CHALLENGES OF DREDGING IN THE ARCTIC AND OTHER DEEP OCEAN LOCATIONS

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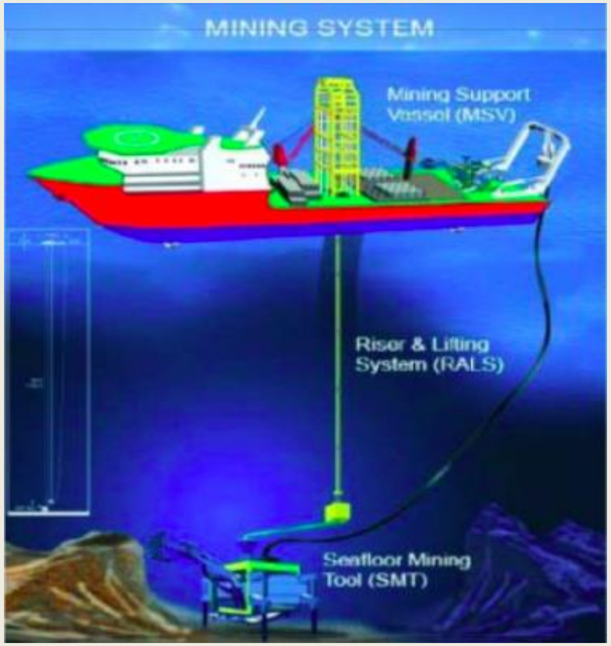
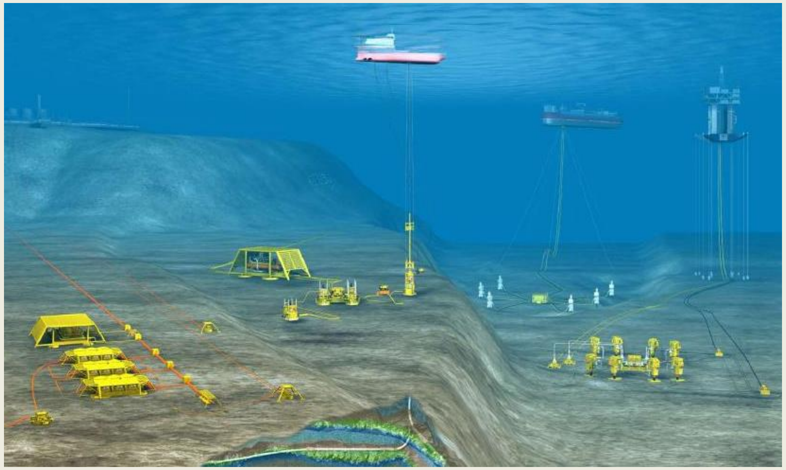
Overview

- ❑Technical challenges in deep ocean dredging/trenching/mining
- ❑ Deep sea dredging/mining technologies
- ❑ Arctic trenching technologies
- ❑ Hydraulic transport for deep sea dredging/mining

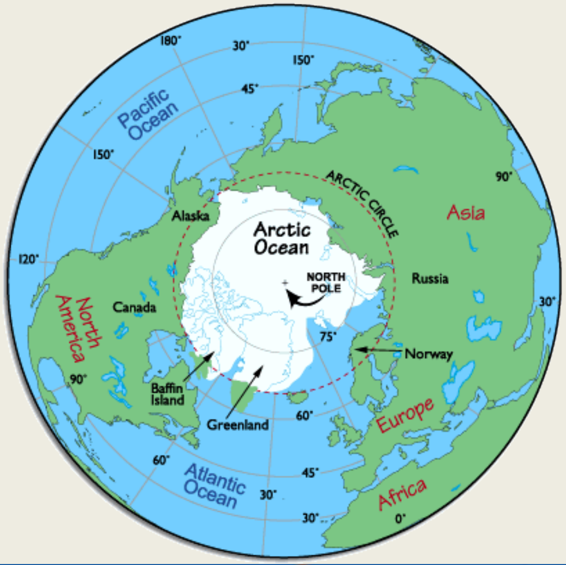
Demand for deep sea dredging

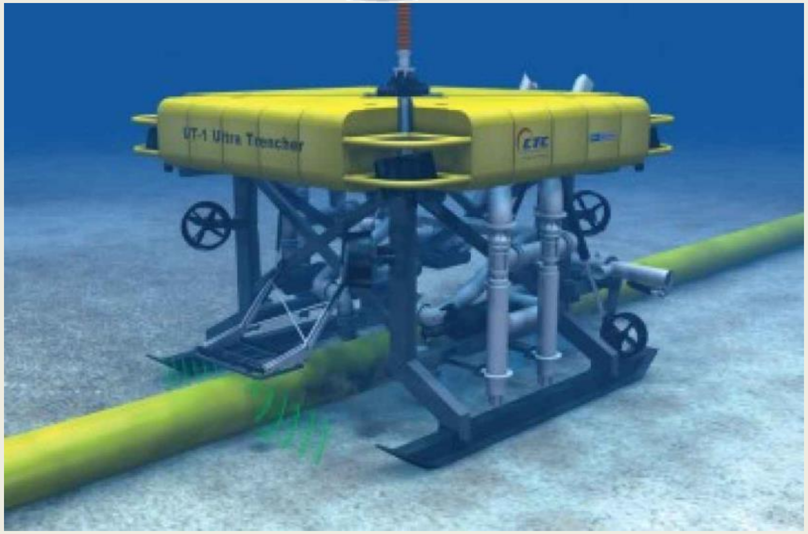




- The demand for essential resources, such as oil, gas and minerals continues to increase.
- Ocean mining sites are usually around large areas of polymetallic nodules or active and extinct hydrothermal vents to get valuable metals (gold, silver, and copper) at depth of 1,400 – 3,700 m.
- Dredging for offshore oil and gas industry is to develop deep water petroleum reservoirs and install subsea equipment (pipeline, subsea manifolds and separators)

