RF/RMRS-98-283.UN
Revision 0

Source Evaluation Report for Point of Evaluation SW027

October, 1998

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

TABLE OF CONTENTS

FIGURES

TABLES

1. EXECUTIVE SUMMARY

Rocky Flats Environmental Technology Site (Site) personnel have completed the initial investigation into, and are continuing the source evaluation of, the cause(s) of reportable 30-day moving averages[1] for plutonium[2] water-quality action levels at the Rocky Flats Cleanup Agreement (RFCA) Point of Evaluation (POE) monitoring location SW027 (Figure 2-1). First reported on July 23, 1998, the reportable values may be summarized as:

- Reportable values were observed at the POE monitoring location on the South Interceptor Ditch (SID) above Pond C-2 (referred to as SW027) for the period May 5, 1998 through August 6, 1998.[3]

When reportable values are measured in waters classified as Stream Segment 5, RFCA further requires a "source evaluation and mitigating action." This Source Evaluation Report is provided according to the *Source Evaluation Plan for RFCA POE SW027,* August 1998 (Revision 3; RF/RMRS-98-259.UN).

Site personnel completed an extensive evaluation of historical data and assessed Site activities and monitoring programs. To date, only contamination from the 903 Pad has been identified as a likely cause of these reportable values. Site personnel conclude that the likely source of the reportable 30-day moving averages for plutonium at SW027 was diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years, particularly from the 903 Pad. Based on the evaluation, Site personnel conclude that no specific remedial action(s) is indicated at this time, other than scheduled remedial actions for the 903 Pad, as the source investigations have identified no other localized source(s) of contamination.

This Report contains no specific recommendations for source control due to the reportable values measured at SW027.[4] The recommended course of action in this report will not compromise protection of human health and the environment since water-quality results downstream of SW027 (at the Pond C-2 outlet and at Woman Creek and Indiana Street) indicate that passive settling in Pond C-2 removed a majority of the plutonium from the water column.

It should be noted that the recommendations of this report do not supplant the regulatory agencies' authority to compel corrective actions when necessary to protect human health and the environment. Nor do the recommendations impair or impede Site implementation of mitigation activities should new sources be identified or if additional reportable water-quality measurements warrant corrective actions.

The Site's proposed course of action includes (1) continuing observation, (2) implementation of scheduled remediation projects, and (3) continuing progress on the Actinide Migration Studies (AMS). Key to understanding water-quality variations on-Site, this multi-disciplinary study and the associated watershed modeling initiative will eventually describe the extent to which, and conditions under which, radionuclides move in the Rocky Flats environs. Site personnel expect these efforts will provide insights into the cause(s) and possible prevention of reportable radionuclide water-quality results.

The Site proposes the following actions as part of the path forward:

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[1] The 30-day moving average activity (pCi/L) for a particular day is calculated as a volume-weighted average of a 'window' of time containing the previous 30-days which had flow. Therefore, there are 365 30-day moving average values for a location that flows all year (366 in a leap year). For days where no activity is available, either due to failed lab analysis or non-sufficient quantity for analysis (NSQ), no 30-day average is reported.

[2] In this report, 'plutonium' refers to Pu-239,240 and 'americium' refers to Am-241.

[3] The latest analytical result returned from the labs covers the period up to 9/9/98.

[4] Future remediation activities scheduled for the 903 Pad may positively influence water-quality at SW027.

1. Continue observation (routine monitoring and special sampling, as appropriate to the evaluation) and ongoing data interpretation to provide understanding of actinide transport directly related to the operation of the Site automated surface-water monitoring network;
2. Continue progress on the AMS as a longer-term technical study to provide understanding of actinide migration to eventually provide insights into the cause(s) and possible prevention of reportable radionuclide water-quality measurements;
3. Continue use of the existing detention ponds to clarify stormwater of potentially contaminated sediment and particulate matter as an effective best management practice;
4. Continue incorporation of stakeholder input through the Water Working Group as outlined in Appendix 5 of RFCA; and,
5. Continue to provide progress reporting through AMS reports, Quarterly RFCA Reports, Quarterly State Exchange Meetings, and informal status/flash briefs.

2. INTRODUCTION

This Source Evaluation Report is provided in accordance with the RFCA (Attachment 5, §2.4(B)) under “Action Determinations”. Specifically, this source evaluation addresses the July 23, 1998 Site notification of reportable 30-day moving averages for plutonium water-quality results in the SID. These reportable values were measured at the POE monitoring location on the SID and upstream of Pond C-2 (referred to as SW027) for the period May 5, 1998 through August 6, 1998.[3] This Source Evaluation Report fulfills the Site commitment as outlined in the *Source Evaluation Plan for RFCA POE SW027*, August 1998 (Revision 3; RF/RMRS-98-259.UN). This Plan was delivered to the Colorado Department of Public Health and the Environment (CDPHE), the Environmental Protection Agency (EPA), the City of Broomfield and the City of Westminster, on August 10, 1998.

Source evaluations require analysis of constituent fate, transport, and loading, as well as statistical analysis and the establishment of water-quality correlations which may indicate the location of a contaminant source. To date, no discrete source of surface-water contamination has been identified and quantified in the SID drainage. Due to the lack of an identified discrete source, the Site has committed to continue routine RFCA surface-water monitoring to identify source areas should reportable water-quality values be measured in the future. This Report describes the progress of source evaluation actions for SID gaging station SW027 and covers data received as of October 7, 1998. The following is included in this Report for POE SW027:

- Hypotheses for source location(s) with supporting and non-supporting information, including preliminary results on source location;
- An assessment of existing monitoring data for SW027;
- Results and analysis of ongoing RFCA monitoring;
- A summary of walk-down activities and observations for SW027;
- A description of potential Source Location monitoring stations[5] for SW027; and
- A summary of current AMS findings with cross-links to source evaluations.

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[5] Source Location monitoring stations are automated gaging stations installed as part of a source evaluation under RFCA. These locations are installed according to the Integrated Monitoring Plan Source Location decision rule and current Site automated surface-water monitoring practices. Operation of these gages is tailored to meet the requirements of each source evaluation.

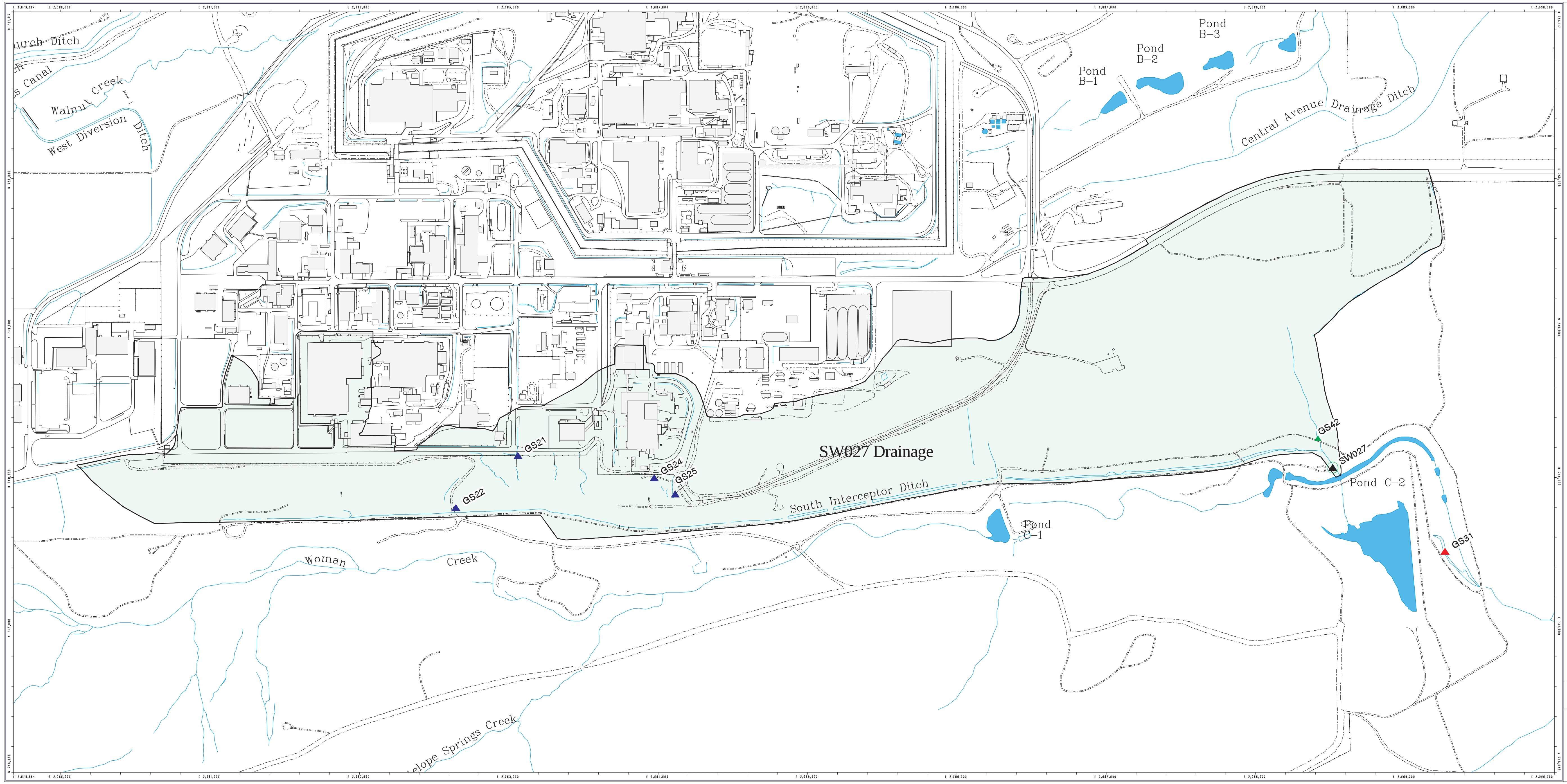

Figure 2-1

Selected Automated Surface-Water Monitoring Locations Tributary to SW027

Legend

Monitoring Location Objective*

- Point of Evaluation
- Point of Compliance
- IA IM/IRA Location
- Ad Hoc
- New Source Detection

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

NOTE:
* The monitoring objective(s) performed at each location are detailed in the Surface Water Section of the Site Integrated Monitoring Plan.

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Scale = 1 : 6950
1 inch represents approximately 579 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

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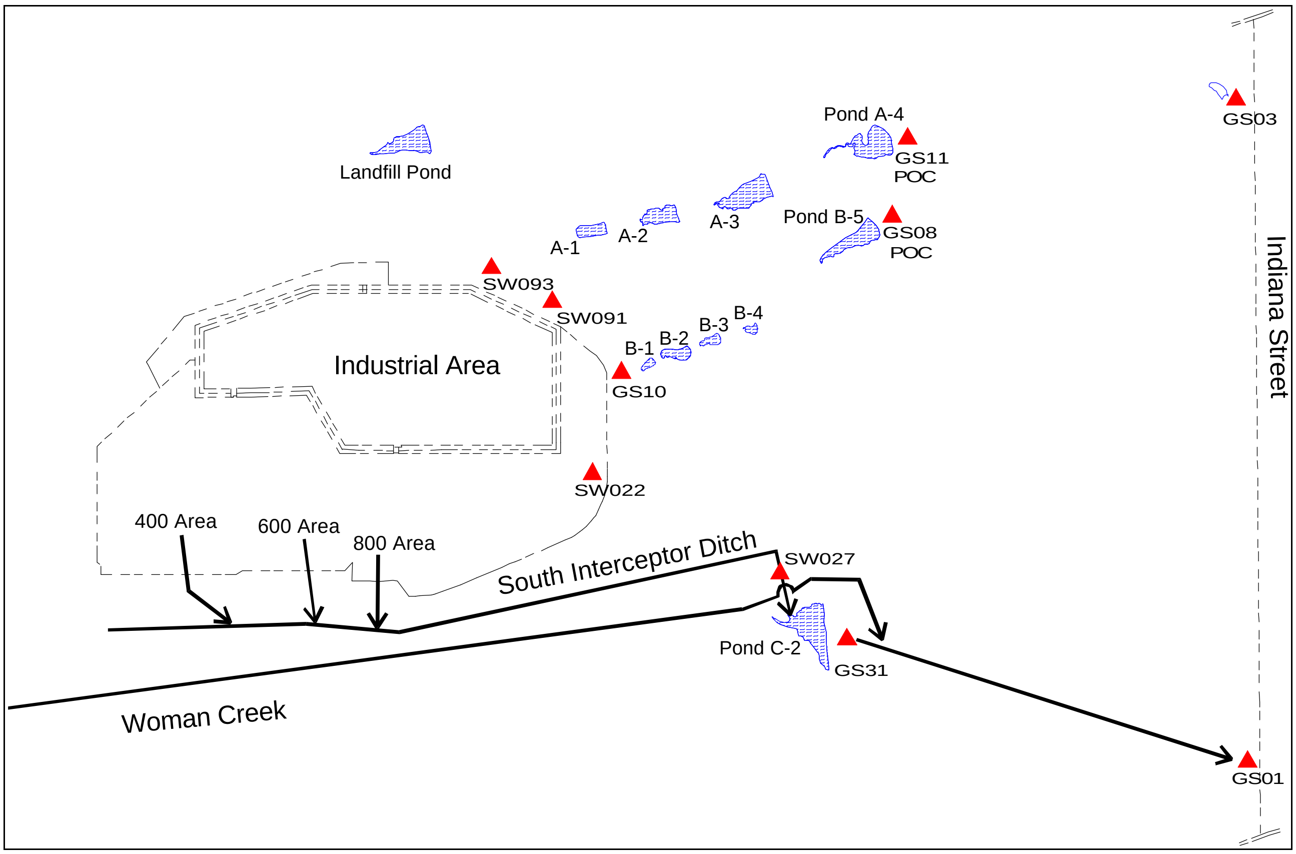
MAP ID: 98-0253-Map1 October 28, 1998

/gis2/projects/fy98/98-0253/map1/sw027-drng.aml

3. BACKGROUND

3.1. Site Hydrology: South Interceptor Ditch

The SID, the subject of this investigation and one of several major Site drainages, receives runoff from the Buffer Zone areas just south of the Industrial Area (IA), and portions of the 800, 600, and 400 Areas (Figure 2-1 and Figure 3-1). Surface-water monitoring station SW027 is located on the SID immediately upstream of Pond C-2. Water from Pond C-2 is discharged directly to Woman Creek, subsequently leaving the Site boundary at Indiana Street. Downstream of Indiana Street, flows continue to the Woman Creek Reservoir for detention. Woman Creek Reservoir is then periodically pump discharged via pipeline to Big Dry Creek.



Only portions of the 400, 600, and 800 Areas are tributary to the SID. Selected automated gaging stations are shown by triangles.

Figure 3-1. Hydrologic Connectivity of SID Drainage.

SID Tributaries and Water Management

Upstream from station SW027, there are no major perennial tributaries flowing to the SID. Due to the substantial storage capacity of the SID, SW027 receives flow only during the spring or following large storm events. Runoff to SW027 is event-driven and is not controlled by Site detention ponds.

All surface-water runoff that flows into the SID and passes SW027 is collected in Pond C-2. The Site detention ponds serve three main purposes for surface-water management: (1) storm water detention and settling of sediments, (2) water storage for sampling and, if necessary, treatment prior to release, and (3) emergency spill control in those instances where a spill cannot be adequately managed without use of the ponds.

Steps in the water collection and transfer process for Pond C-2 are summarized as follows:

- Runoff in the SID flows directly to SW027 and enters Pond C-2;
- After Pond C-2 is filled to roughly 45% of capacity, a predischarge sample of the water is collected by CDPHE. If sample results indicate acceptable water quality, the "batch" of water is pump discharged to below the dam. These batch releases from Pond C-2 occur an average of once per year, depending on the amount of precipitation received at the Site, and involve approximately 10-15 million gallons of water annually.
- Composite samples are collected of the Pond C-2 discharge water at Point of Compliance (POC) GS31, and the water flows on to Woman Creek and POC GS01 (where composite samples are also collected).

As indicated above, all of the IA runoff that flows into the SID is ultimately routed through Pond C-2, detained, and sampled prior to being released to Woman Creek. There is no source of runoff from the IA that can enter Woman Creek without first being detained in Pond C-2.

3.2. SW027 Monitoring Results

As specified in the Surface Water section of the Integrated Monitoring Plan (IMP), Site personnel evaluate 30-day moving averages for selected radionuclides at RFCA POEs and POCs. Recent evaluations of water-quality measurements at POE surface-water monitoring location SW027 (see Figure 2-1) show values for plutonium requiring reporting and source evaluation under the RFCA Action Level Framework. Results for 30-day moving averages using available data at SW027 are summarized below in Table 3-1 and are plotted in Figure 3-2.

Table 3-1. Water-Quality Information from SW027 for the Period: 10/1/96-9/9/98.

Location	Parameter	Date(s) 30-Day Moving Average Required Reporting	Date(s) of Maximum 30-Day Moving Average	Maximum 30-Day Moving Average (pCi/L)	Volume Weighted Average for Water Year 1998 to Date[6] (pCi/L)
SW027	Pu-239,240	5/5/98 – 8/6/98	5/30/98	0.54	0.14

The laboratory narrative for the individual analytical results for the composite samples collected around the period of these reported 30-day moving averages have been reviewed and there is no reason to question the accuracy of these results. These results have not received formal third-party validation to date. A review of historical monitoring data shows that these results are not unusual. Storm-event and grab samples collected at SW027 from WY90 through WY96 (under pre-RFCA protocols) had an arithmetic average plutonium activity of 0.22 pCi/L with a maximum of 2.29 pCi/L. The apparent trend upward during WY98 is likely due to seasonally increasing flow rates and precipitation intensity which result in increased transport of suspended material. Individual composite sample results and details are shown in Table 3-2 for the period of interest. Figure 3-3 shows the mean daily flow rates with the individual composite sample results from SW027.

[6] A water year (abbreviated as WY) is defined as the period from October 1st through September 30th.

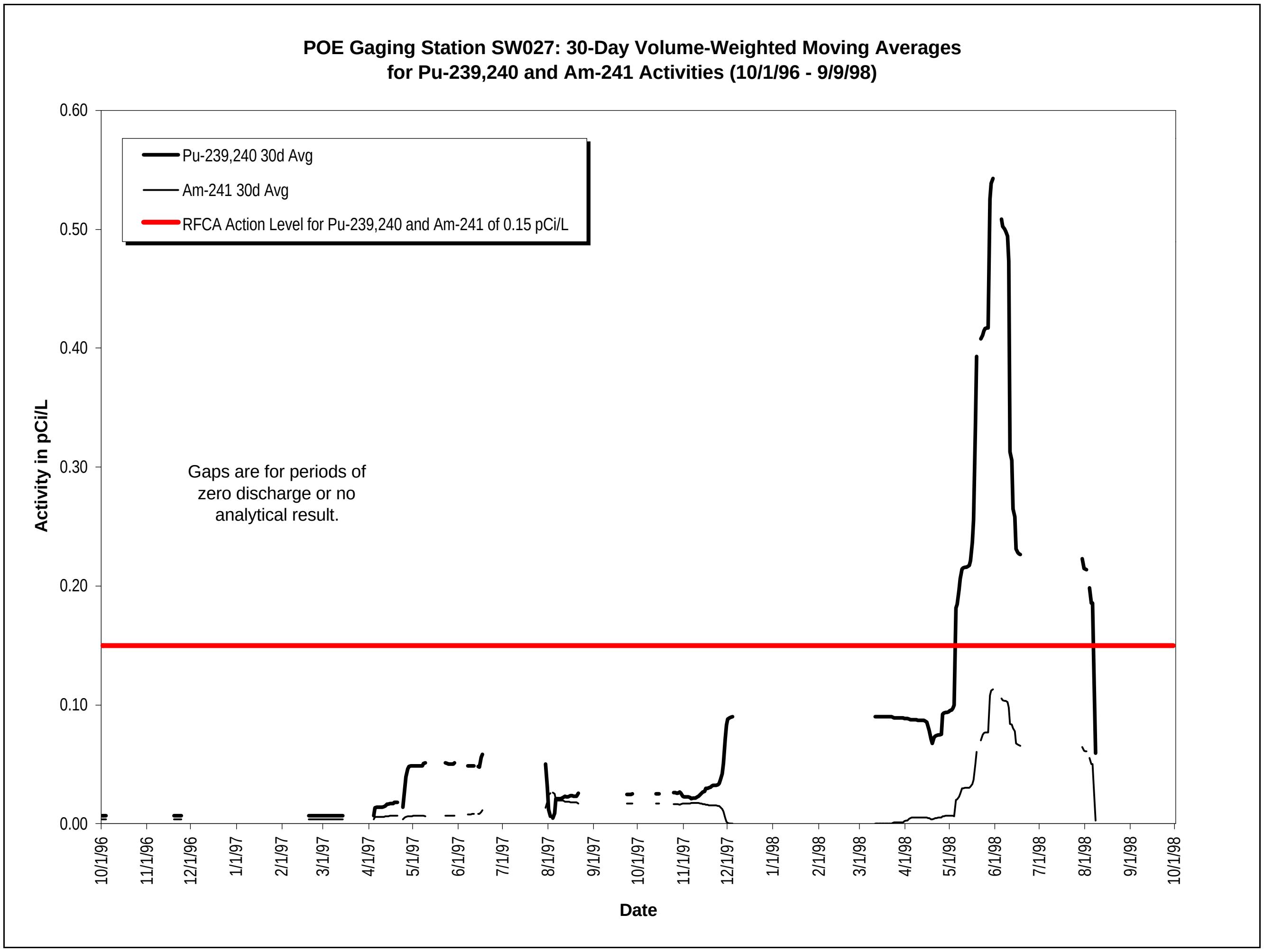


Figure 3-2. Gaging Station SW027 30-Day Moving Averages: 10/1/96 – 9/9/98.

