Port of Waterford
AQUACULTURE ASSESSMENT REPORT

Produced by

AQUAFACT International Services Ltd (APEM Group)

On behalf of

Port of Waterford

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AQUAFACT INTERNATIONAL SERVICES Ltd
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1. Introduction

AQUAFACT International Services Ltd. (APEM Group) was commissioned by [redacted] on behalf of the Port of Waterford (PoW) to carry out an assessment of the potential impact on aquaculture activities within the Port of Waterford and the wider Barrow, Nore and Suir Estuaries in respect of the Port's 2026-2033 Navigation Maintenance Dredging application.

2. Site Description

Waterford Estuary, located in southeast Ireland, is a semi-enclosed coastal water body open to sea through an entrance *ca*. 4.25km wide between Hook Head, Co. Wexford and Dunmore East, Co. Kilkenny. Just north of the mouth of the estuary on its western side is Creadan Head, in which a series of beaches and tidal flats are located and extend north to Passage East. The water surface area covers approximately 80km^2, comprising for the most part of relatively shallow riverine sections; however, a series of deep pockets occur within Waterford Harbour.

Three rivers flow into Waterford Estuary and these are the Suir, the Barrow and the Nore and all are influenced by the tidal cycle within the estuary (see Figure 2.1 for the catchment). The River Suir is tidal *ca*. 60km upstream from the entrance at Hook Head. The River Barrow and the River Nore, which is linked to the River Barrow, are both tidal for *ca*. 55km These three rivers, known as the 3 Sisters, have a combined catchment area of 9,207 km^2, made up of the Suir (3,610 km^2), the Barrow (3,067 km^2) and the Nore (2,530 km^2). The combined average flow rate of the Three Sisters into Waterford Harbour is 157 m^3/s, almost half of which is made up by the Suir (76.9 m^3/s), followed by the Nore (42.9 m^3/s) and the Barrow (37.4 m^3/s) (AQUAFACT, 2021a).

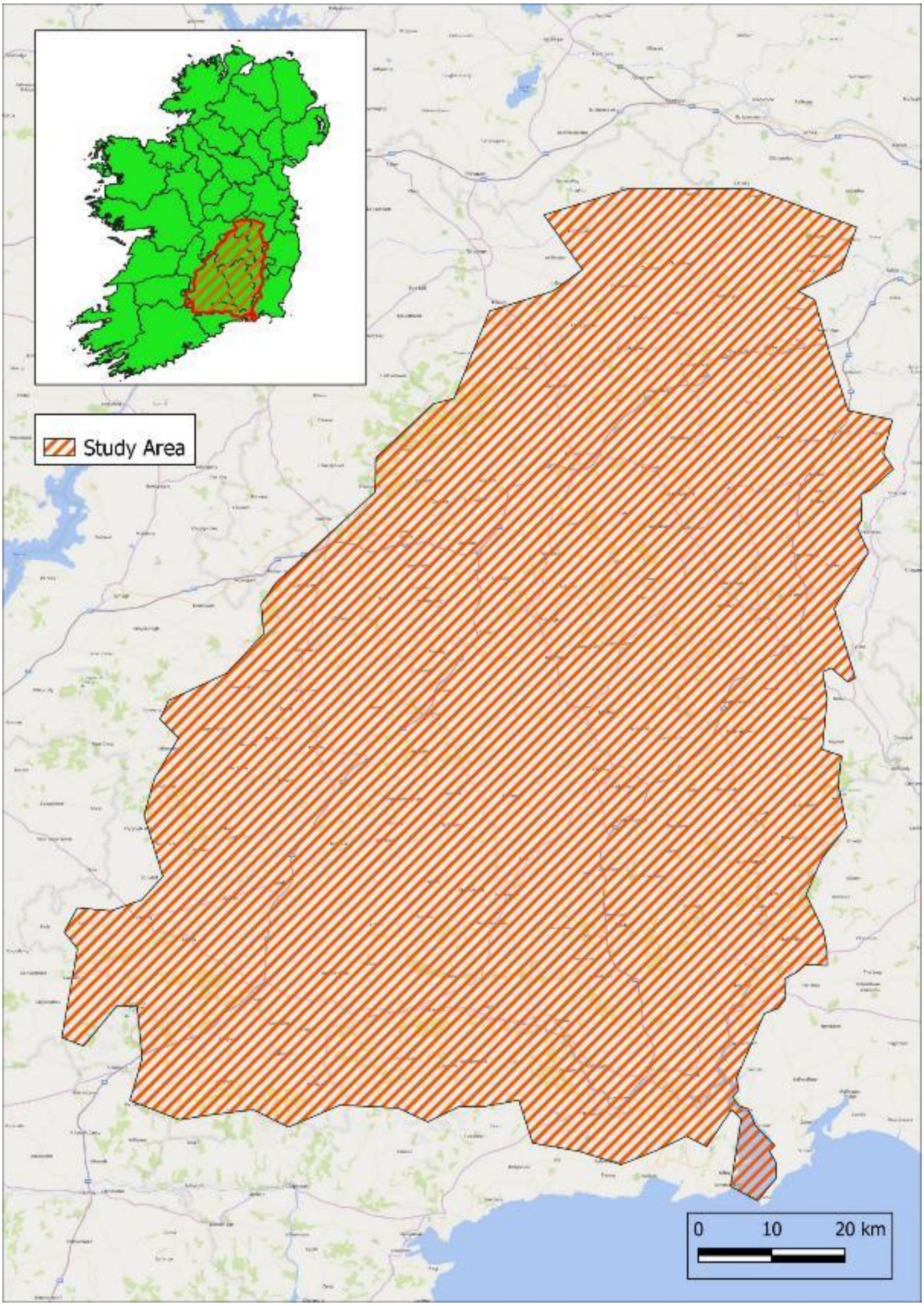

Figure 2.1: Catchment area of the Suir, Nore and the Barrow catchments including the estuarine and coastal waters including Waterford Harbour.

Land use data has been identified in Ireland since 1990 under the CORINE (Co-Ordinated Information on the Environment) initiative established in 1985 by the EU with the aim to create a pan-European database on land cover (EPA, 2003). Land use types are separated into five categories: 1. Artificial Surfaces, 2. Agricultural Surfaces, 3. Forest and semi-natural areas, 4. Wetlands, and 5. Water bodies.

A variety of agricultural land use types have been recorded within the catchment area since 1990. Land use types include:

- Pastures,
- Complex cultivation patterns;
- Lands principally occupied by agriculture with areas of natural vegetation; and
- Non-irrigated arable lands.

Pastures are permanent grasslands characterised by agricultural uses or strong human disturbance. Pastures were calculated to cover 68.1% of the total catchment area in 1990 constituting 58% of the Barrow, 75% of the Nore and 72% of the Suir catchment areas. By 2018, the overall area utilised for pasture had increased to 68.9% of the overall catchment area with the Nore and Suir areas both increasing by 1.6% in pasture cover though the Barrow recorded a decrease of 1.3% in areas used for pasture when compared to 1990.

Complex cultivation patterns are a mosaic of land parcels with different cultivation types including annual and permanent crops as well as pasture. Scattered gardens and houses can feature in this land use type. Complex cultivation patterns covered 1.8% of the total catchment area in 1990. This decreased to 1.7% of land cover by 2018.

Lands principally occupied by agriculture with areas of natural vegetation are areas use primarily for agriculture with natural forests, wetlands and other natural or semi-natural areas being interspersed in a mosaic pattern. In 1990 this land use type covered 1.8% of the catchment area and decreased to 1.6% by 2018. The Barrow and Suir areas both recorded decreases in land cover by this type, though the Nore recorded an increase of 1.2% in land cover from this type from 1990 – 2018. (AQUAFACT, 2021a).

Non-irrigated arable lands include rain-fed agricultural lands populated with non-permanent crops. This land use type covered 11.9% of the catchment area in 1990 and decreased to 9.7% in 2018. This land use type constitutes a large proportion of the Barrow catchment area which decreased by 1.6% (from 20% in 1990 to 19.4% in 2018). The land use cover of the area nearly halved in the Nore catchment area between 1990 and 2018 (9% cover to 4.6% cover) and land cover decreased from 7% to 5.1% by 2018.

Another land cover type that decreased in recent years include transitional woodland scrub *i.e.,* areas represented by herbaceous, bushy vegetation and occasional trees. This land cover type decreased by 4,500 hectares in the overall catchment area from 1990 – 2018 (3% - 2.5%). Areas occupied by peat bogs in the area also fell by 1.2% in the same timeframe, representing a loss of 11,000 ha of peat bogs in the area. (AQUAFACT, 2021a).

Run-off from these land use types will give rise to increased levels of suspended sediments into the water bodies and eventually to Water ford Harbour.

The Port of Waterford's authority limits extends 6.5 km south of a line between Hook Head and Falskirt Rock, encompassing the majority of the estuary. The Port's waterway consists of a primary navigational channel, to the main terminal at Belview and is used for the transit of trade vessels.

The estuary is complex and dynamic in its sediment movement and because of this, sedimentation is highly variable. Sedimentation in the upper estuary is dominated by the tides, with greater sedimentation during a spring tide, due to the greater amount of energy present. Flood tides transport sediment up the estuary in the water column or as bed load. However, the majority of the ebb tide flows are not strong enough to keep the material in suspension and push the sediment back down the estuary. Therefore, the sediment accumulates in the areas of lowest velocity. The outer estuary sedimentation is primarily storm driven and thus highly variable.

The navigation channel into Port of Waterford has, for the most part, good water depths but there are sand bars at Duncannon and Cheekpoint that restrict navigation into the port. These, in conjunction with the berths at Belview, are the primary areas that require dredging at least twice a year. Maintenance of the navigation channel through these bars is essential to ensure the channel remains fit for purpose and safe to use. AQUAFACT has previously carried out subtidal benthic ecology surveys on behalf of the EPA in the Belview Port Area of the estuary (AQUAFACT, 2021b).