Demand for Arctic Trenching



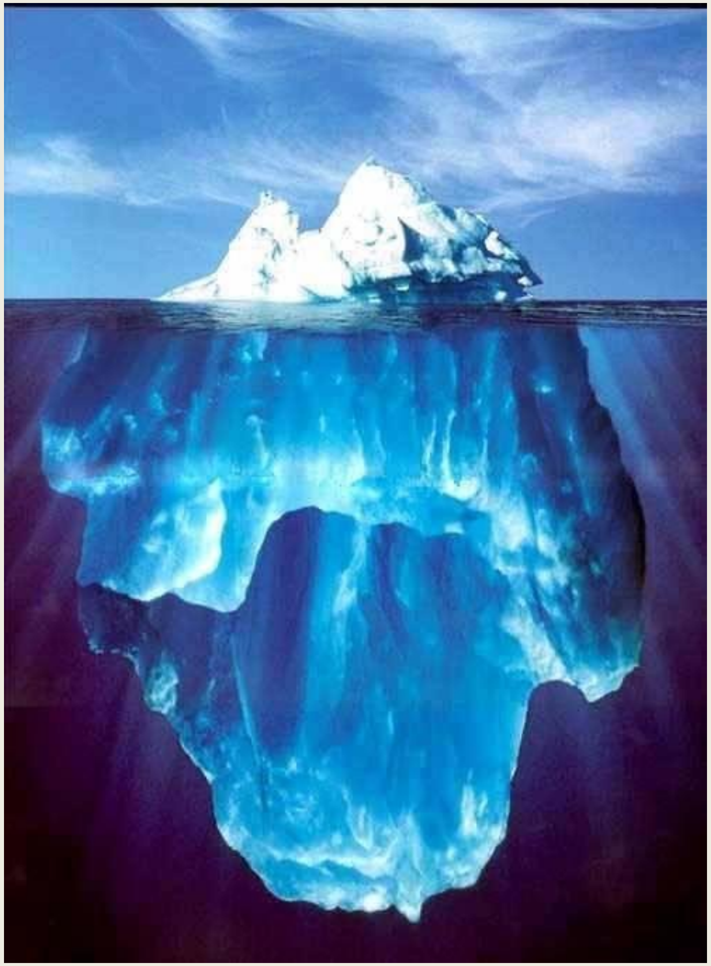


CTC Marine UT-1 Trencher

- Approximately 13% of the undiscovered oil and 30% of undiscovered gas in the world is located North of the Arctic Circle.
- North of Arctic Circle, pipeline trenching is necessary to avoid:
    - Ice gouging
    - Strudel scour
    - Thaw settlement
    - Upheaval buckling

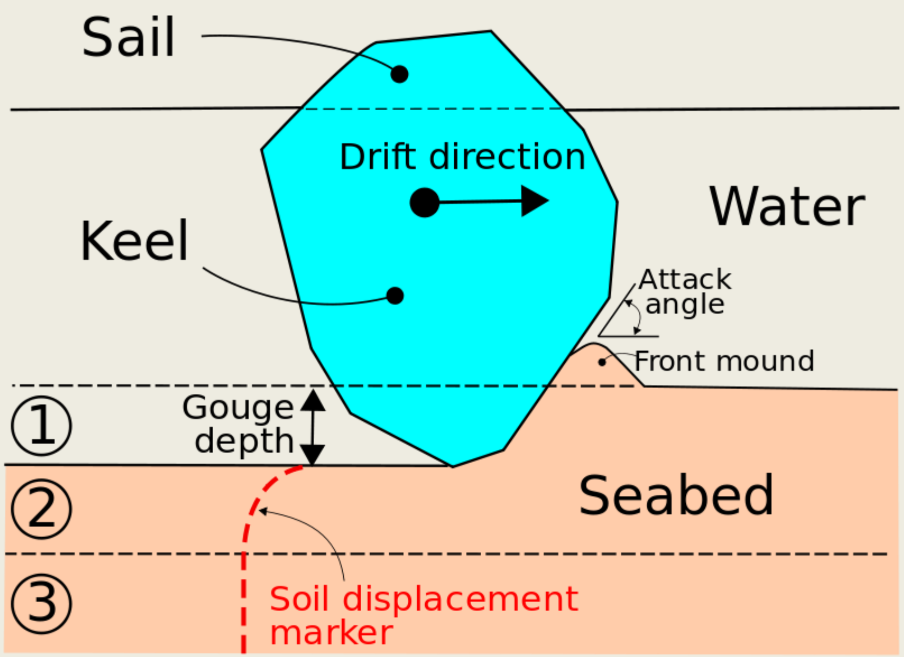
Icebergs & Ice Keels

- Icebergs are a floating mass of freshwater ice (http://www.solcomhouse.com/iceberg.htm)
- Typical Arctic icebergs:
  - 45 m (147.6 ft) tall
  - 180 m (590.4 ft) long.
- About 87.5 % of the iceberg is below the water and is called an ice keel.
- Icebergs the size of a small house are called bergy bits
  - 1-4 m (3.3 – 13.1 ft) in height
  - 5-14 m (16.4 – 45.9 ft) in length
- Smaller icebergs are called growlers:
  - less than 1 m in height and less than 5 m in length.
- Larger icebergs are found in the North Atlantic.



Environmental loads in Arctic area (1)

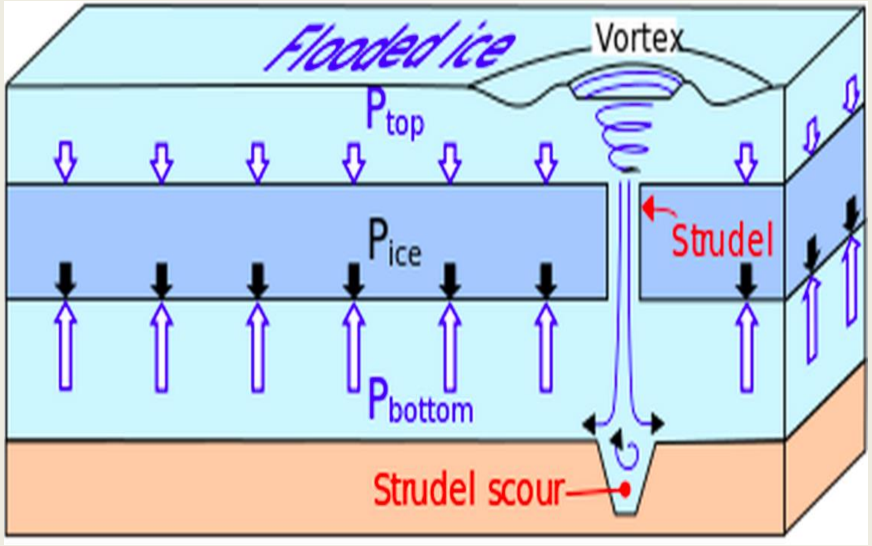
❑ Ice gouging



- Formed by icebergs or sea ice ridge
- When the depth of an ice keel is greater than the water depth, gouges can be developed as a result of lower parts of an ice keel contacting the seafloor.
- Load on seafloor by ice gouging is 10 to 100 MN (2,250,000 to 22,500,000 lb_f)
- Trench depth of 6m (19.7 ft) is necessary for protecting the pipeline

