# A Liquid Piston Engine for Deep Dredging

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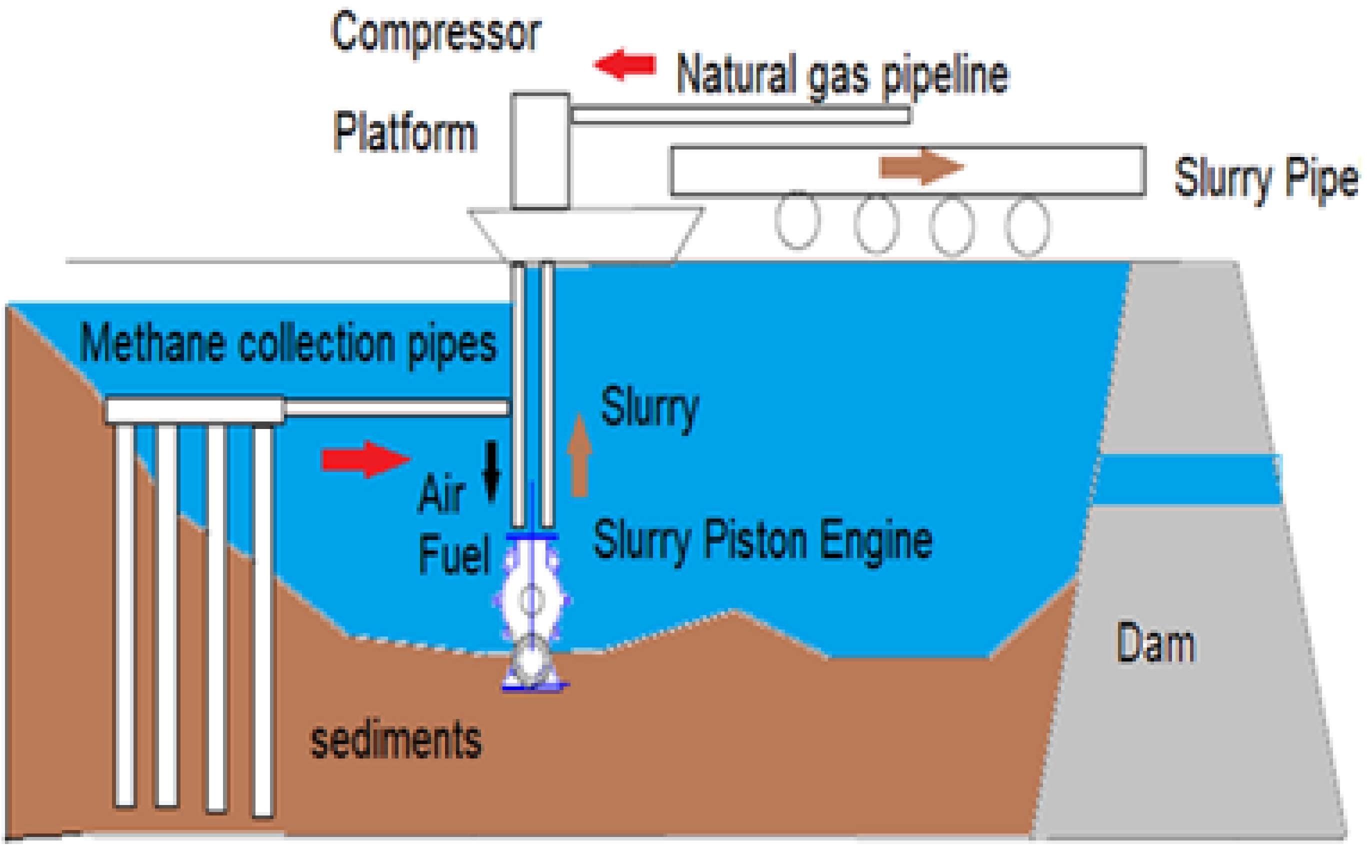
## DEEP DREDGING CHALLENGE

- For depth of 50 ft to 200 ft there are very few solutions for removing sediments
- Flushing is done at a concentration of <30 g/L and involves very large quantities of water

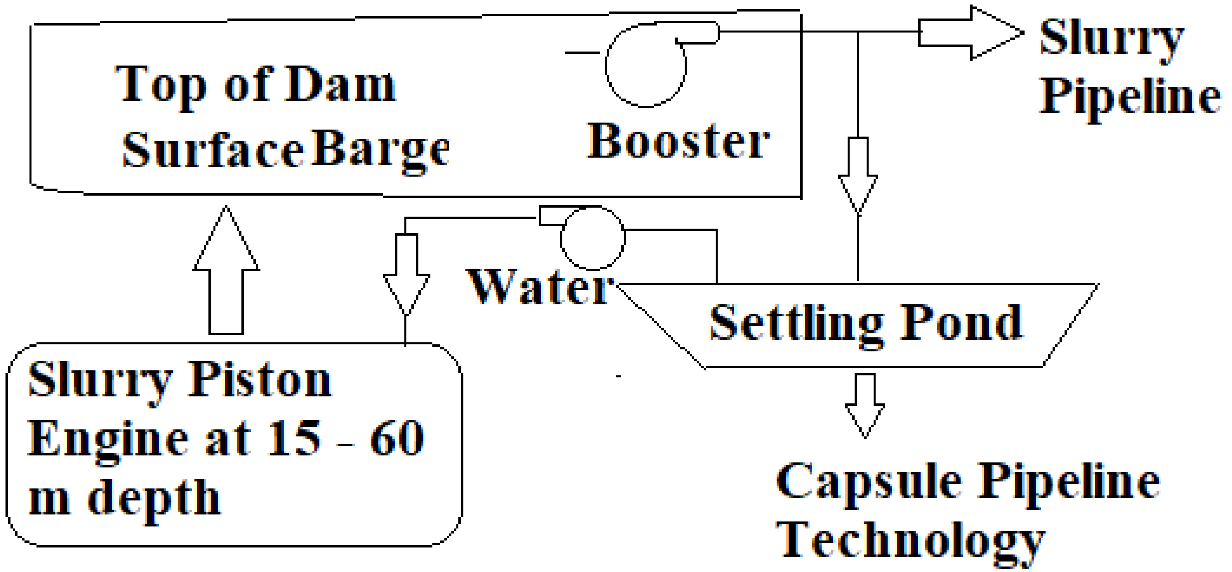
# National Inventory of Dams (army.mil)

