

## DREDGING TECHNOLOGY

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### Summary

Dredging is a well established craft involving floating equipment to deepen, create, or maintain waterways for commercial shipping and navigation, and for other purposes, such as hydraulic mining, landfill and reclamation, and environmental protection. It has developed from an art to a sophisticated hydraulic engineering technique, involving specially designed dredging vessels, pumps and pipelines. Scientific investigation goes hand-in-hand with practical engineering over a worldwide enterprise in improving humankind's water-based living conditions. This article gives a historical review, emphasizing the importance of dredging for commercial and economic purposes, and the development of dredging techniques and the associated equipment. It describes in detail the main features of the various dredging systems and the devices used. It also deals with surveying and positioning systems for mapping out the conditions before and after dredging operations have been carried out, for purposes of control and costing. Some of the harbors in Europe, improved and maintained by dredging, are given as examples, and some of the major canals in the world, where dredging played an important role, are cited. Other uses of dredging are dealt with, and the main procedures in contracting are outlined. A representative selection of illustrations of various types of equipment, dredging sites and development maps is included.

## **1. Introduction**

Not everyone has a clear idea about dredging. It is mostly thought to be a dirty job to clean up a harbor basin, and most land dwellers do not realize the importance of dredging. Inhabitants of a coastal area or a river-estuary know better. They know that without dredging the navigation in ports and rivers will after a while not be possible anymore. Small particles of sand, clay or of organic matter come into suspension, caused by the turbulence of the water of the sea or of the river. On arrival in the calm water of a port, the particles sink to the bottom and sedimentation and siltation take place. Port authorities have to guarantee a specified water depth for navigation by ships. To restore the water depth, dredging has to be done. Fortunately, dredging is no longer the big problem it was in past times, since there is enough modern dredging equipment available, and also competent dredging companies for carrying out the work.

### **1.1. Historical Review**

In the past, when dredging equipment was not yet discovered, mighty and prosperous harbor cities and civilizations declined and died. This was merely because the people did not know how to stop the siltation of ports and rivers. Take for example, the case of Memphis, the capital of Ancient-Egypt. Already some 2000 years BC it was an important harbor on the River Nile, with navigation on the river to the interior and abroad. Then the current in the Nile River changed its direction, and the river silted up. The Egyptians did not know how to solve this problem, and without a good harbor the town of Memphis could not fulfill its important role as capital of the country any longer, so that other towns with good harbors took over this role (see *Dredging in Rivers and Estuaries*).

In Ancient Greece, the important cities of Ephesus (Efeze) and Miletus (Milete) (now situated in Turkey) had their commercial harbors in the mouth of the Meander River. In

the period 800 AD the people could not cope with the capricious Meander River and could not keep it properly in its river bed. The whole river mouth area silted up and shipping was no longer possible. On top of this, in the swampy area a malaria epidemic broke out, so that at last the towns were abandoned. The ruins of these towns can still be found at a distance of about nine kilometers inland from the coastline.

A number of other important towns lost their prominent role because their ports silted up and dredging was not possible. As an example may be cited the port of Aigues-Mortes in France, where in the year 1248 AD, the fleets of the Crusades left to liberate the Holy Land. The mouth of the River Rhone has since silted up, closing the entrance to the port. The old city can still be visited, and is situated at a distance of seven kilometers from the sea. The historical city has not changed much and has not been extended in all those years. Now a small harbor and entrance-channel has been constructed for small fishing boats. In England, the town of Sandwich, which in the Middle Ages was a major port on the South Eastern coast of Great Britain, has undergone the same fate. Other examples of towns that lost their importance due to siltation of their ports are those of Tønder and Ribe in Denmark, and Norden in Germany, and there are many more.

Only very rich towns could afford to invest in costly measures to solve their problems. Amsterdam, for instance, became an important and wealthy town, due to its international harbor trade. The port was situated on an inland sea, the “Zuiderzee,” with an open connection to the North Sea, which was enclosed by a closure dam in the year 1932. In front of the entrance to the port a muddy shallow, called “Pampus,” was generated by siltation.

