Dredging in China under strict environmental controls

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Introduction

CNOOC and Shell Petrochemicals Company Limited (CSPCL) is set to make petrochemicals history in China by building and operating a US$4.3 billion petrochemical complex. The construction of the petrochemicals complex in Daya Bay at the southern coast of China's Guangdong Province started in 2002.

The complex called for the construction of two marine facilities which involved a significant dredging scope of approximately 8 million m^3 of clay. The dredging works were undertaken in 2004 by the Nanjing Changjiang Waterway Engineering Bureau in a venture with Boskalis International.

A key requirement of the project was to preserve the sensitive environment in Daya Bay. Therefore all dredging and navigation was to be performed with minimum damage, interference or disturbance to the environment. CSPCL invested in an extensive monitoring programme and mitigating measures to minimise environmental impact.

This paper describes the dredging project, CSPCL's Sustainable Development strategy, the environmental monitoring activities and the results of the monitoring programme.

Daya Bay dredging project

CNOOC and Shell Petrochemicals Company Limited (CSPCL) is building and operating a US$4.3 billion petrochemicals complex in the Daya Bay Natural Resource Protection Zone. Daya Bay is located at the southern coast of China's Guangdong Province, some 80 km east of Hong Kong. CSPCL is a 50/50 joint venture between Shell Chemicals and CNOOC Petrochemical Investment Limited.

Construction of the petrochemicals complex started in 2002 and the complex was due to start up late 2005. The complex called for the construction of two marine facilities; a dolphin berth approximately 12 km offshore (Mabianzhou) and a marine terminal nearby the complex (Donglian Harbour).

The dolphin berth at Mabianzhou Island is used to import feedstock for the petrochemical complex and receives ships in the range of 60,000 to 80,000 DWT. The dredging works for the dolphin berth involved the deepening of a berthing area and turning basin to a water depth of approximately 15 metres.

Figure 1. Location of Daya Bay in China.

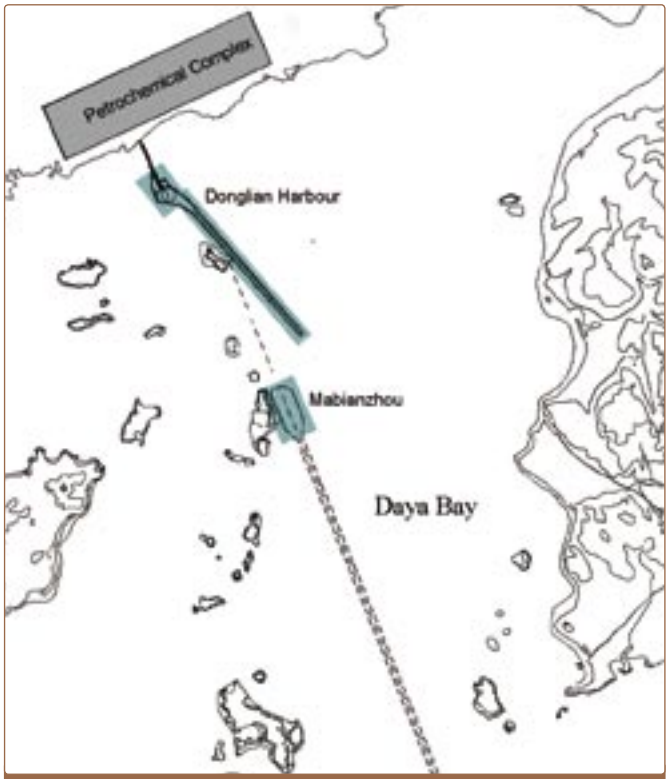

Figure 2. Dredging areas at Donglian and Mabianzhou.

Additional imports and product export of the complex takes place through a dedicated jetty adjacent to the complex site on the northern shore of Daya Bay. The construction of this jetty at Donglian Harbour required dredging of a berthing area, turning basin with connecting area and approach channel to a water depth of approximately 10 metres.

The construction of these two marine facilities involved a significant dredging scope of approximately 8 million m^3. The material to be dredged consisted of clay, varying from very soft fat clay to very stiff lean clay. The quantities of material to be dredged for each area are presented in Table I.