- 92,029 Dams
- 61 years – average year
- 75% High Hazard Potential Dams
- 3% Dams with Hydropower
- 6% Federally Regulated Dams
- 70% State regulated Dams

# A slurry piston engine can operate on natural gas or methane collected from reservoirs



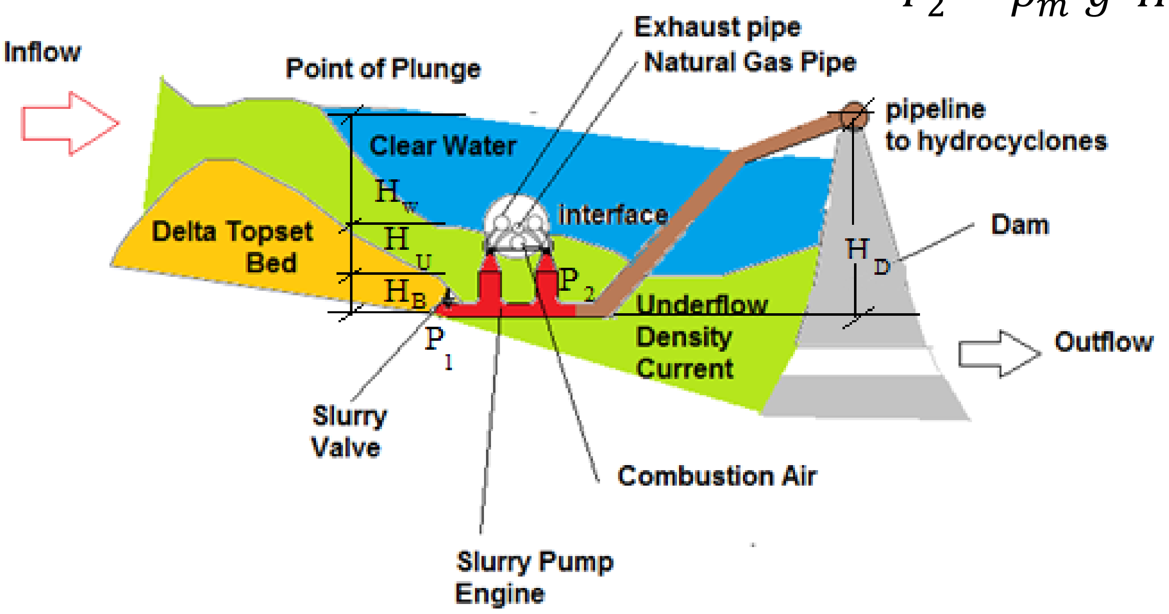
# A slurry piston engine can operate on natural gas or methane collected from reservoirs



# The engine pumps at the differential pressure between conditions on suction and discharge

$$P_1 = \rho_B g H_B + \rho_U g H_U + \rho_W g H_w + P_{atm}$$

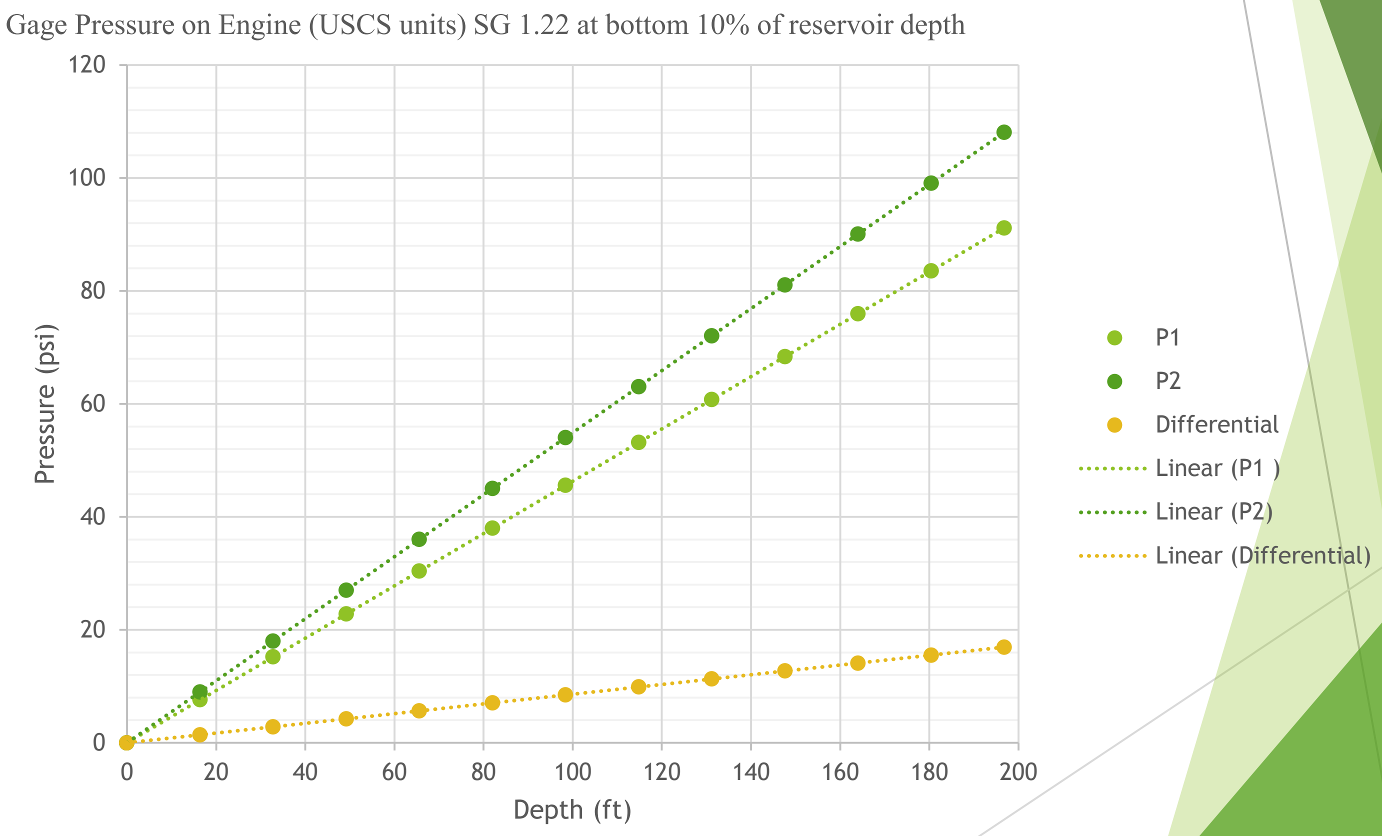
$$P_2 = \rho_m \, g \, H_D + \sum P_f + P_{atm}$$



