MARITIME SOLUTIONS FOR A CHANGING WORLD

#166 - SPRING 2022

TERRA ET AQUA

50 YEARS

CHANGE IS INEVITABLE, EVOLUTION IS OPTIONAL

This special anniversary edition of *Terra et Aqua* marks 50 years of IADC's technical and scientific journal. With an impressive 166 editions since its inception, it has evolved over the decades not only in its appearance but also in its content. One thing that has remained the same however, is its mission. To quote the journal's first editor, Nic Oosterbaan, who wrote in the very first edition, "*Terra* is a journal devoted to the development of ports and waterways and the development of hydraulic engineering in general. Its aims are to disseminate information useful to the civil servant, politician or financial expert who is involved in local problems and bears responsibility for the decisions which have to be made."

Since those words were written, the dredging industry has changed beyond measure. The projects undertaken today, not only in magnitude but also in ambition, are staggering. In turn, such projects have generated incredible innovations in the development of environmentally sound technologies as well as larger, more economically viable vessels. The importance of sustainable dredging practices is a core value held by our members and the industry's attention to sustainability is at the forefront in making the world more climate-resilient. It has also opened the door to new markets, with some dredging companies investing heavily in special equipment for offshore wind projects; a market that is growing rapidly in the transition towards renewable energy – one of the largest global challenges presently facing society.

> ***Terra*'s mission is therefore still as relevant and compelling today as it was 50 years ago.**

The industry continues to think big and is accomplishing feats that technically were impossible when *Terra*'s first edition was published. *Terra*'s mission is therefore still as relevant and compelling today as it was 50 years ago: To disseminate useful information and capture the imagination of those engaged in dredging and maritime construction.

To make clear to officials and the public the economic and technological advantages that the dredging contractor has to offer and the contribution of dredging to the ongoing social and economic prosperity of our world.

Five decades ago, the emphasis was on protecting the land against erosion and flooding. Something Kees d'Angemond talks about in the article on the role of academia in the dredging industry, along with fellow professor Stefan Aarninkhof. Kees' career began in the field of research and his involvement in the Delta Plan, which was established in response to the great floods of 1953, proved an invaluable learning base.

So while change is inevitable, evolution however, is optional. This special edition marks another evolution in the design of the journal with changes to increase the ease and enjoyment for our readers. Someone who saw many evolutions of *Terra* during her 25 years as editor is Marsha Cohen, who shares her story with us on page 50. Also in this jubilee issue, we review the court cases that have had an impact on the industry standards over the past 50 years and explore the progress of health and safety in the dredging industry. And in addition to the 2021 winner of IADC's Young Author Award, whose article you can read on page 14, we caught up some past winners to find out what they're up to now.

Frank Verhoeven, President, IADC

SHAPING THE ENGINEERS OF TOMORROW

During his distinguished career as professor of Coastal Engineering at Delft University of Technology (TU Delft), Kees d'Angremond served as head of Hydraulic and Offshore Engineering, chair of the department of Hydraulic and Geotechnical Engineering, and dean of the faculty of Civil Engineering from 1989 to 2001. Now professor emeritus, he still works as an advisor and independent consultant. We invited Kees to a conversation with Stefan Aarninkhof, professor of Coastal Engineering and chair of the department of Hydraulic Engineering at TU Delft, to talk about their careers in the dredging industry and the role of academia in the industry today.

The path into academia

Kees graduated as a civil engineer from Delft University of Technology in 1963. He worked in the lab of Delft Hydraulics (now Deltares) for two years before being assigned to a project in India, even though as he admits he was far too junior to do the job. Upon his return, he become head of Delft Hydraulics' wind-wave flume where all the breakwaters are investigated.

Around 1970, Eco Bijker, who was the deputy head of the Delft Hydraulics' laboratory, was appointed as the first professor in coastal engineering at Delft University of Technology (TU Delft). Eco was also lecturer at the IHE Delft Institute for Water Education (IHE Delft) at the international course in Hydraulic Engineering for engineers from developing countries. However, there were people from all over the world – from Australia, the USA, Canada, India, Latin America and Africa. Eco had no extra time and so he asked Kees to take over lectures at IHE Delft on breakwater design. There Kees met students from all over the world and expanded his network immensely.

In those early days, the way the Netherlands facilitated these students was insufficient. Adequate housing was not provided and most students didn't have extra money for what was already at that time expensive student rooms, or they were living in less than ideal conditions, for example, five students to one room. Since Kees knew that the conditions were so poor, once a year he invited the whole class of 30 students to dinner at his home and his wife mobilised their children to help with all the cooking. These gatherings allowed him to experience the cultural differences between the many students, knowledge that would serve him well throughout his career. Many of his professional contacts in his working life were actually once his students and also became friends for life.

Kees benefitted tremendously from these early student contacts. In later years, they would meet each other at various conferences such as PIANC. Within the COPEDEC (Conference on Coastal and Port Engineering in Developing Countries) society, there were numerous students who joined those yearly

gatherings. Kees fondly recalls, "Often at a conference, people would come up to me and say 'Kees, do you remember I played hockey in your garden with your kids and that we almost broke a window?'"

Key projects: The Delta Plan

Indirectly Kees also benefitted from early events in the 20th century. The IJssel Lake project with the closure of the Zuiderzee (Southern Sea) and the development of different polders, the repair of the dykes in Walcheren after the destruction in the Second World War, and then the devastating floods of 1953 after which everything came together in the form of the Delta Plan. His professional generation had the good fortune that they grew up with the Delta project, which was really designed as one project; starting with the smallest items and ending up with the closure of the Eastern Schelt. "That was the way it was designed," Kees explains. "The engineers involved in the design wanted to learn during the construction and a great deal of experience was gained as a result.

The IJssel Lake project initiated the founding of Delft Hydraulics in 1927 and facilitated the design of the Afsluitdijk – a major dam and causeway in the Netherlands that closed off the Zuiderzee (a shallow bay of the North Sea), with all the tidal consequences. At the time, it was a major enabler for hydraulic research and formed a strong network for cooperation. As was the Netherlands Centre for Coastal Research (NCK), which over the last 30 years has been a key network for scientific collaboration between different universities, Deltares and the government. Stefan explains, "This is in fact where research on the interaction between hydraulics, morphology and ecology was born with a few pioneers in the field who started developing new research lines. It's actually where the basis for Building with the Nature comes from. Together of course with the many initiatives taken by Ronald Waterman, who promoted the implementation of Building with Nature solutions on real-world projects in The Netherlands as well many other locations worldwide."

> There was a sense of urgency and cooperation was key to making the Eastern Scheldt Storm Surge Barrier a success.

FIGURE 1

Closing a gate of the Eastern Scheldt Storm Surge Barrier.

It's true to say Kees found it a marvellous time in his career. "It was a period when all the barriers and the borders between contractors, government and consultants completely disappeared. There was a sense of urgency and cooperation was key to making the Eastern Scheldt Storm Surge Barrier a success." It's a point that Stefan shares regards the major challenge the world is facing today. "We need that same spirit and sense of urgency when it comes to climate adaptation," he concurs. "Only together can we face this challenge and deal with the future risks."

Introduction into the dredging industry

After the flood disaster in 1953, the Dutch government set about implementing the Delta Plan to safeguard the province of Zeeland from another flood. At that time, ir. P.Ph. Jansen, the director of the Delta Services at the Department of Waterways and Public Works (*Rijkswaterstaat*), was afraid that the capacity of the dredgers was not sufficient to cope with the volumes involved with the closure of the Eastern Scheldt. Because at that time, it was still the plan to close the Eastern Scheldt completely.

Jansen realised that a production of 1,000 m^3 of sand per hour was a hell of a quantity for a dredger. However, he was of the opinion that the capacity was insufficient to handle the job at hand and he urged the larger companies to take part in a joint research project. This research had to be done by an independent institute and the task came to Delft Hydraulics. Kees was selected to negotiate the project management and Jansen selected companies that had research capacity and which would really contribute to the research. Jansen wanted only those companies that could incorporate the results of research in their own companies. In the end, there were six companies of which IHC was one. At a certain point, however, the dredging companies rejected IHC as part of this research consortium. Contractors had invested heavily in the research that could bring them a competitive advantage and they wanted to keep that knowledge in the Netherlands, not export it to foreign contractors as IHC was doing. *Rijkswaterstaat*, one of the paying partners, along with the other partners then agreed to 100% secrecy concerning the research results. And there was another rule – that it should be only pre-competitive research.

It was a tremendous pleasure for Kees to work not only as a project manager on behalf of Delft Hydraulics, but also as secretary of the steering committee that consisted of all the board members of the large dredging companies. He facilitated the negotiations between the group of contractors and Delta Hydraulics and in this way, completely from the research side, Kees entered the world of dredging.

A couple of years after the India project, a second project in Burma came along and Delft Hydraulics asked him again. For a second time Kees agreed. Every two months, he would leave his family in Rangoon and travel from Burma back to Delft for a week to hold a meeting with the technical management of the dredging companies to keep the research project running. In that period, Age Hoekstra, the successor to Eco Bijker at Delft Hydraulics, had joined Adriaan Volker Dredging company and asked Kees to come work for Volker. At a certain moment, Age visited Kees in Rangoon to persuade him and impressed by this enthusiasm, Kees signed a contract with Adriaan Volker. And so Kees' career in the dredging industry began.

Career similarities

Stefan's introduction to the dredging industry was somewhat similar to Kees. In fact, there are many similarities in how both their careers evolved. Stefan had completed a PhD thesis at Delft University of Technology on the video imaging of coastal zones and had been at Delft Hydraulics for 9 years when he became involved in a large-scale research project for the industry-sponsored foundation for dredging-related strategic research, Stichting Speurwerk Baggertechniek (SSB). Then in 2005, the dredging industry was looking for a project manager to lead a series of large-scale field experiments on dredging-induced turbidity, as part of the SSB-TASS programme. People, such as Cees van Rhee, Wim Rosenbrand and Wouter Dirks were heavily involved in this research. At the time, the generation of dredging plumes was one of the major uncertainties on dredging projects, as an increase in turbidity levels is associated with increased light attenuation in the water column and possible smothering of sensitive ecosystems.

To avoid negative impacts, dredging projects often came with strong environmental restrictions, however the scientific basis for these restrictions was not always very strong. First because dredging-induced turbidity plumes were hard to predict and second because limited understanding of the actual impact to sensitive ecosystems at the time. The TASS programme delivered a series of large-scale field experiments around dredging activities in Bremerhafen (Germany), Rotterdam (The Netherlands) and in Western Australia. Moreover, a model was developed (together with HR Wallingford, UK) to enable improved assessment of dredging-induced turbidity both near the dredging works as well as the far-field plume dispersion. The programme had major impact in the field, not least because all outcomes were shared with the dredging, research and consultant community via conferences, training courses and in literature.

> We need that same spirit and sense of urgency when it comes to climate adaptation.

FIGURE 2

Researchers from various universities and knowledge institutes have been closely following the development of the Sand Motor, off the coast near The Hague, since its construction in 2011.

After a year in this role of project manager, Stefan made the move to Boskalis to join their in-house engineering department Hydronamic. One of the major projects he was involved in was the Khalifa Port and Coastal Zone project (UAE), a large-scale port development scheme in a sensitive environment at the Abu Dhabi coastline. The work involved, amongst others, the set-up of an extensive 24/7 environmental monitoring programme and a system for operational plume predictions for different phases of the construction works. An excellent example of a project where all state-of-the-art knowledge on turbidity monitoring, model simulations and adaptive planning came together.

Along with these valuable lessons from practice, the EcoShape Building with Nature programme was established as a strategic sector initiative to develop and implement novel approaches for marine infrastructure

design, based on the principles of Building with Nature. "This development was very close to my heart," explains Stefan, "as it foresaw truly multidisciplinary cooperation based on full-scale pilot experiments in the field. I was therefore very keen to be involved." An opportunity that later transpired when Stefan was first appointed as manager of the case Holland Coast (centred on the famous Sand Motor experiment) and afterwards as programme manager of the overall programme.

Knowledge of the industry

Starting in the industry, Kees had 12 years' experience in hydraulic research and research management but no real practical hands-on experience in the dredging world. He knew the science behind the practice but nothing about the reality of dredging. Therefore, he started in the engineering department of Adriaan Volker. The company that still exists today as AVECO (Adriaan Volker Engineering Consultants).

The first project Kees worked on was a study on an issue he found very alarming – the pollution of dredged material. NGOs were claiming that dredgers were spoiling the environment. Whereas the industry said, "We are not spoiling the environment, we're just handling the material that is contaminated by others." The image of the dredging industry was not very positive in those early days. "There was even a visual hindrance in that all the dredgers of the time were grey," Kees explains. "And there were two shades – Volker grey and Boskalis grey. We used to joke that when you walked through Sliedrecht you could tell who worked for which company purely by the colour of the shed in their back garden."

It is fair to say the reason for dredging's less than positive image was due to lack of knowledge – not knowing what dredging was really about and what the real impact was on the environment. Stefan agrees it played a major role; "The industry didn't know, the public didn't know and the government didn't know; environmental limits were simply copied from one site to another. We simply didn't have better knowledge back then. This has certainly changed over time as a result of the Foundation for Research on Dredging Technique (*Stichting Speurwerk Baggertechniek* (SSB)), a strategic research platform of the Dutch dredging industry." It is about understanding what was happening. "In those days," Kees elaborates, "when a budget estimate for works had to be made, the project engineer would simply take a clay sample and would chew on it and say, well this is difficult clay. And on that basis the price was determined!"

> You're not simply preparing students for scientific work. You're preparing engineers for a life in the real world.

FIGURE 3

Stefan Aarninkhof (left) and Kees d'Angremond.

According to Stefan, the SSB research was also an enabler for scale increase. The big projects in Singapore and Hong Kong would never have been possible without the work of SSB. It goes even further back. All the ports in the Middle East where rock dredging was taking place would also not have been possible without the fundamental research on rock cutting and cutter suction dredgers. In the beginning, dredging companies were very secretive about sharing their research and developments in vessel design and production innovations. This too has changed. Companies realised that closing themselves off from the rest of the world was not wise. If you want to stay a frontrunner in competition, you have to develop your knowledge and technological standards. The moment you stop developing, your competitors will take over.

Early research days

In the mid-70s, Kees was involved in all kinds of research projects. Volker worked with the municipality of Rotterdam carrying out research around the city. Many areas had been reclaimed with contaminated dredged material from the port of Rotterdam and were in fact polluted. Together with the port of Rotterdam, Volker did a joint study with the United States Corps of Engineers (USACE) to find a solution to the problem. First, they had to establish how dangerous the chemicals attached to the silt particles were. Did they enter into foods that were grown in urban gardens in the reclaimed areas? And how thick would you need to cover the polluted soil to eliminate those dangers. Through that project, Kees came to know many colleagues in the US and the Corps. The fact that he is still a member of ASCE-COPRI indicates the importance of that time in his career. Looking at the dredging process today in the port of Rotterdam, it no longer has to do with contaminated sediments. Due to all kind of measures, the water quality has improved tremendously and all the sediment that settles in our estuaries is no longer polluted, which is a great victory.

As already mentioned, research on specific equipment was necessary. There was no specialised equipment at that time, it had to be invented and developed especially concerning the reduction of turbidity. An example is the development of a diffuser to reduce the turbidity when discharging material in a deep pit. For the same purpose, many companies changed the design of the overflow of the trailing suction hopper dredgers so that the turbidity remained close to the bottom.

The attention was not restricted to the disposal of material, it was also attempted to reduce the spill of material at the actual digging location like the cutter of a CSD, the bucket of a BLD and the draghead of a TSHD. The research of the dredging industry together with supply chain partners and research institutes has resulted in several very effective measures such as the green valve system for trailing suction hoppers, which reduces turbidity caused by overflow during the dredging process. The knowledge collected by environmental monitoring was evident in decisions on dredging around coral reefs. And the development of predictive models and simulation tools contributed to knowledge-based decisions.

A more formal approach to training

30 years ago, dredging was considered perhaps more an art than a science. Later came the realisation that a more formal approach to training than practical experience was desirable. When Kees was appointed professor at Delft University of Technology, the only education in the field of dredging was in the faculty of mechanical engineering and core of that course was the construction of dredging equipment. It was not aimed at working with dredgers. Whilst some of the professors tried to introduce the subject, there was hardly a civil engineering student who studied dredging.

Kees was not happy with what the students were taught. When he took over the lectures of Eco Bijker on maintenance of coastlines, Kees saw his chance and started lecturing on the role of dredging. He taught students the theoretical background, how the production process works, as well as how you cost estimate a project and all the factors involved.

"I taught students how a trailing suction hopper dredger works and what impacts the dredging process. I explained how to calculate the cost of a project taking into account the production cycle time, mobilisation, installation and dismantling costs, etc. And most important, factoring in the risk as there are many uncertainties that come into play. What is the risk for the contractor and for the employer? And last but not least, calculating the profit margin. All of which gives you the price to the client." In a later stage, Kees got support from the industry through the *Dutch Association of Dredging Contractors* that made a dedicated part-time teaching role possible.

"We give exactly that same class today," says Stefan. "It's the starting point that provides students with the basic scenario, whereby you can only optimise based on the requirement to maximise production rates. And then we build out with additional requirements, including environmental requirements. If one of the requirements is to take care of a coral reef, located two kilometres from the site, then you have a simple model to estimate how the suspended sediment concentration decreases with increasing distance from the dredging activities. Then additional requirements come into play such as limited emissions allowed, which becomes increasingly important. There are, of course also functional requirements. If you have both good and poor quality sediment, but you need good quality sediment at the location where you're going to construct a port for instance, this also needs to be considered." It's interesting to hear how both professors taught the same class. Today, students receive lectures on both dredging equipment, taught by the Mechanical Engineering department headed up by Cees van Rhee, as well as the more civil engineering elements that Stefan teaches together with Mark van Koningsveld, as part of the Hydraulic Engineering track at the faculty of Civil Engineering and Geosciences.

Teaching the commercial aspects of the industry

According to Kees, it is a responsibility of the university that students are taught the commercial aspects of the dredging industry. He explains, "You're not simply preparing students for scientific work. You're preparing engineers for a life in the real world. Whether it's working for the government, a company, as a contractor or a consultant, students have to realise it's part of their education. You have to realise that everything costs money otherwise you cannot be a proper engineer."

In broadening the conversation, Stefan explains, "This is one element where we want to educate students. At the end of the day, you want to apply your technical knowledge and expertise in a real-world context. And the commercial consideration is one element of that context. You want to employ an engineer who knows how to apply their knowledge to the benefit of something bigger. The environmental aspect is another element. As an engineer, you also need to be able to communicate to an ecologist for instance and to be aware of the impact of dredging activities to the outside world. You don't need to become an ecologist, but you need to be able to interface with people in this and other specialties."

> You have to teach students how to look at a project from so many different perspectives and the local culture is one of them.

Transition from theoretical to practical knowledge

Students today are extremely enthusiastic when they have the opportunity to deploy their technological expertise to the benefit of real-world projects; designing and building interventions to the benefit of society, protecting against flooding for example, and creating opportunities for nature. That's a big driver nowadays according to Stefan. "Off course, there are still those who really go for the big equipment and big projects but the majority of students have a much more altruistic attitude."

From that perspective, the dredging industry has really transformed, starting from the strong core that it has. At the end of the day, dredging companies have successfully built all kinds of complex projects at challenging locations across the world. "When dredgers come in," continues Stefan, "it generally means that there is nothing there. Only a beach and an ocean and there you go. That's still the case, but at the same time, the industry wants to work in a responsible way. That's where high-end dredging companies nowadays are making a difference. And that's something students in particular want to be associated with." Students get the whole story by being shown the entire picture of what the dredging industry looks like and entails. "These links between the industry and all universities, not only Delft University of Technology, are so very important," says Stefan. According to Kees, it goes deep into the philosophy about the role of a university. "You want to employ an engineer who has had an academic education,

FIGURE 4

Kees d'Angremond (front row centre) and Stefan Aarninkhof (directly above) on a field study trip to Chek Lap Kok, Hong Kong (1994).

but you still expect that they also have the practical experience and know how to carry out the job at hand."

A good engineer has an international orientation

Engineers today have to have a broad skill set in that they have to deal with the ecological considerations involved in a project, as well as legal, social and sustainability issues. This is one point Kees is very adamant about. "You have to teach students how to look at a challenge or a project from so many

Field trips give students an invaluable insight into what's expected of them in the industry.

capabilities to keep costs in hand and make a broad, integral evaluation of project effects. The challenge is how to educate such engineers. While universities seemed to have a bias towards the valuation of academic skills, that situation is changing, as Stefan explains: "Over the last few years, the appreciation of engineering and design has been growing again at university. Engineering and designs skills are increasingly recognised as key competences of engineers, along with scientific skills and personal leadership to solve complex problems across the world." In line with this, universities and researchers are no longer evaluated solely on the basis of an indicator such as the number of publications, but on a broader range of qualities and impacts – either in fundamental science, or benefits for society.

The university aims to bring those people together and create an open atmosphere where people from industry, from the outside world, can collaborate. Stefan elaborates, "As an educational institute, Delft University of Technology can say something is important but it's much more convincing if the industry or the government says it's the right way forward and gives it an agenda or a perspective to which the university can contribute."

different perspectives and the local culture is one of them. I think you can compare engineers to doctors in the same way they have to have a completely applied medical education, which is aimed at not only advancing science, but also being able to do your job in the correct manner with patients from different cultures, with different habits and attitudes."

From Stefan's perspective, it's not only dredging engineers that need this orientation, but engineers in general. "If you look at people in the Ministry of Infrastructure and Water Management for instance they also have a diversified background and not only an engineering one. The way Delft University of Technology teaches students makes it distinctive. They are not only focussed on educating engineers and helping them to understand the basics and all the theory, but at the same time students are being taught how to effectively operate in this broader community and to be aware of the impacts of engineering interventions."

In today's landscape, Kees sees this as a major challenge for universities. "On the one hand civil engineers need in depth theoretical knowledge and on the other a wide variety of

Is practical experience an essential element in academia?

