Above: Le coeur de Voh, the world famous mangrove in the form of a heart located only a short distance away from the project site. In 2008, a large part of the lagoons surrounding New Caledonia were inscribed on the list of UNESCO-IUCN World Heritage sites.

INE MOULAERT AND WOUTER SCHIETTECATTE

DREDGING IN NEW CALEDONIA AT A UNESCO-IUCN WORLD HERITAGE SITE WITH CARE FOR NATURE

ABSTRACT

In the Voh region of New Caledonia, Koniambo Nickel SAS has been constructing a new port complex to support a nickel processing plant. The port construction involved dredging of a 4,500 m long navigation channel ending in a turning basin. The marine environment around New Caledonia is renowned for its aquatic fauna and flora. This has been confirmed by enlisting the lagoons of New Caledonia as UNESCO World Heritage. Therefore, specific thresholds and required management actions have been outlined in an Environmental Management Plan (EMP).

To check the EMP requirements, extensive monitoring campaigns had been carried out by different independent parties. Jan De Nul (JDN) was contracted to setup and maintain a telemetry system to continuously monitor the turbidity levels at selected locations around the dredging area. Furthermore, mobile monitoring and daily visual observations of turbidity levels around the dredging works and the disposal zone located 6 km away from the coral reef were carried out.

In addition, different mitigation measures were implemented prior to and during the works to minimise the environmental impact. During the entire project, the turbidity threshold values were never exceeded as a result of dredging activities. Although some visual plumes were observed outside the delineated area, quantitative measurements revealed that turbidity values were well below the EMP thresholds. The coral reefs and seagrass habitats surrounding the dredging and disposal area were not impacted by the increase of turbidity or excessive sedimentation. Marine mammals and turtles were observed around the working area on a regular basis until the end of the works.

The dredging works in New Caledonia proved again that good environmental management, based on both a pro-active and re-active approach, can prevent unnecessary consequences.

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INTRODUCTION

New Caledonia is renowned for its nickel reserves, but also for its aquatic fauna and flora. Therefore, the Koniambo Project in the Voh region (Northern Province of New Caledonia) was carried out with uttermost care for the surrounding environment. As part of the project, Koniambo Nickel SAS needed to construct a new port complex in support of its nickel processing plant. The port will be used to import consumable commodities such as coal, fuels and maintenance stores and will export refined product in 20-foot shipping containers. Dredging works were carried out by Jan De Nul Succursale NC.

The TSHD *Le Bougainville*, the backhoe dredge BHD *Mimar Sinan* and several split-hopper barges (*Concepción, L'Etoile, Le Sphinx* and *Le Guerrier*) were involved in the dredging of a 4,500 m long navigation channel and turning basin, to a design depth of –12.0 m CD. The dredging and disposal areas were surrounded by vulnerable ecosystems like coral reefs and seagrass meadows (Figure 1).

Before the project started, key points of attention had to be identified and adequate responses to these had to be defined. An Environmental Management Plan (EMP)

