ABP Port of Lowestoft

Berth Utilisation Assessment

Years: 2015 to 2017

April 2019





Innovative Thinking - Sustainable Solutions

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1 Introduction

ABPmer has been commissioned to undertake an assessment of the usage and occupancy of berths within the Port of Lowestoft. The study also identifies potential implications of the proposed Lake Lothing Third Crossing (LLTC) Bridge on berth utilisation.

1.1 The proposed LLTC Bridge scheme

Suffolk County Council (SCC) has proposed the LLTC Bridge as a way of alleviating road transport congestion issues in Lowestoft. The proposed LLTC Bridge will span the harbour in the vicinity of North Quay Berth 3. As a result, all of the berths lying from North Quay 3 westwards will be separated from the sea by two bridges. The location of the proposed new bridge is illustrated as Figure 1.

Taken from document reference 1069948-WSP-MAR-LL-RP-MA-0010

Figure 1. Location of LLTC

With the bridge in place, there will be a reduction in available quay face along North Quay. The loss implications of the proposed LLTC Bridge are:

- North Quay 2: effectively lost due to its limited utility;
- North Quay 3: lost in entirety; and
- North Quay 4 East: effectively lost in entirety.

ABP has considered the existing mooring infrastructure and concluded that it would not be practical or feasible to re-arrange bollard restraint points. It follows, therefore, that larger (i.e., longer) vessels that would normally span a number of these berth locations will be displaced by the physical presence of the bridge and its protective fendering. ABP has confirmed that these consequential impacts, when measured in whole berths, increase the potential berth loss to 165 metres (a combination of multiple berths), as illustrated in Figure 2.

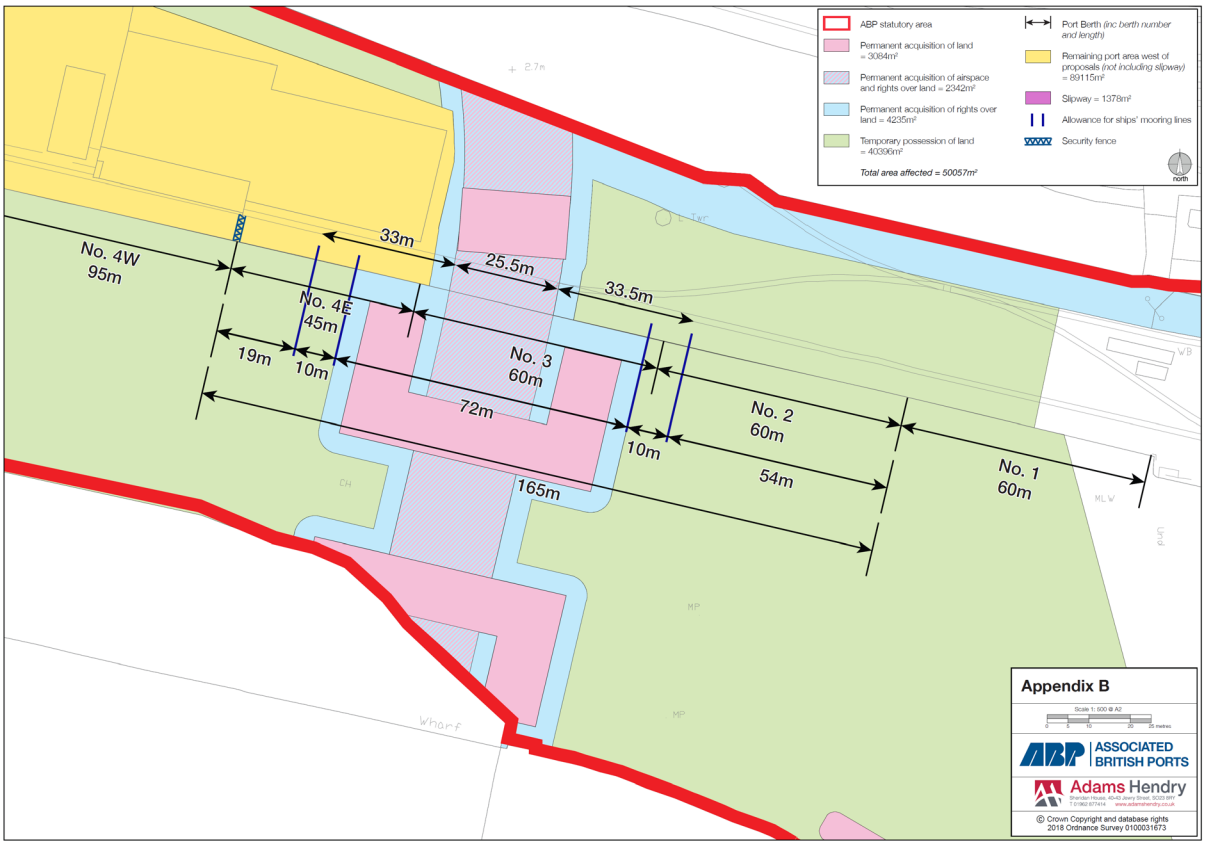

Figure 2. North Quay Berths and location of the proposed LLTC Bridge

This report summarises the analyses that have been completed to assess the berth occupancy ratios (termed "berth utilisation" in this report) for a number of berths across the port, as a representation of the port activity. Berth utilisation is calculated as the percentage of time a berth is occupied by a vessel, or vessels (if double-banked), compared with the total time the berth is available in the year. The analysis is the same as the berth occupancy ratio (BOR), which is often used an indicator of port performance and is described further in Section 4.1. In this report, the berth utilisation is assessed under a number of scenarios representing present and future operations within the Port, both 'with' and 'without' the proposed LLTC Bridge in place.

The report is structured as follows:

Section 1: Sets out the study objectives and introduces the proposed LLTC Bridge scheme.
Section 2: Provides a background to the Port, its responsibility as the Statutory Harbour Authority and its operational berths.
Section 3: Introduces the data used for the analyses, including the vessel movement and berthing information between January 2015 and December 2017.
Section 4: Introduces the berth utilisation analysis method used for this study.
Section 5: The completed berth utilisation analysis is presented here, along with the scenarios implemented to investigate the potential implications of the LLTC Bridge under present and future situations. The assessed berth utilisation results are presented for each respective scenario.
Section 6: Evaluates the results of the different scenarios to gain an understanding of any potential implications from the LLTC Bridge.
Section 7: Summaries the conclusions from this study.

2 About the Port of Lowestoft

The Port of Lowestoft is the UK's most easterly port facility with the capability of accommodating vessels up to 5,000 gross tonnes, as identified in the unpublished port masterplan (ABP, unpublished). The Port of Lowestoft's position in the southern North Sea makes it ideally situated for major new growth markets in energy and construction aggregates, as well as building on its traditional strengths in agribulks and fisheries. Historically, the Port was a centre for the regional fishing industry and ship building. However, this declined up to the 1990s', which also led to a general decline in Port activity. Under a new set of 21st century drivers, Lowestoft took advantage of growth in the offshore wind sector, with the Outer Harbour becoming a busy energy hub. Into the future, the port's consultation draft master plan (ABP, unpublished)– shortly to be published – identifies considerable potential for further growth arising from new offshore wind farm projects as well as further opportunities in other sectors, such as marine aggregates.

2.1 Port safety

ABP is the Statutory Harbour Authority (SHA) for the Port of Lowestoft. As such, it has a duty to ensure and to take fully into account, the navigational and marine safety implications of any proposal that has the potential to impact on the safe operation of the port and the shipping within its harbour jurisdiction. The Port is operational 24-hours a day to accommodate the needs of the port users and is subject to a statutory "open port duty". Deep draught vessels will navigate at higher states of tide irrespective of the time of day, whereas crew transfer vessels associated with the offshore windfarm construction mainly operate during daylight hours.

2.2 Port berths

The Port of Lowestoft can be described in terms of the Outer and Inner Harbours and comprise a variety of quay and berth areas to suit different commercial vessel needs. A summary of all the quays and berths within the Port is shown in Table 1, along with the quay lengths and the operational berth pocket depths in metres below Admiralty Chart Datum (ACD). Figure 3 illustrates the port layout and berth locations that are used to inform this study.

The Outer Harbour, situated east of the existing Bascule Bridge, is a hub for the offshore energy industry and the fisheries industry. The Outer Harbour also contains the Royal Norfolk and Suffolk Yacht Club marina, which is used by leisure craft. The Outer Harbour navigational channel is dredged to 4.7 m ACD, with the channel into Waveney and Hamilton Docks at 3.9 m ACD. Currently vessels of up to 5.5 m draught can be accommodated in the Outer Harbour.

The Inner Harbour comprises of quays running along the north and south banks of Lake Lothing and is located between the Bascule Bridge and Mutford Lock. It serves a wide variety of customers and trades, including agribulks, support vessels for offshore oil and gas installations and repair facilities for vessels. The Inner Harbour is also where the berths with the deepest available water (Town Quay 2 and 3) are located, which can accommodate vessels with a beam of up to 22 m and a draught of up to 6 m.

