This special anniversary edition of Terrae 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, N.C. Dijkstra, 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 aim is to disseminate information useful to the civil servant, politician or financial expert who is involved in social problems and bears responsibility for the decisions which are 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 as well as larger, more economically viable vessels. The importance of sustainable dredging practices as a core value held by our members and the industry, is the focus of discussions in the industry today.

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 industry today.

This article presents a new temporal design method to study the transient stability of pipelines. This article presents a new temporal design method to study the transient stability of pipelines.

Terra’s mission is therefore still as relevant and compelling today as it was 50 years ago.
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 he admits he was far too junior to do the job. Upon his return, he became 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 asked Kees to take over lectures at IHE Delft on breakwater design. Those lectures were given once a year and were attended by students from all over the world, expanding 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, 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 his students and also became friends for life.

Kees benefited 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, they were numerous students who joined those yearly gatherings, expanding his network even further.
There was a sense of urgency and cooperation was key to making the Eastern Scheldt Storm Surge Barrier a success.

The IJssel Lake project initiated the founding of Delta Hydraulics in 1927 and facilitated the implementation of Building with Waterways and Public Works (Rijkswaterstaat). It was a key to making the Eastern Scheldt Storm Surge Barrier a success. "It's a point that Stefan shares regarding 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.

Stefan’s introduction to the dredging industry was somewhat similar to Kees. In fact, there are many similarities in both their careers. Stefan had completed a PhD thesis at Delft University of Technology on the video imaging of coastlines and had been involved in a large-scale research project for the industry-sponsored foundation for dredging-related strategic research, Stichting Speurwerk Baggertechniek (SSB).

Then in 2003, 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 Claus von Rhein, Wim Rosendraper and Walter Glini 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 the raised 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 there was little understanding of the actual impact to sensitive ecosystems at the time. The SSB programme delved into sens of large-scale field experiments around dredging activities in Bremen (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 plumes 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 literature.

After a year in this role, project manager Stefan made the move to Bisalow to join their in-house engineering department Hydromic. 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 close to the Arabian coastline. The work involved amongst others, the set-up of an extensive 247 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 EcoHab-2 building with Nature programme was established as a strategic sector initiative to develop and implement novel approaches for marine infrastructure.
You’re not simply preparing students for scientific work. You’re preparing engineers for a life in the real world.

You've already started your career in ship repair, so you have a good understanding of what it means to be an engineer. You also have a good understanding of the importance of communication and teamwork. You know that these skills will be crucial in your future career. You also have a good understanding of the importance of being able to work well with others. You know that these skills will be crucial in your future career.

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. He got support from the industry through AVECO (Adriaan Volker Engineering Consultants).

The first project Kees worked on was a study on issues faced by the Netherlands due to the pollution of dredged material. The issue was not very positive in those early days. “There was always the view that all the dredgers of the time were grey,” Kees explains. “And there were two shades of grey: Volker grey and Boskalis grey. We used to joke that when you walked through Slieethoven you couldn’t tell who worked for which company because of the colour of their shed in their back garden.”

It is fair to say the reason for dredging loses its shine in the mist of this larger picture.

Early research days

In the mid-70s, Stefan 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 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, Stefan came to know many colleagues in the US and the Corps. The fact that he is still a member of ASCE-CORP 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 kinds of measures, the water quality has improved tremendously and all the sediments that settles in an estuary are 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 dredger 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 amount of material disposed in water. Stefan explains, “For example, if you want to use the actual digging location like the cutter of a CSD, the bucket of a BLP, and the dredgehead of a TSHD. The tool kit of the third 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 formal approach to training

35 years ago, dredging was considered purely by the colour of the shed in their mind. Later on, the industry came to realise that a more formal approach to training practices was desirable. When Stefan 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 engineers but at students preparing to work in the industry. Some of the professors tried to introduce the subject, there was hardly any 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 the chance and started lecturing on the commercial aspects of the dredging industry. He explains, “You’re not simply preparing students for a life in the real world. You’re teaching students to be an engineer for a life in the real world. Whether you work for the government, a company, or as an accountant or a consultant, you have to realise it’s part of their education. You have to realise that everything costs money and you have to realise what good quality sediment can be used for an engineer.”

In broadening the conversation, Stefan explains, “This is one element that we want to educate students to. And at the end of the day you have 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 interface with 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 specialisms.

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 coral reefs, and creating opportunities for nature. That’s a big driver nowadays according to Stefan: “Of 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, it continues Stefan. ‘It generally means that there is nothing there. Only asphalt 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 it goes deep into the philosophy about the role of a university. ‘You want to employ an engineer who has had an academic education, but who has not only the knowledge and technical skills but also the communication skills to be able to interface with people in the wider world.”

You have to teach students how to look at a project from so many different perspectives and the local culture is one of them.
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 job at hand. But you still expect that they also have the international orientation. "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 perspective to which the university can contribute."

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

Field trips give students an invaluable insight into what’s expected of them in the industry. "They’re an opportunity to get an inside view on how the clients work and they can see all the different aspects of an engineering intervention. At the same time students are being taught how to effectively operate in this broader community and take advantage of the impacts of engineering interventions."

Today’s landscape, Keess 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 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 universities. Engineering and design skills are increasingly recognised as key competencies 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 and 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 perspective to which the university can contribute.”

Is practical experience an essential element in academia?

