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Real-time environmental monitoring of dredge spill at the Port of Jebel Ali, UAE

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Silt monitoring survey vessel in Jebel Ali-Dubai

An increasing number of dredging operations now require a varying degree of environmental monitoring. One such project was the maintenance dredging of the approach channel to the Port of Jebel Ali in the UAE earlier this year. As the main contractors, Dredging International NV of Belgium requested the expertise of UK based Chelsea Environmental Ltd to provide a fully integrated, real-time monitoring package to meet the stringent requirements stipulated by the local municipality. Their primary concern was the protection of the corral reefs located just a few kilometres along shore from the entrance to the port.

Monitoring of sediments brought into suspension during dredging activities can be achieved by deploying turbidity monitors which transmit data to the dredging control centre in real time. Turbidity monitors would normally be strategically deployed at fixed locations close to areas of environmental concern and also on survey vessels to track the movement of suspended sediment within the vicinity of dredging operations.

Optical turbidity sensors on their own will not provide data in the density required to describe the dredge plume or enable the calculation of concentrations of resulting sediment that may be transported across defined boundaries in real time to the accuracy required for spill monitoring. In order to attain the spatial detail required Acoustic Doppler Current Profilers (ADCP) are employed.

The ADCP enabled non-intrusive measurements of current speed, current direction and backscatter (sediment related) profiles to be measured through the water column. The instrument measures Doppler frequency shift between acoustic pulses transmitted by the instrument and received return signals reflected from scattering particles such as plankton and suspended sediments in the water column at regular intervals through depth. The frequency shift is then used to infer the local water velocity relative to the instrument. In addition, backscatter signal strength is recorded at each measurement level which, with appropriate calibration, is used to obtain profiles of suspended sediment concentrations.

The main components of the suspended sediment monitoring system as used in the Port of Jebel Ali were 1200kHz and 300kHz ACDPs, optical backscatter turbidity monitors (OBS), electromagnetic current meters and radio modems for data transmission to the shore-based office for processing and display in near real time.

The project

The objective of the project was to measure the quantity of suspended material transported away from all sources of the dredging activities, in particular to measure the amount that passes outside a specified boundary of the dredging or deposition zone. This quantity is usually expressed as a percentage of the amount of material dredged, transported to the deposition site and released at a pre-determined location.

Each of these zones had several sources of sediment brought into suspension such as those derived from large vessels operating within the approach channel, natural discharge from the port, water body movement across the channel etc. To determine the sediment spill it was necessary, therefore, to identify each source within the monitoring zone boundary over a period of time.

Prior to the commencement of dredging operations, baseline monitoring at four reference stations encompassing the dredging, transit and deposition areas was carried out to determine the background sediment concentrations naturally present.

Once background observations were completed, dredging activities commenced comprising three main elements, channel dredging, transportation of dredge material to the deposition site and deposition within a pre-defined area; each element requiring a unique monitoring strategy.

Dredge monitoring was established by sailing transects along pre-defined boundaries (set at 200m either side and parallel to the dredged channel) to determine the concentration profile and dimensions of any spill.

After each dredge run lasting approximately 25 minutes, the dredger sailed for the deposition site 28 km offshore. Monitoring was required at this stage to determine any losses caused by leakage from the hopper doors or in fact by the passage of the dredger itself within the channel. This was achieved by running a background transect perpendicular to the channel axis ahead of the dredger as she made passage offshore. Subsequent transects were made once the vessel has passed the "gate" at set intervals, thus allowing the net spill caused by the vessel to be calculated. Using the available flow data, this spill was projected to the 200m boundary parallel to the vessels track to provide the flux across this boundary.

Deposition monitoring was carried out in a manner similar to that employed during a standard plume

tracking exercise. Immediately after the sediment was released at the surface, a drogue was employed within the main body of the plume. Survey lines were then run perpendicular to the major axis of the discharge patch at regular intervals. A numerical modelling technique was then used to determine the flux crossing the contract deposition boundaries.