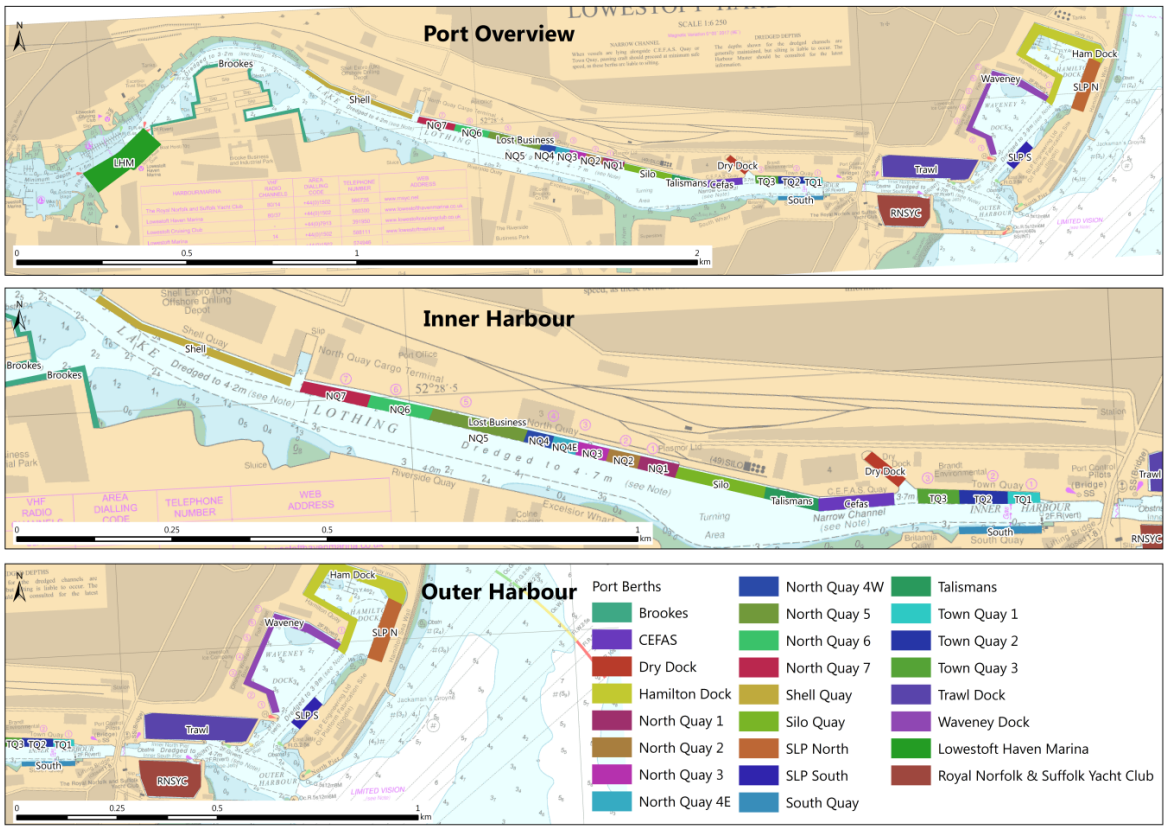

Figure 3. Port of Lowestoft

Table 1. Port of Lowestoft berths

Berths	Owner	Quay Length (m)	Depth (ACD)	Comment
Inner Harbour				
CEFAS Quay	ABP	124	6	Dedicated berth
Dry Dock	ABP			
Lowestoft Haven Marina	ABP			Pontoon berths, leisure craft & CTV maintenance facility
North Quay Cargo Terminal No 4W	ABP	95	3.7	
North Quay Cargo Terminal No 5	ABP	95	4	
North Quay Cargo Terminal No 6	ABP	104	4.7	Dedicated berth - Petersons
North Quay Cargo Terminal No 7	ABP	104	4.7	Dedicated berth - Fendercare
North Quay No 1	ABP	60	3.7	
North Quay No 2	ABP	60	3.7	
North Quay No 3	ABP	60	3.7	
North Quay No 4E	ABP	45	3.7	
Shell Quay	ABP	335	4	
Silo Quay	ABP	152	4	Dedicated berth
Talismans	ABP	78	3.7	
Town Quay Berth 1	ABP	57	3.7	
Town Quay Berth 2	ABP	70	6.2	
Town Quay Berth 3	ABP	70	6.2	

Berths	Owner	Quay Length (m)	Depth (ACD)	Comment
Outer Harbour				
Sladdens Pier	ABP			
SLP North Loadout	ABP/SLP	164	3.9	Dedicated berth
SLP South Loadout	ABP/SLP	95	3.9	Dedicated berth
Hamilton Dock	ABP	330		160 m of Quay area Reserved for Scottish Power (EAOW) as dedicated berths. The positioning of the EAOW pontoons renders a further 28 m inaccessible to vessels and the fishing vessel pontoons occupy a further 77 m of quay length.
Hamilton Dock Berth 1	ABP	59	5	
Trawl Dock	ABP	361	3.7	Full quay length is 611 m, however, 260 m of this is reserved for Greater Gabbard Offshore Wind Limited (GGOWL) as dedicated berths, with an additional 40 m for loading/working. Approximately 250 m of quay is unusable, thereby reducing the usable space to 361 m.
Waveney Dock Berths 1, 2, 3	ABP	165	3.7	165 m of quay length reserved for Greater Gabbard Offshore Wind Limited (GGOWL) as dedicated berths.
Waveney Dock Berths 4-7 and North	ABP	135	3.7	

A summary of the berth properties is provided below:

- The Outer Harbour berth facilities can accommodate around 55% of total CTV vessel numbers that may use the Port, while the Inner Harbour berths facilities can accommodate around 45% of total CTV vessel numbers that may use the Port. These estimates are based on the available and suitable berth space for CTV vessels across the Port and allows for double-banking along Shell Quay;
- At present, 32% of the Inner Harbour berths and 79% of the Outer Harbour berths are dedicated or priority use (Table 1). This accounts for 27% of total port capacity, with respect to the available quay length within the port. The Inner Harbour berths also account for the high berth utilisation estimated for the past scenario; discussed in Section 5.2; and
- Berth areas are counted as 'whole' berths when considering type and size of vessel use. Berths where double banking is normal practice are counted as two 'whole' berths.

2.3 Berthing practices

There are operational practices used for allocating berths for vessels at the Port of Lowestoft which would influence the potential utilisation of berths.

There is an increasing demand for dedicated berths from operators and commercial users within the port, to service their operations. The practice of dedicating berths means that selected berths are allocated to specific operators, giving vessel access priority to those operators. Although other vessels may be placed at the berth, it is not pre-planned and is generally managed at the specific point in time it is required. In the instance that a dedicated berth is used for a common user, the cost of moving a vessel if the berth is required by the priority user is with the common user; an arrangement which is usually declined by the common user.

The Port of Lowestoft has actively responded to demand by adjusting their practices to have dedicated berths allocated to specific operators, giving priority use to those operators, effectively removing them from use by general commercial traffic. At the time of writing there are a number of dedicated berths within the Port, which are assessed as part of this study. These mainly occur within the Outer Harbour docks as summarised in Table 1 above.

Some Quay areas are predominantly used by wind farm crew transfer vessels (CTVs), and have been developed to accommodate these vessels, by use of pontoon berths or appropriate fendering arrangements. On these berths it is common practice to moor the CTVs double banked to maximise the use of quay areas.

Recent changes to the Port's berths that are pertinent to this study include:

- Prior to 2017, Hamilton Dock in the Outer Harbour was a dedicated area for the fishing fleet and leisure vessels berthing on pontoons. Due to the increase in offshore wind related operations and operators, the fishing fleet was relocated from the west end of Hamilton Dock to pontoon berths (previously a Marina), on the north side of Hamilton Dock, at the beginning of 2017. Use of these pontoon berths for leisure craft was discontinued. Hamilton Dock was further developed, and new, commercial pontoons were added to expand the dock capacity to 12 CTV berths. However, the majority of these berths (10) are dedicated berths for two operators to accommodate their CTVs. Only two berths are available for common use.
- Trawl Dock underwent reorganisation at the start of 2017, with the number of berths increased from 10 (comprised of eight dedicated berths and two common use berths) to 18 (comprised of 14 dedicated berths and four common use berths).
- There are seasonal trends within the Outer Harbour Docks, with higher levels of utilisation in the summer season (approximately between April and October) due to calmer sea conditions. However, Offshore Windfarm operations have been known to continue operations into December if project delivery schedules demand this and the prevailing weather allows an extension of the work schedule. The provision of dedicated berths to such operators applies all year round and forms part of a contractual obligation on the port.
- Due to the shallow depths within some of the Outer Harbour, only shallow draught vessels can use the dedicated CTV berths.

3 Data

Data used to complete this berth utilisation analysis includes vessel arrival and departure times (which have been used to calculate the time at berth), berth properties and details of vessels that used the Port. Each of these data types are detailed in the sections below, including the source, any processing carried out on the data and the assumptions made in using the data.

3.1 Data types

3.1.1 Vessel sailings

Information on vessel movements was principally obtained from vessel arrival and departure logs collected by the Port to keep track of the operations within the port and to provide the basis to levy any fees and charges that may apply. The vessel data typically presents the time vessels were observed as entering or leaving the port at the Harbour entrance.

