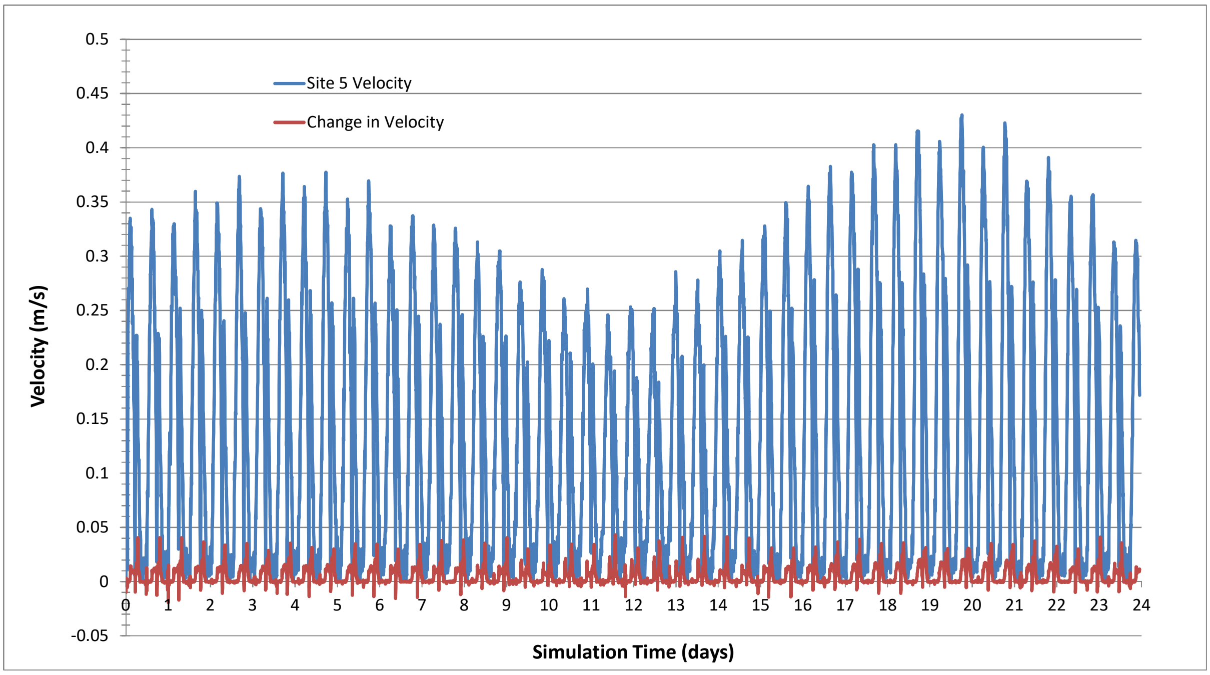

Figure 3-14 Time Series of existing velocity magnitude and computed change at Site 5

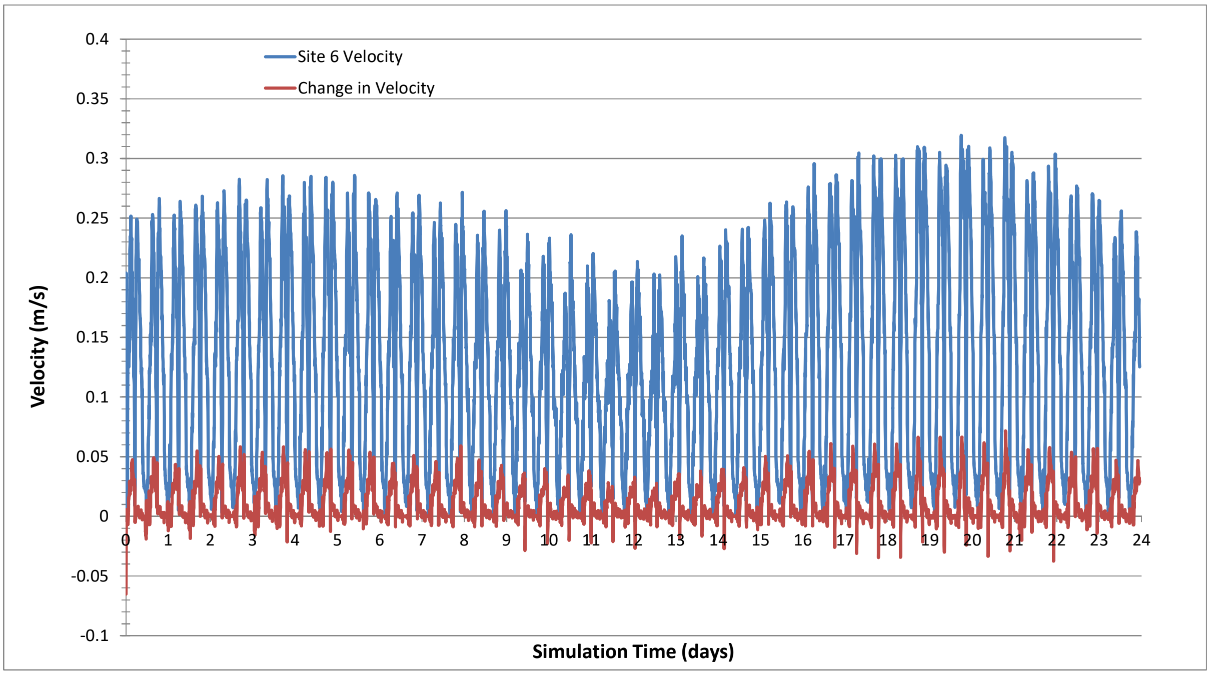

Figure 3-15 Time Series of existing velocity magnitude and computed change at Site 6

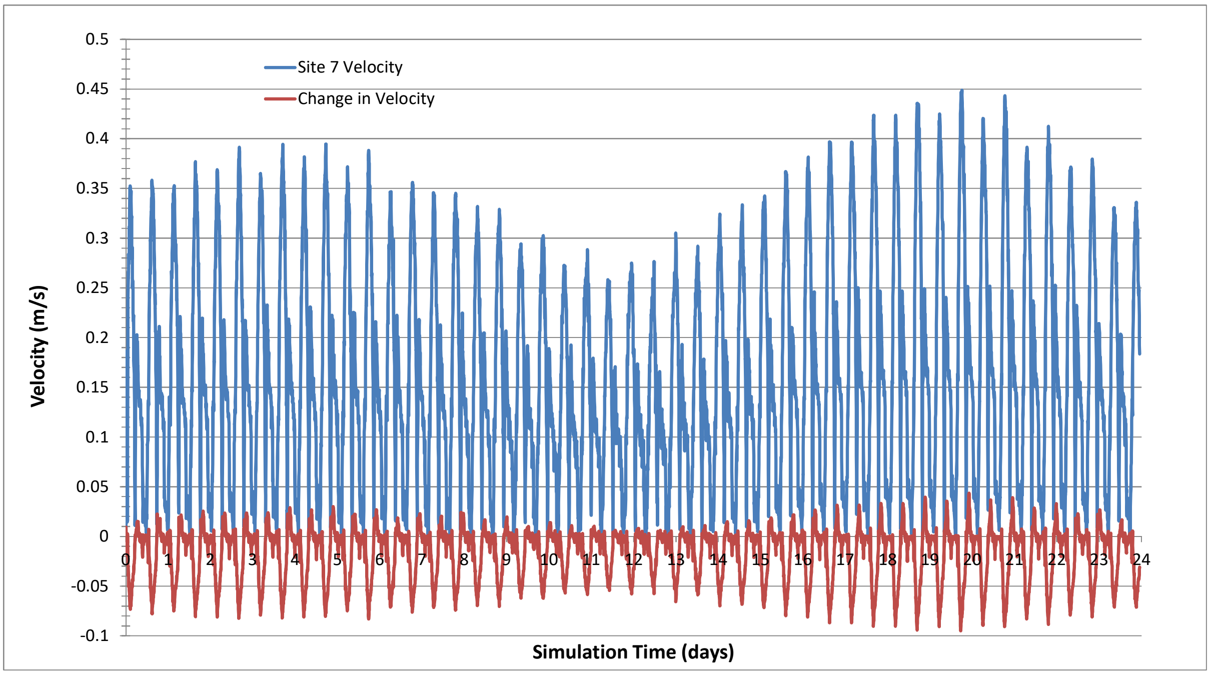

Figure 3-16 Time Series of existing velocity magnitude and computed change at Site 7