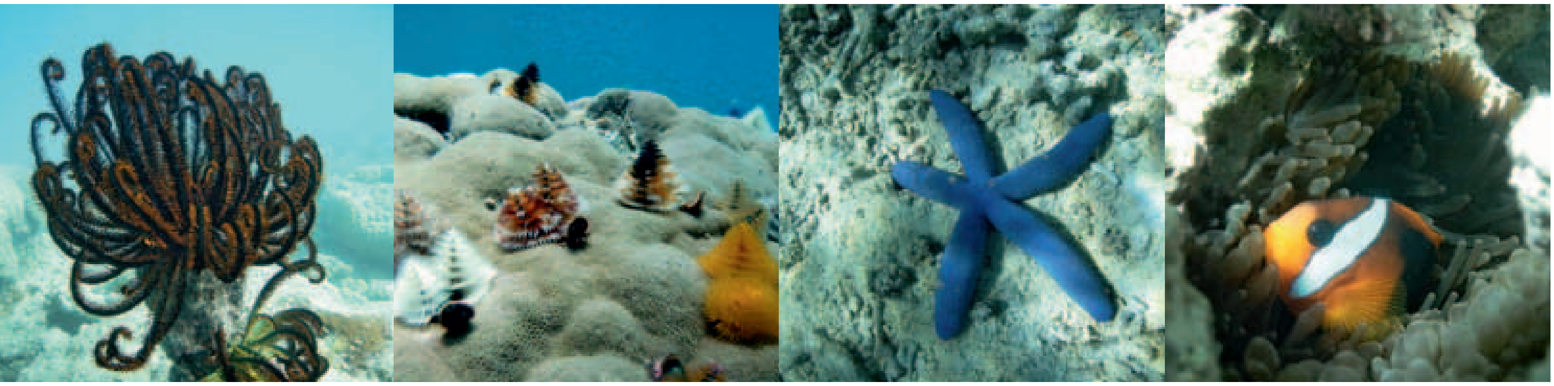

Figure 2. From left to right: Various sealife including the Feather star (*Crinoid*), Christmas tree worms (*Spirobranchus sp.*), Blue linckia starfish (*Linckia laevigata*) and the anemonefish or clownfish (*Amphiprion sp.*).

was prepared, which contained the main environmental concerns and the monitoring and mitigation actions. This document was the main guideline for environmental protection on the project. Several local and international companies took part in the implementation of the EMP.

Several years before dredging started, biological and physico-chemical studies were conducted to take inventory of the initial state of the marine environment in order to evaluate possible future impacts. In the months before dredging started, coral transplantation was done by a local company to rescue and relocate the most important species and formations to nearby less-impacted areas.

During dredging, continuous monitoring of the suspended sediments arising from the dredging activities was needed in order to respond rapidly in case of possible negative impacts on the local ecosystem.

For this purpose, the Marine Environmental Department (MARED) of Jan De Nul was asked to install, maintain and follow up a telemetry system. When dredging activities finished in April 2010, Koniambo Nickel SAS continued the physico-chemical and biological monitoring in order to evaluate the possible impacts of the port activities and the nickel processing plant. This article focuses on the turbidity monitoring done by Jan De Nul during the dredging works.

ENVIRONMENTAL CONSIDERATIONS

In 2008, a large part of the lagoons surrounding New Caledonia were inscribed on the list of UNESCO-IUCN World Heritage sites. Sensitive areas (coral reefs, sea grass habitats) surrounded the area where the entrance channel and turning basin had to be dredged for the development of the new harbour. According to the IUCN (International Union for Conservation of Nature and Natural Resources), the tropical lagoons and coral reefs of New Caledonia are examples of high diversity coral reef ecosystems and form one of the three most extensive reef systems in the world. They are the location for the world's most diverse concentration of reef structures, with an exceptional diversity of coral and fish

Figure 1. Two views of the TSHD De Bourgainville: left, sailing past the coral reefs and right, at the dredging site.

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finished her master in Marine and Lacustrine science at Ghent University and then worked for 5 years at the Sea Fisheries Institute in Ostend, Belgium. There she worked on impact assessments of human activities on the marine environment and monitoring studies of the Benthos. In 2009, she started working for Jan De Nul where she followed up the environmental part on different projects, mainly in Australia and Panama. She is now active in the head office in Aalst, where she compiles environmental management and monitoring plans for new projects, as well as following up currently ongoing projects.

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graduated with an MSc in Applied Biological Sciences at Ghent University, Belgium. He then worked as a research assistant at Ghent University (Department of Soil Management and Soil Care), where he obtained his PhD in 2006. In 2007, he started working for Jan De Nul as site engineer at the Marine Environmental Department, mainly in New Caledonia and Panama.