This information is recorded in a log book by bridge operators and is transcribed into a digital format at the end of each day. The recorded data includes the vessel name, arrival and departure dates and times and the berth used. This data was obtained for a three year period, between January 2015 and December 2017 and is referred to as 'vessel sailings' within this report.

Additional vessel movement data was obtained from the Port And Vessel Information System (PAVIS) records. This data includes pilot boarding and disembarking times, and is managed by the Harbour Master (HM) to facilitate charging. The PAVIS dataset has been used to augment data gaps within the vessel sailings data. Within this report, this dataset is termed 'PAVIS records'.

3.1.2 Vessel details

The vessel information includes:

- The vessel International Maritime Organization (IMO) number and (or) the Maritime Mobile Service Identity (MMSI) number;
- Call sign;
- Vessel type;
- Country of registry;
- Vessel length over all (LOA);
- Vessel beam;
- Vessel summer draught; and
- Vessel gross tonnage.

The vessel details were compiled from a number of sources, including:

- PAVIS records;
- Port records maintained by the Harbour Master's department; and
- Collated from freely available vessels database web resources, of which examples include
    - https://www.marinetraffic.com; and
    - https://www.vesselfinder.com.

3.1.3 Berth details

Information on the berth dimensions, including the quay length, maintained depth, ownership and function has been obtained from the Harbour Master's department and from Admiralty Charts.

3.2 Processing

3.2.1 Missing vessel movement information

Vessel movement data were compiled from multiple sources (as described in Section 3.1.1), with the vessel arrival and departure logs providing the more extensive coverage, for all vessels. The arrival and departure dates and times were checked against the PAVIS records to validate the sailings data for accuracy and consistency and to fill any data gaps, where possible.

3.2.2 Missing vessel details

Vessel details were taken from the available PAVIS records. Gaps in the vessel information were filled by reference to online sources. The Harbour Master, Lowestoft clarified any instances where there were multiple possibilities for vessels associated with a particular vessel name. The collated vessel details were then associated with each respective vessel movement, to provide a more complete picture of the vessel name and properties, the berth used and the period of time the vessel was at berth.

3.2.3 Data cleaning

Grouped berth names

Vessel sailings and PAVIS records have been created from transcribed information, with different operators completing the records. The process of data recording has introduced differing naming conventions for berths being applied over time.

For example; North Quay in the Inner Harbour is comprised of seven individual berths, with varying quay lengths and depths. Within the data records individual berths were sometimes referenced, and on occasion, they were named generically, for example, 'North Quay'. Two approaches were used to account for the differences which are summarised below:

- **Renaming berth names:** based on information provided by the Port, certain berth names used were all representative of the same berth, so the associated berth records were changed to reflect this. For example, Hamilton Dock Berth 1 was also identified as Hamilton Peninsular and Hamilton Quay, so these berth designations were all renamed to Hamilton Dock.
- **Divide records between available berths:** for the records where the overall name was used, the total time and associated records were divided and allocated between the individual berths under the grouped name.

The practical implementation of this approach is considered further in the presentation of the analysis results, in Section 5.

Vessels at berth over successive months or years

Approximately 9% of the overall vessel sailing records represented instances where the vessel arrival and departure date and time were in different months, suggesting that a departure or arrival may not have been properly recorded. Calculating the berth time solely from the times recorded could over-represent the berth utilisation in one month (i.e. the arrival month) and under-represent utilisation in the following month(s). To address the potential anomaly, the applied analysis included a processing routine to correctly assign the berth time to the relevant month.

Vessels at berth for part of an hour period

The analysis has been conducted for hourly periods at the berth. Where a vessel has not been present for at least a full hour, the analysis has not counted that hour period. The result of this analysis ensures that the utilisation of berths is not over-represented.

4 Berth Utilisation Analysis Method

4.1 Berth occupancy ratio

The berth occupancy ratio (BOR) is the ratio of time a berth is occupied by a vessel to the total time available in a period. It has been used as an indicator of port efficiency and to describe whether a port is busy or not by a number of studies (Zamanirad *et al.*, 2017; Mwasenga, 2012). Furthermore, the occupancy ratio can play an important role in port planning and master plan design, as the optimum berth occupancy for a port depends on throughput requirements and the site constraints (Zamanirad *et al.*, 2017). The BOR is represented as:

$$BOR = \frac{T_0}{T_t} \times 100$$

Equation 1. Berth Occupancy Ratio

Where:

BOR Berth Occupancy Ratio as a percentage
T_0 Total time a berth is occupied by a vessel, from berthing to un-berthing
T_t Total time a berth is available for use over the assessed time period. For a 24-hour operational port this equates to 8,760 hours in any year and 8,784 hours in a leap year.

The BOR is equivalent to the berth utilisation used in this study as a representation of port activity. It has been calculated on the same basis as the BOR in Equation 1 using the vessel sailings data described in Section 3.1.1. The berth utilisation analysis in this study is based on a 24-hour operational port, with berths available all year round. In assessing the berth utilisation under the different scenarios discussed in Section 5, the vessel details (Section 3.1.2) and berth properties (Section 3.1.3) were used to inform and implement the scenario assumptions regarding vessel displacement. For example the vessel LOA or draught along with clarification from the HM was used to determine where the vessel record was displaced to. These are described further under the relevant scenario assumptions in Section 5.

4.2 Optimum berth occupancy

4.2.1 What is the optimum berth occupancy for a port?

The optimum berth utilisation for a port is dependent on the functions, operations and services provided by that port and the way the vessels are chartered. For example; in cargo terminals, utilisation of above 70% can be considered high and likely to leading to congestion within the Port and a consequent decline in services (Mwasenga, 2012).

Conversely, low utilisations of less than 50% can signify under-utilisation of the available services and resources. For ports that service liner ships, (for example freight shipping companies, which have to comply with precise shipping schedules) vessels will transit to another port if berth space is not available at the time of arrival. In these instances, especially where competition exists between ports, the berth utilisation does not typically exceed 50 to 60%. Higher utilisation may occur if there are no alternative ports, but this is not the case for the Port of Lowestoft, where alternatives do exist along the east coast. For ports that service chartered ships, utilisation may be much higher (up to 80%) depending on the nature of the cargo, but this subsequently results in significant waiting time of other vessels and a potential decline in services (Mwasenga, 2012).

4.2.2 Port of Lowestoft optimum berth occupancy

A formal assessment of the optimum berth occupancy has not been completed for the Port. However, Port managers for the Port of Lowestoft generally work on the following basis:

- A BOR or utilisation under 50% represents a port where there is potential for further growth and expansion.
- A value between 50% and 70% represents a busy port, but it is most likely balanced with the efficiency and outputs from the port.
- A value of over 75% is considered too busy, with a risk of declining services, efficiency and output.

The above assumptions broadly agree with the occupancy assessments presented by Mwasenga (2012). The utilisation estimates are in line with the port services presently provided by the Port of Lowestoft, which services chartered vessels and provides support for offshore operations.

4.3 Assessed berths

The berths within the Inner and Outer Harbours that are of further relevance to this study are detailed in Table 2. Not all the berths listed in Table 1 are relevant or are discussed in this study as some are privately owned or are on a long term lease to a specific operator, and are managed by that operator , so these berths are excluded from analysis. However, in Hamilton, Trawl and Waveney Docks these contain both dedicated and common use berths (Table 1 and Section 2.3), which are managed by the Port and so are included in the analysis. In the future scenarios (Sections 5.4 and 5.5), any berths that are reassigned for dedicated use remain included in the analysis but are given a utilisation estimate of 100% effectively removing them from common use.

Table 2. Assessed port berths

Inner Harbour Berths	Outer Harbour Berths
North Quay 1	Hamilton Dock (Hamilton Dock and Hamilton Dock Berth 1
North Quay 2	Trawl Dock
North Quay 3	Waveney Dock (Waveney Dock and Waveney Dock North)
North Quay 4E	
North Quay 4W	
North Quay 5	
North Quay 6	
North Quay 7	
Shell Quay	
Silo Quay	
Talismans	
Town Quay 1	
Town Quay 2	
Town Quay 3	

Town Quay 2 and 3 are the deepest berths at 6.2 m below ACD. The deep draught vessels that require such depths are typically longer than each individual quay can accommodate and therefore occupy both berths. Consequently, for the above reason and for the purpose of this study, Town Quay 2 and 3 are considered as one berth, with the assessed utilisation reflecting this.

5 Berth Utilisation Scenarios

5.1 Scenario overview

Analysis of the berth utilisation was completed using the data described in Section 3.1. It was completed for the purpose of assessing the intensity of berth use as a representation of port activity under four scenarios that explored the implications of the LLTC Bridge on port activity. A summary of the four assessed scenarios that are discussed further in the sections below are:

- Past situation without the LLTC Bridge, which describes the baseline and recent conditions based on the representative vessel sailing records between January 2015 and December 2017.
- Past situation with the LLTC Bridge, which investigates the implications of the LLTC Bridge on berth utilisation.
- Future situation without the LLTC Bridge, which accounts for the potential growth of the Port in capturing further opportunities based on the unpublished Port of Lowestoft Port Master Plan (ABP, unpublished) between 2018 and 2036. This was also informed by the "*Offshore Wind opportunities in the Port of Lowestoft*" study by BVG Associates (2018) study.
- Future situation with the LLTC Bridge, which accounts for the potential port growth and investigates the implications of the LLTC Bridge on this growth.

