Field Measurement and Numerical Modelling of Resuspended Sediment due to Tugs

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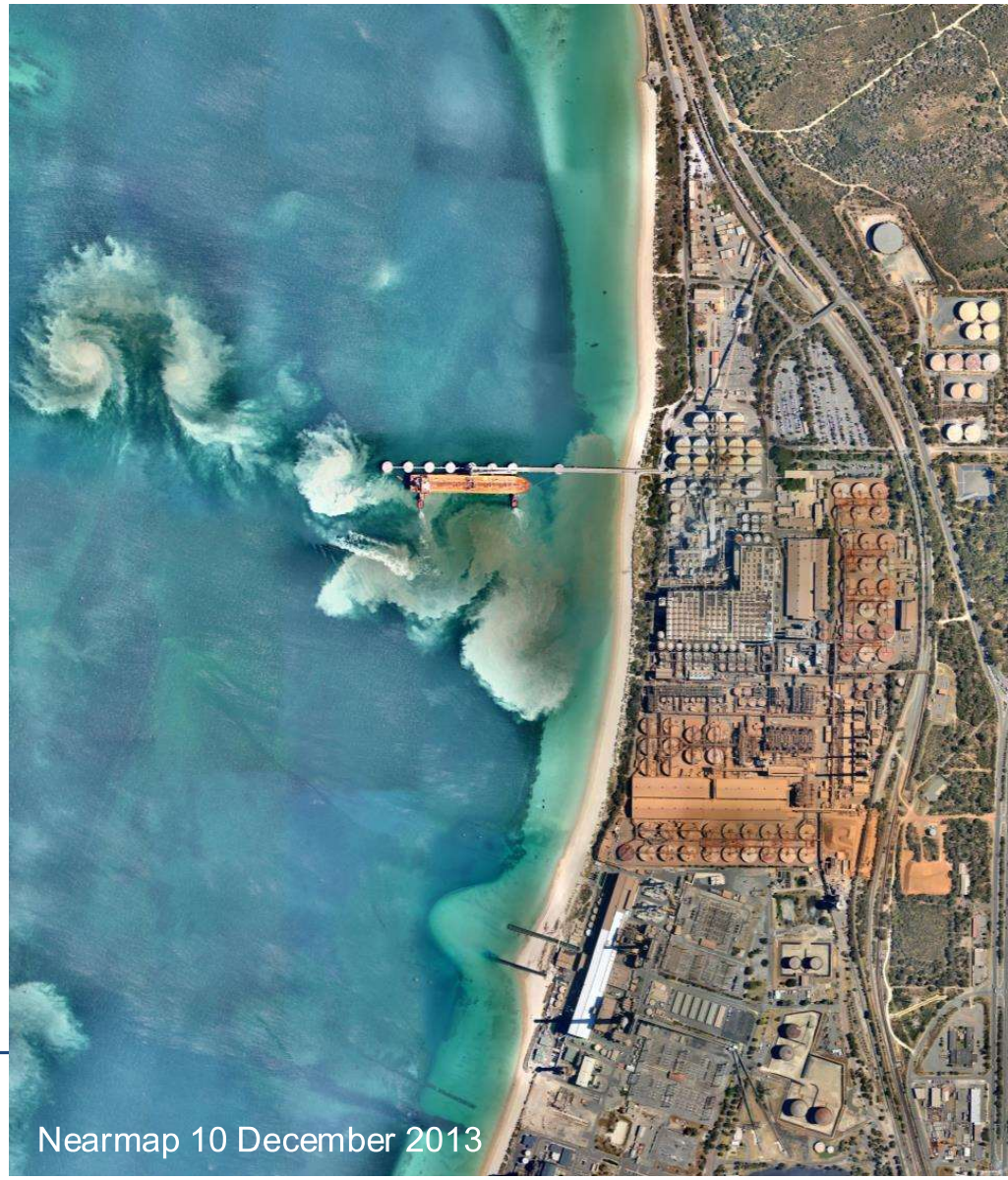
Introduction

Project Location:
Alcoa Jetty, Western Australia.

