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# GROUNDWATER SUPPRESSION AND SURFACE WATER DIVERSION STRUCTURES APPLIED TO CLOSED SHALLOW LAND BURIAL TRENCHES[1]

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## ABSTRACT

Shallow depth to groundwater, surface drainage, and subsurface flow during storm events are major environmental concerns of low-level radioactive waste management operations in humid regions. At two waste disposal sites within the Oak Ridge National Laboratory (ORNL), groups of closed trenches have experienced these problems and have been shown to collect and hold water with seasonal fluctuations ranging from 1 to 2 m. In an attempt to correct these water-related problems, the older of the two sites [Solid Waste Storage Area Four (SWSA 4)] was equipped in September 1975 with asphalt lined drainage-ways designed to prevent infiltration of storm drainage from a 13.8-ha upslope catchment. At the second site (49-Trench area of SWSA 6), the entire 0.44-ha trench area was capped with a bentonite clay cover in 1976. These early attempts at hydrologic isolation have not corrected the water problems, ~~hence there is a need for further remedial action~~. In September 1983, engineered drainage projects were initiated at both the disposal sites. The SWSA 4 project was designed to divert surface runoff and shallow subsurface flow which originates upslope of the site away from the disposal area. The second project, a passive French drain constructed in SWSA 6, was aimed strictly at suppressing the site water table, thus preventing its intersection with the bottoms of disposal trenches. The cost of the two projects was $153,000 (SWSA 6) and $229,000 (SWSA 4), with onsite construction requiring 40 and 60 d, respectively. Postconstruction monitoring for performance evaluation has shown that the water table in the 49-Trench area has been suppressed to a depth >4.9 m below the ground surface over 50% of the site as compared to a depth of only 2.1 m for certain parts of the same area observed during seasonally wet months prior to drain construction. In addition, a

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maximum water table drawdown of 4.0 m was observed at the drain's deepest point. The SWSA 4 project evaluation indicates that 56% of the Winter-Spring 1984 runoff was diverted around SWSA 4 via the drainage system. As a result of the reduced flow in the SWSA 4 tributary to White Oak Creek, a 44% reduction in $^{90}Sr$ flux from SWSA 4 was calculated based on observed discharges and a previously established relation between flow rate in the tributary and $^{90}Sr$ concentration.

## INTRODUCTION

One major concern with the practice of shallow land burial (SLB) of low-level radioactive waste in the eastern United States is the potential for water-waste contact and radionuclide migration. To mitigate these concerns, engineering modifications or use of engineered barriers have been suggested as a possible method of improving the performance of low-level waste (LLW) disposal sites, particularly where natural hydrologic conditions are not ideal. These barriers include such structures as surface water diversion channels, trench covers or seals, trench liners, groundwater-cutoff walls, and trench drainage systems. Regardless of the type of structure being considered, the principal objective is to keep water from coming into contact with the buried waste, or at least to minimize the duration of such contact. A barrier can be constructed either as a part of the routine site operations or as a remedial action after the site, or a particular group of trenches, has been closed. This paper describes the design, construction, and preliminary results of two such engineered modifications implemented at SLB sites at the Oak Ridge National Laboratory (ORNL).

The first project, located in Solid Waste Storage Area Six (SWSA 6) in the vicinity of the 49-Trench area, is referred to as the SWSA 6 French drain (Fig. 1). It surrounds the 0.44 ha disposal site on the north and east boundaries and was designed to intercept shallow subsurface flow and suppress the area water table during the winter months. Collected water exits the drain at stations 0+00 and 8+26, catch basins 2 and 1, respectively (Fig. 1). The second project, aimed at protecting a larger number of closed trenches, was carried out on the northern boundary of SWSA 4 and is referred to as the SWSA 4 drainage project (Fig. 2). Unlike the SWSA 6 French drain, the SWSA 4 drainage project focuses on diverting surface runoff generated from the 13.8-ha upslope catchment around the trench area, and only indirectly attempts to intercept subsurface flow and lower the area water table. It was thus designed primarily as a surface water diversion structure. The following sections of this paper describe the two projects in greater detail.