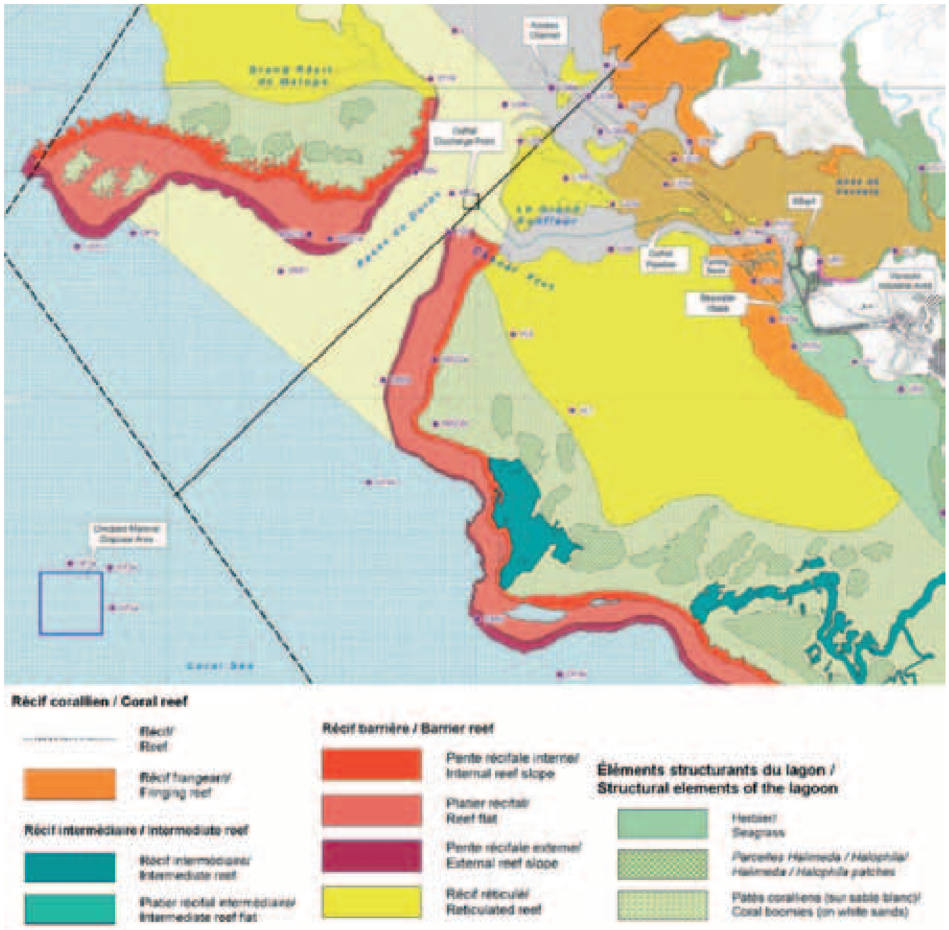

Figure 3. Map of the area with indication of the sensitive areas (source: EIA).

species and a continuum of habitats from mangroves to seagrasses and a wide range of reef forms (Figure 2). Regarding marine fauna, the Environmental Impact Assessment (EIA) mentioned that the following sea turtles are likely to be present in the area: Loggerhead turtle (*Caretta caretta*), Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricate*), Leatherback turtle (*Demochelys coriacea*).

They are all listed on the Red List of the IUCN and are protected under CITES (Convention on International Trade in Endangered Species) of Wild Fauna and Flora and by the North Province of New Caledonia. According to the project's EIA, the marine mammals that would most likely be affected by the Project are those that prefer coastal waters and those that are usually found in the lagoon, i.e., the dugong (*Dugong dugong*), the spinner dolphin (*stenella longirostris*), and the bottlenose dolphin (*tursiops truncatus*) (Figure 3).

Several impacts on the marine environment were considered as possible results of the implementation of the project. The removal of sediments, coral, and sea grass areas by dredging has a direct impact on the marine flora and fauna in that area, but a substantial impact was also expected in the areas adjacent to the dredge area as a result of the high sedimentation and turbidity.

This was expected up to approximately 300 metres from the dredge works. Sessile species (e.g., corals, seagrass) were most at risk, but increased marine traffic could also present a risk to marine mammals (dolphins, whales, dugongs) and sea turtles.

The disposal site was located more than 5 km from the outer reef in order to minimise the possible effects of suspended sediment.

Stratification of the water column might affect the settlement of the discharged sediment (Figure 4): The descending plume of fine material might partially spread laterally as it impacts the region of rapidly changing density (the pycnocline). This part of the plume could most likely affect the outer reef.

Therefore, monitoring was carried out at several stations along the reef to detect possible changes in turbidity.

The Environmental Management Plan (EMP) considered the following areas within the vicinity of the dredging works to have the highest priority for protection:

- Outer barrier reef coral habitats (including the Passe du Duroc) and associated water quality.
- Seagrass habitats south of the predicted high impact zone.
- Mid-lagoon reticulated reef systems south of the Passe du Ronfleur and west of the predicted high impact zone.
- Near shore fringing reef.

