Capsule Pipeline for De-silting Water Reservoirs

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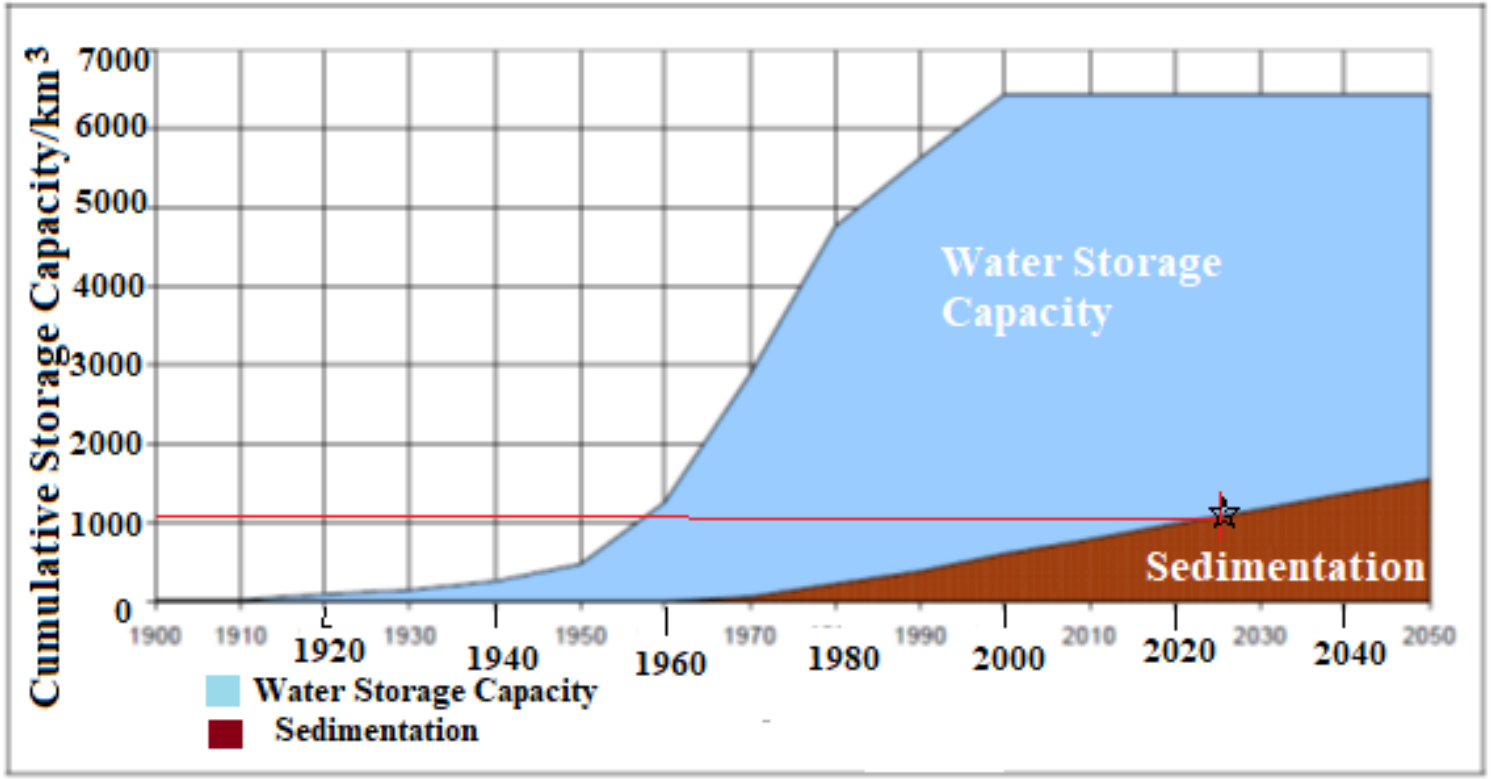
A large number of Reservoirs are filling up with sediments

- Sediments have accumulated in reservoirs and are anticipate to consume 25% of world water storage capacity by 20250