For Stefan, it's a question of balance. "Of course, it has its advantages as you bring hands-on expertise, which comes from having knowledge and experience in the industry. But scientists are also needed. And what about a feeling for policy and good people managers, they are also indispensable. It's all about having a balance. That's something that should be valued." Universities are made up of a group of extremely bright individuals, each with unique skills and talents. Academics by nature are quite competitive, as they need to develop their research profile and win projects and research grants. "However, as far as teamwork goes, they can probably learn from dredging industry, where teamwork is common practice and a prerequisite for successful projects."

"That's something we're trying to develop again, more multidisciplinary projects," Stefan adds. "It is not only important to have all the disciplines on board but they have to collaborate, which is of utmost importance. You need the right people, both in terms of disciplines, but also attitudes." It's something Stefan's department is working on and he takes responsibility of. "It comes down to leadership. Where do you see yourself individually or as a group? How can you develop initiatives with the industry and make it happen? That's the long-term agenda, and for the industry I think that it's important."

The importance of field studies

One of the benefits of Stefan's role is seeing students get inspired. For instance, during study tours to major projects abroad. The student association for Hydraulic Engineering (*Waterbouwdispuut*) is very active in organising such trips and in 2019 travelled to Brazil. Back in 1994, as a student, Stefan was personally involved in the organisation of the tour to Taiwan, Hong Kong and China, together with Tim Helbo, Ronald Roosjen and Janet Kroes. One of the highlights was the visit to the famous Chek Lap Kok airport that was under construction (Figure 4). Kees joined this tour as a supervisor, spending nearly three weeks with the students, sharing his vast experience of working in the Far East. This trip, along with so many others, provide an incredible experience. They not only give students a unique opportunity to get an inside view of international marine infrastructure projects but also invaluable insight into what's expected of them in the industry. "As a contractor, no matter how scientific you are or how many doctoral degrees you have, you have to get your hands dirty to gain credibility within an organisation," explains Stefan. "It's an important characteristic of the industry. As a young employee or as a mid-term career employee, you need to be open to that."

It's one of the reasons why Stefan is keen to maintain the course on field experiments, under the supervision of Matthieu de Schipper. For example, students get to carry out field experiments in the near shore zone where the waves are breaking and you can see the sediments being transported. As Stefan explains, "The course is co-funded by the Dutch Association of Dredging Contractors *(Vereniging van Waterbouwers)*, as they find it important to be able to hire students and young engineers who are experienced with the forces of nature."

No matter how many doctoral degrees you have, you have to get your hands dirty to gain credibility within an organisation.

Real-time monitoring data can also play a role in building up a good and open working relationship with the client. Such data are usually collected as part of large-scale construction projects, for instance, to verify if environmental limit levels are being met. By sharing such data with the client (or even making it publicly available), the contractor gains confidence in the work methods applied and the management of its dredging

FIGURE 5

Students from Delft University of Technology battling the forces of nature during a prototype dune erosion experiment in a container at the Sand Motor (2020).

FIGURE 6

Kees d'Angremond advising on the reclamation methods in Pulau Tekong, Singapore.

operations. A sharp contrast to the days when a contractor would sit on the data to keep the competitive edge for the next project. Stefan confirms, "Of course, it took time to move away from that initial mindset but I think the dredging industry has matured in that sense. How companies communicate to the public has seen a big turnaround. Open communication proved to be a key enabler for the completion of the Port Phillip Bay channel deepening project in Melbourne; sharing of data to inform both stakeholders and the public resulted in turning it into a successful project."

Can academia play a role in sustainable infrastructure?

Dredging companies today have to convince clients and consultants that complex projects should be done in a sustainable way. You need to get all your stakeholders on board from the very beginning, carry out ecosystems services assessment, establish what is the impact your project has on all this and inventorise all the externalities to see how sustainable a project really is. "This is where science and knowledge development is an excellent starting point," comments Stefan. "You have to start building these relationships because knowledge development in itself offers no commercial interest. However, it helps in building trust, not only amongst the companies you work with, but also research institutes, ecologists and NGOs."

Today, NGOs are getting involved at the beginning of a project and seeing the benefits of working that way rather than simply opposing development proposals. The Marker Wadden project is an excellent example of a cooperation between the industry, *Rijkswaterstaat, Natuurmonumenten* (Association of Nature Monuments), as well as universities involved nowadays.

There are many more examples – the Sand Motor is a prime example, where the World Nature Fund was involved upfront in order to help initiate and develop the project.

What's inspirational about the DELTA21 idea is building something at the seaward side of our country to solve a problem inland.

The need for a new Delta department

Today, sustainability is top of mind for all industries. For dredging companies that means the acceptance of working sustainably too. Even in the time of the Eastern Schelt closure there was a concern of the environmental impacts. When the Delta law was signed in parliament, the plan was that the Eastern Scheldt would be closed. Then due to pressure from NGOs and the local population, that decision was turned around. The main concern was the deterioration of the water quality in a stagnant Eastern Scheldt and the complete loss of the mussel and oyster culture near Yerseke. Work had already begun on closing the estuary, so the whole plan had to be changed and instead a Storm Surge Barrier needed to be designed and constructed. It was a massive undertaking. "The whole Delta Plan was aimed at learning towards the more difficult parts of the project," explains Kees. "Then all of a sudden the whole process of learning was changed because we had to build a completely different structure. The whole civil engineering world of the Netherlands was mobilised and was then working on one project for about 10 years and together we solved the issue. We need this same spirit to face the challenges of sea level rise today."

"I totally agree," adds Stefan. "Half of the Dutch and Belgian population live in flood-prone areas and it's a very real concern. When we have 10-metre sea level rise, which is possible in the far future, then people may consider moving further inland to the east. But in the meantime, we cannot sit still and do nothing. There are a lot of opportunities to mitigate the risk to ensure safe living in the low-lying parts of the country. Then there will be the need for hydraulic engineering along with the companies to build the solutions in both a good and sustainable way." According to Kees, we should start making engineering solutions. A new Delta department with dedicated engineers who are not only talking, but are really examining what are the consequences of certain measures. And it should not be limited to the Netherlands. The cooperation with other institutes, such as the US Army Corps of Engineers should be sought.

There is a great need for qualitative assessments, because the question is based far too much on "narratives". As Stefan explains, "At the very least, we should start making an assessment of what is known and what is happening in different scenarios, because the longevity of these large infrastructure interventions is not infinite – you design something to last for 50 or 100 years. Then you can use that assessment for a basis of decision making." One of the plans that is on the table is the DELTA21 idea; a future-proof solution for the south-western Delta, providing a solution for flood protection, energy storage and nature restoration. "What's inspirational about this idea is building something at the seaward side of our country to solve a problem inland. There's a lot of inspiration in this way of thinking. It's all about coming up with solutions and quantifying them, and not going by the 'narratives' or gut feelings. And that's where engineering comes into play." A sentiment fully embraced by Kees; "It needs to not only be dreamed about but it also needs to be calculated."

Greatest achievements

After a moment of contemplation, Kees smiles and says, "I'm most proud of the number of students I've taught during my time as a professor and that they all found their career path." He was a professor for 12 years so approx. 50 students per year, that's 600 graduates in total. "Most of them landed where they should and that's an achievement." He is also proud of his role in the early dredging research programme that he helped start and later his role in Singapore. After his retirement, he was invited by the Singapore Government to help them in a court case with Malaysia, concerning environmental problems. Together with colleagues, he supervised research studies by different labs and evaluated the results. They then made a proposal to the two countries and their recommendation was adopted by the negotiating politicians to settle the court case out of court.

For Stefan, his greatest achievement comes from his role in EcoShape and that he was able to make a difference, not only in the programme itself but also in the change of mindset that it invoked. As he explains, "An important element in the EcoShape network is spanning bridges – beyond the interest of individual parties or persons – to make sure that people come together and start collaborating. Also to develop mutual trust and at the end of the day to create better solutions. Marker Wadden is a nice example of that, but also the Hondsbossche and Pettemer Sea Dunes and the Prins Hendrikzanddijk project are great examples. By coincidence they are all in the Netherlands, but there are many around the world."

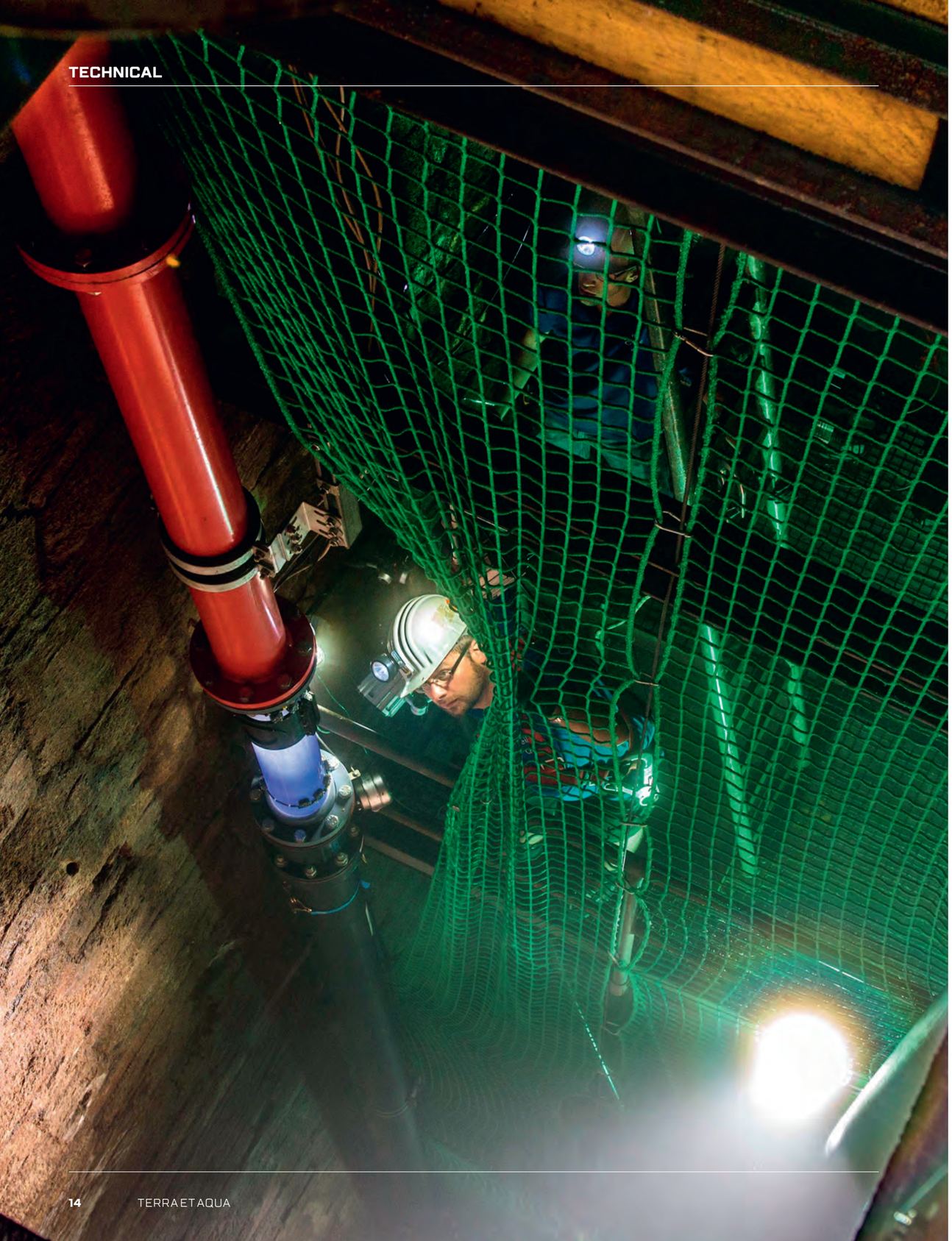
I'm most proud of the number of students I've taught during my time as a professor.

The research initiated in Indonesia is a prime example. "It's just incredible to think of all these dredging companies together with academics and NGOs working together on improving coastal protection in the poorest regions. The business case is still under development but at the end of the day, it's a crucial project for local communities. These are the examples that appeal nowadays to students; engineers who want to bring their sound engineering knowledge into practice in this new environment. It therefore helps greatly if they have seen the hydraulic world from different sides."

Plans for the future

For Kees, his sights are set on the coming few years. As a consequence of his role in the court case in Singapore, he was asked by the Singapore government to assist them in designing some of their land reclamation works. After many years of discussion, designing and debating, it was decided to build a polder in Pulau Tekong, Singapore. A project that he still supervises and one that he's very proud of.

Stefan has many plans for the future, including educating new generations of hydraulic engineers and promoting the concept of Building with Nature as a means to develop climate-resilient solutions. Nature-based solutions can offer excellent opportunities to deal with the uncertainties of climate change. The challenge is to demonstrate that they work, also in tropical environments such as Singapore. "It would be great," he says, "if a joint public-private innovation programme could be initiated that aims to gain experience with these solutions from living lab experiments, that translates this new knowledge into design guidance for future projects and establishes an education centre to raise the engineers of the future.



PIPELINE DESIGN – DENSITY WAVE AMPLIFICATION AND SLURRY DYNAMICS

The effect of density waves and slurry dynamics on slurry pipeline flow assurance cannot be predicted with current slurry pipeline design methods. Current methods are based on steady-state assumptions, assuming that the mixture velocity and density are constant in time and in the pipeline. Therefore, using current design methods a dynamically stable pipeline cannot be guaranteed. Furthermore, new experiments in vertical pipelines show that density wave amplification is possible at mixture velocities far above the critical velocity. This article presents a new temporal design method based on 1D Driftflux CFD, which is able to model growing density waves.

For many years, dredging pipelines have been designed with steady-state models for the energy losses in a pipeline and the energy added by the centrifugal pumps. The design of a hydraulic transport system starts with a criterion for the capacity of the pipeline, in how many sediment the system needs to transport per unit time. Following this, the designer needs to determine the pipe diameter, by estimating the magnitude of energy lost by the slurry as it flows through the pipeline, and the energy generated by the centrifugal pump(s) to drive the system. This is typically done using a steady-state analysis, where it is assumed that the mixture velocity and sediment concentration in the pipeline are constant in space and time. However, a steady flow and concentration are only possible in laboratory circuits and is not representable for the concentration distribution in field pipelines during dredging operations. This is due to the cyclic nature of the sediment feed of dredging pipelines, for instance the swaying and stepping of a cutter suction dredger.

The steady-state design method looks at the intersection of the pump pressure curve and the pipeline frictional losses curve (see Figure 1). The intersection between these two curves is the mixture velocity at which the pipeline will operate (the "operating point") at a given steady concentration. Any changes of the sediment concentration in the pipeline, or flowing through the pump, will cause the operating point to shift, resulting in mixture velocity variations. Both characteristic curves of the pump pressure and mixture frictional losses are typically determined in laboratory circuits under steady conditions.
The operating velocity should be above the critical velocity to avoid blockages and below the vacuum limit to avoid cavitation.
The critical velocity is defined as "the minimum velocity required for transport of solid material through a pipeline without any particle deposition" (van den Berg and Stam, 2013).
The final design includes an estimation of the number of pumps, the required power for the

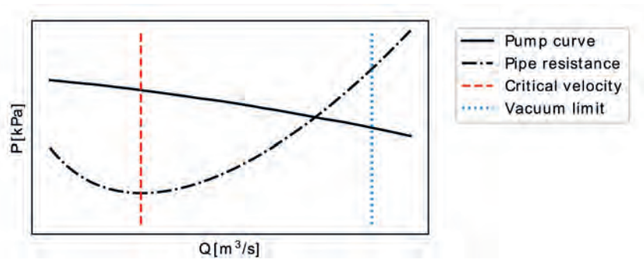


FIGURE 1
An example of the pump pressure-flow curve and the pipe resistance-flow curve. Their intersection is the operating point of the pipeline and should remain between the critical velocity and the vacuum limit.

pump drives and the volumetric concentration of material in the pipeline at an appropriate pipe diameter.

The critical velocity is the preferred safety limit for dredging pipelines. If the operation velocity of a pipeline drops below the critical velocity, the pipeline will block, unless an operator intervenes. This process of pipeline blockage is in its very nature a transient and temporal process that is caused by the minimum in the resistance curve, which defines the critical velocity. Because when the mixture velocity drops below this minimum, the pressure losses will increase, which slows down the mixture. Therefore, more particles will settle out of suspension (if the sediment feed of the pipeline remains unchanged), further increasing resistance and causing the velocity to decrease once more, and more particle settle out of suspensions, etc.
To conclude, the process of pipeline clogging is a transient and temporal process and for long pipelines this process can be slow, where the only indication is that the average mixture velocity slowly drops over time.
This can be difficult to detect considering typical fluctuations of the mixture velocity. The pipeline blockage process can be reversed by slowly lowering the sediment feed into the pipeline and allowing the mixture velocity to increase.

The steady-state design method is suitable to investigate the maximum loading case of a pipeline and its components. However, even when complying to this design methodology, the formation and amplification of density waves is still a common occurrence in the dredging industry and comprises the efficiency and safety of operation (Matoušek, 1997), especially for long pipelines. Density wave amplification is also a large risk for cheaper small diameter pipelines, which typically do not have the same level of monitoring as their larger cousins.
Furthermore, recent advances into deep-sea mining hydraulic transport technology has uncovered a density wave amplification mechanism caused by a different mechanism (de Hoog et al., 2021). To better understand the density wave amplification effect and in general, the effect of transients on pipeline stability, a better temporal design methodology is needed.

In this article, we briefly explain the cause of density wave amplification and its effect on pipeline operation. We introduce the mathematical foundation of a 1D CFD model that can be used to study the effect of time domain processes on the stability of pipelines and the growing of density waves. Finally, an outlook on what can be studied and achieved with a 1D CFD model, such as a temporal stability analysis, feedback controller design and quantifying maximum load for the design of dual fuel and fuel cell based drives, which are the drives of future dredgers.

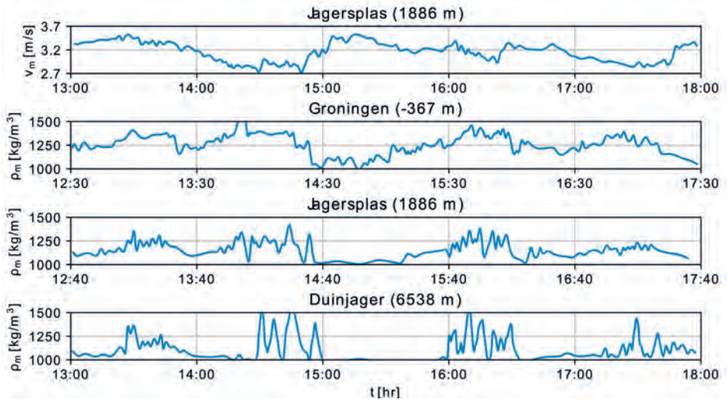


FIGURE 2

An example of a dataset recorded in the Prins Clausplein pipeline, measured on 11.02.1981. Data reconstructed from Matoušek (1997).

Density wave amplification

The growth of density waves in a pipeline is a result of the redistribution of soil from one part of the flow towards another. This can occur even if the soil was injected relatively steady over time. The redistribution of material has been identified to occur under two circumstances (de Hoog et al., 2021). Firstly, redistribution can be caused by deposit formation in the pipeline, which occurs when the pipeline operates with a fluctuating mixture velocity and with an average velocity close to (but above) the deposit limit velocity. This will typically be the case for long pipelines that do not have flow control to keep the mixture velocity steady. The second type of redistribution mechanism was observed for mixture velocities far above the critical velocity (and therefore above the deposit limit velocity), in systems with pipes at different orientations and therefore axial variation of particle velocities. This section briefly explains two case studies that were subject to density wave amplification.

Density waves in horizontal long pipelines

Density wave growth in pipelines remains a common occurrence in the dredging industry, especially with longer pipelines with booster stations. In some cases, density wave growth leads to flow assurance issues. Unfortunately, these cases are not often reported publically. The only publicly reported case was the Prins Clausplein pipeline, used to construct the equally named highway junction near The Hague, in the Netherlands. This pipeline was 10 kilometres long, 650 mm in diameter and had three booster stations, transporting medium to fine sand. The particle size distribution of the sand was very wide, with 12% smaller than 75 μm and 7% larger than 700 μm. The mass medium particle diameter varied in time between 150 μm and 300 μm.

Figure 2 shows an example of data recorded during operation of this pipeline. The top graph shows the measured mixture velocity of the pipeline over time, which was measured at the booster station Jagersplas located at 1886 metres along the pipeline. The three remaining graphs show the measured mixture density at the start of the pipeline (the dredger Groningen) and at 1886 m and 6538 m along the pipeline at boosters Jagersplas and Duinjager respectively. Note: the time axis of the graphs are shifted in time with respect to each other to visualise the development of density waves. The sediment injected at the start of the pipeline is relatively steady varying between 1000 and 1500 kg/m^3. However, at Jagersplas the mixture entering the system between 14:30 and 15:30 hrs had diluted considerably and this same part of the mixture at Duinjager consisted almost exclusively of water. The sand had relocated towards different parts of the flow and accumulated into density peaks. The accumulated material was found back in density waves measured by Duinjager between 16:00 and 16:30 hrs.
The same event occurred for sediment entering at 16:30, found back in density peaks at Duinjager from 17:00 to 18:00 hrs.

Because the pipeline was troubled by density wave amplification, this case study was investigated by Matoušek (1995) and Matoušek (1996a, b). Initially the cause was thought to be an axial variation in particle velocity, as a function of the mixture concentration. More specifically, high-density waves travel faster than low-density parts of the flow and high-density waves would overtake lower densities.
However, Talmon (1999) and de Hoog et al. (2021) show that this is not the case. Specifically, axial velocity variations do exist, due to concentration variations (as measured by Matoušek (1996a)), but causes damping of density waves and not amplification.
Talmon (1999) first introduces the hypothesis of an unbalance between sand sedimentation and erosion from a stationary deposit.
The result of the unbalance is that, at a sufficiently high velocity (around the deposit limit), high-density parts of the flow erode deposits, while low-density parts create deposits. This process is mathematically proven by Talmon (1999), experimentally investigated in Talmon et al. (2007) and further explained by de Hoog et al. (2021).
This effect causes material to be redistributed into high-density waves if deposits are present in the pipeline. The axial velocity variations (due concentration variations, as measured by Matoušek (1996a)) causes the peak of the density wave to propagate forward, since the particle velocity is higher at higher concentration. Under these circumstances, the amplification effect of the erosion and sedimentation unbalance is stronger than the relatively weak damping effect of axial velocity variations. Therefore, the net results is amplification. Amplification ceases once the deposit has been fully eroded.

