OLDIES BUT GOODIES AT MV2
50,000 years ago under the North Sea

ENGINEERING INNOVATIONS
preserving habitats and our coasts

ROCK SOLID
how to link causeways and islands
Guidelines for Authors

*Terra et Aqua* is a quarterly publication of the International Association of Dredging Companies, emphasizing “maritime solutions for a changing world”. It covers the fields of civil, hydraulic and mechanical engineering including the technical, economic and environmental aspects of dredging. Developments in the state of the art of the industry and other topics from the industry with actual news value will be highlighted.

- As *Terra et Aqua* is an English language journal, articles must be submitted in English.
- Contributions will be considered primarily from authors who represent the various disciplines of the dredging industry or professions, which are associated with dredging.
- Students and young professionals are encouraged to submit articles based on their research.
- Articles should be approximately 10-12 A4s. Photographs, graphics and illustrations are encouraged. Original photographs should be submitted, as these provide the best quality. Digital photographs should be of the highest resolution.
- Articles should be original and should not have appeared in other magazines or publications. An exception is made for the proceedings of conferences which have a limited reading public.
- In the case of articles that have previously appeared in conference proceedings, permission to reprint in *Terra et Aqua* will be requested by the editor.
- Authors are requested to provide in the “Introduction” an insight into the economic, social and/or environmental drivers behind the dredging project by the editor.
- An emphasis is placed on articles which highlight innovative techniques and applications.
- By submitting an article, authors grant the IADC permission to publish said article in both the printed and digital versions of *Terra et Aqua* without limitations and remuneration.
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- The digital version will contain a link to the LinkedIn page of the author. In case the author does not agree, please inform IADC (rauwerda@iadcdredging.com).
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COVER

Building 41 km of causeways and 25 drilling islands at the Manifa Oil Field in Saudi Arabia required huge quantities of rock. Amongst other innovative techniques, hydraulically created sand bunds were finished by using extra-long reach excavators from the land side to install a slope protection of a rock underlayer installed on heavy duty geotextile (see page 24).
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After several years of economic doldrums, the global economy is gaining momentum and with it the dredging industry is re-emerging with vigour. Over the last two years, orders for dredging and related projects have been picking up speed and – with the newly built ships in the dredging fleets – the capacity to handle this work has never been better.

Being ready to meet challenges is characteristic of the dredging industry. Despite the sluggish economy of the past years, the major dredging companies did not stop investing in new plant, environmental techniques and research in general. On the contrary. The competitive edge is to be found in R&D and innovation. Now, as the economic climate warms up, the international dredgers are ready to take on port expansion in South America and new land reclamations in the Middle East.

Over time, since the 1990s the dredging industry has certainly consolidated. The top players, the members of the IADC, have emerged as the strongest forces on the dredging scene. But this climb to the top has not been easy. It has been secured by huge investments in R&D. Investments which have resulted in efficiency and cost-effective solutions that can take advantage of the increase in global trade, the search for new energy sources, the challenges of climate change, the expanding cruise ship travel industry and the necessity to meet the requirements of a world population ever more conscious of the importance of sustainability and biodiversity.

This June issue of *Terra et Aqua* finds us on the brink of a major maritime event at which many of these subjects will be profiled – the 33rd World PIANC conference in San Francisco, with the theme, *Navigating the New Millennium*. During this event, the diversity to be found in the dredging and maritime construction industries will be on display. The IADC will also be found at the conference, with a presentation by the Secretary General and a booth (#512), fully stocked with dredging literature and high-tech information.

Right now on display in the *Terra* you are reading are a few of the dredging trends and projects of the last year. For instance, the Maasvlakte 2 expansion of the Port of Rotterdam, the Netherlands has come to its conclusion. Amongst the activities at PoR were the amazing archaeological discoveries of antiquities and fossils from millions of years ago – artefacts never before seen in the Netherlands.

Crossing over the Atlantic to the “New World”, the environmental accomplishments of the USACE’s programme, Engineering with Nature – a complementary effort to Building with Nature and Working with Nature – are described.

And finally a recent major dredging project in the Middle East, in the Kingdom of Saudi Arabia, the Manifa oilfield drilling islands demonstrates the importance of meeting challenges with dedicated teams of engineering experts early on.

Speaking of innovations, remember to check out the new interactive version of *Terra* at the website www.terra-et-aqua.com.
ABSTRACT

This is the fourth and last of a series of articles describing the extensive monitoring related to the construction of Maasvlakte 2, Port of Rotterdam, the Netherlands. As far back as the 1990s during the first studies by the Main Port Rotterdam (PMR) project organisation for Maasvlakte 2 (MV2), archaeology was recognised as a subject of high importance. When the studies for MV2 were restarted in 2004 by the Port of Rotterdam Authorities (POR) a decision was made to tackle this subject as a “risk” item.

The Treaty of Malta (1992) makes it compulsory to look for archaeological remains in or on the seabed. In the Netherlands, this led in 2007 to the (revised) Archaeological Heritage (Management) Act (Wamz). Following this, in 2007 POR signed an archaeological agreement (covenant) with the Cultural Heritage Agency of the Netherlands (RCE) for assistance and guidance during construction. At the start of the project it was clear that the RCE would be the competent authority for the archaeology at sea during construction of Maasvlakte 2. This study concerned two aspects: wrecks and drowned landscapes.

At the start of the construction, an archaeology task group was installed. Based on a guiding paper from RCE, this group, with representatives of POR, RCE and the Rotterdam Bureau of Archaeological Research (BOOR) prepared what the procedure would be depending on location and type of archaeological find.

The interdisciplinary approach sought after by the POR and RCE in which many scientists from different fields and disciplines have worked together, has provided very exciting results. Next to bones also fossil shells, gravel and other specific geological features were sorted out. The natural history museum organised a public friendly weekend in September 2010 during which youngsters under supervision of researchers joined professional and amateur palaeontologists and geologists.

INTRODUCTION

As far back as the 1990s, during the first studies by the Main Port Rotterdam (PMR) project organisation for Maasvlakte 2 (MV2), archaeology was recognised as a subject of high importance. When the studies were restarted in 2004 by the Port of Rotterdam Authorities (POR) it was decided to tackle this subject as a “risk” item. Meetings were organised with the municipal and national responsible archaeological authorities, i.e., the Rotterdam Bureau of Archaeological Research (BOOR) and the Cultural Heritage Agency of the Netherlands (RCE) respectively.

The Treaty of Malta (1992) makes it compulsory to look for archaeological remains in or on the seabed. In the Netherlands, this led in 2007 to the (revised) Archaeological Heritage (Management) Act (Wamz). At the start of the project it was clear that the RCE would be the competent authority for the archaeology at sea during construction of Maasvlakte 2. This study concerned two aspects: wrecks and drowned landscapes. Both were believed to be present at the Maasvlakte 2 location and possibly in the borrow areas offshore.

At the start of the construction, an archaeology task group was installed. Based on a guiding paper from RCE this group, with representatives of POR, RCE, and BOOR, prepared what the procedure would be depending on location and type of archaeological finds. Details were further worked out in protocols.
At the same time a fair amount of money was “reserved” by POR in case archaeological finds did emerge. Thus instead of creating a project budget, a budget reservation was booked. From this reservation, money would be spent only if deemed necessary by the archaeology task group, with a fixed maximum. Based on a desktop study into available data of the larger Maasvlakte area, it was already clear that the likelihood of finding a drowned landscape under or next to Maasvlakte 2 was a real possibility. A special study, followed by an excavation (if possible) would be initiated to tackle this special subject.

The archaeological protocols became part of the tender documents and by doing so they were treated by the companies bidding for the works during the tender period as a “risk” item for which they could make a financial assessment. In 2007 POR signed an archaeological agreement (covenant) with the RCE for assistance and guidance during construction. In the covenant the responsibilities and tasks of RCE and POR were specified as well as the protocols and the budget reservation.

The archaeological agreement (POR and RCE) and the protocols are part of the contract between POR and PUMA, the contractor for Maasvlakte 2. Implementation protocols state how archaeological finds must be treated during construction: Within 24 hours of an archaeological find, the Contractor must inform POR and RCE. Then the archaeology task group, in which now also PUMA was represented, decides what will be done with it.

**AREAS OF INTEREST**

The archaeological investigation for MV2, which started in 2004, indicated that the investigation should focus on (Figure 1):

1. The location where MV2 was to be built;
2. The place where the Yangtze Harbour was to be widened and deepened;
3. The sand borrow area 10-15 kilometres off the coast, southwest of Maasvlakte 2.

**MARITIME ARCHAEOLOGY**

Before the start of the construction work, the seabed of the sand extraction area and the construction area were investigated. Using multibeam bathymetry and sonar equipment, a search was made for objects of historical importance and in particular of shipwrecks or parts thereof. General practice is that prior to the start of a dredging work, bathymetric survey in combination with side scan sonar and magnetometer are carried out – often at high speeds (sailed at 20 knots) which in general is all right for volume assessment and permit requirements.

In archaeological investigations, however, the emphasis is different and so is the order of the surveys. First of all, high definition side scan sonar is sailed, in combination with magnetometer (search for metallic objects) and (if possible and required) shallow seismic. On those locations where anomalies or clear objects are found, high definition fullcover multibeam bathymetry at low speed is sailed to allow an assessment of the object. If still unclear, diver inspection might be needed.

During this investigation, 94 observations were made, which finally led to 9 possible sites of historical wrecks. At these spots, divers looked for anything of archaeological value. At one location in the construction area this resulted in an archaeological field investigation. A wooden shipwreck from the 19th century was excavated (Figure 2).

The MS. Cornelia Maersk, build in 1925, sunk in 1942 in front of the entrance to Rotterdam. The wreck was situated in the area where the new wet infrastructure of Maasvlakte 2 was projected. This wreck was not of archaeological importance, but needed to be removed (Figure 4).

**DROWNED LANDSCAPE: ARCHAEOLOGY AND GEOLOGY IN THE YANGTZE HARBOUR**

In order to make the new wet infrastructure of MV2 accessible for ocean-going ships, the Yangtze Harbour had to be widened, deepened and dredged through. The bottom of the Yangtze Harbour was initially dredged to −17 metres NAP, but in the final configuration needed to be deepened to almost −21 m NAP. This deepening and widening was envisaged to take place at the end of 2011.

However, based on a 2004 desk study and the available geological data, it was believed that the area where the Yangtze Harbour now lies was inhabited by humans in the Middle Stone Age (8800 to 4400 BC). The area from the North Sea to beyond present-day Rotterdam once formed part of a large river delta that was rich in food, with aeolian river dunes, river channels, natural levees and swamps. The river...
FORMATION OF RIVER DUNES

During the last Ice Age, 100,000 to 11,700 years ago, it was bleak and cold. During the coldest period, between about 25,000 and 15,000 years ago, the landscape was bare, with sparse vegetation. Strong winds blew the sand on the surface away and deposited it elsewhere. During the Ice Age, the rivers were of the braided type: they had a wide multiple channel bed which was only completely filled with water in spring when the snow melted. In the summer and autumn, the bare bed was largely dry. The sand of the dry bed was blown by the wind and deposited on to the vegetated low terrace next to the bed which was sparsely vegetated. Here the sand became trapped in the vegetation. In this way, up to 20 m high dunes (donken) were formed. These dunes stood out as dry hills in the delta that formed here later.

