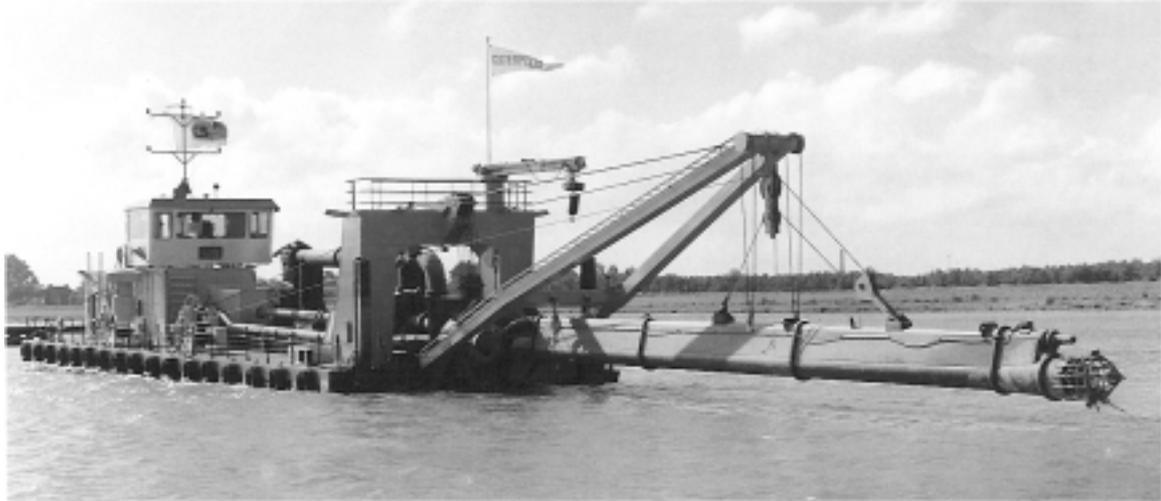


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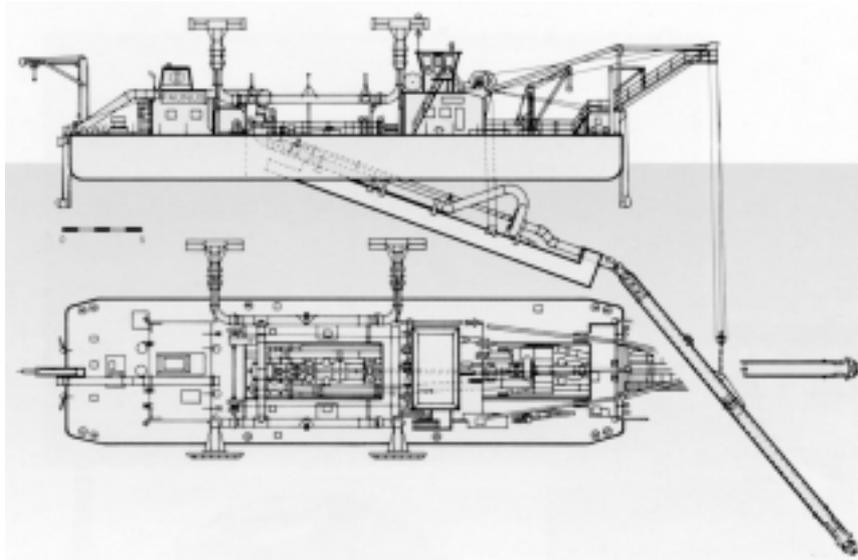
## 4. The Plain Suction Dredger



*Figure 4. 1 A plain Suction Dredger*

### 4.1 General considerations

The characteristic of a plain suction dredger is that it is a stationary dredger, consisting of a pontoon anchored by one or more wires and with at least one sand pump, that is connected to a suction pipe. The discharge of the dredged material can take place via a pipeline or via a barge-loading installation. The suction tube is positioned in a well in the bows of the pontoon to which it is hinged. The other end of the suction pipe is suspended from a gantry or A-frame by the ladder hoist. The ladder hoist is connected to the ladder winch in order to suspend the suction pipe at the desired depth. Excavation of material to dredge is by the erosion of a jetstream and/or the suction flow of the dredge pump and the breaching process (see lecture notes wb3413 the Breaching process) During sand dredging the dredger is moved slowly forwards by a set of winches. To increase the amount of sand flowing towards the suction mouth, a water jet is often directed onto the breach/bank. In this case the jet-pipe is often mounted above the suction pipe.



*Figure 4. 2 Plan view of a PSD*

## 4.2 Areas of application

Plain suction dredgers are only used to extract non-cohesive material. Moreover these dredgers are less suitable for accurate work such as the making of specified profiles. Suction dredgers are very suitable for the extraction of sand, certainly when this occurs in thick layers. Suction dredgers can be seen in working in many sandpits.

If the dredger is equipped with an underwater pump, it is possible to dredge at depths exceeding 80 m. Depending on the pumping capacity; it is possible to transport material over considerable distances via hydraulic pipelines.

Because suction dredgers are often demountable they can also be used in excavation pits which are not on navigable waterways. In general, suction dredgers are relatively light vessels and, although anchored on wires, are usually unsuitable for dredging in open waters (unless specially adapted).

## 4.3 Types of plain suction dredgers

Different type of plain suction dredgers can be distinguished.

### 1. The barge loading plain suction dredger

A dredger which loads the barges which lie alongside it by means of a spraying system. This type is used when the transport distance is too long for hydraulic transport to be economic (**Error! Reference source not found.**).

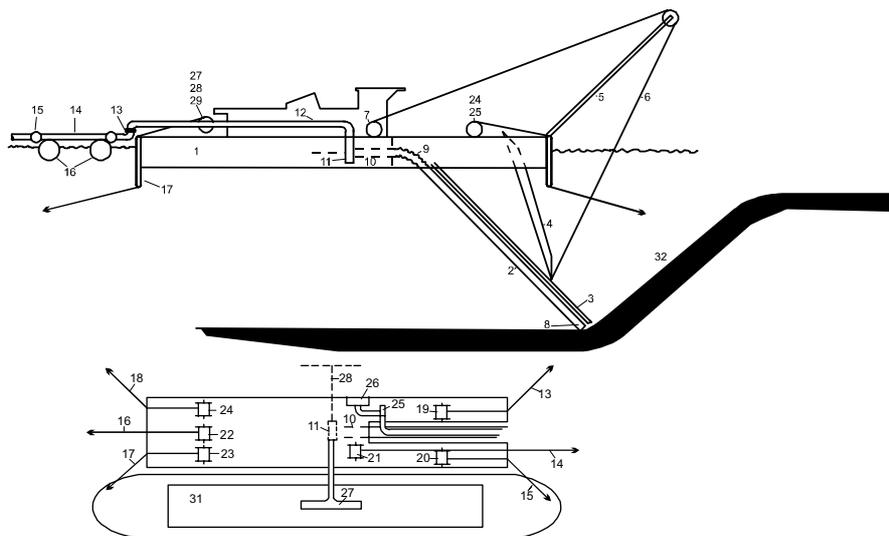


Figure 4. 3 Barge loading PSD

### 2. The reclamation dredger

This dredger pumps the sand ashore via a pipeline and, if necessary, further away to a disposal site or treatment plant (Figure 4. 4).

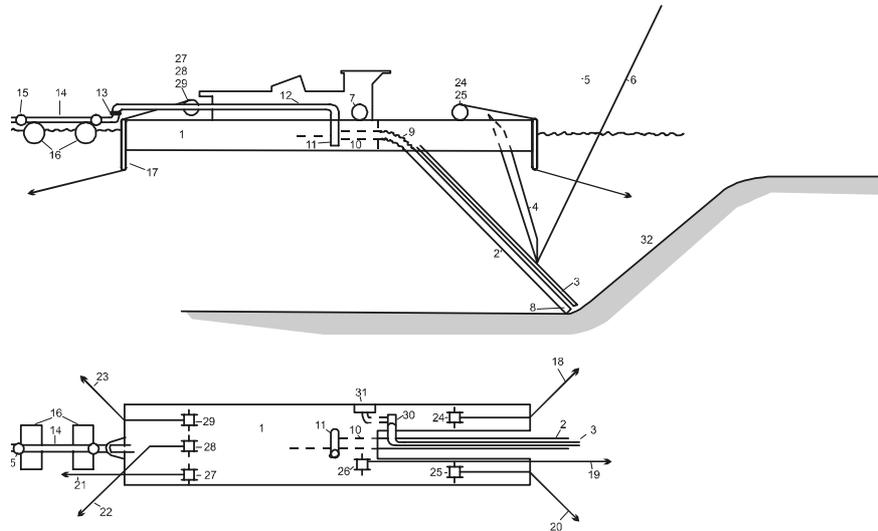


Figure 4.4 Reclamation dredger

### 3. The deep suction dredger

The deep suction dredger. A dredger equipped with an underwater pump. It may take the form of a barge loader or a reclamation dredger. (Figure 4.5)

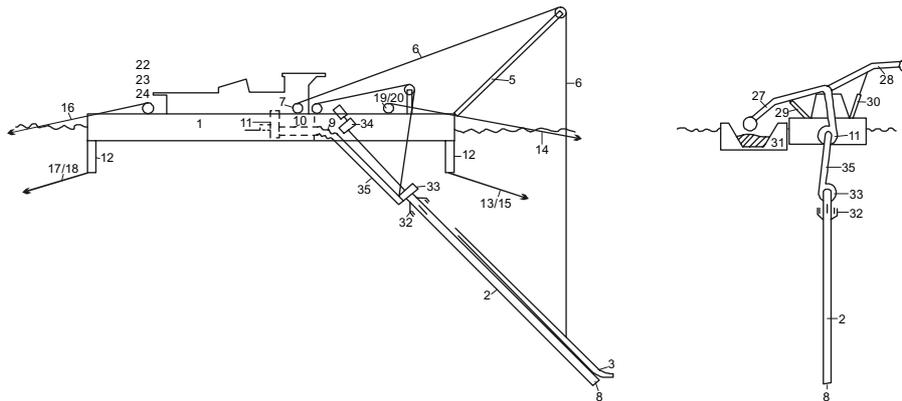


Figure 4.5 The deep suction dredger

### 4. The dustpan dredger

A suction dredger with a relatively wide suction mouth. This dredger is suitable for extracting sand at a reasonably high production rate with a low breach or bank height. With regard to production the cutter suction dredger (Figure 4.6) has superseded this type.

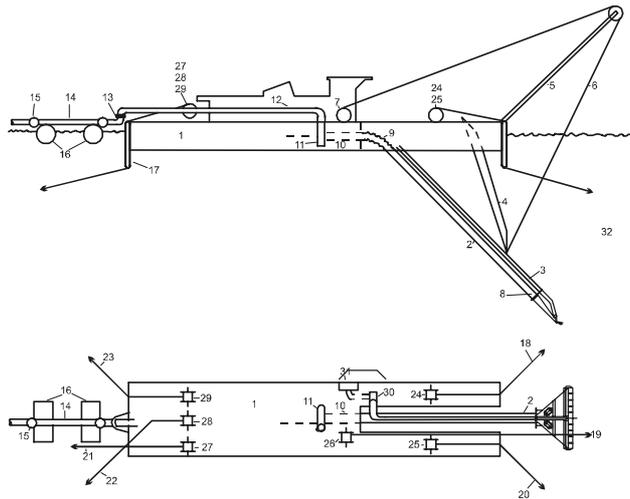


Figure 4. 6 Dustpan dredger

In many cases these types can easily be transformed to another type. The barge loading dredger shown in figure 4.2 can be transformed to a reclamation dredger by connecting a booster just behind this dredger. The same might be possible with reclamation dredgers by placing a sprayer pontoon after the dredger.