Whether a deposit is formed depends on the local concertation and the global mixture velocity, due to the erosion and sedimentation unbalance. These deposits were present, because the Prins Clausplein pipeline operated close to the deposition limit velocity, and sporadically dropped below due to fluctuations in the mixture velocity. This created sporadic deposits, which were entrained into density waves, due to the erosion and sedimentation unbalance. These density waves passed through the boosters and created more mixture velocity fluctuations and thereby new density waves. This interaction continued to initiate density wave amplification. For a more detailed explanation of the process, see de Hoog et al. (2021). To conclude, the Prins Clausplein pipeline formed density waves because the mixture velocity fluctuated and sporadically dropped below the deposit limit velocity. Therefore, maintaining a mixture velocity above the deposit limit velocity should avoid the amplification of density waves, and thereby keep the system stable. Even better is if the mixture velocity is maintained at a constant level by means of feedback control.

Density wave amplification above the critical velocity

For the development of vertical transport technology to be used for deep-sea mining, a 297 metre-long vertical pipeline system was constructed in the summer of 2017 by Royal IHC and TU Bergakedemie Freiberg, in Halsbrücke, Germany. This 150 mm diameter flow loop was partially constructed in a vertical mineshaft, which facilitated a 121 m vertical downgoing pipe and riser. These two vertical pipes were connected to 57 m of horizontal pipes at the top of the flow loop, containing the dredge pump and sediment injection systems. For more details of the setup, see Mueller et al. (2018). Experiments were conducted with two graded sediments: d_{50}= 600 μm sand and d_{50}=11.2 mm gravel. The sediment volumetric concentration was varied as part of the experimental program at 5%, 10% and 15%. Figure 3 shows a schematic overview of the measurement system. Measured parameters were: the delivered concentration C_{vd} (the ratio between the particle flow rate Q_s over the mixture flow rate Q_m, measured with a U-loop pressure measurement between p11...p14), the mixture concentration with a conductivity concentration meter (CCM), the mixture velocity, various pressure sensors along the riser, pump pressure, pump revolutions and drive power. Figure 4 shows an illustration of the pipe circuit and the vertical mineshaft.

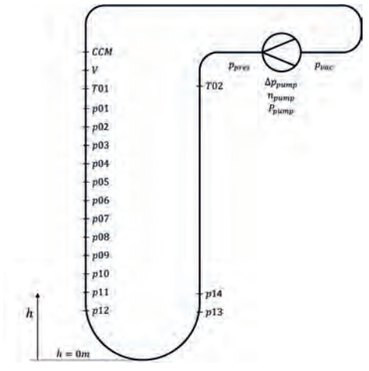


FIGURE 3

A schematic overview of the sensors and the flow loop. The flow direction is from right to left through the pump.

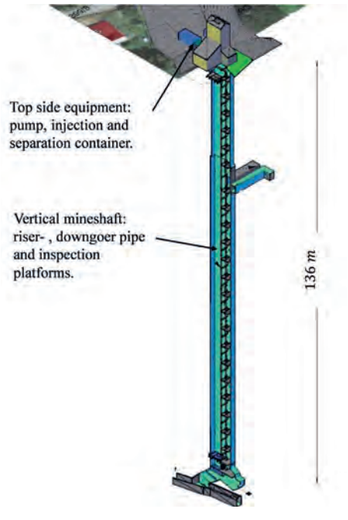


FIGURE 4

A detailed illustration of the Freiberg pipe circuit, showing the topside equipment and the vertical mineshaft with the riser and downgoing pipe.

Density waves can occur at mixture velocities far above the critical velocity.

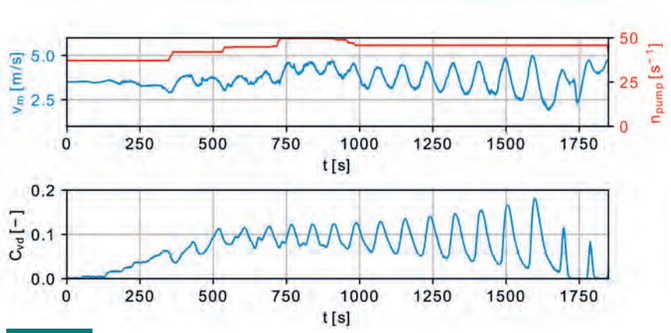


FIGURE 5

An example of a dataset recorded in the Freiberg experimental circuit. D=150mm, d_{50}=11.2mm, c=0.1. Top: the mixture velocity and pump revolutions over time. Bottom: the delivered concentration measured at the bottom of the riser.

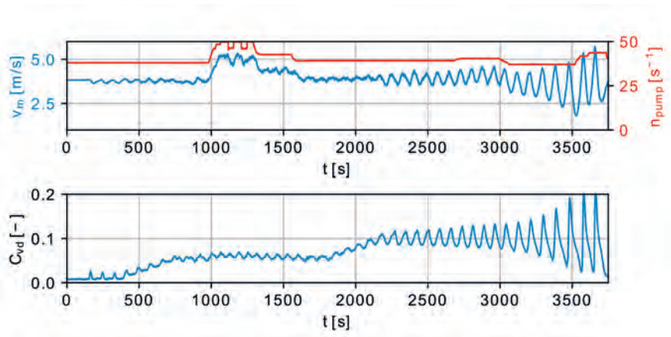


FIGURE 6

An example of a dataset recorded in the Freiberg experimental circuit. D=150mm, d_{50}=600μm, c=0.05,0.10. Top: the mixture velocity and pump revolutions over time. Bottom: the delivered concentration measured at the bottom of the riser.

During the tests density wave amplification was a common occurrence. Almost all experiments showed density wave amplification. The experiments at higher concentration required too much power from the pump drive and therefore these tests had to be ended prematurely (due to the growing density waves). An example of a test with gravel at a volumetric concentration of 10% is given in Figure 5. As part of the experiment procedure, the pump revolutions were kept constant for several minutes and lowered during a few intervals as part of the test. The aim was to acquire data at several constant mixture velocities. However, even though the pump revolutions were kept constant for long periods, the mixture velocity fluctuated as density waves kept growing with each circulation through the loop. Figure 6 shows an experiment with sand, which was initially stable at low concentration (5%) and at high velocity. However, after filling the system to 10% the density wave growth rate significantly increased while the pump revolutions were kept constant over a period of half an hour. The resulting density wave length for all experiments was similar to the system's length.

Transient accumulation in the Freiberg flow loop

The alarming aspect of density wave amplification witnessed in the Freiberg circuit, is that amplification took place at mixture velocities far above the deposit limit velocity and the critical velocity. This is unlike in the Prins Clausplein pipeline, where amplification stops when the mixture velocity remains above the deposit limit velocity. Therefore, the cause of density wave amplification in the Freiberg system is hypothesized to be caused by a different process.

Specifically, the difference in particle velocity between the horizontal and vertical pipelines (whilst the mixture velocity is the same) is thought to contribute to density wave amplification. Particles travel slower in the horizontal pipelines. Therefore, when a density wave flows from the riser into the horizontal pipeline, the material accumulates temporarily and increases in concentration (as continuity dictates). This can be described with the following spatial continuity equation:

$$\frac{\partial}{\partial x}(c \cdot v_s) = 0 \qquad (1)$$

Where c is the volumetric concentration in a pipe, v_s the particle velocity and x the axial coordinate of the pipe. Figure 7 shows a comparison between the particle velocity v_s in horizontal and vertical pipes for the Freiberg flow loop. For the horizontal pipes, the particle velocity can be calculated from empirical relationships of the slip ratio R_s, which is the ratio of particle velocity v_s over the mixture velocity v_m (also known as the transport factor):

$$R_s = \frac{v_s}{v_m} \qquad (2)$$

The slip ratio is an empirical relationship, measurable in a laboratory and available in academic literature (although very uncommon). Examples of academic models are for instance the slip ratio from steady-state two-layer models (Wilson, 2006; Matoušek et al., 2018), or from empirical relationships (Miedema, 2015; Sobota and Kril, 1992). In the illustrative example of Figure 7 the slip ratio model of Sobota and Kril (1992) was applied for the horizontal pipe. For vertical pipes the solids velocity v_s is modeled according to the hindered settling principle (Richardson and Zaki, 1954):

$$v_s = v_m - w_{ts}(1-c)^n \qquad (3)$$

Where w_{ts} is the terminal settling velocity of a particle, c the average volumetric concentration and n the Richardson and Zaki (1954) settling exponent. For the illustrative example in Figure 7 the settling parameter n is modeled according to Garside and Al-Dibouni (1977) and w_{ts} is calculated according to Ferguson and Church (2004) for angular natural grains.

In the Freiberg loop, the slurry flows from a vertical riser into a horizontal pipe. Let us assume the mixture velocity is steady in time and all concentration variation have been damped out apart from one density wave travelling up the riser. As this wave flows from the riser into the horizontal pipe, the particle velocity decreases. This is illustrated in Figure 7, where the particle velocity drops from point "a" to point "b". Continuity dictates that the concentration must increase during this event (Equation 1). This in itself is only a temporally increase of concentration, because once the mixture would flow again into a vertical riser, the particle velocity returns to its original state (from point "b" to "a" in Figure 7). Hence, the concentration decreases and recovers. The concentration increase was only temporarily.

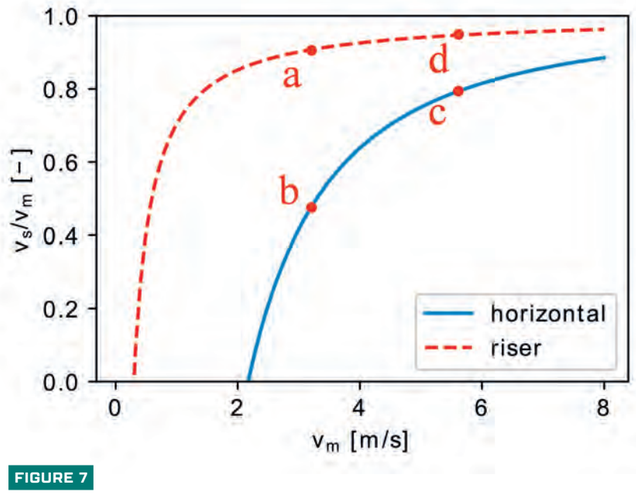


FIGURE 7

The ratio of the solids velocity over the mixture velocity, as a function of the mixture velocity, for horizontal pipes and vertical pipes in the Freiberg flow loop. D=150 mm, d_{50}=600 μm.

The key to understanding density wave amplification in Freiberg is that the mixture velocity also increases as the density wave flows out of the riser and into the horizontal pipe. This is due to the working nature of a centrifugal pump, which does not operate at a constant velocity. Once the density wave flows out of the riser, the load on the pump decreases due to the decreasing in hydrostatic gradient. As this happens, the particle velocity goes from point "a" to "b", towards "c" in Figure 7. Once the wave flows out of the horizontal pipe, the velocity increase is smaller, from point "c" to "d" in Figure 7. Consequently, part of the increased concentration remains. Note that the path from "b" to "c" does not cause a concentration drop, as this does not coincide with a pipe orientation change, therefore $\frac{\partial v_s}{\partial x} = 0$ (whilst $\frac{\partial v_s}{\partial t} > 0$). In the Freiberg system, the density wave flows into to the downgoing pipe once leaving the horizontal pipes before flowing into the riser again. This increases the mixture velocity even further and strengthens this effect. The above explains the working principle behind the transient accumulation hypothesis.

To conclude, density wave amplification in the Freiberg loop is hypothesized to be caused by: 1) a difference in particle velocity when the slurry flows from vertical to horizontal pipes; and 2) a coincidental increase in mixture velocity due to working principle of a centrifugal pump. This velocity difference between vertical and horizontal pipes is smaller at high mixture velocities and at lower concentration. Therefore, under these conditions amplification should not occur, or if it does, the growth rate should be lower. This trend was indeed witnessed during the Freiberg experiments, which supports the transient accumulation hypothesis.

Transient slurry pipeline modelling

The ability to conduct a time domain analysis of a pipeline, and predict density wave amplification, allows a designer to understand these processes better and to investigate methods to avoid density wave growth. To achieve this goal, a full transient model is needed since the pipeline configuration and pump positioning could potentially influence stability, thereby this interaction can become very complex. By using multiphase computational fluid dynamics (CFD), to resolve the particle phase and fluid phase separately, these goals could be achieved. From these findings, we can derive that three key aspects need to be incorporated into the CFD model:

- The particle velocity, as a function of concentration, mixture velocity and pipe orientation (i.e. vertical or horizontal);
- Model stationary deposits, so that density wave amplification in horizontal pipelines can be predicted, as witnessed in the Prins Claus pipeline; and
- A pressure driven solver, to model the pressure provided by the centrifugal pump(s). The pump pressure should be a function of the mixture flow rate, mixture density and particle diameter. The pressure source can numerically be manipulated to model the pump and drive behaviour, and mimic a control feedback system.

Pipelines can be kilometres long; therefore, 3D and 2D simulations are too computationally expensive, as are state-of-the-are discrete particle techniques like CFD-DEM. A long pipeline, where its radial dimensions are very small compared to the axial dimension, lends perfectly to a 1D continuum model. The value and potential of a 1D Driftflux model (or "mixture model") has already been explored

by van Wijk (2016), including pump interaction and a PID feedback controller. Therefore, the model we propose in this article will use similar techniques as the 1DVHT model by van Wijk (2016). The following section presents the numerical foundation of a 1D-two-layer hydraulic transport model (1D-2L-HT) that meets the key aforementioned criteria.

Particle transport equations

The proposed model needs to model stationary deposits, which can be achieved with a two-layer model. The lower layer will always be stationary and will therefore not need its own transport equation. The transfer of mass, between the lower stationary layer and the upper flowing layer, will be modelled with a source term. See Figure 8 for a visualization of the structure of the model.

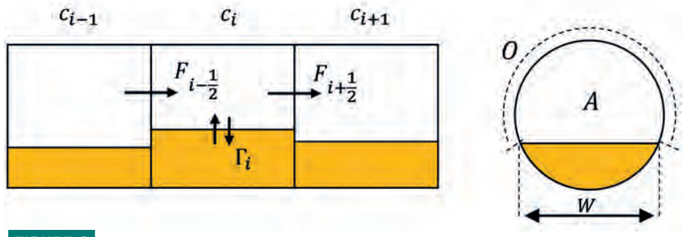


FIGURE 8

Numerical schematic of the 1D two-layer model. The upper layer is the flowing transport layer, while the lower layer remains stationary.

The 1D-2L-HT CFD model is based on the Driftflux or Mixture model (Ishii and Hibiki, 2006). The Driftflux model can model a fluid and a solid phase with a velocity difference, based on the assumption that the particle inertia is small and particles instantly follow changes in the fluid field. With this assumption, only one momentum equation is needed for the entire mixture. This mixture's continuity equation equals:

$$\frac{\partial \rho_m}{\partial t} + \frac{\partial}{\partial x}(\rho_m \hat{v}_m) = 0 \qquad (4)$$

Where ρ_m is the mixture density and $\hat{v}_m$ the mass flow rate based mixture velocity:

$$\hat{v}_m = \frac{\rho_s}{\rho_m} v_s c + \frac{\rho_f}{\rho_m} v_f (1-c) \qquad (5)$$

In the equation above, ρ_s is the solids density, ρ_f the fluid density, v_s the solids velocity, v_f the fluid velocity and c the volumetric concentration of solids. The changing cell volume, due to the two-layer structure, requires special attention in the numerical derivation of the transport and momentum equations. Applying the finite volume method on the schematic presented in Figure 8, and taking into account the changing cell volume, results in the following transport equation (Hirsch, 2007):

$$\frac{\partial}{\partial t}(c \cdot \Delta V) + \sum_{faces}(F \cdot \Delta A) = \Gamma \qquad (6)$$

With c the cross section averaged volumetric concentration of the upper layer, V the volume of the cell area above the bed layer, F the cell face fluxes, A the cross sectional area of the upper layer and Γ the bed layer erosion and sedimentation source term.

The cell face fluxes are modelled as:

$$F = v_s c \qquad (7)$$

with the particle velocity

$$v_s = v_m + v_{s/m}, \qquad (8)$$

where $v_{s/m}$ is a relative velocity model, to model the velocity differences between the solids and the fluid. In Equation 8, v_m is the volumetric based mixture velocity:

$$v_m = v_s c + v_f (1-c) \qquad (9)$$

In Equation 9, v_s is the solids velocity and v_f the fluid velocity. The relative velocity model for horizontal pipes will be based the slip ratio R_s (Equation 2):

$$v_{s/m} = v_m (1 - R_s) \qquad (10)$$

The solids velocity in the vertical pipes is modelled with Equation 3.

Modelling stationary deposits

Equation 6 needs a closure relationship for the bed source term Γ. The erosion and growing of the lower bed layer can be approximated using erosion and sedimentation models, like those used by van Rijn (1986) and van Rhee (2010). The vertical velocity of the top of the bed v_b is modelled as:

$$v_b = \frac{S-E}{\rho_s(1-c-n_b)} \qquad (11)$$

Where S is the sedimentation flux, E is the erosion flux, c is average volumetric concentration of the eroding flow and n_b the porosity of the bed. The source term Γ becomes:

$$\Gamma = v_b c_b \Delta x W \qquad (12)$$

with c_b the bed concentration, Δx the cell size and W the width of the bed layer top. The sedimentation flux

$$S = \rho_s w_{ts} (1-c)^n \qquad (13)$$

is based on settling velocity of the particles, w_{ts}. Additionally, for high concentrated flows the hindered settling principle must be used to correct the settling velocity, through the hindered settling exponent n (Richardson and Zaki, 1954). In a pipeline, the flow over the bed layer is high, therefore the erosion model E should be suitable for high velocity flows. Since high flow velocities create a shear layer zone on top of the sediment bed, where dilatancy reduces the erosion rate (van Rhee, 2010). Fortunately, recent research provides experimental data and models specific for erosion at high flow velocities by Bisshop et al. (2016) and van Rijn et al. (2019), however these models have not yet been applied in pipeline flows. Therefore, the suitability of erosion and sedimentation models in pipeline flows requires further investigation and will be part of future work.

Mixture momentum equation

To model the interaction between resistance forces caused by the slurry and driving forces from the centrifugal pumps, a 1D variation of the Driftflux momentum equation can be used. The differential form of the momentum equation is given in Equation 14. As with the transport equation, the changing cell volume needs to be included in the momentum equation, as time and spatial derivatives of the cross sectional area of the cells.

$$\frac{\partial}{\partial t}(A\rho_m \hat{v}_m) + \frac{\partial}{\partial x}(A\rho_m \hat{v}_m |\hat{v}_m|) = \frac{\partial A p}{\partial x} - \tau_m O - \tau_b W - \rho_m g A \cos\omega + \cdots$$
$$- \frac{\partial}{\partial x}\left[A(1-c)\rho_f (\hat{v}_m - v_f)^2 + Ac\rho_s (\hat{v}_m - v_s)^2\right] \qquad (14)$$

In Equation 14, ρ_m is the mixture density, p the pressure, τ_m the mixture resistance on the pipe wall, τ_b the shear force over the bed layer, O the circumference of the upper layer, W the width of the bed layer and ω the pipe inclination angle. The last term in Equation 14 is an inertia coupling term, which is required to correct for the exchange of momentum between the solids and the fluid when they are subject to a velocity difference. The pump pressure can be modelled as a boundary condition when solving the pressure Poison equation (which follows from Equations 4 and 14). Alternatively, multiple pumps can be modelled by adding an additional $\frac{\partial p_{pump}}{\partial x}$ term in Equation 14 (van Wijk, 2016), however this does require a numerical solver that can cope with large momentum gradients.

Equations 4, 6 and 14 form the foundation of the 1D-2L-HT model. A great benefit of the model structure is that it allows for the simulation of a pipeline system with pipes at all possible orientations, as long as the slip ratio model R_s and the wall friction model τ_m are a function of the pipe orientation. For vertical pipes, the two layers are not needed. Thus, with one solver a complex system can be simulated with pipes at various orientations. The main numerical challenges lie in the correct implementation of erosion and sedimentation models, and the changing cell volume of the upper layer above the bed.

Preliminary simulation results

Figure 9 shows preliminary results of simulations of the Freiberg system. In this case study, the mixture velocity is always above the critical velocity. Therefore, stationary deposits are not present and the two-layer structure of the 1D-2L-HT is not necessary. The pump pressure was modelled using the pump curve of the actual pump used in Freiberg at a fixed RPM. The use of a pump curve at a fixed RPM results in a dynamic mixture velocity. Modelling the pump curve, together with a velocity difference between the horizontal and vertical pipes, is key in order to simulate density wave growth. The results presented in Figure 9 are preliminary, proper validation and matching with experimental data will be published as part of future work.

The Sobota and Kril (1992) and the hindered settling principle was applied to model the particle velocity for the horizontal and vertical pipes, respectively. The pipeline resistance τ_m was modelled with the equivalent liquid concept, where the mixture is modelled as a Newtonian fluid with increased density. This equivalent liquid model is at the moment a placeholder model. A more suitable model, representative of actual flow conditions, will be applied in follow-up research.

The following similarities between the simulation and the data can be identified:

- The time for the density wave to grow is of similar order;
- The waves are formed into distinct saw tooth shaped waves;
- The growth rate has an exponential nature;
- Density wave growth occurs above the critical velocity; and
- The wavelength equals the system length.

To conclude, the preliminary results show that the 1D-2L-HT model is capable of capturing the interplay between the pump dynamics, particle velocity changes and pump load variations, which cause density wave amplification in the Freiberg system. This fact that this preliminary results show good agreement with the measured data, supports the validity of the transient accumulation hypothesis.

The suitability of erosion and sedimentation models in pipeline flows requires further investigation and will be part of future work.