PREHISTORIC HABITATION ON RIVER DUNES

The river dunes were found in the drill cores of the fieldwork. The stratigraphy of the soil consists of a thick layer of (sub)recent North Sea bed, made up of sand and shells. Below this, Middle Stone Age layers of clay and peat have been preserved. Below the peat lies the river dune, the top of which is recognisable by its dark, medium grained sand. This means that sections of the surface on which people walked in the Middle Stone Age, are still intact and well preserved.

This is one of the most important discoveries and allows researchers to form a good picture of this period. Where the North Sea and the port of Rotterdam now lie, there was a fluvial delta formed by the Rhine and Maas 9,500 to 9,000 years ago. The rich flora and fauna made this area very attractive to hunters and gatherers. In the Middle Stone Age, these hunters and gatherers lived in families, in small groups of about ten people. They moved through the region, with the higher river dunes (donken) serving as ‘camping sites’, as they were safe from floods there. There was also sufficient food in the area, such as fish, meat, berries, nuts and fruit. The excavations are providing more information on their way of life.
dunes, also referred to as ‘donken’, were high and dry sandy spots in the wet river delta. These river dunes were ideal places to spend night and live for a short time. Here, the hunters and gatherers once lived high and dry in temporary encampments. Carefully planned fieldwork in the Yangtze Harbour revealed the presence of these sandy dunes located at levels between −17 and −20 m NAP.

**UNIQUE ARCHAEOLOGICAL UNDERWATER RESEARCH**

Systematic research, desk studies followed by field surveys, was carried out investigating the buried former land surface and the possible traces of hominin occupation. This research was unique as it was in the Netherlands the first time that research was done at such a depth (about −20m NAP) and so far to the west of the country. The research was directed in such a way that the scientists used the (assumed) knowledge of how these people would have lived in such an environment in combination with a staged approach zooming in on the most promising results of the previous surveys.

On the basis of existing borings, seismic measurements and Dutch cone penetration tests, an area of approximately 120 hectares was charted. Of the three ‘archaeologically promising’ zones which emerged from these initial investigations, two were looked at in more detail: a buried river dune (donk) and a silted-up channel, where people in the past possibly sailed in their canoes. These two areas were studied more thoroughly by means of highly detailed seismic research and vibrocore sampling. On the buried river dune, archaeological remains were found in three viborcores. This led to the decision to excavate three small sections (pits) around the location of the cores.

**RECONSTRUCTION OF STONE AGE FLUVIAL AREA**

The last obtained vibro soil corings (2010) and the samples obtained from them, combined with all the other field studies and measurements, provided the scientists with a detailed picture of the substrate. In the laboratory, the soil samples are examined further, for example to work out from pollen (paleo-botanic study) what plant growth was like in the past. The biggest surprise (and reward) was that based on the small fragments of unburned and burned animal bone which were found in three samples, it became immediately clear that humans had lived in the area.

These finds date from about 7,500-7,000
B.C., providing the first scientific proof that people lived at this spot in the Early-Middle Stone Age. Up to now, very little was known about this period so far west in the Netherlands. The research done here is unique: the depth, the techniques and the exceptionally well-preserved remains.

EXCAVATION AND FILLING OF BIG BAGS

At the Maasvlakte 2, the construction progress prescribed a very tight time window for the actual excavation in the field. Construction could not be delayed by the archaeological excavation. The period in which the site was accessible for the archaeologists and the field operations was limited to October and November 2011 only. The designated excavation areas were in front of one of the largest and busiest container terminals in Rotterdam’s Yangtze Harbour basin.

After all the preparatory works and contracts were in place, the removal of the overburden, the non-archaeological layers, started at the end of October 2011. In two weeks’ time, 27 October till 9 November 2011, the whole archaeological excavation was completed.

The excavation was contracted to PUMA and supervised by BOOR. The archaeological excavation was based on a programme of requirement that was worked out by the archaeological task force. The starting point was to treat the excavation as an environmental dredging project with high accuracy excavation and digital logging techniques. The contractors’ equipment consisted of: the “Triton”, a floating pontoon with spuds and a fixed crane on a turntable, a large flat working pontoon with a receiving container and two small hydraulic cranes to fill and move big bags.

The excavation was done with a horizontal closing grab operated by wire, as the excavation depth was too deep for a hydraulic grab on a long stick. Positioning was done by dGPS and all data was logged on board of the Triton. The footprint of the grab, in open position, was 2 x 5 m². The excavated layer thickness was limited to 0.15 - 0.20 m, resulting in 1.5 to 2.0 m³ of sediment for each grab. First the overburden, the non-archaeological layers were removed. What remained...
was the archaeological layer (sandy topsoil of the river dune) underneath 0.4 to 0.8 m peat and fluvial clayish material. This sequence was excavated in 4 to 5 steps of 0.2 m each. Because the subrecent marine sand had not been removed completely, every grab was checked on the pontoon. Grabs of the subrecent sand were temporarily stored in a dump barge lying next to the dredge pontoon. Grabs with the peat, clay and dune sand were released in a storage container placed on the large work pontoon. The storage container was emptied by a small hydraulic excavator standing next to the container. From each grab, the excavator filled 2 big bags (size 1 m$^3$) being labelled A and B plus a number. After being filled and labelled they were placed at the end of the work pontoon by the other hydraulic crane. At the end of the day, the bags would be transported to the quay of the Yangtze Harbour approximately 1500 m away from the excavation where they were temporarily stored on land. To double-check on the progress of the excavation, a bathymetry in-survey was carried out by POR’s hydrographic unit at the start of the excavation. At the end of every excavation day, an intermediate survey was carried out with multi-beam equipment. At the end of each excavation a final out-survey was done in the same way.

From the 3 areas thus excavated 316 big bags were recovered, each labelled and assigned X, Y and Z coordinates. The sieving on site at the quay of the Yangtze Harbour took from 1 November till Christmas 2011. The bags were sieved with water from the harbour over a 10 mm and a 2 mm mesh sieve installation. The residues were collected and stored on site in a hot room to dry. Once dried they were dispatched to BOOR’s offices for sorting out of the obvious archaeological and botanical remains (see Figures 17-20).

**FINDS FROM HUNTERS AND GATHERERS**

The first coarse sorting of the material coming from site and worked over in BOOR’s laboratory resulted in some 46,000 small remains of charcoal, wood, bones, burnt bones, fish, (worked) flint, natural stone, bone adze (tool used for working wood) and scrapers (skins). The bone remains are small particles, not bigger than 1 cm, burnt and unburnt animal bone. The unburnt bone demonstrates the presence of animals in the area. The burnt bone is burnt in such a way that it must be the result of human action. Together with the charcoal finds, this is evidence of food preparation, such as the grilling of meat. Charred tuber remains of several plants, amongst which pilewort, were also abundant (see Figures 21-24).

The flint fragments and the minuscule splinters of flint prove that flint was worked in situ to make implements (tools), such as arrowheads, knives and scrapers for cleaning animal skins.

The unique thing about the site in the Yangtze Harbour is that it is the first time in the Netherlands that a complete package of material of this age has been found, including...
well-preserved plant and animal remains that give a good indication of these people’s diet. Many known sites in the Netherlands exist where flint of this age and slightly older has been found, but the organic material (wood, berries, tubers and so on) was always missing because it had decayed through time. Here everything was found together because of the excellent preservation conditions. This yielded spectacular new knowledge about how people at the time lived.

All the sieved material was investigated by specialists, i.e., on charcoal, paleo-botany, flint, animal bones (terrestrial and fish) for in-depth studies. Preliminary (partial) reports are now available and the final reports (in English) with all the combined results put in perspective, will be available mid-2014.

A three-dimensional image of the submerged landscapes and what life looked like there and then has been created. The finds and method have been presented internationally at scientific conferences both at home and abroad. The project as a whole has already led to various scientific publications in the field of archaeology, underwater archaeology, and palaeontology and landscape reconstruction.

LESSONS LEARNT SO FAR IN THE YANGTZE HARBOUR
Treating the archaeological excavation as an environmental dredging project was the ‘right choice’ given the local circumstances. All other techniques that experts proposed were not feasible in view of the boundary conditions: limited time available, excavation depth 17-20 m underwater, high turbidity in tidal water (no visibility for divers), no congestion/delays of ongoing work allowed, deep drafted container terminal next door, and more.

Another lesson learnt dealt with the underwater excavation method. The special grab that was used had proven itself in environmental dredging projects. Here, a heavy grab will sink easily in the ‘soft contaminated’ sediment layer(s). In this case, the archaeological layers contained consolidated very stiff peat that was very difficult to penetrate or break through. Having a grab on a wire, compared to one on a hydraulic stick, means that no extra force for penetration is available. The grab, being prevented to sink into the layer at one side, will no longer excavate horizontally anymore and make a slight hollow. The small dimensions of the pits, with the stiff peat protruding at the sides at some locations resulted in a slight twist of the grab in the horizontal plane (Figures 25 and 26).

All of these were visible in the daily bathymetric surveys and with the help of the electronic logging (X, Y, Z) of each grab, could be dealt with – although it was quite a puzzle in the end.

Fortunately the site stratigraphically consisted of only one archaeological layer with a thickness of 40–80 cm and covering a time span of some thousand years as the drowning of the landscape at the time was quite rapid. This was the result of sea level rise caused by the melting of the ice caps above North America and Scandinavia. Dating took place on samples from the vibrocores taken before the excavation. They had a very precise vertical accuracy, and yielded excellent results.

PALAEONTOLOGY: ‘BY CATCH’ FOR SCIENCE AND THE PUBLIC
There are in the Netherlands to date, no legal obligations regarding palaeontological finds. However, because geologists and archaeologists can gain new insights into the submerged landscapes and their possible inhabitants on the basis of these finds, POR decided to handle all palaeontological finds, such as bones and fossils, with care during the dredging operations. During various Ice Ages, the sea level was so low that what is now the North Sea was dry land. The many finds led to a covenant with the Natuurhistorisch (Natural History) Museum Rotterdam (NMR), which was signed on 16 February 2010.
The POR ensured that all bones from mammoths and other fossil mammals found during the sand extraction on the trailing suction hopper dredgers (TSHDs) and on the new reclamation of MV2 go to the NMR. Thanks to the meticulous records kept by PUMA, the ‘exact’ sand extraction locations and depths are known for most of the finds. Partly as a result of this, the new material is of great scientific value. The palaeontological objects are accessible for scientists and the public; the most beautiful and scientifically interesting specimens are exhibited in the NMR as referred to above, but also in the Port’s FutureLand information centre on Maasvlakte.

Two hundred and more mammal remains
During dredging, a number of larger objects were caught in the ‘bomb grate’ of the drag head of the TSHD, including palaeontological finds. As a result, the POR decided, in consultation with RCE, to organise several specific fishing trips for palaeontological finds in the sand extraction area. In the earlier mentioned protocols such a fishing expedition was referred to as a “Cerpolex” survey in the Netherlands and geared at looking for archaeological and at the same time palaeontological finds.