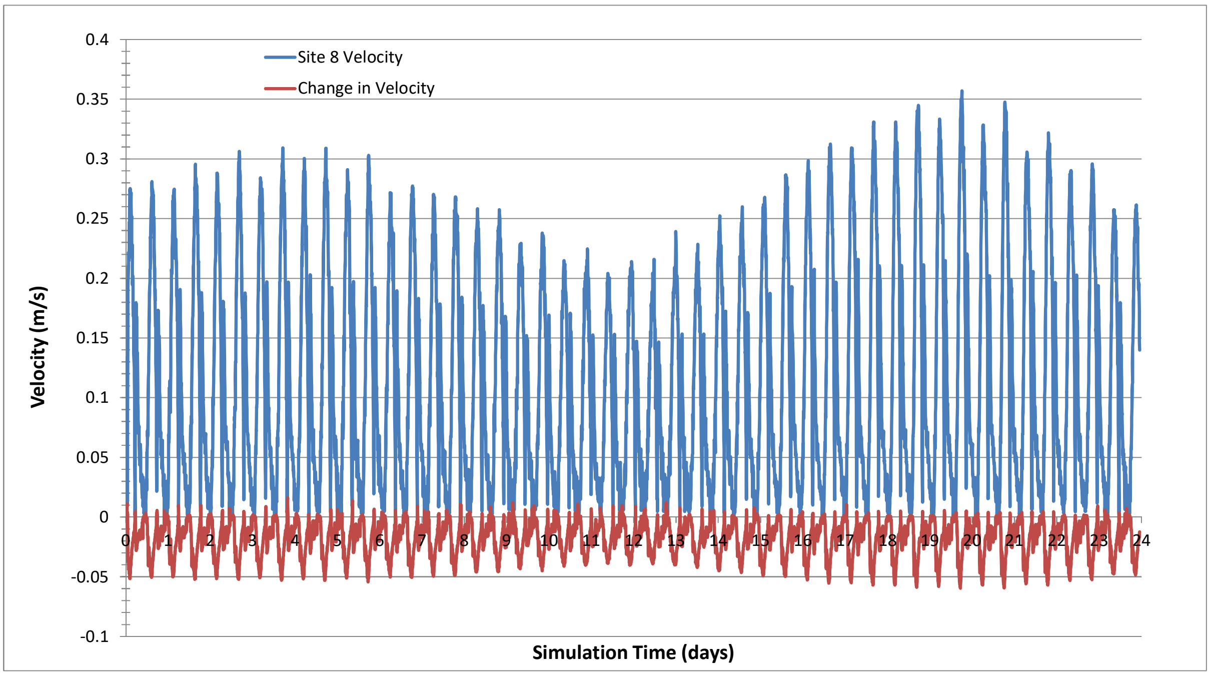

Figure 3-17 Time Series of existing velocity magnitude and computed change at Site 8

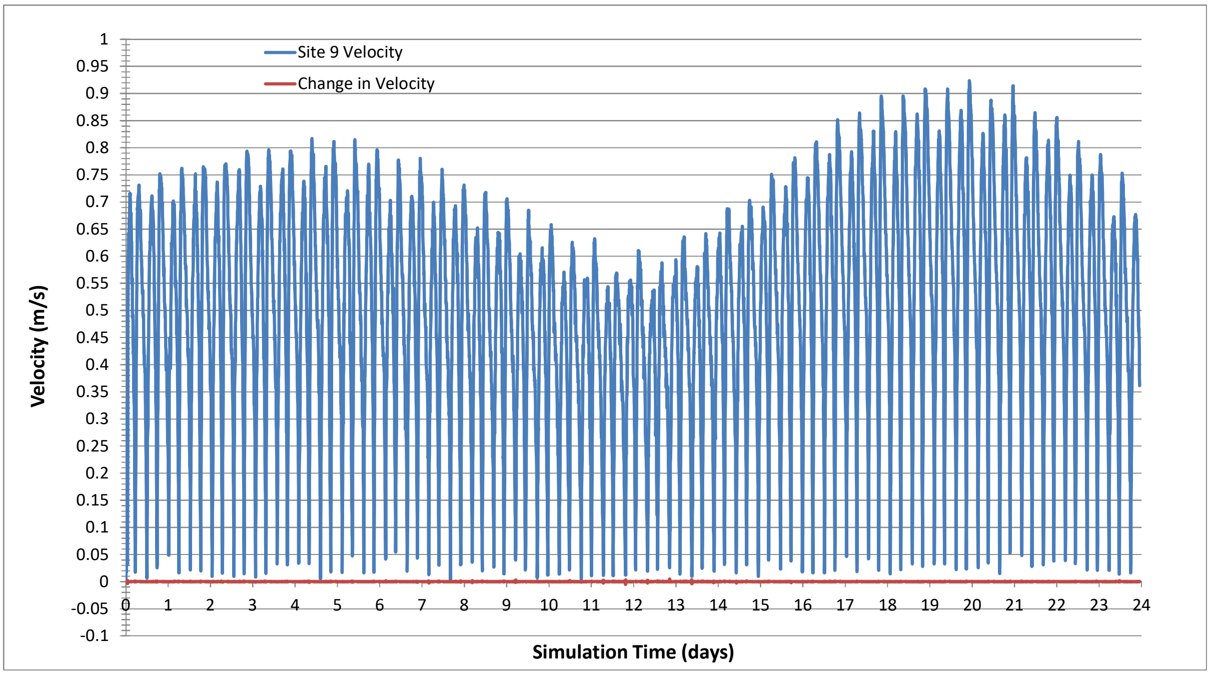

Figure 3-18 Time Series of existing velocity magnitude and computed change at Site 9

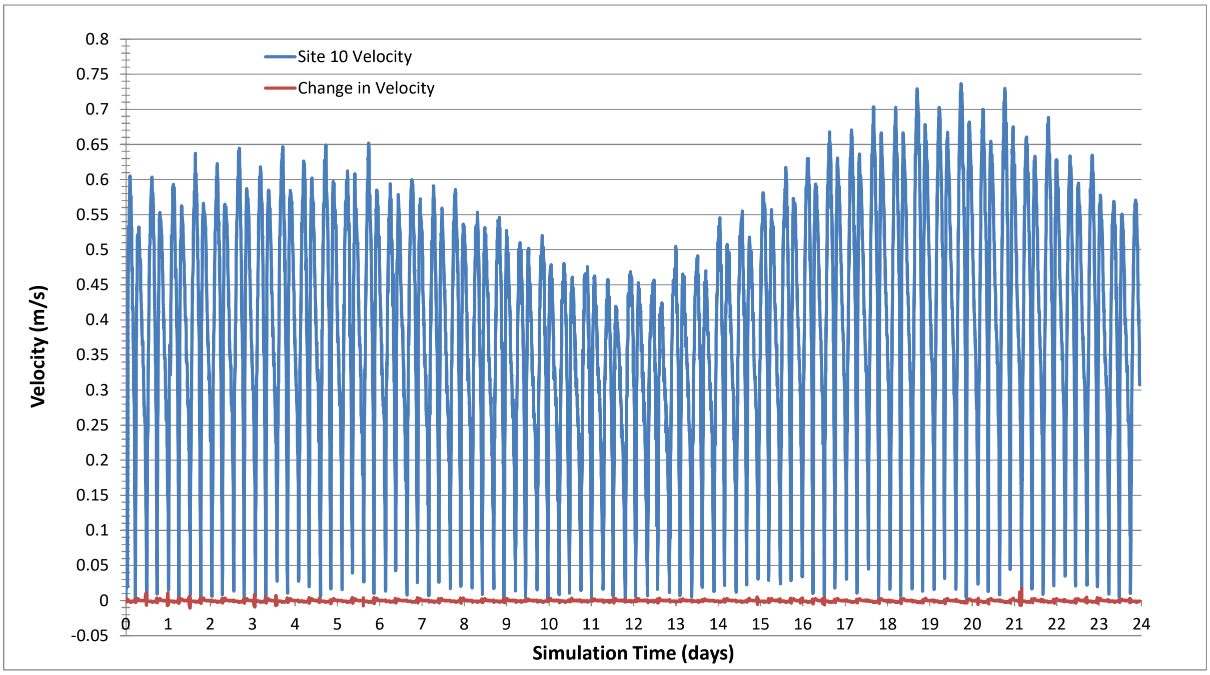

Figure 3-19 Time Series of existing velocity magnitude and computed change at Site 10