Table 3-2. Selected Composite Sample Analytical Results for SW027.

Composite Sample Period	Pu-239,240 (pCi/L)		Am-241 (pCi/L)		Composite Sample Volume (Liters)	SID Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
4/13 - 4/20/98	0.040	0.031	-0.004	0.026	19.2	2.72
4/20 - 4/30/98	0.204	0.065	0.016	0.030	19.4	1.3
4/30 - 5/8/98	0.802	0.156	0.124	0.051	9.4	0.73
5/8 - 5/26/98	0.333	0.115	0.106	0.073	10.6	0.86
5/26 – 9/9/98	0.052	0.035	-0.003	0.031	6.4	0.50

Note: All composite samples listed above were of adequate volume for all required analyses.

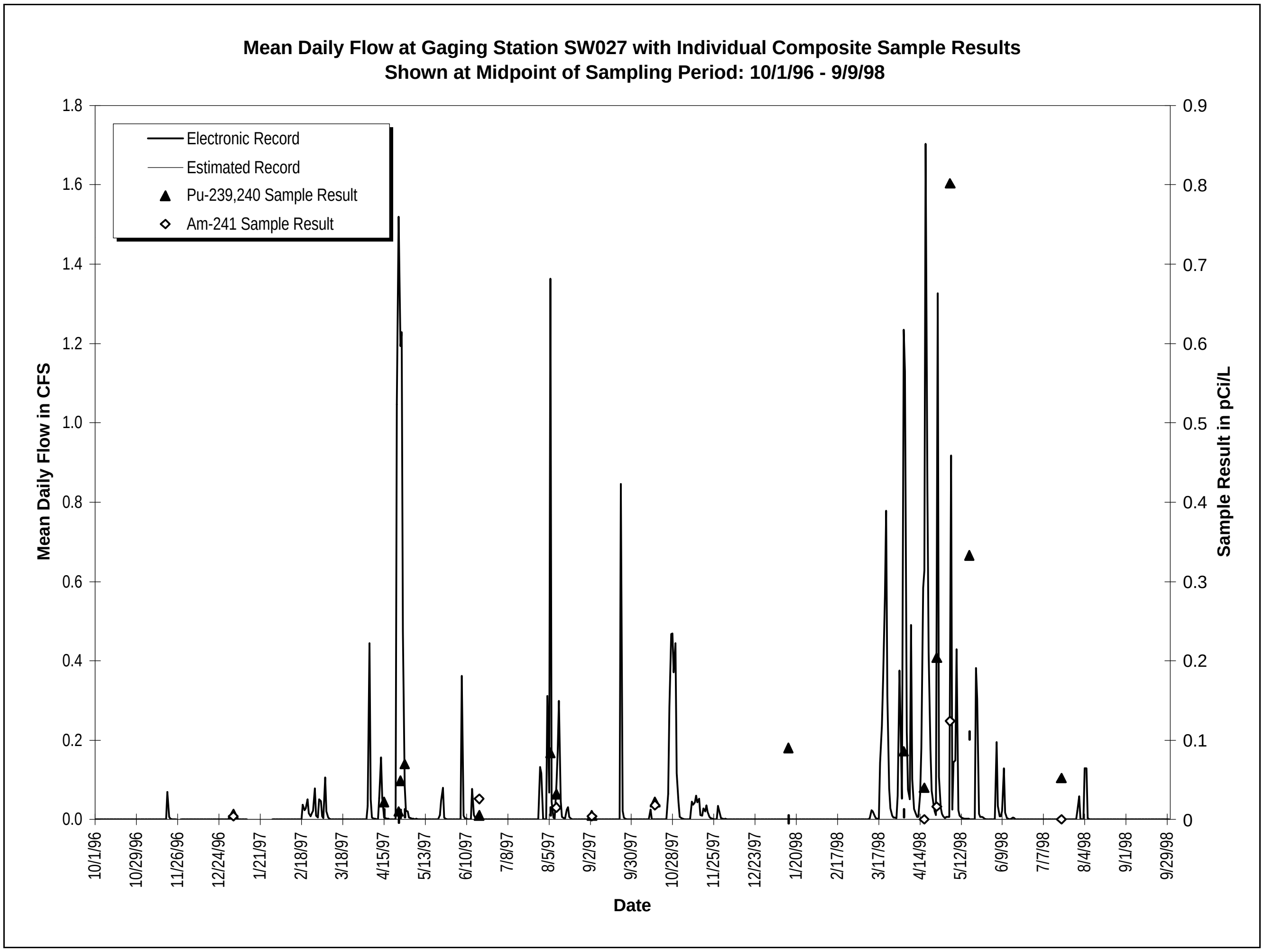


Figure 3-3. Gaging Station SW027 Hydrograph and Sample Results.

The surface water measured at SW027 was subsequently detained in Pond C-2. This water was then batch pump discharged from Pond C-2 during the period 5/21/98 through 5/30/98. Results from the pre-discharge sample collected on 5/5/98 from Pond C-2 were 0.031 ±0.006 pCi/L plutonium. Analytical results for the composite samples collected at POC gaging station GS31 (Figure 2-1) during the Pond C-2 batch discharge were within typical activity levels for that location. Table 3-3 summarizes these results. Analytical results from composite samples collected at POC GS01 (Figure 2-1) also show low radionuclide levels. Table 3-4 summarizes these results.

During this time period, no off-normal conditions were noted in decontamination and decommissioning (D&D), special nuclear material (SNM) stabilization, or environmental restoration (ER) activities that may have affected water quality, nor were there any closure activities occurring in the SID drainage tributary to SW027. This drainage does contain areas of above-background surface-soil contamination, including the 903 Pad and Lip Area.

Table 3-3. Composite Sample Analytical Results for GS31: 5/21/98 - 5/30/98.

Composite Sample Period	Pu-239,240 (pCi/L)		Am-241 (pCi/L)		Composite Sample Volume (Liters)	Pond C-2 Discharge Volume During Sample Period (Million Gallons)
	Result	Error	Result	Error		
5/21 - 5/24/98	-0.001	0.011	0.017	0.042	7.8	5.5
5/24 - 5/27/98	0.001	0.011	0.010	0.026	11.2	4.06
5/27 - 5/30/98	0.010	0.016	0.030	0.036	8.8	3.65

Table 3-4. Composite Sample Analytical Results for GS01: 5/21/98 – 8/11/98.

Composite Sample Period	Pu-239,240 (pCi/L)		Am-241 (pCi/L)		Composite Sample Volume (Liters)
	Result	Error	Result	Error	
5/21 - 5/24/98	-0.005	0.004	0.003	0.021	4.6
5/24 - 5/27/98	0.009	0.015	0.000	0.024	6.0
5/27 - 5/30/98	0.007	0.018	-0.003	0.024	4.6
5/30 – 8/11/98	-0.011	0.010	0.002	0.028	4.4

4. DATA SUMMARY AND ANALYSIS FOR SW027

4.1. Walk-Down of Drainage Area

As part of the Source Evaluation for SW027, a walk-down was performed of the drainage area tributary to SW027 (Figure 2-1) in October 1998. The purpose of the walk-down was to visually identify areas where overland runoff may be transporting distributed contamination to the SID. Once these conditions are inventoried, a variety of watershed improvements (see Section 4.3) or removal activities may be considered in an effort to reduce actinide migration in surface water. Conditions that might indicate a potential source area include the following items:

- Existence of man-made materials in drainage pathways;
- Areas of concentrated fine sediments in drainage pathways;
- Areas which contribute significant quantities of runoff sediment (e.g., steep dirt roads, barren hillsides, and slopes needing revegetation);
- Erosion on radionuclide-related Individual Hazardous Substance Sites (IHSSs);
- Position of radionuclide-related IHSSs in relation to storm water drainage pathways; and
- Overall condition of storm drainage pathways.

The walk-down revealed no evidence of any man-made materials in the drainage pathways that indicate a recent uncontrolled release of contaminants. Areas near the Old Landfill at the western end of the SID contain significant accumulations of man-made materials associated with past landfill operations. Although significant quantities of uranium are associated with this IHSS, plutonium is not a concern. The drainage for SW027 has been historically impacted by industrial storage and disposal operations. Accordingly, there are multiple possible sources of contamination, including plutonium-related IHSSs (discussed in detail in Section 4.2.6). These plutonium-related IHSSs are limited to the 600 and 900 Areas.

Generally, few areas tributary to the SID exhibited signs of high flows. Surrounding dirt roads and hillsides receiving IA runoff from impervious areas did show signs of runoff erosion, and several of these sub-drainages indicated flows that reach the SID. Environmental data for plutonium activities referenced below are discussed in detail in Section 4.2. The following list describes locations that may be contributing plutonium load to the SID based on field observations.

- Areas of the Old Landfill had areas of limited vegetation and signs of runoff reaching the SID. Although significant quantities of uranium are associated with this IHSS, plutonium is not a concern.
- The dirt road directly south of B664 showed signs of erosion and frequent flow which reaches the SID. Soil contamination in this area is considerably lower than for areas further downstream.
- Stormwater culverts draining the areas SE of B664 and S of B850 showed significant headcutting at their downstream outlets. Erosion patterns also indicated that flows from these culverts may reach the SID during certain periods. Average surface-water activity from GS21 (drainage SE of B664) is 0.033 pCi/L plutonium. Average soil and sediment activities in this area are less than 1.0 pCi/g plutonium.
- Stormwater culverts draining the areas S and SE of B881 (GS24 and GS25) showed signs of frequent flows reaching the SID. Flows pass through a small man-made catch basin/wetland before flowing to the SID. Baseflow reaching the SID was apparent during the walk-down. Constant baseflow at GS25 may originate as footing drain discharge and/or domestic leakage. This baseflow, however, is not typically observed at SW027. Average surface-water activity from GS24 and GS25 is 0.093 and .018 pCi/L plutonium, respectively. Nearby surface-water sampling locations show average activities up to 0.34 pCi/L plutonium. Average soil and sediment activities in this area are up to 3.0 pCi/g plutonium.
- Stormwater culverts and ditches draining the areas S of the Contractor Yard and the 903 Pad showed signs of frequent flows originating from the perimeter road just inside the Inner Fence. Many of these flows continue downhill and reach the SID under certain conditions. The ditch which includes sampling location SW055 (directly S of the SE corner of the 903 Pad; average of 6.58 pCi/L plutonium), shows erosion which indicates that flows likely reach the SID during certain conditions. This ditch is interrupted by several small berms that are likely to force flows out of the ditch and onto the hillside. Therefore, it is unclear how much load reaches the SID and how much is deposited on the hillside. Average surface-water activities from sampling locations in this area are up to 54.0 pCi/L plutonium. Average soil and sediment activities in this area are up to 962 pCi/g plutonium. This area received watershed improvements in FY96 and FY97 (Section 4.3), and the local effects on surface-water activities have not been quantified.
- The road from the East Access Road to Pond C-1 shows signs of frequent flows with some erosion. This road was covered with clean fill and revegetated in FY96. The local effects of these watershed improvements on surface-water activities have not been quantified. Historically, average surface-water activities from sampling locations in this area are up to 250 pCi/L plutonium. Average soil and sediment activities in this area are up to 297 pCi/g plutonium.
- Small gullies draining the areas south of the Soil Study Area (east of the 903 Lip Area) showed little sign of flows reaching the SID. However, some flow was observed in these gullies in May 1995. These gullies drain areas with high soil/sediment and surface-water activities. Average surface-water activities from sampling locations in this area are up to 41 pCi/L plutonium. Average soil and sediment activities in this area are up to 647 pCi/g plutonium.
- A gully draining the areas S of the East Access Road and entering the SID just upstream of SW027 (currently monitored by GS42) showed signs of intermittent flows reaching the SID. Significant flow was observed in this gully in May 1995. This gully drains areas with moderate soil/sediment and surface-water activities. The average surface-water activity from a sampling location in this area is 0.165 pCi/L plutonium. Average soil and sediment activities in this area are up to 48 pCi/g plutonium.

4.2. Assessment of Existing Environmental Data

4.2.1. Automated Surface-Water Monitoring Data

Data Summary

Considerable data exists for flow and radionuclide activities at gaging station SW027. Data for flow and radionuclide activities at gaging stations upstream of SW027 are more limited. These gaging stations include GS21, GS22, GS24, and GS25 (Figure 2-1). Information for total suspended solids (TSS), metals, major ions, etc. at all gaging stations is more limited. Additional information for these parameters may need to be collected. Individual results are averages of target, duplicate, and replicate results for each sample. Validated results that were rejected are not included. All activities are for total radionuclides.

Surface-Water Flow Rates and Discharge Volumes

A reliable flow record has been collected at SW027 starting in WY95. Flow record was collected at GS21, GS22, GS24, and GS25 from the spring of 1995 through September 30, 1996. For this comparison, flow data was limited to the period from 5/1/95 through 9/30/96. Relative discharge volume percentages to SW027 for GS21, GS22, GS24, and GS25 are 4.5%, 81.3%, 2.3%, and 8.3% respectively. However, discharge from these gaging stations does not all reach SW027. A significant volume of water is lost through infiltration and evaporation due to the storage capacity of the SID. In fact, GS22 had flow all 519 days of this period[7], while SW027 had flow only 178 (34%) of the 519 days. Therefore, although the discharge measured at upstream gaging stations was 96% of the discharge measured at SW027, it can not be concluded that 96% of the discharge measured at SW027 originated at the upstream gaging stations. Using all flow data collected at SW027 (10/1/94 – 9/30/98), the variation of flow rates and discharge volumes is significant, and coincides with variation in precipitation (as shown in Figure 4-1 and Figure 4-2). Baseflow at SW027 is not continuous, with low flows only occurring from residual direct runoff after storm events and GS22 baseflow when the storage capacity of the SID is full.

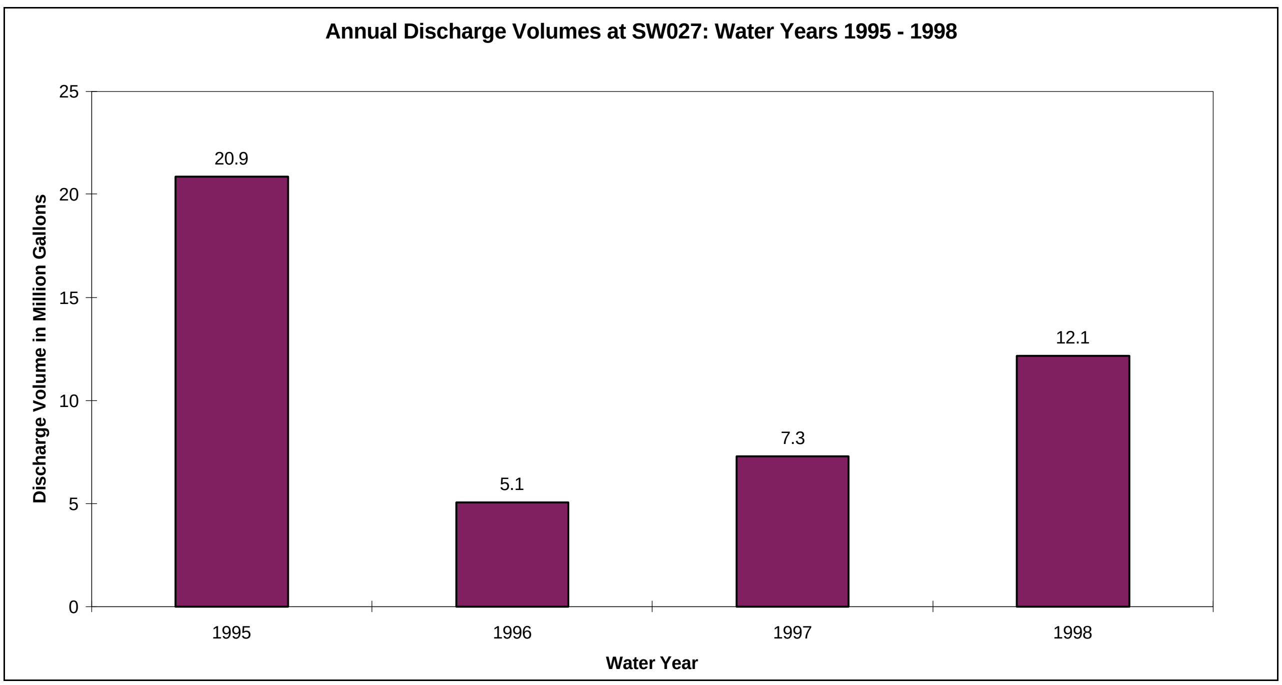


Figure 4-1. Annual Discharge Volumes for SW027.

