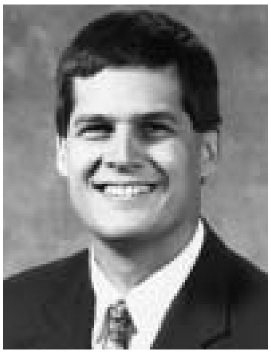
Gregory L. Williams and Kris G. Visser

The *Punaise*: A Remotely Operated Submerged Dredging System



Gregory L. Williams

Gregory Williams is a Research Hydraulic Engineer in the Coastal and Hydraulics Laboratory at the US Army Engineer Waterways Experiment Station (WES) in Vicksburg, Mississippi. He has worked in the Dredging Research Program, Wetlands Research Program and the current Dredging Operations and Environmental Research Program. He received a BSc in Civil Engineering from North Carolina State University, an ME in Coastal Engineering from Old Dominion University, and is currently pursuing a PhD in Ocean Engineering at Texas A&M University.

Kris G. Visser

Kris Visser has a BSc in Civil Engineering and has worked for over 25 years with various Dutch dredging companies. From 1989 on, he has been General Manager of J.G. Nelis responsible for the development of the *Punaise*. In 1995, when the PinPoint Dredging Company was formed by Boskalis, Ballast Nedam Dredging and J.G. Nelis, he became the coordinator of all activities related to this dredge.

Abstract

The *Punaise* (Dutch for "thumbtack") is a remotely operated, water-tight, submerged dredge pump system that can dredge sediments from the seafloor without impact to navigation or being affected by storms. The first *Punaise* was originally designed for silt removal and used in 1991 in The Netherlands. Since then, a second system has been constructed to remove sand for beach nourishment activities. PinPoint Dredging Company, a partnership of J.G. Nelis B.V., Ballast Nedam Dredging B.V. and Boskalis International B.V., operates the *Punaise* system and has most recently used it at beach nourishment project on the Dutch coast during the autumn of 1996. Though the *Punaise* has not yet operated in the U.S., PinPoint Dredging Company and the State of New York planned to demonstrate the *Punaise* technology for inlet by-passing, but a combination of procedural delays and limited geotechnical/geological information prevented implementation within the available environmental time frame.

This paper was written with the intention of presenting a new dredging technology to the US and is funded by the USAE Waterways Experiment Station's Dredging Operations and Environmental Research (DOER) Program. The Innovative Technologies Focus Area within DOER is tasked with identifying new and innovative dredging technologies for potential demonstration and monitoring to help USAE Districts conduct dredging more efficiently. This paper is not intended to be an endorsement for any particular technology or dredging company but merely to identify a technology with potential application in the US. Permission was granted by the Chief of Engineers to publish this paper.

The paper was presented at the WEDA XVIII Conference in Charleston, South Carolina, June-July 1997, and was first published in the Proceedings of the conference. It received the "Most Outstanding Paper"award from the Dredging Contractors of America. The paper is reprinted here in a slightly revised form with permission.

Introduction

Most advances in the dredging industry are modifications to existing equipment. Very infrequently, a new dredging concept is developed. One such innovation in the past seven years is the *Punaise* (Dutch for "thumbtack") dredging system designed and constructed by De Groot Nijkerk Machinefabriek and J.G. Nelis Group of The Netherlands (Brouwer, Visser and van Berk 1991; Brouwer, van Berk and Visser 1992; and Brouwer, Hallie and de Looff 1995).
The *Punaise* is a remotely operated, water-tight submerged dredge that resides on the seafloor and pumps sediment without impact to navigation. Because it is located on the seafloor, it is tolerant of adverse surface wave action which allows it to operate in all types of weather and sea state conditions. The *Punaise* is connected to a shore station via an umbilical which serves not only as the communication connection but also as the discharge line through which the dredged slurry is pumped. The entire dredging process including sinking and floating (i.e. filling and emptying ballast tanks) is controlled from the shore station by one individual. The *Punaise* can thus operate for long periods with relatively low labor costs. Maximum flexibility in sediment removal is attained through the flexibility of repositioning the *Punaise* at the dredging site from time to time with the help of a tug.

Figure 1. The Punaise PN250.

Figure 2. The Punaise PN400 afloat in Amsterdam Harbour under winter conditions.

Punaise Principle of Operation

The *Punaise* operates under the principle of the deep-dredging process (i.e. putting dredge pump as close to the sediment intake as possible). In so doing, the *Punaise* also requires an embedded support that must extend below the suction intake for vertical stability during dredging. Figures 1 and 2 show the two existing *Punaises*, PN250 and PN400, which contain a dredge pump, electric motor, instrumentation, suction intake and vertical support. Specifics for each model are shown in Table I.