The contract for all dredging activities was competitively tendered and awarded in 2003 to the Nanjing Changjiang Waterway Engineering Bureau (NCWEB) in a joint venture with Boskalis Westminster. The NCWEB and Boskalis partnership commenced dredging in Daya Bay early February of 2004.

CSPCL's sustainable development

CSPCL embodies Sustainable Development (SD) as a key consideration in its activities. Sustainable Development is often defined as 'Development that meets the needs of the people today without compromising the ability of future generations to meet their own needs' (Brundtland Commission (1987): 'Our common

TABLE 1: QUANTITIES OF DREDGED MATERIAL

Area	Dredged material (million m^3)
Donglian Harbour	**6.6**
– berthing areas	0.6
– turning basin and connecting area	4.1
– approach channel	1.9
Mabianzhou	**1.4**
– berthing areas	0.3
– turning basin	1.1
Total	**8.0**

Future'). For CSPCL this means that equal consideration is given to the economic, social, and environmental impacts of decisions. SD is embedded in the organisation throughout the lifetime of the complex, both during construction and in the operations phase.

Sustainable development was also a key driver in decision making with respect to the marine construction activities and the dredging activities in particular. Daya Bay is a 'Natural Resource Protection Zone'. It is a rich spawning ground for a number of commercial fish and shellfish and supports a number of coastal towns.

Prior to a final investment decision being taken by the shareholders, an extensive Environmental and Social Impact Assessment as well as a specific Chinese Marine Environmental Impact Assessment were carried out. The collected detailed information about the state of the surrounding environment acted as inputs into the setting of voluntary standards and guidelines for the marine construction activities. The environmental limits for the dredging activities were based on a combination of Chinese legislation and international standards, such as the World Bank guidelines for port construction.

As part of its commitment to SD, CSPCL maintained an open dialogue with the surrounding communities regarding its activities. Prior to the start of marine construction activities an engagement session was held with all local stakeholders, e.g. fishing villages, seashore villages, and relevant government agencies.

This dialogue continued throughout the entire dredging programme with regular updates being published in CSPCL community newsletters. Maps indicating where the activities would be taking place were published on a regular basis. The results of the independent environmental monitoring for dredging, together with all other environmental monitoring, were published on a quarterly basis through the www.cnoocshell.com website.

Environmental requirements

Daya Bay has a rich benthic and pelagic environment with several sensitive areas including biotopes with coral formations, seaweeds, oyster beds, aquaculture sites and fishing areas. According to the findings of the Environmental Impact Assessments (EIA) the main potential marine environmental impacts caused by dredging could be:

- Increased turbidity and reduced water quality
- Possible smothering of coral formations

As part of its commitment to SD, CSPCL required implementation of an Environmental Control Procedure (ECP) during the dredging operations. The objective of the ECP was to monitor any effects on the marine environment during dredging and, if necessary, take appropriate action upon them.

Based on the results of the EIA and the standards set, Boskalis' engineering department Hydronamic designed both the Environmental Control Procedure and the Environmental Monitoring Plan (EMP). The EMP addressed the monitoring activities to be undertaken and the environmental limits to comply with.

The ECP and EMP were both designed in consultation with CSPCL and were approved prior to the start of the dredging works.

A number of 'standard' mitigating measures were defined together with a range of 'optional' mitigating measures. The 'optional' mitigating measures could be implemented if environmental limits were exceeded. One of the main mitigating measures CSPCL invested in was the requirement for all dredging operations being carried out without overflowing. A number of other 'standard' mitigating measures were:

- The use of appropriate dragheads for minimal resuspension and turbidity
- Minimisation of turning in shallow areas
- Utilisation of existing dredged channels
- Restricted access to waters where shallow coral reefs are present
- No anchoring in coral reef areas
- Training and instruction of personal with regard to environmentally responsible working practices

Dredging works

Early February 2004 the dredging works in Daya Bay commenced. NCWEB deployed 2 small size Trailer Suction Hopper Dredgers (TSHD) and mobilised 5 more trailers in the next four months. The small TSHDs with hopper capacities varying between 1,000 to 2,000 m^3, dredged the shallow areas at Donglian Harbour, including approach channel, turning basin, connecting area and parts of the berthing area.