## SWSA 6 FRENCH DRAIN

### Background

SWSA 6 contains 28 ha of gently-to-moderately sloping land, which is divided into several smaller sections by natural gullies and seasonal streams (Fig. 1). The area of concern to this project is a small (0.44-ha)

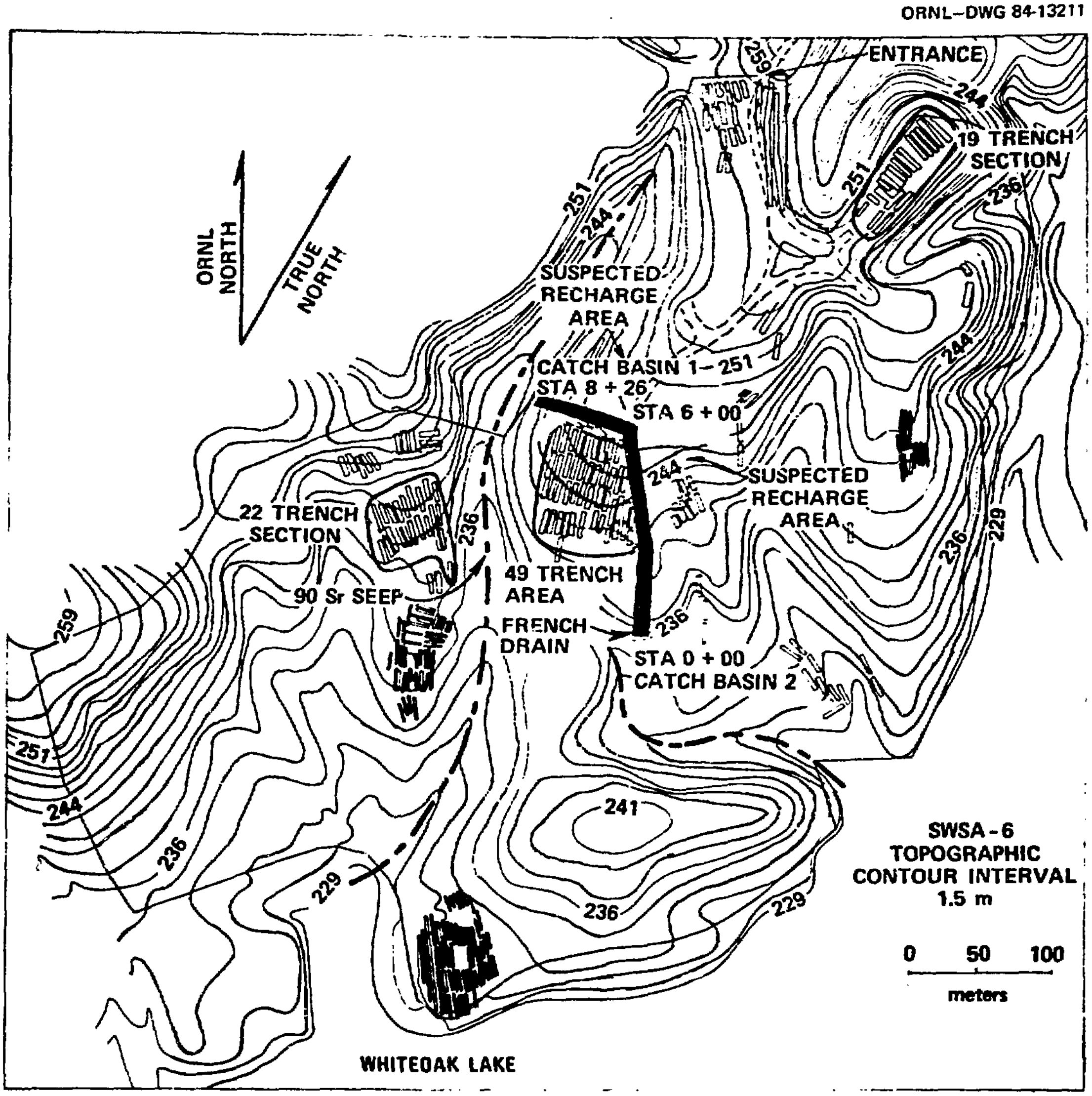


Figure 1. Location of the 49-Trench area French drain within ORNL Solid Waste Storage Area 6.