Long Distance Transport of dredged sediments

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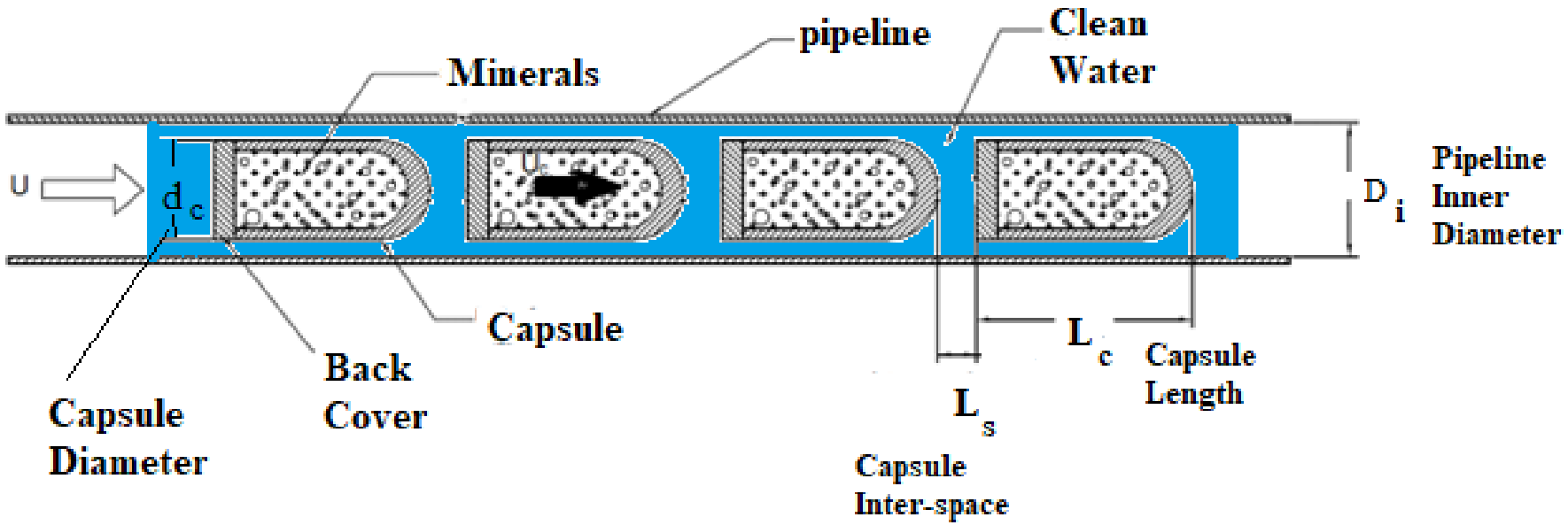
Over the years a number of projects have involved long distance transport of dredged sediments

- San Jacinto Reservoir, Texas, dredging 2,420,000 yd^3 (1.8 $x10^6$ m^3),(sand and debris) up transported to 50,000ft (15.3 km)
- John Redmond, Kansas, 3,000,000 yd^3,(2,3 $x10^6$ m^3) sediments, transported >30,000 ft (9.2 km)
- Lake Decatur 2nd Phase, Illinois, 10,770,000 yd^3,(8,1 $x10^6$ m^3), silts, clays, sands,>transported 45,000 ft (13.7 km)
- Lake Decatur 1stPhase, Illinois, 1,520,000 yd^3, (1.15$x10^6$ m^3), silts, clays, sands, transported >18,000 ft(5.5 km)
- Lake Worth, Texas, 1,4990,00 yd^3, (11,3$x10^6$ m^3), sand/clays/silt, >15,000 ft (4.6 km)
- Loiza (Caraizo), Puerto Rico, 7,800,000 yd^3 (5,9$x10^6$ m^3), transported up to 35,000 ft(10.7 km)

Hydraulic Capsule Pipelines

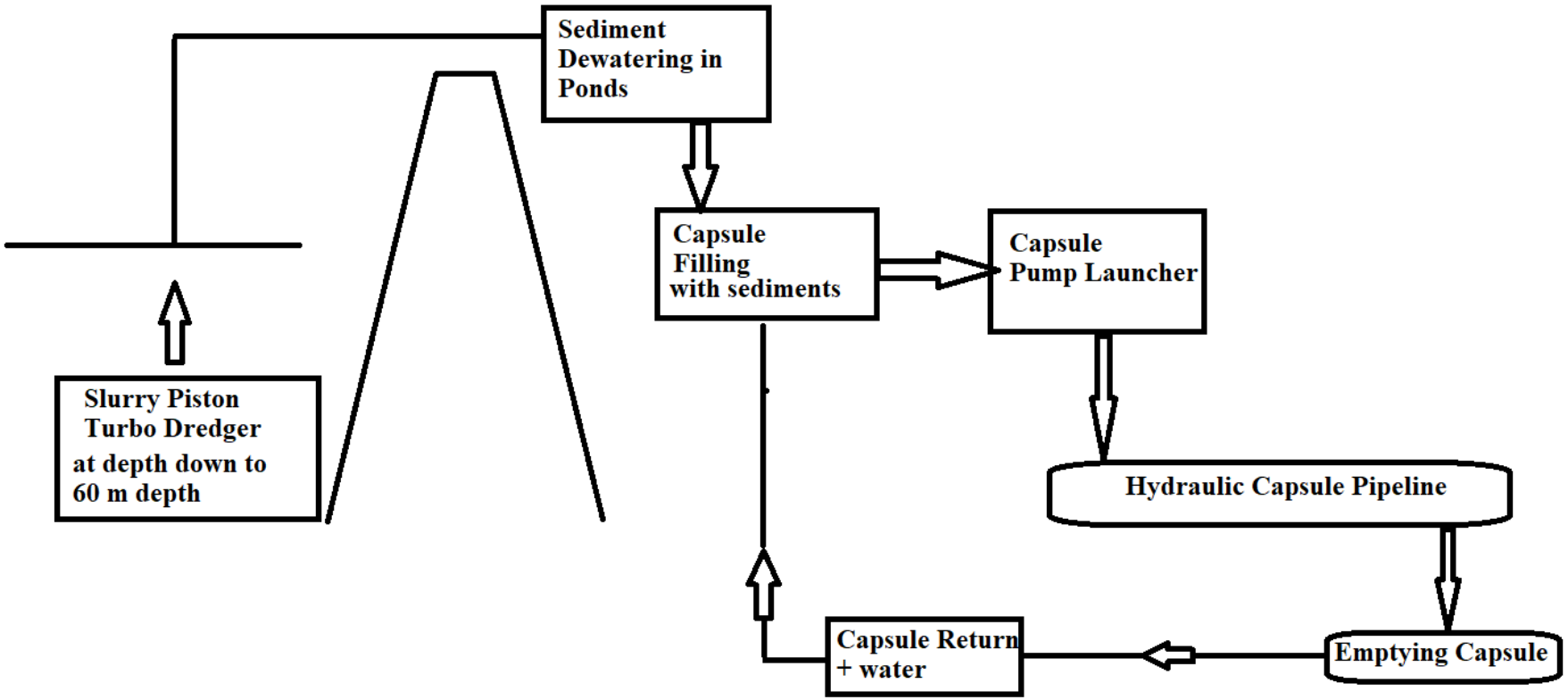
- Originally developed in the 1950's – 1990's to transport pressed coal logs in water pipelines as alternative to slurry pipeline
- Can be filled with capsules up to 80%
- We propose to adapt the technology to transport dredged sediments over long distance

