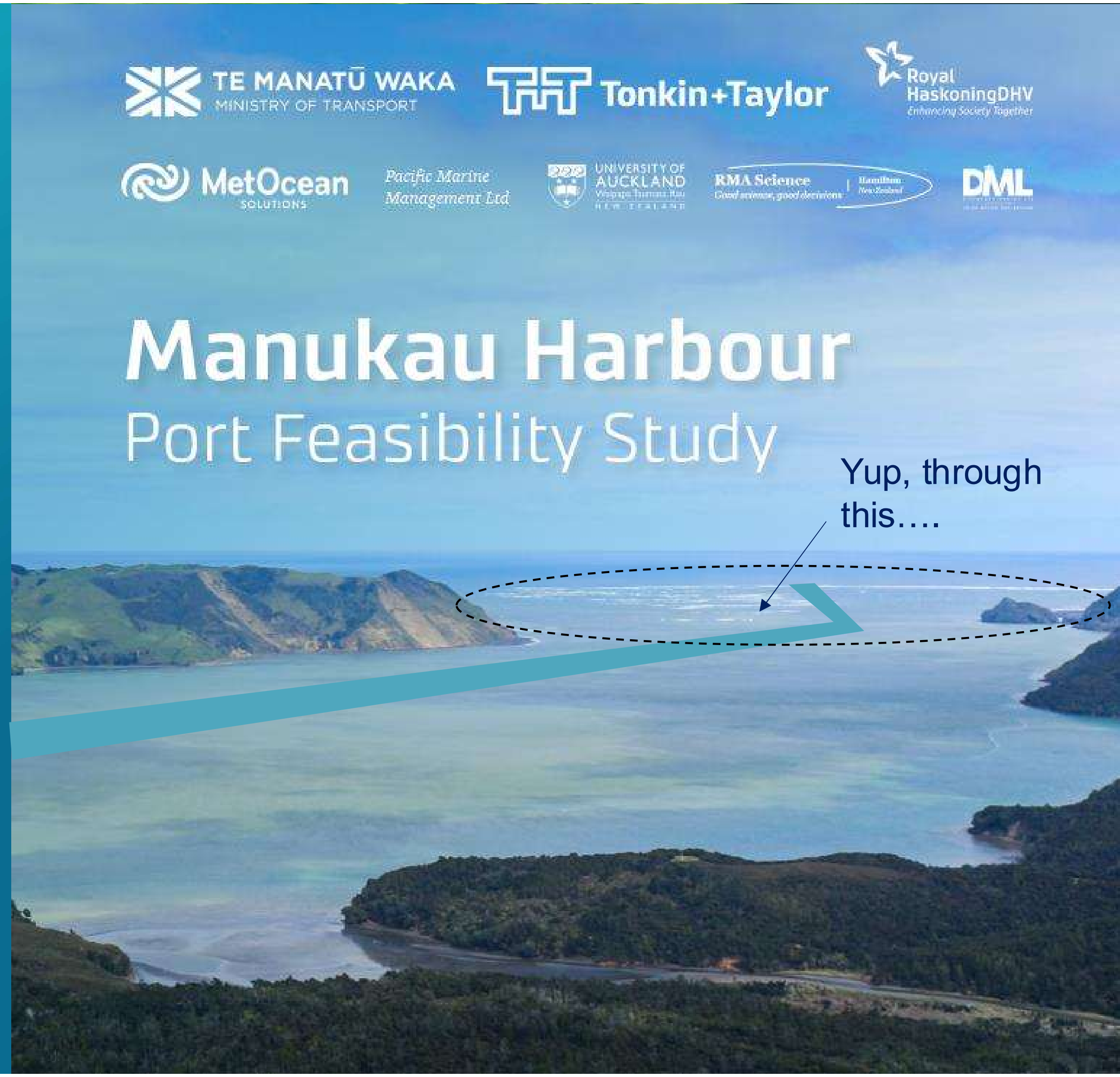
Understanding the dynamics of a large and complex ebb-tidal delta to support a greenfield port feasibility assessment

PIANC APAC Conference

August 2024

Tonkin+Taylor



Background

- POAL capacity
- CBD land value
- Hinterland connections
- Unanswered questior
- Divisive!

Port Future Study (2015) → Sapere Studies (2020) → This technical feasibility study (2023-2024) → National freight and supply chain strategy (>30-year horizon)

Scope

Understand whether it would be technically feasible to establish reliable and safe marine access to a large-scale port in the Manukau Harbour by addressing the information gaps from previous studies:

1. **Marine access** - safe navigation from offshore to inside the harbour
2. **Dredging** – opening and maintaining a navigation channel
3. **West Coast weather** - understanding operational constraints that could be expected due to adverse weather

Assessment of environmental, social and cultural effects were outside of the scope of this study.

Setting and site conditions

NZ's 2nd largest natural harbour covering ~350 km^2

Spring tidal range of 3.6 m with a tidal prism ~1B m^3

Peak flows reach >2 m/s between the N & S headland

N headland volcanic rock, S headland eroding sand cliffs

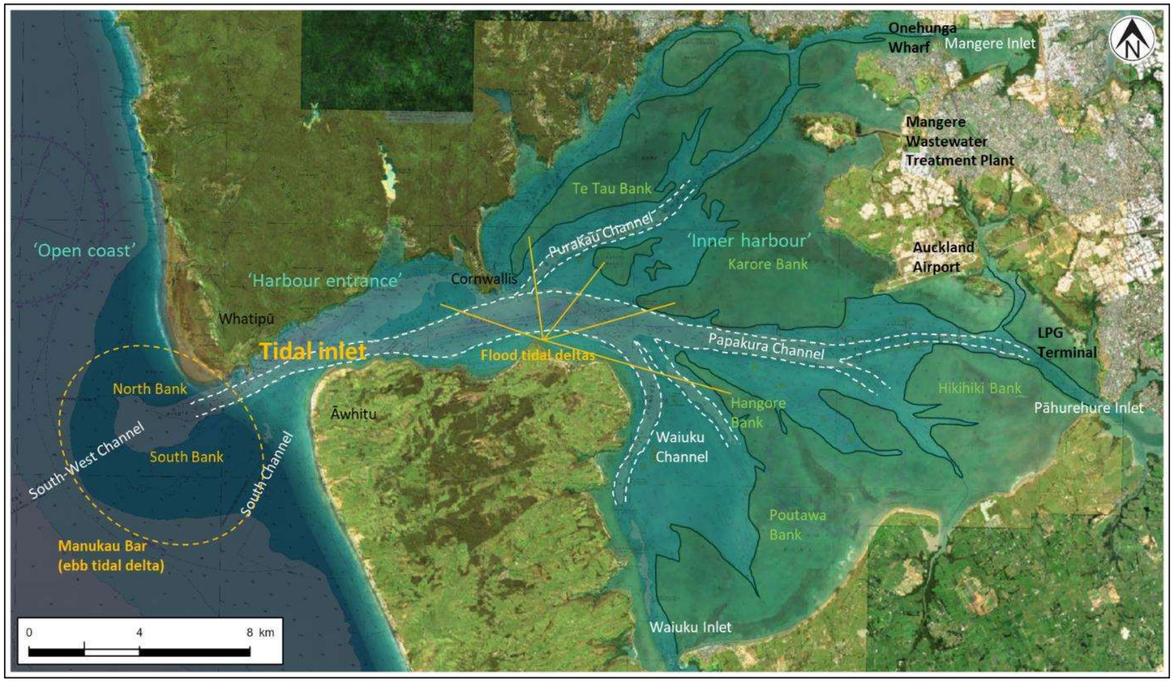
Bar covers 10 km^2, stores 1.3B m^3 sand