#### 4.4 History

In 1851, more than a century after their invention, the first centrifugal pumps were used to excavate sand with hopper dredgers. A few years later (1856) the first attempts were already being made to transport the material onshore via pipelines. Ten years later this idea was demonstrated in the Netherlands during the excavation of the North Sea Canal. (Figure 4.7)

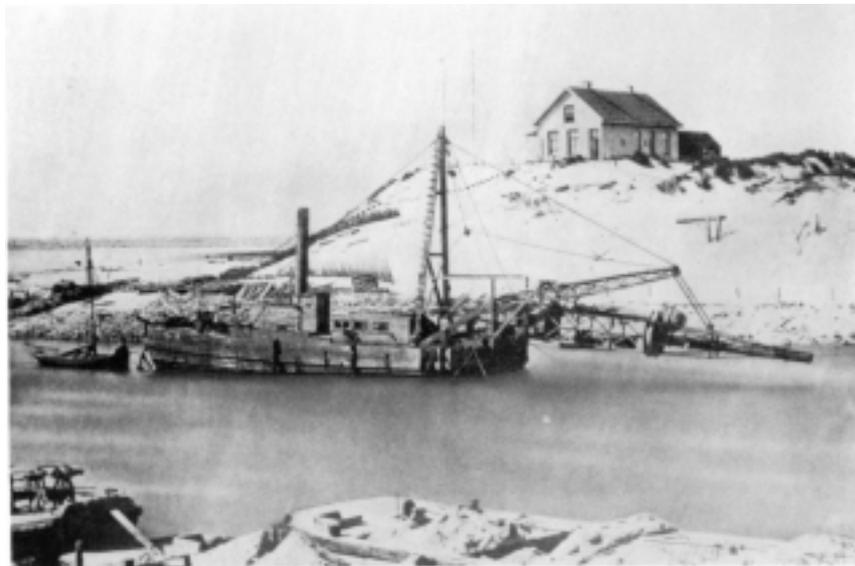


Figure 4. 7 The wooden Hutton Dredger dredging the North Sea Canal

Meanwhile, in 1864, Freeman and Burt patented a flexible floating-pipeline.

From this history it appears clear that the development of the suction dredger was closely linked with the development of the dredge pump. Because at that time little power was available to drive the dredge pump, the reclamation dredger was only used when the distances to the disposal site were short. In the other cases barges were used or the dredger was modified. As the sand pumps became able to withstand higher pressures, the transport distances and pump capacities were increased.

#### 4.5 Working method

The working method of the suction dredger depends on both the progressive collapsing of the breach/bank and the loosening of the sand near the suction mouth by eddies created by the flow of water caused by the sand pump (Figure 4. 8). The progressive collapse of the breach/bank resulting from the dislodgement of particles of soil or of masses of soil as a result of localised instabilities is termed "breaching".

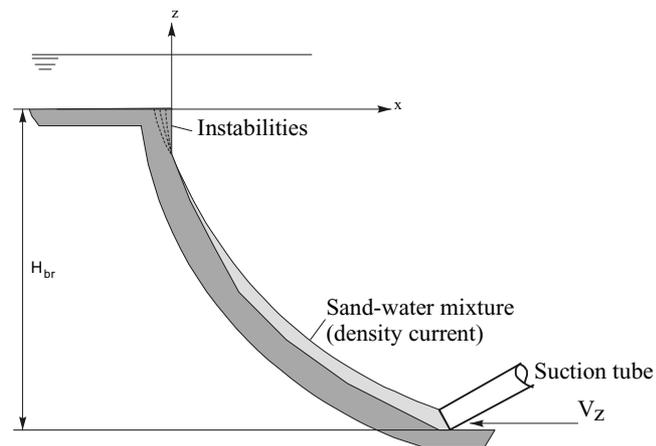


Figure 4. 8 Breaching

This process is essential for the production of a suction dredger and is entirely determined by the soil mechanical properties of the slope, the most important factors being its permeability to water and relative density.

When a suction dredger starts on a new work there is no dredge pit, slope or breach and the angle between the suction pipe and the horizontal is usually very small. The sand that is carried towards the suction pipe lies entirely within the area influenced by the water flowing to the suction mouth. This process causes a small pit to develop in the soil.

The dredger is now drawn forwards a little by means of the bow winch and the suction pipe is set deeper, after which the process is repeated. As the small pit becomes deeper and the angle of the suction tube becomes steeper (more effective for the swirling up and transporting of the sand) the production increases. (Figure 4. 9) This process is continued until the suction mouth is deep enough or until the production is so high that the pump can no longer cope with a further increase. This slow forward movement with the dredger, with simultaneous lowering of the suction pipe is termed 'breaking in' or 'commencing'.

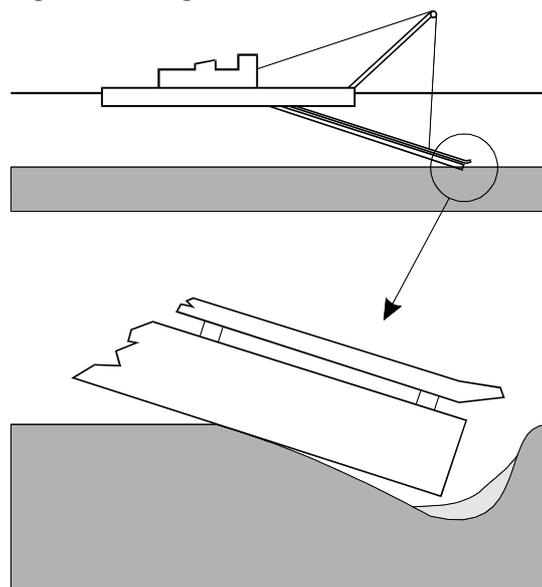


Figure 4. 9 "Breaking in"

The time that is needed to reach a state of equilibrium thus depends on the previously mentioned soil mechanical properties, the height of the slope and the pump capacity of the dredger.

When a state of equilibrium has been reached it is the task of the dredge master to maintain this situation by letting the dredger follow the breach/bank, by regularly hauling the dredger forwards and by continuing to lower the suction pipe for as long as this remains possible.

If the movement of the dredger is too slow, a less steep slope forms and the production is reduced.

If, on the other hand, the forward movement is faster than the transport of the sand, the angle of slope will increase and there is an increasing chance that large scale shearing will occur. The sand concentration may then become so high that the pump cannot cope with it and the mixture ceases to flow. The shearing can be so great that even the suction pipe becomes fast/firmly embedded and, if it cannot be pulled free, another dredger must be used to free it by using suction or must cut it free.

The dredging pattern that is made with a suction dredger generally appears like that shown in Figure 4. 10. As long as it lies within the dredging area, the length of the cut is determined by the positions of the anchors. The anchors are usually placed in such a way that more cuts can be made beside each other from the same position. In addition to the length of the anchor wires, this possibility also depends on the width over which the sand is being excavated. This, in turn, depends on the shear characteristics of the sand layers.

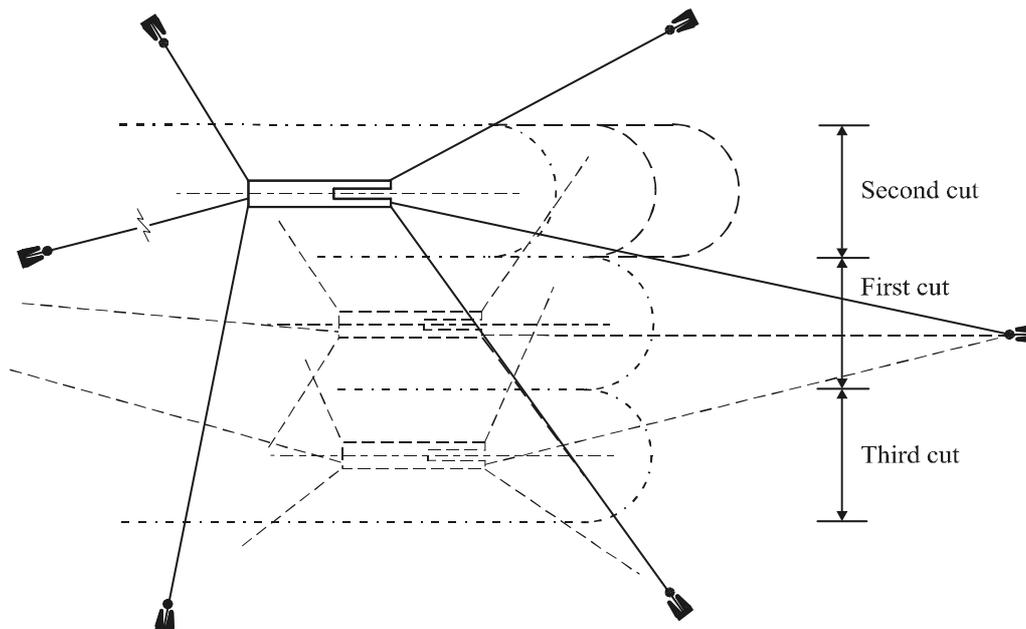
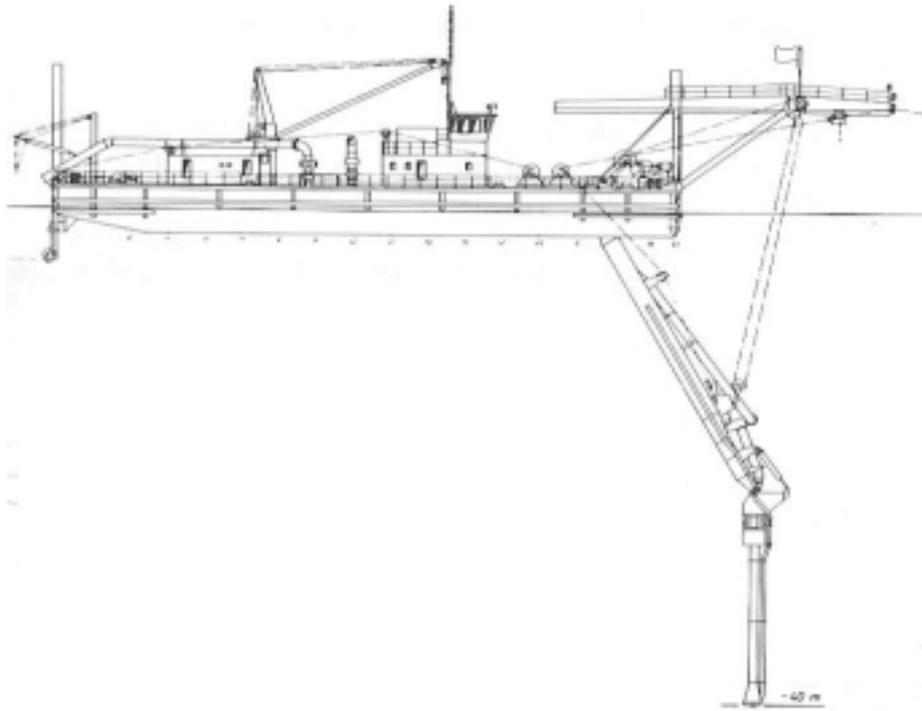


Figure 4. 10 Dredge pattern of a PSD

For suction dredgers equipped with an underwater pump the excavation depth no longer determines the production. This also makes it possible to exploit the dredging area in the vertical sense. In other words, production can be maintained by continuing to lower the suction pipe until the maximum suction depth has been reached. If the production falls below an economic minimum, the pit is abandoned and dredging recommences  $\frac{1}{2}$  to  $\frac{3}{4}$  pit diameter away from it. It will be clear that this dredging method produces a pockmarked excavation area and that considerable amount of sand that cannot be economically excavated remain behind in the dredging area. This is a situation that the managers of the dredging sites prefer not to see.

This method of dredging does provide the possibility to obtain sand from directly beneath a clay layer, but it must be realised that the removal of the sand will cause the clay to lose its stability. In the most favourable case the clay will fall onto the slope in fragments that will be taken up with the sand. If the clay falls in large pieces there is a good chance that these will become fast and block the suction pipe, with all the disadvantages that this can bring. It is difficult for the water needed for mixture formation to flow, especially in the beginning phase when the clay layer has not yet been penetrated.



*Figure 4. 11 PSD with suction pipe of 2 sections*

Water must be brought to the suction pipe via the jet pipe. For the above described excavation method the suction pipe is made in two parts, (Figure 4.11) the lowest section being hinged onto the upper section so that the lowest part is always first suspended almost vertically. With such a suction pipe, moments that occur during horizontal movements can be taken up only to a small extent.

#### **4.6 The design**

When designing suction dredgers the following parameters are important:

- Production capacity
- Suction depth
- Transport distance
- Type of soil

Because suction dredgers are only suitable for the dredging of non-cohesive material, the last parameter plays an important role only in the determination of the diameters of the suction pipe and hydraulic pipeline and the required sand pump capacity.