Project Appreciation:

- Alcoa Jetty accommodates bulk caustic soda unloading and refined alumina loading.
- Two tugs assist during berthing and unberthing procedures.
- Tug propeller-induced current (prop wash) causes resuspended sediment.
- Potential risk of resuspended sediment entrainment into the Perth Seawater Desalination Plant (PSDP) seawater intakes (located ~900m South of Alcoa Jetty).
- Potential risk of tug induced turbidity impacting seagrass habitat (located ~900m west of Alcoa Jetty).



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Objective and Scope

Project Objective:
To assess the risk of resuspended sediment reaching seawater intakes and nearby seagrass areas.

Project Scope:

1. Undertake field measurement of resuspended sediment concentration and plume extent at Alcoa Jetty resulting from tug propeller wash during vessel manoeuvres to provide ground truth data for numerical modelling of resuspended sediment.

2. Undertake hydrodynamic and sediment fate modelling for sediment resuspension and plume dispersion due to tug activity at Alcoa Jetty

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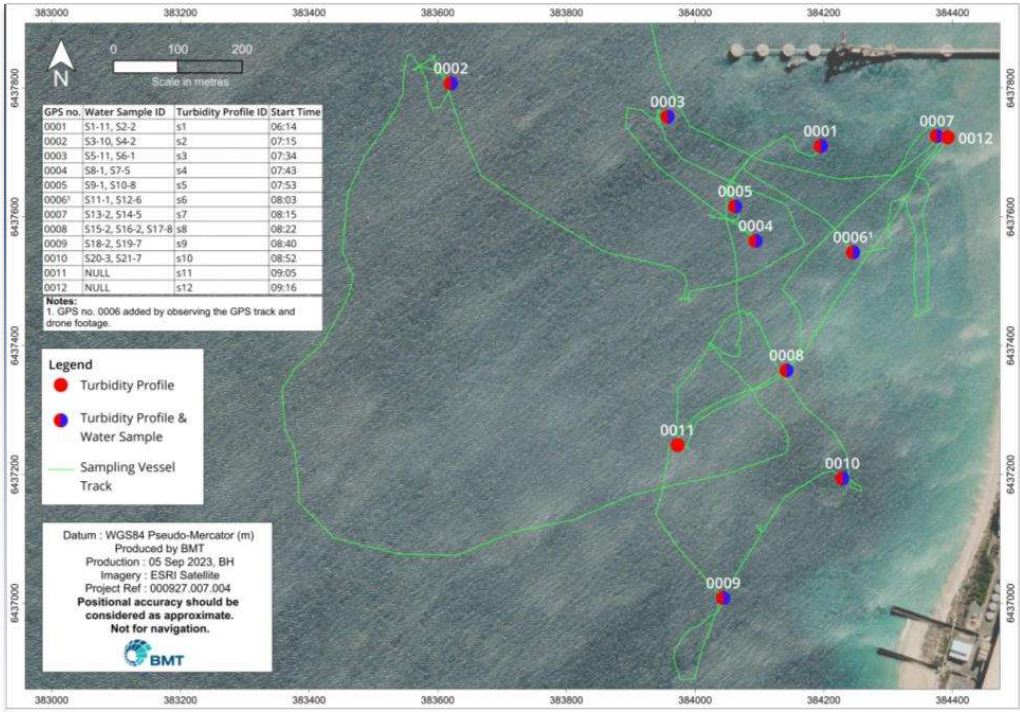
Part 1 - Field Measurements

Field Measurement Campaign

The field measurement campaign was executed on 25/08/2023 between 07:00-10:00, coinciding with arrival of vessel KULJAK ARROW at No.2 berth (south) Alcoa Jetty.