Table I. *Punaise* Specifics

	PN250		PN400	
	SI	English	SI	English
Width	7.8 m	25.6 ft	8.5 m	27.9 ft
Height (without suction pipe)	3.1 m	10.2 ft	6.0 m	19.7 ft
Height (with suction pipe)	8.5 m	27.9 ft	8.7 m	28.5 ft
Draft	7.5 m	24.6 ft	6.5 m	21.3 ft
Working depth	30 m	98 ft	40 m	131 ft
Required sediment thickness				
initial production	6.0 m	19.7 ft	7.0 m	23.0 ft
max production	8.0 m	26.2 ft	10.0 m	32.8 ft
Pump capacity	800 m^3/hr @ 6 bar	1,046 y^3/hr @ 87 psi	2,400 m^3/hr @ 8 bar	3,140 y^3/hr @ 116 psi
Discharge pipe diameter	26.0 cm	10.2 in	40.0 cm	15.7 in
Weight/Mass	47 m-tons	52 tons	95 m-tons	105 tons

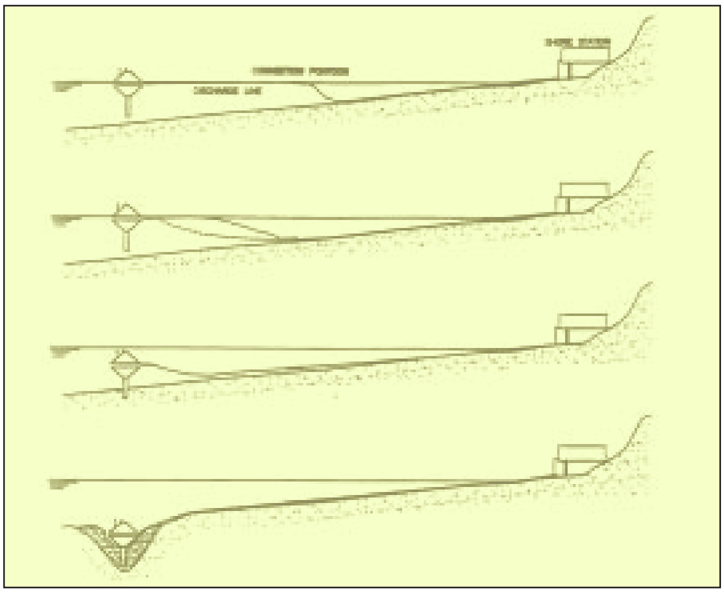


Figure 3. Drawing of the Punaise dredging process.

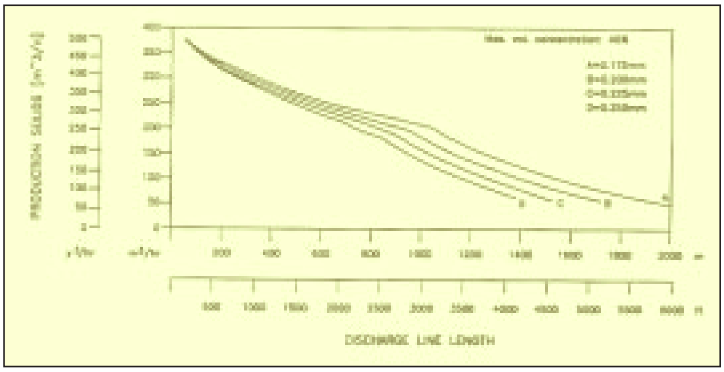
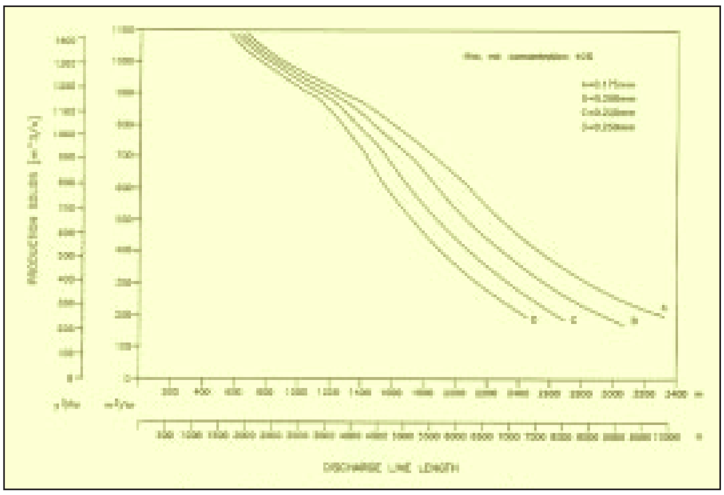


Figure 4. Punaise PN250 production capability.

