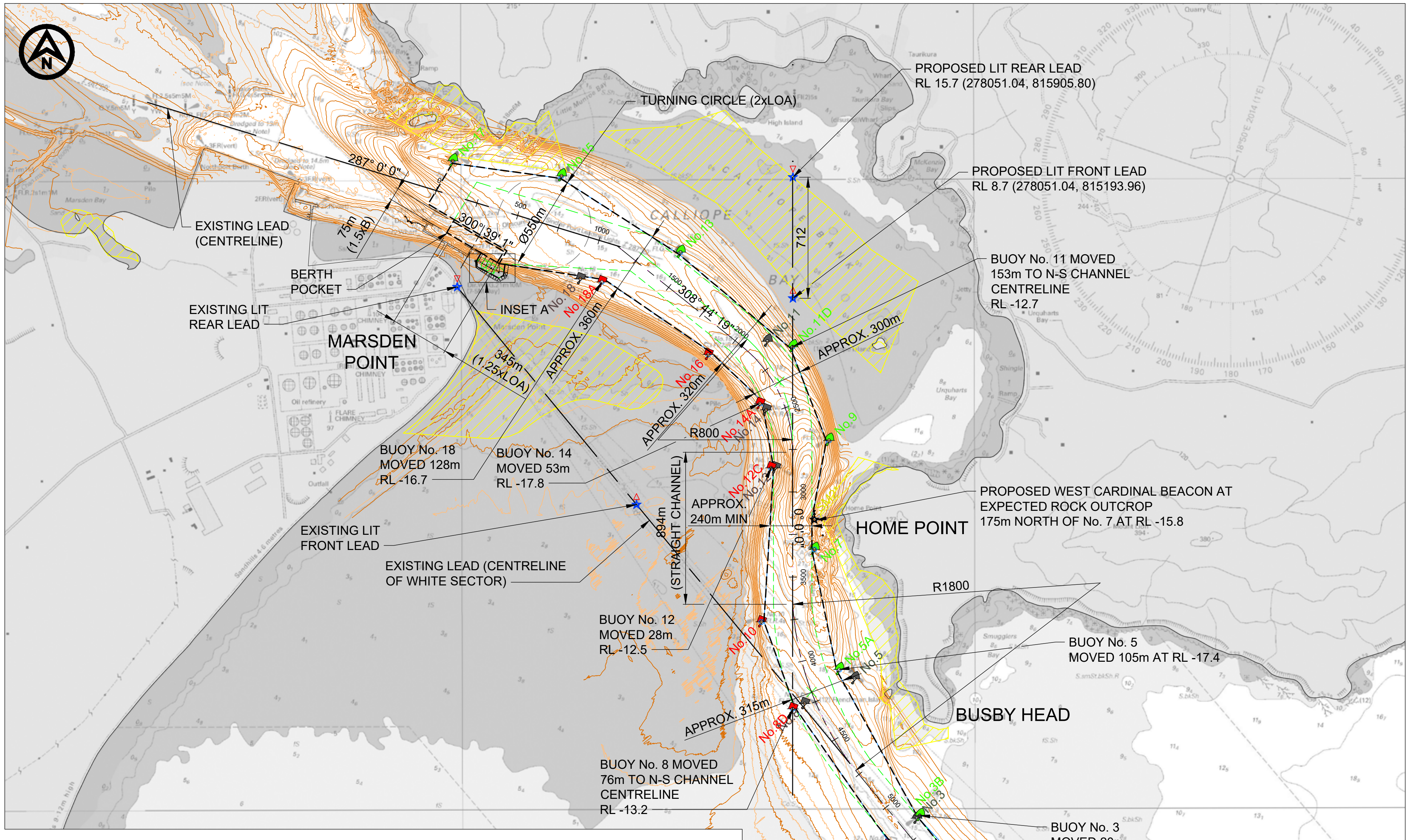
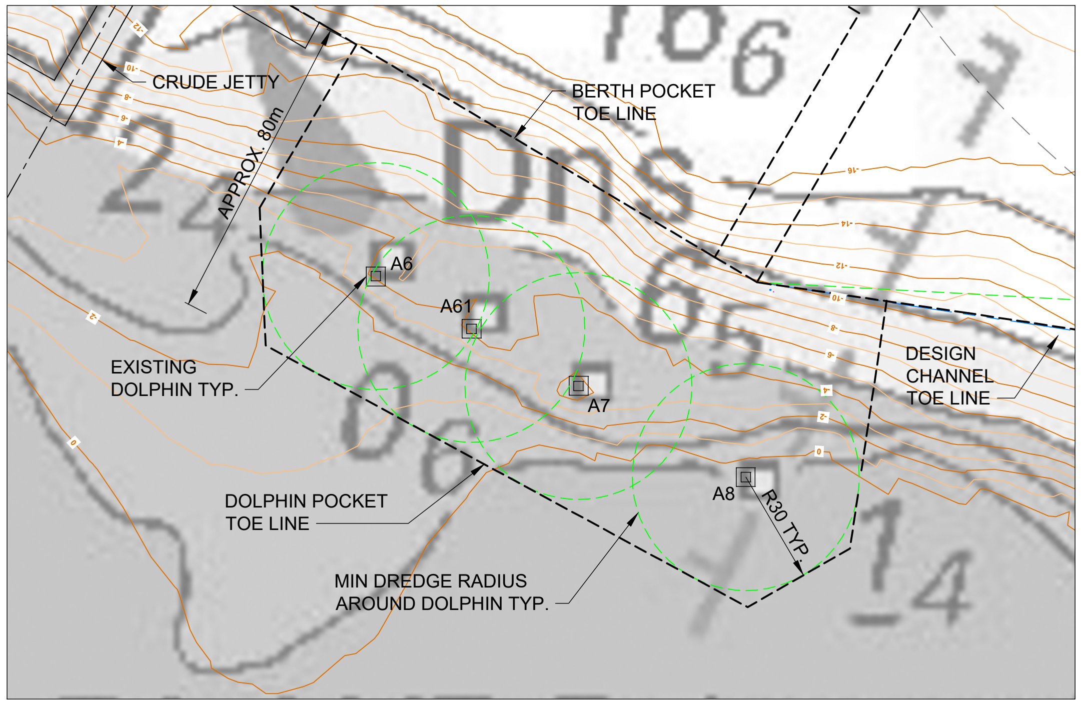
DRAWING No. PA1028/MA/1121

DO NOT SCALE



PLAN - CHANNEL ALIGNMENT
1:15,000 (A1)



INSET A - DOLPHIN POCKET
1:1,000 (A1)

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- THEORETICAL TOE LINE
- THEORETICAL CHANNEL CENTRELINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)

NAVIGATION AIDS:
PROPOSED RELOCATED BUOYS ARE DENOTED WITH A LETTER SUFFIX (e.g. No. 11A)

- LIT STARBOARD BUOY (NTM)
- LIT PORT BUOY (NTM)
- LIT WEST CARDINAL BEACON
- LIT SPECIAL MARK PILLAR BUOY (NTM)
- LIT SAFE WATER MARK PILLAR BUOY
- EXISTING BUOY TO BE RELOCATED
- WAVERIDER BUOY
- LIT REAR LEAD BEACON
- LIT FRONT LEAD BEACON
- LEAD LINE

CONSTRAINTS:

- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.
5. THE DAYLIGHT LEADS ON THE OFFSHORE APPROACH CHANNEL BETWEEN THE FAIRWAY BUOY AND BUOYS 3/6 SHOULD BE MADE MORE SENSITIVE TO ADEQUATELY SHOW THE NAVIGATION LIMITS OF THE NEW CHANNEL AND BE BRIGHT ENOUGH TO SUPPORT OPERATIONS IN ADVERSE ENVIRONMENTAL CONDITIONS. AN ADDITIONAL FRONT LEAD SHOULD BE ESTABLISHED WITH DAY AND NIGHT LIGHTS IN THE CURRENT FRONT LEAD POSITION. THE EXISTING FRONT LEAD SHOULD BE REPLACED WITH A SIMPLE DAY\NIGHT LIGHT LEAD WITH NO DAY SHAPE.
6. NORTHPORT TO REMOVE THE DAY SHAPE TOP STRUCTURE FROM THE EXISTING FORE LEAD STRUCTURE AND PLACE A NEW 1.2m HIGH STRUCTURE (ON TOP) TO HOLD THE PROPOSED LIGHT. LIGHT COLOUR TO BE CONFIRMED.

REV	DATE	DESCRIPTION	BY	CHK	APPD
M	22.09.16	WEST CARDINAL MARK ADDED	BAM	JGC	
L	24.08.16	LEADS AND FAIRWAY BUOY MOVED	BAM	JGC	
K	23.06.16	LEADS MOVED	BAM	RM	
J	22.06.16	FAIRWAY BUOY MOVED	BAM	RM	
H	02.12.15	REISSUED FOR REVIEW	BAM	RM	
G	27.10.15	DREDGING AROUND DOLPHINS ADDED	BAM	RM	
F	23.10.15	LABELS REMOVED	BAM	RM	
E	22.10.15	REVISED SUEZMAX VESSEL	BAM	RM	
D	16.10.15	BUOYS No.2 AND PB1 SHIFTED	BAM	RM	
C	13.10.15	CHANNEL CENTRELINE ADDED	BAM	MP	
B	12.10.15	PROPOSED N-S LEAD ADDED	BAM	MP	
A	10.09.15	REVISED FROM OPTION 4-1	BAM	MP	

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ

PROJECT:
REFINING NEW ZEALAND
CRUDE FREIGHT PROJECT

DRAWING TITLE:
CHANNEL DESIGN
OPTION 4-2
CHANNEL ALIGNMENT

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

20 0 20 40 60 80 100m
1:1000 (A1) 1:2000 (A3)

HASKONING AUSTRALIA PTY LTD
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DRAWN BAM	DATE 26/08/2016	JOB No. PA1028
AUTOCAD REF. PA1028-MA-OP4-2L-98%		
SCALE AT A1 AS SHOWN		
DRAWING No. PA1028/MA/1121		REVISION M

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11
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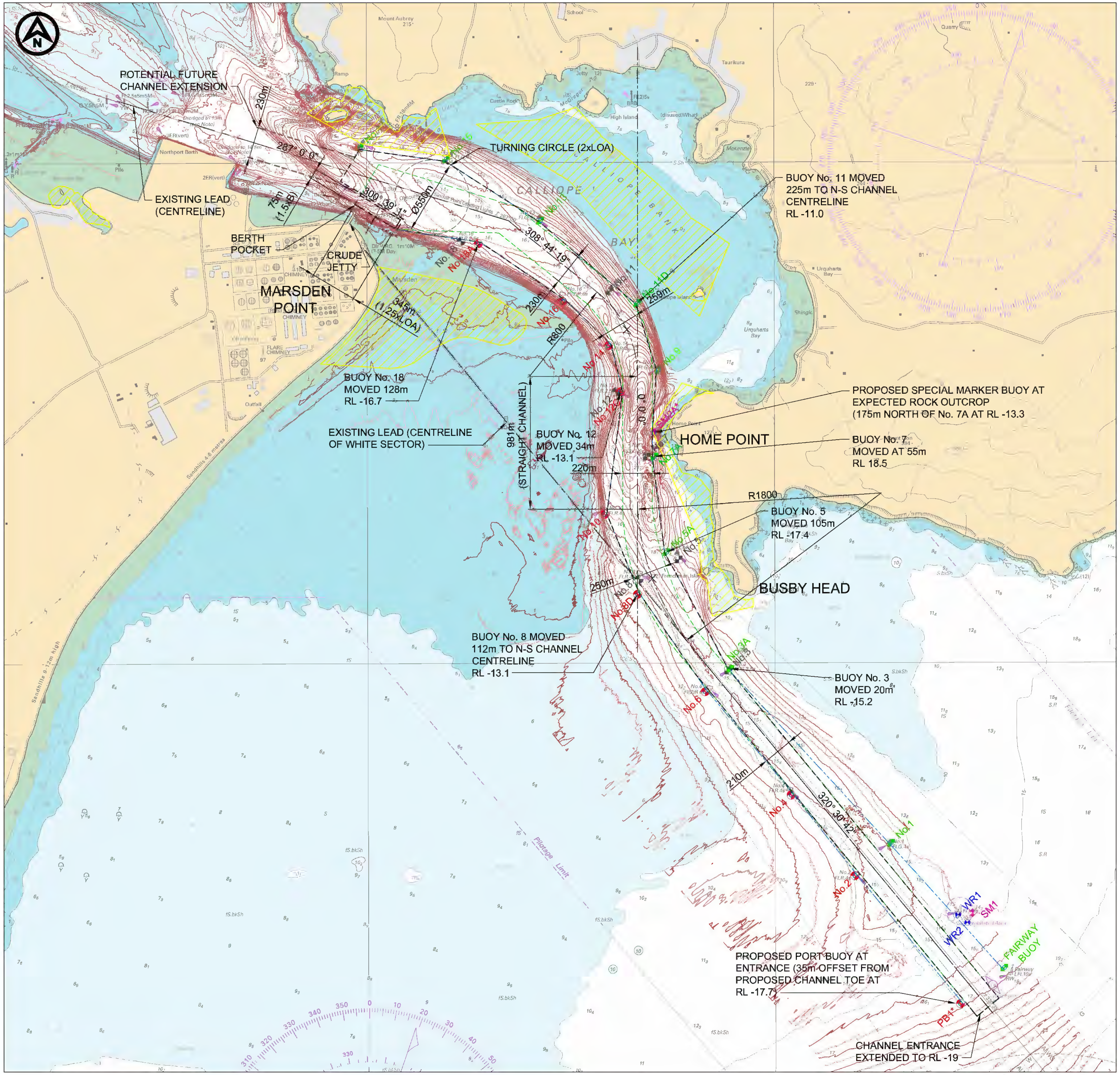


LEGEND:

- PROPOSED CHANNEL TOE LINE
- DESIGN CHANNEL TOE LINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
- OPTION 4-2 REV A DESIGN CHANNEL CENTRELINE
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED AND PREVIOUS REVISIONS
- RELOCATED BUOYS (e.g. No. 11A)
- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 274m AND BEAM (B) = 48m.
5. PROPOSED CHANNEL TOE FOLLOWS DESIGN CHANNEL TOE SOUTH OF BUOY No. 3, AND FOLLOWS BUOY BOUNDARY NORTH OF BUOY No. 3.

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	10.09.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN REALIGNMENT OPTION 5 CHANNEL ALIGNMENT

CHART DATUM

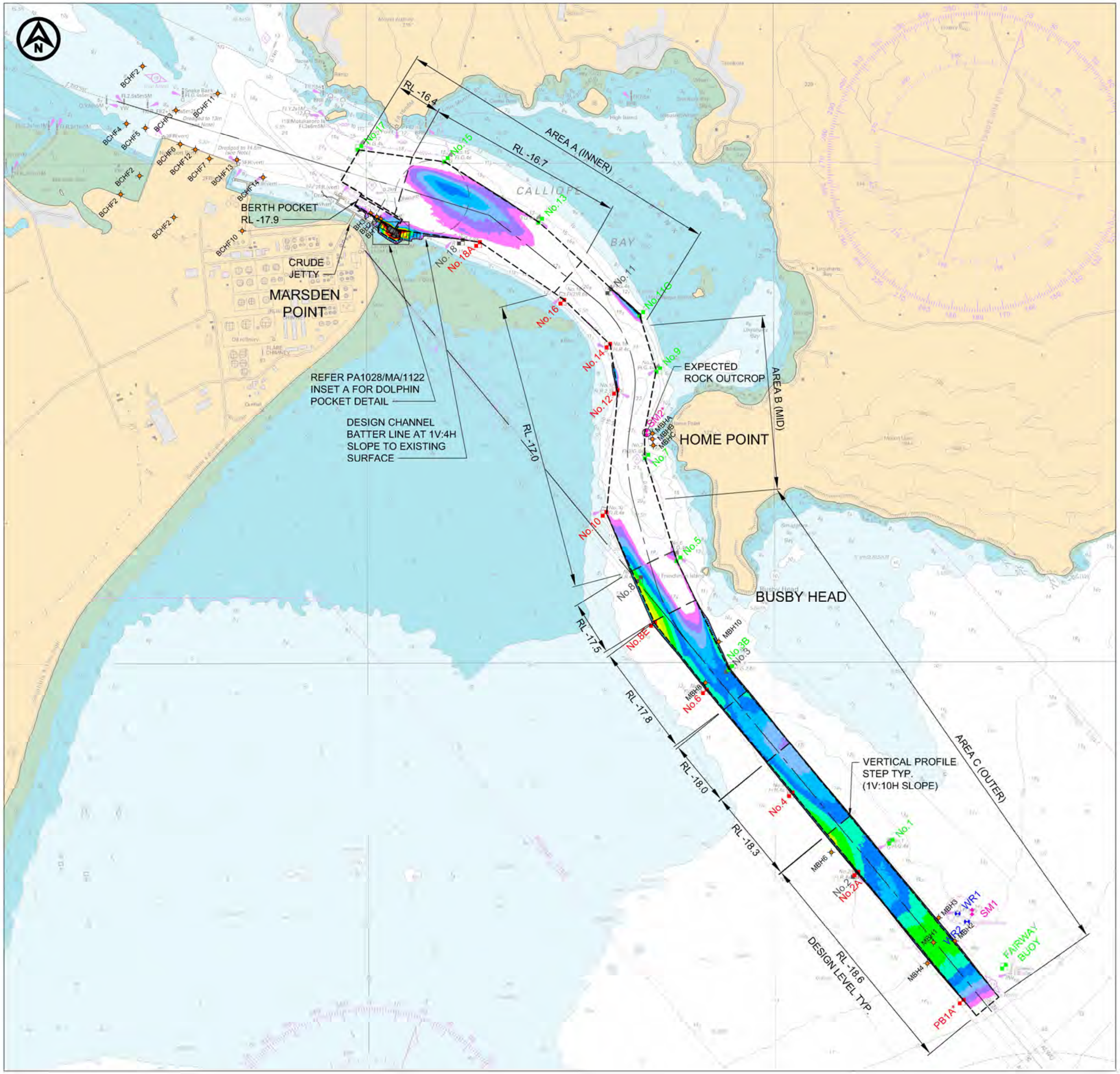
NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

HASKONING AUSTRALIA PTY LTD SYDNEY
Royal HaskoningDHV Enhancing Society Together

DRAWN BAM | DATE 10/09/2015 | JOB No. PA1028
AUTOCAD REF. PA1028-MA-OP5A-DESIGN LEVEL
SCALE AT A1 1:15000
DRAWING No. PA1028/MA/1301 | REVISION A

DRAWING No. PA1028/MA/1202 **DO NOT SCALE**



DREDGING QUANTITIES

AREA	DREDGING VOLUME, TO DESIGN LEVEL (m^3)	DREDGING VOLUME, INCLUDING OVERDREDGING (m^3)
AREA A (OUTER)	2,140,000	2,454,000
AREA B (MID)	6,000	9,000
AREA C (INNER)	436,000	562,000
TOTAL	2,583,000	3,025,000

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- PROPOSED RELOCATED BUOYS (e.g. No. 11A)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED
- HISTORICAL BOREHOLES (e.g. MBH1) (HAWTHORN, 2009) (e.g. BCHF1) (BCHF, 1992-1993)

DREDGED DEPTH BELOW EXISTING SURFACE (m):

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- 5.5 - 6.0
- 6.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- 10.0 - 11.0

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. DREDGING DESIGN LEVELS VARY ALONG CHANNEL AND ARE BASED ON AN APPROXIMATION OF THE 95% ACCESS PROFILE FOR 16.6m VESSEL DRAFT DEVELOPED BY OMC (2015) TO DEFINE DECLARED DEPTHS. ADDITIONAL ALLOWANCES HAVE BEEN ADDED FOR SILTATION TO DETERMINE DREDGING DESIGN LEVELS.
5. DREDGING ALLOWANCES:
   a. A SILTATION ALLOWANCE OF 0.5m (OUTER HARBOUR) AND 0.3m (INNER HARBOUR) HAS BEEN ADOPTED WITH THE OUTER HARBOUR DEFINED AS BEING OFFSHORE OF BUOY No. 5.
   b. AN OVERDREDGING ALLOWANCE OF 0.3m HAS BEEN APPLIED TO ESTIMATE DREDGING VOLUMES.

REV	DATE	DESCRIPTION	BY	CHK	APPD
D	02.12.15	BUOY No.8 MOVED	BAM	RM	
C	02.11.15	CHANGES CARRIED OVER FROM OPTION 4-2	BAM	RM	
B	22.07.15	RELOCATED BUOYS ADDED	BAM	MP	
A	20.07.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ
Your Energy Hive

PROJECT:
REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE:
CHANNEL DESIGN
OPTION 2
DREDGE FOOTPRINT
16.6m DRAFT VESSEL, 95% ACCESS
1V:4H CHANNEL BATTER

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

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+61 2 99290960 Fax
www.royalhaskoning.com Internet

DRAWN BAM	DATE 02/12/2015	JOB No. PA1028
AUTOCAD REF. PA1028-MA-OP2D-95%		
SCALE AT A1 1:15000		

DRAWING No. PA1028/MA/1202 REVISION D

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WORKING DRAWINGS\PA1028-MA-OP2D-95%.DWG 12/2/2015 6:12 PM

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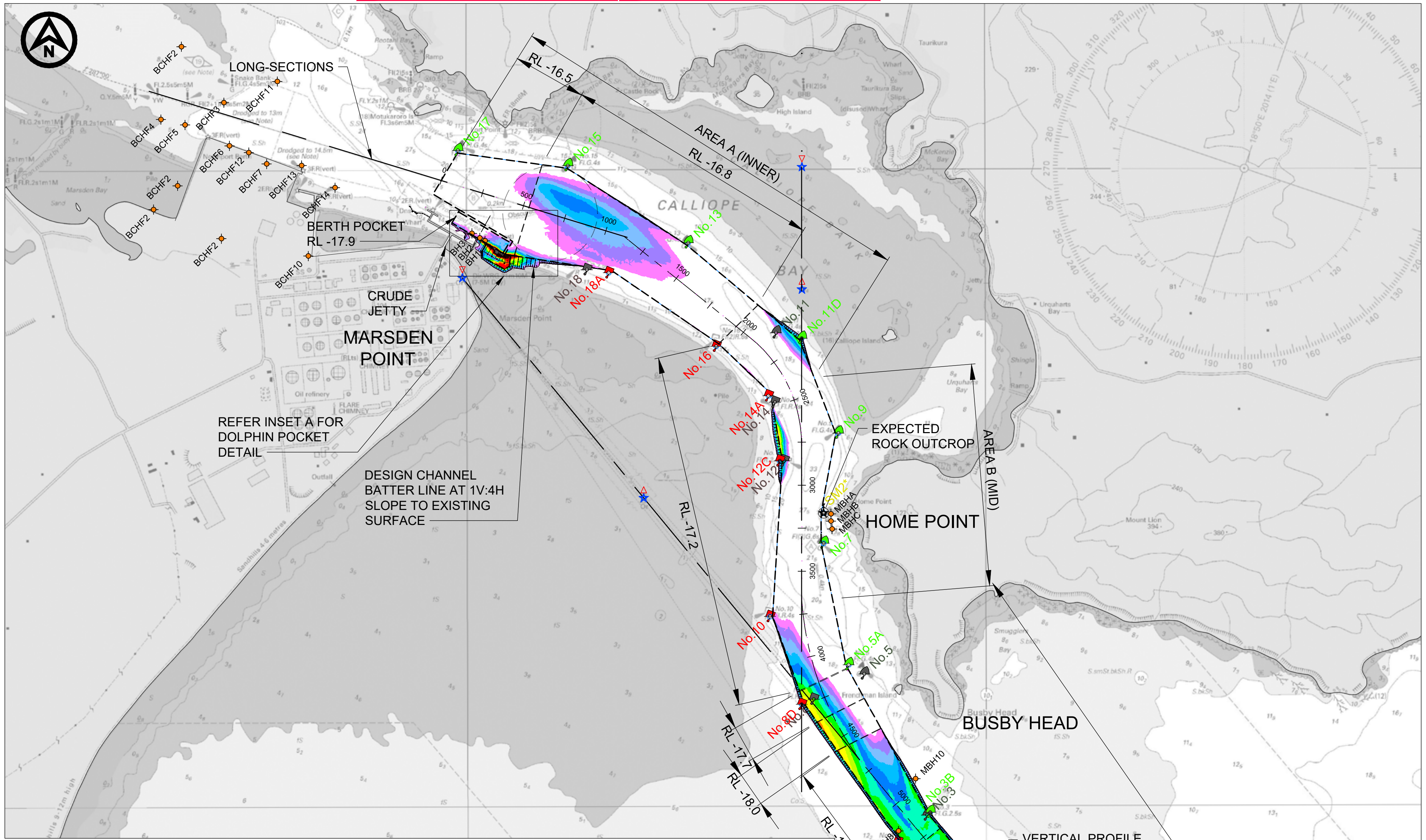

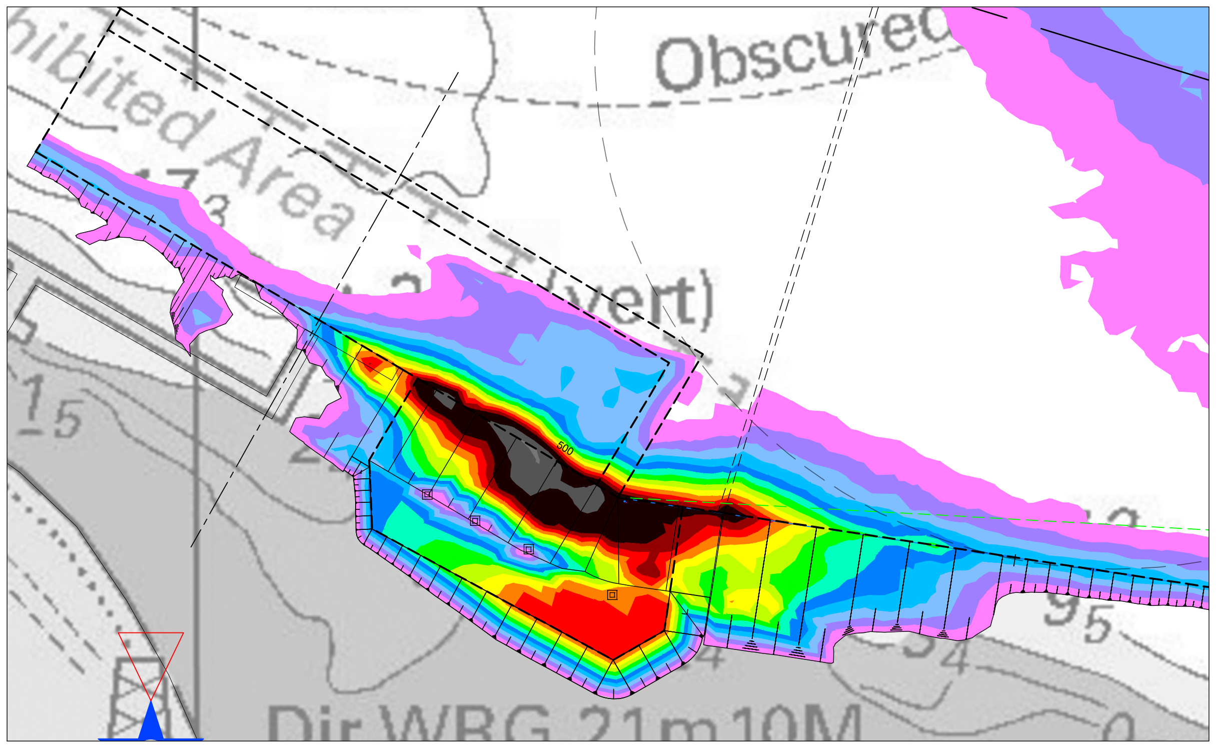

INSET A - DOLPHIN POCKET

1:2,000 (A1)

PLAN - DREDGE FOOTPRINT

1:15,000 (A1)

DREDGING QUANTITIES

AREA	DREDGING VOLUME, TO DESIGN LEVEL (m³)	DREDGING VOLUME, INCLUDING OVERDREDGING (m³)
AREA A (OUTER)	2,652,000	2,971,000
AREA B (MID)	50,000	57,000
AREA C (INNER)	476,000	610,000
TOTAL	3,177,000	3,638,000

LEGEND:

DESIGN TOE LINE

DESIGN CHANNEL CENTRELINE

NAVIGATION AIDS:
PROPOSED RELOCATED BUOYS ARE DENOTED WITH A LETTER SUFFIX (e.g. No. 11A)

LIT STARBOARD BUOY (NTM)

LIT PORT BUOY (NTM)

LIT WEST CARDINAL BEACON

LIT SPECIAL MARK PILLAR BUOY (NTM)

LIT SAFE WATER MARK PILLAR BUOY

EXISTING BUOY TO BE RELOCATED

WAVERIDER BUOY

LIT REAR LEAD BEACON

LIT FRONT LEAD BEACON

LEAD LINE

GEOTECHNICAL:

HISTORICAL BOREHOLES
(e.g. MBH1) (HAWTHORN, 2009)
(e.g. BCHF1) (BCHF, 1992-1993)

DREDGED DEPTH BELOW EXISTING SURFACE (m):

0.0 - 0.5	4.5 - 5.0
0.5 - 1.0	5.0 - 5.5
1.0 - 1.5	5.5 - 6.0
1.5 - 2.0	6.0 - 7.0
2.0 - 2.5	7.0 - 8.0
2.5 - 3.0	8.0 - 9.0
3.0 - 3.5	9.0 - 10.0
3.5 - 4.0	10.0 - 11.0
4.0 - 4.5	

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. DREDGING DESIGN LEVELS VARY ALONG CHANNEL AND ARE BASED ON AN APPROXIMATION OF THE 98% ACCESS PROFILE FOR 16.6m VESSEL DRAFT DEVELOPED BY OMC (2015) TO DEFINE DECLARED DEPTHS. ADDITIONAL ALLOWANCES HAVE BEEN ADDED FOR SILTATION TO DETERMINE DREDGING DESIGN LEVELS.
5. DREDGING ALLOWANCES:
   a. A SILTATION ALLOWANCE OF 0.5m (OUTER HARBOUR) AND 0.3m (INNER HARBOUR) HAS BEEN ADOPTED WITH THE OUTER HARBOUR DEFINED AS BEING OFFSHORE OF BUOY No. 5.
   b. AN OVERDREDGING ALLOWANCE OF 0.3m HAS BEEN APPLIED TO ESTIMATE DREDGING VOLUMES.

40 0 40 80 120 160 200m
1:2000 (A1) 1:4000 (A3)

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
C	17.10.16	INSET ADDED	BAM	JC	
B	22.09.16	ALL CHANGES FROM DRG 1121[M]	BAM	JC	
A	02.12.15	REVISED FROM 95% ACCESS	BAM	RM	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN OPTION 4–2 DREDGE FOOTPRINT
16.6m DRAFT VESSEL, 98% ACCESS
1V:4H CHANNEL BATTER

HASKONING AUSTRALIA PTY LTD
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Royal HaskoningDHV Enhancing Society Together
Level 14, 56 Berry Street, North Sydney NSW 2060
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Internet www.royalhaskoning.com

DRAWN BAM | DATE 14/10/2016 | JOB No. PA1028

AUTOCAD REF. PA1028–MA–OP4–2L–98%

SCALE AT A1 AS SHOWN

DRAWING No. PA1028/MA/1123 | REVISION C

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11
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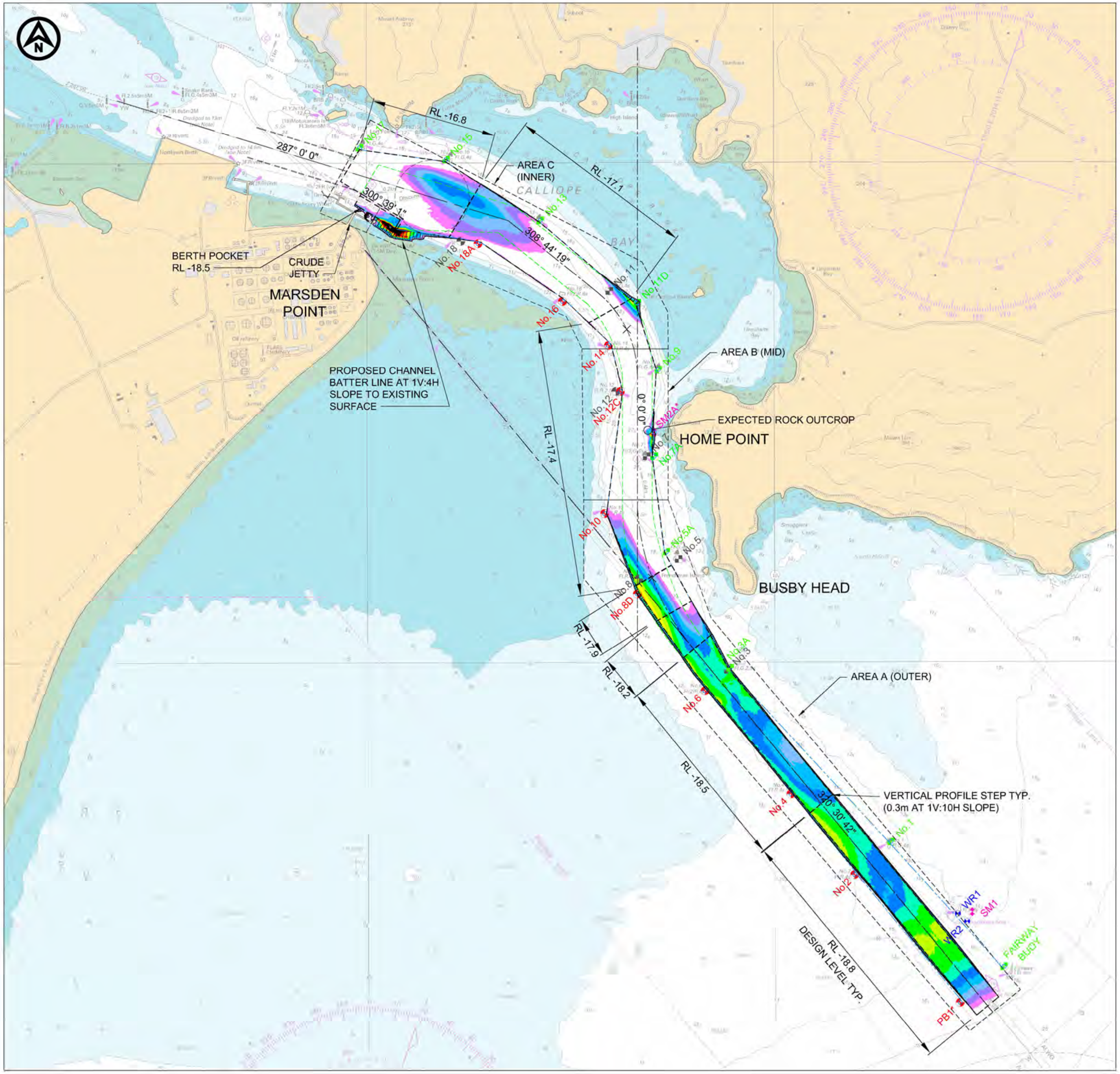

DREDGING QUANTITIES

AREA	DREDGING VOLUME, TO DESIGN LEVEL (m^3)	DREDGING VOLUME, INCLUDING OVERDREDGING (m^3)
AREA A (OUTER)	2,400,000	2,710,000
AREA B (MID)	21,000	25,000
AREA C (INNER)	558,000	704,000
TOTAL	2,979,000	3,439,000

LEGEND:

- PROPOSED CHANNEL TOE LINE
- DESIGN CHANNEL TOE LINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
- STARBOARD BUOYS
- PORTSIDE BUOYS
- WAVERIDER BUOYS
- SPECIAL MARK BUOYS
- EXISTING BUOYS TO BE RELOCATED AND PREVIOUS REVISIONS
- RELOCATED BUOYS (e.g. No. 11A)

DREDGED DEPTH (m):

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- 5.5 - 6.0
- 6.0 - 7.0
- 7.0 - 8.0
- 8.0 - 9.0
- 9.0 - 10.0
- 10.0 - 11.0

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. DREDGING DESIGN LEVELS VARY ALONG CHANNEL AND ARE BASED ON AN APPROXIMATION OF THE 95% ACCESS PROFILE FOR 16.8m VESSEL DRAFT DEVELOPED BY OMC (2014) TO DEFINE DECLARED DEPTHS. ADDITIONAL ALLOWANCES HAVE BEEN ADDED FOR SILTATION TO DETERMINE DREDGING DESIGN LEVELS.
5. DREDGING ALLOWANCES:
   a. A SILTATION ALLOWANCE OF 0.5m (OUTER HARBOUR) AND 0.3m (INNER HARBOUR) HAS BEEN ADOPTED WITH THE OUTER HARBOUR DEFINED AS BEING OFFSHORE OF BUOY No. 5.
   b. AN OVERDREDGING ALLOWANCE OF 0.3m HAS BEEN APPLIED TO ESTIMATE DREDGING VOLUMES.

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	10.09.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN REALIGNMENT OPTION 5 DREDGE FOOTPRINT

HASKONING AUSTRALIA PTY LTD SYDNEY
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DRAWN BAM | DATE 10/09/2015 | JOB No. PA1028
AUTOCAD REF. PA1028–MA–OP5A–DESIGN LEVEL
SCALE AT A1 1:15000
DRAWING No. PA1028–MA–1302 | REVISION A

APPENDIX A: Preliminary Channel Width Assessment – Technical Memorandum

Technical Memo

HASKONING AUSTRALIA PTY LTD
MARITIME & WATERWAYS.

To	:	Dave Martin (Refining NZ)
From	:	Matt Potter / Richard Mocke
Date	:	08 May 2015
Copy	:	Chris Simmons (ChanceryGreen)
Our reference	:	150506_PA1028_prelim channel width_technical memo_rev0
Subject	**:**	PIANC Channel Width Assessment

This memorandum summarises the findings of the preliminary channel width assessment undertaken in preparation for the recent Channel Design Workshop held on 17th April 2015.

Calculation sheets for the PIANC channel design procedure are provided in **Attachment A**. A copy of Workshop presentations given by RHDHV are provided in **Attachment B**. Meeting minutes from the Workshop are provided in **Attachment C**.

1 APPROACH

The PIANC guidelines are an industry recognised standard for design of shipping channels. The concept design procedure for channel width allowances is documented within *Harbour Approach Channels – Design Guidelines* (PIANC, 2014). This procedure was applied to the existing alignment of the shipping channel into Whangarei Harbour to evaluate the channel width required for the Suezmax tankers proposed to access the Marsden Point facility. The PIANC procedure involves the determination of a number of vessel beam multiplier factors from consideration of a range of navigation, metocean and channel conditions. It should be noted that the approach is suitable for the concept design phase of a project and is subject to refinement by fast-time and/or real-time ship manoeuvring simulation to ground truth the proposed channel geometry.

2 INPUT DATA

The main inputs into the PIANC assessment are summarised below and comprised:

- channel design reaches;
- design vessel;
- vessel speed profile;
- wind data;
- wave data;
- current data;
- channel design level;

Issue History:

Issue	Status	Issued By	Issued To	Date
A	Draft – Issued for Client Review	MP/RM	DM (Refining NZ)	28/04/15
0	Final Issue	MP/RM	DM (Refining NZ)	08/05/15

- water level;
- aids to navigation;
- bottom surface condition;
- channel slope; and,
- passing (i.e. one-way or two-way).

2.1 Channel Design Reaches

For purposes of the PIANC assessment, the existing channel was divided into six (6) reaches that corresponded to changes in the alignment of the channel and degree of exposure. These are shown below (refer **Figure 1**) and comprise:

- Reach 1 – Fairway Buoy to Buoy 1/2;
- Reach 2 – Buoy 1/2 to Buoy 3/6;
- Reach 3 – Buoy 3/6 to Buoy 7;
- Reach 4 – Buoy 7 to Buoy 14;
- Reach 5 – Buoy 14 to Buoy 16; and,
- Reach 6 – Buoy 16 to Buoy 17.

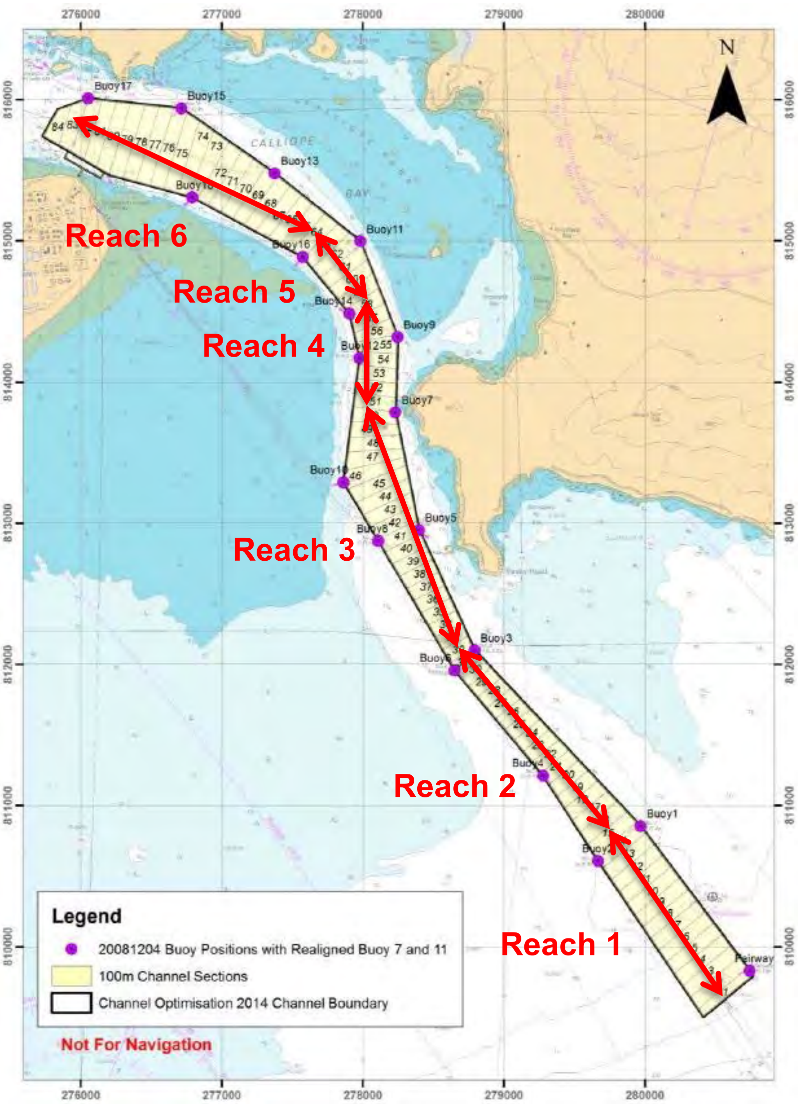


Figure 1: Channel Design Reaches

2.2 Design Vessel

The adopted design vessel corresponded to that used for the OMC channel optimisation assessment for a '16.8m vessel draft' (OMC, 2015). Relevant specifications of this design vessel comprised:

- Vessel type: Tanker;
- 159,057 DWT;
- Beam = 48m;
- LOA = 274m;
- LBP = 264m; and
- Summer Draft = 17.02m.

2.3 Vessel Speed Profile

The vessel speed profile (refer **Figure 2**) was provided by OMC and was used in their channel optimisation assessment. The ‘average’ speed profile was adopted for use in the channel width assessment.

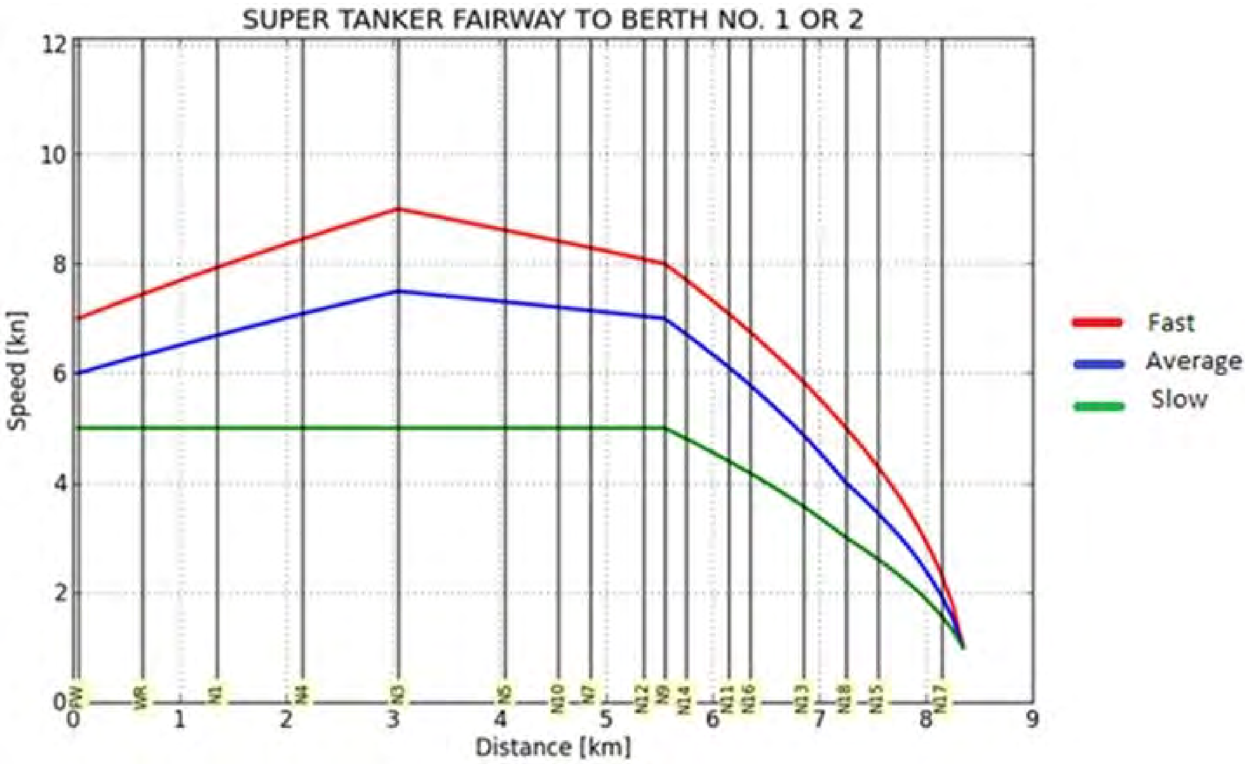


Figure 2: Vessel Speed Profiles

2.4 Wind Data

Wind data was obtained from MetOcean Solutions who provided annual wind roses for two locations, at the offshore limit of the shipping channel (refer **Figure 3**) and at Marsden Point (refer **Figure 4**). It should be noted that this data was based on hindcast wind speeds and not measured wind data.