Waterford Harbour is the location of one of 63 shellfish areas in Ireland. The shellfish area at Waterford Harbour is located at the confluence of the 3 Sisters that flow through the Waterford Harbour into the Celtic Sea (Figure 2.2).

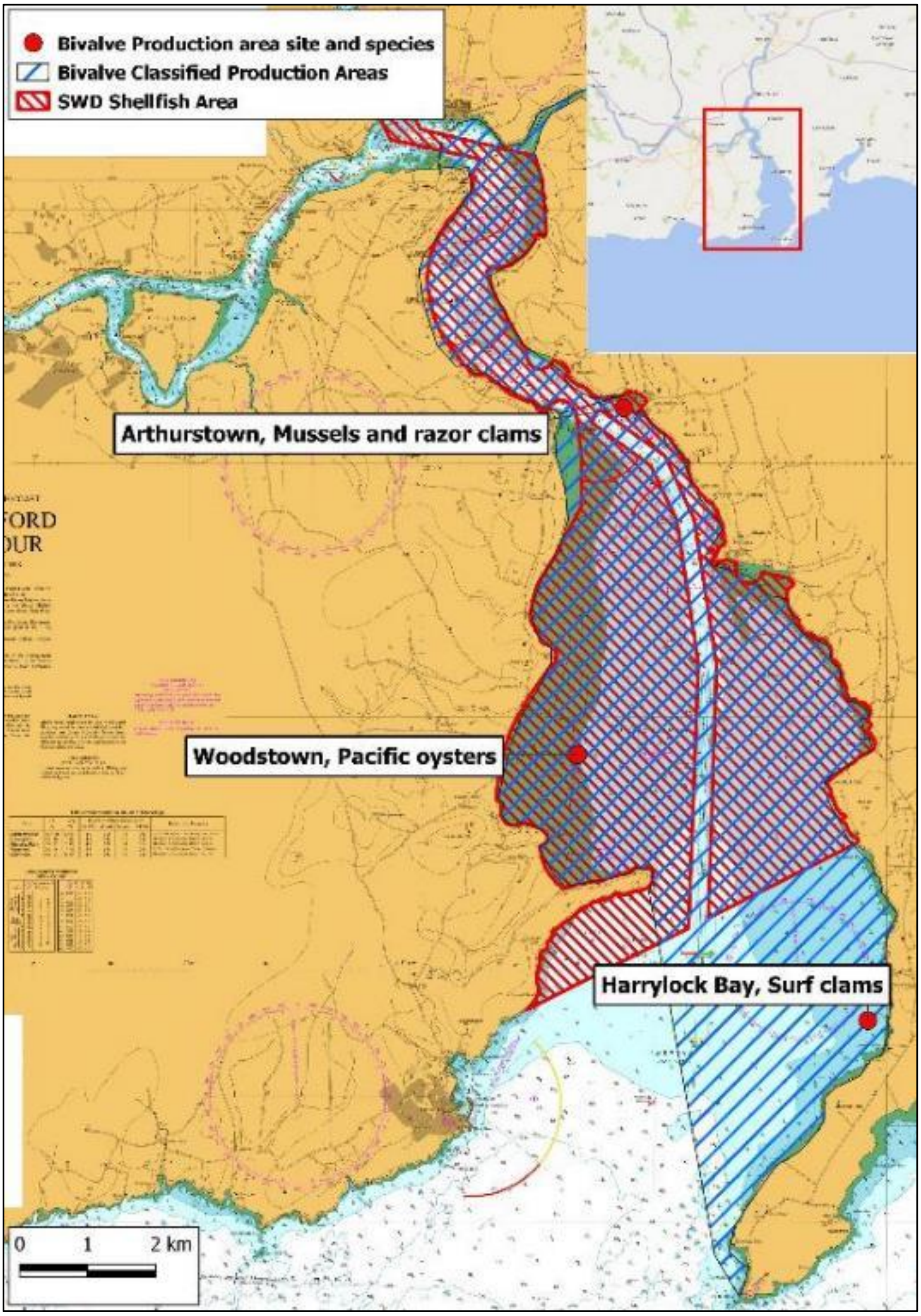

Figure 2.2: Shellfish designated waters within Waterford Harbour (Source: DHLGH, 2021)

The shellfish waters in Waterford Harbour that are designated for the protection of shellfish growth and production cover an area of approximately 30km^2. Waterford Harbour is also the location of a classified bivalve mollusc production area from which live bivalve molluscs may be harvested; in the outer harbour area three sites are sampled including Arthurstown, Woodstown and Harrylock Bay (Figure 2.2). Waterford Harbour is licensed for the production of mussels and Pacific oysters with mussels occupying an area of 176.9 ha and oysters occupying approximately 140.1 ha near Woodstown. The locations of current licensed aquaculture sites in the Harbour are shown in Figure 2.3.

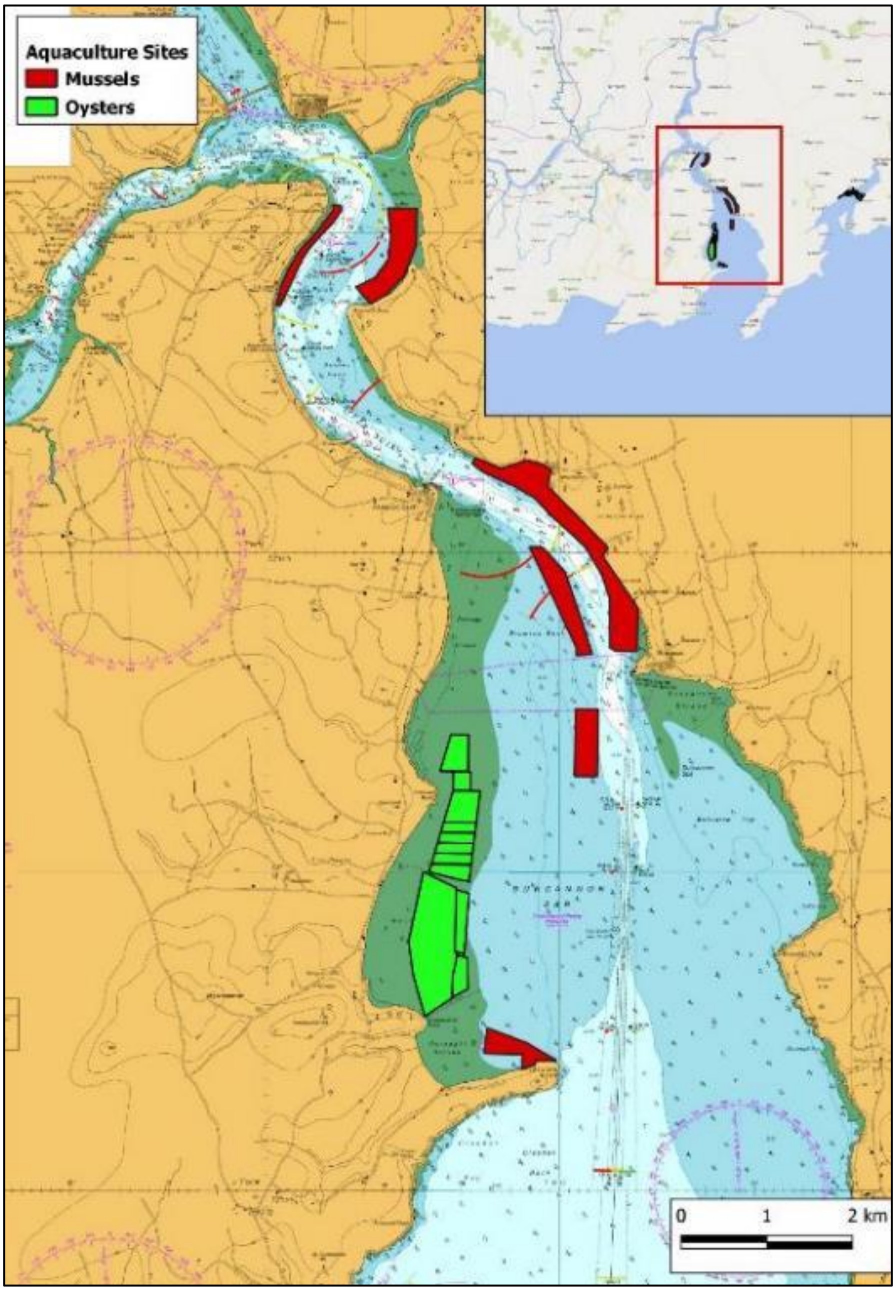

Figure 2.3: Licensed harvesting areas within Waterford Harbour (Source: Ireland's Marine Atlas, 2021).

2.1. Bathymetry

Water depths in Waterford Harbour vary from maximum depths of 20m recorded at the mouth of the harbour to 2m and shallower at Woodstown within the Barrow Suir Nore estuary. This estuarine area is characterised by a deep sinusoidal channel formed as a result of river flow augmented by dredging. The north-south running man-made channel has a maximum depth of approximately 7m and is *ca.* 100m wide. This channel is flanked by relatively shallow waters typically 2 – 4m in depth. Deep areas are also found throughout the inner estuary areas including the late stages of the lower Suir estuary and upper reaches of the Barrow Suir Nore estuary.

2.2. Tidal Currents and flow directions

There is strong tidal action in Waterford Harbour. The mean spring tidal range varies from 3.6m at Dunmore East to 3.9m at New Ross and the mean neap tidal range varies from 2.2m to 2.4m at Dunmore East and New Ross, respectively.

Due to the density of sea water, on both flooding tide and ebbing tides, the water will follow the deepest parts of the channel thereby avoiding the shallower waters where aquaculture in carried out, particularly in the shallow section at Woodtown Strand where *Crassostrea* is cultured. Additionally, as this area dries out *ca* 2 hours after Highwater and remains dry for *ca* 7 hours, it cannot be impact by sediments in suspension in the water column when dry.

2.3. Wave and Wind

Wind in Ireland occurs most frequently from the south and west whilst winds from the north and east occur least often. South and south-easterly winds are most prominent in July and accounted for over 30% of winds recorded at Rosslare from 1957 – 1996, which is the closest recording station to Waterford (see Figure 2.4).