Environmental loads in Arctic area (2)

❑ Strudel scour



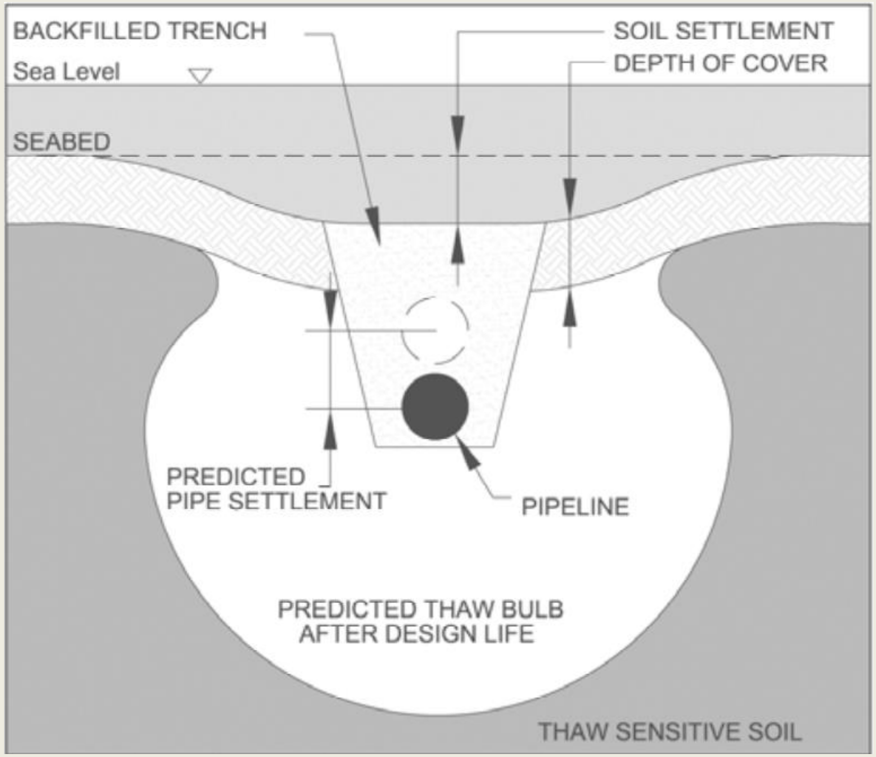
$P_{ice} + P_{top} < P_{bottom}$

Driving pressure = $P_{bottom} - (P_{ice} + P_{top})$

- Strudel scour is generated by bottomfast ice during winter season.
- When river flows meet the bottomfast ice special flows passing through holes in the bottomfast ice sheet are created.
- If the speed of the seawater flow is high enough, it leads to scour of seabed sediments with high hydrodynamic loads acting on subsea pipelines.
- The Strudel scour tends to take place in offshore areas close to river deltas in water depths of 2 - 9m (6.6 -29.5 ft).
- The width of Strudel scours are the order of 10 - 20 m (33 – 66 ft).

Environmental loads in Arctic area (3)

❑ Thaw settlement

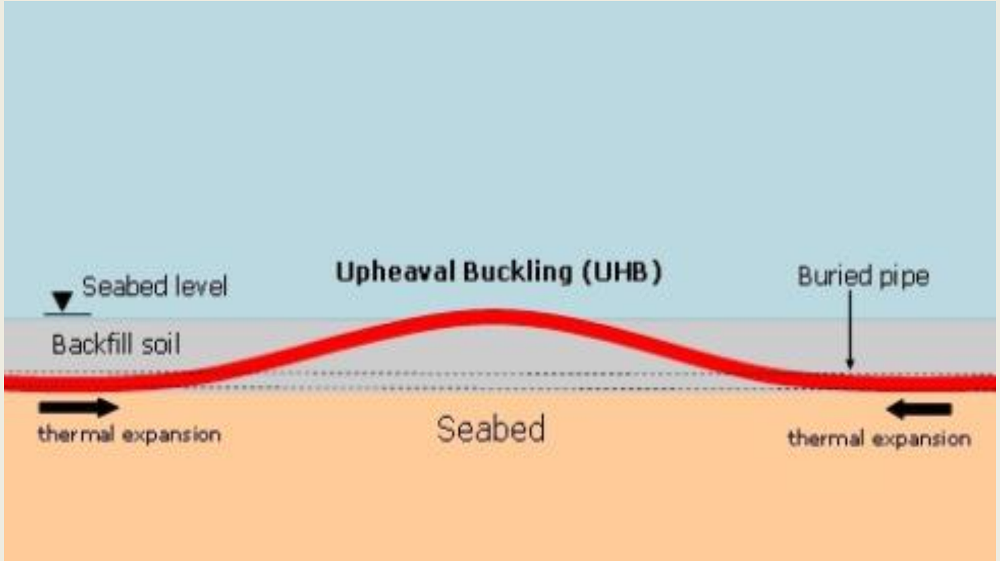


[Paulin et al. (2014)]

- Permafrost is not uniformly distributed in space and time, resulting in uneven temperature distribution.
- During the production through a pipeline, the temperature of surrounding area of the pipeline increases.
- These local rises in temperature cause permafrost thawing, creating local thaw bulbs
- Pipelines can experience significant overstress and bending strain.

Environmental loads in Arctic area (4)

❑ Upheaval buckling



- Upheaval buckling occurs when the temperature and pressure of an operating pipeline are higher than that in the installation period.
- An axial compressible load occurs, resulting in the longitudinal expansion of the pipeline and making the pipeline move upwards.
- Pipeline may be exposed to seawater
- Insufficient trenching depth can lead to additional damage by the ice gouging.

Conventional excavation

Hydraulic backhoe 'OPTIMUS'
(Wasa Dredging Ltd.)

