GEOENGINEERS

September 22, 2004

City of Spokane Public Facilities District
720 West Mallon
Spokane, Washington 99202

Attention: Matt Walker

Subject: Potential Sediment Transport
Convention Center Expansion Project
Spokane Washington
File No. 0110-047-07

The purpose of this letter is to summarize our analysis regarding the potential for significant sedimentation within the City of Spokane sewer system downgradient from a system of settling tanks located at the Convention Center Expansion Project in Spokane, Washington. The settling tanks temporarily store groundwater discharged from project construction dewatering operations and consist of two 18,100-Gallon Worksafe Weir Tanks plumbed in series. A summary of tank specifications is attached to this memorandum. Given that the City of Spokane sewer system will be used for system overflow, we anticipate that instantaneous discharge to the system should not exceed 150 gallons per minute (gpm).

The first step in our analysis was to calculate flow velocity through the system of settling tanks. We assumed the following:

- Steady state conditions (that is, full tanks and flow into the tanks equals flow out of the tanks);
- A discharge rate of 150 gpm, or about 0.33 cubic feet per second (cfs); and
- Cross-sectional area of the tanks perpendicular to flow was assumed to be 64 square feet (ft^2), based on the tank specifications and 1-foot of accumulated sediment in the tank bottoms.

Based on these inputs, we calculated an average flow velocity through the tanks of about 0.16 centimeters per second (cm/s). Per attached Figure 6.7 from Ritter (1986), a flow velocity of 0.16 cm/s results in deposition of sediment particles greater than about 0.02 millimeters (mm) in size. This is within the size range of silt, which runs from about 0.004 to 0.062 mm.

The second step in our analysis was to calculate the residence time through a system of two settling tanks plumbed in series. Assuming a tank length of 40 feet and an average horizontal flow velocity of 0.16 cm/s, we calculated an average residence time of 254 minutes.

Finally, we estimated the amount of time it would take for a fine sand-sized particle of sediment with a nominal diameter of 0.08 mm to settle to the bottom of the tanks. We conservatively assumed a particle shape factor of 0.5 and a temperature of 10 degrees Celsius. Per these assumptions and attached Figure 12.1.2 from Maidment (1993), the resulting particle fall velocity would be about 0.25 cm/s. Given 9 feet of tank height, we estimated fall duration at about 18.3 minutes. Therefore, we estimate that, for the fine sand-sized particle described above, particle residence time would exceed particle fall duration by over an order of magnitude.

Given the results of our analysis and the assumptions listed above, we conclude that discharge from a system of settling tanks located at the Convention Center Expansion Project would not result in significant sedimentation within the City of Spokane sewer system. We estimate that sediment particles greater than about 0.02 mm in size should be retained within the settling tanks. Based on the composition of soil at the site, we do not anticipate high silt content in discharge water. Silt-sized particles that enter the City of Spokane sewer system are not likely to settle out up-gradient of the City's wastewater treatment plant, assuming that flow velocities in the city's pipes are greater than that in the Convention Center Expansion Project settling tanks.

Please contact us if you have any questions regarding the content of this memorandum or require additional information.

REFERENCES

Ritter, D.F., 1986, Process Geomorphology, 2nd Ed.: Dubuque, Iowa, Wm. C. Brown Publishers, 579 p.

Maidment, D.R., 1993, Handbook of Hydrology: New York, McGraw Hill, various pages.