Hydraulic capsule pipelines



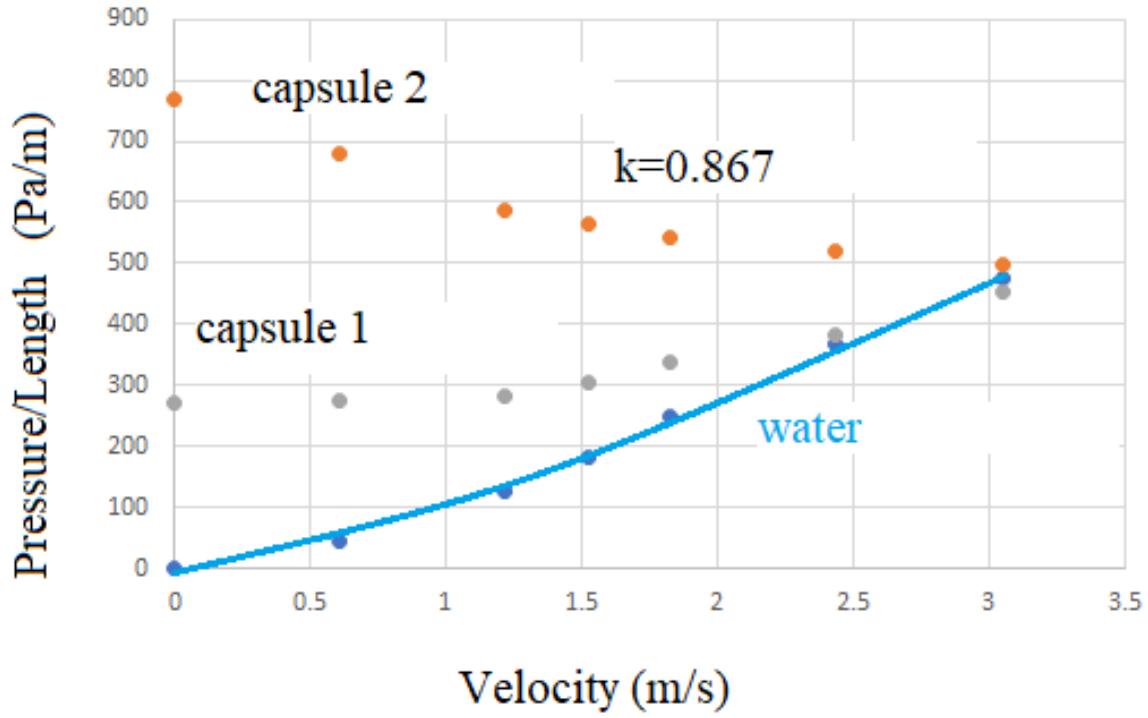
Capsule filled with dry sand

Proposed pipeline technology



Pressure losses

If the overall density of the filled capsule can be maintained below 1300 kg/m³, there is a velocity at which water and capsule pressure losses match