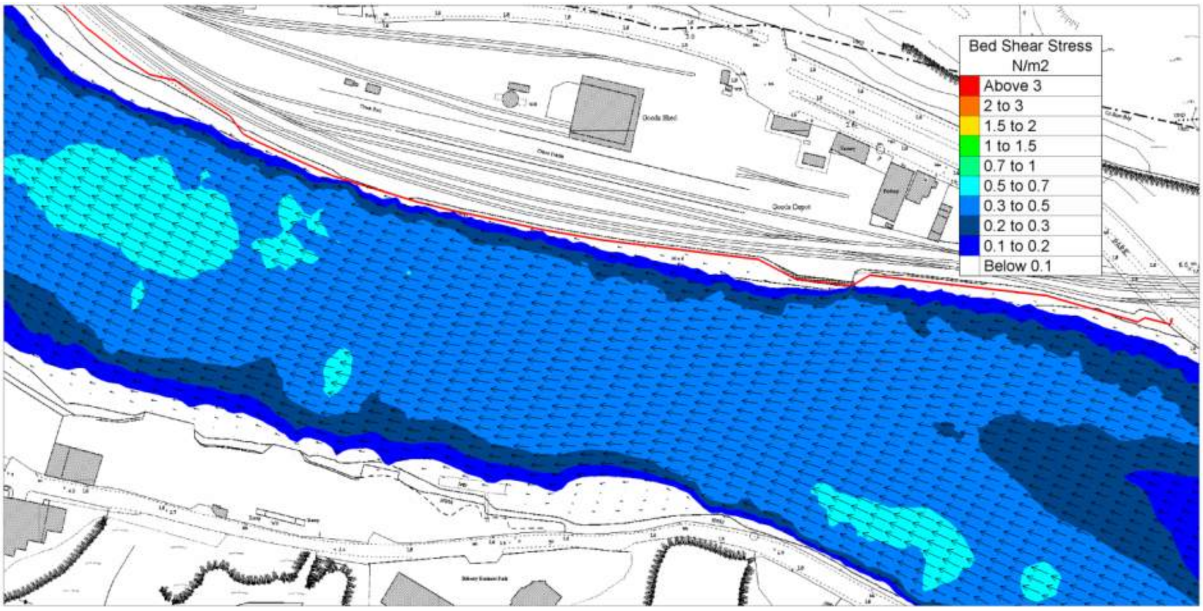

Figure 3-20 Mid-Flood Bed Shear Stress - existing case Neap Tide

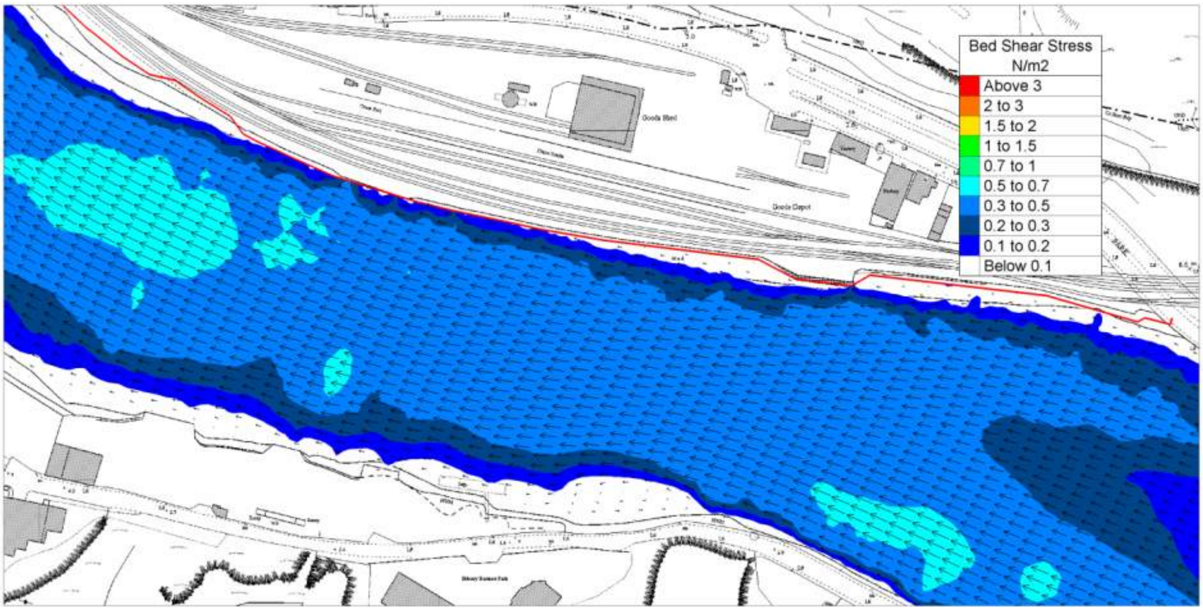

Figure 3-21 Mid-Flood Bed Shear Stress – proposed case Neap Tide

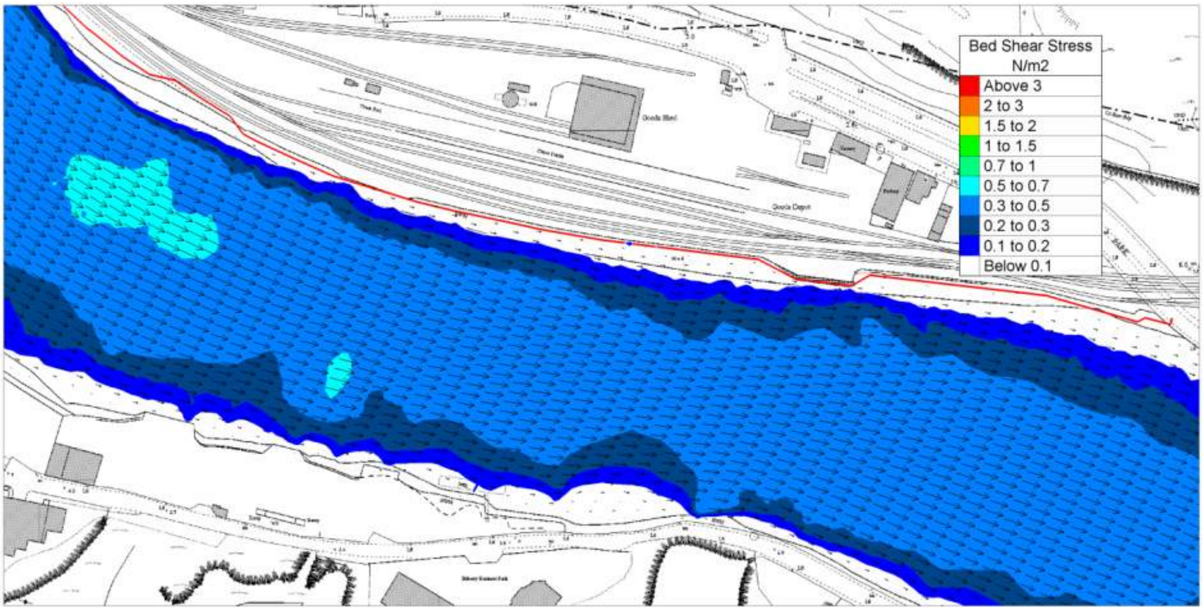

Figure 3-22 Mid-Ebb Bed Shear Stress - existing case Neap Tide

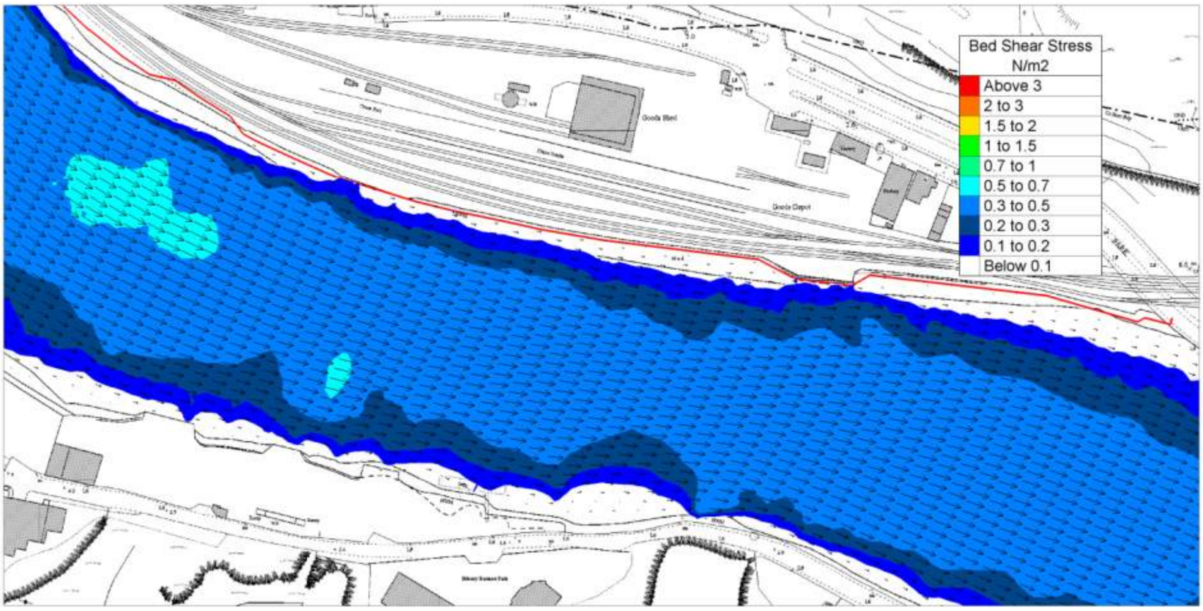

Figure 3-23 Mid-Ebb Bed Shear Stress – proposed case Neap Tide