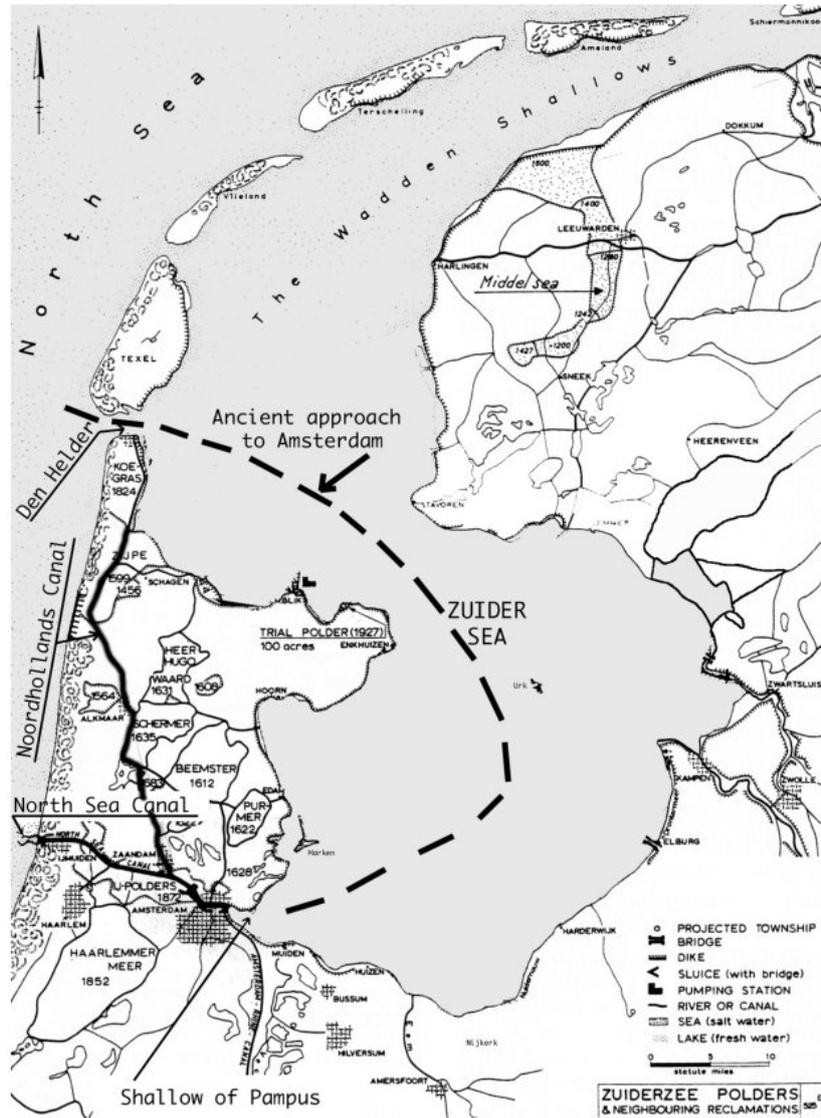


Figure 1. Situation map of the fairway approaches to the port of Amsterdam

Nowadays, it would have been relatively easy to dredge an access channel to the port. It could have been accomplished in a time of some months, but in those days it was simply not possible. Vessels with deep draft had to wait, sometimes for weeks, for a favorable wind, that set up the water level, before they could cross the shallows. Sometimes “ship-camels,” two floating units alongside the flanks of the ship, were used, which could lift the vessels so that the draft could be reduced by 1.50 meters. “Laying for Pampus” is still a common saying in the Dutch language, meaning that one is out of circulation. However, the City Council decided not to give up the prominent position of the port, and to find another access to the North Sea. During the years 1818 to 1824 a 80-km long navigation canal from the harbor of Amsterdam to the fishing village of Den Helder was dug by hand, using shovels, barrows and dredging bails. This canal, the “Noordhollandskanaal,” is still in use for local water transport. However, it is not the shortest connection to the North Sea. Much later, in 1876, the risky venture to make an opening in the natural sand-dune range, which also forms the protection for the low polder landscape against the North Sea floods, was executed, and gave Amsterdam a

direct access to the open sea as shown on the map in Figure 1. This canal, the “Noordzeekanaal,” is still the main entrance to the port of Amsterdam.

