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TURBIDITY PLUME ASSESSMENT BRISBANE RIVER GRAB DREDGE "KEN HARVEY" PORT OF BRISBANE CORPORATION

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Title:	Turbidity Plume Assessment Brisbane River Grab Dredge "Ken Harvey"
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Synopsis:	This report presents an assessment of the turbidity plume caused by the operation of the Grab Dredge "Ken Harvey" whilst in the Brisbane River. The assessment was undertaken to determine the suitability of DoE conditions within the Draft ERA Licence.

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1 INTRODUCTION

WBM Oceanics Australia was commissioned by the Port of Brisbane Corporation (PBC) to undertake an assessment of the turbidity plume generated by the corporation's grab dredger, the Ken Harvey, whilst operating in the Brisbane River.

These works were required to assess the practicability of conditions the Department of Environment (DoE) had stipulated in the Draft Environmentally Relevant Activity Licence (ERA) for the PBC operations within the Brisbane River.

The Ken Harvey is utilised to undertake maintenance dredging within 40 m of berthing facilities within the Brisbane River. This dredging is required to ensure minimum declared depths are provided at berths for shipping.

The clamshell grab is operated by a barge mounted crane operating over the stern. The grab is lowered to the river bed and closed. This is then drawn to the surface by the crane and the material deposited in a split hull hopper barge moored alongside. The procedure is repeated until the hopper barge is full or sufficient material has been excavated for the designated area.

Due to the relatively short jib length of the crane, the maximum reach of the grab is approximately 6m from the stern of the barge. When sufficient material has been excavated from a given area the barge is repositioned by winching on fore and aft anchor lines and excavation is continued in a new area.

Sources of turbidity from the operation are :

- resuspension of material by the grab when it strikes the river bed.
- leakage of material contained in the grab as it is drawn to the surface. The amount of material resuspended peaks as the grab breaks the water surface and displaced water falls from the grab, entraining excavated material.
- loss of material from the previous excavation attached to the grab as it is lowered to the river bed.
- overflow of excess water draining from the hopper barge. The proportion of water contained within each grab (and hence the amount of overflow) is related to the type of material being excavated. All water is contained within the hopper (except some minor leakage) until the level reaches the four overflow pipes situated at each corner of the hopper. Additionally, water drains via the split in the hopper. This has a rubber seal to deck level. Above this level, water drains onto the deck and over the side.

2 DRAFT ERA LICENCE CONDITIONS

The draft ERA Licence supplied to the PBC by DoE stipulates, with respect to the release of wastewater that :

- suspended solid concentrations must not exceed 10 mg/L above a background value where the background value is less than 100 mg/L, or 10% greater than background value where the background value is greater than 100 mg/L
- turbidity must not exceed 2 NTU above a background value where the background value is less than 20 NTU or 10% greater than a background value where the background value is greater than 20 NTU.

The sampling location stipulated by the draft ERA is defined relative to the flow conditions at the time of sampling. At times when tidal flows or other flows are occurring the sampling point is to be not more than 200 m downcurrent of the release point. During slack water conditions and other times when negligible flow is occurring, the sampling location is to be situated not more than 100 m downcurrent of the release point.

The assessment undertaken by WBM Oceanics Australia was based on these criteria.

3 METHODOLOGY AND RESULTS

An inspection of the operation of the Ken Harvey was undertaken on 21 May 1997 by WBM Oceanics Australia staff. The dredger was operating at alongside the Incitec North Berth, approximately 8 km upstream of the river mouth. The dredging procedure was that four grabs were collected and then the barge was winched forward approximately two metres. Total loading time was approximately 90 minutes. Discussions with PBC Dredger Master indicated that this operational procedure was typical of operations within the Brisbane River.

The Incitec North Berth site was selected for this assessment as the experience of the PBC staff indicated that the excavated material was likely to contain a high proportion of fine material (silts), generating the maximum plume for this type of operation. Additionally the assessment was undertaken on the approximate peak of the ebbing tide to simulate maximum movement of the plume. That is, the study provides probable "worst-case" results.

