Current State of the Art Installation Techniques for the In-Situ Reactive Wall Groundwater Treatment Systems

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ABSTRACT

The consideration and use of in-situ reactive wall groundwater treatment systems on remediation projects continues to gain acceptance. Such systems are attractive due to their low initial capital costs and their minimal operation and maintenance costs compared to traditional pump and treat systems. These systems often are used as a polishing step to groundwater treatment in conjunction with source removal and natural attenuation.

In constructing reactive wall groundwater treatment systems, various specialty construction techniques have been utilized. These techniques have included: deep soil mixing, bio-polymer trenching and slurry walls to successfully build funnel and gate systems with replaceable treatment cartridges as well as well as permeable treatment walls containing iron fillings. Such systems have been installed in full-scale and pilot scale applications for various private companies, the Department of Energy and the United States Air Force and others. Several case histories are presented to illustrate these various installation techniques and their applications.

INTRODUCTION

In the 1980's and early mid 1990's, the selected groundwater remedy for many environmentally challenged sites consisted of various pump and treat systems. These systems generally consist of a series of groundwater collection trench to capture or contain a groundwater plume. The contaminated groundwater is then pumped above ground to a groundwater treatment plant for removal or treatment of the contaminants. The groundwater is then wither re-injected into the ground through a system of injection walls or distribution gallery, or discharged into a stream or river through a NPDES permitted discharge point. Depending on the contaminants, the treatment system typically consisted of stripping towers, metal precipitators, bioreactors, and carbon adsorption. These systems are housed in a treatment building and have a typical design life of 20 to 30 years. Groundwater pump and treatment systems are commonly associated with reasonably high capital costs and long-term operation and maintenance costs, which are sometimes significant. Other issues with these systems include air permits, NPDES discharge permits and off-site disposal issues.

In-situ reactive wall groundwater treatment systems, also known as permeable reactive barriers[1] (PRBs), are subsurface permeable barriers that contain a reactive material to treat contaminated groundwater in-situ. The locations of these barriers are such that the existing hydraulic gradient of the groundwater is utilized to pass the groundwater through the treatment media, resulting in a passive treatment system. The advantages of such a system primarily consist of significantly reduced operation and maintenance costs (i.e. no power requirements, building heating or maintenance, or pumps and process equipment to maintain and repair.) Often, operation costs are limited to monitoring only. In addition, no air or NPDES permits are required and off-site disposal is either eliminated or significantly reduced.

Because of the inherent advantages, PRBs have been the focus of many pilot studies using a variety of treatment media and configurations. There are currently over two dozen full-scale installations across the United States, Europe, Australia, with more planned.

PASSIVE REACTIVE BARRIER SYSTEMS

PRB systems can generally be divided into the following general types:

- Continuous Wall
- Funnel and Gate
- Passive Collection with Treatment Reactors
- Injection Well Barriers

Continuos wall PRBs do not impede groundwater flow and eliminate the concern of mounding. Figure 1 shows a generalized section of this system. Where contaminants are primarily light aqueous phase liquids (LNAPLs or “floaters”), a hanging PRB may be installed to intersect only the top contaminated portion of the groundwater. Installation techniques for installing the treatment media consists of traditional excavation and backfill techniques and the use of caisson drilling techniques. More innovative and cost effective techniques include the use of one-pass trenching machines and the use of biodegradable polymer (biopolymer) slurry trenching techniques. Other techniques in pilot-scale stages include deep soil mixing, high-pressure jetting and hydraulic fracturing techniques.

Funnel and gate systems consist of a series of PRB sections or “gates” separated by vertical groundwater barriers or “funnels”. The funnels are used to direct the groundwater into the gates for treatment. These funnels can be constructed using a variety of installation techniques that include:

Slurry Walls

Steel Sheet Pilings with Grouted Interlocks

Waterloo Barrier™ Sheet Piling

HDPE Composite Walls

The types of slurry walls successfully used include; soil-bentonite and cement-bentonite slurry walls, and slurry walls installed using the vibrated –beam method. Figure 2 shows a combination collection trench and HDPE barrier wall constructed at the Oak Ridge, Tennessee DOE facility. This composite collection trench/groundwater barrier was constructed using biopolymer slurry trenching techniques.

Passive collection PRBs with treatment reactors is where a series of underground treatment reactors are substituted in lieu of reactive gates. The reactors can be plumed together in series or parallel to permit the periodic change-out of the treatment media. This system is typically used where activated carbon is the treatment media.