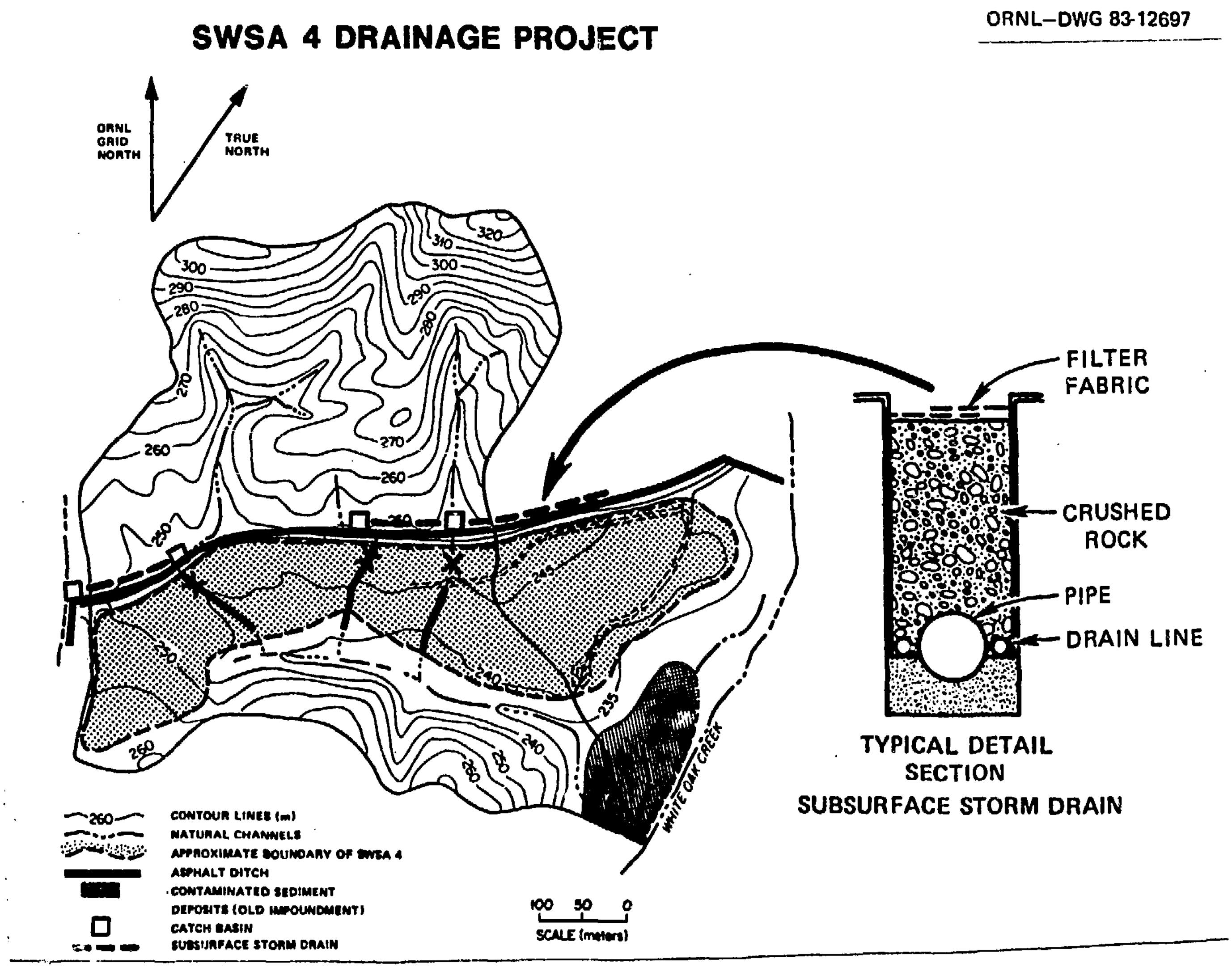


Figure 2. Location of the surface water diversion project within ORNL Solid Waste Storage Area 4.

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subsection of SWSA 6 containing 49 LLW disposal trenches (49-Trench area), which were filled with waste and closed during 1973 and 1974. The waste disposal trenches are underlain by the Middle Cambrian Conasauga Group, which is made up of calcareous shale interlayered with limestone and siltstone (McMaster 1963).