Discussion of model application

System stability analysis

The main application of the 1D-2L-HT model, as described previously, is to evaluate if and how a pipeline system becomes unstable due to transients. The model allows the designer to study the effect of complex changing load dynamics with non-steady sediment inflow conditions. An example is a pipeline system that needs to ascent over a large hill. The hydrostatic mixture gradient is large compared to fictional losses, therefore a non-uniform spatial concentration distribution will cause the pressure delivered by the pump to fluctuate severely when density waves flows up the hill, thereby cause fluctuations of the mixture velocity. If due to these fluctuations, the mixture

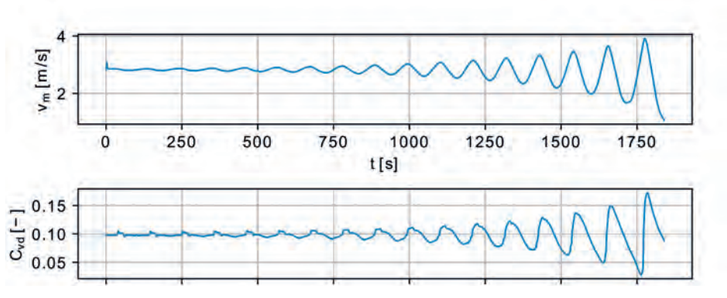


FIGURE 9

Simulation of a sand mixture (d_{50}=600 μm,c=0.10) in the Freiberg system using the 1D-2L-HT model. The pump operates at 1000 rpm.

velocity drops below the deposit limit velocity, density waves could amplify as was the case in the Prins Claus pipeline.

Pump positioning could potentially influence the stability analysis of the system. Continuing with the fictional pipeline above, when a booster pump is placed at the foot of the hill, the booster could help push the density wave upwards, since the pressure delivered by the pump increases when the mixture density flowing through the pump increases (Wilson, 2006). De Hoog et. al. (2021) concludes that the booster stations in the Prins Clausplein pipeline contributed to velocity fluctuations, which initiated new density waves. Positioning all boosters at the start of the pipeline could solve this problem. Even if density waves do amplify, they will no longer flow through a booster and no longer cause the mixture velocity to fluctuate. This hypothetical solution, of intelligent booster pump positioning, can also be investigated using the 1D-2L-HT model. The pressure rating of the pipeline at the boosters should be high enough to allow for this solutions.

The Freiberg system instability is hypothesized to be caused by a difference in particle velocity between vertical and horizontal pipes, coinciding with an accelerating mixture velocity due to centrifugal pump dynamics. The particles travel slower in horizontal pipes, causing "transient accumulation". The particle velocity can be matched better with the vertical pipe by lowering the diameter of the horizontal pipes. Whether this is a valid solution can be investigated with the 1D-2L-HT model. For this specific case, the two-layer structure is not needed as density waves in the Freiberg system amplified at mixture velocities far above the deposit limit velocity and a stationary bed was not present.

Transients can lead to an unstable pump-pipeline system due to density wave amplification.

Controller design

A consequence of density waves is a fluctuating mixture velocity. Furthermore, de Hoog et al. (2021) speculate that feedback control, to keep the mixture velocity steady, could significantly help in stabilising the system. The 1D-2L-HT model can be extended with a simulated feedback control system, as done by van Wijk (2016). This application is especially usefully for horizontal pipes, where density waves are formed rapidly if the mixture velocity drops below the deposit limit velocity. Therefore, maintaining a constant mixture velocity at a safe margin above the deposit limit velocity will avoid density wave growth. However, feedback control is only possible if the drive power has a margin and preferably with an electric motor, which can be controlled more easily. The 1D-2L-HT model can be used to investigate the magnitude of the drive power margin that is needed to facilitate feedback control, and to check whether the control system is able to respond fast enough to maintain a constant flow rate.

Diesel driven pumps have a smaller control range and are therefore more difficult to control. Diesel drives are still commonly applied in smaller and cheaper pipelines. Furthermore, feedback control is only possible in the presence of a flow meter, which is often absent in cheaper pipelines. With the 1D-2L-HT model an alternative of flow meter feedback can be investigated, for example one based on significantly cheaper pressure sensors.

Dynamic drive load analysis for dual fuel and fuel cell drive design

The reduction of drive emissions is probably the current single most discussed topic in the maritime industry, driven by the uncertainty of oil and gas prices and more strict emission legislations (Shi et al., 2015). In the dredging industry, the first dual fuel (DF) dredgers have been built using liquefied natural gas (LNG). These drives reduce the emission of harmful gasses, but are challenging to integrate in a dredging vessel due to the large dynamic loads associated with dredging operations. More specifically, the dual fuel drives switch from the cleaner gas operating mode to a diesel operating mode during heavy transient loads that consequently increases harmful emissions (Mestemaker et. al. 2020). Furthermore, some prime movers such as spark-ignited (SI) engines do not have the ability to switch back to a diesel operating model and will therefore fail. Consequently, the centrifugal pump stops and the slurry pipeline comes to a halt. One solution, to allow DF and SI drives to cope with high transient loads, is an energy buffer to provide energy during these transient events. In addition to DF and SI drives is fuel cell based drives. The fuel cell based drive is a popular and actively researched drive technology for the future. However, this drive needs an even larger energy buffer to cope with transient loads. The 1D-2L-HT model can be used to simulate a slurry system, thereby to quantify and simulate realistic transport conditions where dynamic loads are highest. For a trailing suction hopper dredger, these highest loads (of the entire vessel's drive train) are experienced when the dredger is discharging on a long land pipeline. Since in addition to the power required by the dredge pumps, the fluidising of sand in the hopper requires a large amount of power for the jetting pumps. A transient analysis of the drive (Mestemaker et. al., 2020), with loads simulated with the 1D-2L-HT model, allows the drive designer to ensure continuity of the power train and thereby flow continuity of the pipeline and optimal operation of the dredger.

Conclusions

Steady-state design methods to design hydraulic transport pipelines have their limits and cannot predict the stability of a pipeline with a highly fluctuating mixture velocity. This can lead to the amplification of density waves and compromise the safety and efficiency of the pipeline. When these fluctuations drop below the critical velocity, density waves are formed, further impeding the flow of the pipeline. Even if the mixture velocity is above the critical velocity, transients can lead to an unstable system due to density wave amplification, as seen in Freiberg. To study the transient stability of pipelines, a 1D-2L CFD model is proposed with variable particle velocity and dynamic pump pressure forces. This type of model is great for modelling global behaviour on a large scale and is shown to be able to predict density wave amplification as witnessed in the Freiberg flow loop. Further uses for such a model is the designing control feedback algorithms to maintain flow assurance and dynamic drive load quantification to aid in the design of DF, SI and fuel cell drives. This model will be developed further as part of future research.

FIGURE 10

IADC's Secretary General René Kolman presents the Young Author Award 2021 to Edwin de Hoog for the co-authoring of the research paper, The relevance of time domain effects for the design and stability of hydraulic transport pipelines. The award is presented at industry-leading conferences, with last year's winning author selected from the proceedings of the CEDA Dredging Days, held virtually 28-29 September 2021.

Summary

Traditionally, the design of a hydraulic transport system entails analysing energy sinks and sources of a pipeline system. More specifically, the energy characteristics of the pump and drivetrain are weighted against the frictional energy losses of the slurry in the pipeline. The existence and effect of density wave amplification is familiar to the dredging industry, but the exact cause and working mechanism causing amplification are still under debate. Recent research into vertical hydraulic transport for deep-sea mining has shown that density waves can occur at mixture velocities far exceeding the critical velocity (the industry standard for the minimum safety velocity above which flow is assured). Therefore, this topic is revisited in this article and new 1D CFD techniques are explored with the aim to predict density wave amplification. This article introduces the research and presents a possible 1D CFD model framework to achieve this goal. Preliminary results show that the 1D Driftflux model is indeed capable of modelling density wave amplification. Furthermore, this article provides an outlook of additional applications of 1D Driftflux modelling for hydraulic transport pipelines. Additional application include feedback controller design and aiding in dual fuel drive design.

Edwin de Hoog

Edwin is a research and development engineer at Royal IHC and a part-time PhD candidate at the department of Dredging Engineering at Delft University of Technology, in the Netherlands. He is specialised in hydraulic transport of sand, gravel and manganese nodules. As part of his PhD research, Edwin is developing 1D CFD technology to simulate pump-pipeline systems and the effect of density wave amplification, applicable for long pipelines and deep-sea mining.

Arno Talmon

Arno is assistant professor of Dredging Engineering at Delft University of Technology, in the Netherlands and lectures in hydraulic transport and rheology of slurries. He is also a senior researcher/adviser at the Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, rheology, slurries in mechanised tunnelling, slurries in mining and hydraulic transport. Experimental research into these subjects has led to many new findings.

Cees van Rhee

Since 1985, Cees has been engaged in research for the dredging industry. First at WL|Delft Hydraulics (now Deltares) and then from 1990-2011 at Van Oord. He obtained his PhD at the end of 2002 and since October 2007, he is professor of Dredging Engineering at Delft University of Technology, in the Netherlands. His scientific achievements are modelling of highly concentrated sediment water flows and high velocity erosion of granular sediments.

References

Ferguson R.I. and Church M. (2004)
A simple universal equation for grain settling velocity. *Journal of Sedimentary Research*, 74(6), 933-937.

Hirsch C. (2007)
Numerical computation of internal and external flows. 2nd Edition. Elsevier, United Kingdom.

de Hoog E., Talmon A.M. and van Rhee C. (2021)
Unstable transients affecting flow assurance during hydraulic transportation of granular two-phase slurries. *Journal of Hydraulic Engineering*, DOI: 10.1061/(ASCE)HY.1943-7900.0001913.

Ishii M. and Hibiki T. (2006)
Thermo-fluid dynamics of two-phase flows. 2nd Edition. Springer, USA.

Matoušek V. (1995)
Non-stationary solids flow in a long slurry pipeline with pumps in series – process of material aggregation. 8th International Conference on Transport and Sedimentation of solid particles, Prague, Czech Republic, D5–1–10.

Matoušek V. (1996a)
Solids transportation in a long pipeline connected with a dredge. *Terra et Aqua*, 62, 3–11.

Matoušek V. (1996b)
Unsteady solids flow in a long slurry pipeline with pumps in series – process of material aggregation. *Journal of Hydrology and Hydromechanics*, 44(6), 396–409.

Matoušek V. (1997)
Flow mechanism of sand-water mixtures in pipelines. PhD thesis, Delft University of Technology, Delft, the Netherlands.

Matoušek V. and Krupička J. (2013)
Different types of unsteady flow of solids generated in laboratory slurry pipe loop. In proceedings 16th International Conference on Transport and Sedimentation of solid particles, Rostock, Germany.

Matoušek V., Krupička J. and Kesely M. (2018)
A layered model for inclined pipe flow of settling slurry. *Powder Technology*, 333, 317-326.

Mestemaker B.T.W., Goncalves Castro M.B., van den Heuvel H.N. and Visser K. (2020)
Dynamic simulation of a vessel drive system with dual fuel engines and energy storage. *Energy*, 194, 116792.

Miedema S.A. (2015)
The slip ratio or holdup function in slurry transport. In proceedings WEDA and Texas A&M University Center for Dredging Studies' Dreding Summit and Expo.

Mueller T., van Wijk J.M. and Mischo H. (2018)
EU 'Blue mining' project – building a large-scale test system and flow tests for vertical transport systems in deep-sea mining. *GeoResource Journal*, 3, 38–45.

Richardson J.F. and Zaki W.N. (1954)
Sedimentation and fluidisation: Part 1. *Transactions 699 Institution of Chemical Engineers*, 32, pp.35.

Shi W., Mestemaker B.T.W., den Boer L.J.A., Contessi C. and Zotti A. (2015)
Application of LNG DF engines in dredging vessels. In proceedings CEDA Dredging days. Rotterdam, the Netherlands.

Sobota J. and Kril S.I. (1992)
Liquid and solid velocity during mixture flow. In proceedings 10th Int. Kolloquium massenguttransport durch rohrleitungen, Universitat GH Paderborn, Germany.

Talmon A.M. (1999)
Mathematical analysis of the amplification of density variations in long distance sand transport pipelines. 14th International Conference on Slurry Handling and Pipeline Transport, Maastricht, the Netherlands, 3–20.

Talmon A.M., Aanen L. and Bakker-Vos R. (2007)
Laboratory tests on self-excitation of concentration fluctuations in slurry pipelines. *Journal of Hydraulic Research*, 45(5), 653–660.

van de Berg C.H. and Stam N. (2013)
IHC Merwede Handbook for Centrifugal Pumps and Slurry Transportation. MTI Holland B.V., the Netherlands.

van Rhee C. (2010)
Sediment entrainment at high flow velocity. *Journal of Hydraulic Engineering*, 136, 572–582.

van Rijn L.C., Bisschop F. and van Rhee C. (2019)
Modified sediment pick-up function. *Journal of Hydraulic Engineering*, 145(1), 06018017.

van Wijk J.M. (2016)
Vertical hydraulic transport for deep-sea mining: a study into flow assurance. PhD thesis, Delft University of Technology, Delft, the Netherlands.

Wilson K.C., Addie G.R., Sellgren A. and Clift R. (2006)
Slurry Transport using Centrifugal Pumps. 3rd edition. Springer, USA.

WHERE ARE THEY NOW?

Each year, at selected conferences, the Conference Paper Committee is asked to recommend a prize winner whose paper makes a significant contribution to the literature on dredging and related fields. Since 1987, IADC has presented 42 Young Author Awards. Curious to see where they are now, we asked previous winners what impact winning the award had on them and their career.

Jean-Jacques De Cloedt, President of IADC, presenting the first Young Author Award to J. Marco Groot during the CEDA Dredging Days in Amsterdam, the Netherlands, November 1987.

J. Marco Groot, Manager Rock Department, Boskalis International

Paper: Criteria for the backfilling of excavated trenches for transmission lines and immersed tunnels

What did winning the award mean to you?
It was absolutely an honour to be selected and to be addressed personally by Mr J.J. DeCloedt, IADC's President at that time, during the award ceremony. The prize money was appreciated as well.

What impact did winning the award have on your career?
It did not impact my career directly but it certainly emphasised the importance of gaining knowledge and presenting it in articles. There were quite a few occasions, and even many years later, that external contacts referred to the article as being very useful due to its practical information content.

What are you up to now?
I have had many different steps in my career within the marine dredging and construction industry and spend most of my time working abroad on projects, varying from landfalls, port construction and land reclamation whereby rock installation has been the common thread. Looking back at the past 40 years, I feel that all this experience has contributed to becoming a valued professional within the industry. Four years ago, I moved back to the Netherlands and joined Boskalis. In my present position as Manager Rock Department, I am involved with all rock installation projects worldwide.

Sape Andries Miedema, Associate Professor Dredging Engineering, Delft University of Technology

Paper: The cutting forces in saturated sand of a seagoing cutter suction dredger

What did winning the award mean to you?
International recognition.

What impact did winning the award have on your career?
It connected me to American dredging companies, which resulted in consultancy until now. It also made me encourage and stimulate young colleagues to publish, resulting in many (IADC) awards.

What are you up to now?
Retiring in June 2022.

Charles Hummer presenting Sape Miedema with the award at WODCON XII in Orlando, USA, April 1989.

Marc Van Torre, Professor Emeritus, Ghent University, Belgium

Paper: Navigation in muddy areas: Establishing the navigable depth in the port of Zeebrugge

What did winning the award mean to you?
The award meant a recognition for the relevance of the research projects I was involved in at that time. It also made me aware of the importance of the co-operation between (dredging) companies, port authorities, waterway authorities and research institutions/universities.

What impact did winning the award have on your career?
Awards certainly play a role in an academic career. IADC's Young Author Award also opened doors to international committees of organisations like PIANC and ITTC (International Towing Tank Conference). The appreciation received from IADC also stimulated to continue research in the field of interaction between ships and mud layers.

What are you up to now?
In 2019, I retired as senior full professor and head of the Maritime Technology division at Ghent University. However, I am still involved in (selected) research topics of the Maritime Technology Division (UGent) and of Flanders Hydraulics Research, in the frame of the Knowledge Centre Ship Behaviour in Shallow and Confined Water.

Dr Marc Vantorre (right) receiving the award, together with Karel van Craenenbroeck, from IADC President Robert Brouwer during the CEDA Dredging Days in Amsterdam, the Netherlands, November 1991.

IADC President Robert Brouwer presented Ahmed Mohammed with the young author award during the CEDA Dredging Days in Amsterdam, the Netherlands, November 1993.

Ahmed Rufai Mohammed, General Manager, Engineering and Technical Services, Nigerian Ports Authority

Paper: A low-cost dredging device: A laboratory and field study

What did winning the award mean to you?
It helped in building self-esteem and confidence.

What impact did winning the award have on your career?
The award created opportunity to progress in my career to the post of General Manager in charge of Engineering and Dredging Works in Nigerian Ports Authority.

What are you up to now?
Currently serving as the General Manager, Engineering and Technical Services in Nigerian Ports Authority. This includes overseeing dredging activities at all port locations in the organisation.

Leaf Erickson, Senior Engineer, Coastal Design & Engineering

Paper: Case study on local sediment management at Leeward-Going-Through in Providenciales, Turks and Caicos

What did winning the award mean to you?
Having spent most my life writing technical papers in coastal engineering, this recognition gave me the confidence in going beyond technical details in my approach to add interesting elements of both the design and construction process.

What impact did winning the award have on your career?
I have continued both my professional and academic careers advancing to a Senior Engineering position with the same firm and completing my doctoral studies focused in sediment resources at Florida Institute of Technology.

What are you up to now?
I'm still with Coastal Design & Engineering and currently working on a range of coastal projects, including dredging for the Turks and Caicos Islands Ports Authority's North Caicos and South Caicos Port rehabilitation projects – blending a beneficial use of dredged material for beach and dune restoration projects within a fiscally sustainable construct for both public and private stakeholders.

Leaf Erickson received the award from IADC Secretary General Constantijn Dolmans during WEDA XXV in New Orleans, USA, June 2005.

Stéphanie Groen receiving the Young Award Award from Constantijn Dolmans, Secretary General of IADC, presented at WODCON XVIII, Orlando, USA, May 2007.

Stéphanie Groen, Director Coastal & Climate Change Asia, Aurecon Group

Paper: Environmental monitoring and management of reclamations works close to sensitive habitats

What did winning the award mean to you?
Recognition of this process ensured that over time, EMMP or EMP became the norm for marine and terrestrial projects under construction. Whilst an EIA is done before works start, and EMMP is done during construction to ensure full compliance with EIA long term. For me, this was more important than the EIA alone, as these documents still end up forgotten on a dusty shelve. Nowadays, the EMMP process is a recognised tool for projects under construction.

What impact did winning the award have on your career?
DHI Singapore managed to set the scene with EMMP projects, which were adopted in other countries afterwards. Therefore, with the increase in project exposure, there were more opportunities to improve and automate the process, to become more efficient and deliver more accurate results. Personally, I was fortunate to grow with the organisation, get exposed to more than 15 large reclamation EMMP projects and eventually become Managing Director of Singapore in 2013.

What are you up to now?
Currently, I am the Director Coastal and Climate Change Asia for Aurecon, looking after all sustainability, coastal adaptation and climate change related opportunities in Asia. At Aurecon, we believe that our future economic success has direct links to its sustainability and climate change performance. Therefore, we work with our clients on the transition towards net zero and climate positive solutions, which is good for our business and for our planet.

Suze Ann Bakker, Sr. Project Engineer; Project Lead for Enter Energy Mozambique, Shell

Paper: Uncertainty analysis of the mud infill prediction of the Olokola LNG approach channel

What did winning the award mean to you?
When starting my thesis, probabilistic assessments of dredging volumes were at best uncommon. Winning the award showed that it is worthwhile breaking new grounds.

What impact did winning the award have on your career?
It definitely gave me a kick start in my role. But even more important, it taught me how important assessing uncertainties is when working on large infrastructure and energy projects. To this day, assessing uncertainties helps me in making the right decisions in my projects.

What are you up to now?
So far, I have been very fortunate to have worked in a variety of exciting roles across the globe: from maintenance in Pernis refinery in the Netherlands, to offshore structures engineer on a multi-billion-dollar LNG project in Paris, to lead engineer on a terminal conversion project in Houston, Texas. This led me to my current role working on Shell's global social investment programme, Enter Energy, which brings electricity to refugees in support of Sustainable Development Goal 7. I am truly grateful that I have the opportunity to provide access to improve the lives of displaced people in my country of birth, Mozambique.

Rene Kolman, Secretary General of IADC congratulated Suze Ann Bakker, winner of the award at PIANC MMX in Liverpool, UK, May 2010.

René Kolman, Secretary General of IADC presented Kaitlin McCormick with the award at WEDA 30th Technical Conference and the 41st Texas A&M Seminar in Puerto Rico, June 2010.

Kaitlin McCormick, Senior Manager, Renewable Development, Invenergy

Paper: Masonville dredged material containment facility: Environmental planning, compliance and compensatory mitigation

What did winning the award mean to you?
It was a confidence boost for my technical abilities and expertise associated with navigating complex regulatory frameworks for in-water infrastructure projects. My professional mentor Jane Boraczek had passed away unexpectedly the year before and this award also reflected the support and mentorship (and technical wisdom) she had shared with me.

What impact did winning the award have on your career?
This award helped facilitate further opportunities to learn and advise permitting on coastal and in-water infrastructure within and around the Chesapeake Bay – and began a career of advising and leading permitting for in-water and coastal projects.

What are you up to now?
I serve as a Senior Manager, Renewable Development for Invenergy, the world's leading privately held sustainable energy company. My focus is on permitting energy generation and association transmission infrastructure.

Rudy Helmons, Assistant Professor (Delft University of Technology) and Adjunct Associate Professor (Norwegian University of Science and Technology)

Paper: Modelling the effect of water depth on rock cutting processes with the use of discrete element method

What did winning the award mean to you?
It feels wonderful to win such an award. It's a confirmation that the work that you present is of high quality and that it is perceived by others as highly relevant for the dredging industry. It really is great to receive such a compliment from experts in our field.

What impact did winning the award have on your career?
It's difficult to say. In my case, it gave recognition for the small niche that my research focusses on and it serves as a very good encouragement to notice that others see value in it as well. It did help me to remain within the field of dredging engineering. I have to say, I'm not entirely sure that I'm in the position that I am today because of the Young Author Award. If I go through the list of prevous winners, I notice that I know quite a few of them directly. All those people are talented and seem to share a passion for the field of industry. In that sense, I think that the award is a perfect example of recognising those talented people and giving them encouragement to continue their work.