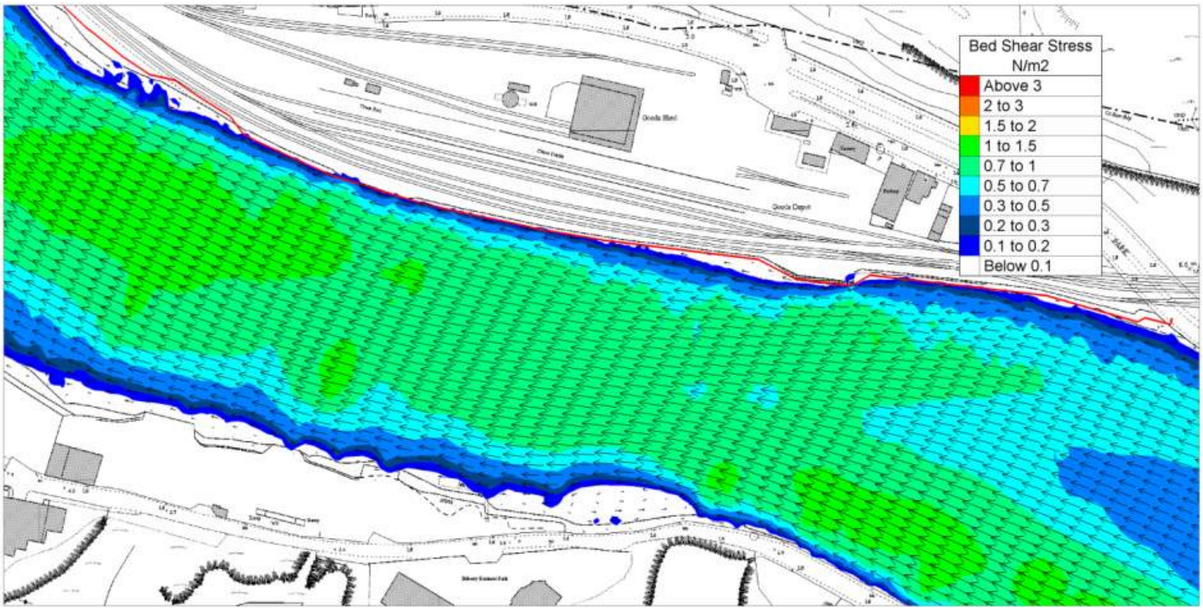

Figure 3-24 Mid-Flood Bed Shear Stress - existing case Spring Tide

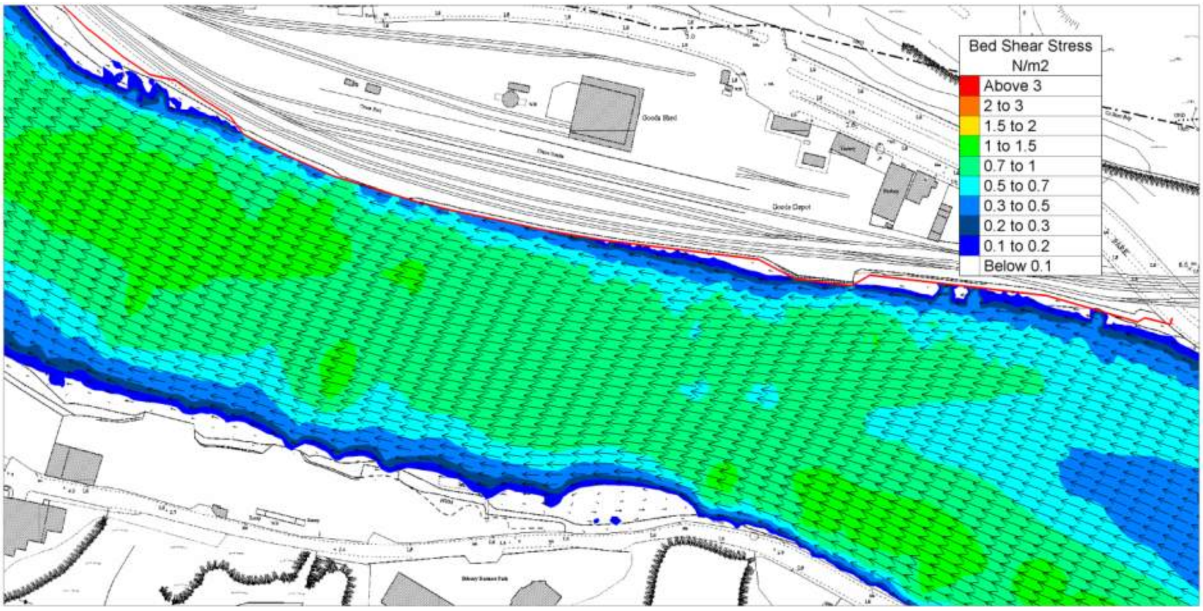

Figure 3-25 Mid-Flood Bed Shear Stress – proposed case Spring Tide

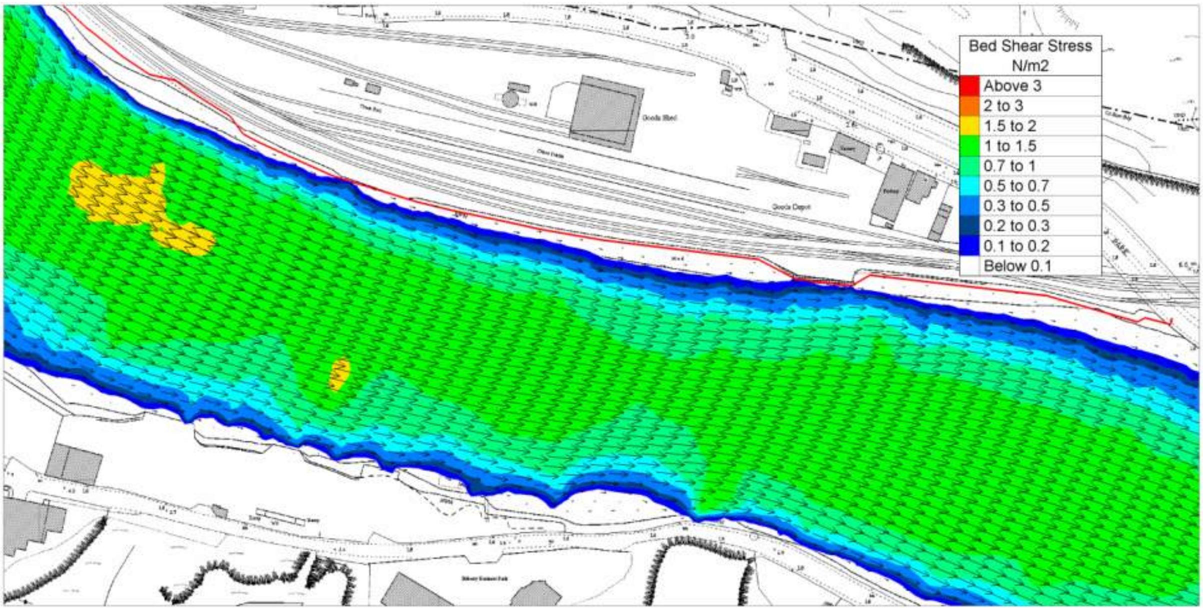

Figure 3-26 Mid-Ebb Bed Shear Stress - existing case Spring Tide

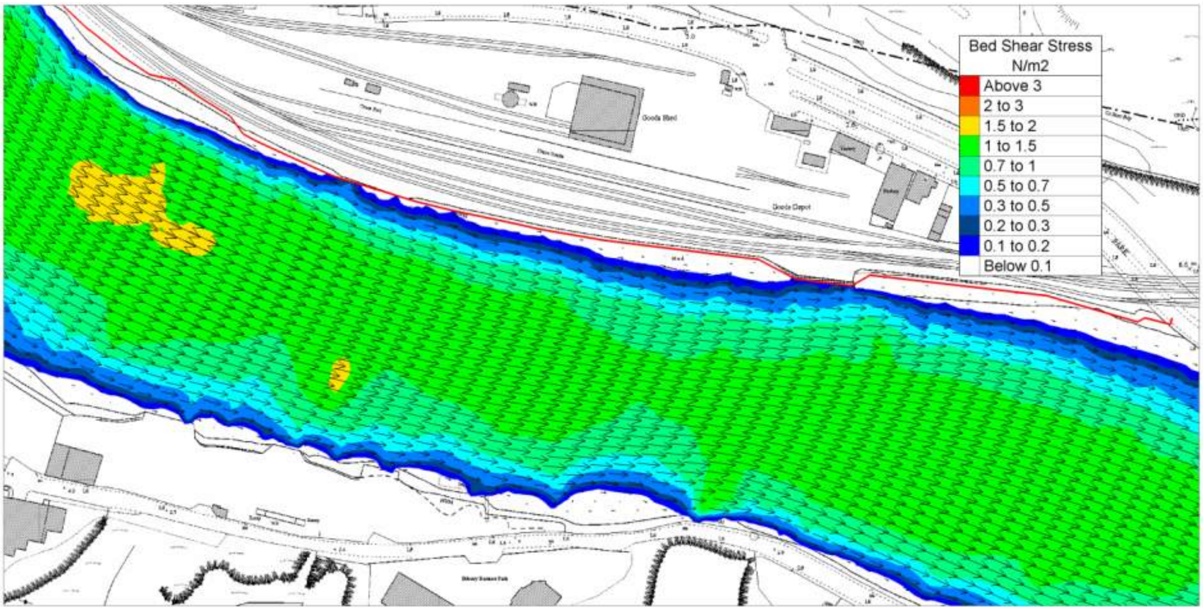

Figure 3-27 Mid-Ebb Bed Shear Stress – proposed case Spring Tide

