STATE OF THE ART IN BIO-POLYMER DRAIN CONSTRUCTION

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ABSTRACT

A common feature of civil engineering design is the "french drain," a trench intended to intercept and collect groundwater and transfer it laterally to a sump. The environmental marketplace ahs created a larger demand for these drains for the purpose of the collection of contaminated groundwater. Traditional construction methods that use trench boxes or shoring, sometimes in combination with dewatering systems, present a number of problems, particularly if the trenches have depths in excess of about five meters.

The Bio-Polymer Slurry Drain (B-P Drain) has provided a new method for construction deep drains that eliminates shoring and dewatering. It does not require a wide excavation, reducing spoil disposal and does not require trench entry by workers, improving safety.

The system uses basic slurry trench technology but, instead of bentonite clay slurry, a guar gum based slurry is used to maintain the open trench. Once the trench is dug to full depth, it is backfilled with a pervious material such as gravel. Wells can be inserted, pipe laterals can be placed, and filter fabric inserted, all under slurry. When the trench is filled, the slurry is chemically and biologically "broken", allowing the slot to collect water.

This paper reviews the current practice as illustrated by these case studies: a collection trench for oil, another for a chemical containment, and a drain constructed inside a slurry wall at a landfill site. The authors believe that this methodology will be subject to wide application once all of its features and advantages are fully realized.

KEYWORDS: Bio-Polymer, drains, groundwater, collector wells, slurry, construction

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INTRODUCTION

One of the most difficult civil engineering projects has always been the construction of deep drains. By definition, these are constructed through soil profiles with flowing groundwater. Control of the excavation side slopes and construction dewatering are difficult problems. Trench collapse is a leading cause of construction worker injury and death.

The concept of trenching under a slurry has been an intriguing technology. The use of slurries to hold open trenches for impervious barriers and structural concrete slurry walls has been common practice for more than thirty years. In a drain application, however, the bentonite clay slurries commonly used would seal the trench walls from water inflow and defeat the purpose of the drain.

Use of biodegradable slurries has changed the technology. Now trenches can be excavated under slurry, backfilled with a pervious mixture, and the slurry degraded to allow for water infiltration.

To the authors' knowledge, the first U.S. use was project in San Jose, California. A B-P Drain, 17m deep and 200m long, was constructed to collect a diesel spill (Hanford and Day, 1988). Numerous additional applications have been completed in the U.S. market, almost all for environmental cleanups (Day, 1990). A similar process had apparently earlier been used to construct drains for dewatering and slope stabilization in France (Bachy, 1982).

The B-P Drain technique provides numerous advantages over conventional construction, some of which are listed below:

<u>Economy</u> – Because the technique does not require dewatering nor sheeting and shoring, it is considerably cheaper to install. Typically, it costs less than half of conventional construction.

<u>Schedule</u> - For the same reasons, the time of construction is much less than for conventional trenching methods.

<u>Safety</u> – Since no one enters the excavation with the B-P Drain method, the method is much safer. There is also less potential for damage to surrounding structures from excavating or dewatering activities.

<u>Environmental</u> – Since most applications are on contaminated sites, another important advantage of the B-P Drain is that it is narrower and generates less excavation spoil. There is also no water generated by temporary dewatering systems.

In the following sections, we look at construction methods, technical factors, and several example case studies.

CONSTRUCTION METHODS

A Bio-Polymer slurry drainage trench (or B-P Drain) is constructed using a modified version of the slurry trench technique. The trench is excavated under slurry using an extended reach hydraulic excavator creating relatively narrow (0.5 to 1.0 meters) trenches up to 20 meters deep. Trench stability is temporarily provided by a polymer based slurry. A permeable backfill (gravel) and extraction structures (wells) are placed in the trench, through the slurry, to complete the construction. Later, the slurry degrades, permitting groundwater to flow through the trench for extraction or injection.

Polymer Slurry

Critical to successful B-P Drain construction is the maintenance and control of the slurry. Guar gum based slurries normally remain effective for only about one day unless treated with additives. Slurry life is affected by atmospheric conditions, soil types, and construction expertise. Typically, a mud engineer or slurry trench specialist trained in the use and control of Bio-Polymer systems directs the slurry mixing. Standard tests include viscosity and filtrate (API 13B) along with other slurry tests specified by ASTM D4380. Slurry treatment primarily consists of the addition of pH modifiers and preservatives which can extend the life of the slurry to as much as a few weeks.