Shortly after closure, it was noted that many trenches were collecting and holding water, particularly during the wet winter and spring months (Arora et al. 1981). To prevent rainfall from infiltrating the cover material and collecting in the trenches after each rain, the entire 0.44-ha area was sealed in October and November of 1976 by applying a bentonite clay cover. This trench sealing operation was expected to result in a dewatering of the underlying trenches.

Despite the bentonite cover, water still collected in the trenches with seasonal fluctuations on the order of 1 to 2 m (Davis and Stansfield 1984). The maximum water level occurs in January, February, and March; the minimum occurs in September and October. The seal may be serving to keep out direct infiltration of rainfall; however, the fluctuating water levels suggest that a faulty seal or alternative mechanism, such as subsurface flow from outside the sealed area, might be contributing to water in the trenches.

With water entering the waste trenches, the potential for radionuclide migration to surrounding surface waters exists. Evidence for such migration has been documented in the creek to the west of the 49-Trench area by Cerling and Spalding (1981). From their analysis of streambed gravels within the White Oak Watershed, it was determined that a $^{90}Sr$ seep exists in this creek and that the source is located within the 49-Trench area. Concentrations of $^{90}Sr$ associated with gravels downstream of the seep were found to range between 1.7 and 8.3 Bq/g and were higher in the immediate vicinity of the seep (20.5 Bq/g). Upstream of the seep, concentrations of $^{90}Sr$ in streambed gravels were closer to background levels, ranging between 0 and 0.08 Bq/g. Thus, the environmental concern associated with the 49-Trench area is the presence of water in the trenches and the movement of soluble $^{90}Sr$ from the buried waste.

## Drain Design and Construction

The drainage system planned for the 49-Trench area was designed to meet two interrelated objectives: (1) to intercept and divert subsurface flow from upgradient recharge areas before it could enter the trenches, and (2) to lower the water table and keep it suppressed during the wet months of the year. With these two objectives in mind, a passive French drain was selected for construction on the north and east boundaries of the site (the direction of suspe ted groundwater recharge).

The two sections of drain were excavated so that they meet in the northeast corner of the site at a depth of approximately 9 m (Fig. 1). The northern leg of the drain begins at station 6+00 (approximate surface elevation = 248 m) and drains westward to catch basin No. 1, located at station 8+26 (approximate surface elevation = 239.4 m). The total length of this northern section of drain is 69 m. The eastern leg of the drain begins at station 6+00 and drains southward to catch basin No. 2, located at station 0+00 (approximate surface elevation = 235.4 m). The length of this eastern section of the drain is 183 m, making the combined length of the two drains 252 m.

Construction began on August 29, 1983, with the excavation of the first 18 linear meters of drain. Excavation was always in the direction of the drain junction (station 6+00), that is, from catch basin 1 to station 6+00 or from catch basin 2 to station 6+00, in order to allow water to drain from the excavation when the water table was encountered. A drain bottom slope of 1% was maintained in both legs of the drain except where unrippable limestone was encountered and steeper bottom slopes were necessary. When the design depth of the drain was reached at a particular station, filter fabric was placed on the sidewalls and crushed stone was placed into the lined excavation to within 0.6 m of the surface using a front-end-loader or conveyor system, depending on the depth of the drain and the likelihood of sidewall slides. When backfilling was completed, the filter fabric was folded over the crushed stone fill material, and the remaining 0.6 m of trench was brought to the original grade by backfilling with site soil. Of the 17-d on-site excavation time, it was estimated that about 5 d (29% of the time) were spent excavating sidewall material that slid into the drain during construction. Essentially all of the 5 d was spent working on the north section of the drain, and in the northern-most 18 m of the east section, where slides were most prevalent because of excavation down dip and along geologic strike. On September 29 the excavation equipment was removed from the site, and construction of the two concrete catch basins began. In October the catch basins were completed and the site was seeded and returned to near original conditions.