To gain a preliminary understanding of the relative contribution of each of the components of the plume generation (see above), spot measurements were undertaken at various depths and locations downstream of the operating dredger.

This indicated that the major component of turbidity plume generation resulted from the resuspension of material caused by the grab as it exited the water. Measurement of the plume created by the hopper discharge indicated this to be a relatively minor component in terms of both time and amount discharged.

3.1 Background Turbidity

The background (ambient) turbidity value was established at a point approximately 100m immediately upstream of the dredge (ie consistent with draft ERA Licence conditions). Turbidity values were recorded at each meter interval throughout the depth profile. This procedure was undertaken twice to establish the variability of background turbidity levels (Table 3.1).

Table 3.1: Results of background *in-situ* turbidity profiles taken 100 m upstream of operating dredge

Depth (m)	Turbidity (NTU) Sample 1, 11:15am	Turbidity (NTU) Sample 2, 11:40am
1	23.8	21.1
2	24	21.2
3	24	19
4	24.2	18.6
5	24.0	22
6	24.7	22.3
7	27	22.4
8	30	21.6
9	31	23.2

The assessment of the turbidity plume was undertaken in two methods. These were aimed at assessing the intensity of the plume at various distances downstream and assessing the degradation of the plume at the depth stipulated by the DoE Draft ERA conditions (2 meters below the water surface). Additionally, an assessment was made particle size distribution of the dredged sediments and of the plume originating from the hopper overflow.

3.2 Plume Turbidity

To assess the extent and intensity of the plume at downstream points, the following methodology was employed. A drogue was released as close as possible astern of the operating dredge in the approximate centre of visible plume. This was then tracked to establish the path of the plume. The procedure was repeated to ensure the consistency of the path.

Sampling locations were established at 10, 50, 100 and 200 m down stream of the dredge on the plume path using a GPS. Measurements of *in-situ* turbidity were taken at each meter interval throughout the depth profile using a precalibrated Hydrolab H20 multiprobe water quality meter.

The operational procedure of the grab dredge (see above) generated pulses of turbid waters rather than a constant plume. To allow for this the meter was held at each depth interval and visual observation of the turbidity readout made over approximately two minutes (grab frequency at the dredge was approximately 1 - 1.5 minutes). The peak value of the turbidity at each depth was then was recorded (Table 3.2)

Table 3.2 : Results of *in-situ* turbidity (NTU) profiles taken at various distances downstream of operating dredge

	Location (Downstream)			
Depth	**10 m**	**50 m**	**100 m**	**200 m**
1	55.8	23	21	19.8
2	38	23	20.6	20
3	36	22.6	20.5	20.6
4	34	22.8	20.7	Seabed
5	34	24	21.9	Seabed
6	31	26.1	Seabed	Seabed
10	52	Seabed	Seabed	Seabed

3.3 Plume Degradation

To assess the degradation of the plume at the depth (2m) stipulated by the DoE in the Draft ERA in terms of distance from the dredge, the following methodology was employed.

The drogue was released as close as practical to the operating grab in the approximate centre of the visible plume. This was then tracked with the turbidity meter set at 2 meters below the water surface. The turbidity value was then recorded approximately every 30 seconds. The drogue was then tracked until several readings within background limits had been recorded. This procedure was then repeated. The results are shown in Figure 3.1