Met Éireann, in accordance with the World Meteorological Organization's (WMO) recommendation, compute climate averages over a 30-year period of consecutive records. Between 1978 and 2007, maximum gusts (short duration peak values) were recorded in October and May and were lowest in August and June (see Figure 2.5).

On average, gusts were greater in the 1971 – 2000 period, however the average monthly wind speeds between the years did not change between 30-year records (see Figure 2.6).

As a result of the channelized nature of the estuary, wind-induced water movements have only a very minor influence on overall current patterns. However, wind has a more marked effect in relation to discharges to the outer harbour area near the ocean boundary. Wind friction on the free surface imparts motion to the superficial water and this motion is transmitted to deeper layers by a complicated process involving viscosity and turbulence. Offshore winds are usually beneficial in carrying effluent plumes offshore as a relatively thin surface layer. Onshore winds tend to contain plumes against the shore and to also deepen plumes as is largely the case in Waterford. (AQUAFACT, 2021a).

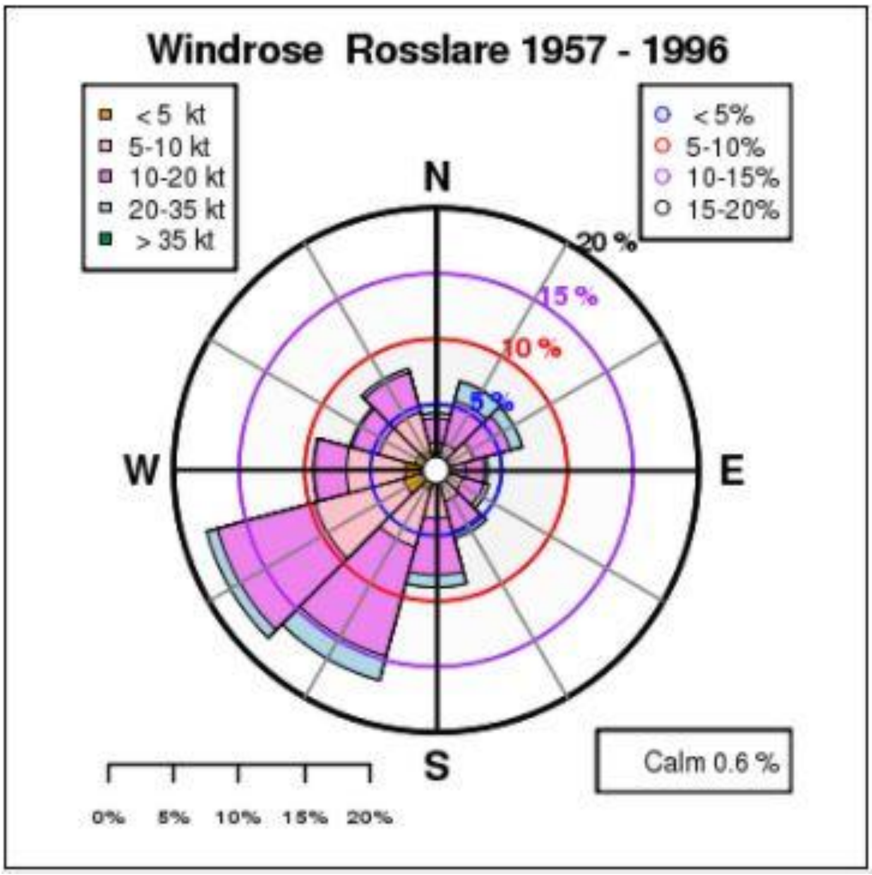

Figure 2.4: Wind rose depicting prevailing winds recorded at Rosslare, 1957 - 1996 (Source: Met Eireann).

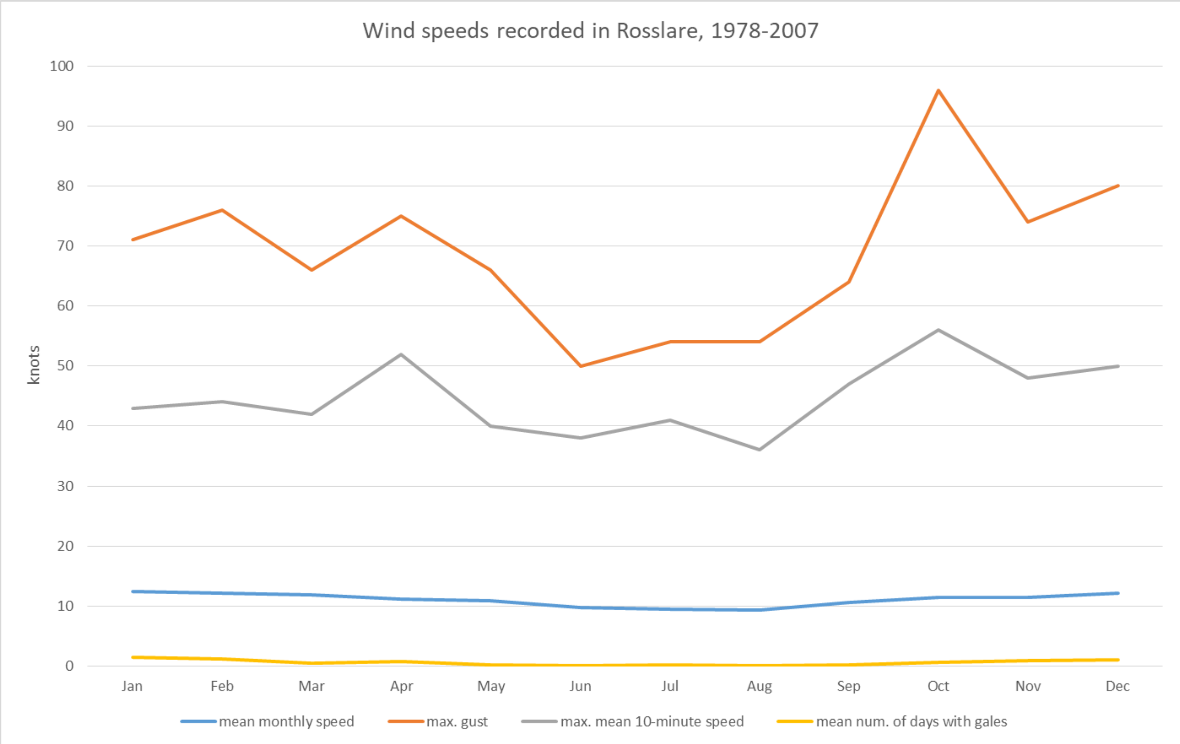

Figure 2.5: Wind speeds recorded at Rosslare, County Wexford, 1978 – 2007.

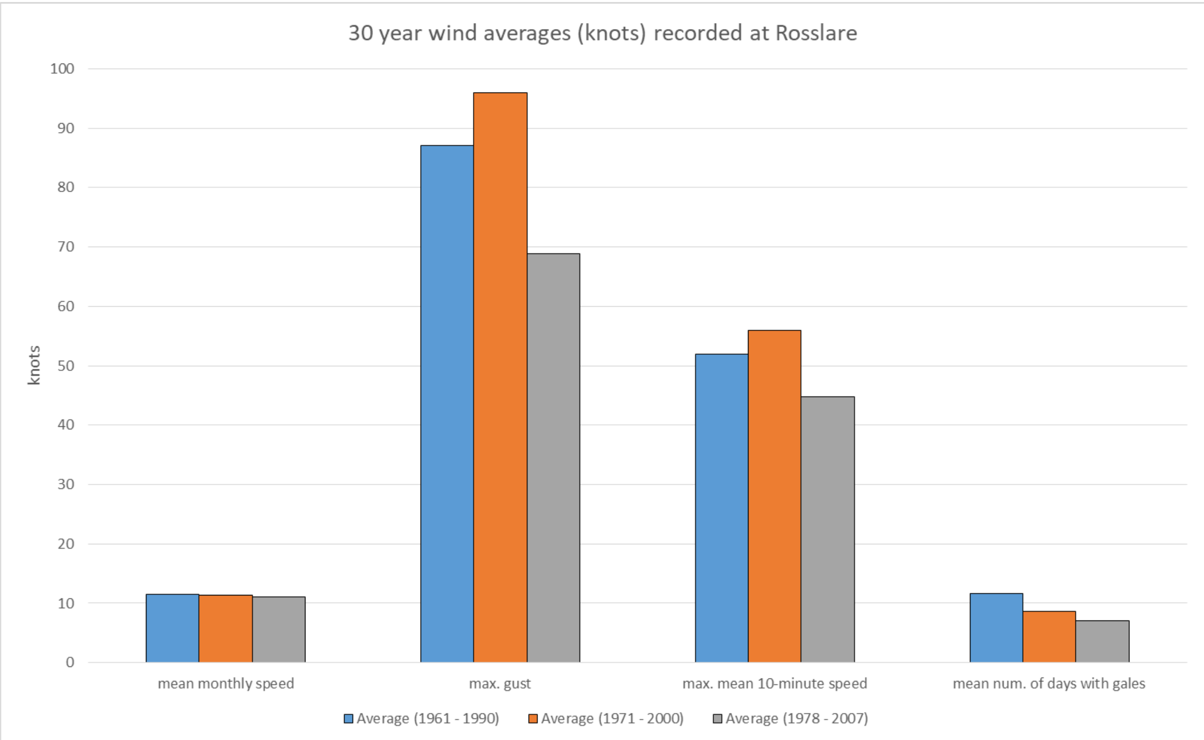

Figure 2.6: 30 year wind speed averages recorded from Rosslare, County Wexford.

2.4. *Rainfall*

Rainfall records indicate highest rainfall occurs in winter months whilst late spring and early summer months experience the driest conditions. Rainfall records were relatively consistent across the 40-year periods; rainfall peaked on average in January and generally decreased to minimal levels in late summer before increasing throughout autumn and peaking again in winter (see Figure 2.7).