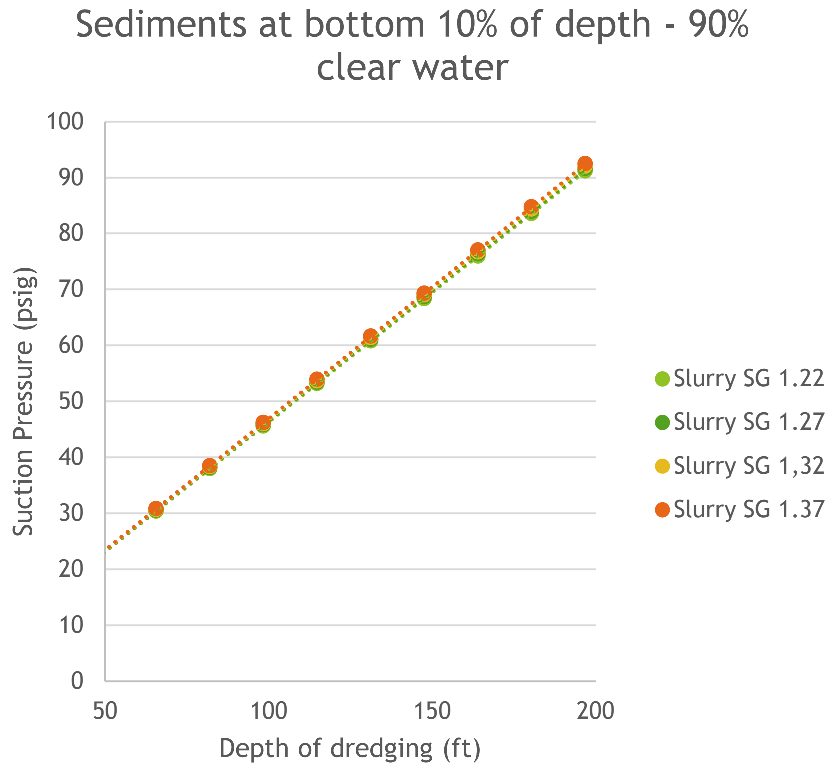
# Consider slurry at SG 1.22 (Weight concentration 28%) at 10% of depth with relatively clear water at 90% of depth

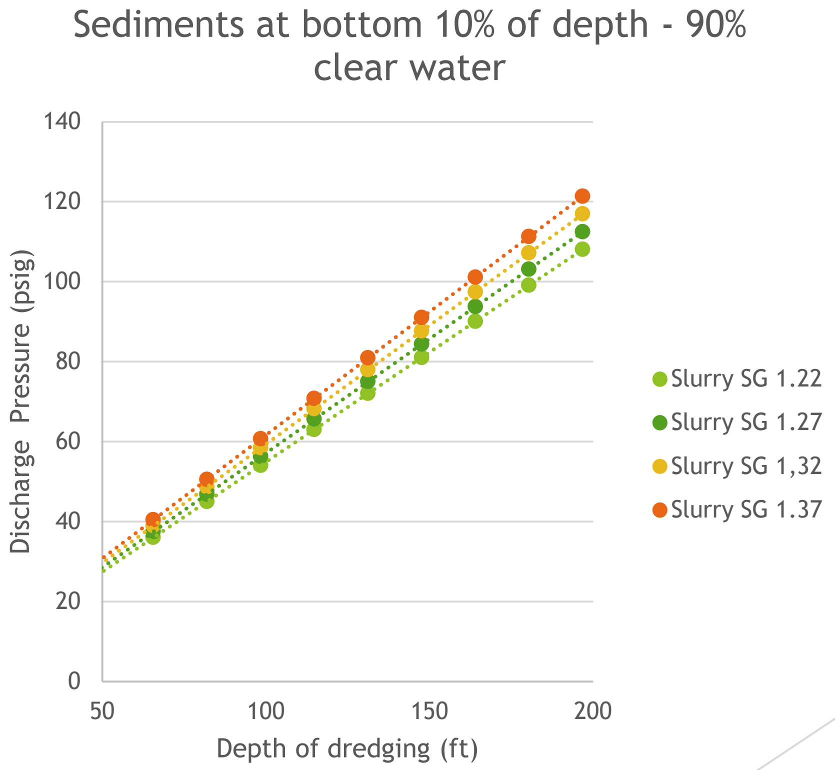
- At 200 ft depth
- Available pressure on suction 91 psig
- Needed pressure on discharge 108 psig
- Differential 17 psig

- Equivalent to removing sediments at 395 g/L



# Pressures


Sediments at bottom 10% of depth - 90% clear water
Suction Pressure (psig)
100
90
80
70
60
50
40
30
20
10
0
50
100
150
200
Depth of dredging (ft)
Slurry SG 1.22
Slurry SG 1.27
Slurry SG 1,32
Slurry SG 1.37