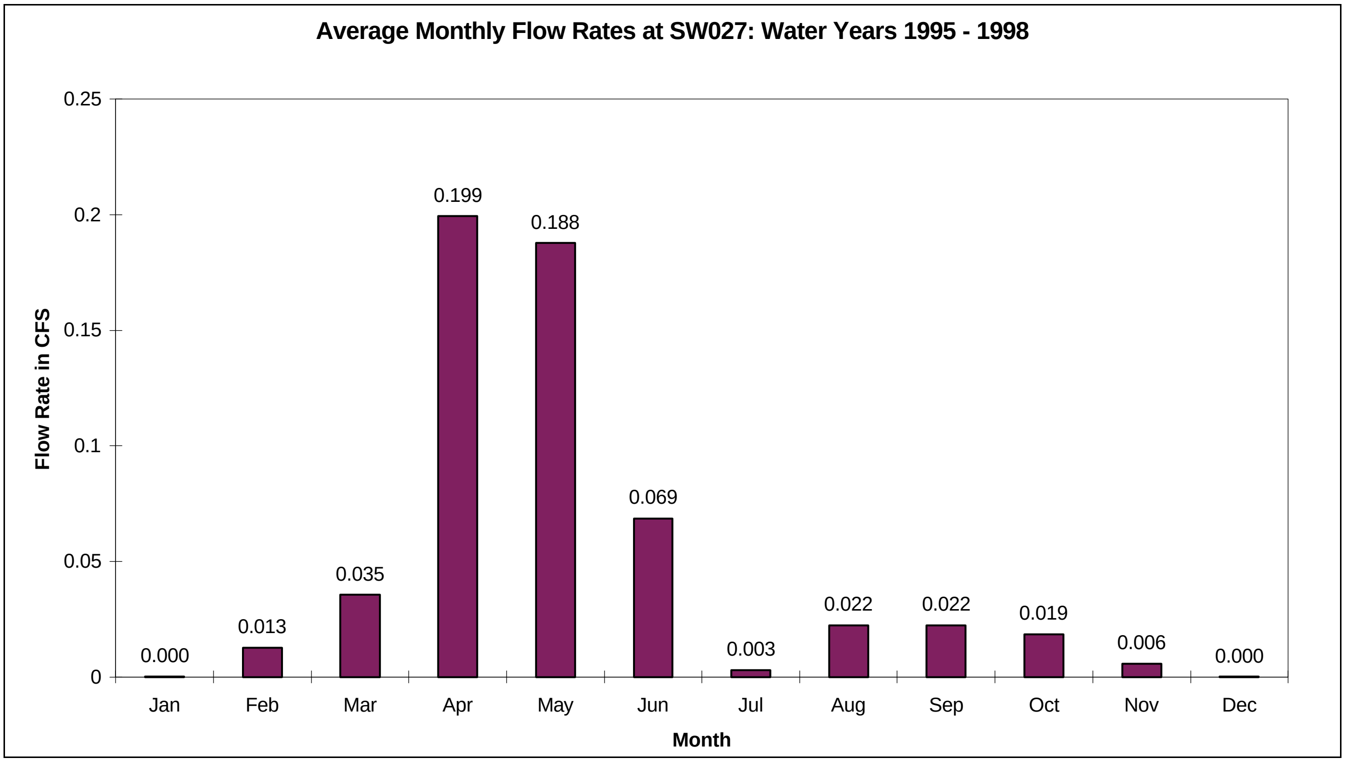


Figure 4-2. Average Monthly Flow Rates at SW027.

Radionuclide Activities

Individual analytical results for plutonium at the gaging stations of interest are shown in Figure 4-3 through Figure 4-7. All sample results are plotted regardless of sampling protocol employed[8] for the period 1/1/90 through 10/1/98. The results from a composite sample collected at SW027 starting on 9/10/98 are not yet available. The variation in activities is evident in these plots. Summary statistics for these results are shown in Table 4-1. These activities are arithmetic averages, which do not take into account the hydrologic conditions during sampling (storm-event, baseflow, etc.), flow rate, discharge volume, or the sampling protocol.

Table 4-1. Summary Statistics for Samples from SW027, GS21, GS22, GS24, and GS25.

Sampling Location	Number of Samples	Average[a] Activity (pCi/L)	Maximum Result (pCi/L)	Standard Deviation[b] (pCi/L)
SW027	46	0.184	2.289	0.460
GS21	10	0.033	0.104	0.032
GS22	8	0.012	0.027	0.009
GS24	11	0.093	0.209	0.066
GS25	9	0.018	0.037	0.013

[a] Arithmetic average
[b] Assumes normal distribution

[7] GS22 shows continuous baseflow. This baseflow is likely sustained by a combination of building footing drains, domestic water leaks, and groundwater infiltration to the sewer system in the 400 Area.

[8] Surface-water sampling protocols have varied at the Site as different programs, investigations, and regulatory agreements have been implemented. Individual grabs, time-paced (scheduled grabs) composites, storm-event (hydrograph rising limb) flow-paced composites, and continuous flow-paced composites are shown.

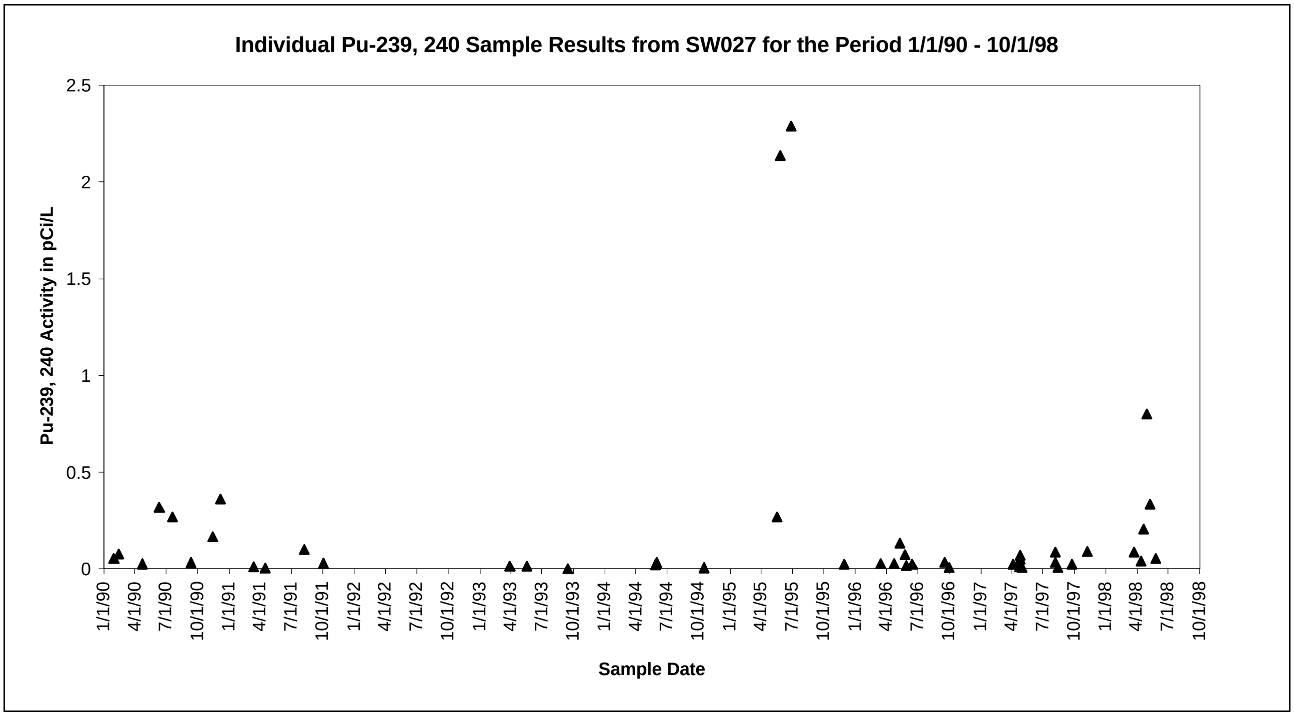


Figure 4-3. Individual Analytical Plutonium Results for SW027.

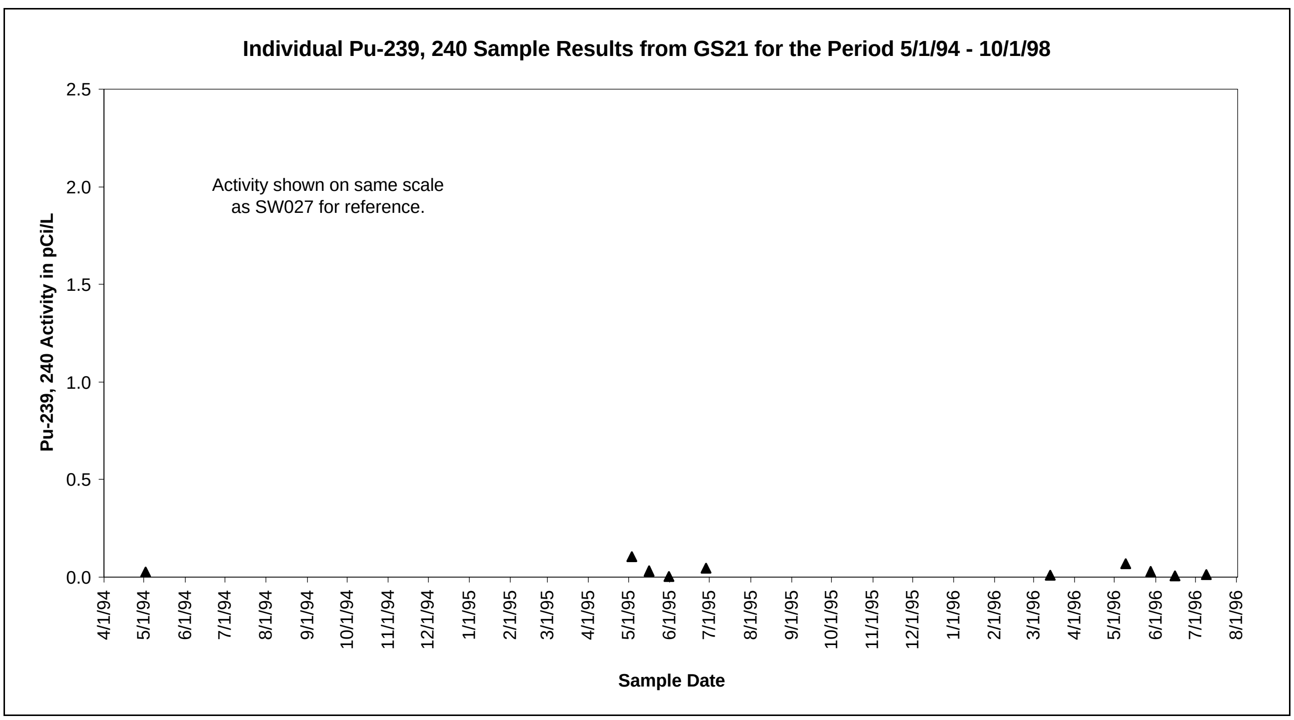


Figure 4-4. Individual Analytical Plutonium Results for GS21.

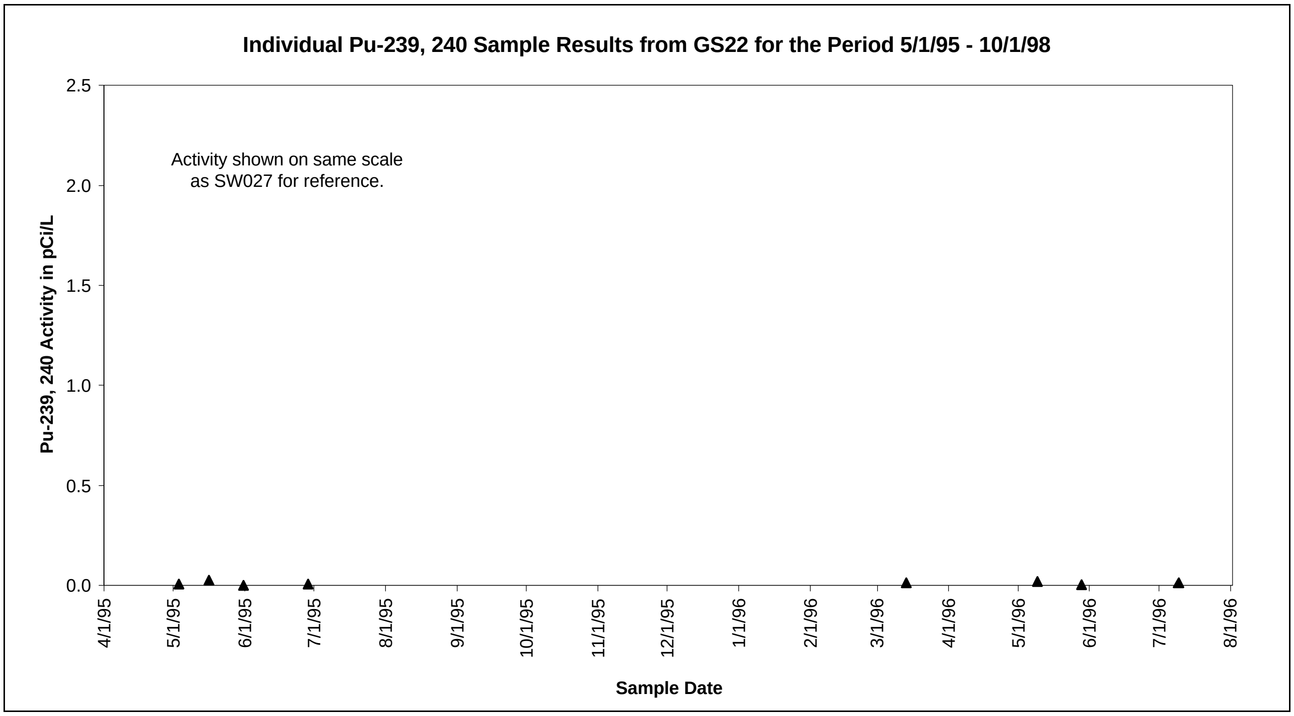


Figure 4-5. Individual Analytical Plutonium Results for GS22.

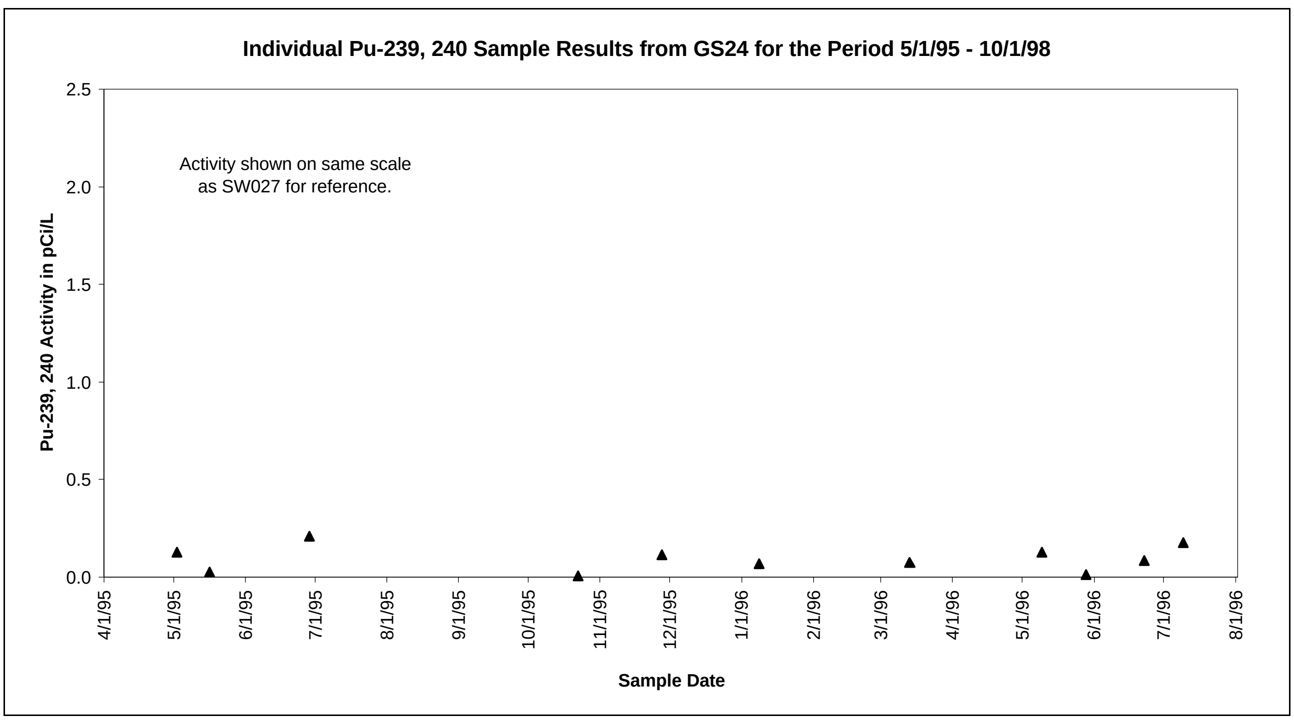


Figure 4-6. Individual Analytical Plutonium Results for GS24.

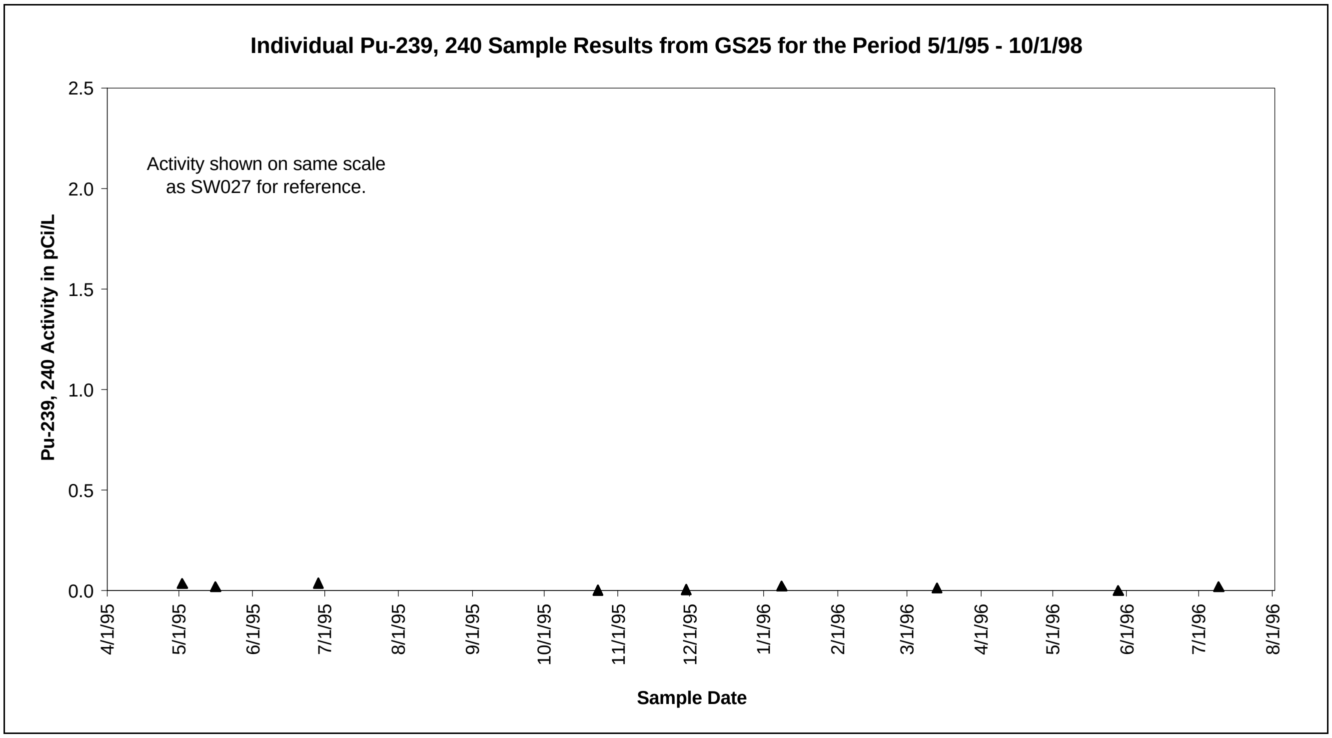


Figure 4-7. Individual Analytical Plutonium Results for GS25.

Figure 4-8 shows the average annual activities at SW027 for WY95 - WY98 when reliable flow record was also being collected. For WY95 - WY96, arithmetic averages are plotted. However, due to the continuous flow-paced sampling protocols currently in place, the more representative volume-weighted average activity is shown for WY97 – WY98. This volume-weighted average is calculated in a fashion similar to 30-day moving average, except that the period is from October 1 through September 30.[9] *It is important to note that although elevated measurements were made this year, the volume-weighted average is comparable to the activities for other years*. The high activities in WY95 are associated with the large runoff events during May and June of 1995.

It is generally agreed that plutonium forms strong associations with particulate matter.[10] If contaminated particles are transported in surface water, then the observed plutonium levels could be correlated with the amount of TSS. The data collected at GS10 is a good example (Figure 4-9) of this phenomenon. During higher intensity precipitation events with increased raindrop impact, greater quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks generally result in increased TSS values due to higher flow velocity and turbulence. The recent elevated results at SW027 (Figure 4-3) are from samples collected during spring precipitation events between April 20, 1998 and May 26, 1998. Figure 4-10 shows the average monthly volume-weighted activity at SW027 for the period of continuous flow-paced sampling.