Natural S and SW-NW channels at the bar, deep tidal channels in the harbour reducing in depth

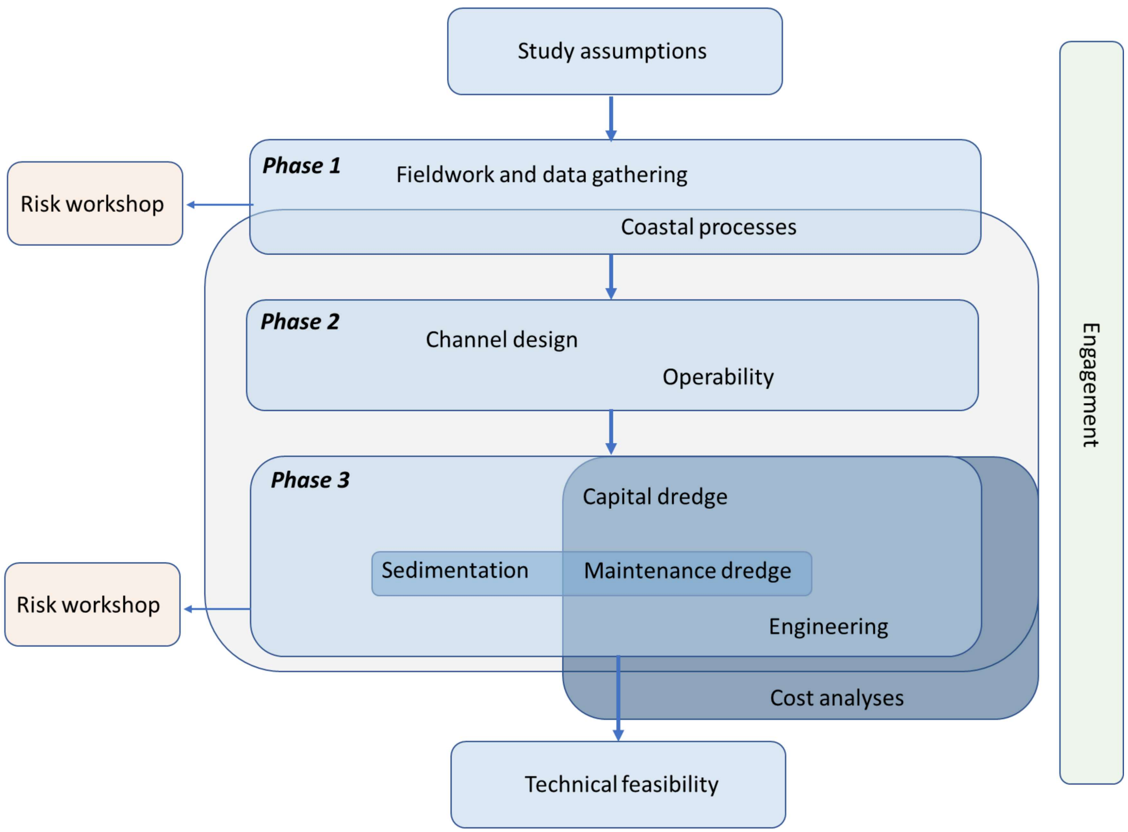
Wind and waves – Southern Ocean swells and Tasman Sea low pressure systems

Ground conditions - sand at Bar and deep channels to fine sand and silt inner harbour

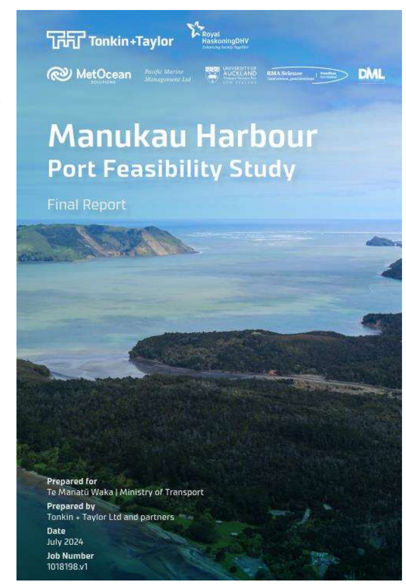
Open coast S to N longshore transport



Methodology



Technical working paper	Title	Led by
TWP 01	Ship traffic and design vessels	Pacific Marine Management
TWP 02	Fieldwork	Tonkin + Taylor
TWP 03	Coastal	Tonkin + Taylor
TWP 03a	Historic bar and channel dynamics	Auckland University
TWP 03b	Metocean modelling	MetOcean Solutions
TWP 03c	Sediment transport modelling	MetOcean Solutions
TWP 04	Navigation channel design	Royal HaskoningDHV
TWP 05	Navigation operability	Pacific Marine Management
TWP 06	Dredging	Royal HaskoningDHV
TWP 07	Engagement	Tonkin + Taylor
TWP 07a	Institutional knowledge	Pacific Marine Management



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Design ships

Large-scale hub port for the North Island

Design ships

- All tide access
- 15k TEU container
- 53.6m beam
- 15.5m operational draft

Parameter	Container			Bulk	Vehicle	Tanker	
	15,000 TEU[1]	10,000 TEU[2]	7,000 TEU[2]	50,000	8,500 CEU	LR2[3]	MR
Deadweight (t)	200,000	125,000	81,000	40,000	41,250	110,000	50,000
Length overall (m)	365	351	272	195	230	260	210
Beam (m)	53.6	45.8	42.8	29	40	45.0	32.2
Max draft (m)	16.0	15.0	15.0	11.5	11.5	15.5	12.6
Load factor	67%	90%	90%	100%	85%	100%	100%
Operational draft (m)	12.4	14.2	14.3	11.5	10.2	15.5	12.6
Air draft (m)	59	53.2	49.3	38.5	49.8	39.5	31.4

Navigation channel

Route selection

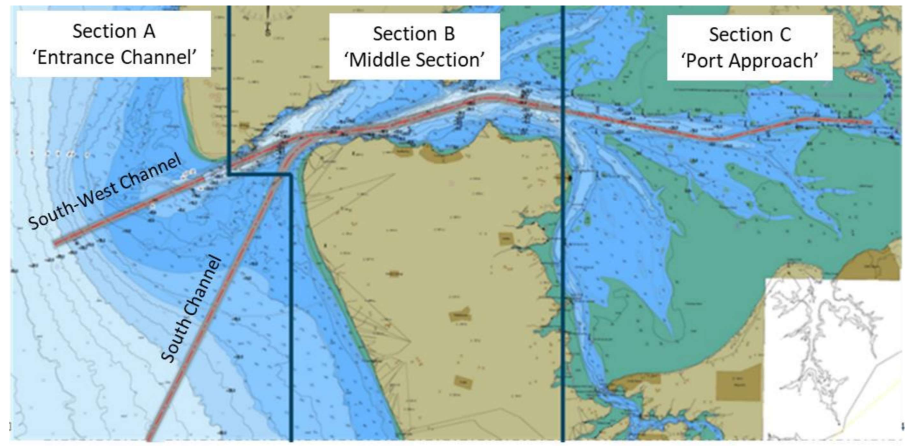
- Followed naturally deep areas where possible
- Split in to 3 sections accounting for different conditions
- SW and S Entrance Channel options, SW favoured