For Stefan, it’s a question of balance. “Of course, it has its advantages as studying hands-on experience, which comes from having knowledge and experience in the industry. But scientists are also needed, and at what about a Feeling for policy and good people managers, they are also indispensable. It’s all about having 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 a common practice and a prerequisite for successful projects."

That’s something we’re trying to develop more multidisciplinary projects.” Stefan adds: “It’s not only important to have all the disciplines onboard but they have to collaborate, which is the most important. 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 a long-term agenda, and for the industry I think that’s important.”

The importance of field studies

One of the benefits of Stefan is seeing students get inspired. For instance, during study tours to major projects abroad. The student association for Hydraulic Engineering (Waterbouwdiscus) is very active in organising such trips and in 2019 travelled to Brazil. Back in 1984 as a student, Stefan was personally involved in the organisation of the tour to Taiwan, Hong Kong and China, together with Tim Hoile, Ronald Roosjen and Janet Knoops. One of the highlights was the visit to the famous Chek Lap Kok airport that was under construction (Figure 4). Keess 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, 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.”

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 operations.

No matter how many doctoral degrees you have, you have to get your hands dirty to gain credibility within an organisation.
The need for a new Delta department

Today, sustainable is by far the top of mind for all industries. For dredging companies that means the acceptance of working sustainably too. Even in the time of the Eastern Scheldt 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 close. 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 an stagnant Eastern Scheldt and the complete loss of the mussel and oyster culture near Yerseke. We hadn’t already begun 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,” says 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 this 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 this is a very real concern. When we have 50-meter 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 training engineers and working with the companies to build the solutions in a good and sustainable way.”

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 in nature and to develop the project. 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 most sensitive areas. The business case is still under development but at the end of the day it’s a crucial project for local communities.

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

Plans for the future

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

Stefan has many plans for the future, including educational advancements of hydraulic engineers and promoting the concept of Building with Nature as a means to develop cleaner solutions that translate the theory into practice. 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 most sensitive areas. The business case is still under development but at the end of the day it’s a crucial project for local communities.

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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 pumps 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 representative 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”) for 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
The critical velocity is the preference safety limit for dredging pipelines. In the operation velocity of a pipeline drops below the critical velocity, the pipeline will block, unless an operation intervention process of pipeline blockage in its very nature a transient and temporal process that is caused by the maximum limit of flow velocity, which defines the critical velocity. Because when the mixture velocity drops below this limit, the pressure losses will increase, which slows down the mixture. Therefore, more particles will settle out of suspension (if the sediment feed to the pipeline is unchanged), further increasing resistance and causing the velocity to decrease once more and more particles settle out of suspension, 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 methodology is suitable to investigate the maximum loading case of a pipeline and its components. However, 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 (Matůšek, 2019) especially for long pipelines. Density wave amplification is also a risk for smaller 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 and sedimentation have uncovered a density wave amplification mechanism caused by different mechanisms (De Hoog et al., 2021). To better understand and design the density wave amplification effect and in general, the effect on transient on pipeline operation, 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 outline 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 ships, which are the drives of future dredgers.

Density wave amplification

The growth of density waves in a pipeline as a result of the redistribution of size from one density to another. This can occur even if the flow is injected relatively steady over time. Their redistribution is material has been identified to occur under two circumstances (De Hoog et al., 2021). Firstly, redistribution can be caused by a deposit formation in the pipeline, which occurs when the pipeline operates with a fluctuating mixture velocity and an average level of mixture 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 has been 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 a variety 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 publicly. 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 a mixture of sand and seawater. The three remaining graphs show the measured mixture density at 150 μm.

Figure 2 shows an example of data recorded during operation of this pipeline. The top graph shows the measured mixture density over the pipeline over time, which was measured at the booster station, Jagersplas, located at 1186 μm along the pipeline. The three remaining graphs show the measured mixture density at the start of the pipeline (the dredger, Groeningen) and at 1186 and 1673 μm along the pipeline at booster stations Jagersplas and Duurnger 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/m³. However, at Jagersplas the mixture entering the system between 16h00 and 16h30 fluctuated considerably and this same part of the mixture at Duurnger consisted almost exclusively of water. The accreted material was transported towards different parts of the flow and accumulated into density waves. The accumulated material was monitored as their larger cousins.

Because the pipeline was troubled by density wave amplification, this case study was investigated by Matůšek (1995) and Matůšek (1996a). Initially, the cause was thought to be an axial variation in particle concentration as a function of the mixture concentration. However, high-density waves travel faster than low-density parts of the flow and high-density waves would settle out of suspension. However, Talmon (1999) and de Hoog et al. (2021) show that this is not the case. Specifically, axial velocity variations does exist, due to concentration variations (as measured by Matůšek (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 a sufficiently high density wave (around the deposit limit) can create small density and particle velocity drops, while low-density parts create deposits. This process is mathematically proven in Talmon (1999), and the material is investigated in Talmon et al. (2007) and further explained by de Hoog et al. (2021).