Guar gum-based slurries provide a high gel strength (Viscosity >40cP) and low water loss (filtrate <25 ml) which permits the efficient transfer of the elevated hydrostatic head of the slurry to the trench walls thereby providing stability. Most soil types can be supported, as long as a slurry head of1 meter or more can be maintained in the trench over the local groundwater table.

As an alternative to the guar slurries, there are some synthetic polymers that can be degraded in a similar fashion. To date, synthetic polymers have seen only limited use and only in applications where trench stability is not critical. Synthetic polymers have a very low gel strength (viscosity <15 cp) and high water loss (filtrate >50 ml); therefore, they are limited to cases with more stable trench geometry and inherently stable soils. Care must be used in the selection of synthetic polymers since some create toxic byproducts when degraded. With continued research, synthetic polymers may prove useful on a wider variety of sites.

After the trench is backfilled, the Bio-Polymer slurry must be treated to initiate degradation and the trench flushed to develop the drain. The efficiency of trench flushing is a function of site conditions and the efforts of the contractor. A highly permeable soil and warm weather will encourage rapid flushing and result in limited excess slurry for disposal. Usually, degraded slurry is used to flush and develop the drain by pumping and recirculating at least three pore volumes of the trench. Simple drawdown tests can be use to demonstrate the effectiveness of the development.

In most cases, a small proportion of degraded slurry will remain as excess and must be evaporated, solidified, or disposed of at a wastewater treatment facility. The BOD (biological oxygen demand) and COD (chemical oxygen demand) of the degraded slurry are similar and initially in the range of 3,000 to 6,000 mg/l. As the degradation continues and with successful initial degradation, the BOD may decrease to 1,000 mg/1 in a week and eventually (about six months) to background levels.

Backfill

Depending on the purpose and design of the drainage trench, different materials can be placed through the slurry into the trench to serve as the permanent, permeable backfill. A typical backfill is a clean, washed gravel such as pea gravel or crushed stone. A backfill with an engineered gradation or a filter fabric envelope can be used when the surrounding soil conditions would cause plugging or silting.

The backfill is placed through the slurry via tremie pipe or by sliding the backfill down the slope of the previously placed backfill to displace the slurry and minimize segregation. Sands and finer backfills must be prewetted to be tremied while coarser backfills, such as pea gravels, can be placed dry. Tremie placement should be used around wells and other structures to ensure accurate alignment.

Woven filtration fabrics are preferred over other geotextile since the degraded slurry can be flushed from the weave. Placement of geotextile in a slurry-filled trench requires special equipment and procedures. Geotextile will naturally float and so they must be weighted to be placed through slurry. Concrete weights and temporary frames are most often used to facilitate placement and provide ballast. End tubes may also be used to still wave action in the trench which can disturb placement efforts. Continuity of the geotextile is provided by overlapping the sheets.

Usually, the backfill is extended up to near the surface and always above the water table. Typically, the top 1 to 2 meters of the trench is backfilled with excess trench spoil or other soil to cap the trench and limit surface water infiltration. This zone may also support buried vaults, discharge piping, and pump controls.

Extraction Structures

The most economical means of removing collected groundwater in a B-P Drain is through well casings with pumps. With a permeable backfill, wells can be spaced about 100 meters apart. Stainless steel, galvanized steel, polyvinylchloride and polyethylene well casings have all been used successfully. Groundwater chemistry may dictate the selection of nonmetallic materials or other special considerations in extremely corrosive groundwaters. Inexpensive submersible, progressive cavity, or ejector pumps are available which can operate in corrosive groundwaters and pump at the very low extraction rates (35 1pm or less) required in most applications.

For a limited number of cases, a horizontal drainage pipe may be required along the bottom of the trench. The utility of horizontal pipes for groundwater collection is often overestimated. Drain pipes must have perforations which may be more restrictive than gravel alone in transmitting groundwater. Closer well spacing and deeper trenches can almost always provide equal performance and a lower initial cost and with reduced maintenance costs. In most groundwater extraction applications, the presence of pipe in a gravel-filled trench does not affect the performance of the system and is redundant.

In those few instances where a drainage pipe is required, special pipe-laying equipment of a design similar to cable-laying equipment is used. The pipe, of course, must be fully flexible and corrugated for strength. A separate pipe-laying machine travels over the slurry-filled trench behind the excavator, laying the pipe through the slurry while simultaneously bedding and backfilling around the drain pipe through a tremie. Pipe grade is controlled by survey control of the pipe laying boom. Small diameter sumps or wells (100 to 600 mm diameter) are either attached directly to the drain pipe or place directly beside the drain pipe perforations for continuity.

