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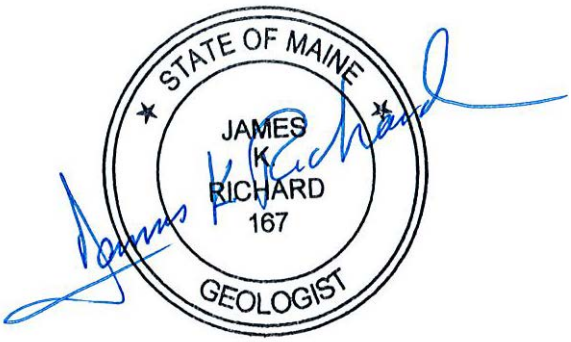
LIMITED FEASIBILITY STUDY OF TREATMENT OPTIONS

FOR

GROUNDWATER DISCHARGING FROM AN ARTESIAN WELL

AT

BOGGY BROOK REGIONAL VOCATIONAL CENTER



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MARCH 2011
JN: 6115

LIMITED FEASIBILITY STUDY OF TREATMENT OPTIONS
FOR
GROUNDWATER DISCHARGING FROM AN ARTESIAN WELL
BOGGY BROOK REGIONAL VOCATIONAL CENTER
Completed for the Maine Department of Environmental Protection

Introduction and Purpose

The Maine Department of Environmental Protection (Department) wishes to install a permanent treatment system on a well formerly used as a water supply for the Boggy Brook Regional Vocational Center located at 112 Boggy Brook Road in Ellsworth (see attached Location Map). The well is contaminated with relatively low concentrations of tetrachloroethene (PCE) and trichloroethene (TCE) and reportedly overflows under natural artesian pressure at a rate of approximately 1.5 gallons per minute. It is believed that the natural overflow of the well is functioning to isolate the contaminant plume and for this reason, the Department does not want to plug it or otherwise stop the flow. If the discharge is allowed to continue, it will have to be treated so that the PCE concentrations are below the MEG prior to discharge.

At the Department's request, CES has completed a limited feasibility study to evaluate possible treatment alternatives and to recommend an alternative that meets the Department-specified requirements. Because of its limited nature, the current investigation was undertaken primarily as a desk-top exercise and focused on various combinations of proven treatment methods. Bench testing and pilot studies were not completed as part of the current scope of work.

In 1995, the Department discovered PCE in the well serving the vocational center. Hydrogeologic investigations conducted at the time identified a probable off-site source of the contamination and a carbon treatment system was installed on the well. Subsequently, municipal water was provided to the center and the well was taken off line.

Location and Setting

The BBVC lies northwest of the downtown area of Ellsworth on the southwest side of Boggy Brook Road. A site sketch for the vocational center, showing the approximate location of the well, is attached as Figure 2. The Maine Geological Survey (MGS) surficial map of the area (Weddle, 2010) shows the site to be underlain by relatively thin deposits of glaciomarine clays and fine sands of the Presumpscot Formation. Bedrock beneath the site is comprised of the Ellsworth Schist (MGS, Pollock, 2008).

Topography in the vicinity of the vocational center is subdued and slopes southeasterly at .012 feet/foot. The site is drained by two local drainages that discharge to Gilpatrick Brook. Gilpatrick Brook flows southeasterly, discharging to the Union River approximately 1.2 miles from the vocational center. The stream gradient for this segment is approximately 33 feet/mile.

The Vocational Center well is located at Latitude 44.5753137 degrees N and Longitude 68.45838089 degrees W. A driller's log is unavailable for the well but geophysical logging was completed on August 8, 2005 by Northeast Geophysical Services. These logs indicate that the well is at least 217 feet deep and is characterized by at least three, and probably four, fracture zones which contribute groundwater to the well bore. The wellhead is protected by a small

wooden well house and the natural flow from the well is diverted to an adjacent drainage swale via a pitless adapter and drain line which was installed below grade by the Vocational Center.

