TECHNICAL PAPER CST-07-004

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BASIC QUESTIONS TO ASK ABOUT GRAVITY WATER QUALITY VAULTS

There are two basic types of water quality vaults. One type relies on gravity settling and flotation for the separation of pollutants, and the other relies on filtration. Some devices are hybrids that use both techniques. An additional element that is employed for many vaults is the use of a bypass to avoid treating higher flows. With the introduction of so many new products into the market, it is difficult for specifying engineers and regulators to assess the potential effectiveness of a particular vault. The process is complicated by the fact that most products, especially the new ones, are untested. Even tested products typically have several similar models, and it is just not feasible to test each one.

The good news is that each type of vault has basic physical principles that govern their performance, and gravity vaults are relatively easy to assess.

BYPASS

The first over-reaching principle is the use of a bypass to avoid high flows. It is important to understand that treatment goes to zero when a vault is on bypass. Numerous products claim high efficiencies at low flows, and can probably deliver good performance at that level. When the performance is “flow weighted” so that the zero performance is considered, they simply cannot measure up. One basic principle is that if the performance goal is to remove “X%” of sediments at “Y cfs,” and the device does not even treat the flow, it cannot possibly measure up. Often, just because “XYZ Technologies” has one device that has been tested to remove 80% of sediments at some flow, a badly undersized model of the same manufacturer will be selected for economic reasons, and approved by an agency based on name recognition.

Both specifying engineers and regulators need to pay attention to the required treatment flows, and demand that properly sized devices are specified in every case. Bypassing should be a red flag to a reviewer, and lowered only when it is evident that the device is capable of treating the required flows. There is a side issue that needs to be addressed that also involves bypassing. When possible, the consequences of bypassing higher flows as it affects trash, vegetative debris, and mass loads of larger particles need to be considered. When bypassing, all the trash, vegetation, and tons of sediment are untreated. By the letter of the law, bypassing after the water quality flow is permissible, but if there are sensitive water bodies or BMPs downstream, it might not be advisable. Something like a sand filter or bio-retention facility downstream could suffer greatly from the increased loads produced by a bypassing vault upstream. The same is true of wet or dry ponds, lakes, or sensitive habitat that would be affected by trash, too many nutrients, or excessive sediments.

PARTICLE CAPTURE

Particle capture is poorly understood by most people because there are several complex factors that affect capture. Stokes Law is widely cited, but the falling rate of particles in quiet water does not directly apply to the dynamic conditions in a vessel. In addition, particle size, shape and density have a profound effect on settling rates, and all of these factors are highly variable from site to site and storm to storm. With all that said, the Hydraulic Loading Rate (HLR) is the dominant factor in determining capture rates and should be the prime consideration in evaluating the potential performance of any vessel. Some people refer to this parameter as "surface loading." The HLR is simply the surface area, divided by the flow rate. Usually this is expressed as gallons per minute (gpm) per square foot. The lower the HLR the better, so that a 25 gpm/ft^2 might be considered good, and 50 gpm/ft^2 might be considered bad. As a matter of fact, an HLR of 25 gpm/ft^2 is about what is required to provide good suspended sediment removal efficiency in most cases.

The important thing to know is that the HLR is easy to compute for any vault. Simply divide the footprint (use πr^2 for circular structures) by the claimed treatment flow. Be aware that some manufacturers will test a device with a good HLR (usually their smallest device), and try to project the good results up through a product line where the HLR of bigger vaults is much worse. A study of the HLR for an entire product line will immediately tell you whether you should accept testing of one vessel as implying performance of others. It is also valid to compare the HLR of competing products to get a good general idea of comparative performance. Outlandish claims that are not backed up with good testing will be immediately exposed by the poor HLR of the proposed system. HLR is not the only thing to consider in a gravity based vessel, but it certainly is the main thing.

See "TECHNICAL PAPER CST-07-001" for a full explanation of Hydraulic Loading Rates.

RESUSPENSION

Re-suspension of material already collected is a concern for any BMP. The re-suspension of any given particle is primarily governed by the velocity of the water moving across a sediment bed. This principle has been well studied, and the results are easy to understand. There are many factors other than speed, but they play a minor role in the types of sediments typically encountered in stormwater. The main exception to this is the relative density of the material subject to re-suspension. Obviously heavy material like metal objects, and light material like organic debris will not behave like sand as far as re-suspension is concerned. Still, given any specific material, higher flow velocities will cause more re-suspension than low velocities. Velocity is clearly the dominant factor at work when re-suspension is a concern.