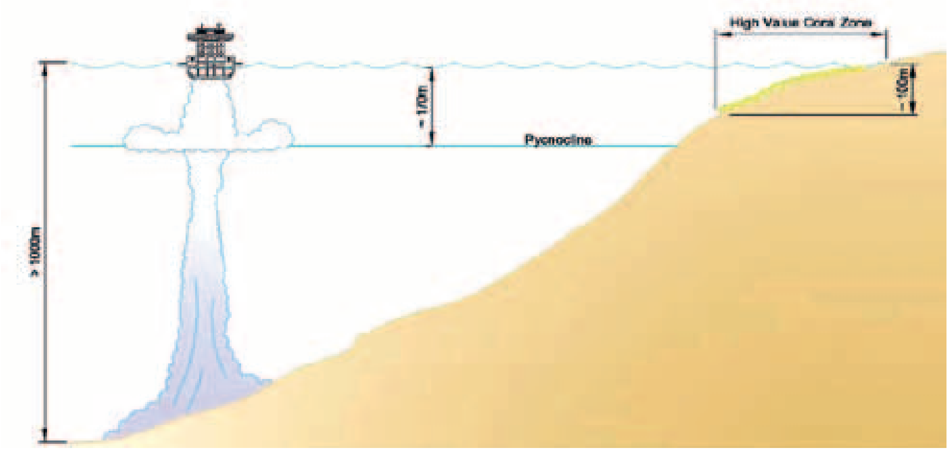

Figure 4. Possible effect of pycnocline on sediment settlement at the disposal site (source: EIA).

ENVIRONMENTAL CRITERIA

Regarding turbidity, two types of monitoring sites were specified in the Environmental Management Plan (EMP) – an investigation site and an action site.

Investigation sites were located in the proximity of the zones of operation (dredge channel and offshore disposal area) and were used to gain a better understanding of the way dredging activities affect sediment resuspension and turbidity. Their purpose was also to identify turbidity values above a specified "investigation value", which were different for the lagoon and the offshore sites (Table I).

To each investigation site belonged an action site. These were located closer to the sensitive areas in order to monitor whether an increase of the turbidity was reaching the various sensitive habitats. Threshold investigation values and action values as well as corresponding actions to be implemented, were defined for these action sites.

When an investigation value was exceeded, the source had to be sought and the frequency of monitoring had to increase. If action values were exceeded an action had to be taken in accordance with the EMP.

ENVIRONMENTAL MONITORING

Turbidity Monitoring

Besides the environmental monitoring by local and international companies, part of the marine environmental programme was carried out by the Marine Environmental Department (MARED) of Jan De Nul. This ensured a quicker response time by engineers who are closely involved with the dredging process (Figure 5).

In order to check compliance with the thresholds outlined in the EMP and ensure continuous monitoring, telemetry buoys were used at most of the action sites. These telemetry buoys (Figure 6) were equipped with a multi-parameter probe. On site verifications, calibrations and maintenance were conducted regularly to ensure reliable measurements and proper functioning of the equipment.

All the data collected from these buoys was transmitted by a radio modem inside the buoys and sent to a receiver station near the office where data was automatically processed by the Environmental Monitoring System (EMS). The EMS is a computer interfaced programme that can receive data strings sent out by various devices, such as buoys, weather stations, … It automatically analyses the data strings and subsequently puts it on the dedicated project website where it becomes available for any involved party.

Besides posting the data on a website, the EMS software also sent alert messages by means of SMS (text message) in case turbidity exceeded the threshold levels or when a problem occurred with one of the buoys. In this way, turbidity levels could be followed up continuously. Furthermore, the telemetry system enhanced the reliability of the data acquisition, because it allowed a rapid intervention in case of technical problems (e.g., malfunctioning sensor, biofouling, …).

Table I. Threshold values in NTU (Nephelometric Turbidity Unit) as stated in the EMP.

Site type	Threshold value	Required action
INVESTIGATION	Investigation value Lagoon - > 70NTU Offshore - > 10NTU	When this value is exceeded, an investigation is required to determine the source of the elevated value.
ACTION	Investigation value Lagoon - > 30NTU	This is the value above which investigation and more frequent monitoring is required. The source of the value is also checked.
	Action value Lagoon - >30NTU for 3 days or > 70NTU Offshore - > 10NTU	When this value is exceeded an action is required. If it is found to result from dredging activities then the management responses specified in the EMP must be implemented.