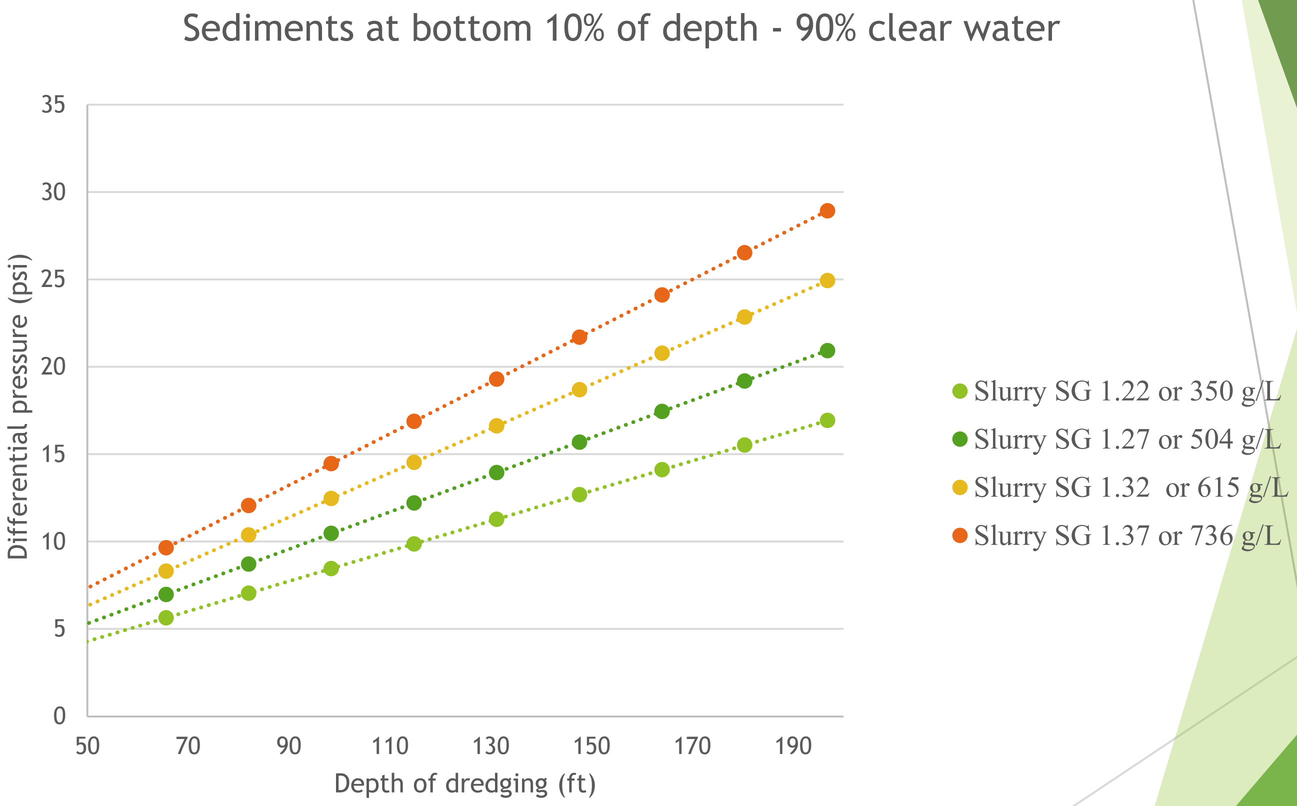

Sediments at bottom 10% of depth - 90% clear water
Discharge Pressure (psig)
140
120
100
80
60
40
20
0
50
100
150
200
Depth of dredging (ft)
Slurry SG 1.22
Slurry SG 1.27
Slurry SG 1,32
Slurry SG 1.37

# Extending the analysis to slurry SG 1.22 to 1.37

## Required differential pressure 17 to 29 psi

- SG 1.22; $C_W$=28%; 350 g/L; ΔP=17 psi at 200 ft depth
- SG 1.27, $C_W$=33.5%; 504 g/L; ΔP=21 psi at 200 ft depth
- SG 1.32; $C_W$=38.1%;615 g/L; ΔP=25 psi at 200 ft depth
- SG 1.37; $C_W$= 42.5%; 736 g/L; ΔP=29 psi at 200 ft depth

- ***Current purging practice 30 g/L***



# Goals of lab tests

1- Develop differential pressure of 17 to 29 psi
to simulate pumping a mixture of sand and water
At a depth of 200 ft
from specific gravity of 1.22 to 1.37 (Weight concentration from 28% to 42.5%)

# Goals of lab tests

2-To increase removal of sediments from current purging at 30 g/L to 350 - 736 g/L by deep dredging

# Goals of lab tests

3-Build the first ever slurry engine in the world using modern electronics

4- Demonstrate its safe use in lab conditions (no injuries)

# Goals of lab tests

5- Test the concept of cutting jet instead of cutter to simplify operation and reduce wear at 200 ft depth

# Lab tests

- A prototype was built
- 8” bore
- Operates on propane
- 150 mm (6”) swing check valve
- Recirculating jet
- Testing on water and slurry