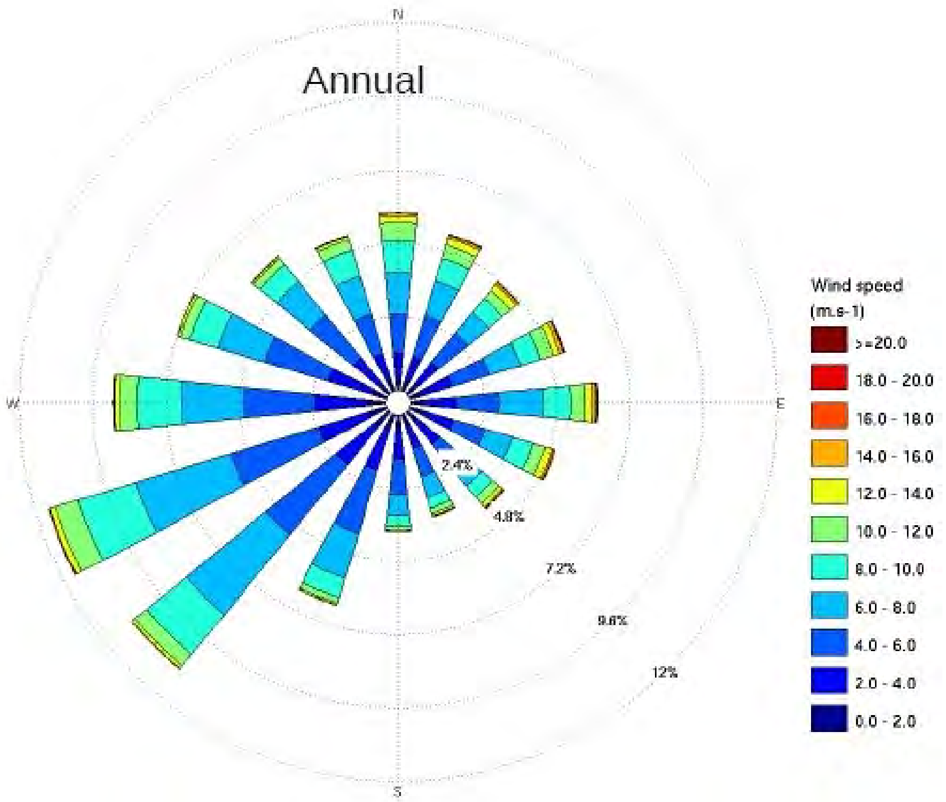


Figure 3: Annual Wind Rose at Offshore Limit of Shipping Channel (MetOcean Solutions, 2015)

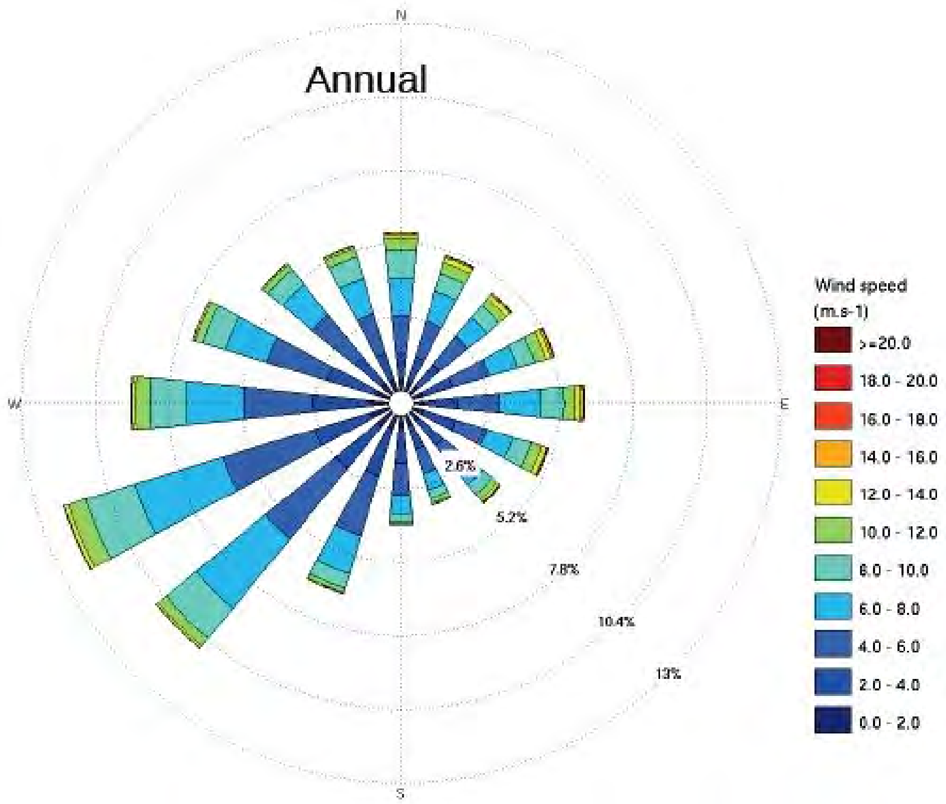


Figure 4: Annual Wind Rose at Marsden Point (MetOcean Solutions, 2015)

2.5 Wave Data

Wave data from Waverider Alpha (refer **Table 1**) was provided by OMC. The 99th percentile swell value of H_s = 2.4m was transformed to the centre of each channel Design Reach using the wave attenuation factors provided by OMC (refer **Table 2**). The resultant 99th percentile wave conditions within each Design Reach are summarised in **Table 3**.

Table 1: Wave Data from Waverider Alpha (OMC, 2015)

Table 4: Wave Statistics one hour before HW over a period of two years at the Waverider Alpha.

	HsSea	HsSwell	TpSea	TpSwell
1	0.00	0.00	4.08	7.14
10	0.07	0.19	4.08	8.00
20	0.09	0.25	4.76	8.70
50	0.22	0.43	6.67	10.53
80	0.48	0.75	6.90	20.00
90	0.73	1.05	6.90	22.22
99	1.55	2.40	6.90	22.22

Table 2: Wave Attenuation Factors (OMC, 2015)

Table 3: Wave Attenuation at time ship passes (at Fairway approx 1 hour before HW)

		Percentile
BNID	Location	50
6	Approx Location of WR Buoy	1.00
7	Reach 1 Centre	1.00
22	Reach 2 Centre	0.80
41	Reach 3 Centre	0.36
54	Reach 4 Centre	0.24
63	Reach 5 Centre	0.24
74	Reach 6 Centre	0.24

Table 3: 99th Percentile Wave Conditions

Location	Wave Attenuation Factor	Swell Height (H_s, m)
Reach 1 (centre)	1	2.4
Reach 2 (centre)	0.8	1.9
Reach 3 (centre)	0.36	0.9
Reach 4 (centre)	0.24	0.6
Reach 5 (centre)	0.24	0.6
Reach 6 (centre)	0.24	0.6

2.6 Current Data

Current data for each Design Reach was provided by OMC and is summarised below in **Table 4**. 99th percentile values were adopted to characterise the current conditions in each Design Reach. It was assumed that these values represented longitudinal currents and that cross-currents were “negligible” (less than 0.2 knots in the PIANC procedure) in all reaches.

Table 4: Current data (OMC, 2015)

Table 1: Predicted Current Velocity at time ship passes for transit Fairway to Berth (at Fairway approx 1 hour before HW)

		Percentile: Current Velocity [knots] (+ = flood)						
BNID	Location	1	10	20	50	80	90	99
7	Reach 1 Centre	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Reach 2 Centre	0.22	0.22	0.25	0.29	0.32	0.32	0.32
41	Reach 3 Centre	0.93	0.94	1.03	1.22	1.34	1.34	1.34
54	Reach 4 Centre	1.20	1.22	1.33	1.58	1.74	1.74	1.74
63	Reach 5 Centre	1.04	1.06	1.16	1.39	1.54	1.54	1.54
74	Reach 6 Centre	1.06	1.07	1.18	1.41	1.57	1.57	1.57

2.7 Channel Design Level

The channel design level adopted corresponded to the 95% access channel design prepared by OMC for a ‘16.8m Vessel Draft’ in their channel optimisation assessment (OMC, 2015). The minimum level was determined within each Design Reach and used in the PIANC width assessment.

2.8 Water Level

The water level adopted for the PIANC width assessment was the mean high water neap tide (+2.32m CD). This was considered to represent an average ‘high water’ access condition for vessels entering the Port.

2.9 Aids to Navigation

Aids to navigation were characterised as “good” in the PIANC design procedure, which corresponds to the provision and availability of paired lighted buoys/lighted leading lines, availability of pilots and DGPS.

2.10 Bottom Surface Condition

The bottom surface condition was characterised as “smooth and soft” in the PIANC design procedure.

2.11 Channel Slope

The channel slope was characterised as having “sloping channel edges and shoals”, which corresponds to channel batters that are not flatter than 1V:10H.

2.12 Passing

It was assumed that channel would be ‘one-way’ for the design vessel.

3 FINDINGS

The results of the PIANC channel width assessment are summarised in **Table 5** and detailed calculation sheets are provided within **Attachment A**.

Table 5: Results of PIANC Channel Width Assessment

Reach	Description	Beam Multiplier	PIANC Width (m)	Existing Channel Width (m)	
				Min.	Max.
1	Fairway Buoy to Buoy 1/2	4.0	192	389	454
2	Buoy 1/2 to Buoy 3/6	4.0	192	200	373
3	Buoy 3/6 to Buoy 7	3.7	178	201	429
4	Buoy 7 to Buoy 14	3.9	187	270	296
5	Buoy 14 to Buoy 16	3.9	187	300	391
6	Buoy 16 to Buoy 17	3.9	187	359	585

4 CONCLUSIONS

The results in **Table 5** indicate that PIANC channel widths for the proposed Suezmax design vessel range between 178 m (3.7 x beam) and 192 m (4.0 x beam). These widths are all considerably narrower than the existing buoyed channel in all Design Reaches. As such, dredging (i.e. deepening) to provide access for the design vessel is unlikely to be required over the full channel area defined by the existing navigation buoys.

Refinement of the channel width design is possible by:

- further compartmentalisation of Design Reaches;
- refinement of metocean input data based on measured data sources (where possible) and feedback on typical operating conditions from pilots at the Port;
- optimisation of the channel alignment; and,
- consideration of bend geometry.

The above findings were presented by RHDHV at a Channel Design Workshop held on 17th April 2015 (refer **Attachment B**). A record of discussions during the Workshop is contained within the meeting minutes (refer **Attachment C**). A summary of the main outcomes from the Workshop that are relevant to the channel design is provided below:

- measured wind data at Marsden Point is to be obtained to verify the hindcast wind data provided by MetOcean Solutions;
- Refining NZ are to liaise with MetOcean Solutions and OMC to refine the wave attenuation model and to obtain modelled and measured current data (particularly over the entrance area) to improve consistency with NorthTugz/pilots observations and confidence in channel design outcomes; and,
- realignment of the channel is proposed to improve navigability, particularly through the Home Point stretch, 'Option 4' (refer **Figure 5)** was considered to be the preferred alignment for further consideration by the Harbourmaster and NorthTugz/pilots.

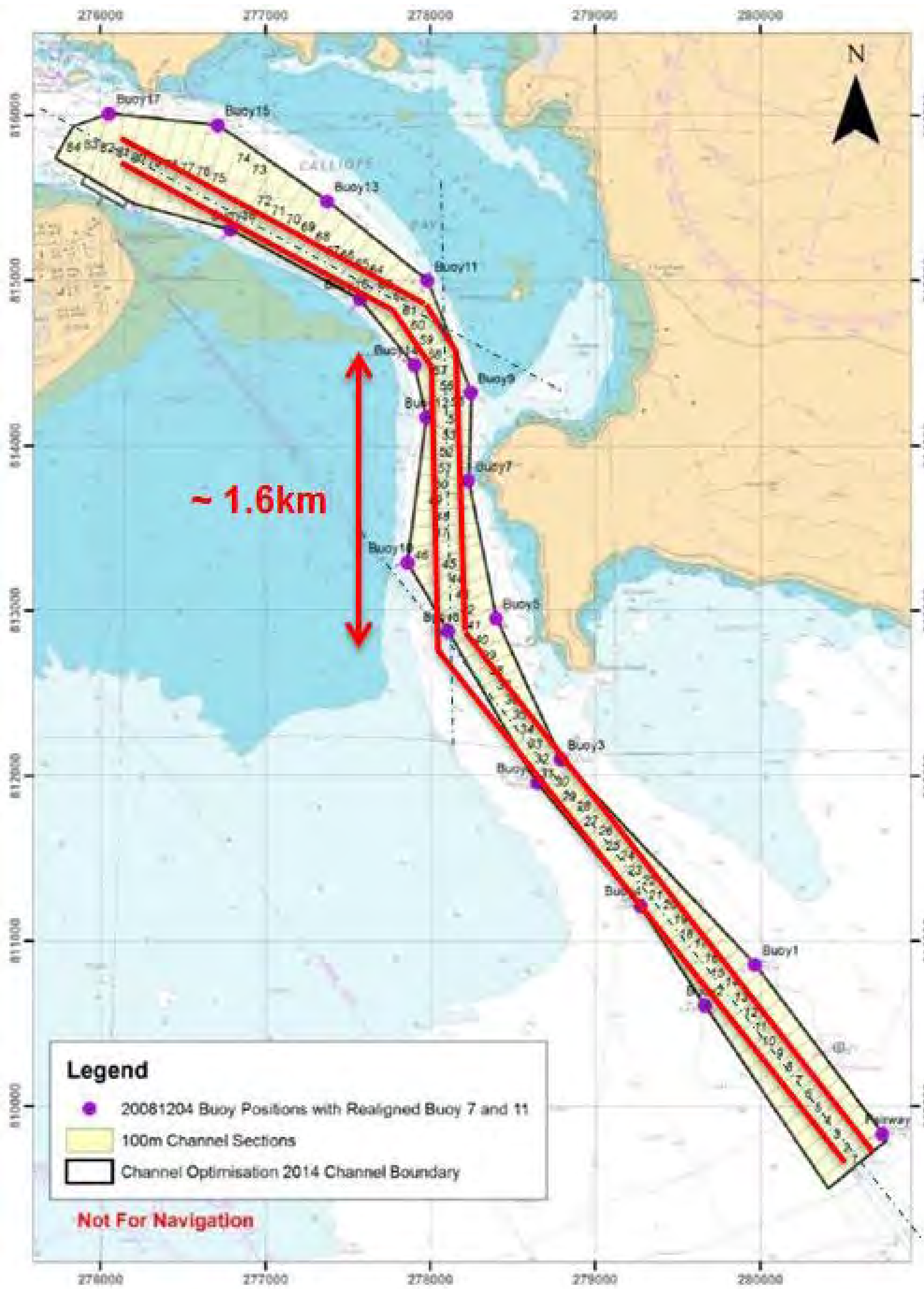


Figure 5: 'Option 4' channel alignment

ATTACHMENT A
PIANC Channel Width Calculations

Ship Manoeuvrability	Good	Moderate	Poor
Basic Manoeuvring Lane, W_{BM}	1.3 B	1.5 B	1.8 B

Table 3.4: Basic manoeuvring lane W_{BM}

<table>
<tr><th>Width
W_i</th><th>Vessel Speed</th><th colspan="2">Outer Channel (open water)</th><th colspan="2">Inner Channel (protected water)</th></tr>
<tr><td>(a) Vessel speed V_s (kts, with respect to the water)</td><td></td><td colspan="4"></td></tr>
<tr><td>$V_s \geq 12$ kts</td><td>fast</td><td colspan="4">0.1 B</td></tr>
<tr><td>8 kts $\leq V_s <$ 12 kts</td><td>mod</td><td colspan="4">0.0</td></tr>
<tr><td>5 kts $\leq V_s <$ 8 kts</td><td>slow</td><td colspan="4">0.0</td></tr>
<tr><td>(b) Prevailing cross wind V_{cw} (kts)</td><td></td><td colspan="4"></td></tr>
<tr><td>- mild</td><td>fast</td><td colspan="4">0.1 B</td></tr>
<tr><td>$V_{cw} <$ 15 kts</td><td>mod</td><td colspan="4">0.2 B</td></tr>
<tr><td>(< Beaufort 4)</td><td>slow</td><td colspan="4">0.3 B</td></tr>
<tr><td>- moderate</td><td>fast</td><td colspan="4">0.3 B</td></tr>
<tr><td>15 kts $\leq V_{cw} <$ 33 kts</td><td>mod</td><td colspan="4">0.4 B</td></tr>
<tr><td>(Beaufort 4 - Beaufort 7)</td><td>slow</td><td colspan="4">0.6 B</td></tr>
<tr><td>- strong</td><td>fast</td><td colspan="4">0.5 B</td></tr>
<tr><td>33 kts $\leq V_{cw} <$ 48 kts</td><td>mod</td><td colspan="4">0.7 B</td></tr>
<tr><td>(Beaufort 7 - Beaufort 9)</td><td>slow</td><td colspan="4">1.1 B</td></tr>
<tr><td>(c) Prevailing cross-current V_{cc} (kts)</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>- negligible $V_{cc} <$ 0.2 kts</td><td>all</td><td colspan="2">0.0</td><td colspan="2">0.0</td></tr>
<tr><td>- low</td><td>fast</td><td colspan="2">0.2 B</td><td colspan="2">0.1 B</td></tr>
<tr><td>0.2 kts $\leq V_{cc} <$ 0.5 kts</td><td>mod</td><td colspan="2">0.25 B</td><td colspan="2">0.2 B</td></tr>
<tr><td></td><td>slow</td><td colspan="2">0.3 B</td><td colspan="2">0.3 B</td></tr>
<tr><td>- moderate</td><td>fast</td><td colspan="2">0.5 B</td><td colspan="2">0.4 B</td></tr>
<tr><td>0.5 kts $\leq V_{cc} <$ 1.5 kts</td><td>mod</td><td colspan="2">0.7 B</td><td colspan="2">0.6 B</td></tr>
<tr><td></td><td>slow</td><td colspan="2">1.0 B</td><td colspan="2">0.8 B</td></tr>
<tr><td>- strong</td><td>fast</td><td colspan="2">1.0 B</td><td colspan="2">-</td></tr>
<tr><td>1.5 kts $\leq V_{cc} <$ 2.0kts</td><td>mod</td><td colspan="2">1.2 B</td><td colspan="2">-</td></tr>
<tr><td></td><td>slow</td><td colspan="2">1.6 B</td><td colspan="2">-</td></tr>
<tr><td>(d) Prevailing longitudinal current V_{lc} (kts)</td><td></td><td colspan="4"></td></tr>
<tr><td>- low
$V_{lc} <$ 1.5 kts</td><td>all</td><td colspan="4">0.0</td></tr>
<tr><td>- moderate</td><td>fast</td><td colspan="4">0.0</td></tr>
<tr><td>1.5 kts $\leq V_{lc} <$ 3 kts</td><td>mod</td><td colspan="4">0.1 B</td></tr>
<tr><td></td><td>slow</td><td colspan="4">0.2 B</td></tr>
<tr><td>- strong</td><td>fast</td><td colspan="4">0.1 B</td></tr>
<tr><td>$V_{lc} \geq$ 3 kts</td><td>mod</td><td colspan="4">0.2 B</td></tr>
<tr><td></td><td>slow</td><td colspan="4">0.4 B</td></tr>
<tr><td>(e) Beam and stern quartering wave height H_s (m)</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>- $H_s \leq$ 1 m</td><td>all</td><td colspan="2">0.0</td><td colspan="2">0.0</td></tr>
<tr><td>- 1 m $< H_s <$ 3 m</td><td>all</td><td colspan="2">~0.5 B</td><td colspan="2">-</td></tr>
<tr><td>- $H_s \geq$ 3 m</td><td>all</td><td colspan="2">~1.0 B</td><td colspan="2">-</td></tr>
<tr><td>(f) Aids to Navigation (AtoN)</td><td></td><td colspan="4"></td></tr>
<tr><td>- excellent</td><td></td><td colspan="4">0.0</td></tr>
<tr><td>- good</td><td></td><td colspan="4">0.2B</td></tr>
<tr><td>- moderate</td><td></td><td colspan="4">0.4 B</td></tr>
<tr><td>(g) Bottom surface</td><td></td><td colspan="4"></td></tr>
<tr><td>- if depth $h \geq 1.5\,T$</td><td></td><td colspan="4">0.0</td></tr>
<tr><td>- if depth $h < 1.5\,T$ then</td><td></td><td colspan="4"></td></tr>
<tr><td>- smooth and soft</td><td></td><td colspan="4">0.1 B</td></tr>
<tr><td>- rough and hard</td><td></td><td colspan="4">0.2 B</td></tr>
<tr><td>(h) Depth of waterway h</td><td></td><td>$h \geq 1.5\,T$</td><td>0.0 B</td><td>$h \geq 1.5\,T$</td><td>0.0 B</td></tr>
<tr><td></td><td></td><td>$1.5\,T > h \geq 1.25\,T$</td><td>0.1 B</td><td>$1.5\,T > h \geq 1.15\,T$</td><td>0.2 B</td></tr>
<tr><td></td><td></td><td>$h < 1.25\,T$</td><td>0.2 B</td><td>$h < 1.15\,T$</td><td>0.4 B</td></tr>
<tr><td>(i) High cargo hazards</td><td></td><td colspan="4">See explanation in box(i) overleaf</td></tr>
</table>

Table 3.5: Additional widths W_i for straight channel sections

Width for bank clearance (W_{BR} and/or W_{BG})	Vessel Speed	Outer channel (open water)	Inner channel (protected water)
Gentle underwater channel slope (1:10 or less steep)	fast moderate slow	0.2 B 0.1 B 0.0 B	0.2 B 0.1 B 0.0 B
Sloping channel edges and shoals	fast moderate slow	0.7 B 0.5 B 0.3 B	0.7 B 0.5 B 0.3 B
Steep and hard embankments, structures	fast moderate slow	1.3 B 1.0 B 0.5 B	1.3 B 1.0 B 0.5 B
Note: W_{BR} and W_{BG} are widths on 'red' and 'green' sides of channel			

Table 3.6: Additional width for bank clearance W_{BR} and W_{BG}

Width for passing distance W_p	Outer Channel (open water)	Inner Channel (protected water)
Vessel speed V_s (knots)		
- fast: $V_s \geq 12$	2.0 B	1.8 B
- moderate: $8 \leq V_s < 12$	1.6 B	1.4 B
- slow: $5 \leq V_s < 8$	1.2 B	1.0 B

Table 3.7: Additional width for passing distance in two-way-traffic W_p

PIANC (2014) CHANNEL WIDTH ASSESSMENT
REACH 1: Fairway Buoy to Buoy 1/2

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-18.19	m CD	95% Access, minimum channel design level in Reach 1	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	6.8	knots	"average" speed profile, varies from 6kts at Fairway Buoy to 6.8kts at Buoy1/2	OMC, 2015
(b) Prevailing cross wind (V_{cw})	24	knots	"Mild" V_{cw}<15 knots, "Low" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	MetOcean Solutions hindcast data, Offshore Location, Max. 12m/s
(c) Prevailing cross current (V_{cc})	0	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Assume cross current is negligible
(d) Prevailing longitudinal current (V_{lc})	0	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	OMC, 2015 99th percentile current data
(e) Beam and stern quartering wave height (H_s)	2.4	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	20.51	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.21	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.5	1m<Hs<3m	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.2	1.15T<=h<1.5T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.0	B
Total Channel Width [Outer Channel]	**192**	**m**
Total Channel Width [Inner Channel]	4.0	B
Total Channel Width [Inner Channel]	**192**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
REACH 2: Buoy 1/2 to Buoy 3/6

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-17.65	m CD	95% Access, minimum channel design level in Reach 2	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.5	knots	"average" speed profile, varies from 6.8kts at Buoy 1/2 to 7.5kts at Buoy 3/6	OMC, 2015
(b) Prevailing cross wind (V_{cw})	24	knots	"Mild" V_{cw}<15 knots, "Low" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	MetOcean Solutions hindcast data, Offshore Location, Max. 12m/s
(c) Prevailing cross current (V_{cc})	0	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Assume cross current is negligible
(d) Prevailing longitudinal current (V_{lc})	0.32	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	OMC, 2015 99th percentile current data
(e) Beam and stern quartering wave height (H_s)	1.9	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.97	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.17	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.5	1m<Hs<3m	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.2	1.15T<=h<1.5T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.0	B
Total Channel Width [Outer Channel]	**192**	**m**
Total Channel Width [Inner Channel]	4.0	B
Total Channel Width [Inner Channel]	**192**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
REACH 3: Buoy 3/6 to Buoy 7

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.87	m CD	95% Access, minimum channel design level in Reach 3	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.5	knots	"average" speed profile, varies from 7.5kts at Buoy 3/6 to 7.3kts at Buoy 7	OMC, 2015
(b) Prevailing cross wind (V_{cw})	24	knots	"Mild" V_{cw}<15 knots, "Low" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	MetOcean Solutions hindcast data, Marsden Point Location, Max. 12m/s
(c) Prevailing cross current (V_{cc})	0	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Assume cross current is negligible
(d) Prevailing longitudinal current (V_{lc})	1.34	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	OMC, 2015 99th percentile current data
(e) Beam and stern quartering wave height (H_s)	0.9	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.19	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.13	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	3.5	B
Total Channel Width [Outer Channel]	**168**	**m**
Total Channel Width [Inner Channel]	3.7	B
Total Channel Width [Inner Channel]	**178**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
REACH 4: Buoy 7 to Buoy 14

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.86	m CD	95% Access, minimum channel design level in Reach 4	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.3	knots	"average" speed profile, varies from 7.3kts at Buoy 7 to 6.8kts at Buoy 14	OMC, 2015
(b) Prevailing cross wind (V_{cw})	24	knots	"Mild" V_{cw}<15 knots, "Low" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	MetOcean Solutions hindcast data, Marsden Point Location, Max. 12m/s
(c) Prevailing cross current (V_{cc})	0	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Assume cross current is negligible
(d) Prevailing longitudinal current (V_{lc})	1.74	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	OMC, 2015 99th percentile current data
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.18	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.13	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	3.7	B
Total Channel Width [Outer Channel]	**178**	**m**
Total Channel Width [Inner Channel]	3.9	B
Total Channel Width [Inner Channel]	**187**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
REACH 5: Buoy 14 to Buoy 16

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.71	m CD	95% Access, minimum channel design level in Reach 5	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	6.8	knots	"average" speed profile, varies from 6.8kts at Buoy 14 to 5.8kts at Buoy 16	OMC, 2015
(b) Prevailing cross wind (V_{cw})	24	knots	"Mild" V_{cw}<15 knots, "Low" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	MetOcean Solutions hindcast data, Marsden Point Location, Max. 12m/s
(c) Prevailing cross current (V_{cc})	0	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Assume cross current is negligible
(d) Prevailing longitudinal current (V_{lc})	1.54	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	OMC, 2015 99th percentile current data
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.03	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.12	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	3.7	B
Total Channel Width [Outer Channel]	**178**	**m**
Total Channel Width [Inner Channel]	3.9	B
Total Channel Width [Inner Channel]	**187**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
REACH 6: Buoy 16 to Buoy 17

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.31	m CD	95% Access, minimum channel design level in Reach 6	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	5.8	knots	"average" speed profile, varies from 5.8kts at Buoy 16 to 2kts at Buoy 17	OMC, 2015
(b) Prevailing cross wind (V_{cw})	24	knots	"Mild" V_{cw}<15 knots, "Low" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	MetOcean Solutions hindcast data, Marsden Point Location, Max. 12m/s
(c) Prevailing cross current (V_{cc})	0	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Assume cross current is negligible
(d) Prevailing longitudinal current (V_{lc})	1.57	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	OMC, 2015 99th percentile current data
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	18.63	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.09	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.0	Negligible	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	3.7	B
Total Channel Width [Outer Channel]	**178**	**m**
Total Channel Width [Inner Channel]	3.9	B
Total Channel Width [Inner Channel]	**187**	**m**

ATTACHMENT B
Channel Design Workshop Presentations

Royal HaskoningDHV
Enhancing Society Together

ROYAL HASKONINGDHV

- 7,000 staff world wide
- Head Office Netherlands
- 50+ staff Haskoning Australia
- Haskoning Australia located in Sydney, Melbourne, Gold Coast, Newcastle and Perth
- All Haskoning Australia offices specialising in, maritime, coastal and estuarine projects

Royal HaskoningDHV
Enhancing Society Together

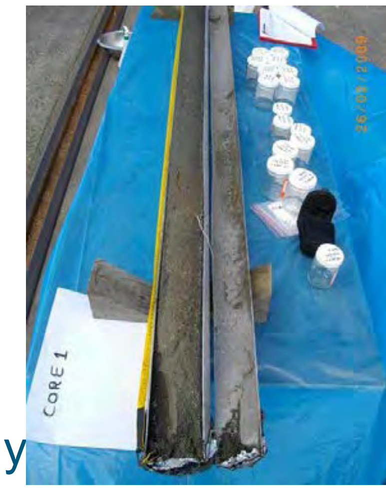
KEY AREAS OF EXPERTISE

- dredging and reclamation including sea disposal and land disposal
- maritime structures (quay walls, wharves, jetties, dolphins, etc.)
- coastal structures (breakwaters, seawalls, rock pools, beach access including; disability access and viewing platforms etc.)
- marine sediment and water quality testing; coastal processes and hazard assessment
- marinas, small craft facilities and boat launching ramps
- coastal and estuary management planning
- environmental assessments and approvals
- river and estuary studies
- geotechnical engineering
- submarine cables

Royal HaskoningDHV
Enhancing Society Together

PROJECT EXPERIENCE

- Port of Hastings Dredge Material Management
- Abbot Point Port Development
- PWCS Terminal 4 Project
- Kooragang K7 Expansion and K8-K10 Project
- Sydney Desalination Project Water Delivery Alliance
- Port Kembla Outer Harbour Development
- Port Kembla Management of Declared Depths Study
- Newcastle Port Sea Disposal Permit Applications
- Zambezi River Coal Barging Project Pre-Feasibility Study
- Mozambique Future Corridors-Greenfield Engineering Study
- Port Kembla Coal Terminal Berth 101 Marine EA
- INPEX Ichthys LNG Project – Dredging Expert Panel
- Newcastle Port ‘Area E’ Review of Environmental Factors
- Brisbane Airport – New Parallel Runway Project
- New Doha Port Project
- Wiggins Island New Coal Terminal



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PROJECT EXPERIENCE

- James Point Port Development
- Lumsden Point
- Esperance Port Expansion Project
- Ranobe Sands Export Facility
- Tonkolili Iron Ore Project
- Pepel Channel Dredging Project
- Southdown Magnetite Iron Ore Project
- Bunbury Berth 14
- Oakajee Port Development
- Cape Lambert Port Upgrade
- Fremantle Outer Harbour
- Newcastle Harbour Channel Improvement Project
- Dampier Port Upgrade

(Refer to Handout for Channel Design Specific Experience)

CHANNEL WIDTH ASSESSMENT

- PIANC (2014) *Harbour Approach Channels – Design Guidelines* supersedes previous 1997 guideline document
- Compiled in close co-operation with IAPH (International Association of Ports & Harbours), IMPA (International Maritime Pilots Association) and IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities)
- Channel width assessment is based on determination of vessel beam multiplier factors from consideration of a range of navigation, metocean and channel conditions
- Approach is suitable for concept design phase and is subject to refinement by fast-time and/or real-time ship manoeuvring simulation

CHANNEL WIDTH ASSESSMENT

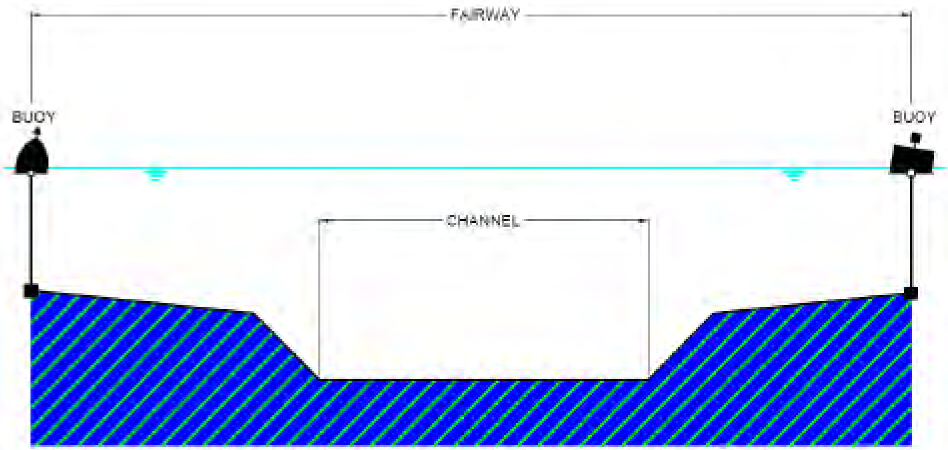

Figure 3.1: Channel and fairway definition
(where channel is defined by the channel bed width or width at nominal bed level)

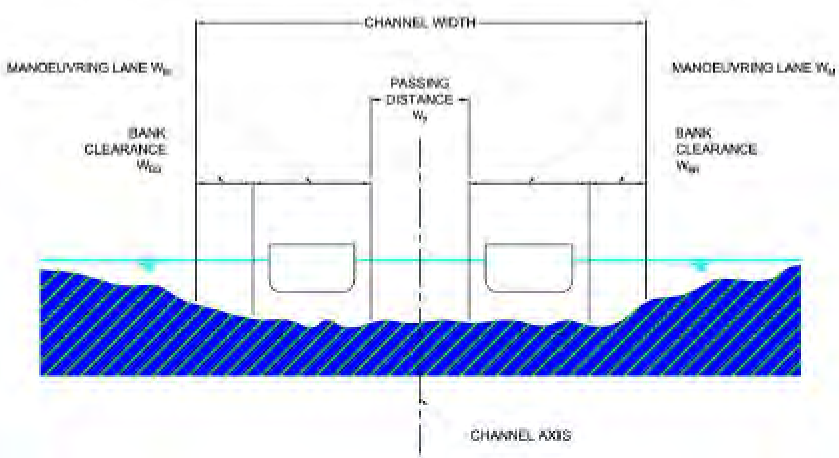

Figure 3.2: Elements of channel width

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CHANNEL WIDTH ASSESSMENT

The overall bottom width W (see Figure 3.2) of an access channel with straight sections is given for a one-way channel by:

$$W = W_{BM} + \sum W_i + W_{BR} + W_{BG} = W_M + W_{BR} + W_{BG} \qquad (3\text{-}3)$$

and for a two-way channel by:

$$W = 2W_{BM} + 2\sum W_i + W_{BR} + W_{BG} + \sum W_p = 2W_M + W_{BR} + \sum W_p + W_{BG} \qquad (3\text{-}4)$$

where:
W_{BM} = width of basic manoeuvring lane as a multiple of the design ship's beam B, given in Table 3.4
$\sum W_i$ = additional widths to allow for the effects of wind, current etc, given in Table 3.5
W_{BR}, W_{BG} = bank clearance on the 'red' and 'green' sides of the channel, given in Table 3.6
$\sum W_p$ = passing distance, comprising the sum of a separation distance between both manoeuvring lanes W_M (see Figure 3.2) and an additional distance for traffic density, given in Table 3.7.

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CHANNEL WIDTH ASSESSMENT

Width W_i	Vessel Speed	Outer Channel (open water)	Inner Channel (protected water)
(a) Vessel speed V_s (kts, with respect to the water)			
$V_s \geq 12$ kts	fast	0.1 B	
8 kts $\leq V_s <$ 12 kts	mod	0.0	
5 kts $\leq V_s <$ 8 kts	slow	0.0	
(b) Prevailing cross wind V_{cw} (kts)			
- mild	fast	0.1 B	
$V_{cw} <$ 15 kts	mod	0.2 B	
(< Beaufort 4)	slow	0.3 B	
- moderate	fast	0.3 B	
15 kts $\leq V_{cw} <$ 33 kts	mod	0.4 B	
(Beaufort 4 - Beaufort 7)	slow	0.6 B	
- strong	fast	0.5 B	
33 kts $\leq V_{cw} <$ 48 kts	mod	0.7 B	
(Beaufort 7 - Beaufort 9)	slow	1.1 B	
(c) Prevailing cross-current V_{cc} (kts)			
- negligible $V_{cc} <$ 0.2 kts	all	0.0	0.0
- low	fast	0.2 B	0.1 B
0.2 kts $\leq V_{cc} <$ 0.5 kts	mod	0.25 B	0.2 B
	slow	0.3 B	0.3 B
- moderate	fast	0.5 B	0.4 B
0.5 kts $\leq V_{cc} <$ 1.5 kts	mod	0.7 B	0.6 B
	slow	1.0 B	0.8 B
- strong	fast	1.0 B	-
1.5 kts $\leq V_{cc} <$ 2.0kts	mod	1.2 B	-
	slow	1.6 B	-
(d) Prevailing longitudinal current V_{lc} (kts)			
- low	all	0.0	
$V_{lc} <$ 1.5 kts			
- moderate	fast	0.0	
1.5 kts $\leq V_{lc} <$ 3 kts	mod	0.1 B	
	slow	0.2 B	
- strong	fast	0.1 B	
$V_{lc} \geq$ 3 kts	mod	0.2 B	
	slow	0.4 B	
(e) Beam and stern quartering wave height H_s (m)			
- $H_s \leq$ 1 m	all	0.0	0.0
- 1 m < H_s < 3 m	all	~0.5 B	-
- $H_s \geq$ 3 m	all	~1.0 B	-
(f) Aids to Navigation (AtoN)			
- excellent		0.0	
- good		0.2B	
- moderate		0.4 B	
(g) Bottom surface			
- if depth $h \geq 1.5\ T$		0.0	
- if depth $h < 1.5\ T$ then			
- smooth and soft		0.1 B	
- rough and hard		0.2 B	
(h) Depth of waterway h		$h \geq 1.5\ T$: 0.0 B	$h \geq 1.5\ T$: 0.0 B
		$1.5\ T > h \geq 1.25\ T$: 0.1 B	$1.5\ T > h \geq 1.15\ T$: 0.2 B
		$h < 1.25\ T$: 0.2 B	$h < 1.15\ T$: 0.4 B
(i) High cargo hazards		See explanation in box(i) overleaf	

Table 3.5: Additional widths W_i for straight channel sections

Ship Manoeuvrability	Good	Moderate	Poor
Basic Manoeuvring Lane, W_{BM}	1.3 B	1.5 B	1.8 B

Table 3.4: Basic manoeuvring lane W_{BM}

Width for bank clearance (W_{BR} and/or W_{BG})	Vessel Speed	Outer channel (open water)	Inner channel (protected water)
Gentle underwater channel slope (1:10 or less steep)	fast moderate slow	0.2 B 0.1 B 0.0 B	0.2 B 0.1 B 0.0 B
Sloping channel edges and shoals	fast moderate slow	0.7 B 0.5 B 0.3 B	0.7 B 0.5 B 0.3 B
Steep and hard embankments, structures	fast moderate slow	1.3 B 1.0 B 0.5 B	1.3 B 1.0 B 0.5 B
Note: W_{BR} and W_{BG} are widths on 'red' and 'green' sides of channel			

Table 3.6: Additional width for bank clearance W_{BR} and W_{BG}

Width for passing distance W_p	Outer Channel (open water)	Inner Channel (protected water)
Vessel speed V_s (knots)		
- fast: $V_s \geq 12$	2.0 B	1.8 B
- moderate: $8 \leq V_s < 12$	1.6 B	1.4 B
- slow: $5 \leq V_s < 8$	1.2 B	1.0 B

Table 3.7: Additional width for passing distance in two-way-traffic W_p

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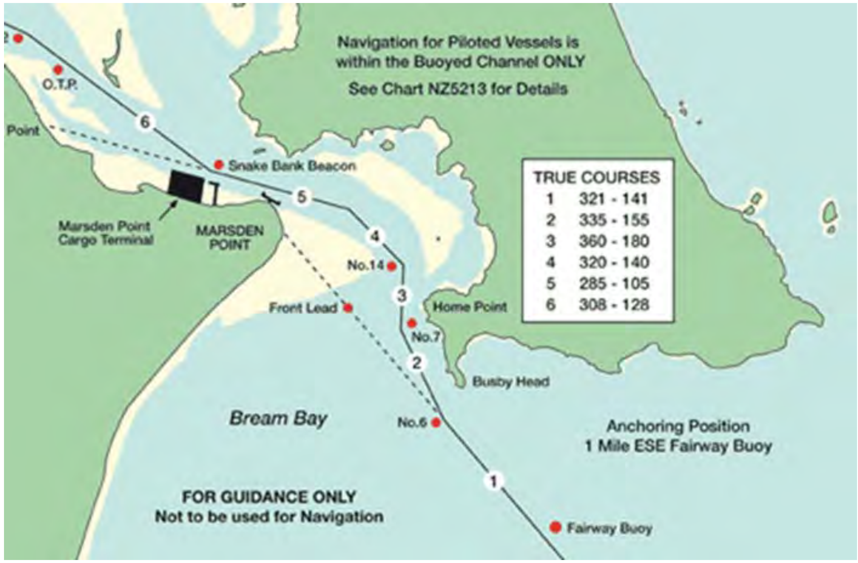
CHANNEL WIDTH ASSESSMENT

- Existing channel divided into 6 reaches:
  - Reach 1 – Fairway Buoy to Buoy 1/2
  - Reach 2 – Buoy 1/2 to Buoy 3/6
  - Reach 3 – Buoy 3/6 to Buoy 7
  - Reach 4 – Buoy 7 to Buoy 14
  - Reach 5 – Buoy 14 to Buoy 16
  - Reach 6 – Buoy 16 to Buoy 17



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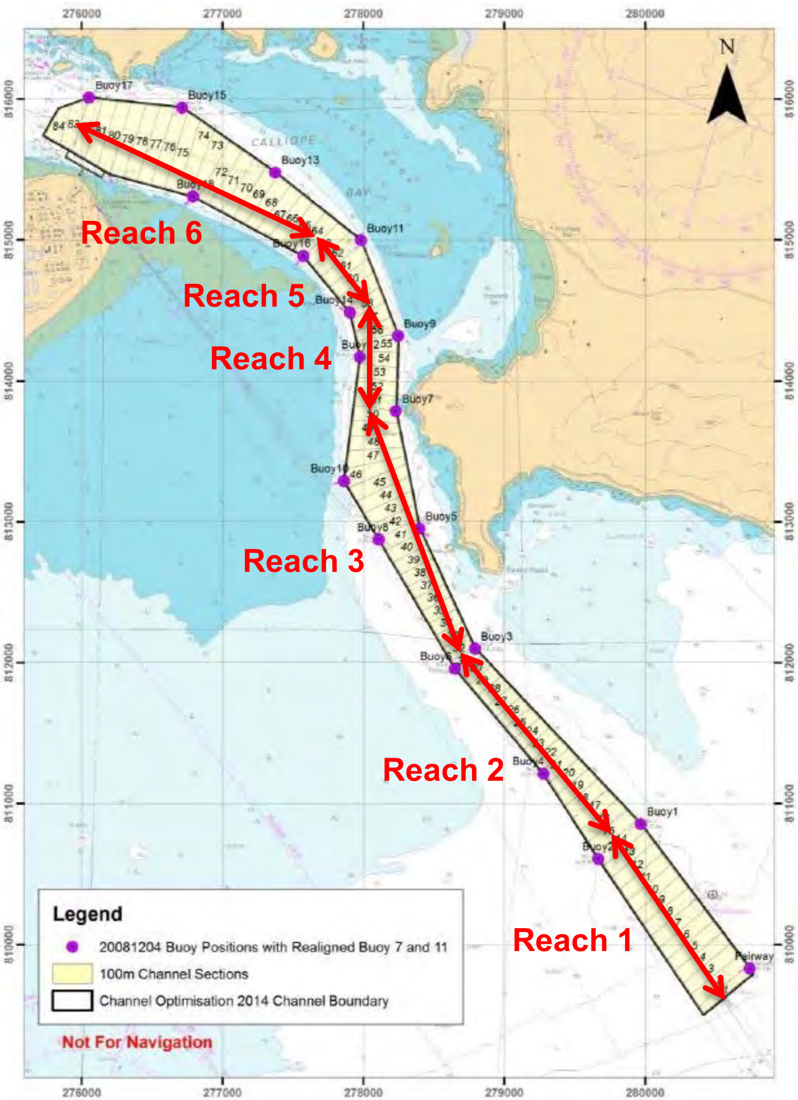
CHANNEL WIDTH ASSESSMENT



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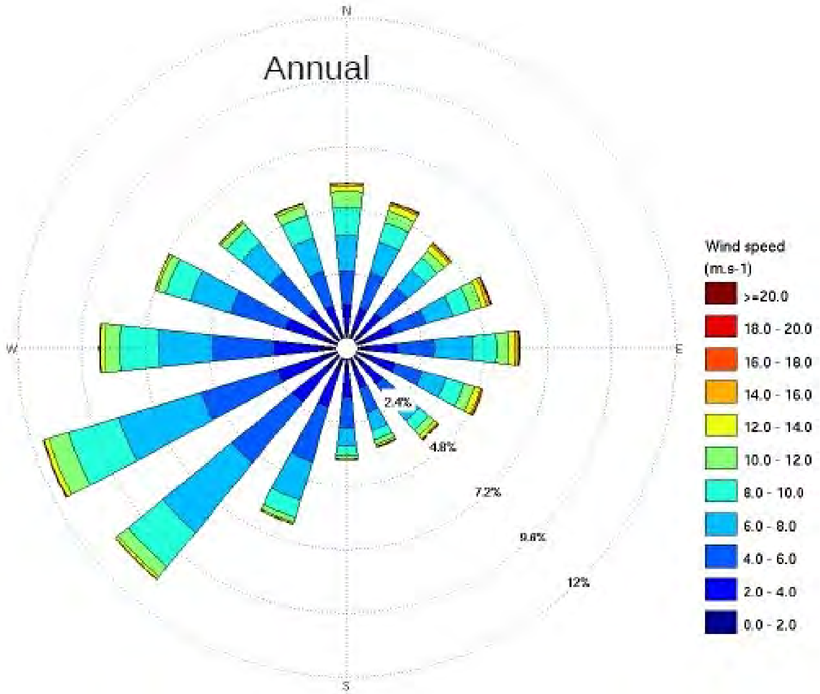
CHANNEL WIDTH ASSESSMENT

- Wind Data (MetOcean Solutions hindcast data)
  - Offshore (Shipping Channel limit) annual winds used for reaches 1 & 2
  - 99th percentile wind speed values adopted



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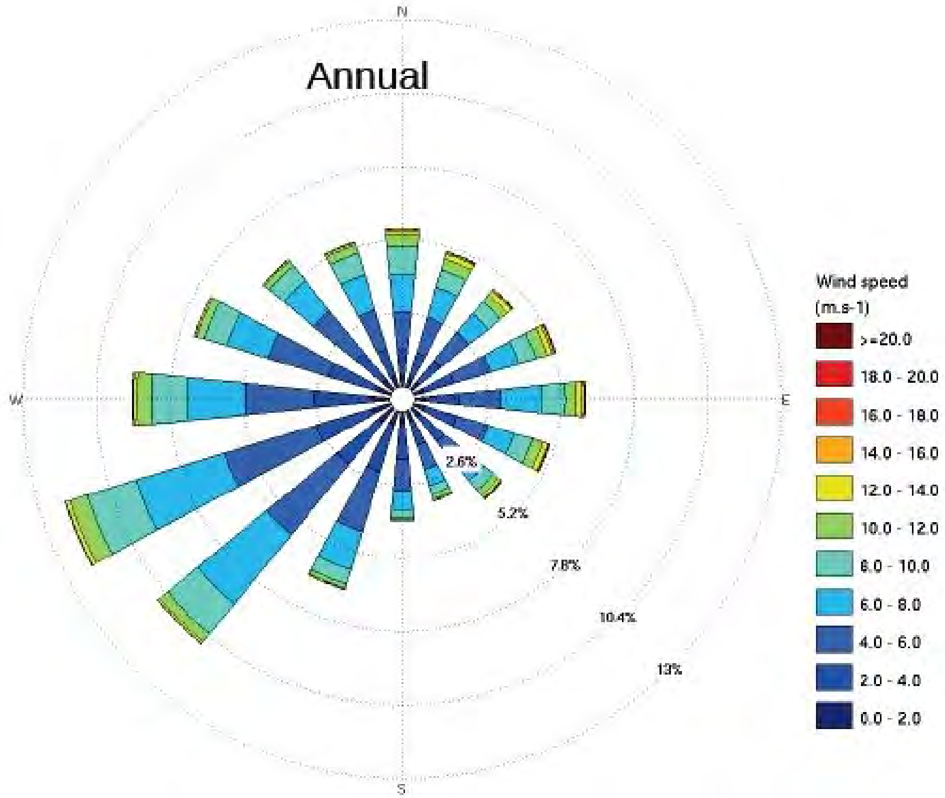
CHANNEL WIDTH ASSESSMENT

- Wind Data (MetOcean Solutions hindcast data)
  - Marsden Point annual winds used for reaches 3, 4, 5 & 6
  - 99th percentile wind speed values adopted



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CHANNEL WIDTH ASSESSMENT

- Current Data (OMC, 2015)
- 99th percentile current velocity values adopted

Table 1: Predicted Current Velocity at time ship passes for transit Fairway to Berth (at Fairway approx 1 hour before HW)

		Percentile: Current Velocity [knots] (+ = flood)						
BNID	**Location**	**1**	**10**	**20**	**50**	**80**	**90**	**99**
7	**Reach 1 Centre**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	**Reach 2 Centre**	0.22	0.22	0.25	0.29	0.32	0.32	0.32
41	**Reach 3 Centre**	0.93	0.94	1.03	1.22	1.34	1.34	1.34
54	**Reach 4 Centre**	1.20	1.22	1.33	1.58	1.74	1.74	1.74
63	**Reach 5 Centre**	1.04	1.06	1.16	1.39	1.54	1.54	1.54
74	**Reach 6 Centre**	1.06	1.07	1.18	1.41	1.57	1.57	1.57

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CHANNEL WIDTH ASSESSMENT

- Wave Data (OMC, 2015)
- 99th percentile swell value from Waverider Alpha adopted
- Attenuation factors used to transform waves to Reaches

Table 4: Wave Statistics one hour before HW over a period of two years at the Waverider Alpha.