What are you up to now?
In my current positions at Delft University of Technology and Norwegian University of Science and Technology , I am mainly responsible for the research and education related to the application of deep-sea mining. In those positions, I try to combine the expert knowledge from dredging industry with other fields of industry and research, for example, deep-sea biology/geology, oil/gas technology, mining industry and bulk handling.

Rudy Helmons received the award from Rene Kolman, Secretary General of IADC at CEDA Dredging Days in Rotterdam, the Netherlands, November 2015.

BUILDING A PROACTIVE SAFETY CULTURE WITHIN A MARINE CONTRACTOR ORGANISATION

It is hard to imagine a time when safety was not deemed important, when Personal Protective Equipment (PPE) was not used and little was done in the way of prevention. A few decades ago, occupational health and safety was not considered as important for the vast majority of companies. Instead, incidents and emergencies were handled as they occurred, as effectively as possible given the limited technology and resources available. Today, those times have changed. This article explores the progress of health and safety in the dredging industry and QHSSE professionals, Ton van de Minkelis and Christophe Leroy share their experiences in building a proactive safety culture.

History of health and safety within the industry

Health and safety, or HSE (Health, Safety and Environment as it is now referred to) is very different today from 50 years ago. The idea of workplace HSE has advanced tenfold and continues to improve, resulting in the gradual decrease of injury incidents. Recent changes include the introduction of stricter legislation and sentencing guidelines. However, health and safety was not always a priority. What we see as the standard way of working today was not the case just a few decades ago.

Today, company cultures have evolved entirely. A specialised occupational health and safety system combined with a strong company (safety) culture are must-have elements of any organisation in order to improve the safety performance. Relating health issues to occupations and their environments goes back further than you might think. In fact, the first known instance of correlation between health and work was in the 4th century BC when Hippocrates noted lead toxicity in workers of the mining industry. Since then, there has been a long list of professionals,

Photo © Van Oord

physicians and researchers examining work environments and the impact they have on a human's health and well-being.

Due to rising number of incidents in the 1970s, the idea of occupational health and safety began gaining momentum. Governments around the world implemented an appropriate legislative framework to set and enforce standards that would improve the safety conditions of the workplace. Unfortunately, as is often the case, a few major catastrophes accelerated this process. First, the Seveso disaster of 1976, in which an explosion at a chemical plant in Meda, north of Milan, released a chemical cloud containing the highly toxic dioxin. Thousands of animals died and many local residents experienced health problems for decades. In 1984, more than half a million people in Bhopal, India, were exposed to toxic gas from a chemical processing plant with poorly-maintained pipes. Within a month, 80,000 people had died. And in 1988, the Piper Alpha platform in the North Sea, 190 km north-east of Aberdeen, Scotland, exploded and sank killing 165 crew on board.

The International Safety Management (ISM) code

Relevant for the dredging industry was the introduction in 1998 of the International Safety Management (ISM) code by the International Maritime Organization (IMO). The purpose of the ISM code is to provide an international standard for the safe management and operation of ships and for pollution prevention. It was born out of a series of serious shipping accidents in the 1980s. The worst of which was the roll-on/roll-off ferry Herald of Free Enterprise that capsized moments after leaving the Belgian port of Zeebrugge on the night of 6 March 1987, killing 193 of its 539 passengers and crew. The cause of this and other accidents was a combination of human error on board and management failings on shore.

> **Improving the culture can not only improve safety, but also efficiency and well-being.**

Following these catastrophes, the world began focusing on environmental health and safety more than ever before. The chemical and the oil and gas industry led the charge, establishing a set of fundamentals to help ensure product and asset safety, environmental protection and occupational health. As a result, the occupational health and safety performance in the dredging industry at the end of the 1990s was mainly driven by legislation and certain clients.

Fast forward to 2022 and the dredging industry has achieved significant progress concerning its occupational health and safety performance after having adopted the right mindset over the last decades. The changes are a result of a long journey, with the necessary "learning" hiccups along the way. As well as the key moments and changes within the industry, there has been one continuous factor over the past 50 years – the motivation and willingness to improve.

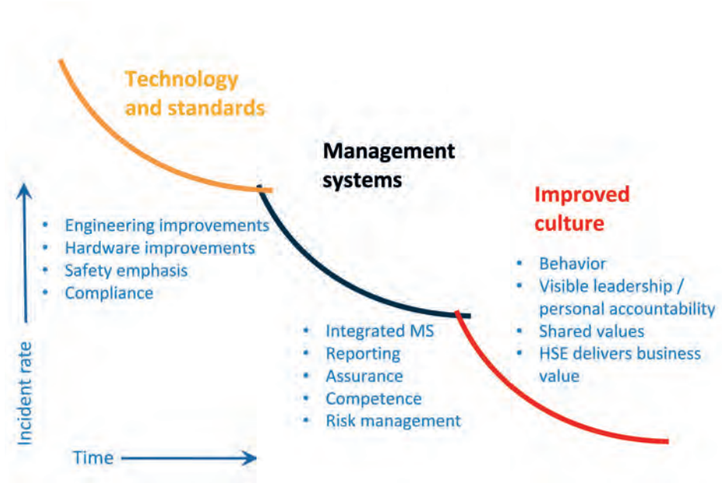


FIGURE 1

The three main shifts that improved occupational health and safety performance over the past decades.

Health and safety performance

There are three main shifts that improved occupational health and safety performance over the past decades:

1. Improvement of technology and standards.
2. Implementation of management systems.
3. Change in culture.

The theoretical scheme in Figure 1 shows how these three shifts influenced the reduction of the incident rate over time. However, it is important to note that today the three topics cannot be separated and continuous effort given to all three is necessary in order to improve even further. This is especially the case when, for example, new activities are implemented and new equipment is used such as in the renewable energy market.

Safety culture concept: Hearts and Minds model

The Hearts and Minds model originated in Shell and is based on a £20 million research programme carried out in the 1980s, 1990s and 2000s – research that is still going on today. The fundamental concept behind Hearts and Minds is that the implementation of a safety management system is the starting point to improving safety and operational performance, not the end. Through leveraging the people in an organisation, companies can improve the way tasks are performed, the conditions under which they are performed and the safety management system itself – thereby improving the "culture" of the organisation. Improving the culture can not only improve safety, but also efficiency and well-being.

An organisation's safety culture is "the way we do things around here in respect of safety". It is a simplified way of understanding the common attitudes, beliefs and behaviours of a team, project or organisation that results in their collective approach to managing safety. Culture improvements are a way of improving safety that do not focus on individual workers, but on an organisation as a whole. Ultimately, an organisation with a high level of safety has created an environment and means that encourages and enables a safe operation.

The concept of safety culture was first introduced by the INSAG (International Nuclear Safety Group) who attributed the cause of Chernobyl Nuclear accident to a lack of safety culture. The concept of "safety culture" relates to a general concept of dedication and personal responsibility of all those involved in any safety related activity at a nuclear power plant. The Chernobyl accident was assessed with this "culture" concept and they concluded that not only those involved in the operational stage lacked an adequate safety culture, but also those involved in other stages of the lifetime of a nuclear power plant (i.e. designers, engineers, constructors, equipment manufacturers, ministerial and regulatory bodies, etc.).

> **There has been one continuous factor over the past 50 years – the motivation and willingness to improve.**

Safety culture ladder

The safety culture ladder (shown in Figure 2) characterises the different levels of cultural maturity and the change process that is necessary to achieve a lasting change at the personal and organisational culture level. The various characterisations of the cultural levels help organisations to discover the gap between their present level of cultural maturity and the aspired level.

Experience shows that by using a maturity model in a transformation process people become aware of the gap between the aspired level and their current attitude and behaviour, and through several steps develop the desire to commit to the required safety behaviour.

FIGURE 2

The safety culture ladder.

At the lowest level of the ladder, we find the "pathological culture" where nobody cares to understand why accidents happen and how they can be prevented. At the highest level, the "generative culture", HSE is no longer a topic of separate discussions. HSE is totally integrated in the business and therefore part of everything that is being done. In between, there is the "reactive stage" in which a great deal of attention is given to safety after an accident has happened. In the "calculative stage", people are of the opinion that they have everything in place. They can "tick the boxes" and demonstrate that everything necessary, according to the books, is being done. In the "proactive stage", they have everything in place but are still looking for further improvements.

Conclusions

Under pressure from its offshore customers, the dredging industry took measures in the 1990s to systematically reduce the number of industrial accidents. A number of phases (see Figure 1) were completed that are comparable to other industries: 1) improvement of technology and standards; 2) implementation of management systems; and 3) culture change.

In the past decade, all major dredging companies have started a company safety programme with attention to safety awareness and behaviour with the aim of continuously improving safety performance. The overall goal being to grow towards a proactive safety culture. To achieve this goal, genuine attention from senior management is indispensable. The Hearts and Minds model offers perspective for an organisation to take feasible steps.

Gradually, safety is gaining awareness and attitude among management, employees and contractors, and companies are building a mature safety culture that ultimately influences a safe working environment in day-to-day operations.

CASE STUDY 1: SAFETY CULTURE OF VAN OORD

Since 2013, QHSE Director, Ton van de Minkelis has been involved in the safety journey of Van Oord. Responsible for continuously driving the safety culture to a higher level, he describes his experiences and the key interventions that have proven successful in continuously reinforcing safety awareness and behaviour within the organisation.

Safety in practice

In the years 2003–2010, Van Oord set up a fully integrated management system, certified at the time against the well-known international quality, environment and safety standards. It is noticeable that the number of registered accidents within the organisation increased in the first few years (Figure 3). This is explained by the fact that an organisation starting to implement an incident procedure must learn to report incidents. In general, only major incidents are reported in the initial phase involving people who suffer permanent injuries or worse. The peak in the numbers in 2007 can be explained by the fact that Van Oord executed a number of large-scale projects in the Middle East involving many foreign employees. This served as a turning point for the industry when awareness arose that procedures in themselves do not actually improve safety in day-to-day operations.

As a result, Van Oord made a start on putting the paper management system into practice. A QHSE department was set up to develop practical instructions and training tailored to the inexperienced employees who were recruited and deployed locally. In retrospect, this effort and supervision of the construction site paid off. A fact also reflected in the accident figures.

Management attention to safety

In 2011, senior management became acquainted with the Hearts and Minds model and asked an external consultancy to supervise a safety culture programme.

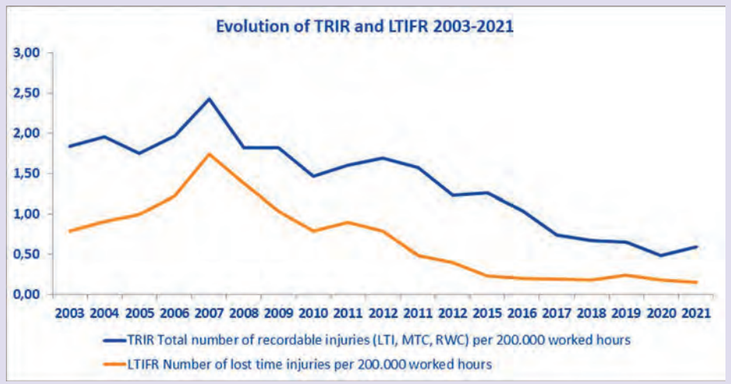


FIGURE 3

Number of personal injuries within Van Oord over the past 20 years.

Discussions were held with the top 40 executives of the organisation about their perception of safety and what ambitions they had regarding the safety performance of the company. Based on these conversations, the consultants concluded that management was, at that time, very reactive; step two on the safety culture ladder (see Figure 2). The consultants explained to senior management that their own behaviour was key for success. Whilst the result was the ambition to create a proactive safety culture, senior management realised there was a long road ahead in changing the culture. And so the decision was taken to recruit a senior QHSE professional who would be an integral part of the Management Committee.

Safety Leadership Training programme

In 2013, as the new QHSE Director, I started developing a Safety Leadership Training (SLT) programme. The content of the training, in addition to an explanation of the loss–control risk model, is focused on behaviour, leadership, exemplary behaviour and cultural factors that are important. Time is given to discuss the dilemmas encountered in practice in an interdisciplinary manner. When the programme began, the plan was to train all managers and vessel captains of the company within two years. Looking back on this first period, the active involvement of the CEO and COO was extremely important. They emphasised the importance of safety at the start of each training programme and received the improvement proposals from the group at the end of the day, which they then discussed in the evening.

Later, the target group was expanded to include all key personnel within the organisation, including staff departments. After a two year break due to the COVID-19 pandemic, the 100th SLT will be held this spring. During the course, participants are introduced to the safety culture of Van Oord and learn what is expected of them as leaders. It also provides an opportunity for people to meet new colleagues from other departments and to discover that everyone can contribute to safety from their own discipline. It became clear that the success formula of the Safety Leadership Training programme is: multidisciplinary groups of participants; time in the programme for participants to reflect on their own role as a safety leader; and that an Executive Committee member is always present to interact with participants.

Monitoring the safety culture

Safety culture is intangible and difficult to capture in objective measures. However, it is important to test a safety culture programme for its effectiveness as well as to evaluate which aspects should receive more attention in the programme. In 2014, TNO was commissioned to measure the effectiveness of the Safety Leadership Training (SLT) programme and to investigate the safety culture among the top 450 managers within the company. The survey showed that the safety culture had transformed into the calculative stage (see Figure 2). In addition, the safety behaviour of supervisors who had participated in the SLT was assessed more positively by their colleagues and direct reports.

In 2016, the measurement was repeated amongst all employees of the organisation. The awareness of the new corporate safety campaign was also measured. The results of this survey indicated that most departments and areas scored quite well on the proactive safety level. The extent to which staff feel safe to speak out and give feedback was also measured. This showed that giving feedback to each other and being open to feedback should be improved. In 2018, the decision was taken to certify the safety culture on the basis of the NEN Safety Culture Ladder (SCL) Certification Scheme. Without additional measures, Van Oord has been certified at level 4 SCL from that time on.

> **Whilst the result was the ambition to create a proactive safety culture, senior management realised there was a long road ahead in changing the culture.**

FIGURE 4

Van Oord's safety principles and life-saving rules.

Corporate safety campaign: Say YES to safety

It is important for a large company to develop an appealing safety campaign that is in line with the company values. Derived from the company values "care" and "working together", five safety principles were defined as guidance for personal behaviour expected of all Van Oord staff and contractors. The safety principles are about taking responsibility for health and safety, leading by example, giving feedback and being familiar with the procedures and reporting incidents.

Nine life-saving rules (see Figure 4) have been defined on the basis of the analyses of serious accidents from previous years. The common safety icons used in the industry were used, where possible, for the campaign materials.

Risk management

The basic principles for managing and mitigating project risks are contained in a well-organised process covered by the HSE risk management flowchart (see Figure 5). Hazard Identification and Risk Assessment, Job Safety Analyses (JSA) and Permit to Work (PtW) and the Last Minute Risk Assessment (LMRA) are used

FIGURE 5

HSE risk management flowchart.

in all companies within the dredging industry. Within Van Oord, safety tools are explained in a practical training course, which is mandatory for all project employees. The success of such safety tools strongly depends on how they are used in practice. The role of the direct supervisor is therefore decisive in this regard. That is why active supervision and the openness and trust to stop the job are integrally part of the model.

New role of HSE professionals

Getting the company's HSE staff involved in the transformation of the organisation's safety culture should not be forgotten, as they too must change their approach and behaviour. An unambiguous approach and use of the safety procedures by all HSE professionals is in itself a challenge. However, if an organisation shifts to a proactive safety culture, HSE professionals must learn how best to ease the transformation process. The line/project managers will feel intrinsically responsible for safety and will demand more and different requirements from the HSE professionals on their projects. The role of HSE staff is shifting from a hand-on safety officer on site, to a sparring partner who has to provide safety/technical support in the design and project preparation phase and a more coaching role in the execution phase of a project.

Continuous attention to safety culture

Experience shows that after years of a declining trend in the number of accidents, the safety performance of Van Oord remains at a plateau (see Figure 3). This is a critical moment. It is the phase in which senior management is quite satisfied with the outcome of the culture programme. The sense of the "new" is gone and the top of the organisation is occupied with new issues that require priority, such as sustainability and digitisation. Complacency is lurking and the chance that the safety culture will fall back is a real danger. In 2019, a number of serious accidents occurred within Van Oord in a short period. This served as a wake-up call and prompted the company to organise a large-scale safety event, the Safety News Alert. Following its success, another major event was organised in 2021 with the theme Thanks to Safety, where the subject of mental health and well-being was explicitly discussed.

Maintaining and improving the safety culture of an organisation is a long-term process. Constant attention to safety at all levels, with a focus on learning from mistakes and improving processes is necessary. In addition, training and educating newcomers is essential to the company's safety performance. It is vital that they know what is expected of them and understand the importance of their contribution to safety for the company as a whole.

CASE STUDY 2: SAFETY CULTURE OF JAN DE NUL

With over 23 years as a QHSSE specialist, Christophe Leroy has worked on many international dredging and offshore projects. He has seen many changes and transitions in the approach towards occupational health and safety in the dredging industry over that time. He shares his experiences in his role as QHSSE Manager for Jan De Nul, having built the company's safety management system and culture.

The importance of training

My first few months as QHSSE advisor working for a joint venture (JV) on an offshore project was a challenge. For a start, I was the first QHSSE advisor working on international projects for Jan De Nul Group. As a result, no one in the company was able to train or guide me in my new function, except for some external persons with oil and gas experience who had been hired for the project.

The situation today is completely different. An extensive training programme is in place for all new personnel joining the organisation. This includes an intensive four weeks familiarisation with the company, the business aspects and the management systems, etc. Training of personnel within Jan De Nul Group is continuous throughout an employee's career. It is both essential for personal development as well as for the continuous improvement of company performance.

The importance of training and education is increasing due to fact that the number of trainees is significantly on the rise. This can be attributed to several factors, such as more vessels, shorter swings (i.e. 6 weeks on/6 weeks off opposed to 2 months on/1 month off), less seafarers, more sophisticated equipment and techniques, etc.

Slowly but surely, the mentality towards occupational health and safety in the maritime industry changed.

Today, QHSSE professionals are an integral part of project teams.

Therefore, we focus on:

1. Safeguarding knowledge, following both failures and successes.
2. Sharing knowledge: on the job, but also by means of traditional classroom sessions.
3. Enhancing skills via simulation-based training, involving the use of equipment and computer software to model a real-world scenario.
4. Improving guidance and support from head office to assist the teams on board and on site.

The changing role of a QHSSE advisor

Going back to my first assignment within the company, within the JV, my tasks and responsibilities were not clear – not to me, nor to my colleagues. A QHSSE advisor was a kind of nuisance on site, an obligation under the contract with the oil and gas client and not as a benefit to improve the overall process. Some examples: The instructions that I received from the JV project management was "to keep the client satisfied with reports, without causing too much trouble for the people carrying out the work". After an incident investigation, it was stated "we use our equipment until it breaks" versus planned maintenance. On my second project, the primary tool of a QHSSE advisor was a camera to "catch people". Oil spills, large or small, were not considered as important.

Fast-forward 23 years and it's a very different story. Today, QHSSE professionals are an integral part of project teams, working together to assess and control all aspects of the works. Incidents are thoroughly investigated and preventive actions are put in place to prevent reoccurrence. Assets are subjected to rigorous planned maintenance systems. Spills of any type, large or small, are taken seriously and even more important is the mentality that "prevention is better than cure". Needless to say, the education of occupational health and safety professionals has improved tenfold over the years. For instance, in Belgium, the Masters programme in Prevention and Environmental Management, which did not exist 20 years ago, is widely popular and a huge success.

Occupational health and safety ambitions and subsequent performance used to be client or audit driven. However, slowly but surely, the mentality towards occupational health and safety in the maritime industry changed. The initial support to do so came from oil and gas clients, as well as government legislation. At a later stage, renewable energy clients also set the standards. QHSSE in general became more professional and had a larger contribution on the safe way of working. Companies now have the maturity to define their own values and ambitions. Companies strive for a high safety performance because it is important for themselves, not because a client or auditor asks them to do so.

Safety standards and certification

Besides the influence of clients, the implementation of the ISM code on board of vessels resulted in a large shift in mentality and performance. When I started in 1999, all but a few vessels of the Jan De Nul fleet had gone through the complete process of ISM certification. One of my tasks was to assist the last remaining vessels for their intermediate audit. During the preparation of these vessels, it was obvious that safety management systems were not sufficiently organised or implemented on board. For example, regarding fire drills, fire suits were found in original packaging, there were no assigned firefighting teams and crew had not even been trained on how to put on the fire suits.

The situation today is that the implementation of a safety management system as per ISM has been a huge lever to raise the safety performance on vessels. This includes creating safe working practices and working environments, making suitable safeguards against potential risks and continuously improving the safety management skills of personnel, as well as the development of emergency response plans for both safety and environmental protection. By adopting the Offshore Vessel Management and Self-Assessment (OVMSA), Jan De Nul aims for the higher level of safety.

In the 1990s, many large companies were already ISO9001-certified. The standard for

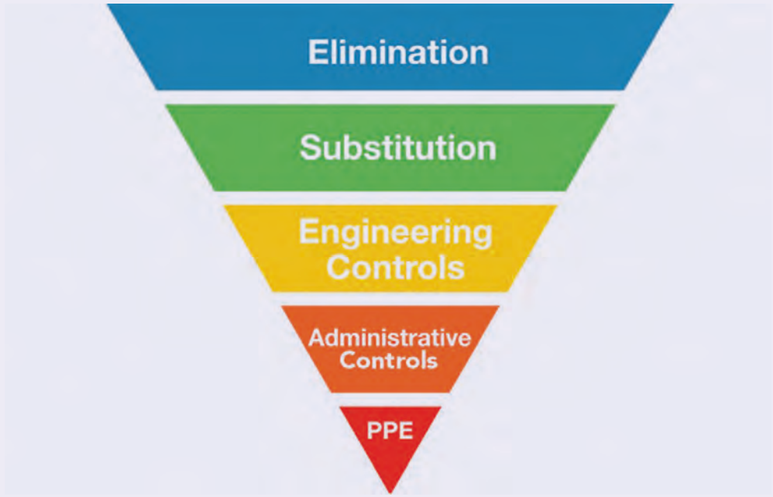


FIGURE 6
Hierarchy of controls.