Effect of sediment concentration on density wave amplification

Density wave amplification, this case study was investigated by Matůšek (1999) first introduces the hypothesis of an unbalance between sand sedimentation and erosion from a stationary deposit. The result of the unbalance is that a sufficiently high density wave (around the deposit limit) can create small density and particle velocity drops, while low-density parts create deposits. This process is mathematically proven in Talmon (1999), and the material is investigated in Talmon et al. (2007) and further explained by de Hoog et al. (2021). The effect of sediment concentration on density wave amplification is investigated in Matůšek (1999) and de Hoog et al. (2021). The mass medium particle diameter was measured with a U-loop (between 150 μm and 500 μm). The delivered concentration range between 14:30 and 15:30 hrs had diluted the feed of the pipeline more than expected at the booster stations Jagersplas and Duurnger respectively. The flow loop was partially constructed in a vertical minislab, which facilitated a 1D fieldwork pipe and riser. These two vertical pipes were connected to 57 m of horizontal pipelines, transporting a mixture of sand and seawater. The sand had relocated towards the flow loop. The flow direction is from right to left through the pump.

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 Bergakademie Freiberg, in Halsbrücke, Germany. This 150 mm diameter flow loop was partially constructed in a vertical minislab, which facilitated a 1D fieldwork pipe and riser. These two vertical pipes were connected to 57 m of horizontal pipelines, transporting a mixture of sand and seawater. The sand had relocated towards the flow loop. The flow direction is from right to left through the pump. FIGURE 3 A detailed schematic of the flow loop, showing the topside equipment and the vertical minislab with the riser and downgoing pipe.
Density waves can occur at mixture velocities far above the critical velocity.

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 11% is given in Figure 6. 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 several 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 at a 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 is that it is not about varying quite rapidly. The Freiberg circuit is that amplification took place at mixture velocities far above the deposit limit velocity and the critical velocity. This is unlike the Prins-Clausen 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:

\[ \frac{d}{dx} (c \cdot v_p) = 0 \]  

Where \( c \) is the volumetric concentration in a pipe, \( v_p \) the particle velocity and \( x \) the axial coordinate of the pipe. Figure 7 shows a comparison between the particle velocity \( v_p \) 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 \( v_p \) over the mixture velocity \( v_m \) (also known as the transport factor):

\[ R_s = \frac{v_p}{v_m} \]  

The slip ratio is an empirical relationship, measurable in 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, 2008; Matusik et al., 2018), or from empirical relationships (Molenda, 2016). Sobota and Hirt (1992) In the illustrative example of Figure 7, the slip ratio model of Sobota and Hirt (1992) was applied to the horizontal pipe. For vertical pipes, the solids velocity \( v_s \) is modeled according to the hindered settling principle (Richardson and Zaki, 1951):

\[ v_s = v_m - \left( v_m - v_p \right) \cdot \left( 1 - c/n \right) \]  

Where \( v_p \) is the terminal settling velocity of a particle, \( c \) the average volumetric concentration in the Richardson and Zaki (1954) settling exponent. For the illustrative example in Figure 7, the settling parameter is modeled according to Kita (1977) and \( v_p \) is calculated according to Farguson and Church (2004) for angular granules.

In the Freiberg loop, the slurry flows from a vertical riser into horizontal pipes. Let us assume the mixture velocity is steady in time and an instantaneous variation has been damped out apart from one density wave traveling 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 “b” (Equation 1). This in itself is only a temporary increase of concentration, because the mixture would flow again into a vertical pipe, the particle velocity returns to its original state (point “a” to “a” in Figure 7). Hence, the concentration decreases and recovers. The concentration increase was only temporary.

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. Since the density wave flows out of the riser, the load on the pump decreases, thus the decreasing in hydrostatic gradient. As this happens, the particle velocity drops from “b” to “c” towards “d” in Figure 7. Once the wave flows out of the horizontal pipe, the particle velocity increases from point “c” to “d” in Figure 7. Consequently, part of the increased concentration remains. This is why the path from “b” to “c” does not cause acceleration drops as the wave leaves the pipe. Therefore, the pipe orientation change, therefore, \( m = n \) (which \( m \) and \( n \) in the Freiberg system, the density wave flows into the descending 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 a difference in particle velocity when the slurry flow travels from vertical to horizontal pipes, and a subsequent increase in mixture velocity due to the working principle of a centrifugal pump. The 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 it is necessary to consider dynamic very complex. By using multiple computational fluid dynamics (CFD) models, it becomes possible to separately assess the two different systems, each one of these systems has to be explored.
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 is modeled with a source term. See Figure 8 for a visualization of the structure of the model.

The 1D-2L-HT CFD model is based on the Driftflux 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 react to changes in the fluid flow. With this assumption, only one momentum equation is needed for the entire mixture. This mixture continuity equation is as follows:

\[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0 \]

Where \( \rho \) is the mixture density and \( \rho_0 \) the fluid density. \( \mathbf{v} \) is the fluid velocity and \( \rho \) 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 first-order method on the isometric schematic presented in Figure 8 and taking into account this two-phase approach, results in the following transport equation (Ishii, 2007).

Modelling stationary deposits

Equation 6 needs a closure relationship for the bed source term \( F \) the erosion and growth of the lower bed layer can be approximated using erosion and sedimentation models, like those used by van Rijn (1985). The vertical velocity of the top of the bed is modelled as:

\[ \mathbf{v}_b = \frac{\rho_b \mathbf{F}}{\rho_0} + \mathbf{v}_c \]

With \( \rho_b \) the bed density and \( \mathbf{v}_c \) the settling velocity. The horizontal bed velocity \( \mathbf{v}_b \) can be derived from the bed shear stress and the porosity of the bed. The source term \( F \) becomes:

\[ F = v_b \sigma_\text{bed} \Delta t \]

In Equation 14, \( \rho_b \) is the mixture density, \( \rho \) the pressure \( \rho \) the mixture resistance on the pipe and \( \mathbf{v}_b \) the bed resistance over the bed layer of the circumference of the upper layer, \( W \) and \( h_\text{ref} \) the cross sectional area of the pipe, and \( \sigma_\text{bed} \) the porosity of the bed. The bed shear stress can be used as:

\[ \sigma_\text{bed} = \frac{F}{A} \]

The bed contribution to the total shear force over the bed layer can be modeled as:

\[ F = \sigma_\text{bed} W \]

With \( \sigma_\text{bed} \) the bed shear stress, \( W \) the width of the bed layer, and \( h \) the height of the bed layer.