NCWEB brought a dipper dredger and a grab dredger on site to dredge the shallowest areas in the berthing pockets as well as the areas close to the Donglian jetty. Six self-propelled split hopper barges transported the material arising from the dipper and grab dredgers to the offshore disposal area.

In July Boskalis' large size TSHD 'Queen of the Netherlands' was mobilised to dredge the turning basin and berthing area near the Mabianzhou dolphin berth. After five weeks the trailer was demobilised again and NCWEB's small trailers completed the remaining dredging close to the dolphin berth.

All dredged material was transported to the disposal area some 25 km offshore.

One of the Chinese trailers was equipped with a plough and was used to even out ridges which optimised production of the TSHDs.

Dredging works at Mabianzhou and Donglian were completed in October and November of 2004 respectively.

Environmental monitoring plan

Monitoring locations

Based on the results of the EIA's 17 locations throughout Daya

Figure 3. Queen of the Netherlands dredging in Daya Bay.

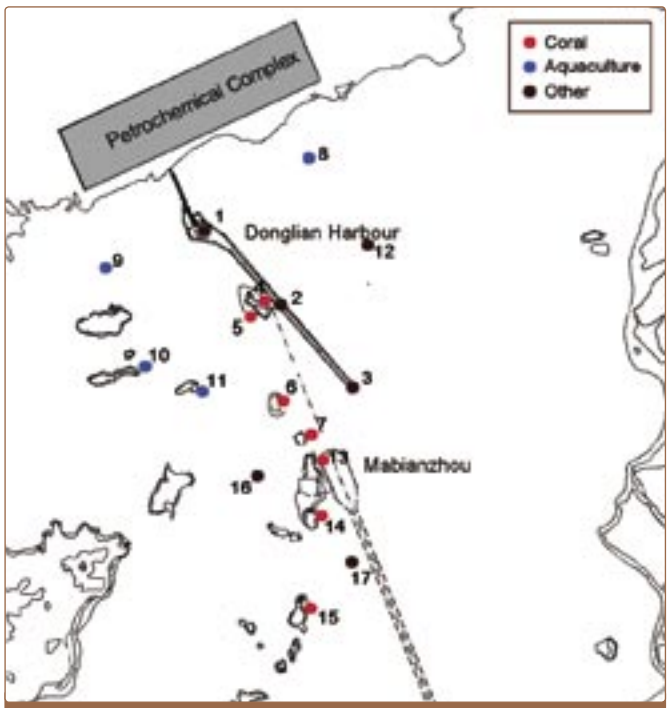

Figure 4. Monitoring locations.

Bay were defined for water quality monitoring. The locations defined included: 7 coral sites, 4 aquaculture sites, 3 sites inside the dredging area and 3 sites for background measurements.

Water quality monitoring

Water quality parameters were measured on a daily basis at all monitoring locations. The parameters measured included turbidity, dissolved oxygen (DO), salinity and water temperature. A direct reading instrument YSI 6600 was used for measuring the water quality parameters while current velocity and direction were measured by an Acoustic Doppler Current Profiler (ADCP).

The devices were operated from a purpose-built frame mounted on the deck of the monitoring vessel 'Yangpingji 88'. All measured data was stored on the monitoring computers onboard the vessel and post-processed in the site office at the end of each day.

During the first two months of the dredging project water samples were taken at the locations inside the dredging area. The samples were taken to the laboratory and analysed for active phosphate and total inorganic nitrogen concentrations.

During these two months water samples were also taken for analysis of SSC (Suspended Solid Concentration). During water sampling, YSI turbidity measurements were logged at the same time. SSC values were plotted against their corresponding turbidity loggings. The relation was updated at two week intervals. No variations in the relation at different areas were found and one relation was used for the whole dredging area.