Injection well barriers involve the use of a line of injection wells to inject a treatment media, such as nutrients to create a biofilm barrier[2] or oxygen releasing compounds[3] to help biologically degrade contaminants. In-situ recirculating wells are often used with this system.

TREATMENT MEDIA

Successfully used treatment media in PRB systems have included

Zero-Valent Iron

Limestone

Activated Carbon

Various Biological Nutrients

Oxygen and Hydrogen Releasing Compounds

Zero-valent iron (iron fillings) is presently the most widely used treatment media and Environmental Technologies Inc. of Ontario, Canada licenses its use[4]. This treatment media is used on the degradation of chlorinated solvents, such as TCE and PCE using an abiotic reductive dehalogenation process. Two of these iron filings PRB systems have been installed using biopolymer trenching techniques in lieu of more expensive conventional trenching techniques that require the use of trench boxes or temporary sheeting and shoring.

Limestone, which has been used to treat acid mine runoff in the mining industry, can be used as a treatment media to increase pH. An increase in the groundwater pH can help immobilize some dissolved metals in groundwater.

The use of activated carbon has a long term track record of removing various contaminants in aboveground water treatment systems. Through the use of subsurface reactors, this treatment media can be periodically replenished in PRB systems.

The injection of various biological nutrients into an injection well barrier or distribution trench can also be used for the in-situ treatment of groundwater. One such recent application involved the injection of a solution of diluted blackstrap molasses to enhance microbial reduction of dissolved metals into less soluble versions. In this application, hexavalent chrome was reduced to trivalent chrome and then to chromium hydroxide[5].

Oxygen and hydrogen releasing compounds have been used in injection well barriers on a large number of sites. In addition to PRB application, this technology has been used on numerous sites across the country.

Currently, several treatment materials for sequence treatment are being considered in PRB applications where groundwater plumes contain a mixture of contaminants.

CASE HISTORIES

To illustrate actual applications of some of these various PRB techniques, presented below are three recent case histories on which the authors have been involved.

Tifton, GA.

At a Superfund site in southern Georgia, a pilot-scale in-situ groundwater remediation system was installed. This system consisted of slurry wall, installed using the vibrated beam method, groundwater collection and distribution trenches, and three concrete treatment reactors.

The vibrated beam slurry cutoff wall was installed on the down-gradient side of the collection trench. This resulted in mounding the groundwater to provide sufficient head pressure to move the groundwater from the collection trench into and through the reactors.

The reactors contained a granular activated carbon used to remove pesticide contamination form the groundwater. As figure 3 illustrates, the vaults and collection trench were connected via a network of piping and valves, which ultimately transported the treated water to a distribution trench, where it is introduced back into the groundwater.

Carbon replacement is performed by shutting off flow from the primary reactor and re-directing flow through one of the secondary reactors during carbon change-out.

The total installation cost for this system, excluding design, permitting and carbon materials was approximately $500,000.

<u>Fort Bragg, CA</u>

In northern California, a funnel and gate project was constructed to treat contaminated groundwater at a former wood-treating site[6]. The funnel/gate consisted of a 600 foot long 25 foot deep-bentonite slurry wall, which was penetrated in four areas by activated carbon gates. These gates collected impact water through gavel collection trenches and then discharged the water through pipes in the slurry wall into gravel-filled infiltration galleries as shown in Figure 4.

The combined flow rate through all four gates was 20 gallons per minute. The time between carbon changeouts was selected to be 4 years, based in estimated concentrations and volume of carbon. Monitoring points were located before, within, and after the treatment gate to assure that water-quality objectives were not exceeded. Whenever the mid-gate measuring point exceeded water-quality objectives, the carbon in that gate was removed and replaced.

Carbon replacement was easily achieved by vacuuming out the wet spent carbon as slurry, using aboveground slurry pumps. After dewatering the gate using the upgradient monitoring well, dry fresh carbon is poured into the gate.

The cost of this system, including design, permitting and installation was less than $500,000.

<u>Cape Canaveral, FL.</u>

In one of the first know applications of its kind a combination of deep soil mixing and vibro-installation techniques was recently utilized to construct a PRB at a government facility located in eastern Florida. This pilot program determined the feasibility of in-situ treatment of local groundwater contamination consisting of chlorinated solvents using iron filings, and an alternative installation method for the construction of a PRB. Figure 5 shows a plan and isometric view of this system.