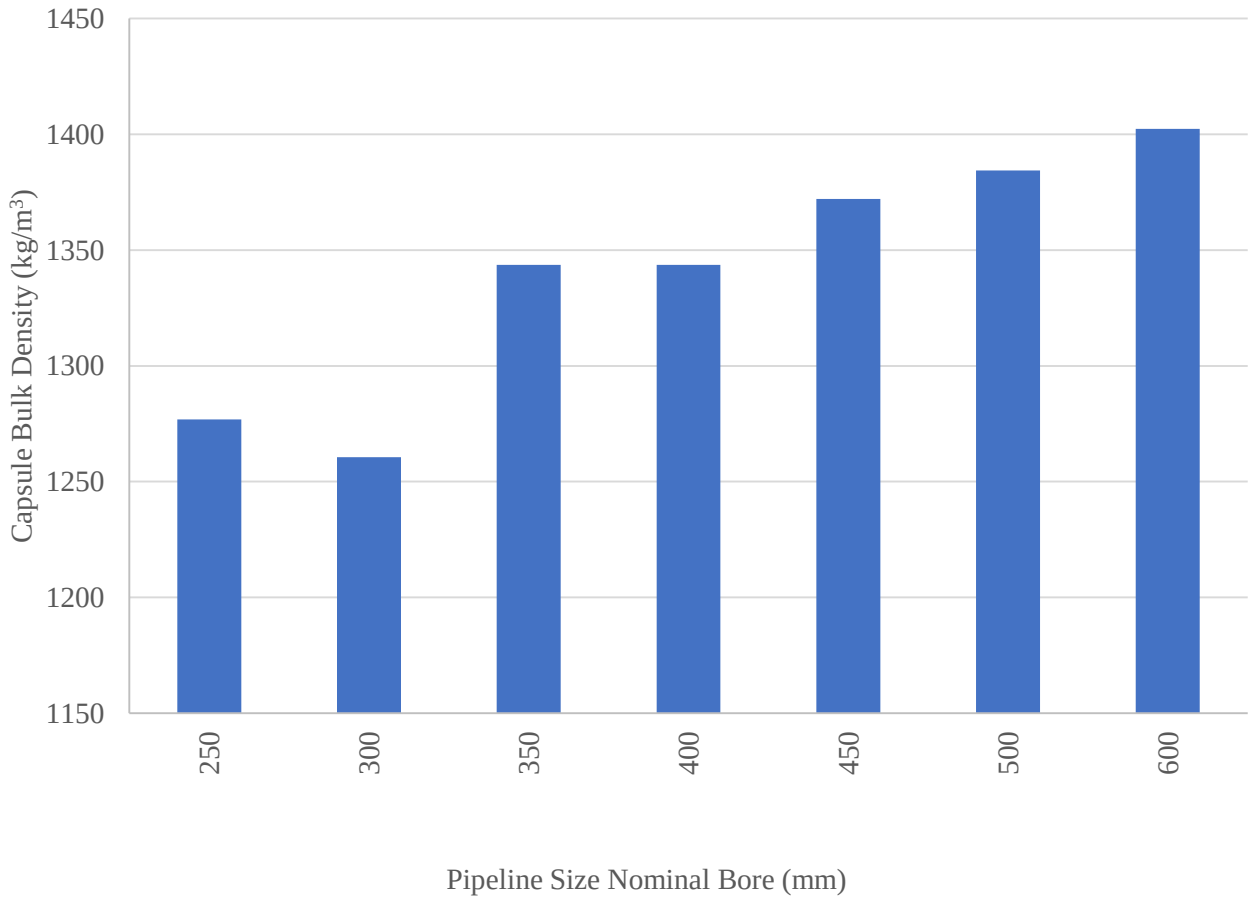


- Pressure losses per unit length for capsules with diameter ratio of 0.867. capsule 1 has a density of 1250 kg/m^3, while capsule 2 has a density of 1125 kg/m^3. They start with a high pressure at zero velocity but drop to a value equal to water at a value called the low-pressure velocity around 3 m/s – After Kruyer (1972) for tests in a 4” (100 mm NB) pipe with capsules 24.5 inch (622 mm) long