Figure 5. Punaise PN400 production capability.



During setup prior to dredging, the shore station is established and the umbilical is floated to the dredging site. The *Punaise* is then connected to the umbilical and positioned at the appropriate location for sinking to the seafloor. Once positioned, the ballast tanks are filled and the *Punaise* settles to the bottom. Fluidisers are then activated which allow the vertical support (best described as an extension of the suction pipe) to settle into the sand bottom. When the suction intake reaches the level of the bottom, dredging begins. As material is removed, a crater or pit is formed with the *Punaise* located at the lowest point. Dredging continues and crater/pit size grows (*Punaise* settles further into bottom) until either the desired dredging depth is reached or resistant bottom features (e.g. bedrock, clay) prevent further settling. A schematic showing this process is shown in Figure 3.

Punaise production depends on both the sand grain size and the pumping distance. Figures 4 and 5 show the relationship of sand grain size and pumping distance to solids production for each *Punaise*, respectively.

Punaise Projects in Europe

After constructing the first *Punaise* prototype (PN250) in 1990, a lump-sum contract was awarded to remove 600,000 m^3 of silt per year for two years in Flushing Harbour in The Netherlands. The dredge was permanently positioned in the center of a turning basin where the silt was concentrated. From this position, the fresh clean silt was pumped through a submerged pipeline directly to the Schelde estuary which ends in the North Sea. The system proved to be very reliable.

Minor maintenance and repair works simply required refloating of the dredge, while major maintenance required that the dredge be disconnected from the discharge pipeline and umbilical. During a continuous period of more than three months, the dredge was submerged at a depth of 16 m and regularly pumped silt to the discharge location. This two-year period also allowed for testing and improvement of various design criteria.

In 1993, a demonstration contract was signed between the Dutch Ministry of Public Works and the contractor J.G. Nelis to conduct a beach nourishment project. Owing to the effort of the Ministry of Economic Affairs, who supports innovative technology with risk loans, the decision was made to construct a bigger and more powerful dredge specially suitable for pumping sand from a borrow-pit at sea in the coastal zone.

The shape of the dredge was adapted to allow dumping sand on top as from a hopper dredge. To facilitate continuous production in consolidated sand layers, the support pipe was fitted with hydraulic cylinders to raise and lower the pipe in the hull of the dredge.

This allows closing of the normal suction opening halfway down the support pipe. The material to be

Figure 6. The new click-in system, the male part.

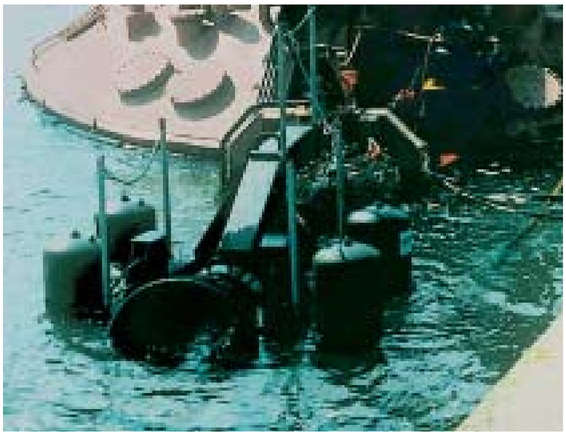


Figure 7. The female part of the click-in system.

Figure 8. The coupling is completed.

dredged must then enter at the bottom of the support pipe thus creating steep (unstable) side slopes in the sand layers.

Based on the experience with the *Punaise* PN 250, a new Programmable Logic Controller (PLC) programme was developed to control the dredge. Fiber optics were used for communication between the shore station and dredge. In 1995 a modified lay-out of the umbilical was designed, and a new "click-in" modification was implemented to the connection between the dredge and flexible discharge line to improve the flexibility of the system (Figures 6, 7 and 8).