	HsSea	HsSwell	TpSea	TpSwell
1	0.00	0.00	4.08	7.14
10	0.07	0.19	4.08	8.00
20	0.09	0.25	4.76	8.70
50	0.22	0.43	6.67	10.53
80	0.48	0.75	6.90	20.00
90	0.73	1.05	6.90	22.22
99	1.55	2.40	6.90	22.22

Table 3: Wave Attenuation at time ship passes (at Fairway approx 1 hour before HW)

		Percentile
BNID	Location	50
6	Approx Location of WR Buoy	1.00
7	Reach 1 Centre	1.00
22	Reach 2 Centre	0.80
41	Reach 3 Centre	0.36
54	Reach 4 Centre	0.24
63	Reach 5 Centre	0.24
74	Reach 6 Centre	0.24

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CHANNEL WIDTH ASSESSMENT

- Design Vessel:
  - Tanker
  - 159,057 DWT
  - Beam = 48m
  - LOA = 274m
  - LBP = 264m
  - Draft = 17.02m
- Channel Design Level = minimum design level within each Reach corresponding to OMC 95% access
- Water level: mean high water neap tide used as high water access condition
- Passing: One-way

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CHANNEL WIDTH ASSESSMENT

- PIANC Channel Type:
  - Reach 1,2 = “Outer Channel”
  - Reach 3,4,5,6 = “Inner Channel”
- Vessel Manoeuvrability: “Poor” (tankers/bulk carriers)
- Cross Wind: “Low” 15kts$<V_{cw}<$33kts
- Cross Current: “negligible” in all reaches

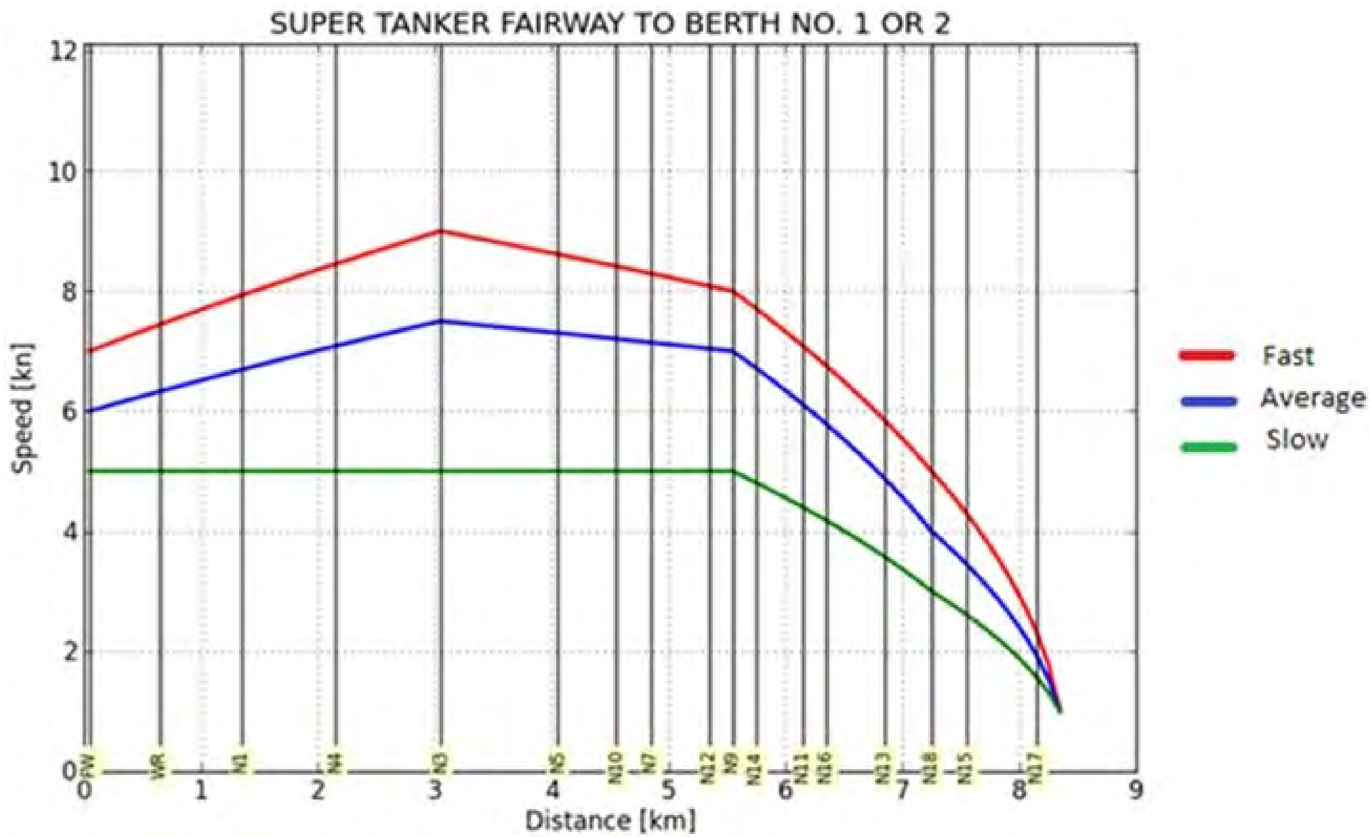
An approach channel is defined as any stretch of waterway linking the berths of a port and the open sea. There are two main types:

- An outer channel in open water and exposed to waves that can produce significant vertical ship motions of heave, pitch, and roll
- An inner channel that lies in relatively sheltered waters and is not subject to wave action of any significance to large ships

The channel normally terminates at its inner end in a manoeuvring area (turning and/or berthing area) which allows stopping, turning and berthing manoeuvres to be undertaken.

CHANNEL WIDTH ASSESSMENT

- Vessel Speed Profile:
  - “average” speed profile adopted from OMC (2015)



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CHANNEL WIDTH ASSESSMENT

- Longitudinal Current
  - Reach 1,2,3 = “Low” V_{lc}<1.5kts
  - Reach 4,5,6 = “Moderate” 1.5kts<V_{lc}<3kts
- Wave Height:
  - Reach 1,2 = 1m<H_s<3m
  - Reach 3,4,5,6 = H_s<1m
- Aids to Navigation: “Good” (paired lighted buoys/lighted leading lines, availability of pilots and DGPS)
- Bottom Surface: “smooth and soft”
- Channel Slope “sloping channel edges and shoals”

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CHANNEL WIDTH ASSESSMENT

Reach	Beam Multiplier	PIANC Width (m)	Existing Fairway Width (m)	
			Min.	Max.
1	4.0	192	389	454
2	4.0	192	200	373
3	3.7	178	201	429
4	3.9	187	270	296
5	3.9	187	300	391
6	3.9	187	359	585

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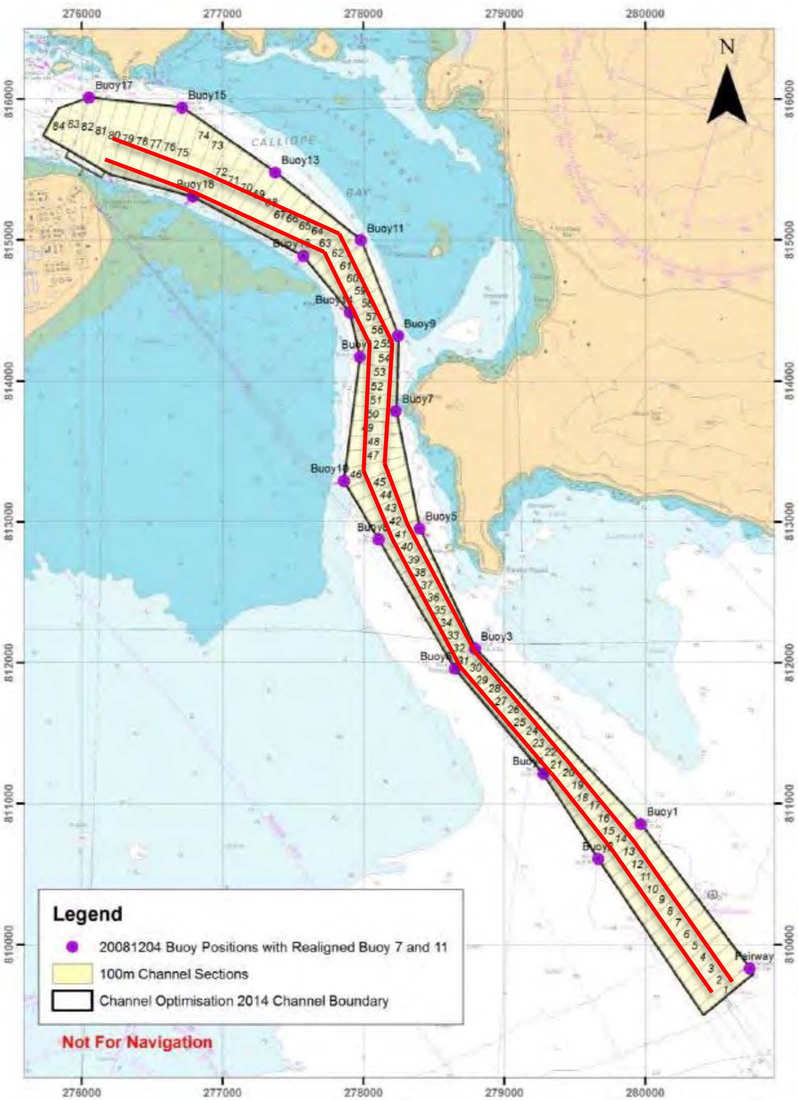
CHANNEL WIDTH ASSESSMENT



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COMPARATIVE ASSESSMENT

Location	LOA (m)	B (m)	DWT (tonnes)	Channel Width (m)	Factor
Gladstone	315	55	220,000+	180	3.3 B
Newcastle	300	50	-	175	3.5 B
Parker Point	-	55	350,000	170	3.1 B
Cape Lambert	-	55	323,000	210	3.8 B
Port Hedland	340	55	260,000	183-229	3.3-4.2 B
Albany (planned)	300	50	180,000	195-210	3.9-4.2 B

(Source: CMST, 2006)

CHANNEL WIDTH DESIGN STAGE

- Concept Design:
  - Empirical Methods used (e.g. PIANC)
  - Initial assessment for straight channel sections (this work)
  - Further consideration for channel bend allowances
- Detailed Design
  - Fast-time navigation simulation models
    - multiple runs and ship types used to identify critical cases for further assessment, suitable for feasibility stage studies, portable - can be done at client offices
  - Real-time navigation simulation models
    - Focus on critical and emergency cases, used for final design, fixed - must be done at specialist facility (e.g. AMC)
  - Physical model investigations
    - rarely used (for navigation assessments)

REFINING NZ
CHANNEL ALIGNMENT OPTIONS
April 2015

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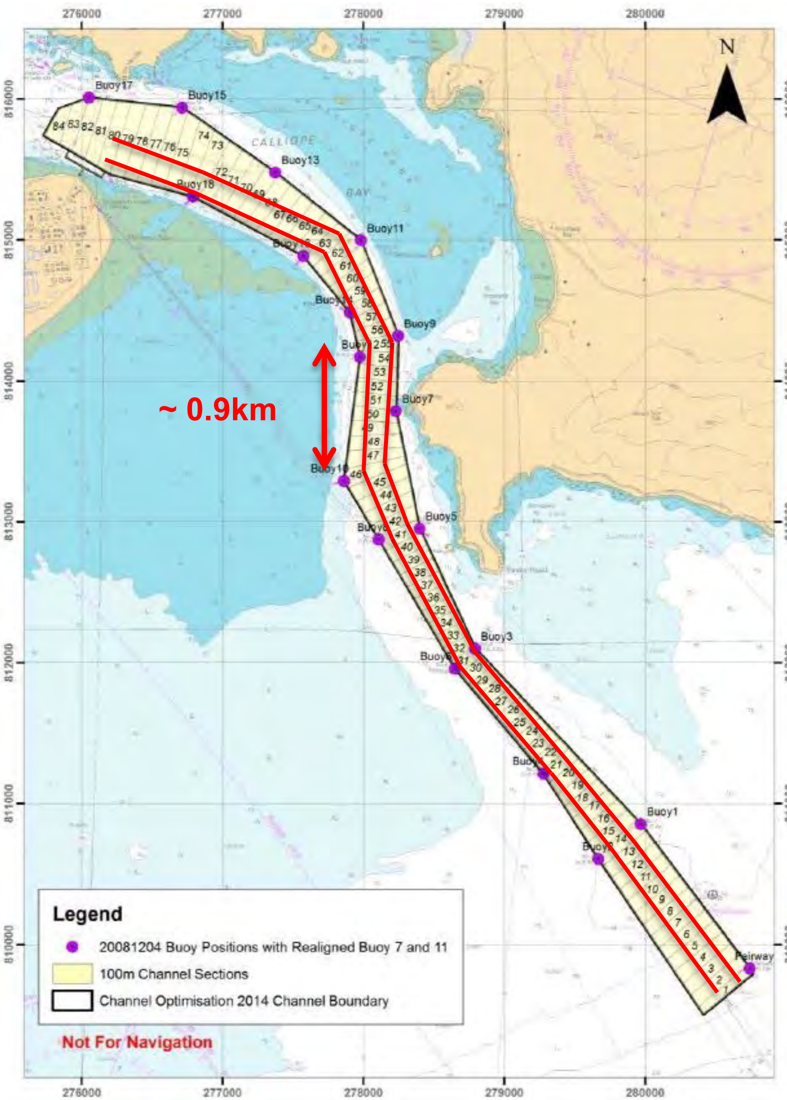
CURRENT ALIGNMENT (OPTION 1)



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PIANC (2014) RECOMMENDATION

- Between bends
  - Distance ≥ 5*L_{max}
  - L_{max} = 274m
  - Distance ≥ 1.37km

Straight channel sections are preferable to curved ones and the designer should strive for an alignment consisting of a series of straight sections connected by smooth bends, where necessary, without abrupt angles (see Figure 3.3). Individual sections may have different widths and depths and be navigated at different speeds.

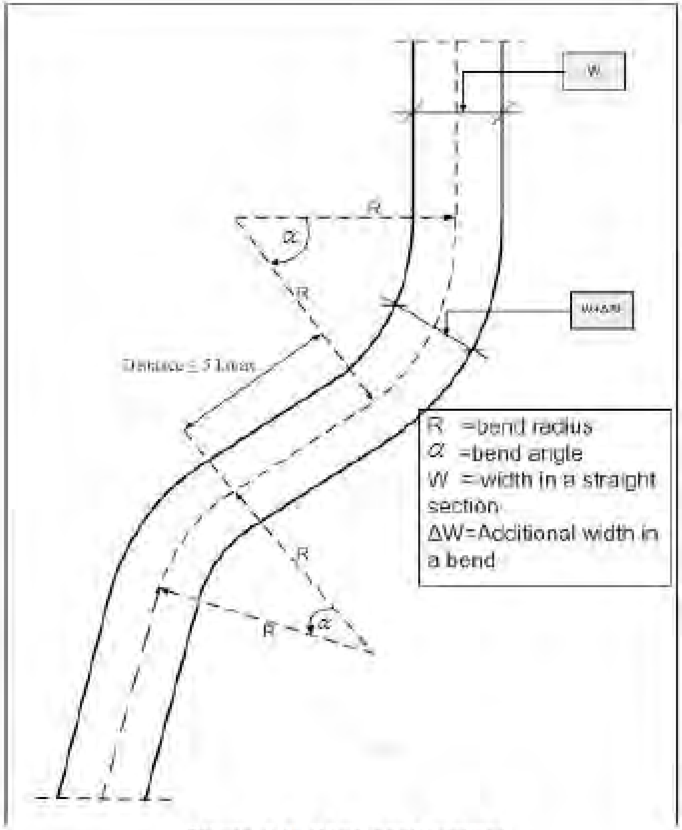

Figure 3.3: Bend configuration

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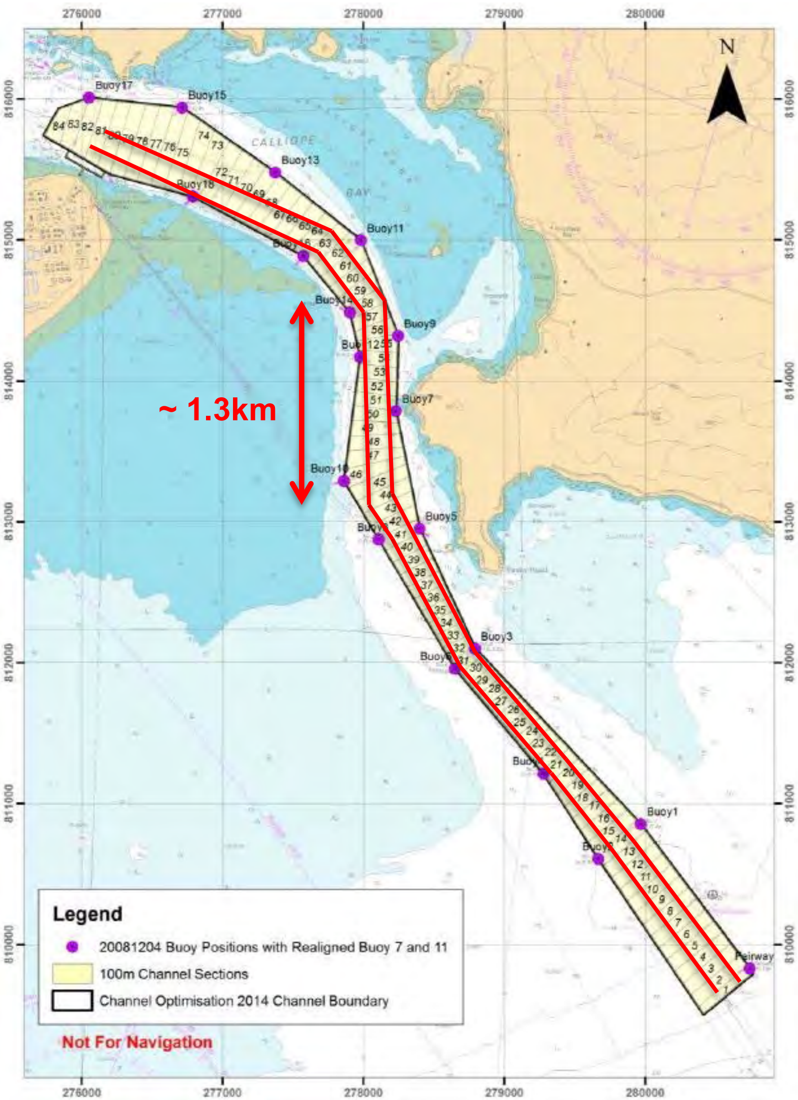
HP REALIGN – INSIDE F/WAY (OPTION 2)



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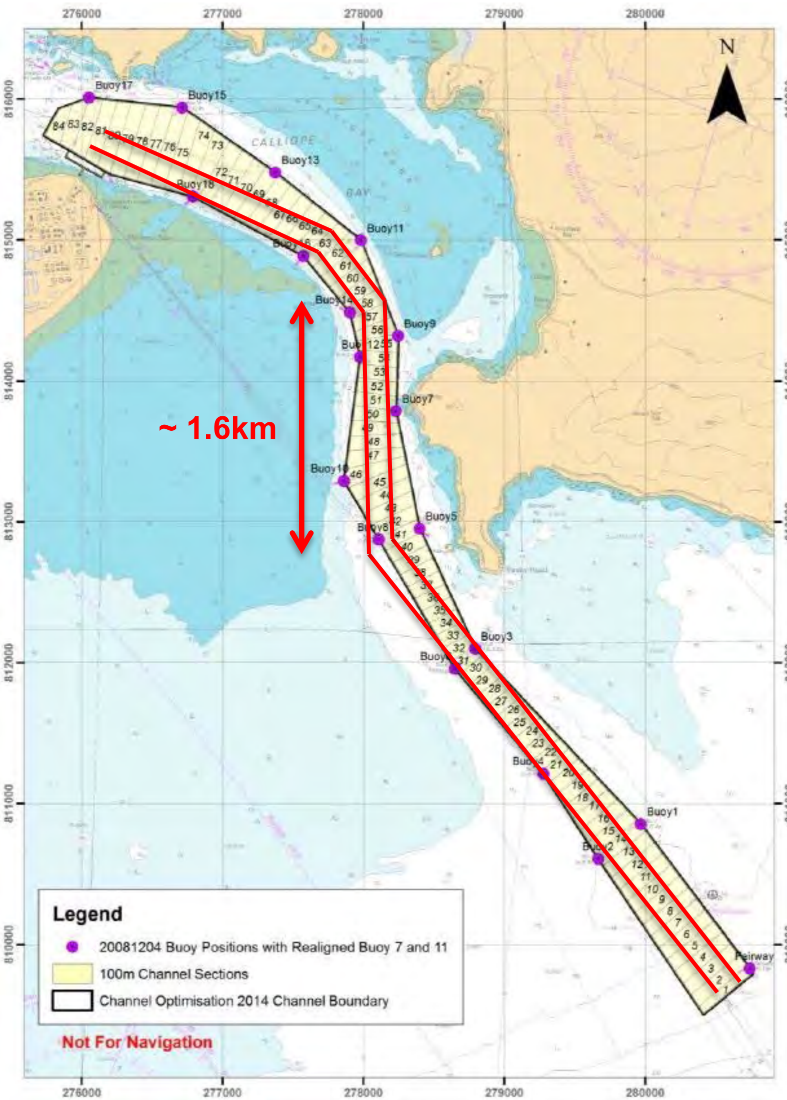
HP REALIGN – OUTSIDE F/WAY (OPTION 3)



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CONCLUSIONS

- Current straight section at Home Point is well under PIANC (2014) recommendations and would lead to difficult navigational conditions at a very critical location
- PIANC (2014) would recommend at least 1.3-1.4km between channel bends for proposed design ship
- Realignment within the existing fairway could achieve ~1.3km straight section (just under recommendation)
- Realignment just outside existing fairway could achieve ~1.7km (well above recommendation)
- Consider re-locating and re-assigning Buoy 7 as Cardinal Mark (marking hazard)

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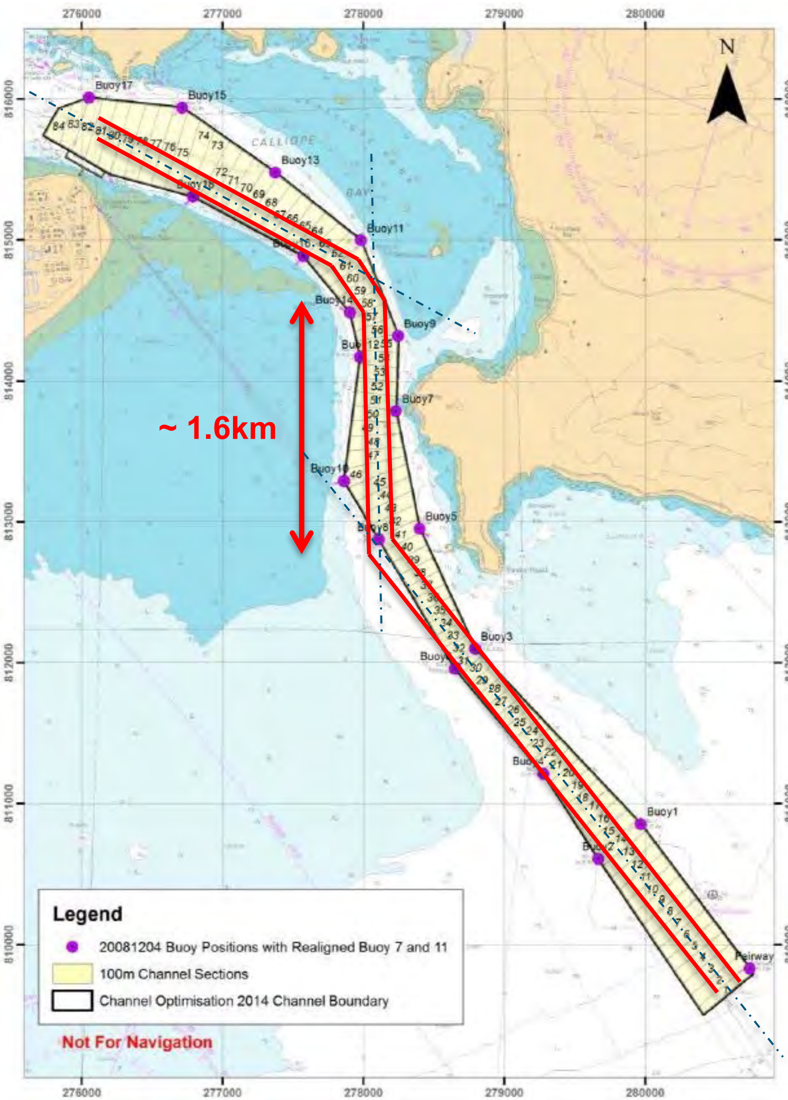
HP REALIGN – REMOVE KINKS (OPTION 4)



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ATTACHMENT C
Channel Design Workshop Minutes

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MARITIME & WATERWAYS

Minutes

Present	:	Dave Martin (**DM**) - Refining NZ Mike Swords (**MS**) - Refining NZ Jim Lyle (**JL**) – Harbourmaster Jon Moore (**JM**) – Northport Greg Blomfield (**GB**) – Northport Tom Greig (**TG**) – NorthTugz/pilots George Walkinshaw (**GW**) - NorthTugz/pilots Andrew Baker (**AB**) - NorthTugz/pilots Richard Mocke (**RM**) - RHDHV
Absent	:	
Date	:	17/04/15
Copy	:	All present, Chris Simmons (ChanceryGreen)
Our reference	:	Meeting Minutes_Refining NZ Channel Design Workshop_17Apr15_revC
Subject	**:**	Refining NZ - Channel Design Workshop

1 Introduction

The following minutes were recorded during Refining NZ's Channel Design Workshop held in association with representatives from Refining NZ, Whangarei Harbourmaster, Northport, NorthTugz/pilots and RHDHV on 17th April 2015 at Refining NZ boardroom, Marsden Point.

DM from Refining NZ (RNZ) commenced by providing a brief background to the project and work undertaken to date, specifically that completed by OMC considering 3 different design ship depths Following general introductions to all present, **DM** introduced **RM** from Royal HaskoningDHV (RHDHV) who has been appointed to assist RNZ in regards to the dredging, disposal and channel design aspects of the project.

RM provided a brief background of RHDHV's capabilities and previous project experience across Australasia and oversees on multiple port development/dredging/disposal/reclamation projects.

Issue History:

Issue	Status	Issued By	Issued To	Date
A	Draft – Issued for Client Review	RM	DM (Refining NZ)	26/04/15
B	Draft – Issued to NorthTugz pilots	RM	TG & GW (NorthTugz)	28/04/15
C	Updated Draft – Issued for Comment	RM	All workshop participants	29/04/15
0	Final Issue	RM	All workshop participants	08/05/15

RM also provided a handout of their specific channel design experience across a number of projects and the tasks that had been undertaken on those projects.

DM went on to invite those present to provide any specific comments in regards to navigational issues at the port, prior to getting into the channel design work in detail, to include any discussions around the following points:

- Approaches to Fairway Buoy and passage into (and/or out of) port facilities
- Any particular limiting conditions that exist (winds, waves, directions, etc)
- Both challenging and more straightforward sections of the channel
- Pinch points, geographical features controlling navigation (Home point, Muir bank, etc)
- Procedure for escort and turning of vessels
- Procedure for attaching and detaching tug lines
- Procedure for passing traffic

GW provided most of the feedback in this discussion, the main points being:

- The current tugs were capable of push/pull only and were not escort tugs and, therefore, would have some limited ability to control very large ships
- Transiting Fairway and Jetty approach were not a problem
- The critical section of the existing channel was from Buoy 3/6 through to Buoy 16. Navigating around Buoy 5 also provided a number of navigational challenges
- On a good ebb tide may have to add 4 to 5 degrees to course setting
- Generally run slow at shoal, speed up and then slow again at 3/6 buoy
- Typically, tugs will meet the ship at Buoy 4 (weather dependent)
- During departure, tugs will assist with swinging the ship off the berth and then run with the ship as far as Buoy 7
- No ship passing was undertaken for any vessels under pilotage operations (smaller vessels may pass in the channel)
- Limiting conditions from winds were in the order of 30 knots, above which transits were not undertaken, although wind gusts could get up after a go decision had been made
- Similarly with swell, conditions above Hs=2.5m, however normally the DUKC system would restrict transits anyway at and above this height

2 Preliminary channel design

RM proceeded to discuss the preliminary channel design that had been undertaken using the PIANC (2014) method:

- PIANC (2014) Harbour Approach Channels – Design Guidelines supersedes previous 1997 guideline document
- Compiled in close co-operation with IAPH (International Association of Ports & Harbours), IMPA (International Maritime Pilots Association) and IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities)
- Channel width assessment is based on determination of vessel beam (B) multiplier factors from consideration of a range of navigation, metocean and channel conditions
- Approach is suitable for concept design phase and is subject to refinement by fast-time and/or real-time ship manoeuvring simulation

RM presented wind data that had been provided by Metocean Solutions Ltd (MSL) who are providing metocean design services for the project. The data presented showed the prevailing wind directions from the W-SW which was questioned by **GW** who felt that the winds from the E were generally more prevalent. **RM** noted that the data appeared to show that whilst the winds from the W-SW were more persistent, it appeared that the winds from the E were generally stronger.

TG asked about the source of the data to which **RM** said that it appeared to be hindcast data. **DM** noted that wind data was collected at Marsden Point. **RM** said he did not know if this data was available and would follow up with MSL if it can be obtained.

[Action#1: **RM** to contact MSL to obtain measured wind data at Marsden Point]

RM then presented the current and wave data that had been provided by OMC. The current data (primarily due to tidal streams) along the channel appeared realistic (up to 2 knots) but **GW** suggested that it could be higher in places, including around Home Point. He also noted that there can be higher cross currents between Buoys 1/2 and 3/6 during ebb and flood stream tides than that which OMC had noted.

RM noted that increases in cross currents had a much greater impact on channel width requirements than a similar increase in longitudinal (or along channel) currents and that this would certainly be worth investigating further. There was a general discussion and it was noted that there did not seem to be any tidal stream current measurements or previous hydrodynamic/current modelling studies for the channel. **DM** noted that MSL would be looking into this further and that he would discuss options with MSL to obtain measured and modelled tidal stream current data, particularly over the section identified as presenting more challenging cross-current conditions.

[Action#2: **DM** to discuss with MSL to provide modelled and measured current data, particularly over the entrance area to improve confident in channel design outcomes]

The wave data presented appeared to be an accurate reflection of the maximum offshore wave conditions. **RM** explained that OMC had provided attenuation factors such that the inner channel wave heights were about 24% off the offshore wave heights. **TG** noted that there had been some issues with the DUKC allowing passage offshore but not inshore and he felt that the wave attenuation was greater than that assumed by OMC. **DM** noted that MSL will also be investigating this and the information could be passed onto OMC to update their DUKC system, once available.

[Action#3: **DM** to liaise with MSL and OMC in regards to providing a more accurate wave attenuation model outputs once this work had been complete]

RM then went on to discuss the method in which PIANC (2014) factors are calculated and also handed out a sheet describing how the factors were calculated based on factors including:

- Ship manoeuvrability
- Prevailing winds, waves and currents (longitudinal and cross currents)
- Vessel speed
- Nature of seabed and channel banks
- Navigation aids; and
- Waterway depth

RM noted that PIANC (2014) assumes that ships are manoeuvred under their own propulsion – i.e. without the assistance of tugs. The results indicated a recommended channel width of 4.0*B along the outer channel section and 3.9*B along the inner channel, where Buoy 3/6 marks the approximate division between the inner and outer channels.

RM also presented results from other ports (in Australia) that regularly handle similar sized vessels. These indicated some were operating as low as 3.1-3.5*B but he noted that was likely due to the pressure to handle larger ships into existing channels (which would probably require more towage capacity to handle these vessels). Channels being upgraded or for more recent port developments were more in the range of 3.9-4.2+*B, depending on the factors occurring at the site.

GW asked about vessels departing in ballast which were more subject to more significant windage and surface currents and, hence, more difficult to control. **RM** noted that it was possible (and recommended) to determine both laden and ballast cases but, in his experience the laden case tended to be the controlling factor for channel design. [Post meeting note: **RM** investigated why this had been the case on the projects he had undertaken and found that the ballast draft had been less than the natural seabed depth at the exposed locations where this had been the case, hence the channel was effectively unconfined – or partly confined with the ballast ship draft further up the dredge profile where it is wider].

3 Preliminary channel alignment

RM produced a plan showing the required dredge channel width within the existing channel and following the existing channel alignment. This included five changes in channel alignment. He then explained that PIANC (2014) also recommended a minimum length of channel between bends of 5*Lmax, which for the 274m design vessel would work out to be around 1.37km.

RM noted that through the critical Home Point stretch, the current channel was around 0.9km maximum – probably less once taking off the curved sections between this straight section. With such a distance, PIANC (2014) would note that it would be likely to experience significant navigational issues, which appears to be the case at this time.

RM then presented an alternative to straighten up the Home Point section within the existing channel/fairway which would bring this stretch up to around maximum 1.3km (Option 2) and another to move the channel outside of Buoy 8 which could achieve a straight section of up to 1.6km (Option 3).

TG and **GW** felt that this option (Option 3) would help to improve navigational conditions, however some improvements to the existing leads may be required. They also noted that in order to align the ships along the (narrower) channel, a bouy further out from the current Fairway Buoy may be required to ensure that any ships do not “cut corners”.

Some further discussion was held in regards to simplifying the channel around buoys 14-16 and, as a result, a further option (Option 4) was developed. This option was considered the preferred by the Harbourmaster and NorthTugz/pilots to take forward for further consideration.

4 Next Steps

RM noted that PIANC (2014) recommended the following steps in regards to channel design:

- Concept Design:
    - Empirical Methods used (e.g. PIANC)
    - Initial assessment for straight channel sections (this work, now completed)
    - Further consideration/allowances for channel bends, turning and berthing areas
- Detailed Design
    - Fast-time navigation simulation models (FTS)
        - multiple runs and ship types used to identify critical cases for further assessment, suitable for feasibility stage studies, portable - can be done at design or client offices
    - Real-time navigation simulation models (RTS)
        - Focus on critical and emergency cases, used for final design, fixed - must be done at specialist facility (e.g. AMC)
    - Physical model investigations
        - rarely used (for navigation assessments)

DM said he was conscious that **JL** would be away for some time and that they would like to be able to progress with the design work in his absence but not without his approval. **DM** asked if it would be possible to, say, complete the concept design and (if undertaken) the FTS as the timing of that work is likely to be during his absence. A report would be prepared on completion of this work.

JL said he would be comfortable with that arrangement as he realised he was going to be away for some time and agreed that the project needs to progress. He said that RNZ should work closely with the pilots to develop the channel design. **DM** confirmed this would be the case and, also, any finalisation of the design would also only take place with RTS which would only occur after the Harbourmaster had returned from leave. It was all agreed that this seemed the best approach to keep the project progressing.

[Action#4: **DM** to liaise with pilots to develop channel design and then provide report to Harbourmaster on outcomes for his review and prior to final design]

5 Dredging and Disposal

JM asked about the proposed dredging and disposal options that RNZ were considering. **DM** explained that they had advice from their environmental experts in regards to offshore disposal options and that three sites were under consideration: one in Bream Bay close to the dredging; and a further two in deeper water offshore. Sampling and modelling would be undertaken to assess the site. **DM** noted that RNZ also aware of Northport's desire for an onshore option, although would likely incur additional costs. He also explained that RNZ would still pursue offshore disposal options in the event that landside disposal alone was not of a sufficient quantity, not possible/achievable in the timeframe available and/or unsuitable material was encountered.

JM noted that they were concerned about any dredge spoil making its way back into the channel over time and also that they had a preference to be able to use it for their own facility as they had consent to expand but no sand available to do so. **RM** asked about the volume of sand they could accommodate. **GB** said that they could probably take a smaller volume right now (say 100-200,000m^3) at the existing area but, with a bund around the expansion area, probably accommodate around 1Mm^3. **JM** suggested that Northport may be in a position to financially contribute to the project to obtain this sand and suggested future commercial discussions were needed to be held at an appropriate time.

JM also noted that the current shoal patch appeared very stable and suggested that the modelling should be able to show why this is so and any impact due to dredging and disposal.

[Action#5: **DM** to liaise with **JM/GB** in regards to the option to use dredge material for Northport reclamation]

GB noted that their surveyors had suggested that a few of the high spots in the outer channel could be due to the existence of harder material. **DM** said that they would investigate this further with their geomorphology experts.