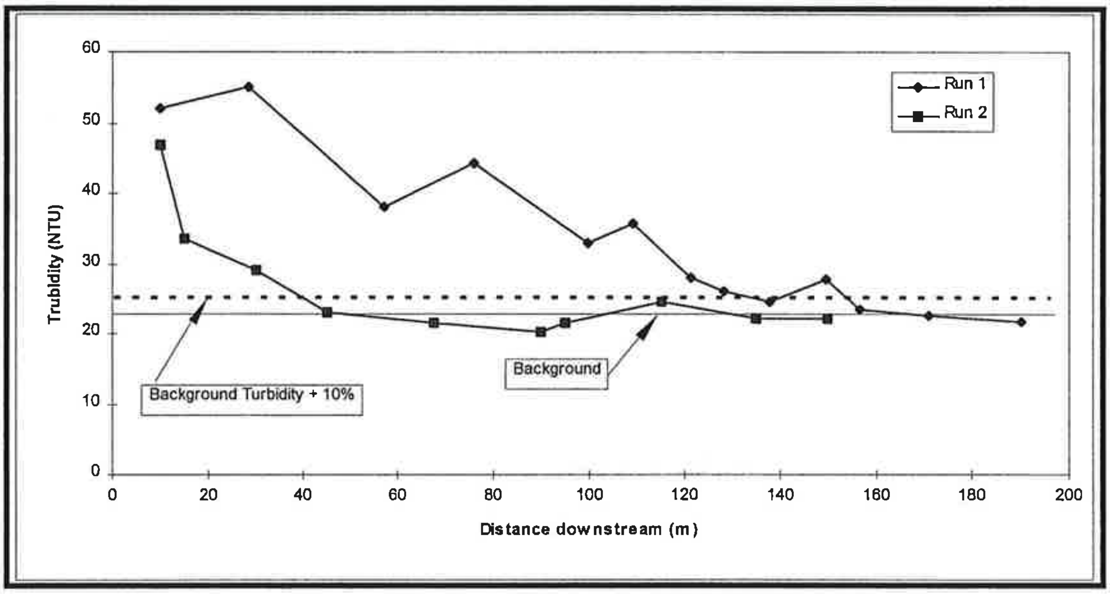

Figure 3.1: Turbidity results at two meters below the water surface alongside drogue.

3.4 Particle Size Distribution

Two samples of the sediments were collected directly from the grab and analysed for particle size distribution (Figure 3.2). This indicated that the sediments were predominantly silts (93% >0.075 mm), with a small sand fraction.

Figure 3.2: Particle size distribution of sediments dredged from the Incitec north berth.

3.5 Hopper Discharge

The discharge from the hopper formed a relatively minor component of the turbidity plume created by the operation of the dredge. Discharge did not occur until maximum hopper load was approached (approximately 60 - 70 minutes after commencing works).

Discharge volumes were low, restricted by the diameter of discharge pipes (approximately 50 mm) and the nature of the material (silty material inhibits the passage of water). Discussions with the dredger crew indicated that a greater volume of discharge would be expected when the material was predominantly coarse material (sand).

Discharge also flowed from the hopper through the split in the hull which allows the disposal of the material (split hull hopper). This split was sealed with a rubber seal to deck level. Water flowed through the split above this level onto the deck and subsequently over the side of the barge into the river. Again this was a relatively minor component.

The PBC dredger crew had installed small detention devices to prevent the material from dispersing across the deck mainly as a safety precaution. These retained a small portion of silt material.

In addition to the plume created by the operation of the grab, the plume created by the hopper discharge was visible on the water surface approximately 80 - 100 m astern the hopper barge. The plume was approximately two meters wide and generally extended less than one meter into the water column. Turbidity measurements made at approximately 100 m astern the hopper barge were 10 - 15% above background levels. The path of the plume was impacted by turbulent effects caused by the Shell Products Berth approximately 120 m downcurrent of the hopper barge. Measurements made downcurrent of this point did not detect any turbidity above background levels.

4 TURBIDITY VERSUS SUSPENDED SOLIDS CRITERIA

The conditions specified by the draft ERA licence stipulate both suspended solid concentrations and turbidity criteria (Section 2).

Both the monitoring exercise undertaken in conjunction with this study and previous similar studies have indicated that there are logistical difficulties leading to potentially unnecessary time and cost penalties in the monitoring of both suspended solid concentrations and turbidity.

This stems from the high degree of temporal variability in the plume at a given monitoring location due to the nature of the plume (pulse effects) and other external factors, such as current turbulence.

It was found during the present monitoring exercise that :

- the visual intensity of the plume varied as eddies and swirls in the current moved downcurrent;
- the measured turbidities varied significantly, typically in the range of mean ±50% over a period of several minutes; and
- for two monitoring runs undertaken 25 minutes apart, the turbidity results obtained were significantly different along the plume centerline (Figure 3.1).