Goals

The goal of the current study is to identify the most cost-effective long term solution for treating the natural discharge from the well to reduce PCE concentrations below the applicable guideline of 0.6 µg/l, prior to its release to the environment. The Department has established four criteria which must be met in order for a treatment alternative to be considered:

1. Treatment systems requiring electrical power will not be considered;
2. The current natural discharge rate from the well of 1.5 gpm will not be diminished by the recommended treatment system;
3. The recommended treatment system will utilize as few mechanical parts as possible; and
4. The recommended treatment system will be designed to function for a minimum of ten years.

Considerations for System Selection

The approach to completing this Feasibility Study was largely driven by the four limitations defined by the Department.

- No external power sources considered. The requirement that no external power be supplied to the treatment system necessarily limits the alternatives to a passive system utilizing only the natural flow rate of the well or the force of gravity to move the water through the treatment system. This approach would work for a passive aeration system but as described below, would not be suitable for contact media systems installed directly in the well bore.

- No reduction in discharge rate of the well. It is unclear whether the observed flow rate of 1.5 gpm is due to ample aquifer capacity but low pressure, a lower aquifer capacity but higher pressure, or some combination of the two conditions. For this reason, it was determined that alternatives utilizing the well's natural hydraulic pressure to move the water through a treatment system would place backpressure on the well, likely reducing the well's flow rate.

- Treatment system should have as few mechanical parts as possible. This requirement will ultimately enhance the longevity of the chosen system as it will limit the maintenance required and the potential for mechanical breakdown.

- Treatment system to last a minimum of 10 years. A system designed to last for a minimum of 10 years must meet two important criteria:
    - The system must be simple and robust; and
    - The system must be designed so as to be easily cleaned and maintained.

The following additional factors were considered in selecting the most feasible alternative for treatment.

- Preliminary testing by the Department indicates that the iron and manganese concentration in the discharge is very low. However, given the fact that the treatment scheme will result in the introduction of air to the water, the potential for the formation of at least some iron scale and biological fouling by iron-consuming bacteria should be anticipated. The chosen system will have to function under these conditions.

- The system will be required to operate under freezing conditions necessitating installation below grade.

- A system utilizing aeration could be hard piped to the well provided the aeration system was passive, such as in allowing water to fall onto rocks, screens, or other materials designed to atomize or otherwise incorporate air into the discharge water.

- In determining the amount of available pressure for use in moving water through a media-based treatment system, there must be an air gap between the well and the treatment system so that back pressure is not put on the well. This limits the available driving pressure to the total amount of available hydraulic head. Approximately six feet of total head is available in close proximity to the well while as much as 15 feet is available if a system were to be extended to the southeasterly property line.

- The necessary requirement that no additional back pressure be placed on the well will likely create at least some biological and chemical precipitation challenges. To avoid additional back pressure, the supply line between the well and the inlet side of the treatment system will have to be vented, allowing the ground water to come into contact with oxygen in the atmosphere resulting in iron oxide and biomass growth on surfaces and in any treatment media used in proportion to the concentrations of these metals in the ground water.

- In the absence of pilot tests or evaluative bench testing, it is difficult to predict the effectiveness of any aeration system. While aeration is a good alternative when energy can be added to the system (i.e. pumps), the low pressure available in a gravity fall system will make the effectiveness difficult to quantify.

- A similar argument as above can be applied to other types of systems such as bioremediation. To be effective, these systems must have sufficient contact time for the biological activity to consume the VOC's in the water prior to discharge. The natural flow rate of 1.5 gallons per minute from the well will likely not provide the contact time necessary for bioremediation systems to be effective.

Approach

Based upon the expected time frame for implementation, the requirements established by the Department and the additional considerations described above, CES believes that the best approach will be to use a proven technique where the effectiveness in treating known concentrations of PCE/TCE can be quantified in advance to ensure that contaminants are not

released to the environment is concentrations exceeding the Maine DHS Maximum Exposure Guidelines (MEG) and Ambient Water Quality Criteria (06 096 CMR Chapter 584).