Sincerely,

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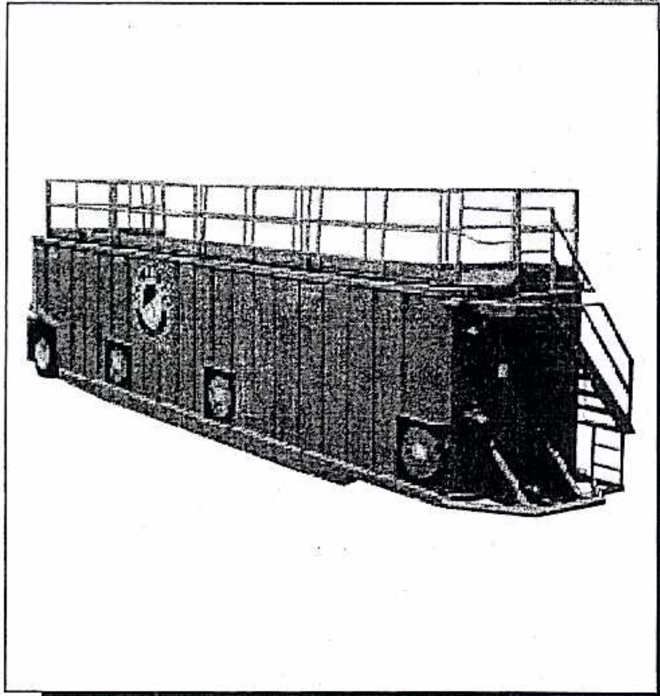
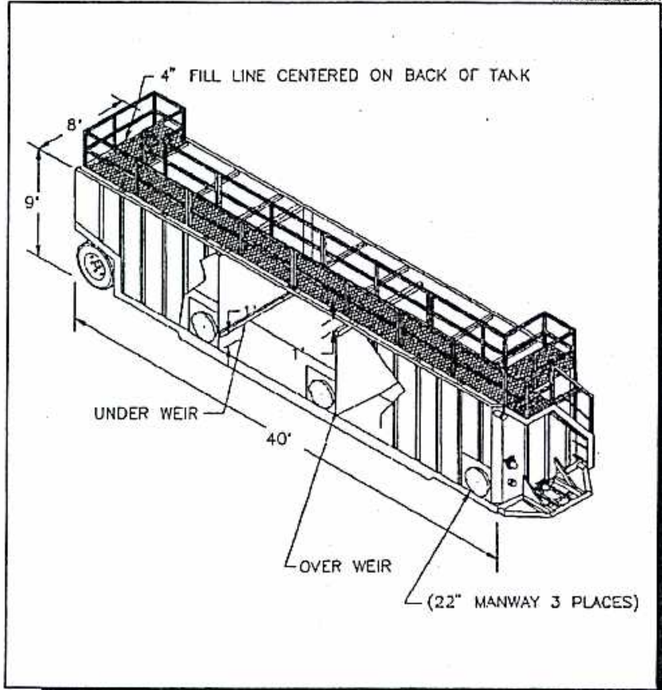
cc: Bill Peacock, PE, City of Spokane

STEEL TANKS



18,100 Gallon Weir Tank



Tank Dimensions

18,100 GALLON WORKSAFE™

WEIR TANK

FEATURES

- Over and under Weirs
- Safety stairway
- Complete guard rail system
- "V" shaped floor with 4" valves at each end for quick cleaning
- Easy to move and transport

TECHNICAL

WorkSafe™ Weir tanks come with a "V" shaped floor, allowing any residual fluid in the tank to easily flush out through the floor level 4" valves. Staircase, guard rails, and four 22" manway hatches are standard equipment. This allows easy monitoring of the fluids and easy cleaning when finished.

MATERIAL SPECIFICATIONS

Steel construction with cross style internal bracing. Two 4" Butterfly valves located at either end of the "V" shaped floor. Permanently attached axles for maximum maneuverability. Staircase attached to front end and a guard rail system on the tank walkway. Three 22" manway hatches. Each tank comes equipped with over and under weirs for simple seperation of liquids. These tanks are open top with a walkway and complete guard rail running the length of the tank.

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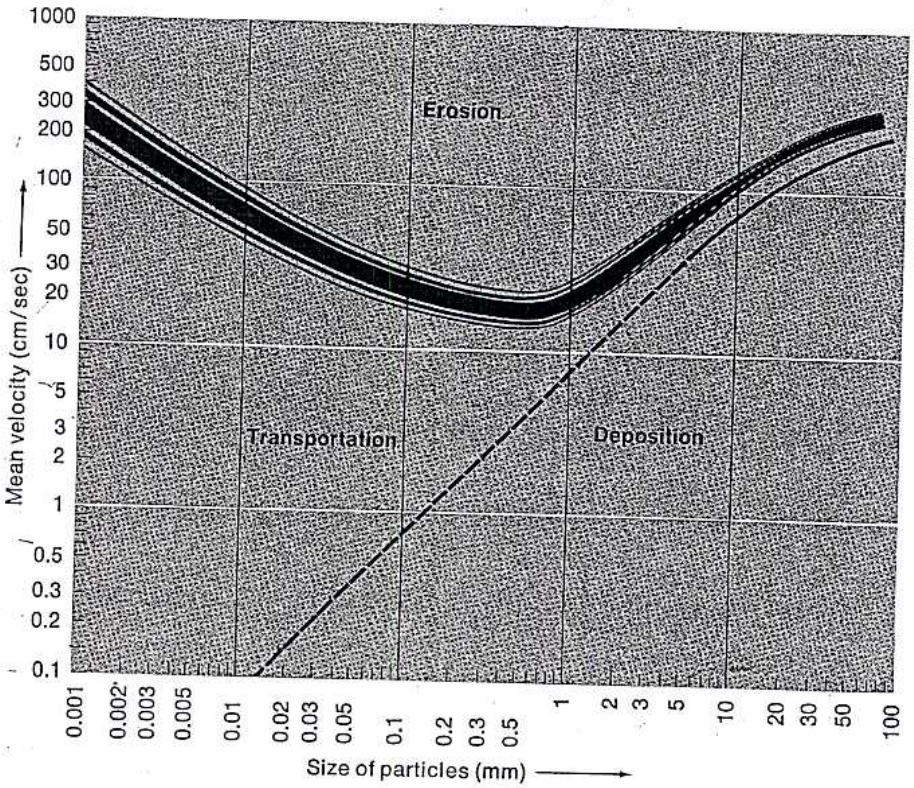
Figure 6.7.
Mean velocity at which uniformly sorted particles of various size are eroded, transported, and deposited.