Data collection:

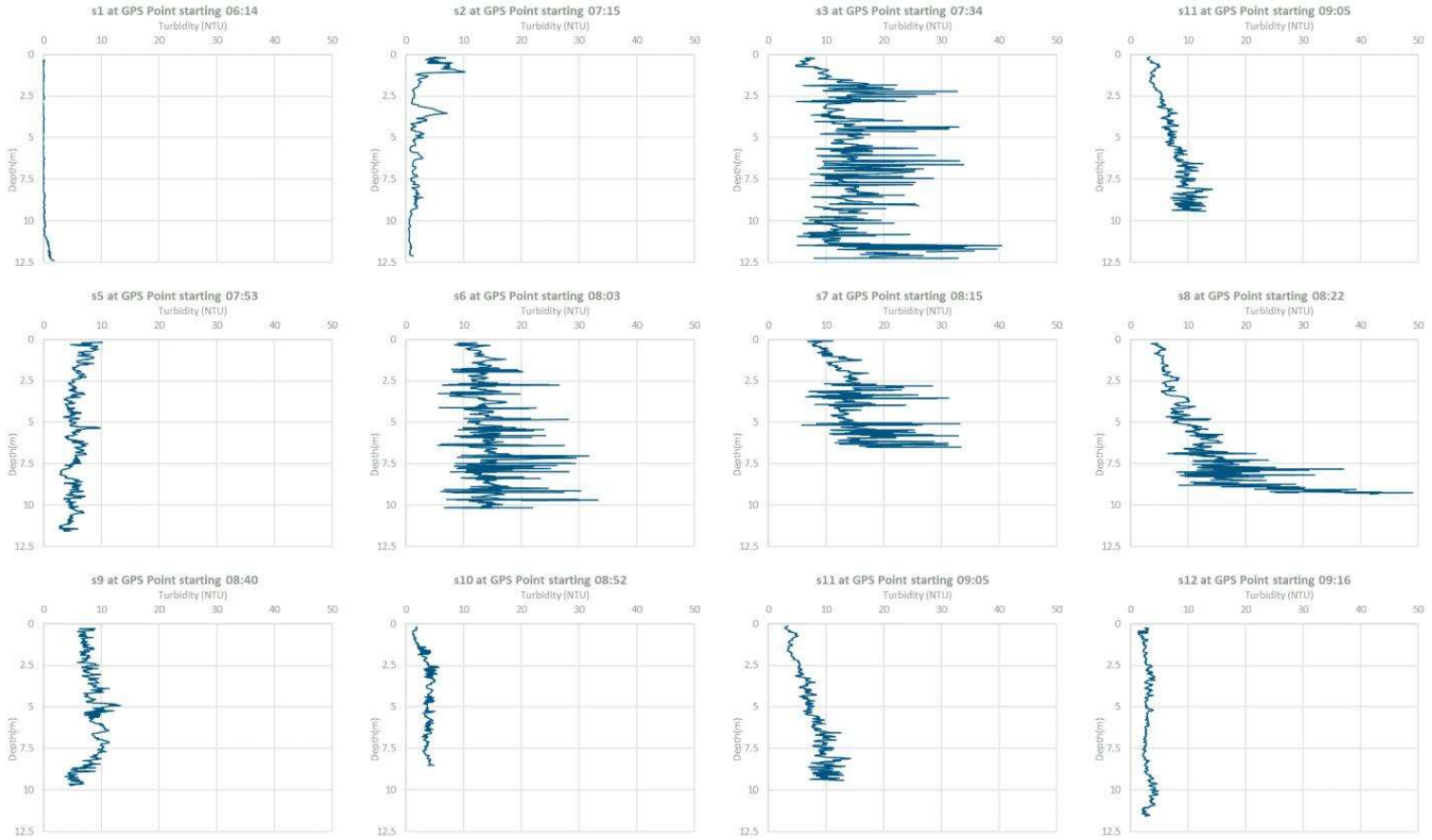
- Drone aerial imagery
- Turbidity profile
- Water sample collection
  - Particle Size Distribution (PSD)
  - Total Suspended Solids (TSS)