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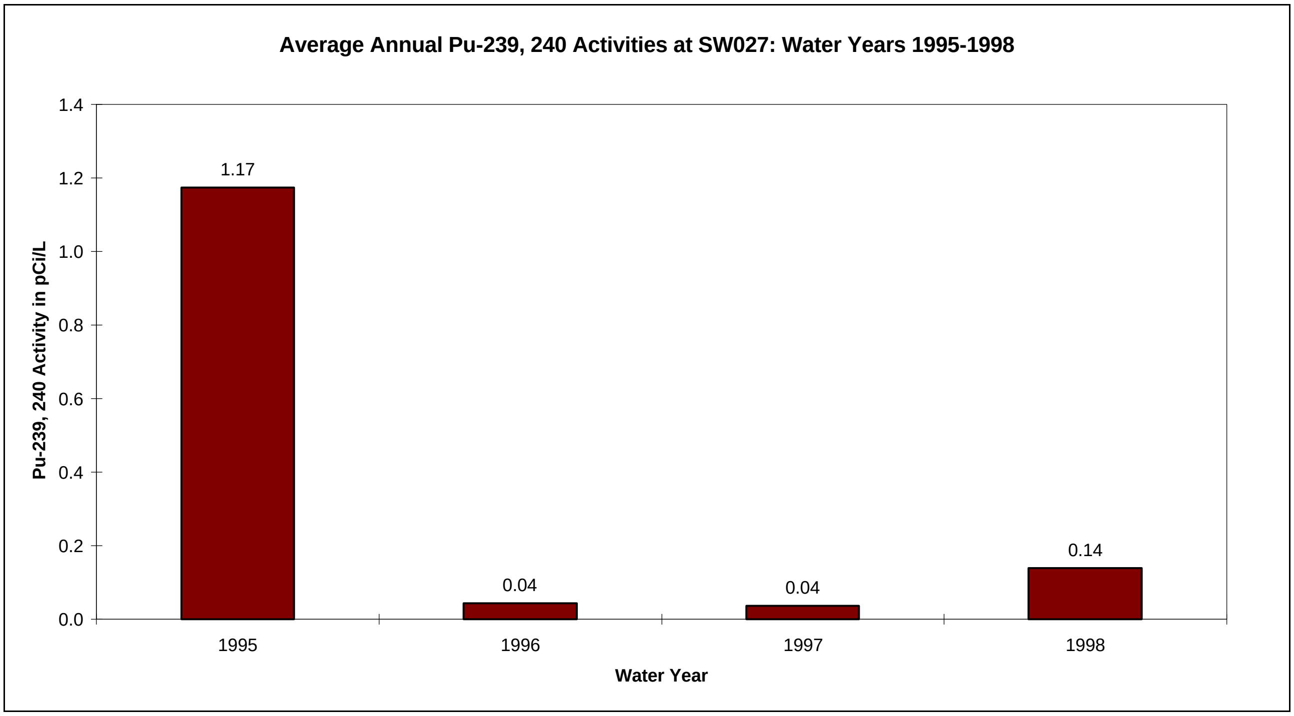
[9] Each carboy has a load in pCi calculated from the activity and the associated creek discharge volume. The total load in pCi for all samples is then divided by the total creek discharge volume to give the volume-weighted activity in pCi/L.

[10] Recent AMS results provide additional confidence in this conclusion.



Volume-weighted average is plotted for WY97 and WY98. Arithmetic average is plotted for WY95 and WY96.

Figure 4-8. Average Annual Plutonium Activities for SW027.

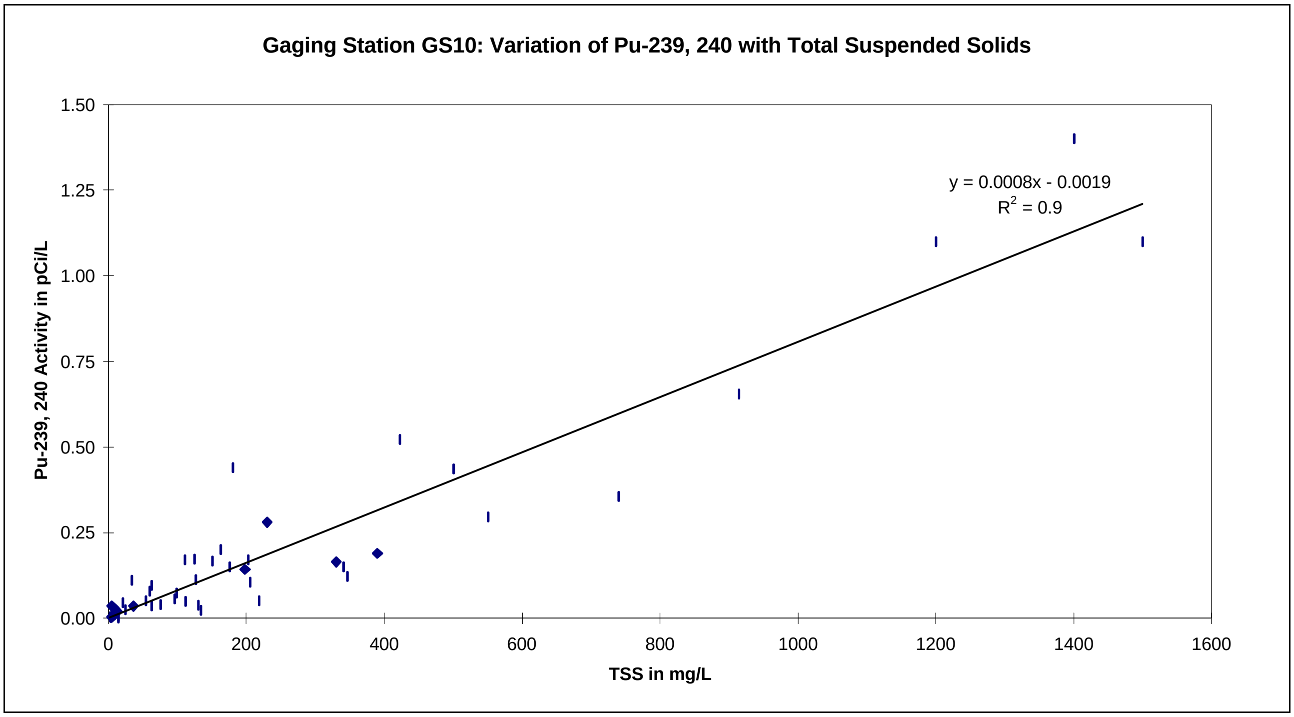


Figure 4-9. Variation of Plutonium with Total Suspended Solids at GS10.

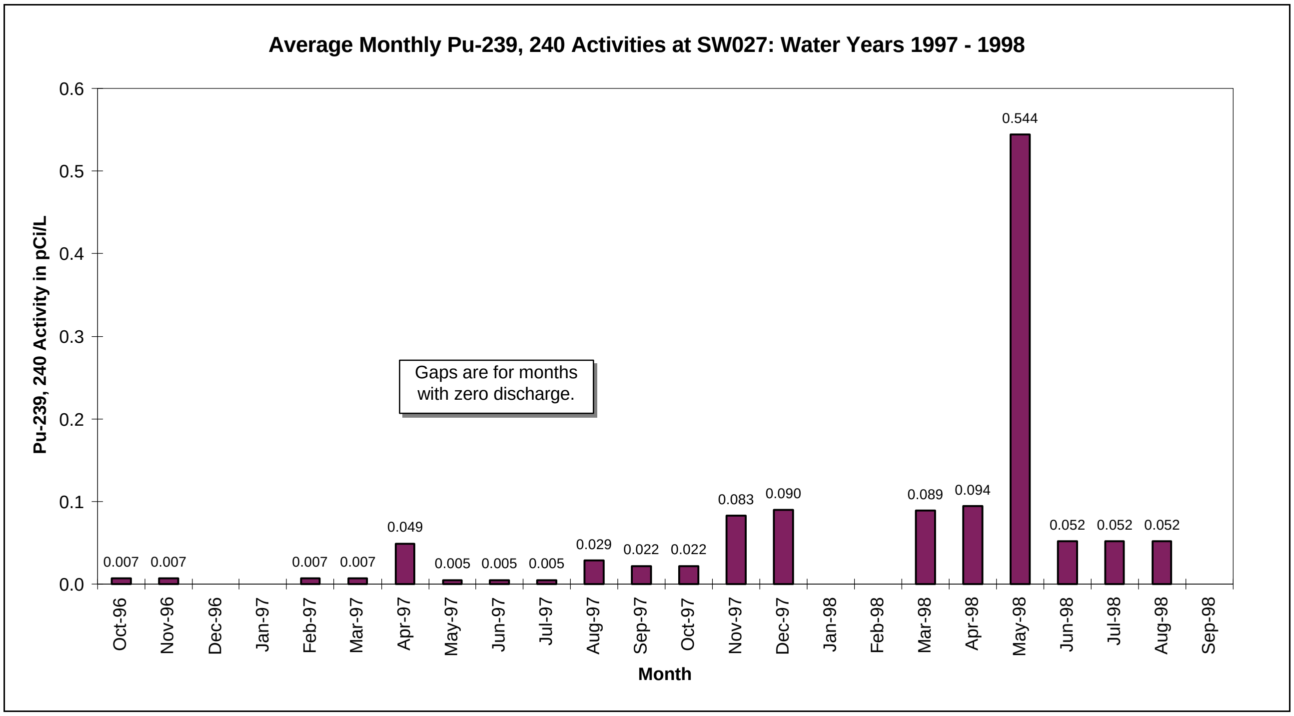


Figure 4-10. Average Monthly Plutonium Activities at SW027: Water Years 1997 – 1998.

Loading Analysis

WY95 - WY98 Monitoring Data

Annual loads for SW027 in micrograms are plotted in Figure 4-11. For WY95 - WY96, the arithmetic average activity is multiplied by the associated total annual discharge volume, then converted to micrograms. For WY97 – WY98, the activity for each flow-paced composite is multiplied by the associated discharge volume, then converted to micrograms and totaled.

Loading for various sub-drainages tributary to SW027 was estimated by multiplying the arithmetic average plutonium activity at the gaging stations (which define the sub-drainages) by the corresponding discharge volume for each gage during the same period. Only discharge and plutonium activity data for 5/1/95 through 9/30/96 were used. This is the period when all gages were operating simultaneously. Figure 4-12 shows that the monitored sub-basins measured approximately 3% of the plutonium load measured at SW027. These sub-basins are all within the IA and west (generally upwind and upgradient) of the 903 Pad. In other words, 97% of the plutonium load measured at SW027 likely originated from areas *other than* the upstream gaging station sub-basins. This gain indicates that plutonium entered the SID downstream from these gaging stations, most likely from areas contaminated by the 903 Pad.

Table 4-2. Plutonium Loads at SID Gaging Stations for the Period 5/1/95 – 9/30/96.

	Pu-239,240 Loads in µg				
Period	**GS21**	**GS22**	**GS24**	**GS25**	**SW027**
5/1/95 – 9/30/96	1.7	10.7	2.3	1.7	505.4

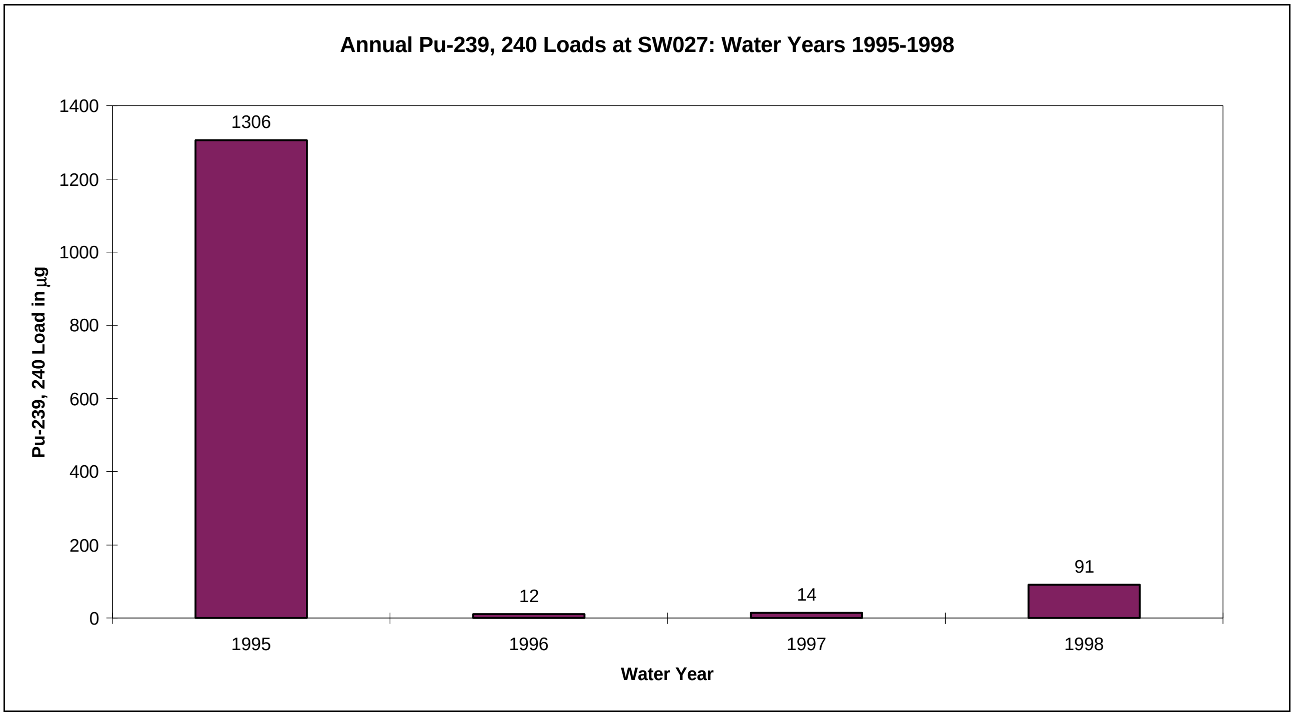


Figure 4-11. Annual Plutonium Loads at SW027.

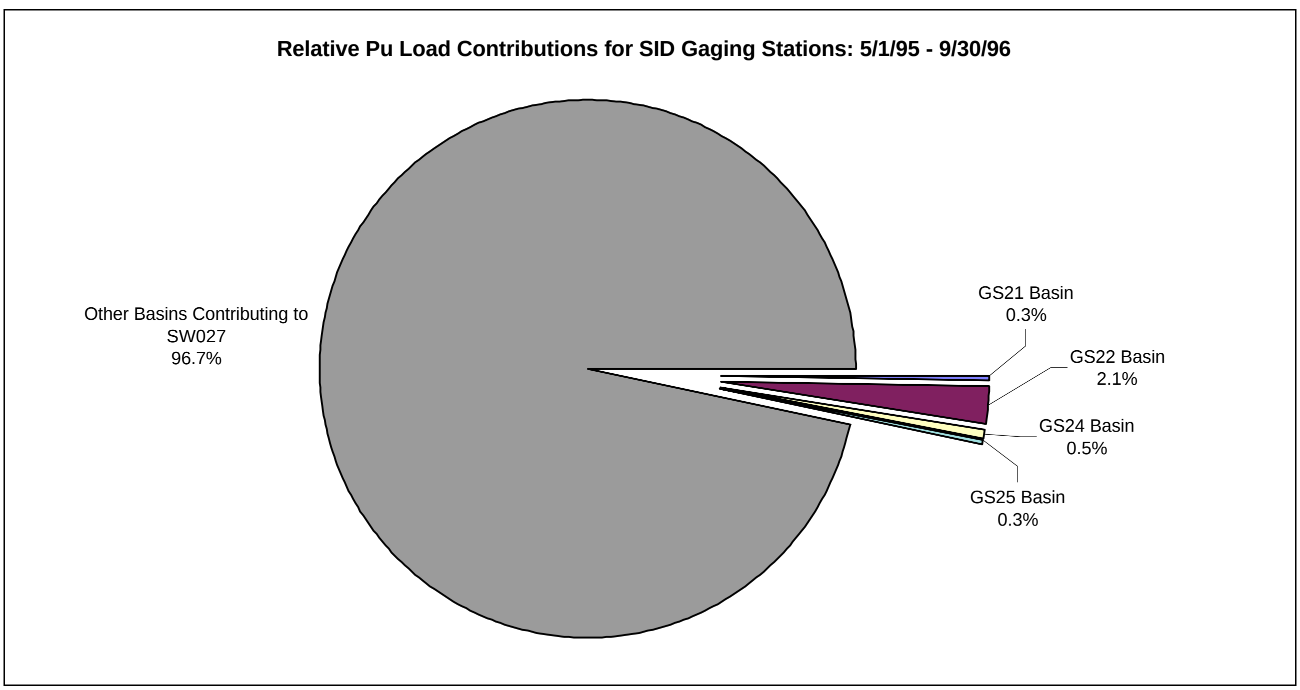


Figure 4-12. Relative Sub-Basin Loads to SW027: 5/1/95 – 9/30/96.

Loading analysis was also performed on Pond C-2 to assess the plutonium removal efficiency. The period evaluated extended from the end of the Pond C-2 discharge in FY97 (1/23/97 – 1/29/97) through the end of the second Pond C-2 discharge in FY98 (5/21/98 – 5/30/98). The plutonium associated with the C-2 valve test on 12/16/97 was not included in this analysis since the plutonium discharged was associated with the outlet work hardware and not the pond water. Figure 4-13 shows that 91% of the plutonium entering Pond C-2 at SW027 was removed during this period.

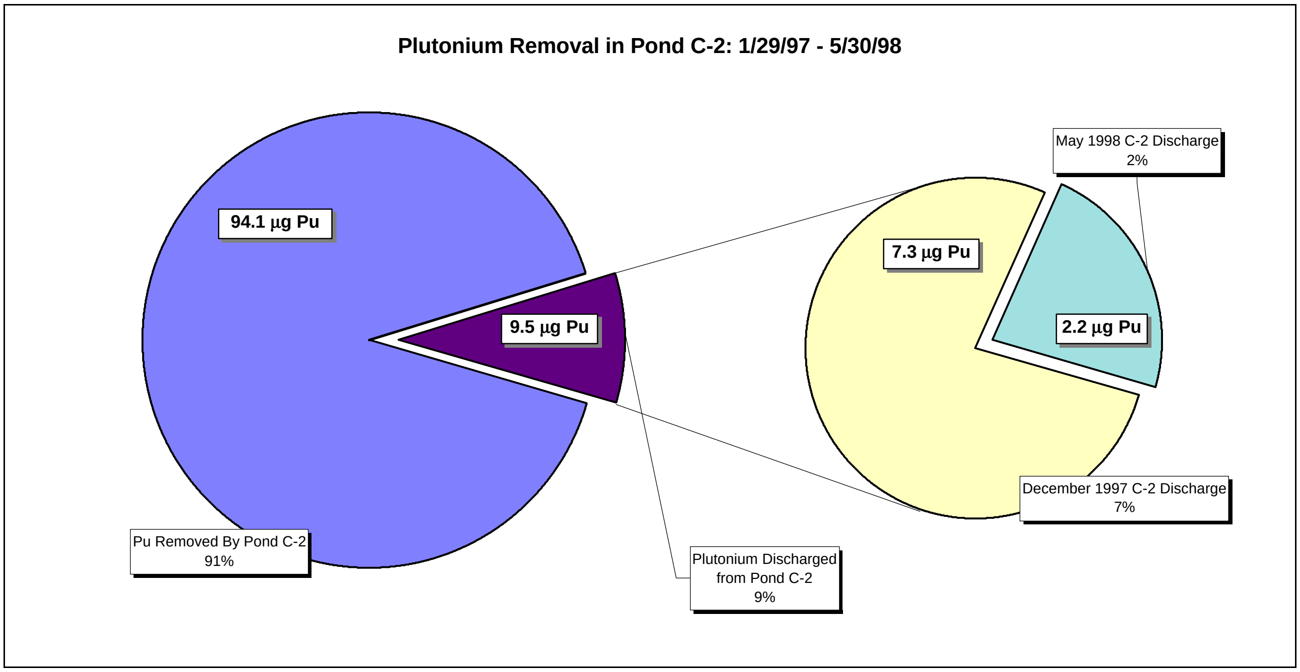


Figure 4-13. Plutonium Removal in Pond C-2: 1/29/97 - 5/30/98.