#### 4.6.1 The production capacity

As in other dredgers, the market forces in relation to the sites where the dredger can be used determine the production capacity. As mentioned earlier, the plain suction dredger is much used in the extraction of sand for landfill sites and for the concrete industry.

For this too, it is important to know the production capacity per week or per hour. In the Netherlands, to a limited extent, the labour agreements between the trade unions and industry permit a working week of 168 hrs, thus an entirely continuous operation.

Often this is restricted to only four nine-hour days (36 hrs). The percentage of hours during which effective dredging can take place, however, is not equal. With a 36-hr week, major repairs are often carried out during overtime. When using barge transport, for example, the percentage of downtime resulting from the absence of barges is lower during a 36-hr week than during a continuous working week, since part of the downtime is made up when the dredger has stopped work at the end of the day.

If, during a 168 hr working week, the number of effective working hours is  $0.75 \cdot 168 = 126$  and during a 36 hr working week the effective hours are  $0.86 \cdot 36 = 30.6$ , the production ratio is  $126/30.6 = 4.1$  instead of  $168/36 = 4.7$ .

For the design of the dredging installation, and thus for the vessel also, the production per hour is more important than the daily, weekly or monthly production. In many cases, in order to prevent overloading of the drives, even shorter time intervals are considered. If the production capacity is known, this requirement can be translated into:

1. A sand flow rate
2. A sand concentration

$$\text{Since: } Q = Q_{\text{mixture}} * \frac{C_{\text{vd}}}{1-n} \quad (4.2)$$

with

Symbol		description	dimension
Q	=	Production	[m <sup>3</sup> /s]
Q <sub>mixture</sub>	=	Flow rate	[m <sup>3</sup> /s]
C <sub>vd</sub>	=	Delivered concentration	[-]
n	=	Porosity	[-]

The anticipated average concentration depends on the behaviour of the soil in the breach/bank (see lecture notes ‘Dredging Processes’). The maximum suction concentration is determined on the basis of the types of soil and the insight of the designer.

The maximum average concentration that can be transported by a pipeline depends on the ratio maximum grain diameter/pipe diameter and the length of the pipeline. In long pipelines aggregation (increased concentration) may occur as a result of density variations during dredging (Matousek, 1995).

As rule of thumb, a maximum average density of  $1500 \text{ kg/m}^3$  ( $C_{\text{vd}} = 30\%$ ) is often used for sand. On the basis of this assumption the flow rate is now fixed because the production capacity is taken as a given value.

#### 4.6.2 The suction depth

A second important design parameter is the suction depth. This determines whether an extra underwater pump is needed to achieve the required production. When the suction depth increases, if the use of an underwater pump is not considered the suction pipe diameter and also the pump flow must be increased. At the same time the concentration must be reduced to avoid reaching the vacuum limit (under-pressure at which cavitation occurs). This can lead to the pumping of low concentrations and thus much water, which is uneconomic.

With the aid of the suction formula one can determine if a submerged pump is useful and how deep below the waterlevel the pump has to be fitted on the suction tube. The suction formula is a force balance over the suction tube. The pressure difference over the suction tube equals the weight of the mixture in the suction tube and the friction due to the flow.

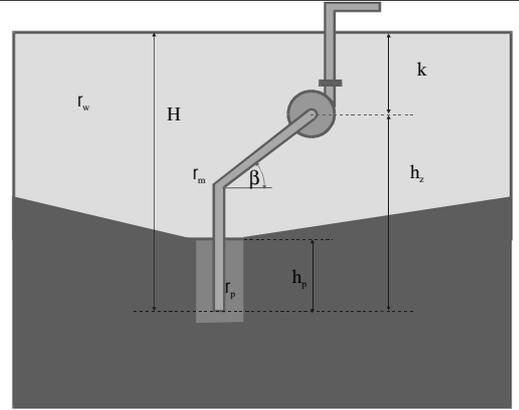


Figure 4.12 scheme for suction formula

$$\rho_w g(H - h_p) + \rho_p g h_p - p_{pomp} = \rho_m g h_x + \frac{1}{2} \rho_m v^2 \left( 1 + \zeta + \lambda \frac{L}{D} \right)$$

with

$\rho_w$	= density water	[kg/m <sup>3</sup> ]
$\rho_p$	= density suspended sand in the pit	[kg/m <sup>3</sup> ]
$\rho_m$	= mixture density in the suction tube	[kg/m <sup>3</sup> ]
$H$	= waterdepth	[m]
$h_p$	= depth of pit	[m]
$h_x$	= suction height	[m]
$p_{pomp}$	= pressure in front of the pump	[N/m <sup>2</sup> ]
$v$	= mixture velocity	[m/s]
$\zeta$	= entree loss factor	[-]
$\lambda$	= Darcy Weisbach headloss factor	[-]
$L$	= total length suction tube	[m]
$D$	= diameter suction tube	[m]

Because  $h_x = H - k$  the equation can be written as:

$$\rho_w g(H - h_p) + \rho_p g h_p - p_{pomp} = \rho_m g(H - k) + \frac{1}{2} \rho_m v^2 \left( 1 + \zeta + \lambda \frac{L}{D} \right)$$

This results in:

$$\rho_m = \frac{\rho_w g(H - h_p) + \rho_p g h_p - p_{pomp}}{g(H - k) + \frac{1}{2} v^2 \left( 1 + \zeta + \lambda \frac{L}{D} \right)}$$

For the boundaries given in Figure 4.13 the maximum dredgeable mixture density is calculated for different depth of the dredge pump below thw waterlevel

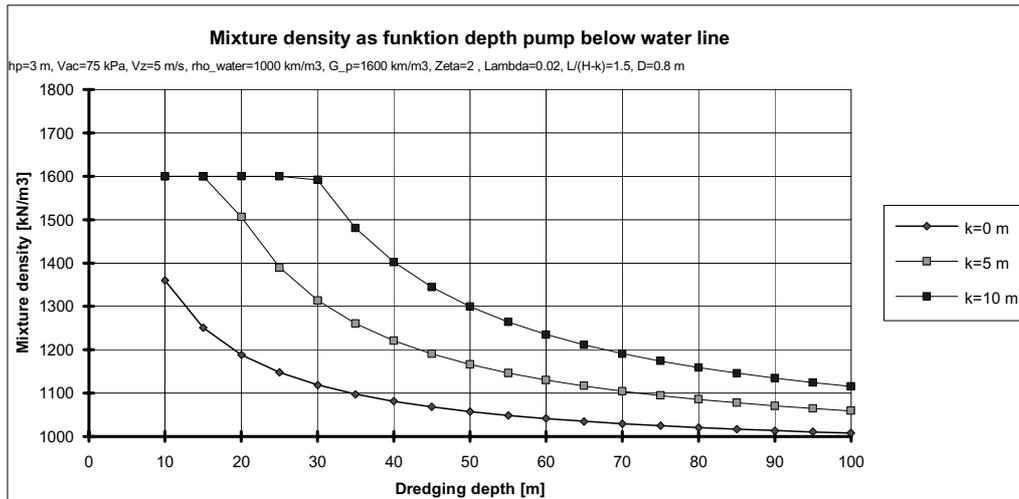


Figure 4. 13

The above graph (Figure 4. 13) is derived from this equation

In order to dredge, from a depth of 30 m, a density of  $1500 \text{ kg/m}^3$  the dredge should be place almost 8.5 m below the waterline.

A pump on the waterline can pump a density of  $1120 \text{ kg/m}^3$ . In the second case, if the same production is required, the flow should be:  $\frac{Q_0}{Q_5} = \frac{\rho_5 - \rho_w}{\rho_0 - \rho_w} = \frac{1500 - 1000}{1120 - 1000} = 4.17$  as great.

With the same pumping velocity this leads to a suction pipe of a diameter that is 2 times as big.

For a given decisive vacuum and a maximum suction concentration it is possible to determine whether an underwater pump is necessary and, if so, how far under water this pump must be positioned, as a function of the required suction depth.

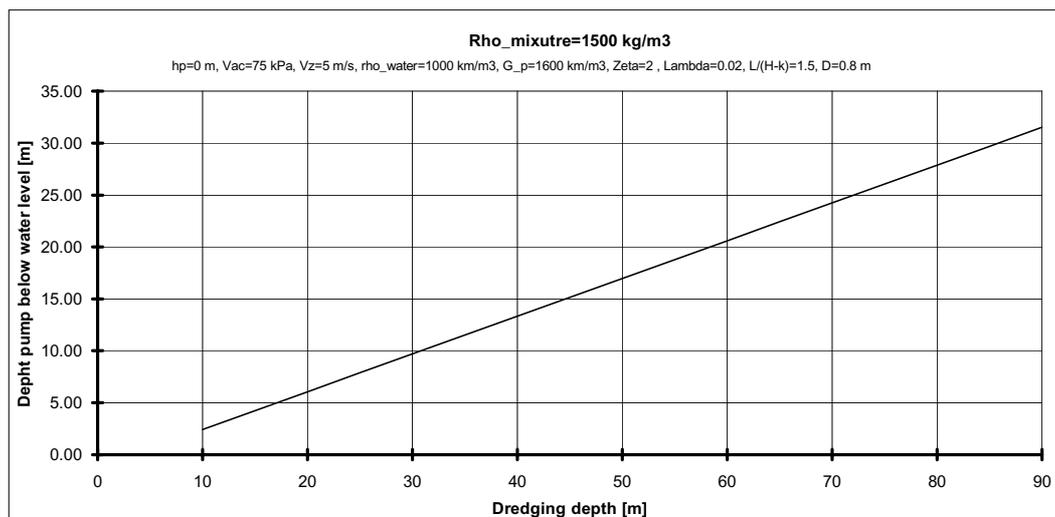


Figure 4. 14

From the above graph (Figure 4.14) it appears that to pump a mixture density of  $1500 \text{ kg/m}^3$  at a depth of 50 metres the pump must be positioned 17 metres under water.

Of course whether or not an underwater pump is mounted is a question of economics. The cost of fitting an underwater pump is considerable and, moreover, the suction depth can have a great influence on the ladder construction and thus on the pontoon construction. It is also necessary to hoist the suction pipe above water for inspection.

#### 4.6.3 The transport distance

The transport distance makes demands with regard to the installed sand pump capacity and/or the need to load barges. The need for barge loading depends whether the required transport distance is too long to be economically covered by the use of a hydraulic pipeline. It is also possible that the use of a pipeline may not be feasible from the point of view of hindrance to shipping. Suction dredgers may also be designed exclusively for barge unloading. In general, if material does have to be transported by a hydraulic pipeline there is still the option to place a booster station with the necessary capacity behind the plain suction dredger.

If the suction dredger is equipped with an underwater pump the chosen discharge pressure (and thus capacity) can be such that during the loading of barges only the underwater pump is used. The pipeline system and valves can also be designed for this. The grain size and the distance over which the material must be transported determine the required manometric pressure for the discharge pump(s). It is also possible to choose an underwater pump of higher capacity than is needed to unload the barges. The surplus capacity can then be used during discharging. The maximum discharge pressure that a dredger can supply depends on the quality of the shaft sealing of the last pump. Often values exceeding 25 - 30 bar are not permitted.

#### 4.6.4 The dredging installation

Under the dredging the following components are included

- Suction and discharge pipe
- The dredge pumps
- The dredge pumps drives
- The jet pumps
- The jet pump drives

##### 4.6.4.1 Suction and discharge pipe diameter

The critical velocity that is necessary to keep the dredged material in motion determines the maximum suction and pressure pipe diameters.

Thus:  $v_{kritiek} = (F_{l,h} + F_{l,v}) \sqrt{2g(S_s - 1)D}$  in which the value of  $F_{l,h}$  is determined by the material to be pumped. (See lecture notes "Dredging Processes")  $F_{l,v}$  is the correction for sloping transport and has a maximum value of .333  
(See also the relevant Section 2.2.4.3. of Hopper dredgers).