The following sections present the berth utilisation analysis and results completed for each scenario, including the varying assumptions of vessel displacement and port operations growth patterns. The future scenarios are calculated based on adjusted vessel movement data from the available years (i.e. 2015-2017).

All the scenarios explored the annual variations in berth utilisation for all berths, based on the time when vessels were berthed for a full hour (see Section 3.2.3). A representation of the assessed berth utilisation for the four scenarios, based on the 2017 data is illustrated in Appendix A.

The berth utilisation is expressed as the percentage time per year for the berths detailed in Table 2 above.

5.2 Scenario 1: Past situation without the LLTC Bridge

This scenario assessed the utilisation based on conditions within the Port between January 2015 and December 2017. In early 2019, the Port announced that it had won additional business – for the purposes of the various analyses included in this report, that new business is included in the "Future Scenarios" presented (Scenarios 3 and 4, Sections 5.4 and 5.5 respectively). The assessed period between January 2015 and December 2017 was considered to be applicable and representative of the underlying port activity, and although it may be out of date, it still demonstrates the dynamic characteristics of the Port.

5.2.1 Scenario assumptions

The three years of data (between 2015 and 2017) was used as the baseline upon which further scenarios were evaluated. The changing number of berths between 2015 and 2017 in Hamilton and Trawl Docks were accounted for in the results.

Shell Quay has historically been used for accommodating offshore Platform Supply Vessels. More recently the berth area was used to support the Galloper windfarm installation vessels (CTVs). The utilisation estimates applied under the past scenarios for this berth assumes up to nine vessels are typically moored single banked, which is represented within the available data.

5.2.2 Results

The results of the assessed utilisation for the past situation without the LLTC Bridge are set out in Table 3 and illustrated in Appendix A.1 for the 2017 data.

Table 3. Assessed berth utilisation for the past situation without the LLTC Bridge

Berth Name	2015 (%)	2016 (%)	2017 (%)
Hamilton Dock	72.0	59.3	67.5
North Quay 1	42.0	38.7	27.5
North Quay 2	8.9	13.2	28.0
North Quay 3	25.4	29.9	31.5
North Quay 4E	9.4	19.3	30.3
North Quay 4W	0.0	21.5	16.6
North Quay 5	15.1	10.0	36.7
North Quay 6	14.4	52.0	99.0
North Quay 7	19.2	49.9	40.5
Shell Quay	0.0	2.9	50.6
Silo Quay	30.9	21.7	28.7
Talismans	34.1	50.0	32.6
Town Quay 1	15.2	55.2	83.3
Town Quay 2	5.3	26.4	41.1
Town Quay 3	17.9	23.5	43.6
Trawl Dock	61.7	40.9	52.7
Waveney Dock	39.5	23.9	34.5
Lost Business	N/A	N/A	N/A
Average across all port berths	24.2	31.7	43.8
Average across the Inner Harbour berths	17.0	29.6	42.2
Average across the Outer Harbour berths	57.7	41.4	51.6

The average berth utilisation across all the assessed berths for the 2017 data is about 44%. The average utilisation within the Inner Harbour berths is approximately 42% and for the Outer Harbour berths is 52%. In previous years the Outer Harbour typically has a higher utilisation than the Inner Harbour. This difference is considered to relate to the redevelopment and reorganisation of Hamilton and Trawl Docks, which created more berth space, as described in Section 2.1. Of the ABP managed quays and berths, the highest individual berth utilisation occurred at North Quay 6, a deep water berth and Town Quay 1. These berths are both located in the Inner Harbour.

For each berth, the results demonstrate generally increasing utilisation between successive years, which occurs due to the changing operations and operators on the berth. A good example is at Shell Quay, which has low utilisation in 2015 and 2016, but a significant increase in 2017 with the requirement for further berths to accommodate CTVs in relation to the Galloper Offshore Wind Farm construction.

Berths that demonstrate similar utilisations through the years suggest a consistent level of operations through the time period. There was only one instance where there is a decreasing trend between 2015 and 2017, which was at North Quay 1 and occurred as a result of the relocation of vessels along the other North Quay berths.

In the following sections that assess the different scenarios summarised in Section 5.1, the potential changes to the utilisation are discussed in relation to the 2017 estimations.

5.3 Scenario 2: Past situation with the LLTC Bridge

This scenario assesses the potential changes in the berth utilisation across the port with the LLTC Bridge in place, based on the past utilisation estimates. Information on the potential changes to the port berths is obtained from the Draft Discussion document on the "*Impact of the Lake Lothing Third Crossing on Ship Berthing at the Port of Lowestoft*" (ABP, 2018b). The identified changes to the port berths which are used to inform the LLTC Bridge scenarios include:

- The loss of North Quay 3 in relation to the bridge infrastructure and safety exclusion zones immediately adjacent to the bridge pillars; and
- The reduction in the usable quay length of North Quay 2 from 60 m to 50 m, thereby only enabling smaller vessels (around 30 m LOA) to use it rather than the typical 40 – 50 m LOA vessels.
- The reduction in the usable quay length of North Quay 4E to around 19.5 m, which renders it unusable.

5.3.1 Scenario assumptions

The baseline vessel sailing records (i.e. between 2015 and 2017) were edited to represent a situation with the LLTC Bridge in place. The following assumptions were applied from information derived from ABP (unpublished) and with direction by the Harbour Master:

- Berths North Quay 3 and 4E would be lost entirely due to the bridge infrastructure and exclusion zones. Vessels that were originally berthed at these locations would all be displaced to North Quay 4W or North Quay 5;
- The quay length associated with North Quay 2 was reduced from 60 m to around 50 m, which meant that only smaller vessels with a length over all (LOA) of up to 30 m would be able to berth safely. Therefore, vessels with a LOA above 30 m would be displaced to North Quay 4W or North Quay 5;
- Shell Quay would displace approximately half of its baseline CTV users and operators to Talismans Quay west of the LLTC Bridge. This is because CTV operators are the main users of this quay and their operations are time critical in nature. Therefore, having to navigate through two bridge openings would have a negative impact on their operations. CTV operators have already expressed a concern about the time implications to the Port (*pers comm*, Gary Horton), and so the assumption that up to 50% of the baseline operations would be moved, has been applied to the analysis. For those vessels remaining at Shell Quay, up to nine vessels could be moored single banked at the same time.

The above scenario assumptions were used to displace vessels sailing records between berths and the results are presented in Section 5.3.2 below.

5.3.2 Result

The results of the assessed utilisation for the past situation with the LLTC Bridge in place are set out in Table 4 and illustrated in Appendix A.2 for the 2017 data.

Table 4. Assessed berth utilisation for the past situation with the LLTC Bridge in place

Berth Name	2015 (%)	2016 (%)	2017 (%)
Hamilton Dock	72.0	59.3	67.5
North Quay 1	42.0	38.7	27.5
North Quay 2	2.7	5.5	24.2
North Quay 3	Berth Lost		
North Quay 4E	Berth Lost		
North Quay 4W	0.0	21.5	16.6
North Quay 5	49.2	48.8	56.3
North Quay 6	14.4	52.7	99.0
North Quay 7	19.2	49.9	40.5
Shell Quay	0.0	0.4	25.3
Silo Quay	30.9	21.7	28.7
Talismans	34.1	58.2	94.4
Town Quay 1	15.2	55.2	83.3
Town Quay 2	5.3	26.4	41.1
Town Quay 3	17.9	23.5	43.6
Trawl Dock	61.7	40.9	52.7
Waveney Dock	39.5	23.9	34.5
Lost Business	N/A	N/A	N/A
Average across all port berths	26.9	35.1	49.0
Average across the Inner Harbour berths	19.2	33.5	48.4
Average across the Outer Harbour berths	57.7	41.4	51.6

Under this scenario, changes in berth utilisation would occur at North Quay 2, 3, 4E, 4W and 5, Shell Quay and Talisman Quay due to vessels being displaced.

A reduction in utilisation would occur at North Quay 2 and a complete loss in North Quay 3 and 4E; these vessels would be displaced to North Quay 4W or North Quay 5 for which an increase in utilisation would then occur. At Shell Quay, the applied assumption means that half of the operators and their associated CTVs would move to Talismans Quay, which results in Talismans Quay increasing in utilisation to over 90% (based on the 2017 utilisation estimate).

The influence of the LLTC Bridge is reflected in the average utilisation across the Inner Harbour berths and the port in general. The average utilisation across the Inner Harbour increases to approximately 48% (Table 4), up from the 42% estimated for the same berths under the past scenario (Section 5.2.2). The increased utilisation occurs as a result of the same vessel traffic being accommodated across fewer berths due to the loss of the North Quay 3 and 4E berths with the LLTC Bridge in place.

5.4 Scenario 3: Future situation without the LLTC Bridge

This scenario assesses the potential future growth of the Port and the resulting influence on berth utilisation. Under this scenario, the LLTC Bridge is not in place, any changes in the berth utilisation are solely in relation to future commerce within the Port and the displacement of existing operations to enable any new customers and growth. The sources and information used to develop this scenario include:

- The consultation draft Port of Lowestoft Port Master Plan (shortly to be released) (ABP, 2019a) and BVG Associates (2018) study;
- New business wins announced in 2018/19 by ABP (e.g. Peterson);
- Presently ongoing discussions between the Port and potential new customers and clients; and
- Identified future markets that the Port is actively targeting.