- Type:
  - Hydraulic backhoe dredge
  - Clamshell bucket dredge
- The dredgers are operated on a barge, which maintains its location by using spuds.
- A berm is built in the near-shore region for dredging in shore crossing regions that is an alternative to a barge.
- Limitation:
  - A combined 15-m (49.2-ft) water and trench depth using a long-reach or extended backhoe
  - Long working hours

Ploughing

Multi-pass plough 'AMP500'
(Deep Ocean Group)

- Both post-lay and pre-lay trenching
- Relative high trenching speed, used for long pipelines
- The design and size of a plough are determined by the required force to pull the plough that is calculated by the trench depth and the type of soil.
- Trench depth
  - Single-pass ploughs: 2-3 m (6.6 – 9.9 ft)
  - Multi-passes ploughs: 8-10 m (26.2-33 ft)

    (the trench width is 8m (26.2 ft)
- No limitation of water depth up to 3,000 m (9840 ft).
- High working speed of 400 to 500 m/hr, (maximum speed of 800 to 1,100 m/hr)

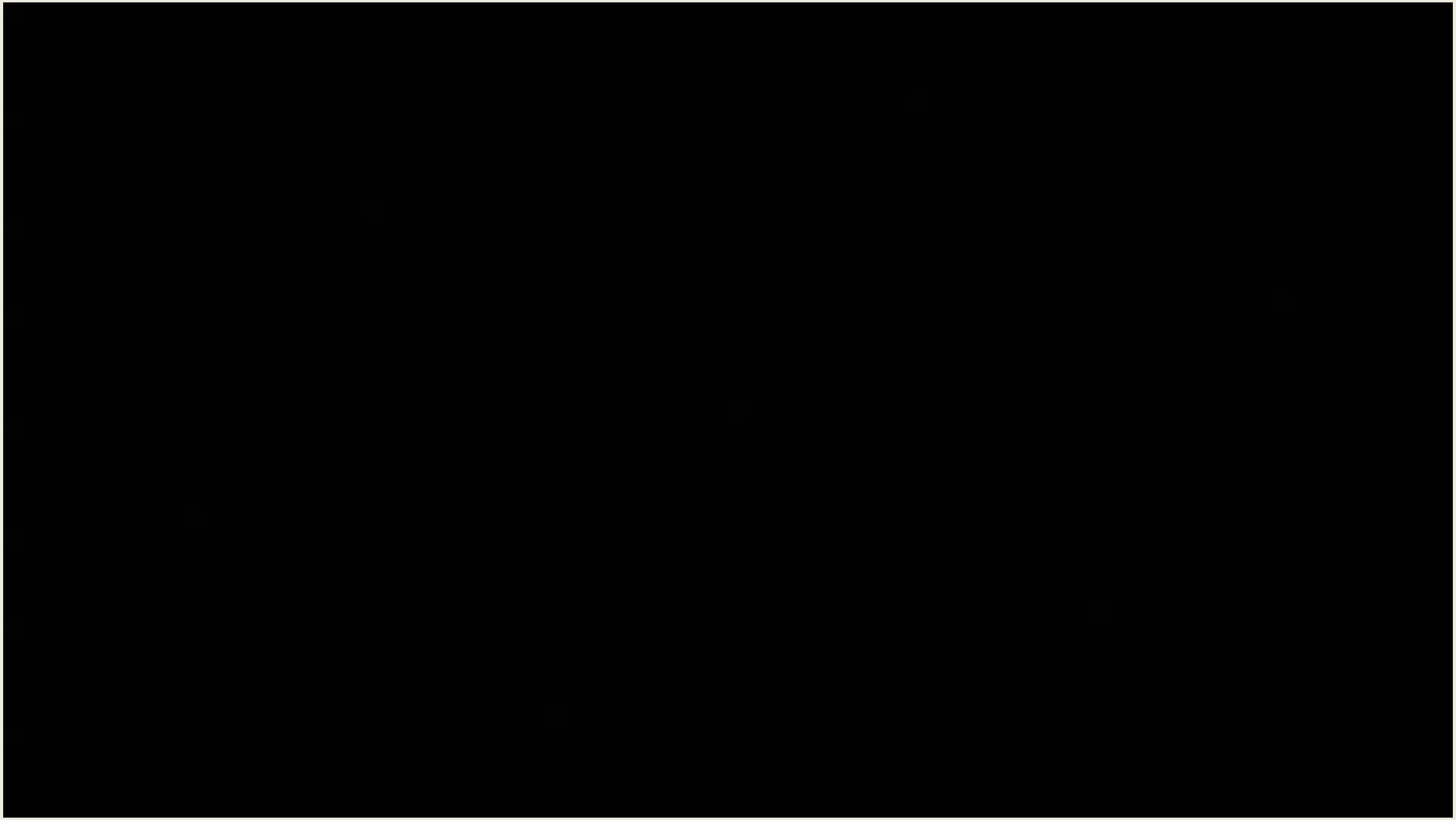
Jetting

ROV trenching unit 'T1200'
(Helix Energy Solutions Group).

- Jetting device lowers pipelines using high-pressure water jets.
- Type:
  - Jet sleds
  - Jetting ROVs
- Jet sleds or jetting ROVs
- Trench depth
  - Single-pass ploughs: 2.5-3 m (8.2-9.9 ft)
  - Multi-passes ploughs: 6 m (19.7 ft)

    (the trench width of 2 - 3 m (6.6-9.9 ft)
- No limitation of water depth up to 3,000 m.
- High working speed : 300 - 400 m/hr
- Not sufficient to cut through rock

Oceaneering GTO ROV Dredge



Mechanical Trenching

Chain cutter trencher 'T3200'
(Deep Ocean Group)

- Type:
  - Barge-mounted chain cutters
  - Crawler style trenchers
- Both of which rely on hydraulic power to operate their cutter and/or tracks
- Need large buoyancy tanks to make the trencher sink
- Trench depth
  - Single-pass ploughs: 2-3 m (6.6-9.9 ft)
  - Multi-passes ploughs: 6 m (19.7 ft)
    (the trench width of 2 m)
- Trench rate is 300 - 400 m/hr
- Good for excavating in hard soil condition.