Data Correlations

Data correlations in this section were performed using all available data from 1/1/90 through the present, unless specifically noted.

<u>Flow Rates and Total Suspended Solids</u>

As noted above, plutonium forms strong associations with particulate matter (as shown in Figure 4-9 for GS10). When these particles are transported in surface water, then any associated plutonium also moves. During high-intensity precipitation events, with increased raindrop impact, higher quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks generally result in increased TSS values due to higher flow velocity and turbulence.

Figure 4-14 and Figure 4-15 show the variation of plutonium activity with flow at SW027. The activity plotted is the analytical result for the sample; the flow is the average of the flow rates for each composite grab sample. An upward trend would generally indicate the increased movement of plutonium during higher flow rates. This can occur when the source is widespread (movement through overland flow and raindrop impact), or when the source exists in the streambed itself (movement through increased scouring). These are the trends commonly observed at other Site monitoring locations. A downward trend may indicate that groundwater may be a source. For example, during low flow rates a contaminated groundwater source could make up the larger proportion of the flow, and result in higher activities. During direct runoff periods when relatively cleaner surface water enters the creek, the groundwater source would be diluted, resulting in lower creek activities. Figure 4-14 shows variable activities associated with the same flow rates.

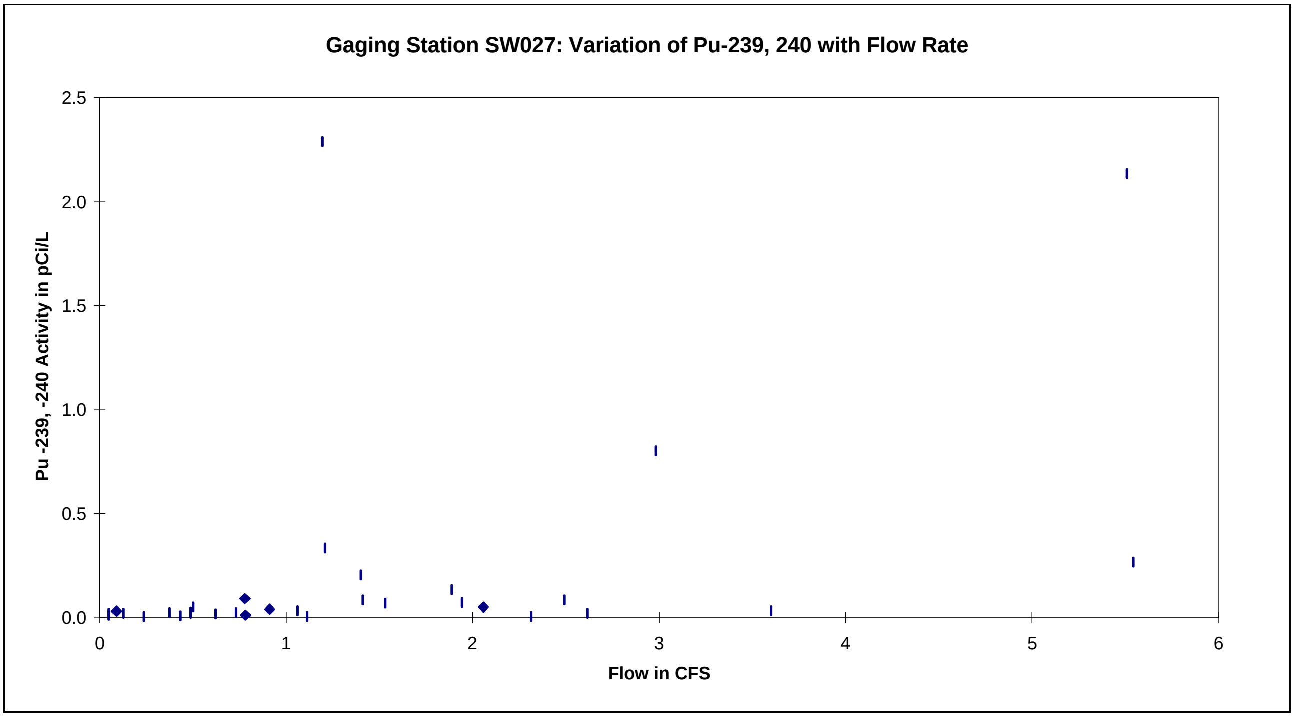


Figure 4-14. Variation of Plutonium Activity with Flow Rate at SW027.

Samples collected during the spring of 1995, when unusually high overland flow was noted from contaminated areas east of the 903 Pad, were not included in Figure 4-15. The observation of overland flow and the high activities of this water (see Section 4.2.2) indicate that areas east of the 903 Pad were contributing plutonium to the SID at this time. The high precipitation coupled with saturated soil conditions resulted in overland flow from areas that show minimal flow under normal conditions. The fact that the two samples collected at SW027 during this time show the highest plutonium activity to date indicates that the 903 Pad is likely the predominant source of plutonium in the drainage. When these two results are not included in the plutonium vs. flow evaluation, a more apparent trend appears with activities generally increasing with flow rate is observed (Figure 4-15).

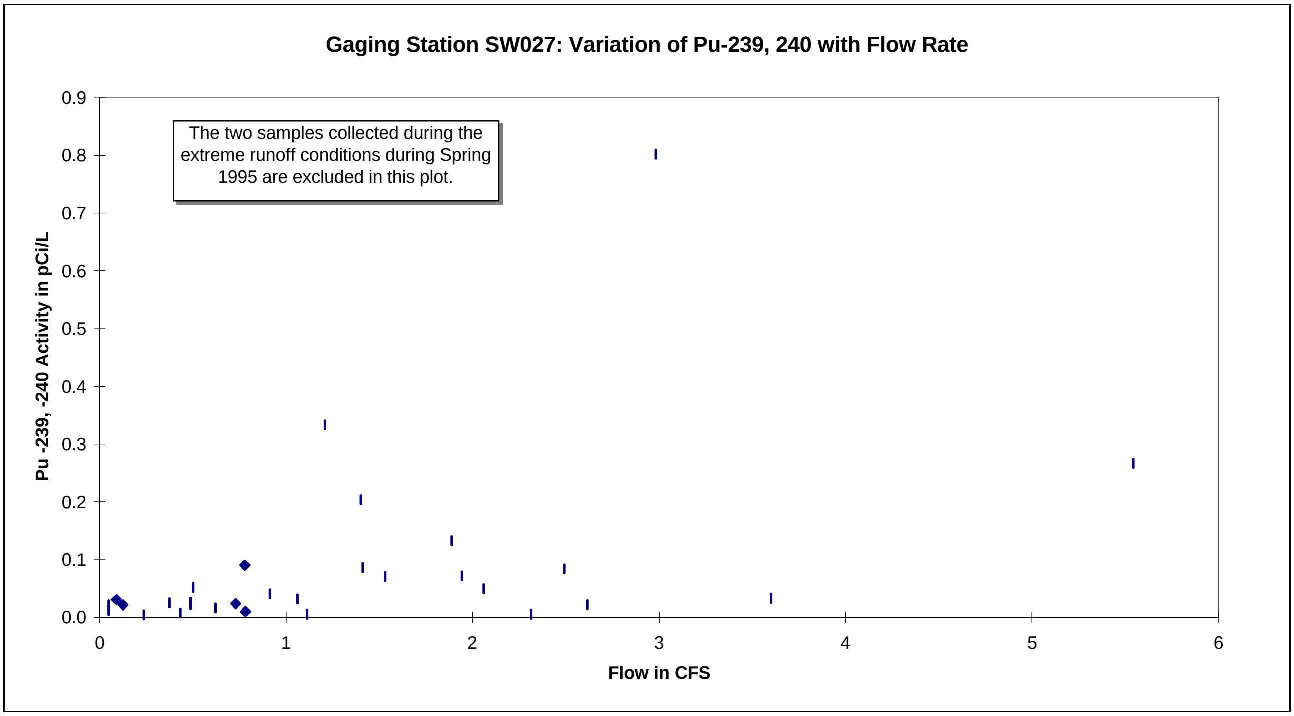


Figure 4-15. Variation of Selected Plutonium Activities with Flow Rates at SW027.

<u>Precipitation</u>

Assuming that the vast majority of plutonium in the SW027 drainage is associated with soils and sediments, then increased precipitation (and flow rates) or increased precipitation intensity (raindrop scouring) could result in increased transport to SW027. Figure 4-15 indicates that plutonium activities generally increase with increasing flow rates. Since the SID is an ephemeral ditch with no baseflow and a hydrograph punctuated by direct runoff from during precipitation events, the flow rate is directly influenced by precipitation depth, soil moisture conditions, and available SID storage.

Figure 4-16 and Figure 4-17 show daily precipitation depths superimposed on the 30-day moving average for plutonium during Water Years 1997 and 1998. In both figures, an increase in the 30-day moving average is apparent during the spring months (April, May, June), with significant increases occurring immediately after significant precipitation events. These increases in the 30-day moving average also occurred during periods of higher soil moisture conditions, which likely resulted in overland runoff from distributed contamination southeast of the 903 Pad. Consequently, overland runoff may make up a larger proportion of the flow reaching SW027. In other words, the relatively cleaner runoff from impervious IA drainages such as the 400 Area (measured by GS22; see Section 4.2.1) mixed with overland runoff with higher plutonium activities. In addition, during the spring, the SID generally flows continuously. Therefore, there is no available storage in the SID to detain runoff, and overland runoff that reaches the SID may also flow to SW027.

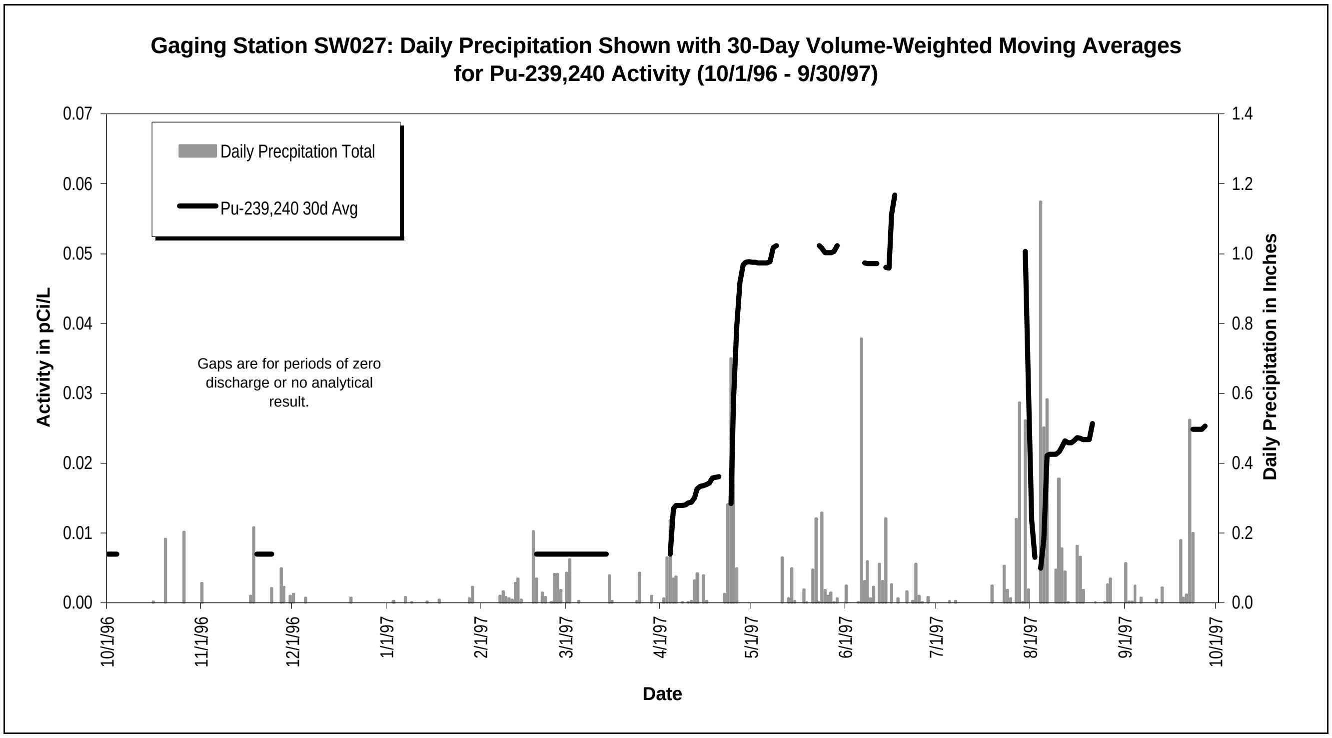


Figure 4-16. Daily Precipitation Totals and 30-Day Moving Averages for Plutonium at SW027: Water Year 1997.

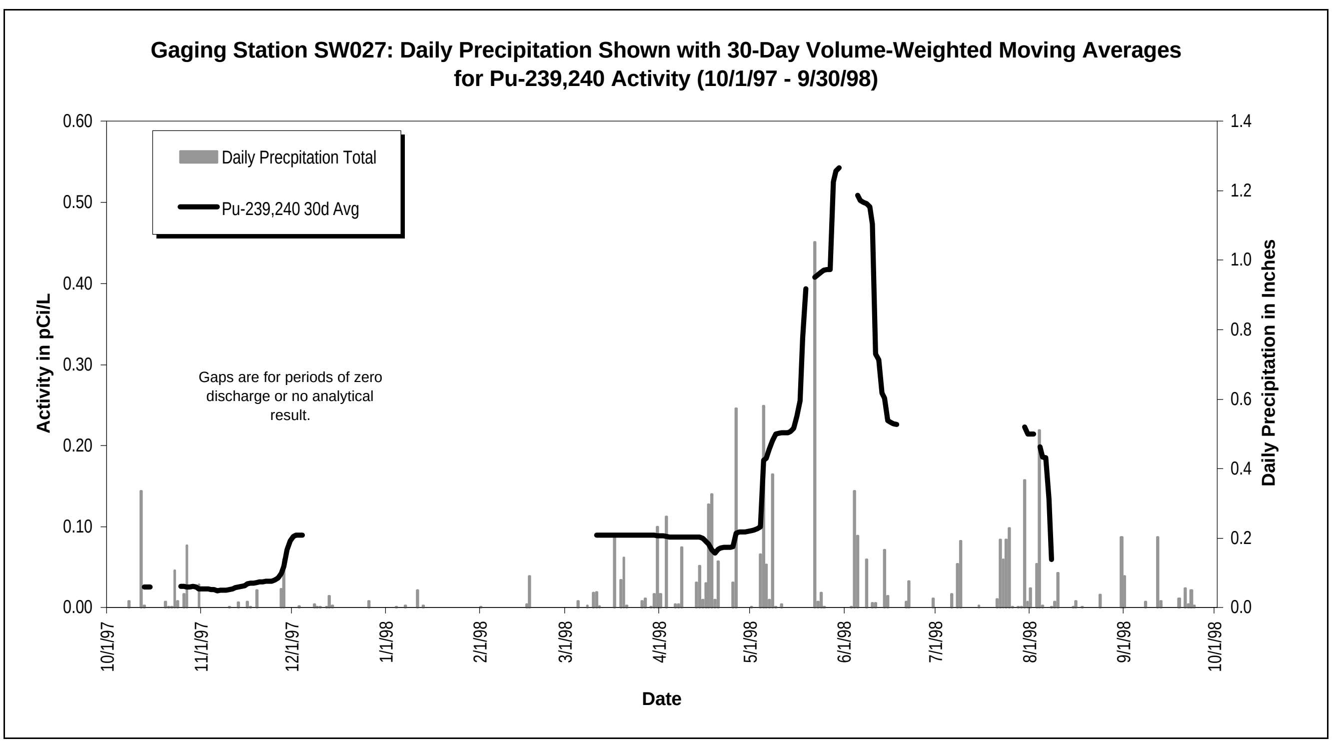


Figure 4-17. Daily Precipitation Totals and 30-Day Moving Averages for Plutonium at SW027: Water Year 1998.

The inverse response in the 30-day moving average at SW027 can be seen in late summer. Significant precipitation events can also be seen during the monsoon conditions that Colorado generally experiences in August. However, the 30-day moving average at SW027 during this period decreases in Figure 4-16 and Figure 4-17. This is likely due to lower soil moisture conditions which result in little overland runoff reaching the SID. Therefore overland runoff may make up a smaller proportion of the flow reaching SW027, while runoff with relatively lower plutonium activities from impervious IA drainages may still reach SW027 for large runoff events. In addition, during this period, the SID may be dry for much of its length. In both figures, no flow was measured at SW027 during part of June and most of July. Therefore, a significant portion of the runoff reaching the SID goes to storage before reaching SW027. Under these conditions of ponded water, infiltration, and low flow rates, it appears that a portion of the plutonium load is lost to the streambed as TSS settles.

Real-Time Water-Quality Parameters: Turbidity, Nitrate, Specific Conductivity, and pH

Average turbidity, nitrate, specific conductivity, and pH values for each composite sample collection period were calculated by averaging the readings at the time of each grab sample. Real-time water-quality data was available for the period March 1996 through August 1998. Variation of plutonium activity with the corresponding water-quality parameters was evaluated graphically. Results are presented in Figure 4-18 through Figure 4-21. No correlations were observed between any real-time water quality parameters and plutonium activity at SW027. This may be partially due to effects of seasonality which are not differentiated in this type of analysis.

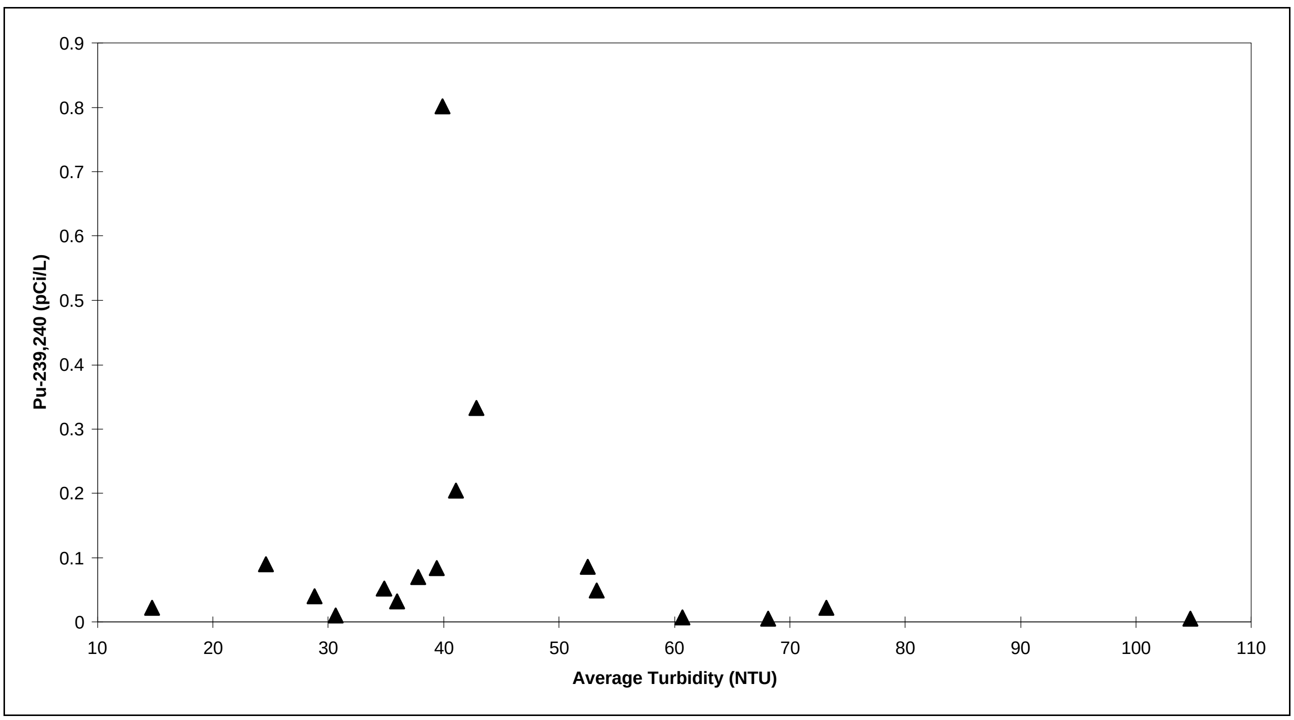


Figure 4-18. Variation of Plutonium Activity with Average Turbidity at SW027.