In October 2009, the fishing boat OD7 spent two days in the borrow area trawling for finds. This trip was so successful that it was decided to carry out some more trips. For the in-situ silt (SPM) measurements that were required for environmental reasons, the POR used a fishing boat BRA-7 which was at sea for a week for each campaign. Consequently, in 2010 the BRA-7 was chosen to fish for mammoth fossils and archaeological finds on six Saturdays at the end of the silt measuring week. Thanks to the TSHDs, which kept exposing new and deeper parts of the borrow area, the fossil finds in particular were spectacular: over two hundred top-quality mammal remains, such as teeth, vertebrae and bones, have now been added to the collection of the NMR.

Three quarters of the finds are from the woolly mammoth (*Mammuthus primigenius*), including the longest mammoth thighbone (as yet) found in the North Sea, two virtually complete and exceptionally large pelvic bones and a tusk (Figures 27 and 28). Other animal species from the Late Pleistocene fossils which were dredged up from the sand extraction area are reindeer, steppe wisent, aurochs, Irish elk, red deer, woolly rhino, wild horse, cave lion, harp seal and otter.

![Figure 27. In October 2009, a 133 cm long thigh bone of a woolly mammoth was dredged up. This is to date the largest fossil bone found in the North Sea in the Netherlands.](image)

![Figure 28. Drawing of a woolly mammoth with the tusk, pelvis and thigh bone indicated in red.](image)

![Figure 29. On 18 August 2010, the BRA-7 dredged up the first fossilised hyena dung ever found in the Netherlands.](image)

![Figure 30. Below and right: A naturally backed knife, type 3, (cf. Bordes 1961), known as a ‘hand-rug-mes’ in Dutch, is an artefact made by a human, probably 30 to 50 thousand years ago. No human remains (bones) were found near it.](image)
Special finds

The perfect fossilisation of this relatively young (Late Pleistocene) piece of hyena excrement is exceptional (Figure 29). Research at the NMR revealed that the light brown fossilised dung had been produced an estimated 30,000 to 40,000 years ago by a cave hyena (*Crocuta crocuta spelaea*). The so-called coprolite, measuring 55 x 44 millimetres, has been incorporated into the museum’s collection and is now exhibited there. The presence of this predator had previously been demonstrated by dredged-up fossilised skeleton parts and, most importantly, by typical signs of a hyena having fed on (mammoth) bones. Other artefacts such as a naturally backed knife were also found (Figure 30).

GEOLOGICAL CONTEXT, THE “ENVELOPE”

The success of the ad-hoc fishing trips for archaeo- and palaeontological finds of 2010 were discussed in the archaeological task force. It was decided that, if to be continued, a more scientific approach would be appropriate and a budget was made available from the reservation for archaeological research. As an integrated approach with the University of Leiden, NMR, Naturalis Leiden, Deltares and TNO, a scientific research project was formulated.

The design of this geological-palaeontological search thus differed from that of the earlier fishing trips. Previous results (finds) were looked at in advance in combination with the geological structure of the slopes of the borrow area where most of them were coming from, resulting in short tracks at predetermined locations and depths. Again, this time the north-western slope of the borrow area would be the target, but with a more systematical and methodological approach (Figures 31 and 32).

Set-up

The northern slope area in PUMA’s sand extraction pit was investigated in depth. Along with the bottom trawl, a Side Scan Sonar (SSS) was used. Use was also made of a shallow seismic profiler (xStar) and a Boomer (sparker). The SSS is used to look sideways along the seabed for objects which protrude from the bed. With the xStar and the Boomer, one can look in the bed at the substrate’s structure.

Furthermore, a number of overlapping (in depth level) vibrocore borings were carried out perpendicular and parallel to the northern

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**YANGTZE HARBOR AND SAND EXTRACTION OFFSHORE (SUBMERGED LANDSCAPE)**

The results already showed that people lived here in the Middle Stone Age, the period after 9,700 BC. From the results of the borrow area, it is now known, partly from the flints and tools found, that people also roamed the cold steppe (what is now the seabed) in the Old Stone Age.

It is important to know if the archaeological and landscape finds at the Yangtze site can be connected with the landscape research in the sand borrow area, some 10-15 km south-westward of the Yangtze site. The scientists, including physical geographers and geologists, were interested in the piling up (sequences) of landscapes. As a section of the bed of the North Sea was dug up in the sand borrow area to a maximum depth of 20 metres below the original seabed, the composition of the layers could be determined and dated. The top layer of the slope in which vibrocores have been placed (see Figure 35) should hopefully coincide with the lowest part of the vibrocore set in the Yangtze Harbour, thus connecting the two sites geologically. This may help with the reconstruction of the landscape sequence. The reconstruction study could produce unique scientific knowledge: A great deal of dredging has been done in the North Sea, but never before was this type of research conducted on such a scale.
slope (Figures 33, 34 and 35). Using these data, the geological structure and stratigraphy of the pit was mapped in detail. With the aid of samples from the borings, the age of the various differentiated layers will be ascertained. Dating results of the samples by Optically Stimulated Luminescence (OSL) are expected to become available later in 2014. The OSL method allows sand grains to be dated. In this way all palaeontological finds from the fishing trips can be placed in their geological and temporal context. The beds have been “dated” indirectly by looking at their heavy mineral composition. From this, a maximum age of 250,000 years is expected for the deepest bed.

During the fishing trips, the catches from the two bottom trawl nets were looked at separately, systematically and sorted into, among other things, bone material, flint, stone, gravel, fossil shells and wood. Also, a general characterisation was given of, for example, the presence of lumps of clay, chunks of peat, residues of wood and the quantity of serpent stars and starfish. The data gathered also allowed a more statistical evaluation of the find in relation to their geological context.

**DATING SAND LAYERS**

Under the guidance of TNO | Geological Survey of the Netherlands, the age of the samples from the layers from the vibrocores is determined via Optically Stimulated Luminescence (OSL) dating and the sediments are carefully analysed. OSL is a relatively new dating technique. Some minerals emit a small light signal when they are heated or a light is shone on them. This light, or luminescence, can be used to date sediments, pot fragments and a number of other artefacts.

Luminescence dating has a longer measuring range (250,000 years) than the commonly used $^{14}$C or carbon dating method (approx. 50,000 years). The OSL dating takes a long(er) time to carry out, i.e., from 9 to 12 months and is not yet a common exercise. The results at MV2 will become available later in 2014.

Palaeontological research on the whale and mammoth bones dredged up using the popular $^{14}$C dating method produced a striking result: both heavyweights apparently lived in the same place between about 32,000 and 38,000 years ago. Shells were also dated to about the same period. But did the whales walk on the steppe then or, did the mammoths swim in the sea?

It seems that the method for $^{14}$C-dating shell and bone material of this age and older found underwater has some problems. It looks like the shells and bones are contaminated by fresh carbon material that is added to the shells and bones through the recrystallisation of calcium carbonate from the groundwater by bacteria which live in this porous material.

As a result of this ‘contamination’ with young carbon, the $^{14}$C method seems to yield an age of 32,000 to 38,000 years for all shells and bones of this age and much older. By comparing the OSL dates with the $^{14}$C ‘age’ of the fossils from the sand, new light will be shed on this problem later in 2014.
ARCHAEOLOGY AND PALAEOONTOLOGY ON THE OUTER SANDY CONTOUR OF MV2

Simply speaking: the sand taken from the offshore borrow area is put “up-side” down on the Maasvlakte 2 seabed by dumping, rainbowing and pumping ashore. So all the remains of previous life gathered with the paleo-fishing trips can be found in the sand on the surface of Maasvlakte 2 as well.

The newly created beach protection (the outer contour with sand dunes) of Maasvlakte 2 was searched three times by a group of palaeontologists, geologists and archaeologists before it was opened to the public. PUMA willingly assisted in providing search areas with exact X, Y and Z coordinates. Through PUMA’s meticulously held logs of the dredging locations, these areas could be linked to the area of origin in the borrow area (Figure 36).

The beach was worked over systematically, and archaeological and palaeontological finds and stones and gravel were safeguarded in two ways: mechanically and hand-picked. As a result of time constraints and the fact that the accessibility of an active working site is difficult, it was investigated if other “gathering” techniques could be employed.

An often-heard shortcoming of the fishing trip with a trawling net was that small animal remains were hardly found. The idea was to use a conventional beach cleaning machine that would be compared with hand picking. The beach cleaner used was 2 m wide, depth of the knife-conveyor belt variable (up till 15 cm) and a sieve mesh # of 20 mm. The test was done twice: once in February 2010 and once in June 2010. In total 16 Big Bag (~1 m$^3$ volume) were filled by the beach cleaner, covering an area of approx. 16,000 m$^2$.

One bag from each of the predetermined and stacked out areas on the beach was sorted out at the natural museum Naturalis in Leiden (Figures 37, 38 and 39).

The sorting out was a huge job. The natural museum organised a public friendly weekend in September 2010 during which youngsters under supervision of the researchers participated next to professionals and amateur palaeontologists and geologists (Figures 40 and 41).

Next to bones also the fossil shells, gravel and other specific geological features were sorted out. This was done to see if correlations could be made related to the geological layers in the borrow area and whether or not a statistical analysis was feasible on the finds and these associated constituent parts.

Many remains of animals from the mammoth group from the Pleistocene and archaeological artefacts from the Late Pleistocene and Holocene have been found. Finds include teeth from a white shark, a beaver and a rhinoceros.

A lot of unique fossil shells were also found, and a large number of fossil marine animals and flints. Some remains proved to be between 50,000 and a million years old. The white shark tooth must definitely be a couple of million years old. The shark did not live here; the tooth has been transported here by the palaeo-Scheldt river that cut through Tertiary deposits in Belgium that are famous for these shark teeth.

The shells could help with the reconstruction of the landscape. Furthermore, the shells and shark teeth provide indications of the origin, i.e., brought in from the north or south by ice sheets or rivers. Researchers are now busy investigating how old the shells are.

A HUMAN FIND AFTER ALL

After the beach was opened to the public many enthusiastic amateurs began searching daily for fossils and archaeological stuff. On 19 March 2013, one man, Walter Langendoen, who already had found some 30 hyena coprolites, was lucky and found two small pieces of bones that later on proved to be human. With the permission of the finder POR had the pieces investigated by experts and after $^{14}$C-dating they proved to be ~7,600 BC, the same age as the site of the Yangtze Harbour dune. Mr. Langendoen also found two spear points made of bone most probably from the “same” humans. $^{14}$C-dating for those finds is still in progress.

Figure 42. Part of a human skull, 9600 years old, found at MV2. This piece links the three scientific programmes: geotechnical and palaeontological work at the borrow area and on the sandy beach and the Yangtze Harbour archaeology.

Figure 43. The track of TSHD Volvox Maxima on 23 June 2010 (X,Y plot).

Figure 44. Box plot showing the draghead depth along the track of Figure 43, in percentiles.

Figure 45. Track plotted in the borrow area.
The geological envelope "reconstructed"

POR has access to the "book keeping" of PUMA during the construction of Maasvlakte 2. In order to comply with the dredging permit regulations, the position of each dredger is continuously logged, as well as the status signals of the complete dredging cycle over the whole day. Furthermore each load brought to shore is guided and registered to a specific placement location that is also logged. Using these data in a reversed mode it is possible, in principle, if the exact coordinates of a find on MV2 are known, to 'look-up' which dredger was the last one that delivered a load of sand at that particular area. Once the name of the dredger and the data and time of delivery are known the path in the borrow area can be reconstructed.