Sedimentation rate monitoring

At locations where coral is present, sedimentation rate monitoring was carried out on a weekly basis. Coral formations can be found at several locations in Daya Bay. Most of them are located in shallow water areas near islands because of their need for light. A number of the coral formations were located close to the dredging areas and serious concern was given to the preservation/protection of them.

As part of the monitoring plan inspection of coral coverage with sediment took place on a weekly basis. The purpose of the inspection was twofold; visual inspection by divers and sedimentation rate monitoring with sediment traps. Once a week, a team of scuba divers took movie-shots of the corals and collected the sediment trap samples. In the office the movies were examined to establish visually any sedimentation on the corals. The samples were taken to a laboratory where the weights of the samples were analysed and the average sedimentation rate per day [kg/m^2/day] was determined.

Monitoring of turtles and whales

Monitoring of turtles and whales was carried out during daylight hours. The monitoring was carried out through visual detection of turtles or whales at the water surface by a dedicated person on the bridge of the TSHDs and transport barges.

If turtles were observed near the dredging area, turtle deflectors could be deployed on the TSHD's draghead. In case whales were observed near the dredging area, speed limits would be enforced.

No sightings of turtles and whales were reported during the project and as such no turtle deflectors were installed.

Control of offshore disposal

All disposal events by both TSHDs and transport barges were recorded. Time and coordinates of the disposal were reported in the weekly reports to CSPCL.

Environmental Control Procedure

Following CSPCL's requirements, an Environmental Control Procedure (ECP) was designed and implemented in the Environmental Monitoring Programme. Processing, analysing and interpreting of the monitoring data as well as the information paths to CSPCL were carried out in accordance with the Environmental Monitoring Control Procedure.

Strict environmental limits for SSC levels and sedimentation rates were set at coral sites and aquaculture sites. The following environmental limits were applicable throughout the whole project:

- SSC at coral sites: 50 mg/ltr
- SSC at aquaculture sites: 50 mg/ltr or background + 30% (highest value is the critical value)
- Sedimentation rate: 0.1 kg/m^2/day

No limits were applicable for locations inside the dredging area or background locations.

The monitored data was processed and evaluated in the office at the end of each day. The results were included in the daily reports and presented to CSPCL in the weekly reports. Any exceeding of the environmental limits was to be reported to CSPCL immediately while the monitoring results were studied and interpreted. The findings of this interpretation were to be described in a Limit Exceeding Report (LER).

If ongoing exceeding was observed, a detailed study of the monitored data had to be carried out to determine the source(s) of the increased SSC in the water. Since an increase in SSC levels and sedimentation rates can be caused by different sources the following possible sources were pre-defined and had to be addressed in the study:

- Natural fluctuations of SSC in the waters of Daya Bay due to changing weather conditions like wind and waves, which creates turbulence in the water
- Natural (seasonal) fluctuations of SSC in the waters of Daya Bay due to unknown factors
- Rain fall and heavy rain fall (during monsoon period) carrying sediment from land to water
- Dredging operations of Contractor
- Marine operations in Daya Bay of other contractors

When it was concluded that exceeding of SSC limits were caused by the dredging works, appropriate action should be undertaken by means of implementing 'optional' mitigating measures in the dredging operations. Results of the study were to be discussed with CSPCL as well as any adjustment to the

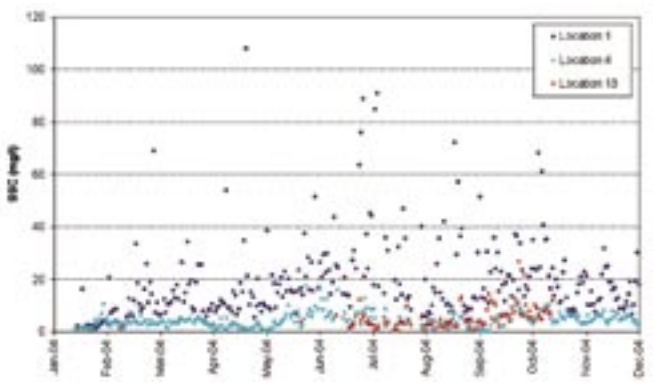

Figure 5. Measured SSC at locations 1, 4 and 13, Jan '04 – Dec '04.

dredging works in case 'optional' mitigating measures were applied.

