Wall-and-Curtain for Subsurface Treatment of Contaminated Groundwater

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Abstract: A Permeable Reactive Barrier (PRB) facility, that can be hydraulically manipulated, was installed at Chalk River Laboratories in December 1998 to prevent a subsurface strontium plume from contaminating a wetland. This new technology is completely passive, allows flows and effluent concentrations to be measured directly and the groundwater capture zone to be adjusted. In the present application, a 28-m cut-off wall extends into till or to bedrock through a 12-m thick aquifer. Perforated piping backs granular zeolite in front of the cut-off wall. The elevation head in the perforated piping governs the amount and dimensions of the in-coming groundwater. Results have indicated predictable changes in capture-zone width and thickness with adjustments in elevation head and have indicated acceptable spatial variations of pore-water velocity within the PRB. This facility treats 1.51E+07 litres per year (7.6 gallons per minute), while controlling the diversion of 1.0E+07 litres per year of clean groundwater that overlies the plume and would otherwise enter the PRB. This facility has prevented the discharge of 1.85E+7 Bq of ^{90}Sr, has maintained pristine conditions in the adjacent wetland and is predicted to do so for 10 to 40 years.

In the early 1950's a pilot plant, on the property of Atomic Energy of Canada Ltd, Chalk River, Ontario, was operated to decompose and reduce the volume of ammonium nitrate solutions containing mixed fission products. As a result of difficulties with the pilot plant, some of these solutions were released into the ground through pits lined with crushed limestone. Hydrogeological investigations, performed or reported by Killey and Munch (1987), showed that the release of these solutions resulted in ^{90}Sr-contamination of a 400-m long section of aquifer and, by the mid to late 1990's, it appeared that contaminated groundwater would be passing beneath the margin of a wetland. The hydraulic conductivity of the aquifer is on the order of 9E-03 to 2E-02 cm/s, and the groundwater velocity is relatively rapid compared with the migration rate of ^{90}Sr.

PRB design goals were 1) to halt the migration of the ^{90}Sr before it could reach the wetland discharge area and 2) to provide the same high-quality monitoring of flow and concentration that is characteristic of pump-and-treat. Stopping or slowing the migration of ^{90}Sr was important because strontium behaves somewhat like calcium in biological systems, and the introduction of ^{90}Sr to wetlands results in an accumulation in vegetation and soils followed by release to down-stream water courses.

The PRB is called a Wall-and-Curtain (Figure 1) because it features a steel, sheet-pile, cut-off wall fronted by a curtain of granular reactive media. There is also a series of extraction wells along the front of the cut-off wall, behind the reactive curtain. A concrete manhole, adjacent to the wall and curtain, provides a low head volume and a control point for two drain pipes, one from the curtain and one from an up-gradient horizontal drain. The up-gradient drain was constructed to allow controlled removal of shallow uncontaminated groundwater and to reduce the total amount of

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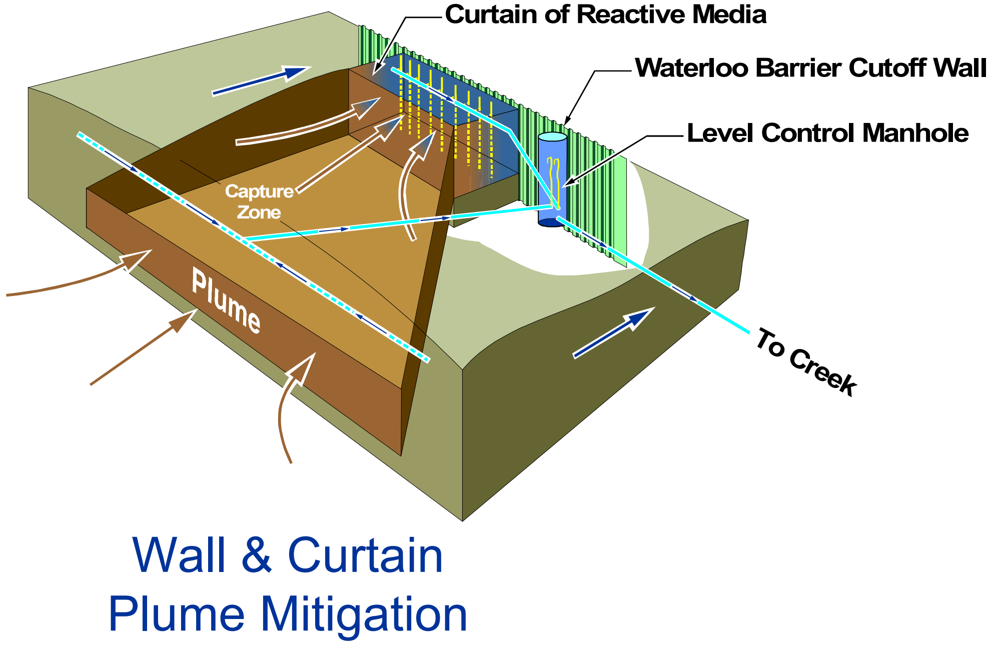
water entering the PRB and prolong its effectiveness. The level-control manhole drains via a subsurface pipe to a creek, located at a topographically lower elevation.