# Lab tests

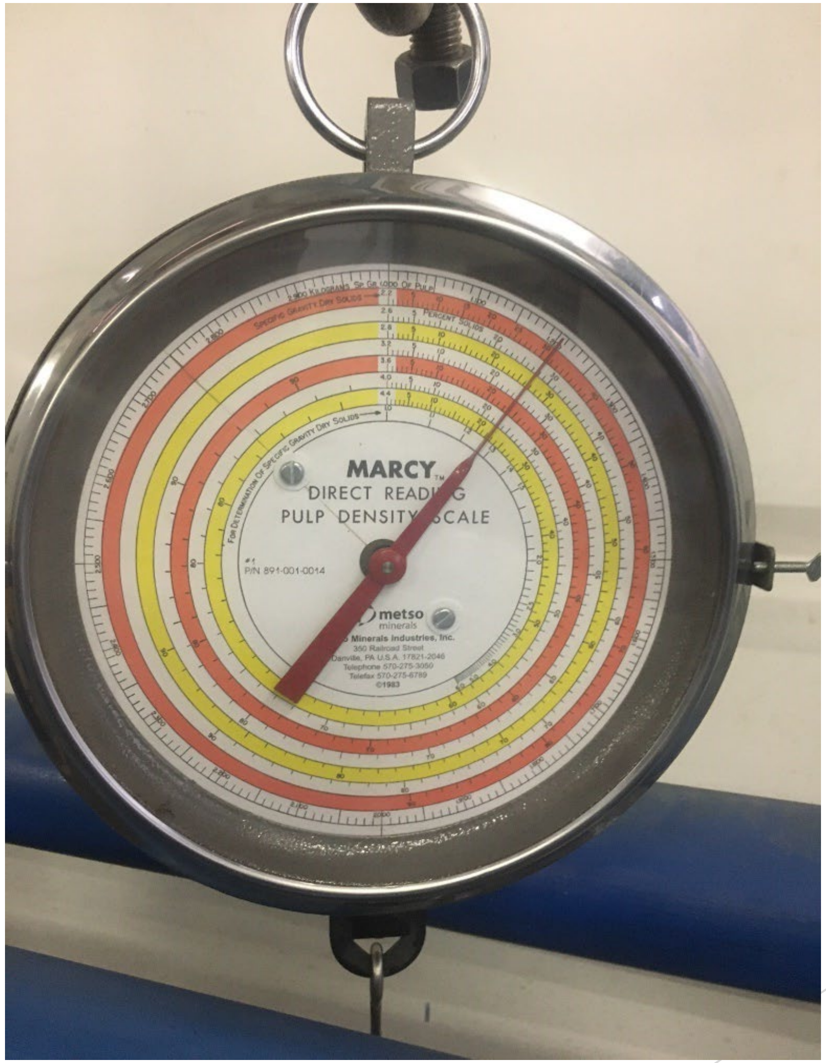
- Rectangular conical bottom tank 4.5 m high
- Coarse sand based slurry added in increments of 30 lbs up to 360 lbs
- Conical shape of tank concentrates sand to the bottom

# Lab tests

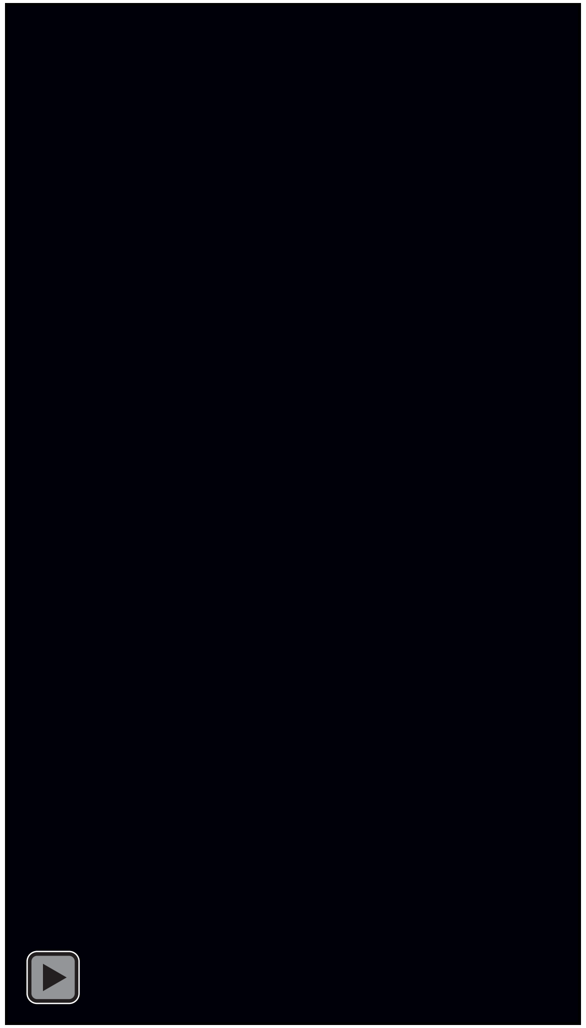
- Tests using propane for fuel
- Differential pressure controlled by globe valve
- Recirculating jet used to simulate picking up relatively fresh sediments

# Test procedures

- A number of tests were conducted
- Sand was added in increments of 30 lbs in 300 gallons of water up to 360 lbs
- Valves of engines consist of solenoid valves controlled by a microprocessor
- Weight concentration was measured using a Macy scale during tests (e.g $C_W$ 28% (right))