5.4.1 Scenario assumptions

The baseline vessel sailing data (i.e. between 2015 and 2017) was edited to represent the potential growth of the Port as identified through the various sources listed above. The assumptions which underlie this scenario are summarised in the following sections.

Offshore windfarm related activities

Under the baseline conditions, up to 24 CTVs regularly used the Port and were mainly located in the Outer Harbour, specifically Hamilton and Trawl Docks, which were operating at capacity. A limited number operated out of Shell Quay as this is the only other berth that enabled the loading and offloading of people due to the access gangways and pontoons.

Under the future scenario, the consultation draft of ABP's port master plan and BVG Associates (2018) identified up to 50 CTVs regularly using the Port, which represents twice the number of CTVs identified in the baseline data. As Hamilton and Trawl Docks are already operating at capacity, the additional CTVs would operate out of Shell Quay.

In addition to the increased CTV traffic, there is expected to be two service operation vessels (SOVs) associated with larger offshore windfarm projects (ABP, unpublished). Anticipated visits are one a week (with each being at sea for 14 days). When in port, these vessels would be at berth for 12 – 24 hours and would nominally be assigned to Town Quay 2 and 3. However, in the instance that berths are assigned as dedicated berths for another port user (see bullet points below), these vessels would be lost business.

Other offshore energy opportunities

It is understood that there are various other offshore energy (oil, gas and other renewables) opportunities are in discussion with the Port at the time of writing, one of which has been successful with operations beginning in 2019 (Peterson). It is assumed that these opportunities would entail up to nine core platform supply vessels (PSVs) using the port, with a vessel visit every day and up to two vessel visits every second day. A total of up to 600 visits are expected per year and when in port these vessels would be at berth for up to 12 hours.

Whilst it is possible that there may be a successful outcome for ABP with regards to securing both opportunities, a conservative probability of success of 50% is assumed for the opportunity still under negotiation – in effect this conservative approach has already been met by the relocation of Peterson's to the Port. The vessels associated with these two oil and gas opportunities would be based out of

North Quay 6 and 7 (opportunity 1) and Town Quay 2 and 3 (opportunity 2) due to their deep draughts. Despite the probability of success, the frequency of the visits would mean that North Quay 6 and 7 and Town Quay 2 and 3 would become dedicated berths to the particular operators, thereby excluding them from common use. On this basis North Quay 6 and 7 and Town Quay 2 and 3 would be fully utilised at 100%.

Marine aggregate opportunities

There are two potential marine aggregate opportunities for the Port of Lowestoft which would require the reinstatement of a marine aggregate landing. This is currently being actively explored by the Port. The Port of Lowestoft is working with commercial partners (Network Rail) to put together an investment package. The package being developed is to enable the Port to take advantage of the co-location at Lowestoft of rail and port facilities allowing the landing and easy transportation of dredged marine aggregates to inland markets.

The second opportunity is in relation to the construction of the Sizewell C new build nuclear power plant, in which the Port of Lowestoft could also have a potentially important role to play (ABP, unpublished). Associated with both of these opportunities are up to nine visits per week (comprising of daily vessel visits and an additional vessel twice a week), totalling up to 450 visits per year. A conservative probability of success of 40-50% is assumed for both opportunities. The vessels associated with these two aggregate opportunities would both be based out of North Quay 1 and 2. The landing and transfer of aggregate material would require berth-side infrastructure. This requirement and the frequency of vessel visits would mean that North Quay 1 and 2 would become dedicated berths to the particular operators and thereby excluding them from common use. On this basis North Quay 1 and 2 would be fully utilised at 100%.

Vessel displacement

The existing vessels and users of North Quay 1, 2, 6 and 7 and Town Quay 2 and 3 would be displaced as a result of the respective oil and gas and aggregate opportunities. Vessels with a draught of up to 4 m would be relocated between North Quay 3, 4E and 5. For vessels with a draught of over 4 m, 50% of these vessels would be relocated to North Quay 5, while the other 50% would be lost business.

Vessel double-banking

With the potential growth within the Port and associated increase in CTV traffic to support offshore windfarm operations, it is envisaged that double-banking would be required on some berths to accommodate these vessels. Not all berths within the Inner Harbour are suitable for double-banking, with only Shell Quay and Talismans Quay being identified as suitable. There is capacity for 18 vessels, double-banked along Shell Quay and four vessels double-banked along Talismans Quay.

In future scenario without the LLTC Bridge, double-banking would not be required on Talismans Quay, which will remain in common use. In the future scenarios with the LLTC Bridge the analysis includes double-banking on Talismans Quay as described in Section 5.5.1.

5.4.2 Result

The results of the assessed utilisation for future without the LLTC Bridge are set out in Table 5 and illustrated in Appendix A.3 for the 2017 data. The analysis used adjusted vessel movement data (Section 5.1), which were edited in line with the stated scenario assumptions.

Table 5. Assessed berth utilisation for the future situation without the LLTC Bridge

Berth Name	Adjusted 2015 (%)	Adjusted 2016 (%)	Adjusted 2017 (%)
Hamilton Dock	72.0	59.3	67.5
North Quay 1	100.0	100.0	100.0
North Quay 2	100.0	100.0	100.0
North Quay 3	57.8	70.1	64.6
North Quay 4E	24.3	50.4	57.0
North Quay 4W	0.6	27.9	7.1
North Quay 5	31.1	36.0	55.9
North Quay 6	100.0	100.0	100.0
North Quay 7	100.0	100.0	100.0
Shell Quay	64.4	43.3	98.1
Silo Quay	30.9	21.7	28.7
Talismans	34.1	50.0	32.6
Town Quay 1	15.2	55.2	83.3
Town Quay 2	100.0	100.0	100.0
Town Quay 3	100.0	100.0	100.0
Trawl Dock	61.7	40.9	52.7
Waveney Dock	39.5	23.9	34.5
Lost Business	3.3	49.1	99.1
Average across all port berths	60.7	63.4	69.5
Average across the Inner Harbour berths	61.3	68.2	73.4
Average across the Outer Harbour berths	57.7	41.4	51.6

The analysis results indicate there would be a marked increase in utilisation across the Inner Harbour of the Port, with the average utilisation increasing to about 73% (Table 5). The Outer Harbour Docks are presently at capacity, so there is no foreseen growth without major changes to the present infrastructure. The assessed changes include the increase in utilisation of all the North Quay berths and Shell Quay and the allocation of six berths dedicated for specific port users resulting in 100% utilisation of these berths.

Most notable is that a large proportion of the Inner Harbour berths would all be operating at a utilisation of approximately 60% and higher, which in terms of port operations can be considered to be busy, a point considered further in Section 6. For Shell Quay, maximum utilisation over the assessed timescale is at 98% based on double banking 18 vessels (Table 5). The estimated increase in CTV traffic (ABP, unpublished) would necessitate the need for double banking of vessels along this berth. Therefore, the presented future scenario results for Shell Quay are all based on double banking up to 18 vessels Table 5), equating to a utilisation of up to 98%.

Under this scenario, there is no change to the utilisation at Talismans Quay, which is the only other berth in the Inner Harbour that can receive a CTV. It may be that part of the high utilisation at Shell Quay could be accommodated at Talismans Quay, which is adopted in the LLTC Bridge scenarios (Sections 5.3 and 5.5).

No change is assessed for Silo Quay as Silo Quay is the only berth from which grain can be loaded and unloaded. This means that at present, this berth is predominantly kept free for grain vessels, which give relative short notice of their arrival. This situation is likely to continue in the future.

A further notable change under this scenario is that there is likely to be a proportion of lost business due to the limited availability of berths with sufficient depth to accommodate vessels with draught of over 4 m. Under this scenario assumption, approximately 50% of the vessels with draughts of over 4 m from North Quay 6 and 7 and Town Quay 2 and 3, would be displaced to North Quay 5, while the other 50% would be lost from the Port. The proportion of lost business would equate to approximately 99% utilisation of a berth. The assessed percentage of lost business means that long term berthing would not be possible, such as occurred for the "Wilchief 1" vessel, which berthed at North Quay 6 for a 15-month period.

Under this scenario, there is still the potential for *ad hoc* berthing in relation to North Quay 4W, although not for CTVs or deep draught vessels.

5.5 Scenario 4: Future situation with the LLTC Bridge

This scenario explores the potential future growth of the Port with the LLTC Bridge in place and the resulting influence on berth utilisation. The sources and information used to develop this scenario are the same as have been applied in the future scenario without the LLTC Bridge (Section 5.4) and the changes to the port berths are as presented in Section 5.3.

5.5.1 Scenario assumptions

The scenario assumptions in terms of the growth of the Port described in Section 5.4.1 and the displacement of operations and vessels due to the construction of the LLTC Bridge described in Section 5.3.1, both apply here with the following exceptions:

- Any vessels that would have been displaced to North Quay 3 as a result of the formation of dedicated berths would be displaced further to North Quay 4W and 5.
- Operations at Shell Quay would increase and involve double-banking (Section 5.4.1). However, due to the LLTC Bridge, 50% of operators would be displaced to Talismans Quay (Section 5.3.1), which would mean all their associated operations would also move to Talismans Quay. Berthing at Talisman's Quay will require double-banking.