GPS no.	Water Sample ID	Turbidity Profile ID	Start Time
0001	S1-11, S2-2	s1	06:14
0002	S3-10, S4-2	s2	07:15
0003	S5-11, S6-1	s3	07:34
0004	S8-1, S7-5	s4	07:43
0005	S9-1, S10-8	s5	07:53
0006¹	S11-1, S12-6	s6	08:03
0007	S13-2, S14-5	s7	08:15
0008	S15-2, S16-2, S17-8	s8	08:22
0009	S18-2, S19-7	s9	08:40
0010	S20-3, S21-7	s10	08:52
0011	NULL	s11	09:05
0012	NULL	s12	09:16

Notes:
1. GPS no. 0006 added by observing the GPS track and drone footage.

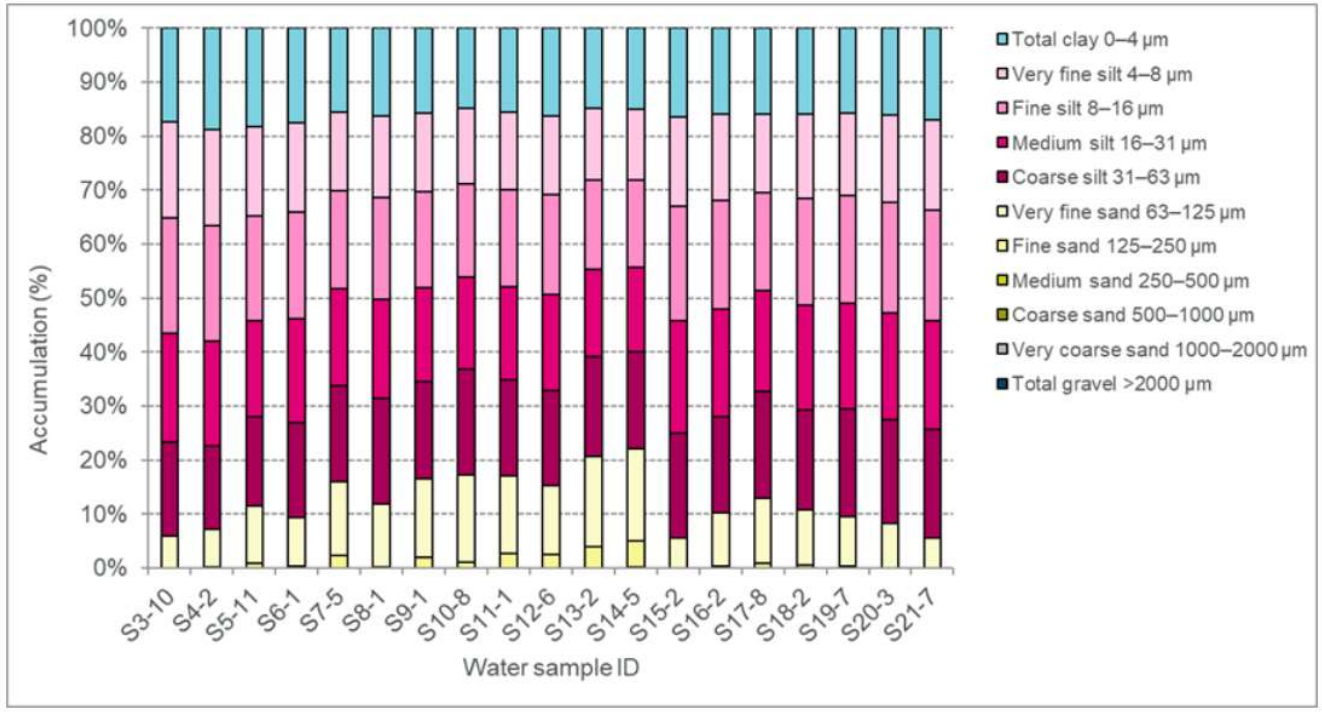
Turbidity Profile Measurements



Particle Size Distribution (PSD)

Sediments present in the samples were largely comprised of:

- 62-78% silts (4-63 µm)
- 14-19% clays (0-4 µm)
- 5-17% very fine sand (63-125 µm)
- <5% fine sand (125-250 µm) in most samples
- 0% larger than medium sand (>500 µm) due to the higher settling velocities



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Total Suspended Solids (TSS)

The TSS ranged from 5 to 51 mg/L at different locations and times during the suspended sediment plume evolution.