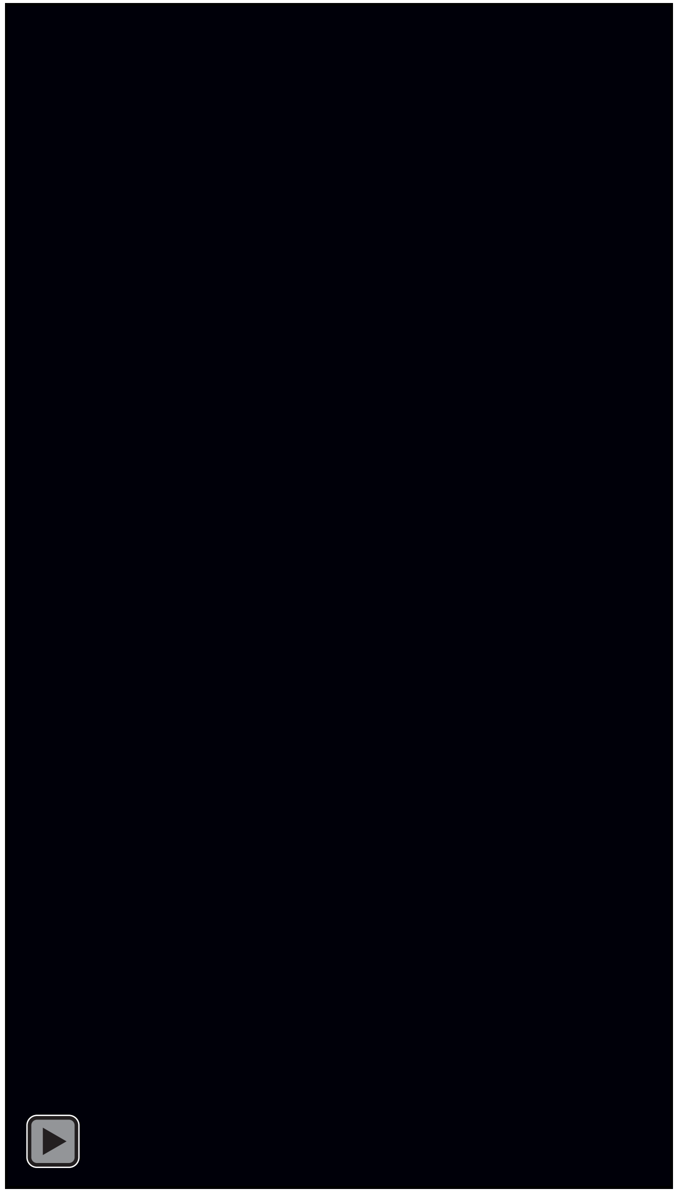


# Ignition at 10 seconds intervals
# Air applied at 15 psi and propane at 17 psi



# During exhaust pressure in combustion chamber drops to 2 psig but rises to 40 psig at detonation.

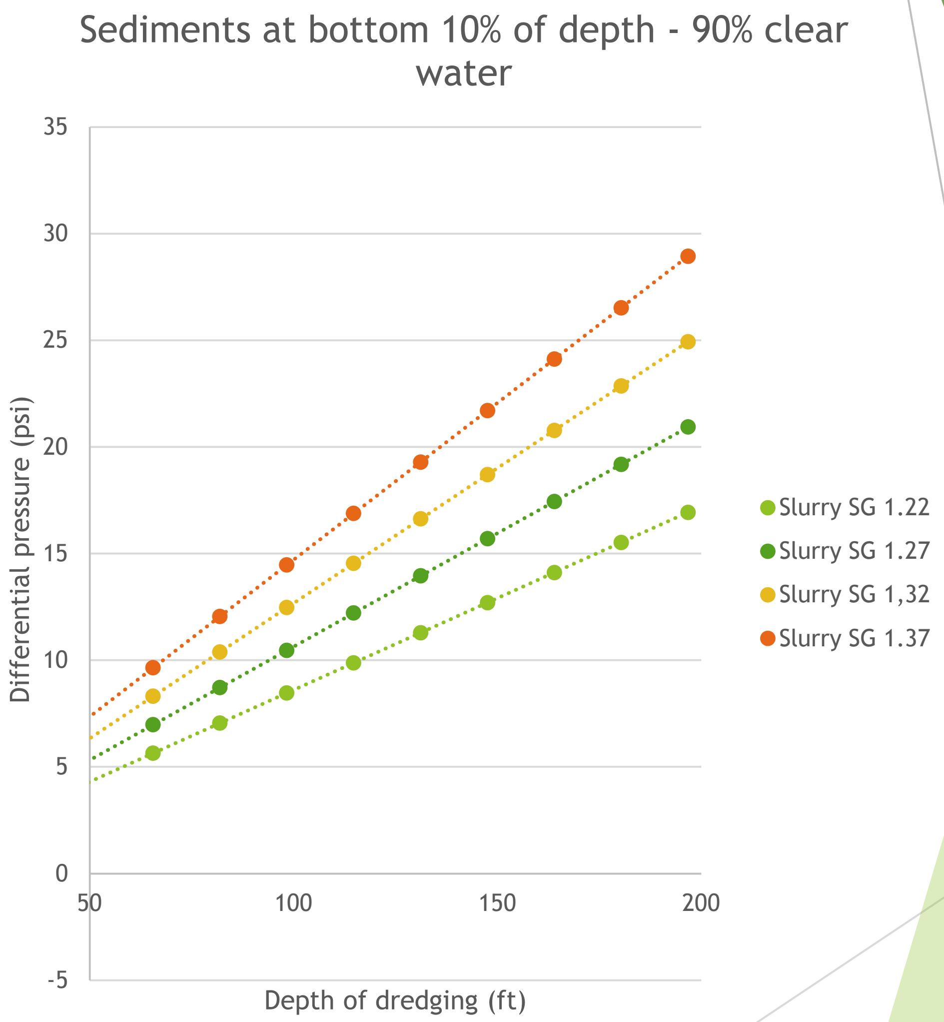
Pressure of slurry initially at 4 psi but rises following ignition to 20 -30 psig