Of course it is unknown where exactly the bones have been picked up by the dredger, but the whiskerplot gives a fair indication of the average depth along the track and the variations (percentiles) around it. The most probable layer(s) where the bone fragments could come from fall within the 14C date.

A web-based application (App) has been developed on the basis of the above procedure. Any enthusiastic amateur can report archaeological and palaeontological finds on the beach through this App. This will yield a unique database of finds with exact X, Y and Z coordinates, which will help scientists to analyse the gathered information. In return, the amateurs get back a possible date of how old their find is and what type of find it is. This approach has let to the development of a web-based checker for finds on the outer perimeter of MV2: see website www.oervondstchecker.nl. This application which works on a smartphone, laptop or PC, was launched on the 25 January 2014.

For the skull fragments found on the outer perimeter this yield the following: Coordinates: N 51 57'45.761" & E 003 57'38.698". The placement area that contains those coordinates lists the TSHD Volvox Maxima as last dredger bringing sand on 23 June 2010. Based on this information the track of the Volvox Maxima can be reconstructed from the black box data and is shown in Figure 43.

The depth percentiles are shown in Figure 44, with a median depth of 27.5 m NAP (CD) lying in deposits of the Early Holocene. The depth information from the box plot is matched with the geological information obtained by the TNO/Deltares surveys into the composition of the geological layers in the borrow area. The track is plotted in the borrow area in Figure 45. The earlier mentioned web application is based on the same procedure and principle.

CONCLUSIONS

By identifying the archaeology as a normal project “risk” at a very early stage of the project, it could be successfully integrated into the Maasvlakte 2 construction project. Because of the joint efforts of the contractor PUMA, the archaeological task force and the (geo)archaeological and palaeontological specialist, all the desired research could be carried without interfering with the harbour construction. It did not delay the works at any moment.

The interdisciplinary approach sought after by the POR and RCE in which many scientist of different fields and disciplines (geology, archaeology, palaeontology, paleobotany, malacology, and so on) had to work together, provided very promising results. The reports of the research described above are in their final stages and will be available mid 2014 (in English, Moree and Sier).

With the human bone found on the outer contour, mid-2013 and dated ~7000 B.C., the link between the three different projects described in this article, was closed. The humans that lived at the Yangtze Harbour 9000 years ago could be linked to the borrow area, as the remains of a human from that period was found on the Maasvlakte 2 brought there by the TSHD bringing sand from the borrow area.

On 25 January 2014 a public friendly book on the archaeology, drowned landscapes and palaeontological findings related to the construction of the Maasvlakte 2 was released by POR in their information Centre Futureland as part of the archaeo-palaeontological exhibition showing the finds from Maasvlakte 2. POR and RCE, in collaboration with the participating parties, will organise an International Symposium in 2015 to present the final results of the Yangtze Harbour excavation and the findings of the projects.

REFERENCES


Web-based paleo/arceho checker for finds from the outer perimeter of Maasvlakte 2: www.oervondstchecker.nl


ABSTRACT

The US Army Corps of Engineers’ “Engineering With Nature” (EWN) initiative supports sustainable development of infrastructure by advancing technical and communication practices in order to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes. The tools and projects that have been developed through EWN support planning, engineering, and operational practices that beneficially integrate engineering and natural systems to produce more socially acceptable, economically viable, and environmentally sustainable projects.

The EWN initiative’s focus on developing practical methods provides an achievable path toward an ecosystem approach to navigation infrastructure development. By combining sound science and engineering with advanced communication practices, the EWN initiative is providing a robust foundation for collaborative project development. Engineering With Nature is being pursued through innovative research, field demonstrations, communicating lessons learned, and active engagement with field practitioners across a wide range of organisations. The objectives of EWN are consistent with those communicated in the “Working with Nature” philosophy of the World Association for Waterborne Transport Infrastructure (PIANC) and the “Building with Nature” initiative of EcoShape Foundation, a public-private knowledge institute in the Netherlands.

INTRODUCTION

Pursuing the objective of sustainable development of navigation infrastructure poses both challenges and opportunities for the US Army Corps of Engineers (USACE). Advancing best practices will involve identifying the practical actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable and environmentally sustainable projects. Engineering With Nature (EWN) is a USACE initiative that supports more sustainable practices, projects, and outcomes by working to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes (www.engineeringwithnature.org; Figure 1). The EWN initiative’s focus on developing practical methods provides an achievable path toward an ecosystem approach to navigation infrastructure development and operations that is applicable across multiple USACE missions and business lines.

Science, engineering and demonstration projects within the EWN initiative illustrate the use of:
1) science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits;
2) natural processes to maximum benefit, thereby reducing demands on limited resources, minimising the environmental footprint of projects, and enhancing the quality of project benefits;
3) approaches that will broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits;
4) science-based collaborative processes to organise and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.

The objectives of EWN are consistent with those communicated in the Working with Nature (WwN) philosophy of the World
The WWn philosophy seeks win-win solutions for navigation development projects by promoting project development that proceeds in the following way:
1) establishing project need and objectives;
2) understanding the environment;
3) making meaningful use of stakeholder engagement that identifies win-win options; and
4) preparing project proposals/designs to benefit navigation and nature.

In parallel, the BwN approach advocates a different way of thinking, acting and interacting. Building with Nature strives to:
1) gather and develop ecosystem knowledge enabling water-related building with nature;
2) develop scientifically based and location-specific design rules and environmental norms;
3) develop expertise in applying the BwN concept;
4) demonstrate that BwN solutions work, with practical examples; and
5) determine ways to ensure that the BwN concept is adopted by society.

Project examples are collected in the web-based BwN Design Guideline (www.ecoshape.nl/en_GB/wiki-guideline.html).

The following project summaries are provided to illustrate the range of supporting projects that are completed or underway.

**Sustainable Sediment Management through Strategic Placement and Innovative Beneficial Use Practices**
Sediment management is a costly and challenging endeavour. Designated placement sites are limited in space and environmental restrictions limit where sediment can be placed and how it can be used. The EWN initiative, in collaboration with the Regional Sediment

**EWN IN PRACTICE**
The EWN initiative is developing and demonstrating, through multiple projects, the capabilities that are needed to achieve sustainable, triple-win project outcomes.

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Is the Technical Director for Civil Works at the US Army Engineer Research and Development (R&D) Center. He is responsible for integration of Environmental, Flood Risk Management and Navigation Research and Development and is Chair of the Committee on the Marine Transportation System Integrated Action Team for R&D. He received his BSc and MSc in Coastal Engineering in 1981 and 1983, respectively, from the University of Florida.

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**Figure 1.** The EWN approach provides overlapping benefits resulting in more sustainable projects.
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Management (RSM) Programme, is focusing technology development and field demonstrations to highlight opportunities for innovative sediment management practices that can reduce operational costs while also providing for an expanded range of environmental benefits as shown in Figures 2 and 3.

Members of the EWN team have been collaborating with the Philadelphia, Jacksonville, Mobile, New Orleans, San Francisco, and Buffalo Districts of USACE (in addition to others) on a range of navigation projects where EWN approaches can provide more sustainable solutions for sediment management.

EWN principles and practices are being used by Philadelphia District to plan and design post-Hurricane Sandy dredging projects that will create new environmental habitats along the coast of New Jersey.

In-bay, thin-layer placement of sediment is currently being pursued and demonstrated by Mobile District as an alternative to using the ocean dredged material disposal site. The in-bay alternatives would provide substantial cost savings, reduce fuel usage associated with as much as a 30 mile transit distance, while providing for several beneficial uses of sediment. The EWN team members partnered with the RSM Programme to provide technical and scientific support in identifying and monitoring placement sites in Mobile Bay. Sediment placement within Mobile Bay will help to retain sediments within the system, provide opportunities for wetlands and marsh creation, and provide hundreds of acres of critical habitat.

Science that Informs How Biology Makes Use of Engineering

Threatened and Endangered Species significantly affect many USACE mission areas (e.g., flood risk management, navigation, hydropower generation, water supply). The interior population of Least Tern (ILT) (Figure 4) has been federally listed as endangered since 1985. ILT populations are generally associated with sandbar habitats on large rivers of the central United States and, as such, have caused considerable conflict in several USACE mission areas, leading to increased expenditures.
The USACE has over 100 miles of navigation infrastructure. Building Habitat into Navigation Infrastructure 201737/file/RC-1699-FR.pdf. www.serdp.org/content/download/18101/ The final project report can be found at the influence of sea-level rise and bird habitat effects on installation land use and training. in alternative, long-term investment strategies that would minimise the compounding influence of sea-level rise and bird habitat effects on installation land use and training. The final project report can be found at www.serdp.org/content/download/18101/201737/file/RC-1699-FR.pdf. Sustainable Management of Contaminated Sediment In 2009, ERDC team members collaborated with the US Navy and the private sector in developing and publishing a US Department of Defense (DoD) technical guide on the use of Monitored Natural Recovery for contaminated sediment sites (www.serdp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-200622). Development of the guidance was sponsored by DoD’s Environmental Security Technology Certification Programme to support clean-up activities within the Department. The US Navy estimates that its sediment cleanup liabilities include $1 billion in future remediation costs. The guidance document provides a science and engineering framework for utilising naturally occurring physical, chemical and biological processes to accomplish risk reduction at contaminated sediment sites. The guidance illustrates opportunities for applying EWN for sediment cleanup at substantially lower costs – both in economic and environmental terms – compared to conventional methods that predominantly rely upon sediment removal. GIS Database of Projects Demonstrating EWN Practices The Engineering With Nature Project Mapping Tool (EWN ProMap) is a geography-based data viewer for communicating information about projects that illustrate EWN opportunities. The EWN ProMap can be accessed at http://155.82.160.6/applications/opj/V013/public/viewer.swf. The EWN ProMap, shown in Figure 6, provides project information on water resources projects that illustrate key attributes of the EWN approach: 1) Science and engineering are used to produce operational efficiencies;
These structures are sustainable in that they create and/or improve habitat for fish, macro-invertebrates and other species in the river. In addition, the structures utilise the river’s energy to maintain navigable depths in the main channel, improve current sets through the navigation spans of several bridges, and deposit sediment downstream of the chevrons for increased environmental diversity in the reach, which ultimately reduces dredging. The St. Louis District’s projects embody the EWN concept by demonstrating how cost-effective engineering practices can enhance the habitat value of navigation infrastructure.

In the late 1990s, as a part of a capital dredging project on the Cape Fear River in Wilmington, North Carolina, an offshore hard-bottom reef was constructed using rock dredged from the river. Standard practice would have been to dispose of the rock in the designated disposal site. However, members of the project team in the Wilmington District recognised the opportunity to create a regionally rare form of coastal habitat in the South-East Coast of the United States. The project team collaborated with engineers and biologists to design the offshore reef called the Wilmington Offshore Fisheries Enhancement Structure (WOFES). The reef’s longest arm, known as Leg “A”, is approximately one nautical mile in length and sustainable fisheries by providing essential habitat for juvenile fish, crabs, and shrimp. Multiple benefits including recreation, shoreline and storm protection, marsh restoration and habitat creation are achieved as a result of this project.