## Results and Discussion

The effectiveness of the SWSA 6 French drain has been evaluated by comparing the 49-Trench area water table elevation records before drain construction with those taken after construction, particularly for the wet winter months. Analyses of these data also identify any waste trenches that were completely drained of intratrench water as a result of drain construction. Such a comparison in the two water table maps (February 1983, before construction and February 1984, after construction) indicates a significant postconstruction change in the water table with drawdown toward the drain bottom extending $\sim$60 m into the 49-Trench area. The site water table no longer mimics surface topography but rather slopes toward the bottom of the drain drawing the water table down $\sim$4 m in the northeast corner of the site where the two drains intersect.

A critical depth to water across the 49-Trench area, and one which has been used to evaluate the success of the drain in suppressing the site water table, is 4.9 m. This is the depth at which the water table will no longer intersect the bottoms of the waste disposal trenches, thus eliminating this periodic trench inundation as a mechanism for maintaining "bathtub" conditions in trenches. Results of the postconstruction water elevation survey show that approximately 50% of the 49-Trench area has maintained such a suppressed water table through winter 1984 resulting in protection of $\sim$29 of the 49 waste disposal trenches from contact with rising groundwater (Fig. 3). Monitoring wells at a distance of $>$60 m from the drain centerline, depicted as solid circles in Fig. 3, have not

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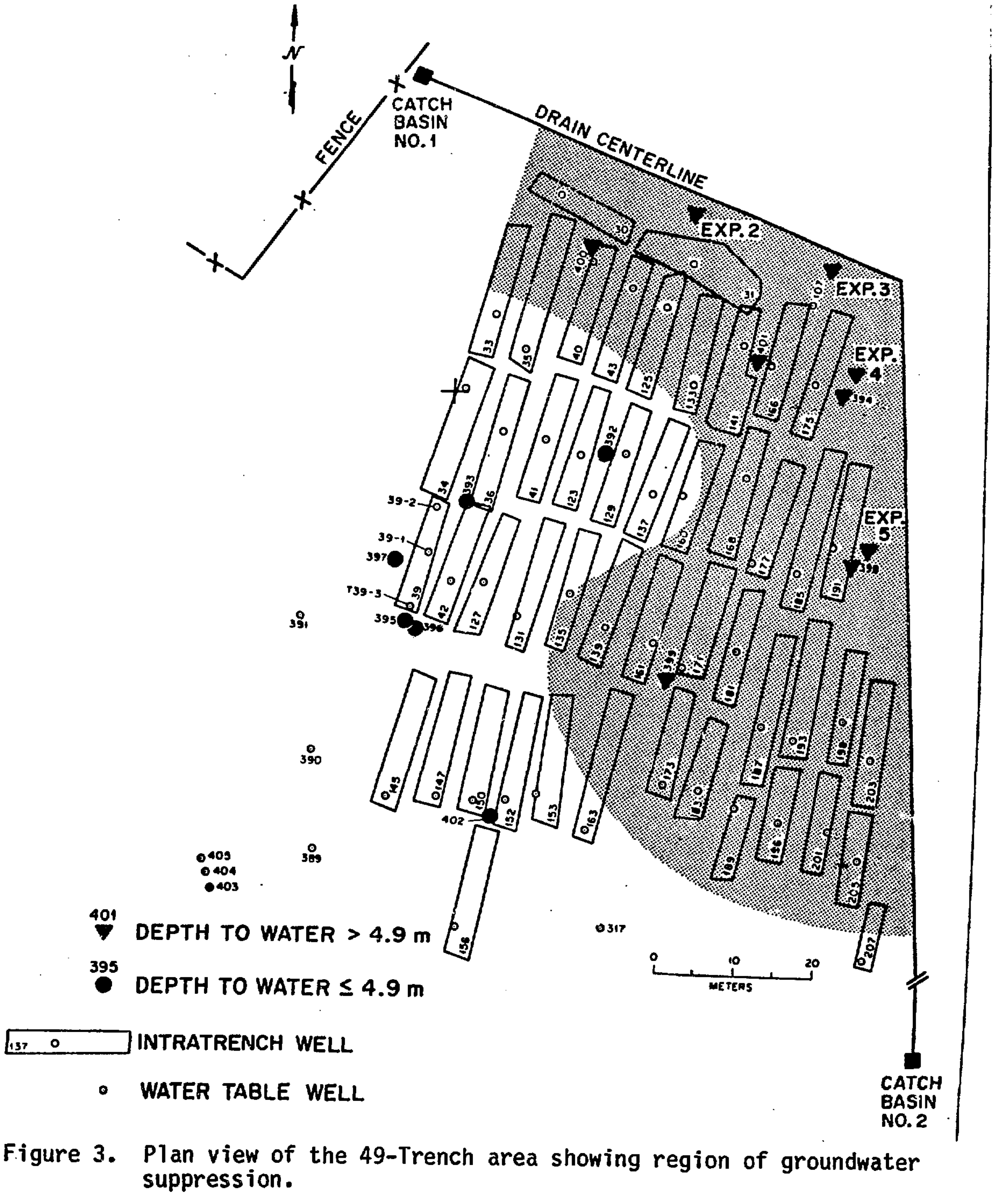