Pressure losses

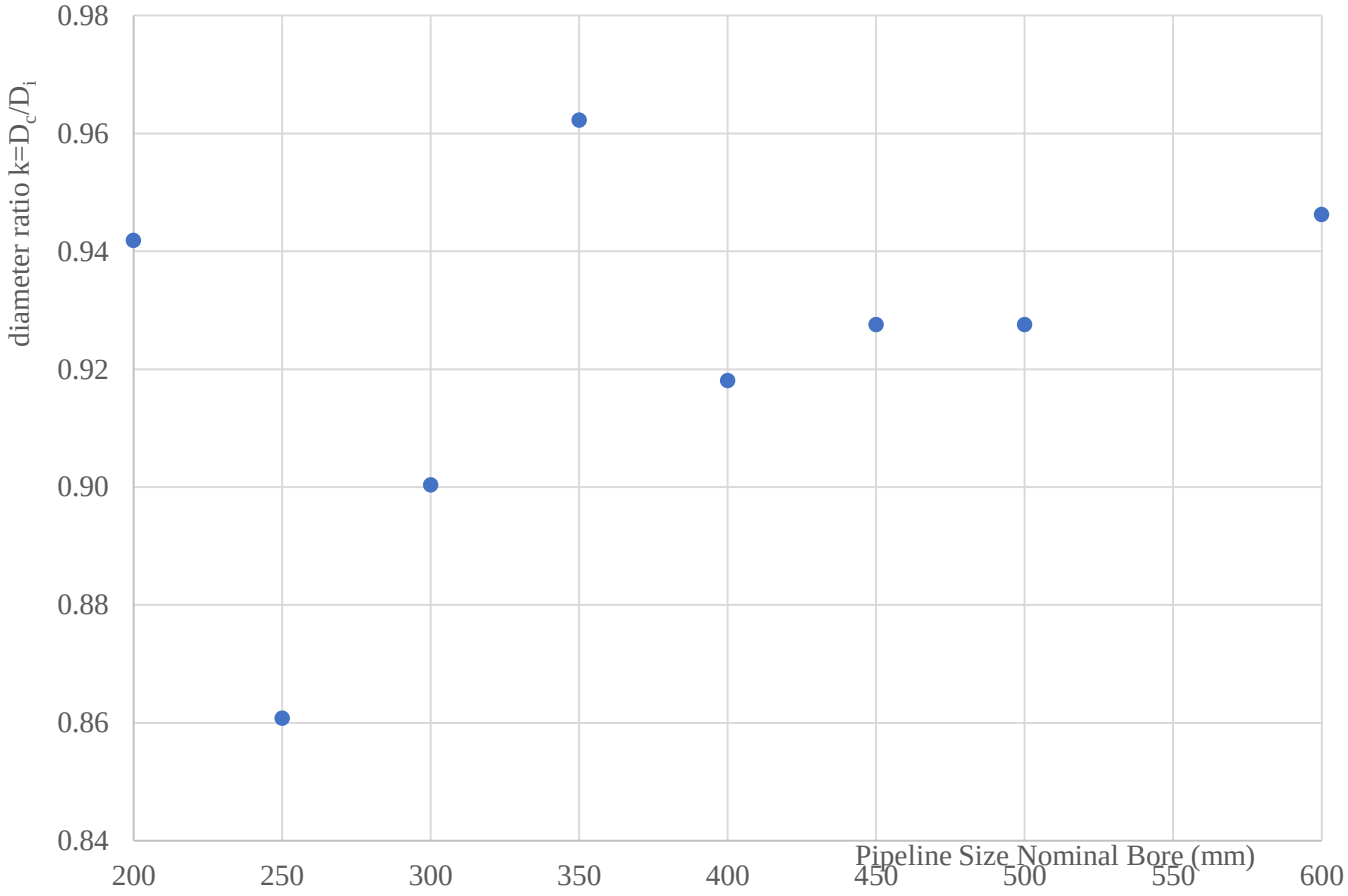
- To minimize pressure losses in capsule pipelines, we can conceive capsules made out of HDPE pipe, one size smaller than the steel pipeline in which they flow

Capsule Bulk Density



- Assumptions :
- Wet sand SG 2
- Capsules HDPE DR7, one size smaller than steel pipeline

Diameter Ratio k



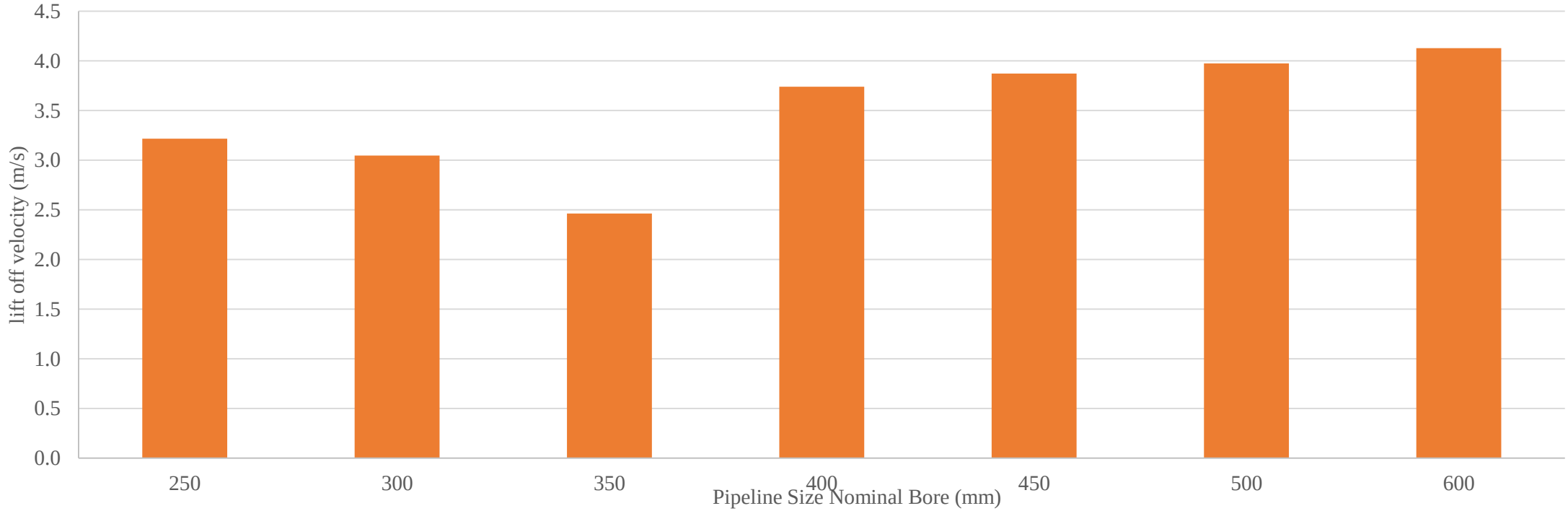
- The diameter ratio between capsule outer diameter and pipeline inner diameter is a critical parameter
- Capsules HDPE DR7, one size smaller than steel pipeline