To create the PRB, a series of 6 inch diameter casings were first driven using a vibratory hammer form the ground surface to the confining layer which was located at a depth of approximately 40 feet. The iron filings were them gravity fed into the casings for their full depth. The vibratory hammer was then used to extract the casings, leaving a column of iron filings in-place. The depth of soil mixing equipment (Figure 6) equipped with a 5 foot diameter auger was then used to blend the columns of iron filings with the sandy soils to create a continuos treatment wall.

The total installation cost for this pilot system, excluding design, permitting and iron filings was approximately $200,000. The cost of iron filings is typically in the $425 to $450 pre ton range and has a field bulk density ranging from 140 to 180 pounds per cubic foot.

CONCLUSIONS

As the number of pilot-scale and full-scale installations increase and long-term performance data becomes available, this technology is expected to continue to gain regulatory acceptance and additional applications to various sites across the country. Proper site characterization and modeling are critical foe the success of this technology to any particular site.

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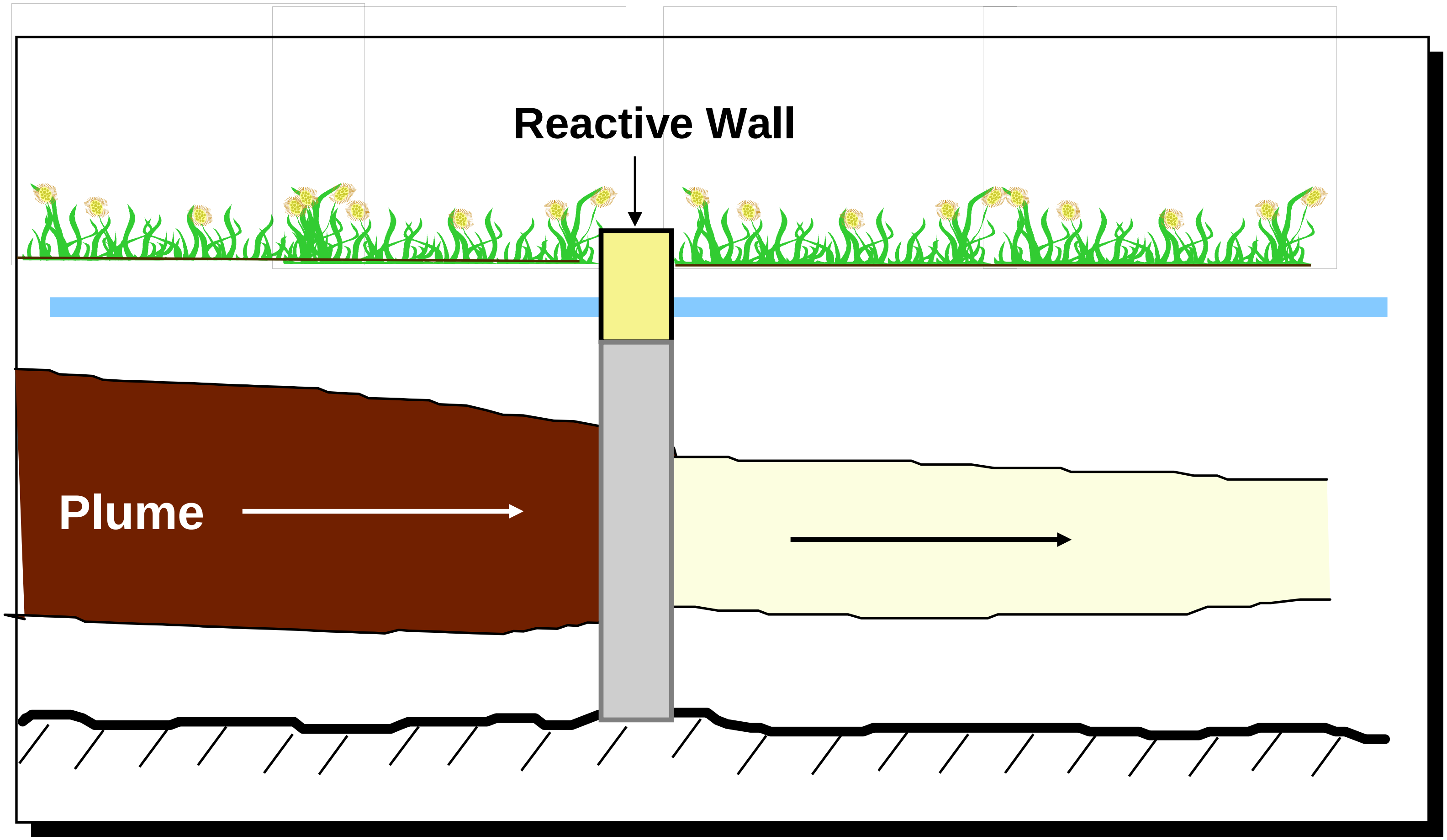