If both the critical velocity and the average concentration have been determined, the relation between pipeline diameters and production is:

$$Q = Q_{mixture} * \frac{C_{vd}}{1-n} = v_{krit} \frac{\pi D^2}{4} \frac{C_{vd}}{1-n} = F_l \sqrt{2g(S_s - 1)D} \frac{\pi D^2}{4} \frac{C_{vd}}{1-n} \approx 1.5\pi D^{2.5} \frac{C_{vd}}{1-n} \quad [m^3/s]$$

with

Symbol	=	description	dimension
Q	=	Production	[m <sup>3</sup> /s]
Q <sub>mixture</sub>	=	Flow rate	[m <sup>3</sup> /s]
D	=	Pipe diameter	[m]
C <sub>vd</sub>	=	Delivered concentration	[-]
S <sub>s</sub>	=	Relative density of the solids=ρ <sub>s</sub> /ρ <sub>w</sub>	[-]
n	=	Porosity	[-]
g	=	Gravity	[m/s <sup>2</sup> ]
V <sub>cr</sub>	=	Critical velocity	[m/s]

Figure below give the results of the equation for C<sub>vd</sub>=30%

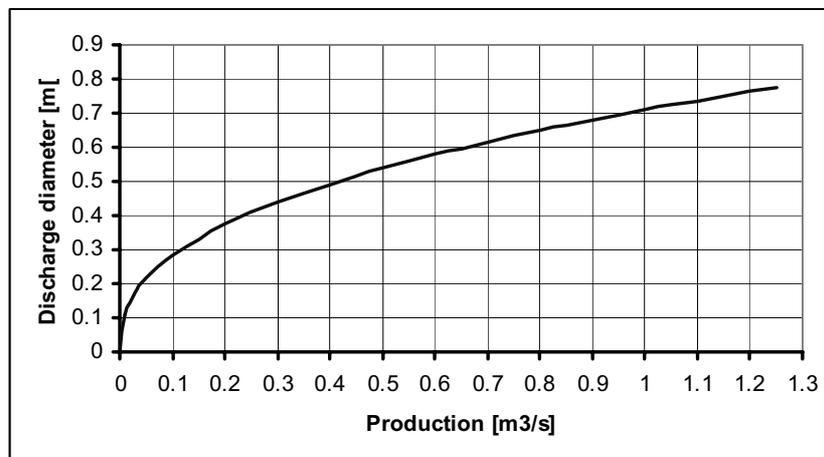


Figure 4. 15 Minimum discharge diameter

#### 4.6.5 The dredge pump

##### 4.6.5.1 Pump types

Now that the capacity, the required pressures on both sides of the pump and the power are known under the various transport conditions, the type(s) of pump can be selected.

The pump types, centrifugal, semi axial or axial are determined by the specific speed of the pump; defined as:

$$n_s = \frac{\omega\sqrt{Q}}{(gH)^{\frac{3}{4}}} = \frac{\rho^{\frac{3}{4}}\omega\sqrt{Q}}{(p)^{\frac{3}{4}}}$$

For discharge pumps the specific speed  $n_s$  is in the interval between 0.25 and 0.50 (Figure 4.16). With the aid of this figure the type of pump and impeller can be chosen.

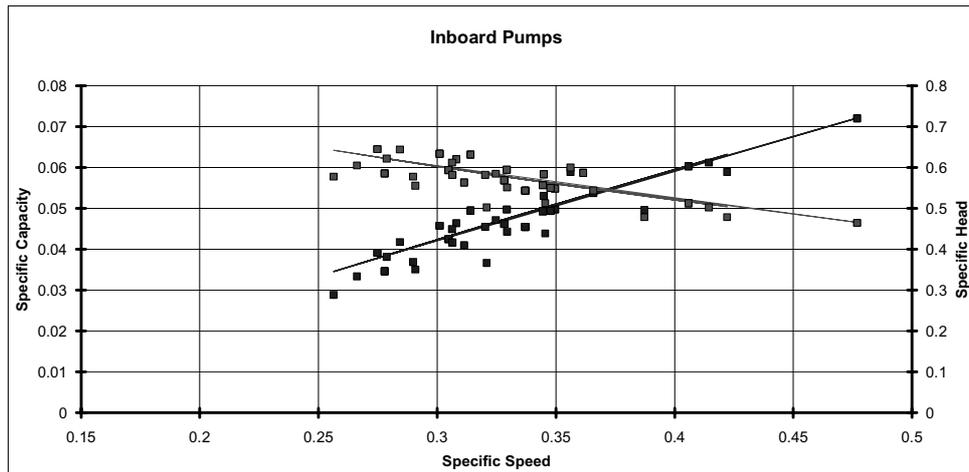


Figure 4. 16

For the underwater pump usually a higher specific speed is taken than for the discharge pumps, but for the sake of standardisation the same pump is often selected. One should ask oneself whether the position of the maximum efficiency point could still reasonably satisfy the stipulated demands with regard to the flow. This is also valid when no underwater pump is fitted. In such a case stipulations must be made with regard to the suction properties (NPSH value) of the inboard pump.

Other factors also play a part in the selection of a pump and impeller:

- A three, four or five blade impeller. Depending on the required minimum passage between the blades.
- Single or double walled pump. (considerations relating to wear.)

If long transport distances have to be covered the question arises of whether one large pump or two smaller ones will be needed. In addition to the specific revolution speed the peripheral velocity of the impeller also plays a part. To limit wear, the peripheral velocity of the impeller is limited to 35 to 40 m/s. This also limits the maximum manometric pressure. Whether or not one or more delivery pumps are needed depends on the total required delivery pressure and delivery pump power.

#### 4.6.5.2 The sand pump drives

Underwater pumps often have electric drives, but hydraulic drives and even direct diesel drives may be encountered. If barge loading is required, a controllable drive is necessary. With a fixed revolution speed the variations in flow resulting from differences in concentration and grain size are often too big for the efficient loading of the barges. Diesel drives are often used for the delivery pumps, but of course electrical drives are possible too

### 4.6.6 Jetpumps

#### 4.6.6.1 Pump type

The flow of the water pumps depends on the required functions of these pumps. Two functions can be distinguished:

1. *The activation of the breach process of the bank.*

Suction dredgers are usually equipped with a water jet for this purpose. The speed of the jet flowing from the water jet decreases hyperbolically with the distance from the water jet in accordance with:

$$v_L = \frac{6D}{L} v_0 \quad \text{See Figure 4. 17}$$

Here:

$v_L$  = Velocity of the jet at distance L in m/s.

D = Diameter of the jet nozzle in m.

L = Distance to the jet nozzle in m.

$v_0$  = Velocity of the jet at the nozzle in m/s.

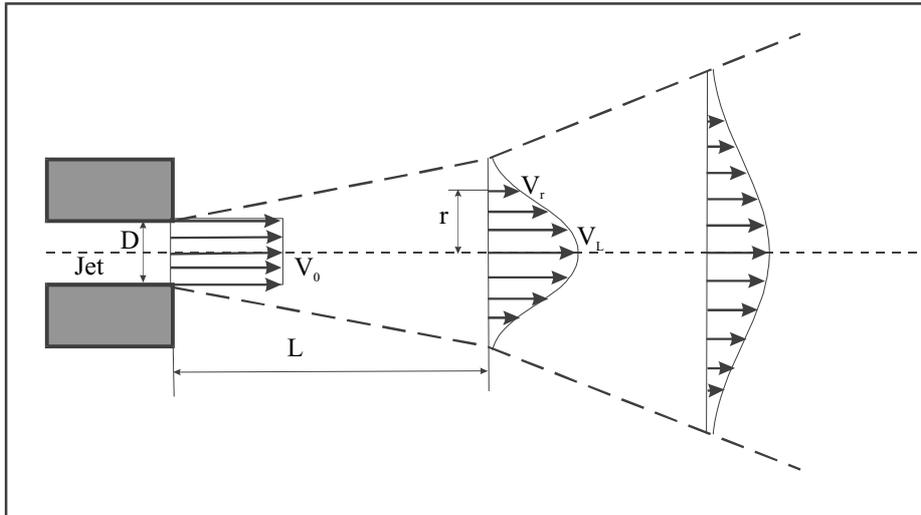


Figure 4. 17 Flow establishment of a jet

Example.

If the pressure at the nozzle is 500 kPa and the jet nozzle has a diameter of 0.3 m and a minimum velocity in the centre of the jet \*\*at the breach/bank of 3 m/s is needed to activate the breach/bank, the maximum distance to the breach/bank is:

$$L = 6D \frac{v_0}{v_L} = 6D \frac{\mu \sqrt{\frac{2p}{\rho}}}{v_L} = 6 * 0.3 \frac{0.6 \sqrt{\frac{2 * 500}{1}}}{3} = 11 \text{ m}$$

The decrease in velocity towards the edge of the jet can be calculated with:  $\frac{v_r}{v_L} = e^{-90 \left(\frac{r}{L}\right)^2}$ .

Here  $v_r$  = the velocity of the jet at distance r from the centre.

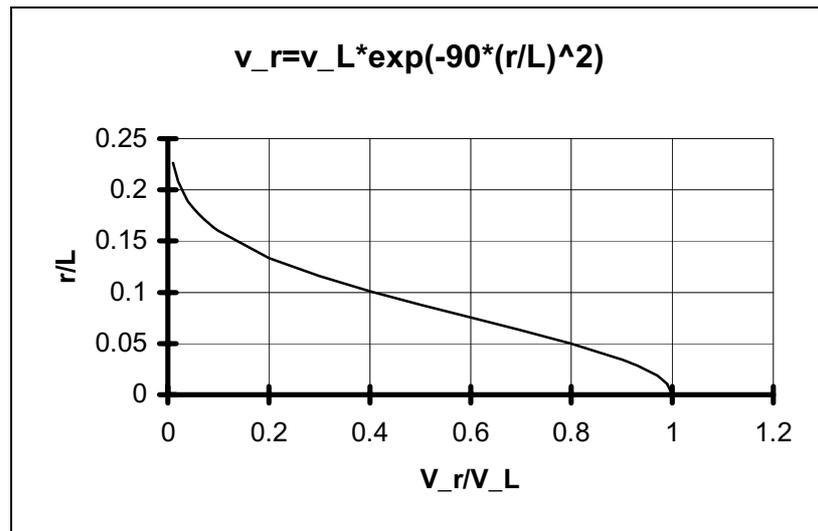


Figure 4. 18 jet velocity as function of the radius  $r$ .

At a distance of 11 m and with a relation of  $\frac{v_r}{v_L} = 0.4$  the diameter of the jet is as shown in the

graph below  $D = 2 \frac{r}{L} L = 2 \cdot 0.1 \cdot 11 = 2.2$  m

In other words, the influence of the water jet is only very local.

The jet flow is:  $Q_j = \frac{\pi D^2}{4} v_0 = \frac{\pi \cdot 0.3^2}{4} 18.9 = 1.34$  m<sup>3</sup>/s

and the power at the water pump:  $P_j = \frac{Q_j \cdot p}{\eta} = \frac{1.34 \cdot 500}{.8} = 838$  KWatt

## 2. The maintenance and control of mixture forming.

In this case, when it is assumed that no water from the environment can be sucked in because the suction mouth is completely embedded in the soil, it is necessary to satisfy the volume

balance:  $\frac{Q_j}{Q_m} = 1 - \frac{C_{vd}}{1-n}$

Here:

$Q_j$  = the jet flow m<sup>3</sup>/s

$Q_m$  = the sand flow in m<sup>3</sup>/s

$C_{vd}$  = the transport concentration [-]

$n$  = the pore number [-]

Figure 4. 19 gives a graphical representation of the equations.

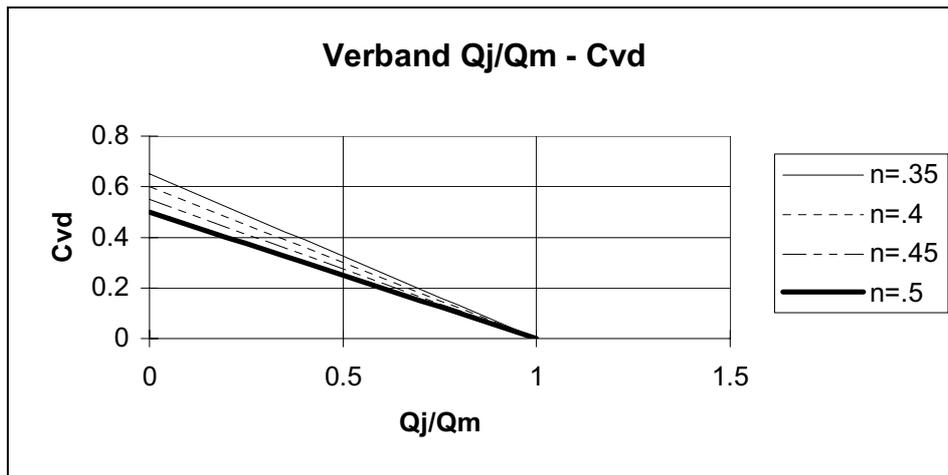


Figure 4. 19

Example:

If  $C_{vd} = 0.25$  and  $n=0.5$  (loose packed sand), then  $\frac{Q_j}{Q_m} = .5$

The area of influence by the jet is now less important, as long as the water that is added benefits mixture formation.