Punaise Technique

Energy and data supply

Electrical power is supplied by two diesel driven generators located at the shore station on the beach (Figure 9). The total installed electrical power is approximately 1200 kW and is divided in 800 kW/3000 V used for the sand pump electric motor and 150 kW/660 V used for the auxiliary equipment. The umbilical is composed of 11 mm core diameter electrical cables, which provide a relatively cheap and flexible system so that future changes in working distance and/or electrical power can easily be adapted (Figure 10).
Choosing the appropriate core diameter depends upon several factors including: electrical power, distance from dredge to shore, cable handling, connector type, and cable price. For electrical power, a compound of voltage and current is limited to 3000 V (the Dutch standard for unprotected cables). In addition, there is a need for increased power for increased dredging distances offshore. Proper and effective cable handling is limited for cables larger than 11.3 mm in diameter, and inexpensive, moldable connecters for diameters larger than 11.3 mm do not exist. Therefore, the only way to exceed the 11.3 mm core diameter limit is to use parallel cables, which increases the cost. For example, the umbilical in *Punaise* PN400 consists of 12 separate cables of 11 mm diameter and 1,500 m long. This total 18,000 m length of cable costs approximately $250,000. Doubling this for parallel cables would have significant impacts to unit production costs. Not only does the electrical cable lead to a maximum 1,500 m umbilical, but the fiber-optic data transmission between the dredge and the on-shore control unit also has limitations. Using cable sections between 150 m and 300 m long required at least eight lens-based underwater fiber-optic connectors to prevent water penetration in the fiber tip. This type of connector has an optical signal loss of approximately 3 dB. Adding this to the signal loss of the fiber-optic fiber with a calculated spare of 4 dB results in a total loss of 30 dB along the 1,500 m length of cable, which is the maximum allowed with existing reliable LED-based light sources.

Remote control dredging

The unmanned dredge is controlled by one operator from the shore station using standard personal computers for visualising and controlling all the processes and PLCs for the signal input and output (Figure 11).
All signals, 420 digital and 105 analog, are updated and logged every second. All processes (except diving and floating) are fully automated so the operator only tracks operation status which is visualised on a monitor.

Figure 9. The control units and generators were placed near the foot of the dunes.

Figure 11. The unmanned dredge is controlled by one operator from the shore station using standard personal computers for visualising and controlling all the processes and PLCs for the signal input and output.

Figure 10. The umbilical contains 11 mm core diameter electrical cables, a relatively cheap and flexible system.

Diving and floating remain manually controlled because the various external factors require an experienced operator that is able to react faster than a computer. The dredging process is displayed on a separate monitor which includes a window showing the last 10 minutes of operation to track trends. Additionally, the complete filling of the 1,500 m discharge pipe is shown so the operator can determine the specific "critical flow" based on the mass of sand in the pipe. The primary variable which the operator can influence is density. Using water jets at the suction mouth and 2 bypass valves located immediately before the pump entrance, the operator can easily adjust the sand/water mixture with only a few mouse clicks at the computer. Another monitor shows the status of shore based equipment (generators, air compressors and fuel supply). Finally, daily reports showing production results, equipment status, fuel consumption, and *Punaise* movements and location can be produced at the end of each day's operation. In the event of a fiber-optic failure where communication between the dredge and shore station is lost, the dredge can operate autonomously via a special programme in the dredge's PLC. If the connection fails, the dredge automatically opens all the bypass valves and pumps clean water to shore thereby removing all of the sand from the discharge pipe. To retrieve the dredge, the operator can supply air at 5 bars to the *Punaise* through one of two air hoses in the umbilical which allows the dredge to empty its ballast tanks and rise to the surface.

Table II. *Punaise* Projects in The Netherlands

	Bloemendaal	Zandvoort	Heemskerk
Year	1994	1994	1996
Volume	255,000 m^3	350,000 m^3	475,000 m^3
Length of replenishment	2,500 m	2,000 m	1,600 m
Volume/length	103 m^3/m	175 m^3/m	297 m^3/m
Fill elevation	+3.5 m MWL	+3.5 m MWL	+4.0 m MWL
Slope	1:30	1:30	1:30
Maximum pumping distance	2,700 m	2,000 m	1,900 m
Length submerged pipeline	1,000 m	1,000 m	1,100 m

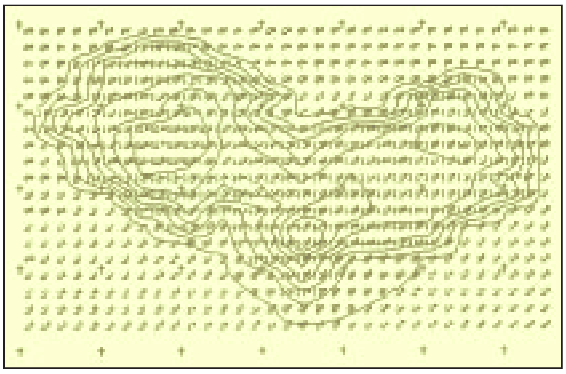


Figure 12. Depth contours of dredge pit at maximum area. Dredging was limited to -25.00 m MWL, and the resulting pit was kidney shaped.