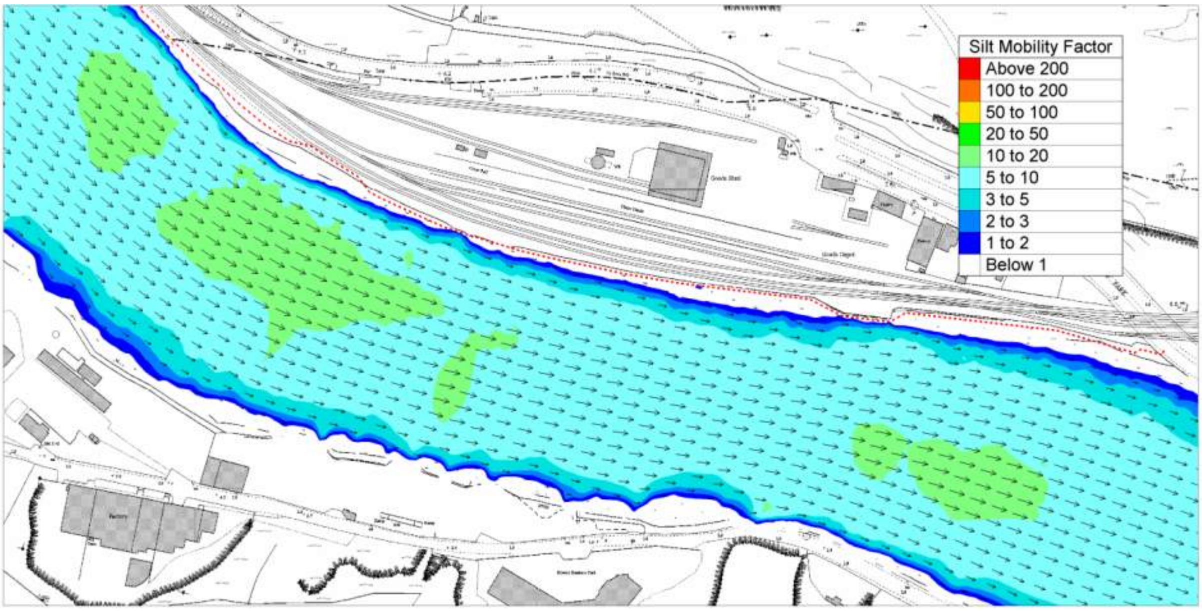

Figure 3-28 Fine Silt Mobility Factor at Mid-Ebb Neap Tide – existing case

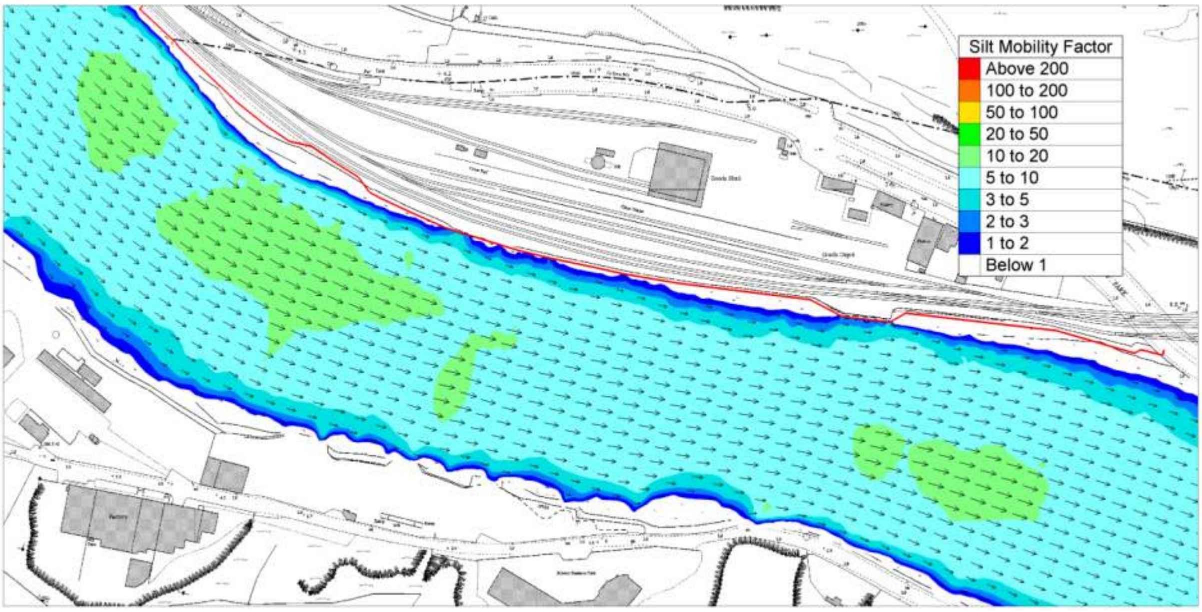

Figure 3-29 Fine Silt Mobility Factor at Mid-Ebb Neap Tide– proposed case

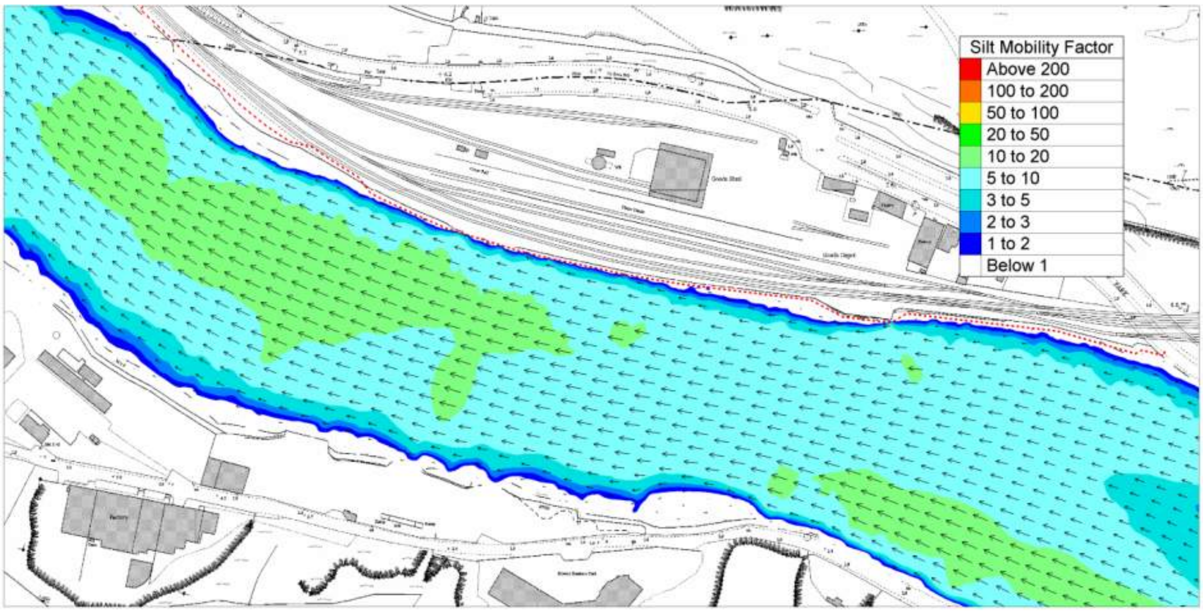

Figure 3-30 Fine Silt Mobility Factor at Mid-Flood Neap Tide– existing case

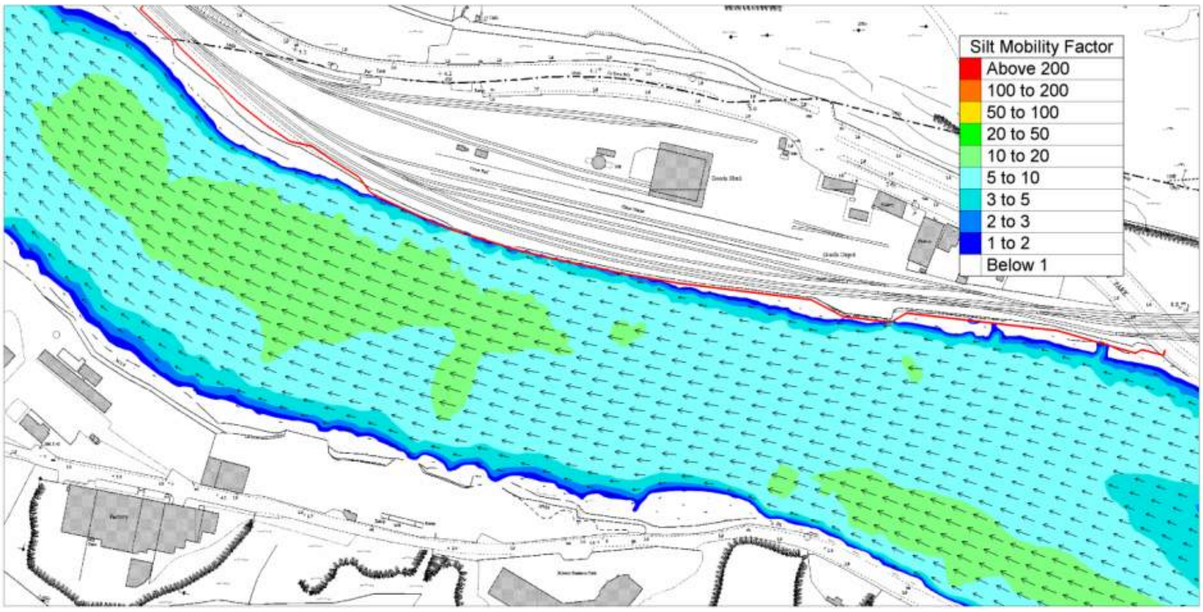