The water pumps are chosen in the same way as the sand pump

#### 4.6.6.2 Jetpump drives.

In case of activation the breaching process required pressure and capacity will always be constant. So separate diesel engines are frequently used.

In the other case, the mixture forming process a speed control engine is required to control the density.

## 4.7 General layout

The hull consists of a simple U-shape pontoon. De width of the pontoon is determined by stability and sometimes by the distribution of the loads. (Figure 3.1.7) The length of the pontoon is in certain way determined by the length of the suction pipe, the number dredge inboard pumps or by the requirements for mooring barges along side.

Loads on the suction pipe resulting from the dredging process are relatively small, so are the loads on the pontoon. For small plain suction dredgers the dredgepump is situated in the engine-room, however a separate pump room is certainly advisable from safety point of view, in particular for the bigger dredgers. Nowadays even small dredgers do have a submerged pump.

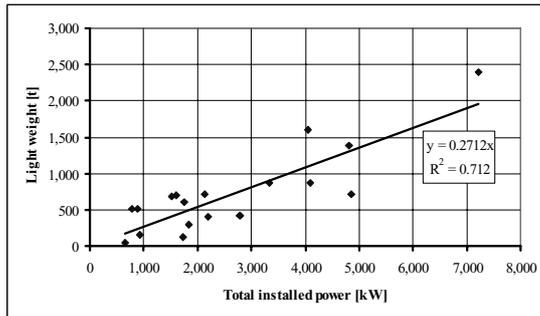


Figure 4. 20

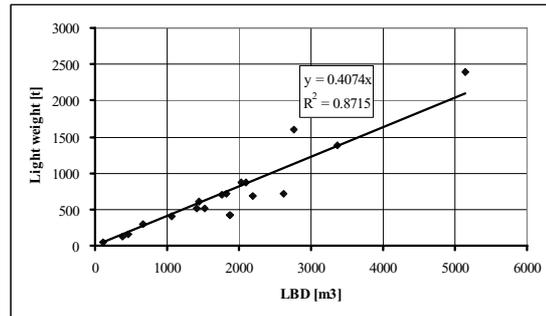


Figure 4. 21

The lightweight of the plain suction dredgers depend on the total power installed. (Figure 4.20), while the volume of the pontoon is 2.5 times the light weight (Figure 4.21).

The main ships parameters vary widely; L/B between 3 and 8 and B/T between 7 and 3.5, because the length is mainly determined by the factors mentioned above. (Figure 4.22)

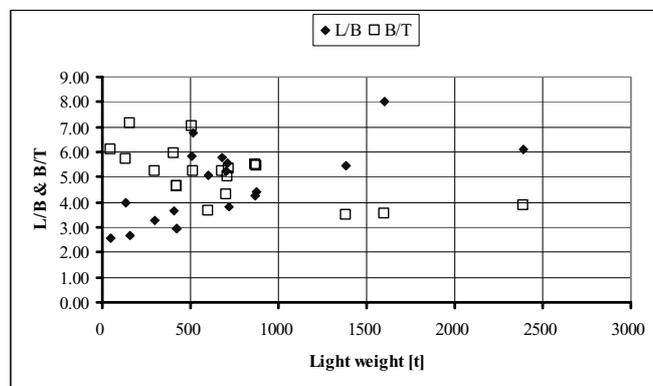


Figure 4. 22

Figure 4.23 shows the dredger Seeland, with a total installed power of 3200 kW and a maximum dredging depth of 40 m. The dredger is build under the classification of the Germanische Lloyd GL + 100 A 4 dredger.

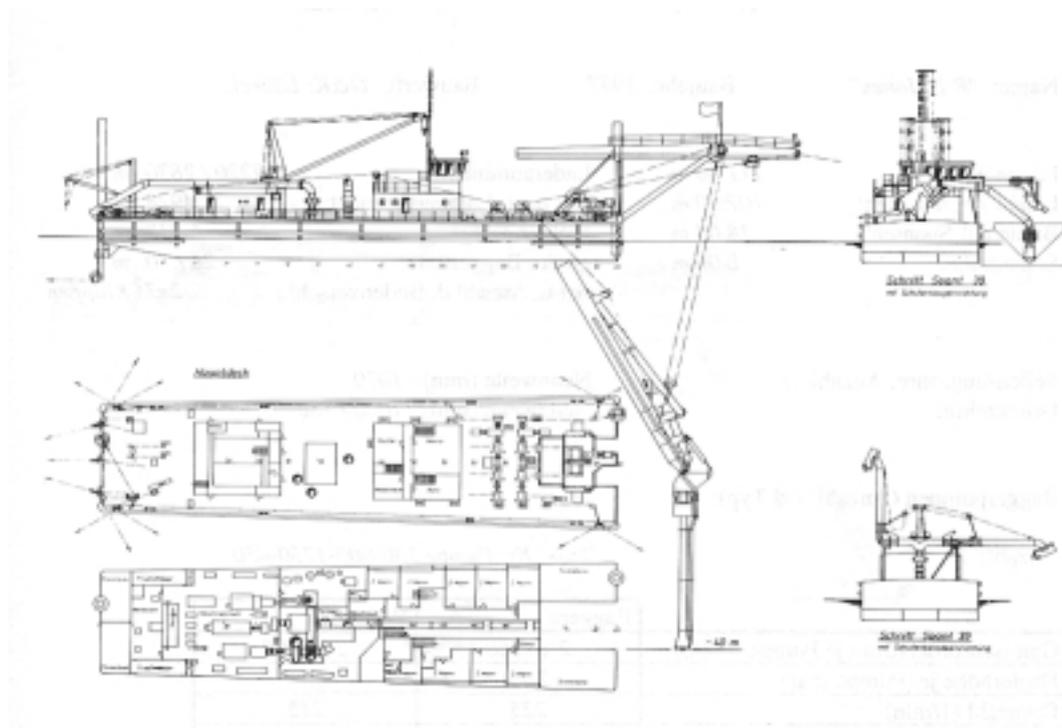
The length of the suction pipe often determines the length of the well. With very long suction pipes or two-part suction pipes the catamaran principle is often used. The suction pipe is then hinged onto the stern of the pontoon (Figure 4.2) This is certainly not essential.

Sometimes special gantries are designed to carry the long suction tube (figure 2.23).



**Figure 4. 23**

In deep dredgers with an articulated pipe, the lower pipe is fastened to the upper pipe by hydraulic cylinders, in which case it is not necessary to have a long well (Figure 4.24).



*Figure 4. 24 Plain Suction \_Dredge Seeland, Yard Orestein and Koppel*

*Lübeck Germany*

In other cases an additional pontoon is connected to the main pontoon by means of a special construction (Figure 4.24 PSD Weesperkaspel).

The engine room, pump room, fuel tanks, water tanks and storeroom are all located in the pontoon. On small suction dredgers the sand pump is located in the engine room, while large suction dredgers have a separate pump room. The control cabin, and if required, crew quarters are above deck. The anchor winches are also on deck



Figure 4. 25

Figure 4.25 shows an offshore plain suction dredgers designed for significant wave heights of 2.75 m and a total installed power of 7425 kW. The coupling with the floating pipeline is in the middle of the port side where the movements of the pontoon are minimum when working in waves. This is in contradiction with dredgers for inland waters. They do have the connection on the aft of the pontoon.

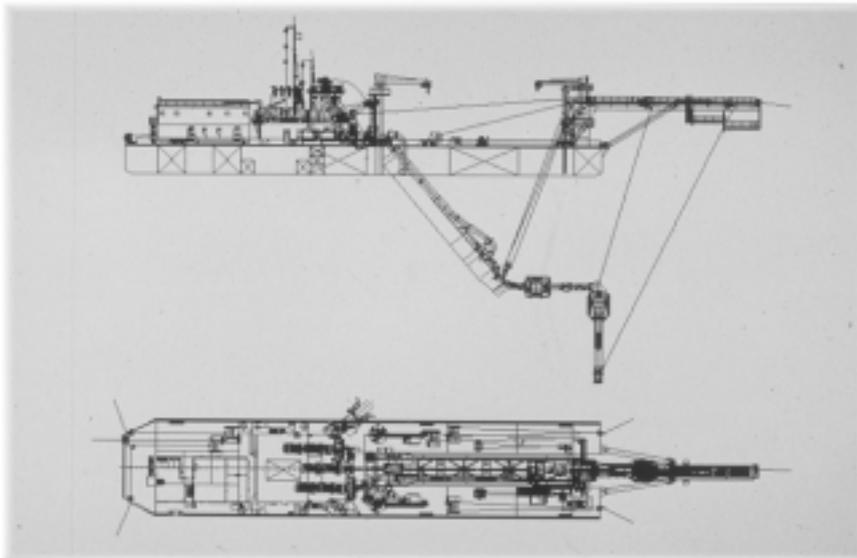


Figure 4. 26 General arrangement of an offshore plain suction dredger, Yard IHC Holland

## 4.8 Technical construction

### 4.8.1 The hull

As previously mentioned, the hull usually consists of a simple U-shaped pontoon. The width of the pontoon is determined by stability considerations and varies from 6 m for small to 20 m for large deep dredgers. The length of the dredger is usually determined by the requirements relating to the length of the suction pipe and/or the need to accommodate barges alongside and by the warping of the barges.

The ladder gantry, which usually takes the form of an A-frame, provides the link between the pontoons, which are separated by the well. By deep dredgers, having a suction pipe in the raised position pointed very far ahead of the pontoon, the gantry is a relatively heavy structure (Figure 4.23 and 4.27).



Figure 4. 27

#### 4.8.2 The dredging equipment

The dredging equipment will be discussed according to the flow of the mixture.

##### 4.8.2.1 The suction mouth

Suction mouths of plain suction dredgers are in many cases very simple. The end of the pipe is just covered by a screen to avoid pump blockage by boulders and debris (Figure 4.1, 4.28 and 4.29)



Figure 4. 28



Figure 4. 29

In many cases jet nozzles are situated around the suction mouth to activate either the breaching process and/or the mixture forming (Figure 4.30)

When the suction mouth is fully penetrated in the sand, water jets are necessary to fulfil the requirements for the mixture forming. In that case jets are situated around the suction mouth (figure 4.31)



Figure 4. 30

Figure 4. 31 Suction mouth of the sea going  
PSD DECIMA

#### 4.8.2.2 The suction pipe

For many suction dredgers the suction pipe, together with the jet water pipe, forms a strong construction (Figure 4.32). To strengthen the suction pipe this it also equipped with a jacket pipe through which the jet water flows to the suction mouth. If this jacket pipe is divided into sections, these can also be used as float tanks to reduce the underwater weight of the suction pipe.



Figure 4. 32

With bigger dredgers, and certainly at greater suction depths, these constructions are too weak and it is necessary to turn to the use of a ladder (Figure 4.19). If an underwater pump is used, the upper part of the suction pipe must certainly be constructed as a ladder in order to transfer the heavy weight to the hull.

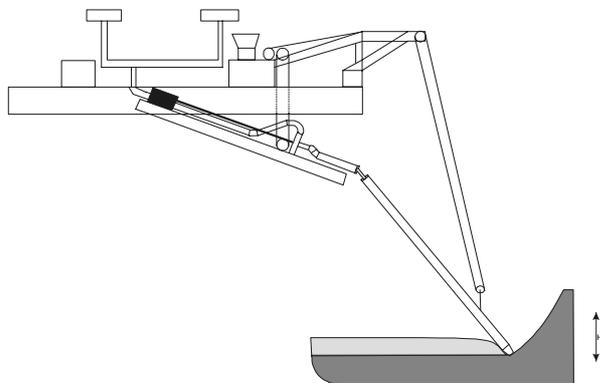


Figure 4. 33

On the suction pipe there is often a water admitting valve or breaching valve. If, as a result of irregular shearing of the breach/bank the vacuum becomes so high that the pump starts to cavitate and threatens to cut out, water can be admitted through this valve to keep the process going. This valve, which was formerly operated manually, is currently regulated automatically by the under pressure in front of the pump.