5.5.2 Result

The utilisation results for the future with the LLTC Bridge scenario are set out in Table 6 and illustrated in Appendix A.4 for the 2017 data. The analysis again used adjusted vessel movement data (Section 5.1), which were edited in line with the stated scenario assumptions.

Similar to the future situation without the LLTC Bridge, there is limited change to the Outer Harbour Docks as these Docks are presently at capacity (Section 5.4.1), and most of the changes are assessed to occur within the Inner Harbour. Across the Inner Harbour berths there is a large increase in the average utilisation with estimates of around 88% (Table 6). The increased utilisation is due to the increased vessel traffic discussed under the future scenario (Section 5.4.2 and Table 5) being accommodated on fewer berths. The increased utilisation across the Inner Harbour berths also influences the utilisation across the port in general with an average estimate of 81%.

Aside from the dedicated berths in North Quay 1, 2, 6 and 7 and Town Quay 2 and 3, notable increases in utilisation occur for North Quay 4W and 5 and Talismans Quay. The berth utilisation on North Quay 5 increases to a maximum of 86%, as vessels are further displaced from North Quay 3 and 4E. At Shell Quay, the berth utilisation does decrease considerably to approximately 32% compared with the future scenario (Table 5), based on double banking 18 vessels, reflecting the impact of vessels being displaced because of the LLTC.

Table 6. Assessed berth utilisation for the future situation with the LLTC Bridge in place

Berth Name	Adjusted 2015 (%)	Adjusted 2016 (%)	Adjusted 2017 (%)
Hamilton Dock	72.0	59.3	67.5
North Quay 1[1]	100.0}	100.0}	100.0}
North Quay 2[1]	100.0}	100.0}	100.0}
North Quay 3	Berth lost		
North Quay 4E	Berth lost		
North Quay 4W	23.9	64.5	56.3
North Quay 5	67.3	82.1	85.9
North Quay 6	100.0	100.0	100.0
North Quay 7	100.0	100.0	100.0
Shell Quay	15.6	5.1	32.1
Silo Quay	30.9	21.7	28.7
Talismans	125.7	127.9	165.8
Town Quay 1	15.2	55.2	83.3
Town Quay 2	100.0	100.0	100.0
Town Quay 3	100.0	100.0	100.0
Trawl Dock	61.7	40.9	52.7
Waveney Dock	39.5	23.9	34.5
Lost Business	3.3	49.1	99.1
Average across all port berths	70.1	72.0	80.5
Average across the Inner Harbour berths	73.2	79.7	87.7
Average across the Outer Harbour berths	57.7	41.4	51.6

[1] Berths are combined to facilitate one large commercial vessel, for the marine aggregate opportunity.

The most notable assessed change occurs at Talismans Quay, with the utilisation increasing considerably to over 165%, based on double banking up to four CTV vessels. The high utilisation at this berth is due to CTV operations (i.e. at approximately 133% after double banking) of operators that explicitly would not want to be west of the LLTC Bridge at Shell Quay. Talismans Quay has a smaller capacity for having multiple vessels berth at any one time, with only two vessels single banked and a maximum of four vessels double banked. Based on the perceived increase in CTV traffic and the estimated utilisation of 133% after accounting for four berth spaces at this quay, Talismans Quay would not be able to accommodate the required number of CTV vessels, resulting in the loss of CTV operators and up to 14 CTV vessels. The high utilisation already necessitates the need for double-banking on this berth. It should be noted that even with the double banking there is not enough berth space to accommodate all the required vessels. This point is considered further in the discussion in Section 6.

The identified potential loss of business associated with deep draught vessels, with a draught of over 4 m and introduced in Section 5.4.2 is also applicable here. Combined with the loss of CTV operators would potentially have adverse economic implications on the operations of the port.

6 Discussion

The results of the various scenarios demonstrate that some berths are currently busy with berth utilisation estimates of over 60% (based on the understanding presented in Section 4.2.2). In the past scenario, the port berths are generally underutilised with an average utilisation estimated of approximately 44% for all berths. Under the future scenario however, the assessed average berth utilisation is within this optimal range at approximately 70%, comprising of approximately 52% and 73% average utilisation for the Outer and Inner Harbour berths respectively (based on the 2017 estimates, Table 5, Section 5.4.2).

With the potential growth within the port and the construction of the LLTC Bridge, the average utilisation increases to approximately 81% across all berths, comprising of approximately 52% and 88% average utilisation for the Outer and Inner Harbour berths respectively (Table 6). The presence of the LLTC Bridge and the loss of two berth spaces increase the utilisation to a point where the port can be considered to be too busy, with a risk of declining services, efficiency and output particularly within the Inner Harbour (Section 4.2.2). The presented estimates of the future scenario with the LLTC Bridge includes all the CTVs at Talismans Quay, although this is unlikely to be the case as there is insufficient capacity to berth all the vessels, as discussed above. Instead, it is more likely that there will be a loss of CTV operators and their associated business, which is discussed further below.

The 2017 berth utilisation analysis results suggest that under all four scenarios, the busiest berths will be in the Inner Harbour. This includes North Quay 6, Shell Quay and Town Quay 1, which all have utilisation percentages of 50% and above (Appendix A). North Quay 6 and Shell Quay are located west of the proposed LLTC Bridge, while Town Quay 1 is east of the proposed Bridge. Information provided by the Port states that Hamilton Dock, Trawl Dock and Waveney Dock are all operating with no capacity for any further vessels without major port infrastructure development (*pers comm*, Gary Horton). With the LLTC Bridge in place under both the past and future scenarios, the berth utilisation does increase further across the available berths, with the requirement for double banking of vessels, in particular CTV vessels on the Shell and Talismans Quays. However, under the past scenario the LLTC Bridge would have less of an influence on the utilisation and port activity.

With the potential future growth of the Port and expected new customers and operations (some of which have since materialised), the implications of the LLTC Bridge are more significant across all the Inner Harbour berths and in particular the berthing of CTV vessels on Shell and Talismans Quays. A much higher proportion of berths within the Inner Harbour would be operating at utilisation of around 60% and above. For example, instead of the three berths identified under the past scenario above, 10 berths would be exceptionally busy, leaving only North Quay 4W and Silo Quay for common use. However, as previously discussed, Silo Quay is the only berth available for the transfer of grain. Therefore, this berth has been, and will most likely be, left available to accommodate grain vessels, noting that these vessels give relative short notice of their arrival (*pers comm*, Gary Horton). The result is that there would be only one common user berth within the Port, a situation which the Port would want to avoid.

The situation at Shell and Talismans Quay under the future scenario with the LLTC Bridge would require double-banking of vessels at both berths to support the CTV traffic within the port. Historically, Shell Quay has accommodated up to nine vessels along the 335 m quay wall, however, implementing double banking would mean that Shell Quay could accommodate up to 18 vessels (using access pontoons) (ABP, unpublished). However, it is the case that implementing a less dense development of berth space may create operational benefits.

With the construction of the LLTC Bridge, half of the future CTV operators can be expected to move away from Shell Quay (which is west of the LLTC Bridge) to a berth east of the LLTC Bridge and the proposed berth to accommodate these operators and their vessels is at Talismans Quay. However, Talismans Quay is currently a repair berth and would be required to maintain this function in addition to accommodating CTV traffic. Talismans Quay typically has only one vessel berthed at any one time, but with smaller CTVs, a maximum of four vessels could be accommodated through double banking. With double banking, the resulting high utilisation (estimated at 133%, based on four berth spaces), strongly indicates that Talismans Quay would not be able to accommodate all the required CTV traffic under the future situation with the LLTC Bridge. The high utilisation occurs due to the CTV operators and vessels displaced from Shell Quay. As Talismans Quay is not able to accommodate all the displaced operators and vessels from Shell Quay, there is a high likelihood for the loss of up to 14 CTV vessels, equating to a significant proportion of this business from the Port.

Furthermore, it is possible that operators will not agree or permit the double banking of vessels, due to the time critical nature of their operations and health and safety concerns relating to safe access. This would increase the likelihood of the loss of operators and their associated vessels due to the limited capacity to service them. The potential loss in CTV traffic and operations would be in addition to the lost business associated with deep draught vessels.

Overall, the analysis indicates that under the assessed potential growth of the port operations and services, there would be an associated loss of business, principally in relation to the loss of CTV operators from the port, due to the constraints on berthing space resulting east of the LLTC Bridge, were the proposed scheme to be constructed.