Figure 7 shows an example of turbidity data recorded at a telemetry buoy during June 2009. During most of the time, turbidity levels stayed below 10 NTU. On the 9 June 2009 some biofouling occurred around the wiper of the probe, resulting in turbidity values rising up to 70 NTU.

After cleaning, values dropped immediately below 2 NTU. On the 15 June, a few spikes were observed, probably caused by marine fauna or detritus passing in front of the sensor eye. Also on the 29 June some spikes in turbidity were registered. On site investigation revealed that these outliers were caused by a technical problem of the sensor. After maintenance of the contacts of the sensor, turbidity values returned to normal.

Disregarding the erratic values as a result of biofouling and technical problems, Figure 7 also reveals the influence of dredging on the natural turbidity pattern. Between the 15 and 24 June 2009, the BHD was dredging closer to the telemetry buoy.

The influence of this dredging operation is reflected in the higher and more variable turbidity values during that period. However, turbidity remained mostly below 10 NTU, and returned rapidly to background values from the moment that dredging stopped in that nearby area.

Besides the fixed monitoring stations, mobile monitoring was also conducted to measure turbidity at several other locations in the lagoon and near the disposal area. This enabled the environmental engineer to adjust the monitoring campaigns to the ever changing working, hydrodynamic and weather conditions. In this way the advantages of fixed and mobile monitoring were being used simultaneously.

Besides measurements, also visual monitoring of the turbidity plume was conducted on a daily basis, from all dredging equipment as well as from survey vessels, to check for migration of the plume outside the pre-defined delineated area. These observations were reported to all relevant parties on a daily basis, as plumes outside the delineated area triggered monitoring at the closest (or most likely affected) action sites.

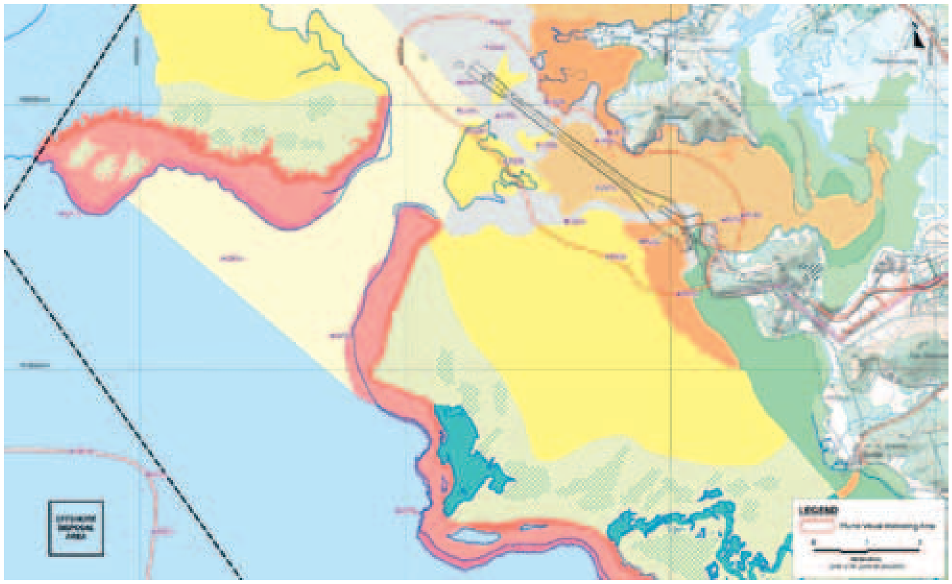

Figure 5. Map of the area with indication of monitoring locations and Plume Visual Monitoring Area (source: EMP).

Although not included in the contractual requirements, different plume monitoring studies were also performed during the project. This monitoring was undertaken to develop a greater understanding of the effects that individual dredging activities have on the dispersion of turbidity. Examples of the activities that were monitored are: turbidity plumes from the TSHD and the BHDs (Figures 8 and 9), propeller wash during the shifting of barges, disposal activities and the sailing to and from the disposal site. The monitoring was executed using different turbidity sensors and a current profiler while sailing different tracks in and near the generated turbidity plumes with a survey vessel.