Figure 3. Plan view of the 49-Trench area showing region of groundwater suppression.

been affected by the drain's drawdown and continue to register water levels ≤4.9 m deep in response to rainfall events.

In addition to suppressing the water table over 50% of the 49-Trench area, the drain has actually dried up five of the waste trenches, probably through direct hydraulic connection via fractures in the shale. These are trench numbers 30, 31, 175, 203, and 205 and are seen in Fig. 3 to be in close proximity to the drain. None of the remaining trenches in the area have shown this dramatic "drying up" response. In fact, many have continued to show a pattern of rising intratrench water levels in November, December, and January, after drain construction. This postconstruction rise in intratrench water levels, particularly for those trenches in the shaded region in Fig. 3, suggests that the bentonite clay seal is leaking, and the water is entering the trenches as surface infiltration and not as rising groundwater or lateral subsurface flow.

## SWSA 4 DRAINAGE PROJECT

### Background

SWSA 4 is a 10.0-ha portion of the 24.6-ha catchment shown in Fig. 2. The waste disposal trenches are underlain by the Middle Cambrian Conasauga Group, which is made up of calcareous shale that is interlayered with limestone and siltstone (McMaster 1963). The site was opened for shallow land disposal of low-level radioactive waste in 1951. Both trenches and auger holes were used for disposal and were excavated to depths as great as 6 m. Wastes, containing emitters of gamma and beta radiation, were covered with native soil when trenches were filled. Those trenches containing alpha radiation emitters were capped with concrete (Lomenick and Cowser 1961). SWSA 4 was closed for disposal in 1959 and shortly thereafter Cowser et al. (1961) reported that the water table was high enough to result in contact between wastes and groundwater throughout most of the area. Following closure, uncontaminated fill and construction debris were used to cover much of the area. In some cases, the fill reached depths as great as 6 m. This loose fill material is believed to have the tendency to increase infiltration and result in higher water table elevations.

In 1975, three small channels that carry flow across SWSA 4 were covered with asphalt to reduce or eliminate infiltration, and thus reduce leaching of wastes within the disposal site (Fig. 2). Evaluation of the effectiveness of the asphalt treatment on the small channels showed, however, no change in concentration of $^{90}$Sr released in SWSA 4 runoff (Tamura et al. 1980). Because SWSA 4 was the most important nonpoint source of $^{90}$Sr to White Oak Creek in 1979 (Stueber et al. 1981), more detailed examination of the problem was conducted. Results of the extensive field studies at SWSA 4 concluded that at least 80% of the $^{90}$Sr transport (estimated at $\sim 3.7 \times 10^{10}$ Bq/year or 1 Ci/year) was associated with surface runoff generated upslope from the burial area and recommended that a runoff diversion system be constructed to route flows around and away from buried wastes (Huff et al. 1982).

## Drainage Design and Construction

The water diversion project in SWSA 4 was designed primarily to intercept and divert surface runoff from the undisturbed catchment area, which is upslope from the disposal site (Fig. 2). The system collects the runoff from an area comprising 56% of the total watershed area and diverts it either east or west around the disposal site to streams that discharge into White Oak Lake. The diversion system consists of three components: (1) a paved interceptor channel parallel to Lagoon Road which collects surface runoff (heavy solid line in Fig. 2); (2) four catch basins that receive runoff from the interceptor channel and from intermittent streams draining the upslope area (open squares in Fig. 2); and (3) an underground storm drain system which discharges runoff around the disposal site (heavy dashed line in Fig. 2).

