NEW STANDARDS FOR MITIGATING DREDGING IMPACTS IN SENSITIVE HABITATS IN SAUDI ARABIA

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We propose a systematic approach to monitoring and managing dredge operations based on industry best practice advice, tailored to the specific conditions in the Red Sea, including the following key elements: 1) Relocation of corals from the direct dredging footprint, 2) Development of a site and project-specific dredging environmental management plan, 3) Undertaking turbidity and coral monitoring, 4) Turbidity plume hindcast and forecast, 5) Adaptive management involving all key project stakeholders. The paper lists the above key elements and presents a case study from Sindalah Island where the system was successfully applied – the first time such an approach has been implemented in the Middle East region.

Keywords: sustainable dredging; adaptive monitoring and management; coral relocation; turbidity plume hindcast and forecast;

INTRODUCTION

The Kingdom of Saudi Arabia has, as part of its established Vision 2030, placed emphasis on the diversification of the economy to reduce reliance on the oil and gas and petrochemical sectors. A key component of this drive towards diversification includes the ambition to increase non-religious tourism. Saudi Arabia has identified a number of development opportunities along the Red Sea, the deep narrow sea that lies between the Arabian Peninsula and Africa, see Figure 1. The Red Sea is recognized as a global biodiversity hotspot with high species endemism.

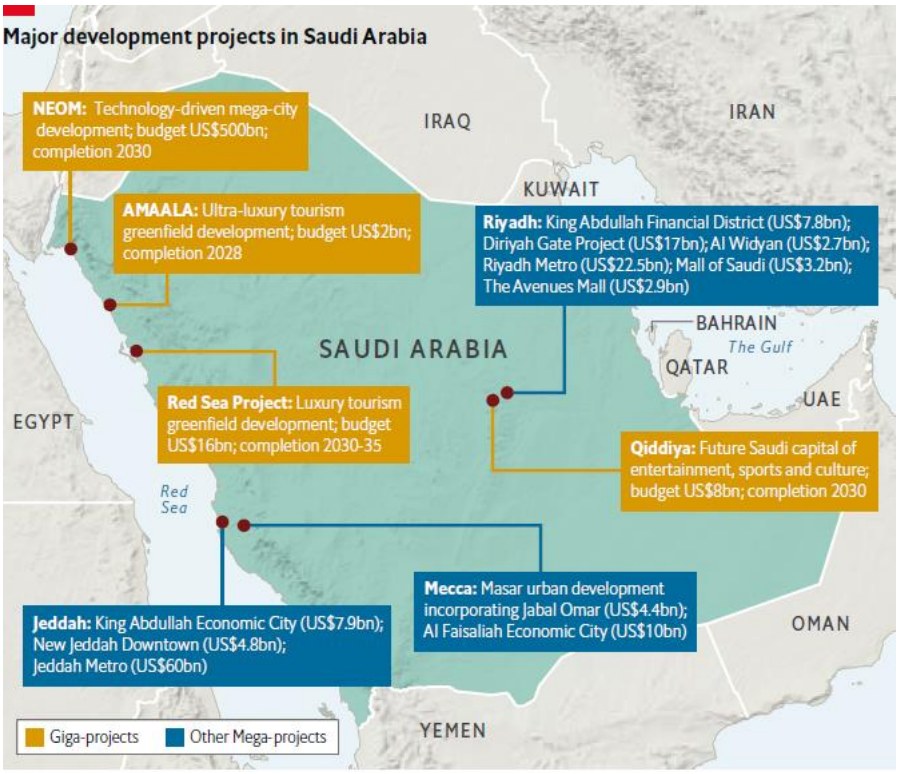

Figure 1. Overview of GIGA projects in Saudi Arabia, modified from https://www.eiu.com/n/campaigns/saudi-arabia-business-environment.

Protection and enhancement of the natural capital within the proposed development areas has been identified as a central tenant driving the planning process. However, the development of successful tourist destinations often requires marine infrastructure, such as marinas. Marina construction requires dredging of shallow areas to obtain adequate draft for the vessels that will utilize the marina.

Dredging in or near sensitive habitats, such as coral reef systems, should be avoided where possible due to the potential negative impacts on these systems. Potential impacts to corals from dredging include, but may not be restricted to, direct habitat loss in dredging area and lethal or sub-lethal impacts from degradation of water quality (i.e. from suspended sediment) and sediment deposition.

Figure 2. Coral reef from the Red Sea.

In this paper we define how dredging works should be planned, monitored, and managed to increase the likelihood of sustainable development in and around ecologically sensitive marine habitats.