The St. Louis District has led the way for river engineering with its use of chevrons that direct flows to maintain the location of the navigation channel while preserving the function of secondary channels for habitat along the Mississippi River as shown in Figure 8.

Examples of projects included in the EWN ProMap are Mobile District’s Deer Island Restoration Project, St. Louis District’s use of river chevrons, and Wilmington District’s coastal reef constructed of rock dredged from the Cape Fear River, North Carolina. The Deer Island project aims to re-establish marshes along the Mississippi coast. The completed restoration is shown in Figure 7.

This project represents an EWN opportunity by demonstrating the use of strategic placement of sediment for beneficial use of dredged material. The project approach maintains sand in the littoral coastal system and contributes to
Leg “B” is 2,000 feet long (Figure 9). Fisheries surveys performed after construction of the structure have documented the environmental benefits associated with the project, which has served as the location for multiple fishing tournaments since its construction.

**EWN for Coastal Resilience**
Coastal systems are a critical component of the infrastructure of the United States. The USACE recognises the need to encourage and sustain the resilience of these coasts. Engineering With Nature research scientists created a research partnership in 2012 that seeks to accomplish three goals:

1) Advance the efficiency of engineering and operational practices involving dredging and dredged material management;
2) Expand and extend environmental benefits produced through sediment management; and
3) Improve the resilience and sustainability of coastal systems facing short- and long-term uncertainties related to climate change and other drivers.

The collaboration draws together scientists and engineers from ERDC, US Fish and Wildlife Service, US Geological Survey and other organisations to develop capabilities to characterise and manage coastal wetlands in response to sediment and nutrient flux, climate change and sea level rise, and beneficial use of dredged sediments. The project is applying advanced technologies for measuring, predicting and promoting mineralogical sediment processes in coastal wetland environments in order to sustain these features into the future. The tools and technologies developed through this collaboration support planning, engineering and operations in coastal systems. This joint effort represents a research partnership that spans the Navigation, Ecosystem Restoration, and Flood Risk Management business lines of the USACE.

**EWN ACTION PROJECTS**
The multiple benefits gained through EWN applications are ideal for field demonstrations. Investments are being made in EWN Action Projects in order to demonstrate EWN principles and practices across a range of applications. The current EWN Action Projects and descriptions are listed below. Six of the seven projects connect ERDC scientists and engineers with technical staff in USACE Districts to foster collaboration and implementation of new practices. Additional information related to these projects is available at www.EngineeringWithNature.org.

**Sediment Retention Engineering to Facilitate Wetland Development (San Francisco Bay, California)**
This EWN Action project is ongoing at two restoration sites in San Francisco Bay where evaluations of project performance, including reduction in wave energy, circulation, sedimentation, channel morphology, and vegetative cover will be measured as a function of berm morphology. The results will be used to develop guidelines and best practices in the design of berms intended to speed accretion and channel formation in bay restoration projects.

**Realising a Triple Win in the Desert: Systems-level EWN on the Rio Grande (Albuquerque, New Mexico)**
Three recently completed system-level studies on the Middle Rio Grande (MRG) used EWN to achieve sustainable development of water resources in the desert. These studies balanced social, environmental, and economic considerations using traditional benefit metrics (i.e., habitat units) to support transparent decision-making. The MRG projects will be used to document the benefits, in the form of ecosystem goods and services, which are being produced.

**Atchafalaya River Island Creation through Strategic Placement (Morgan City, Louisiana)**
This EWN Action project provides biological and hydrological monitoring data to quantify benefits and otherwise improve the understanding of the maturation of beneficial use of dredged material within the Atchafalaya Basin. The project documents how a river island was successfully created using dredged material, taking advantage of the natural hydrological processes inherent in the system.

![Figure 8. Chevrons at Bolter’s Bar on the Mississippi River help maintain the location of the navigation channel while preserving secondary channels for habitats.](image1)

![Figure 9. Survey of the Wilmington Offshore Fisheries Enhancement Structure, a constructed offshore reef.](image2)
Project findings will help direct future dredged material placement practices in the basin and other riverine systems.

**Portfolio Framework to Quantify Beneficial Use of Dredged Material (New Orleans, Louisiana and New England)**

This EWN Action Project is developing an analytical approach for evaluating beneficial use projects as a portfolio of opportunities that must balance both risks and benefits. Developing a balanced project portfolio requires information about the array of project risks (e.g., implementation, project performance, and so on) as well as the array of expected project benefits, including the amount of enhancement as a function of the material properties and the benefits achieved from the project.

**Ashtabula Breakwater Tern Nesting Habitat Demonstration Project (Ashtabula, Ohio)**

The Ashtabula breakwater tern nesting demonstration project is creating and evaluating simple, low cost modifications to the concrete blocks used to repair the breakwater that will provide habitat for birds. The design includes incorporation of suitable nesting substrate (gravel) and predator deterrence features. If the demonstration is successful, it will provide a means of returning the common tern (*Sterna hirundo*) to the local bird community. Historically, the common tern nested in the area, but has not been recorded locally for decades because of the lack of suitable habitat.

**Living Shoreline Creation through Beneficial Use of Dredged Material (Duluth, Minnesota)**

This EWN Action project will identify and develop low-cost, shallow-water dredged material placement methods, utilizing both engineered and natural processes. The methods will be used to maximise the habitat value achieved by using the dredged material to restore aquatic and wetland habitat. Finding cost-effective approaches for material handling that will produce the desired habitat is critical for development of future shoreline habitat restoration projects in the Great Lakes.

**A Sustainable Design Manual for Engineering With Nature Using Native Plant Communities**

The Sustainable Design Manual describes how to utilise plant communities within the built environment and to create sustainable landscapes that perform engineering functions. The design manual is important because it promotes native plant communities, which in turn support native fauna. Many plant communities exist on USACE lands and will provide stability in designed landscape elements that are part of USACE facilities and landscapes throughout the US.

**REFERENCES**


**CONCLUSIONS**

Solutions that beneficially integrate engineering and natural systems can greatly support sustainable development of navigation infrastructure. “Engineering With Nature” enables more sustainable delivery of economic, social and environmental benefits associated with infrastructure while directly supporting USACE’s Civil Works strategic planning goals and other directives. Such directives encourage creating synergies between sustainability and the execution of projects and programmes.

Many past, current and planned projects in the U.S. exemplify aspects of the EWN approach by:

1) Making use of science and engineering to generate operational efficiencies;  
2) Maximising the productive use of natural process;  
3) Expanding the range of benefits provided by projects; and  
4) Applying science-based collaborative approaches.

As indicated through the project descriptions above, a wide variety of projects illustrating the EWN approach in marine coastal, riverine, and lake environments are currently in place and there are major opportunities for the USACE to incorporate EWN principles into future projects. In 2013, the EWN project team received the USACE Chief of Engineers Environmental Award in Natural Resources Conservation. This achievement confirms support in advancing the use of EWN within current and future practice. It ensures that EWN will continue to be pursued through innovative demonstrations, communicating about lessons learnt, focused research and development, and active engagement and collaboration with our partners and stakeholders. Ultimately, EWN provides an emerging and innovative path to more sustainable projects.
MANIFA OIL FIELD: LARGE SCALE EXPERIENCES WITH BREAKWATERS – AN INNOVATIVE APPROACH

ABSTRACT
The shallow waters of the Manifa Oil Field make it impossible to use common offshore oil drilling platforms. For that reason Saudi Aramco opted for the construction of 25 oil drilling islands covering the entire Manifa Oil Field. The scope of the Project comprised the design and construction of some 41 kilometres of main causeway and associated lateral (secondary) causeways that provide vehicle and service access to the production islands and two water injection islands.

The article describes the large number of physical model tests conducted which permitted optimising the rock revetment design. It also deals with the practical management of a large scale quality control programme for the rocks. Specifically it describes some aspects of the extensive follow-up on rock quality parameters that varied with source; and the comparison and design evaluation of the different rock properties encountered at the different quarries. The initial costs and efforts for setting up a well-functioning Quality Management System (QMS) are substantial but are easily recovered in the long run during the project.

INTRODUCTION
The Manifa Field Causeway and Island Construction Project is by far one of the most prestigious projects ever realised in the Kingdom of Saudi Arabia. The Manifa Oil Field is one of the Kingdom’s most important crude oil fields. The field can deliver 900,000 barrels of heavy crude oil per day when fully operational. It is the largest single offshore development ever undertaken by Saudi Aramco since the company’s establishment.

The Jan De Nul (JDN) Group engineered, procured and constructed the Manifa Oil Field Causeway and Islands Project as Main Contractor. The combined value of the contracts for the Jan De Nul Group makes it one of the largest dredging contracts in recent years – worth 1.2 billion dollars. The Project is located on the east coast of Saudi Arabia, in the Arabian Gulf about 250 kilometres south of Kuwait. The site of the Manifa Causeway Project covers an area comparable to the size of Manhattan (Figure 1).

INNOVATIVE APPROACH
This article deals with the practical management of a large scale quality control programme for the rocks. Specifically it will describe some aspects of the extensive follow-up on rock quality parameters that varied with source; and the comparison and design evaluation of the different rock properties encountered at the different quarries (Figure 2).

Also the organisation of the test results obtained from a large number of physical model tests, performed to complement the design work for this massive project, is discussed in detail. This data included determining the damage criteria, based on testing classical overtopping discharge and armour layer movement.

The implementation of such a large scale quality programme in combination with a large number of model testing supported the engineering and essentially allowed the optimisation of the design to a large extent, therefore resulting in an economical and efficient design and construction.

LOCATION AND CONSTRUCTION
The location is critically complex. The shallow waters over the Manifa Oil Field, with a
Over a period of 3 years, 27 islands each with 10 well locations, as well as causeways with a total length of 41 kilometres, including 14 bridges – of which the longest is 2.4 kilometres – and 3 berthing areas with 2 roll-on /roll-off facilities for supply vessels, were designed and built (Figures 4 and 5).

This included road surfacing and pipeline and cable trays for the export lines and the SCADA system. Several shore approaches for pipelines and cables had to be dredged and abandoned pipelines had to be removed. The causeways and islands essentially consist of hydraulically created sand cores, finished with a slope protection of armour and/or underlayer rock installed on a heavy duty geotextile (Figure 6). Several innovative installation techniques for the geotextile have been used. Rock has then been installed from the land side as well as from the waterside,
again with a variety of techniques. The enormous rock volumes necessitated the provision from different sources with very different properties. A large amount of rock quality data was obtained from the monitoring programme set up for the project. After the reclamation was completed, each island was compacted and finished with a marl layer to receive the drilling equipment (Figure 7). Finally, asphalt roads were constructed on the causeways and the bridges (Figure 8).

To preserve the existing marine fauna and flora, as well as the livelihood of the local fishing community, bridges – instead of dikes – were chosen for connecting islands, in order to allow the continued flow of the tides in and out of the bay and thus preserve the original water quality (Figure 9).