Hydro-meteo Monitoring

Hydro-meteo conditions were monitored with a weather station, a Waverider buoy (offshore) and an AWAC current profiler (in the lagoon). Wave height was an important factor to be monitored as it was stated in the EMP that the dredgers and supporting vessels had to operate within a safe range of wave and wind conditions (as determined by the captain of each ship).

This measure helped prevent incidents which could have resulted in an environmental impact. The Waverider data were needed to validate the reliability of wave predictions by Fugro and Argoss, as these forecasts were used to plan dredging operations and to justify weather delays.

ENVIRONMENTAL MANAGEMENT

Dredging Area

The following management actions were implemented to minimise the generation of turbidity plumes by dredging:

- Dredging in accordance to wind and wave conditions.
- All vessels needed a pre-mobilisation check of all the seals and performance checks were executed during dredging.
- No overflow or discharge from barge or dredge hoppers was allowed during the dredge operations apart from the following routine operational requirements;
  - Overflow through funnel with "anti-turbidity valve" is limited to 5 minutes at the end of each filling cycle
  - Decanting from barges alongside the Backhoe Dredger is limited to 5 minutes at the end of each filling cycle
  - Use of LMOB (Lean Mixture Overboard System) is limited to 5 minutes at the beginning of each dredge run
- Barge decks should be washed down to remove sediment before the barge leaves the dredge area
- When outside the dredge channel, vessels should navigate in a manner which minimises sediment resuspension, particularly near coral reefs or seagrass beds.

Figure 6. Left, the construction of the new port facility at New Caledonia. Above, Telemetry buoy anchored near the working area.

Disposal Area

Regarding the disposal of dredged material, the following requirements were specified:

- The dredged material had to be released only within the limits of the approved disposal area.
- The dredged material had to be released fast to minimise the turbidity plume.
- Vessels had to take the shortest possible safe navigable route and avoid spillage by not overloading and limiting transport to within safe operating conditions.
- Wash down of the empty dredge or barge hoppers to remove residual sediments was only allowed inside the disposal area.
- Pumping out of seawater from empty hoppers had to be ceased before the vessel came to within 1 km off the reef or 500 m off the entrance to Passe du Duroc.

Flora and Fauna

To minimise direct and indirect disturbance to marine flora and fauna, the following management actions were implemented:

- All floating plant had to arrive with non-fouled hulls, and to have performed adequate hopper washing and ballast water exchanges in full accordance with New Caledonian and international requirements.
- Environment awareness training (including information on marine animals) was given to all personnel and crew.
- Care was taken to prevent injury to native fauna as a result of dredging and disposal activities.
- Turtle deflectors (suspended chain type) were installed on the drag arms of the TSHD dredger (Figure 10).
- Observations of sea mammals and turtles had to be reported to the environmental engineer and subsequently transferred to all relevant parties.

Additional Protection Measures

- At the most sensitive areas, dredging operations proceeded with a backhoe dredger. For this particular project this was considered the most environmental friendly dredging method.
- A few times per year, during full moon, the phenomena "coral spawning" takes place. In order to cause no disturbance to the corals, dredging operations were planned in such a way that no turbidity was produced during this period.
- Periodical inspections of the vessels were