Experience has shown that laying a drain pipe using weighted sections can also be used but only in very short (15 meters or less) trenches which can be placed in a single step. In longer sections, the buoyancy of the flexible pipe creates folds at the end of each weight, which become crimped when the trench is backfilled. Since all work is performed in the blind, under slurry, breaks in the pipe cannot be easily detected and repairs are extremely difficult and costly. Purpose-built pipe-laying equipment is recommended for al but the shortest trenches.

In general, conventional manholes or lift stations are not recommended for a number of reasons. First, conventional manholes constitute a confined space which can allow unauthorized access. Second, pumps, control facilities, and access to same can be provided through conventional well equipment at a much lower installation cost. Duplex systems can be provided using multiple well casings for backup pumps. Third, conventional manholes must be constructed by conventional means (sheeting, shoring and dewatering) negating a significant portion of the savings provided by the B-P Drain installation. Finally, concrete manholes are sealed structures which are only attached to the drain field through the perforated pipe. A much larger radius of influence can be provided by using a perforated sump or well, and in the case of failure of the drainage pipe, the perforated sump or well provides a safety factor for ensuring the continued service of the drainage trench.

CASE STUDIES

Most B-P Drains are installed to collect contaminated groundwater where the depth of the excavation makes conventional trenching impractical and soil conditions make well fields ineffective. A wider application of the B-P Drain method is possible when the designer and the specialty contractor work together to fully exploit the advantages of the technique. The following case studies portray some of the more complicated systems installed to date and illustrate the potential for B-P Drains on other sites.

Oil Skimmer in South Texas

A refinery had to collect floating waste oil which was leaving the site and appearing as a sheen on the adjoining Houston Ship Channel. A high water table, numerous utility lines, full soils, and limited working space made conventional excavation difficult and expensive. The B-P Drain method was selected to create a deep trench in which was placed a geomembrane barrier to block oil seepage, while still allowing a clean groundwater to pass under and into the waterway. Wells were placed in the trench to remove floating product which was collected by the barrier. Figure 1 shows a schematic of the completed system.

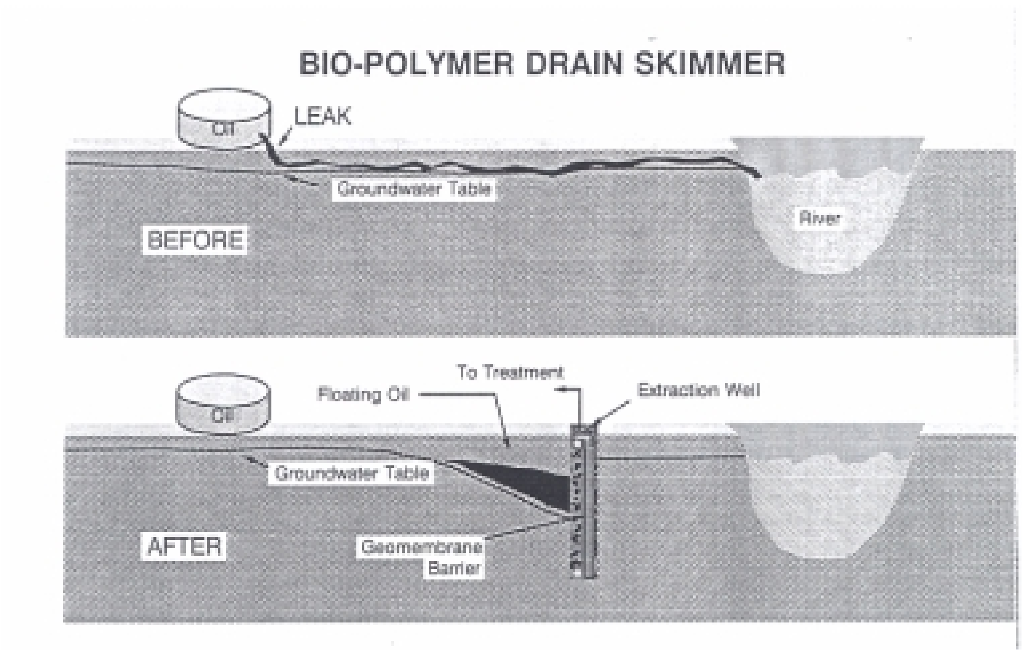

Figure 1. Schematic of Oil Skimmer Interceptor Trench

Geomembrane panels were prefabricated and HDPE joints welded to the membrane. The panels were stretched over frames which held the geomembrane during installation and jointing. An interlocking dovetail joint was used which was later grouted to complete the seal.