The sedimentation flux:

\[ S = \frac{v_b \rho \Delta t}{1 - (1 - R_s)^n} \]

Equation 13 needs a closure relationship for the hindered settling exponent \( n \). The hindered settling principle must be used to correct the settling velocity through the hindered settling exponent \( n \) (Hirsch, 2007): and \( n \) is a fit parameter. The lower bed layer is high, therefore the erosion model \( E \) should be suitable for high velocity flows.

Discussion of model application

The 1D-2L-HT model is capable of capturing the complex behavior of pipeline flows. Therefore, this new model can be applied to simulate the interaction between resistance forces caused by the slurry and driving forces and the changing cell volume. The velocity difference between the upper layer remains stationary. Mixture momentum equation

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\[ \rho \mathbf{v} \cdot \nabla \mathbf{v} + \rho_\text{bed} \mathbf{v}_b \cdot \nabla \mathbf{v}_b = \nabla \cdot \tau - \rho_\text{bed} \mathbf{v}_b \cdot \nabla \rho_\text{bed} \]

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To conclude, the preliminary results show that the 1D-2L-HT model is capable of capturing the complex behavior of pipeline flows. Therefore, this model can be applied to simulate the interaction between resistance forces caused by the slurry and driving forces and the changing cell volume. The velocity difference between the upper layer remains stationary. Mixture momentum equation

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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 upward, since the pressure delivered by the pump increases when the mixture density flowing through the pump increases (Wilson, 2008). De Hoog et al. (2021) concludes that the booster stations in the Prins Claus 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 booster and no longer cause the mixture velocity to fluctuate. This hypothesis is a solution of intelligent booster pump positioning that can be investigated using the 1D-2L-HT model. The pressure rating of the pipeline at the booster station is high enough to allow for this solution.

The Freiberg system instability is hypothesized to be caused by a difference in particle velocity between vertical and horizontal pipes, controlling with an accelerating mixture velocity due to centrifugal pump dynamics. The particles travel slower in horizontal pipes, causing a ‘transient accumulation’. The particle velocity can be matched better with the vertical pipes by lowering the diameter of the horizontal pipes. Whether this is a valid solution can be investigated using the 1D-2L-HT model. The pressure rating of the pipeline at the booster station is high enough to allow for this solution.

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 stabilizing the system. The 1D-2L-HT model can be extended with a simulated feedback control system, as done by van Wijk (2018). This application is especially useful 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 secure 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 flowmeter feedback can be investigated, for example, 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 gases, 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 increase 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 mode 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, fuel cell based drives are becoming popular and actively researched as drive technology for the future. This drive has an even larger energy buffer to cope with transient loads. The 1D-2L-HT model can be used to simulate a system, whereby 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 explained when the dredger is discharging on a long land pipeline. Since in addition to the high power required for the dredge pump, the fuelling of sand in the hopper requires a large amount of power for the jetting pumps. A transient analysis of this 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 fluid 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 modeling global behaviour on a large scale and is shown to be able to predict density wave amplification as witnessed in the Freiberg flowloop. Further usage 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 and SI and fuel cell drives. This model will be developed further as part of future research.

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

Traditionally, the design of a hydraulic transport system involves analysing energy sinks and sources of a pipeline system. More specifically, the energy characteristics of the pump and driven 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 mining has shown that density waves can occur at mixture velocities far exceeding the critical velocity (the hydraulic transport. Experimental research into these subjects has led to many new findings.

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. He has special interest in hydraulic transport of sand, gravel and manganese nodules. As part of his PhD research, Edwin is developing ICFD technology to simulate pumps, pipelines 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 becomes interested in transport and testing of slurries. He has a wide research background at the Eddy and Sediment Dynamics Department of Delft University with 35 years of experience. His specialties relate to modelling sediment dynamics, rheology, slurries in mechanised tunneling, slurries mixing 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 WL|Delft Hydraulics (now Deltares) worldwide. Cees is also a senior researcher/adviser at the Institute for Environment and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience. Key qualifications relate to dredging, sediment dynamics, Ecology and Sediment Dynamics Department of Deltares with 35 years of experience.

References


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 careers.

Marc Van Torre, Professor Emeritus, Ghent University, Belgium

What impact did winning the award have on your career?

The award meant a recognition for the work IADC awarded me involvement in that area. It also made me aware of the importance of the cooperation between (dredging) companies, port authorities, waterway authorities and research institutes/universities.

What are you up to now?

I have continued my work at the Technical University of Ghent, but have retired from my position as head of the Maritime Technology division. I have continued to contribute to the industry. Four years ago, I moved back to Canada, where I now work as a Senior Professor at the Florida Institute of Technology.

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

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 port locations in the organisation.

Leaf Erickson, Senior Engineer, Coastal Design & Engineering

What impact did winning the award have on your career?

The award certainly emphasised the importance of practical information content.

What are you up to now?