Met Éireann has recorded rainfall from the Waterford area since 1850. More recently, Met Éireann have used Long Term Averages (LTAs) to put rainfall values into context. Figure 2.8 shows the average monthly rainfall accumulation from 1981 to 2010. It can be seen from this map that the southeast of Ireland is one of the country's relatively drier regions when compared to winter rainfall levels in western areas.

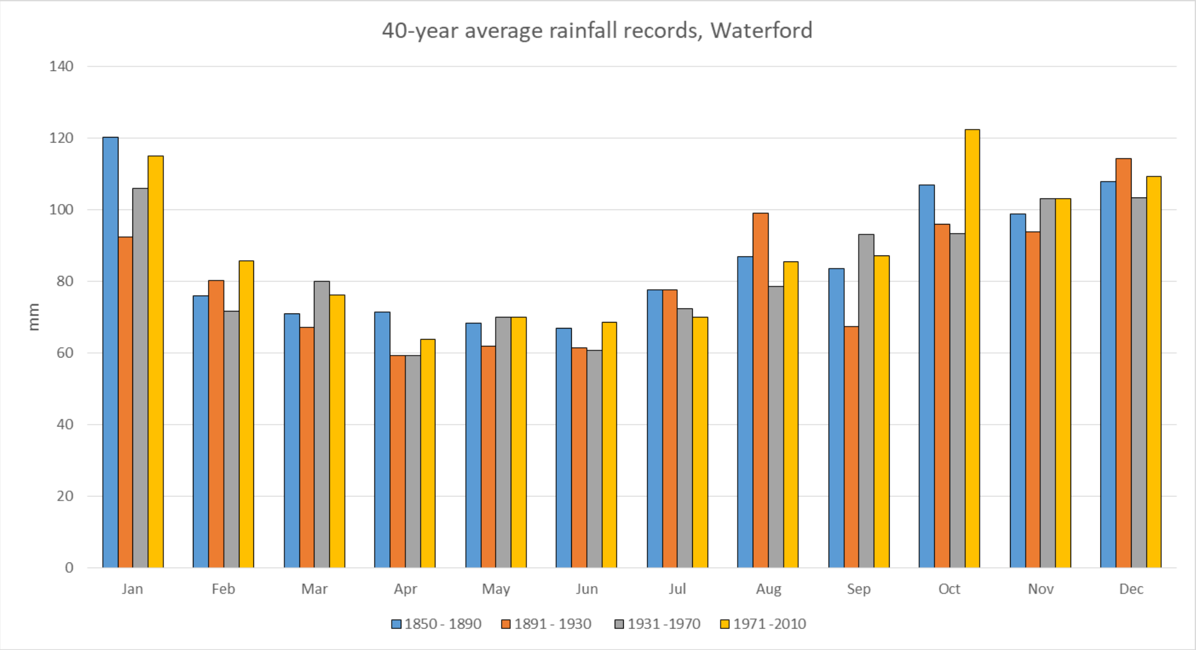

Figure 2.7: Monthly average rainfall (mm) within 40-year averages from 1850 to 2010 (Source: Met Eireann).

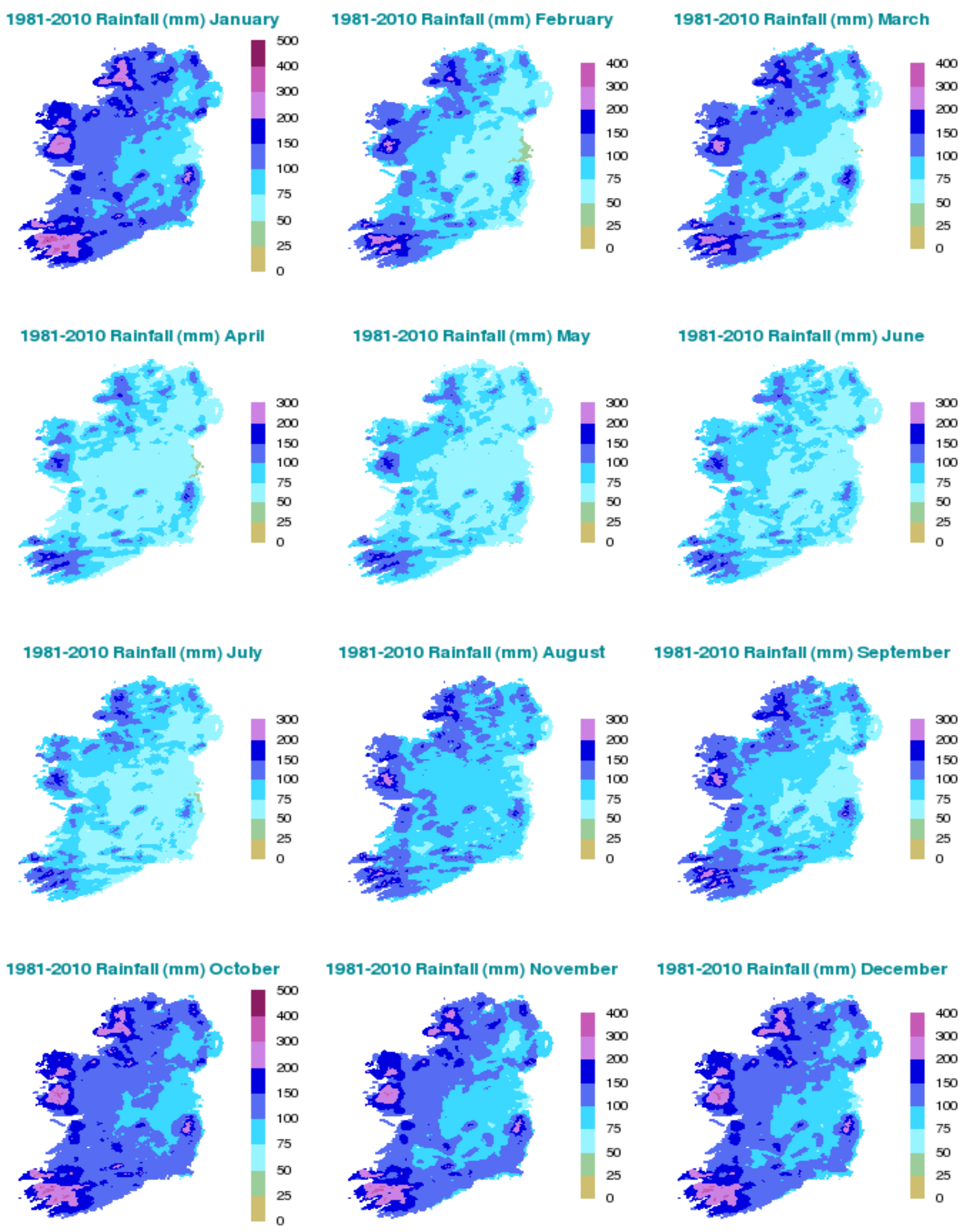

Figure 2.8: Average monthly rainfall (mm) data from January to December for 1981 to 2010 for Ireland (Source: Met Eireann).

2.5. Salinity

Salinity is the saltiness or dissolved salt (sodium chloride, magnesium, calcium sulphates and bicarbonates) content of a body of water. Freshwater typically has a salinity of <0.5 PSU and seawater typically has a salinity of between 30-35 PSU. The EPA collect, manage, and process data regarding the physical and chemical parameters of water in relation to the WFD including salinity.

2.6. Sediment

Loss on Ignition (LOI) is a measurement of the organic content of sediment samples. LOI has been recorded by the Marine Institute since 2013. Records of LOI reveal sediments with higher carbon content occurring at relatively upstream locations when compared to those located in the lower Waterford Harbour areas (Figure 2.9).

Due to the size of the catchment area drained by the rivers, it is likely that the contribution of organic material *e.g.,* leaves and soil run off, from the catchment area will be significant. The organic content of sediments leading to increased LOI% was seen at stations in the Lower Suir Estuary, New Ross Port and Barrow Suir Nore Estuary, relative to records of lower sediment LOI% at stations in the Waterford Harbour likely due to the hydrographic conditions of the lower harbour area.

The sediments within the harbour are classified as slightly gravelly muddy, gravelly muddy sand, sand, muddy sand, and gravelly sand according to Folk (1954). Organic matter values range from 1.97% to 9.33%. (AQUAFACT, 2021a).

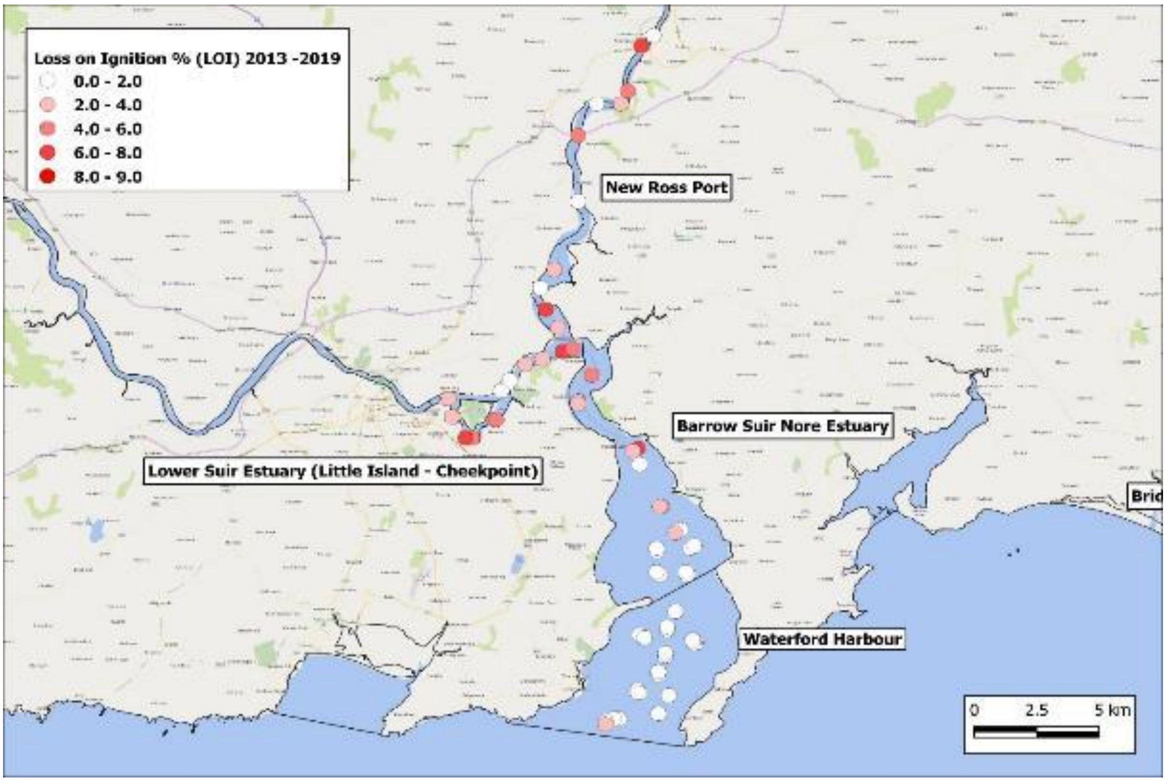

Figure 2.9: LOI (%) of sediment samples from Waterford Harbour, 2013 – 2019. **(AQUAFACT, 2021a).**