A trench 400 meters long and 6 meters deep was constructed between the waterway and the plant access roadway. The installation sequence for placing the geomembrane panels is shown in Figures 2 and 3. Due to the presence of the geomembrane, extensive development of the rain was required to ensure adequate flushing behind the barrier. The installation schedule was about one month.

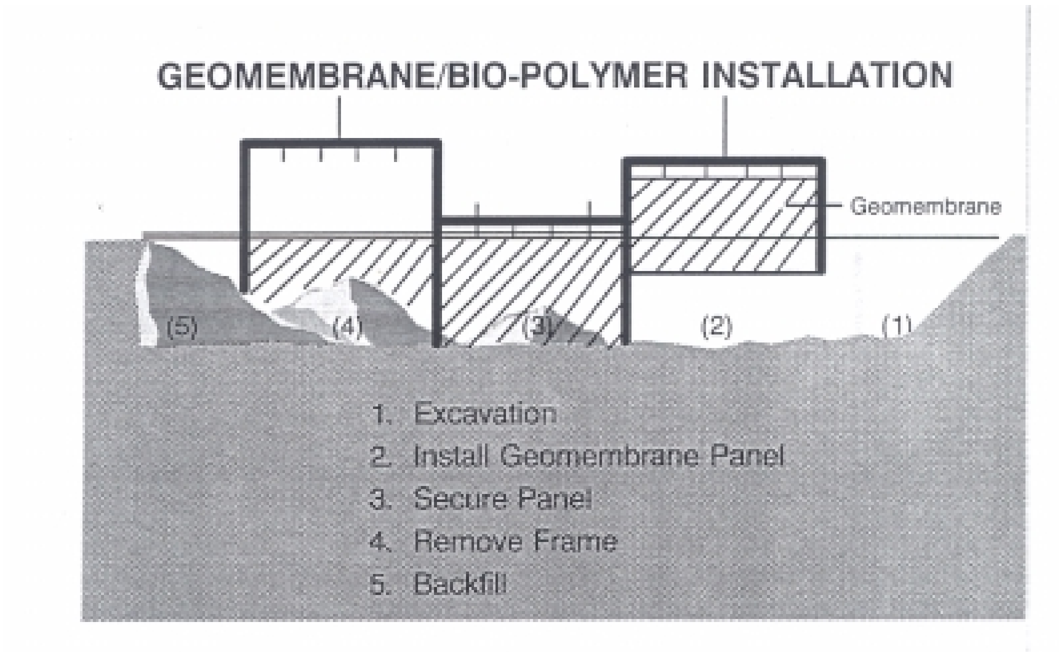

Figure 2. Sequence for Installation of Geomembrane in Bio-Polymer Trench

Figure 3. Installation of Geomembrane Panel

Collection Trench in Northern California

A major manufacturing plant needed to contain a plume of spoiled processing chemicals. An on-site treatment and containment system was designed which called for a down-gradient, soil-bentonite slurry wall and B-P Drain. Due to regulatory requirements, a horizontal drainage pipe was included in the design. Well casings were placed at 100m intervals, and cleanouts for the pipe were provided near the wells. A cross-section of the parallel trenches is shown in Figure 4.