With the above being said, the current situation does provide an opportunity to conduct research pertaining to the effectiveness of various treatment techniques, methods, and combinations of methods. Good examples of these would be various aeration and bioremediation schemes. Current plans are to use the approaching summer months to experiment with various treatment methods and to evaluate their effectiveness. It is anticipated that this work will continue into the early Fall of 2011. These results will be used to determine which treatment alternative should be installed for the long term.

It is expected that the chosen system will include a mechanism that anticipates at least some media-fouling and provides for continued effective operation while avoiding the need for constant maintenance. While it is anticipated that a certain level of visual and chemical monitoring will be needed regardless of the chosen alternative, the goal should be to minimize this requirement.

Considered Alternatives

Alternatives considered for treatment of the PCE-contaminated water included:

- no action;
- passive aeration;
- bio-remediation;
- activated carbon treatment; and
- a combination of activated carbon treatment with an additional carbon stage or any other option.

These options were selected based upon their anticipated effectiveness, feasibility of implementation, and projected costs.

Option 1: No Action

No action would be taken and the artesian well would continue to flow as-is.

Effectiveness: Based upon a comparison of sampling and analysis of BBVC well effluent for PCE conducted in 1995 and 2010, concentrations have decreased from 86 µg/l in 1995 to 8.2 µg/l in 2010, illustrating that natural attenuation should eventually lead to effluent PCE concentrations below applicable guidelines. However, current effluent PCE concentrations continue to be above the applicable guideline of 0.6 µg/l and therefore cannot be discharged in conformance with Department regulations. The no-action alternative is therefore ineffective for treatment of the BBVC well effluent in the short-term.

Feasibility of Implementation: No action is necessary to implement the no-action alternative.

Cost: Costs associated with the no-action alternative include periodic sampling and analytical costs to monitor effluent PCE/TCE concentrations.

Option 2: Passive Aeration

The natural terrain of the former BBVC property would be utilized to passively aerate the well effluent. The available head for this type of system range from somewhat less than six to more than 15 feet depending upon where on the property the treatment system is placed and how it is configured.

Effectiveness: Passive aeration has proven to be an effective method of remediating VOC contaminated water in typically large-scale settings, such as stream flow or higher volume mechanically-assisted flow, and relies primarily on turbulence, time, and contact of contaminated water with air. Turbulence will be difficult to achieve due to the low flow rate of the BBVC well and the typically gradual slope of the former BBVC property in the vicinity of the well, as well as the limitation concerning use of electrical power. Therefore, the parameters of time and air contact would need to be maximized for effective treatment. In the absence of bench testing or pilot study results, it is difficult to anticipate and nearly impossible to quantify the effectiveness of this type of system in lowering the observed concentrations of PCE to levels below the applicable guidelines.

Feasibility of Implementation: Numerous simple methods of passive aeration are possible which incorporate very few, if any, mechanical parts. Construction of a passive aeration system could be accomplished by a general contractor with oversight by an environmental professional (EP). Based upon the effectiveness discussion above, in order to maximize the parameters of time and air contact, effective implementation of the passive aeration option may require a physically large system consisting of any combination of spillways, holding tanks, etc. Though no specific limitation has been set on system size, implementation of this option could potentially involve ground disturbance to property boundaries as depicted on publicly available tax maps.

Cost: Costs associated with the passive aeration option are primarily related to initial construction, with ongoing periodic maintenance, sampling, and analytical costs as secondary factors. The preparation of more detailed cost estimates are not justified at this time given the uncertain effectiveness of the system. However, should the Department choose to consider this alternative as a pilot project, the construction and monitoring costs can be quickly be developed.

Option 3: Bio-Remediation

Bio-remediation is a widely accepted method of remediation of VOCs in water, relying on biological degradation of contaminants into progressively less harmful compounds. Bio-remediation options include in-situ, down-well treatment, and treatment in lagoons or in holding tanks external to the well.

Effectiveness: The success of bioremediation techniques depends upon providing adequate contact time for the biological activity to metabolize the contaminants. Assuming a system can be designed to provide the time needed, bioremediation can be an effective method for removing VOCs from water.