3. Navigation Maintenance Dredging 2026-2033

Waterford Harbour is complex and dynamic in its sedimentation movement and because of this sedimentation is highly variable. Sedimentation in the upper estuary is dominated by the tides, with greater sedimentation during spring tides, due to the greater amount of energy present. Flood tides transport sediment up the estuary in the water column or as bed load. However, the majority of the ebb tide flows are not strong enough to keep the material in suspension and push the sediment back down the estuary. As a result of this, the sediment accumulates in the areas of lowest velocity. In the outer estuary sedimentation is primarily storm driven and thus highly variable.

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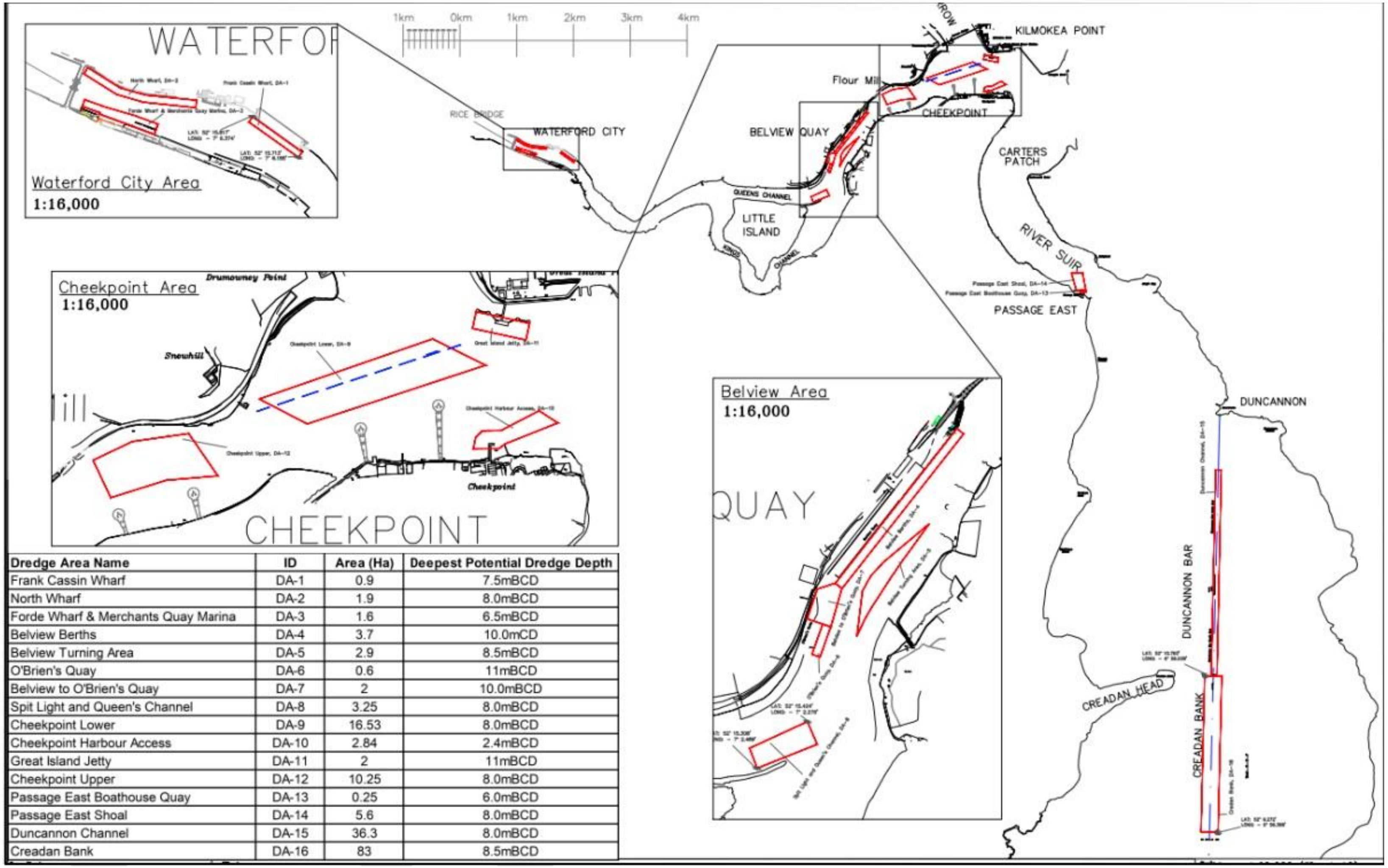
The current licence (S0012-03) expires on the 31st of December 2025 and therefore the Port of Waterford is seeking an 8-year duration Dumping at Sea Permit and Foreshore Licence to run inclusively from 2026 to 2033. It has requested that the maintenance dredging required be allowed to be undertaken at any time during this period as identified by regular hydrographic surveys. Any maintenance operations will be dictated by the extent of sedimentation that has occurred in each area of the harbour. These rates can fluctuate significantly, based on inclement weather resulting in storm conditions and high rainfall. Severe sedimentation has occurred in the past after a storm event and this contingency is included to ensure that the port can act immediately to reduce the build-up and allow trade to continue. The existing dumping at sea permit does not allow ploughing to occur between the start of March and the end of June, with the exception of those sites at Cheekpoint where ploughing is restricted to spring tides periods only. Bed levelling is permitted to be undertaken at all times of the year. No change to this is proposed. Similar to the current permit, the Port Authority has requested that 823,513 wet tonnes are permitted to be disposed of at the offshore site from 2026 to 2033 inclusive. There has been no increase in the permitted quantity of sediment disposed of at the offshore site since the inception of the site.

Sedimentation rates can vary considerably depending on the severity of weather conditions, river flow and prevailing wind directions. Severe sedimentation has occurred in the past after a storm event and this contingency is included to ensure that the Port of Waterford can act immediately to reduce the build-up and allow trade to continue. Therefore, further to this regular disposal activity, the Port Authority has also requested that an annual contingency tonnage of 175,000 dry tonnes be allocated to this disposal site should extreme weather events cause an inundation of sediment. This increased allowance is requested due to the inclusion of Creadan Bank on the application, which is located in an extremely dynamic area and represents a significant risk in extreme events. As per previous permits, this allocation would only be deposited if the dredging of this material is required to maintain navigable depths, as evidenced by pre-dredge and post dredge bathymetric surveys. The use of the contingency allowance would be subject to the prior written agreement of the EPA. This contingency allowance is not requested as part of the regular annual tonnage as it is likely it will not be needed, and it would unnecessarily increase the annual permitted dumping tonnage. However, failure to include an allowance for inundation events would be irresponsible of the port, considering the estuary’s history of such events. The inclusion of the contingency figure means that an emergency application to the EPA would not be required for an extreme weather/inundation event when a quick response to the conditions may be required. Under its current permit/licence, the port is permitted to plough dredge a maximum of 159,165 wet tonnes annually. No change to this tonnage is proposed.

The proposed dredging areas to be maintained by Port of Waterford are shown in Figure 3.1. The location of the disposal site to the west of Hook Head is presented in Figure 3.2.



Dredge Area Name	ID	Area (Ha)	Deepest Potential Dredge Depth
Frank Cassin Wharf	DA-1	0.9	7.5mBCD
North Wharf	DA-2	1.9	8.0mBCD
Forde Wharf & Merchants Quay Marina	DA-3	1.6	6.5mBCD
Belview Berths	DA-4	3.7	10.0mCD
Belview Turning Area	DA-5	2.9	8.5mBCD
O'Brien's Quay	DA-6	0.6	11mBCD
Belview to O'Brien's Quay	DA-7	2	10.0mBCD
Spit Light and Queen's Channel	DA-8	3.25	8.0mBCD
Cheekpoint Lower	DA-9	16.53	8.0mBCD
Cheekpoint Harbour Access	DA-10	2.84	2.4mBCD
Great Island Jetty	DA-11	2	11mBCD
Cheekpoint Upper	DA-12	10.25	8.0mBCD
Passage East Boathouse Quay	DA-13	0.25	6.0mBCD
Passage East Shoal	DA-14	5.6	8.0mBCD
Duncannon Channel	DA-15	36.3	8.0mBCD
Creadan Bank	DA-16	83	8.5mBCD

Figure 3.1: Proposed Dredging Areas to be Maintained by Port of Waterford (Malone O'Regan, 2023).

3.1.1. Trailing Suction Hopper Dredger

Due to the specific characteristics of the Port of Waterford the Trailing Suction Hopper Dredger (TSHD) is the primary dredging method used to maintain the design depth of the navigational channels, and the other accessible areas of the Port's berths. The areas to be dredged will be identified regularly by hydrographic survey.