[Action#6: **DM** to discuss the possible existence of harder materials along the outer channel with RNZ geomorphology experts]

After some further general discussions, the meeting concluded

6 Follow up Actions

No	Who	What	When
1	RM	Contact MSL to obtain measured wind data at Marsden Point	ASAP
2	DM	Discuss with MSL to provide modelled and measured current data, particularly over the entrance area to improve confident in channel design outcomes	ASAP
3	DM	Liaise with MSL and OMC in regards to providing a more accurate wave attenuation model outputs once this work had been complete	On completion of wave modelling
4	DM	Liaise with pilots to develop channel design and then provide report to Harbourmaster on outcomes for his review and prior to final design	During concept/initial detailed design
5	DM	Liaise with Northport in regards to the option to use dredge material for their reclamation areas	During concept/initial detailed design
6	DM	Discuss the possible existence of harder materials along the outer channel with RNZ geomorphology experts	ASAP

APPENDIX B: PIANC Channel Design Calculations

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 2 CHANNEL DESIGN
REACH 1: Fairway Buoy to Buoy 1/2

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-18.19	m CD	95% Access, minimum channel design level in Reach 1	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	6.8	knots	"average" speed profile, varies from 6kts at Fairway Buoy to 6.8kts at Buoy 1/2	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.3	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	0.4	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	2.4	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	20.51	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.21	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.5	1m<Hs<3m	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.2	1.15T<=h<1.5T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.3	B
Total Channel Width [Outer Channel]	**206**	**m**
Total Channel Width [Inner Channel]	4.3	B
Total Channel Width [Inner Channel]	**206**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 2 CHANNEL DESIGN
REACH 2: Buoy 1/2 to Buoy 3/6

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-17.65	m CD	95% Access, minimum channel design level in Reach 2	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.5	knots	"average" speed profile, varies from 6.8kts at Buoy 1/2 to 7.5kts at Buoy 3/6	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.3	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	0.4	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	1.9	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.97	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.17	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.5	1m<Hs<3m	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.2	1.15T<=h<1.5T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.3	B
Total Channel Width [Outer Channel]	**206**	**m**
Total Channel Width [Inner Channel]	4.3	B
Total Channel Width [Inner Channel]	**206**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 2 CHANNEL DESIGN
REACH 3: Buoy 3/6 to Buoy 7

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.87	m CD	95% Access, minimum channel design level in Reach 3	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.5	knots	"average" speed profile, varies from 7.5kts at Buoy 3/6 to 7.3kts at Buoy 7	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.3	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.3	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.9	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.19	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.13	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	3.8	B
Total Channel Width [Outer Channel]	**182**	**m**
Total Channel Width [Inner Channel]	4.0	B
Total Channel Width [Inner Channel]	**192**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 2 CHANNEL DESIGN
REACH 4: Buoy 7 to Buoy 14

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.86	m CD	95% Access, minimum channel design level in Reach 4	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.3	knots	"average" speed profile, varies from 7.3kts at Buoy 7 to 6.8kts at Buoy 14	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.5	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.5	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.18	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.13	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.0	B
Total Channel Width [Outer Channel]	**192**	**m**
Total Channel Width [Inner Channel]	4.2	B
Total Channel Width [Inner Channel]	**202**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 2 CHANNEL DESIGN
REACH 5: Buoy 14 to Buoy 16

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.69	m CD	95% Access, minimum channel design level in Reach 5	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	6.8	knots	"average" speed profile, varies from 6.8kts at Buoy 14 to 5.8kts at Buoy 16	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.7	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.5	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.01	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.12	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	1.0	Moderate	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.8	Moderate	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.7	B
Total Channel Width [Outer Channel]	**226**	**m**
Total Channel Width [Inner Channel]	4.7	B
Total Channel Width [Inner Channel]	**226**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 2 CHANNEL DESIGN
REACH 6: Buoy 16 to Buoy 17

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.31	m CD	95% Access, minimum channel design level in Reach 6	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	5.8	knots	"average" speed profile, varies from 5.8kts at Buoy 16 to 2kts at Buoy 17	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.7	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.5	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	18.63	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.09	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	1.0	Moderate	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.8	Moderate	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.7	B
Total Channel Width [Outer Channel]	**226**	**m**
Total Channel Width [Inner Channel]	4.7	B
Total Channel Width [Inner Channel]	**226**	**m**

BEND GEOMETRY

OPTION 2 CHANNEL DESIGN

Bend No.	Entry Channel Heading	Exit Channel Heading	Vessel Beam	Vessel LOA	Bend Radius*	Entry Channel Width	Draft Angle Width^	Response Time Width"	Bend Width	Exit Channel Width
	(deg. from North)	(deg. from North)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	321	345	48	274	1370	210	12.2	19.2	240	190
2	345	9	48	274	1370	190	12.2	19.2	230	200
3	9	301	48	274	800	200	20.9	19.2	270	230

* 5 x LOA recommended, Table 3.8 PIANC 2014

^ Eqn. 3-5 PIANC 2014

" Eqn. 3-6 PIANC 2014

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 4 CHANNEL DESIGN
REACH 1: Fairway Buoy to Buoy 1/2

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-18.19	m CD	95% Access, minimum channel design level in Reach 1	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	6.8	knots	"average" speed profile, varies from 6kts at Fairway Buoy to 6.8kts at Buoy 1/2	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.3	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	0.4	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	2.4	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	20.51	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.21	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.5	1m<Hs<3m	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.2	1.15T<=h<1.5T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.3	B
Total Channel Width [Outer Channel]	**206**	**m**
Total Channel Width [Inner Channel]	4.3	B
Total Channel Width [Inner Channel]	**206**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 4 CHANNEL DESIGN
REACH 2: Buoy 1/2 to Buoy 3/6

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-17.65	m CD	95% Access, minimum channel design level in Reach 2	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.5	knots	"average" speed profile, varies from 6.8kts at Buoy 1/2 to 7.5kts at Buoy 3/6	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.3	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	0.4	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	1.9	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.97	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.17	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.5	1m<Hs<3m	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.2	1.15T<=h<1.5T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.3	B
Total Channel Width [Outer Channel]	**206**	**m**
Total Channel Width [Inner Channel]	4.3	B
Total Channel Width [Inner Channel]	**206**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 4 CHANNEL DESIGN
REACH 3: Buoy 3/6 to Buoy 7

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.87	m CD	95% Access, minimum channel design level in Reach 3	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Outer Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.5	knots	"average" speed profile, varies from 7.5kts at Buoy 3/6 to 7.3kts at Buoy 7	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.7	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.3	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.9	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.19	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.13	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	1.0	Moderate	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.8	Moderate	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.0	Low	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.5	B
Total Channel Width [Outer Channel]	**216**	**m**
Total Channel Width [Inner Channel]	4.5	B
Total Channel Width [Inner Channel]	**216**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 4 CHANNEL DESIGN
REACH 4: Buoy 7 to Buoy 14

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.86	m CD	95% Access, minimum channel design level in Reach 4	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	7.3	knots	"average" speed profile, varies from 7.3kts at Buoy 7 to 6.8kts at Buoy 14	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.3	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.5	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.18	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.13	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.3	Low	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.0	B
Total Channel Width [Outer Channel]	**192**	**m**
Total Channel Width [Inner Channel]	4.2	B
Total Channel Width [Inner Channel]	**202**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 4 CHANNEL DESIGN
REACH 5: Buoy 14 to Buoy 16

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.69	m CD	95% Access, minimum channel design level in Reach 5	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	6.8	knots	"average" speed profile, varies from 6.8kts at Buoy 14 to 5.8kts at Buoy 16	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.7	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.5	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	19.01	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.12	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	1.0	Moderate	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.8	Moderate	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.7	B
Total Channel Width [Outer Channel]	**226**	**m**
Total Channel Width [Inner Channel]	4.7	B
Total Channel Width [Inner Channel]	**226**	**m**

PIANC (2014) CHANNEL WIDTH ASSESSMENT
OPTION 4 CHANNEL DESIGN
REACH 6: Buoy 16 to Buoy 17

INPUT DATA

Parameter	Value	Unit	Comment	Source
Vessel Type	Tanker	n/a		
Vessel Size Class	Suezmax	n/a		OMC, 2015
Vessel Dead Weight Tonnage (DWT)	159,057	tonnes		OMC, 2015
Vessel Beam (B)	48	m		OMC, 2015
Vessel Length Overall (LOA)	274	m		OMC, 2015
Vessel Length Between Perpendiculars (LBP)	264	m		OMC, 2015
Vessel Draft (T)	17.02	m	summer draft	OMC, 2015
Channel Design Level	-16.31	m CD	95% Access, minimum channel design level in Reach 6	OMC, 2015
Mean High Water Neap (MHWN) tide level	2.32	m CD		Tonkin & Taylor, 2015
Channel Type	Inner Channel	n/a	"Outer Channel" = open water, "Inner Channel" = protected water	PIANC, 2014
Passing	One-way	n/a	"Two-way" or One-way"	
Vessel Manoeuvrability	Poor	n/a	"Poor" = tankers/bulk carriers	PIANC, 2014
			"Moderate" = container vessels/car carriers/RoRo vessels/LNG&LPG vessels	PIANC, 2014
			"Good" = twin propeller ships/ferries/cruise vessels	PIANC, 2014
(a) Vessel Speed (V_s)	5.8	knots	"average" speed profile, varies from 5.8kts at Buoy 16 to 2kts at Buoy 17	OMC, 2015
(b) Prevailing cross wind (V_{cw})	20	knots	"Mild" V_{cw}<15 knots, "Moderate" 15 knots <=V_{cw}<33 knots, "Strong" V_{cw}>33 knots	Marsden Point, 5% annual exceedance wind speed 10m/s, MetOcean Solutions measured data
(c) Prevailing cross current (V_{cc})	0.7	knots	"Negligible" V_{cc}<0.2 knots, "Low" 0.2 knots<=V_{cc}<0.5 knots, "Moderate" 0.5 knots<=V_{cc}<1.5 knots, "Strong" V_{cc}>=1.5 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(d) Prevailing longitudinal current (V_{lc})	1.5	knots	"Low" V_{lc}<1.5 knots, "Moderate" 1.5 knots<=V_{lc}<3 knots, "Strong" V_{lc}>=3 knots	Max. ebb or flood current velocity +/-1hr from HW, Auckland Ports ADCP Data 2015
(e) Beam and stern quartering wave height (H_s)	0.6	m	"Hs<=1m", "1m<Hs<3m", "Hs>=3m"	OMC, 2015 99th percentile swell data
(f) Aids to Navigation	Good	n/a	"Excellent" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots, DGPS and Electronic Chart Display and Information System (ECDIS)	PIANC, 2014
			"Good" = paired lighted buoys with radar deflectors/lighted leading lines with availability of Pilots and DGPS	PIANC, 2014
			"Moderate" = anything less than the facilities mentioned above	PIANC, 2014
(g) Bottom Surface	smooth and soft	n/a	"smooth and soft" or "rough and hard"	PIANC, 2014
(h) Depth of waterway (h)	18.63	m	at Mean High Water Neap tide (MHWN)	
Depth to Draft Ratio (h/T)	1.09	n/a		
Channel slope	sloping channel edges and shoals	n/a	"gentle underwater channel slope (1:10 or less steep)" or "sloping channel edges and shoals" or "steep and hard embankments, structures"	PIANC, 2014

CHANNEL WIDTH CALCULATION

Parameter	Beam (B) Multiplier	Category	Comment	Source
Basic Manoeuvring Lane (W_{BM})	1.8	Poor	"Good" = 1.3B, "Moderate" = 1.5B, "Poor" = 1.8B (Table 3.4)	PIANC, 2014
(a) Vessel Speed (V_s)	0.0	Slow	"Fast" V_s>12 = 0.1B, "Moderate" 8<V_s<12 = 0.0B, "Slow" 5<V_s<8 = 0.0B (Table 3.5(a))	PIANC, 2014
(b) Prevailing cross wind (V_{cw})	0.6	Moderate	See Table 3.5(b)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Outer Channel]	1.0	Moderate	See Table 3.5(c)	PIANC, 2014
(c) Prevailing cross current (V_{cc}) [Inner Channel]	0.8	Moderate	See Table 3.5(c)	PIANC, 2014
(d) Prevailing longitudinal current (V_{lc})	0.2	Moderate	See Table 3.5(d)	PIANC, 2014
(e) Beam and stern quartering wave height (H_s)	0.0	Hs<=1	Hs<=1m = 0.0B, 1m<Hs<3m = 0.5B, Hs>=3m = 1.0B (Table 3.5(e))	PIANC, 2014
(f) Aids to Navigation	0.2	Good	See Table 3.5(f)	PIANC, 2014
(g) Bottom Surface	0.1	h<1.5T	See Table 3.5(g)	PIANC, 2014
(h) Depth of waterway (h) [Outer Channel]	0.2	h<1.25T	See Table 3.5(h)	PIANC, 2014
(h) Depth of waterway (h) [Inner Channel]	0.4	h<1.15T	See Table 3.5(h)	PIANC, 2014
Width for Bank Clearance (W_B)	0.3	sloping channel edges and shoals	See Table 3.6	PIANC, 2014
Additional Width for Channel Passing (W_p)	0.0	Not Required	See Table 3.7	PIANC, 2014

Total Channel Width [Outer Channel]	4.7	B
Total Channel Width [Outer Channel]	**226**	**m**
Total Channel Width [Inner Channel]	4.7	B
Total Channel Width [Inner Channel]	**226**	**m**

BEND GEOMETRY

OPTION 4 CHANNEL DESIGN

Bend No.	Entry Channel Heading	Exit Channel Heading	Vessel Beam	Vessel LOA	Bend Radius*	Entry Channel Width	Draft Angle Width^	Response Time Width"	Bend Width	Exit Channel Width
	(deg. from North)	(deg. from North)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	321	6	48	274	1370	210	12.2	19.2	250	220
2	0	301	48	274	530	200	31.5	19.2	280	230

* 5 x LOA recommended, Table 3.8 PIANC 2014

^ Eqn. 3-5 PIANC 2014

" Eqn. 3-6 PIANC 2014

APPENDIX C: Desktop (Portable) Simulation Study Report

RNZ DESKTOP SIMULATION STUDY
Report prepared for Royal HaskoningDHV for Chancery Green on behalf of Refining New Zealand Limited

Revision 3.0
12 August 2016

Prepared by: be software

Executive Summary

This desktop simulation study was undertaken from 27 to 31 July 2015 and from 29 to 30 September in support of the proposed approach channel realignment and deepening to accept 16.8 metre draft vessels on arrival at Marsden Point for Refining New Zealand Limited (RNZ).

The study looked at the feasibility of four different channel designs (denoted Option 2, Option 4, Option 4-2 and Option 5) for a number of typical vessels that currently utilise the port, in addition to the design ship, being a Suezmax Class Oil Tanker having a length overall (LOA) of 274m, beam of 48m and draft of 16.8 m.

The study found that:

- All channel designs were feasible with operational limitations up to a 30 knot wind and slack tide high water arrival of the design ship, following current operational procedures for the port.
- The Option 4 channel designs are preferred by the pilots as they provide a simpler approach through the critical turn area in the vicinity of buoy 14. This allows the pilots to execute a constant radius turn which is easily monitored. It also provides more sea room for all departing vessels to clear the rocky outcrop at Home Point safely, particularly during ebb tides and strong offshore winds. Simulated scenarios outside current operational procedures were carried out by the pilots in full spring flood and ebb tides with the design ship in ballast to look at all possible worse case scenarios. Following a historical near grounding involving a larger vessel, operational parameters are currently in place to ensure Suezmax size vessels are not sailed on ebb tides. The pilots wished to test the design ship in ballast on full ebb tides to fully test the channel designs under the widest possible parameters. Of the two designs, the Option 4-2 was considered the optimum as it allows the most sea room for the arriving vessel and has a larger radius of turn in the channel alignment for both arrival and departure vessels. Greater sea room and improved bend radius significantly improves existing channel safety margins especially under adverse weather conditions.
- Minimal realignment of existing navigational buoys is necessary with all channel designs.
- An improvement in the existing leading sector light and buoy lights will be necessary to properly indicate navigable water in the approach channel from the fairway buoy to buoys 3/6.
- Existing tugs are capable of handling the design ship under normal operational conditions.
- Existing operational tug procedures for departing vessels need to be reinforced for all channel designs.
- Existing tugs under the simulated emergency scenarios in this study raise some potential issues which may require further investigation /analysis as part of separate risk /safety review.
- The proposed channel design alignments will potentially assist in an emergency scenario by providing more searoom.

Table of Contents

1 INTRODUCTION

This simulation study was conducted at Marsden Point in the offices of NorthTugz at Marsden Point from 27 to 31 July 2015. A second round of simulation was conducted in Melbourne in the office of Be-Software from 29 to 30 September 2015.

The study is required for the proposed expansion of the port to receive deeper draft Suezmax Oil Tankers, to 16.8 metres draft. The proposed expansion will involve dredging and buoyage realignment in the approach channel to Northport and the oil berths at the RNZ Marsden Point facility. The design ship for this study is a Suezmax Oil Tanker with an LOA of 274m and a beam of 48m and a draft of 16.8m, noting that this class of ship periodically visits Marsden Point but is part loaded with a maximum 14.7m draft.

The first three days of the simulation study were used to validate two different channel designs (denoted as Option 2 and Option 4) and the next two days were used to investigate berthing and tug utilisations and emergency response measures in the new channel designs.

In the second round of simulation, 29 to 30 September, two additional channels designs (Option 4-2 and Option 5) were validated. Additional berthing simulation was done to investigate a new berth pocket and further emergency response measures were tested in the two new additional channel designs.

The Option 2 channel alignment closely matched the current channel alignment to Marsden Point, keeping within the existing navigation buoys, except at buoy No 11 which was slightly relocated to accommodate the recommended channel design guidelines.

The Option 4 channel alignment also matched, in general, the current alignment except with the purpose of reducing the number of alignments and bends, again in order to meet preferred design standards. This required the relocation of the existing No 8, No 12 and No 11 buoys.

The Option 4-2 channel alignment is similar to Option 4 but takes advantage of some deeper water on the inside of Buoy No 14 and also the possibility to move the N-S channel alignment slightly to the east so as the eastern edge of the dredge channel coincided with Buoy No 7. By making these amendments, a Radius=800m bend around the (now relocated) No 14 buoy is possible. This is a significant improvement in the radius of bend available in Option 4 (Radius=580m). This alignment also eliminates the need for any dredging along the edge of the bank between Buoy 16 and 18. To achieve the Option 4-2 alignment required the relocation of the existing No 3, No 8, No18, No 14, No 12 and No 11 buoys.

The Option 5 channel alignment involved a movement of the N-S channel alignment further to the east. This will require dredging in the vicinity of Home Point. It is designed to eliminate all dredging adjacent on the western side of the channel at the expense of dredging on the eastern side at Home Point. This required the relocation of the existing No 7 and No 12 buoys.

2 AIMS OF THE STUDY

The desktop simulation study aimed to:

- Investigate the implications for navigation safety and changes to buoyage necessary for the arrival of a Suezmax class vessel of draft 16.8 metres utilising all channel designs Option 2, Option 4, Option 4-2 or Option 5 in the proposed realignment and deepening of the approach channel to RNZ Marsden Point Crude Oil Berth.

- Confirm that other current shipping to Refining NZ and Northport facilities would be able to continue to safely navigate the channel design options.

3 STUDY PARTICIPANTS

Royal HaskoningDHV:
Matt Potter

Refining New Zealand RNZ:
Dave Martin (Business Opportunities Manager)

NorthTugz Pilots:
George Walkinshaw
Kirit Barot
Hugh Pevy
Tom Greig
Andrew Baker

Harbourmaster:
Jim Lyle

NorthTugz Tugmaster:
Simon Noakes

Be Software:
Bruce Goodchild

In addition, other representatives from RNZ, Northport, NorthTugz, COLL and BP together with the Deputy Harbourmaster also attended some of the simulation.

In Melbourne, the simulation was run by Bruce Goodchild with linkage via the internet to the other participants in particular Kirit Barot and Richard Mocke.

4 SIMULATOR OVERVIEW

Be-Software provided portable simulation equipment to undertake this study at the NorthTugz offices at Marsden Point. It also provided the simulation equipment via internet from its' Melbourne office.

The desktop simulation incorporated an instrument console and vision display covering 200 degrees of horizontal field of view displayed on 36" TV monitors. Vision could also be aligned via a camera control which allowed the pilot to move position to any location on the bridge or wing of the ship.

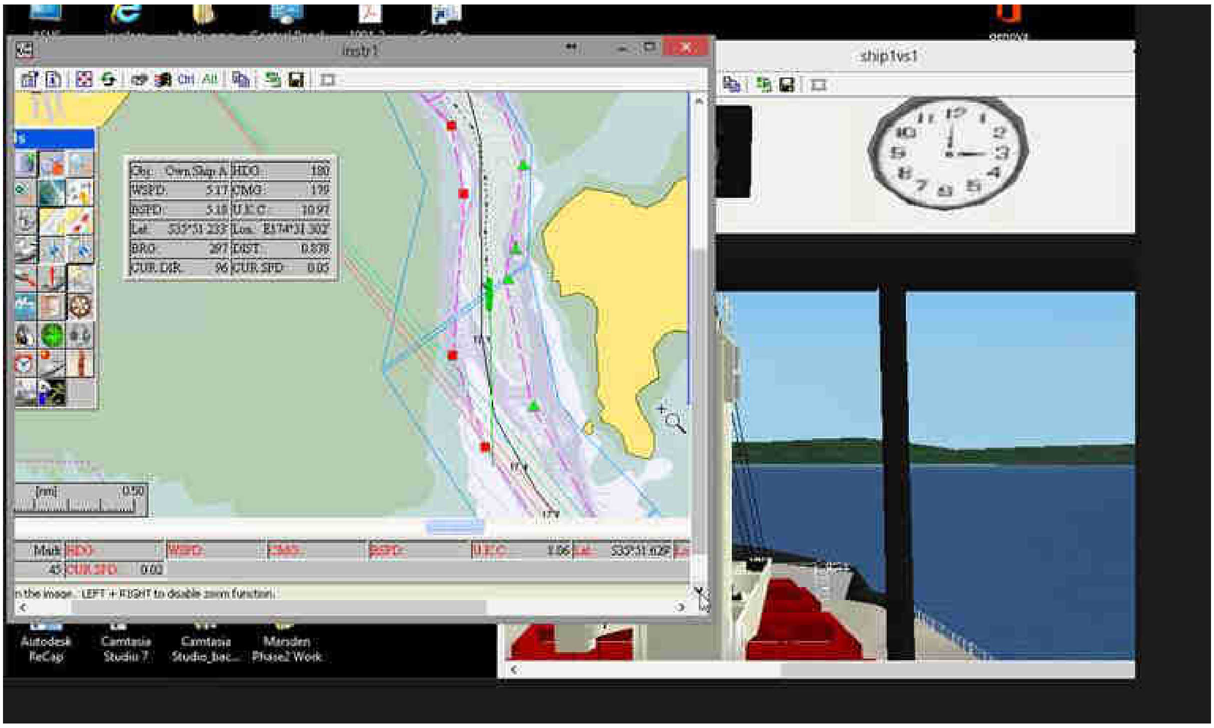
The instrument console incorporated ARPA radar and manoeuvring displays showing speeds, engine RPM, rudder angle and rate of turn. Real instrumentation was provided for the steering and telegraph units.

An instructor display was positioned alongside the instrument console and vision display to allow one or two man operation of the system. The instructor station doubled as the electronic chart system which showed the different channel options and associated bathymetry, topography and wharf structures. A remote instructor station was used for recording of simulation runs and editing of hydrodynamic, visual and environmental models. The system was operated in real time and accelerated mode (i.e. 2 times real time)

The software used for the project was a Lanterna Ship handling System which was specifically developed for research studies and pilot training. Details on the Be software package are available on the website www.be-software.net.

NorthTugz Pilots attending the Desktop Simulation in New Zealand

Captain Kirit Barot MV Asia Pearl 2nd August 2015



Simulation View via Internet from Melbourne

5 AREA MODEL AND CHANNEL DESIGNS

A basic Marsden Point area model was developed to provide a visual scene and incorporate the new channel designs. The new channel designs were titled Option 2, Option 4, Option 4-2 and Option 5.

From the base Marsden model, new area models were constructed for the simulation as follows:

MODEL ID	DESCRIPTION	CHANNEL ID
Marsden	Existing Approach Channel	Existing
Marsden2	Option 2 alignment within existing buoyage	Option 2
Marsden4	Option 4 optimum alignment	Option 4
Marsden4a	Revised Option 4 optimum alignment	Option 4.2
Marsden5	Option 5 alignment (shifted east)	Option 5

Throughout the Report, for ease of reference, each channel design will be identified by the names in the third column (i.e. Channel ID).

6 ENVIRONMENTAL DATA

Environmental data inputs for the simulation were provided through Royal HaskoningDHV.

6.1 Tidal Streams

Tidal stream patterns were based on Acoustic Doppler Current Profiler (ADCP) current measurements.

Tidal streams were modelled on the basis of a 25 metre grid spacing with an updated tidal vector provided for every 15 minutes. The simulator was able to interpret the tidal stream at six minutes intervals over the operational area from the Fairway buoy to the Crude Berth. Tidal stream data was identical through the five channel designs - Existing, Option 2, Option 4, Option 4-2 and Option 5.

6.2 Wave Models

Wave data was obtained from the underkeel clearance modelling previously undertaken by OMC International (2015) and comprised wave percentile data from the Alpha waverider buoy and estimated wave attenuation factors at different points along the approach channel alignment.

Each simulation was carried out in a multiple wave environment. Swell waves varied from 2.0 m Hs with a 22 second period to 1.0 m Hs with a 13 second period at the wave rider buoy. Wave direction was uniformly at a bearing of 090 (i.e. East). Swell height varied within the model area based upon OMC wave attenuation data. Swell waves progressively diminished into the inner harbour as per the OMC model to a minimum of 0.24 of the value at the wave rider buoy.

In addition, for each wind condition a wind wave of height 0.3m to 0.5 m with a period of 6 to 7 seconds was used. The direction and height of wave depended on wind force and direction.

6.3 Wind Forces

Winds were stipulated as steady or gusting for each simulated run. Wind speeds varied from 15 to 30 knots. Gusts varied in intensity by 20% with a 20 degree spread in direction. Wind shadow effects were incorporated where appropriate. Wind shadowing dropped the wind speed by 20%. For example, a wind speed of 25 knots was decreased to 20 knots in a shadow area behind Home Point, as was defined by the pilots.

7 SHIP MODELS

The design vessel for this study was a Suezmax Oil Tanker with a LOA of 274m, a beam of 48m and a draft of 16.8m which was represented in the simulation by the Samsung158 which had a LOA of 274 m, a beam of 45.1m and a draft of 17m.

Samsung158 was provided at three draft conditions:

ID	SHIP	CONDITION	DRAFT FORWARD	DRAFT AFT
SML	Samsung158	Loaded	17.0m	17.0m
SMP	Samsung158	Part- loaded	14.5m	14.5m
SMB	Samsung158	In - ballast	7.0m	7.5m

At Marsden Point, Suezmax Tankers of these dimensions are currently handled in both the ballast and part loaded conditions. The loaded Suezmax to 17 metres has not been handled to date due to insufficient water in the existing channel at some locations. The full loaded vessel is more difficult to handle in strong tidal streams due to its deeper draft. It also has a larger turning diameter and is more prone to overshooting a turn due to the larger displacement in comparison to the partly loaded ship. At the present time, the Suezmax vessels in ballast condition are restricted to flood tide only and the part loaded conditions are only handled at slack water when tidal streams are at their lowest velocity.

It should be noted that all references to load conditions refer to the ship model used in the simulation, not the actual design vessel which has a slightly larger beam and less draft.

A log vessel was represented by the handy max bulk carrier, the Gundulic with an LOA of 189m, a beam of 31m, which was provided in one loaded draft condition:

ID	SHIP	CONDITION	DRAFT FORWARD	DRAFT AFT
GL	Gundulic	Loaded	11.9m	12.0m

Tugs used in the simulation exercises were based on data sheets available on the Northport's website. Two tugs were nominated for use and are summarised below:

ID	SHIP	BOLLARD PULL	TYPE	SKEG	ESCORT Designated
BB	Bream Bay	70	ASD	Docking with extended closed forward skeg [1]	No
T	Takahiwai	50	ASD	No	No

Reference:

1. *Tug Use in Port A Practical Guide Henk Hensen Second Edition pp169-172 Section 10.1.3*

An Aframax class oil tanker based on the vessel Seamaster was available for simulation. However this vessel was not used as the Suezmax vessel was considered a better test platform for the channels options as they are larger, heavier and deeper vessels. The Aframax vessel LOA 243m Beam 43m was provided at two draft conditions:

ID	SHIP	CONDITION	DRAFT FORWARD	DRAFT AFT
AML	Seamaster	Loaded	14.5m	14.5m
AMB	Seamaster	In ballast	8.0m	9.0m

Details of ship models used are contained in the pilot cards of the vessels provided in **Appendix 1.**

8 SIMULATION RUNS SUMMARY

This section provides a summary of the simulation runs, organised according to day. Further details on simulation runs and debriefing run notes are provided in **Appendix 4**. Run plots are provided later in the report (see **Appendix 5**).

8.1 Day One

Runs 1 to 3 were arrival and departure exercises using the existing channel with the Suezmax in part loaded and ballast condition (i.e. SMP and SMB). The objective of these runs was to prove the validity of the ship models as both conditions of this vessel are handled currently. The SMP was considered by the pilots, an accurate representation of that class of vessel in part loaded condition. The SMB was considered accurate by one of the pilots, however another expected to see a greater angle of drift when passing the vicinity of buoy 7 on departures. This was analysed with reference to the provided tidal stream data and ship model data and the comment noted. No changes were made to the simulation and subsequent runs and information provided by other pilots indicated the SMB was indicative of the class of vessel in a ballast condition.

Run 4 was a departure using the simulated underpowered log vessel GL and this vessel was considered indicative of such a ship by the pilots. This was verified on the 2nd August when detailed information was gathered whilst witnessing a departure of the log ship Asian Pearl during a strong ebb tide (see **Appendix 2**). After Run 8 a change was made to the rudder speed of GL as the response was considered too slow by the pilots. From Run 5, channel Option 2 was introduced and a series of departure runs were undertaken using the SMB and GL under conditions of full ebb spring tidal streams. Average environmental conditions were simulated with regard to winds and waves. In general terms it was found that Option 2 represented the existing channel between buoys 3\6 to buoy 14.

Runs 12 to 20 were arrival runs using SML with an accelerated simulation time in the channel Option 2. Environmental conditions were average but varied for each run. Runs 12, 15 and 17 demonstrated what would happen if delayed accidentally in initiating a turn at buoy 14. This is shown in track envelope 1 in **Appendix 3**, where the ship is well to the north and in danger of hitting buoy 11 or grounding. Runs 13, 18, 19 and 20 demonstrated some better control in initiating the turn. Track envelope 2 was prepared for these runs in **Appendix 3** and it shows that safe exits from the turn were possible if turning was initiated at the correct time.

Runs 21 to 24 were departure runs in channel Option2 using SMB under average environmental conditions but with the scenario of delay in initiating the turn, around buoy 14. The effects of the full ebb tidal stream were seen in that the vessel was significantly set to the east. Both buoys 9 and 10 were hit by the ship on these runs. It should be noted that this is not a current operational scenario but is considered representative of what would happen if large tankers or logships, were not turned sufficiently early around this bend. Track envelope 3 in **Appendix 3** was prepared for these runs and shows the vessels on the edge of the channel toeline and in some cases hitting buoys 9 and 10.

The final run for the day Run 25 was an arrival on SML in the Option 4 channel under average environmental conditions, which presented no problems.

8.2 Day Two

Runs 26 to 40 were all arrival runs in the Option 4 channel. Track envelopes 4 and 5 illustrate these runs and are provided in **Appendix 3**. The envelopes show the turns being successfully done apart from Run 29 which indicates a late initiation of turn at buoy 14.

Runs 26 to 37 were in the Option 4 channel with the SML arriving. These runs were mainly done under limiting environmental conditions with wind speeds of 30 knots gusting. The pilots were happy with the response of the deeper drafted SML and considered that it was representative of its class. There was much comment on the buoy positions for this channel, in particular, buoy 11 and 12. A summary of these comments is provided in the findings of the simulation (see **Section 9**) and the conclusions and recommendations (see **Section 10**) of this report.

An arrival with the GL as a log ship was simulated in Runs 38, 39 and, 40. Both flood and ebb tide arrivals were simulated. In general, the pilotage was done well. Runs 38 to 40 are shown in black in the same track envelope 5 (see **Appendix 3**). The log ship was considered to be handled successfully in the Option 4 channel.

Run 41 represented a low water arrival of SMP which is done operationally currently and it was successfully simulated.

Runs 42 to 45 were departure runs using both the SMB and GL under limiting environmental conditions in channel Option 4. The ships were considered to be successfully handled in this channel. The witnessing of the departure of the Asian Pearl on the 2nd August in a strong ebb tide (see **Appendix 2**) confirmed the realism of the simulation with the present operational conditions for departure of log ships. The shifted positions of buoys 8 and 11 were commented on to provide alternatives to leads for the central north-south leg of the Option 4 channel alignment. Upon reflection, the pilots considered it was necessary for fixed leads to be provided on this leg of the Option 4 channel.

Run 46 was an arrival using the SMP in the Option 2 channel. This run showed that the ship could be comfortably handled through the Option 2 channel.

8.3 Day Three

Runs 47 and 48 were undertaken with a new pilot who completed arrivals using the SML in the Option 4 and Option 2 channels. The swept track paths were well to the north rounding buoy 14. This was reported to be a normal procedure for this pilot in rounding buoy 14 to have the ship further to the north of buoy 16 when completing the turn. The effect of deeper draft with the SML was noted and was considered realistic by the pilot.

Run 49 was a night time arrival in channel Option 4 with commentary on the leads and buoy positions provided by the pilot. It was more difficult but done quite well.

Runs 50-52 were departures using SMB on a full ebb tide in channel Options 2 and 4 under limiting environmental conditions. It should be noted that this is a scenario not done operationally at this time but was successfully simulated. These runs can be compared with Runs 42 to 45, - which included log ship departures and the results were successful in all cases.

Runs 53 to Run 60 were arrival and departure runs under limiting environmental conditions with two new pilots in attendance. Both channel Options 2 and option 4 were simulated and the ships were considered to be handled successfully in the two channel options.

Run 54 was a demonstration of the dangers of having residual starboard swing on the SML when approaching Buoy 14 and commencing the turn to port.

A debriefing meeting was held after Run 60 with four pilots in attendance. The outcomes of this meeting were that:

- Option 4 was considered to be the preferred channel provided that channel was defined buoy to buoy throughout, except the outer channel section (i.e. offshore of buoys 3\6). Option 4 provided more sea room for manoeuvres due to the favourable position of buoy 12 (shifted to the west) in this option, particularly for departures. It allowed more room to keep clear of the rocky outcrop off Home Point which is at times subject to strong onshore wind and tidal streams that force ships toward this location. This was considered by the pilots based on their experience, particularly important for underpowered ships.

- It was important that dredging be extended to buoys 13 and 15 to provide a wider turn radius around buoy 14 and more sea room in the event of an emergency and also to provide space to the north for emergency anchorage.

- It was important that no buoys be moved inwards from their present positions in the inner and middle channel sections (i.e. inshore of buoys 3\6) so that the extent of the existing buoyed navigation area is not reduced. It was considered that buoys 11 and 8 could be aligned to provide a north south centreline for the Option 4 channel. There was considered to be some opportunity to move buoy 5 inwards a small undefined amount if required to minimise dredging. Buoy 7 could be moved northwards to show the limit of the navigable water, however provision of an additional beacon positioned directly off the Home Point rock outcrop was preferred by the majority of pilots.

- The approach channel from the fairway buoy to buoys 3 and 6 is the same for Option 2 and 4 and it was important that:

- The lead light be correctly aligned and calibrated with the proposed approach channel alignment to give warning when approaching the toelines. Furthermore the leadlight should to be upgraded to give better visibility when ships are further offshore when lining up and have more reliance on the lead light in poor weather conditions.

- An additional red port hand buoy should be established abreast of the Fairway buoy.

- Buoy lights should be upgraded for better visibility

Runs 61 to 63 were approaches to the fairway buoy under limiting environmental conditions of wind and swell. The proposed new port hand buoy abreast of the fairway buoy was introduced. The ship was brought into the approach channel adequately.

Runs 64 to 66 were departures on SMB and GL under limiting environmental conditions in channel Option 4. Runs 67 to 69 were arrivals using SML and GL under limiting environmental conditions in channel Option 4. Track envelopes 6 and 7 were generated for both these scenarios (see **Appendix 3**). They presented no great difficulty for the pilots.

8.4 Day Four

Run 70 was an arrival with SML and tugs BB and T were used to control the ship in the normal manner in the approach to the Crude Berth. Limiting environmental conditions were simulated and it was noted that it took considerable tug and engine power to arrest the speed of the ship SML and some adjustment may be required on the part of the pilot when considering their speed passing buoy 18 on arrival. Run71 was a further arrival using tugs to control the deceleration of the ship in the approach to the berth. This was achieved adequately.

Run72 was completed using tugs to control the berthing at the Crude Berth with the SML under limiting environmental conditions with an offshore wind (i.e. SW). This was executed successfully.

Runs 73 and 74 were arrivals with SML in channel Option 4 and limiting environmental conditions with a new pilot. The turns were successfully executed and demonstrated the need to correct the port swing of the ship on completion of the turn rounding buoy 14.

Runs 75 and 76 were a comparison of arrivals with SML and SMP under limiting environmental conditions using channel Option 2. Track envelope 8 (see **Appendix 3**) was developed for these two runs and showed the difference that the increased displacement made on the turn radius of the ship. Run 77 was a full inbound arrival from before the Fairway buoy to buoy 16 using SML under average environmental conditions. This run was executed successfully.

Runs 78 and 79 were arrival simulations completed by a new pilot using SML in channel Option 4. Runs 80 to 83 were departures with the new pilot in channel options 2 and 4 under limiting environmental conditions for the SMB. In all cases the simulation runs were completed successfully.

Runs 84 to 89 introduced arrival emergency scenarios when rounding buoy 14 in limiting environmental conditions using existing available tug assistance. Rudder jams and engine failures were simulated. The ship grounded a number of times in the simulations and the rudder jam full to starboard was considered the most dangerous scenario for an arriving vessel at buoy 14. Track envelope 9 was developed for these runs and it is provided in **Appendix 3**.

Runs 90 and 91 simulated using the existing tugs to control SML in arrival at the Crude Berth landing on the berth with an onshore wind (i.e. North) at limiting environmental conditions. The existing available tug power was able to control the vessel but it landed heavily on the fenders both runs. Impact speed was above 0.1m/second which is within operational limits of the berthing control systems.

8.5 Day Five

Runs 92 to 96 were arrivals with emergency scenarios of rudder jams, engine failures or blackouts. Environmental conditions were at limiting levels. Channel Option 4 was used as it was considered to offer the most sea room and only existing available tug power under current operational configurations was utilised.

From the results, it was found that some deficiencies in the use of tugs and available tug designs could impact on the ability to prevent the ship from grounding in certain extreme cases. It was considered that channel Option 2 would offer no substantial improvement or degradation in these emergency situations.

After lunch operational advice on the use of the tugs was provided by Simon Noakes of NorthTugz. Run 97was unsuccessful due to a loss of vision during the simulation. Runs 98 to 101 were departure runs using SMB and GL in channel Options 2 and 4 under limiting environmental conditions with emergency scenarios comprising- blackout or engine failure. Without tug assistance, the ships were in danger of grounding and needed tugs to remain close to the ship. Runs 102 to 104 were arrival runs using SML in limiting environmental conditions. Blackouts and rudder jams were again simulated using existing available tug configurations with attempts to indirect tow. The rudder jam full to starboard was considered the most dangerous scenario for an arriving vessel at buoy 14.

Following Run 104 there was a final washup meeting. The meeting reiterated points raised in the meeting on Wednesday 29\07\15, including:

- Channel Option 4 was the preferred channel design provided the channel was defined buoy to buoy throughout the inner and mid channel sections (i.e. inshore of buoy 3\6). Option 4 represented more sea room for manoeuvring due to the favourable position of buoy 12 (shifted to the west) in this option, particularly for departures.

- It was important that no inner or mid channel buoys be moved inwards from their present positions so that the existing navigation area is not reduced.

Buoys 11 and 8 could be aligned and lighted with a distinctive flash pattern to provide a north south centreline on the Option 4 channel.

- There was considered to be some possibility to move Buoy 5 inwards a small undefined amount, if required, to minimise dredging.

- Buoy 7 could be moved northwards to show the limit of the navigable water, however a beacon positioned directly off the Home Point rock outcrop was preferred by the majority of pilots.

Additional points which were raised at the washup meeting included:

- Option 4 offered better sea room for arriving vessels in the event of an emergency in the area of buoy 14 and offered the benefit of a single course change as compared to a multiple course change in that area. The same was true in the departure situation. Less course changes will simplify the turn and allow a constant radius turn to be executed, which can be easily monitored by pilots.

- It was important that proposed dredging be extended to buoys 13 and 15 to improve the turn radius around buoy 14 and buoy 11 on arrivals to improve sea room in the event of an emergency and also provide an area for emergency anchorage.

- It was considered that if the existing tugs within the port were all available (a total of 4), they would be adequate to move a dead ship onto the Crude Berth under conditions of slack water. This was not simulated.

- Existing tug power was considered to be adequate for most emergencies between buoys 3\6 and the Crude Berth. It was important that tugs were available virtually immediately for both arrivals and departures as without tug assistance vessel groundings were likely in an emergency.

- There was discussion on the level of training of the tugmasters and mode of operation and configurations of the tugs for an emergency. No firm conclusions were reached apart from the need for specific emergency procedure training.

- Rudder jams full to starboard would be highly likely to cause the ship SML to run aground in the vicinity of buoy 11 in the event of the jam occurring between buoys 12 and 14 on an arriving ship. This is potentially also a problem for existing log ships although this was not simulated.

- Use of anchors to slow the vessels with speeds in excess to 2 to 3 knots is likely to break the anchor cable but would assist in slowing the ship.

- In the event of a rudder jam particularly to starboard it was important to stop the engine and use tugs immediately.

8.6 Day Six Melbourne

Further details on simulation runs and debriefing run notes are provided in **Appendix 4**. Run plots are provided later in the report (see **Appendix 5**).

- After establishing an internet linkage for participants, Bruce Goodchild and Kirit Barot commenced simulation runs with Bruce Goodchild acting as Pilot and Kirit Barot observing and commenting. During this day, winds were simulated largely from south to northwest. Runs 105 to 108 were arrivals using the SML in Channel Option 4-2. This presented no difficulty with these runs done under limiting environmental conditions with wind speeds of 30 knots gusting. Run 109 was an arrival using SML in Channel Option 4-2 with Kirit Barot acting as pilot. It was a successful run under limiting environmental conditions with wind speeds of 30 knots gusting. Track Envelope 10 in **Appendix 3** was developed from these runs.

- Run 110 was an arrival with SML using Channel Option 5 under limiting environmental conditions with wind speeds of 30 knots gusting. The run was successful, however, the ship passed close to buoy 18A due to the ship over swinging. The position of buoy 18A was considered acceptable.

- Runs 111 to 115 were arrivals with SML using Channel Option 4-2 under limiting environmental conditions with wind speeds of 30 knots gusting. Starting at buoy 7, the ship speed was varied to observe the possible effect on the turn round buoy 14. It was seen that a faster speed of 8 knots ensured greater control and assisted in counteracting the port swing when the ship exits the turn. Track Envelope 11 in **Appendix 3** was developed from these runs.

- The simulated logship GL was used for runs 116 and 117. These were both arrival runs using Channel Option 4-2 under limiting environmental conditions with wind speeds of 30 knots gusting and with full ebb and full flood tide. Both runs were successful.

- Runs 118 to 122 were arrivals of the SML and berthing using Channel Option 5 under limiting environmental conditions with wind speeds of 30 knots gusting. These runs were to test the channel and suitability of a revised berth pocket for the crude berth. It was considered that the revised berth pocket did not require any change to the approach procedures of the Pilots. Track Envelope 12 in **Appendix 3** was developed from these runs. The runs were all successful.

- The simulated logship GL was used for runs 123 to 124. These were arrival runs using Channel Option 5 under limiting environmental conditions with wind speeds of 30 knots gusting and with full ebb and full flood tide. All these runs were successful.

- Run 125 was a departure run with the SuezmaxB from the crude berth to clear of buoy 7. Using Channel Option 5 under limiting environmental conditions with wind speeds of 30 knots gusting and with a full ebb tide. This is a scenario which is not done operationally. Following a historical near grounding involving a larger vessel, operational parameters are currently in place to ensure Suezmax size vessels are not sailed on ebb tides. The pilots wished to test the Suezmax in ballast on full ebb tides to fully test the channel designs under the widest possible parameters. This run tested the Channel 5 alignment and also the adjusted berth pocket dimensions. It was successful. Runs 126 to 130 were full ebb tide departures of the SuezmaxB using Channel Option 5 under limiting environmental conditions with wind speeds of 30 knots gusting. In two of the runs the ship was significantly to the east. Track Envelope 13 in **Appendix 3** was developed from these runs.

- Runs 131 to 135 tested the alignment of Channel Option 4-2 with full ebb tide departures of the SuezmaxB under limiting environmental conditions with wind speeds of 30 knots gusting. Once again a not an operational scenario. Track Envelope 14 in **Appendix 3** was developed from these runs. The runs were successful. A comparison of track envelopes 13 and 14 in **Appendix 3** shows the ship was kept in general further to the west and safe with Channel Option 4-2 compared to Channel Option 5.

8.7 Day Seven Melbourne

- Channel alignment runs were commenced but using winds largely from east to north. Runs 136 to 140 were departures using Channel Option 4-2 of the SuezmaxB with full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting. The runs were successful and Track Envelope 15 in **Appendix 3** was developed from these runs.

- Runs 141 to 143 were departures using Channel Option 5 of the SuezmaxB with full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting. Track Envelope 16 in **Appendix 3** was developed from these runs. In general, the ship was further east in these runs compared to similar departures (Runs 136 to 140) using Channel Option 4-2.It must be noted that this is not operationally done. Following a historical near grounding involving a larger vessel, operational parameters are currently in place to ensure Suezmax size vessels are not sailed on ebb tides. The pilots wished to test the Suezmax in ballast on full ebb tides to fully test the channel designs under the widest possible parameters.

- Emergency scenarios were simulated in Runs 144 and 145 with SuezmaxB using Channel Option 4-2 with full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting. With a power blackout in the vicinity of buoy 14 and buoy 12 and no tug assistance, the ships were running outside the channel and in danger of running aground within a couple of minutes. These non operational scenarios were considered by the pilots, worst case situations to fully test the channel designs.

- Departures of the SuezmaxB in full flood tide using Channel Option 4-2 were simulated in runs 146 to 148. These runs were again under limiting environmental conditions with wind speeds of 30 knots gusting. These runs were completed successfully. Runs 149 to 150 were departures of the SuezmaxB in full flood tide using Channel Option 5. Run 150 due to a delayed turn had the ship well to the east and in danger of hitting buoy 9, buoy 7 and Beacon SM2A. These were considered by the pilots, worst case scenarios.

- Runs 151 and 152 were two night time arrival scenarios with SuezmaxL using Channel Option 4-2. It was seen that the north south centreline lead lights were effective in positioning the ship in the channel between buoy 8 to 14. Also the beacon light on SM2 was effective as a reference point for identifying the other buoys at night. In run 151, an initial mistake on the part of the pilot created a flow on effect of misjudging turns. The ship approached the berth well to the south and hit buoy 18A but did not run aground. It was considered a not unrealistic scenario of pilot error. The run illustrated the need to maintain buoy to buoy dredging and to not restrict the available searoom. A successful result was achieved with Run 152.

- Run 153 was a night time departure with SuezmaxB in Channel Option 4-2. A full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting were simulated. This was considered by the pilots, a worst case scenario. Once again the beacon light on SM2 was effective as a reference point for identifying the other buoys at night. Passing buoy 12, the ship suffered a power blackout with rudder centred amidships. Two minutes into the emergency with water speed dropping to six knots, Bream Bay pushed at 11 ton onto the port quarter at an angle of 60 degrees to the ship's hull. The tug successfully kept the ship in the channel and clear of buoy 8.

- Run 154 was a day time departure with SuezmaxB in Channel Option 4-2. A full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting were simulated. Passing buoy 14, the ship suffered a power blackout with rudder hard to starboard. Two minutes into the emergency with water speed dropping to four knots, Bream Bay pushed at 15 ton onto the port quarter at an angle of 60 degrees to the ship's hull. Increasing push to 28 ton as the ship slowed and with the rudder centred, the tug was able to overcome the starboard swing but was unsuccessful in clearing buoy 10. With a smaller ship or under less environmentally limiting conditions, it was considered possible the tug could have maintained the ship in the channel.