Quality Management Systems was first published in 1987. In 1996, two standards were released covering management systems for occupational health and safety (OHSAS 18001 – today known as ISO 45001) and environmental (ISO 14001). While implementing these standards, the focus was often "how to pass the next audit" and procedures were adopted "because the auditor raised a non-conformity".

The implementation and follow-up of a management system is very much incorporated in today's daily business as it keeps us from deviating. Improvements are made to adopt one integrated management system instead of various management systems that co-existed next to each other. There is a wide range of audits and inspections. Every week, audits are performed by external parties, such as authorities, clients, certification bodies or internally. The number of safety drills per year is more than 1,000.

Safety by design

Planning the work and dealing with risks was more a matter of paperwork in the old days. Risks were often mitigated by defining the correct Personal Protective Equipment (PPE). Employees were not too much involved when risks and mitigating actions were defined. Today, as part of the Plan-Do-Check-Act circle, risks and opportunities are assessed during every step of the process, from company and project level to Last Minute Risk Assessment (LMRA) on the work floor.

Dealing with risks brings us to the hierarchy of control pyramid (as shown in Figure 6), which is a system for controlling risks in the workplace. It is a step-by-step approach to eliminating or reducing risks and ranks risk controls from the highest level of protection and reliability through to the lowest and least reliable protection. Eliminating the hazard and risk is the highest level of control in the hierarchy, followed by reducing the risk through substitution, isolation and engineering controls, then through administrative controls. Reducing the risk through the use of PPE is the lowest level of control.

Today, safety awareness is such that PPE is only the last resort and safety by design – that aims to anticipate and prevent harm that might occur while using equipment rather than trying to implement remedies after the harm has occurred – is the start of each new project.

A way to build strong employee buy-in is to involve them in the process from day one. Establishing a safety committee with employees from all areas of the organisation provides a forum for different opinions and issues. Some examples are the on board safety committees and the safety awareness programme Image-Think-Act (ITA) and its ambassadors through whom a two-way communication concerning safety issues are addressed.

As the scheme in Figure 3 shows, the incident trend in Van Oord decreased, until a certain bottom was reached. All systems were in place but serious accidents still occurred all too often and other actions next to improving the management system were required.

Unfortunately, also within Jan De Nul Group, we reached that moment in 2014 when two serious incidents occurred within a short period. The conclusion was that no additional procedures were required but the culture and awareness of people had to be improved. Also in this respect, the oil and gas sector paved the way with the Hearts and Minds model. It took a long time before everyone was convinced that having incidents is an indicator for processes not under control, resulting in a higher chance of damages and a less profitable business.

Positive approach and collaboration

The dredging industry has significantly grown. Occupational health and safety has even been incorporated in Corporate Social Responsibility (CSR) policies. Health and safety does not only create a better working environment for own co-workers, but also for those people and stakeholders involved and affected by the activities. CSR is nothing else than a "duty of care", an expression which has been around since the 1800s.

In 2015, Jan De Nul Group launched its first campaign to improve the safety culture across the entire company. The campaign Image-Think-Act (ITA) promotes safety awareness focussing on: 1) leadership; 2) critical risks and life-saving rules; 3) ownership and accountability (Just culture); and 4) communication. The ITA programme focusses on operational control, i.e. the way to achieve less incidents instead of just achieving the target of less incidents. In 2021, the ITA programme was supplemented by the Code Zero programme that focusses on the goals "Zero Accidents", "Zero Waste", "Zero Emissions" and "Zero Breaches".

Companies used to be ashamed of incidents. There was no openness; lessons were certainly not shared with outsiders and sometimes even not with insiders. Since I joined IADC's safety committee in 2014, I have been actively involved in promoting a more open environment where dredging contractors can learn from each other's lessons. The purpose is still to grow as an industry. Safety is less considered as an area where the different contractors need to compete with each other but more as a possibility to improve as a whole. This open culture is a clear sign that the dredging industry as a whole has developed to a higher level of safety culture.

Instead of analysing incidents, where we focus on the negative impact, we shift our focus to successes. I once came across the comparison with the way a football coach manages their team: more games are won by addressing what the players do well instead of pointing out their weaknesses. That positive approach works is also translated to our industry in monitoring leading indicators (e.g. number of trainings, reporting of near misses, etc.) and adopting a positive safety culture, which is easier to build and maintain amongst employees.

Collaboration amongst various teams can create the right synergy to improve processes and work situations. Therefore, Jan De Nul Group has established an operational control committee, one for each of its business units, with members from various departments. On a monthly basis, improvement suggestions rising from good ideas as well as from incidents are analysed and concrete actions are defined to share knowledge and continuously improve the safety and operational control level.

> **This open culture is a clear sign that the dredging industry as a whole has developed to a higher level of safety culture.**

Summary

This article explores the progress of health and safety in the dredging industry and HSE professionals, share their experiences in building the safety culture within marine contractor organisations. Having built the safety management system and culture of Jan De Nul, Christophe Leroy shares his knowledge and lessons learned during his career within the dredging industry. And Ton van de Minkelis describes the systematic approach he has successfully applied to raise the safety culture at Van Oord to a higher level.

Ton van de Minkelis

Ton holds a bachelor's degree in Mechanical Engineering and a masters in Industrial Engineering and Organisation Development from Eindhoven University of Technology. From 1990-1993, he worked as a manufacturing engineer at Fokker Aircraft and in 1993 became Technical Manager at Det Norske Veritas responsible for all certification schemes in Benelux. In 2000, Ton joined Fokker Aerostructures as SHE-Q Director. Since 2013, he is QHSE Director of Van Oord, responsible for the deployment and improvement of the QHSE policy within the global organisation.

Christophe Leroy

In 1996, after completing two master degrees in Electro-mechanical Engineering and Civil Engineering, Christophe worked as a civil superintendent for Mansfelder Kupfer und Messing in Germany. In 1999, he joined Jan De Nul Group as Project Quality/HSE Manager and for 14 years worked on various international dredging and offshore projects around the world. Since 2015, Christophe is QHSSE Manager, responsible for the Quality Health Safety Security Environmental vision and strategy of the entire Jan De Nul Group, including daily development and implementation of QHSSE systems and monitoring the QHSSE performance.

References

Aerossurance (2016)
Chernobyl: 30 years on – Lessons in safety culture. Report 26 April. http://aerossurance.com/safety-management/chernobyl-30-years-on

Energy Institute
Heart and Minds model and toolkit. https://heartsandminds.energyinst.org

Jan De Nul (2021)
Code Zero programme, https://www.jandenul.com/code-zero

NEN
Safety Culture Ladder and web tool. https://www.nen.nl/arbeid-veiligheid/safety-culture-ladder

Roznowski A. A. (2015)
Building a proactive safety culture through the use of safety analysis and job safety analysis audits, *Terra Aqua*, #140, pp19-25, September.

Shell Global Solutions International B.V. (2016)
Heart and Minds Programmes The road map to improved HSE Culture, Symposium Series No 151.

Step change in safety (2000)
Changing Minds: A practical guide for behavioural change in the oil and gas industry.

Swuste P., van Gulijk C., Zwaard W., Lemkowitz S., Oostendorp Y., and Groeneweg J. (2019)
Van Veiligheid naar Veiligheidskunde (From safety to safety science), VakMediaNet, Alphen, The Netherlands.

Van Oord (2016)
Say YES to Safety Guidance, https://www.vanoord.com

50 YEARS OF CASE LAW THAT TRANSFORMED MARINE INFRASTRUCTURE CONTRACTS

This article reviews various court cases over the past 50 years and considers their influence on marine infrastructure contracts and the allocation of risk between contract parties. The establishment of case law and legal precedent is an ever-evolving process, it being dependent on claimants to put their disputes through the court process to seek the outcome they desire. It is often a long and costly process. The rise of adjudication in various common law jurisdictions and countries means that often disputes are resolved without recourse to the courts and various industry standard contracts have arbitration as the final and binding mechanism to resolve disputes.

Arbitration not litigation

All marine infrastructure contracts make use of a dispute resolution clause. The terms of this clause may vary depending on the nature of the project and the type of contract chosen. Parties are free to select the type of dispute resolution process that suits their needs. More often than not parties prefer to resolve any disputes in private rather than in a public forum such as litigation in the local courts. Quite often arbitration is chosen in marine infrastructure projects as the mechanism to reach a final and binding decision and it is regularly seen in the widely used FIDIC suite of contracts. Arbitration is a process in which the parties in a dispute use an independent, impartial third party to make a decision on the dispute.

For a process to be considered arbitration, it must involve an impartial third party, which can be a single person or a team of three people (a tribunal). It is a confidential process. Confidentially in arbitration refers to the fact that the proceedings, materials disclosed or created during proceedings and the arbitral award cannot be disclosed by the tribunal, parties, their representatives, witnesses or any other individuals attending without the consent of the parties. So this means that anyone who is not a party to the arbitration cannot rely on the arbitral decision as a precedent in other situations.

A precedent is a principle or rule established in a previous legal case that is either binding on or persuasive when deciding subsequent

cases with similar issues or facts. Common-law legal systems place great value on deciding cases according to consistent principled rules, so that similar facts will yield similar and predictable outcomes, and observance of precedent is the mechanism by which that goal is attained.

Case law, in common-law jurisdictions, is the set of decisions of the courts or other rulings that can be cited as precedent. In most countries, including most European countries, the term is applied to any set of rulings on law, which is guided by previous rulings. Essential to the development of case law is the publication and indexing of decisions for use by lawyers, courts and the general public, in the form of law reports.

Judges are bound by the law of binding precedent in England and Wales and other common law jurisdictions. This is a distinctive feature of the English legal system. In many countries throughout the world, particularly in mainland Europe, civil law means that judges take case law into account in a similar way, but are not obliged to do so and are required to consider the precedent in terms of principle. They are however, often considered as persuasive.

While all court decisions are precedent (though at varying levels of authority as discussed throughout this article), some become "leading cases" or "landmark decisions" that are cited often whilst others are passed over. A number of the cases cited in this article have or are in the process of becoming landmark decisions, which legal practitioners and arbitral tribunals have to or will follow.

This is where arbitration and the common law jurisdiction legal system differs. Disputes have to be resolved in a court for a precedent to be set which is published and can be later relied on by others. It is a little a chicken and egg situation as in arbitration proceedings the parties may quote legal precedent to support their case so the development of legal precedent is vitally important.

Disclaimer clauses are rarely tested in the courts and the results vary widely.

FIGURE 1

Drilling and blasting is a specialised operation. Photo © Anko Bos.

It should be appreciated that only a small fraction of disputes end up in the courts and this only occurs when litigation is chosen as the method of resolving disputes. It is for this reason that such decisions and precedents are eagerly examined and discussed.

Case law 50 years ago – two Australian cases

Looking back at what issues and events were current 50 years ago, there were two significant legal cases in 1972 that are worth looking at: Dillingham Constructions Pty Ltd v Downs (1972) and Morrison-Knudsen International Co Inc v Commonwealth (1972). Two cases both involving ground condition claims but with radically opposing decisions.

Dillingham, the claimant, contracted with the New South Wales Government to deepen Newcastle harbour. When work began, the claimant did not attain the anticipated rate of progress because the blasting operations designed to break up the harbour floor were unsuccessful. Other methods of working had to be adopted with consequent delay and expense. There were disused coal mine workings under the harbour and the claimant concluded that these were the reason for the ineffectiveness of the blasting. The government had known of the workings all along.

The claimant sued the government claiming damages for breach of warranty and negligent misrepresentation inducing entry into the contract. With respect to the latter, they alleged that the New South Wales Government owed and was in breach of a duty to take reasonable care in providing details relevant to the condition of the work site, a duty which obliged the government to disclose the presence of the coal mine workings. Justice Hardie, in the New South Wales Supreme Court, found for the government in respect of both the contract and duty of care claims. In rejecting the contractor's claim, Justice Hardie stated that a party who has contracted to carry out building work on or under land is duty bound to satisfy themselves of the nature and characteristics of the land both on the surface and below it.

This decision in retrospect seems quite a harsh decision but the general rule is that a contracting party is not subject to a duty of disclosure and that mere silence cannot amount to misrepresentation. Contrast this with the civil law requirements of "good faith" where such failure to disclose would more likely have been unacceptable.

Now some 50 years later and the standard construction contracts, such as the FIDIC Blue Book *Form of Contract for Dredging and Reclamation Works* (Second edition) and other contracts in the FIDIC suite, require that an employer shall have made available to the contractor for his information, prior to base date, all relevant data in the employer's possession on sub-surface conditions at the site. The NEC contract goes further by including site information in the contract itself and referring to publicly available information or other information that an experienced contractor could reasonably have expected to have or obtain.

It is worth contrasting the decision in Dillingham with Morrison-Knudsen International Co Inc v Commonwealth. Morrison-Knudsen was an action by a contractor against the employer for negligence. The contractor claimed that basic information supplied by the employer at pretender stage "as to the soil and its contents at the site of the proposed work was false, inaccurate and misleading... the clays at the site, contrary to that information, contained large quantities of cobbles."

It was decided that a factual misrepresentation made during pre-contractual negotiations by one party and relied on by the other may give rise to liability under the Misrepresentation Act 1967. In an appropriate case, such liability could attach to inaccurate information about ground conditions.

As Chief Justice Barwick stated: "The basic information in the site information document appears to have been the result of much highly technical effort on the part of [the employer]. It was information which the [contractors] had neither the time nor the opportunity to obtain for themselves. It might even be doubted whether they could be expected to obtain it by their own efforts as a potential or actual tenderer. But it was indispensable information if a judgment were to be formed as to the extent of the work to be done..."

So two cases on sub-surface conditions but with radically differing outcomes. In both these cases, it was all dependent on what was pleaded before the court. When comparing the present situation with 50 years ago, the good news is it is now standard practice to have a provision that all relevant data in the employer's possession is given to the contractor.

Only a small fraction of disputes end up in the courts and this only occurs when litigation is chosen as the method of resolving disputes.

However, in the past 20 years or more, the author has seen the rise of sinister "disclaimer" and "non-reliance" clauses, mostly in common law contracts where liability for the accuracy of any information provided is disowned by the employer. These disclaimer clauses are rarely tested in the courts and the results vary widely depending on the disclaimer wording.

Mid-1970s – UK cases

Later in the 1970s, there were two cases that followed: Bacal Construction (Midlands) Ltd v Northampton Development Corporation (1975) and Howard Marine and Dredging Co Ltd v A Ogden and Sons (Excavations) Ltd (1978).

In the former case, Bacal the contractor, had been provided with a soil survey when tendering. A letter from the quantity surveyor then required the soil conditions disclosed to be assumed by the contractor in relation to six foundation blocks it was required to design and price. No indication was given as to the presence of tufa, a spongy soft material, and the foundations had to be redesigned. The Court of Appeal agreed with the decision of the trial judge that the employer had warranted that the soil information was accurate.

The Bacal case does not sit easily with the idea that there is no implied warranty given by the employer in relation to tender information. Where the employer instructs the contractor to design and build on the basis that it must assume soil information is correct, an implied warranty by the employer has been found to exist. This is presumably why the employer's legal advisors seek to include disclaimer clauses in the contract.

It highlights the distinction between an employer who says certain soil conditions are assumed and leaves it to the contractor to investigate the actual conditions, and an employer who requires the contractor to assume certain conditions when submitting a tender or producing a design. This remains an item of contention almost 50 years later as wording is often used that states the contractor at time of tender has to "investigate" the site when all that can be done is to "inspect" the site. Care should be taken when such investigation wording is used as the implications are potentially very significant.

Howard Marine and Dredging Co Ltd v A Ogden and Sons has become a landmark decision and is quoted in many legal textbooks and commentaries. Ogden Ltd wanted to hire some barges from Howard Marine in order to dispose of excavated clay at sea. Mr O'Loughlin, Howard Marine Ltd's employee, told Mr Redpath, Ogden Ltd's employee that their German built barges could carry 1600 tonnes (deadweight, rather than cubic capacity). This was based on the Lloyd's Register for barges. Unfortunately, and highly unusually, the Lloyd's Register was actually incorrect. The true capacity was not 1600 but 1055 tonnes. Mr O'Loughlin was aware that the German shipping documents stated the correct figure of 1055 tonnes. But he preferred the Lloyd's Register. The charter party contract for the hire of the vessel stated Ogden Ltd's acceptance of the barges confirmed they were in every way satisfied. When the barges proved to be insufficient for the task, Ogden Ltd refused to pay the full price. Howard Marine Ltd terminated the agreement and sought payment of all the outstanding payments.

Howard Marine Ltd stated they had reasonable grounds to believe their false statement, because the Lloyd's Register was the "bible". The Court of Appeal (Lord Denning MR, Bridge LJ and Shaw LJ) all held there was

FIGURE 2

Jack-up barges are often used for site investigations.

no breach of warranty, but decided by a majority that Howard Marine Ltd was liable for breach of duty under Misrepresentation Act 1967 s 2(1).

1980s – Australia and UK cases

The Westham Dredging Company Pty Ltd v Woodside Petroleum Development Pty Ltd (1983) is an interesting and unique case to Australia. It was brought under section 52 of the Trade Practices Act 1974 (Cth) which states that corporations are prohibited from engaging in "unconscionable" and "misleading or deceptive" conduct. This legislation is unique in that the statutory provisions are not limited to consumer transactions but extend to cover the pre-contractual and contractual relationships entered into between commercial parties themselves.

Westham, the claimant, argued that the site investigation was insufficient in that it did not fully describe the actual soil conditions so was misleading. Judge St John found that the Trade Practices Act was concerned with protecting consumers and that it was not possible to extend the operation of the Act to protect commercial interests. Provisions of the Act were to be read down by reference to the heading "Consumer Protection". This decision in Westham was subsequently overruled by the Full Federal Court in Bevanere Pty Ltd v Lubidineuse on the basis that Judge St John's views were inconsistent with the binding authority provided by the High Court in Hornsby.

Some cases become "leading cases" or "landmark decisions" that are cited often.

The UK case of Blue Circle Industries v Holland Dredging Co (1987) is a case where works involved dredging in Larne Lough in Ireland to enable larger vessels to dock. The tender referred to the dredged material being deposited in areas approved by the public authorities, the intention being to discharge the material excavated in suitable areas in the Lough.

An alternative plan was agreed to use the excavated material to form an artificial bird island. The employer accepted the contractor's quotation for this work by letter, which stated that an official works order would follow in due course. The execution of the works to construct the island was unsuccessful and the employer brought proceedings. It was argued by the contractor that this was not a variation to the works within the confines of the contract but a separate contract in its own right. The decision in Thorn v Mayor and Commonalty of London, a case heard way back in 1876, influenced the court.

In Blue Circle, it was held that if the additional or varied work were so peculiar, so unexpected and so different from what any person reckoned or calculated upon to such an extent that it is not contemplated by the contract, then it would constitute a separate contract. The judge in the case considered that the construction of the bird island was wholly outside the scope of the original dredging contract and therefore constituted a separated contract.

1990s – UK cases

In June 1991, the Court of Appeal decided the case of Humber Oil Terminal Trustees Ltd v Harbour and General Works (Stevin) Ltd concerning unforeseeable ground conditions and the application of clause 12 of the Institution of Civil Engineers (ICE) conditions of contract. This was the first case where the notion of the "experienced contractor" was tested in court. FIDIC's own clause 12 in the 1987 Red Book and later clause 4.12 in the FIDIC 1999 suite of contracts has many similarities with ICE's clause 12.

A ship named "Sivand" had damaged the harbour installations owned by Humber as a result of negligent handling. Humber had engaged Harbour and General as contractors to carry out repairs under the ICE conditions of contract. The contractors used a jack-up barge, equipped with a 300 tonne fixed crane.

Whilst it was lifting a large concrete soffit, the barge listed, became unstable and collapsed. It was a total loss. Extensive damage was caused to plant and equipment, and much delay and other expense ensued.

Harbour and General claimed under clause 12 of the ICE conditions that the collapse of the barge with its consequences was due to physical conditions, which could not reasonably have been foreseen by an experienced contractor. Humber argued against this, saying that the collapse was a consequence of the contractor's temporary works, and by reason of 8(2) of the ICE conditions was the responsibility of the contractor.

An arbitrator had found that although the soil conditions at the base of the leg of the barge were foreseeable, there must have been a very unusual combination of soil strength and applied stresses just before the failure occurred. This constituted a physical condition for the purposes of clause 12, which could not have been foreseen by an experienced contractor.

This was maintained on appeal. Still Humber were unsatisfied and they appealed to the Court of Appeal on the basis that: 1) an applied stress could not be part of a physical condition as it was transient and could not be "encountered"; and 2) in circumstances such as this, clause 12 must be over ridden by clause 8(2), which placed on the contractors an unqualified responsibility for the adequacy, stability and safety of all site operations and methods of construction.

Once again, the Court of Appeal rejected the appeal. It held that applied stress, namely the loading of the barge, may be a part of a physical condition within the meaning of clause 12, since the nature of the ground cannot be discovered without an actual or notional application of some degree of stress on it. They also held that clause 8(2) concerning itself with contractor's temporary works, did not limit or restrict the ambit of clause 12. Consequently the contractor was entitled to be paid for all the costs and consequences of the jack-up barge collapse.

This case had a significant impact on the adverse physical condition provisions in contracts that were subsequently drafted by both the NEC (New Engineering Contract) published by the Institution of Civil Engineers in 1993 as well as the later publication of the FIDIC Rainbow Suite in 1999. The NEC3 Contract in its core clause 60.1 (12) states: The contractor encounters physical conditions which:

- are within the site;
- are not weather conditions; and
- an experienced contractor would have judged at the Contract Date to have such a small chance of occurring that it would have been unreasonable for him to have allowed for them.

Only the difference between the physical conditions encountered and those for which it would have been reasonable to have allowed is taken into account in assessing a compensation event.