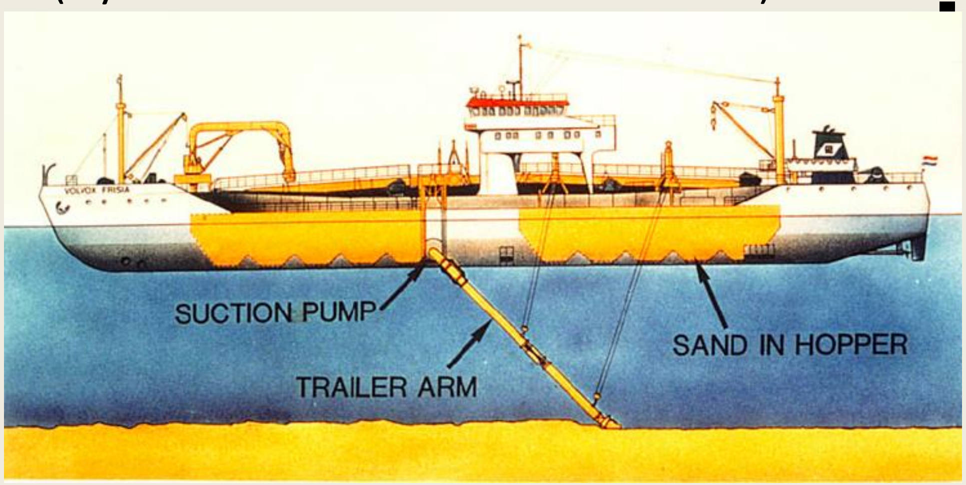
Cutter suction dredge

Self-propelled cutter suction dredger 'D'ARTAGNAN'
(Royal IHC 2015a)

- Cutter suction dredges break hard materials through a rotating cutter located in front of the suction inlet.
- The broken materials are transported through the pipeline.
- Maximum water depth: 35 m (115 ft)
- Trench depth: >5 m (16.4 ft) with trench width of 10 m (33 ft)
- Dredging rate: 60 m/hr (197 ft/hr)

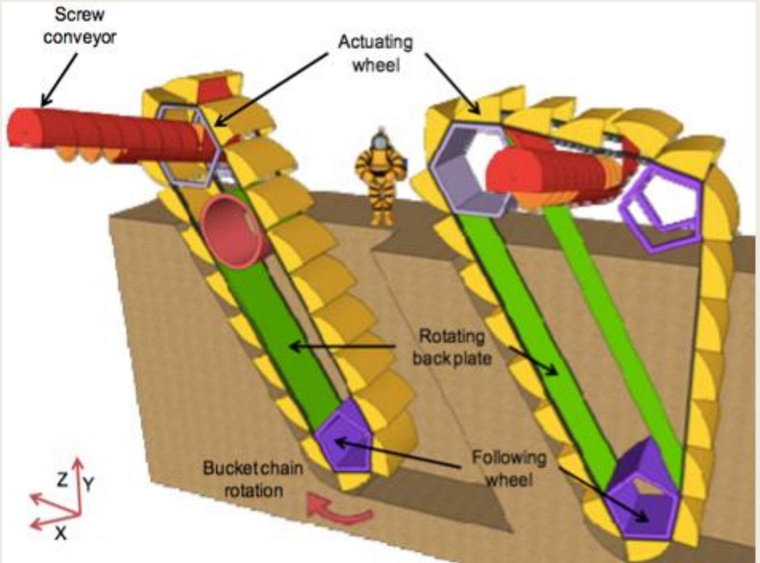
Trailer suction hopper dredge

Trailer hopper suction dredger ‘1000 M3’
(Hydromec Maritime Solutions 2015)

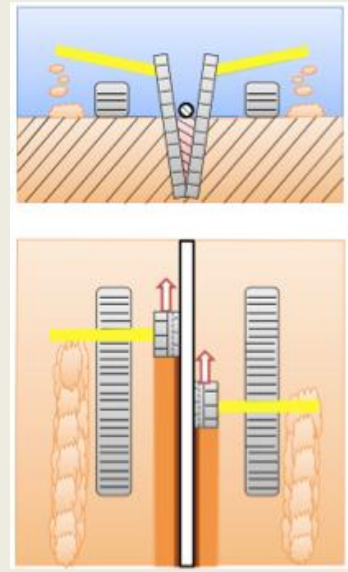


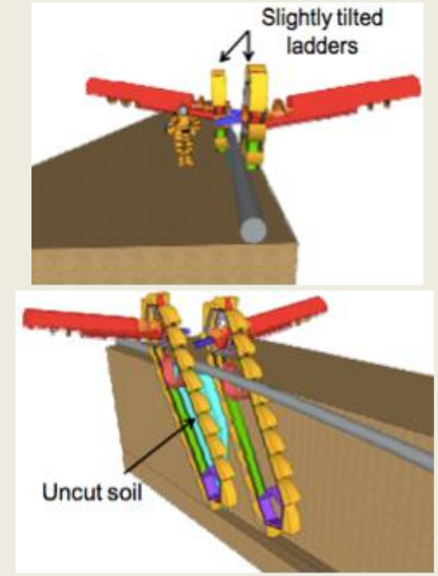
- Trailer suction hopper dredge erodes the sediments through a drag head with pumps on the drag arm.
- the dredged material is transported to hopper through pipeline.
- Maximum water depth: 155 m (508 ft)
- Trench depth: >5 m (16.4 ft) with trench width of 10 m (33 ft)
- Dredging rate: 60 m/hr (197 ft/hr)

Arctic subsea bucket ladder trencher



Left: compact ladder trencher
Right: triangular ladder trencher





Twin ladder method

arctic subsea bucket ladder trencher (Vaartjes et al. 2012)