MITIGATION HIERARCHY

The standard IFC mitigation hierarchy must be applied in the planning of the projects. This includes a thorough impact assessment that evaluates viable alternatives as a form of avoidance (IFC, 2019). Thus, alternatives must be thoroughly considered before deciding to dredge close to sensitive habitats. This is best done though a multicriteria analysis where different location options are considered putting a high weight on potential environmental impacts.

Once the marina location has been fixed, the next level of mitigation should be applied, including:

1) Critical habitat surveys and development of targeted, site-specific ecological management plans
2) Relocation of corals from the direct footprint
3) Installation of effective silt curtains around the dredging area
4) Turbidity plume monitoring, hindcast and forecast.
5) Adaptive management of dredging activities.

Critical habitat survey and coral relocation

Detailed ecological surveys of marine habitats are initially conducted to understand the need for management intervention. Where necessary, site-specific management strategies aimed at achieving No Net Loss of biodiversity, as minimum, are implemented. Where coral relocation is considered necessary the proponent should obtain national regulatory approval to undertake a relocation program to remove healthy coral from the dredging footprint.

Healthy corals and Tridacna giant clams are removed from the dredge zone and attached to substrate at a suitable receptor site. Receptor sites must also be surveyed to confirm carrying capacity. In areas where local reefs are already at healthy equilibrium / no carrying capacity, artificial substrate can be utilized, see Figure 3. Relocation of corals is a labour intensive task that requires oversight by suitably experienced marine scientists, see Figure 4.

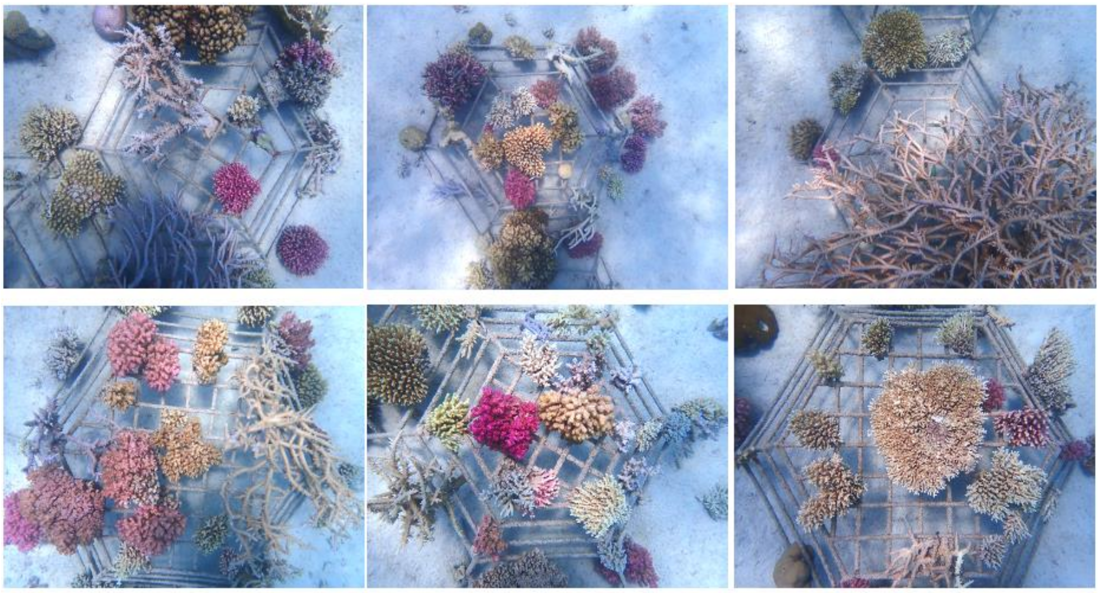

Figure 3. Artificial substrate used for coral relocation in areas where there is no empty hard substrate (mostly the case).

Figure 4. Coral relocation is a time consuming and delicate task. Coral are gently removed from their substrate and moved to the new location.

Installation of Effective Silt Screens

In most of the shallow coastal lagoons in the Red Sea, the waves and currents are relatively weak, which means that silt screens are normally relatively effective. A single or double silt screen should be installed around the working area when the conditions allow. The silt screens are effective in retaining the larger sediment fractions (larger than medium to coarse silt). The finer silt and mud fractions that are suspended in the water column for a long time will, however, escape the silt screen when the tides flush water in and out of the working area. The plumes which escape generally consist of smaller concentrations of suspended sediment. As a consequence, the plumes will not deposit as much sediment on the sensitive habitats due to the small fall velocity of the finer fractions.