Figure. 1. Schematic of the Wall-and-Curtain PRB showing major components:



Numerical modeling provided a design framework and important visualizations of how the components of the Wall-and-Curtain could be used to manipulate a groundwater flow field (Lee et al., 1998). Sandbox modeling demonstrated the workings of the integrated physical system and provided a sense of the best construction sequence (Lee, 2000). Earlier studies (e.g. Cantrell, 1996 and Fuhrman et al. 1995) had suggested that a commercially available zeolite, clinoptilolite, would be an excellent candidate for preventing the migration of ^{90}Sr plumes. *In situ* tests of clinoptilolite using the field column method of Young et al. (1990) were performed within the ^{90}Sr-plume. Results showed that 14 x 50 mesh clinoptilolite would be suitable, both chemically and physically, for a PRB under the geochemical conditions of the site.

Construction of the Wall-and-Curtain was completed and the system was operating in December 1998. The facility (Figure 1) has a 28-m cut-off wall; an 11-m wide, 2-m thick curtain (118 cubic meters) of granular clinoptilolite and ten extraction wells connected to the control manhole. The extraction wells provide a constant-head boundary at the back of the reactive material. The elevation head in wells is controlled by the elevation of the outlet overflow located in the control manhole. The up-gradient drainage, with its own elevation control, diverts shallow, uncontaminated groundwater away from the PRB.

Performance has been nearly flawless since the system began operating. The Wall-and-Curtain PRB treats 1.51E+07 litres per year (7.6 gpm) of contaminated groundwater, while diverting 1.0E+07 litres per year of clean groundwater. The groundwater entering the system contains ^{90}Sr at concentrations of 0.1 to 100 Bq/L. The water flowing out of the system meets Canadian drinking water quality guidelines, and the facility has prevented the discharge of 2.7E+09 Bq of ^{90}Sr into the adjacent wetland over the past two years.

Leakage beneath the wall is 0.8 gpm. This is not surprizing because there was little or no low permeability material into which the steel wall could be keyed and the sheet pilings were not grouted to the bedrock. Leakage may or may not be serious because the contaminated water can be preferentially drawn into the PRB. However, if leakage can be significantly reduced, future performance monitoring will be simplified and confidence that contaminants are not reaching the wetland will be improved.

By adjusting the flow rates of the PRB and then observing the altered water-table configurations, we established confidence that the plume was being captured as intended. Two tracer tests were also conducted to determine the flow paths immediately in front of the PRB. Monthly measurement of flow rates and analysis of samples from the two drainage pipes have shown that the Wall-and-Curtain is mitigating the discharge of ^{90}Sr to the wetland. The system demonstrates several principles of subsurface engineering that may have applications elsewhere: the utility of hydraulic manipulation, the value of controlling flow-rate and capture width, the use of up-gradient drainage to divert water that does not need to be treated, and the value of monitoring at a pipe outflow without the factor of 3 to 10 errors inherent in the Darcy method. Hydraulic adjustment can also be made to accommodate future changes in PRB permeability should that occur.

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