**CHALLENGES**

The Project was characterised by significant technical and logistical challenges. For instance, because work was done in shallow waters, only vessels with limited draught could be deployed for the construction of the Manifa oilfield.

The construction and dredging fleet consisted of 11 dredging units, including cutter suction dredgers, trailing hopper dredgers and split hopper barges. About 50 auxiliary vessels such as tugboats, multicats, crew vessels, and fuel vessels were deployed, as were 40 barges and pontoons, including several heavy lift crane barges, positioning pontoons, floating workshops and a floating batching plant for offshore concrete (Figure 10). About 300 pieces of heavy equipment varying from extra-long reach excavators, dump trucks, wheel loaders, bulldozers, compactors, rollers and concrete mixers, were used (Figure 11).

The very large quantity of rocks required to be installed as rock protection on the islands were mainly purchased in the Kingdom of Saudi Arabia at a multitude of quarries, up to 600 kilometres inland from the worksite. Nevertheless, because of the high demand for rock on the worksite, rocks from quarries in Oman had to be transported to Manifa over
The number of different gradings had to be limited for logistical reasons (Figure 12). Before transporting a batch of rocks, each batch was tested on a daily basis for density and resistance in laboratories at the quarries and at the project site. Actual field drop tests (Figure 13) were performed as well as shape and grading verification. The massive stream of test results required setting up a practical and performance QMS structure able to respond quickly, and to follow the construction progress.

The main logistical challenge was to deliver and supply the equipment and the materials such as rocks, aggregates, containers, equipment, fuel, food, and so on, to such a remote working place where JDN was the first contractor to arrive. At peak periods a workforce of more than 3,000 workers from more than 40 different nationalities, were at work simultaneously. Sourcing this workforce at short notice and accommodating them in the empty desert required ingenuity. A camp in line with Saudi Aramco’s very high standards was constructed in the remote desert (Figure 14).

**PHYSICAL MODEL TESTING**

The rocks were treated as precious stones, and the consumption of these precious stones had to be kept to an absolute minimum. The design life of the project is 50 years. Several case studies were performed for many different locations in the work and for a storm with a return period of 100 years. The required different gradings for the rock revetment on different locations was obtained through detailed numerical wave modelling and then tested by physical modelling in wave flumes and wave basins (2D/3D) (Figure 15).

To optimise the design of the rock revetments, a large number of physical modelling tests have been done in a 2 dimensional wave.
particular shallow water conditions, where waves are depth-limited and empirical damage formulae fall outside of their applicable ranges. The amount of model test results made available in the project constitutes an important database that may well complement and expand the current state of the art.

In a 3-Dimensional wave basin at DHI in Denmark, the corner of the islands and bridge head sections have been tested, to check the stability of the gradings under a 3D wave attack. Again, armour damage has been investigated by expressing the number of displaced zones relative to the total amount of rock in a particular zone. In order to understand the particular 3D situation in combination with angled wave attack, due distinction was made between different areas on the slopes (hence the different colour bands in Figure 18). The approach allowed better localisation of problem areas and hence directing the efforts towards where they were needed. Starting from the extensive database of the physical model results, a final task then consisted in making sure that the design in the real world was consistent with the model. The numerically determined design wave conditions over the vast project area have been divided into areas of similar parameters (grouping), which could then be assimilated with one or more particular model test and type of revetment design.
quarry is located some 600 km inland from the coast, the closest 50 km. A traffic management plan was set up in coordination with the Client and the Saudi Authorities to safely guide the trailers to the site. Rocks from Oman quarries were transported to Manifa over water. Some 12 million tonnes of rock of 6 different gradings were transported to the site. Daily 400 trucks and trailers were received and offloaded on the stockpile areas (see Figure 19) and the rock loading jetties.

QUALITY MANAGEMENT SYSTEM

To guarantee the quality of the materials used in the work, as well as the construction itself, an extensive Quality Management System (QMS), based on internationally accepted ISO standards, was introduced, in close coordination with Client and Suppliers. The QMS has been set up in line with the JDN Group Corporate Quality Management System based on ISO 9001. A team of more than 30 quality inspectors was responsible for the implementation, follow-up and constant improvement of this QMS. An important part of the QMS is internal audits, of which 13 have been executed, and these internal audits are an indispensable tool to continuously correct the quality system where necessary.

Besides Method Statements and Procedures, the QMS requires working with materials with confirmed quality complying with the project specifications. Quality control on the construction materials is an important part of the daily site activities. Project specific tests and inspections were identified and were performed on sand materials, aggregate materials, rock materials, geotextile, cement and concrete, base course materials, marl, asphalt aggregates, steel rebars, tubular steel piles, fibre glass products, coating and welding (Figure 20).

Three fully equipped site laboratories were constructed to be able to follow and perform the considerable amount of tests. About 7,000 individual lab tests were concluded during the execution period of the project. Given the remote location of the project and the necessity to be able to correct and interfere immediately in case of negative trends in the test results, the installation and operation of the site laboratories proved to be a cost-effective approach.

ROCK REVETMENT

The entire work area covered not less than 80 km². The logistical co-ordination and transport over land and over water of construction materials and equipment was one of the biggest challenges of the project. In total 121 km of rock revetment was installed. This whole project was about rock and its logistical arrangements to get the required quantity of rock within the required quality, timely on the stockpiles and on the different worksites.

Six quarries were used, spread out over the desert in eastern Saudi Arabia. The furthest...
needed in order to decide which combination of batches is going to be needed to result in a good moving average of the W50 for each particular constructed area on site. It appeared that due distinction was necessary between the different rock suppliers, different laboratories and the different origin and nature of the rock. A similar procedure was set up for the sand borrow areas and reclamation areas, and use of geotextile.

### Operations

In operational phase, the quality management programme was essentially built around the acceptance of batches of 10,000 tonnes of rock, as described in reference literature. The Rock Manual (1st and 2nd editions) was one of the main references adopted. Acceptance of batches is therefore based on a combination of laboratory tests for the intrinsic properties of the rock (density, water absorption, …) and on site tests for the properties of the individual armour stones location and finally the location where the rock was used. A good stockpile management and traceability from quarry up to installation was implemented and maintained. Based on the W50 of the batches in the quarry a good stockpile management and traceability was

Traceability of materials is obviously required. Near the stockpile area 3 weigh bridges were operational, registering every incoming rock load. An extensive document control allowed tracing each batch of rock, based on the quarry source, supplier, grading, stockpiling and use of geotextile.
(blockiness, shape, ...) and the properties of the rock as a granular material (e.g., grading, see Figure 21).

The challenge was to produce representative sampling for every batch (laboratory and field tests) subject to the inspection process. Since the time required to produce a laboratory result sometimes took more than the time schedule for the job could allow, an early attempt was made to examine if reliable relationships could be established between the fast tests (or tests that produce a nearly immediate result) and the so-called slow tests.

It appeared that due distinction was necessary between the different rock suppliers and the different origin and nature of the rock. An example of such a relationship for a particular type of rock from one area in a certain quarry is given in Figure 21. Based on these kinds of relationships it was possible to establish safe working limits. Careful continued observation of the evolution of these relationships with time was necessary however in order to continue to produce conclusions with confidence.

The design of the rock revetment is based on average values of the main rock parameters characterising the rock in its performance in accordance with the Rock Manual (The use of rock in hydraulic engineering, CIRIA, 2007). It is therefore inherently recognised that these parameters are varying over the revetment with areas of slightly lesser performance balanced by areas with higher performance. As a result, the quality programme had to monitor the average values. However, in a project of this size over such a large area, variances could not be allowed to err on the lower side for too long even though the overall average was respected. This could have resulted in non-acceptable large areas of lower performance. To avoid this, the following approach was developed at quality management level.

A first criterion was established whereby rock properties were only averaged over a limited period of time and were compared to the average design standards. Secondly, an absolute lower limit for judging each individual batch remained in place. Such a combined approach can be found in the Rock Manual for the assessment of the acceptance of a batch parameter based on multiple tests from the same batch, but has been in an innovative way extended to the evaluation of the evolution of the characteristics of the rock (such as W50) in time. Constant production at the lower limit.

Wmin does evidently not yield an average W50 guarantee at the end of the job. A sample chart of the evolution of the W50 of the rock in time can for a particular quarry be found in Figure 23. Such figures could be used to steer the rock suppliers.

It was finally also established that due care was necessary when taking a representative sample. From an analysis of the data of the weigh bridge at the site entrance, together with the results of a rock counting campaign, reliable values for the mean mass Mem for a given batch could be determined. The ratio Mem/M50 was found to be systematically higher than unity for some of the quarries and some of the gradings. It appeared that this could be directly associated with the way in which the rock and the grading were mined.

Some of the gradings at particular quarries were typically mined as a by-product for...
another quarry activity; other gradings were clearly the main purpose of the quarry activity. It appeared to affect to an important extent the way a representative sample was taken in the quarry. An idea of quarry mining activity is given in Figure 24.

Rock degradation
The lifetime of the structure being well specified, a systematic approach was adopted with respect to possible causes of degradation of the rock with time. Probably for the first time, the provisions for reduction of the W50 during the lifetime as detailed in the Rock Manual version 2007 were applied on such a big scale. The design gradings of the job were upgraded in order to cope with the natural degradation of the rock once it is installed on the slopes.

Before installation on the slope, rock typically underwent a considerable amount of manipulations. Mining at the quarry, transport to site, delivery on site, transfer to an island, offloading … may all be sources of successive minor and major breakage of rock. In order to quantify the weight loss caused by an important amount of manipulations, a series of successive drop tests was organised. This allowed having a good idea on the weight loss as a function of the number of manipulations.

CONCLUSIONS
Several challenges presented themselves in the execution of this major project in the Kingdom of Saudi Arabia. First of all, the location is critically complex. The shallow waters of the Manifa Oil Field made it impossible to use common offshore oil drilling platforms and an innovative solution of building oil drilling islands connected by causeways was designed. Shallow waters however demand ships with a limited draught.

Rock was obviously the key player in the success of this project: Although rocks were mainly purchased in the Kingdom of Saudi Arabia at several quarries, up to 600 kilometres inland from the worksite, more was needed. The high demand for rock on the worksite meant that rocks from quarries in Oman were transported to Manifa by sea. This demanded that a practical and well thought-out Quality Management System be set up in time and in close cooperation with all parties involved, i.e., the design and engineering team, the construction team, the QAQC department, and the Client. The initial costs and efforts for setting up a well-functioning QMS are substantial but are easily recovered in the long run during the project.

A large number of physical model tests were conducted and this permitted optimising the rock revetment design to a large extent – which was critical. In an innovative way, a relation between specific rock parameters was identified. This was helpful in early acceptance of the materials before arrival on site.

In addition, a big logistical challenge was to deliver and supply the equipment and the materials such as rocks, aggregates, containers, equipment, fuel, food, and so on, to such a remote working place. A workforce of – at peak periods – more than 3,000 workers from more than 40 different nationalities, had to be sourced in a short notice and had to be accommodated.