Most specifying engineers and regulators have no idea of what velocities are needed to re-suspend particles of a certain size. The re-suspension velocities are much lower than most people think. The chart below shows the velocities that will re-suspend particles of various sizes.

Scouring Velocities

Particle Size	Velocity (m/s)	Velocity (ft./s)
2000	0.72	2.36
1000	0.51	1.67
500	0.36	1.18
250	0.25	0.84
125	0.18	0.59
62	0.13	0.42
31	0.09	0.29
16	0.06	0.21
8	0.05	0.15
4	0.03	0.11

A velocity of 0.29 feet/second will re-suspend 31 micron particles, and a velocity of 0.42 feet/second will re-suspend 62 micron particles. The smallest sand particles are about 62 microns, so it is apparent that controlling re-suspension of silt and clay depends on keeping velocities low in the vessel. These values immediately demonstrate how most wet ponds and many other vessels have critical re-suspension problems both at the point where pipes or other conveyances enter the system, and where constrictions within the pond or vessel force high flow velocities. The key to proper design is to slow velocities upon entry, avoid turbulence of any kind, avoid constrictions at all costs, and strictly control the velocity of water across sediment beds, especially where the smallest particles are likely to be encountered. Many site specific designs and many manufactured products have restrictions in the worst possible locations adjacent to sediments beds and adjacent to where the smallest particles are likely to gather.

The first evaluation you need to make about any system is whether or not there are design flaws that will foster re-suspension. A very simplistic evaluation of velocities will give a reasonable answer you can utilize. Simply take the flow rate through the vessel in cubic feet per second, and divide it by the size of the constriction in square feet. This will give you a rough velocity. Water flowing at 2 cubic feet per second will have to move at about 2 feet per second to flow through a 1 square foot opening. The fact that there are losses due to the shape of the opening and the types of edges that the flow must pass through will mean that the actual average velocity will be a little higher than this simplistic calculation, and the velocity might be higher or lower in certain regions of the flow as it passes through the opening, but the rough calculation can tell you a lot. In the example above, you would immediately know that 2 foot per second velocity would re-suspend particles over 1,000 microns in size, and that this would not be acceptable.

This makes it sound like re-suspension is rampart at low flows, and that re-suspension must be avoided at all costs, but the reality is that re-suspension will seldom be a major player in a well designed system. This is due to two main factors, and a third one that is design independent. The first important factor is that only surface particles are available to re-suspend. Analyzing the potential re-suspension for a device at a given flow velocity is important, but it is more important to realize that all particles under a specific size will not instantly re-suspend at a given velocity.

The second important factor is that water quality flows are typically expressed as peak flows. This means that the peak flow is only realized for an instant. All other flows are below the peak. It is critical to understand how often a vessel might be exposed to flow velocity that could re-suspend certain particles, and the duration of such flows. Potential re-suspension is not the over-reaching parameter that would stop the use of a particular BMP. It is important, but capture is much more important than re-suspension in the larger scheme of things.

The third design independent parameter is the maintenance of BMPs. Maintenance seems to be practically non-existent in traditional land based approaches. Somehow, captured materials will “go away” or be mysteriously absorbed, never to be seen again. It is a fact that all materials captured by any means will eventually either wash downstream, be leached into the water, or escape as gases into the atmosphere unless they are removed. One advantage of manufactured devices is that they are almost always subjected to rigid maintenance and cleaning standards. Material that has been removed from a vessel has no re-suspension potential. Cleaning a BMP interrupts the exposure to high velocities permanently. This is unlikely to occur in a land based system, but practically inevitable in a manufactured one.

Overall, the prospect of re-suspension is not as important as avoiding bypassing too soon, and not as important as ensuring that a proper sized vessel has been chosen, based on the HLR.

See “TECHNICAL PAPER CST-07-002” for a full explanation of re-suspension rates.

SUMMARY

To evaluate any proposed gravity type separator, including a brand new one, use the following criteria:

1. Be sure the device treats the water quality flow at the very least, without bypassing.
2. Look for an HLR in the twenties’, somewhere under 25 gpm/sf would be best. If you have especially small particles, go lower. Compare the HLR of every model in a product line.

3. Look for design flaws that will cause excessive re-suspension. Avoid velocities over 0.40 fps if possible. Remember that re-suspension is not the prime criterion.
4. Insist on cleaning and maintenance on a planned basis for all BMPs.