I am still working in the dredging industry and currently am serving as the General Manager Works in Nigerian Ports Authority.

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

What impact did winning the award have on your career?

It connected me to American dredging companies, which resulted in consultancy work. It also made me aware of the importance of external contacts referred to the article as being very useful due to its practical information content.

What are you up to now?

Looking back at the past 40 years, I feel 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.

J. Marco Groot, Manager Rock Department, Boskalis International

What impact did winning the award have on your career?

I have had many different steps in my career within the marine dredging and construction industry, and most of my time working abroad on projects, varying from offshore ports, construction and land reclamation where 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.

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Charles Hummer presenting Sape Miedema with the award at WODCON XII in Orlando, USA, April 1989.
**Stéphanie Groen, Director Coastal & Climate Change Asia, Aurecon Group**

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

What did winning the award mean to you?

Recognition of the process ensured that over time, EMMP or EMP became the norm for marine and terrestrial projects under construction. Whilst an EMMP is dealing with uncertainties is when working on large infrastructure and energy projects.

What impact did winning the award have on your career?

Stéphanie Groen managed to list the scene with EMP 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 2015.

What are you up to now?

To this day, assessing uncertainties helps me in making the right decisions in my projects. To date, assessing uncertainties helps me in making the right decisions in my projects. To date, assessing uncertainties helps me in making the right decisions in my projects.

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

**Paper: Uncertainty analysis of the mud infill prediction of the Oklointa LND approach channel**

What did winning the award mean to you?

Suze Ann Bakker was very good encouragement to notice that her research focusses on and it serves as a platform for others to see value in it as well. It did help her to remain within the field of dredging engineering.

What impact did winning the award have on your career?

Suze Ann Bakker's work on the award at PIANC, MIM, in London, UK in 2013 helped facilitate further opportunities to learn and advise permitting professionals on coastal and in-water infrastructure. The award helped to provide access to energy and improve the lives of displaced people in her country of origin.

What are you up to now?


**Rene Kolman, Secretary General of IADC**

**Paper: Modelling the effect of water depth on rock cutting processes**

What did winning the award mean to you?

Rene Kolman was very good encouragement to notice that his work was of high quality and that it is perceived by others as highly relevant and seems to share a passion for the field. In that sense, I think that the award is a perfect example of recognising the contributions of those talented people and giving them encouragement to continue their work.

What impact did winning the award have on your career?

Rene Kolman’s work on the award at PiANC, MIM, in London, UK in 2013 helped to provide access to energy and improve the lives of displaced people in his country of origin.

What are you up to now?

Rene Kolman is a Senior Manager, Renewable Development, Invenergy.

**Kaitlin McCormick, Senior Manager, Renewable Development, Invenergy**

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

What did winning the award mean to you?

Kaitlin McCormick was very good encouragement to notice that her research focused on and it serves as a platform for others to see value in it as well. She helped to remain within the field of dredging engineering.

What impact did winning the award have on your career?

Kaitlin McCormick was very good encouragement to notice that her research focused on and it serves as a platform for others to see value in it as well. She helped to remain within the field of dredging engineering.

What are you up to now?

Kaitlin McCormick is a Senior Manager, Renewable Development, Invenergy.
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...
SAFETY

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 appropriate legislative frameworks 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 17 June, in which an explosion at a chemical plant in Medea, north of Milan, released a chemical cloud containing the highly toxic dioxin. Thousands of people 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. In a month, 85,000 people had died. And in 1988, the Piper Alpha platform in the North Sea, 190 km north-east of Aberdeen, Scotland, exploded and sank. 165 crew on board were killed 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 container ship Herald of Free Enterprise that capsized moments after leaving the Belgian port of Zeebrugge on the night of 6 March 1987.

The 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

Health and safety performance

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

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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 ongoing 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 cannot only improve safety, but also efficiency and well-being.

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

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 away 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 an environment that encourages and enables a safe operation.

The concept of safety culture was first introduced by the IAEA (International Atomic Energy Agency) 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 corporate and personal responsibility of all those involved in any safety-related activity at a nuclear power plant. The Chernobyl accident was associated 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.).

Safety culture ladder

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

Experience shows that by using a maturity model in a transformation process people become aware of the gap between the aspirered level and the cultural level they are operating at. They can ‘tick the boxes’ and demonstrate that everything necessary, according to the book, is being done. In the ‘proactive stage’, they have everything in place but are still looking for further improvements.

Conclusions

In the past decades, 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 is 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. Companies are building a mature safety culture that ultimately influences a safe working environment in day-to-day operations.

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

CASE STUDY 1: SAFETY CULTURE OF VAN OORD

Since 2013, QHSE Director, Tonvão de Mello has been involved in the safety journey of Van Oord. Responsible for continuously driving the safety culture to a higher level, he describes 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 and environment and safety standards. It is notable that the number of registered accidents within the company increased in the first few years (Figure 3). This is explained by the fact that an organisation is only able to identify and incident procedure must learn to report on the accident figures.

Management attention to safety

Although the number of personal injuries within Van Oord over the past 20 years has decreased by 60% since 2003, 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 responsible for the company. Based on these conversations, the consultants concluded that management that their own role as a safety leader; that an Executive Committee member is always present to interact with participants.

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 in 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 as 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, 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 close-control risk model, is focused on behaviour, 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 staff members within two years. Looking back on this first period, the active involvement of the CEO and CDO 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.