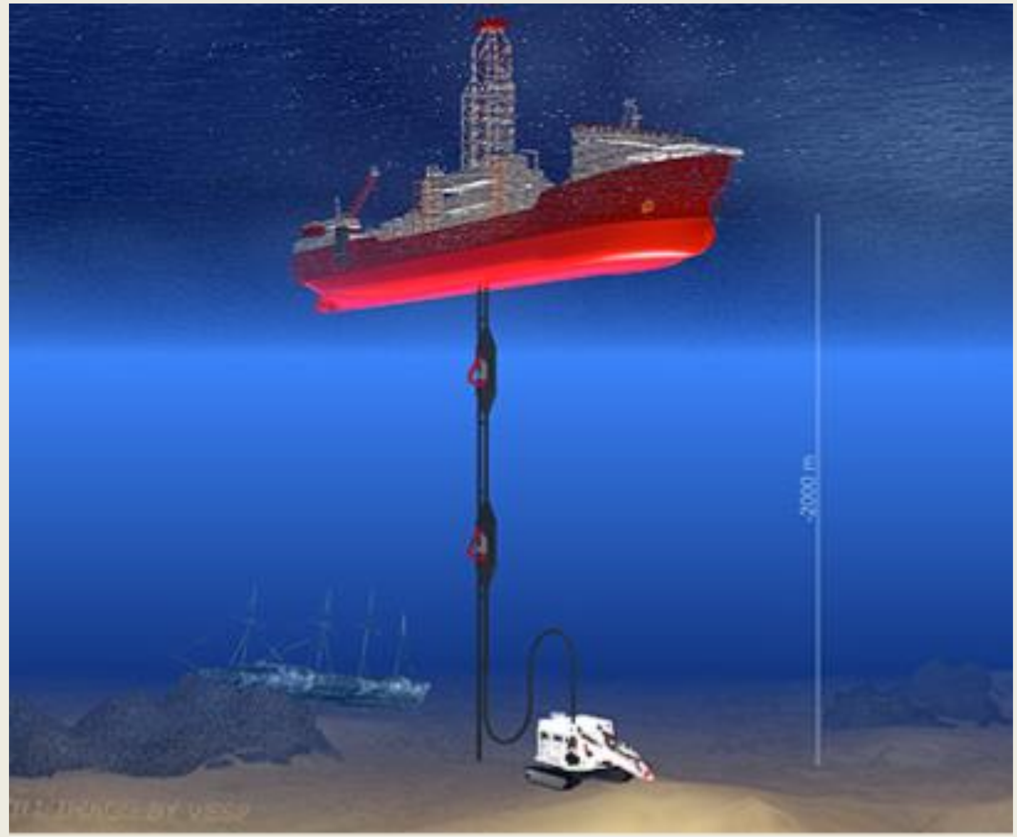
- Smaller size and less weight than normal bucket ladder trenchers
- Triangular ladder trencher guarantees a better bucket emptying ability
- Bucket emptying process is conducted using a screw conveyor passing through an actual wheel.
- Twin ladder method is used for pipeline handling.
- Trench depth: 6m (19.7 ft); Maximum trenching speed: 70m/hr (230 ft/hr)

Challenges of dredging/mining in deep sea

- High investment
  - Highly technical machines
  - Long umbilical and pipeline
  - Suitable materials for deep water
  - Equipment is large in size and only used for dredging
- Difficulty for site exploration and excavation.
  - Equipment for seafloor bathymetric survey
  - ROVs and autonomous underwater vehicles
  - High-efficient operation and positioning of seafloor mining tool
- Transportation of dredged materials
  - Arrangement of many pumps to transport the material from seafloor
  - Displacement and bending moment of riser
  - Inappropriate transportation method can make surface support vessel "dead cargo"

Deep sea dredging/mining concept

- Seafloor mining tool
- Hydraulic transport system
- Surface support vessel



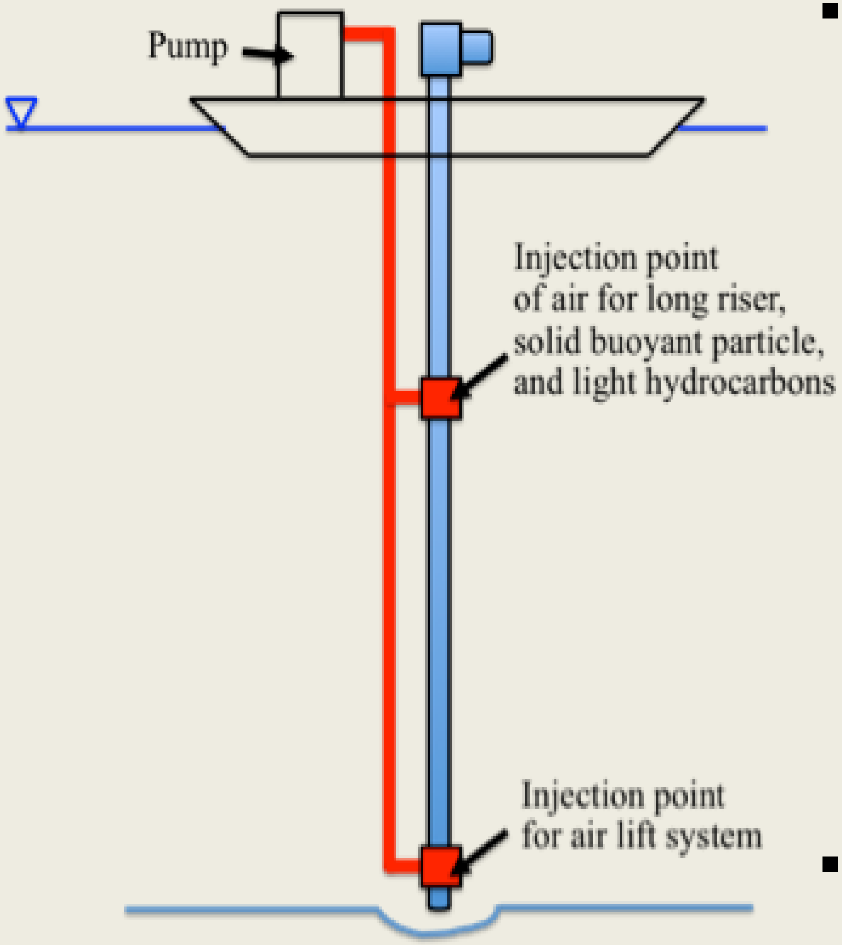
Concept employing a single seafloor mining tool connected to the mining support vessel by the vertical transport system.
(Royal IHC 2015b)

Seafloor mining tool

- The surface mining tool aims at the excavation of target materials and transportation of these materials to the hydraulic transport system (HTS).
- The selection of the surface mining tool (SMT) is based upon the soil conditions.
  - Plain suction nozzle: good for soil with little cohesion
  - The mechanical excavation tools: good for the sand or rock
- Mechanical excavation tools have to withstand the reaction force during mechanical excavation, and the power needed has to be supplied from the surface support vessel.