Samples S1-11 and S2-2 were reference water samples taken prior to the liquid bulk vessel and tug arrival, showing <1 mg/L TSS in ambient waters.

Water sample ID	Sample date	TSS (mg/L)	TSS analysis date
S1-11	25/08/2023	<1	28/08/2023
S2-2	25/08/2023	<1	28/08/2023
S3-10	25/08/2023	11	28/08/2023
S4-2	25/08/2023	7	28/08/2023
S5-11	25/08/2023	37	28/08/2023
S6-1	25/08/2023	45	28/08/2023
S7-5	25/08/2023	19	28/08/2023
S8-1	25/08/2023	10	28/08/2023
S9-1	25/08/2023	18	28/08/2023
S10-8	25/08/2023	9	28/08/2023
S11-1	25/08/2023	36	28/08/2023
S12-6	25/08/2023	32	28/08/2023
S13-2	25/08/2023	36	28/08/2023
S14-5	25/08/2023	51	28/08/2023
S15-2	25/08/2023	14	28/08/2023
S16-2	25/08/2023	11	28/08/2023
S17-8	25/08/2023	44	28/08/2023
S18-2	25/08/2023	15	28/08/2023
S19-7	25/08/2023	23	28/08/2023
S20-3	25/08/2023	5	28/08/2023
S21-7	25/08/2023	7	28/08/2023

Field Measurement Video

Part 2 – Hydrodynamic and Sediment Fate Modelling

Hydrodynamic and Sediment Fate Modelling

Tuflow's flexible mesh solver, TUFLOW FV, together with its Sediment Transport (ST) module provided the power needed to simulate sediment resuspension and plume dispersion.

- SWAN and TUFLOW FV (previously calibrated)
- ST Module (previously uncalibrated, but post calibrated by field observations)

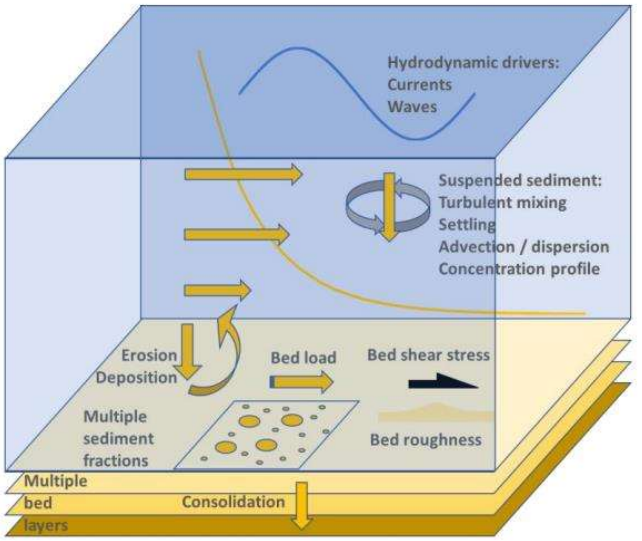
Typical summer, autumn, and winter conditions were modelled, capturing seasonality and variability of currents.

Simulations tracked silt and clay sediment fractions to represent material resuspended by tug prop wash.

Sediment Transport Module

Sediment Transport Module Configuration:

- A baseline ambient (no tug activity) and “bed warmup” sediment transport simulations were run in preparation for the production runs.
- PSD and settling velocities were used as model input parameters.



Tug Resuspension Source Term Derivation:

- Momentum source boundary condition was calculated based on the tug propeller thrust and applied in conjunction with the plume source.