The FIDIC 1999 suite (with the exception of the Silver Book) now defined "unforeseeable" meaning not reasonably foreseeable by an experienced contractor by the date for submission of the tender and "physical conditions" meaning natural physical conditions and manmade and other physical obstructions and pollutants, which the contractor encounters at the site when executing the works, including sub-surface and hydrological conditions but excluding climatic conditions.

Both NEC3 and FIDIC 1999's wording are a seismic shift from the past and it is the author's opinion would likely have not come about but for the Humber Oil case. It supports the rationale that in certain instances it is in the construction industries best interest to have disputes litigated in the courts rather than arbitration when a legal precedent needs to be set. Later in this article, in more recent events in 2021 concerning the NEC contract and the obligation to act in "a spirit of mutual trust and co-operation", this has proven to be the case.

2000s – various cases

In the early 2000s, the offshore wind market was in its infancy. A claim arose on a project that went to the courts, Enertrag (UK) Ltd v Sea & Land Power and Energy Ltd (2003).

As part of an offshore wind farm project, Enertrag (one of the wind farm developers) approached Sea & Land Power and Energy (SLP) to manufacture a weather mast as part of its project. Fabrication of the mast began before a formal contract was entered into between the two parties. It was later agreed that installation of the mast would constitute a variation of the agreement to manufacture the mast. When the installation of the mast failed, Enertrag brought proceedings against SLP for delivery of the mast and for the cost of an alternative onshore meteorological system.

SLP counterclaimed that the installation failed as a result of Enertrag who did not carry out a soils investigation and selected the proposed alternative sites for the mast. SLP also said that the delay was caused by adverse weather conditions that were a force

The Humber Oil case had a significant impact on the adverse physical condition provisions in contracts that were subsequently drafted.

FIGURE 3

Offshore wind projects are a significant part of the energy transition.

majeure (i.e. outside either of the parties' control) event under the terms of the agreement for which Enertrag had accepted the risk. Enertrag denied this and said that SLP was responsible for both providing a "turn-key" service and for carrying out the necessary soil investigations and for selecting an appropriate vessel to carry out the work.

The court had to consider in Enertrag v SLP which of the causes was the dominant cause of the failure. After considering the facts, the court stated that the dominant cause of the failure to install the mast was the failure of SLP who should have properly interpreted its own expert advice and in turn advised Enertrag that proper soil investigations were needed. Such a failure amounted to a material default under the terms of the variation, which constituted the entire agreement between the parties and superseded all negotiations, representation or agreements that took place before the variation.
And so the notion of the "experienced" contractor was starting to develop teeth but it would only be in subsequent cases in 2006, 2014 and 2015 that would flesh out the extent of what an experienced contractor would be expected to do.

In 2006, a decision was rendered in the case Associated British Ports v Hydro Soil Services NV and others which dealt with adverse physical conditions, the experienced contractor and when design is considered "fit for purpose".

The next frontier in case law will be testing in the courts of the application of disclaimer and non-reliance clauses in contracts.

Associated British Ports (ABP) engaged Hydro Soil Services to carry out strengthening works to a quay wall at Southampton, UK. The contract was for a lump sum and based on the ICE conditions of contract. Hydro in turn engaged a consulting engineer to carry out the design of the strengthening works to the quay wall. The design required ground anchors to be attached to the steel wall and also the insertion of high pressure vertical grout columns along the berth. Whilst the work was being carried out, the sheet piles cracked and bulged. In some places, the bulging was almost 1 metre from the original installed position. Remedial work was required.

ABP claimed damages for breach of contract by the contractor and the contractor brought a counter claim under clause 12 for unforeseen physical conditions. In addition, a claim was made against the consulting engineer for their design. ABP argued that the works were not fit for their purpose and that the contractor should pay for all rectification work.

Based upon expert evidence, it was found that the existing condition of the sheet piling wall did not account for the widespread bulging and cracking that had taken place during the grouting. The potential over stressing of the sheet pile wall was something that an experienced contractor should have seen and therefore the clause 12 claim failed. The spacing of the columns was greater than the design spacing and there was insufficient sheer strength of the grout wall. As a result, the works were unfit for their purpose.

Equally, it was held that the design of the columns was unfit for their purpose. The original design spacing could not be adhered to and the revised greater spacing had been designed by the consulting engineer. The final design should have catered for potential variance of acceptable workmanship tolerances. The only issue arising from workmanship was the decreased diameter of the columns, which was simply bad workmanship.

In a previous case of Mirant v Ove Arup, the court found that an engineer had a duty to warn irrespective of assumptions that were made during the design. In this ABP v Hydro case it was found that the design had not taken into account the potential tolerances that might occur once the work was carried out and this failure was said to be negligent. An engineering designer therefore needs not only to warn their clients about every assumption made, but also consider construction tolerances in respect of every aspect of their final complete design.

2010 to today

The cases of Obrascon Huarte Lain SA v Her Majesty's Attorney General for Gibraltar (2014) and Van Oord UK Ltd/SICIM Roadbridge Ltd v Allseas UK Ltd (2015) have been the subject of much discussion in legal circles as they are seen as definitive cases on the notion of what is expected of the experienced contractor. Both involved adverse physical conditions claims by the contractors.

These cases have been reported on in detail in *Terra et Aqua* #162 in the article "Adverse Physical Conditions Legal Developments and changes in risk profiles". The reader is invited to download the article from the IADC website to gain a more detailed understanding of both cases; the Obrascon case being concerned with the expected volume of contaminated material on a brownfield airfield site in Gibraltar and SICIM concerning the expected amount of peat, which could be encountered for the construction of a roadway in the Shetlands. When rejecting Obrascon's claim, Justice Akenhead stated: "The contractor cannot simply accept someone else's interpretation of the data and say that is all that was foreseeable.

In the SICIM case, the judge rejected the supposition that SICIM was entitled to treat the soil report as a type of "guarantee". He stated further that it is a matter for contractors' judgment as to the extent to which they rely on the information, referring to the decision in Obrascon, and as a matter of common sense he stated that "every contractor knows that ground investigations are only 100% accurate in the precise locations in which they are carried out, and that it is for an experienced contractor to fill in the gaps."

The contractor has the burden of satisfying the experienced contractor test on the balance of probabilities.

It is precisely the "gaps" and extrapolation between borehole locations and the degree of variation between these data points that need to be assessed and to which the experienced contractor test will apply. The contractor has the burden of satisfying the experienced contractor test on the balance of probabilities and cannot solely rely on the employer's site data alone as a sort of guarantee. This is clear from the decisions of Obrascon and SICIM, along with other recent case law that reinforces this fact.

To conclude, the most recent landmark case occurred in 2021 in the Scottish Court of Sessions. All the earlier cases covered in this article were largely about soil conditions. The following case is different and relates to the NEC contract omission of scope and good faith under a common law jurisdiction – good faith principles that are much more usual under civil law jurisdictions.

The dispute was on the Aberdeen Harbour Expansion Project in Scotland and centred on the ability of the main contractor Dragados to omit works from the scope of work of its dredging subcontractor Van Oord, and how such omissions should be valued under an amended NEC3 Engineering and Construction Subcontract Option B (priced contract with bill of quantities).

The trial judge held in 2020 that the main contractor's omission of works and awarding them to other subcontractors was a breach of contract, but the subcontractor still had to comply with the instruction and that the rates for future work could be reduced in the same manner as for a lawful omission. The judge also held that even if there was a breach of the obligation to act, "in a spirit of mutual trust and co-operation," it would still result in the same reduction to rates.

The trial decision was appealed in October 2021 in Van Oord UK v. Dragados UK (2021) CSIH 50. The Scottish Inner House confirmed that the instruction was a breach of contract but reversed the other finding concerning the reduction to the rates for future work. The appeal court highlighted the importance of the obligation to act, "in a spirit of mutual trust and co-operation," and found rates cannot be reduced if a compensation event is based on a breach of contract.

The appeal court observed that the obligation to act "in a spirit of mutual trust and co-operation," is not merely an aspiration but also reflects and reinforces the general principle of good faith in a contract. The court identified three existing authorities for this: a contracting party will not in normal circumstances be entitled to take advantage of its own breach as against the other party; a subcontractor is not obliged to obey an instruction issued in breach of contract; and clear language is required to place one contracting party completely at the mercy of the other.

It was recognised that the contract allowed the contractors prices to be reduced for a lawful reduction in the work scope, but the appeal court considered that if a party does not act, "in a spirit of mutual trust and co-operation," it cannot seek a reduction in prices. It was therefore necessary to evaluate the contractor's conduct in instructing the omissions. The appeal court noted each breach of contract was a compensation event under the contract and could only be valued as such.

FIGURE 4

Van Oord's Goliath with Backacter 1100 excavator can be equipped with a 40 m³ bucket. Photo © Van Oord.

For a lawful omission, the omitted works are valued on the basis of the shorter schedule of costs and this calculation may produce a value greater than the amount payable under the bill of quantities resulting in a shortfall. Under the NEC form for a lawful omission the contractor may be entitled to recover this shortfall from the amount payable for future work.

The rate of anticipated production is therefore very important. At tender stage a "blended" rate was used for dredging, which averaged out the cost of easier and more difficult works. The subcontractor argued the omissions took out the easier work, leaving a disproportionately higher share of the more difficult work. In this case, there was first a reduction in the work scope for which the subcontractor was not paid and for any subsequent work the contractor sought to significantly reduce the rate, making any subsequent outstanding work unprofitable.

The appeal court concluded that such amendment to the rates and prices applies only to a lawful change and does not apply where an instruction is issued in breach of contract. This is because such an instruction would be invalid and not fall within the clause entitling a rate reduction.

The appeal court also noted that there is no obligation to obey an instruction given in breach of contract. "NEC3 should not be charter for contract breaking," it concluded. What is interesting is that the appeal court saw obligation to act, "in a spirit of mutual trust and co-operation," as having a real function. It is not merely an aspiration, it affects how other provisions in the contract operate.

Similarly, it is useful for contractors and subcontractors in the marine infrastructure industry now to have confirmation by way of a legal precedent that the obligation to obey instructions is limited to valid instructions issued under the contract and that a compensation event, which is a breach of contract, cannot result in a reduction of the contractor's rates and prices.

Conclusions

In looking back over the past 50 years, one can see that development in case law over the decades has had not only an impact on the development in contracts but also has helped in setting benchmarks for effective dispute resolution. The notion of the experienced contractor being a case in point, this has developed from a position that the contractor can totally rely on the site investigation prepared by the employer to the position now that the contractor has to make a reasonable and informed judgement of what lies between testing and sampling locations.

The author believes the next frontier in case law will be testing in the courts of the application of disclaimer and non-reliance clauses in contracts. Evidence in the way of court decisions is mixed on this as it depends on the specific wording and each clause is unique to its own contract. The non-reliance clause is the most sinister contract amendment seen in the last two decades as it usually specifies that the contractor warrants that they have not relied in any matter on the site investigation information to determine their prices or method of execution of the works. Time will tell when these clauses come before a court. It should be noted that no industry standard contract in the market today includes disclaimer or non-reliance clauses.

Summary

Published case law that has impacted the marine infrastructure field is very sporadic in nature. This is due to the fact that most disputes between parties are either settled directly as part of a dispute resolution process or referred to arbitration, which is a confidential process. When disputes are referred to the courts and rulings made, it gives legal practitioners an insight into the application of various legal precedents. This article reviews various court cases over the past 50 years, decade by decade, and considers their influence on contracts and the allocation of risk between contract parties. The marine infrastructure sector has contributed to a number of landmark cases right up to the present day and this has a positive impact on the development of standard contracts and the risk allocation between the contracting parties.

David Kinlan

David is a Quantity Surveyor with 35 years' experience in commercial management, pre-contract review, risk assessment, dispute avoidance, dispute management, adjudication and arbitration. He is currently a practising adjudicator and has been actively involved in both adjudication and arbitration claims. David has published various articles in *Terra et Aqua* and is the author of the book, *Adverse Physical Conditions and the Experienced Contractor.*

References

Clark W. (2021)
Construction Disputes – Seeking Sensible Solutions, London Publishing Partnership, UK.

Eggink E. (2020)
A Practical Guide to Engineering, Procurement and Construction Contracts, Informa Law by Routledge, UK.

Fédération Internationale des Ingénieurs Conseils (FIDIC) (2016)
Form of Contract for Dredging and Reclamation Works, Second Edition (Blue Book).

Fédération Internationale des Ingénieurs Conseils (FIDIC) (1999)
Conditions of Contract for Construction for Building and Engineering Works designed by the Employer, First Edition (Red Book).

Websites
https://www.bailii.org/form/search_cases.html
https://www.fenwickelliott.com/research-insight/newsletters/dispatch
http://www.cmguide.org/archives/3566

Table of cases
- Dillingham Constructions Pty Ltd v Downs (1972) 2 NSWLR 49
- Morrison-Knudsen International Co Inc v Commonwealth (1972) 46 ALJR 265
- Bacal Construction (Midlands) Ltd v Northampton Development Corporation (1975) 8
- BLR88, CA
- Howard Marine and Dredging Co Ltd v A Ogden and Sons (Excavations) Ltd (1978) 1 QB 574, CA
- Humber Oils Terminal Trustees Ltd v Hersent Offshore Ltd (1981) 20 BLR 16, QBD
- Westham Dredging Company Pty Limited v Woodside Petroleum Development Pty Limited; Maunsell and Partners Pty Limited; Stichting Nederlands Adviesbureau Voor Ingenierswerken In Het Buitenland (1983) FCA 30; (1983) 66 FLR; 14 (3 March 1983)
- Blue Circle Industries plc v Holland Dredging Company (UK) Ltd. (1987) 37 BLR 40
- Humber Oil Trustees Ltd v. Harbour and General Works (Stevin) Ltd (1991)
- Enertrag (UK) Ltd v Sea & Land Power and Energy Ltd [2003] EWHC 2196 (TCC)
- Associated British Ports v Hydro Soil Services NV and others [2006] EWHC 1187
- Obrascon Huarte Lain SA v Her Majesty's Attorney General for Gibraltar [2014] EWHC 1028 (TCC) (16 April 2014)
- Van Oord UK Ltd/SICIM Roadbridge Ltd v Allseas UK Ltd (2015) EWHC 3385 TCC
- Van Oord v Dragados UK Ld 2021) ScotCS CSIH

EDITOR-IN-CHIEF FOR QUARTER OF A CENTURY

As IADC celebrates 50 years of its quarterly journal, it seemed only fitting to speak to its longest standing editor, Marsha Cohen, who stood at the helm of *Terra et Aqua* for 25 years. We caught up with her at her home in Florida to talk about the highs, the lows and a good dose of serendipity.

When and how did you decide to become an editor?
Well, I left university in the late 1960s with a bachelor's degree in English. At that time, as a woman you either became a teacher or went into publishing and I knew I absolutely did not want to teach. So I landed up in New York and was offered a job at The Viking Press. It was an old, independent, very elite publishing house where salaries were low because you were honoured to be working there. The job they actually offered me wasn't in editorial however, but in production. I was like, what's production? I mean, what does that actually mean?

I found out quickly enough. Production meant doing cost estimates, choosing cloth for covers and paper and doing corrections. In those days all the correction work was done by hand. Sometimes we would get books from England and would have to take all the double "l's" out and remove the "u's" from "harbour". It was wild. Viking had a fabulous list of authors, like James Joyce and John Steinbeck. I learned so much. We would visit printers and typesetting plants. Then slowly typesetting, which was originally done manually with lead, and letterpress printing, were phased out and replaced by electronic setting and offset printing. I always say this stint in production served me well. It taught me the real nitty gritty of the trade. And that's how I sort of fell into publishing.

What brought you to the Netherlands?
I had worked in a couple of places in New York, then in 1970 I decided that I was done with Nixon, the Vietnam war and all of that. At that time, my cousin was already living in the Netherlands and was saying, 'You really have to come over. You'll love it. It's swinging.' And so like a lot of young people I did. I was just going to go for a couple of months and then I met Dominique Boer, the man who would later become my husband and well, I stayed. I was actually supposed to go back to graduate school at Columbia University to study creative writing because I really wanted to write. But I just decided, it's okay, I'd rather be in the Netherlands. After a while I got a job at Elsevier.

There I started working on technical and scientific journals, editing the weirdest assortment of subjects. That was my first foray in publishing in the Netherlands. I lived in NL for seven years and was doing freelance work here and there, and had started a family. Then my husband, who was editor in chief working for the VNU, a large Dutch magazine publishing company, had the opportunity to work for them in the USA. So we decided to move. When that job ended, he didn't want to go back to the Netherlands and we decided to stay in the New York area and start our own communications company. It was a challenge. But we both had exactly the same sort of inclinations in communications and anything that came our way we simply took on.

Meet Marsha Cohen

Marsha Cohen received a degree in English language and literature in the USA. After working at The Viking Press in New York and Elsevier Publishers in the Netherlands, she co-founded a communications company, The Tappan Group BV in The Hague with many governmental clients. In 1991, she became editor of *Terra et Aqua* journal and a PR advisor to the International Association of Dredging Companies (IADC). She has co-edited and written several books on dredging related subjects. Since January 2016, she is a freelance journalist for the dredging industry.

Photo left and previous page © Alyson Benison

As chance would have it, we started working for the Netherlands Chamber of Commerce in the USA, producing a magazine from scratch promoting Dutch–American relations. A mix of culture and business.

Then via via we were introduced to the new communications director for the Dutch tax office. We had developed a system using algorithms to improve communications and used that to redesign the form for payroll withholding taxes that you fill in when you get hired, which was 12 pages long at the time. There were no computers so they would mail the form to people. The postage costs alone were outrageous not to mention the paper costs. We reduced the form to four pages.

> When I think of windmills, I always have to think of Don Quixote. Oh, those dredgers, tilting at windmills.

It proved very successful and is actually in a museum in Germany. The tax office had thousands of forms but they said it couldn't keep working with an American company and needed a company somewhere in the Netherlands. So, we rented out our house in New Jersey thinking we wouldn't be overseas that long, moved to The Hague and continued our company. We hired in a couple of people to join us and in a couple of years we went from a staff of two to 80 people.

How did you come to join IADC?

Boy Opmeer, who owned a printing company in The Hague that we used, walked into my office one day and said 'I have a client who has a journal and they want me to do it, but I don't speak English. Would you like to work together and bid on it with me?' We made a presentation and they liked it, and we signed a contract for two years. That's how I came to work for IADC, because we were both clients of Opmeer Printing. It was totally serendipitous. Truly. I feel like many things in my life were serendipitous and this was certainly one of them.

What was your knowledge of IADC?

Zero. Peter Hamburger was the Secretary General at the time and had just been hired. He wanted to change the direction of IADC. I had no clue what dredging was and I had never heard of IADC, so actually I didn't know what direction they were going in because I didn't know where they were coming from, but he wanted to make IADC more PR oriented. And I had this company, Tappan Groep with 18 graphic designers and so we took the existing journal and made a new design. More readable, more user-friendly for a broader audience. I don't think as an American I had ever heard the word dredging. I simply plunged in there and said OK, I can make a journal, but you have to tell me what it needs to be about. And Peter and the Public Relations Committee taught me what dredging is all about.

Can you tell me about the originals of *Terra et Aqua*?

The journal was started by a group of engineers back in 1971. It's first editor was Nic Oosterbaan and it was called Dredging/Dragage. In those days, it was black and white with technical drawings but it was still quite basic. Somewhere down the line in the 80s, IADC decided they wanted to upgrade. They stopped producing it in-house and hired Elsevier in England to make it. It then became a glossy, colour cover with an image in the middle but black and white inside. The journal was a small fish in the big pond of Elsevier however, and IADC decided they needed to bring it back to the Netherlands. They wanted someone who would just be devoted to *Terra et Aqua* and give it the attention it deserved. The journal then was very low key and was not being published regularly.

When I took over, IADC wanted to publish it three times a year and we started producing 32 pages; 16 pages black and white, and 16 pages with a second colour. Then one day Boy Opmeer suggested that if we were to print the journal four times a year, we would fall under the category of a regular publication, which reduces the mailing rates considerably. We calculated it out and indeed, it created enough financial possibility to publish four times a year. This meant we could bulk buy paper for four issues, which cut down costs even further. The postage cost went down. I guess it was 1993 when we became a quarterly journal. Clearly a case of a magazine printer knowing more about Dutch media law than I. We were a great team with the added value that comes from a real partnership.

Slowly we started expanding the budget because once we saw that *Terra et Aqua* was successfully speaking to people and was actually coming out on time and fulfilling the industry's wishes, things really turned a corner. We started printing in full colour. And increasing the number of pages. Also from an editorial and content perspective, we changed. The journal wasn't just for people in the dredging industry but also for those who come into contact with the dredging industry. The philosophy being that while you might be, let's say a one-time user of the dredging industry's capacity, we – the industry – do this work all the time. We know what we're doing. So depend on us to give you the information and let us explain to you what it is that we actually do. You know, dredging did not always have a great reputation. Protests were not uncommon. NIMBY was a keyword – Not in My Backyard. With *Terra et Aqua* we developed a vehicle to reach out and educate a broader public, to win the trust of decision-makers and stakeholders.

What are the considerations of producing a journal for a worldwide audience?

One thing that was very important was to realise that the journal was going all over the world and being read by many people for whom English is a second language. That comes with its own set of challenges regarding how you present information in an understandable way. In addition, you are trying to inform non-technical people. You really had to think about the length of your sentences and how to present tough technical information logically so it could be more easily absorbed. Those considerations didn't always fall into the consciousness of the dredging community. I mean, they are engineers doing what they're doing They are experts in science and maths. I said, you have to teach me about dredging and I'll teach you about communicating. That's the deal. And it worked!

How would you characterise dredging professionals?

I found people in the dredging industry from the get-go to be wonderful. They were warm. They were open. They may not have known anything about graphic design but that was beside the point. People were anxious to share their knowledge with me because I knew nothing and they would spend hours explaining things. These articles would come in and I would say, OK but we have to make this more comprehensible for a person like me. Then we would go through it because what often happens with people who are technical is that they assume that others have the knowledge they have. That's fine if you're writing for a fellow engineer but you can't always assume that with a broader public, especially stakeholders and government officials. My value was in knowing how to write and their value was being able to explain it to me. They were all so enthusiastic about what they were doing and that enthusiasm is totally contagious.