The above observations fit rather nicely the curves produced by Hjulström (1939) and shown in figure 6.7, which relate current velocity, particle size, and process; as figure 6.8 shows, Rubey's size classes seem to fall along the trend of the boundary between erosion and transportation, that is, the threshold velocity needed to initiate motion. The velocity that produces erosion of clay-sized particles is in some cases as great as that needed to entrain larger material. This explains the commonly observed phenomenon of coarse particles being transported across stationary material of a smaller size.

Unfortunately, flumes are not useful in the study of competence when particles are larger than pebble size. Most competence investigations of coarser sediment have therefore been made in natural rivers or canals and, for reasons explained earlier, employ shear stress as the diagnostic hydraulic variable (Lane 1955; Fahnestock, 1963; Kellerhals 1967; Scott and Gravlee 1968; Church 1972, 1978; Baker 1973b; Baker and Ritter 1975). Shear stress analyses such as these have produced widely divergent results concerning competence. Andrews (1983) suggests that much of this variation comes from our failure to consider sediment characteristics in the competence analyses. He was able to show that the size distribution of bed material has a significant effect on the shear stress required to entrain a particle of any given size. The variation in estimates of competence also prompted Bradley and Mears (1980) to combine a number of earlier techniques to gage the velocity and depth associated with entrainment.

annual average sediment concentrations are, respectively, 3.54 and 27.5 kg/m^3. The Yellow River in China is the greatest sediment-carrying stream in the world. Its annual average sediment concentration is 37.6 kg/m^3 and the maximum measured sediment concentration has reached 911 kg/m^3. The sediment concentration for 100 percent pure bulk sediment is about 1650 kg/m^3.

For a Newtonian fluid μ, the dynamic viscosity of the water-sediment mixture varies with sediment concentration by volume as follows (Einstein and Chien[33]):

$$\mu = \mu_f(1 + 2.5S_v) \tag{12.1.12}$$

Krone[75] found that

$$\mu = \mu_f e^{2.5S_v} \tag{12.1.13}$$

where μ_f is the dynamic viscosity for the pure fluid and S_v is the sediment concentration in the fluid by volume.

Fall Velocity. The terminal fall velocity of a sediment particle depends on the effects of size, shape, and density of a sediment particle, the effects of fluid density, and turbulence. Figure 12.1.2 provides the fall velocity for various sediment sizes and shapes under different water temperatures. The set of curves for $K = 0.5$ has fall velocities in the range of 0.2 to 100 cm/s, respectively; the second set of curves for $K = 0.7$ (closed to well-rounded natural sediment particles) has fall velocities in the range of 0.1 to 100 cm/s. The third set of curves for $K = 0.9$ has fall velocities in the range of 0.1 to 50 cm/s, respectively.

The effect of particle shape on fall velocity is significant. Schulz, Wilde, and Albertson[109] found that the drag coefficient, which determines the fall velocity of a particle, varies greatly with the Reynolds number based on particle size.

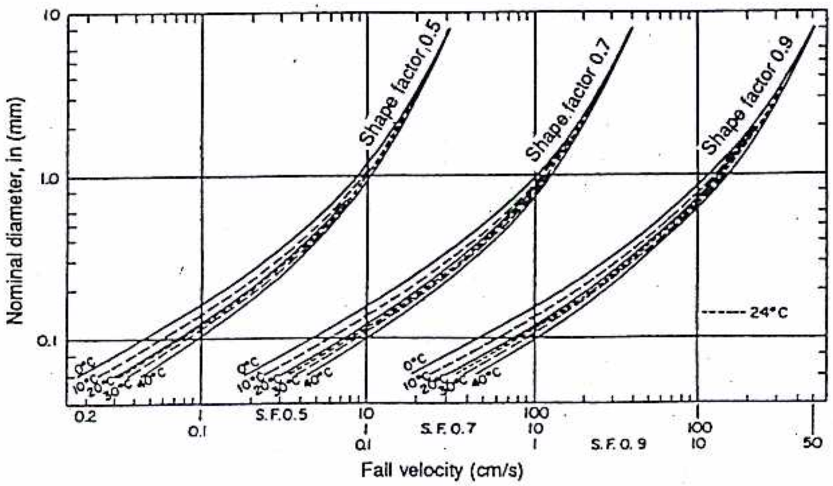


FIGURE 12.1.2 Sediment particle fall velocities.[129] Sediment fall velocities for three shape factors $K = 0.5, 0.7, 0.9$. Each set of curves uses a different horizontal scale for shape factor (S.F.).