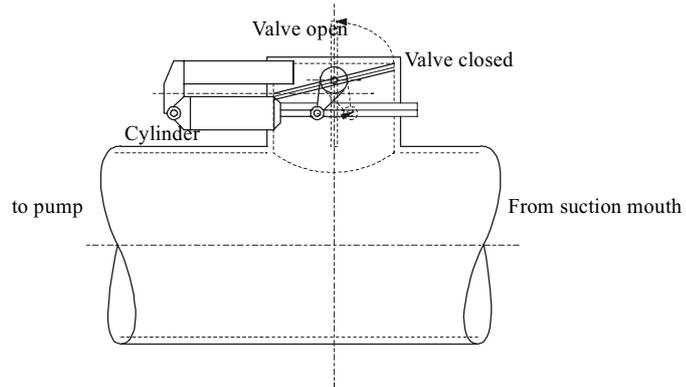


Figure 4.34

To ensure good control it is advisable to provide the valve with two openings, a big one for sudden emergencies and a second smaller valve that can be used for fine control with a continuously high vacuum.

A rubber suction hose forms the link between the suction pipe and the pipelines on board. This rubber hose is equipped with vulcanised steel rings, which prevent it from collapsing when under pressure occurs in it. The centreline of the suction hose is at the same height as the hinge and often lies beneath the waterline (Figure 4.35).

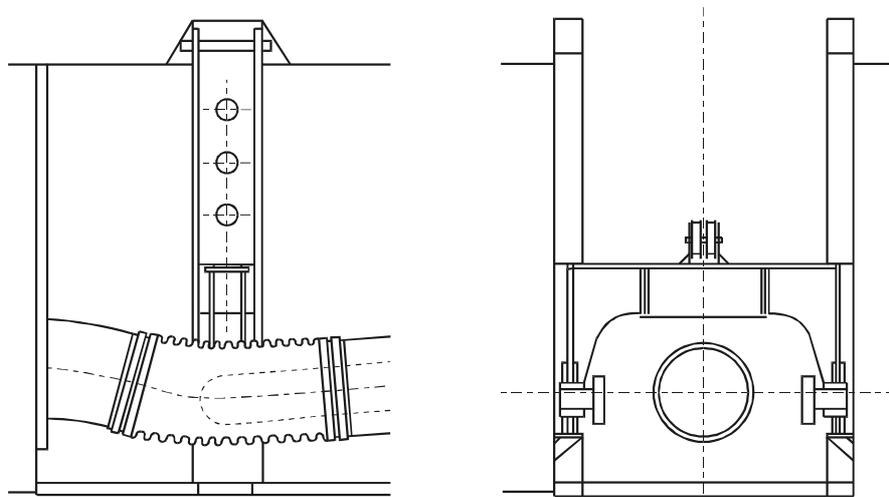


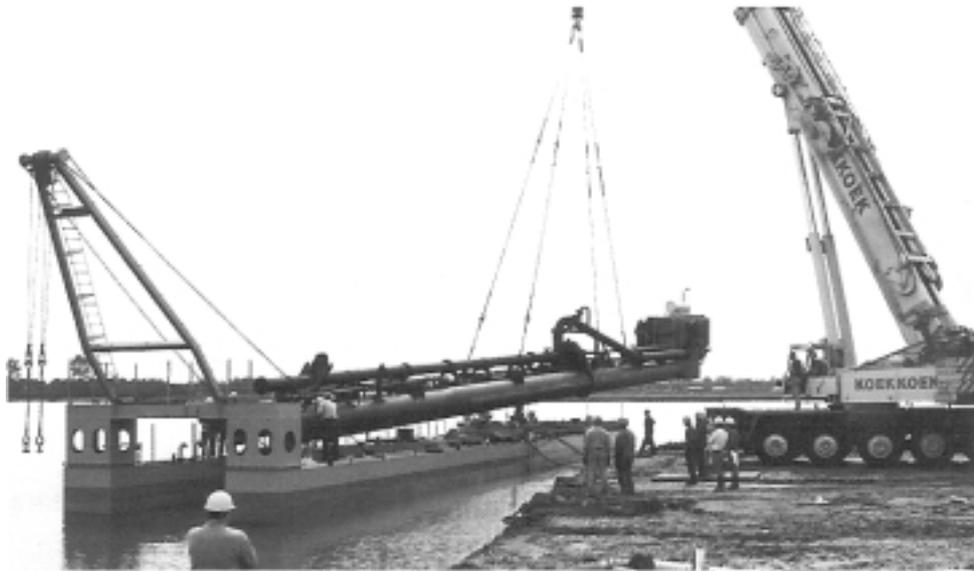
Figure 4.35

To prevent water from flowing in during pump inspections a so-called “outboard valve” must be fitted onboard before the pump

PSD’s without a submerged pumps have to be designed in such away that the suction pipeline is as short as possible. Where the suction pipeline comes above water, the chance of taking in air must be reduced to the minimum. (Taking in air has the same effect as cavitation.)

#### 4.8.2.3 The sand pumps

Barge-loading suction dredgers usually have only one pump, even when the dredger is equipped with an underwater pump, while reclamation dredgers have one or more inboard pumps independent if provided with an underwater pump.



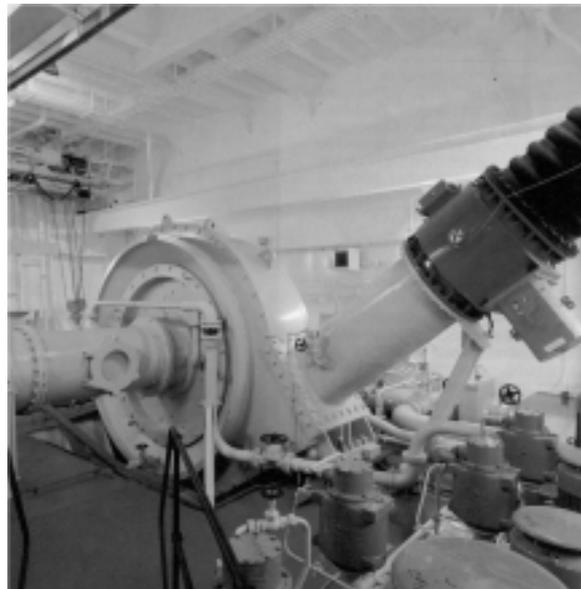
*Figure 4.36 View on ladder with pump for a PSD*

When suction dredgers do not have an underwater pump, efforts must be made the position of the first pump must be as deep as possible below the water line. This means on the base of the pontoon. As well as good discharge characteristics, the first pump must also have good suction characteristics, thus a high decisive vacuum and/or a low NPSH value.

If the dredger is equipped with an underwater pump the layout is less critical. In that case aspects such as accessibility for inspection and repairs play a more important role. The onboard pump is then only required to possess discharge characteristics. For the required specific speed for these pumps referred is to chapter 2.2.3.5 Dredge pump.

Submerged pumps have mainly a single wall, while inboard pumps have either a single or a double wall.

If there is more than one inboard pump the layout must be chosen in such a way that, if desired, it is also possible to work with the ladder pump and one inboard pump. An inspection hatch must be provided for every pump, so that the pump and the impeller can be inspected and, if necessary, debris can be removed.



**Figure 4.37 Double wall pump**

#### 4.8.2.4 The sandpump drives

The underwater pump often has an electric drive while the inboard pumps are powered by diesel engines. Diesel direct driven submerged pumps is till today in use for relative low powered pumps. See also chapter 3.2.3.4

#### 4.8.2.5 The discharge pipeline

Reclamation dredgers pump the dredged material ashore by means of a floating pipeline and, if necessary, to a more distant disposal site via the land pipeline.

Because the movement of the suction dredger is considerably less than that of a cutter suction dredger, it is not necessary to connect the discharge pipeline of the vessel to the floating pipeline by means of a swivel on the stern of the vessel. Often the discharge pipeline is connected to the floating pipeline by means of a delivery hose/pressure hose (a floating rubber hose). This can be mounted either on the stern of the vessel or on the port or starboard side.



Figure 4. 38 The sea-going PSD AURORA with the discharge pipeline connected on starboard

#### 4.8.2.6 Sprayers

If the dredged material has to be loaded into barges alongside because the transport distance is too long for pipeline transport to be economic, sprayers which are connected to the discharge pipeline are fitted on both sides of the dredger. The number of sprayers that is fitted on each side of the dredger depends on the capacity of the dredger and the size of the barges and varies between one and four per side.

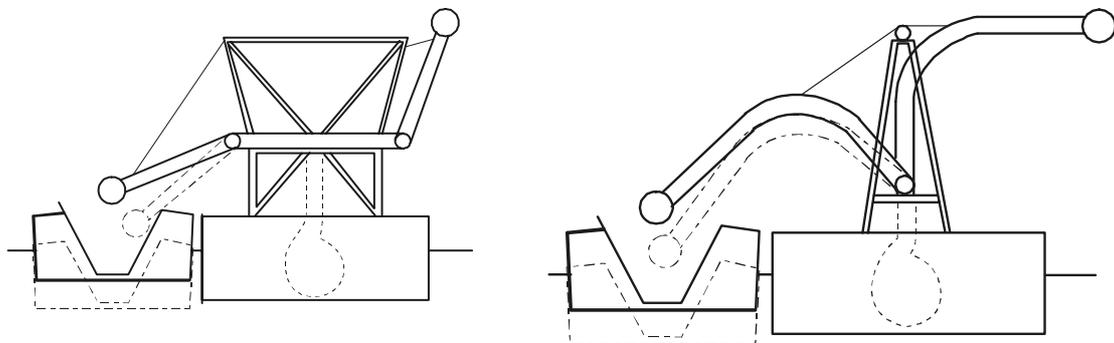


Figure 4. 39 Two different types of sprayers

To prevent barges from being unevenly loaded, the sprayers must be positioned as closely as possible to the centreline of the barge (Figure 4.39). Sometimes extra measures are necessary for this. For example, when it is necessary that to satisfy the demand that free fall of the dredged material must be prevented, the sprayers must be positioned as low as possible.

The capacity of the pump and the pipeline plan must be designed in such a way that on each side a barge can be loaded simultaneously. The sprayers are moved by means of winches or by a hydraulic system.



*Figure 4. 40 barge loading with movable sprayers*

#### **4.8.2.7 Jet-pipeline and pump**

The jet pipeline is of such a size that the pipeline loss remains within acceptable boundaries. It is advisable to design the bends, valves, crossovers etc. as large as possible in order to keep the losses within acceptable limits.

Often a sand pump is used as a jet pump to keep the wear between limits. This is certainly advisable when the dredger is a barge loading suction dredger. The water surrounding the dredger due to the overflow of the barges is diluted by fine sand particles, and thus the water taken in by the water pump.

#### **4.8.2.8 The winches**

Besides the ladder winch and the auxiliary winches, the Suction dredger is equipped with six winches for mooring:

- one bow winch
- two forward side winches
- two after side winches
- one stern winch to maintain tension on the bow winch

#### **4.8.2.9 The ladder winch**

The ladder winch that serves to adjust to the correct dredging depth is usually mounted on deck. If the hoisting wire runs through one or more blocks, the lowest block is fastened to the suction pipe by a rod (Figure 4.41). This is to prevent the block from being fouled by sand when dredging an irregularly shearing breach/bank. At present slow running electric or hydraulic drives are used.

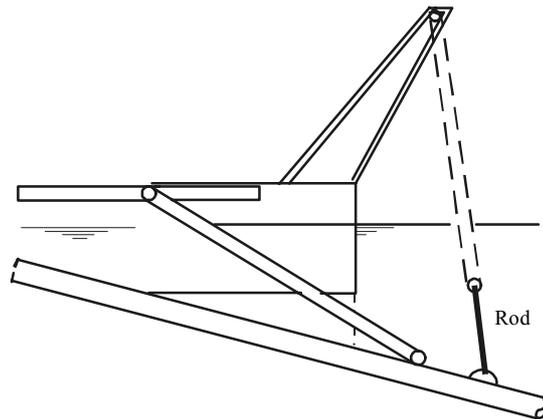


Figure 4. 41

#### 4.8.2.10 The bow winch

With the aid of the bow winch the suction pipe is held against the breach or bank. For the optimum control of the suction process good control of the bow winch is essential. It must be possible to pay out the bow winch quickly when moving the bow anchor. Bow winches are mounted on or below deck. Because of the great length of the bow wire, the bow winch usually has a large drum.