To start the dredging operations, the TSHD will sail to the area to be dredged. Once in the vicinity of its dredging area, the TSHD will lower the draghead(s) to the seabed and dredging can commence. The centrifugal dredge pump, installed inside the dredger, takes up a mixture of water and soil through the draghead and suction pipe, and pumps the mixture into its integral hopper. The sediment will settle in the hopper and, if advantageous, only the water is discharged through an adjustable overflow system. When the draught of the vessel reaches the dredging loading mark or when circumstances do not allow for further loading, dredging will cease, and the suction pipe hoisted on deck. The dredger will fill its hopper in each of the identified dredging areas as efficiently as possible.

Upon filling its hopper, the dredger will sail to the licensed disposal site and slows to approximately one to two knots. The dredger will then open bottom doors, or split along its hull, to allow the release of its contents over several minutes. During the disposal operation the dredger is travelling at between one to two knots within the disposal area. Due to this, the material is spread over the disposal site and ensures against accumulation of material within an isolated area (*i.e.,* the centre of the disposal site). This process is repeated for each disposal operation, with the master of the vessel referring to the previous disposal locations used within the on-board tracking system and selecting a new disposal location within the licensed area. By using as much of the disposal site as possible any impacts of excessive accumulation in one location from the disposal activity will be minimised.

This process will be continued until interim hydrographic surveys show that the required safe navigation depths required have been achieved and dredging can cease.

3.1.2. Plough Dredging

A plough vessel generally uses, if available, a bulldozer type plough to relocate material, although a standard open box plough can suffice on occasion. Sediment movement is achieved by towing a bottomless rectangular box-shaped fabricated steel implement behind a powered vessel, usually a small workboat or tug. When used correctly, the plough is suspended at a controlled height from an A-frame mounted over the stern of the towing vessel. Height, or depth of submergence, is controlled by a deck mounted hoist winch. The cutting blade at the leading edge of the plough slices the surface sediment which is then contained within the sides and rear of the following plough until reaching an area where the bed level is lower than the suspended level of the plough, whereupon the contained sediment falls from the open bottom of the plough. The plough is then raised above the general seabed level and the towing vessel returns to the area from which sediment is to be moved and repeats the cycle.

Ploughing is also undertaken regularly at Cheekpoint Lower Bar. The Port of Waterford has invested considerable time and effort over the last number of years to study the sedimentation regime that occurs at Cheekpoint Lower Bar. This is because it is the primary dredging cost for the Port annually. From a variety of studies and observations, the Port have ascertained with confidence that sedimentation is significantly greater over spring tide periods. Sedimentation rates on the spring tide can commonly be 2 to 3 times greater than the neaps, and on occasion considerably more. Turbidity monitors in and around Cheekpoint have reflected this assertion as the spring tide energy mobilises significant amounts of sediment around the estuary generally. A hydrodynamic model developed by the Port has corroborated this hypothesis. Therefore, the decision was taken to undertake ploughing during spring tide periods to minimise the amount of sediment settling in the area while it was still fluid and unconsolidated. The premise of these operations is prevention rather than cure. Also, environmentally, ploughing on spring tides is also more attractive due to the naturally elevated background levels of suspended sediment that are present. The port has used this preventative technique over the past number of years in compliance with its current licence/permit. Furthermore, the Port is currently looking at long term solutions to try and minimise or negate the sedimentation and associated dredging requirement at Cheekpoint Lower Bar and is seeking to progress these options.

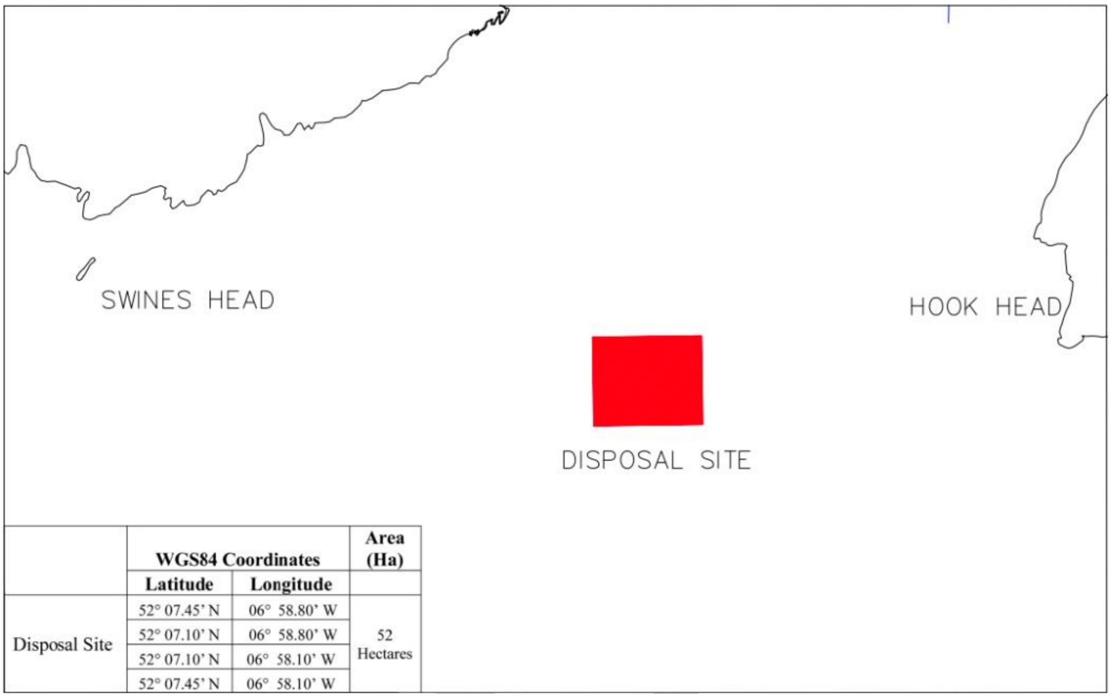
3.1.3. Mechanical Dredging

There is also the potential for utilisation of a mechanical dredger in some areas. These dredgers use a bucket lowered to the seabed to excavate the targeted sediment material which is then raised to the surface. However, these dredgers do not have any means of transporting the dredged sediment so 'hopper barges' are required to be filled and transit to the licensed disposal site. The areas that may require the use of a mechanical dredger are limited to quay walls and berths where material has been compressed and has consolidated to a degree that it cannot be removed by other methods of dredging. This option is not favoured by the Port as it is significantly more expensive that the use of a TSHD/plough and it is only utilised as a last resort when conditions dictate the standard processes are technically unfeasible.

3.1.4. Disposal Site

The offshore disposal site (Figure 3.2) proposed for this application has been in use for the Proposed Development since 1996. The dredging methodology, volume and local site characteristics have not changed in the intervening period, so all historical studies undertaken with respect to the dump site and its impacts are deemed to be relevant.

Given the location of the disposal site and the distance to the nearest aquaculture site at Woodtown, there is no potential for impact on this site from the disposed material.



	WGS84 Coordinates		Area (Ha)
	Latitude	Longitude	
Disposal Site	52° 07.45' N	06° 58.80' W	52 Hectares
	52° 07.10' N	06° 58.80' W	
	52° 07.10' N	06° 58.10' W	
	52° 07.45' N	06° 58.10' W	

Figure 3.2: Offshore Disposal Site.

4. Discussion

4.1. Suspended Solid Concentration and Sedimentation

Naturally occurring, tidally generated suspended solid concentrations were modelled by Delft Hydraulics (Eysink *et al*., 2000) and vary between 50 and 500mg/l at both Belview Point in the River Suir and at Garraunbaun Rock near Ferry Point in the White Horse Reach of the River Barrow. In contrast, at Cheekpoint, the confluence of the River Barrow and the River Suir, the tidally generated suspended solids concentrations were typically less than 150mg/l. Downstream in the River Suir, between Passage East and Buttermilk Point, naturally occurring, tidally generated suspended solids exceeded 1,000mg/l. Tidally generated suspended solids at Duncannon Bar within the Suir Estuary were above 100mg/l at bed and mid-water on spring tides. Background suspended sediment concentrations (SSC) (of the fraction) in the Cheek Point area vary dynamically during the tidal cycle, with maximum concentrations at 0 to 2 hours after maximum ebb and flood currents and minimum concentrations at 0 to 2 hours following slack water (Rijn, 1990).

ABP Marine Environmental Research Ltd. (ABPmer) modelled the impact of plough dredging at Cheek Point Lower (ABPmer, 2017). The modelling showed that the dispersed sediment would move throughout the estuary, with the vast majority moving up-estuary, but would generally be confined to the area between Buttermilk Point and Little Island. The greatest effects were seen throughout the estuary at the end of the plough disturbance scenario (8 days with ploughing ceasing on Day 4). These effects fall back to background levels within about four days following cessation of ploughing on falling spring tides. Most material would be moved (transported and eroded) on the flood tide and during spring tides whereas neap tides would predominantly be accretional. The modelling identified locations of temporary sediment storage (later eroded) as well as sediment 'sinks', where accretion would be more permanent, notably the southern edge of the Cheekpoint section, adjacent to the maintained channel. Maximum SSC (suspended sediment concentrations) (above background) at the point of disturbance were around 2,500 mg/l near-bed at the time of peak flows and 1,500 mg/l during slack flows. One day following completion of plough disturbance, peak SSC would reduce by over an order of magnitude at the disturbance site. Maximum concentrations away from the disturbance location, for the most part, would occur on peak flood flows as 'pulses' that rarely last for longer than 30 minutes per tide.

Individual spikes can reach 1,000 mg/l at some locations. Elevated SSC that last for several hours are generally in the range 150-250 mg/l, depending on location, on spring flood tides, and lower on ebb tides. Average elevated concentrations are rarely above 50 mg/l. These values compare against the measured background SSC level, which were recorded between 350 and 600 mg/l between Carter's Patch and the River Barrow, on a typical spring tide, increasing to up to 1,000 mg/l during an observed storm event. Sedimentation as a result of the plough disturbance is for the most part temporary, accumulating during periods of slack water, or in areas of eddy circulation. With the exception of identified 'sink' areas, accumulations are small, a few millimetres to 1 to 2 centimetres. Most accumulations are re-eroded on the following peak flows (predominantly on the flood). In the areas around Carter's Patch, sedimentation of up to 1.5 cm was present for a maximum period of 6 hours before being re-eroded and in all cases, sedimentation rates and SSC levels increase after *c*. 2 days of ploughing. This indicates that this is the timescale for disturbed material (probably the coarser fraction) to move up- and down-estuary, before returning through the Cheekpoint area (AQUAFACT, 2017).