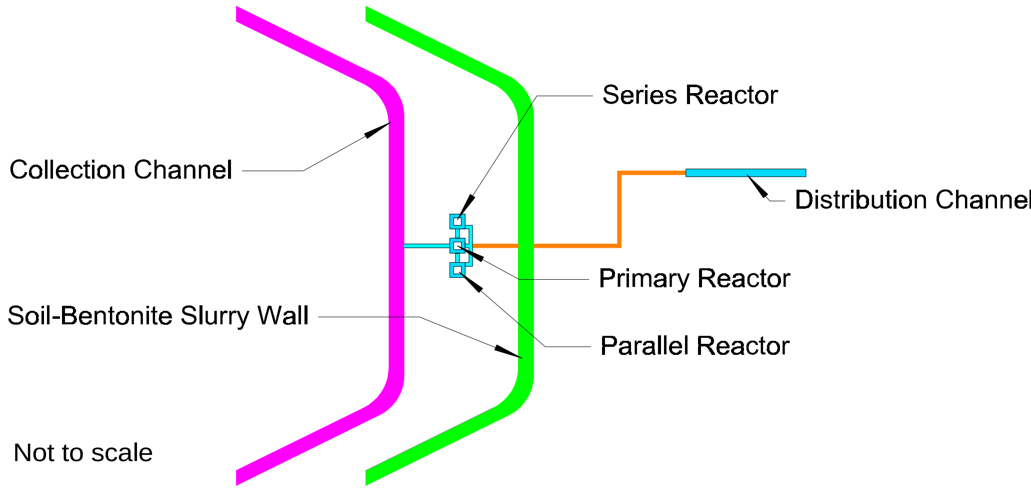
Figure 1

Courtesy of environmetal technologies inc.

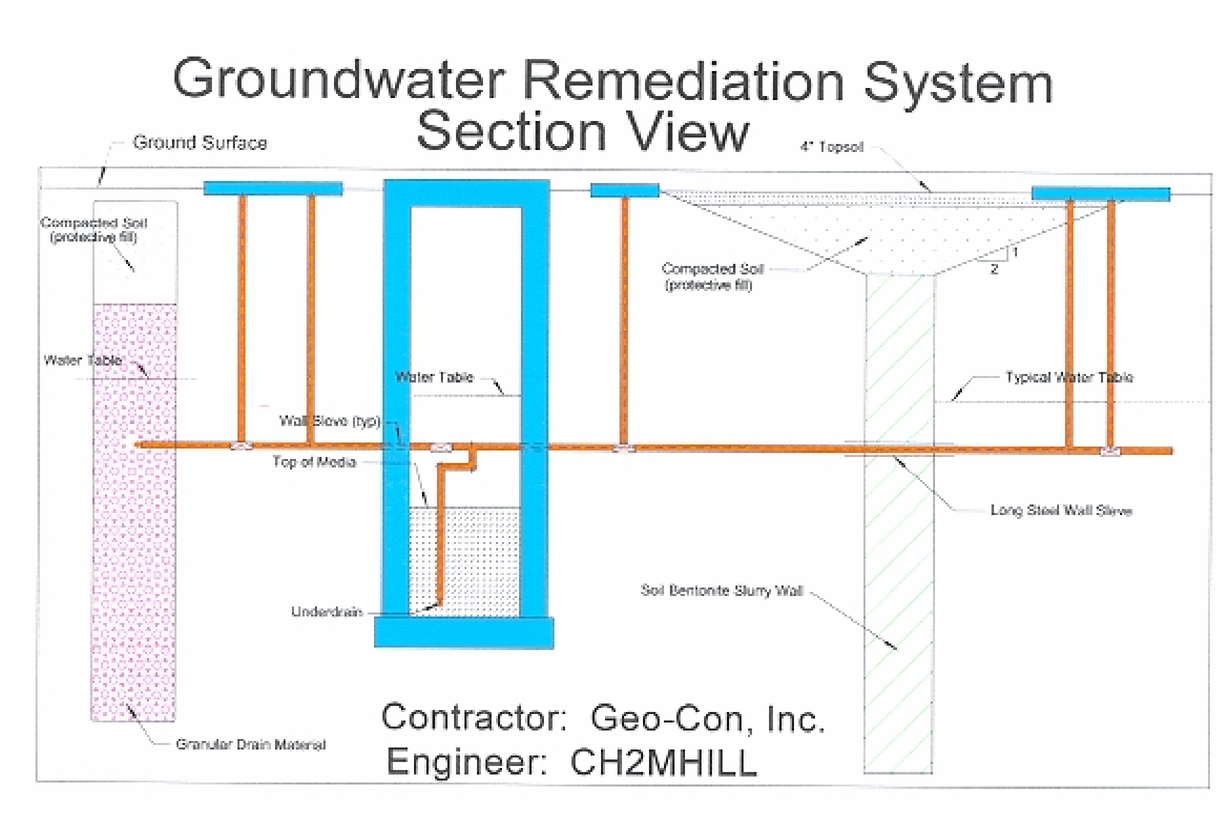
HDPE Curtain Wall/Collection Trench
Oak Ridge, Tennessee