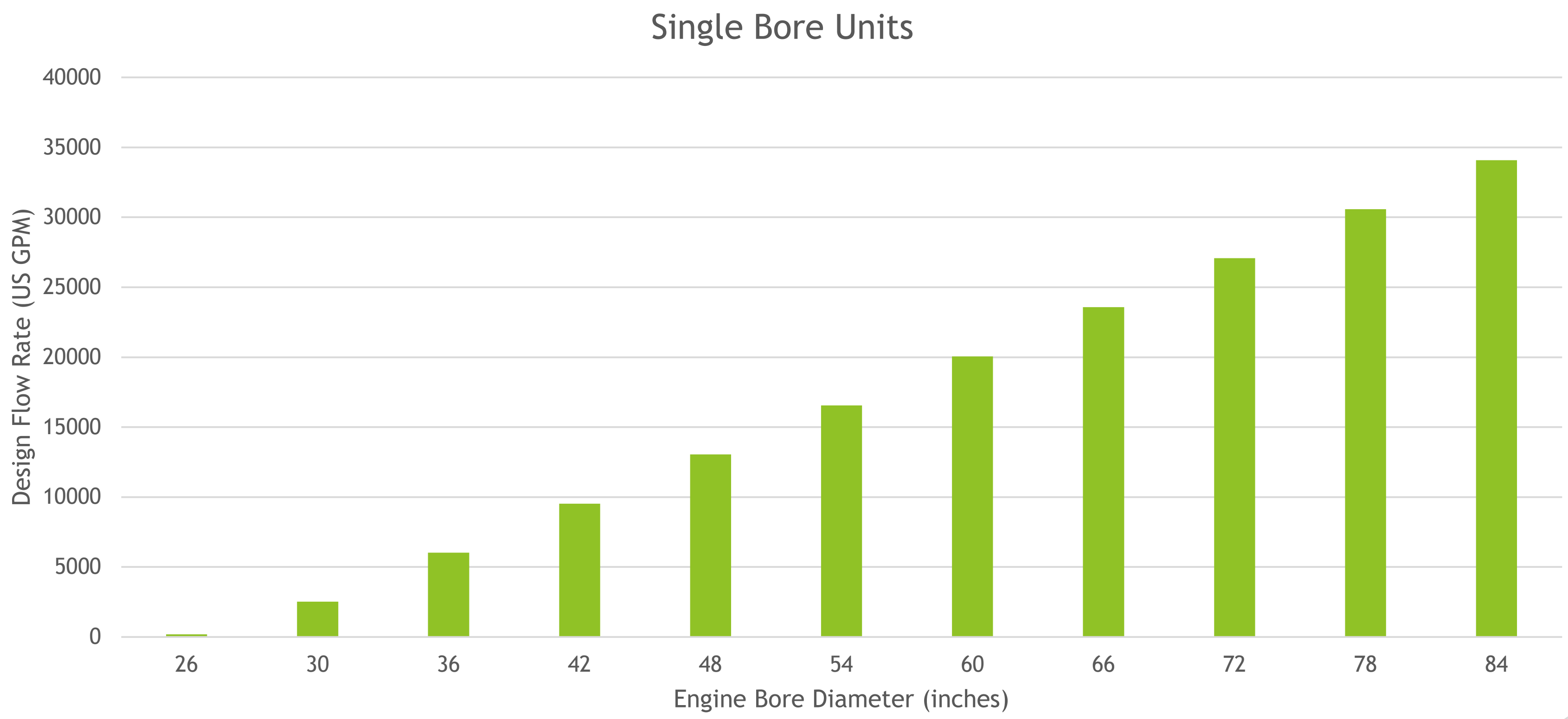
# Discharge of slurry at top of tank

# Results of lab tests

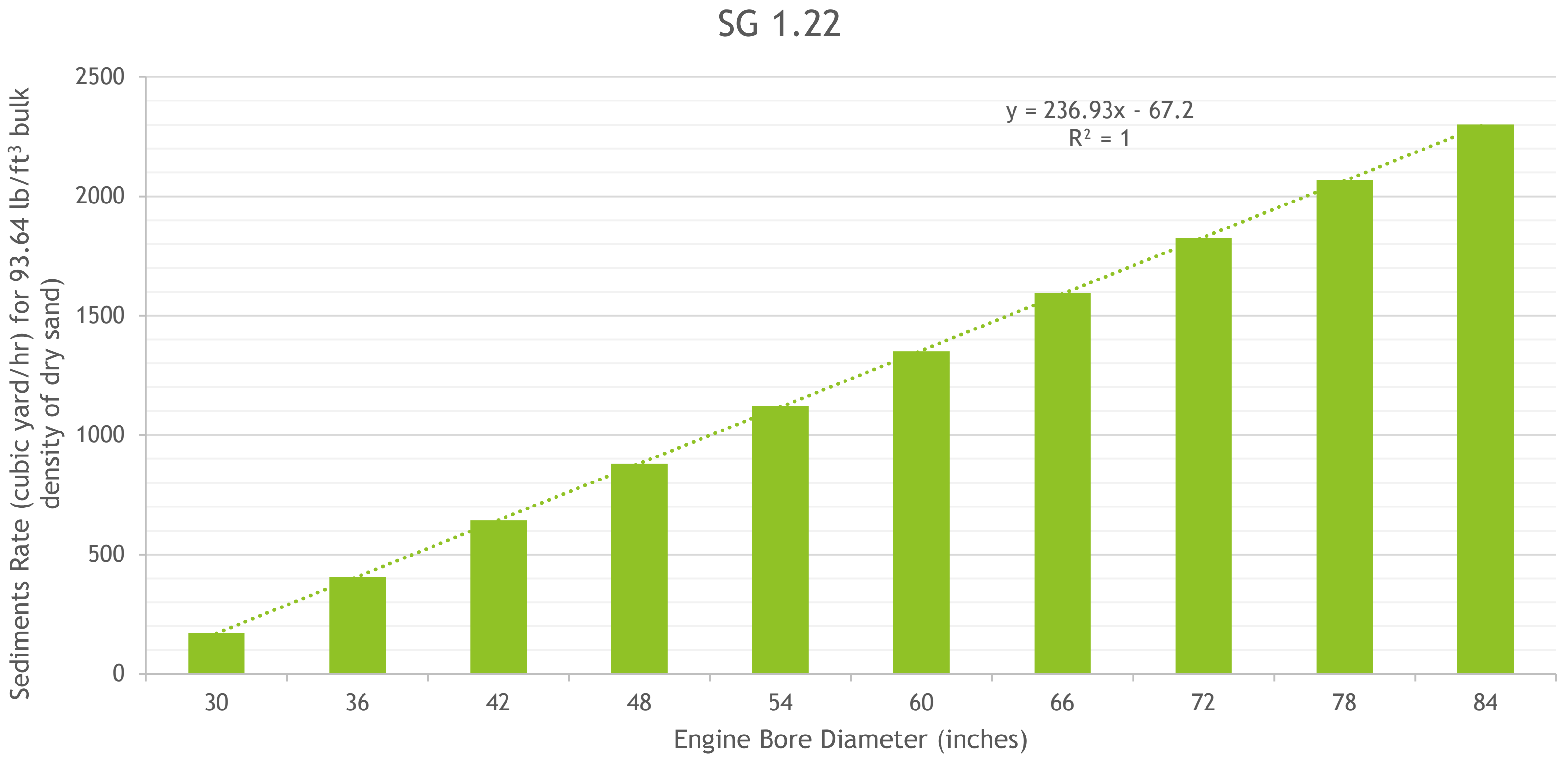
- We were able to create differential pressure of 16 - 25 psig in our lab corresponding to dredging at 200 ft as SG 1.22 to 1.32
- We can increase the removal of sediments from 30 g/L associated with flushing to 400g/L to 600 g/L using  the Slurry Pulsejet Engine
- We demonstrated successful use of a gaseous fuel against a slurry of coarse sand,



# Proposed sizes for commercial applications



# Sediments rate in cubic yards/hr for dry sand at bulk density of 94 lbm/ft$^3$ (1500 kg/m$^3$)



# Paonia reservoir, Gunnison County, Colorado

- Was at a depth of 6250 ft ASL in 1962
- *average annual rate of sedimentation has been 161,000 cubic yards per year ".*
- The liquid level is at 6450 ft ASL,
- Maximum dredging would be 50 to 160 ft.
- this could be handled by a 30" single bore slurry piston engine operating over 4 months

# The Cochiti reservoir, New Mexico

- Has accumulated 54 million cubic yards at depth as deep as 219 ft.
- This reservoir has sand and gravel in the delta and fine silt near the outlet
- This could be handled by a single bore 48” slurry piston engine or a couple smaller 36” bore engine operating 3 to 4 months a year.