Figures 4.1 and 4.2 show the differences in SSC immediately at the end of ploughing (Plough +0 days) and 4 days following cessation of ploughing (Plough +4 days) at ebb and flood tide respectively. Figures 4.3 and 4.4 show the differences in sedimentation immediately at the end of ploughing and 4 days following cessation of ploughing at high water and low water respectively.

Delft Hydraulics modelled the impacts of trailer-suction hopper dredging activities at the Duncannon Bar on the spreading of suspended sediment in the estuary of the River Suir (Eysink *et al.,* 2000). Environmental Tracing Systems (ETS) undertook a fluorescent particle tracing study in order to determine the fate of dredged material from Cheek Point Harbour (ETS, 1998). The turbidity generated by the dredging activity must be weighed against the turbidity which results from natural processes *e.g.,* storm surges, and the background turbidity *e.g.,* navigation, that occurs in the dredging areas before, during and after the dredging activity. The majority of suspended sediment generated due to dredging activities is at depth *i.e.,* close to the seafloor. In its initial deliberations, Delft Hydraulics (Eysink *et al.,* 2000) considered that the additional turbidity above background levels 50m around the dredging Trailing Suction Hopper Dredge would be of the order of *c*. 250-300mg/l of suspended solids. However, the modelling concluded that the increase in suspended sediment concentrations above background would be of the order of 100mg/l within 50m of the dredger. Assuming suspended solids in the channel are at the upper end of this observed range *i.e.,* 100mg/l, the suspended solids concentrations local to the dredger are likely to increase to the order of 250mg/l at Cheekpoint and 200mg/l at Duncannon Bar.

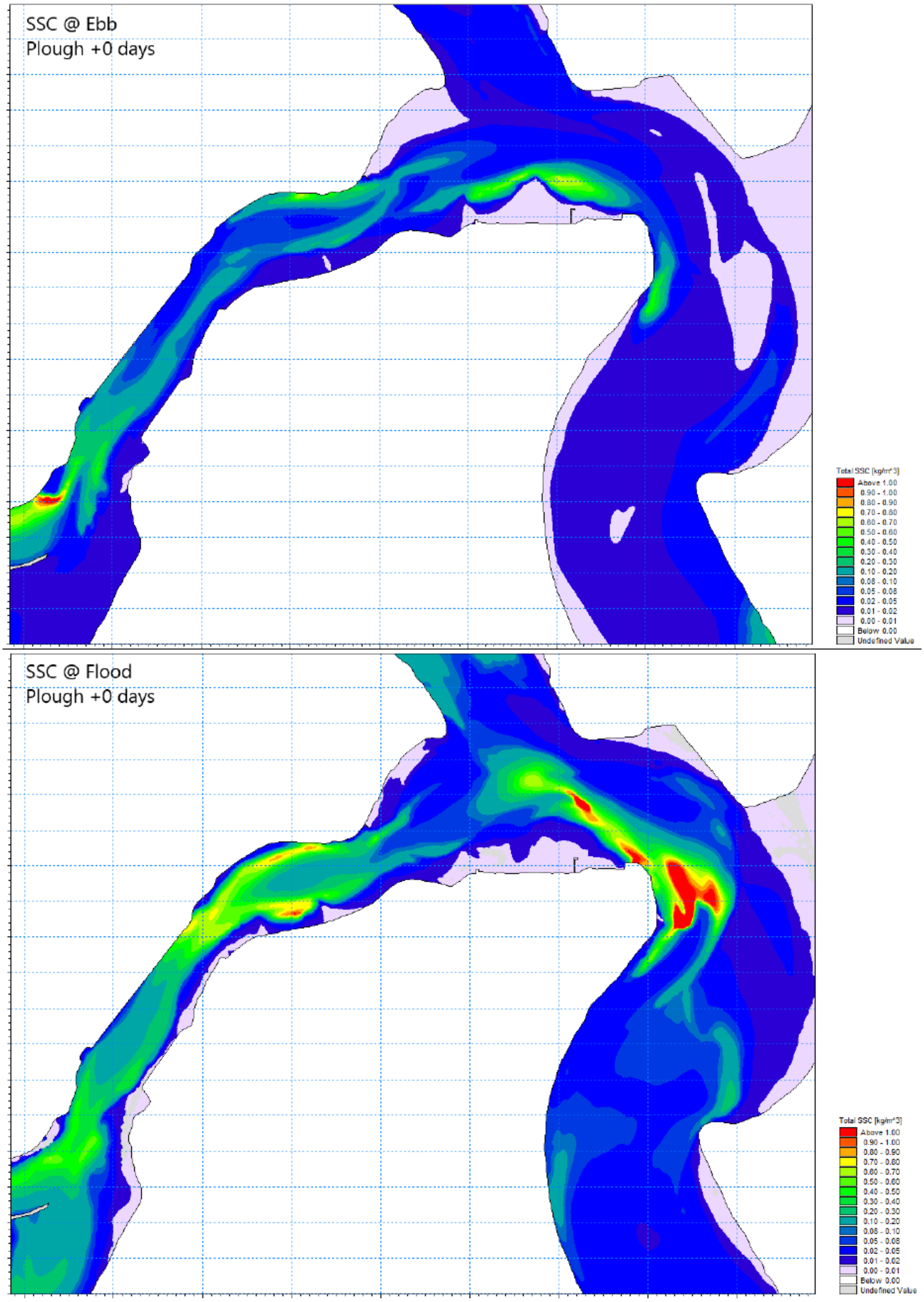


Figure 4.1: SSC at ebb and flood tide immediately at the end of ploughing.

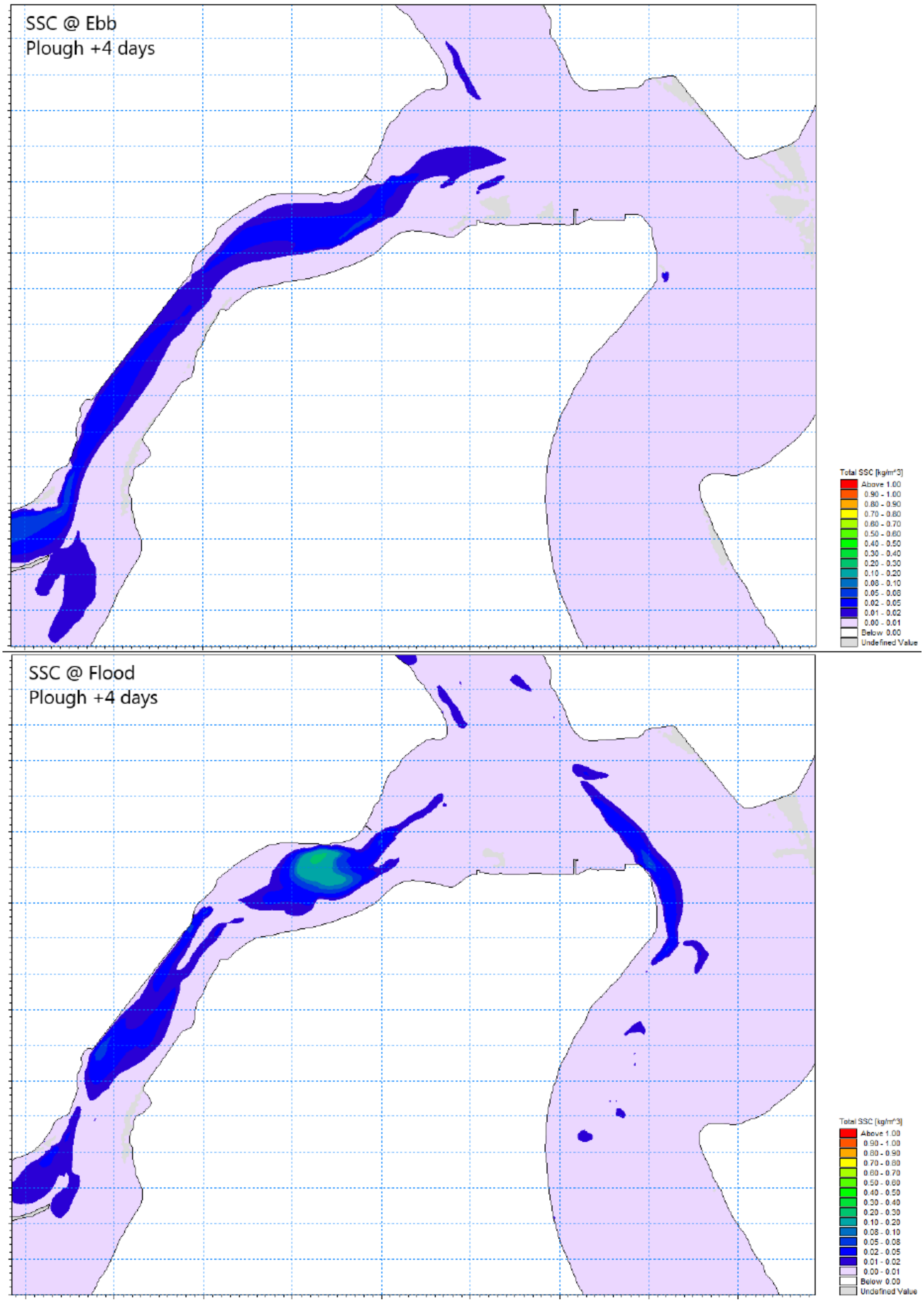


Figure 4.2: SSC at ebb and flood tide 4 days following cessation of ploughing.