Figure 2

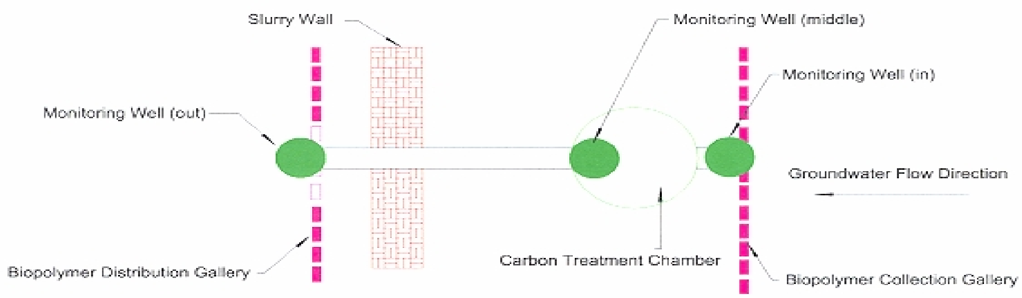
Groundwater Remediation System
Plan View



Marzone Superfund Site
Tifton, GA

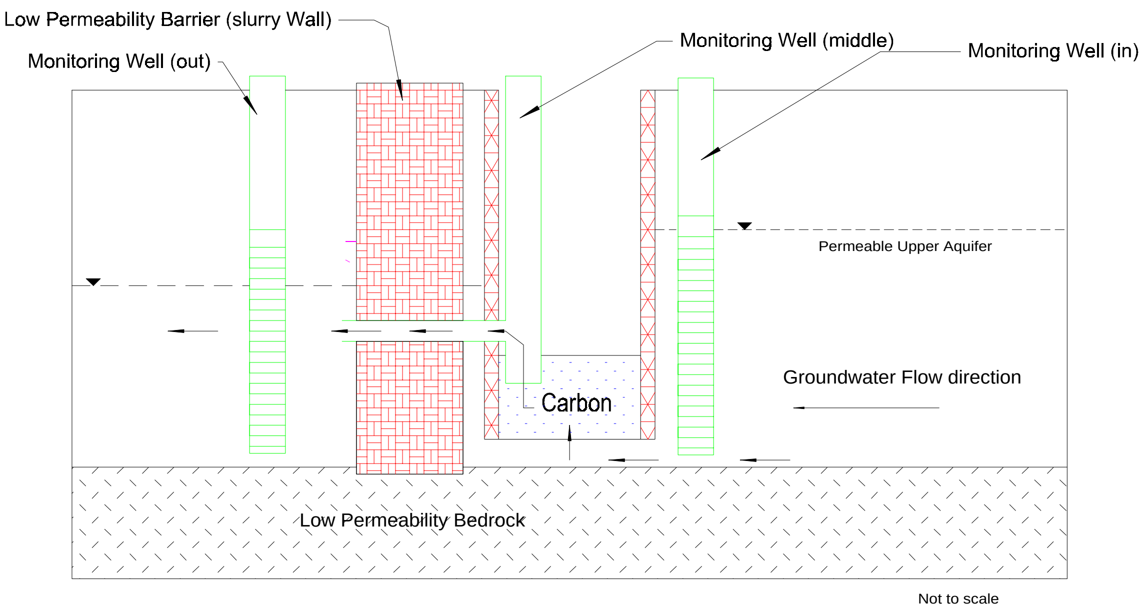


Funnel and Gate Remediation System
Plan View



Contractor: Geo-Con, Inc.
Engineer: Geraghty & Miller, Inc.