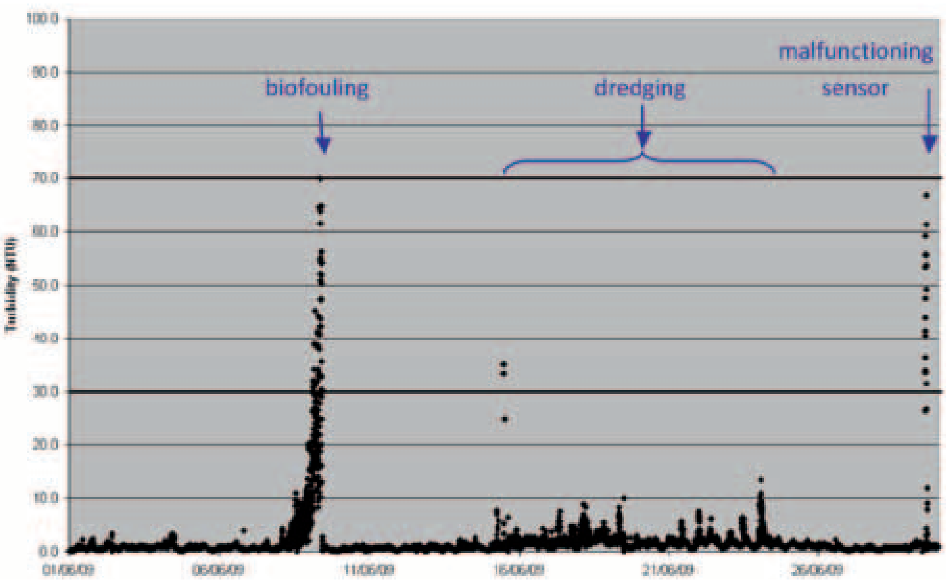

Figure 7. Turbidity values measured at a telemetry buoy during June 2009.

Figure 8. Above, turbidity plume created during dredging by the TSHD De Bougainville.

Figure 9. Left, turbidity plume created by the works of the BHD Mimar Sinan.

conducted in order to keep the crew aware of the importance of the environmental concerns.

Mitigation measures in case turbidity threshold was exceeded

In case the turbidity thresholds would have been exceeded, despite dredging operations being in accordance with the EMP specifications, a "Rapid Visual Assessment" had to be carried out at the seagrass and coral sites to evaluate possible signs of stress. The EMP mentioned the following possible measures to reduce turbidity at the dredging area:

- Increase distance to impacted area by moving dredgers further away
- Reduce prop wash by altering dredge and/or barge movement
- Implement silt curtain
- Temporal suspension of dredging activities

Had turbidity thresholds been exceeded at the offshore stations, relocation of the disposal area further offshore was a possible option to reduce turbidity.

Figure 10. Turtle deflector installed on the drag head of the TSHD.

RESULTS

During the entire project, the turbidity threshold values were never exceeded as a result of dredging activities. During periods without dredging activity, however, turbidity levels were sometimes higher owing to natural causes (e.g., sediment supply by rivers, resuspension of seabed sediments).

Excessive rainfall sometimes resulted in an increased sediment supply towards the lagoon. This caused turbidity to rise above the threshold limits at some locations inside the lagoon. Nonetheless, after the rainy period, turbidity levels rapidly declined back to normal values.

Dredging by the TSHD without overflow resulted in sediment plumes of 100-150 m wide, with peak turbidity values above 100 NTU just after passage of the TSHD, decreasing to maximum values of 40-50 NTU after 10 minutes. Turbidity further decreased at a rate depending on particle size. Dredging by the TSHD with overflow (during 5 minutes) resulted in a similar plume width (150 m), but turbidity values were higher, especially during the first 15 minutes after dredging.

The monitoring results showed that the sediment plume generated by the BHD was rather limited. Wind and current may cause the plume to drift over a larger area, but in general, the maximum turbidity dropped below 30 NTU within 175 m from the dredging location.

However, monitoring showed that turbidity plumes generated by prop wash during shifting of barges can be much denser and larger than those generated by the dredging action of the BHD, depending on the seabed material and the keel clearance.

During sailing and maneuvering in shallow areas, the propellers caused resuspension of seabed material. Monitoring showed that this "prop wash" generated large turbidity plumes. During sailing in "deep water" (5 m between keel and seabed), a narrow