Proactive Turbidity Plume Monitoring

A proactive turbidity monitoring and management system should be implemented where coupling operational models (hindcast/forecast) and measurement data ensures eco-compliance and minimizes the risks. The system includes:

- Water Quality buoys provide real-time feedback
- Drones or satellite images provide inspections of the dredging activities and plume dispersion
- Plume dispersion modelling to hindcast and forecast turbidity plumes
- Silt curtain and other mitigation measures, inspected by third party

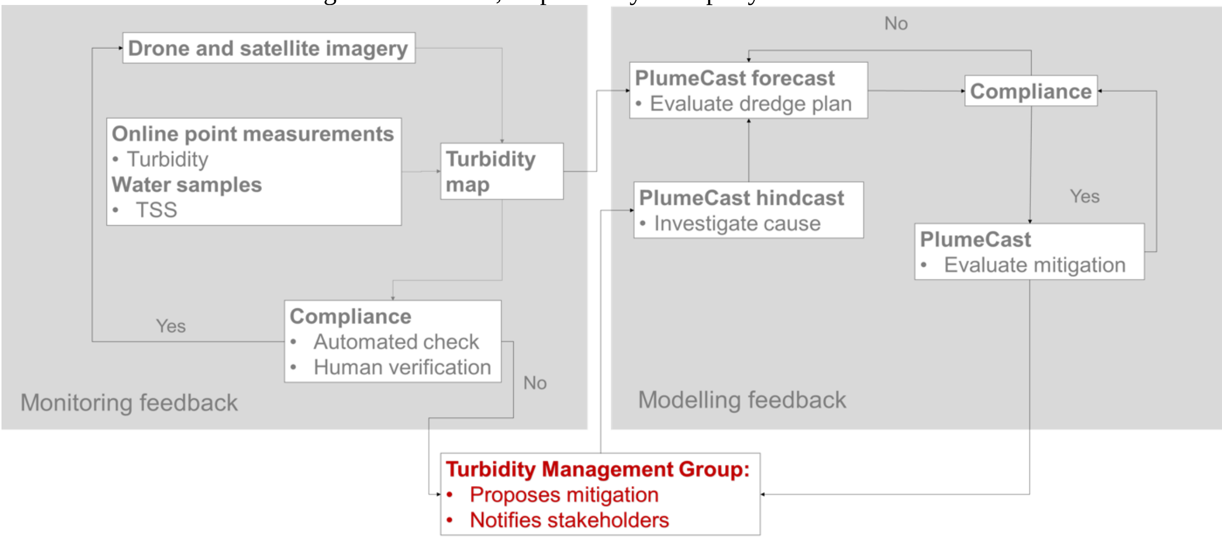

Figure 5. Overview of turbidity monitoring and management system.

Weekly Turbidity Management Group meetings should be conducted with involvement of all concerned stakeholders (Project Owner, environmental consultant, Dredging Contractor, PMC). Discussion should include:

1) Compliance of turbidity plumes from previous week.
2) Forecast of turbidity plumes for coming weeks presented and mitigations (if needed).
3) Surveys of critical habitat discussed in relation to established turbidity thresholds.
4) Third party inspection of mitigation measures.

CASE STUDY: DREDGING OF SINDALAH MARINA

Sindalah Island

NEOM is developing Sindalah Island to be an ultra-high end tourist destination. The development masterplan includes a marina, for which 600,000 m3 of sediment was to be dredged. See Figure 6.

Figure 6. Overview Sindalah Island Masterplan.

Marine Ecological Baseline

Sindalah Island is located in a proposed marine reserve with high value habitats, notably coral reef and seagrass. Ninety-four (94) species of coral have been recorded around Sindalah. The south-west of the island has the highest coverage and species diversity. A variety of growth forms are present, with Acropora and Montipora the most diverse genera. The species include a number of that are listed as being Critically Endangered, Endangered or Vulnerable to extinction on the IUCN Red List. The presence of these endangered species means that careful assessment and management actions must be implemented.

The marina basin is a natural, shallow embayment with seagrass beds and macro-algae. The shallow reef crest supports highest coral diversity and densities (15-25% cover), at deeper depths, the substrate is predominantly sandy with coral bommies. The estimated coral footprint was 1,437m^2 or around 5% of the dredge footprint. The upper estimate of coral colonies within dredge zone was around 13,000. Relocating 13,000 coral colonies is a major undertaking.