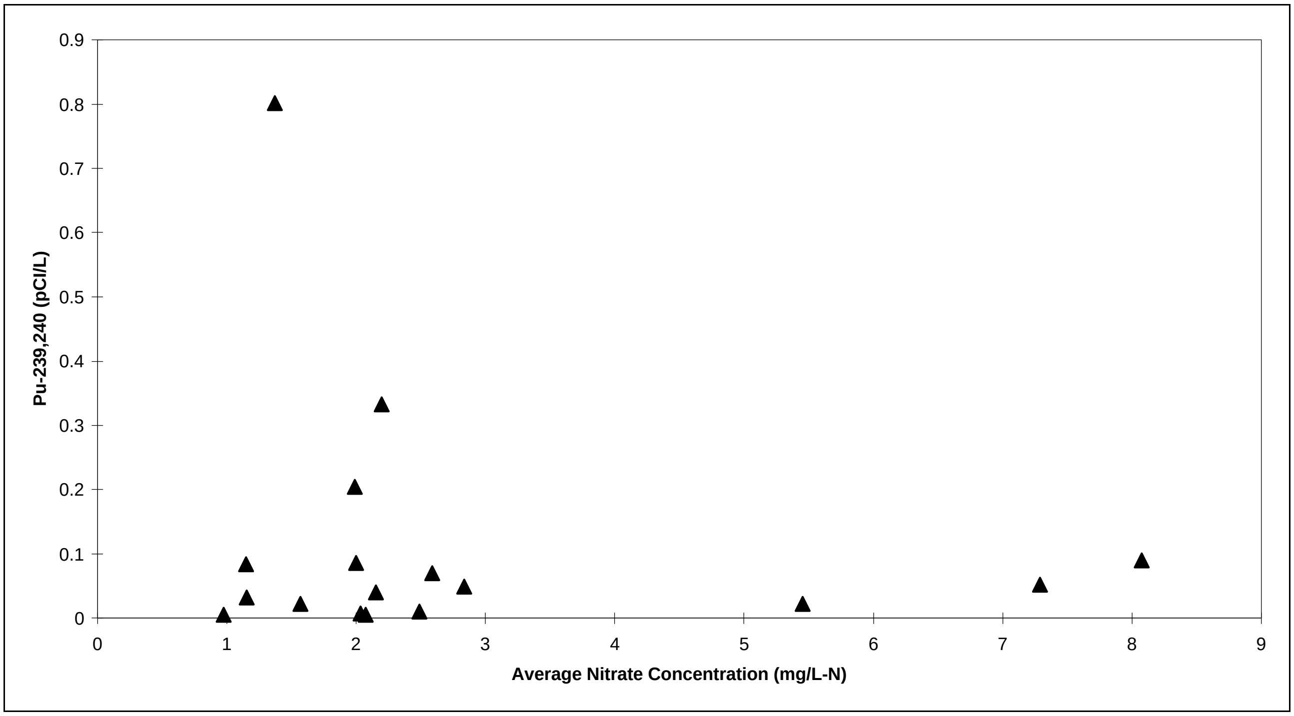


Figure 4-19. Variation of Plutonium Activity with Average Nitrate at SW027.

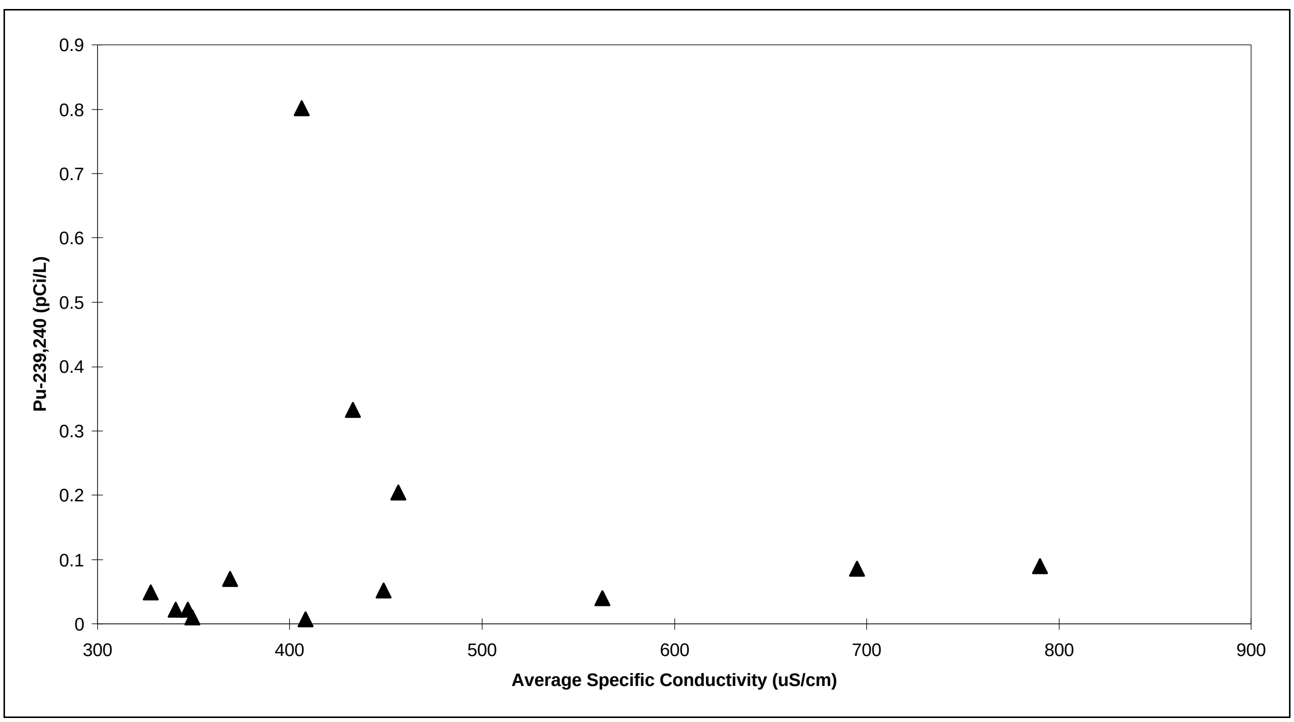


Figure 4-20. Variation of Plutonium Activity with Average Specific Conductivity at SW027.

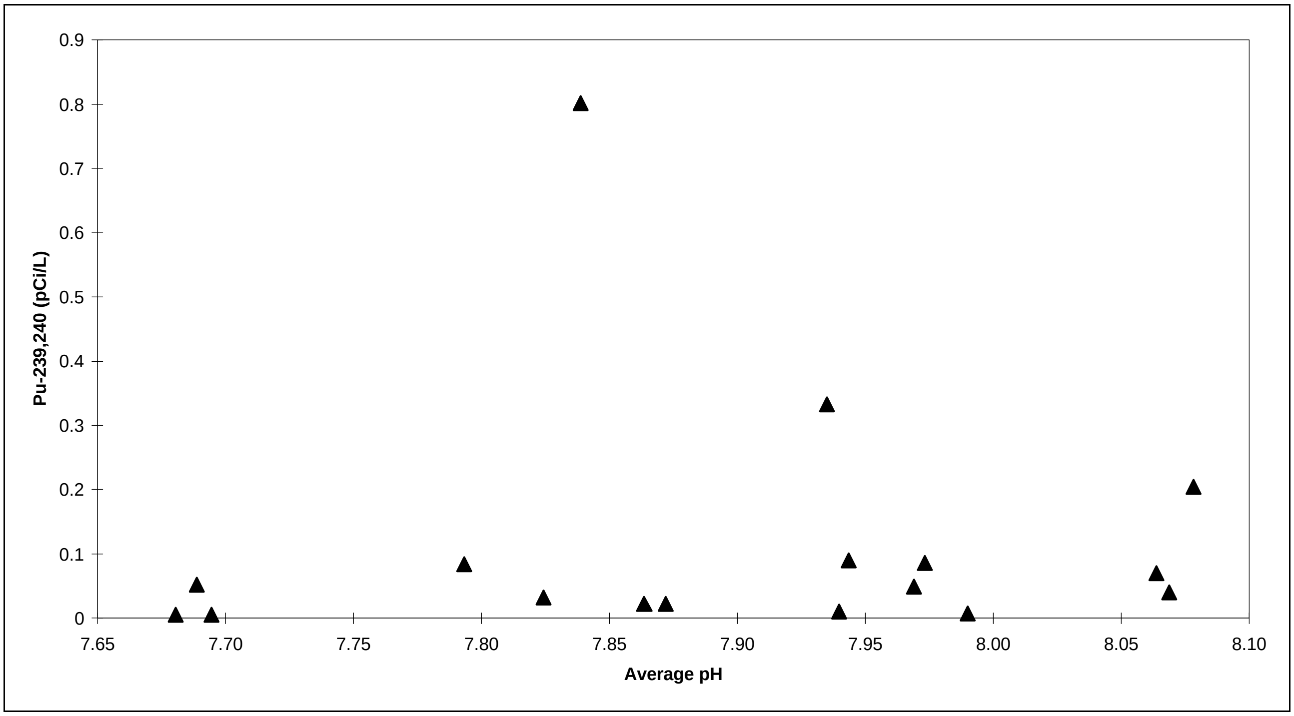


Figure 4-21. Variation of Plutonium Activity with Average pH at SW027.

4.2.2. Sitewide Surface-Water Data

A review of historical data provided the basis for this investigation of surface-water plutonium activities within the SW027 drainage basin. Historical data for this investigation were derived from the Rocky Flats Soils and Water Database (RFSWD, formerly RFEDS). Only sampling locations tributary to SW027 were included in this investigation (see Figure 4-22 for locations). Tributary sampling locations were identified using the Site's Geographic Information System (GIS) to select sampling locations within the SW027 drainage boundaries. The GIS-generated sampling location list was used to formulate an RFSWD query for all historical radioanalytical data. The query produced 668 usable radioanalytical data records for plutonium, which were sorted by location and analyte type (dates returned: 8/20/86 – 7/9/96). Negative analytical results were set to zero for calculation purposes. Data collected at SW027 under RFCA monitoring and not in SWD were also included. Average plutonium activity values were then generated for each location, which resulted in 54 surface-water values for evaluation. The filtered data were inspected and mapped to identify portions of the SW027 drainage basin associated with high plutonium contamination in surface-water runoff. These average plutonium activities are posted in map view in Figure 4-22 and presented in Figure 4-23 .

To evaluate the surface-water data, frequency distribution plots were generated using the logarithmically sized bins (less than or equal to 0.000, 0.01, 0.1, 1.0, 10.0, 100.0, or 1000) for grouping average plutonium values. Figure 4-23 shows the results. A review of the average values indicates differences of several orders of magnitude. The greatest number of surface-water values, 17 occurrences, were observed in the 1.0 to 10 pCi/L range. Many of the values greater than 1.0 pCi/L are associated with samples collected during the significant overland runoff period during the wet spring of 1995. In addition, all of these values are for locations east of the 903 Pad. The second greatest count, 16 occurrences, was observed in the 0.01 to 0.1 pCi/L range. All but three of the locations associated with these values are located upstream of the areas most impacted by contamination from the 903 Pad. This spatial distribution of average values indicates that contamination from the 903 Pad provides the likely source of plutonium measured in surface water for the SID drainage.

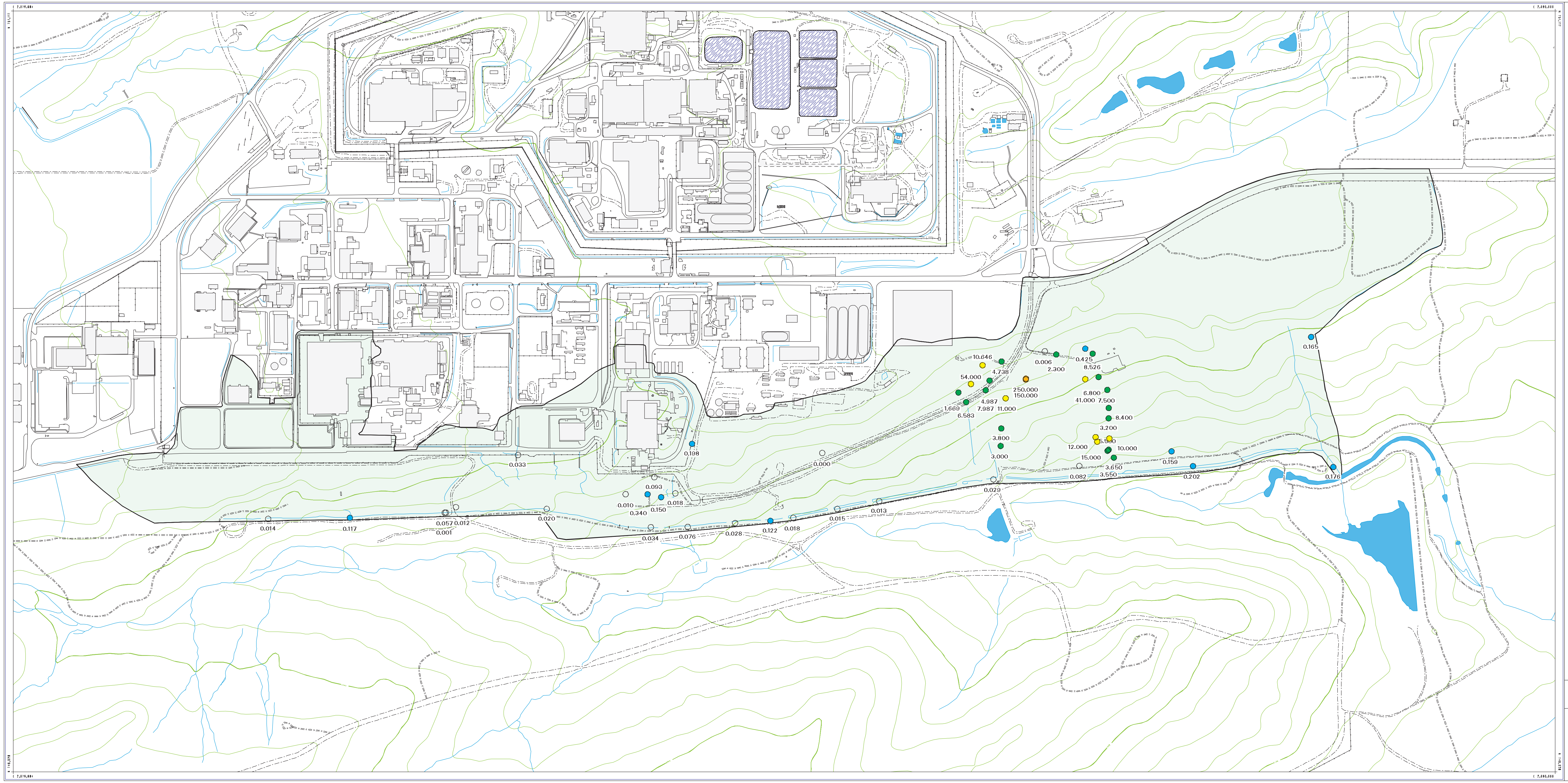


Figure 4-22

Surface Water Sampling Locations Tributary to SW027

Average Pu (pCi/L)

EXPLANATION

Pu Activity pCi/g

- -0.1 - 0.1
- 0.1 - 1.0
- 1.0 - 10.0
- 10.0 - 100.0
- 100.0 - 1000.0
- Greater than 1000.0

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrograpny, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotograpns. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was capture by the Remote Sensing Lab, Los Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing perfromed by MK, Winter 1997.

Scale = 1 : 6580
1 inch represents approximately 548 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:
Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
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P.O. Box 464
Golden, CO 80402-0464

MAP ID: 98-0253-Map3

October 28, 1998

/gis2/projects/fy98/98-0253/map3/sw027-swpu.aml

Figure 4-24 shows the spatial variation of average surface-water activities in the west to east direction. From this figure it is evident that locations east of the 903 Pad (the majority of windblown contamination from the 903 Pad traveled east-southeast; see Figure 4-29) have significantly higher activities. This trend suggests that the 903 Pad may be negatively influencing surface-water quality in the SW027 drainage.

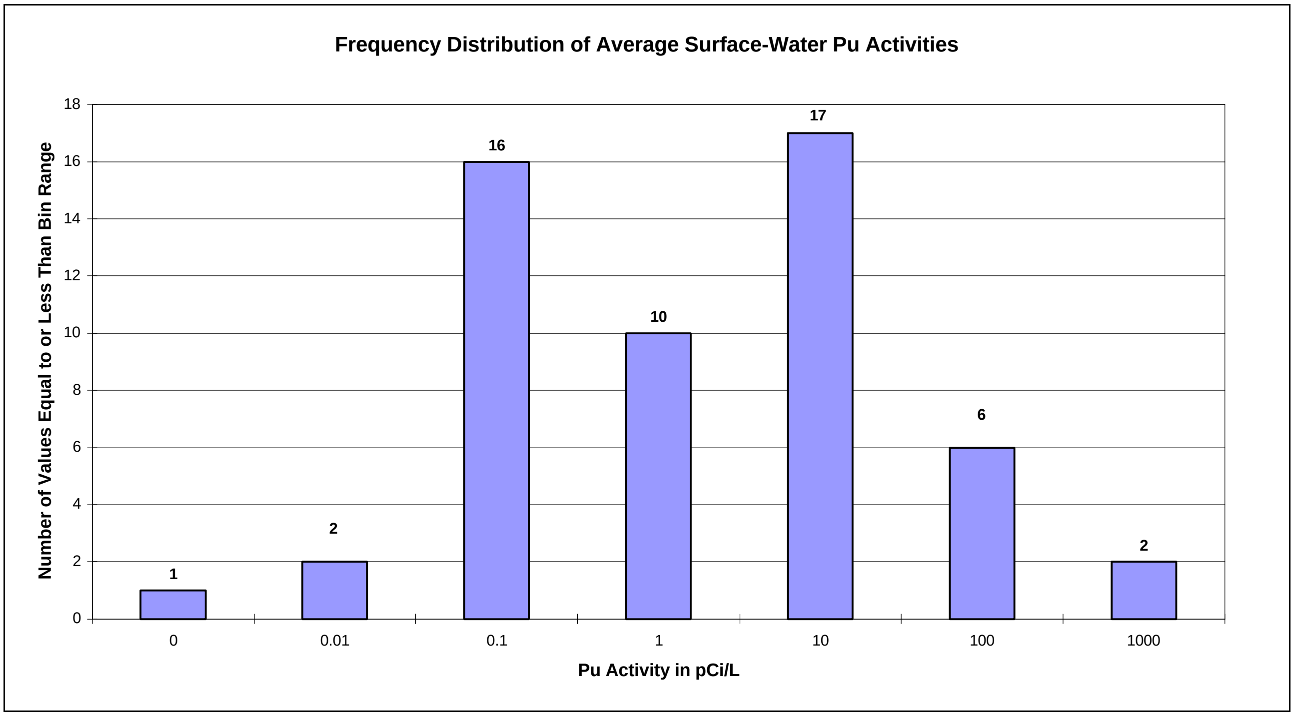

Figure 4-23. Frequency Distribution of Average Plutonium Activity for Surface-Water Sampling Locations within the SW027 Drainage Basin.