#### 4.8.2.11 The side winches

The side winches control the position and direction of the dredger in both the cut and in the dredging area. Side winches are usually mounted on deck and are electrically or hydraulically driven.

#### 4.8.2.12 The stern winch

The stern winch has a secondary function, namely to maintain tension on the bow wire, and it does not determine the production. Like the side winches it mainly comes into action when the dredger is being moved to another cut. The stern winch is usually mounted on the stern deck and electrically or hydraulically driven.

#### 4.8.2.13 The auxiliary winches

The moving of the sprayers and the warping of the barges is usually done by separate winches.

One or more jib cranes may be fitted and used to lift heavy parts during repairs.

#### 4.8.2.14 The fairlead

To sail the barge from and to the dredger fairleads are used to bring the side line wires on a sufficient depth below the water level that the barge can sail over the wires.

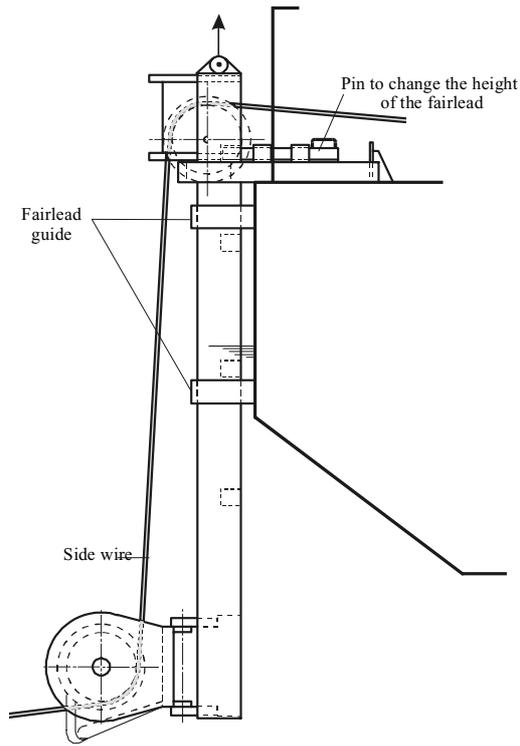


Figure 4. 42 Fairlead

### 4.9 The dredging process

The dredging process of a suction dredger can be subdivided into

1. The behaviour of the breach/bank during dredging also termed the breach/bank production.
2. The suction production of the dredger.
3. The discharge production of the dredger.

The last two productions will not be considered in these lecture notes. They will be treated in a course on dredge pumps and pipeline transport because the calculations involved are similar for all types of dredger.

#### 4.9.1 The production of the breach

When a vertical suction pipe is lowered into a sand layer quickly, narrow pit forms with almost vertical side slopes (Figure 4.43).

The diameter of the pit decreases from the top downward with time so the sand grains and sand fragments glide down under the force of gravity.

The velocity at which the instability of the slope moves depends on the permeability and the relative density of the sand layer and is roughly 20 to 40 times the permeability, depending on the slope and the angle of internal friction of the breach.

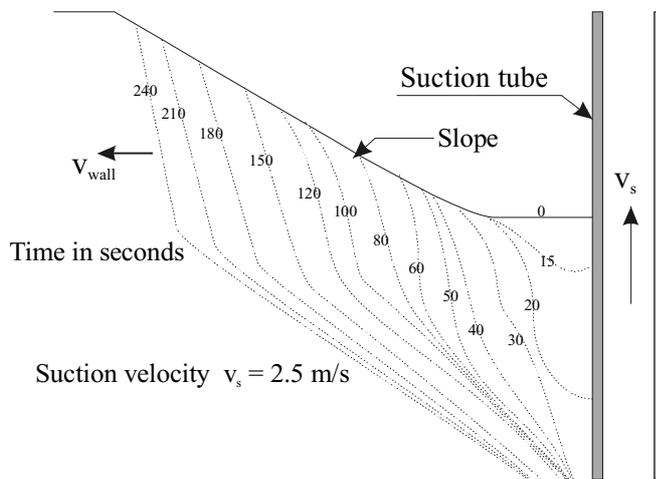


Figure 4. 43

Detailed information about this process can be found in the lecture note wb3413 the “Breaching process” .

When, under laboratory conditions, a 2-D suction mouth is moved forward with a constant speed at the base of a breach, a slope with an angle  $\beta$  will occur which is much steeper than the angle of internal friction. (Figure 4.4)

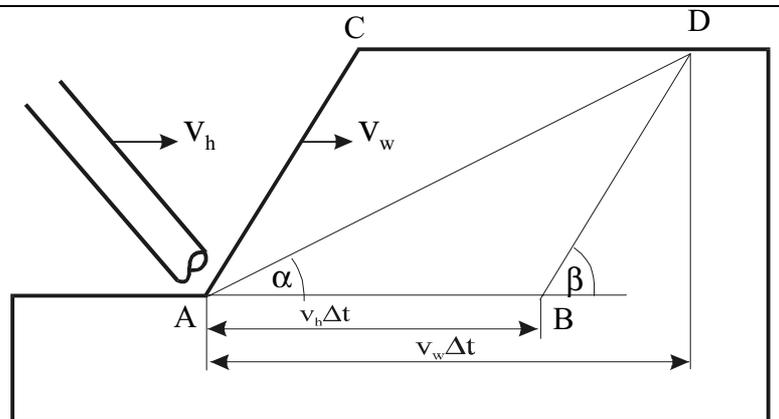


Figure 4. 44

The relation between  $v_w$  and  $v_z$  follows from the similarity of shape after a time  $\Delta t$ .

$$v_w \cdot \Delta t = \frac{H}{\tan \alpha} \quad \text{and} \quad v_h \cdot \Delta t = \frac{H}{\frac{1}{\tan \alpha} - \frac{1}{\tan \beta}}$$

From this it thus follows that:

$$v_h = v_w \left\{ 1 - \frac{\tan \alpha}{\tan \beta} \right\}$$

Production per metre wide:

$$Q_{sand} = v_h \cdot H = v_w \cdot H \left\{ 1 - \frac{\tan \alpha}{\tan \beta} \right\}$$

Here H is the height of the breach/bank.

The cause of the steeper slope is caused by the dilatancy (an increase of porosity) due to the shearing of the sand matrix. When the porosity increases pore water has to flow to these large pores. When this happens slowly a decrease in pore pressure will occur and an increase in the effective stresses causing an increase in stability. When sufficient water has flowed into the pores the under pressure and additional stability will vanish.

When a 3D suction pipe is moved forward horizontally at a constant speed a pit forms the slope of which is at its steepest directly in front of the suction pipe (Figure 4.45). The slope decreasing at the sides to a value  $\alpha$  that is determined by the eroding effect of the density current flowing towards the suction mouth. The angle  $\beta$  between the slope just in front of the suction pipe and the horizontal can be derived according to above. If all the material is removed, the production will be:

$$Q = W \frac{H}{2} v_h = v_h \frac{H^2}{\tan \alpha}$$

However, due to the movement of the suction tube not all the material from the side slopes will reach the suction mouth and spillage will occur.

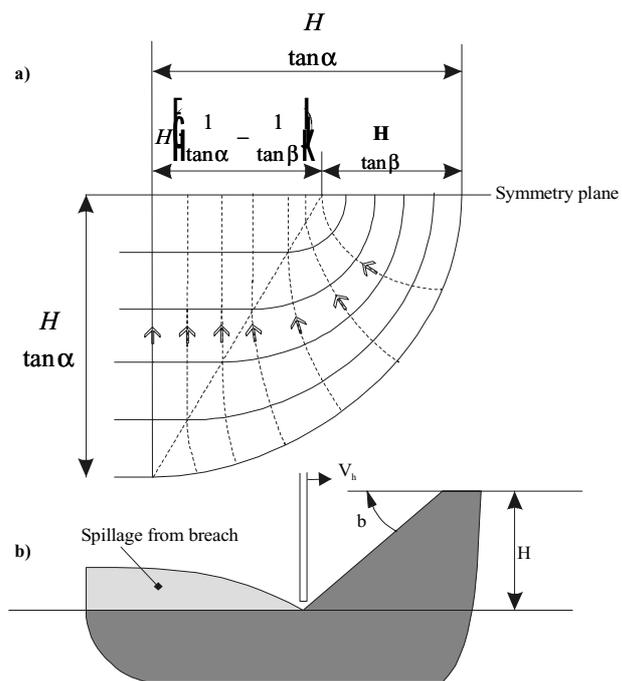


Figure 4. 45

This spillage can be calculated with the following production balance can be set up:

$$\frac{H-S}{\tan \alpha} H v_h - \frac{2S}{2} \frac{S}{\tan \delta} v_w = \frac{(H-S)^2}{\tan \alpha} v_h$$

with:

**Symbol**

**Declaration**

**Dimension**

H	Maximum pit depth	M
S	Height of spillage	M
$v_h$	Horizontal velocity suction mouth	m/s
$V_w$	Distortion (Wall) velocity	m/s
$\alpha$	Minimum slope angle	angle of internal friction
		$^\circ$

The first term is the volume per unit of time passing through area of the plane TAR, the second term is the production from the face BAT and BRA with  $\frac{1}{2}S$  being the average height retrogressive erosion or wall over the area considered and the term on right side of the equation is the volume per unit of time passing through a plane with the final cross section.

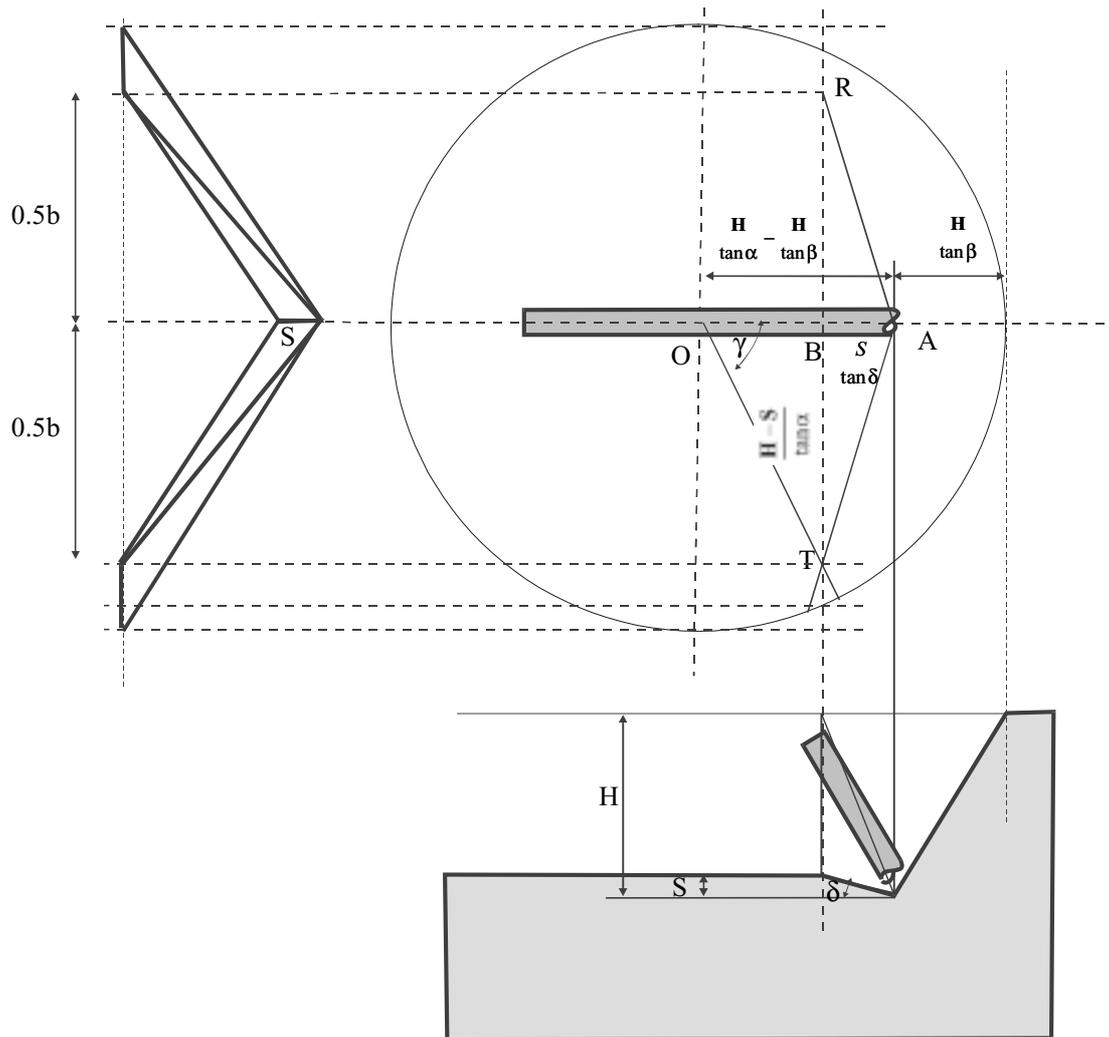


Figure 4. 46

This leads to:

$$\frac{H^2 - HS}{\tan \alpha} - \frac{S^2}{\tan \delta} \frac{v_w}{v_h} = \frac{H^2 - 2HS + S^2}{\tan \alpha}$$

$$H^2 - HS - S^2 \frac{\tan \alpha}{\tan \delta} \frac{v_w}{v_h} = H^2 - 2HS + S^2$$

$$S = 0 \text{ and } S = \frac{H}{1 + \frac{\tan \alpha}{\tan \delta} \frac{v_w}{v_h}}$$