Coral Relocation

Healthy corals and *Tridacna* giant clams were removed from the dredge zone and attached to artificial substrate at the receptor site. Morbid, diseased or bleached corals were not removed. Frames had to be used because no hard substrate without corals was available. KBD translocated ∼9,500 heads of coral during a 3-week window of opportunity in June 2021. 73% of coral removed from impact zone, a total of ~600 frames were used.

Adaptive Dredge Management

Once the corals had been relocated and the silt screen had been installed, the adaptive monitoring and management system was implemented. The key components of this system consisted of:

- Double silt screens around the work area.
- WQ monitoring buoys installed and maintained by the contractor, providing real-time feedback.
- Use of drones to provide aerial inspections of the dredging activities and plume dispersion, supplemented by satellite images.
- Use of hydrodynamic modelling to hindcast and forecast turbidity plumes
- Weekly Turbidity Management Group with involvement of all concerned stakeholders (NEOM, KBD, DHI, Dredging Contractor, PMC)

Figure 7 provides a drone shot of the working area prior to commencement of dredging activities. The double silt screen surrounding the work area is clearly visible in the image.

Figure 7. Drone shot of the site prior to commencement of dredging operations.

The dredging at Sindalah commenced slowly, with a daily dredging rate around 3000 m^3/day. The slow dredging occurred in the access channel close to the silt-screens. In this period, the sediment plumes were well retained within the silt-screens, as shown in Figure 8. This was also predicted by the TMS system, see Figure 9. The slow dredging rate during this period, combined with relatively weak currents, was contributing to limiting the spreading of sediment plumes.

Figure 8. Sediment plume staying inside the silt screens.

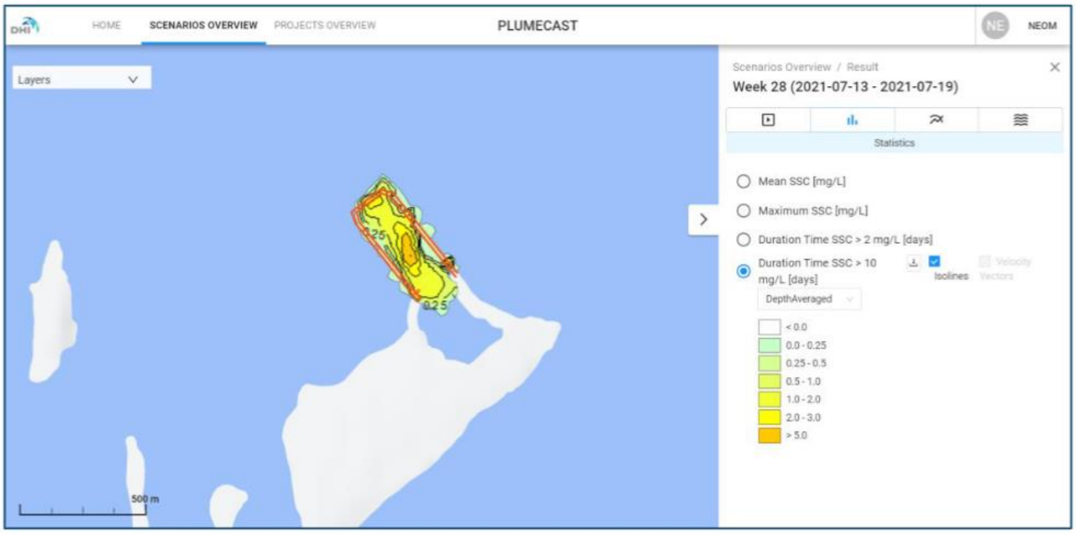

Figure 9. Prediction of duration time with SSC larger than 10 mg/l. The system is predicting the plumes to stay inside the silt screens.

When production was increased to between 6-9,000 m^3/day, the system forecast predicted an increase in sediment escaping silt-screens when dredging near the mouth of marina, see Figure 10. The model forecast showed problematic plumes escaping, especially when dredging near mouth with an increased production rate. At the mouth, the strongest currents flow across the entrance to the marina which causes sediment to escape in this area. In response, the Contractor proposed a change to the dredging plan to limit duration of dredging near the mouth. The model prediction for new dredging plan showed less plumes escaping the silt-screens and the new plan was subsequently implemented.