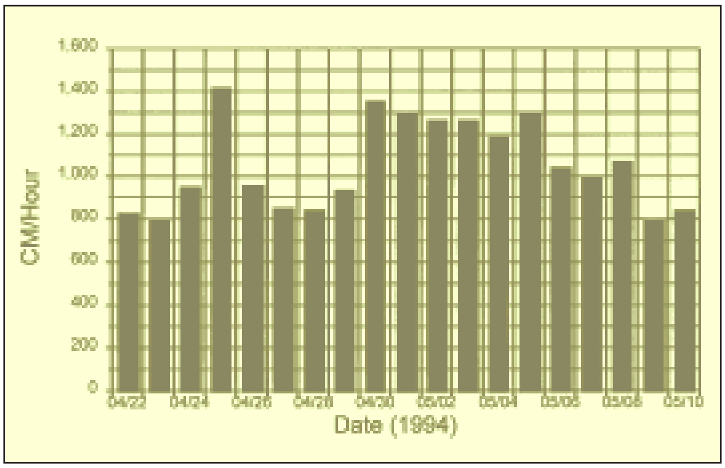
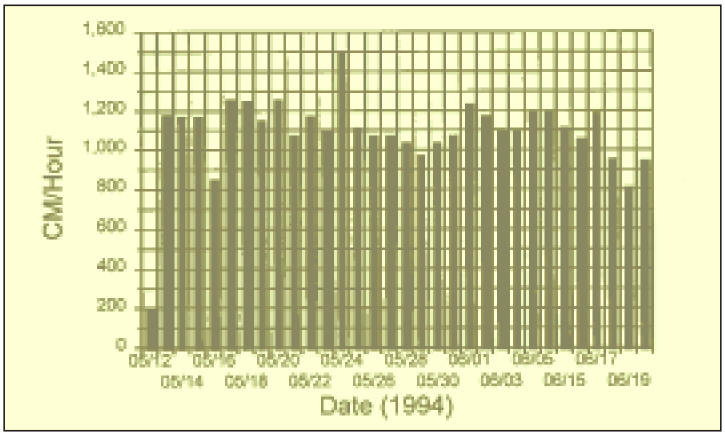


Figure 13. Average hourly production by day for Bloemendaal.

Figure 14. Average hourly production by day for Zandvoort.



Beach Replenishment Projects in The Netherlands

The dredge *Punaise* PN400 was constructed primarily for three projects all on the central North Sea coast west or northwest of Amsterdam. Details of these projects are summarised in Table II.
For the 1994 projects, the Dutch Ministry of Public Works monitored the effects of a temporary sand re-handling pit in front of the coastline at -7.00 m MWL. The monitoring programme indicated that the negative effects on the coastal morphology and the macrobenthic community on the seabed adjacent to the borrow pit area were either small or immeasurable. Turbidity levels measured in the breaker zone did not exceed the usual background values and there was no evidence of any movement of the pit towards the coast or in any direction.

During the demonstrations in 1994, the *Punaise* was allowed to create its own pit to meet the total quantity to be dredged with no limitation placed on pit size (area). Dredging was limited to -25.00 m MWL, and the resulting pit was kidney shaped (Figure 12).

For the project conducted in 1996, the *Punaise* was restricted to work in an area of 100 m x 60 m and depth of 25.00 m MWL. The contours of the re-handling pit at the original depth were 250 m x 150 m. After removing 150,000 m^3 from the pit, the *Punaise* received dredged material dumped from a hopper dredge for onshore pumping.

Production
The 1994 projects were conducted in April and May during calm/normal weather conditions. The average hourly productions per day are shown in Figures 13 and 14 for Bloemendaal and Zandvoort, respectively.
In October and November 1996, the Dutch Ministry of Public Works initiated the beach nourishment project at Heemskerk to test the performance under heavy weather conditions (Figure 15). During the two-week period from 1-13 November, the system was tested during a series of storms. A wave rider buoy located offshore recorded storm conditions approaching a 10 on the Beaufort Scale. Beaufort Scale 10 can be described as follows:

- sea specification–very high waves with long over-hanging crests; resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; on the whole, the surface of the sea takes a white appearance; the tumbling of the sea becomes heavy and shock-like; visibility affected
- equivalent wind speed at 10 km–mean 52 kts, limits 48-55 kts
- probable height of waves–9.0 m

During the first days of the storm, production increased because of an increasing pit production, and the pit slopes changed from 1:3 to 1:5 as a result of breaking waves. After dredging and pumping approximately 150,000 m^3 from the pit, additional material was to be supplied by a hopper dredge near the beginning of the storm period. However, owing to the adverse weather conditions, hopper dredge operations did not begin until 13 November. This test thus showed the vulnerability of a continuous production if a hopper dredge and

Figure 15. Test project, November 1996, at Heemskerk, under heavy weather conditions (Beaufort 9).