Feasibility of Implementation: Given the site conditions at the vocational center and the seasonal limitations for operation, it is unlikely that external contact tanks or lagoons could be used to provide the necessary contact time for bioremediation to be effective leaving only a "down-hole" method for consideration as part of this scenario. However, this method is best applied when a well serves as an access point into the aquifer allowing the introduction of bioremediation agents directly into the ground water system. The fact that this well discharges naturally at 1.5 gpm due to artesian pressure effectively short circuits the ground water flow and brings it to the surface, limiting the available contact time to slightly more than two hours (one foot of rise per minute times an assumed available depth of 125 feet). This time frame is not nearly long enough to allow biological activity to significantly affect the PCE concentration.

Cost: According to the manufacturer's recommendations, a typical down-hole system lasts from three to six months. Costs associated with a bio-remediation treatment system include initial installation costs, regular media maintenance and replacement costs, and periodic sampling and analytical costs. A number of delivery options are available, including passive delivery options appropriate within the constraints of this project. Initial set up for such a system would range from $1,000 to $2,500 depending upon how many individual canister units were installed in the well. On-going costs would be approximately $200/month multiplied by the number of canisters installed plus necessary water sampling and analysis

Option 4: Activated Carbon Treatment

The use of activated carbon is a proven approach for the removal of VOCs from water supplies and is likely to be at least part of any solution due to the proven nature of the technology. Carbon can be used in any number of physical configurations as dictated by the circumstances.

Effectiveness: Given its long history of use, it is possible to quantify the effectiveness of activated carbon media and to predict long term usage costs in the design phase. Given the anticipated iron concentration in the effluent water, it is expected that any adsorption media, including carbon, will foul readily with biofilm and oxidized iron. To remain effective in treating the contaminated waste stream, the carbon solution will require a design that anticipates this fouling as well as providing for periodic monitoring of water quality.

Feasibility of Implementation: Due to the widespread use of this treatment method, acquisition of media and disposal of used media should be straightforward. Construction of a carbon treatment system could be accomplished by a general contractor with oversight from an EP. Long-term implementation may require higher maintenance depending on fouling characteristics.

The concentrations of PCE and TCE were provided to Great Lakes Carbon Treatment, Inc. (GLCT), a major supplier of carbon adsorption media, with a request for a recommended carbon media that would be less prone to carbon fouling. GLCT recommended GLCT-CBV-830L, a granular carbon media used where iron and biological fouling are anticipated. Given the reported concentrations of PCE and TCE

and the measured water flow rate, a properly designed system would require only 2.2 pounds of carbon annually, including a 50% safety factor. This calculation suggests that iron and/or biological fouling may cause a larger need for maintenance than for PCE and TCE adsorption. Clearly a carbon system could easily be effective provided elements to handle the anticipated fouling were incorporated into the design.

Practical limitations for installing and maintaining carbon media are much greater than the 2.2 pounds per year required for treatment at the observed contaminant levels. Great Lakes Carbon Treatment, Inc. recommends that the activated carbon vessels each contain at least 200 pounds of media to ensure good contact time, serviceability, and to allow for natural fouling.

Cost: Costs associated with an activated carbon treatment system include initial installation costs, regular carbon media maintenance costs, and periodic sampling and analytical costs. The cost for the anti-fouling carbon media described above is currently $1.50 per pound. Clearly the cost of the media alone is insignificant compared to the cost associated with installation, removal and disposal of used media and disposal costs for expended media.

Option 5: Combined Treatment

Contamination of the well at BBVC could provide an opportunity to experiment with treatment options for which the effectiveness cannot be determined at this time. As perceived in this case, a "combined treatment" alternative would combine an upgradient experimental stage with a final polishing stage consisting of activated carbon. The polishing stage will ensure that there is no release of contaminated water to the environment due to the failure or ineffectiveness of the experimental phase. By modularizing the pilot treatment stage, it would be possible to evaluate new passive treatment technologies before they are implemented at other contamination sites. For this option, any single experimental method chosen would be considered a pilot study. Once the effectiveness of one pilot system is evaluated, it could be removed and replaced with another one. This would provide opportunities to collect hard data concerning the effectiveness of various aeration schemes and alternative adsorptive media applications.