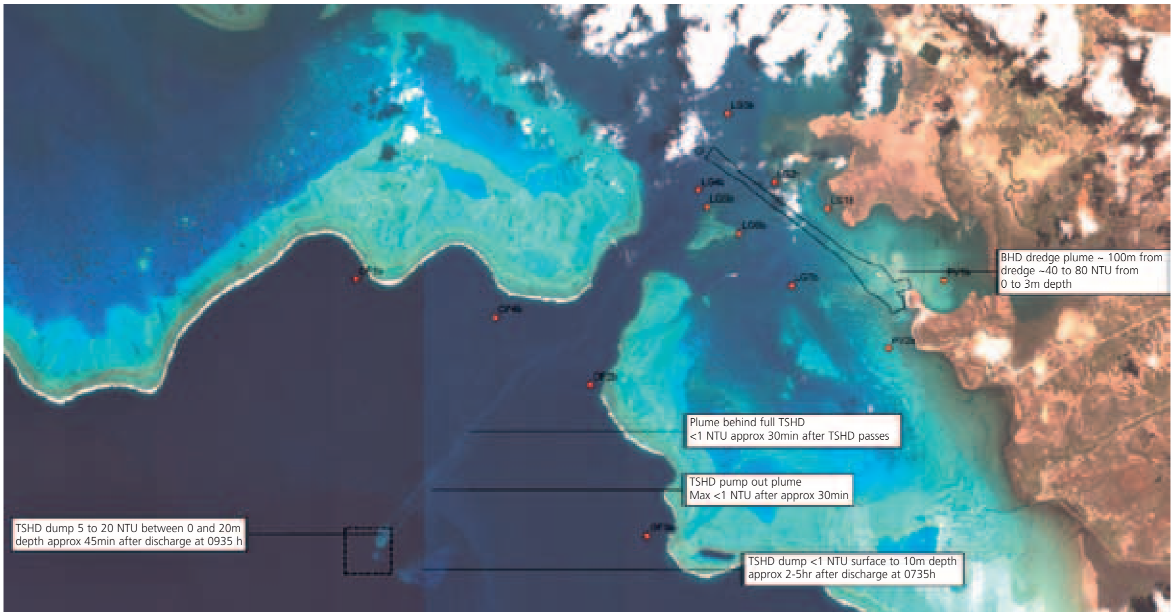

Figure 11. Satellite image taken on 21/09/2008 with indication of the NTU of the different plumes (source: KBR and Koniambo Nickel SAS).

plume was observed (about 50 m wide) with turbidity values above 100 NTU, that settled out within 45 minutes. In shallow water (2 m keel clearance), the plume was wider and settled out less quickly. The plume width increased further when the SHB was maneuvering in shallow water instead of sailing straight. The results indicated that prop wash can generate sediment plumes that are wider and more turbid than the dredging plumes caused by the TSHD.

Prior to mobilisation to New Caledonia, the seals of the vessels were renewed, in order to prevent leakage of sediment. Monitoring surveys showed that leakage from the TSHD and SHB was minimal: Turbidity was only slightly elevated (about 3 NTU) compared to background values. During visual monitoring, it was rarely observed that a plume did go outside the defined "plume visual monitoring area" (see Figure 5). Inside the lagoon, nine observations were made of turbidity plumes outside the delineated area. These turbidity plumes triggered monitoring at the closest (or most likely affected) action sites. Measurements at these sites never showed an exceedance of the turbidity thresholds (except for the rain event of 25/03/2009). In most cases, turbidity was less than 10 NTU.

During the project, several sea mammals (dolphins, porpoises and dugongs) and turtles were observed every week in the vicinity of the working area.

Koniambo Nickel SAS conducted also monitoring by remote sensing. During the dredging, KBR was asked to analyse satellite images based on ground-truth data, in order to investigate the distribution and intensity of the turbidity plumes generated by the dredging activities. Although, several turbidity plumes and traces could be observed on the images, simultaneous data acquisition on site revealed that turbidity values were low (Figure 11).

CONCLUSIONS

Dredging works necessary for the expansion of human activities can go hand-in-hand with nature. This was clearly demonstrated on the project in New Caledonia. During the entire project, the turbidity threshold values were never exceeded as result of a dredging activities.

Besides measurements, also visual monitoring of the turbidity plume was done on a daily basis. Although some visual plumes were observed outside the delineated area, quantitative measurements revealed that turbidity values were well below the EMP thresholds. Marine mammals and turtles were observed around the working area on a regular basis until the end of the works, indicating that the animals did not flee the area and thus did not experience a major impact from the works. Although dredging finished in April 2010, Koniambo Nickel SAS have continued physico-chemical and biological monitoring in order to follow up possible impacts of future port and plant activities.

The dredging works in New Caledonia proved that good environmental management, based on both a pro-active and re-active approach, can prevent undesired negative consequences. A pro-active approach includes a thorough knowledge of the surrounding environment, preparation of different plans and procedures, modelling studies to indicate possible impact areas and environmental induction of all personnel.

The re-active approach includes the continuous monitoring of turbidity and water quality during dredging activities and implementation of a management plan which allows changes in dredging operations whenever threshold values are exceeded.