Whereas average and maximum turbidity readings may be obtained readily over a set period, the results being immediately available, water sampling for suspended solids gives a more instantaneous "snapshot" of this parameter. Thus, many samples must be taken to derive representative results, and the results are not known until after laboratory analyses. This precludes suspended solid concentrations from being used realistically as a reactive monitoring indicator.

Thus, for practical monitoring in the river, port and Bar cutting areas where fine silt/clay sediments are involved, we recommend the use of in-situ turbidity (NTU) criteria only. This would thus provide :

- realistic temporally representative results when averaged over (say) 2-3 minutes
- immediate information which could be used for reactive purposes to modify the dredging process; and
- a turbidity measure closely related to the environmental value of the area.

Previous monitoring of dredging operations in the Brisbane River undertaken by WBM Oceanics Australia has shown that, for fine sediments, there is a consistent relationship between turbidity and suspended solid concentrations. Results from these monitoring exercises have been assessed to develop the relationship :

$$\textit{Suspended Solid} = 1.1061 \times \textit{Turbidity} + 4.2832$$

Regression analysis of this relationship indicated that a close correlation ($r^2 = 0.9$) existed between recorded turbidity values and suspended solid concentrations. Hence, suspended solid concentrations, if required, can be determined directly from turbidity results for monitoring purposes.

5 CONCLUSIONS

5.1 Monitoring Results

The salient points from the assessment of the turbidity plume created by the PBC dredger "Ken Harvey" in the Brisbane River are :

- the operational procedure produces a pulse effect with respect to the turbidity plume.
- maximum turbidity values related to the retrieval of the full grab breaking the water surface, causing a relatively intensive plume over an area of approximately 100 m^2. This plume is confined to the surface layers, generally not extending below 2m depth.
- some turbidity was caused by the resuspension of bed sediments by the grab. This was a minor component of the plume and did not extend by approximately 2 m above the river bed.
- The contribution of the hopper discharge to the turbidity plume was relatively minor. It produced a band of turbid water approximately 2 m wide astern of the hopper. The plume was visible approximately 100 m astern the dredge but was confined to the surface layers being less than 1 m thick
- grab related turbidity levels at two meters below the water surface were at background levels within 100 - 150 m downstream of the dredge
- *in-situ* profiling did not detect appreciable increases in turbidity levels at any depth beyond 150 m downstream.

5.2 Conformance with Draft Criteria for Tidal Flow Conditions

The conclusion of the above points is that compliance with the conditions stipulated by DoE in the draft ERA licence for tidal flows (Section 2) should be possible without alteration to the present working procedure and/or plant.

It should be noted however that this conclusion is based on the assessment presented above undertaken during an ebbing tide.

Additionally, for the reasons outlined above (Section 4) it is suggested that monitoring be based upon in-situ turbidity results. The conditions relating to suspended solid concentrations should be removed from the ERA licence.

5.3 Slack Tide Criteria

The draft ERA conditions also define a sampling location for slack tide or periods of negligible flow as 100 m directly downcurrent. The licence fails to further define the "slack tide or other times or negligible flows" criterion.

Absolute local "slack" tide would only occur for a very short time period. Monitoring during this period would not be logistically possible. Additionally, a minimum flow criterion would need to be established to determine "negligible" flow conditions. This would further complicate the licence conditions without gaining significant or relevant information on the behaviour of the plume.

It is therefore suggested that the "slack tide or other times or negligible flows" criteria be removed and all sampling be undertaken at the 200 m downcurrent location.

If the criteria was to remain in the ERA we would suggest slack water be defined as ±30 minutes local high/low tide. It should be noted that the practicality of collecting representative samples within this "slack tide" time frame be questionable. Negligible flow could be defined as <0.02m/s at the sampling location. may

5.4 Temporal Variability Provision

From the analysis of the in-situ turbidity results, it is clear that there is a high degree of spatial and temporal variability in the plume intensity. The licence conditions should acknowledge and reflect this situation.

The turbidity condition should therefore be altered to compensate for this variability by including a time component. It is therefore suggested that condition C5 of the Draft ERA include :

"The turbidity value shall be established as an arithmetic mean of at least 10 readings taken over at least a five minute period at the specified depth at the sampling location."

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