7 Conclusion

Following completion of the berth utilisation analysis under the four assessed scenarios, the following may be concluded:

- Two berths within the Inner Harbour, namely North Quay 6 and Town Quay 1 currently exhibit high rates of utilisation (over 70% under the past scenario, both with and without the LLTC Bridge).
- Hamilton Dock in the Outer Harbour is the busiest Outer Harbour berth with a utilisation of 68%, although this dock and Trawl Dock are operating at capacity due to the number of dedicated berths.
- Several opportunities are being targeted for future commerce and operations within the Port. With an assumed 50% probability of success, these opportunities would increase the utilisation across the port, with six berths becoming dedicated berths and so removed from common use. With the construction of the LLTC Bridge, up to 10 berths would be operating at a utilisation of 70% with only one common use berth, namely North Quay 4W.
- The assessed future situation with the LLTC Bridge in place indicates a utilisation of approximately 81% across the port, which is assumed to be representative of a busy port. The high utilisation would in turn be expected to lead to congestion within the port and a decline in services.
- There is a strong potential for lost CTV business, due to most of the available CTV berths being west of the LLTC Bridge at Shell Quay. A number of operators have expressed concerns about potential restrictions to their time critical operations in navigating through two bridge openings. The only alternative berth east of the LLTC Bridge is at Talismans Quay, which has a limited capacity and can only accommodate a maximum of four CTVs. Where an operator has more than four CTV vessels and does not want to operate west of the LLTC Bridge, the Port can expect to lose the business of that operator.

8 References

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9 Abbreviations/Acronyms

ABP	Associated British Ports
ACD	Above Chart Datum
BOR	Berth Occupancy Ratio
CTV	Crew Transfer Vessel
HM	Harbour Master
LLTC	Lake Lothing Third Crossing
LOA	Length Over All
PAVIS	Port and Vessel Information System
SCC	Suffolk County Council
SHA	Statutory Harbour Authority
SOV	Service Operation Vessels

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendix



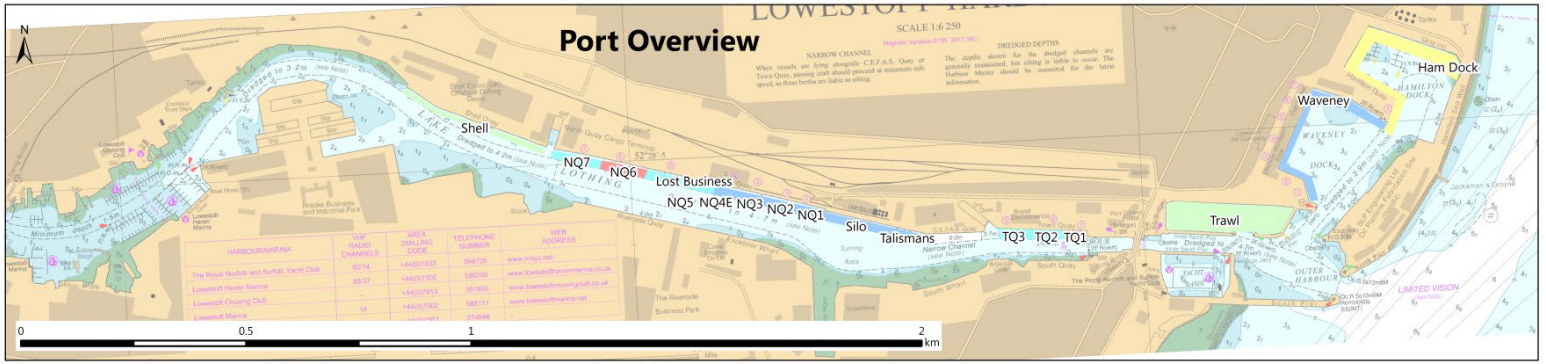


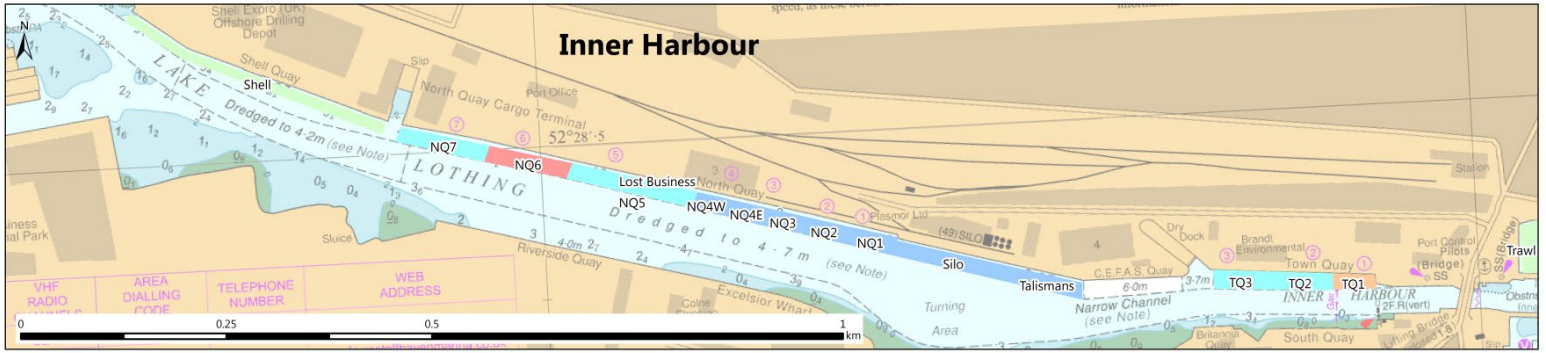
Innovative Thinking - Sustainable Solutions