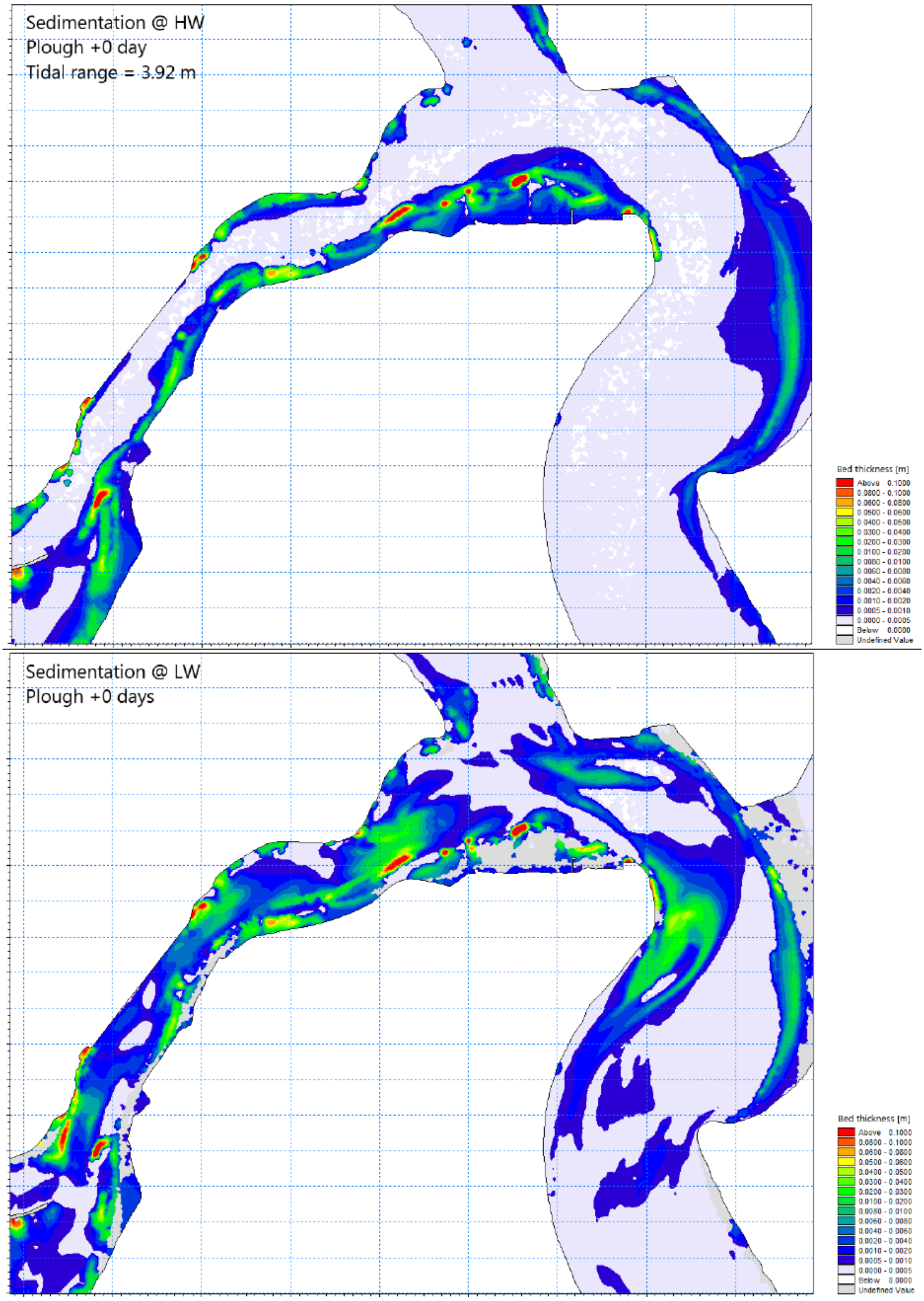


Figure 4.3: Sedimentation at high and low water immediately at the end of ploughing.

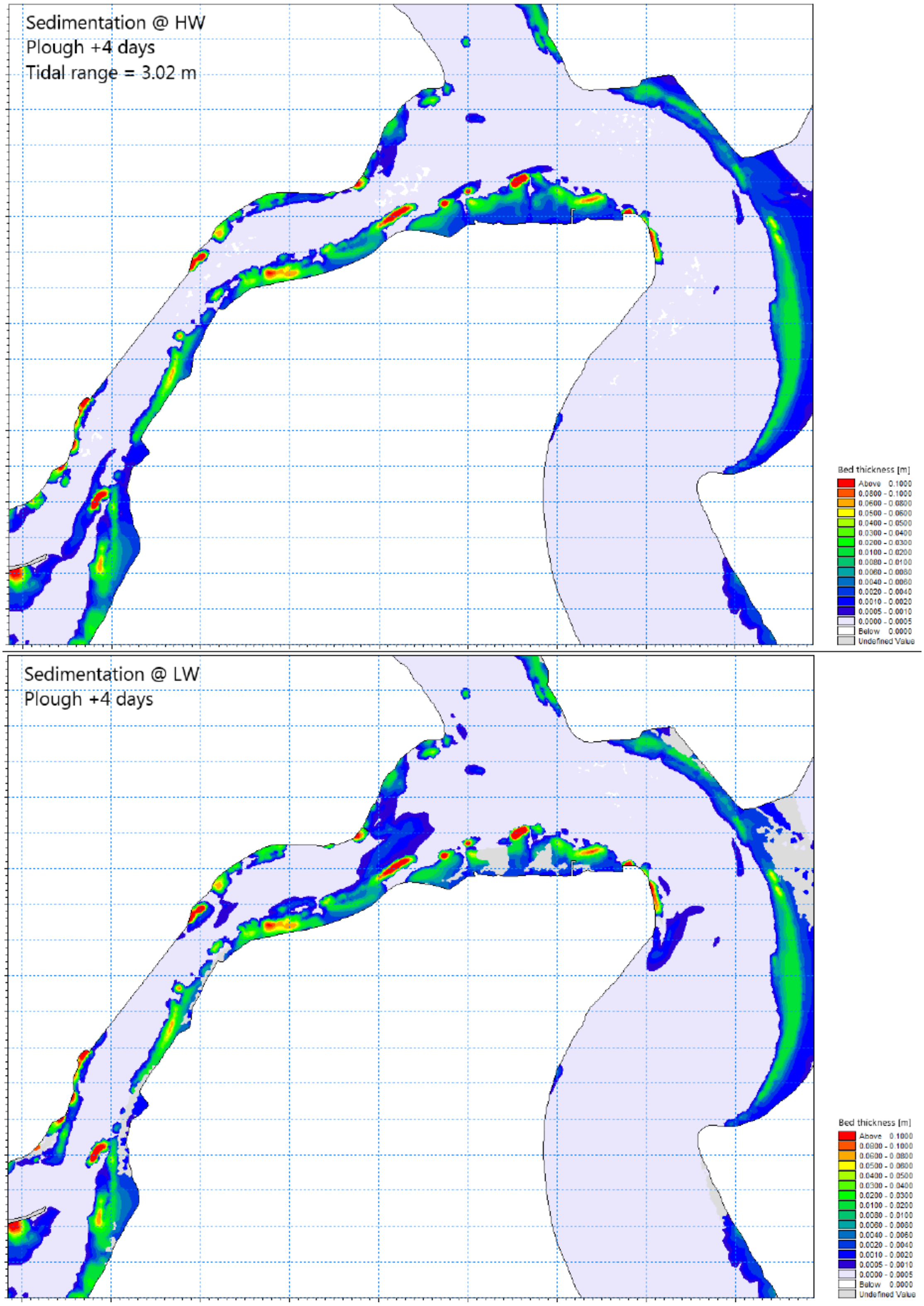


Figure 4.4: Sedimentation at high and low water 4 days following cessation of ploughing.

Overall, predicted levels of deposition with Waterford Harbour are low. No deposition of sediment is predicted by the model for the Woodtown area.

4.2. Assessment of Impact

When considering the sensitivity of the aquaculture species in the area to the proposed dredging activities, the sensitivity to extraction (dredging) as well as the sensitivity to siltation, both heavy siltation (30cm burial) and light siltation (5cm burial) is considered. However, as extraction does not occur in aquaculture sites, it can have no impact on either cultured species.

Based on the sedimentation models, sedimentation as a result of the plough disturbance is for the most part temporary, accumulating during periods of slack water, or in areas of eddy circulation. With the exception of identified 'sink' areas, accumulations are small at a few millimetres to 1 to 2 centimetres. Most accumulations are re-eroded on the following peak flows, predominantly on the ebb. In the areas around Carter's Patch, sedimentation of up to 1.5 cm was present for a maximum period of 6 hours before being re-eroded and in all cases, sedimentation rates and SSC levels increase after *c*. 2 days of ploughing. This would be considered light siltation (5cm burial).

Oysters and mussels have evolved over geologically long periods of time (many hundreds of millions of years) to live in areas where suspended sediment levels can be either highly variable (as in estuaries) or stable (see Hawkins *et al.,* 1996; Raghunathan *et al.,* 2003; Dutertre *et al*., 2009: Barillé *et al.,* 2011; Lunt and Smee, 2020 *inter alia*).

Cunningham (2021) reviewed water quality data collected by 2 sensors in Waterford Harbour and these included turbidity. The deployment period covered dredging campaigns during July 2020 through February 2021. One of Cunnigham's conclusions was that the effect of dredging /ploughing has not caused any significant departure from the natural background pattern of turbidity.

With regard to fluctuations in salinity, Giese and Pearse (1979) comment that oysters (including both *Ostrea* and *Magellana (Crassostrea*) are very tolerant of variable salinities while Gosling (2015) states that many bivalves are euryhaline, that is they can tolerate an extremely wide range of salinities in their natural environment. Gosling goes on to say that Blue Mussels (*Mytilus edulis*) can tolerate salinities ranging from 4 – 5 psu to fully marine conditions while Rock Oysters (*Magellana*/*Crassostrea*) occur in salinities from 5 – 35 psu.

3. Conclusion

Given the physical oceanographic conditions in Waterford Harbour, the already turbid character of its waters, the fact that both oysters and mussels have evolved to live in such conditions and that the predicted levels of suspended sediments generated by the dredging and disposal activities are low, the level of impact of such activities on aquaculture species is extremely low.

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