Figure 3-31 Fine Silt Mobility Factor at Mid-Flood Neap Tide– proposed case

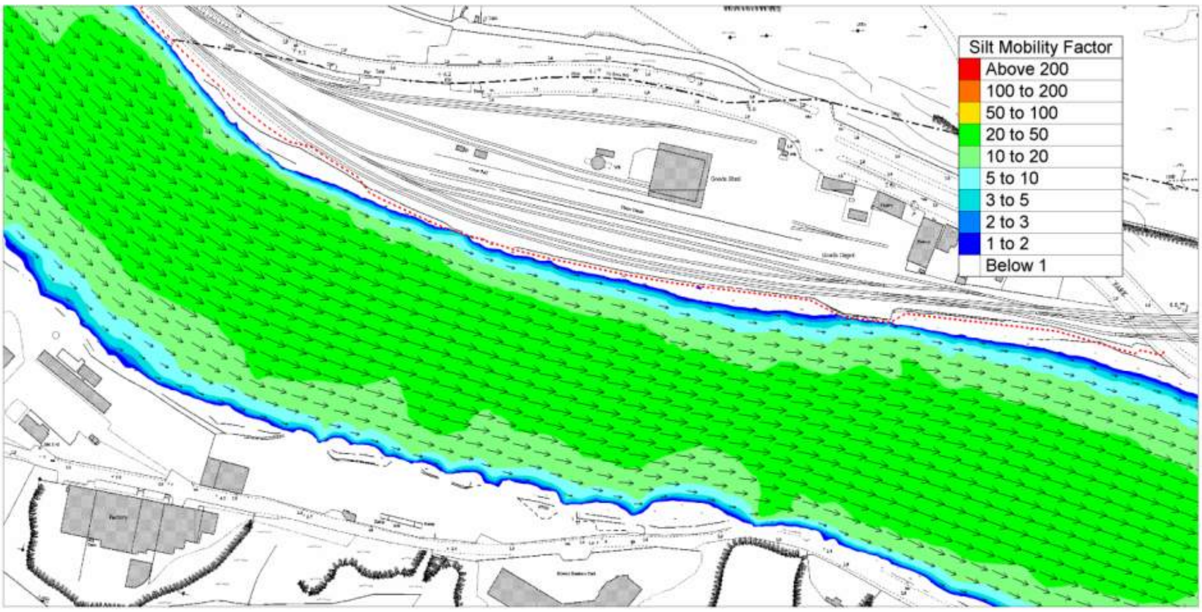

Figure 3-32 Fine Silt Mobility Factor at Mid-Ebb Spring Tide – existing case

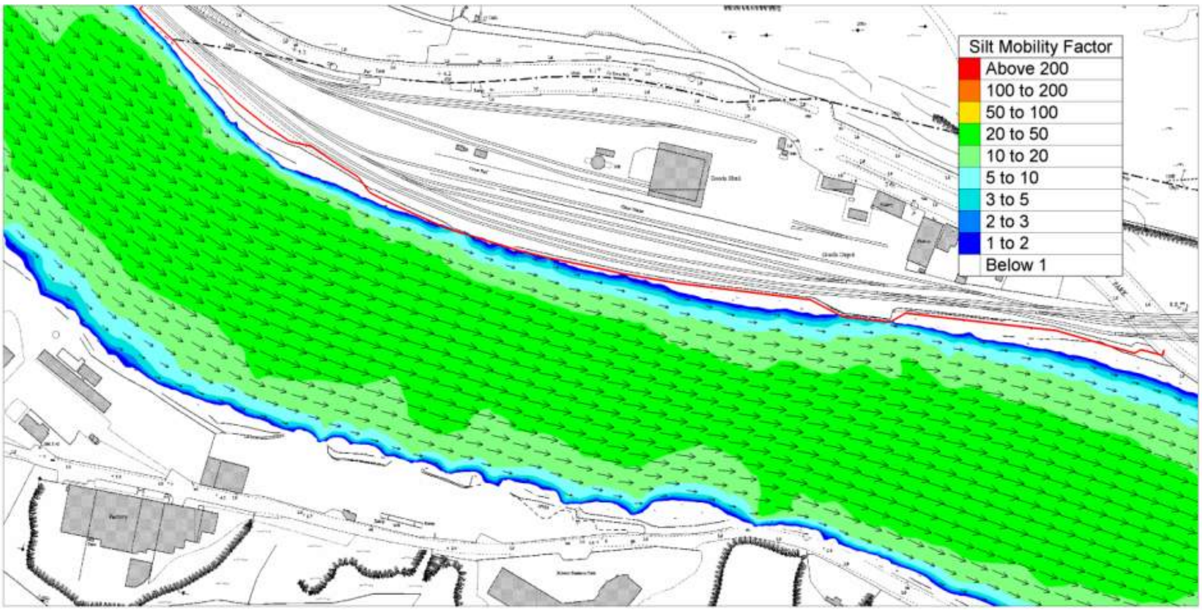

Figure 3-33 Fine Silt Mobility Factor at Mid-Ebb Spring Tide– proposed case

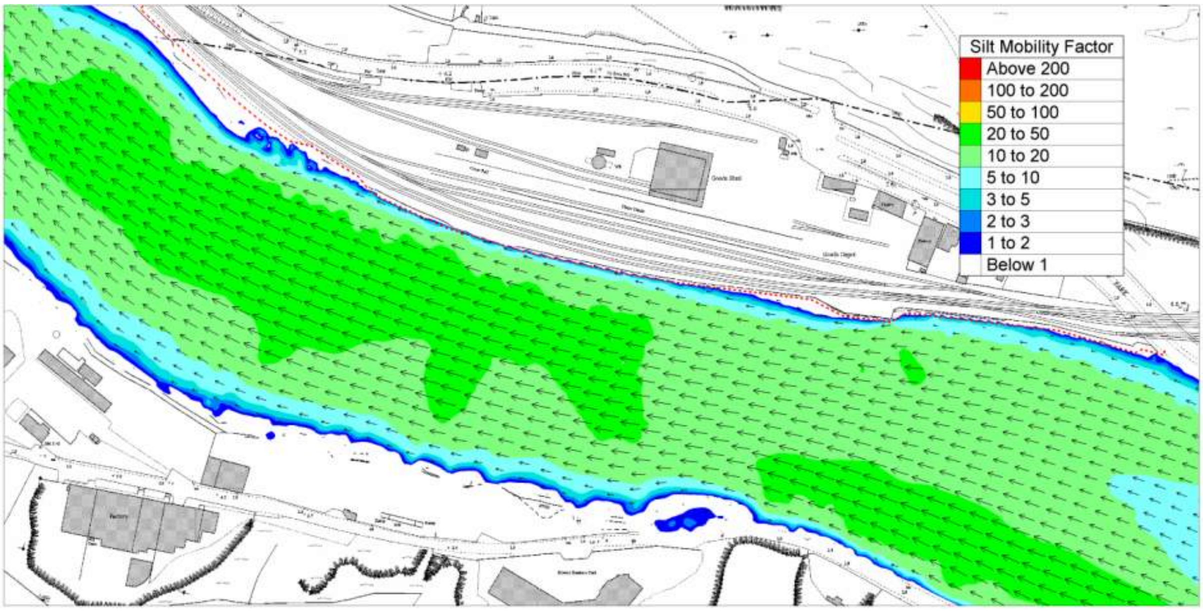

Figure 3-34 Fine Silt Mobility Factor at Mid-Flood Spring Tide – existing case