Lift-off velocity calculations

- The capsule goes through different phases from being stationary in a pipe , to a state where lift and buoyancy forces add up to eliminate any contact with the walls. At which point the mechanical friction by sliding over the walls of the pipe are eliminated.
- This would correspond to lift-off velocity

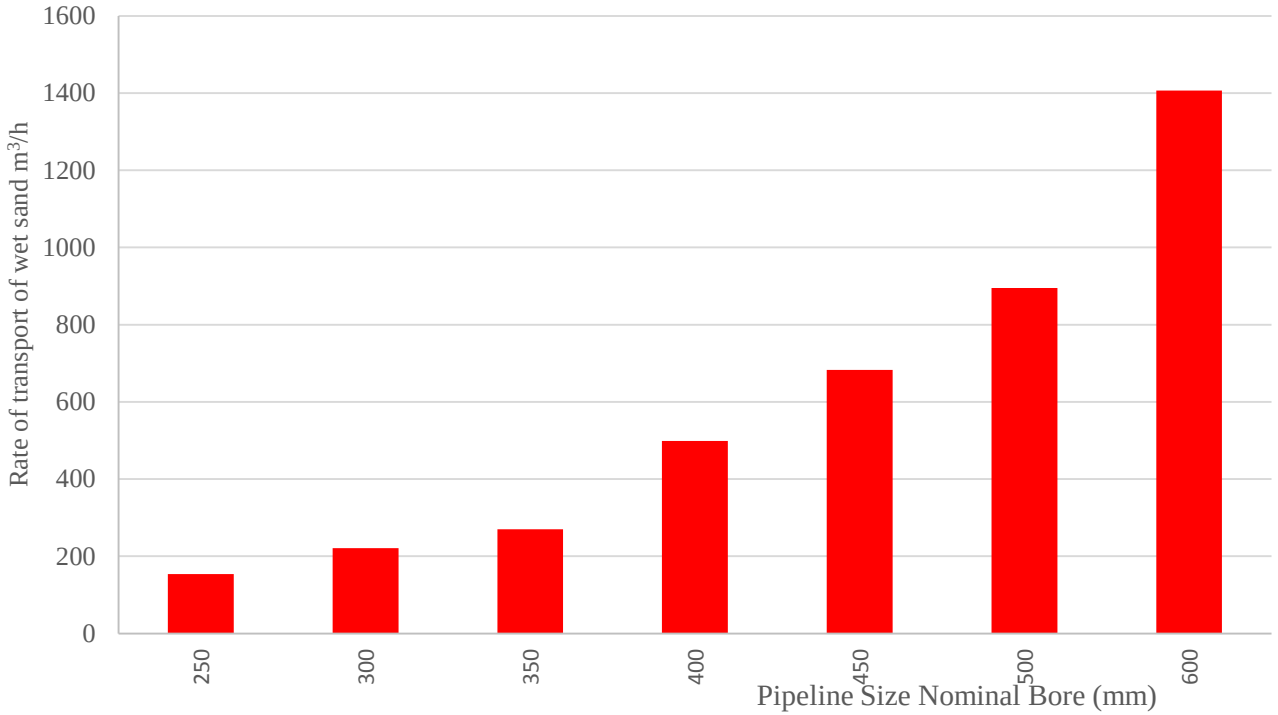
Lift-off velocity for capsules transporting wet sand with SG 2.0

At 90% lift-off velocity



Rate of transport of wet sand with SG 2.0 in HDPE capsules in steel pipes at 80% fill ratio

The pipeline may have its length occupied at 80% by capsules – When capsules move at lift-off velocity the following rates of sediments are transported in HDPE capsules