The same difficulties have been experienced by the town of Rotterdam, situated at a distance of 35 km from the open sea on the bank of the River Meuse. A sandbank in the river mouth caused big problems for vessels with heavy draft in reaching the port. The now simple job of dredging an access way through the sandbank could not then be done, due to lack of knowledge and good technical equipment. Instead, a new navigation canal was dug by hand as shown on the map in Figure 2. At the entrance of the canal the navy-port, “Hellevoetsluis” was founded. Much later, in the years 1866 up to 1872, the risk was taken to make an opening in the sand-dune range and the 33-km long fairway to Rotterdam, the “Nieuwe Waterweg” was dredged.

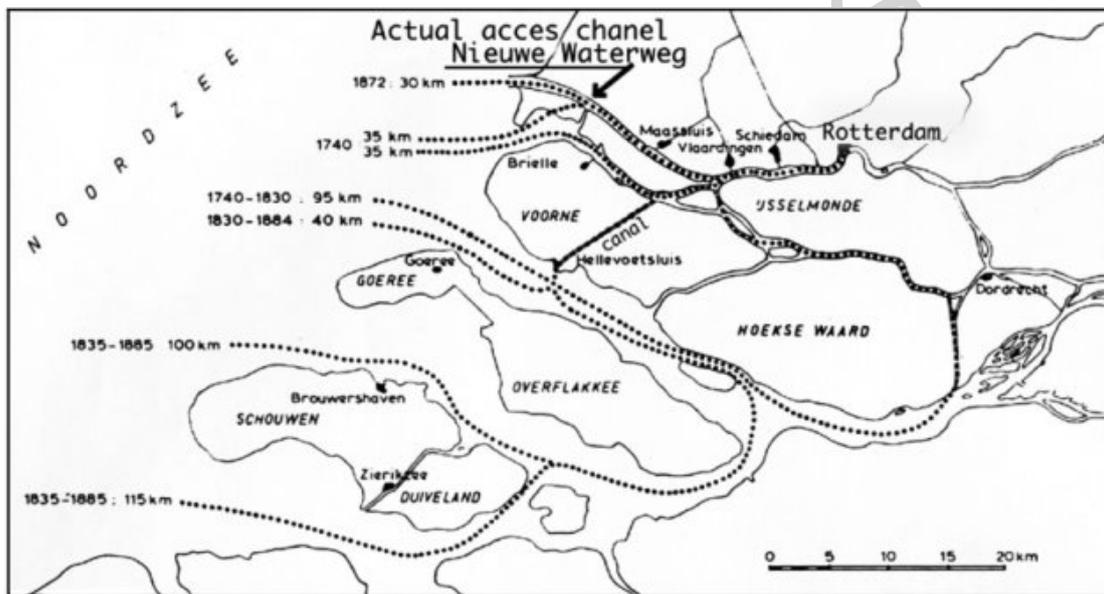


Figure 2. Situation map of the fairway approaches to the port of Rotterdam

In Belgium the towns of Bruges and Gent had the same problems, but in those cases artificial access to the sea was also made. In Germany, the port of Bremen, situated about 70 km upstream on the River Weser had access difficulties for the newly-built ships with a greater draft. Deepening the fairway in the Weser River was at that time technically not possible. The problem was solved by founding a new town, Bremerhaven, in 1827, with a deep seaport located directly on the mouth of the river. In the meantime, the technology of dredging had been so far advanced that the fairway to Bremen has also been deepened for large seagoing ships (see *Dredging of Rivers and Estuaries*).