The target group was expanded to include all key personnel within the organization including staff and direct reports. After a two-year break due to the COVID-19 pandemic, the 10 000th SLT was 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 its multidisciplinary nature 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 seems to be the norm in the company. In 2018, TNO was commissioned to measure the effectiveness 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.

Corporate safety campaign: Say YES to safety

It is important for a large company to develop an appealing safety campaign that is inline with the company values. Derived from the company values “caring 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.

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 Analysis (JSAs) and Permit to Work (PTW) and the Last Minute Risk Assessment (LMRA) are used.

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.

Life-saving rules

Life-saving rules are found in the culture.
in all companies within the dredging industry. Within Van Oord, safety skills are explained in a practical training phase which is mandatory for all project employees. The success of such safety skills strongly depends on how they are actually applied. 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 integral parts 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 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 the safety of everyone engaged in the project, which is a crucial step forward. 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 integral parts of the model.

CASE STUDY 2: SAFETY CULTURE OF JAN DE NUL

With over 23 years as a QHSE 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 HSE Advisor and the changes that have been made.

The importance of training
My first few months as a QHSE advisor working for a joint venture (JV) project were challenging. I was a new hire and needed to familiarise myself with the organisation’s safety culture and procedures. The training schedule was extensive and included topics such as safety procedures, equipment use, and incident response. This was crucial for me to understand the responsibilities and expectations placed on the team members.

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

The changing role of a QHSE advisor
The role of QHSE professionals has evolved significantly over the years. In the past, the primary tool of a QHSE advisor was a camera to document incidents and failures. However, in recent years, the approach has shifted towards a more coaching role in the execution phase of a project. The advisors now work closely with the teams to assess and control all aspects of the project, ensuring that safety is integrated into all phases.

Today, QHSE 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 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 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 of the management systems, etc. Training of personnel within JanDeNul Group is continuous throughout an employee’s career. This 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 the need to ensure that trainees are 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.

Complacency is lurking and the challenge that the safety culture will fall back to a real danger. In 2018, 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. Additional training and education play a crucial role. The situation today is completely different. An extensive training programme is in place for all new personnel joining the organisation.

There is no longer just one or two people responsible for safety. Today, safety is a collective responsibility and everyone is accountable for their own actions.

The situation today is that the implementation of the ISM code on board of vessels resulted in a large shift in mentality and performance. When started in 1999, all but a few vessels of the Jan De Nul fleet had installed the ISM Code. By 2019, almost all vessels were compliant.

Occupational health and safety are now an integral part of the company’s risk management system. Training is mandatory for all personnel, and the importance of safety is emphasised throughout the organisation.

Today, QHSE professionals are an integral part of project teams.
Quality Management Systems was first published in 1997 in 1998, two standards were released covering management systems for occupational health and safety (OHSAS 18001) and environmental (ISO 14001). While implementing these standards, the focus was often on “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 introducing new systems for occupational health and safety (OHSAS 18001 – today known as ISO 45001) and environmental (ISO 14001).

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 chain in Van Oord started with a certain bottom which 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 long time before everyone was convinced that having an incident 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 focusing on: (1) Leadership; (2) critical risks and life-saving rules; (3) teamwork and accountability (Just Culture); and (4) communication. The ITA programme focuses on operational safety culture, 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 focuses on the gaps Zero Accidents, Zero Waste, Zero Emissions and Zero Breakas.

Companies used to be ashamed of incidents. There was no open culture; lessons were certainly not shared with outsiders and sometimes even not with insiders. Since 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 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 focuses to successes. I once came across the comparison with the way a football coach focuses to successes. I once came across the comparison with the way a football coach focuses to successes. I once came across the comparison with the way a football coach focuses to successes. I once came across the comparison with the way a football coach focuses to successes. Instead of pointing out weaknesses, that positive approach works in order to improve the 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 arising from good ideas as well as from incidents are analysed and concrete actions are defined to improve knowledge and continuously improve the safety and operational control.

Summary

This article explores the progress of health and safety in the dredging industry and HSE professionals, their experiences in building the safety culture within marine contractor organisations. Having built the safety management systems 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.

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

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Christophe Leroy

In 1996, after completing two master degrees in Electro-mechanical engineering and management, Christophe Leroy started his career as a site engineer for Androni Immobiliare, a construction company in Rome. From 1996-1999, he joined the Van Oord Group as a Project Quality/HSE Manager and has been working on various international oil and gas offshore projects around the world. Since 2015, Christophe is QHSE 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 QHSSSE systems and monitoring the QHSSSE performance.
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 of facts. Common-law legal systems place great value on deciding cases according to consistent principles, so that similar cases 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 the majority of European countries, the term is applied to any set of rulings on law, which is guided by precedent. Essentials 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 a 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 against varying levels of authority, as discussed throughout this article, some become ‘leading cases’ or ‘landmark decisions’ that are cited often whilst others become “leading cases” or “landmark decisions” that are cited often. In the process of becoming leading cases, which legal practitioners and arbitral tribunals have to do or will follow.

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

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 made little impact. The contractor’s affidavit stated that there was no appreciable damage. However, the contractor was contractually bound to the employer to investigate the site when all that can be done is to “inspect” the site. Case should be taken when such investigation wording is used as the implications are potentially very significant.

Howard Marine and Dredging Co Ltd v Australian Iron and Steel Ltd (1978) is another example of a case where no notice of the contractor’s failure to disclose would more likely have been unacceptable.