Effectiveness: The discussion concerning effectiveness of activated carbon treatment applies here. Regardless of the pilot method placed up-stream of the polishing stage, effluent from the system should be "clean." The effectiveness of the pilot stage will determine the longevity of the carbon media used in the polishing stage. For effectiveness of the pilot stage, discussion of the previous options applies.

Feasibility of Implementation: The feasibility of implementing the combined treatment option stems from the choice of pilot stage option. The feasibility of implementing each option applies, as well as the feasibility of implementing an activated carbon treatment system. Maintenance of the combined treatment option will necessarily be greater than any single option as two systems will need to be maintained.

Cost: As with the straight carbon system above, costs associated with the combined treatment option include the installation and maintenance costs of a carbon treatment

system plus installation and maintenance of the pilot system. Sampling and analytical costs would compound as well in order to monitor both pilot and polishing stage performance.

Recommended Treatment System

CES recommends installation of a combined treatment solution as discussed above consisting of a passive aeration pilot stage followed by a carbon media polishing stage. . This approach will maximize learning opportunities and could ultimately lead to increased effectiveness and lower implementation costs at other contaminated sites where groundwater treatment is required.

CES initially recommended that both the experimental (pilot) stage and the polishing stage utilize carbon adsorption technology. The experimental and polishing stages would be configured differently to allow the evaluation of planned, progressive failure could be used to optimize the volume of carbon needed while providing for immediate availability of clean carbon once fouling has occurred. Cost projections for this approach were higher than expected however, necessitating that other Stage 1 options be considered. Following discussions with Department personnel in which the merits of various combined treatment system configurations were considered, it was determined that a more detailed consideration of passive aeration for the first stage was in order. It was also suggested by the Department that the combined system be initially configured using readily available materials that would be inexpensive to purchase and therefore allow greater flexibility for modifying the system in the discovery phase. The Department agreed with CES' suggestion that once a final configuration is established, the final system can be constructed in conformance with the Department criteria for year-round operation and a 10-year lifespan.

A conceptual sketch of a pilot-stage passive aeration treatment setup is depicted in Figure 3. The following design elements are included.

- An air-gap design (vented) to prevent back pressure on the well.
- Gravity drop through a static mixer(s) to break up the water and begin the aeration process.
- Additional gravity drop from a perforated pipe onto clean #4 stone which has been placed in the base of an 18-inch diameter HDPE corrugated culvert (cut in half longitudinally).
- Cascading flow along a 16-foot section of culvert for additional aeration
- Lining of the existing drainage swale with black plastic to prevent the escape of contaminated water to the ground and to capture heat to promote increased volatization.
- A provision for multi-point sampling to monitor effectiveness.

The use of a static mixer to break up the water flow is an experimental usage of a device originally designed for another purpose. However, its configuration is such that it is expected to provide substantial aeration to water falling through the mixing vanes. Photos and a description of the proposed static mixer are included as Appendix A.

The pilot stage would be followed by a polishing stage consisting of a standard "bottom-up" carbon-media contactor located at the discharge end of the passive aeration system. The polishing stage would initially consist of a single tank but could be expanded to two tanks in the

final configuration to provide redundancy and to allow one chamber to be cleaned while maintaining flow through the system.

The system as conceived would be temporarily installed above grade to allow for ease of access during the experimental phase. Once a final configuration is determined, the permanent installation will likely be installed below grade in a ventilated, vault to prevent freezing. and would be designed to allow access to all components for maintenance and repair as needed. Specific details for installation would be developed as part of a future detailed design phase should the Department choose to pursue this option.

Estimated Costs for the Recommended Alternative

A summary of expected construction and long-term operation costs is presented in Table I and is presented separately for the pilot stage and the polishing stage for clarity. These are estimated worst-case scenario costs based upon conversations with suppliers and contractors and as such should not be used for bidding purposes. More detailed costs should be developed as part of a detailed design which can be submitted to potential contractors for bidding purposes.