Punaise are used together when weather is uncooperative. Figure 16 shows the daily production of the *Punaise* during this time period. Figure 17 shows the hopper dredge volume placed per day, Figure 18 shows the measured wave heights, and Figure 19 shows the evolution of the pit side slopes.

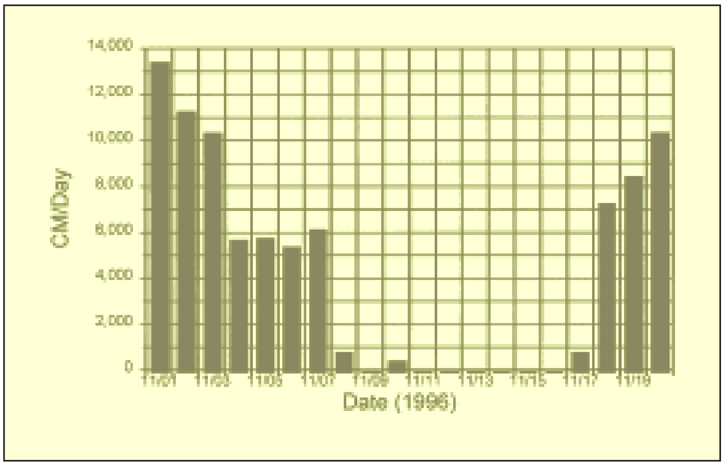
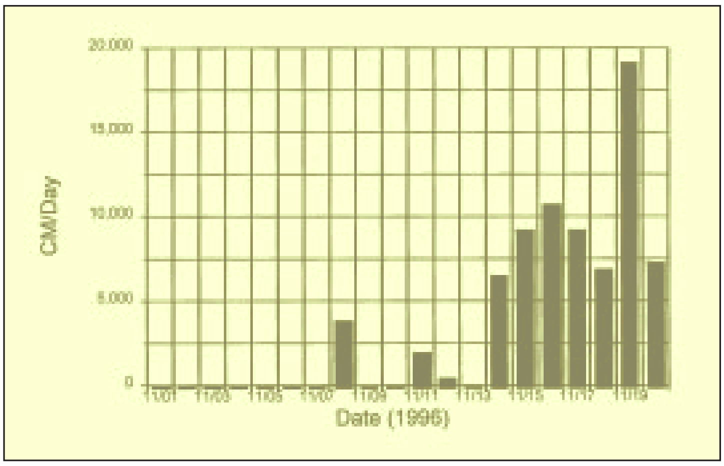


Figure 16. Daily production of the Punaise during the storm conditions at Heemskerk.

Figure 17. Volume placed by hopper dredge at Heemskerk.



Cost figures

To minimise the costs for mobilisation and installation, all of the equipment, except the hull of the dredge, is stored in containers and is transported by ship to a harbour near the dredging location. Assembling of the discharge pipeline, umbilical and establishing the units for control and power supply normally takes about 4 weeks.

The unit cost for the three demonstration projects conducted in The Netherlands was \$4.71/m^3 (\$3.60/y^3). The cost for the hopper dredge component filling the pit was \$1.63/m^3 (1.25/y^3).

The New York "Experience"

The New York State Department of State (NYSDOS) and PinPoint Dredging Company planned to conduct a demonstration of the *Punaise* system at Shinnecock and Jones Inlets on the south shore of Long Island during January and February 1997. This demonstration was intended to investigate the feasibility of using the *Punaise* to conduct sand bypassing at structured inlets in the US. A detailed effort to monitor equipment effectiveness, crater surveys, and beach surveys near the crater and placement sites was planned. Shinnecock and Jones Inlets each have chronic downdrift erosion problems, so the demonstration would have provided an opportunity to evaluate the technology as well as place much needed sand on the downdrift beaches. The demonstration was to have bypassed approximately 153,000 m^3 from each inlet to the downdrift beaches. Project costs included:

– $500,000 for mobilisation/demobilisation;
– $560,000 for dredging at Shinnecock; and
– $660,000 for dredging at Jones.

Assuming an equal distribution of mobilisation/demobilisation costs between inlets, total project costs were estimated at $810,000 for Shinnecock and $910,000 for Jones. These costs translate to respective unit costs of $5.29/m^3 ($4.05/y^3) and $5.95/m^3 ($4.55/y^3) at each inlet. The higher unit cost at Jones Inlet was the result of a longer pumping distance (NYSDOS 1996). In November 1996, NYSDOS contracted for sediment cores to be taken at each dredging location to determine the sand thickness available for Punaise operations. A total of five cores (4-6.1 m long and 1-12.2 m long) were taken at each site between 19 November and 4 December.