## 1.2. The Importance of Dredging

The importance of the development of dredging technology for humankind became obvious with the construction of large canal projects, such as the Suez Canal and the Panama Canal. The sea-connections between the oceans were shortened by thousands of miles.

However, dredging is also important on land. In low lands and areas in river estuaries it is a vital necessity to be protected against floods from the sea or from the river. Dikes and dams have to be built by dredging machines, and water storage reservoirs and hydropower station intakes may need to have sediment removed from them by dredging.

On coasts with erosion, sand fill on the beaches has to be made with spoil obtained from dredging operations. In many other places, sand fill by dredging and pumping is carried out for industrial areas, town extensions, airports, harbors, artificial islands, offshore industry, construction of roads etc. (see *Hydraulic Structures in Coastal Defense; Sedimentation, Silting and Desilting of Reservoirs; Land Reclamation*).

Making trenches in rivers or the sea for pipelaying or tunnel construction is also an item of importance. Furthermore, dredging technology is applied for the mining of minerals, such as sand, gravel, tin, and diamonds.

In order to maintain standards of life and to sustain a sound social and economic development structure, it will always be necessary to invest in new infrastructural projects, and to engage in new construction projects. In many such projects dredging is a key factor. Therefore, it is clear that dredging is indeed an important life-support system.

## **2. Development of Dredging Equipment**

In this section, a survey is given of the development of dredging devices from the simplest to the most complicated. It starts out with dredging bails, scratchers and scrapers, bucket devices and various types of suction dredgers. Hopper dredgers developed to contain the spoil before being dumped away from the dredging site. For removing the material apparatus, such as cutters, back-hoes, dippers and grabs were developed. Ultimately, water jetting devices were developed for the water-injection dredging system.

In addition, auxiliary equipment, such as barges, dump trucks, bulldozers, pipelines and booster pump-stations are required. In the following sections, these components are discussed in more detail.

### **2.1. The Dredging Bail**

The simplest dredging tool was the dredging-bail as shown in Figure 3. It could only be used for mud and soft soils. The bail consists of a wooden pole with an iron frame to which a bag of fine netting material is attached. The person dredging holds the pole over one shoulder and pushes the iron frame to the bottom of the water. The pole is then dragged back up so that the net is filled with dredging slurry. The net can be emptied on shore or in a pram. Of course, this method can only be used in shallow water and for small-scale jobs. The dredging-bail is not much in use anymore.



Figure 3. Dredging bail

## 2.2. The Scratcher

The scratcher, or “krabbelaar,” was built in 1435 for maintenance dredging in the Scheldt River. It was a sailing-vessel towing a large underwater rake as shown in Figure 4. Making use of the tidal current, sediment at the seabed could be agitated, so that the tidal current to the open sea transported the mud. This type of agitation dredging was relatively effective, but could only be used during a favorable tidal stream. Similar units of this kind have been built in several places.

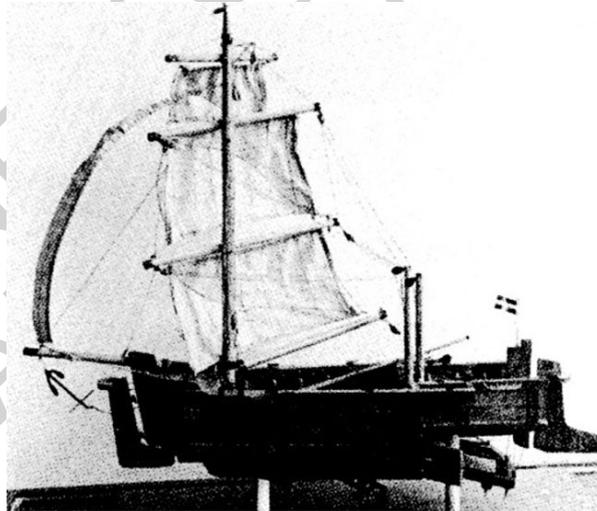


Figure 4. The agitation dredger “Krabbelaar” (scratcher), which was operating in the Scheldt estuary in the fifteenth century