All in all, an end product of good quality was the result of the intentional effort, intelligent guidance and skillful execution by the entire workforce – the design and engineering team, construction team, QAQC department and the Client.
ADVERSE PHYSICAL CONDITIONS & THE EXPERIENCED CONTRACTOR
BY DAVID KINLAN

When it comes to planning and executing a major dredging project, innumerable people participate: project engineers, researchers, tender coordinators, safety managers, legal advisors and onwards. When these experts are in the process of designing and planning, one thing stands out: the contract defining each parties’ responsibilities must be as clear and comprehensive as possible and take into account as many risk factors as possible. In that context, the question arises: what are foreseeable conditions and what are not? How are risks to be accounted for? And who is responsible if an unforeseen “adverse physical condition” arises?

David Kinlan’s new book attempts to answer these questions. Kinlan is a freelance Chartered Quantity Surveyor and Queensland Registered Adjudicator with 25 years of experience in the marine infrastructure industry; he worked for many years at Ballast Nedam Dredging as a contracts manager and since then has been an independent consultant. He has worked on many of iconic dredging projects and his observations in this book are based not only on research by on firsthand experiences.

Since encountering an adverse condition that has not been foreseen can have deep financial consequences and impacts on the delivery date of a project, owners (employers) and contractors alike have a vested interest in getting the right balance between risk and reward. In Chapter 1 the factors in the allocation of risk are examined and a number of countries are used as examples. Chapter 2 emphasises the importance of the site investigation and the necessity that all parties understand what circumstances they may encounter before operations start. Although site investigations can and are often conducted by contractors, Kinlan suggests that the employer has a role in specifying local conditions. After all it is the employer’s backyard. The role of the FIDIC contract and the use of various models and need to identify potential issues are also presented. In Chapter 3 the concept of ‘foreseeability’ as generally accepted in various countries (Australia, the UK) is discussed and some practical examples are given.

Chapter 4 is devoted to defining ‘adverse conditions’, explaining contract clauses on the subject and examining the FIDIC regulations and US Army Corps of Engineers acquisition regulations. And Chapter 5 continues with the legal formalities of encountering adverse conditions, such as giving prompt notification to the pertinent authority. Both a notification of the cause of the problem and a suggested cure may be required. Kinlan provides case histories that make this clear and in Chapters 6 and 7 he gives specifics and sample wording about what needs to be included in a claim, including the elements known as CEES (Cause, Effect, Entitlement and Substantiation). Chapter 8 deals with establishing the costs of a claim, which is not as easy as it sounds. And finally Chapter 9 addresses “How to Avoid or Minimise Claims”. This is of course the point. Avoidance is the aim. Dispute Review or Adjudication Boards exist because something has gone wrong.

Still as Kinlan points out in Chapter 10, some things are not knowable even for an experienced contractor and, in that case, it is to everyone’s advantage if contracts are clear and a reasonable and speedy conclusions to claims can be found.

Unforeseeable adverse conditions remain a risk factor and this concise book gives the contractors and their clients a good guideline for managing difficult circumstances.

Available from: Amazon.com or http://tinyurl.com/nyk4k3r
NAVIGATION STRUCTURES: THEIR ROLE WITHIN FLOOD DEFENCE SYSTEMS – RESILIENCE AND PERFORMANCE UNDER OVERLOADING CONDITIONS

BY INCOM WORKING GROUP 137
€ 40.00. 43 pages. Illustrated.

Past examples of flood defence systems indicate that some structural flood control systems may have exacerbated – rather than reduced – the amount of damage from flooding, for example, when levees create a false sense of security that leads to over-development in floodplains.

This InCom Working Group 137 guidance offers suggestions for flood defence systems (FDS) so that inland navigation can develop environmentally friendly approaches in which accepted river training methods, like straightening rivers, are reassessed. For example: Polders are low-lying flood plains enclosed by embankments, separated from the river and are used on the Rhine River to allow for floods to be alleviated. Storing water by means of vegetation, soil, ground and wetlands, all of which are capable of retaining water, should have priority over swift water run-off. The report points out that an efficient flood risk management system needs to be complemented with integrated watershed management, retention zones, restricted developments in flood plains, land use planning, awareness raising, flood resistant construction, drainage and water storage improvement, effective evacuation planning and other measures.

Also, the report accepts the inevitable: Flood defence structures may fail at some point, whether because of degradation, overloading or design error. Recommendations are thus offered for minimum system performance and public safety aspects of navigation systems, integrated with FDS. These ideas may help prevent the loss of human life and limit catastrophic environmental hazards that endanger public health, disrupt lifeline services or destroy critical infrastructure needed for emergency response.

INITIAL ASSESSMENT OF ENVIRONMENTAL EFFECTS OF NAVIGATION AND INFRASTRUCTURE PROJECTS

BY ENVICOM WORKING GROUP 143
€ 50.00. 55 pages. Illustrated.

This EnviCom Working Group 143 report provides guidance for conducting an initial assessment of environmental effects of navigation and infrastructure projects. It is largely a planning-based activity that establishes the project scope and objectives; gathers existing information needed to perform the assessment; develops the conceptual model and reaches a conclusion about the level of risk and whether more assessment is required. Projects related to navigation and infrastructure include but are not limited to maintenance and new work dredging, port and harbour development (e.g., terminals, berthing facilities, barge flotilla areas and turning basins) and construction of waterways, locks, canals, quays, breakwaters, jetties and groins.

The approach focuses on current environmental concerns and is suitable as a first step in assessing potential effects on Special Protected Areas (e.g., European Union Habitats Directive 92/43). It is consistent with European Union Directive 2011/92/EU (dated December 13, 2011) as well as with the risk assessment framework for environmental concerns as developed in the United States (USEPA, 1998; NRC, 2009; ASTM, 2009) and in Germany (BfG, 2004).

The process identifies aspects of navigation and infrastructure projects requiring investigation and highlights the need to investigate possible alternatives early in the project definition phase, aiming for a more holistic approach in which the project needs are harmonised with environmental or ecological concerns (e.g., Working with Nature, ecosystem-based management). This approach serves the needs of risk assessors, decision makers and stakeholders and provides an instrument to understand the strengths, weaknesses and limitations of infrastructure projects with respect to the environment – focusing on avoiding unacceptable impacts and creating win-win situations.

DESIGN OF LOCK GATES FOR SHIP COLLISION

BY INCOM WORKING GROUP 151
€ 50.00. 56 pages. Illustrated.

Current practice for the design of lock gates and approach structures is a relatively standard activity for a suitably experienced engineering company if the design requirements and the load cases are clearly specified. Relevant, robust, reliable and effective software is available to assess the strength (stress, deformation, buckling, damage limitations, and so on) of lock gates and approach structures even if extreme load cases must be considered. The design aspects other than strength, such as opening and closing arrangements, service life, water tightness, sensitivity to vibrations, installation, maintenance, who pays for gate repairs (administration or vessel owner), are the matter of the designer’s specialisation and experience in hydraulic structures.

This InCom Working Group 151 report raises a number of questions such as: What are the design issues to be considered in determining the effects of ship collision on gate structures and approach works? What are the mass and hull form of the vessel – which shapes cause the most severe damage? What is the effect of added hydrodynamic mass? What level of damage is acceptable? What are the recommendations to prevent/minimise collision damage?

All three reports are available at www.pianc.org -> publications
http://www.pianc.org/technicalreportsbrowseall.php
• Email: info@pianc.org
SEMINARS / CONFERENCES / EVENTS

**WEDA DREDGING SUMMIT & EXPO 2014**
**JUNE 15-18, 2014**
**FAIRMONT ROYAL YORK, TORONTO, ONTARIO, CANADA**

In June 2014 the Western Dredging Association and Texas A&M will hold its Annual Dredging Summit & Expo 2014 at the landmark Fairmont Royal York Hotel in Toronto, Canada. With the theme, “Expanding the Dredging World”, delegates will experience another educational technical programme that will promote the exchange of knowledge in fields related to dredging, navigation, marine engineering and construction, as well as the enhancement of the marine environment.

The Conference will begin with a pre-conference tour of Toronto, a city that has a multi-cultural population of people from over 200 countries. An accompanying persons’ programme will also be organised. Upon completion of the technical programme, post-conference visits to a Niagara-on-the-Lake boat tour, Niagara Falls and Cambridge Farmer’s Market will be available. A trip to Stratford that reflects the prosperity and grandeur of Stratford’s Victorian Past are also planned.

For further information contact:
Larry Patella
WEDA Executive Director
• Email: weda@comcast.net
www.westerndredging.org

**ENVIRONMENTAL ASPECTS OF DREDGING**
**TWO-DAY TRAINING COURSE**
**JUNE 18-19 2014**
**HOWBERY PARK, WALLINGFORD, OXFORDSHIRE, UK**

This two-day training course – organised by HR Wallingford, the Central Dredging Association (CEDA) and the International Association of Dredging Companies (IADC) – covers the scope and importance of the environmental aspects of dredging projects, the management of dredged material and the typical legislative conditions and controls imposed by international conventions and regional agencies. In addition to presentations of the subjects, participants will be challenged in case studies to apply the principals discussed.

The course, conducted by Nick Bray and Frans Uelman, provides an overview of the environmental aspects of dredging, the latest technology and equipment that apply to dredging and the management of dredged material. It includes presentations and workshops.

Day 1 - Wednesday 18 June
Introduction and frameworks
Projects and effects

Day 2 - Thursday 19 June
Dredged material management
Impact and investigations
Workshop on an environmental project
Planning
Philosophies and the future

Who Should Attend?
The training course is aimed at: consultants and contractors in dredging related industries; professionals from different governmental bodies, whether municipalities, district water boards, ports and harbour authorities or central government.

Course Information
Cost: £550 (+VAT) per delegate.
Hotel rooms at the Springs Hotel in North Stoke can be booked at a discounted rate from between 17 to 19 June. Book directly and mention code ‘HRWA 170614’. The course fees include dinner on the evening of Wednesday 18 June at The Springs Hotel.

To register:
http://tinyurl.com/qc9ya8w
the registration page of HR Wallingford (click on ‘Book now’).

For further information:
http://tinyurl.com/qd96g8k

**4TH INTERNATIONAL SYMPOSIUM ON SEDIMENT MANAGEMENT**
**SEPTEMBER 17-19, 2014**
**FERRARA, ITALY**

The 4th International Symposium on Sediment Management (I2SM) will be held in Ferrara, Italy, September 17-19, 2014, during the RemTech Expo. It is being organised by Ferrara Fiere Congressi, Politecnico di Milano - Department of Civil and Environmental Engineering - Environmental Section and the École des Mines de Douai. RemTech Expo 2014 is the most specialised event in Italy dedicated to remediation technologies and territory requalification. Companies, public administrations, associations, institutions, professionals, university, industry, oil sector, real-estate and planning sector. The aim of I2SM is to get together academics, professional figures and public agencies involved in sediment issues to discuss the state-of-the-art.

The conference will begin with a plenary session (morning of September 17) with invited speakers; the conference will continue in 2/3 parallel sessions on the different topics. There will be also two special sessions, one of which on the management of sediments in
IADC SEMINAR ON DREDGING & RECLAMATION
JUNE 23-27, 2014
DELFT, THE NETHERLANDS

In co-operation with UNESCO-IHE, Delft, the IADC is presenting its renowned seminar on dredging and reclamation. Aimed at (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organizations who have to execute dredging projects, the IADC has organised the Seminar at numerous venues often in co-operation with local technical universities. Since 1993 this week-long Seminar has been successfully presented in Delft, Singapore, Dubai, Buenos Aires, Abu Dhabi, Bahrain and Brazil. As is appropriate to a dynamic industry, the Seminar programme is continually updated. In addition to basic dredging methods, new equipment and state-of-the-art techniques are explained.