Shinnecock Inlet

Three of the cores taken at the Shinnecock site (approximately 6.1 m water depth offshore of the updrift fillet), showed good quantities of sand to a depth of approximately 12.2 m (sand thickness of approximately 6.1 m). One 6.1 m core showed the start of a dark brown mud layer at a depth of 11.6 m (5.2 m thickness). This mud layer extended at least to -13.3 m (6.7 m bottom thickness). The 12.2 m core at Shinnecock also showed mud at the 11.3 to 12.2 m depth and then continuously from about -12.6 m to the bottom of the core at -17.9 m (Alpine Ocean Seismic Survey 1997). From Table I, one can see that the PN400 would not be an effective tool at Shinnecock because the required minimum sand thickness to begin production exceeds 7.0 m which is greater than that available at this location. If the PN250 were considered (required minimum sand thickness is 6.0 m), then only minimum production would be attained at three of the core locations.

Jones Inlet

At Jones Inlet, the 6.1 m cores indicated a relatively clean sand (one instance of mud about 0.12 m thick) to the bottom of the core. However, the 12.2 m core showed the beginning of a clay sand mix at about -12.5 m (bottom thickness of 5.7 m). Below 13.6 m depth, to the bottom of the core, material was a hard clay (Alpine Ocean Seismic Survey 1997). Implications for *Punaise* operations were therefore similar to Shinnecock in that the PN250 would have been mildly effective to a certain depth, but never reaching a depth for maximum production, while the PN400 would not be effective at any of the five core locations.

Because the cores taken at each site indicated that no more than a 6.1 m thick layer of clean sand was available for dredging at either site, the *Punaise* demonstration project was cancelled. Although the PN250 (and possibly the PN400) could probably have dredged

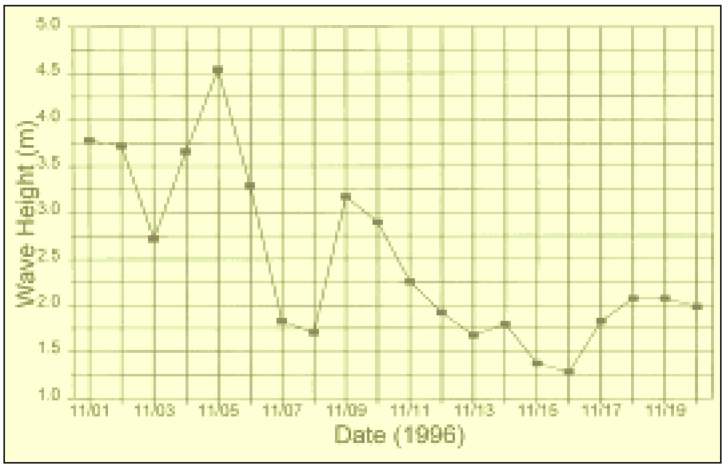
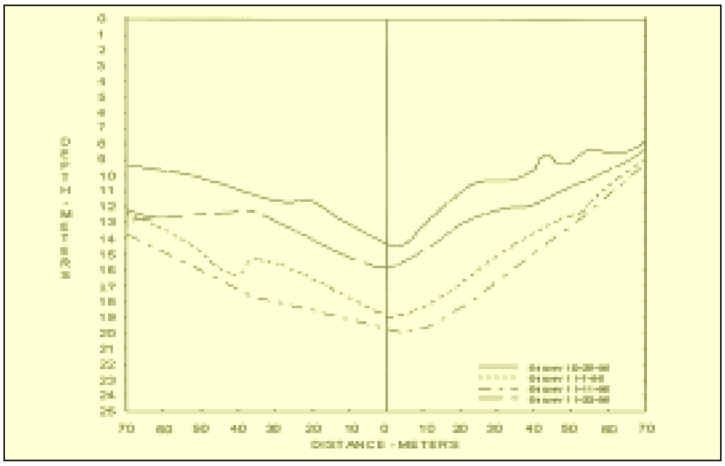


Figure 18. Wave heights during storm period at Heemskerk.

Figure 19. Pit side slopes generated during November 1996 project at Heemskerk.



some sand, the location of a clay layer would have required frequent repositioning thus reducing dredging efficiency and greatly increasing costs.