## 2.3. The Underwater Scraper

In areas without a current, or with only a slight current, a type of underwater scraper was used as shown in Figure 5. An underwater rake was attached below an anchored pontoon. The ensemble was towed to the shore by means of winches. The dredged slurry was disposed of on the shore. In 1686, such a craft was already in operation. The

underwater scraper- or drag-method is still in use, but it is usually towed by a tug. It is an effective method for smoothing out a bed surface of a just-dredged area.

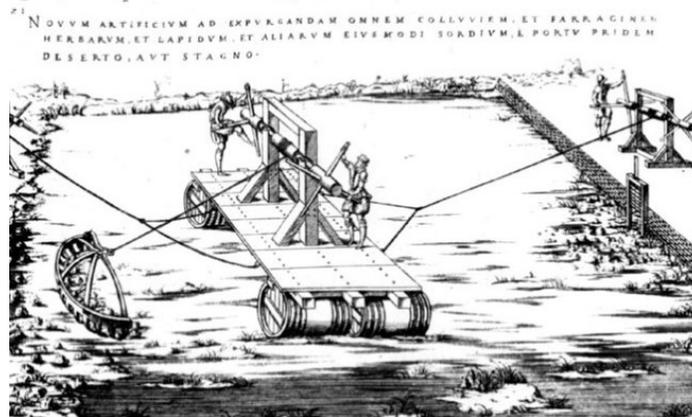


Figure 5. Outline drawing of an underwater scraper

#### 2.4. Mud-Mills and Bucket-Wheels

As a further development, a mechanism was invented to lift the mud from the bottom and out of the water. Already in 1492, Leonardo da Vinci made a design for a bucket-wheel dredger, driven by human power. There is no evidence that it was ever constructed or worked.

In the Netherlands, there has always been a great deal of siltation in the ports and canals. To keep navigation going the soft mud had to be dredged. Two patents for a new type of mud-dredging machine were granted in 1589. The mud from the bottom was pushed upwards along a wooden gutter by an upwards-turning chain to which wooden boards were attached. The gutter hung slantingly from the dredging vessel to the bottom. At the upper end of the gutter the mud fell down into another gutter, and sideways into a pram or barge. In the eighteenth century many mud-mills were in operation in the area of Amsterdam, and later also in Antwerp, Bremen and Danzig. The first were driven by human treadmills as shown in Figure 6, and later the larger types were driven by horses.

In the meantime, a variety of bucket-wheel types were developed and placed in operation. In 1738, a bucket-wheel dredger was in operation on the River Weser in Bremen. A windmill mounted on the dredger-pontoon drove it along. The dredging slurry was loaded into a barge alongside the ship. However, this type of propulsion saw no further development. Instead, the development went more and more in the direction of a system using a chain of buckets, and the construction material was changed from wood to iron and steel.



Figure 6. Mud-mills in operation. One is driven by a human treadmill, a second driven by horsepower

### 2.5. The Bucket Dredger

After the introduction of the steam engine, the old machines with a chain of buckets could be developed into what is now called a bucket dredger. In 1802, the first steam-power driven bucket dredger was utilized in Britain for the excavation works on the Caledonian Canal and on the River Thames. In 1824, an English-made steam-driven bucket dredger made a trial dredging experiment in Amsterdam for comparison with an old-fashioned horse-driven mud-mill, but the productivity of the mud-mill was better. British-made steam driven bucket dredgers were put into use in the Gotha Canal in Sweden (1822), in Rotterdam (1824), and in Hamburg (1834). Some years later they were also constructed in Germany and Belgium, and in 1857 in the Netherlands (see Figure 7). For a long period, this type of dredger has been successfully working all over the world.