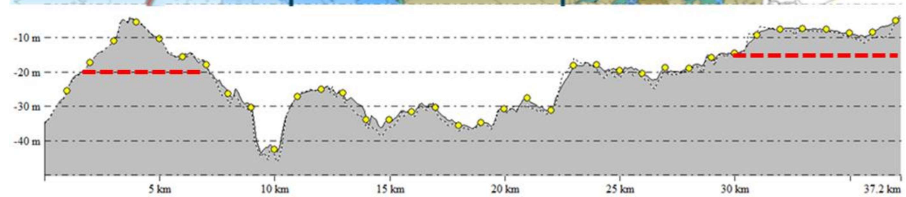
Design process

1. PIANC (2014) harbour approach guidelines
2. UKC – optimised the depth
3. Fast Time Simulation – confirmed horizontal dimensions

Concept navigation channel

- One-two-one lane to accommodate forecast traffic
- Dimensions (see table)





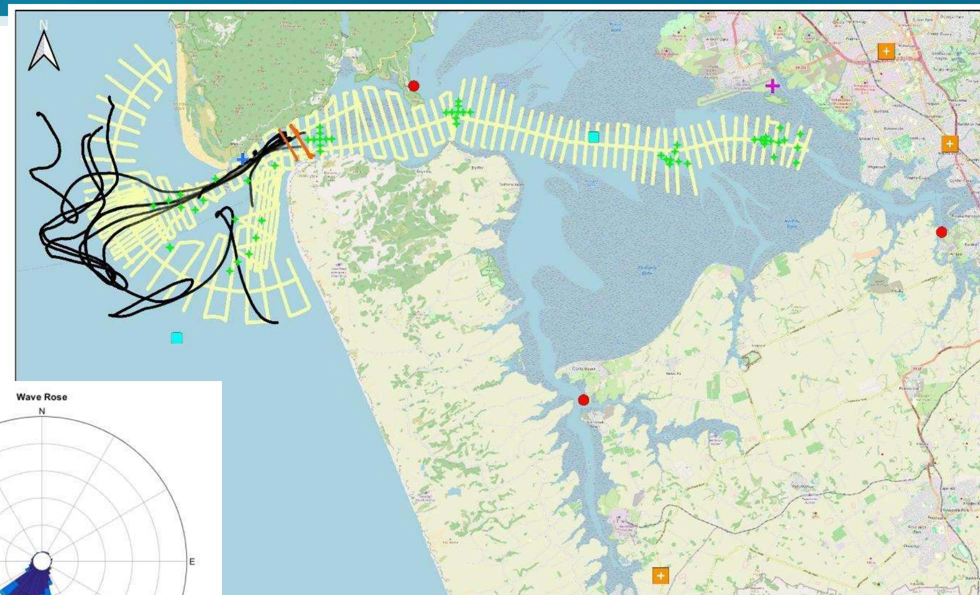
Section	Width (m)	Depth (m CD)	Over dredge (m CD)	Side slopes	Length (km)
A Entrance Channel	295	-19	-20	1V:25H above -12mCD 1V:7.5H below -12mCD	9
B Middle Section	410	Naturally deep	Naturally deep	1V:5H	15.3
C Port Approach	220	-16	-16.5	1V:5H	12.6
				Total	**36.9**

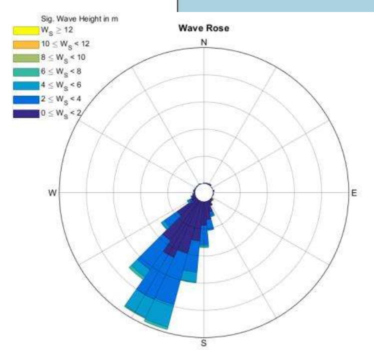
Fieldwork & data gathering

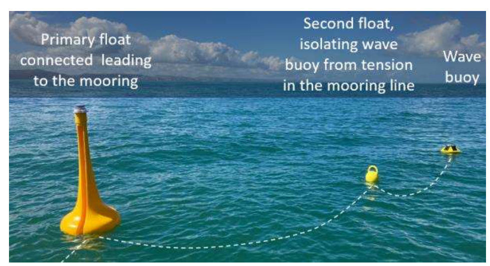
Aim was to acquire data that could be relied upon for all aspects of the study, in particular input, calibration and verification of numerical models

- Bathymetry
- Waves
- Water levels
- Currents
- Sediments – PSD, density & suspended sediment
- Camera

+ existing data: wind, water level, boreholes, historic bathy surveys, sediment samples, suspended sediment, geochemical, aerials, satellite imagery







Fieldwork - bathymetry

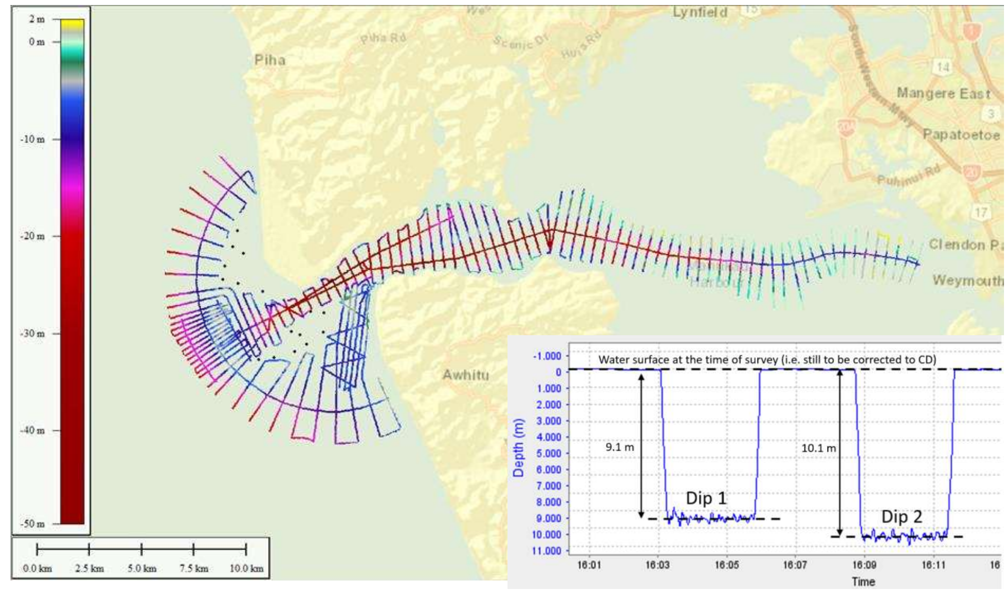
The most comprehensive survey since 1989 covering 360km of the harbour entrance and inner harbour channels

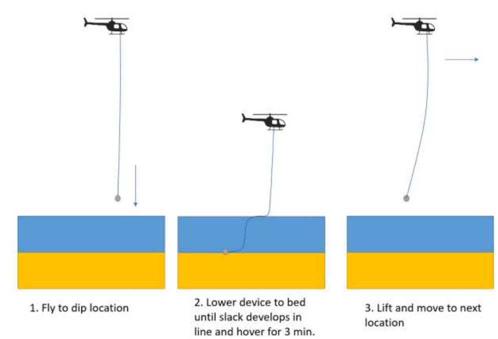
Challenging environment!