The theoretical production without spillage, according equation  $Q = v_h \frac{H^2}{\tan \alpha}$ ,

the real production  $Q = \frac{v_h H^2}{\tan \alpha} \left[ \frac{\frac{v_w}{\tan \delta}}{\frac{v_h}{\tan \alpha} + \frac{v_w}{\tan \alpha}} \right]^2$ , and

the spillage production  $Q_{\text{spillage}} = \frac{v_h H^2}{\tan \alpha} \left[ \frac{\frac{\tan \delta}{\tan \alpha} v_h}{\frac{\tan \delta}{\tan \alpha} v_h + \frac{v_w}{\tan \alpha}} \right]^2$

Laboratory measurements have shown that  $\frac{\tan \alpha}{\tan \delta} = 4.77$ .

However, in practice appeared that the angle  $\alpha$  is small too. Taking  $\alpha = \delta$  results in a production of:

$$Q = \frac{v_h H^2}{\tan \alpha} \left[ \frac{v_w}{v_h + v_w} \right]^2 = \frac{v_h H^2}{\tan \alpha} \left[ \frac{1}{\frac{v_h}{v_w} + 1} \right]^2$$

#### 4.9.2 The production of the pumps

The sand flowing towards the suction mouth will be taken up by the dredger and must be transported away by means of barges or pumped to the disposal site via a pipeline. Depending on the pipeline system and the position(s) of the sand pump(s) the following situations may occur.

More sand flows to the suction mouth than the pumps can handle. The pump is the limiting factor and this criterion can be subdivided as follows:

- The under-pressure/vacuum in front of the pump is the limiting factor. The under pressure in front of the pump is so high that cavitation occurs, resulting in the loss of the discharge pressure. The pump then cuts out. The only good remedy is to position the underwater pump deeper.
- The discharge pressure is the limiting factor. The discharge distance is so long that the pressure required for the critical velocity of the mixture is higher than the pump can deliver. A stationary deposit will be formed in the pipeline, with the chance of a totally blocked pipeline. Depending on the loading on the engine, consideration can be given to the installation of a pump with a larger impeller or to changing the transmission ratio in the gearbox. If the loading of the engine is already maximal the maximum concentration has been reached.
- The pump torque is the limiting factor. This is the contrary situation to the above mentioned limiting pressure situation. The remedy is to use a smaller impeller.

### 4.9.3 The production of the barges

The pump production of a barge loading stationary suction dredger is not the same as the amount of material transported by means of barges. This is caused by the overflow losses that occur during the loading and also the bulking that occurs because the sand in the barges often has a lower density than the in situ density. These two factors must be taken into account when determining how many barges are required.

The number of barges follows from:

$$n = \frac{P(1-ov)\beta}{P_{bak}} = \frac{P(1-ov)\beta}{\frac{L_{bak}}{t_{cyclus}}} = \frac{P(1-ov)\beta}{L_{bak}} t_{cyclus} \quad (4.24)$$

Here:

N	= number of barges	[-]
P	= pump production	[m <sup>3</sup> /s]
Ov	= overflow loss	[-]
β	= bulking factor	[-]
L <sub>barge</sub>	= load of barge	[m <sup>3</sup> ]
T <sub>cycle</sub>	= cycle time	[s]

As a rule of thumb the percentage smaller than 100 μm can be taken as overflow losses.

The bulking is determined by the difference volume weight in situ and in the barge. With strongly graded material the volume weight in the barge is ± 19 kN/m<sup>3</sup> and with uniform material this can decrease to ± 18 kN/m<sup>3</sup>. For the calculation of the bulking reference should be made to Section 2.6.3.1.

The cycle time of the barge is composed of:

- the loading time
- the sailing time
- the discharge time
- the return sailing time
- waiting times for bridges, locks etc.

In addition to the fact that the pit or the pump can be \*maatgevend, with a barge-loading dredger, a situation may occur in which the barges are \*maatgevend. In other words there are not enough barges. A situation that may have a variety of causes such as:

- weather and wave conditions
- shipping
- Bridges and lock
- Unequal speeds of the barges
- Loss of time by the barge
- Delays on the dredger
- Loss of time at the discharge site

It will be clear that when using a barge-loading dredger there is always a chance of delays due to the absence of a barge.

Because the above mentioned delays can be reasonably well estimated with regard to their average values and standard deviations, the Monte Carlo Simulation can provide insight into the probability of delay resulting from the absence of barges.

#### 4.10 The dustpan dredger

As appears in chapter 4.9.1, the production of the suction dredger is proportional to the square of the breach height. With low breach heights the production remains lower than the discharge capacity of the pump. In order to compensate this to some extent, a broad suction mouth, the dustpan head, is mounted on the suction pipe. The width of the dustpan head is 10 - 15 times the diameter of the suction pipe. In addition a large number of spray nozzles are mounted on this suction head, which by means for water jets stimulate breaching process. Moreover they are necessary to prevent the suction head from becoming blocked. The working effect of the spray nozzles can be calculated in the same way as is given in chapter 4.5.6.1.

In fact, the dustpan dredger has been superseded by the cutter suction dredger, which, with a considerable larger width of cut, can attain a much higher production on low breaches/banks.

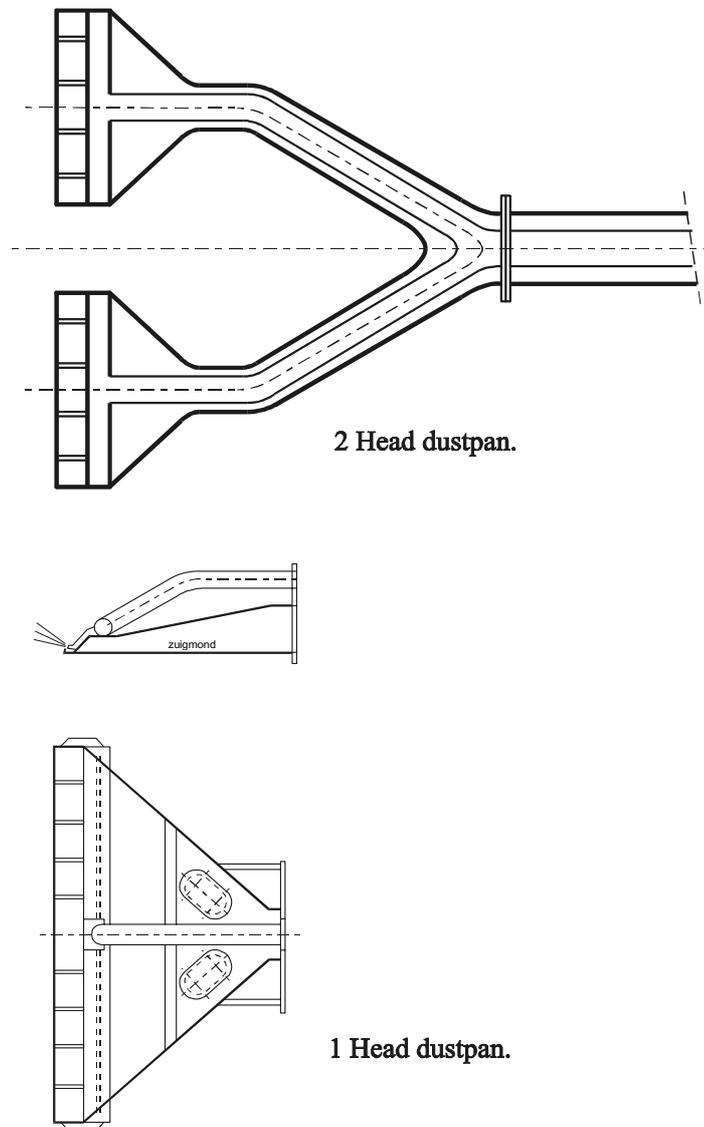


Figure 4. 47 Dustpan heads

Dustpan dredgers are now only used for small projects or on special dredgers such as the “Cardium.” The “Cardium” is equipped with 6 suction pipes and suction pumps, each with two suction mouths, in order to ensure that the bottom is at the correct depth (the foremost suction mouth is in dustpan mode) and is flat and clean immediately before a block mattress is laid down (clean up model).

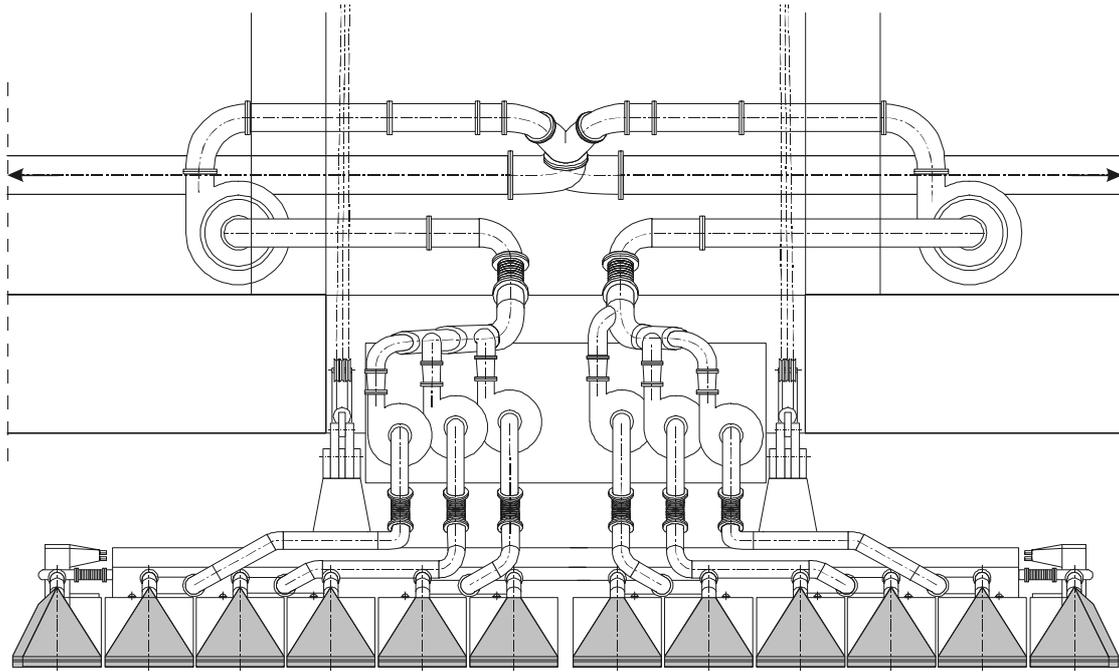


Figure 4. 48 Dustpan head with pump and pipe in scheme of the mattress laying vessel "CARDIUM"

#### 4.11 References

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