Several sampling locations with average activities above 0.15 pCi/L plutonium are located in tributaries that are known to occasionally contribute flow to the SID are presented below:

- SW31295, 3.0 pCi/L;
- SW31195, 3.8 pCi/L;
- SW31395, 11.0 pCi/L;
- SW055, 6.58 pCi/L;
- SW077, 7.99 pCi/L;
- SW058, 4.99 pCi/L; and
- SW125, 0.2 pCi/L.

The values measured at these locations indicate sub-drainages that may be candidates for watershed improvements (see Section 4.3) which may help reduce the migration of plutonium in surface-water. Additionally, there are other sub-drainages that flow infrequently except under unusual conditions (i.e. spring 1995) and show much higher average activities.

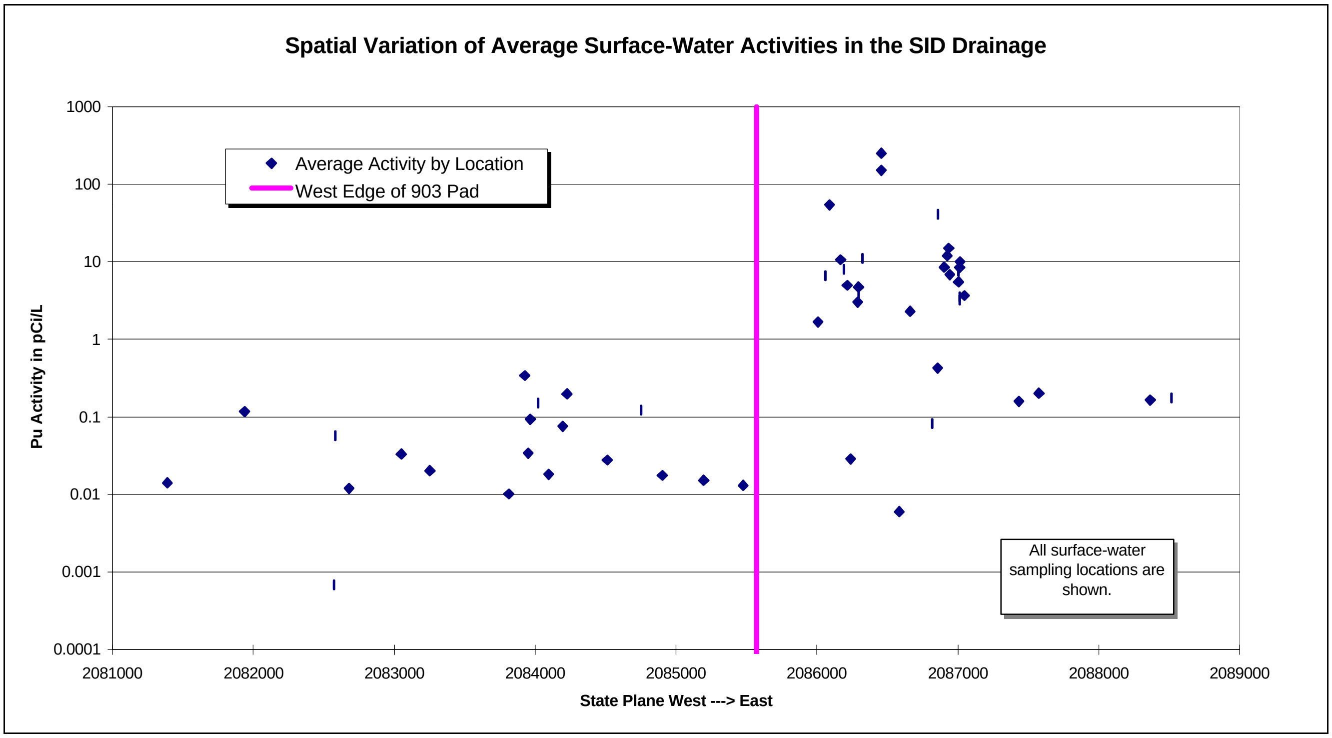

Figure 4-24. Spatial Variation of Average Surface-Water Activities in the SID Drainage Area.

4.2.3. Gamma Spectroscopy Information

In FY93 and FY94, IA Operable Units were surveyed by gamma spectroscopy (HPGe detector). The HPGe instrumentation was used to measure Am-241 activities in IA surficial soil materials. Am-241 is a decay product of Pu-241 and an important indicator of potential plutonium sources. These gamma spectroscopy data are of somewhat limited utility because of the large radius of investigation (approximately 30 feet) used for the measurements. This radius of investigation created the potential for monitoring results to be errantly impacted by radioactivity emitted from within nearby buildings, often referred to as "shine," and also to miss small, localized activity sources. With these factors in mind, the results from this survey were reviewed as part of the SW027 source investigation.

Data mapping indicates that, within the SW027 drainage basin, elevated surficial americium activity may exist in the soils near B664[11] (south side), and south and east of the 903 and 904 Pads. Gamma spectroscopy data are posted in map view in Figure 4-25.

4.2.4. Data Generated by Recent Site Projects

Site closure activities, including building D&D work, building modifications, ER projects, excavation work and routine day-to-day operations are ongoing continually at multiple locations around the Site. Activities conducted during FY98 were assessed to determine whether or not they represented a plausible source of the plutonium that resulted in the elevated activities observed at Station SW027. These activities are discussed below.

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[11] Buildings are listed as B### (e.g. B771 for Building 771).

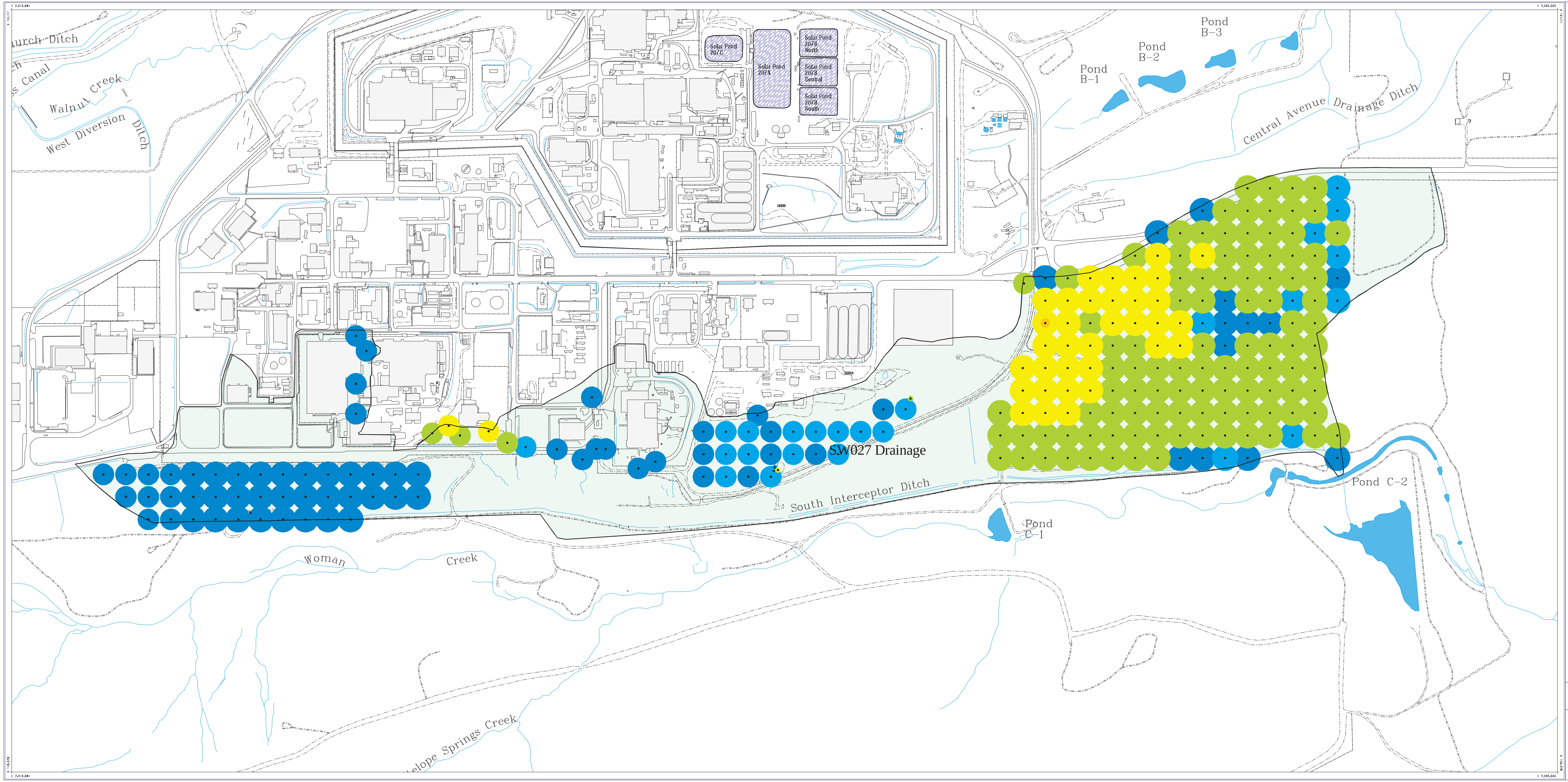

Figure 4-25

Gamma Spectroscopy Data in SW027 Drainage Am-241 pCi/g

EXPLANATION

HPGe Data Ranges--

- 0.0 - 0.1
- 0.1 - 1
- 1 - 10
- 10 - 100
- 100 - 1000
- 1000 - 10000

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

NOTE:
Raw field data which has not been evaluated and may be influenced by building shine.

The HPGe field of view (FOV) or radius of influence, assumes a homogeneous surface distribution. The FOV represents a circle where 90% of the flux originates. The radius, for each HPGe sampling location, is based on the height of the detector above the ground.

DATA SOURCE:
HPGe data from Ron Reiman, Gamma Survey Group, Safeguard Measurements, EG&G Rocky Flats, Inc. June 1994
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Scale = 1 : 6500
1 inch represents approximately 542 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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P.O. Box 464
Golden, CO 80402-0464

MAP ID: 98-0253-Map5

October 28, 1998

/gis2/projects/fy98/98-0253/map5/sw027-hpge.aml

D&D / Building Modification Work

D&D activities occurred throughout RFETS during FY98. However, no buildings were demolished within the SW027 drainage basin during that time frame. Buildings 440 and 881 were the two buildings within the SW027 drainage basin that had significant D&D or building modification work occurring in FY98. This work is described below:

<u>Building 881</u>

The Building 881 FY98 Performance Measure involved disposing of the building's waste chemicals by 3/31/98. This task, involving a wide variety of chemicals in volumes ranging from approximately 100 mL vials up to 55-gallon drums, was completed on schedule (Albin, October 1998). The majority of these chemicals were packaged and shipped away for treatment. A small percentage that met Internal Wastestreams criteria were routed to the Site Wastewater Treatment Plant.

There were five cases of incidental waters sampled and dispositioned from Building 881 during FY98. Three of these waters did not meet either the nitrate or conductivity criteria specified by the *Control and Disposition of Incidental Waters* procedure (RMRS, 1997a) and were sent to Building 891 for onsite treatment. The other two incidental waters, from Room 286 in the Building 881 basement, met all incidental waters criteria and were discharged to the environment (within the SW027 basin). These waters, with gross alpha activities of 10 pCi/L (+/- 3) and 11 pCi/L (+/- 2) were both below the 40pCi/L gross alpha standard for incidental waters (Barker, October 1998).

<u>Building 440</u>

The transuranic waste/transuranic mixed waste (TRU/TRM) Repackaging Module project was ongoing throughout FY98 on the west side of B440. This project involved installing a glovebox and associated ventilation equipment for waste packaging operations that are scheduled to begin in April, 1999. Therefore, waste was not processed in this area during FY98 (Bannister, October 1998).

Other activities occurring in B440 during FY98 included routine waste handling operations (involving movement of closed drums and standard waste boxes) and D&D of a paint booth (not involving radioactive contamination). FY98 B440 operations are not suspected of causing the reportable plutonium values in the SW027 basin.

ER Projects

No ER projects were conducted in FY98 that involved actual remediation work in the SW027 drainage basin. Other potentially relevant FY98 ER projects and their potential impacts are discussed below.

<u>Trench 1 Source Removal Project</u>

The Trench 1 (T-1) Source Removal Project, located at the eastern edge of the IA in the South Walnut Creek drainage basin, was conducted in the spring and summer of 1998. It involved the removal and stabilization of depleted uranium (DU) metal chips, stored in drums, and other contaminated debris and soil from a trench used to bury waste from 1954 to 1962 (RMRS, October 1998).

Prior to excavating the waste material, a 30,000 square foot free-standing structure (tent) was erected over the T-1 site to shelter the area and workers from the elements (i.e., wind and precipitation) during excavation activities. Excavation work occurred from June 10, 1998 through August 20, 1998 within the enclosure. During this time, a total of 170 drums were removed from the excavation, including 132 "intact" drums of DU waste, 28 "non-intact" drums of DU waste, and 10 drums of "intact" cemented cyanide waste (RMRS, October 1998). The final excavation was approximately 230 feet long by 15 feet wide by 10 feet deep.

It is not suspected that the T-1 project caused the reportable sample results measured at SW027 for the following reasons:

- The T-1 project site is not located within the SW027 drainage basin;
- The enclosure/tent over the T-1 excavation prevented transport of materials via surface water runoff and minimized airborne material transport pathways; and
- The primary contaminant of concern for the project was DU, not plutonium, the contaminant with reportable values measured at monitoring station SW027.

903 Pad Pre-Remedial Investigations

Roughly the southern third of the 903 Pad is located in the SW027 drainage basin. Investigatory work for the remediation of the 903 Pad was conducted from February through September of 1998. This work involved drilling approximately 40 shallow boreholes, two deep boreholes, collecting over 200 HPGe measurements, and collecting two surface soil samples on and around the 903 Pad. This work was performed with strict radiological controls and monitoring in place, as documented in the project's Radiological Work Permits. Equipment used in this investigation was radiologically surveyed before being removed from the project site. Because of the strict controls and on-site monitoring in place, an acute release of plutonium sufficient enough to cause the reportable values at station SW027 would first have been detected by the monitoring equipment used by the sampling team on the Pad itself. This work is therefore not suspected of causing the reportable sample results measured at SW027.

Excavation Work and Routine Site Operations

Excavation work and routine operations at the Site are subject to the Site Incidental Waters program. Water collected in utility pits, valve vaults, or excavations is sampled prior to being dispositioned. Following sampling, such water is pumped to the ground if the water quality is acceptable, or sent to an on-Site treatment facility if sample results indicate the water is not suitable for a release to the environment.

Summary of Recent Site Activities Impact on SW027

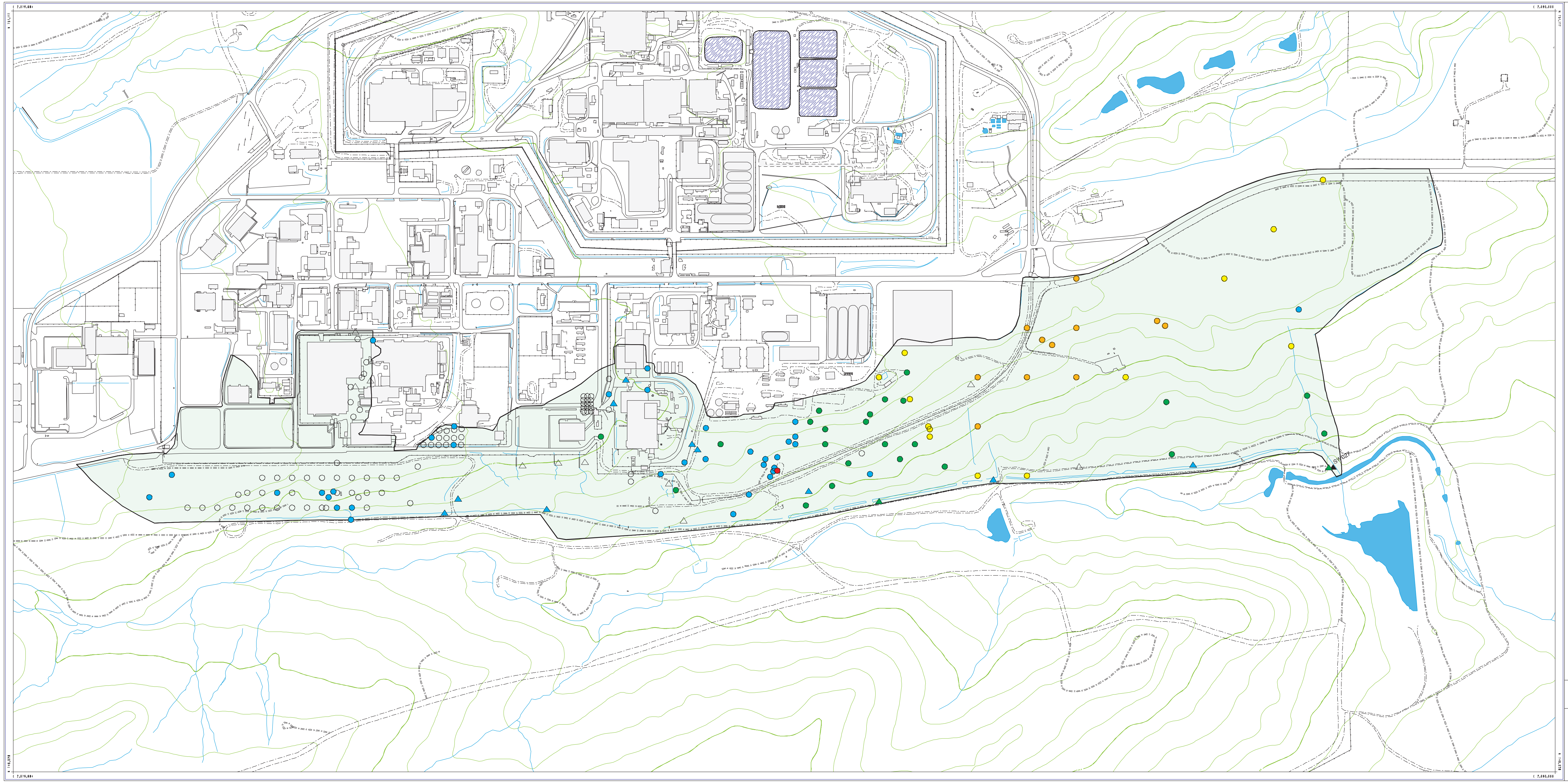
For the reasons outlined above, it is concluded that neither D&D, construction, ER, excavation, nor routine operations caused a release that resulted in the elevated plutonium activities measured at SW027. Rather, the elevated activities are attributed to plutonium source(s) created by historic Site operations, atmospheric fallout, and natural actinide transport processes.

4.2.5. Surface-Soil and Sediment Information

An analysis of historical data provided the basis for this review of surface-soil and sediment plutonium activities within the SW027 drainage basin. The surface-soil and sediment review relied on historical radioanalytical data obtained from RFSWD and the AMS. Only sampling locations tributary to SW027 were included in this investigation (see Figure 4-26 for locations). Tributary locations identified by GIS were used to formulate an RFSWD query for all historical radioanalytical data. The query produced 354 radioanalytical data records for plutonium, which were sorted by location and media type. Negative analytical results were set to zero for calculation purposes. For trench soil data, only the results from 0.0 to 4.5 cm depth were used. Average plutonium activity values were then generated for each location, which resulted in 161 surface-soil and 22 sediment values for evaluation. To evaluate the surface-soil data, frequency distribution plots were generated using the logarithmic sized bins (less than or equal to 0.000, 0.01, 0.1, 1.0, 10.0, 100.0, 1000, or 10,000 pCi/g) for grouping average plutonium values. To evaluate the sediment data, frequency distribution plots were generated using equal sized bins (from <0.0 to 2.0 pCi/g at 0.05 intervals) for grouping average plutonium values. The histogram results are plotted in Figure 4-27 and Figure 4-28. The average plutonium values are also presented in a color coded map view in Figure 4-26. For the map view, colors were selected to grade from lower plutonium activities to higher plutonium activities to identify variation by location. Figure 4-29 shows the distribution of plutonium in surface-soil for the SW027 drainage and surrounding areas. Using these estimated distribution contours, the areal average plutonium activity for the SW027 drainage is approximately 130 pCi/g.