Bathy LiDAR – waves and turbidity ruled this out

Jet ski – too dangerous

Resulting method = Hydrographic survey + helicopter dipping



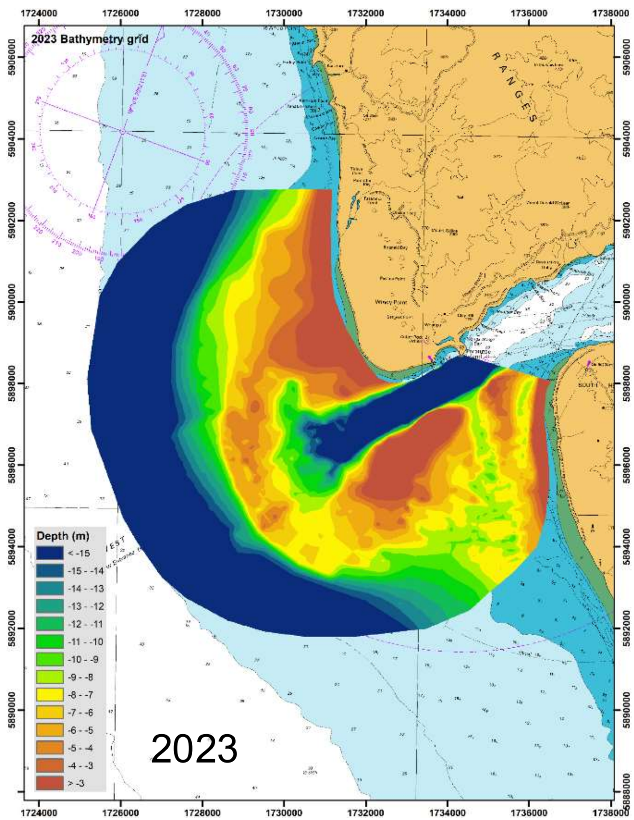


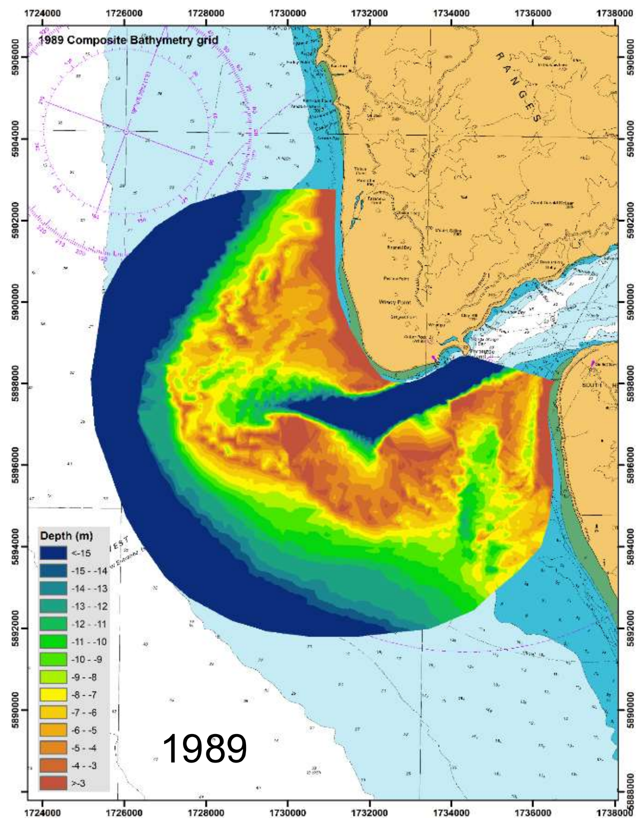
Bar morphology

Using the newly gathered 2023 bathymetry we could compare to existing datasets to see change over time