Due to the complexity of required monitoring, two survey launches were engaged, each having a fully integrated system developed by Chelsea Environmental comprising an ADCP, a fixed array of OBS, a near-surface Electromagnetic Flow Meter (EFM), pumped samplers, differential GPS, gyro compass, echo sounders, and associated PC's.

The ADCP measured water flow from just below the surface to near seabed, together with suspended solids from the backscatter intensities using a single vertical acoustic beam. Near surface measurements were obtained using the EFM referenced to the vessels gyro compass and OBS sensors.

All sensors were used to provide real-time information on sediments brought into suspension during the dredging operations and the associated current velocities and directions. These data were then processed onboard to determine the sediment fluxes. The OBS sensors provided continuous measurements at different levels through the water column to provide data by which the ADCP was calibrated and checked through the dedicated onboard software. Additionally, standard pumped sampling techniques for determining suspended sediment concentrations were made to regularly calibrate and re-calibrate the OBS sensors. The pumped samples, taken alongside each sensor, were sent ashore for analysis in the field laboratory.

ADCP backscatter is calibrated at background levels over the whole water depth to provide reliable calibration data. Water absorption coefficients are determined by this "calibration run".

The data generated by the ADCP and its corrections based on the water absorption coefficients, temperature and depth are therefore interpreted with the help of the information from calibrated optical turbidity sensors.

Each vessel was equipped with two networked PC systems to log and process survey data:

- ADCP control PC – running RDI Transect software used as the primary method for measuring and displaying raw velocity and sediment concentration data;
- Sediment plume processing PC – running software developed in-house and used to log data from ancillary sensors during the collection phase and to process data on-line.

The project also required the installation of three monitoring stations around areas of coral to the south west of the entrance of the port. The purpose of these stations was to provide a real-time, 24 hour indication relating to the flow regimes and sediment concentrations directly around the reefs.

ADCP – Suspended Sediment Monitoring System

Dredge spill monitoring software

The plume tracking software used during the Jebel Ali project adopted a semi-empirical approach to determining the sediment concentration and mass discharge across specified transects. The software was designed to provide a flexible but reliable tool for use both in the field and in the office for post-processing. Preliminary estimates of the concentration distribution, and optionally discharge, were derived offshore. These data were then reprocessed using more sophisticated algorithms in order to provide more reliable estimates for the daily and weekly reports.

The offshore system consisted of two PCs, the first running the RDI Transect package, and the second running the Chelsea Environmental "Plume" package. The transect package outputs backscatter and velocity data at two to three second intervals, with the navigation, echo sounder, gyro compass and ancillary current meter proving data at the same interval. The OBS were interrogated and returned the most recent average concentration every two seconds. The data were displayed in real time in either digital or graphical form. The real time data were processed using the most appropriate set of calibration coefficients, with the derived sediment concentration plotted to the screen display on the PC running the "Plume" package. All calibration and other site specific data were logged such that the raw data could be reprocessed using either the same or revised ancillary data.

The output from the post processing included:

Data for updating the calibration files.

The calculation of a "typical" concentration profile. (This is the concentration profile describing the "background" sediment distribution, these data may be subtracted from the "downstream" transect. Data for the calculation of the profile was derived from the ADCP and OBS sensors.)

A comparison of the OBS measured concentrations at appropriate depths. (These data can be used to update the empirically derived calibration coefficients.)

A comparison of the current speed and direction between EFM sensors and the ADCP data.

- Discharge calculations – the discharge across a transect expressed either relative to a background sediment load, or as an absolute sediment load.
- Concentration and velocity distribution – the calibrated concentration distribution derived from the ADCP, and the observed speed and direction of the flow.
- Raw data files suitable for archiving.

Extensive site observations over a four month period have demonstrated the reliability and flexibility of the package. Development work is still underway, specifically to improve the automatic filtering of bad data, and to enhance the presentation of the velocity data.