It's interesting, I was having lunch recently with a group of people and everyone was telling about their careers. I had to explain to them what dredging and maritime construction are. How it touches everyday life. Seriously, nobody knew. I live in Florida part time and the New York area the rest of the year. In both places, we are threatened by hurricanes and we have beaches that are eroding. Dredging companies come in and replenish the coastlines. Dredging is at the forefront of environmental protection of our coastlines. There are big resiliency programmes going on at the moment in the New York/New Jersey area because of the hurricanes and all the damage that was done a few years ago by Hurricane Sandy. Although the Jones Act imposes limitations on international companies dredging in the USA, the scientists and engineers be it in Europe or the USACE or the Far East, exchange information with each other all the time. The collegiality amongst those in the industry is special. The industry is filled with down to earth people who are excited by what they do. And more than ever in this time of climate change and rising sea levels the industry is so important.

FIGURE 1

In the search for renewable energy, the major dredging companies embody the idealism and ingenuity of the mythical Spanish hero, Don Quixote.

When I see the projects dredging companies have accomplished over the years, and I see how much attention is paid to Building with Nature and other environmental remedies. Over the course of three decades, environmental dredging went from contaminated clean-ups and NIMBY to Building with Nature and sustainable development. I think dredging is the workhorse of the maritime industry. It's on nobody's radar until they actually need something and then suddenly their eyes are opened to what the industry is about. And then there's the whole wind energy market with windfarms at sea and plenty of work for the dredging industry. There are some great pictures in *Terra et Aqua* of dredgers off the Belgian coast transporting those enormous wind turbines. It's funny but when I think of windmills, I always have to think of Don Quixote. Oh, those dredgers, tilting at windmills.

What impressed you about the dredging industry?

It's innovative spirit. There's so much research that goes into dredging. You mentioned to me you're doing an interview with Kees d'Angremond. He was one of those people that I met in the very beginning. He was part of a generation of people that remembered the floods of 1953. That affected Belgium and England too. Everyone was concerned about what was going to happen and realised that solutions had to be found.

One of the largest projects that came out of that time was the building of the Oosterschelde – Eastern Scheldt Storm Surge Barrier, part of the Delta Works. The construction of dams, sluices, locks and barriers started in 1958 and lastly almost 40 years. It's amazing how the government interacted and worked with the dredging industry to find innovative solutions to protect the low-lying country. Then in the 70s, environmental issues became a major concern and the industry had to change course and figure out a way to operate whilst not disturbing the natural habitat. That was really a huge turning point and I think that was what inspired the young people of Kees' generation. He was one of those people who saw first-hand what happens when you don't take care of your dykes and coasts. It was this major event that was a turning point that inspired this great generation of people.

What was one of the projects that fascinated you most?

In the first years that I worked on *Terra et Aqua*, one of the biggest projects that was just beginning was the building of Hong Kong's International airport. One of the things that people always joked about was that when you flew into Hong Kong you flew between the skyscrapers and could literally look out your window and into someone's living room. And it was true. When I flew to Hong Kong for a conference that's the way it was and it was really scary. Like, are we gonna make it? And so the British government – it was still British at the time – along with Hong Kong decided to build a much safer airport out at sea.

> There was no such thing as transferring a 10 MB photo at the press of a button, so people used to FedEx and mail me photographs.

Various proposals were made. One of them was to knock down a mountain and use the material to create an island on which to build the new airport. Then one of the European dredgers came with the alternative idea to unite a small, hilly island, Chek Lap Kok, with a smaller nearby island, Lam Chau, to create a big enough area on which to build. It took 237 million m^3 of reclaimed sand to transform the islands into a mammoth 1,250-hectare platform secure enough to bear the weight of buildings and airplanes. At the time, it was the largest reclamation project ever executed and required the deployment of half the world's trailing suction hopper dredgers to Hong Kong. There were the Japanese, the Chinese, the British, the Dutch, the Belgians. And since all the names of the vessels were totally incomprehensible, they gave them all numbers.

FIGURE 2

Arial overview of the two islands merged into one to create Chek Lap Kok airport.

The day I flew home from Hong Kong was the day that the bridge connecting the new platform to the mainland was opened. There was no airport yet, just a platform but there were all these boats and ferries, all tooting their horns in celebration. It was wonderful to experience. I mean, that was really the beginning because after that the Far East became the place to be. Dredging companies started winning contracts in Singapore and Malaysia to build land reclamations and artificial islands. And then of course the Middle East opened up, with Dubai and Abu Dhabi and the Palm Islands.

You created nearly 100 issues of *Terra et Aqua*. What was your greatest challenge?

The hardest thing was acquisition of articles. I would say that was my number one headache and it made me really appreciate our Public Relations Committee and member companies. That was really the bread and butter of *Terra*, to get articles from our member companies and then fill the journal with other research papers from students doing PhDs as well as companies in related fields. We were always open to those researchers worldwide who wanted to contribute. These are busy people, so trying to get someone to find time in their schedule to write an article and explain what they were doing, that was a challenge.

As was the need for good photography. At that time, we were only printing hard copies. There was no such thing as a digital version and photographs for print need to be a lot of MBs. That said, nobody understood when I would say I need a high-resolution photograph. There was also no such thing as transferring a 10 MB photo at the press of a button, so people used to FedEx and mail me photographs. Some of the companies had fabulous photographs too. The photographs of the building of Hong Kong airport were impressive. As were those of Maasvlakte 2 another monumental project that we covered in its many aspects in *Terra et Aqua*. And the massive projects in Scandinavia, Storaebelt and Oresund. When I first started as editor, the member companies would send out photographers and often make aerial photographs to capture the projects. It was probably in my first year that I went to every single IADC dredging company and plundered their photography archives. There were a lot of slides too. Remember those?

Then everyone got digital cameras, so instead of paying photographers, they started sending me 'point and shoot' photos made by crew members – of very dubious quality. Whenever I had a chance, at a conference or on vacation, I would go out of my way to take photographs with my high-end digital camera. Trying to explain the photography requirements needed for print and getting good photographs remained tough. Not to mention asking authors to supply photos of themselves. I know it's a serious business, but I'd say, smiling is allowed.

What are you most proud of during your time as editor?

There have been many memorable issues of *Terra* but there are three that I stand out in my mind. December 1999 (#77). We were going into the year 2000 and I don't know if you remember, but everyone was sure that the world was coming to an end. Like everyone's computer was going to crash. People wouldn't fly on 31 December. We decided to do a millennium of dredging and hired somebody to help me write the history of dredging: From hand-grab to jumbo. This issue was also the first big change in the cover design and layout. We thought it's the year 2000, we're going to do it all different, which was very exciting. The whole project required a load of research – starting with Leonardo da Vinci – and writing and rewriting and was just enormously interesting.

The second one was the 100th issue that we published in September 2005. For that one we changed the whole design again and presented a wide range of infrastructure projects over the past 40 years. It was a deep-dive into the modern dredging industry and a tremendous hunt for photographs. Every IADC member company provided texts about each and every project. In fact it was really a book, and we published both a hard cover and soft cover version and now the whole PDF is online.

My third pick is the June 2007 edition (#107). Because it was so different than anything we'd done before – or since. I think it was ground breaking. Constantine Dolmans was then Secretary General and totally fascinated with Ronald Waterman's concepts. Ronald is really the father of the whole Building with Nature movement and Constantine wanted to do a special issue based on Waterman's book. His concepts led to the Sand Motor, constructed off the coast near The Hague, and a similar project in the UK. It has revolutionised how we think of using nature to enhance dredging projects rather than working against the natural forces of water and land.

What other publications did you work on at IADC?

The longer I was there, the more communication initiatives arose. Rene Kolman, IADC's Secretary General now and the one I worked with the longest, had new ideas and he often asked me to help. We did multiple Facts About brochures and the annual report and the Dredging in Figures report. One of the first publications I worked on was Dredging for Development, a 64-page booklet that came out every few years. The first edition was in collaboration with the International Association of Ports and Harbors, and there have been three editions after that.

One of my favourite projects was when we celebrated the 50th anniversary of IADC and created the book *Beyond Sand & Sea*. It was comprehensive and complicated. The book chronicles 50 years of maritime masterpieces from 1965-2015 with 200 pages of photographs and text. I worked with Jurgen Dhollander, who was Senior PR and Communications Officer at IADC at the time and Renato Rauwerda and Melanie Taal. We had a great team. And I think we were all very proud when that launched. Probably one of the last big multi-year projects I worked on was IADC's Knowledge Centre – a massive undertaking and really an incredible resource for dredging. And another great team effort.

> *Terra et Aqua* played an important role in reaching out to make dredging comprehensible to a wider audience.

FIGURE 3

Memorable issues of *Terra et Aqua* and the book, *Beyond Sand & Sea*.

What are your thoughts on *Terra et Aqua* as it is now?

I think with the redesign back in 2018, that was the moment that *Terra* really blossomed. I mean, visually blossomed and became what it is now. Informationally and technically, it grew over the years and played an important role in reaching out to make dredging comprehensible to a wider audience. But this new design took it to the next level. It was a major decision that was motivated by the *Beyond Sand & Sea* book. I felt like that book was such a tribute to the dredging industry, what it had become and how it had evolved, the attention to the environment, to the development of new technologies, and to finding solutions to really tough problems.

How did you see the dredging industry change throughout the years?

First of all, the dredging industry consolidated and the bigger companies acquired or merged with smaller companies. Then the whole maritime industry changed with the arrival of mega container ships, which led to the increase in size of dredging ships – jumbo dredgers – and created so much work for the dredging industry. Ports weren't deep enough to accommodate these ships. Just look what happened in the Suez Canal last year.

A prime example is when the port authority in Panama realised that the canal couldn't handle the growing capacity. Talk about projects. That was so impressive. To go in there and figure out how to enlarge the canal and to build an extra lock. They had to blast. It's all hard rock. There are a couple of articles in *Terra* on what they did to create that new lock.

What I found so fascinating, not only about *Terra et Aqua* in general but about the dredging industry specifically, was in order to complete a project the importance of stakeholders became key. You can't do anything anymore unless you consult with your stakeholders. They have to understand what you're doing. In Panama, they had a referendum to decide whether or not to allocate money to make the improvements to the canal. The government and the dredgers had to really explain what they were doing, how they were going to do it, how it would create jobs and be a boost to the economy. That was a big change from people just going in and starting to dig somewhere and we'll see where we land up kind of thing.

How you communicate with the public became so important. The dredging industry really picked up and learned from the lessons of others in that regard. As in the case of Shell that was embroiled in a public dispute over the decommissioning and disposal of the Brent Spar, a redundant oil storage installation in the North Sea. The dredging industry looked at what were Shell's failings and thought what lessons can we apply to our projects?

Also in Melbourne, before dredging started to widen the harbour channel in what was a pristine environment, there was a lot of public opposition. There were kayakers out on the water alongside the Queen of the Netherlands TSHD with big signs saying 'Tell the Queen to go home!' The dredgers and the government said we have to figure out a way to explain our plans to everyone. As a result, the company spent a long time explaining what it was going to do, and actually learning from the people, listening to the things that were bothering them, and addressing those issues. I think the experiences of the Panama Canal and in Melbourne are both examples of how important transparency can be.

You travelled to many events around the world. Any standout memories?

One of the things that I really appreciated about being part of the industry was travelling to so many places and finding out about different cultures. It's an opportunity I don't think I would have ever had in my wildest dreams. You can travel everywhere as a tourist but it's a totally different experience when you're travelling for business. You're there working and are part of a community. And in the case of dredging, it's an industry that is trying to improve the well-being of society. You get such a different insight into the culture, into the economics and the social structures of a country.

That also comes with weird experiences. I remember we were in Kuala Lumpur for a PIANC event and we had a booth.

> There's something romantic about dredging, the willingness of its employees to venture all over the world, combined with its workhorse practicality.

The secretary of transport for Darwin, Australia invited us all to dinner and I was the only woman in the group. In the Far East, very often they serve a whole fish with the guest of honour getting the head with eyeballs intact. Well, as the only woman I got the honour. I looked at that fish head for a very, very long time but I just couldn't bring myself to eat it.

And how were your sea legs?

One of the first times I went out on a ship it was dredging out in the North Sea and we were shuttled out on a tender to the ship. So I'm there with my life vest on and my hard hat, and we climb on board. It's my first time on a dredging ship, so I'm taking lots of pictures, talking to the captain, generally excited by getting toured around the machine room and the bridge. Then the ship returns to shore to discharge its large load of sand. Well, they unload the sand and all of a sudden the ship's much higher out of the water, the ballast is gone. And then came the time for us to disembark. One of the crew simply threw down a rope ladder off the side of the ship and said, 'Don't look down or you'll get dizzy and fall between the ship and the tender'. And I'm like, OK. I'll just walk back down that ladder. Sort of. I swear it was like walking from the top of a six-story building. I thought how do these people do this? It was really terrifying. Then the colleague I was with starts to descend and he actually looks down, and just freezes. He was just standing there frozen to the spot and the crew literally had to talk him down the ladder. So my sea legs were fine, but I didn't know I had a fear of heights!

You were editor of *Terra et Aqua* for 25 years and I get the sense no regrets.

None whatsoever. I feel like my life has just been a series of serendipitous decisions. I mean the fact that I decided to go to the Netherlands in 1970. I actually travelled by a Norwegian freighter from Brooklyn to Antwerp having no idea where Antwerp was, or what they were speaking when I got off the ship. Then I took the train to Amsterdam. When we came into Antwerp, we had to go through all these locks. Now of course I understand why – because the harbour of Antwerp is situated on an inland waterway. So we went through this series of locks and I never thought about it at the time. It was just a great experience, sitting on the deck, watching this ship go up and down. But I realise now these locks are just one of the things that the dredging industry does.

That reminds me of the *Environmental Aspects of Dredging* book that we wrote. That was also a monumental project. I worked on that with Nick Bray and Gerard van Raalte. Well Nick was in England, Gerard was in Abu Dhabi and I was in the USA. We were on this round the clock schedule with someone, somewhere always working. Oh, and the printer was in India. You know that to me was what dredging was about. Everyone was everywhere all the time, in crazy places. Nowhere is off limits, dredgers without borders. I remember I did an interview once with someone who was working in the Gorgon gas fields off the west coast of Australia. First off, I was in the USA and we had to figure out the time difference. We ended up with him on his mobile phone, standing on this gas platform out in the middle of the sea, giving me an interview.

I don't know, there's something romantic about dredging, the willingness of its employees to venture all over the world, combined with its workhorse practicality and the huge amount of research and innovative thinking that propels it forward. So no, I have absolutely no regrets. I landed up there by chance and I think I just lucked out and had an incredible job for 25 years.

Are you still involved with the dredging industry?

When I left IADC back in 2015, I started writing articles for an American dredging magazine so I kept my fingers in the pie for a little bit longer. I got to know the American industry better and the people at the Western Dredging Association (WEDA). I'm actually working on a project for WEDA at the moment. Also, for about five years, I was on call to help out on the *Terra*. I keep in touch with what's going on in the industry. I still read all the newsletters, as well as IADC's website and of course *Terra et Aqua*. I feel like it's kept my brain functioning, having to plunge into the 21st century and keep up to speed with everything. It's all good and in these times of crazy threats from climate change, dredging has a higher profile than ever. The practical implications of maritime engineering and dredging appeal to my inner belief that we are custodians of this planet. I'm glad to be a part of it. Keep tilting at the windmills!

UPCOMING COURSES AND CONFERENCES

Dredging and Reclamation Seminar
27 June–1 July 2022 7–11 November 2022
IHE Delft Venue to be confirmed
Delft Singapore

For (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organisations that execute dredging projects, IADC organises its international Dredging and Reclamation Seminar. The five-day course covers a wide range of subjects, from explanations about dredging equipment and methods, rainbowing sand and placing stone to cost estimates and contracts. There is no other dredging seminar that includes workshop exercises covering a complete tender process, from start to finish. Site visit included. Register for the seminar at: https://bit.ly/IADC-events.

WEDA Dredging Summit and Expo '22
25–28 July 2022
Marriott Marquis
Houston, Texas

Organised by the Western Dredging Association (WEDA), the Dredging Summit and Expo '22 is a technical conference to promote the exchange of knowledge in fields related to dredging, navigation, marine engineering and construction. The theme for this year's conference is "Building the future of dredging". The conference aims to provide a forum for improvement of communications, technology transfer and cooperation amongst associations and societies, whilst emphasising the importance of understanding and development of solutions for problems related to the protection and enhancement of the marine environment. Visit https://dredging-expo.com.

Dredging for Sustainable Infrastructure Course
27–28 September 2022
HR Wallingford
Oxfordshire, UK

The 2-day course is based on the philosophy of the book, *Dredging for Sustainable Infrastructure*. Experienced lecturers describe the latest thinking and approaches, explain methodologies and techniques, and demonstrate through engaging workshops and case studies, how to implement the information in practice. Participants will learn how to achieve dredging projects that fulfil primary functional requirements, whilst adding value to the natural and socio-economic systems. Register for the seminar at https://bit.ly/DfSIcourseUK.

COVID-19
Due to the COVID-19 pandemic, events can be postponed or cancelled. IADC has been following the Dutch authorities' advisory measures with regard to limiting the spread of the virus and is keeping a close eye on the situation. We advise checking the IATA website regularly for COVID-19 travel regulations per country (https://www.iatatravelcentre.com).

Nominations for IADC Safety Awards 2022

Conceived to encourage the development of safety skills on the job as well as heighten safety awareness, the awards recognise the exceptional safety performance of a particular project, product, vessel, team or employee. Two safety awards will be presented in 2022: one to a dredging organisation and a second to a supply chain organisation active in the dredging or offshore industry. This concerns subcontractors and suppliers of goods and services. There is no limit to the number of nominations that can be submitted and the awards are open to both IADC members and all other dredging contractors. Summit your nominations before 31 May 2022 via https://bit.ly/SafetyAward2022.

Financing Sustainable Marine and Freshwater Infrastructure Conference
1 December 2022
Venue to be confirmed
Dubia, UAE

How can private capital accelerate the green transition in marine and freshwater infrastructure? This is the overarching question that will be explored during the IADC conference, Financing Sustainable Marine and Freshwater Infrastructure. The 1-day conference aims to create awareness for the need to clarify sustainable concepts and associated financial structures in order to familiarise the financial sector with the financing of green coastal, river and port projects, and to develop ideas to bring this to mainstream infrastructure investment asset classes. The report, *Financing Sustainable Marine and Freshwater Infrastructure: A joint study to explore financing of green coastal, river and port projects*, will provide the basis of the conference programme. For more information and how to register visit https://bit.ly/ConfDubai2022.

Main members

DEME Group
Head office Belgium
+32 3 250 5211
info@deme-group.com
www.deme-group.com

Dutch Dredging
Head office The Netherlands
+31 184 411 999
info@dutchdredging.nl
www.dutchdredging.nl/en

Group De Cloedt – DC Industrial N.V.
Head office Belgium
+32 2 647 12 34
office@groupdecloedt.be
www.groupdecloedt.be

Gulf Cobla (L.L.C.)
Head office United Arab Emirates
+971 4 803 7777
gc-info@gulfcobla.com
www.gulfcobla.com

Hyundai Engineering & Construction Co., Ltd.
Head office South Korea
+82 2 746 1114
webmaster@hdec.co.kr
www.hdec.co.kr

Jan De Nul Group
Head office Luxembourg
+352 39 89 11
info@jandenulgroup.com
www.jandenul.com

National Marine Dredging Company
Head office United Arab Emirates
+971 2 5130000
nmdc@nmdc.ae
www.nmdc.com

Penta-Ocean
Head office Japan
+81 3 3817 7181
poc_international_web@mail.penta-ocean.co.jp
www.penta-ocean.co.jp

Rohde Nielsen A/S
Head office Denmark
+45 33 91 25 07
mail@rohde-nielsen.dk
www.rohde-nielsen.dk

Royal Boskalis Westminster N.V.
Head office The Netherlands
+31 78 6969 000
royal@boskalis.com
www.boskalis.com

TOA Corporation
Head office Japan
+81 3 6757 3800
webmaster@toa-const.co.jp
www.toa-const.co.jp

Van Oord
Head office The Netherlands
+31 88 8260 000
info@vanoord.com
www.vanoord.com

Colophon

Editorial
For editorial enquiries, please email editor@iadc-dredging.com or call +31 (0)70 352 3334. Articles featured in *Terra et Aqua* do not necessarily reflect the opinion of the IADC Board of Directors or of individual members.

Editor
Ms Sarah Nunn

Editorial Advisory Committee
Mr Robert de Bruin, Chair
Mr René Kolman, Secretary General
Mrs Vicky Cosemans
Mrs Heleen Schellinck
Mr Arno Schikker

Board of Directors
Mr Frank Verhoeven, President
Mr Junji Katsumura, Vice President
Mrs Els Verbraecken, Treasurer
Mr Theo Baartmans
Mr Niels de Bruijn
Ms Mieke Fordeyn
Mr Neil Haworth
Mr Philip Hermans

Design
Smidswater, The Hague, The Netherlands

Layout
Robert Dumay Graphic Design, Zierikee, The Netherlands

Printing
Tuijtel B.V., Hardinxveld-Giessendam, The Netherlands

ISSN 0376-6411

How to subscribe?
To receive a free print or digital subscription, register at www.iadc-dredging.com/terra-et-aqua/subscribe.

Call for submissions
Published quarterly, *Terra et Aqua* is an educational and professional resource that features cutting-edge innovations to disseminate knowledge throughout the dredging industry. Are you an author, researcher or expert in dredging or a related field? Do you want to share your innovative research, papers or publications with the dredging industry? Then submit your proposals to the editor at editor@iadc-dredging.com for consideration.

Terra et Aqua is published four times a year by
International Association of Dredging Companies
Stationsplein 4
2275 AZ Voorburg
The Netherlands
www.iadc-dredging.com

MIX Paper from responsible sources FSC® C007225
carbon neutral natureOffice.com | NL-077-843295 print production

IADC stands for "International Association of Dredging Companies" and is the global umbrella organisation for contractors in the private dredging industry. IADC is dedicated to promoting the skills, integrity and reliability of its members as well as the dredging industry in general. IADC has over one hundred main and associated members. Together they represent the forefront of the dredging industry.

www.iadc-dredging.com

IADC