- Run 155 was an arrival with the SuezmaxL using Channel Option 4-2 under limiting environmental conditions with wind speeds of 30 knots gusting. Passing buoy 12 the ship suffered a power blackout with rudder amidships. Aft tug Bream Bay was used to pull back then indirect pull stern to starboard at 80 to 85 ton. Water speed of ship between 6 and 7 knots. Ship cleared buoy 11C no problem.

- Run 156 was a night time arrival with the SuezmaxL using Channel Option 4-2 under limiting environmental conditions with wind speeds of 30 knots gusting. Run 157 was a night time arrival with the SuezmaxL using Channel Option 5 under limiting environmental conditions with wind speeds of 30 knots gusting. Both runs were run in accelerated simulation time (normal speed x 2) and were successful.

- The simulated logship GL was used for runs 158 to 161. These were all departure runs using Channel Option 4-2 under limiting environmental conditions with wind speeds of 30 knots gusting and with full ebb and full flood tide. All the runs were successful.

- Run 162 was a day time departure with SuezmaxB in Channel Option 4-2. A full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting were simulated. The ship completed the transit past buoy 7 successfully. An ebb tide departure for this size vessel is not done operationally but was simulated to check the channel designs rigorously. Following a historical near grounding involving a larger vessel, operational parameters are currently in place to ensure Suezmax size vessels are not sailed on ebb tides. The pilots wished to test the Suezmax in ballast on ebb tides to fully test the channel designs under the widest possible parameters.

- Run 163 was a day time departure with an emergency. SuezmaxB was using Channel Option 4-2 simulating a full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting. Passing buoy 12 there was a power blackout and the rudder jammed 10 degrees to starboard. Vessel hit buoy 10 within three minutes of blackout and with no tug assistance provided. An ebb tide departure for this size vessel is not done operationally but is a theoretical scenario which was chosen by the pilots in order to test the full set of environmental parameters.

- Run 164 was a day time departure with SuezmaxB in Channel Option 4-2. A full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting were simulated. Passing buoy 8 there was a main engine failure. The ship continued out through the Outer Channel with steering available and safely passed buoy 1.

- Run 165 was a departure with SuezmaxB in Channel Option 4-2. A full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting were simulated. The ship completed the transit past buoy 7 successfully.

- Run 166 was a day time departure with SuezmaxB in Channel Option 4-2. A full ebb tide and under limiting environmental conditions with wind speeds of 30 knots gusting were simulated. Passing buoy 14, the rudder jammed at starboard 18 degrees. Using engine and tug assistance, the ship was stabilized within the channel successfully after a heroic struggle. (see **Debriefing Notes Appendix 4**)

9 FINDINGS

9.1 Channel dimensions

All the channels: Option 2, Option 4, Option 4-2 and Option 5 were tested. Testing included full ebb tide departures with the design ship in ballast which is not done operationally but was a simulated scenario considered by the pilots as the worst possible case. Following a historical near grounding involving a larger vessel, operational parameters are currently in place to ensure Suezmax size vessels are not sailed on ebb tides. The pilots wished to test the Suezmax in ballast on ebb tides to rigorously test the channel designs under the widest possible parameters. From the Fairway buoy to buoys 3 and 6, the options are the same with a channel width of 210 metres. This was considered to be adequate for the design ship and existing ships provided there were improvements in the navigation aids. Swell conditions could be simulated up to 2 metres Hs and period 22 seconds. However, it was considered by the Pilots that the DUKC system would cut out any arrivals if the swell height was above 1m Hs, based on the current DUKC operation. Swell accessibility may change in the future subject to the final channel design.

Most of the simulation activity was performed in the areas between buoys 3/6 and buoy 16. In this area channel Option 2, Option 4, Option 4-2 and Option 5 would support the arrival of the design vessel SML. However, there was a clear preference amongst the pilots for Option 4 and Option 4-2 as it simplified the arrival approach around the critical area at buoy 14. The westward move of buoy 12 in Option 4 made this approach a single turn around buoy 14 rather than a series of turns. Similarly the north westward move of buoy 14 in Channel Option 4-2 provided more searoom for the arriving ship in this area and increased the radius of the turn to 800m. The increase in radius of the turn and increase in searoom in the area bounded by buoy 14 to 12 to 11 to SM2, makes Channel Option 4-2 superior to Channel Option 4. See Table 1 in **Section 10.2**.

These are improvements over the existing channel and Option 2 because the simplification of the turn and more searoom will improve execution and monitoring of the turn on the part of the pilot. The Channel Option 5 was suitable for the arriving ship however it provides less sea room. See Table 1 in **Section 10.2**.

The Option 4 and Option 4-2 improvements also are of benefit for the same reasons of simplification of the turn in the departure cases for existing vessels. It also provides more sea room in the area bounded by Buoy 7 to 12 to 14 to 9 for the clearing of the rocky outcrop off Home Point than the existing channel, Option 2 and Option 5. See Table 1 in **Section 10.2**. The simulations demonstrated that vessels were able to successfully execute the turn rounding buoy 14.

9.2 Arrivals

All the channels: Option 2, Option 4, Option 4-2 and Option 5 simulations demonstrated that the design ship could navigate this arrival turn at buoy 14 adequately without tug assistance under non-emergency conditions. The ship tended to turn wider due to the increased displacement of the fully loaded Suezmax over the partially loaded condition. This is illustrated in Run 75 and 76 (see track envelope 8 in **Appendix 3**). The proposed re dimensioned berth pocket was considered to not make any change to the berth approach.

In the arrival condition, there was the chance of a delayed turn which would put the ship in danger of hitting of buoy 11. This is the present situation now with a partially loaded Suezmax (SMP) in the existing channel and it was demonstrated in the simulations. It is also the case with other vessels including log ships. Therefore in all the channels, Option 2, Option 4, Option 4-2 and Option 5 it was important to move buoy 11 to the new designed position further east of its existing location and keep the channel dredged 'buoy to buoy' from buoy 11 to 15. This provides adequate room in the case of a delayed turn around buoy 14 and particularly assists in an emergency situation in the same area.

There was a clear indication from the pilots that the dimensions of the existing channel be maintained or widened with all channels Option 2, Option 4, Option 4-2 and Option 5 between buoys 3\6 to the berth and dredging must be 'buoy to buoy' in all cases. Option 5 does not meet the maintaining or widening of existing channel dimensions. See Table 1 in **Section 10.2**.

The pilots clearly preferred channel Option 4 and channel Option 4-2 provided that proposed dredging was 'buoy to buoy' and the existing channel dimensions were not narrowed between buoys 3/6 to the berth. It was important that no buoys be moved inwards from their present positions so that the extent of the existing buoyed navigation area was not reduced. Buoys 11 and 8 could be aligned to provide a north-south centreline for the Option 4 and 4-2 channel. There was some opportunity to move Buoy 5 inwards a small undefined amount if required to minimise dredging between Home Point and Busby Head.

Buoy 7 could be moved northwards to show the limit of the navigable water, however an additional beacon positioned directly off the Home Point rock outcrop was preferred by the majority of pilots. In Option 2, additional buoys were introduced south of Home Point to gate the channel but this was deemed of no value and the existing natural depths in this area were generally deeper than dredging levels. In Option 4-2 a set of leads was introduced in Taurikura Bay to define the north south centreline. These were found particularly helpful at night.

It was considered that Channel Option 4-2 was superior to Channel Option 4 due to the increase in turn radius around buoy 14 and also the increase in searoom particularly for the arrival vessel available with Channel Option 4-2. See Table 1 in **Section 10.2**.

From the simulation it was found that all channel designs were adequate and the design ship could be safely manoeuvred for arrivals. In all cases, it was found that the pilot must:

- Be alert to commence the turn in the optimal position.

- Control the rate of turn of the ship carefully.

- Maintain an adequate speed through the turn to ensure the ship will exit the turn in a stable condition but can also be slowed in time for arrival off the berth.

9.3 Departures

Using the existing ships which currently depart the port, it was found that all channel designs were adequate, except for Channel Option 5 due to less available searoom. See Table 1 in **Section 10.2**. However, there was a clear preference from the pilots for channel Option 4 or Channel Option 4-2. Option 4 offers a single turn around buoy 14 whilst Option 2 is a linked turn, which is more difficult to complete. The position of buoy 12 (shifted to the west) with Option 4 gives the pilot more room to keep to the west and avoid the dangers of shallow water off Home Point. This also has the effect of widening the channel for the pilot at a critical area.

Channel Option 4-2 offers a wider turn around buoy 14 than Channel Option 4. The radius of turn available with channel Option 4 is 580m, compared to Channel Option 4-2 which has a radius of 800m due to buoy 14 being shifted north westward. The wider radius of turn allows the arriving ship to turn at a slower rate of turn for a given speed. This is much easier to achieve particularly with less manoeuvrable vessels

The simulations showed the dangers of delayed turns or slow turns around buoy 14 for example in Runs 21 to 24 (see track envelope 8 in **Appendix 3**). This was simulated with the SMB in channel Option 2 but according to the pilots is an indicative case for handling of other smaller tankers and log ships in the existing channel. Further examples are seen in the comparison of departure runs between channel Option 4-2 and Option 5 (see track envelopes 13, 14, 15 and 16 in **Appendix 3**) The area in the vicinity of buoy 7 and Home Point is to be avoided due to the presence of strong tidal streams and hard rock. Channel Option 5 is the least desirable channel alignment as it offers the least room to manoeuvre and this was borne out in simulations. (see track envelopes 14 and 16 in **Appendix 3**).

Option 4 and Option 4-2 were considered to be preferred to Option 2 as it allows the pilot to manoeuvre the ship further west in the departure case and clear the dangerous area around Home Point. Option 4 offers slightly more searoom than Option 4-2 and both are significantly more than Option 2 and Option 5. Both Option 4 and Option 4-2 are both effective for the departing vessel in the area between buoy 12, 14, 9, SM2 and 7, however Option 4-2 offers a superior turn radius rounding buoy 14.

Once clear of buoy 7, all options are adequate to proceed outwards to buoys 3/6.

9.4 Swell conditions

For arrivals of the design ship SML, swell heights up to 2m are manageable. The pilots considered that a 1m swell was all the DUKC would accept and that the new DUKC parameters will be critical with respect to the rolling and squat in a large swell.

9.5 Tidal streams

Good information was available on the tidal streams in the vicinity of buoys 3/6 up to the area off the Crude Berth. The pilots were surprised by the lack of cross streams in the vicinity of buoy 7 in an ebb tide. However, there was a weak set onto buoy 7 experienced during arrivals in a flood tide just before high water. In all cases the design ship could be controlled under the tidal streams simulated in the operational area using current operational procedures.

Departure of the SMB in full ebb tide is outside existing operational procedures, however it was considered to be a worst case scenario. It should be noted that the ADCP data used to represent tidal stream was obtained during a 2.5m spring tide range and would be considered to be representative of the upper limit of tidal streams experienced in the port.

9.6 Wind conditions

Winds of 30 knots with gusts from 30 to 36 knots were simulated and the ships were controllable. Wind directions were varied to create the least optimal conditions but were all managed adequately.

9.7 Navigation aids

Buoys are used to mark the extents of the existing channel and the existing buoys will be utilised throughout to mark the extents of the proposed Option 2, Option 4 Option 4-2 and Option 5 channels. The existing buoys were considered to be inadequately lighted (too weak) by the pilots and the buoys were difficult to see on the simulation during daylight but this was improved for the Melbourne round of simulations.

Between the Fairway buoy and buoys 3/6, the buoys should remain in position (in particular the starboard hand buoys) or be moved outside the toeline as is required at buoy 3. It was important to maintain the existing wider buoyed channel for shallower draft vessels. The buoys should be lighted with a synchronized pattern, however this was not simulated. A new red port hand buoy should be added to the start of the narrower deep outer channel and be positioned abreast of the existing Fairway buoy.

The existing lead light marking the offshore approach channel was considered to be too insensitive by the pilots and this was demonstrated in the simulations. The sectors of the main lead should adequately show the navigation limits of the new channel and be bright enough to support operations in adverse environmental conditions.

In the area from buoys 3/6 to the Crude Berth it was important that no buoys be moved inwards from their present positions so that the extent of the existing buoyed navigation area is not reduced.

Buoys 11 and 8 could be aligned to provide a north-south centreline for the Option 4 and Option 4-2 channel and Option 5 channel. It was considered that these buoys should have a distinctive light characteristic. If these buoys were used for this purpose, it was initially considered there would be no need for a set of leads on this leg of the Option 4 channel.

However, on reflection, the pilots considered there was a need for a set of fixed leads for this leg due to concerns with background lighting and poor visibility conditions.

This was verified using Channel Option 4-2 on day seven in Melbourne, when the set of fixed leads proved very useful. It was considered that buoys 12 and 14 should be lighted to show a pattern which showed both buoys simultaneously or very close together to assist identification by the pilot, and this was seen in the Melbourne simulations on day seven.

There was some possibility to move Buoy 5 inwards a small undefined amount in option 2, option 4 and option 4-2, to minimise dredging, if required. Run 166 and run 136 demonstrated to maintain plenty of searoom in the area of buoy 5. Buoy 7 could be moved northwards or southwards in all the channel options to show the limit of the navigable water however an additional beacon SM2 positioned directly off the Home Point rock outcrop was preferred by the majority of pilots.

9.8 Tugs

For the arrivals with design ship SML, it was considered that the available existing tug capability was adequate for all channels Option 2, Option 4, Option 4-2 and Option 5 under normal operations, including berthing.

In an emergency situation, there is a question whether the existing tugs would be able to provide emergency support for the arriving SML design ship. Simulations showed that the critical area was the turn at buoy 14. The simulation was intended only as a feasibility exercise for channel design and navigational safety, rather than a risk assessment. Where there are possible risk issues which have arisen, they should be subject to a risk assessment and if necessary any consequential consideration by relevant stakeholders.

- The operational scenario simulations for the design ship arriving, found that in the event of a rudder jam to port or main engine failure or a power blackout, the existing tugs should be able to control that situation. This covers the majority of possible incidents.
- The operational scenario simulations for the design ship arriving, also found that the existing tugs may not be able to control the SML in the event of a rudder jam hard to starboard.
- From the departure scenarios simulated, it was evident from the simulation that if tugs were not in the immediate vicinity of the ship and could not assist within two to three minutes, the departing vessel was highly likely to run aground or hit a buoy. This was considered a worst case scenario but is largely directly related to the speed of ship and velocity of tidal stream, so is applicable to any ship type. This was tested in the area from buoy 14 to buoy 7 in the simulations. One simulation (Run 164) was conducted with an engine failure in the vicinity of buoy 8 on departure. In Run 164 it was found the ship SMB had sufficient momentum to clear the Outer Channel. In three simulations (Runs 153, 154 and 166) tug assistance was provided within two minutes of the emergency and was successful in controlling the situation, in two out of three attempts.

10 CONCLUSIONS AND RECOMMENDATIONS

From the simulation study the following conclusions and recommendations are offered:

10.1 Channels and the design vessel Suezmax SML

- The channel designs Option 2, Option 4 Option 4-2 and Option 5 are all suitable for the design ship SML in wind conditions up to 30 knots and swell conditions up to 2 metre at the wave rider buoy. Arrival transits should only be attempted at slack water following the current operational procedures for the port.

- All channel designs are suitable for day arrivals. Three night arrivals were simulated and were all successful. Significant improvements were made to the night time model from photos provided by Kirit Barot. However, if night transits are intended, then further simulations are needed to support this and test navigation marker configurations ,lighting and provide training for the pilots

- The Option 4-2 Channel is the preferred channel with the channel dredged buoy to buoy (except for the outer section between buoys 3/6 and the Fairway buoy where it is 210m wide). See Table 1 **Section 10.2** for a navigational comparison of the channel options.

- The positions of the buoys from the Fairway buoy to buoys 3/6 should be maintained in their current positions unless they are located inside the proposed channel toeline, as is the case with buoy 3. Buoy 3 needs to be moved north eastward to conform to the Option 4-2 design. An additional red port hand buoy should be placed abreast of the Fairway buoy. The buoys between buoy 3/6 to the Crude Berth should generally remain in their present positions as they are used by the pilots to mark an acceptable channel width and provide the indications for the initiation of turns. Buoys 8 and 11 can be moved and lighted with a distinctive flash pattern to provide a north-south transit line up the Option 4-2 approach to buoy 14.However the set of Leads on this leg were considered more useful. It is important to move buoy 11 to the new designed position east of its current location. Buoy 14 should be moved north westward and buoy 12 should be moved westward to conform to the Option 4-2 design. Buoy 5 can be moved in slightly to minimise dredging, if required. Buoy 7 should remain in its current position and a new beacon established to mark the extent of the navigable water off the Home Point rock outcrop. Buoys 10, 13, 14, 15, and 16 should all remain in their current positions. Buoy 18 should be moved eastward to conform to the Option 4-2 design. It was considered that by dredging further north to in line with buoys 11, 13 and 15, a suitable area would be available as an emergency anchorage and that this would provide an escape route if there was an emergency (i.e. loss of rudder control or engine power) when rounding buoy 14.

- The daylight leads on the offshore approach channel between the Fairway buoy and buoys 3/6 should be made more sensitive to adequately show the navigation limits of the new channel and be bright enough to support operations in adverse environmental conditions.

10.2 Comparison of Channel Options

Table 1 Comparison of Channel Options

Channel Option / Factor	Existing Channel	Option 2 Channel	Option 4 Channel	Option 4-2 Channel	Option 5 Channel
Design vessel suitability	Not suitable for 16.8m draft Suezmax.	Suitable for 16.8m draft Suezmax Design Vessel by dredging.	Suitable for 16.8m draft Suezmax Design Vessel by dredging.	Suitable for 16.8m draft Suezmax Design Vessel by dredging.	Suitable for 16.8m draft Suezmax Design Vessel by dredging.
Buoyage locations	Buoyage used for turning transits is familiar to pilots	Buoyage used for turning transits is familiar to pilots.	New buoyage locations will require pilots to re establish turning transits	New buoyage locations will require pilots to re establish turning transits	New buoyage locations will require pilots to re establish turning transits
Sea room area – Inner channel	Between Buoy 14, 11, 9, and 12 117300m²	Between Buoy 14, 11A, 9, and 12 130000m²	Between Buoy 14, 11B 9, and 12A 133700m²	Between Buoy 14A, 11C, 9, and 12B 141800m²	Between Buoy 14, 11D, 9, and 12C 118200m²
Sea room area – Mid channel	Between Buoy 14, 12,7,9 137500m²	Between Buoy 14, 12,7,9 137500m²	Between Buoy 14, 12A,SM2,7,9 151400m²	Between Buoy 14A, 12B,SM2,7,9 147500m²	Between Buoy 14, 12C,SM2A,7,9 124900m²
Constraint at buoy 11	Buoy 11 is a constraint when arriving ships turn around buoy 14	Buoy 11 moved eastward to 11A allows more searoom for the arriving ship around buoy 14 for both normal operations and emergencies.	Buoy 11moved eastward to 11B allows more searoom for the arriving ship around buoy 14 for both normal operations and emergencies.	Buoy 11moved eastward to 11C allows more searoom for the arriving ship around buoy 14 for both normal operations and emergencies.	Buoy 11 moved eastward to 11D allows more searoom for the arriving ship around buoy 14 for both normal operations and emergencies.
Constraint at buoy 12	Buoy 12 is a constraint for both arriving and departing ships as it necessitates a series of turns when rounding buoy 14.	Buoy 12 is a constraint for both arriving and departing ships as it necessitates a series of turns when rounding buoy 14.	Buoy 12 is moved westward to 12A allowing • a single radius turn around buoy 14 • Radius 500m Rate of Turn required at 7 knots = 25.9°/min • a simpler turn more easily monitored and executed allows departing ships more searoom to the west to clear the rocky outcrop at Home Point	Buoy 14 is moved north westward to 14A and Buoy 12 is moved slightly westward to 12B and buoy 5 is moved to 5A allowing • a single radius turn around buoy 14 • Radius 800m Rate of Turn required at 7 knots = 16.2°/min • a simpler turn more easily monitored and executed • **allows** departing ships more searoom to the west to clear the rocky outcrop at Home Point	North-south Channel is realigned eastward with buoy 12 moved to 12C and buoy 7 moved to 7A and SM2 is moved eastward to SM2A. Buoy 5 is moved inward to 5A. allowing • a single radius turn around buoy 14 • Radius 800m Rate of Turn required at 7 knots = 16.2°/min • a simpler turn more easily monitored and executed
Mid channel alignment	Channel alignment in approach to Buoy 14 on the arriving ship is not straight.	Channel alignment in approach to Buoy 14 on the arriving ship is not straight.	Channel alignment in approach to Buoy 14 on the arriving ship is straight north south allowing a set of leads and alignment of buoys 8A and 11B to define the centerline of the channel.	Channel alignment in approach to Buoy 14A on the arriving ship is straight north south allowing a set of leads and alignment of buoys 8C and 11C to define the centerline of the channel.	Channel alignment in approach to Buoy 14 on the arriving ship is straight north south allowing a set of leads and alignment of buoys 8D and 11D to define the centerline of the channel.
Constraint at Home Point	Rocky outcrop at Home Point is a constraint for departing ships.	Rocky outcrop at Home Point is a constraint for departing ships.	Rocky outcrop at Home Point is a constraint for departing ships however the movement of buoy 12 westwards allows departing ships more searoom to the west to clear this area.	Rocky outcrop at Home Point is a constraint for departing ships however the movement of buoy 14 north westwards to 14Aand buoy 12 slightly westward allows departing ships more searoom to the west to clear this area.	Rocky outcrop at Home Point is removed however there is effectively less searoom in the approach to this area from the north.
Emergency anchorage	Emergency anchorage is available between buoys 11 to 15.	Emergency anchorage is improved between buoys 11A to 15 by movement of buoy 11 eastward. Dredging would extend buoy to buoy through the inner and middle sections of the channel for the 16.8 m draft Suezmax design vessel.	Emergency anchorage is improved between buoys 11B to 15 by movement of buoy 11 eastward. Dredging would extend buoy to buoy through the inner and middle sections of the channel for the 16.8 m draft Suezmax design vessel.	Emergency anchorage is improved between buoys 11C to 15 by movement of buoy 11 eastward. Dredging would extend buoy to buoy through the inner and middle sections of the channel for the 16.8 m draft Suezmax design vessel.	Emergency anchorage is improved between buoys 11D to 15 by movement of buoy 11 eastward. Dredging would extend buoy to buoy through the inner and middle sections of the channel for the 16.8 m draft Suezmax design vessel.
Outer Channel Width	Outer Channel is naturally wide for vessels up to a draft of 14.8 metres.	Outer Channel is limited to 210 m width for 16.8m draft Suezmax design vessel due to dredging.	Outer Channel is limited to 210 m width for 16.8m draft Suezmax design vessel due to dredging.	Outer Channel is limited to 210 m width for 16.8m draft Suezmax design vessel due to dredging.	Outer Channel is limited to 210 m width for 16.8m draft Suezmax design vessel due to dredging.
Overall Assessment	Marginal. Can be brought up to Adequate by improvements around Buoy 11.	Adequate. Very similar to the existing channel with improvements made.	Adequate. Significant improvements in available searoom but with a smaller radius turn around buoy 14 for the arriving ship.	Optimum. Significant improvements in available searoom and with a larger radius turn around buoy 14 for the arriving ship.	Marginal. Some improvements but a significant loss in some searoom for the departing ship.

Colour key:

	Optimum	Ideal under both operating and extreme conditions, no issues encountered
	Adequate	Very good under operating conditions, manageable under extreme conditions
	Marginal	Adequate under operating conditions but poor under extreme conditions
	Inadequate	Poor under both operating and extreme conditions, may be considered unacceptable from a navigational risk perspective

10.3 Tugs

The existing tugs Bream Bay and Takahiwai were considered to be adequate for an arriving design ship SML for normal operations from buoys 3/6 to the Crude Berth using channel Option 2, channel Option 4, channel Option 4-2 and channel Option 5. The existing tugs could assist in decelerating the ship in the approach to the berth and to put the vessel alongside the berth for a normal berthing operation at slack water. The Bream Bay is the most capable of the tugs and it is recommended to be tethered on the centre lead aft.

The existing tugs would be able to deal with the majority of emergency situations for the arriving ship. However, in the event of a rudder jam full to starboard in the vicinity of buoy 14 with an arriving ship, the existing tugs would have difficulty in providing sufficient tug forces to prevent the ship grounding. It is a consideration to be resolved independently of this work.

Shifting a dead ship from emergency anchorage to berth was not simulated but can be verified by further simulation, if required.

Departing vessels were simulated with tug assistance located more than five minutes away. In the event of an emergency, that was too late for the tugs to provide any assistance to prevent grounding in the area between buoy 14 to buoys 8/10. This is applicable to the current situation and to all the channel designs.

It is recommended that the procedure in place by Northtugz for departing vessels should be reinforced to ensure that tugs attend in the vicinity of the departing vessel as a minimum, until the ship has cleared the rocky hazard at Home Point (buoy 7) and the pilot is comfortable with the approach to buoys 3/6.

References:

1. *Tug Use in Port A Practical Guide HenkHensen Second Edition pp169-172 Section 10.1.3*
2. *http://www.towingsolutionsinc.com/technology-escort_tugs.html et al*
3. *Tug Use in Port A Practical Guide HenkHensen Second Edition p 152 pp137-140 Section 9.4.1*
4. *Hydrodynamic Aspects of Ship Handling Tugs Brandner 1994 et al http://www.rina.org.uk/hres/1994-2%20Brandner%20-%20Hydrodynamic%20Aspects%20of%20Shiphandling%20Tugs.pdf*
5. *Review of New Zealand's Oil Pollution Preparedness and Response Capability Maritime New Zealand February 2011 pg 25 Section 7.1.1 https://www.maritimenz.govt.nz/Publications-and-forms/Environmental-protection/OPPRC-Review-February-2011.pdf*

APPENDIX 1: PILOT CARDS for SUEXMAX TANKER and GUNDULIC (LOGSHIP)

MANOEUVRING CHARACTERISTICS

Name:
Suezmax

Ship Type: Oil Tanker

Drafts : Ballast F 6.6m A 9.2m Load FA 17.0m

Minimum Steering Speed

Normal Loaded Condition 3 kns

Maximum Available Rudder Angle

Hard Starboard 35
Hard Port 35

Principal Particulars

LOA 274m LBP264 Bm 45.1
Displacement 78305 171298
Single Propellor RHFP
Engine Type Diesel 16460 KW
Bowthruster na

Time and Distance to Stop

Note: Using Engines Full Astern and with minimum application of rudder

	Normal LOADED		Normal BALLAST	
Sea Speed	Time	Distance	Time	Distance
Full Sea Speed	11m	2407	19m	3518
Full Speed				
Half Speed				
Slow Speed				

Warning

The response of the vessel may be different if the following conditions are not met

Calm Sea
No Current
Water depth twice the vessels draft
clean hull

Engine Order/ RPM (Propellor Pitch)/Speed Table

Engine Order	RPM	Loaded Speed	Ballast Speed	Pitch
Full Sea Speed	98	14.5	15.5	
Full Ahead	76	10.9	12.3	
Half Ahead	63	8.8	10.5	
Slow Ahead	45	6.1	7.5	
Dead Slow Ahead	30	4.4	4.9	
Dead Slow Astern	30			
Slow Astern	45	Bridge_Bow	190	
Half Astern	63			
Full Astern	76			

TURNING CIRCLE DIAGRAMS

Loaded Condition		Ballast Condition	
Full Sea Speed	Half Ahead	Full Sea Speed	Half Ahead

Be-Software Genova Italia

Name:
Gundulic

Ship Type: General Cargo

Drafts : Loaded 11.9/ 12.0

Minimum Steering Speed

Normal Loaded Condition 3 kns
Normal Ballast Condition 2.5 kns

Maximum Available Rudder Angle

Hard Starboard 35
Hard Port 35

Principal Particulars

LOA 190.3 LBP 180.3 Bm 31
DISPLACEMENT 56417 T
Single Propellor RHFP Screw Diam 6.2
Engine Type Diesel 8635 KW

Bowthruster nil

Time and Distance to Stop

Note: Using Engines Full Astern and with minimum application of rudder

	Normal LOADED		Normal BALLAST	
Sea Speed	Time	Distance	Time	Distance
Full Sea Speed	13' 13"	1.4 nm		
Full Speed				
Half Speed	9' 48"	0.75 nm		
Slow Speed				

Warning

The response of the vessel may be different if the following conditions are not met

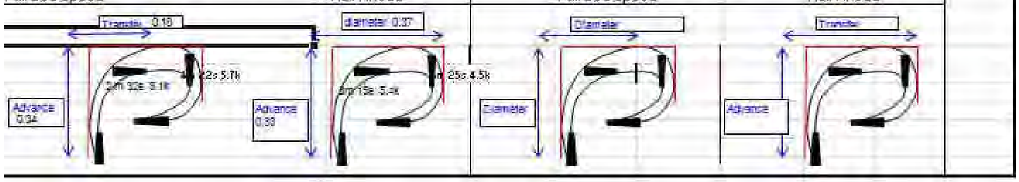
Calm Sea
No Current
Water depth twice the vessels draft
clean hull

Engine Order/ RPM (Propellor Pitch)/Speed Table

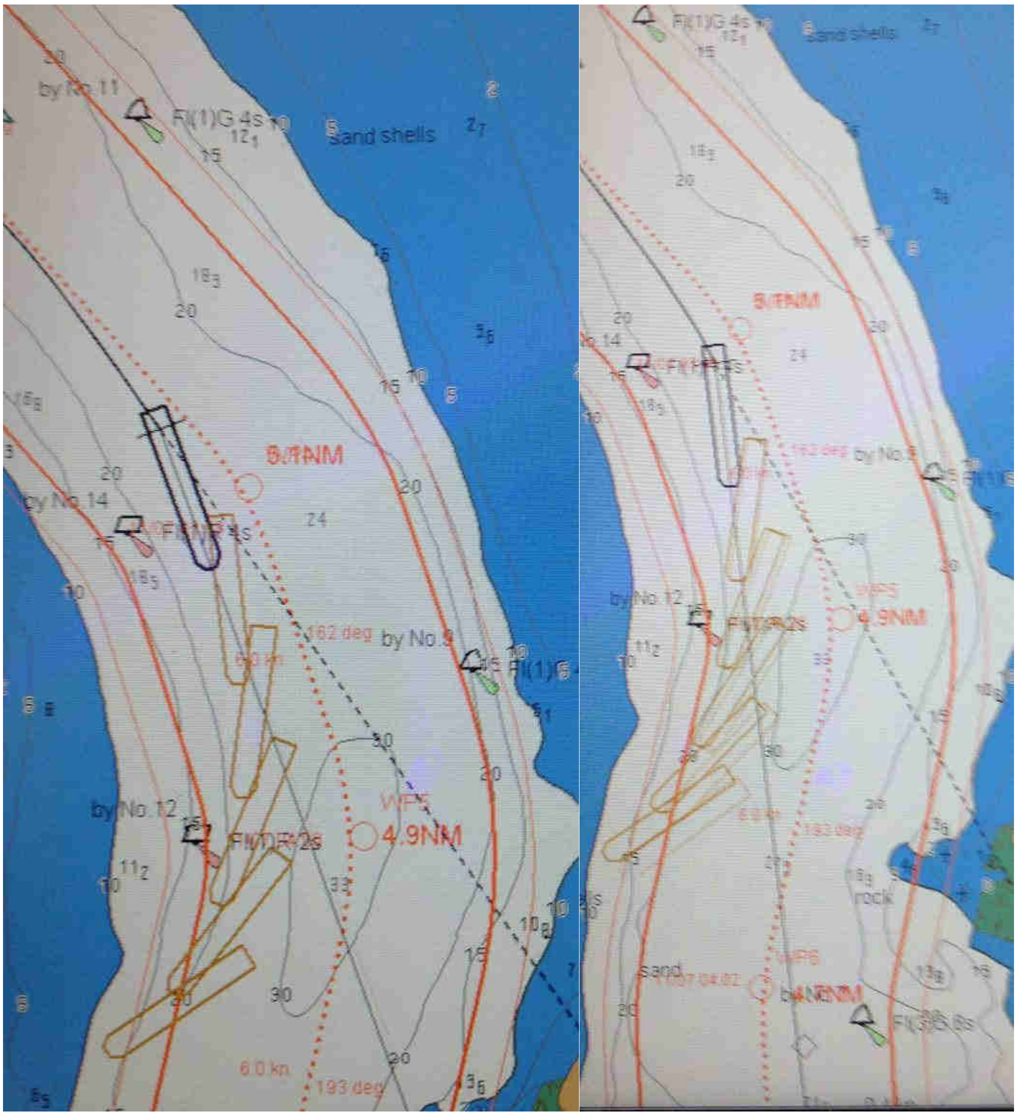
Engine Order	RPM	Loaded Speed	Ballast Speed
Full Sea Speed	122	15	
Full Ahead	90	10.2	
Half Ahead	82	9.5	
Slow Ahead	60	6.5	
Dead Slow Ahead	38	3.8	
Dead Slow Astern	-38		
Slow Astern	-60		
Half Astern	-82		
Full Astern	-90		

TURNING CIRCLE DIAGRAMS

Loaded Condition		Ballast Condition	
Full Sea Speed	Half Ahead	Full Sea Speed	Half Ahead



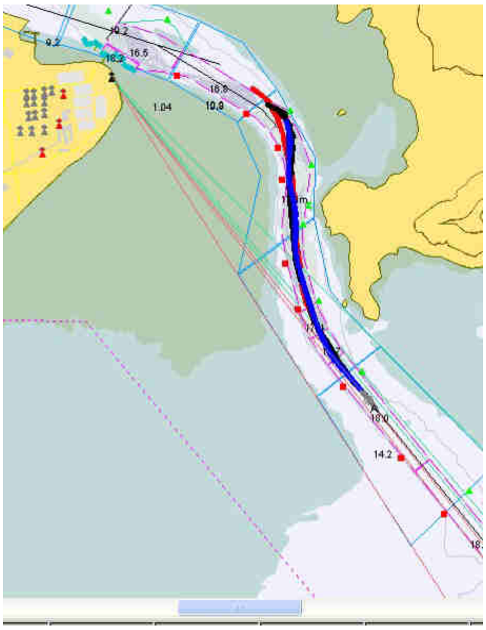
APPENDIX 2: August 2nd DEPARTURE LOGSHIP ASIA PEARL FULL EBB TIDE



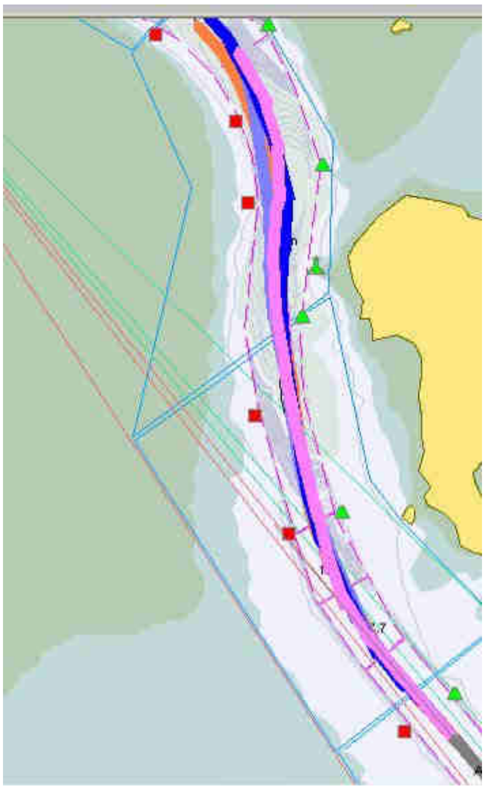
Asia Pearl Logship, 2nd August 2015 Spring Ebb Tide, 2.5 hrs after HW, LOA 180m, Beam 28m, Draft 10.5m. Vessel rounding Buoy 14. Brown ship shapes show predicted path if no corrective navigational measures taken.

Asia Pearl Logship, 2nd August 2015 Spring Ebb Tide, 2.5 hrs after HW, LOA 180m, Beam 28m, Draft 10.5m. Vessel passing Buoy 7. Brown ship shapes show predicted path.

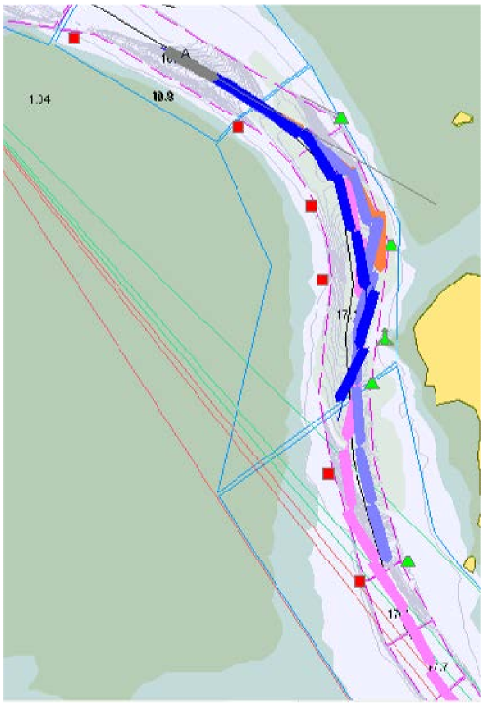
APPENDIX 3: TRACK ENVELOPES



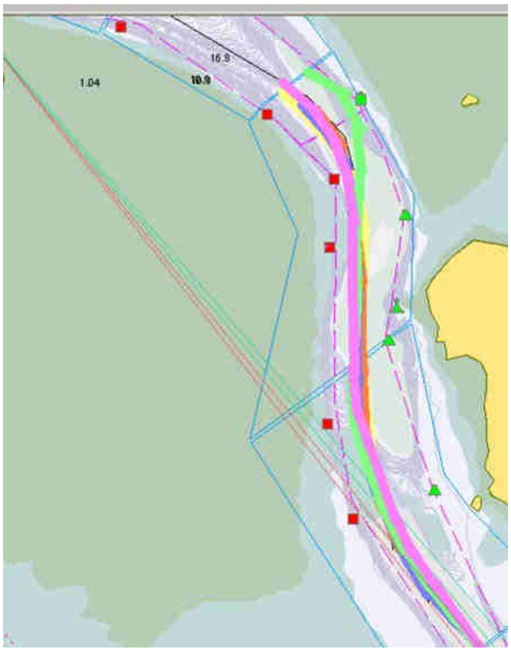
Track Envelope 1: SML Arrival
Runs with late initiation of turn
Channel Option 2 - Runs 12, 15 and 17



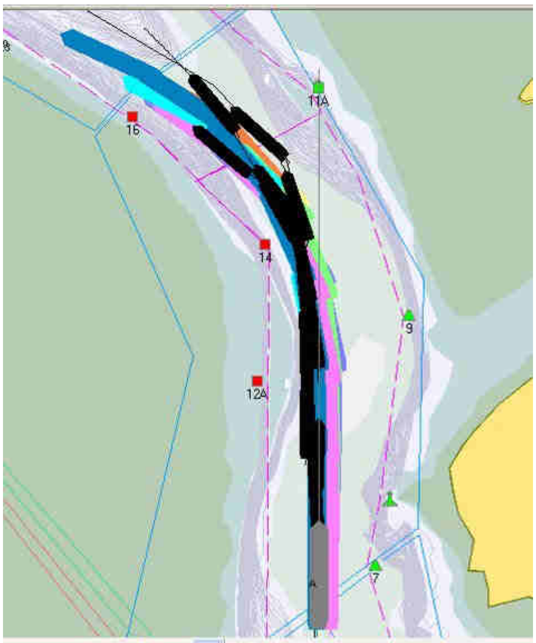
Track Envelope 2: SML Arrival
Optimum initiation of turn
Channel Option 2 - Runs 13, 18, 19 and 20



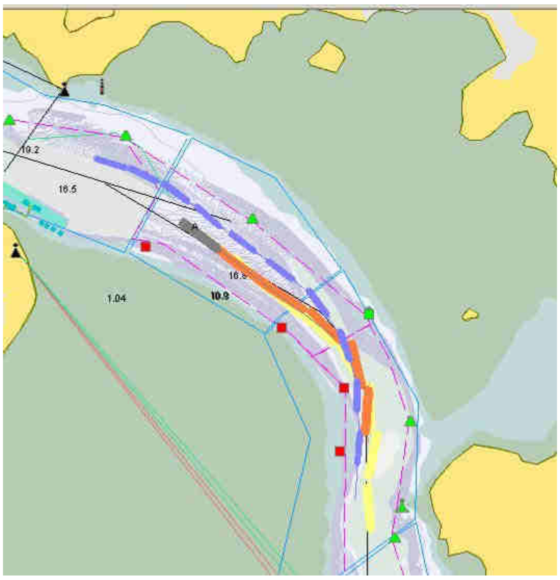
Track Envelope 3: SMB Departures
Late in initiating turn
Channel Option 2
Runs 21-24



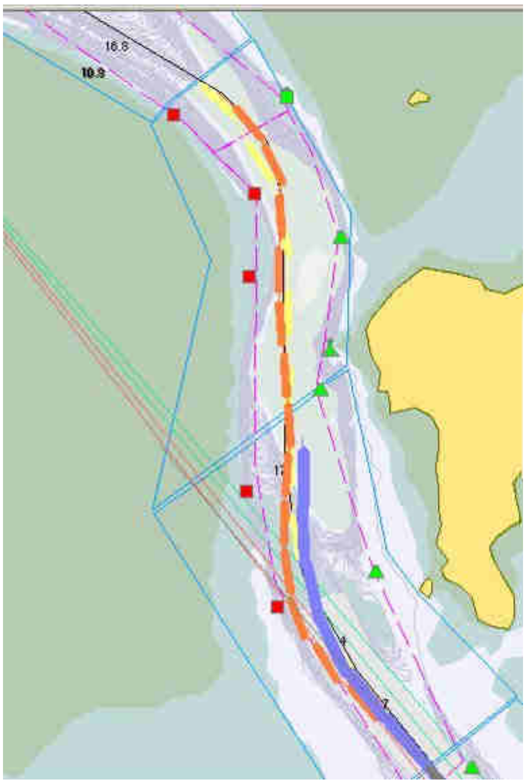
Track Envelope 4: SML Arrivals
Lime green track shows a late initiation of turn
Channel Option 4
Runs 26-30 and Run 29



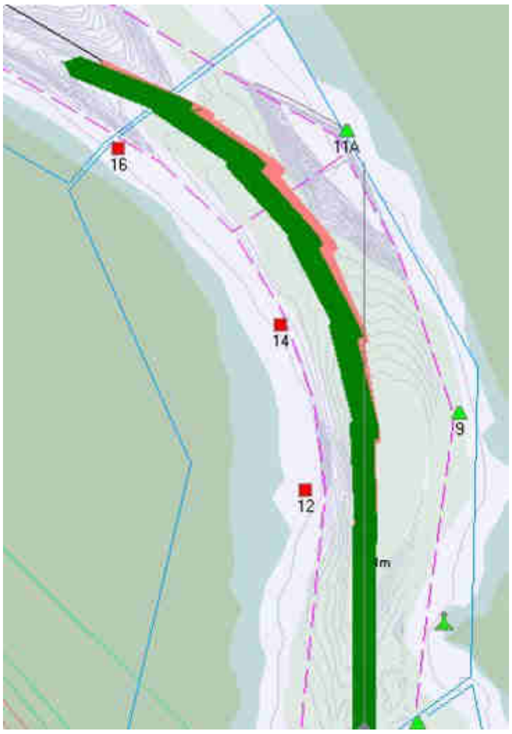
Track Envelope 5: SML and GL Logship (GL shown in Black) Arrivals
Channel Option 4
Runs 31-40



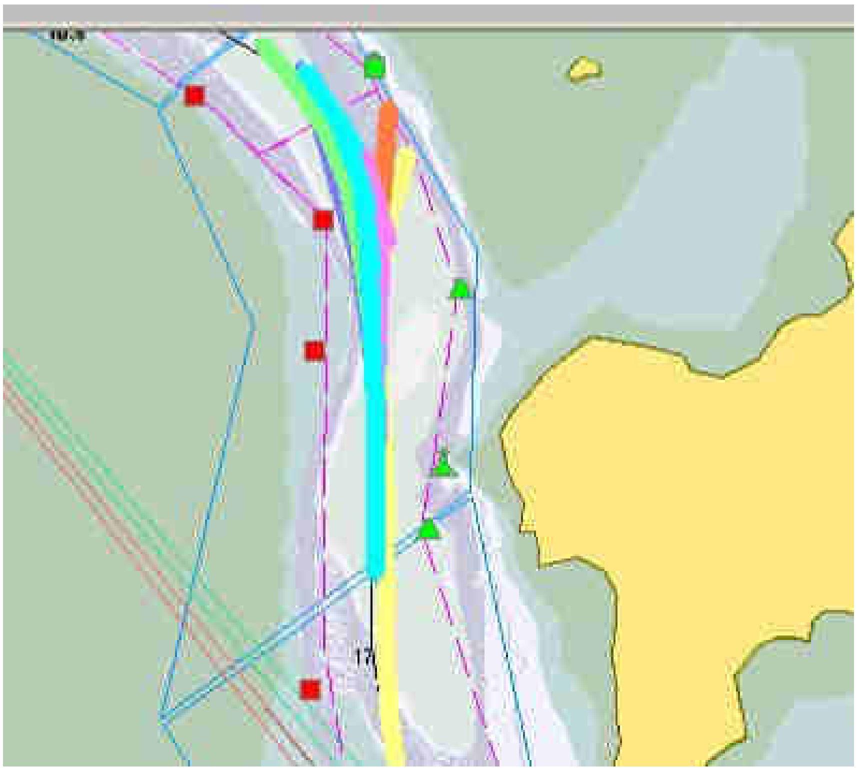
Track Envelope 6: SML and GL Logship (in light blue) Departures
Channel Option 4
Runs 64-66