1989 bathy undertaken by Navy over 2 year period

Comparison shows significant fluctuations in bed levels and channel orientation

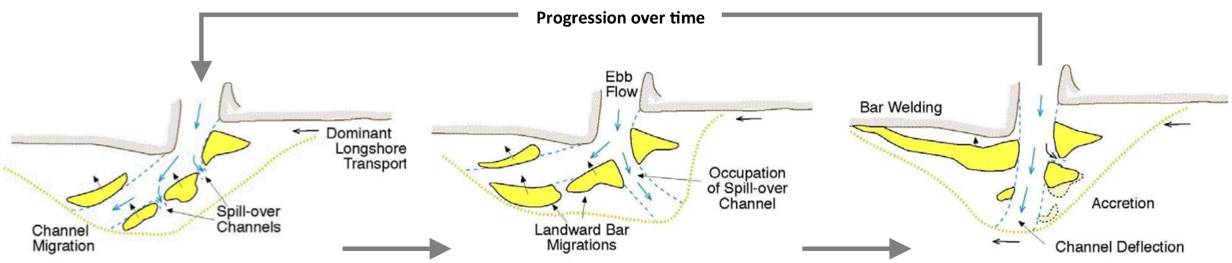


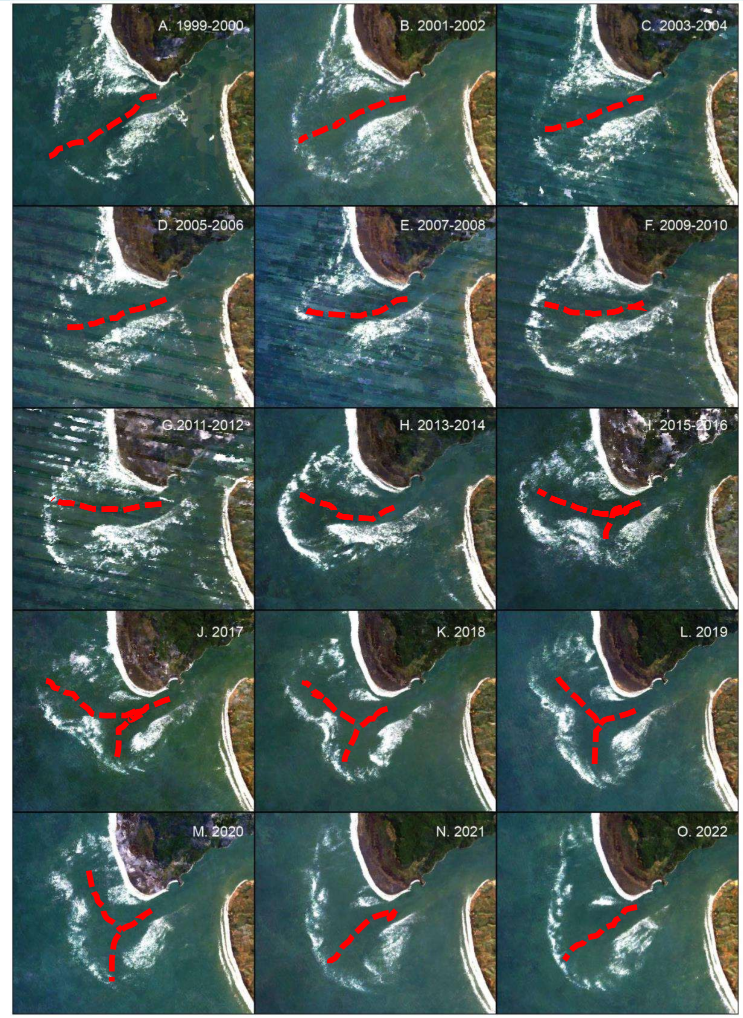


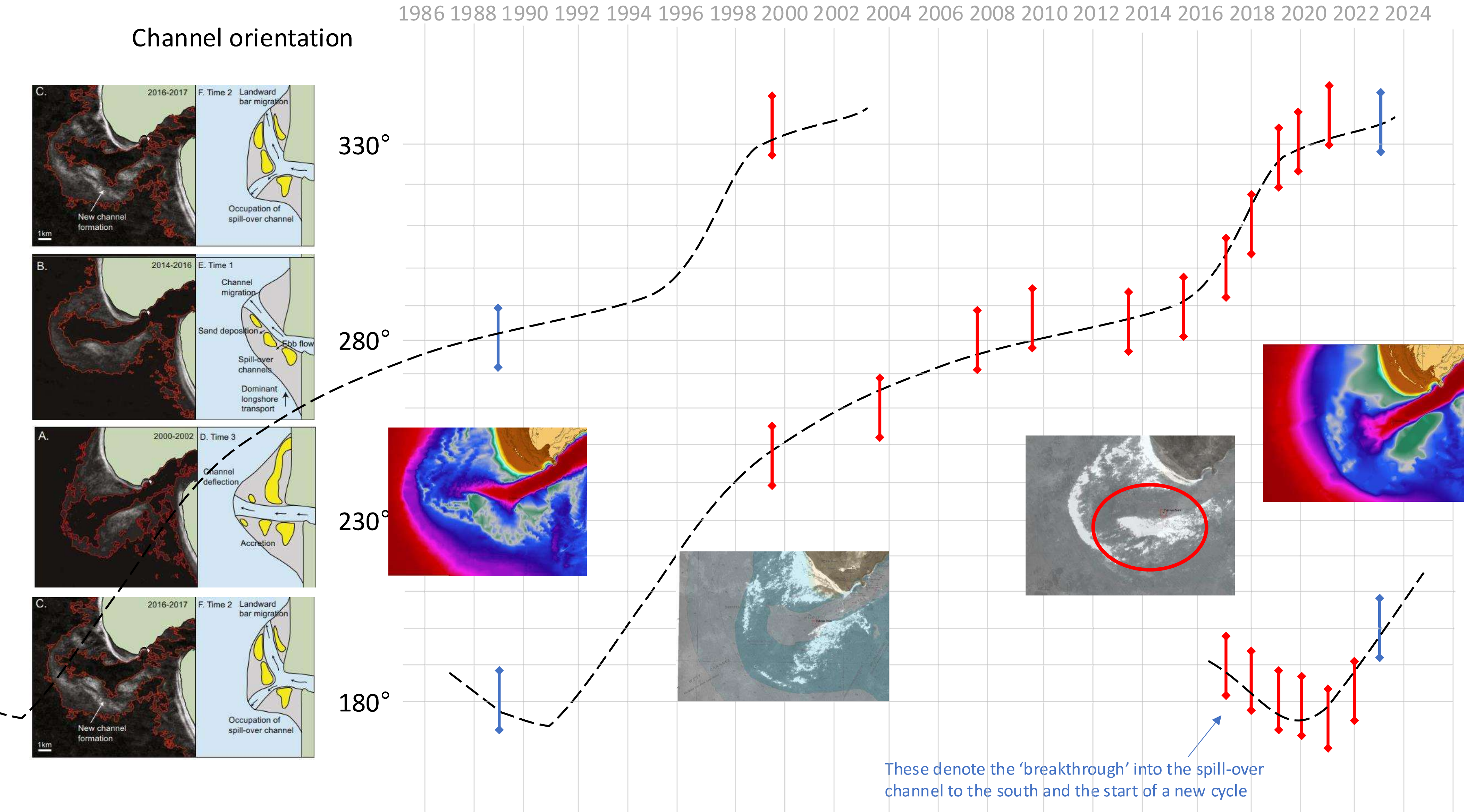
Bar morphology

Taking the analysis further we used satellite imagery which revealed a ~25-30 year cyclic pattern of bar morphology

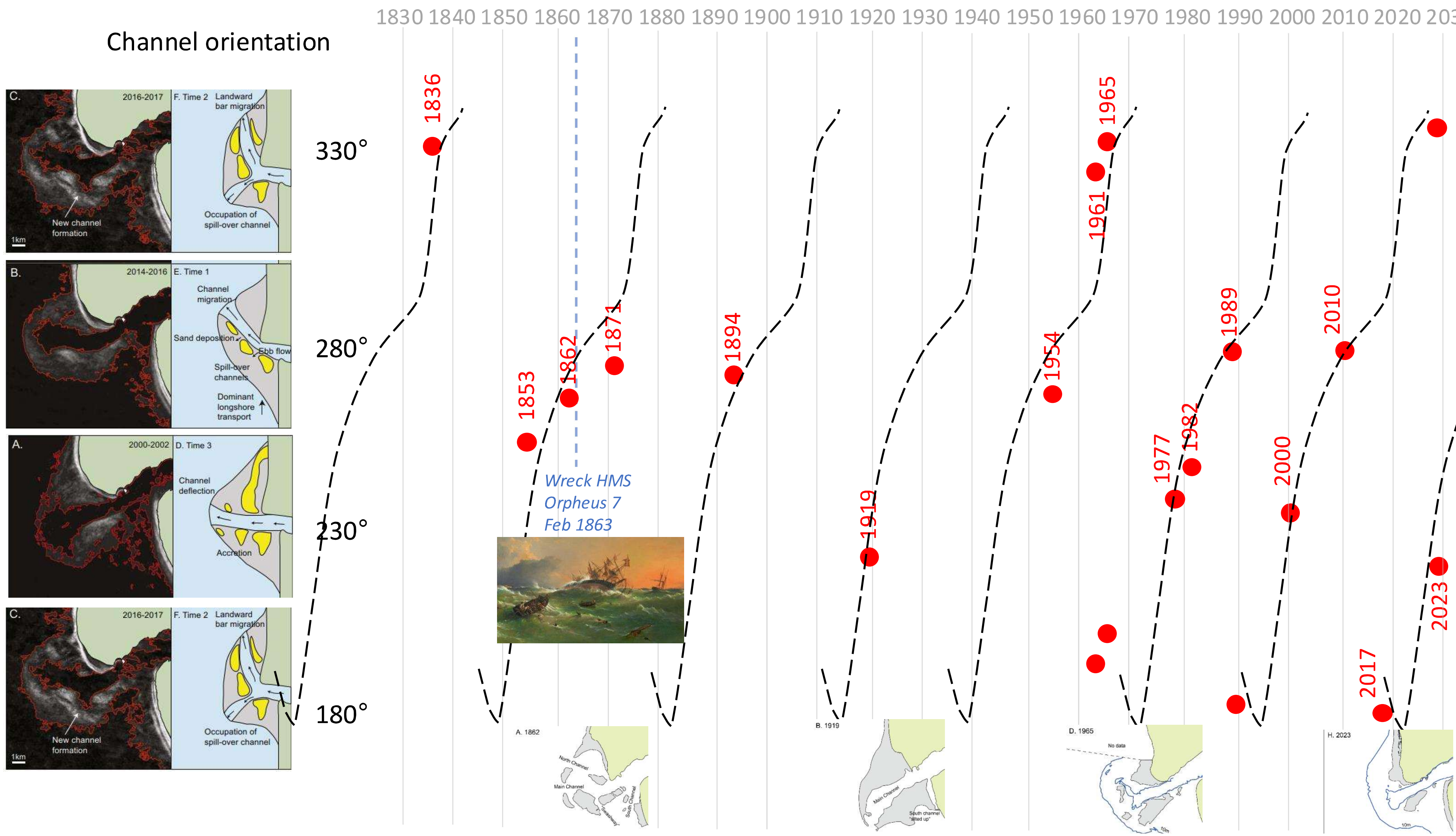
This pattern of channel and bank migration fits the ebb tidal delta breaching conceptual model by FitzGerald et al. (2000) well