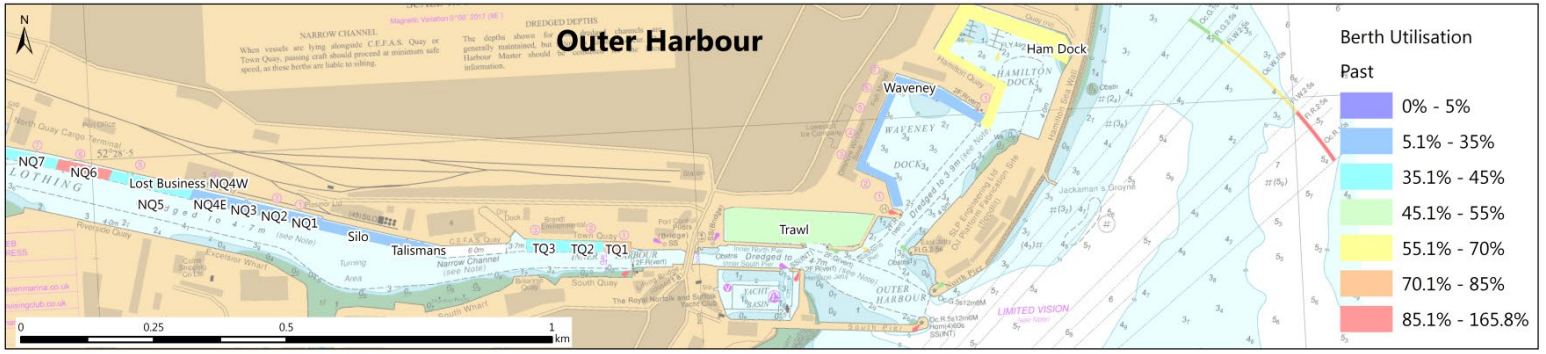
ABP mer

A Berth Utilisation Results

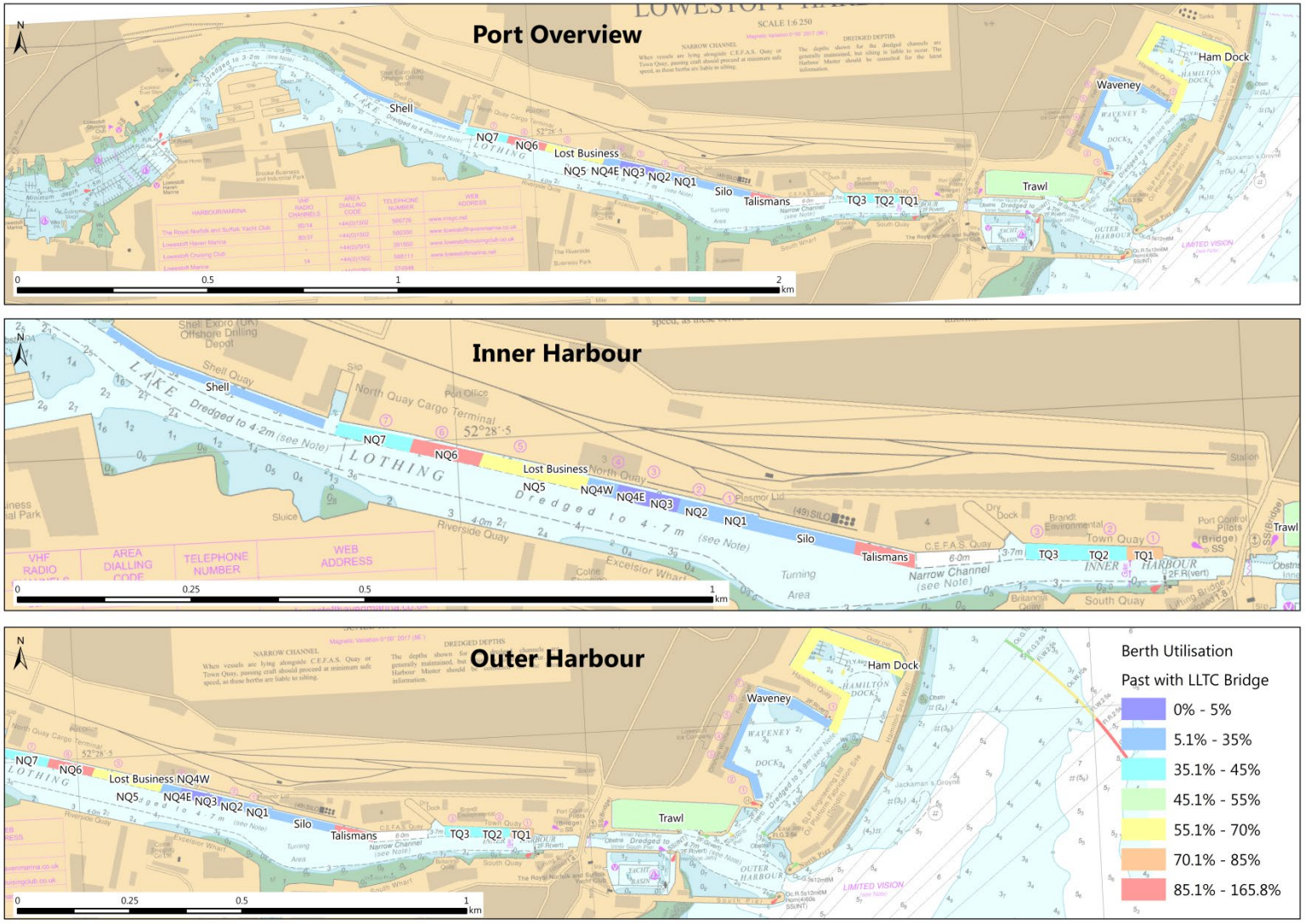
A.1 Past Scenario



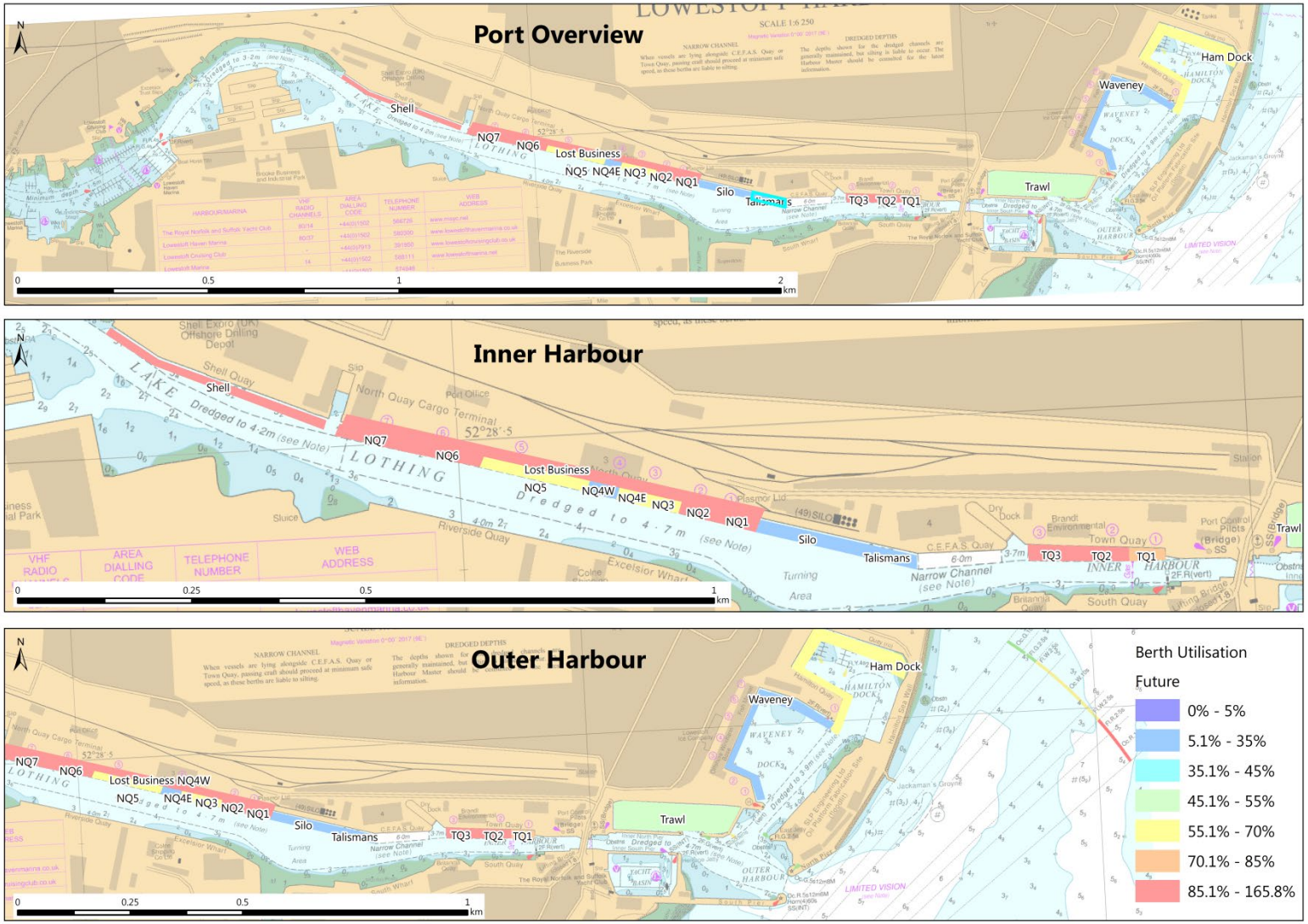




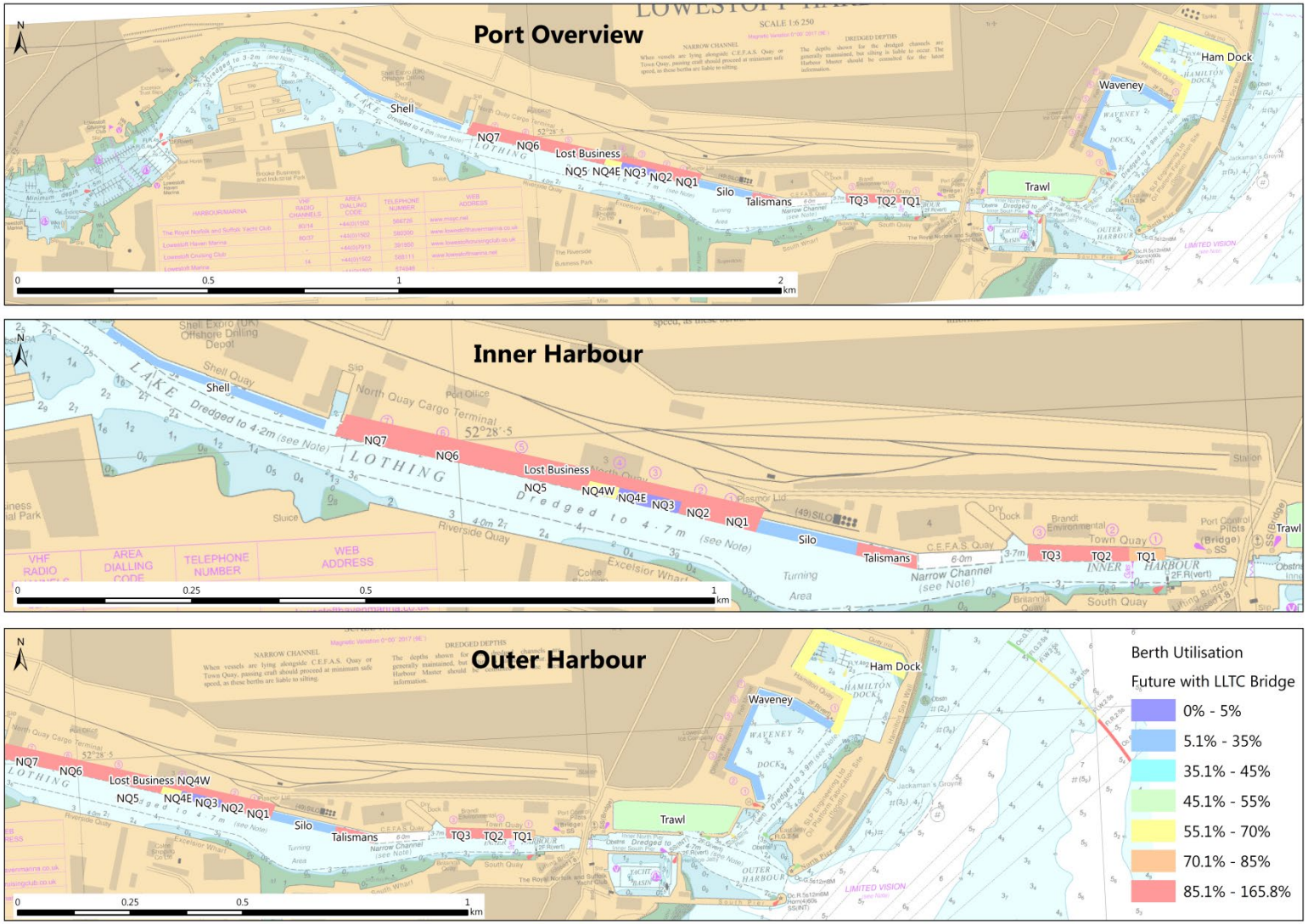
A.2 Past Scenario with LLTC Bridge



A.3 Future Scenario



A.4 Future Scenario with LLTC Bridge



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