Punaise Operation in the US

Prior to (and since) the effort started by NYSDOS, no other project has considered using the *Punaise* system for dredging in the US. One reason for lack of US work has been little known legal issues associated with the Merchant Marine Act of 1920 (more commonly known as the "Jones Act" named for its author, Senator W.L. Jones) which may limit the ability of the *Punaise* to operate in waters of the US. The "Jones Act" is a detailed act that deals with a wide range of port and maritime trade issues. Because of section 27 of the Merchant Marine Act of 1920, which restricts US coastwise trade between the contiguous and non-contiguous states and territories to only US flagged vessels, the name "Jones Act" has become synonymous with US cabotage laws in general. The impact to dredging is related to an amendment of still another act

which states that all dredging activity be governed by section 2 of the Shipping Act of 1916 and section 27 of the Merchant Marine Act of 1920. So even though dredging itself is not restricted to US flagged vessels in the Jones Act, per se, subsequent amendments have made the Jones Act the authority for governing dredging activities (Powers 1996). This law is reflected in Title 46 U.S.C. App. § 292.
Therefore, before NYSDOS could enter into a contract to use the *Punaise* for bypassing at Shinnecock and Jones Inlets, they first had to seek a ruling from the US Customs Service on whether the *Punaise* dredging system was prohibited by the "Jones Act."
In August 1996, the US Customs Service issued a ruling on the legality of *Punaise* operations in the US. The US Customs Service decision is based on two requirements from the law, namely that to be prohibited, "it must be engaged in dredging and it must be a vessel" (US Customs Service 1996). The US Customs Service showed that the *Punaise* was indeed involved in dredging, but since it neither carried a crew nor merchandise nor was self-propelled, it could not be considered a vessel. Therefore, the *Punaise* is not prohibited by the "Jones Act" from working in the US.

Future Plans

In 1996 the Dutch dredging companies J.G. Nelis B.V., Ballast Nedam Dredging B.V. and Boskalis International B.V. entered into an agreement for the exploitation of the PinPoint technology with the dredges *Punaise* PN250 and *Punaise* PN400. All three partners are working together in this agreement to develop and improve this innovative dredging method. Stuyvesant Dredging Company in New Orleans, a fully owned company of Boskalis International is the primary contractor of the *Punaise* in the US. Currently, there are plans to build a *Punaise* dredge (PN250) to specifically address dredging and bypass problems around the many inlets along the sandy US east coast. PinPoint Dredging expects to execute the first demonstration project in the US in early 1998.

Conclusions

The *Punaise* is a new concept in dredging technology able to conduct dredging operations in and near navigation channels with minimal impact to ongoing navigation. Some of its advantages include:
- submerged;
- remotely operated;
- shore connected by a communication/discharge umbilical;
- only one operator required;
- automated operation; and
- mobility for movement within a borrow area or to other locations for dredging operations.

Previous work in the Netherlands has proven the technology to be an effective system to dredge and pump material for traditional beach nourishment projects.
The *Punaise* is also especially adept for working in storm conditions at relatively low costs. Because it has been ruled that the *Punaise* is not restricted for operations in the US by the "Jones Act," Stuyvesant Dredging Company is actively seeking a US site to perform dredging and/or bypassing operations. PinPoint Dredging company is currently considering a design modification to allow better access to thicker sand layers in shallower waters. Possible sites for consideration include Long Island, NY, Delaware and Florida. USAE Waterways Experiment Station, through the Dredging Operations and Environmental Research Program, is assisting Stuyvesant and PinPoint Dredging Companies to locate a demonstration site and will monitor production, fuel consumption, mobilisation and demobilisation, and so on, to evaluate the equipment effectiveness. Preliminary plans are to select a demonstration site and commence dredging/bypassing early in FY 1998.

References

Alpine Ocean Seismic Survey.
"Final Report: Vibracore Sampling at Jones and Shinnecock Inlets, Long Island, New York." 1997.

Brouwer, J., Visser, K.G. and van Berk, H.
"Silt Removal with the Punaise, A Flexible Self-Burying Dredging System." *Proceedings of CEDA/PIANC*. Amsterdam, The Netherlands. November 1991.

Brouwer, J., van Berk, H. and Visser, K.G.
"The Construction and Nearshore Use of the Punaise, A Flexible Submersible Dredging System." *Proceedings of XIIIth World Dredging Congress (WODCON)*. Bombay, India. April 1992.

Brouwer, J., Hallie, F.P., and de Looff, A.P.
"Marine Environmental Effects of Sand Extraction at Nearshore Locations." *Proceedings of XIVth World Dredging Congress (WODCON)*. Amsterdam, The Netherlands. November 1995.

NYSDOS.
New York State, Department of State Memorandum. Subject: Update on sand bypassing demonstrations at Shinnecock and Jones Inlets. 5 Sep 1996.

Powers, J.
"Looking at the Jones Act: Cabotage Laws and The US Dredging Industry." *International Dredging Review*. August 1996.

US Customs Service
Memorandum RE: Punaise, Dredging, 46 USC. App. § 292. August 2, 1996.