Seafloor mining tool
(Vercruijsse and Lotman 2010)

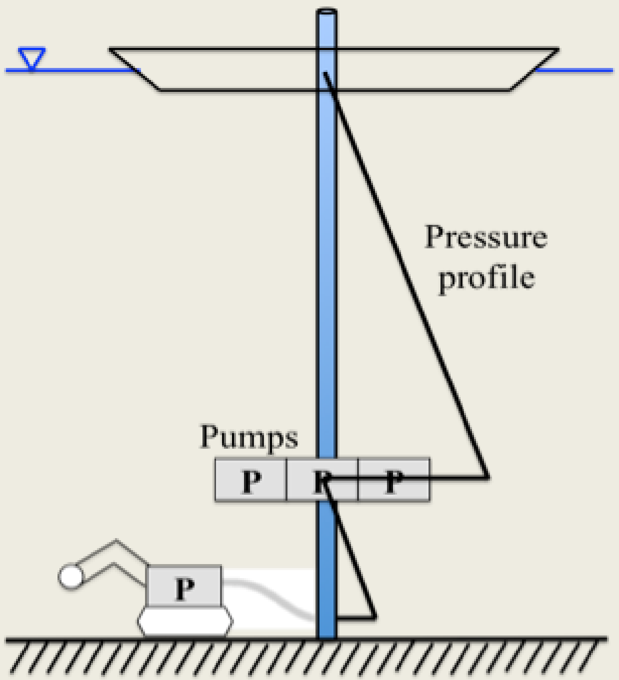
Hydraulic transport system (1)



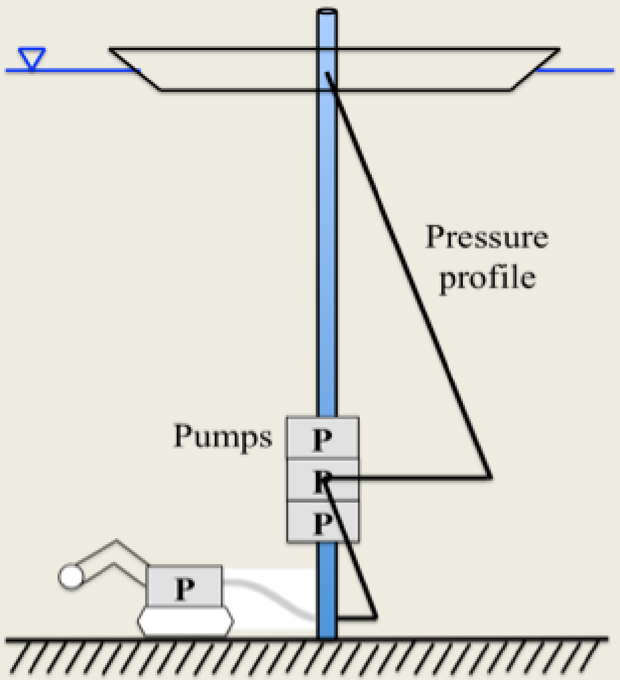
- Air Lift
  - Compressed air is provided at injection point to create mixture of water and air. This mixture has lower density compared to the surrounding fluid, which makes fluid travel upward.
  - Fewer mechanical parts below the sea surface (less maintenance)
  - Simple and reliable
  - Low efficiency in case of long riser due to isothermal expansion of air, which decreases the water content in the upper portion of the pipe
- Solid buoyant particles & light hydrocarbons
  - No isothermal expansion
  - Requires additional equipment to store, pump, and separate

Hydraulic transport system (2)

- Pumps used for dredging
  - Centrifugal pumps (High flow rate, low pressure)
  - Positive displacement pump (Low flow rate, high pressure)
  - Fewer mechanical parts below the sea surface (less maintenance)