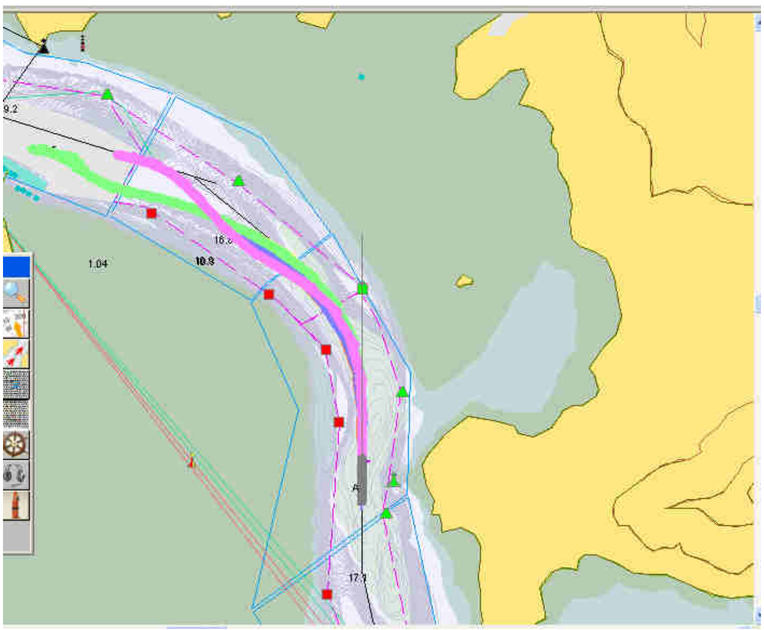
Track Envelope 7: SML and GL (SML in light blue) Arrival
Channel Option 4 - Runs 67-69



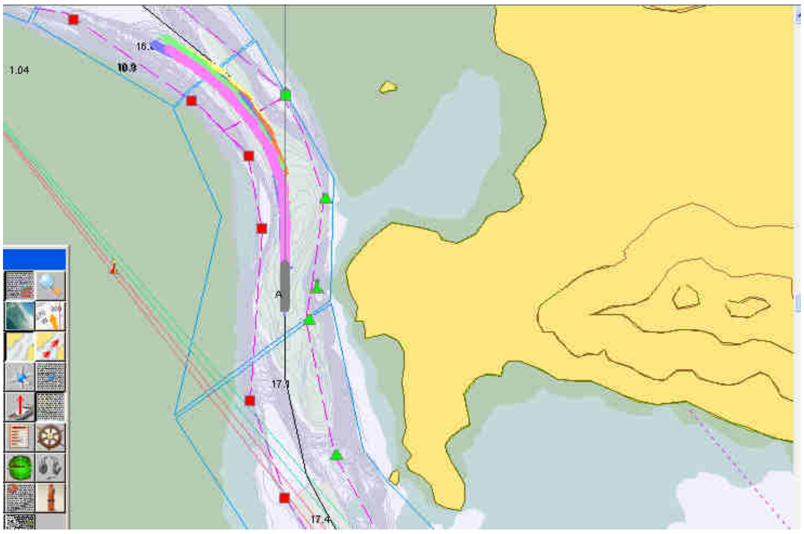
Track Envelope 8: SML and SMP (SML is the pink track) Arrivals
Channel Option 2 - Runs 75-76



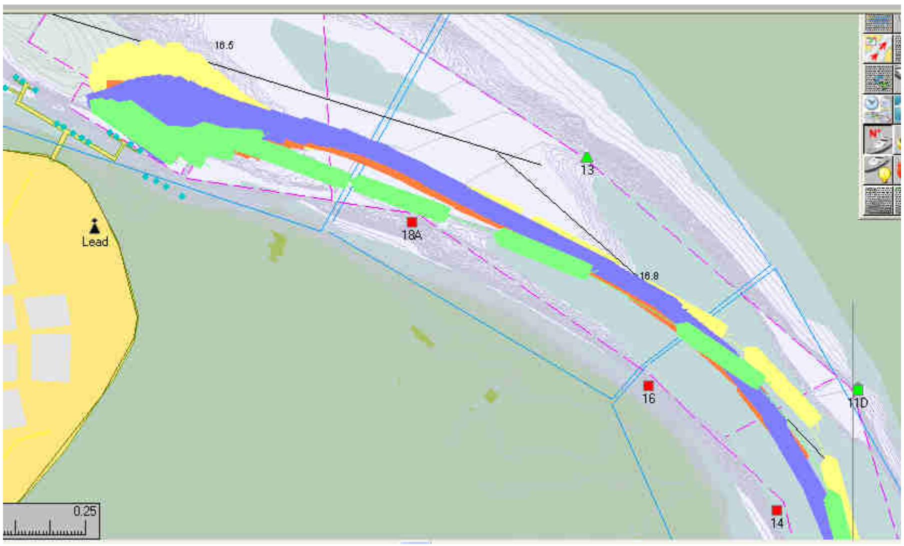
Track Envelope 9: SML Arrivals
Vicinity of Buoy 14 with Emergency
Channel Option 4
Runs 84-89



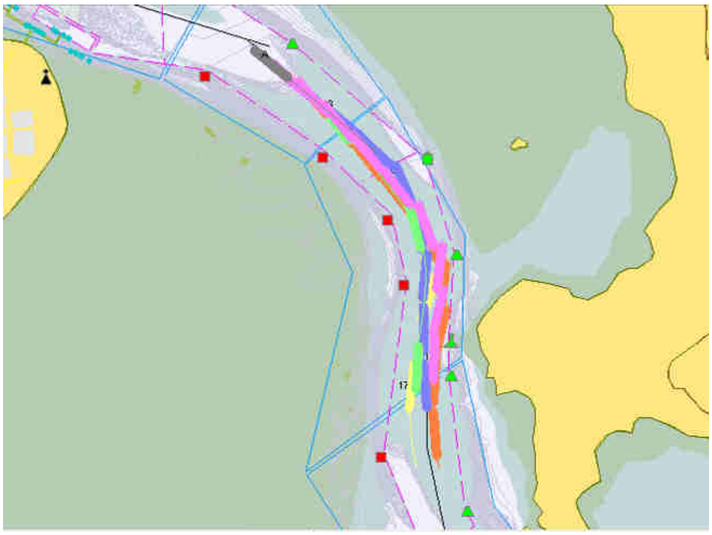
Track Envelope 10 SML Arrivals
Vicinity Buoy 14 Channel Option 4-2
Runs 105-109



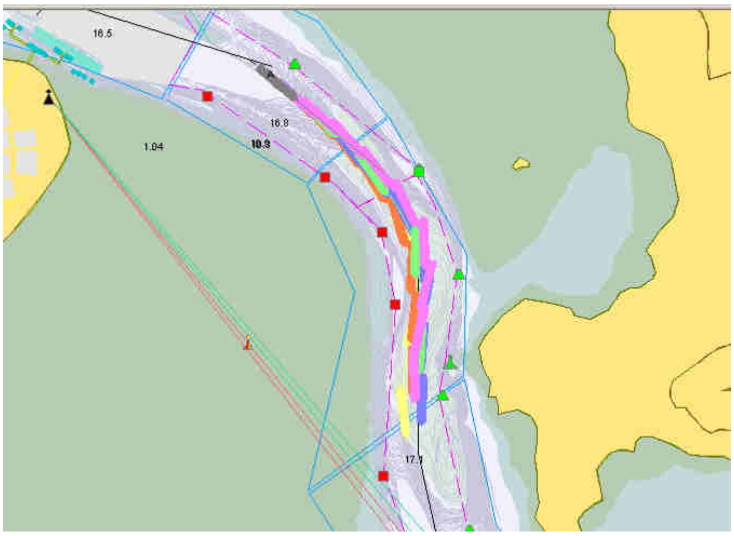
Track Envelope 11 SML Arrivals
Vicinity Buoy 14 Channel Option 4-2
Runs 111-115



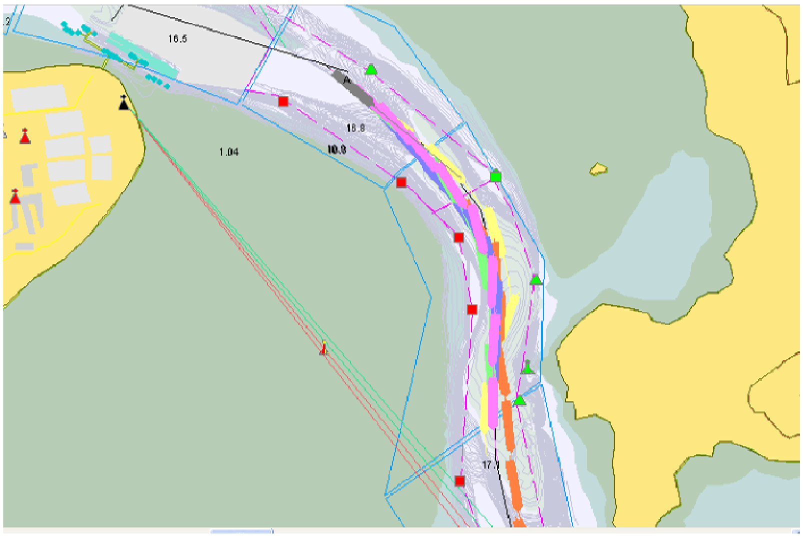
Track Envelope 12 SML Arrivals
Vicinity Buoy 14 to Berth Pocket Channel Option 5
Runs 118-122



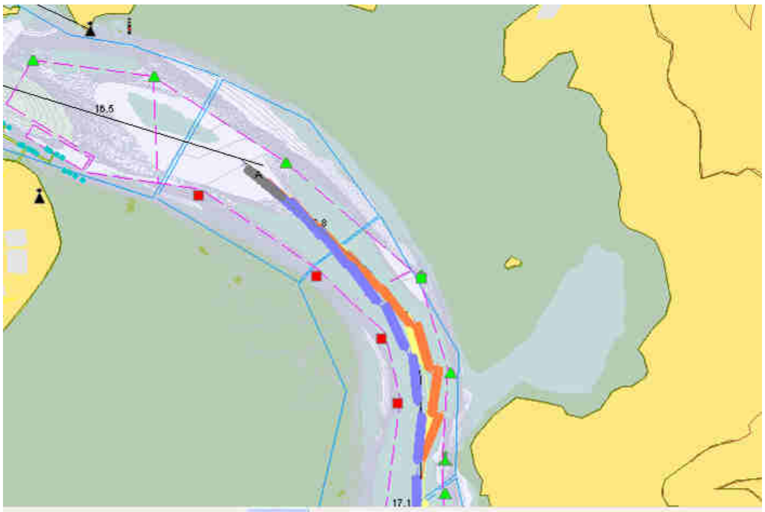
Track Envelope 13 SMB Departures
Vicinity Buoy 13 to Buoy 7 Channel Option 5
Runs 126-130



Track Envelope 14 SMB Departures
Vicinity Buoy 13 to Buoy 7 Channel Option 4-2
Runs 131-135



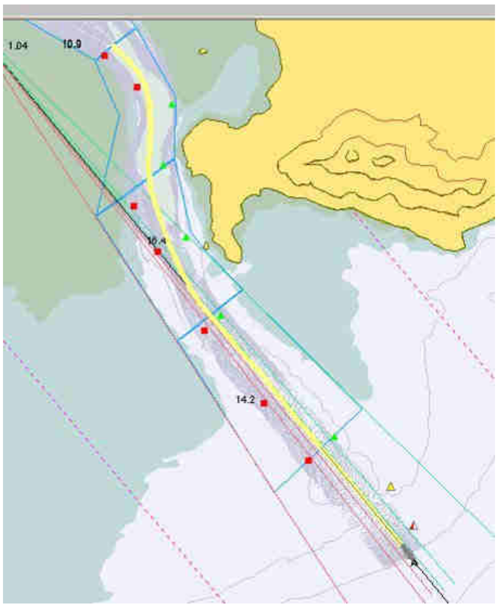
Track Envelope 15 SMB Departures
Vicinity Buoy 13 to Buoy 7 Channel Option 4-2
Runs 136-140



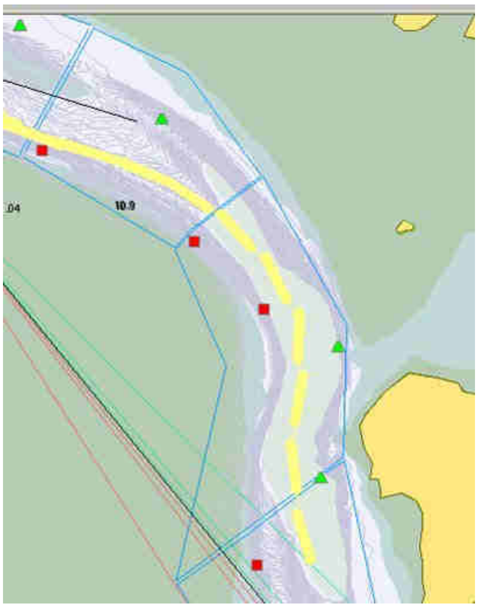
Track Envelope 16 SMB Departures
Vicinity Buoy 13 to Buoy 7 Channel Option 5
Runs 141-143

APPENDIX 4 SIMULATION RUN SUMMARY

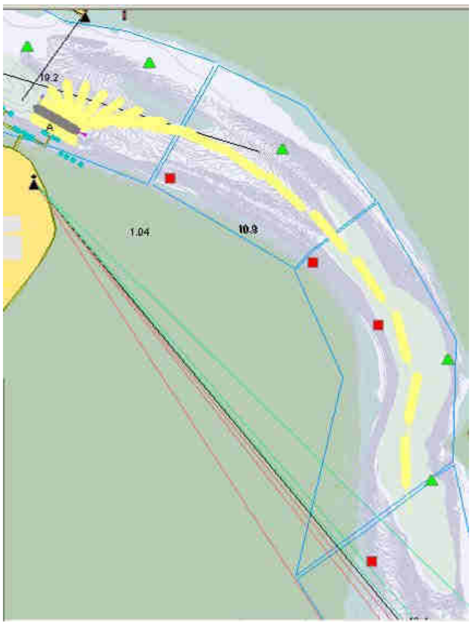
APPENDIX 5: RUN PLOTS



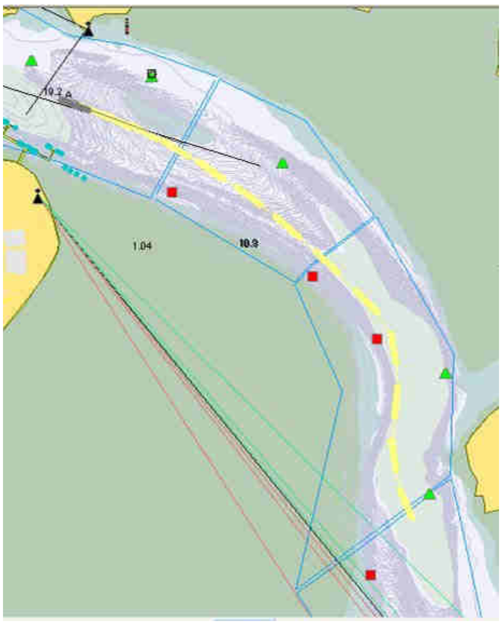
Run 001



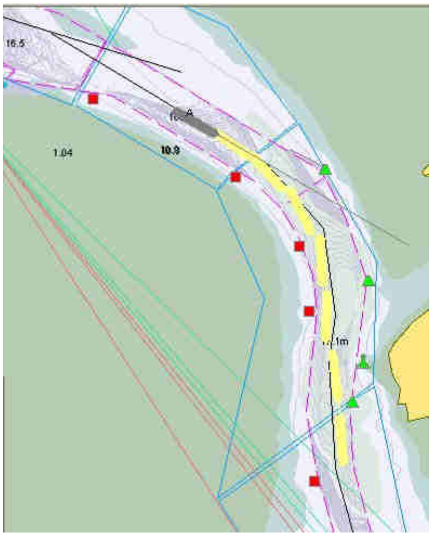
Run 002



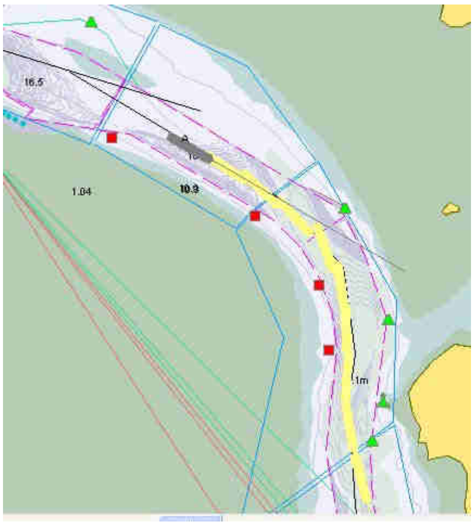
Run 003



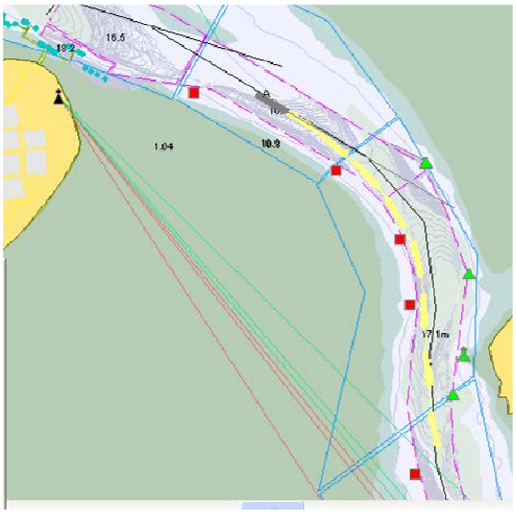
Run 004



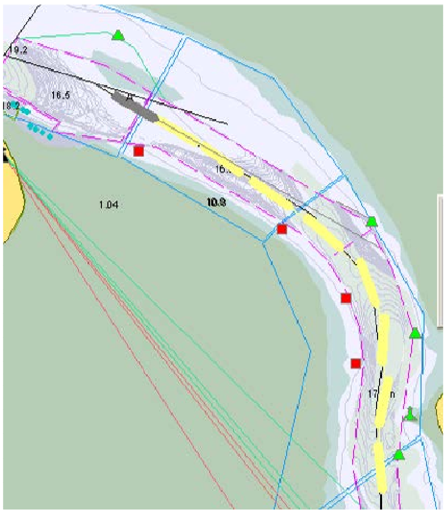
Run 005



Run 007

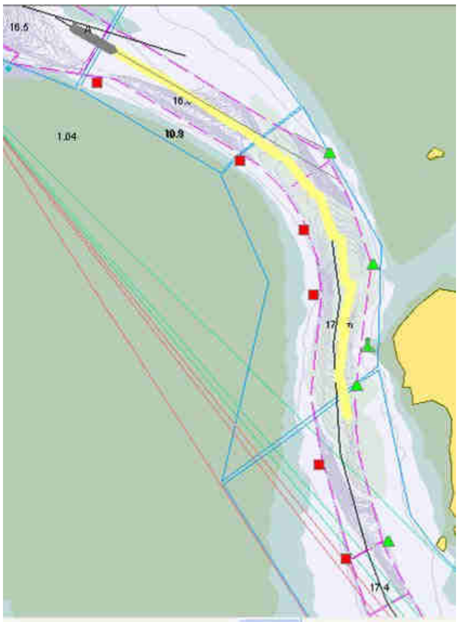


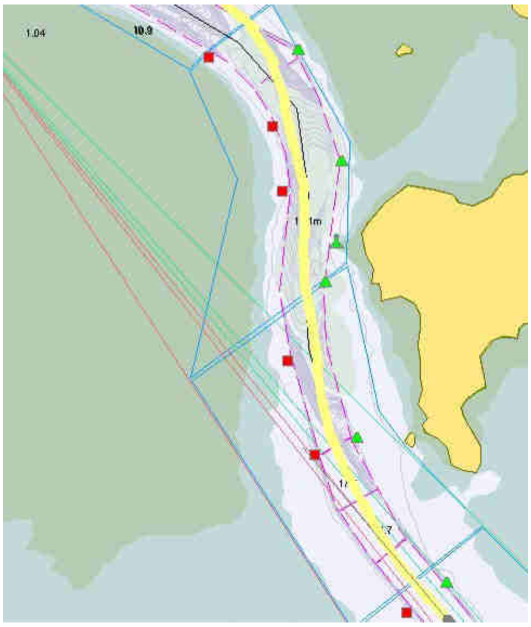
Run 009



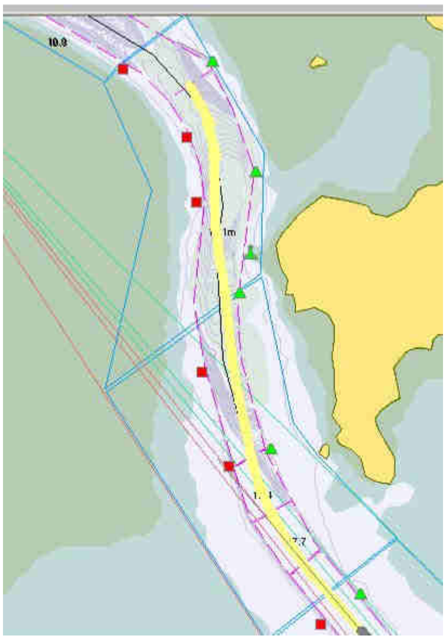
Run 010

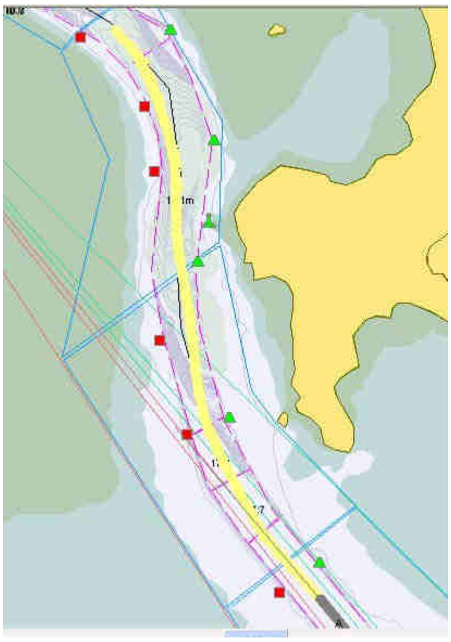
Note: see avi files for runs 6 and 8



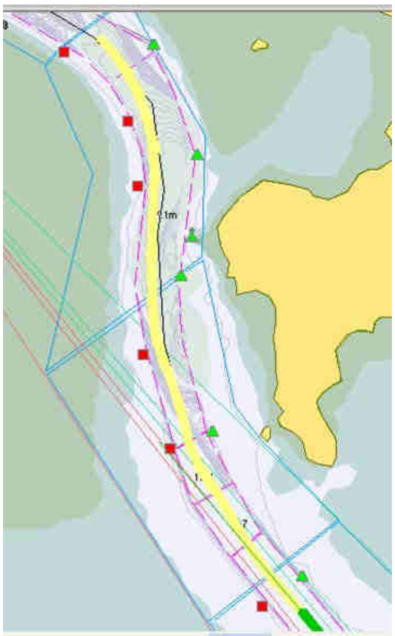


Run 011 **Run 012**

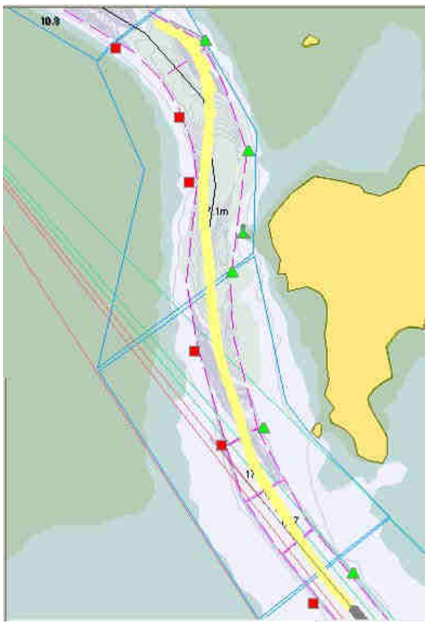




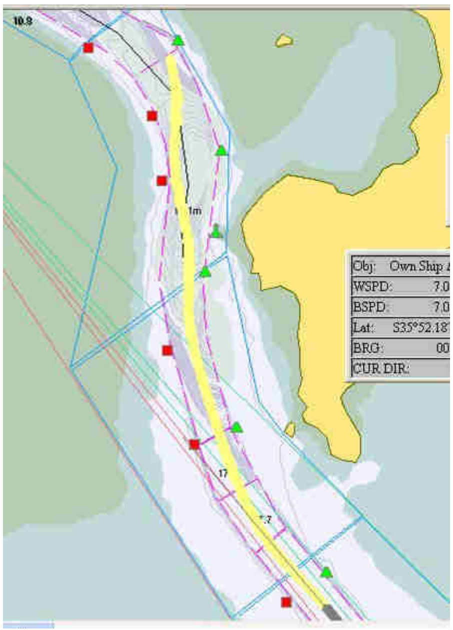
Run 013 **Run 014**



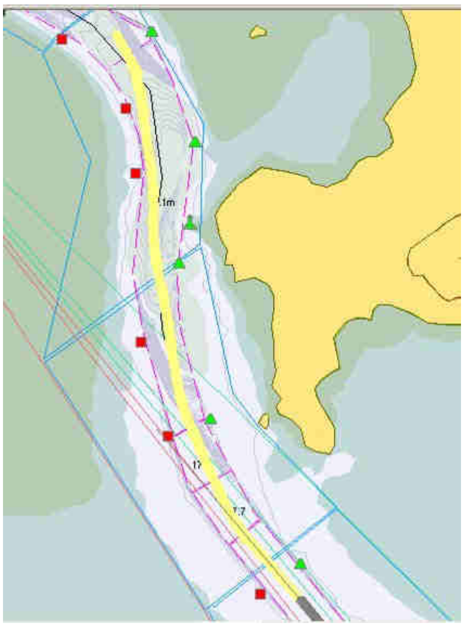
Run 015



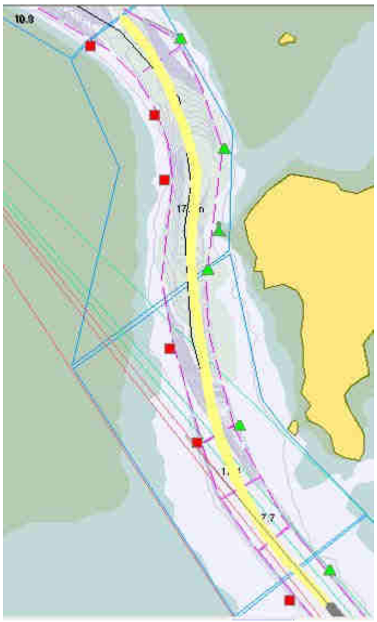
Run 016



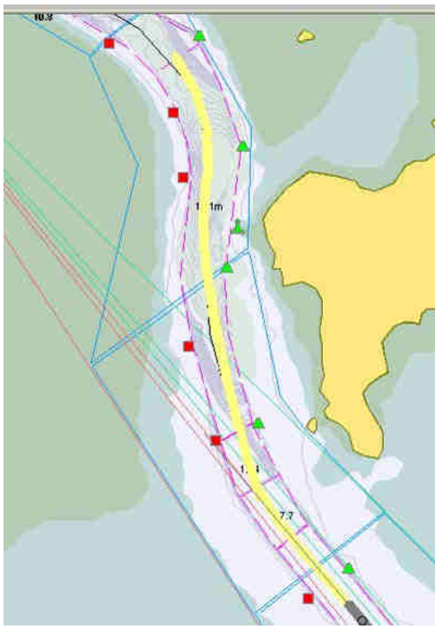
Run 017



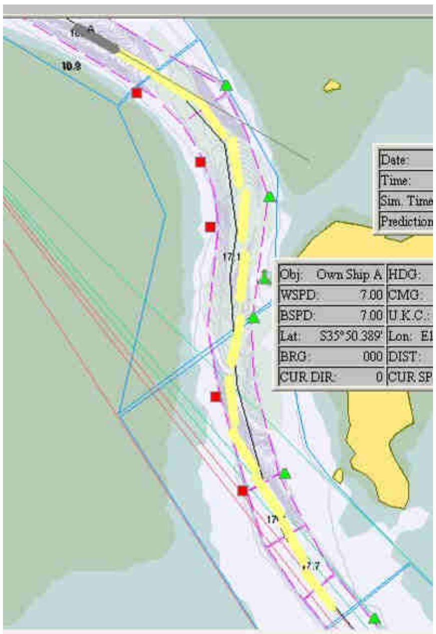
Run 018



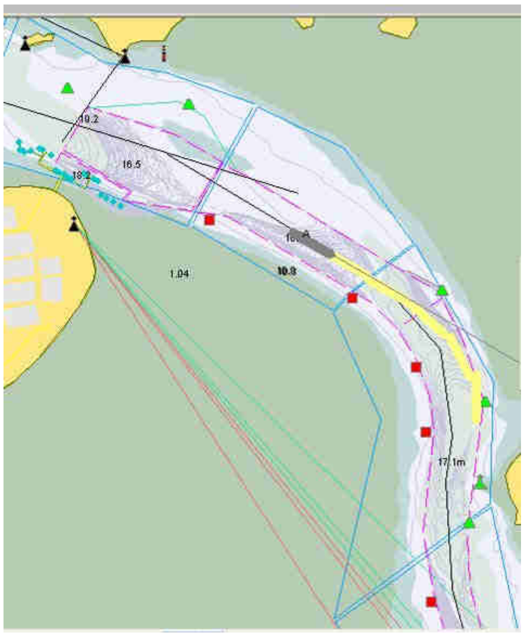
Run 019



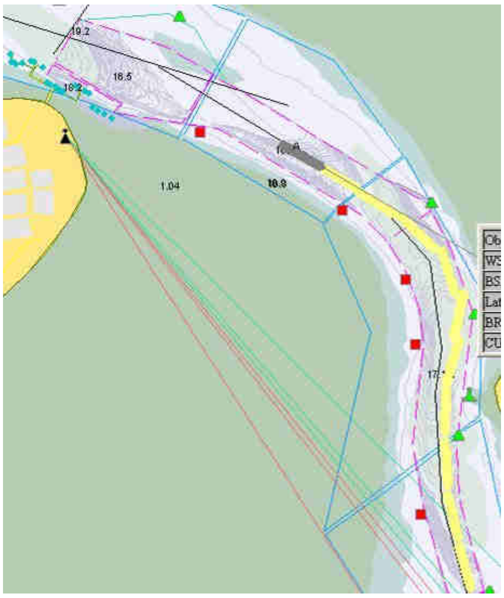
Run 020



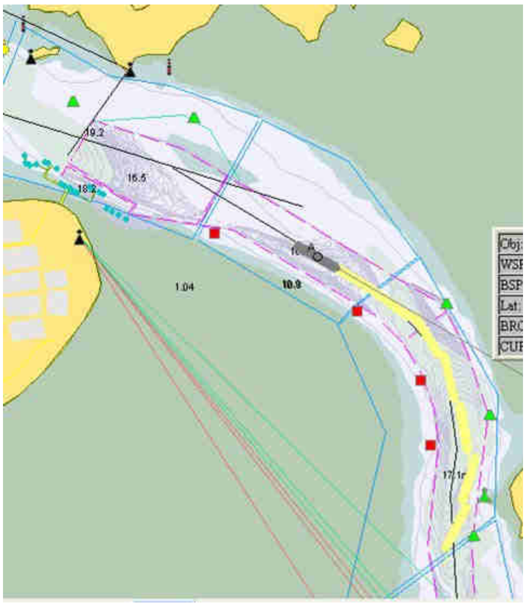
Run 021



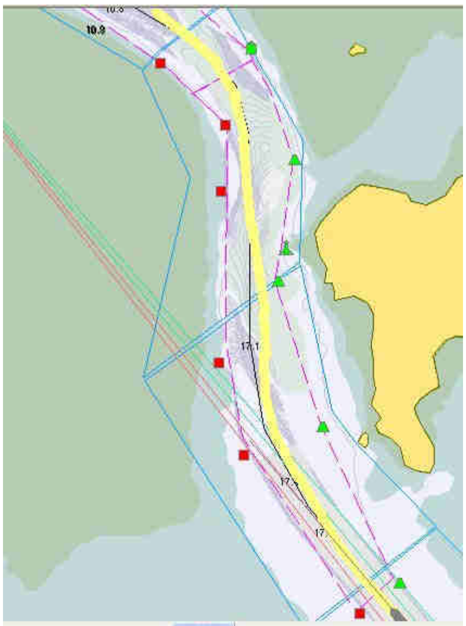
Run 022



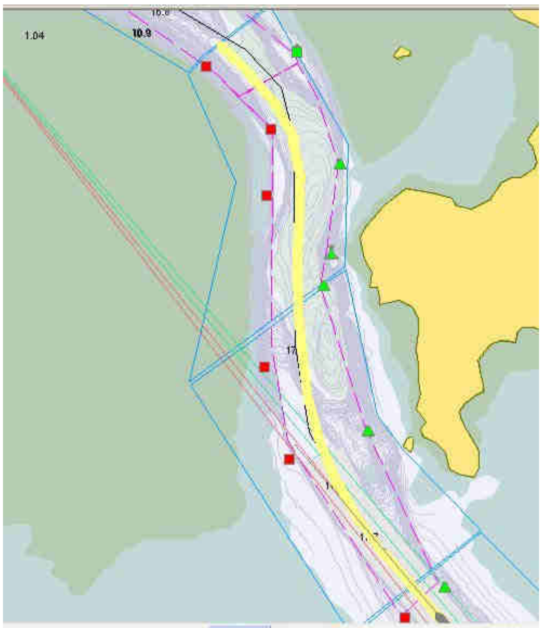
Run 023



Run 024



Run 025



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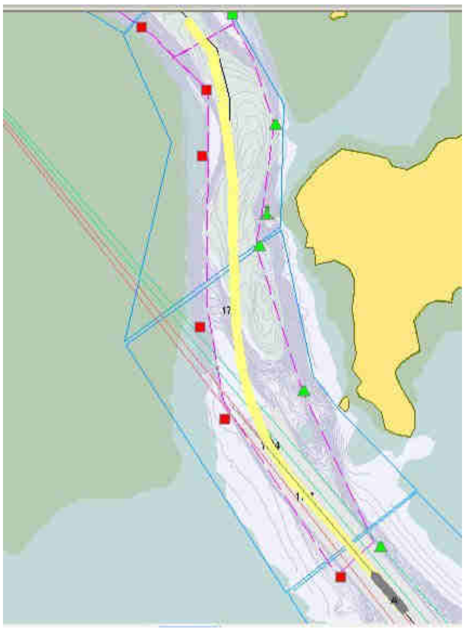

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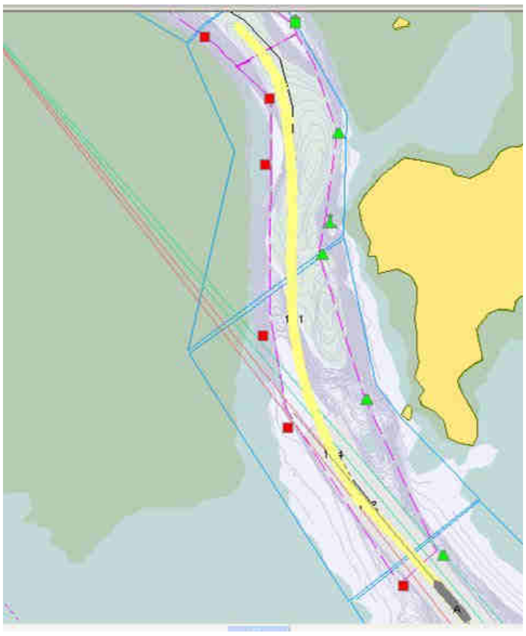

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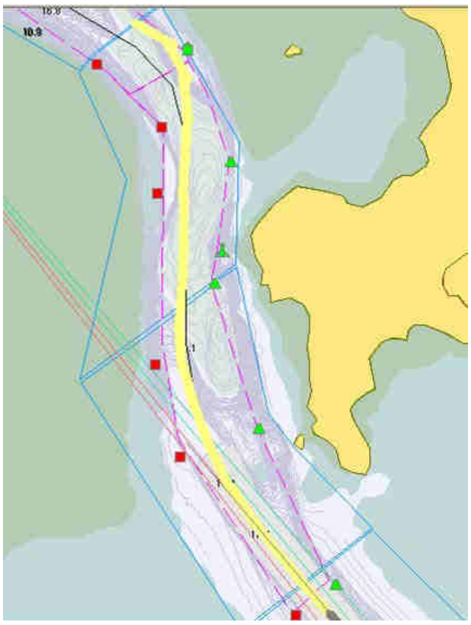

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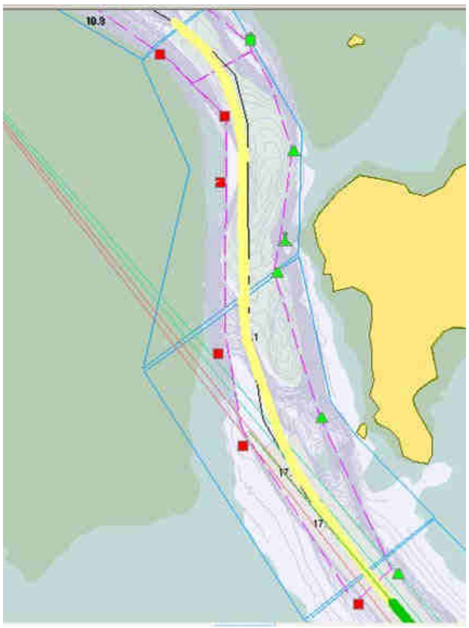
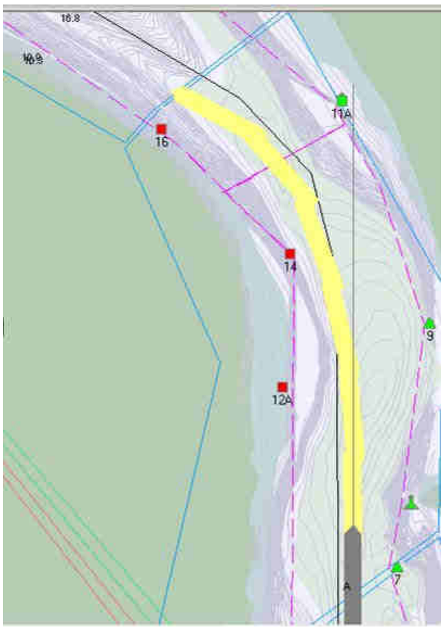
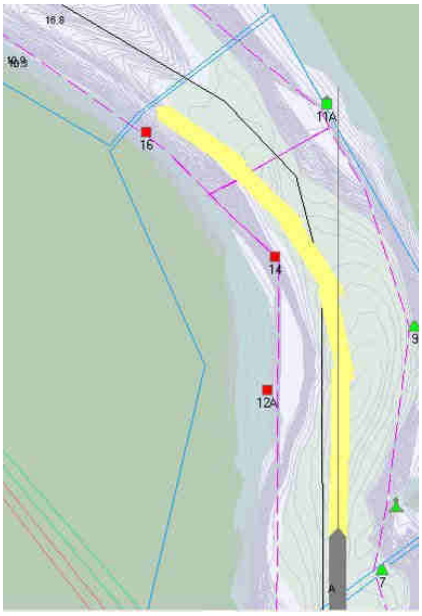


Run 030

Run 031



Run 032



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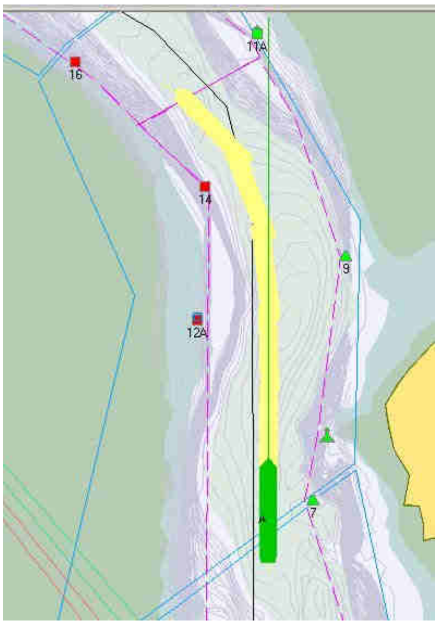

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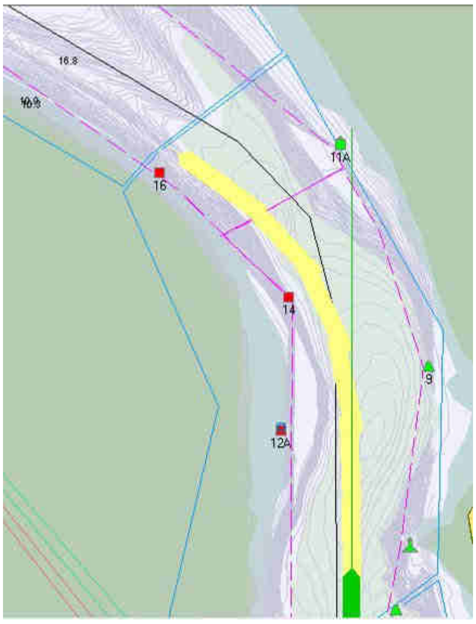

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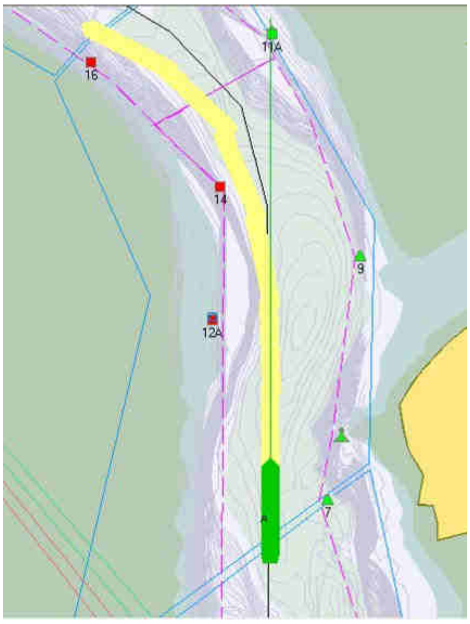

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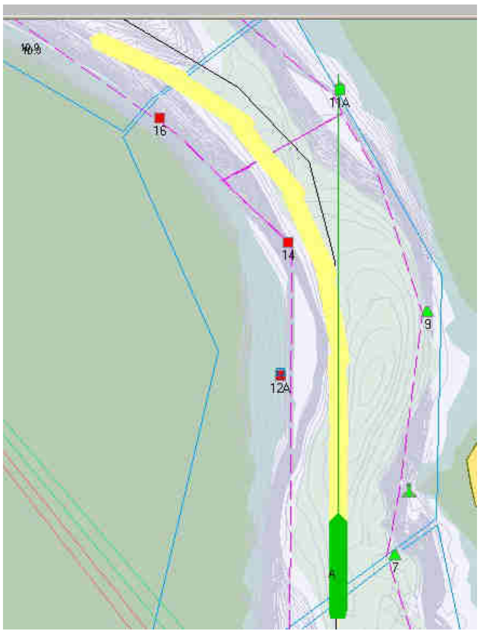

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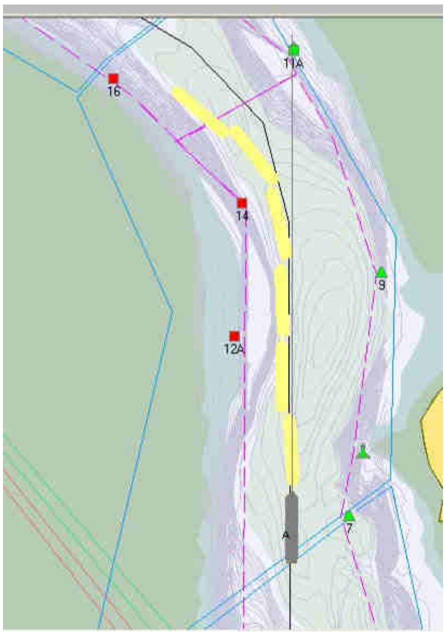
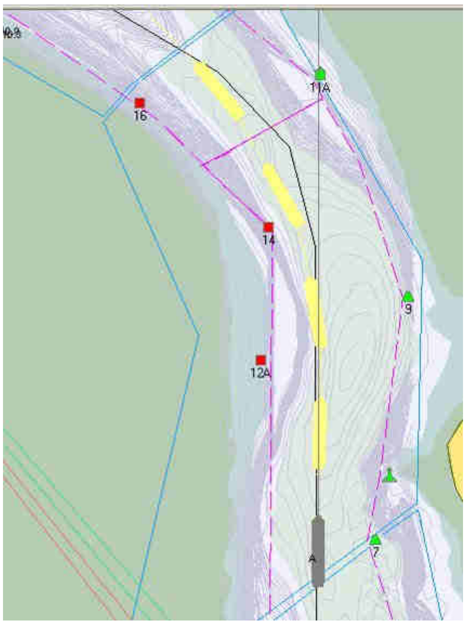