Anticipated costs for construction of the system to be used in the evaluation phase are less than $4,000. These costs represent only 10% of the total cost of operating the system for a 10-year period. If we assume that it will cost an additional $5,000 to install the system in its final configuration, construction costs would still represent only about 20% of the total costs for a 10-year period.

Construction Costs:

Construction costs assume that initially, the system will be installed above ground for a limited period of time to allow ease of modification and evaluation. Once a final configuration is determined, construction costs for the permanent installation can be more accurately estimated.

Initial construction costs include:

- Clearing and grubbing of vegetation from the swale area
- Installation of stormwater BMPs to prevent off-site sedimentation
- Plumbing of the well discharge to the inlet side of the passive aeration system;
- Parts, supplies and labor for constructing the passive aeration stage and the polishing carbon treatment system; and
- Initial charging of the polishing carbon vessel.

Operations and Maintenance Costs: Operations and maintenance costs have been estimated for a 10-year life span and are presented in 2011 dollars. Operations and Maintenance costs are difficult to estimate until the actual rate of carbon usage can be quantified. While the quantity of carbon required to remove the known concentrations of PCE can be estimated with a good degree of accuracy, the effects of iron oxide and biomass fouling are not as easily predicted. For this reason, it is recommended that the 10-year cost estimate be revisited after the first year to refine the long-term cost projections.

Projected Operations and Maintenance costs include:

- Carbon change-out on the polishing stage; estimated to be required semi-annually; and
- Periodic water quality sampling to monitor treatment system effectiveness; this will be refined after the first year to reflect accumulated data trends.

Summary and Additional Recommendations

Existing ground water contamination in the general area of the BBVC is being controlled by the naturally-flowing artesian well. Treatment of the discharge is required to reduce existing PCE concentrations to levels below the current action level of 0.6 µg/l. In order for this well to continue to successfully capture the contamination and limit the growth of the contaminant plume, the flow from the well must be maintained. Down-hole treatment installations that would restrict flow can therefore not be used.

The recommended approach provides a great deal of flexibility for experimentation and evaluation of various treatment alternatives. CES recognizes that the current situation at the BBVC provides a unique opportunity to study and quantify the treatment effectiveness of a number of passive methods as long as the quality of the discharge meets current MEGs. For this reason, a two-stage approach has been recommended that will provide definitive treatment in a final polishing stage. This polishing stage will be preceded by a pilot stage that can be used for experimentation purposes.

Because the treatment system will discharge to surface waters of the State (Gilpatrick Brook) it is important to note that it may be necessary to discuss this project with the Bureau of Land and Water Quality. While it is unknown if any chemical parameters could exceed the Maine Ambient Water Quality Standards, the potential exists that iron and manganese discharge guidelines, along with others, could be exceeded.

Terrain Navigator, © Maptech 800-627-7236

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U.S.G.S. TOPOGRAPHIC QUADRANGLE
ELLSWORTH
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HANCOCK COUNTY TECHNICAL CENTER
ELLSWORTH, MAINE

LOCATION MAP FIGURE 1

3/10/2011
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MAINE OFFICE OF GIS AERIAL IMAGERY

APPROXIMATE PROPERTY BOUNDARY

APPROXIMATE WELL LOCATION

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HANCOCK COUNTY TECHNICAL CENTER
ELLSWORTH, MAINE
SITE SKETCH FIGURE 2