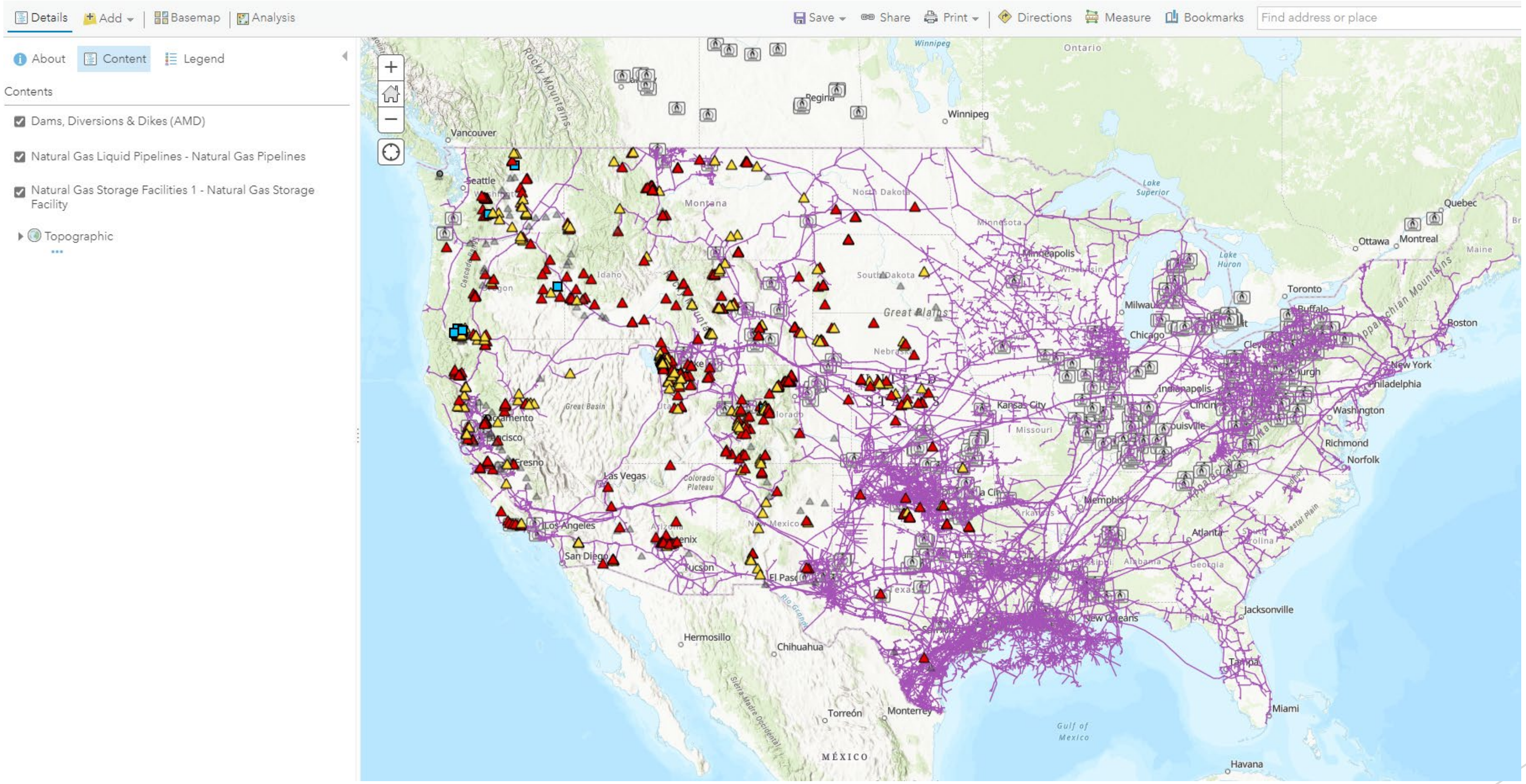
# Tuttle Creek reservoir – Missouri River

- No hydropower at facility
- Used to have 30 miles of open water but down to 14 miles now
- Considered to be #1 in need of repair amongst 400 dams in danger across the nation
- 4 million cubic yard a year
- Two 78 inch bore engines operating each 1000 hours /year or four 54 inch bore engines

# Black Canyon Dam

- *The report (Ubing, 2019) describes the ability to flush sediments from the reservoir is limited due to concern for the downstream environment. The downstream environment will likely be impaired if large amounts of sediment are flushed from the dam because flushing events are restricted to the low flow season, when the downstream environment is least resilient to large sediment loads*
- If we assume a peak influx of 3g/L as in some other rivers, this would be 603kg/s of sediments at  flows of 7085 cfs (2167 T/h).
- This would require a single bore engine of 1.8 m (72”), or  four smaller 48” bore engine at different locations. These smaller units will operate 3 to 4 months a year

# There is a large network of natural gas pipelines near large reservoirs



# Methane Emissions from Reservoirs

- Lakes and water reservoirs contribute to 20% world emissions of methane .
- Methane is produced in lakes and reservoirs from degradation of organic matter entrapped in sediments.
- Methanogenesis is the process of producing methane by microbes known as methanogens.
- Published data (Bartosiewicz et al (2021)) on emissions estimated that the annual production of methane in reservoirs, lakes, wetlands and other freshwaters was around 469 and 865 Tg/year. (1 Tg = 1 million metric tonne).

# Acknowledgements

- We wish to thank the USACE and USBR (Guardians of Reservoirs) for their financial support during the development of the submersible internal combustion dredging system

- For more information
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- www.Mazdak.international