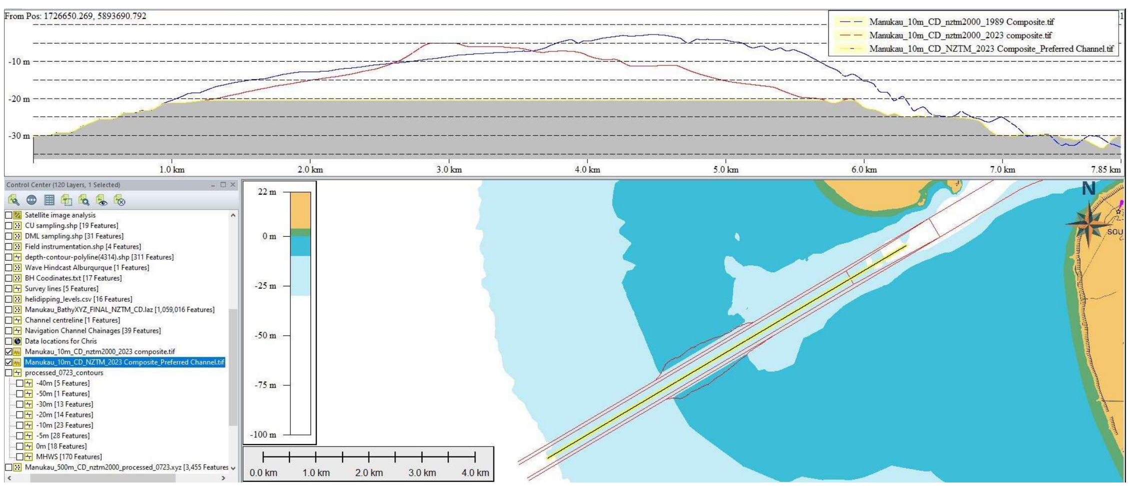
Channel orientation
1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
330°
280°
230°
180°
C. 2016-2017
New channel formation
1km
F. Time 2 Landward bar migration
Occupation of spill-over channel
B. 2014-2016
E. Time 1
Channel migration
Sand deposition
Ebb flow
Spill-over channels
Dominant longshore transport
A. 2000-2002
D. Time 3
Channel deflection
Accretion
C. 2016-2017
New channel formation
1km
F. Time 2 Landward bar migration
Occupation of spill-over channel
These denote the 'breakthrough' into the spill-over channel to the south and the start of a new cycle

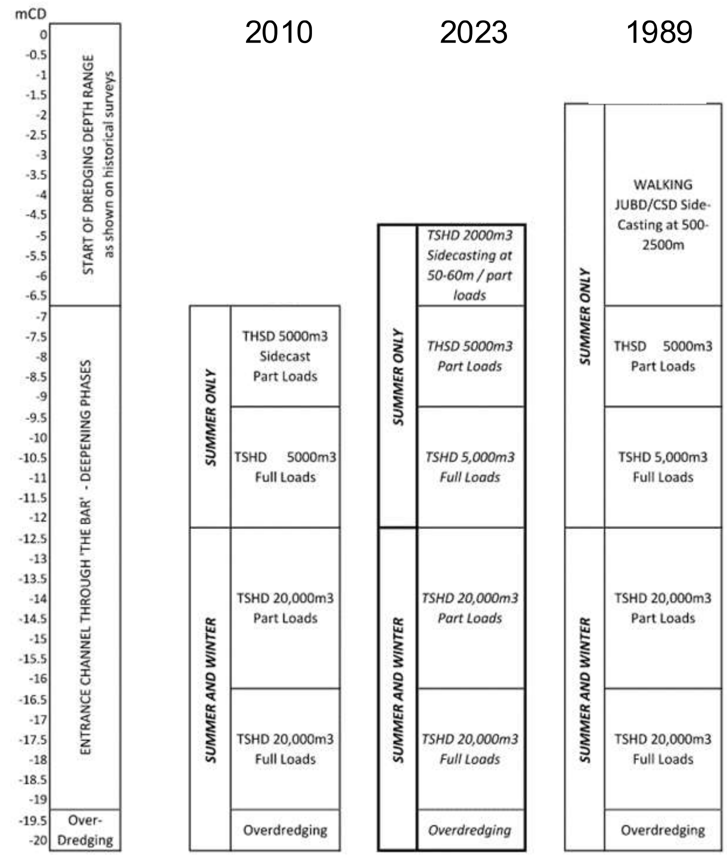


Channel orientation
1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
330°
280°
230°
180°
C.
2016-2017
F. Time 2
Landward bar migration
New channel formation
Occupation of spill-over channel
1km
B.
2014-2016
E. Time 1
Channel migration
Sand deposition
Ebb flow
Spill-over channels
Dominant longshore transport
A.
2000-2002
D. Time 3
Channel deflection
Accretion
1836
1853
1862
1871
1894
1919
1954
1961
1965
1977
1982
1989
2000
2010
2017
2023
Wreck HMS Orpheus 7 Feb 1863
A. 1862
North Channel
Main Channel
South Channel
B. 1919
Main Channel
D. 1965
No data
H. 2023

Capital dredging

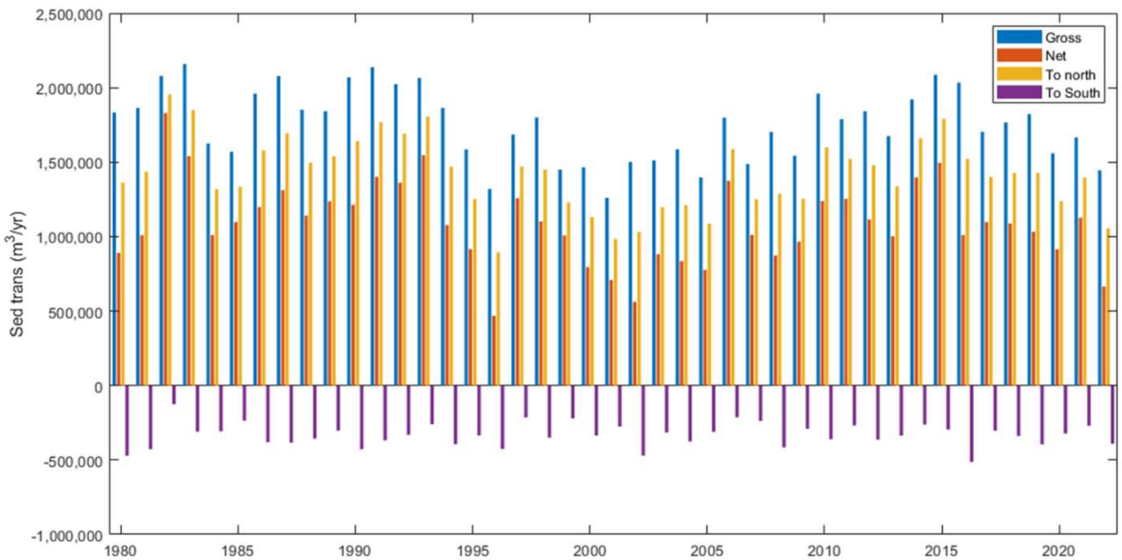
- To understand bar morphology implications to capital dredging we investigated 3 scenarios
- The different starting depth changes the equipment selection – some more challenging than others
- The volumes change significantly between scenarios 37M m^3 for 2023 compared to 54M m^3 for 1989