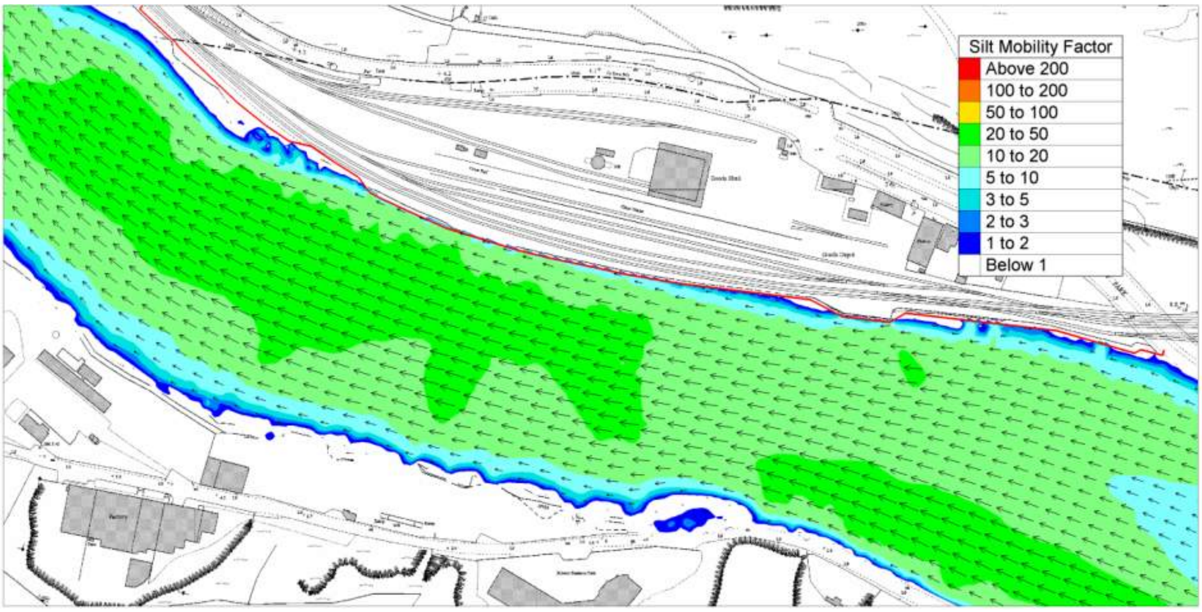

Figure 3-35 Fine Silt Mobility Factor at Mid-Flood Spring Tide– proposed case

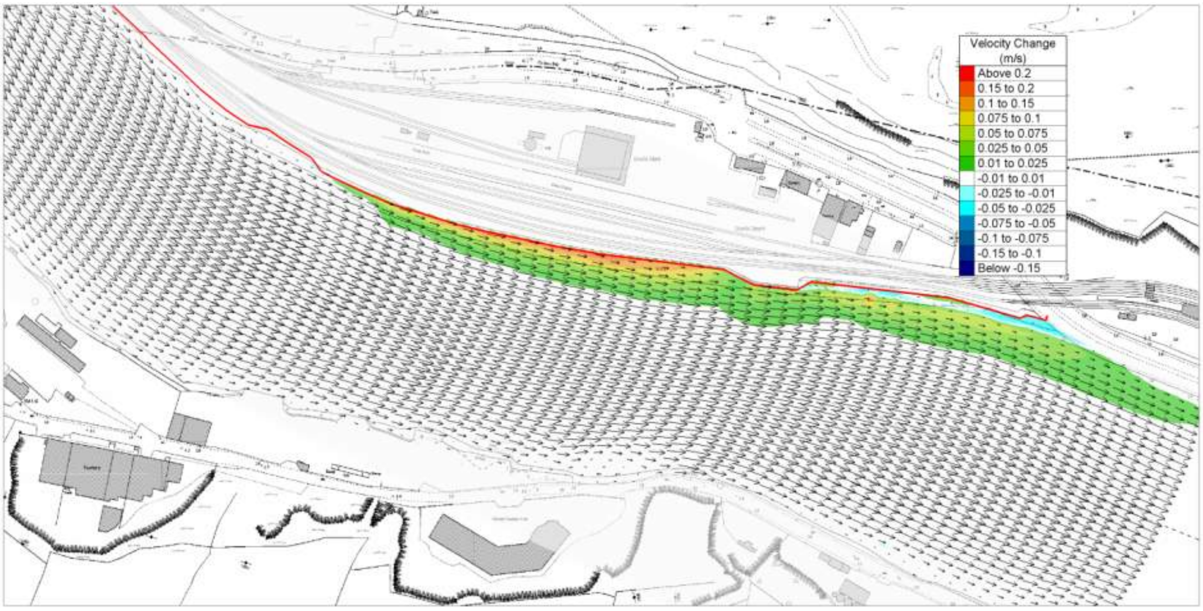

Figure 3-36 Computed change in velocity magnitude ebbing tide for a 200year return period storm surge event

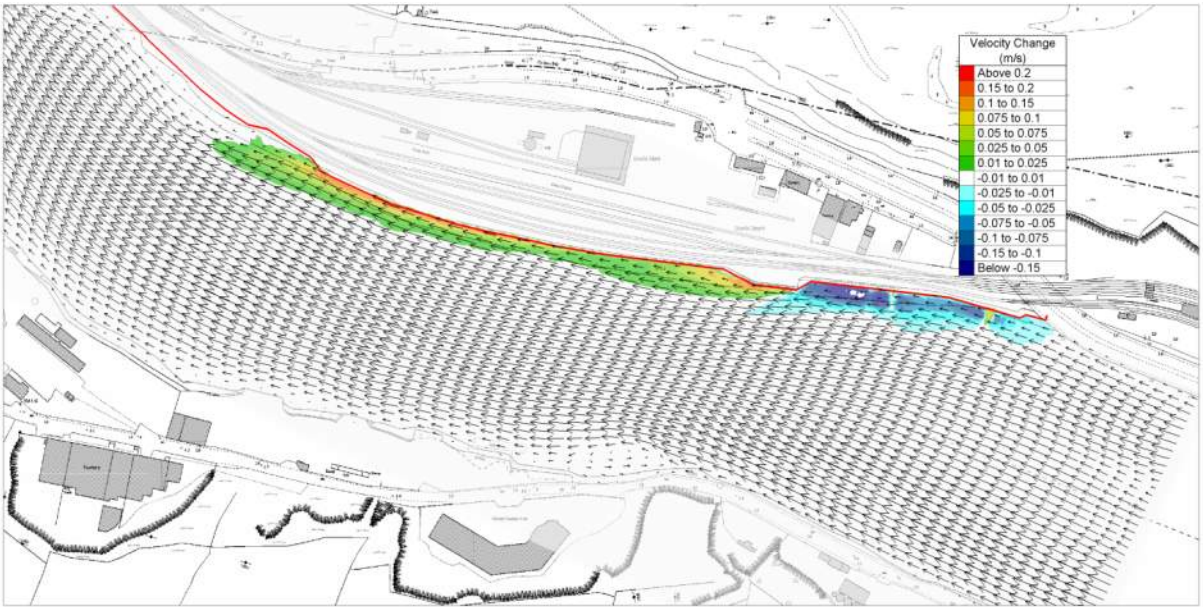

Figure 3-37 Computed change in velocity magnitude flooding tide for a 200year return period storm surge event

