Groundwater Barriers and Outlets

A. Introduction

When there exists a possibility that groundwater may be diverted and follow the path of the new sewer, groundwater barriers should be constructed in adequate numbers to prevent groundwater migration down sewer trenches.

Subsurface barriers are designed to prevent or control groundwater flow into, through, or from a certain location. Barriers keep fresh groundwater from coming into contact with a contaminated aquifer zone or ground water from existing areas of contamination from moving into areas of clean groundwater. Usually it is necessary to incorporate other technologies, such as pump-and-treat systems, with groundwater barriers.

B. Groundwater Barriers

The types of barriers commonly used include:

- Slurry trench walls
- Grout curtains
- Vibrating beam walls
- Bottom sealing
- Block displacement
- Sheet piles
- Sheet curtains

1. **Slurry Trench Walls:** Slurry trench walls are placed either upgradient from a waste site to prevent flow of groundwater into the site, downgradient to prevent off-site flow of contaminated water, or around a source to contain the contaminated groundwater. A slurry wall may extend through the water-bearing zone of concern, or it may extend only several feet below the water table to act as a barrier to floating contaminants. In the former case, the foundation should lie on, or preferably in, an underlying unit of low permeability so that contaminants do not flow under the wall. A slurry wall is constructed by excavating a trench at the proper location and to the desired depth, while keeping the trench filled with a clay slurry composed of a 5% to 7% by weight suspension of bentonite in water. The slurry maintains the vertical stability of the trench walls and forms a low permeability filter cake on the walls of the trench. As the slurry trench is excavated, it is simultaneously filled with a material that forms the final wall. The three major types of slurry backfill mixtures are soil bentonite, cement bentonite, and concrete. Slurry walls, under proper conditions, can be constructed to depths of about 100 feet.

   Slurry trench walls are reported to have a long service life and short construction time, cause minimal environmental impact during construction, and be a cost-effective method for enclosing large areas under certain conditions. A concern regarding the use of a slurry wall where contaminated materials are in direct contact with the wall is the long-term integrity of the wall. In such cases, the condition of the wall needs to be verified over time by groundwater monitoring.

2. **Grouting Curtains:** Grouting is the process of pressure-injecting stabilizing materials into the subsurface to fill, and thereby seal, voids, cracks, fissures, or other openings. Grout curtains are underground physical barriers formed by injecting grout through tubes. The amount of grout needed is a function of the available void space, the density of the grout, and the pressures used in setting the grout. Two or more rows of grout are normally required to provide a good seal. The grout used may be either particulate (i.e., portland cement) or chemical (i.e., sodium silicate) depending on the soil type and the contaminant present. Grouting creates an effective barrier to groundwater movement, although the degree of completeness of the grout curtain is difficult to ascertain. Incomplete penetration of the grout into the voids of the earth material permits leakage through the curtain.

3. **Vibrating Beam Walls:** A variation of the grout curtain is the vibrating beam technique for placing thin (approximately 4 inches) curtains or walls. Although this type of barrier is sometimes called a slurry wall, it is more closely related to a grout curtain since the slurry is injected through a pipe in a manner similar to grouting. A suspended I-beam connected to a vibrating driver-extractor is vibrated through the ground to the desired depth. As the beam is raised at a controlled rate, slurry is injected through a set of nozzles at the base of the beam, filling the void left by the beam's withdrawal. The vibrating beam technique is most efficient in loose, unconsolidated deposits, such as sand and gravel.

4. **Bottom Sealing:** Another method that uses grouting is bottom sealing, where grout is injected through drill holes to form a horizontal or curved barrier below the site to prevent downward migration of contaminants.

5. **Block Displacement:** Block displacement is a relatively new plume management method, in which a slurry is injected so that it forms a subsurface barrier around and below a specific mass or "block" of material. Continued pressure injection of the slurry produces an uplift force on the bottom of the block, resulting in a vertical displacement proportional to the slurry volume pumped.

6. **Sheet Piles:** Sheet pile cutoff walls have been used for many years for excavation bracing and dewatering. Where conditions are favorable, depths of 100 feet or more can be achieved. Sheet piling cutoff walls can be made of wood, reinforced concrete, or steel, with steel being the most effective material for constructing a groundwater barrier. The construction of a sheet pile cutoff wall involves driving interlocking sheet piles down through unconsolidated materials to a unit of low permeability. Individual sheet piles are connected along the edges with various types of interlocking joints. Unfortunately, sheet piling is seldom water-tight and individual plates can move laterally several to several tens of feet while being driven. Acidic or alkaline solutions, as well as some organic compounds, can reduce the expected life of the system.

7. **Sheet Curtains:** Membrane and synthetic sheet curtains can be used in applications similar to grout curtains and sheet piling. With this method, the membrane is placed in a trench surrounding or upgradient of the plume, thereby enclosing the contaminated source or diverting groundwater flow around it. Placing a membrane liner in a slurry trench application also has been tried on a limited basis. Attaching the membrane to an underlying confining layer and forming perfect seals between the sheets is difficult but necessary in order for membranes and other synthetic sheet curtains to be effective.

Source: The Pan American Center for Sanitary Engineering and Environmental Sciences, CEPIS.

C. Outlets

1. Where a storm sewer discharges into a natural channel or irrigation ditch, an outlet structure should be provided that will blend the storm sewer discharge into the natural channel flow in such a way as to prevent erosion of the bed or banks of the channel. As a minimum, all storm sewer pipes that outlet to drainageways will require flared end sections with apron guard for pipe diameters 18 inches or larger. Storm sewers 30 inches in diameter or greater require a footing at the outlet. Footings may be required for pipe diameters less than 30 inches.

2. In an instance where the discharge velocity is high (higher than those outlined in Section 2F-2, Tables 2F-2.03 and 2F-2.04) or supercritical, prevention of erosion of the natural channel bed or banks in the vicinity of the outlet requires an energy dissipating structure, such as:
   - Rip rap
   - Concrete slab
   - Gabions
   - Headwalls and wing wall with stilling basins
   - Flow transition mats

3. Outlets should drain at a receiving drainageway or connect to an existing storm sewer. Outlets should not drain across sidewalks or directly to streets. Outlets should not be located on slopes without adequate erosion protection and means of conveyance between the outlet and receiving drainageway or storm sewer. Erosion protection on a slope that does not extend beyond the outlet is often inadequate, as runoff velocity will increase down grade of the outlet.