Sediment transport

Seasonal and year to year variation but average net longshore transport rates from S to N are ~1.5M m^3



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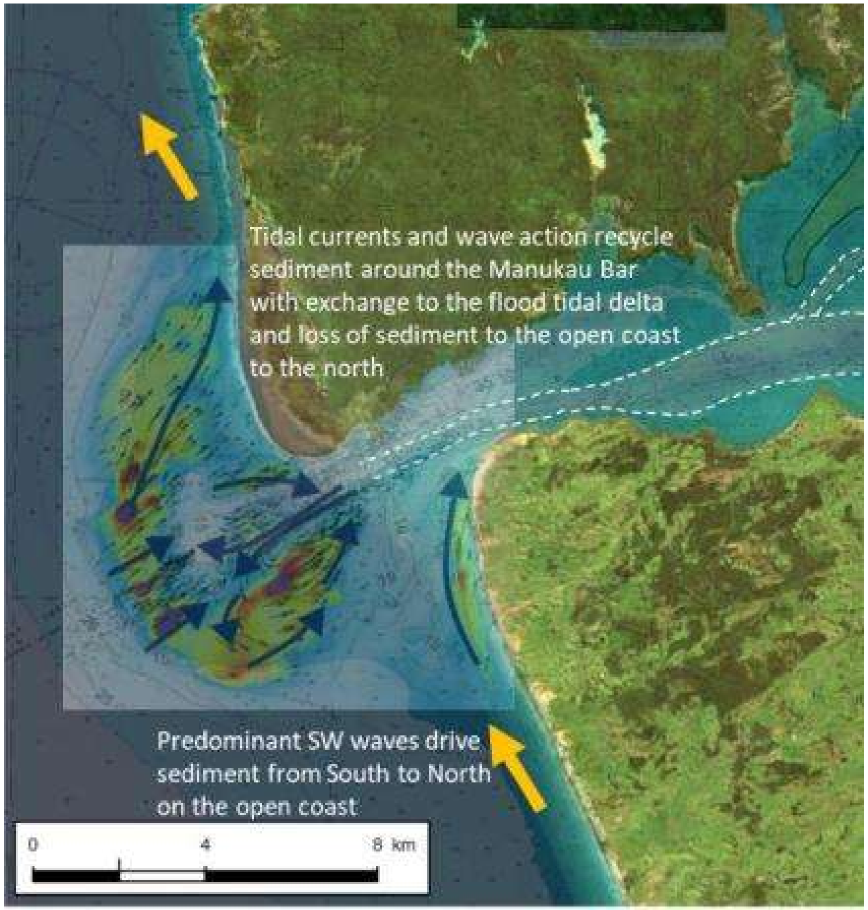
Sediment transport

Seasonal and year to year variation but average net longshore transport rates from S to N are ~1.5M m^3

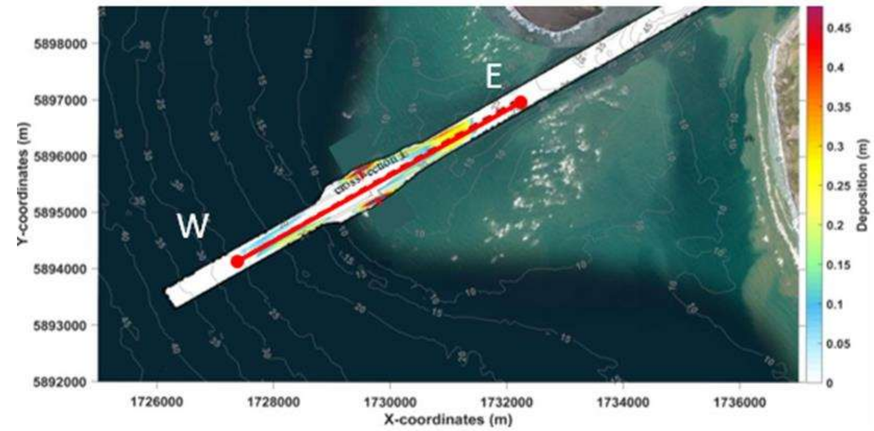
Storage and transport of sediment around the Bar is complex – sediment is deposited in the channels and moved offshore on the ebb tide deposited on the outer Bar before being recycled by wave action across the N and S banks and redeposited back into the channel with only a portion bypassing to the N

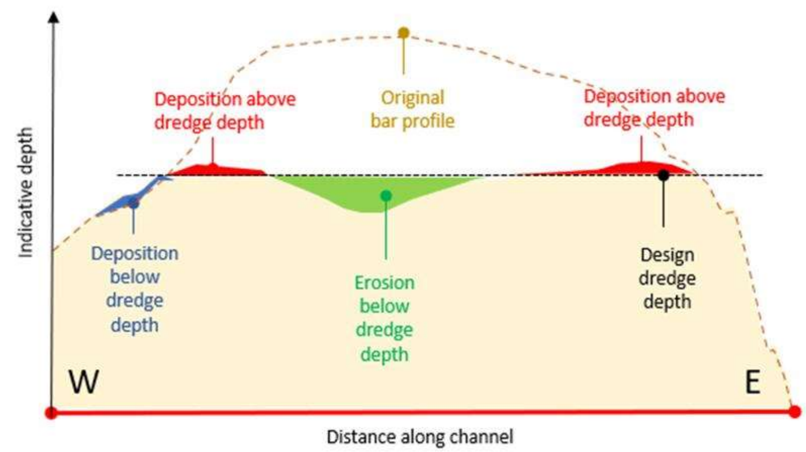
Therefore, the net longshore transport rate is not a reliable measure to inform the maintenance requirement



Maintenance dredging

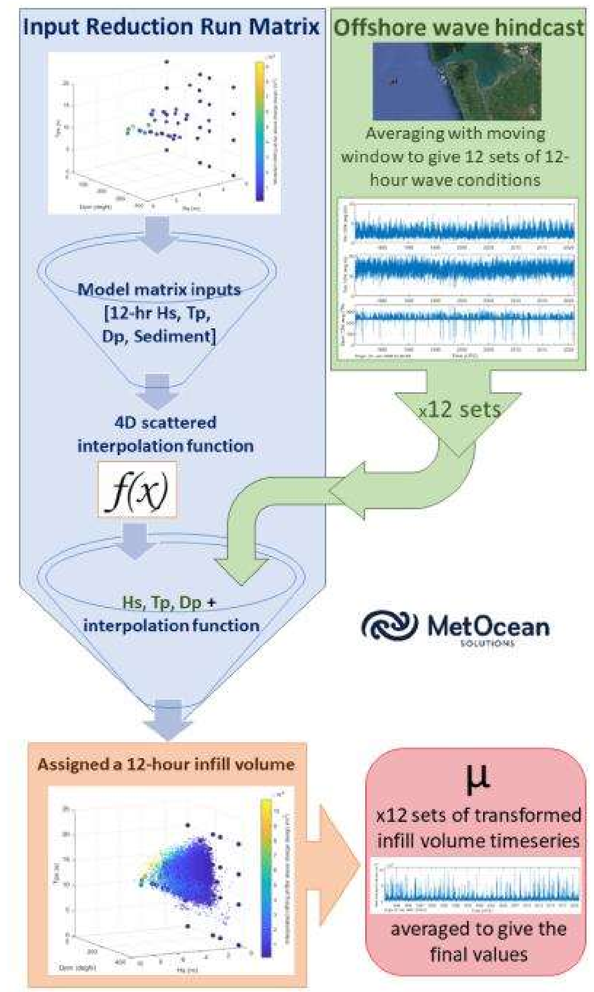
- Modelling indicates erosion through the centre of channel, accumulation at the ends