Commercial Cutter Suction Dredgers

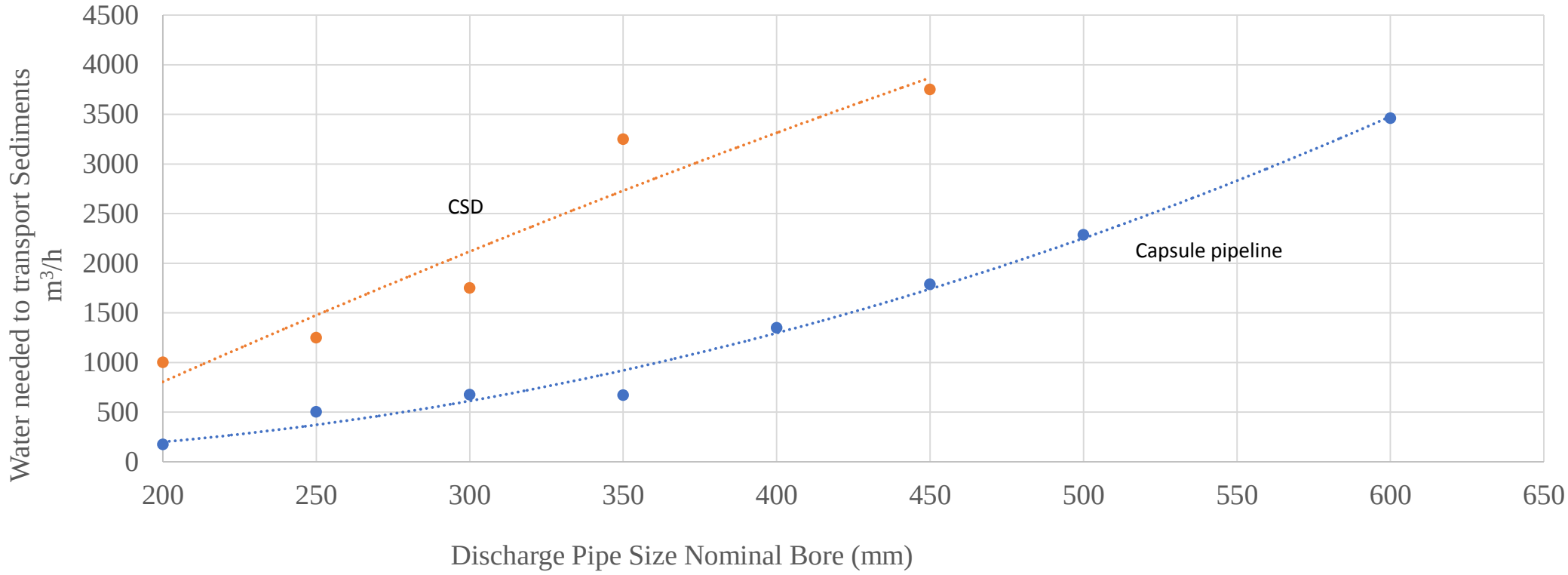
Commercial cutter dredgers move sediments at water to sediment ratio of 5 to 6

Pressure from pump is typically limited to 60 m head but performance decreases on coarse sand and gravel

source	https://www.dredginghoses.com				http://www.hiddredger.net/
model	CSD-8	CSD-10	CSD-12	CSD-14	CSD-18”
size	200 mm	250 mm	300mm	350 mm	450 mm
Water flow (m^3/h)	800 - 1200	1100-1300	1500 – 2000	3000-3500	3500 - 4000
Sediments (m^3/h)	150 -200	200-250	250 - 300	300 - 400	700 – 1000
Discharge distance (m)	800	1000	1200	1500	1500 - 2000
Suction pipe (mm)	250	300	350	400	450 mm
Discharge pipe (mm)	200	250	300	350	450 mm
Volume of water /volume of sediments	6 – 5.3	5.5 – 5.2	5 – 5.55	6.65 – 5.85	5 - 4
Maximum dredging depth (m)	10	12	12	13	13

The capsule pipeline water requirements

The capsule pipeline uses 40% less water than the CSD to transport sediments



Pressure Losses

When the conditions of Kruyer & Ellis are satisfied with capsule SG <1.3, they developed equations of pressure loss based on conditions in the annulus between capsule and pipeline

- For turbulent conditions in the annulus
- $\frac{dP}{dx} = 0.14\rho_w{}^{0.75}\mu^{0.25}\left[\frac{V_{bw}-kV_c}{1-k^2}\right]^{1.75}\left(\frac{1}{D_i-D_c}\right)^{1.25}$

- V_{bw} = bulk velocity of water
- D_i = pipeline inner diameter
- k = ratio of D_c/Di
- μ = viscosity of water (Pa.s)

V_c = capsule velocity

Dc = capsule diameter

ρ_w = density of water (kg/m^3)

CAPSULE PIPELINES FOR RESERVOIR DE-SILTING AND MINING APPLICATIONS

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The invention is subject to patent application 17/649,556 with USPTO