Run038

Run 039



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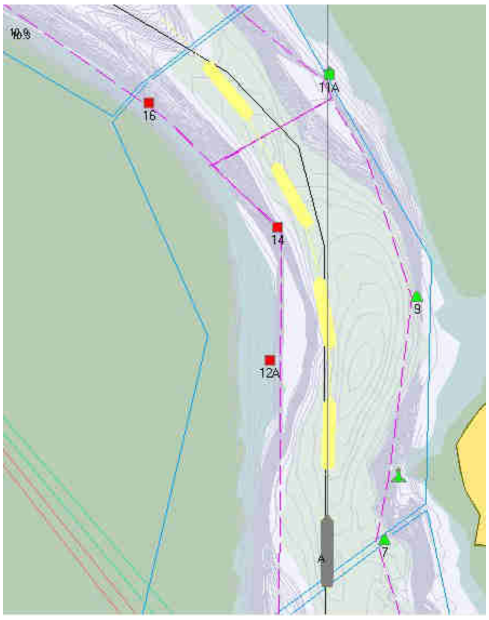

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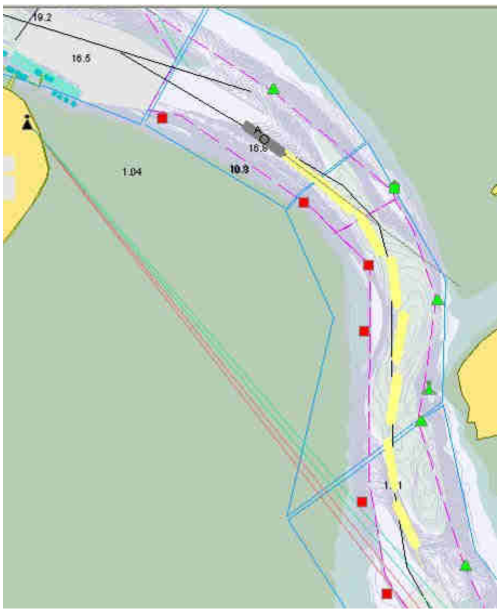

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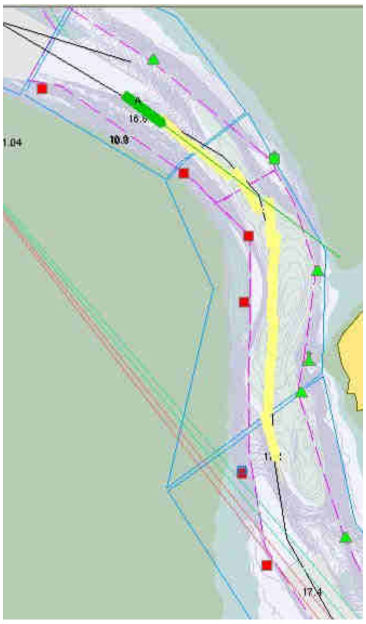

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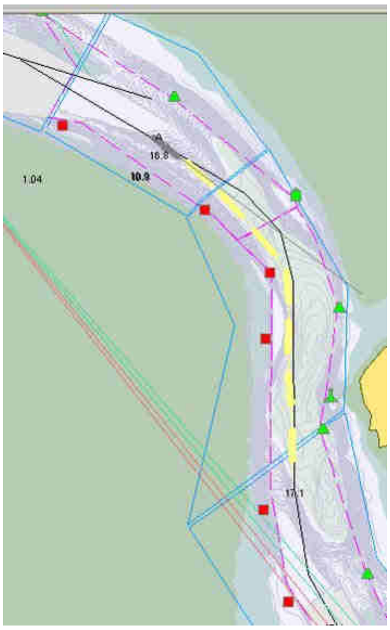
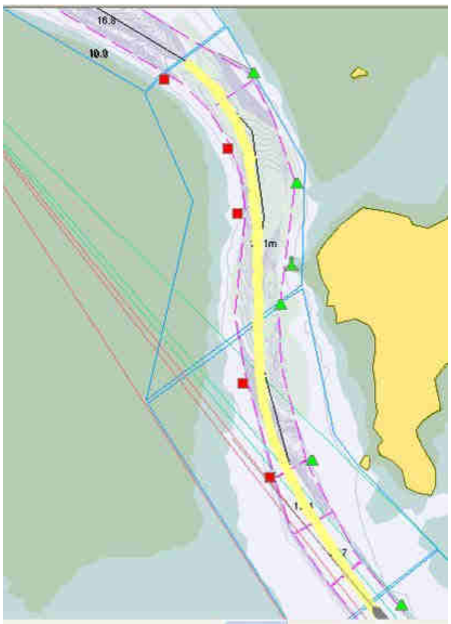


Run044

Run 045



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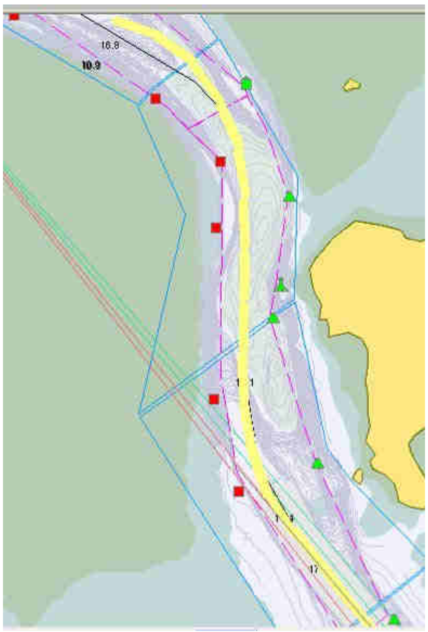

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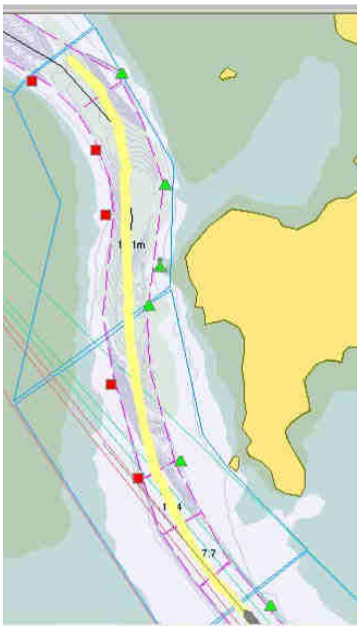
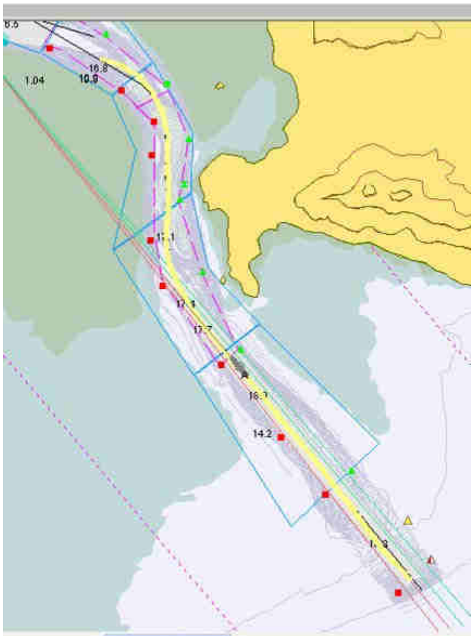
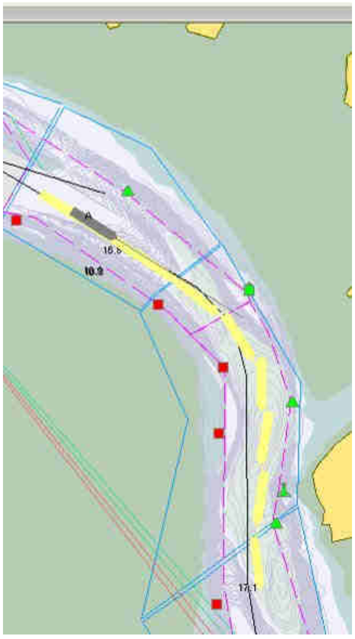


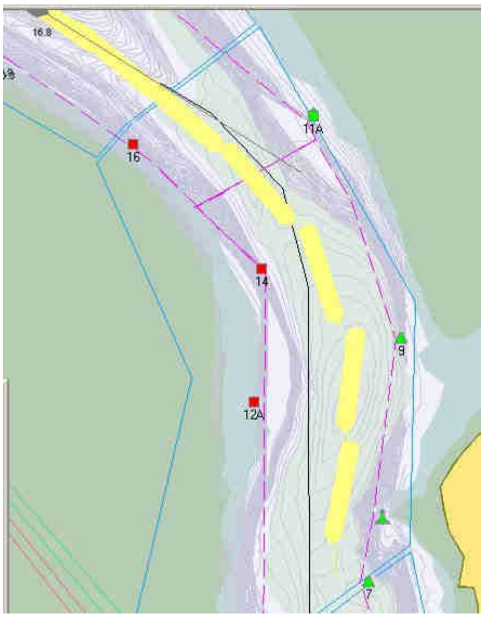
Run 048



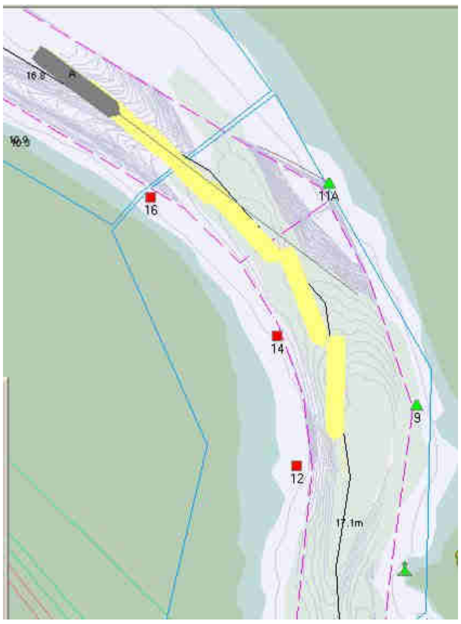
Run 049



Run 050



Run 051



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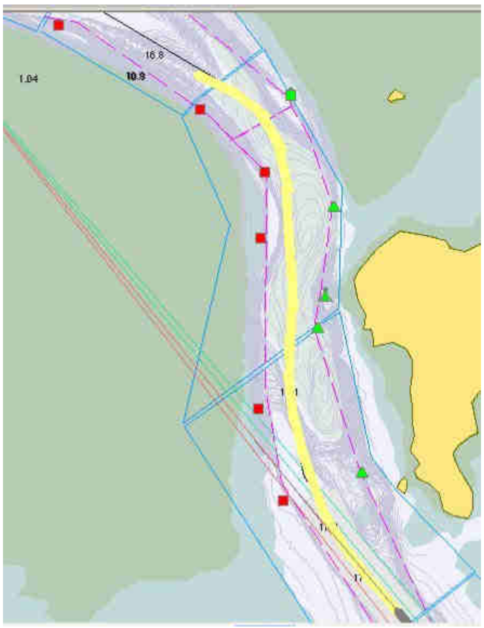

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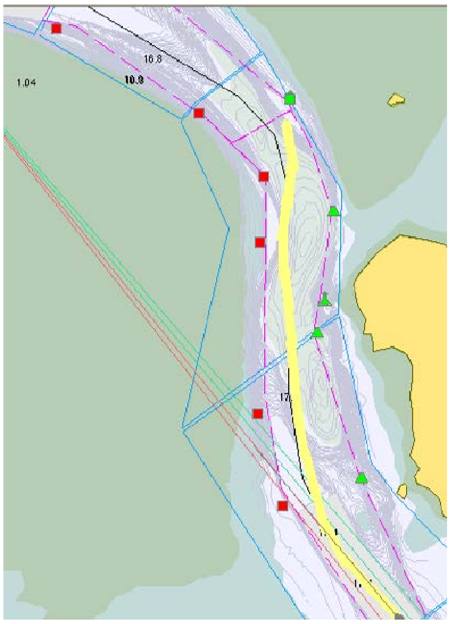

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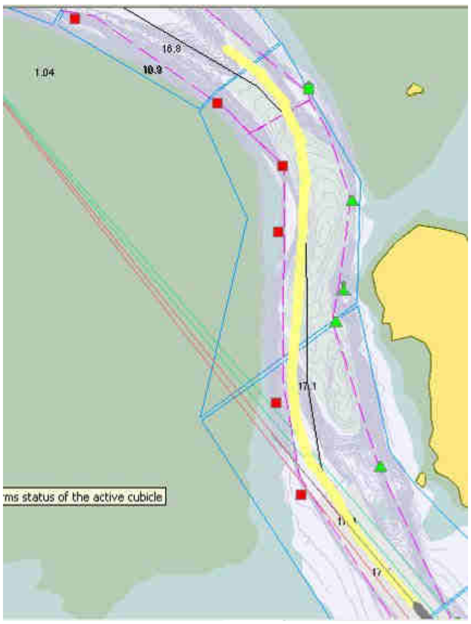

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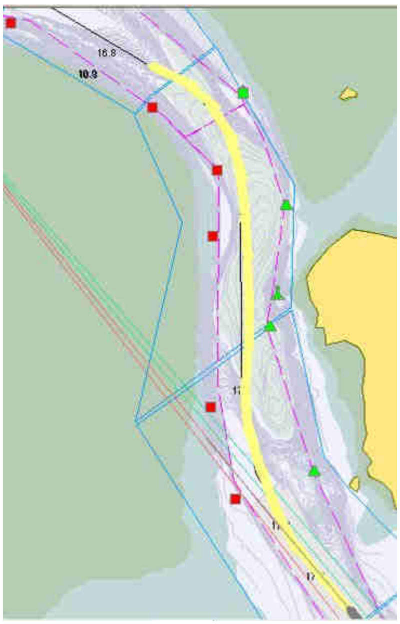
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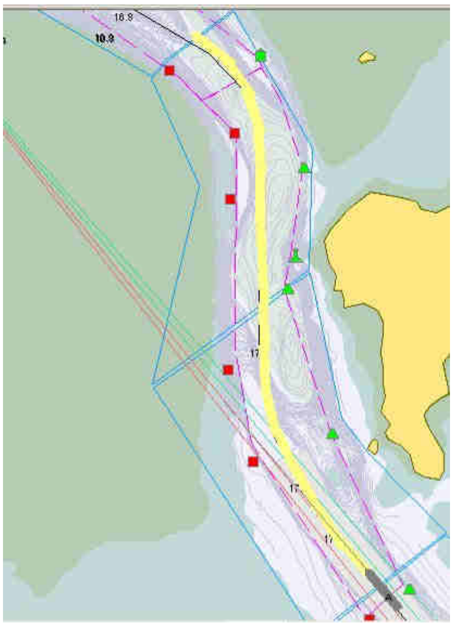
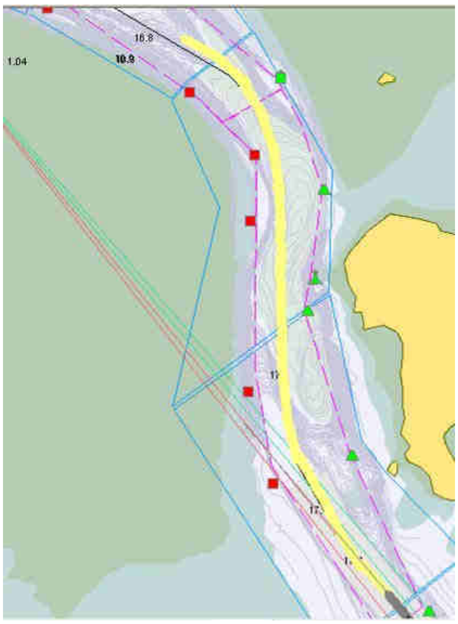
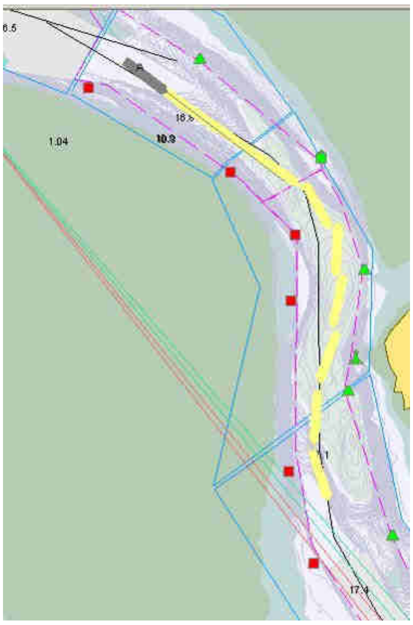
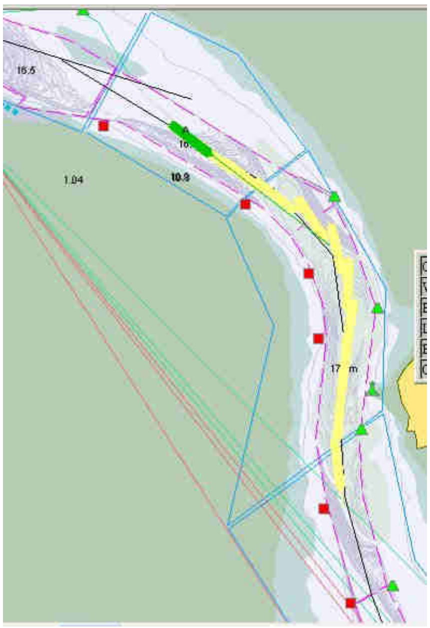
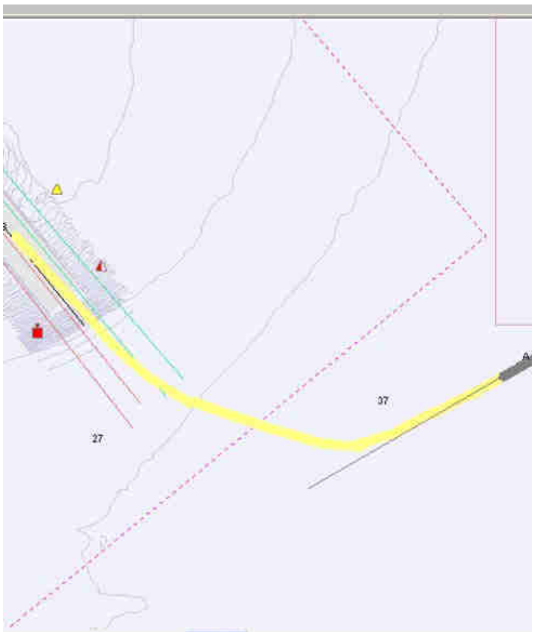

Run 057

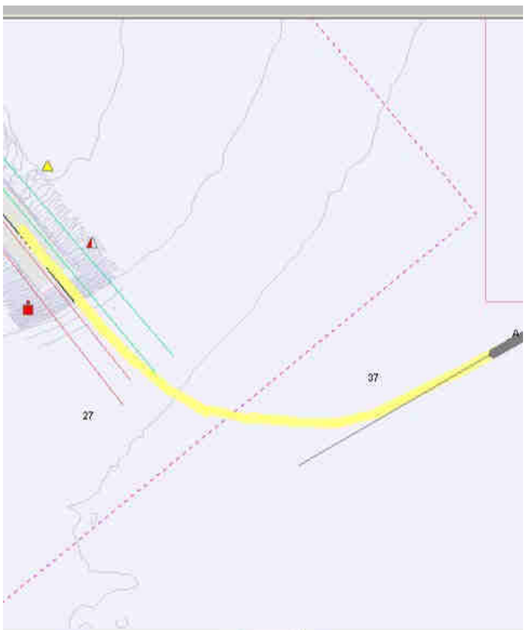

Run 058



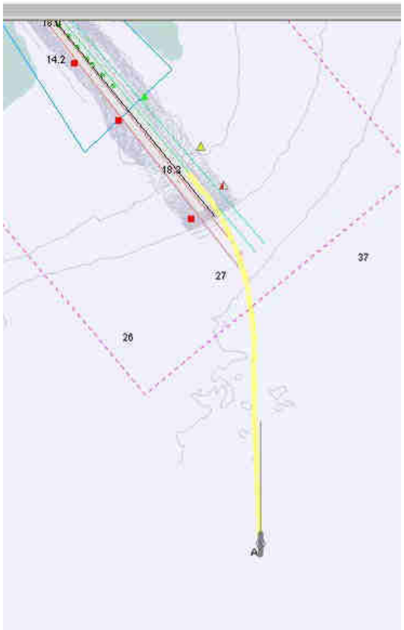


Run 059 **Run 060**

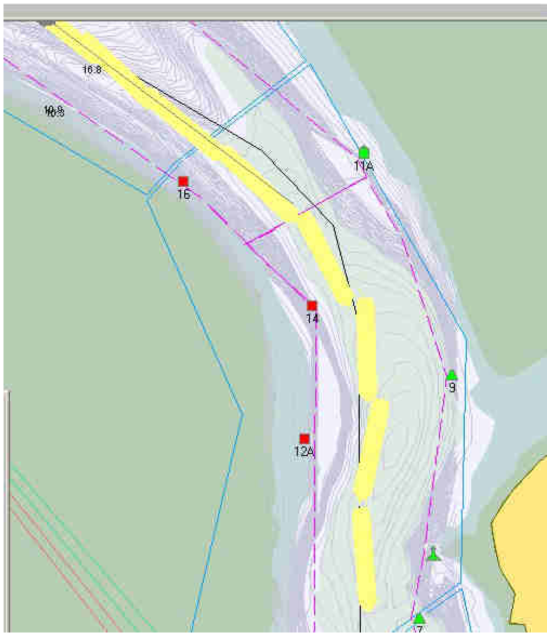




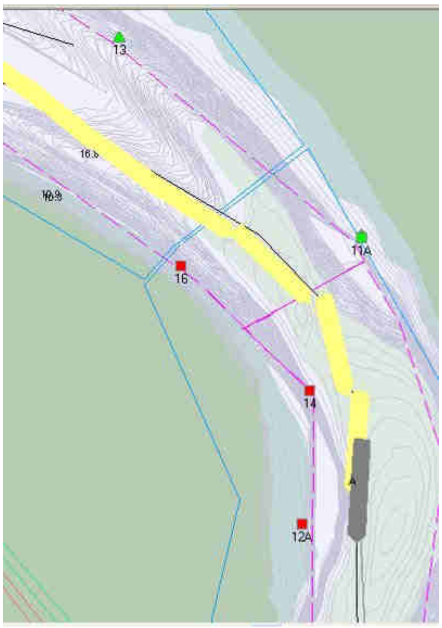
Run 061 **Run 062**



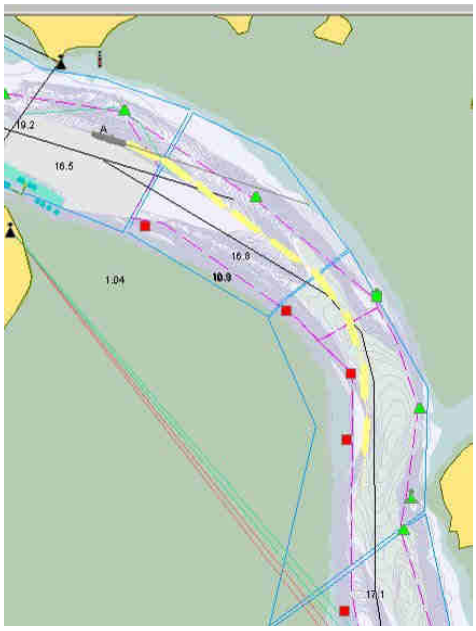
Run 063



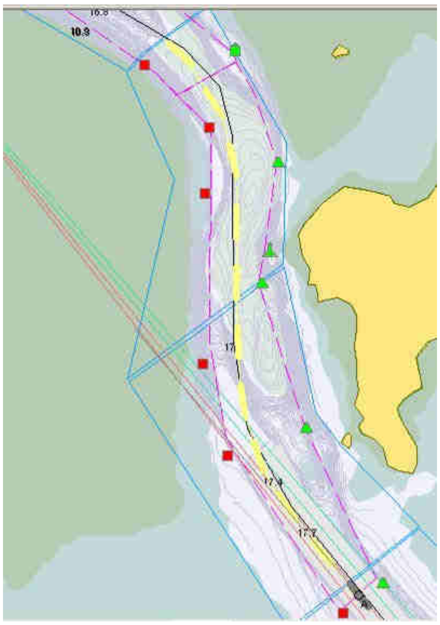
Run 064

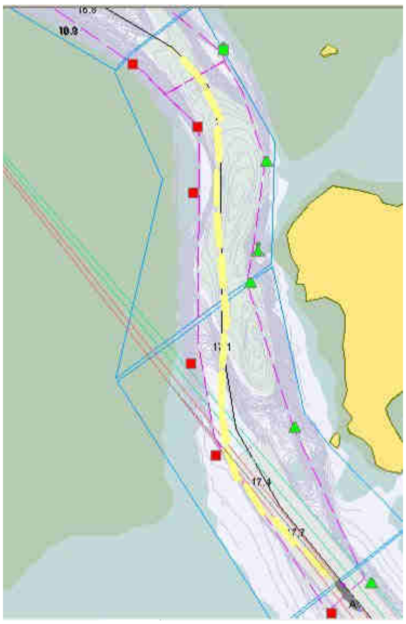


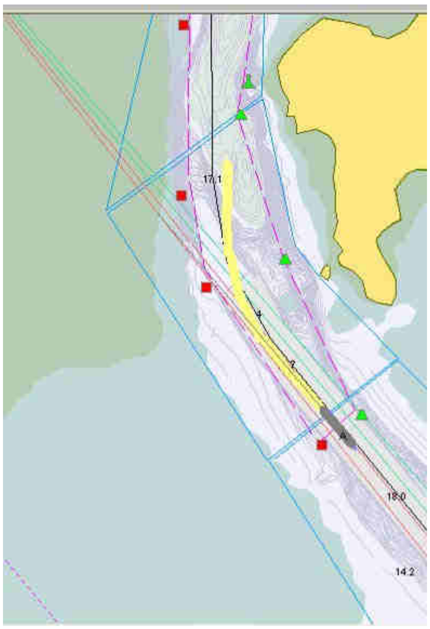
Run 065



Run 066


Run 067


Run 068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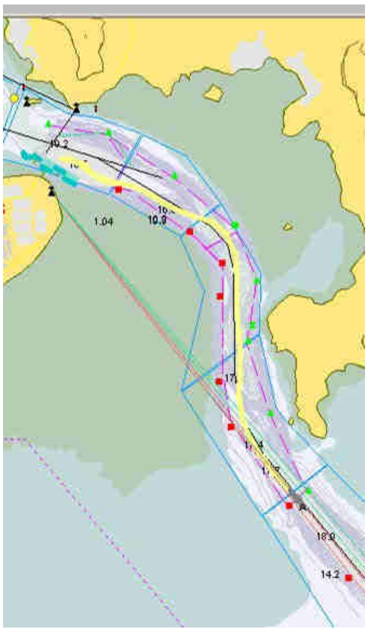
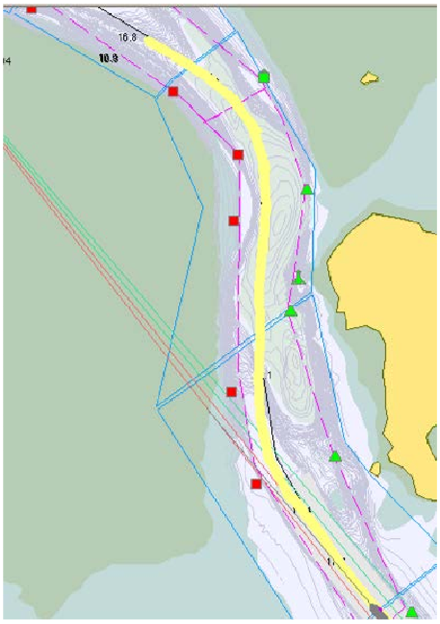
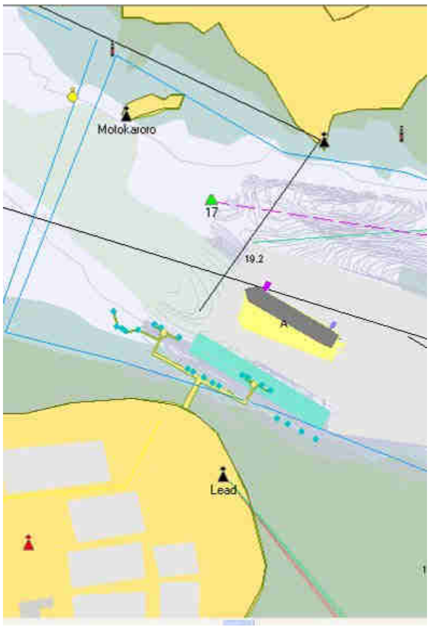
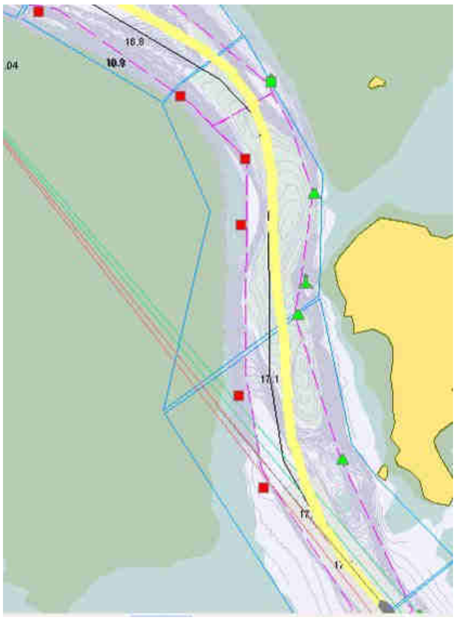

Run 070



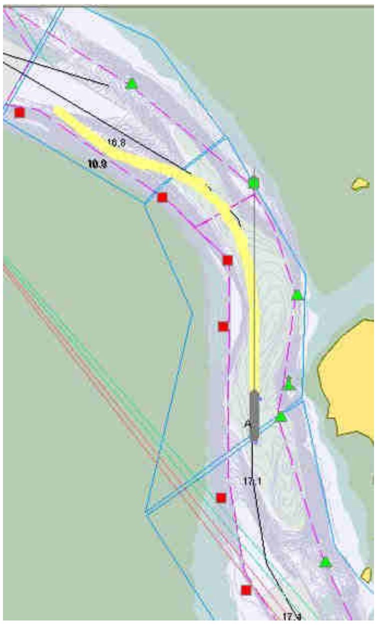
Run 071



Run 072



Run 073



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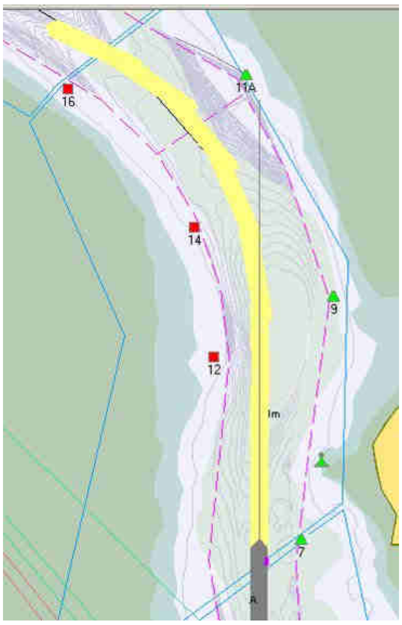
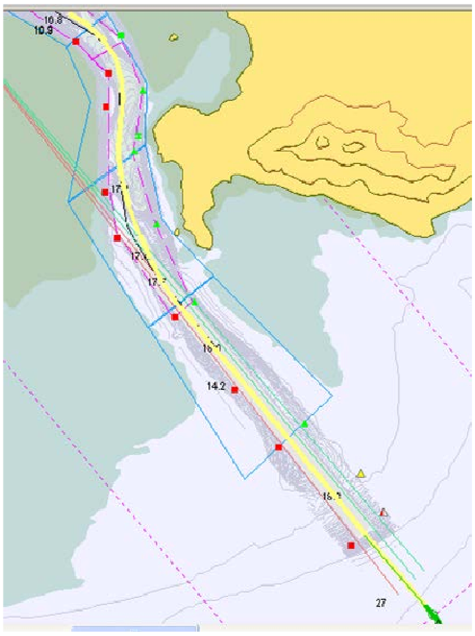
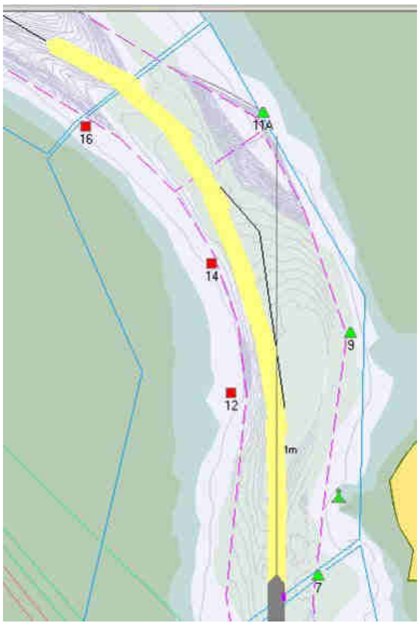


Run 075

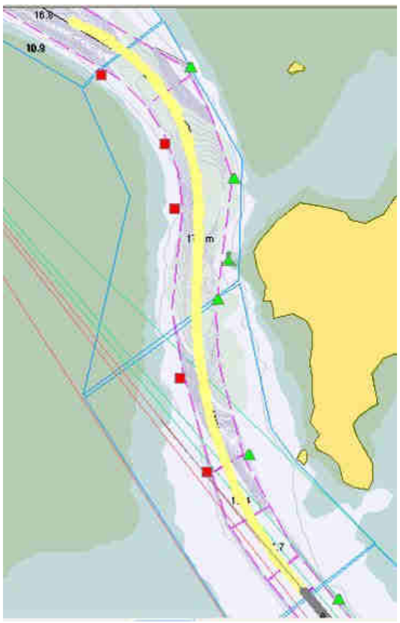
Run 076



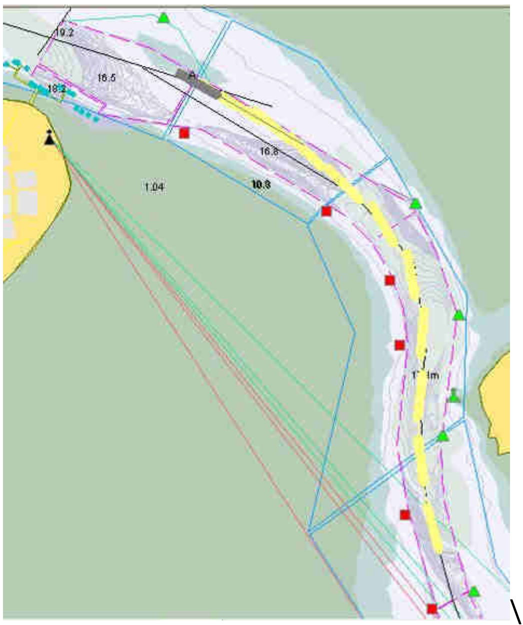
Run 077



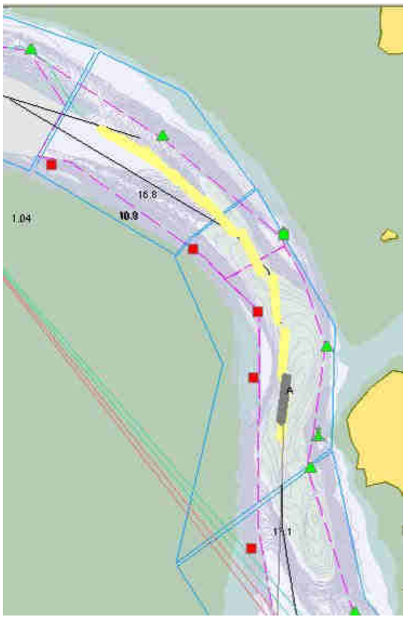
Run 078



Run 079



Run 080



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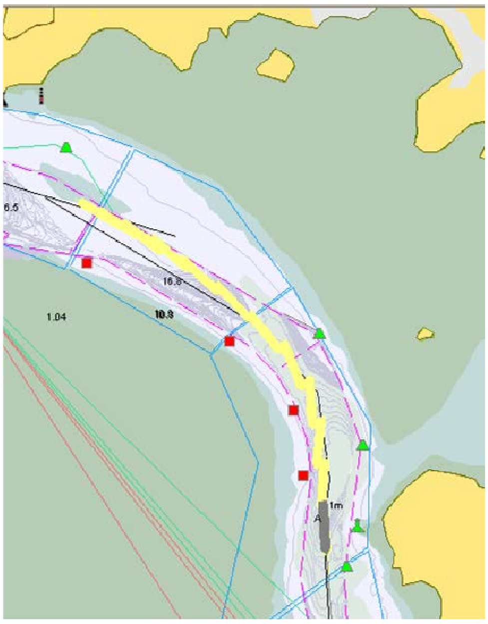
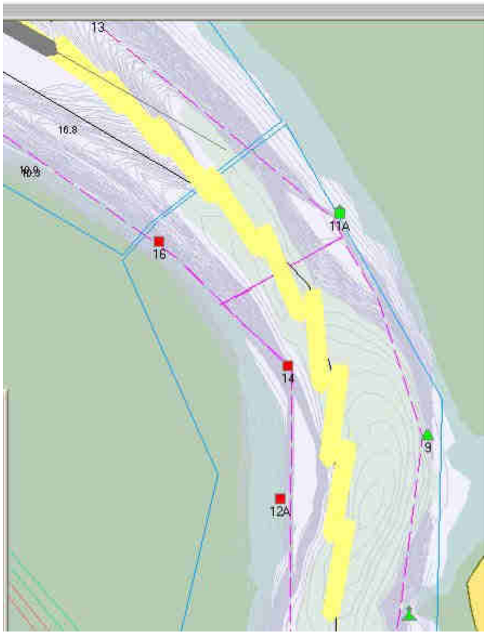
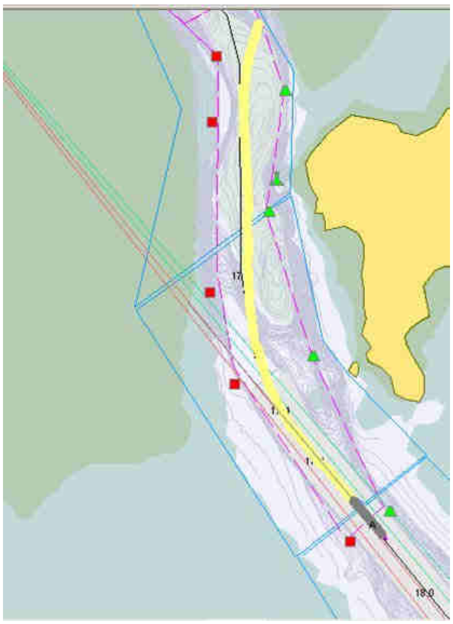


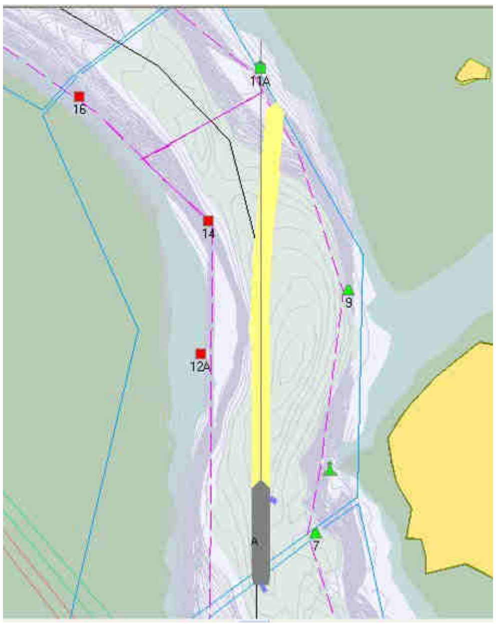
Run 082



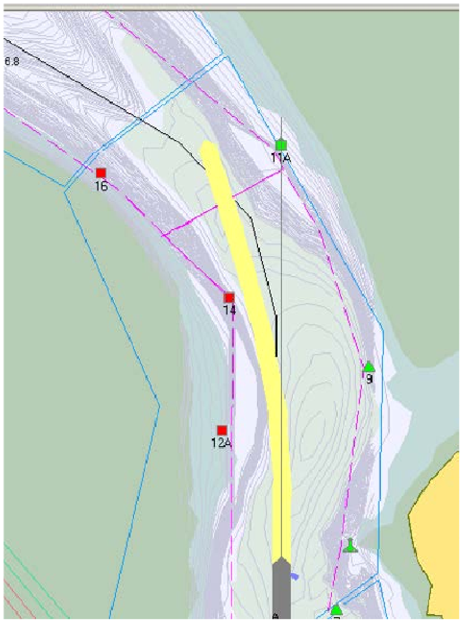
Run 083



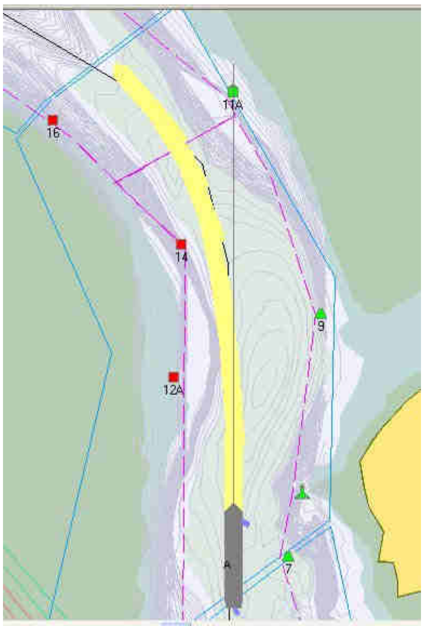
Run 084



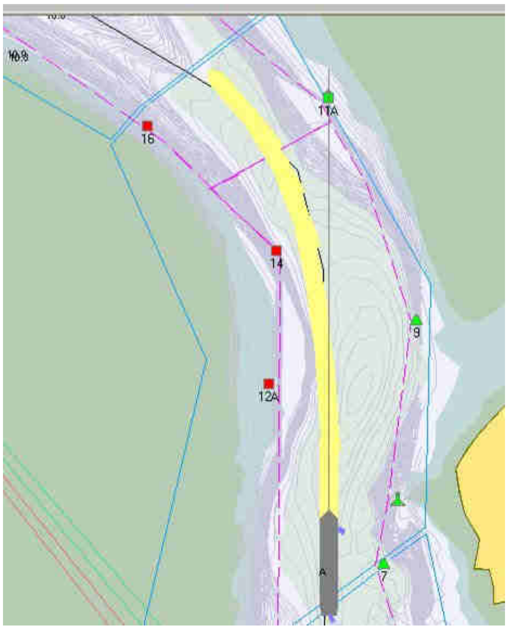
Run 085



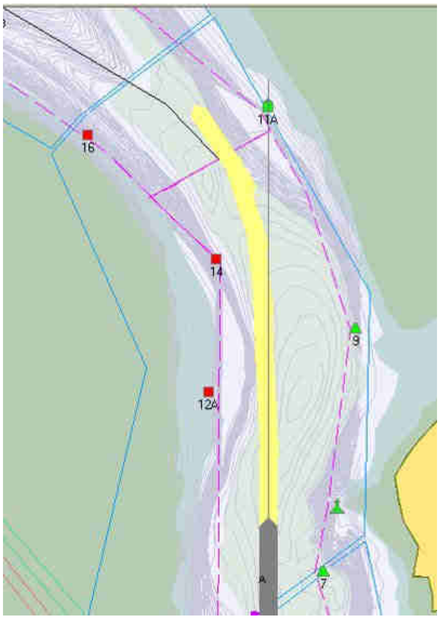
Run 086



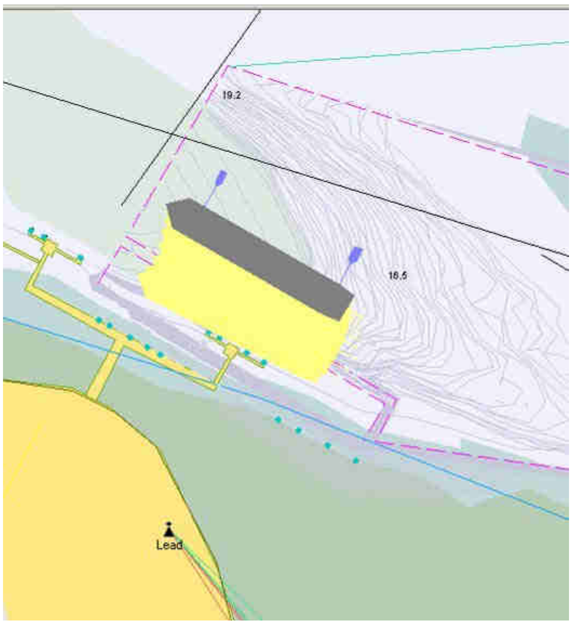
Run 087



Run 088



Run 089



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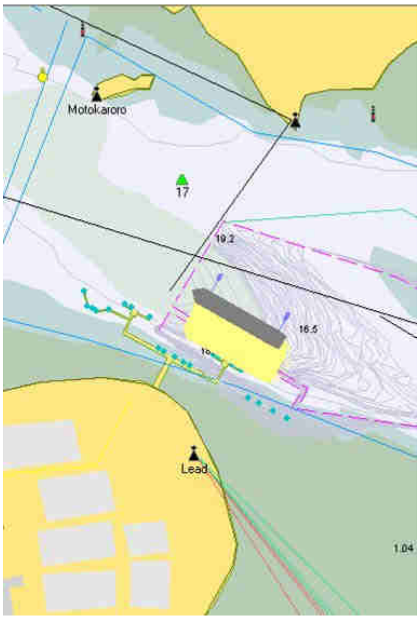
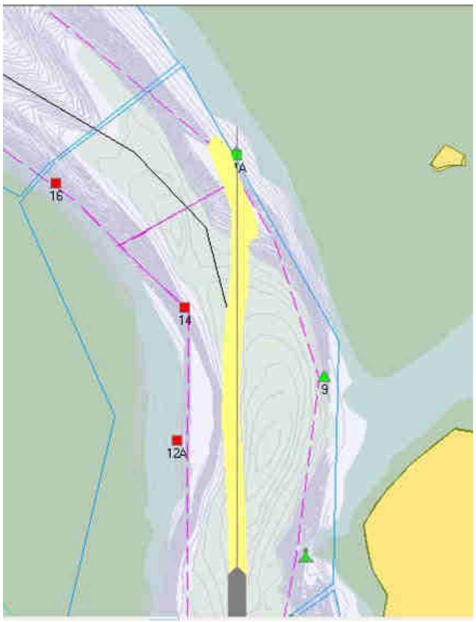
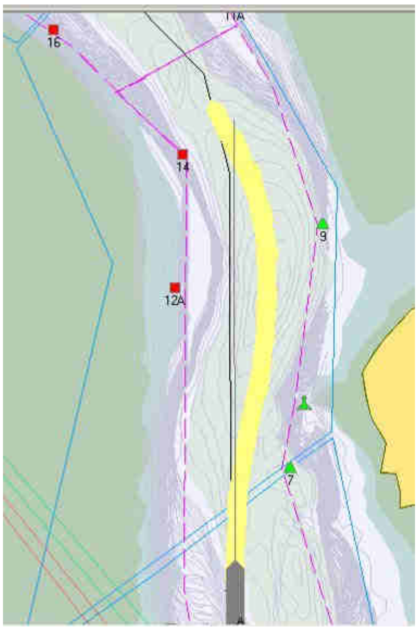


