Taking Redesign Head On

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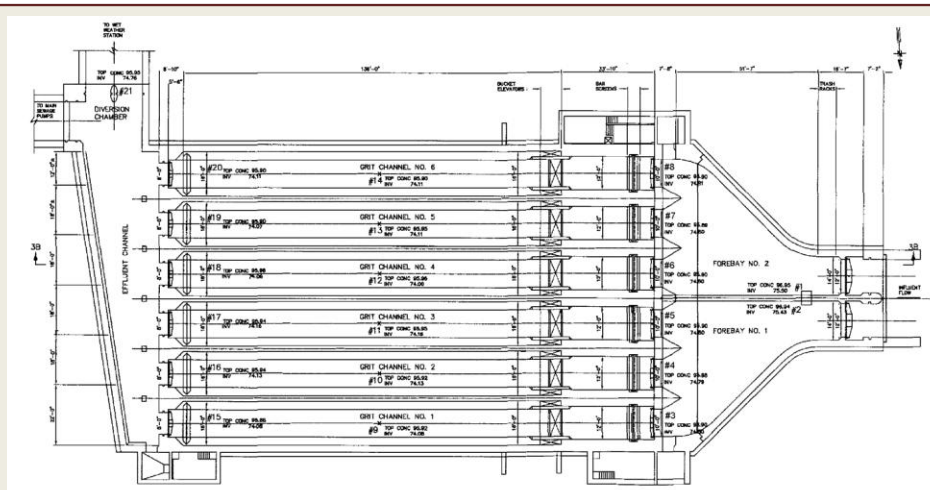
All wastewater treatment plants encounter this decision at one time or another: inflow to the site changes and you need to decide … do we replace or redesign the facility? When the Passaic Valley Sewerage Commissioners (PVSC) faced this decision for the headworks of their treatment plant in Newark, New Jersey, USA, engineers grappled with one challenge that many sites in this scenario see: no room to install a new portion of the facility without reconstructing large portions of the entire site and facing the looming expense of that reconstruction. Instead, site operators and engineers examined the possibility of redesign: Was it feasible? Would it work? What would be the best way to go about a redesign that fits both scheduling and budget priorities?

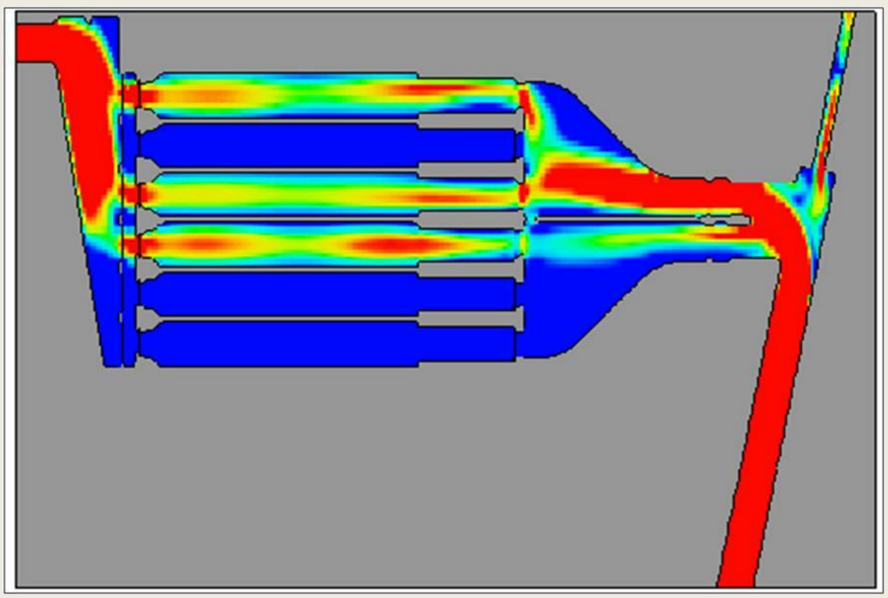
The original facility

The existing grit and screening removal facility was constructed in 1973 to replace and upgrade the plant's original headworks, which had been built in 1924. The 1973 redesign was constructed to handle an inflow of approximately seventy-five percent industrial waste, much of it oil and grease. The inlet structure of the 1973 headworks was comprised of a forebay chamber that expanded from the 12 foot influent sewer line into a 90 foot wide chamber. This chamber led into 6 grit removal tanks, which utilized vertical bucket elevators for mechanical removal of the grit.