Experimental Validation Using Field Measurement Results:

- Maximum modelled plume TSS within ~100m of the tug was ~50 mg/L (consistent with the sampling and analysis).
- Modelled plume TSS at up to 800m from the tug were potentially low compared to the sampled and analyzed, 23 mg/L.
- Raw model outputs were scaled to match the measured TSS in the vicinity of the PSDP seawater intake.
- Further calibration work may be required to address this potential discrepancy.

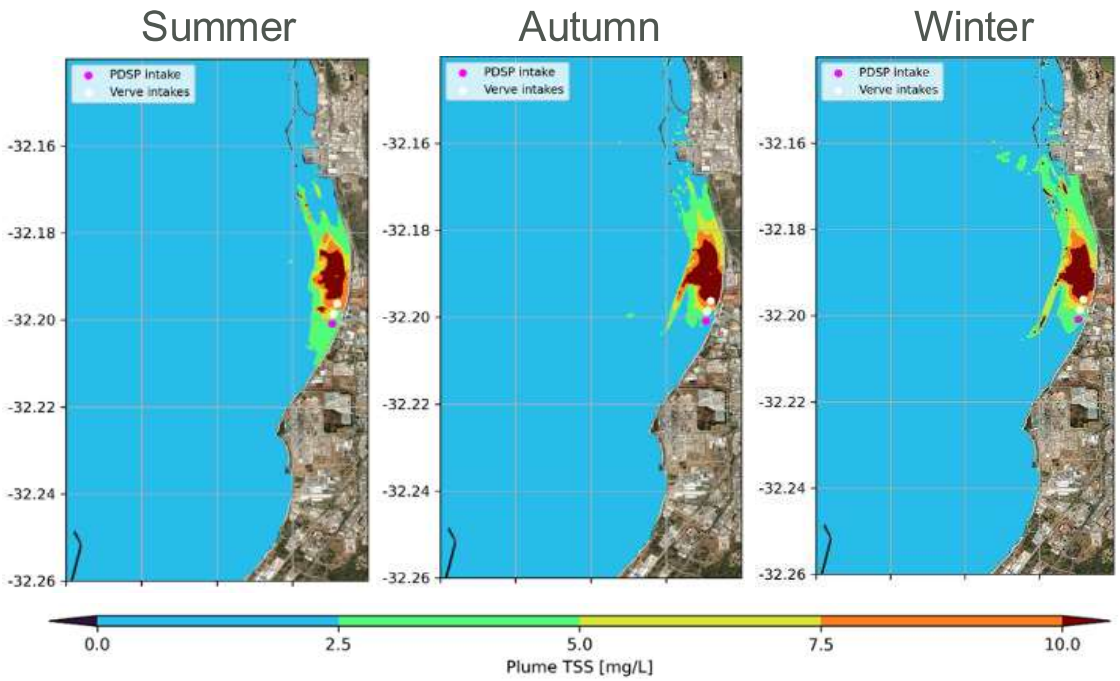
Results

Risk at seawater intake:

- Zone of influence (98th-percentile tug plume where TSS>2.5mg/L) encompassing the seawater intake.
- Duration of tug induced TSS was extracted as a percentage of simulated time in exceedance of a 9mg/L (threshold level) resulting in 0.5% for January, 0.1% for May and 0% for July
- Potentially low risk of entrainment issues

Risk at Seagrass Location of Interest:

- Low levels of TSS was extracted at 2-3m above the seabed at the seagrass point of interest.
- Potentially low risk of environmental impact to the seagrass area.



Discussion and Conclusion

Discussion:

- The study timing required early model development.
- Field measurement results were only available near the end of the study, allowing comparison with uncalibrated model results.
- Results of depth averaged TSS from the uncalibrated numerical simulation were scaled to represent the TSS levels from field sampling.
- Further model refinements are possible using or collecting additional field data.

Conclusion:

- Low risk of sediment entrainment at the seawater intake due to tug prop wash, and a low risk of impacting the seagrass.
- The study demonstrates the capability of the proposed modelling and measurement framework for accurately assessing the risk associated with tug propeller sediment resuspension.

Thank you

Q&A session

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