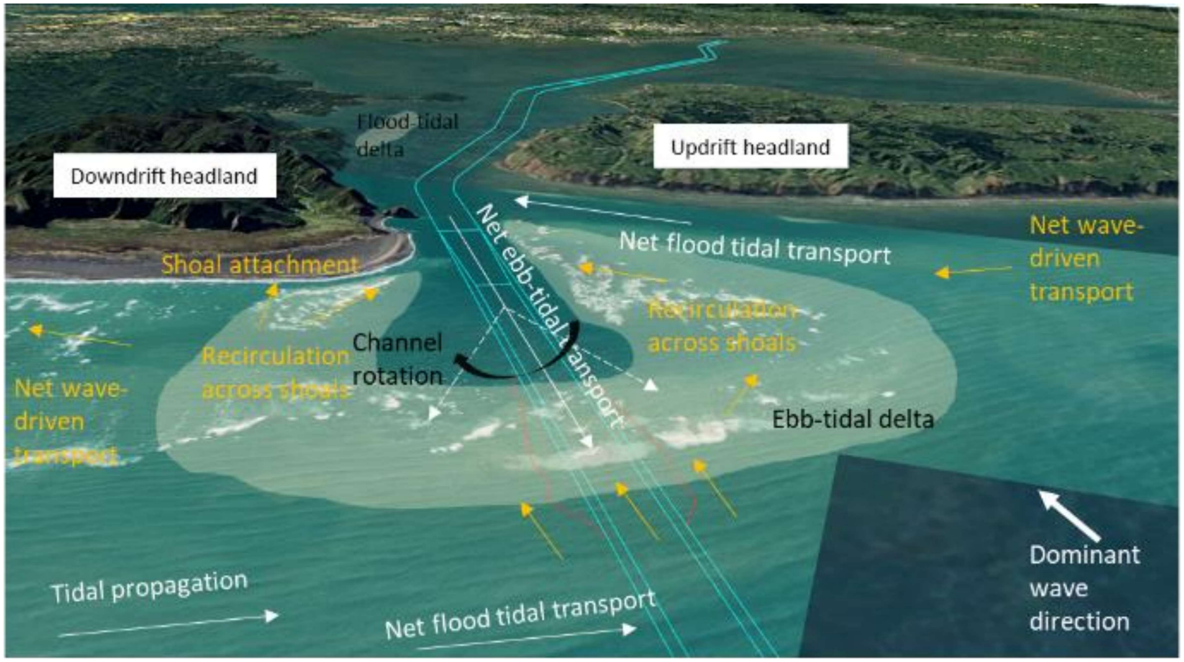
Maintenance dredging

- Modelling indicates erosion through the centre of channel, accumulation at the ends
- Sediment infilling the Entrance Channel above the design depth is estimated as 5 to 8 M m^3/year



Maintenance dredging

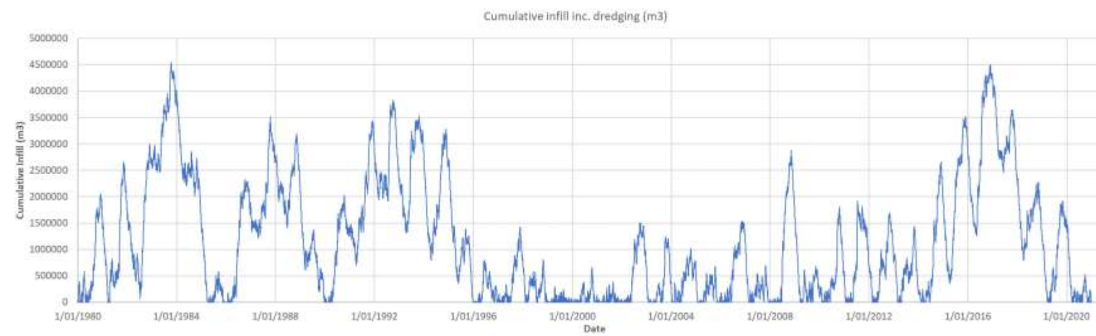
- Modelling indicates erosion through the centre of channel, accumulation at the ends
- Sediment infilling the Entrance Channel above the design depth is estimated as 5 to 8 M m^3/year
- Infilling is largely from sediment recirculated within the system – which is much higher than the longshore transport rate
- This equates to ~0.5% of the total volume of sand in the ebb-tidal delta
- Placement of dredge spoil important
  - Deflate the bar
  - Flood (or starve) adjacent coast
  - Control inter-decadal movement

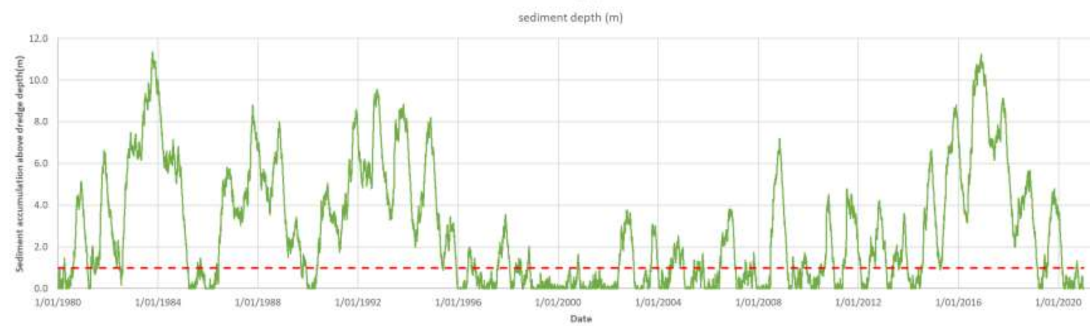


Maintenance dredging

Equipment

- To achieve the maintenance dredge volumes a TSHD 10,000 m^3 would be required, working throughout the year
- Daily production rates of 50,000m3/day with operable conditions Hs<3m
- Clearing channel during calm periods critical to maintaining channel depth





Summary of findings

- The Manukau Bar is a large and complex system of sediment storage and transport
- Large scale cycles at around 30 year period
- Establishing a navigation channel through the Manukau Bar is shown to be technically feasible but:
  - The capital dredging method, volumes, risk and cost are dictated by the state of the Bar at the commencement of the works
  - Maintenance dredging volumes are high (5-8 M m^3/year) due to the recirculation of sediment
  - To achieve the maintenance dredging a dedicated dredger would be needed working throughout the year undertaking pre-emptive dredging in the calmer summer months and within available weather windows in the winter
  - Placement of dredge spoil critical to manage bar and coastal system

So not ludicrous, but very technically challenging…

Acknowledgements

Further information available at: https://www.transport.govt.nz/area-of-interest/infrastructure-and-investment/manukau-harbour-feasibility-study/