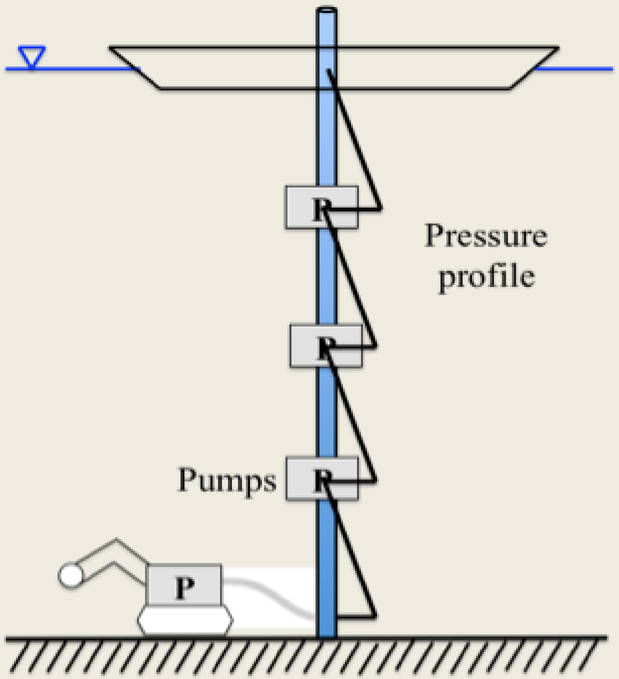


(a) Positive displacement pumps in parallel

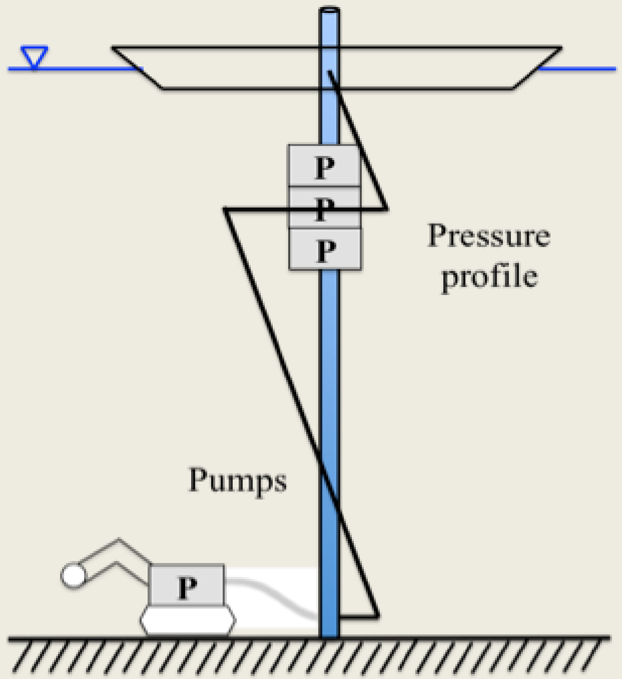


(b) Centrifugal pumps in series

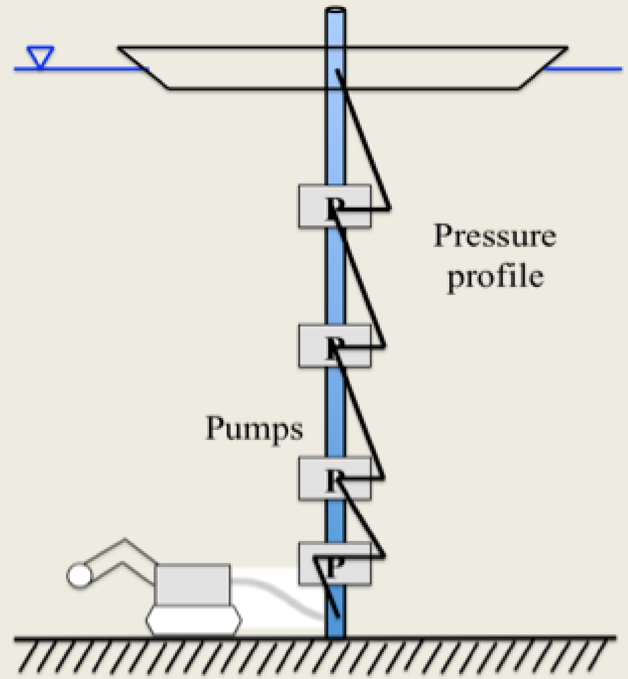
Hydraulic transport system (3)



(c) Centrifugal pumps distributed over the riser

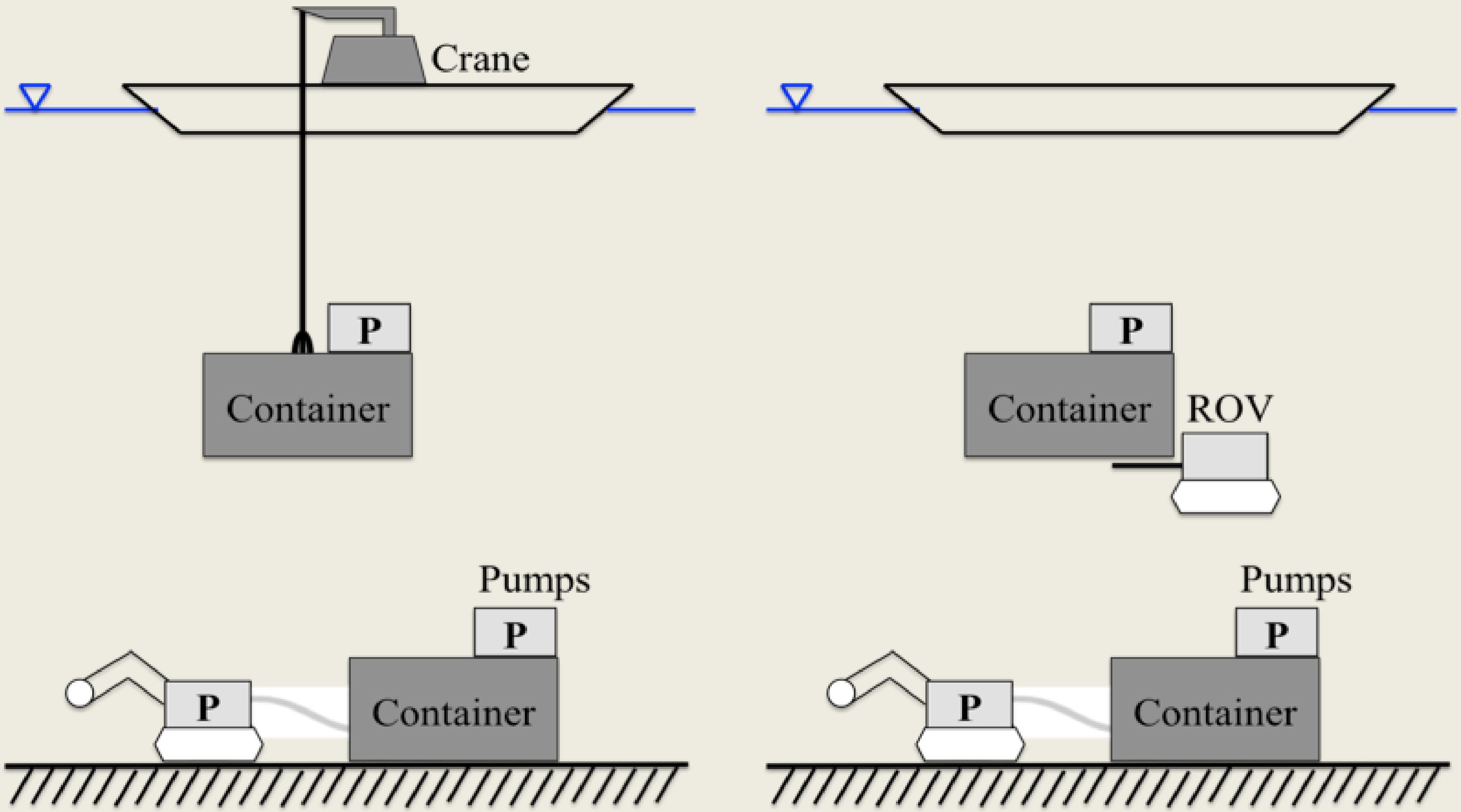


(d) Centrifugal pumps installed in near to the surface



(e) Centrifugal pumps without pumps on the surface mining tool (SMT)

Another concept for deep sea dredging



Summary

- Trenching in Arctic locations is needed to prevent damaging forces on subsea pipelines due to ice gouging, strudel scour, thaw settlement, and upheaval buckling
- Trenching methods are conventional excavation, ploughing, jetting, mechanical trenching, and hydraulic dredging equipment.
- Dredging in deep water locations are challenging due to the great depths.
- The combination of the seafloor mining tools (SMTs), hydraulic transport systems (HTSs), and surface support vessels (SSVs) is considered as an optimum method for deep water mining or dredging.
- Concepts that use containers and cranes can be practical. The HTSs can be replaced by the use of containers. The transportation of the dredged materials can be done by filling containers with the dredged material and by moving it to SSVs. The transportation of containers can be conducted by means of a crane, ROV or container buoyancy.

Thank You

- **Questions**