Original headworks facility

The large forebay was designed to capture the large amounts of grease and oil in the influent by trapping the material in the forebay. Unfortunately, the 1973 design that worked well for an oil and grease removal system also acted as an ideal grit chamber, but without any means of removing the captured grit. Because of the expansion of the cross sectional area of the forebay, the increase in width from 12 feet to 90 feet, the influent velocity would drop below 2-3 feet per second, the acceptable velocity to keep grit suspended and moving. The result: Eight to ten foot accumulations of grit would pile up in the entire forebay area during dry weather flows. In times of heavy rain and high flow through the facility (up to 700 MGD), slugs of material from these grit piles would be swept into the subsequent grit removal chambers, causing complete overload and mechanical failure of the grit removal equipment. Even in low flow periods the forebay design itself resulted in uneven flow and uneven grit distribution between the six grit tanks. The costs of manually cleaning the facility and completely replacing the grit removal mechanisms at least once per year drove the need to change the facility so that it could handle the grit content in the influent.



Simulation of influent flow through original headworks design (red indicates higher flow velocities, blue lower); clearly influent does not flow at consistent velocities through all 6 grit tanks (on the left)

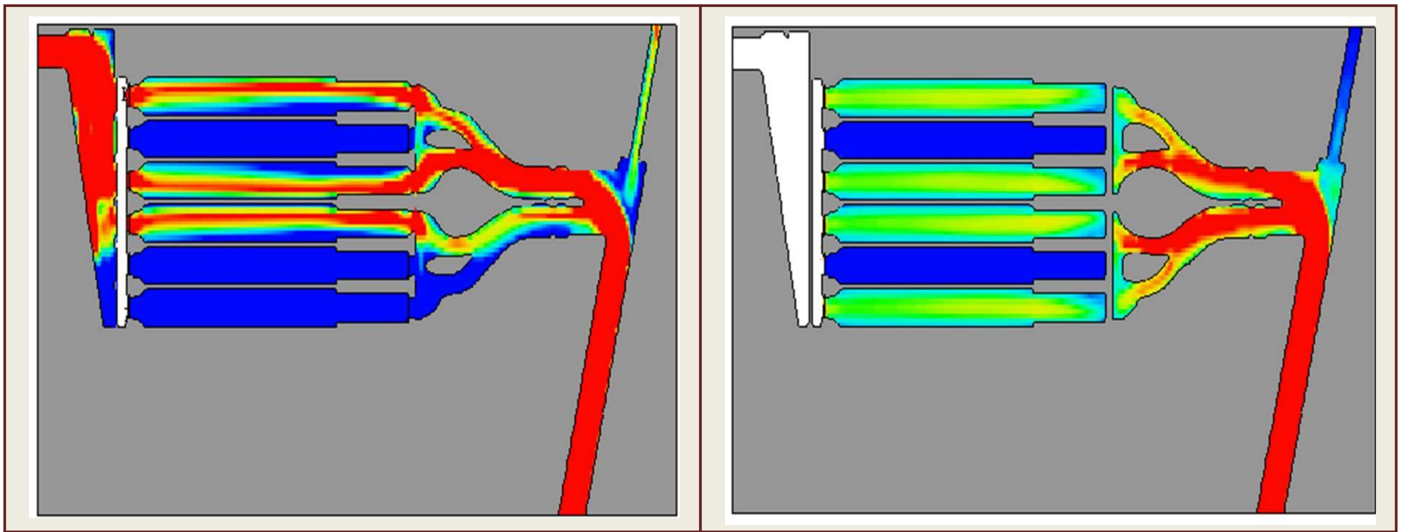
Replace or redesign?

Replacement of the grit removal facility was simply not practical. In the treatment plant, there wasn't existing and available space in which engineers could place a new installation. For a full replacement, the entire plant would need to be both redesigned and reconstructed – a massive undertaking and expense. The best option was to redesign the existing removal facility to meet ongoing needs, if PVSC could verify new design options and eliminate the risk of installing costly new equipment that didn't perform significantly better than the existing structure.

The engineers for the redesign, Greeley and Hansen of Philadelphia, Pennsylvania, turned to Alden, one of the oldest continuously operating hydraulics laboratories in the world, for redesign support. Located in Holden, Massachusetts, Alden's fluid flow engineers and environmental consultants were known for their extensive experience with computational and physical fluid flow modeling, both of which they proposed as tools in the redesign process. With this recommended blend of new and old technology, computer simulation and physical modeling, PVSC proceeded. The redesign focused on assuring that grit passed through the forebay area into the grit removal tanks rather than building up in the forebay and also improving the removal process utilized in the grit chambers, so that the headworks could appropriately handle the quantity of grit being processed.