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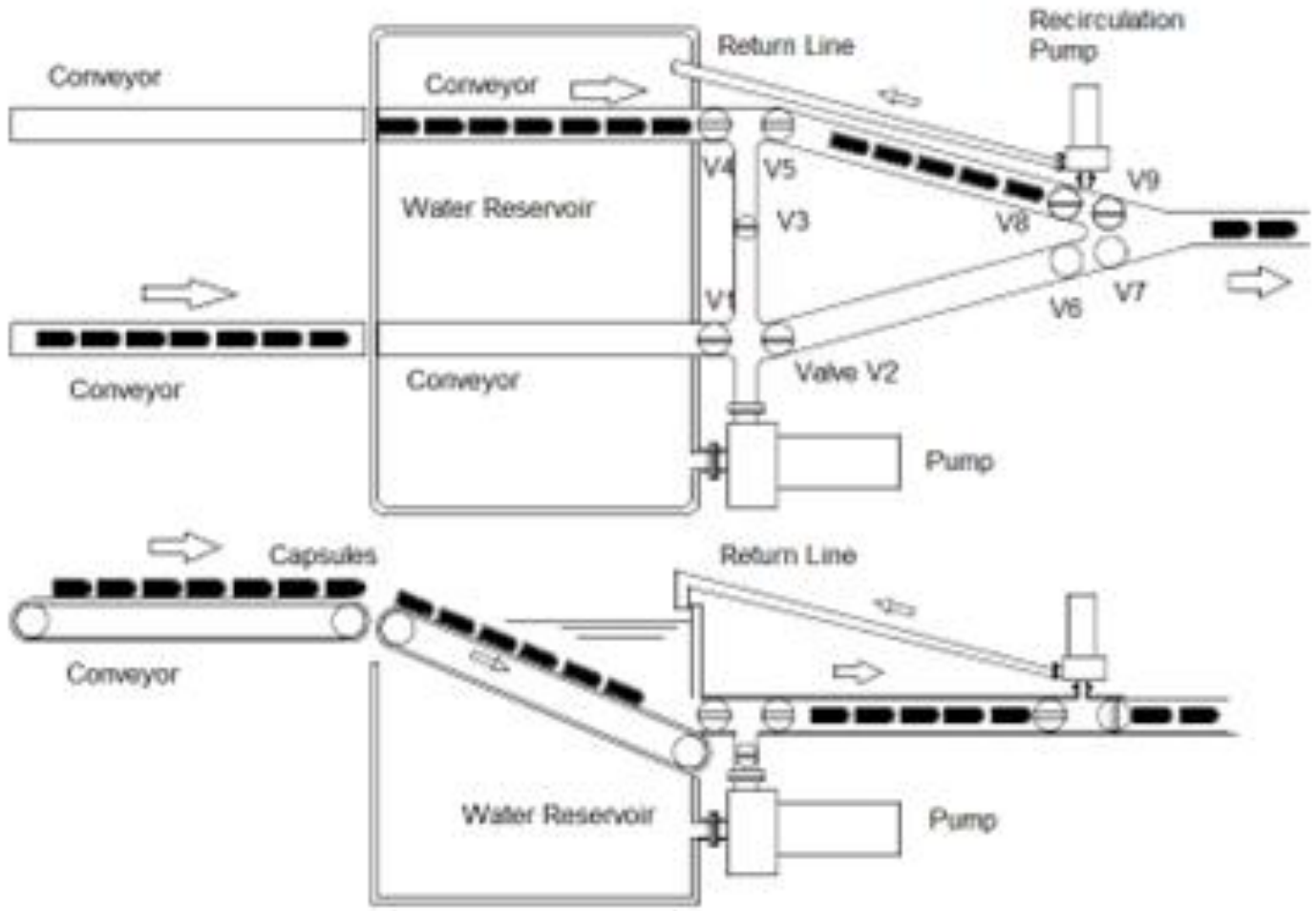
Conventional Capsule Launching technology



New hydrojet capsule launching technology

Water discharged at end of pipeline is clean and can be returned to reservoir or re-used to return empty capsules and new capsules – This reduces most of the water needed for transport in conventional slurry pipelines

Conclusion

- Using HDPE pipe material (DR 7) for capsules for steel pipeline size up to 24” or 600 NB, we obtain capsule bulk density of 1250 to 1400 kg/m^3 when transporting wet sand at specific gravity of 2.0
- The Criterion of low-pressure loss at lift-off velocity becomes possible to satisfy.
- At the fill ratio of 80% it is possible to match current commercial Cutter Suction Dredging systems.
- The corresponding volume flow rate of water to transport sediments is reduced by 40% .
- The water consumption can be practically reduced to nil when the water is recycled with empty capsules in a separate return pipeline.

Conclusion

- There are currently no commercial incentives for dredging contractors to save on water during transport of sediments and they are paid by the cubic yard delivered. Owners of reservoirs, federal and state regulators are encouraged to offer incentives to contractors to reduce water consumption and return the water after dredging to the reservoir. This is possible by using the hydraulic capsule pipeline technology.
- The hydrojet capsule pipeline concept offers a new opportunity to feed capsules directly into the pipeline from conveyors. It is simpler than previous lock and pump systems developed in the 1970’s.

Acknowledgement

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