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 doubted 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 owned 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 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 issue is that a contracting party is not subject to a duty of disclosure and that mere silence cannot amount to a misrepresentation. Contrasting 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 Designing 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 data, 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 requiring it to be made publicly available or other information that an experienced contractor reasonably expected to have to or obtain.

It is worth contrasting the decision in Dillingham v Morrison-Knudsen International Co Inc v Commonwealth (1972) with the Bacal case in which the contractor was not required to carry out a ground investigation but was expected to have to or obtain information supplied by the employer at tender stage “as to the soil and its contents at the site of the proposed work” (see also the case of Bacal in relation to six foundation blocks it was required to design and build). It was decided that a factual misrepresentation made during pre-contractual negotiations by one party led by the other may give rise to liability under the Misrepresentation Act 1867 in appropriate cases such liability could be attached to inaccurate information about ground conditions.

As Chief Justice Barwick stated: “The basic information in the site investigation document appears to have been the result of much highly technical effort on the part of the employer. It was information which the [contractor] 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 professional or actual tenderers. But it was indispensable information if adjustment 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 whether was pleaded before the court. When comparing the present situation with 50 years ago the good news is how it is now a standard practice to have a provision that all relevant data in the employer’s possession is given to the contractor.

However, in the past 20 years or more, this author has seen the rise of sinister “claimer” 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 Northumbrian Development Corporation Ltd (1975) and Howard Marine and Dredging Co Ltd v Australian Iron and Steel 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 soils conditions detailed in the survey to be assumed by the contractor in relation to six foundation blocks it was required to design and build. The contractor was not given to the contractor that the soil information was inaccurate.

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 seized on both these cases 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 and wording often is that the contractor at time of tender has to “investigate” the site all that can be done is to “inspect” the site. Case should be taken when such investigation wording is used as the implications are potentially very significant.
Some cases become “leading cases” or “landmark decisions” that are cited often.

CONTRACTS

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

The trial decision was appealed in October 2021 in Van Oord UK v Dragados UK (2021) CSIH B30. 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 design, in a spirit of mutual trust and co-operation, and found rates could not be reduced if a compensation event is based on 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 principles of good faith 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 claim works to the 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 therefore the rate for future work could be reduced in the same manner as for a lawful omission. The judge also held that even if there was abreacanh of the obligation to act in a spirit of mutual trust and co-operation” it would still result in the same reduction not to rates.

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

The following case is different and relates to the application of conditions in a road construction contract. The experience contractor test will apply.

The contractor had the burden of satisfying the experienced contractor test in a more detailed understanding of both aspects of their final complete design. The contractor has the burden of satisfying the experienced contractor test will apply.

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

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

The contractor had the burden of satisfying the experienced contractor test on the balance of probabilities.
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 at which coupled 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 that 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 amount payable for future work.
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 become a teacher or went into publishing and I knew 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 a lot of young people did. I just decided 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.
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 office. We had developed a system using withholding taxes that you fill in when you get your pay slips. This was a huge step forward. We had to fill in 500,000 tax forms for people. The postage costs alone were enormous, being 12 pages long at the time. There were no computers so they would mail them to us. The printer would make two copies, each with red and blue 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 outsourced this to a printer, 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 I knew 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 expanding 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 – or – the industry might do this work all the time. We know what we’re doing. We can talk to you about what we’re doing and that enthusiasm is contagious. 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 bring the latest 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 sufficient technical information in a logical way so it could be more easily absorbed. These considerations didn’t always fall into the consciousness of the dredging community. I mean, they are engineers doing what they’re doing. They’re 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 this because what often happens with people who are technicians is that they assume that others have the knowledge that 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 of officials. My value was in knowing how to write and the value was being able to explain it in a way that they were all scientists but it was about what they were doing and that enthusiasm is contagious.

I was interested at having lunch recently with a group of people and everyone was talking 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 is 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 research programmes going on at the moment in the New York New Jersey area because of the hurricanes and 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 do it. In Europe or the USA the Act is now on the Far East, exchange information with each other all the time. The collegiality amongst engineers and 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.

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

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’Aroy and you were one of those people that I met in the very beginning. He was part of the first generation that was active in reclaiming the land in the 1953 floods of 1953. That affected Belgium and England too. Everyone was concerned about how was going to happen and realised that solutions had to be found.

When I see the projects dredging companies have been working on, it’s 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.

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 companies came with the alternative idea to unite a small, rocky island Chek Lap Kok within a smal nearby island, Lam Chau, to create a big enough area on which to build. It took 237 million m3 of reclamed sand to transform the islands into a 1,250-ha platform secure enough to bear the weight of buildings and airplanes. At this time, it was the largest reclamation project ever executed and required massive coordination of the world’s largest 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 nicknames.

The day I flew home from Hong Kong was the day that the bridge connecting the new places to the mainland was opened. There was no port yet, just a platform on where there were all these boats and ferries, all testing their horn and Mikawat. 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 reclamation projects. The transition of course was the Middle East opened up with Dubai and Abu Dhabi and the Palm Islands.

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 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.

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. We had a Senior Editor and a Senior Executive Director, and I think he went by the name of Public Relations Committee and member companies. That was really the bread and butter of Terra et Aqua. We invited companies to send us articles and then fill the journal with other research papers from students doing PhDs as well as company in related fields. We were always open to those researchers worldwide who wanted to contribute. These archivous people, so trying to get someone to first think 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 needed to be a lot of MBs. That said, nobody understood when you said 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 to.