The storm drain system (detailed in Fig. 2) was constructed in two sections: a 183-m western section of maximum depth equal to 6.4 m and a 293-m eastern section with a maximum depth of 4 m. Both sections of drain were designed with a bottom slope of $\sim$1%. At the same time the storm drain pipe was being placed in the excavation, smaller perforated pipe was installed on the trench bottom, and the excavation was backfilled with crushed stone. The perforated pipe and crushed stone serve to drain any shallow subsurface flow entering the excavation which might otherwise flow southward under the asphalt interceptor ditch and into the waste trenches. All construction was initiated in August 1983 and completed $\sim$60 days later in October.

## Results and Discussion

To evaluate the effectiveness of the SWSA 4 drainage project, a simple water flow model was constructed for the site. Prior to any surface water diversion, the discharge from the disposal site entered White Oak Creek via a small tributary (SWSA 4 tributary) and consisted of the runoff from the entire watershed. The flow was thus a function of the total drainage area. After the diversion structures were completed, the discharge from the SWSA 4 tributary consisted of runoff from the area south of the asphalt ditch (Fig. 2). The remaining runoff was diverted around the disposal site as discussed earlier.

To estimate changes in flow in the SWSA 4 tributary, discharge at the diversion outfalls and at the SWSA 4 tributary outlet were measured at weekly intervals from February through May 1984. Data were evaluated to determine the percent flow diverted on each of 20 individual dates. The mean percent flow reduction for all measurements was 56% (standard error of mean = 3.9%, n = 20). There was a wide range of scatter (24 to 88%) in the instantaneous diversion rate, with no apparent correlation between flow rate and percentage of flow diverted. Thus, it was assumed that the amount of runoff diverted was a constant 56% of the combined total. Continuous records at the SWSA 4 tributary were used to compute the total volume diverted during a 6-month period (November 1983 through April 1984) when flow data from the diversion channels were not available. Measured flow from SWSA 4 during this period was 40,100 $m^3$, the volume diverted was estimated as 51,100 $m^3$, and the combined total was 91,200 $m^3$.

The next, and perhaps most important, step in estimating the effectiveness of the diversion involves calculating the reduction in $^{90}Sr$ flux resulting from the decreased flow in the SWSA 4 tributary. In a study by Huff et al. (1982), a correlation was derived relating the concentration of $^{90}Sr$ (C Bq/mL) to the discharge (Q L/s) of the SWSA 4 tributary.

$$C = [6.3722 - 0.02132Q + 13.3955\exp(-0.06592Q)]\ 0.01667 \qquad (1)$$

The inverse exponential relationship shown in Eq. (1) indicates that periods of low flow exhibit high $^{90}Sr$ concentrations, while high flow periods exhibit low $^{90}Sr$ concentrations. Using this previously derived relationship, continuous flow records at the SWSA 4 tributary, and the assumed 56% diversion of total flow, hourly values for $^{90}Sr$ flux with and without the diversion were calculated and summed. Since continuous flow records were available for the 6 month period between November 1983 and April 1984, this interval was used in the calculations. The flux was computed as the product of the $^{90}Sr$ concentration and the corresponding flow in the SWSA 4 tributary. Based on the November 1983-April 1984 period of continuous flow record and a 56% flow reduction, the estimated flux from the tributary was 9,916 MBq. Without diversion, the estimated flux would have been 18,352 MBq, hence there was a reduction of 8,436 MBq or 46% over the 6-month period.

In summary, the results of the diversion evaluation have shown that an average flow reduction of 56% and an estimated $^{90}Sr$ flux reduction of 46% have resulted from the surface water diversion project. If this estimated flux reduction continues, the annual release of $^{90}Sr$ from SWSA 4 should be reduced from the current $3.7 \times 10^{10}$ Bq or 1 Ci to $\sim 1.99 \times 10^{10}$ Bq or 0.54 Ci, decreasing the total discharge of $^{90}Sr$ from White Oak Dam by 23%. Although groundwater is often considered the dominant mechanism for solute migration from waste disposal sites, the SWSA 4 diversion project has demonstrated that surface runoff can play a significant role and must be considered in planning new sites and carrying out corrective measures at existing sites.

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