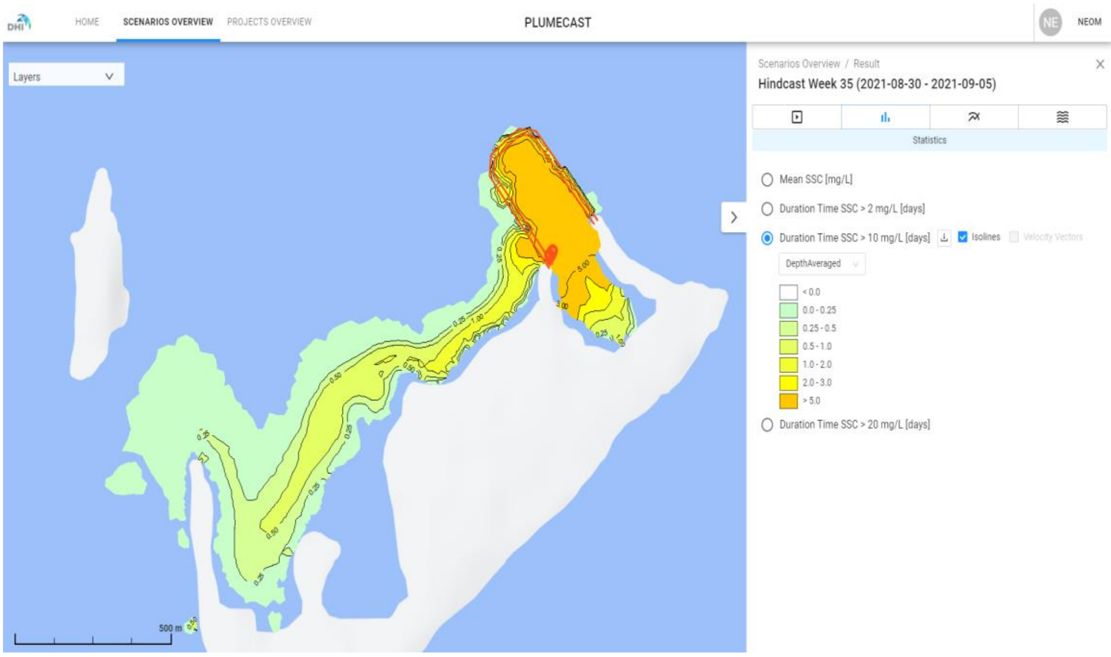

Figure 10. Prediction of duration time with SSC larger than 10 mg/l. It is seen the system is predicting sediment escaping along the north shoreline of Sindalah. A change in the dredge plan improved the situation.

The sediment plumes generated during the dredging varied a lot from day-to-day depending on the type of sediment being dredged. During periods where the material with fines content were encountered, dense sediment plumes were generated, see Figure 11.

Figure 11. The generated sediment plumes depends greatly on the material being dredged. Sometimes the material contained a large percentage of fines leading to intense plumes being generated.

The highly variable sediment composition on the bed makes the forecast and hindcast challenging and underlines the need for both modelling and in-situ measurements to improve on the understanding of the dynamics of the sediment plumes.

Benefits of TMS for Sindalah Island

The Weekly turbidity management group was a good touch point for checking and ensuring environmental compliance.

By working with the data from water quality buoys (comparing it to model predictions), the modelling group automatically carried out a rigorous quality check on the received data. Satellite and drone images were used to confirm the horizontal extent of plume dispersion.

The system allowed for pro-active dredge plan changes; the dredge plan was changed following an orange warning from the system. A different sequence of dredging reduced the plumes escaping the silt-screen to avoid impacts, thus avoiding a stop work order.

Silt-screen inspections by third parties identified gaps and weather damage that were subsequently fixed by contractor.

Coral monitoring surveys detected no degradation caused by sedimentation outside of a pre-defined 100 m buffer zone.

DISCUSSION

This is the first time the adaptive monitoring and management system has been applied in the Middle East region. Dredging in sensitive habitats should be avoided wherever possible. When dredging is necessary, meticulous monitoring and management is necessary.

The state-of-the-art programme includes:

- On-line WQ buoys providing real-time data
- Drone surveillance provides high-quality aerial overview and flexible monitoring windows
- Satellite images available as redundancy
- Hindcast and forecast modelling
- Regular engagement with all project stakeholders
- Enables the pro-active adaptation of dredge plans
- Post-completion review and lessons learnt workshops

Using a combination of data from the water quality buoys, drone / satellite images and numerical modelling, a complete understanding of the sediment plume dynamics could be obtained which in turn allows for making informed decisions with respect to managing the dredging operation.

In all dredging projects, the goal must be to finish as fast as possible without damaging the sensitive habitats. A complete understanding of the sediment plume dynamics helps to make the best decisions to achieve this desired outcome.

REFERENCES

IFC, (2019): Guidance Note 6 Biodiversity Conservation and Sustainable Management of Living Natural Resource. January 1, 2012 (updated June 27, 2019).