To optimise the chances of the successful completion of a project, contracting parties should, from the start, fully understand the requirements of a dredging project. This five-day course strives to provide an understanding through lectures by experts in the field and workshops, partly conducted on-site in order to give the “students” hands-on experience.

Highlights of the programme
Day 1: Why Dredging?
   The Need for Dredging/Project Phasing
Day 2: What is Dredging?
   Dredging Equipment/Survey Systems (includes a site visit)
Day 3: Production of various types of dredgers
   (includes a visit to a dredging yard)
Day 4: Preparation of a Dredging Contract, Reclamation, Tender, Cost Pricing
Day 5: Contracts

An important feature of the Seminars is a site visit to a dredging project being executed in the given geographical area. This gives the participants the opportunity to see dredging equipment in action and to gain a better feeling of the magnitude of a dredging operation.

Each participant receives a set of comprehensive proceedings with an extensive reference list of relevant literature and, at the end of the week, a Certificate of Achievement in recognition of the completion of the coursework. Please note that full attendance is required for obtaining the Certificate of Achievement.

Costs
The fee for the week-long seminar is €2,250.- (inclusive VAT). The fee includes all tuition, seminar proceedings, workshops and a special participants’ dinner, but excludes travel costs and accommodations. Assistance with finding hotel accommodation can be given.

Other Upcoming IADC Seminars in 2014
• October 27 to October 31, Singapore (in co-operation with the National University of Singapore).

For further information contact:
Jurgen Dhollander, International Association of Dredging Companies
Tel: +31 70 352 3334
• Email: dhollander@iadc-dredging.com
http://tinyurl.com/q7fjr4q

22ND INTERNATIONAL FEDERATION OF HYDROGRAPHIC SOCIETIES’ CONFERENCE AND EXHIBITION
OCTOBER 28-30 2014
ABERDEEN, SCOTLAND

With its theme, Energy & Enterprise, the conference attracts a wide international audience drawn from all sectors of the hydrographic and related professions.

In addition to keynote addresses and paper presentations, the conference features an introductory Student Presentation Session for which there will be a prize of £500 for the best adjudged contribution. Other agenda items include a 60-plus stand exhibition, workshops, local technical visits and an IHO-led session and stakeholder forum.

For further general information:
• Email: hydro14@ths.org.uk
www.hydro14.org.uk

dams and the other on policy and practice in the remediation of contaminated sediments in different countries. About 150 contributions from 38 different countries have been accepted for oral presentation or poster display.

The official language of I2SM 2014 is English. Simultaneous translation (English to Italian) will be available for some sessions. On the day after the end of the Symposium, Saturday, September 20, 2014, technical visits to the Venice area are being scheduled, with reference to sediment management issues (treatment and confinement) in the Lagoon. Sediment treatment plants and sediment confinement areas are to be visited by coach and by boat, respectively.

For general information about the Symposium and registration contact:
• Email: i2sm@remtechexpo.com

For enquiries about the scientific programme contact:
• Email: i2smscientific@remtechexpo.com
CALL FOR PAPERS

IAPH HAMBURG 2015
29TH WORLD PORTS CONFERENCE
JUNE 1-5, 2015
CONGRESS CENTER HAMBURG (CCH), GERMANY

The 29th IAPH World Ports Conference will take place under the theme of “smartPORT Hamburg”. The specialised conference that caters to an international audience will deal with the economic, ecological and political challenges ports are facing in today’s world of economic and climate change.

As the host of the conference the Port of Hamburg will demonstrate how changing requirements can be met and the measures, including IT-supported projects, that can be taken to achieve higher cost effectiveness, improve safety and security, and generate a higher level of sustainability. The following subjects are being addressed:

1. smartPORT logistics – challenges and possible solutions
   Technical innovations, land restructuring, expansion of the transport route network and modern communication paths combined with high data transparency are just some of the measures the Hamburg Port Authority (HPA) is implementing to create the basis for economic growth in the Port of Hamburg.

2. smartPORT energy – challenges and possible solutions
   To ensure a win-win scenario for both business and the environment, innovative mobility concepts, renewable energy sources and the interlinking of energy-generating plants and consumer plants to promote the efficient use of resources are at the forefront of the HPA’s approach. Innovative and viable energy supply strategies which benefit business as well as the environment play an increasingly important role in the competitiveness of a port.

3. Law and global trade – trends and challenges
   Contractual choice of law and jurisdiction: Currently most national legal systems play a subordinate role in international contractual relations even if the parties are deeply anchored in traditional maritime clusters with long-standing legal traditions and institutions. What are the advantages of global technical standardisation? Be it LNG supply, shore power, IT processes or the measuring of emissions – ports can benefit from standardisation in many aspects. Liability in ports: Is the international maritime convention system sufficient to protect ports in the event of shipping accidents and other maritime incidents within ports? Do the currently ratified conventions and the liability sums contained therein provide sufficient coverage?

4. Port financing and pricing in different countries – between theory and practice
   Port financing is an issue in public-policy discussions: What stakeholders are involved in port financing? What roles do private business and politics play? When is action required at a regional and/ or national level or at an international level required? What long-term and what project-related financing models have proven successful?

5. Cruise Shipping – Challenges and possible solutions
   In the past years the cruise industry has seen phenomenal growth, and for many ports the cruise business has become an important economic factor. However, rising passenger numbers and ever larger cruise ships have delivered fresh challenges to ports and cities. As a result, ports are increasingly investing in cruise facilities.

Requirements:
You are active in the port industry, logistics or industrial sector, or work with a port authority, in international politics or science and you would like to hold a lecture of interest (in English) at the conference working sessions on one of the following topics.

Your application:
Deadline: June 15, 2014. Please send your application (max. 4 MB) by e-mail to papers@iaph2015.org. It should contain a lecture abstract (max. 250 words) as well as detailed information (CV) about your person (incl. photograph).

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21ST WORLD DREDGING CONGRESS & EXHIBITION (WODCON XXI)
JUNE 13-17, 2016
HYATT REGENCY HOTEL, MIAMI, FLORIDA, USA

WEDA is happy to announce that the 21st World Dredging Congress & Exhibition (WODCON XXI) will be held at the Hyatt Regency Hotel in Miami, Florida, USA from June 13-17, 2016.

First Call for Papers
Interested authors are invited to submit one page abstracts (less than 400 words). The abstracts must contain a descriptive title, author(s) contact information (name, company, address, phone, email).

Deadline for abstracts is September 15, 2015.
Abstracts are to be emailed to the chair of the respective regions (CEDA, EADA, & WEDA). The Technical Papers Committee will review all abstracts and notify authors of acceptance and provide final manuscript instructions for production of the WODCON proceedings on CD’s. Submission and acceptance of an abstract means that one or more of the authors must register, attend the WODCON XXI, and give the presentation in English. One full registration with payment must be made when the draft manuscript is submitted.
Innovations in Dredging Topics
Abstracts presenting both practical applications as well as applied research are encouraged. Topics may include but are not limited to: Improving Dredge Safety; Innovative Equipment and Techniques; Dredging Research & Education; Budgeting & Cost Estimating; New Dredging Equipment; Dredging for Flood Control; Geotechnical Aspects of Dredging; Navigation Channel Design; Treatment of Dredged Sediments; Land Reclamation; Surveying & Mapping; Dredging for Beach Nourishment; Environmental Dredging & Capping; Deep Sea Mining/Dredging; and Beneficial Reuse of Dredged Sediments

Important Deadlines
• Abstracts Deadline September 15, 2015
• Notification of Acceptance /Author Instructions October 15, 2015
• Draft Manuscripts January 15, 2016
• Reviewer Comments to Authors March 1, 2016
• Final Manuscripts April 15, 2016

World Dredging Congresses (WODCONs) are organised once every three years by WODA, the World Organisation of Dredging Associations. First organised in 1967 in New York and held throughout the world since, this series of congresses has become the most important event for dredging professionals worldwide. WODCONs, the only worldwide events dedicated exclusively to dredging and maritime construction, provide a unique platform for researchers and practitioners from industry, academia and governments to meet and discuss dredging.

Registration will be available at the beginning of 2016. Registration fees, technical visits & social events and additional information will be posted on the website (www.wodcon2016.org) in early 2016.

For further information:
• Email: Western Dredging Association:
  info@westerndredging.org

ICE COASTAL MANAGEMENT CONFERENCE
SEPTEMBER 7-9, 2015
THE NETHERLANDS

The Institution of Civil Engineers (ICE) is a registered charity that strives to promote and progress civil engineering. Founded in 1818 and granted royal charter in 1828, its aim is to “foster and promote the art and science of civil engineering”. Now the ICE represents nearly 80,000 members worldwide. ICE Conferences offer robust forums for debate; attracting senior level speakers and delegates and unbeatable opportunities to network, share knowledge and discuss common challenges and solutions.

This eighth event in the ICE Coastal Management conference series be held in September 2015 in the Netherlands. The conference will take place in the week commencing 7 September, and will be held over 2 days, plus a 1 day technical visit. ICE’s Coastal Management conferences are recognised for focus on current issues, research and practical application. They are a notable forum for forthright discussion, highlighting advances and solutions as well as identifying key areas of debate.

The conference is seeking papers on top international coastal projects that offer practical learning, innovative and integrated solutions. To change mind-sets and encourage new ways of understanding and managing our coasts. Papers are welcome on any topics that capture these themes, and in particular;

• Changing society, changing coast
• Integrating coastal science engineering and planning
• Coastal development and adaptation
• Our ability to change the coast
• Emerging requirements challenges and solutions
• Learning from the past to apply to the future
• Understanding change and dealing with uncertainty

Abstracts can be submitted from 31 March to 31 July 2014. An abstract must be no more than 2000 words and written in English. It should clearly and concisely outline the material being proposed for presentation. Identify the subject area and the author’s perspective, define if it is a case study or report of new research, and whether it contains information about unusual methods or new techniques. Confirm what the conclusions of the paper will be, highlighting their importance. Submissions will be reviewed by the Organising Committee, and authors notified in September 2014 whether their abstract has been selected for the conference. Successful authors must then submit a draft paper to be reviewed by the Technical Committee.

Registration for the conference will open in due course.

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Articles should be original and should not have appeared in other magazines or publications.

An emphasis is placed on articles which highlight innovative techniques and applications.

In the case of articles that have previously appeared in conference proceedings, permission to reprint in
will be requested by the editor.

As emphasising “maritime solutions for a changing world”. It covers the fields of civil, hydraulic
social and/or environmental drivers behind the dredging project by the editor.

Digital photographs should be of the highest resolution.

Original photographs should be submitted, as these provide the best quality.

Students and young professionals are encouraged to submit articles based on their research.

An exception is made for the proceedings of conferences which have a limited reading public.

For the digital version, authors are requested to provide extra material such as additional

If underlayer installed on heavy duty geotextile (see page 24).

An article is subject to approval by the EAC and no article will be published without approval

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