Appendix 2

Statistical methodology outline – Development of Intensity component of Turbidity Triggers

The below is a summary of the methodology set out in the Environmetrics Australia Report: *Statistical Considerations Associated with the Establishment of Turbidity Triggers: Candidate Methodologies for Large Scale Dredging Projects dated 11 May 2017*

Step 1: Raw data collected by turbidity monitoring stations and sent via telemetry to data warehouse facility.

Step 2: Raw data undergoes preliminary inspection and quality assurance using a combination of both manual and automated processing tools to produce *functionally-assured (F-qaqc)* data.

The purpose of the *F-qaqc* step is to check the consistency and integrity of the data obtained from the monitoring instruments and, where appropriate, to take remedial action. These activities include, but are not limited to:

- Flagging and if necessary, removing readings obtained when equipment was known to be faulty, unreliable, or unserviceable;
- Flagging, but **not** removing readings obtained during adverse weather or oceanographic conditions;
- In the case of dual-instrument deployments, aggregating readings in accordance with agreed protocols;
- Implementing agreed protocols in the case of instrument failure for a dual-instrument deployment.

Step 3: Functionally-assured data then is subjected to rigorous analysis using a variety of statistical procedures to produce *statistically assured data*. Activities within this step include:

1. Identify extreme and unusual data in terms of their *statistical* properties and address as required;
2. Use statistical data imputation techniques in accordance with agreed protocols to overcome problems created by blocks of missing data;
3. Apply the Kolmogorov-Zurbenko (KZ) filter, in accordance with agreed protocols, to attenuate the influence of extreme, transient observations; and

Step 4: Establish TSS-NTU relationship(s)

In order to assimilate the modelled turbidity data (in units of mg/L) with the monitoring data (in NTU) models describing the TSS-NTU relationship need to be established. This involves:

1. Using the complete baseline data record of depth-profiling data at all sites to establish the relationship between sub-surface total suspended sediment concentrations (in mg/L) and contemporaneous measurements of NTU;
2. Additional statistical analysis to establish whether significant spatial variations in the empirical TSS-NTU relationship are evident. If this is the case, *separate* (site-specific) TSS-NTU

models will be used in step 5 below; if not – a single 'omnibus' TSS-NTU model will be used in step 5 below.

Step 5: Convert the modelled data to NTU and combine with measured baseline

1. The TSS-NTU relationship(s) from step 4 will be applied to the modelled TSS concentrations (for an indicative year for the harbour model and for 10 years for offshore model) at each monitoring location to convert predicted TSS concentrations into NTU. At each monitoring site, the timestamp on the modelled output will be used to match a converted TSS value with the measured turbidity obtained at the same day, month, and hour during the baseline monitoring campaign;
2. The converted TSS and baseline NTU values obtained at step 5.1 will be added together to obtain a~~n~~ ~~annual (or longer)~~ time-series (annual or longer) of ***total turbidity*** in NTU at each monitoring location;
3. The ***total turbidity*** data obtained at step 5.2 will be used as the basis for determining trigger values for each monitoring location.

Step 6: Calculate the *Intensity* parameters for each site for all three tiers

1. Using the *total turbidity* data at each monitoring location, calculate the Intensity (NTU) for each tier as the relevant percentile in Table 1 of the data obtained in step 5.3

Table 1

Turbidity Trigger	Intensity level $(1-\alpha)$	Nominal Intensity Trigger	Intensity (NTU)	Allowable duration of exceedance (hours) per rolling 30 day period
Tier 1	0.8	$Y_{(1-\alpha)}^{(1)}$	$I_{(1-\alpha)}^{(1)}$	144
Tier 2	0.95	$Y_{(1-\alpha)}^{(2)}$	$I_{(1-\alpha)}^{(2)}$	36
Tier 3	0.99	$Y_{(1-\alpha)}^{(3)}$	$I_{(1-\alpha)}^{(3)}$	7.2

2. For a chosen intensity level $(1-\alpha)$ determine the nominal intensity triggers, $Y_{(1-\alpha)}^{(i)}$, $i = 1,2,3$;
3. For a nominal intensity trigger $Y_{(1-\alpha)}^{(i)}$ determine the corresponding upper limit $I_{(1-\alpha)}^{(i)}$ such that the probability that the $(1-\alpha)$ percentile of a sample of *n* filtered turbidity readings (obtained at the end of step 3) exceeding $I_{(1-\alpha)}^{(i)}$ is no more than 1% The determination of $I_{(1-\alpha)}^{(i)}$ shall be based on part (c) of Theorem 7.1 in DasGupta (2008) . The upper limits $\left\{ I_{(1-\alpha)}^{(i)} , i = 1,2,3 \right\}$ so determined are referred to as *'intensity'* and form the basis of all monitoring and compliance activities.