A number of 'optional' mitigating measures which could be implemented were:

- Scheduling of dredging operations in certain areas with respect to tide and currents
- Minimising turning of TSHDs when dredging near sensitive areas
- Reducing the use of jet water on the dragheads
- Deployment of silt curtains around sensitive areas when all other measure fail

Monitoring results

SSC measurements

The environmental limits were not exceeded during the dredging period.

Results of SSC measurements at locations 1, 4 and 13 are plotted in Figure 5. Location 1 is inside the dredging area and on occasions high SSC levels up to 100 mg/ltr were monitored, mainly when dredging activities were undertaken close to the monitoring location during the time of measuring. No environmental limit was applicable for this location.

At the coral sites, which are closest to the dredging area, locations 4 and 13, no exceeding was recorded. Moreover the means of the monitored SSC levels at those locations were in the range of the background SSCs.

Sedimentation rate monitoring

The limit for sedimentation at coral sites was not exceeded during the dredging works. Higher sedimentation rates were often monitored after periods of rough weather conditions, but on average the measured sedimentation was about 2 to 3 times lower than the set limit.

However, two months after the start of the dredging works during the months of March and April, a significant increase in Algae growth on and near coral formations was noticed on the diver's movies. CSPCL was informed and the cause of the increased algae growth was investigated.

Increased algae growth is often caused by increase of nutrients or water temperature. Results of the water sample analyses for phosphate and nitrogen however, did not show a structural increase of released nutrients. Water temperature on the other hand, had increased significantly over the past two months, and was very likely to have been the cause of the considerable algae growth. This was confirmed by the South China Sea Fisheries Institute (SCSFI) which was consulted by CSPCL on this issue. Moreover, SCSFI stated that the abundant algae growth can be noticed each year during spring time.

Typhoon event

Daya Bay has a subtropical marine monsoon climate with frequent typhoons passing the region in summer and autumn. A typhoon procedure was incorporated in the dredging plan in case a typhoon warning was given by the authorities.

On 15 July 2004 a typhoon warning was given and all ships, including dredging equipment, survey and monitoring vessels, were ordered to find shelter in the selected anchorage areas. On 17 July the typhoon passed Daya Bay at approximately 50 km to the south moving west towards Hong Kong. Wind speeds of over 30 m/s (108 km/hr) were recorded. No wave data is available from inside Daya Bay. However, wave conditions inside the bay are likely to have been very rough since the bay is exposed greatly to the ocean swell.

Due to the typhoon event, daily monitoring of water quality was interrupted for two days. Although weather conditions were rough the monitoring was resumed in the afternoon of the 18th. SSC levels in the water returned to background values within 2 days.

The weekly monitoring of the sedimentation rate at coral sites was not affected. Sedimentation rates at location 4 are about 5 times higher after the typhoon event. At locations 13 and 15, which are located further offshore and therefore less sheltered, the sedimentation rates are even up to 10 times higher.

Mitigating measures

Since no environmental limits were exceeded during the dredging project, it was not necessary to implement optional mitigating measures. The standard mitigating measures turned out to have sufficient effect as in minimizing the impact on the environment. However, a number of times the dredging schedule was adjusted taking into account tide and currents. This was done in dredging areas which were close to coral sites, for example location 4. The dredging schedule was adjusted to prevent (more) increase in turbidity in sensitive areas, which might have resulted into an exceeding of the environmental limits.

Conclusions

SSC and sedimentation rate limits were not exceeded during the dredging project.

Natural influences like a typhoon, rough water conditions in general and sea water temperature changes had significant impact, although short term, on the environment.

The combination of strict environmental controls, investment in mitigating measures and an open dialogue with all stakeholders led to a dredging programme that met everyone's expectations and resulted in minimal impact on the environment.

It was demonstrated that, despite the strict environmental controls, with proper planning of the dredging operations, adequate and accurate monitoring, and management of environmental effects, dredging and environmental care can well go together.

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