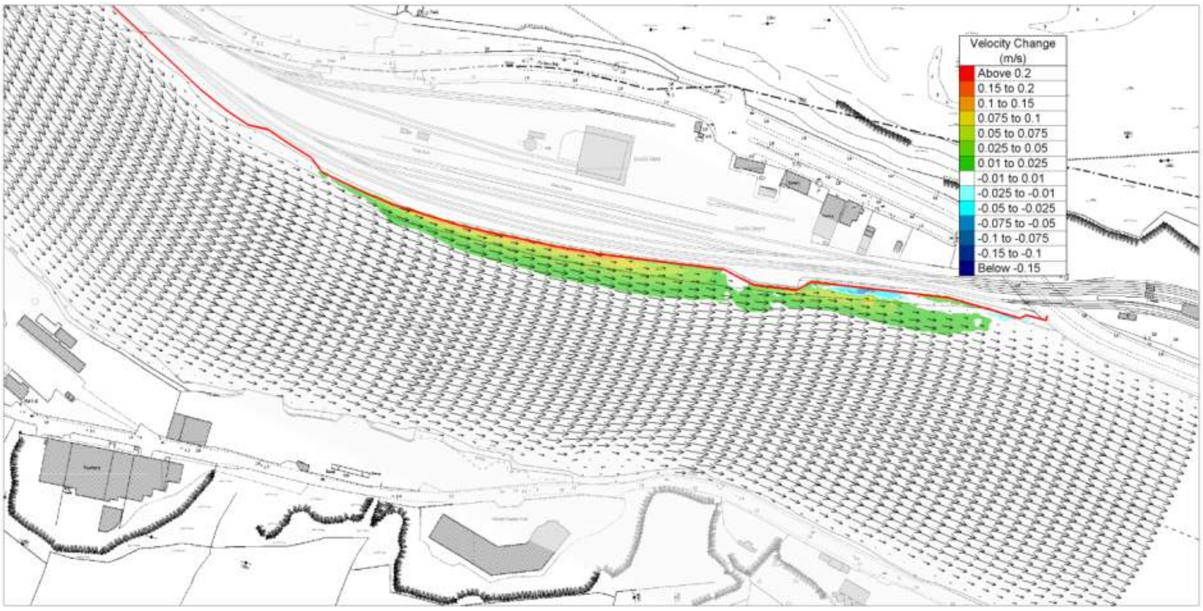

Figure 3-38 Computed change in velocity magnitude ebbing tide for a 100year return period river flood event coinciding with a high spring tide

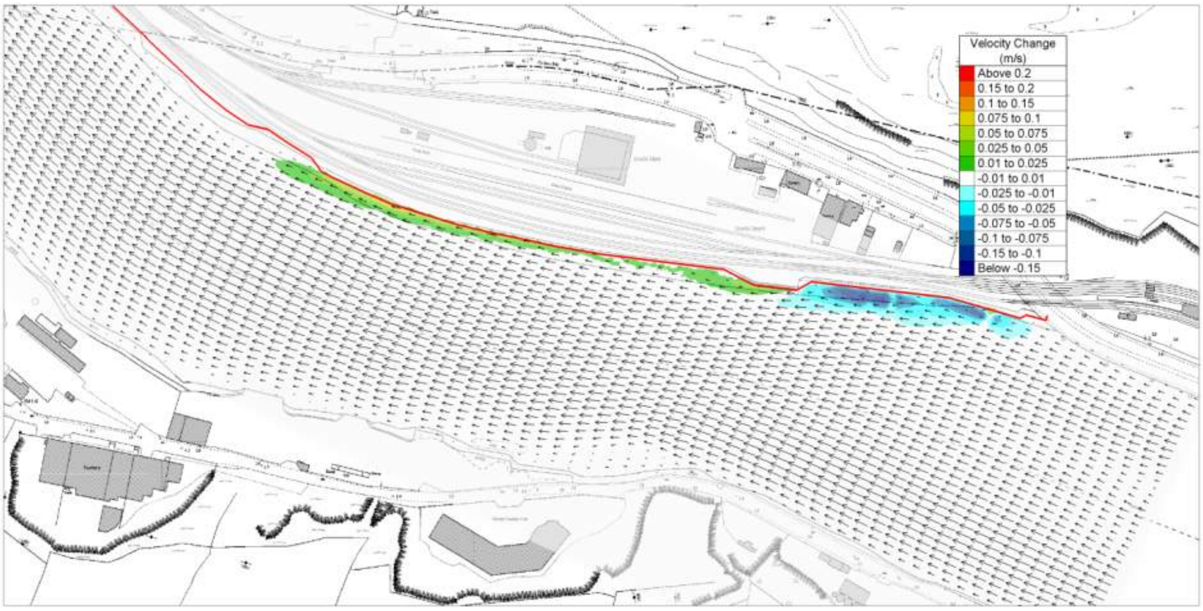

Figure 3-39 Computed change in velocity magnitude flooding tide for a 100year return period river flood event coinciding with a high spring tide

4. CONCLUSIONS

A hydrodynamic assessment was performed on the proposed sheet piled flood wall associated with the proposed Waterford City and County Council Flood Defences West Scheme to assessment the potential implications on scouring within the River Suir Estuarine channel. A local Telemac2d model was developed for this purpose with a high-resolution variable mesh. Pre-development and post -development models were developed using the same mesh structure to minimise numerical error in comparing hydrodynamic results.

A high-resolution bathymetric survey of the estuarine channel was conducted by Murphy Surveys Ltd. to provide recent bed elevations for input to the hydrodynamic model. The two-dimensional local model was driven by a 1-dimensional model that covered the entire tidal zone from Open Sea at Waterford Harbour Mouth and extending up the full Barrow, Nore and Suir tidal reaches so as to ensure correct tidal flows and elevations are computed for driving the local 2-d model.

The hydrodynamic model examined normal river flow and tidal conditions, both spring and neap tides and also the more extreme flood events associated with tidal storm surges and fluvial flood events in the River. The effect of the proposed flood defence wall and associate storm outfall structures (3 No. storm outfall) will generally increase flows along the bank in the vicinity of the vertical Flood Wall over the existing case.

The hydrodynamic simulations both normal tidal conditions and extreme flood events show an increase in velocity magnitude along the middle section of the flood wall alignment on both ebb and flood flows and a reduction in velocity locally in the vicinity of the outfall structures. The higher increases in velocity between existing and proposed cases occur on the spring tides and on the flooding tide with a general local increase of 0.05m/s and larger increases along the toe of the Flood wall of 0.075 to 0.1m/s. These local changes are not significant in comparison to the computed baseline velocity magnitudes under the present existing situation. There is no perceptible change in flow velocities in the main, deeper channel section or at the opposite far bankside. The predicted upstream and downstream changes to the flow velocity magnitude at the near bank is local and not very extensive or significant.

The sediment mobility assessment shows that under both existing and proposed cases sufficient velocities are generated on both flooding and particularly ebbing spring tides to mobilise only the fresher unconsolidated fine silts that might at slack tides temporarily deposit along the channel bank in the vicinity of the proposed flood wall. The conclusion reached from this analysis is that the computed velocity increases from the proposed vertical sheet piled wall are relatively small and of insufficient magnitude to produce sufficient shear stresses (i.e. generally <0.7Pa) that would result in any potential significant erosion of the permanent consolidated sediments /muds on the channel bed and banks in the vicinity of the affected area.

The proposed storm outfalls and extension towards the channel bank edge associated with the proposed defences are shown due to their raised bed elevation at their soffit and outfall wing walls and apron to reduce the tidal velocities on the ebbing and flooding tides at the bank immediately local to the outfalls. These works do not result in any noticeable increases in flow velocities elsewhere. The construction of these outfalls will involve temporary sheet piling cofferdams to protect construction activities at each outfall. The effect of these cofferdams will be to result in a similar pattern as the permanent outfalls in respect to local reduction in velocities but over the complete tidal cycle. Such localised sheltering is likely to give rise to a local increase in the deposition rate of silt at the channel bank immediately in the wake of the outfalls.