Funnel and Gate Remediation System
Section View



Contractor: Geo-Con, Inc.
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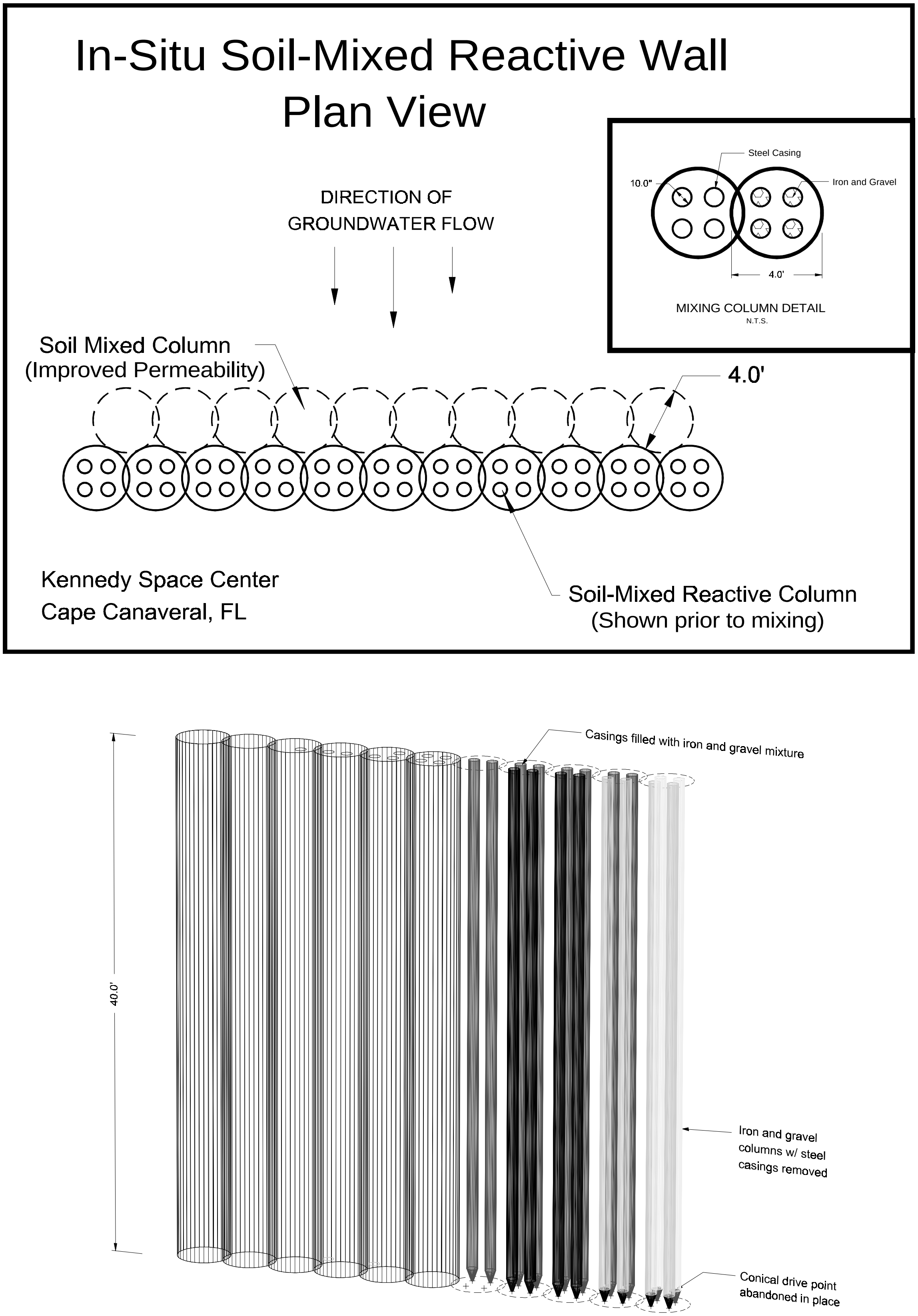
Figure 4



IRON FILING COLUMNS

Figure 5

Soil Mixing Equipment
Cape Canaveral, Florida

Figure 6