3/11/2011
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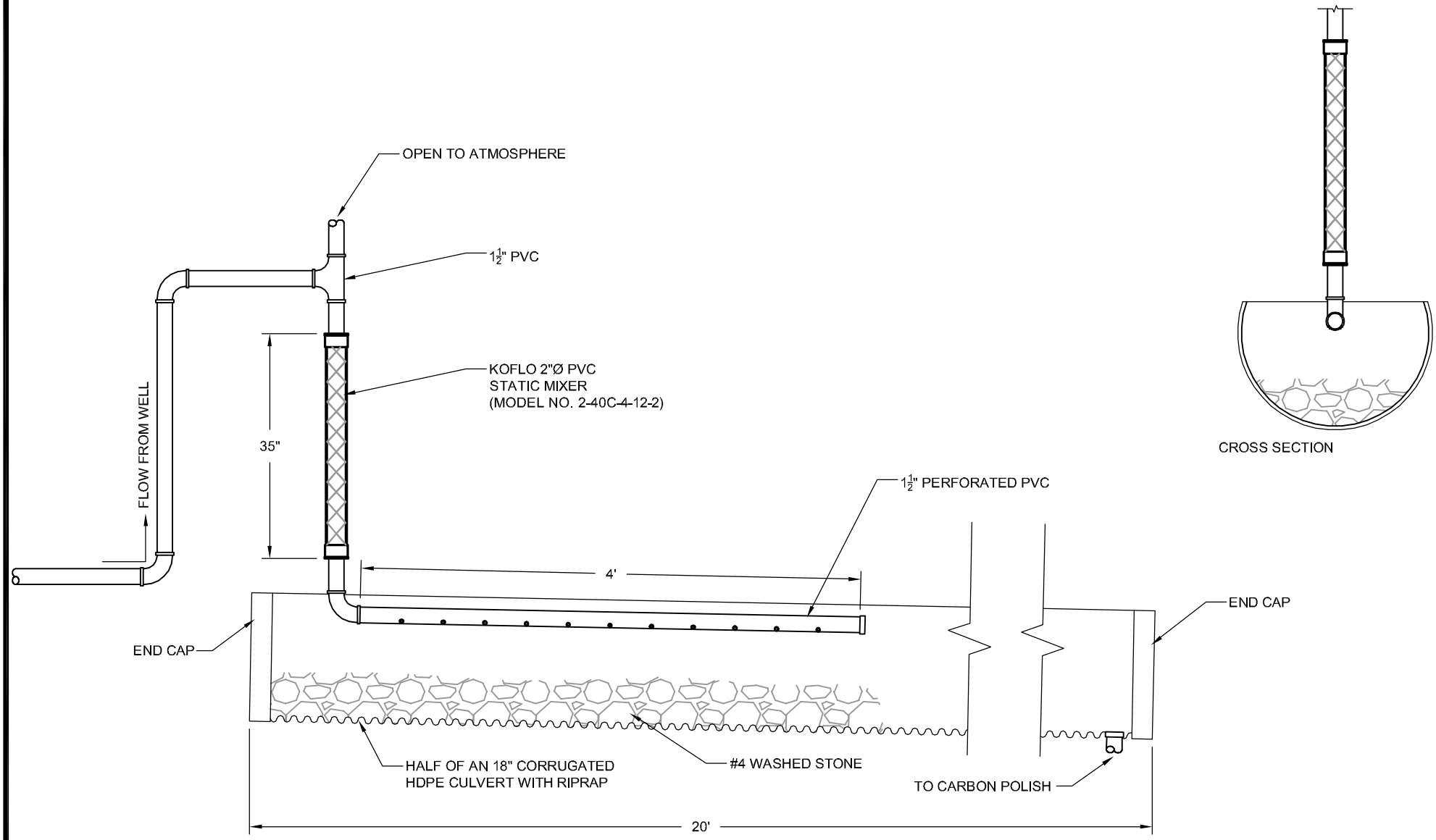
NOTES:
1) ASSUME PVC PIPE AND FITTINGS



PASSIVE AERATION PILOT STAGE

HANCOCK COUNTY TECHNICAL CENTER	BY: BH	DWG:	CES INC
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FIGURE 3	REV DATE:	SCALE: NTS	

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Table I - Aeration

Estimated Treatment Costs for Groundwater Effluent at
Boggy Brook Regional Vocational Center, Ellsworth, Maine