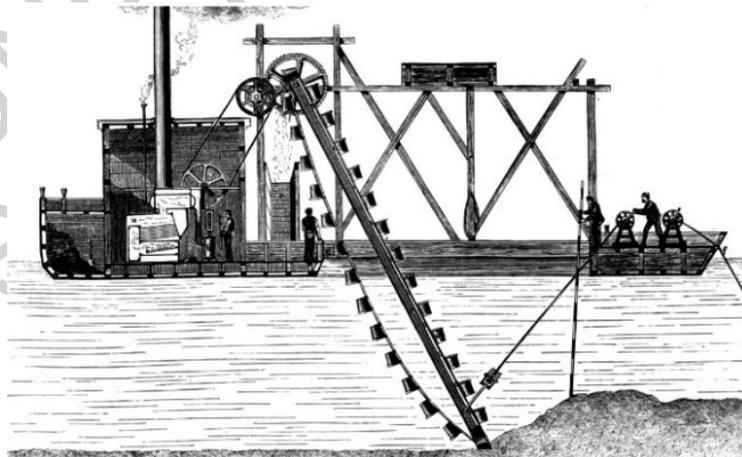


Figure 7. Ancient German steam-driven bucket dredger

At the start of the twenty-first century, most of the bucket dredgers are diesel-electric or diesel-hydraulic driven, as shown in Figure 8. The digging is done by means of a chain of buckets, guided on a ladder hanging from a gantry in the middle of the pontoon. The

ladder goes down in a well of the pontoon and can be lowered or hoisted by a winch on the A-frame over the well. In this manner the dredging depth can be regulated. An engine-driven pinion on top of the ladder makes the bucket chain move over the ladder. At the bottom of the water, the buckets, one by one, dig into the soil, and take the dredged material up to the top of the ladder as shown in Figure 8. There it falls out of the buckets and arrives by a chute into a barge. The dredger is anchored on six anchors and systematically moves as it is being driven by winches in the area to be dredged, swinging on the bow-anchor. The dredged material can be transported to a dumping area by barges. The modern bucket dredger can also dredge solid material. For very hard soils, a rock bucket chain must be mounted. Solid rock must first be crumbled by drilling and blasting. In the last fifteen years many bucket dredgers have been taken out of service, since other types of dredgers have become more economic.



Figure 8. Modern diesel-electric driven bucket dredger

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## Biographical Sketch

**Rudolf van den Bosch**, Engineer, was born in Amsterdam in 1932. He has thirty-seven years of experience in dredging and civil engineering. After having completed his studies in civil engineering, he worked in the Netherlands, for the State Direction on the Zuider Sea Works and was engaged there in dredging and dike construction. After that, he became Manager of a contracting enterprise in The Netherlands and realized many dredging- and civil-engineering projects throughout the country. He later became General Manager of the German subsidiary, and was responsible for the execution of its contracts, such as for river regulation works and dredging on the rivers Rhine, Main, Moselle, Ems, Weser and Elbe. In addition, he was also responsible for the construction of harbors, quay walls, industrial areas and pipeline crossings under rivers and canals. In 1975 he changed over to another employer and became Area Manager for an internationally operating dredging company, based in Rotterdam. Since then he has been Project Manager for dredging projects in Walvis Bay, Namibia and in Wales, UK. Later on, as Area Manager, he was responsible for contracting projects in France, Germany, Spain, Scandinavia and Eastern Europe, and for their proper execution. Next, he became Area Manager for the Far East, stayed in Jakarta, and was responsible for projects in Indonesia, Malaysia, Bangladesh and India. In 1982 he returned to Europe and was appointed General Manager of his employer’s office in Bremen, Germany. He was the promoter of the new method of water injection dredging, which has now been applied worldwide. After retirement, he now resides in France.