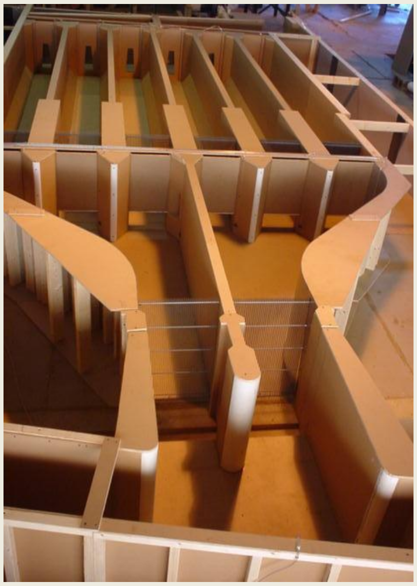
The forebay redesign

The forebay redesign required the ability to understand whether new hydraulic design alternatives could maintain the carrying velocities necessary to keep the grit in suspension and flowing into the removal tanks. Alden used computational fluid dynamics (CFD) to simulate the flow behaviors of various forebay design options. With the CFD results, PVSC was able to quickly see the effects of channelizing the forebay and to subsequently refine the width and shape of these new channels. CFD also allowed engineers to assess the influent velocity at any point in these channels, to verify the grit carrying capacity of each design alternative. Iterating and fine tuning the options, this initial CFD work led to the formulation of a proposed new forebay design.



Channelized forebay redesigns, early (left) and later fine tuned (right) to ensure that flow throughout the entire forebay and the 6 grit tanks remained consistent and above the grit carrying velocity.

This proposed design was then physically modeled to identify areas where grit would accumulate due to otherwise unanticipated low flow rates and recirculation areas. Alden built 1:9 scaled models of the existing headworks and to the proposed new design. Appropriately scaled plastic material was used in the model study to replicate the transport and settling characteristics of the grit seen in the actual facility. This plastic-grit was introduced into the fluid moving through a physical model and areas of accumulations were identified in the redesigned forebay channels. Through an iterative process involving both subsequent CFD and physical modeling, the channelized forebay design was fine tuned to eliminate grit accumulations.



Original (left)and redesigned (right) physical models of the forebay and grit tanks (constructed by Alden)

The next step: make sure the grit chambers could handle grit removal.

Grit removal revamped

As an alternative to the mechanical chain and bucket elevators used in the 1973 design, PVSC was considering the use of submersible pumps for vertically pumping the grit out of the grit tanks and into a cyclone degritter and grit classifier. This new set up would be a significant change in grit removal technology and thus needed significant validation before installation. One major concern for this system was that grit would potentially build up in the sump areas around the pumps and clog the pumps in times of heavy flow. To optimize the grit removal system – the sump geometry, pump sizes, and pump discharge piping designs – PVSC and Alden used a similar iterative simulation and physical modeling process to the one used in the forebay redesign.

Alden provided CFD analyses for different configurations of sump geometries and pump sizes to ensure that the grit remained suspended in the fluid rather than settling in the sump area. A grit flushing system was modeled to assure that the grit would be kept in suspension at all times to prevent clogging of the pump suction. The system was designed to operate continuously and, in combination with the sump geometry, assures that accumulations of grit do not occur in the sump. This CFD analysis was paired with physical modeling, again using the plastic-grit material, to validate and optimize the design.

Sump and solid pump physical model

PVSC Conclusions

PVSC constructed a full size pilot of the new sump, pumps, and grit removal system in one of the six grit removal channels. The system has been in operation since 2006 without any grit deposition problems. In June 2011, the first phase of the forebay channelization was placed into operation with excellent results. The new installation operated successfully through the recent Hurricane Irene at flows exceeding the design loads. The use of design tools such as CFD and physical modeling greatly reduced the risk of failure in a design that corrected complex hydraulic problems in an existing facility. PVSC was able to successfully improve its plant's operation at a fraction of the cost of a new facility.

Mr. Johansson is the Director of Hydraulic Modeling at Alden and has over 20 years of experience in hydraulic modeling. He obtained his Bachelor of Science degree in Mechanical Engineering in 1995, from Worcester Polytechnic Institute and is currently in charge of the day-to-day operations for the Alden hydraulic modeling group. He also provides supervision of numeric and physical studies, from the proposal stage through to completion, for electric power utilities, water supply and treatment, architect-engineering firms, equipment manufacturers and governmental agencies

Mr. Lipke is the Chief Operating Officer for the Passaic Valley Sewerage Commissioners in Newark, New Jersey, USA. He is in charge of the operations, maintenance, and engineering for one of the largest wastewater treatment facilities in the Unites States. A Professional Engineer, he earned Bachelor and Master degrees in Civil Engineering from the City College of New York. Responsible for the rehabilitation and upgrading of the treatment works, he has guided the design and construction of a multimillion dollar program of plant improvements from headworks to outfall.