	Work Items	Unit Price	Unit	Estimated Quantity	Initial Cost*	Annual Cost First Year	Annual Cost Years 2-10	10-year Estimated Cost*	Comments
Pilot Stage-Passive Aeration	Construction								
	Clear and grub drainage area	300	LS	1	300				**Note: Applies to both Pilot and Polishing Stages** These costs do not reflect the construction costs for the permanent installation but only for construction of the prototype system. Additional costs will be incurred to construct the final system to accomodate the final configuration within a structure that will shield it from the elements and prevent freezing.
	Install and maintain silt fence	150	LS	1	150				
	18"x20' HDPE corrugated culvert (cut in half LW)	350	ea	1	350				
	#4 stone, washed	75	ton	1	38				
	Industrial plastic sheeting (4-mil)	0	sq. ft.	2000	60				
	2-in dia. PVC mixer	200	ea	1	200				
	Misc. plumbing (parts and installation)	250	LS	1	250				
	Separation fencing (woven wire)	2	foot	200	400				Includes protection for polishing stage as well
	Total Construction - Pilot Stage				**1,748**			**1,748**	
	Operations and Maintenance - Sampling and Analytical								
	Startup testing (2 sample events)	80	sampling event	6		480		480	3 locations (inlet, outlet of mixer, outlet of culvert)
	Evaluation testing	80	sampling event	3		240		240	start up plus one addition round during first year
	Semi-annual testing	80	sampling event	3			480	4,320	3 samples x 2 times per year x 9 years
	Total analytical - Pilot Stage							**5,040**	
	Pilot Stage Total:							**6,788**	Pilot Stage or Polishing Stage can discontinued at any time once effectiveness of the other stage is known

Carbon Polishing System	Construction								
	Carbon Media Tank	300	each	2	600			600	Single initially, then tandem Installation
	Treatment System Plumbing	500	Lump Sum	1	500			500	Plumbing Associated with Polishing System
	Carbon Media - Initial Installation	4.25	per pound, installed	100	425	425		850	Based on Clean Harbors mobilization plus100# of media in the first tank. 100# replaced each year (alternating tanks). Year two will require additional expense (not shown) of additional 100# of media for second tank.
	Total Construction - Polishing Stage				**1,525**			**1,950**	
	Operations and Maintenance - Sampling and Analytical								
	Carbon Change-Out (semi-annual first year)	1,200	Per Change-Out	2		2,400		2,400	Change out quarterly first year, annually years 2-10. Assumes used media will be disposed as hazardous waste.
	Carbon Change-Out, years 2-10 (estimated annually)	1,200	Per Change-Out	1			1,200	10,800	
	Startup (baseline) sampling	80	sampling event	1	80			80	outlet, one location
	Quarterly Sampling (first year)	80	sampling event	4		320		320	1 sample x 4 rounds
	On-going sampling (semi-annual)	80	sampling event	18			1,440	12,960	1 sample x 2 rounds x 9 years
	Total analytical - Pilot Stage				80	2,720	2,640	$26,560	
	Polishing Stage Total:							**$28,510**	Pilot Stage or Polishing Stage can discontinued at any time once effectiveness of the other stage is known

Total Construction Costs*	$3,698	PERCENTAGE OF TOTAL	10%
Total 10-year O&M Costs*	$31,600	PERCENTAGE OF TOTAL	90%
Total 10-year Cost*	**$35,298**		

* NOTE: All costs presented in 2011 U.S. Dollars

APPENDIX A

Koflo Corporation

View Drawing

Contact Us: 1-800-STATICS
782-8427

Clear PVC Static Mixers, Series 308

In response to a growing need for high quality PVC static mixers at a lower price, Koflo developed the Series 308 PVC Static Mixer. This unit is a clear PVC static mixer, which unlike other static mixers, allows for a visual inspection of the mixing process. All Series 308 static mixers are made in standard 6 element and 12 element configurations. Additionally, all PVC static mixers are edge sealed to the inside of the housing. The advantages of edge sealing are twofold. Not only does edge sealing increase mixing efficiency, but this bonding method also increases the structural integrity of the entire mixer. All mixers come standard with male NPT threads. Sizes 3/8"- 2" are in stock for immediate delivery.

One of the primary uses of the Series 308 static mixers is in the dilution of polymers and flocculants. With proper blending, it is quite common to recover the cost of a mixer in a relatively short period of time, due to the lower chemical costs associated with better mixing.

Other static mixer application include

- Admixing of water treatment chemicals
- pH control
- Chlorination and ozonation
- Process control sampling