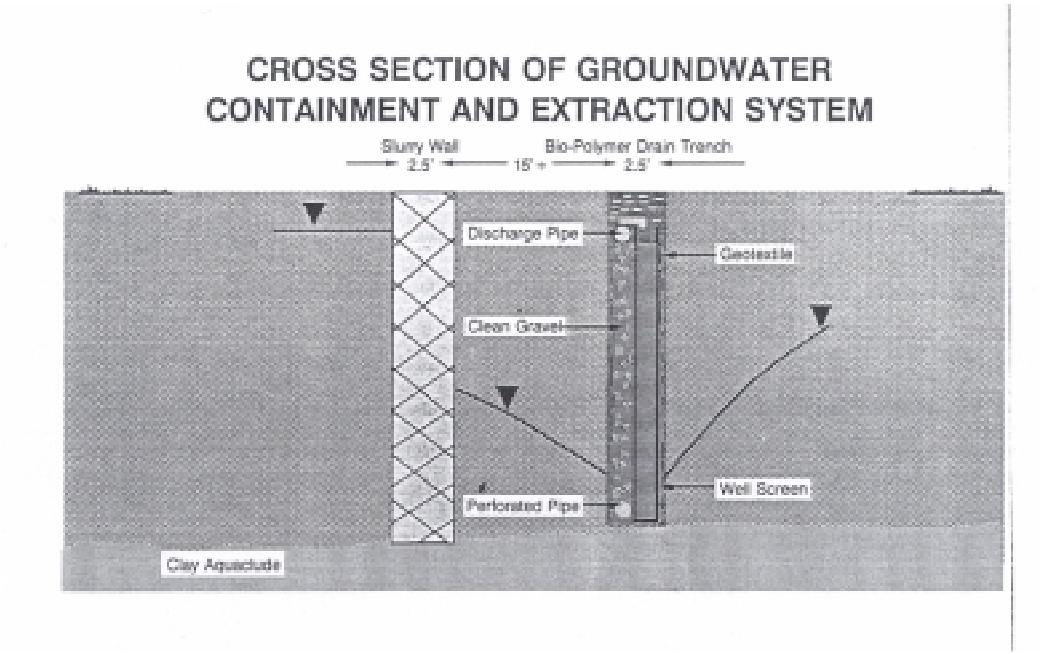

Figure 4. Cross Section of Groundwater Containment System

A drought in the area made it necessary to use runoff water as the slurry mixing water. The water had to be sterilized to limit biological growth and along with the hot summer weather, increased additive requirements to protect the slurry from premature degradation.

the B-P Drain was constructed through clays and silts up gradient and parallel to the cutoff wall. The trench was excavated 0.75 meters wide and about 9 meters deep and lined with a woven geotextile. The pipe laying machine (Figure 5) laid and bedded a 150mm diameter perforated pipe through the slurry. Extraction wells 300mm in diameter and 100mm diameter monitoring wells were placed in the trench alongside the perforated pipe. Construction time for the project was less than two months.

Figure 5. View of Pipe Installation in Bio-Polymer Trench

Landfill Dewatering In Ohio

A nuclear fuels processing plant had a mixed waste landfill that required closure. Plumes of contaminants were caused by the fluctuations in the groundwater table saturating the base of the landfill. The remedy was to construct a soil-bentonite slurry wall up gradient and a B-P Drain parallel to the landfill to divert groundwater and finally cap the landfill to prevent infiltration. A schematic of the dewatering plan is shown in Figure 6.

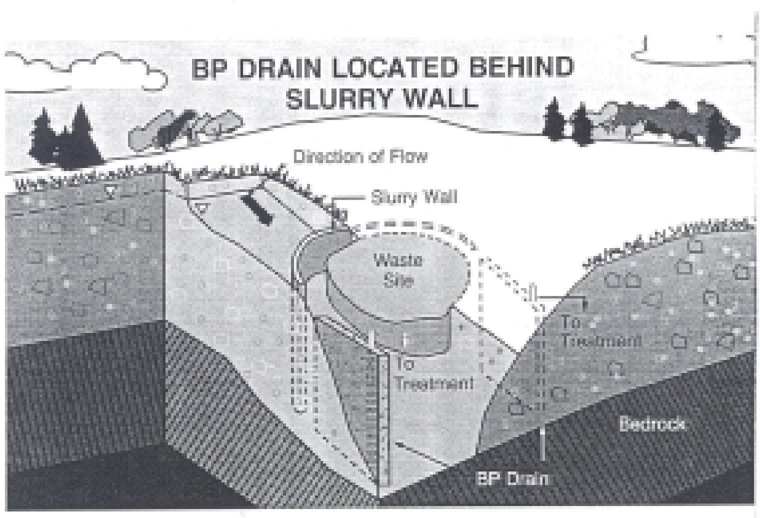

Figure 6. Schematic of Slurry Wall and Bio-Polymer System to Dewater Landfill

Regulatory deadlines made it imperative to perform the construction in the winter. The cold weather made it difficult to pump and mix the slurry and complicated efforts to degrade the slurry.

A soil-bentonite slurry wall 250 meters long and two 125 meter long B-P Drains were constructed up to 15 meters deep. Each B-P Drain was one meter wide, lined with a woven geotextile, and equipped with a single extraction well. After nearly a year of operation, each trench produces a steady 19 lpm (5 gpm). A photo of the installation is shown in figure 7, construction of all trenches required less than one month.

Figure 7. View of Slurry Trench Installation

CONCLUSION

The B-P Drain methodology provides anew means for constructing difficult deep drains. Where appropriate, they also provide significant savings of time and money, as well as improving worker safety and general environmental exposure. The projects completed to date have generally been for environmental containment purposes, although the process lends itself to civil works as well. We see a considerable potential for future applications of this technique.

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