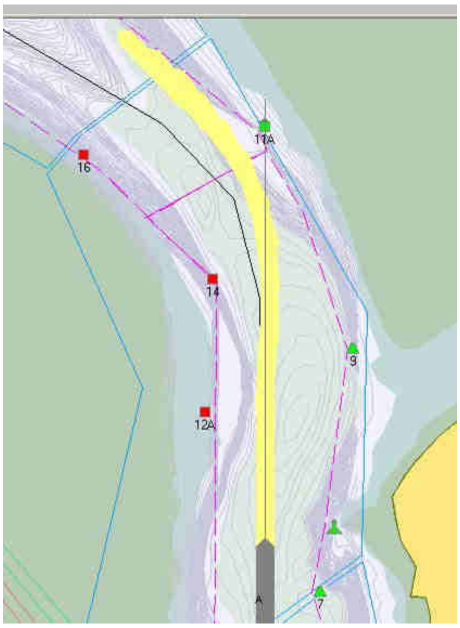
Run 091



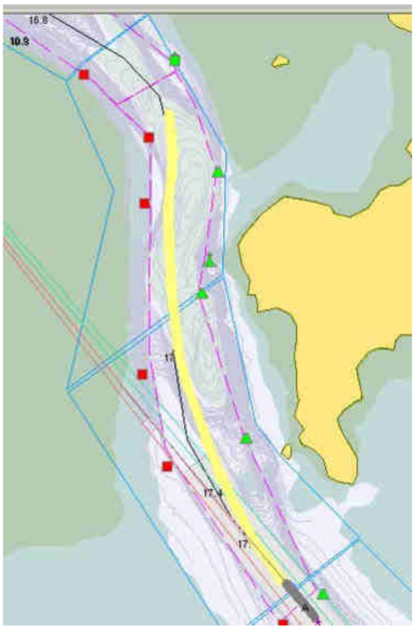
Run 092

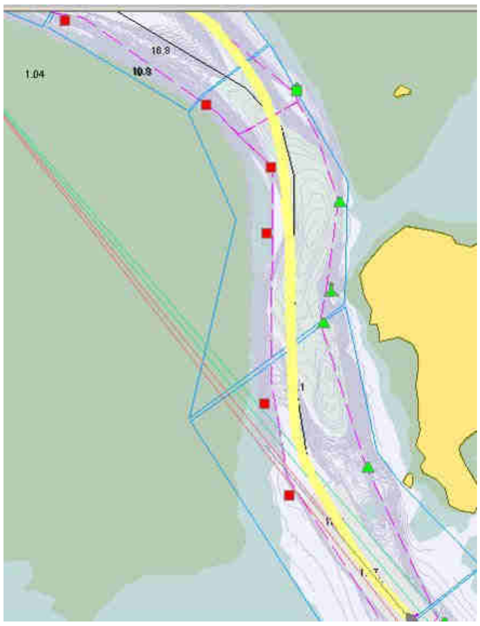


Run 093

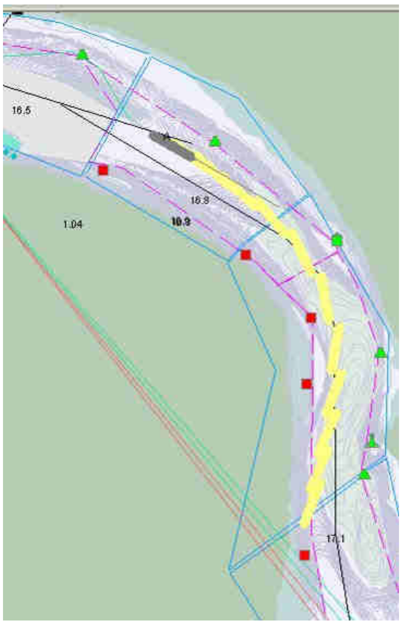


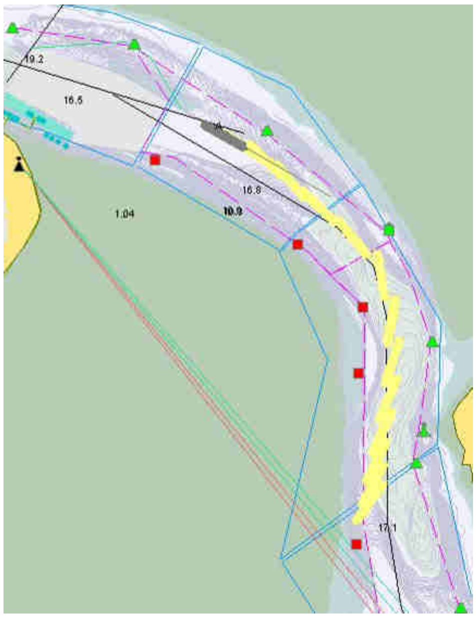
Run 094





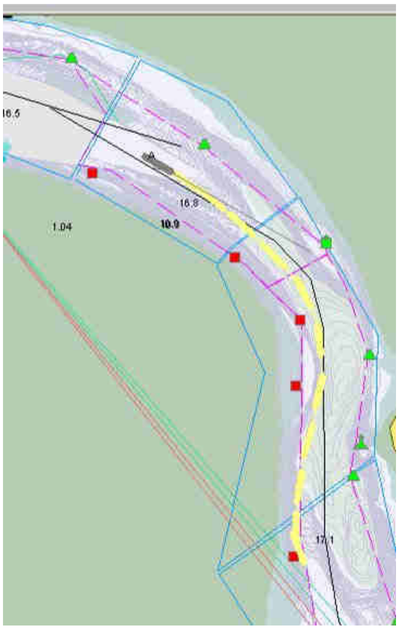
Run 095 **Run 096**





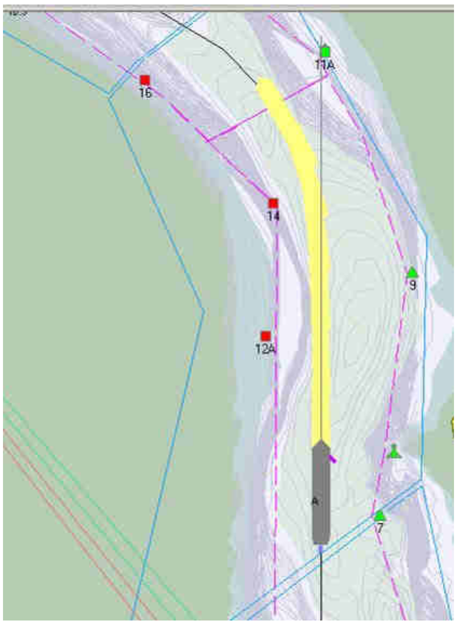
Run 098 **Run 099**

Note: Run 097 not recorded

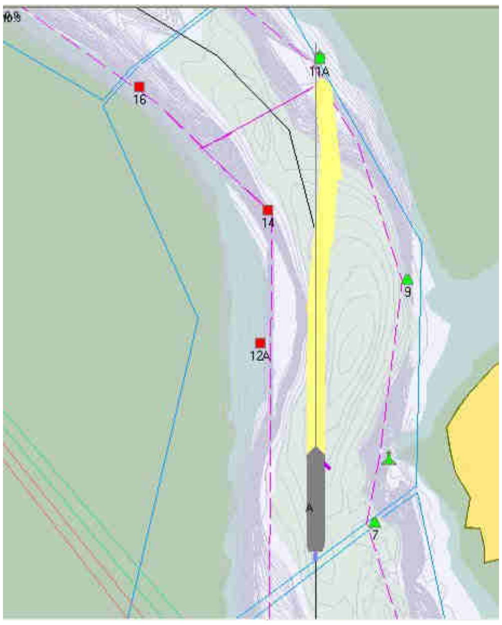


Run 100

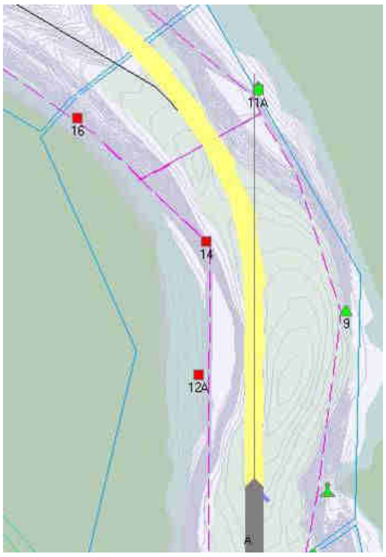
Run 101



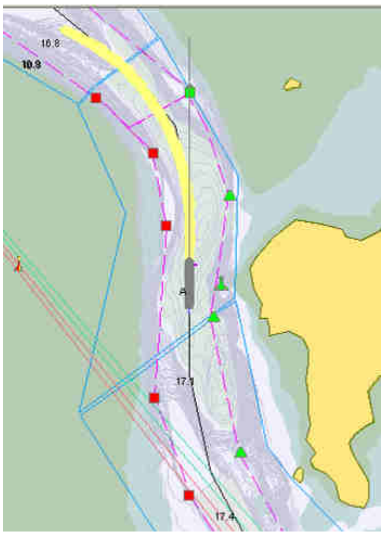
Run 102



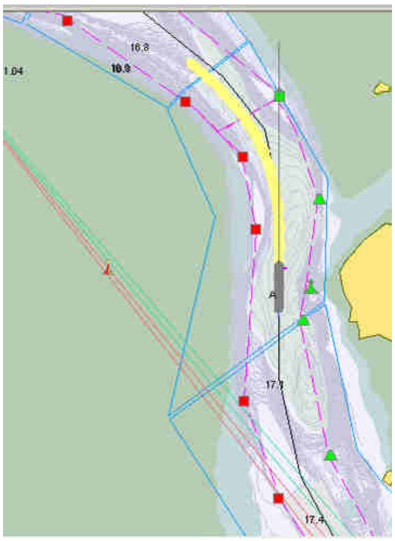
Run 103



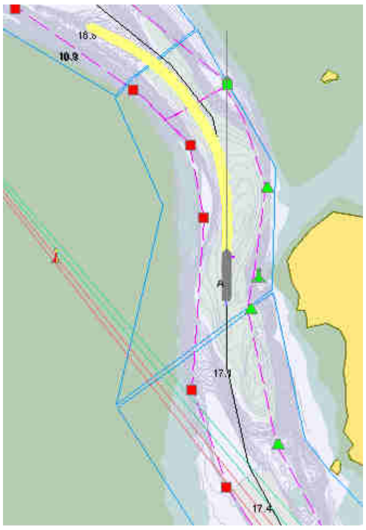
Run 104



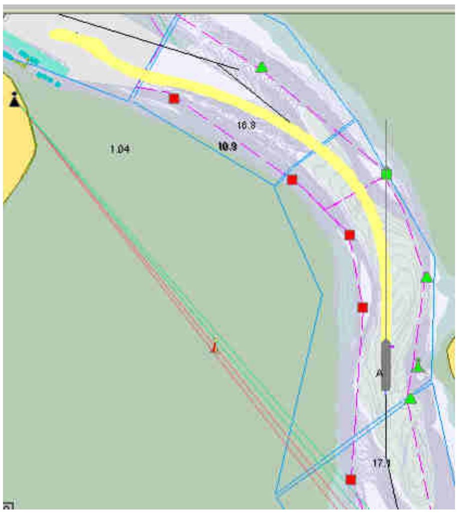
Run 105

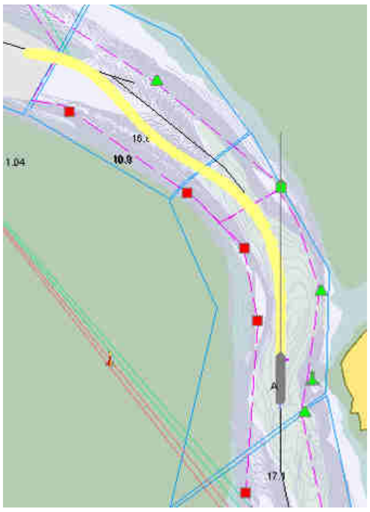


Run 106

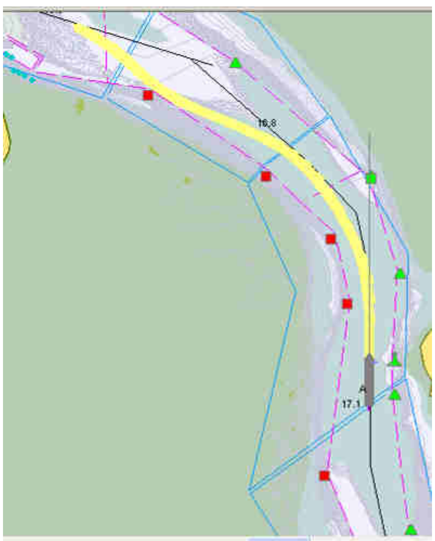


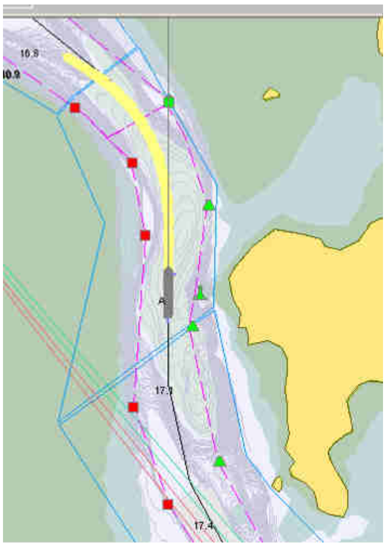
Run 107



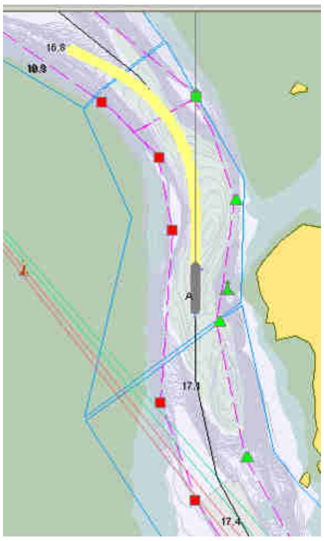


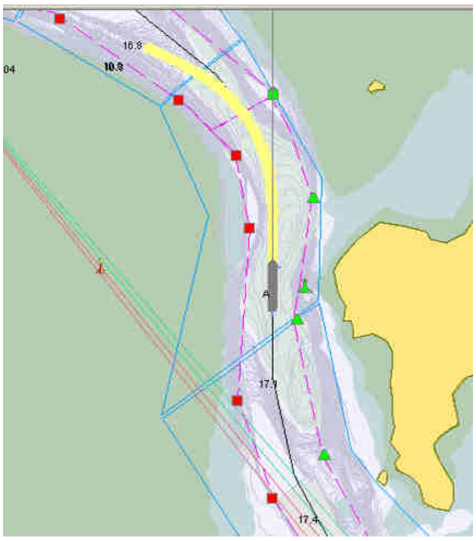
Run 108 **Run 109**



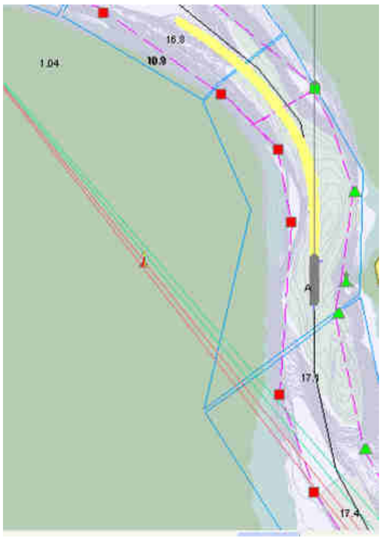


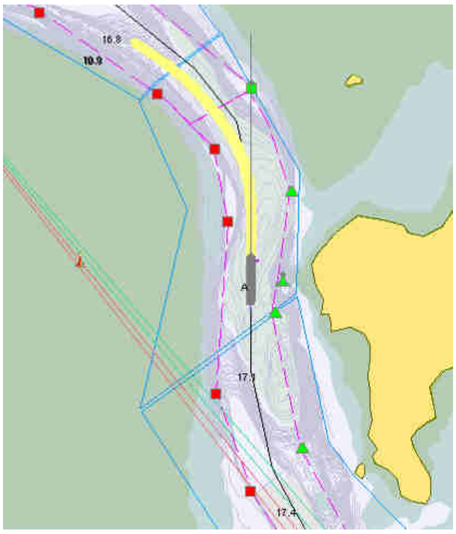
Run 110 **Run 111**



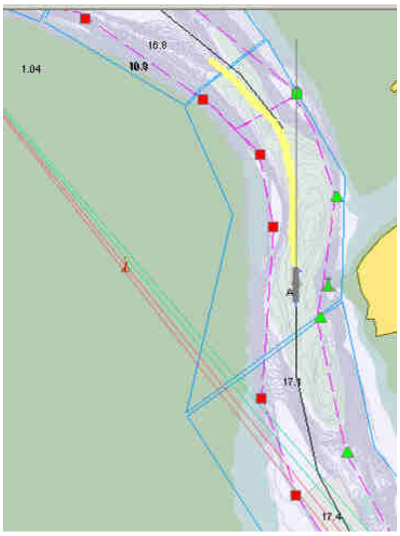


Run 112 **Run 113**

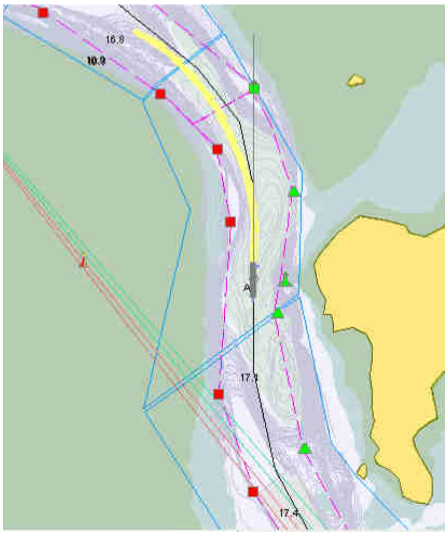




Run 114 Run 115

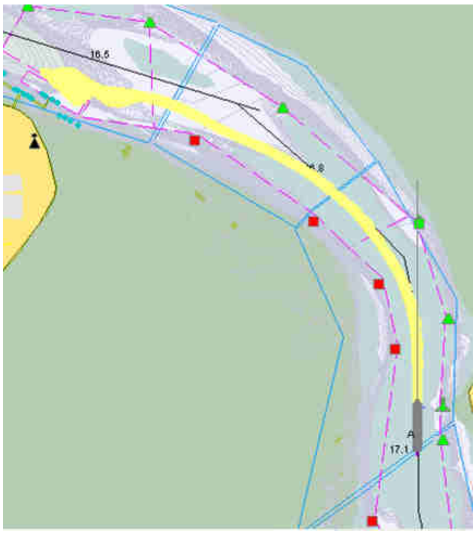


Run 116

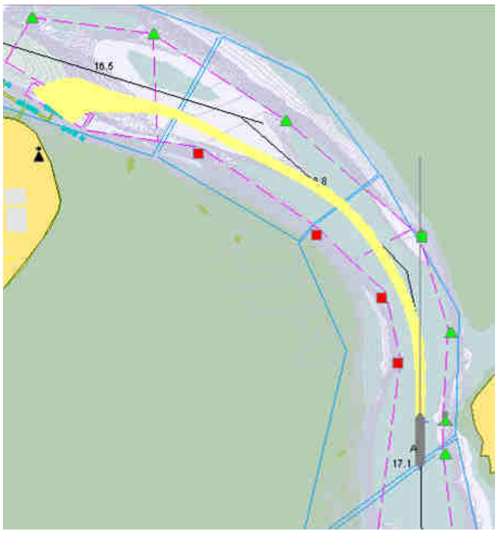


Run 117

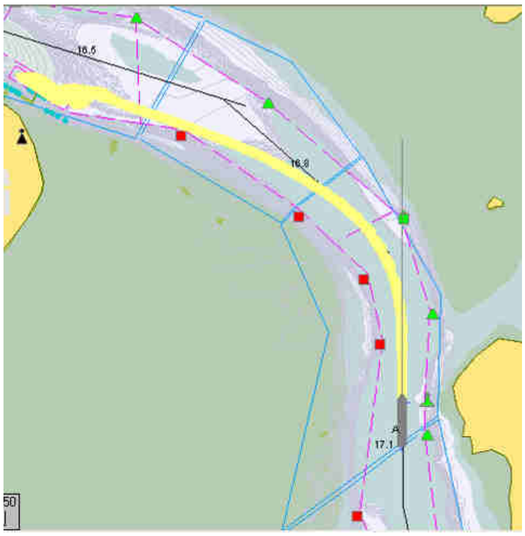
Run 118



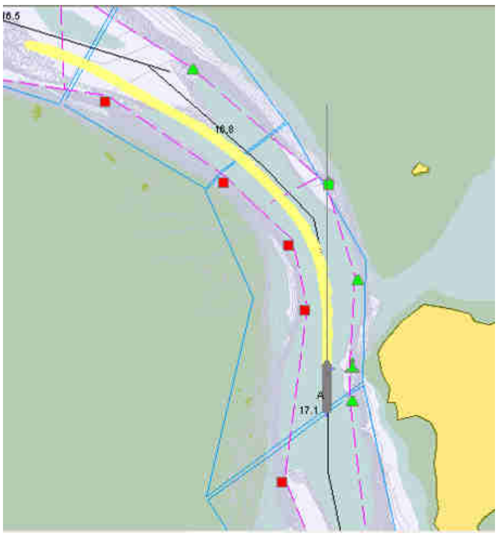
Run 119



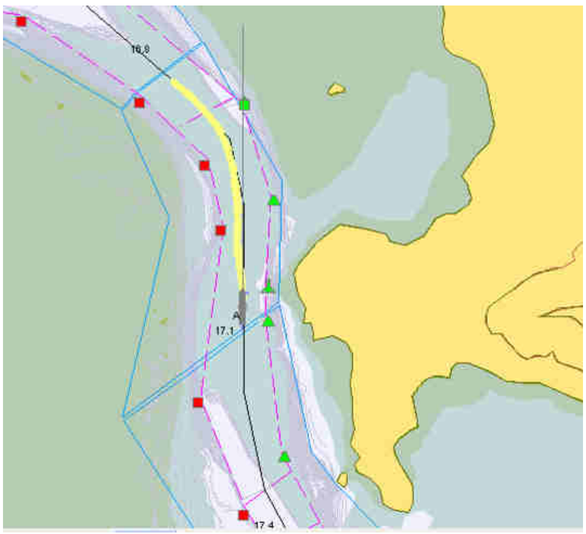
Run 120



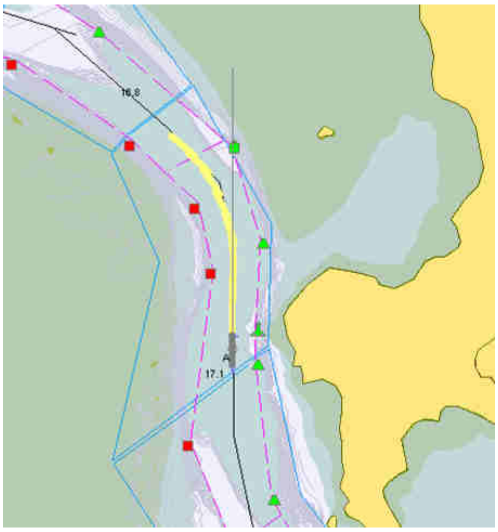
Run 121

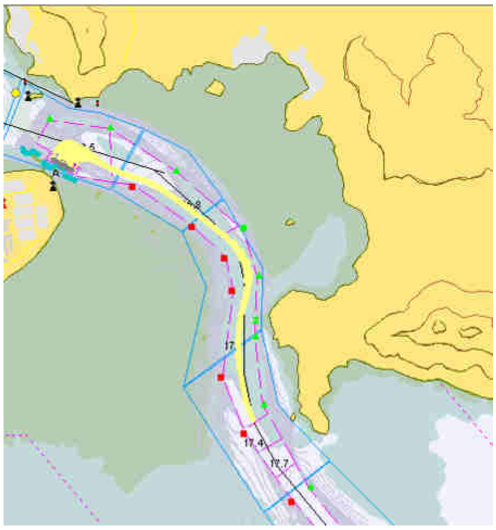


Run 122

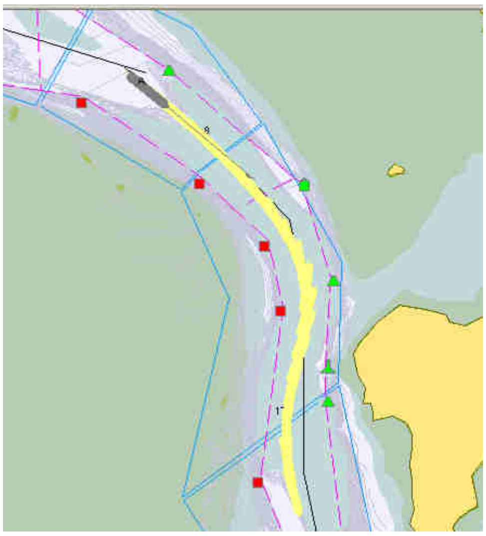


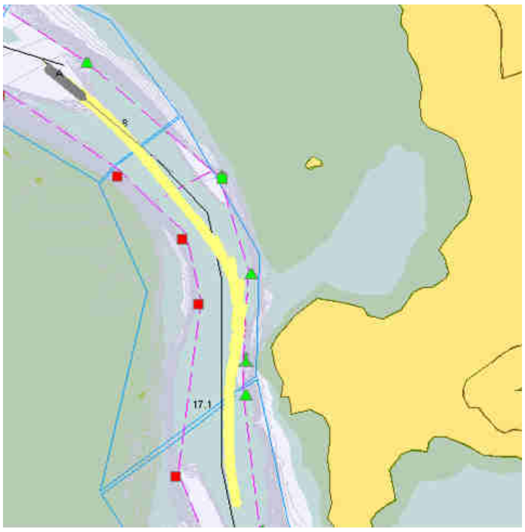
Run 123



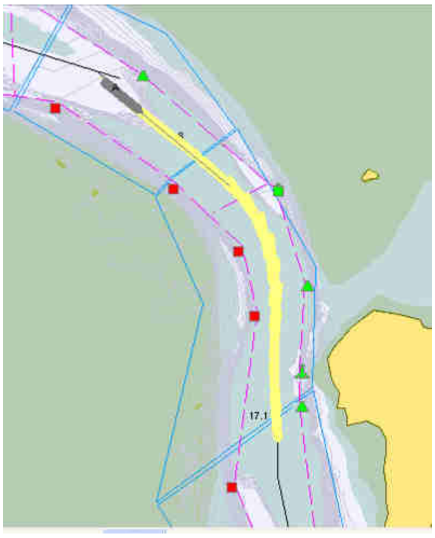


Run 124 **Run 125**

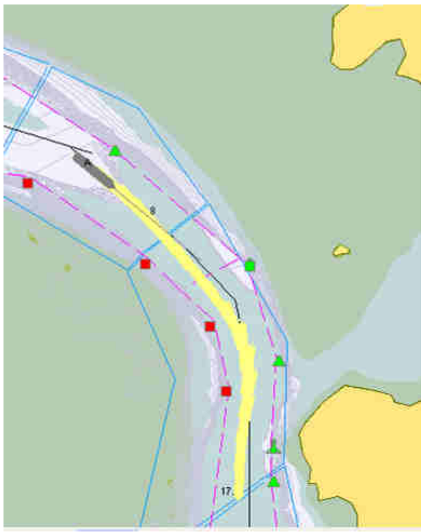




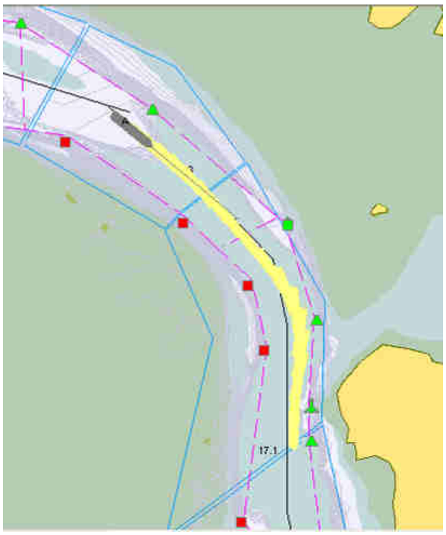
Run 126 **Run 127**



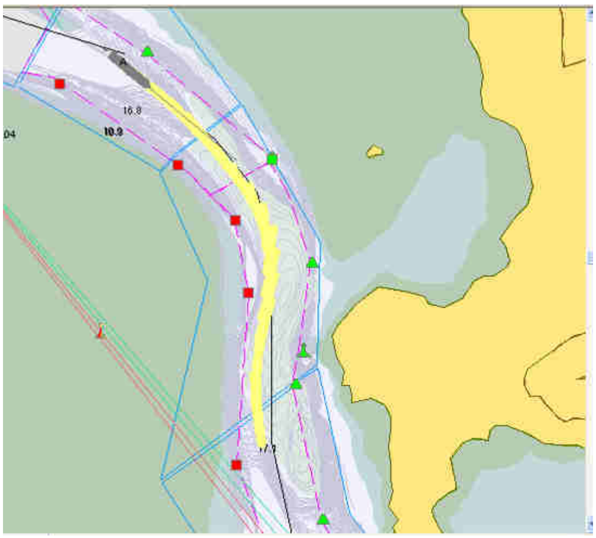
Run 128



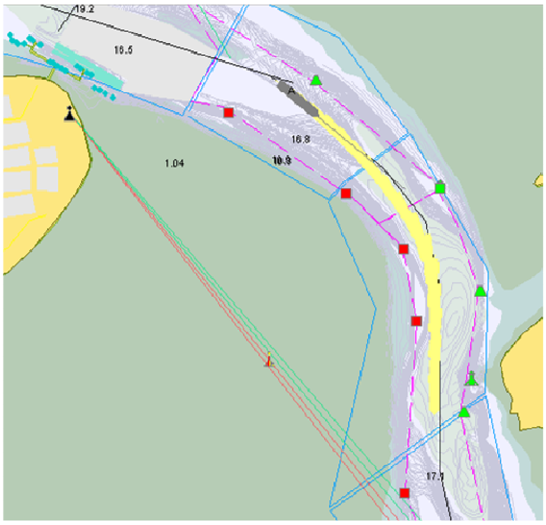
Run 129



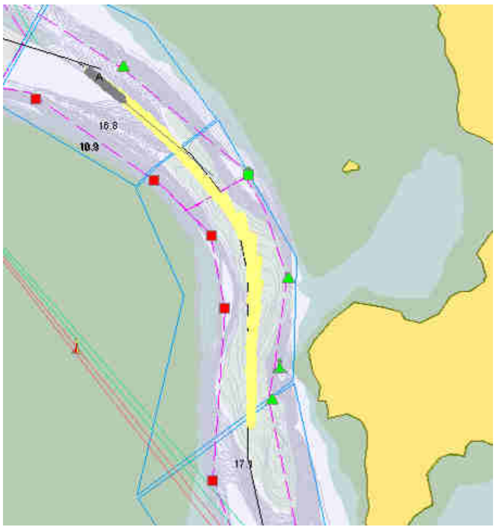
Run 130



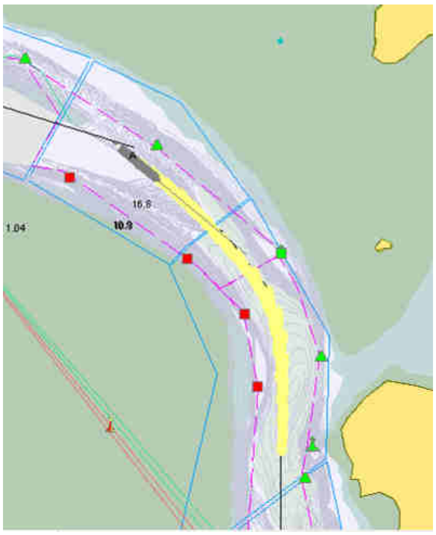
Run 131



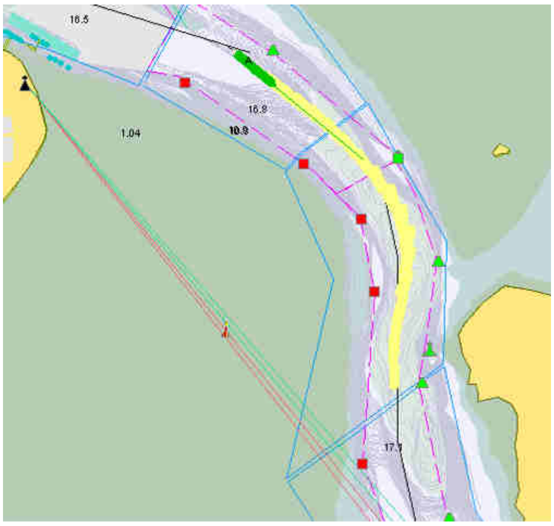
Run 132



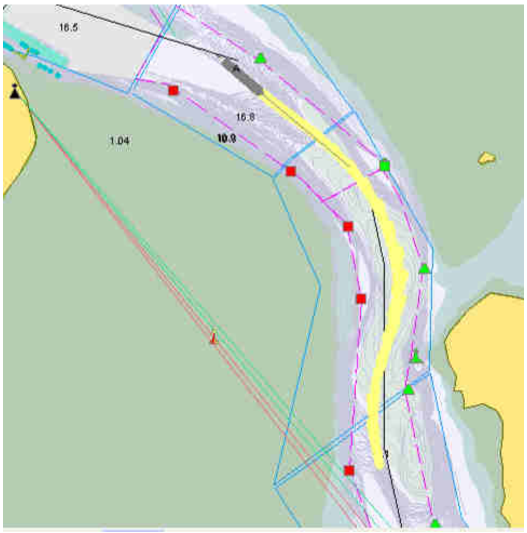
Run 133



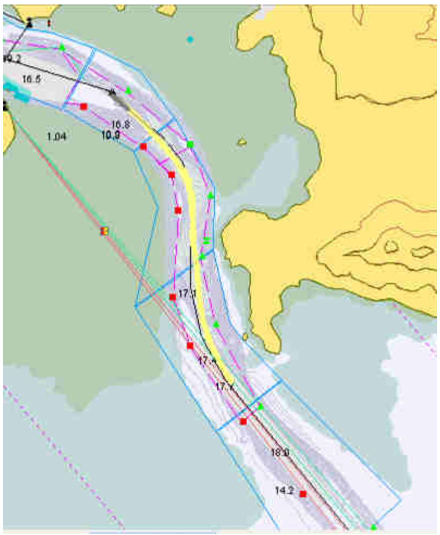
Run 134



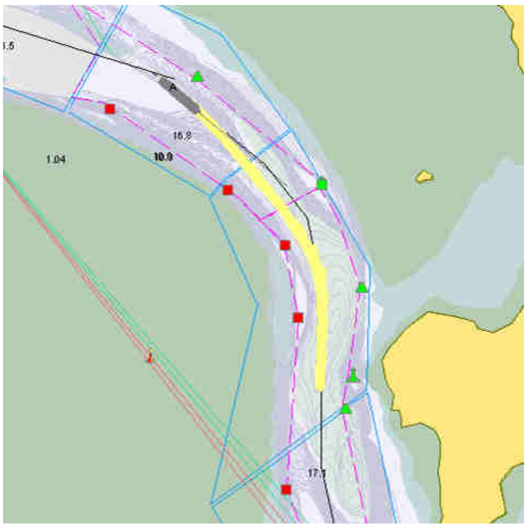
Run 135



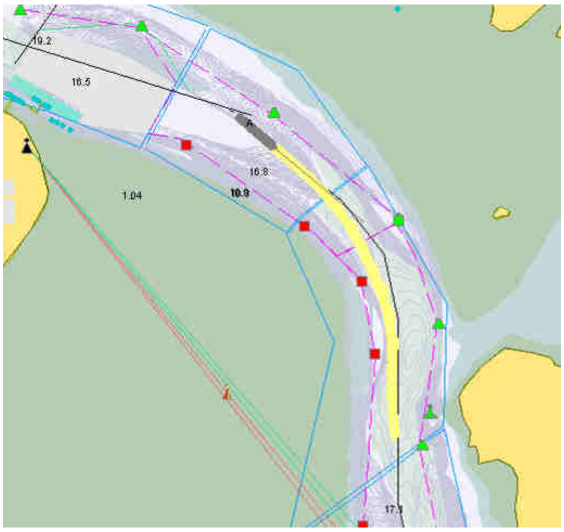
Run 136



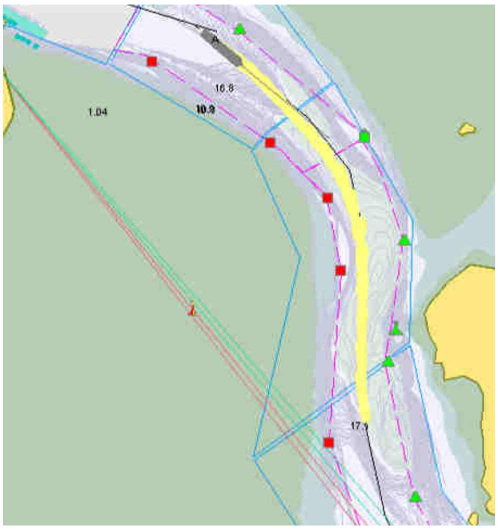
Run 137

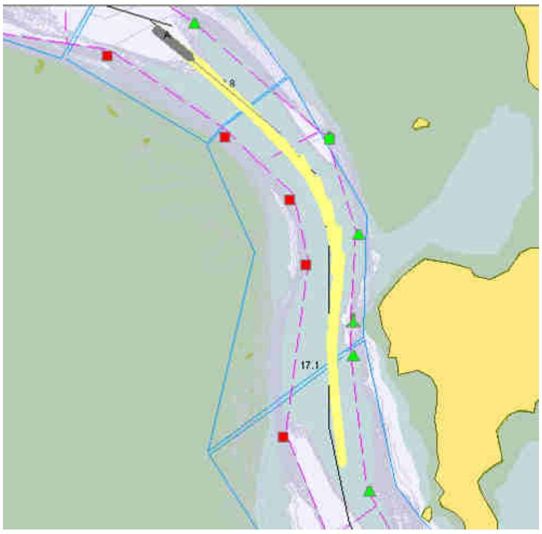


Run 138

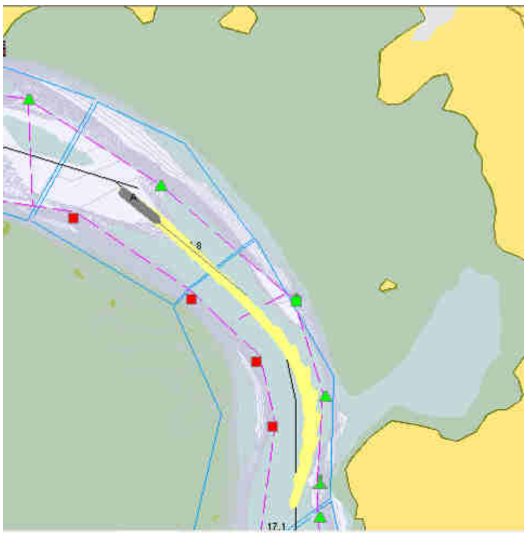


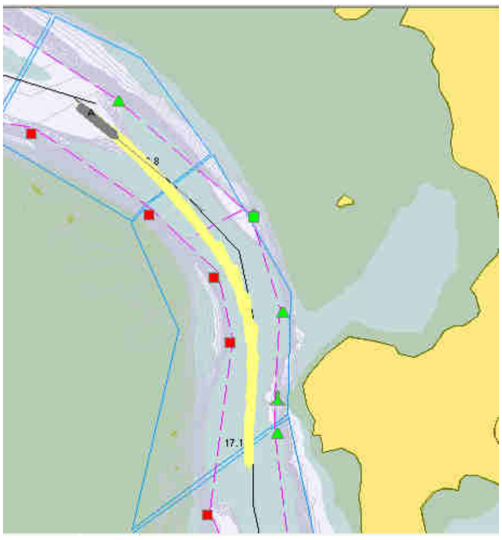
Run 139



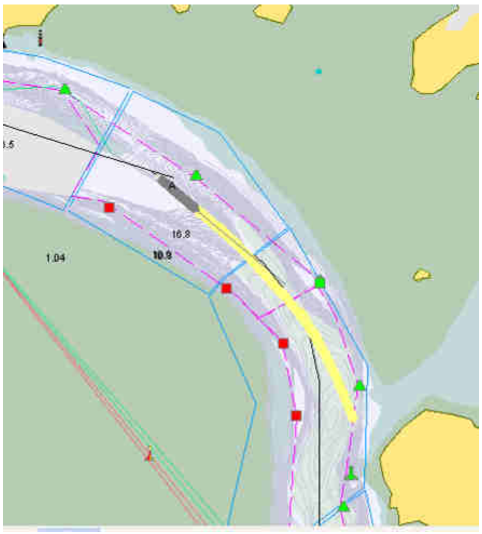


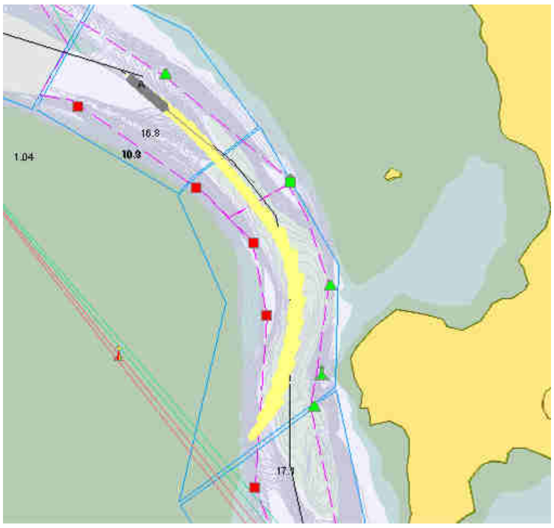
Run 140 Run 141



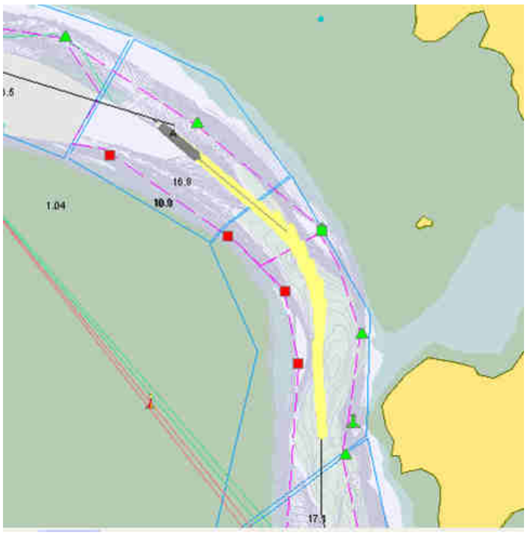


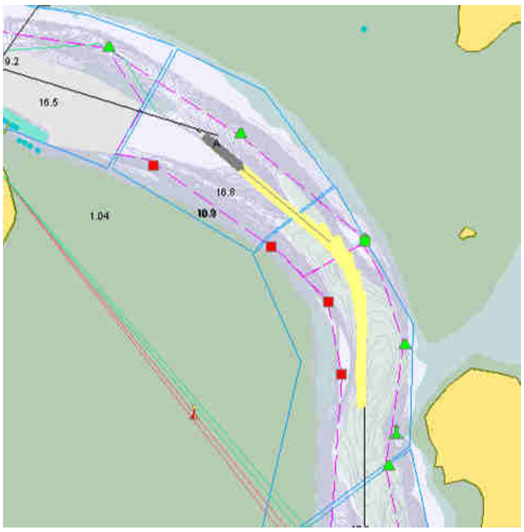
Run 142 Run 143





Run 144 **Run 145**





Run 146 **Run 147**