The photographs of the building of Hong Kong airport were impressive. As were those of Maastricht 2 and another monumental project that we covered in no many aspects in Terra et Aqua. And the massive projects in Scandinavia Storabiel and Oresund. When I first started as editor, the member companies would send out photographs and often make aerial photographs to capture the projects. It was probably my first year that went to every single A4-sized size and framed their photographs archives. There were a lot of slides too! Remember those?

Then everyone got digital cameras. So instead of paying photographers, they started sending someone there to take photos made by crew members—or very dubious quality. Whenever I had a chance, at a conference or a job fair, I would always ask, can you 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 knew it was a serious business, but I always smiled a welcoming.

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

There have been many memorable issues of Terra. But there is one that stands out in my mind. December 1999 (#77). We were going into the year 2000 and didn’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 even keep their 35mm film and SLR cameras and then the new millennium of dredging and had 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 lot of research—starting with Leonardo da Vinci—and writing, rewriting and was just an enormously interesting.

The second one was the 20th anniversary issue that we published in September 2005. For that one we changed the whole design again and presented a wide range of infrastructure projects of the past 40 years. It was a deep dive into the modern dredging industry and an unforgettable hunt for photographs. Every company that contributed a story provided us with a few photos. And we published both a hardcover and softcover 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 did before—or so I think. It’s a ground-breaking. Constantin Daimana was then Secretary General and totally fascinated with Ronald Waterman’s concepts. Ronald truly became the father of the whole Building with Nature movement and Constantin wanted to do a special issue based on Waterman’s book. His concepts led to the Sorted Horizon construction on the coast near The Hague, and a similar project in the UK. He 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 you were there, of course, the more communication initiatives you were able to do. Rene Kolman, IADC’s Secretary General then, and I worked on a digital newsletter that came out every two weeks. The first edition was in collaboration with the International Association of Ports and Harbours and there were 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.

Terra et Aqua played an important role in reaching out to make dredging comprehensible to a wider audience.
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 it blossomed and became what it is now. Informationally and technically, it really blossomed. I think with the redesign back in 2018, that was the moment that Terra really blossomed.

What did you find so fascinating, not only about Terra et Aqua in general, but about the dredging industry specifically, 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 dredging companies had to really explain what they were doing, how they were going to do it, how it would create jobs and how it would be good for the economy. That was a big change from people just going in and starting to dig somewhere and we’re like, where did we land up doing this?

How you communicate with the public became so important. The dredging industry really picked up and internalised 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, redundant oil storage installation in the North Sea. The dredging industry looked at what Shell’s failings were 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 placate 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 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 people’s lives. 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 abust.

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

The secretary of transport for Darwin, Australia, invited us to dinner and she was the only woman in the group in that first East Asia trip. I 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 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 that 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 I stand at the ship so much higher out of the water, the ballast is gone. And then I came the time was to disembark. One of the crew simply throws 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 just walk back down that ladder. Sort of. I thought I was walking like walking on 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 to descend on the actually looked down and just freezes. He was just standing there frozen to the spot. I thought I can’t do it. I’m just going to be sick. I thought 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 talking about when I got off the ship. Then I took the train to Amsterdam. And when I got there I 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 never thought about it at the time. It was just an amazing experience. Sitting on the deck, watching this ship go up and down. But realise how 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 remember with Nick Bray and Gerard van Raaij. Nick was in England, Gerard was in Abu Dhabi and I was in the USA. We were in this round the clock schedule with someone, somewhere always working. Oh, and the printer was in India. You know that some was what we found was about what was the dredging was about. Everywhere was everywhere at the time. In crazy places. Never out of limits, dredgers without borders. I remember I did an interview once with someone who was working in the Doran 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 mobile phone standing on a sandbank off of a offshore platform 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 practicability and the huge amount of research and innovative thinking that propels it forward. So, I have no regrets. I really feel like I have, it was a real privilege having had that experience. I feel like my life was really unique.

And the printer was in India.
UPCOMING COURSES AND CONFERENCES

Dredging and Reclamation Seminar
27 June–1 July 2022
The Hague, The Netherlands
For (future) decision makers and their advisors in governments, port and harbour authorities, offshore companies and offshore contractors. This conference offers participants the opportunity to network with other decision-makers, discuss challenges and potential solutions with experts, and learn about the latest developments in the dredging and reclamation industry.

WEDA Dredging Summit and Expo ‘22
28–29 July 2022
Minneapolis, Minnesota, USA
The WEDA Dredging Summit and Expo is the largest gathering of dredging professionals worldwide. This year’s event will feature technical presentations, workshops, and an exhibition floor showcasing the latest technology and equipment in the industry.

Dredging for Sustainable Infrastructure Course
29 December 2022–1 January 2023
Delft, The Netherlands
This course provides an overview of the latest developments in sustainable infrastructure, with a focus on dredging and reclamation.

Financing Sustainable Marine and Freshwater Infrastructure Conference
1 December 2022
Dubai, UAE
This conference will bring together experts to discuss the latest trends and opportunities in financing sustainable infrastructure projects in the marine and freshwater sectors.

Nominations for IADC Safety Awards 2022
Concluded to encourage the development of safety skills on the job as well as highlight safety awareness, the awards recognise the exceptional safety performance of a particular project, product, vessel, team or employee. Two safety awards will be presented: one to a dredging organisation and another 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 non-members.


Call for submissions
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