Figure 4-26

Surface Soil & Sediment Sampling Locations Tributary to SW027



EXPLANATION

Pu Activity pCi/g

- -0.1 - 0.1
- 0.1 - 1.0
- 1.0 - 10.0
- 10.0 - 100.0
- 100.0 - 1000.0
- Greater than 1000.0

Monitoring Locations

- Point of Evaluation
- Surface Soil Samples
- Sediment Samples

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

Scale = 1 : 6580
1 inch represents approximately 548 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:

Rocky Mountain Remediation Services, L.L.C.
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MAP ID: 98-0253-Map4

October 28, 1998

/gis2/projects/fy98/98-0253/map4/sw027-sssd.aml

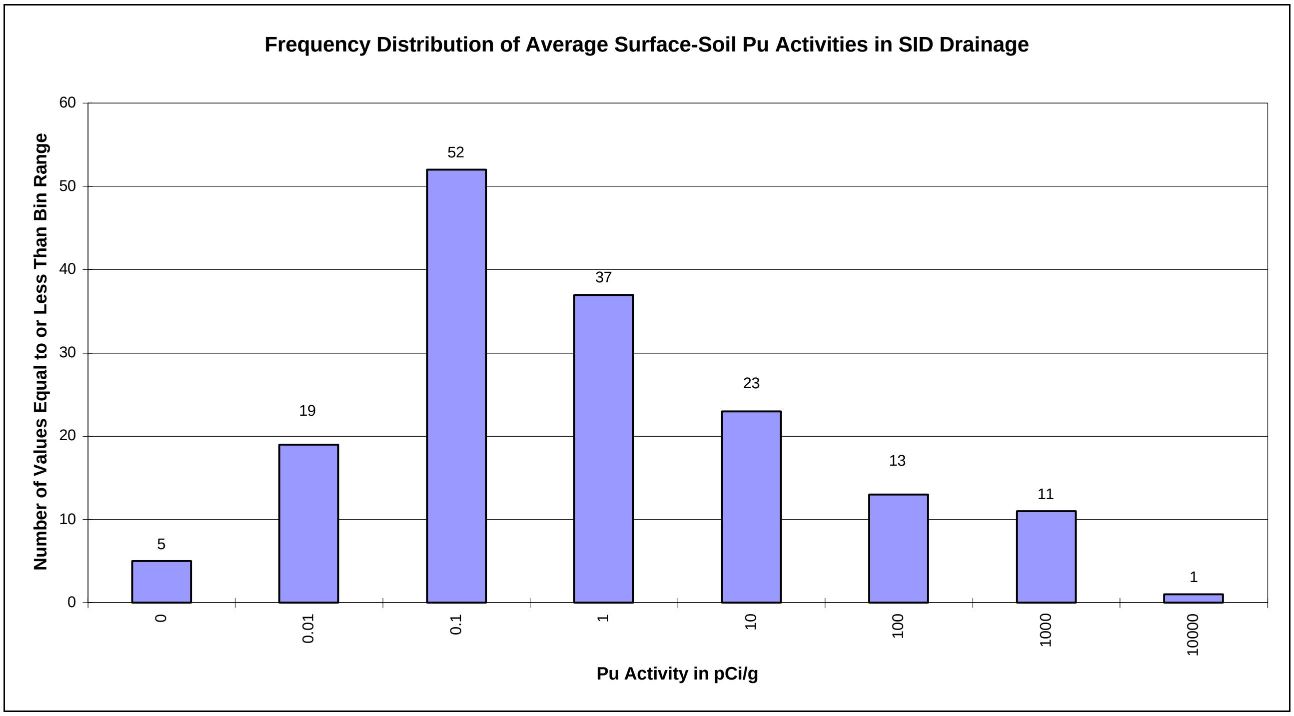

Figure 4-27. Frequency Distribution of Average Plutonium Activity for Surface-Soil Sampling Locations within the SW027 Drainage Basin.

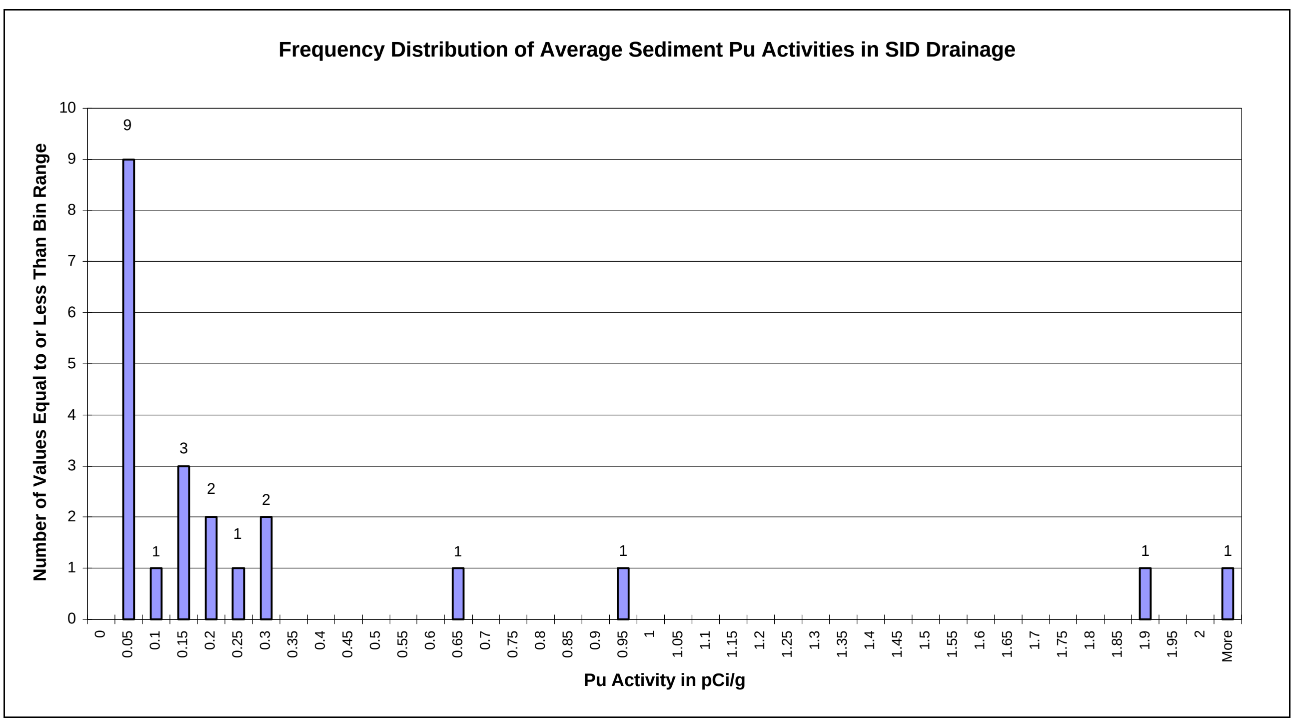

Figure 4-28. Frequency Distribution of Average Plutonium Activity for Sediment Sampling Locations within the SW027 Drainage Basin.

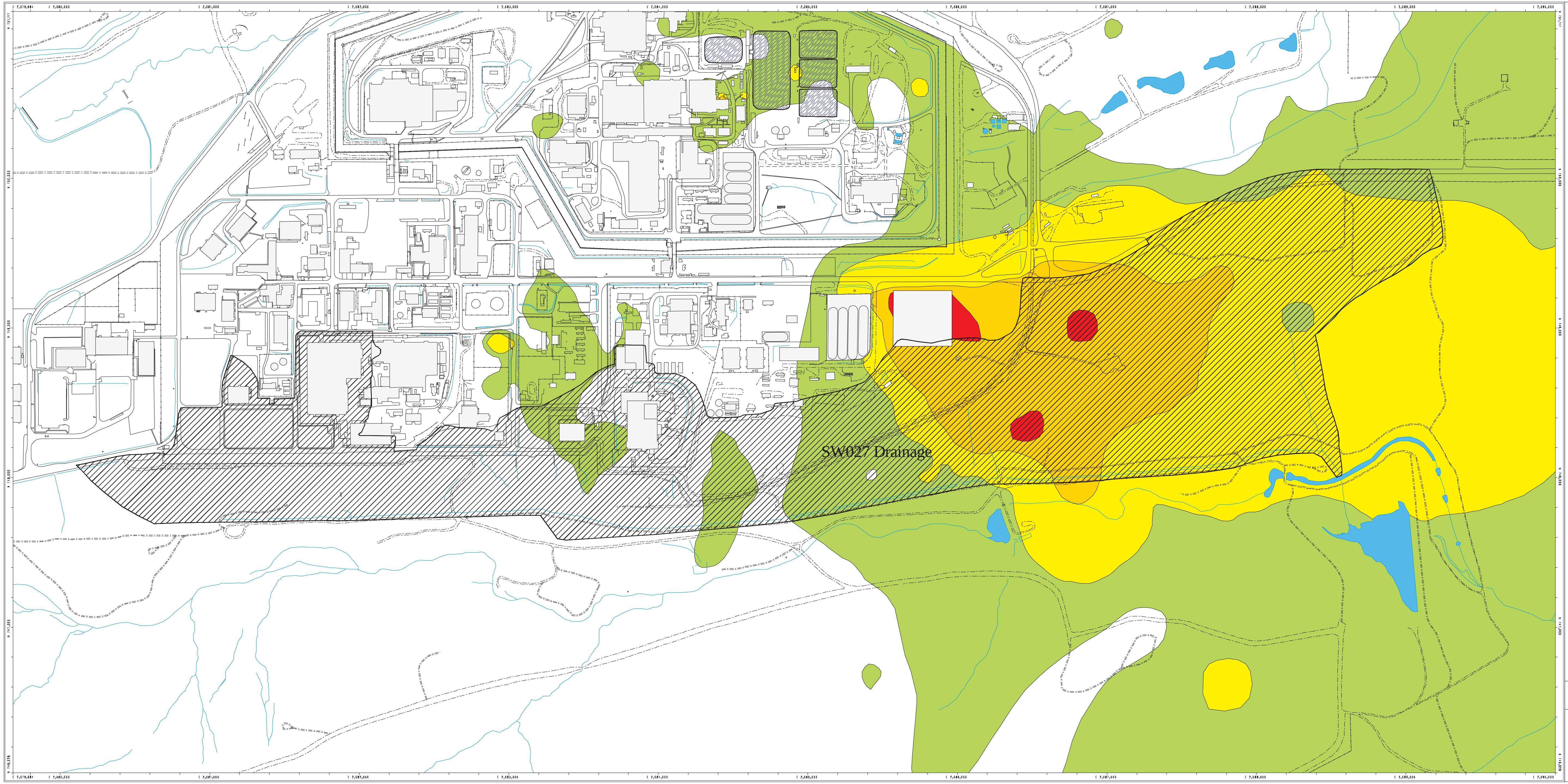

Figure 4-29

Distribution of Surface Soil Plutonium in the SW027 Drainage

EXPLANATION

- Less than 1 pCi/g
- 1 pCi/g or greater but less than 10 pCi/g
- 10 pCi/g or greater but less than 100 pCi/g
- 100 pCi/g or greater but less than 1000 pCi/g
- 1000 pCi/g or greater

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

NOTE:
Contours were developed using data from surface soil sampling locations extracted from RFEDS/SWD. Contours were edited using professional judgement from grids created by kriging.

Scale = 1 : 6720
1 inch represents 560 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:
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P.O. Box 464
Golden, CO 80402-0464

MAP ID: 98-0253-Map2 October 28, 1998

/gis2/projects/fy98/98-0253/map2/ss-pu-cntr.aml

A review of the average values indicates differences of *several* orders of magnitude for plutonium activities of surface-soils and sediments within the SW027 drainage area. The highest number of surface-soil values, 52 occurrences, was observed in the 0.01 through 0.1 pCi/g range. The second greatest count, 37 occurrences, was observed in the 0.1 through 1.0 pCi/g range. The extreme high surface-soil values, 12 in the 100 to 10,000 pCi/g range, are associated with Ryan's Pit[12] and areas east of the 903 Pad. The highest average plutonium value, 2,321.8 pCi/g, was measured at sampling location SS100493, at Ryan's Pit.

The greatest number of sediment values, 9 occurrences, was observed in the 0.00 to 0.05 pCi/g range. All but one of the locations associated with these values are located upstream of the areas most impacted by contamination from the 903 Pad.

Figure 4-30 and Figure 4-31 show the spatial variation of average surface-soil and sediment activities in the west to east direction. From both figures, it can be seen that locations east of the 903 Pad (the majority of windblown contamination from the 903 Pad traveled SE; see Figure 4-29) have measurably higher activities. This indicates that the 903 Pad is the predominant source of plutonium contamination in the SW027 drainage.

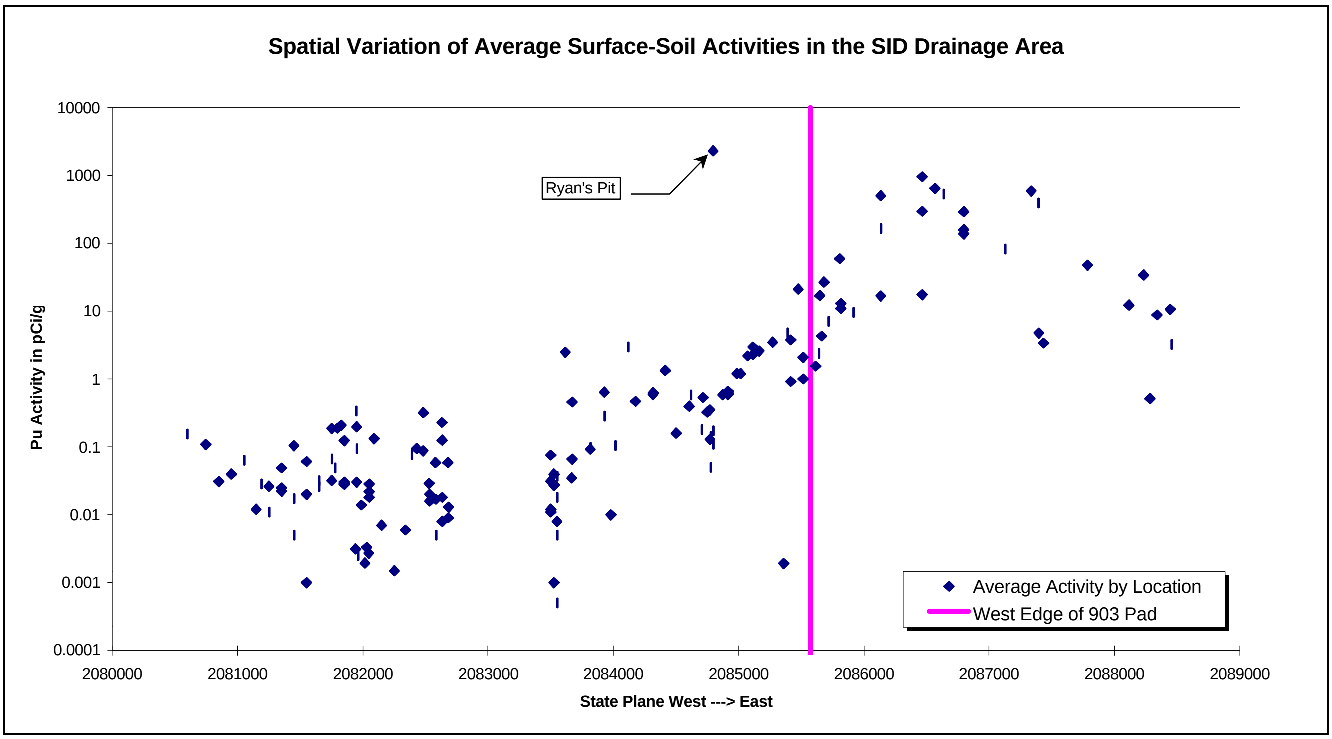


Figure 4-30. Spatial Variation of Average Surface-Soil Activities in the SID Drainage Area.

12 Ryan's Pit was remediated in September 1996. The remediation effort included the covering of Pu contaminated soils with clean cover. Therefore, the contaminated source soils are no longer available for transport in overland runoff. However, contamination that may have migrated downstream may still be available for transport.

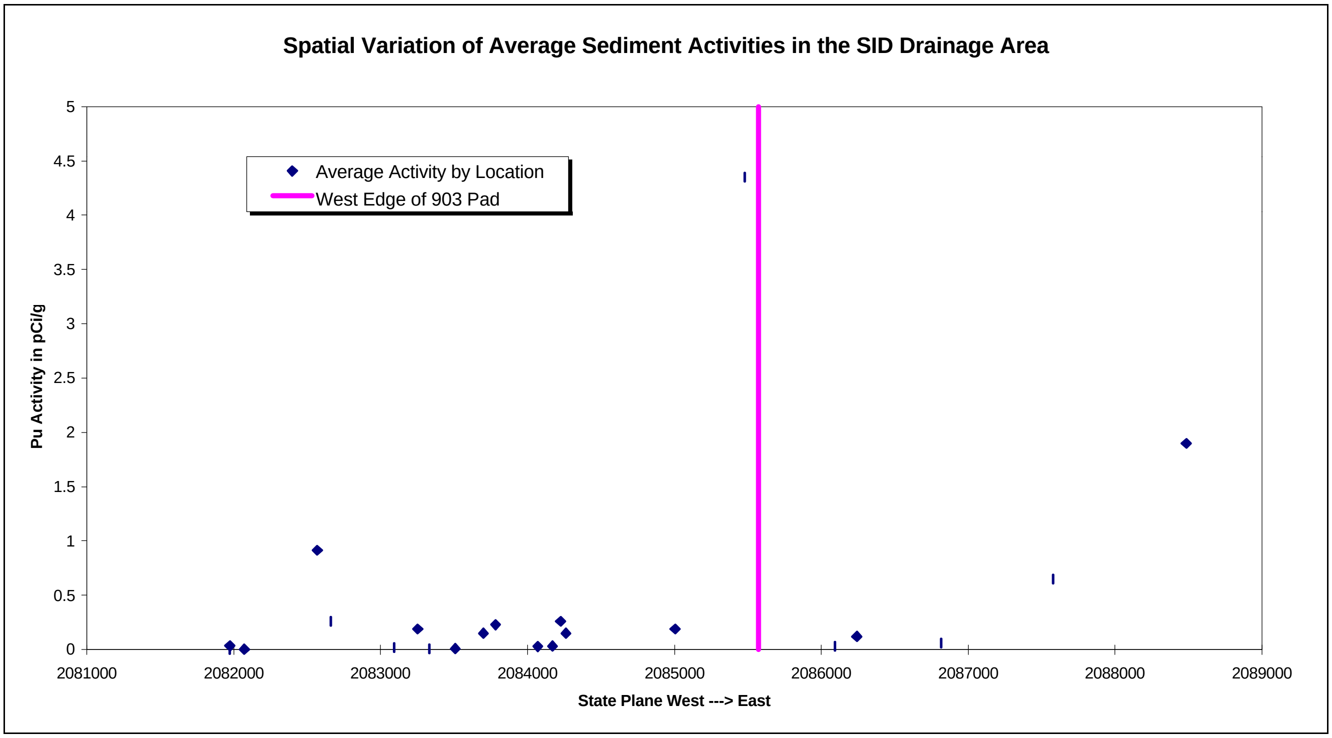


Figure 4-31. Spatial Variation of Average Sediment Activities in the SID Drainage Area.

4.2.6. Historical Release Report Information

A multitude of potential sources of radionuclide contamination exist within the boundaries of the SW027 drainage basin. From the Site Historical Release Report (HRR) (US DOE, 1992), thirty-one plutonium- and general radionuclide-contaminated IHSSs were identified to be completely or partially within this drainage. The plutonium IHSSs are listed and described in Table 4-3. Plutonium-related IHSSs are posted in map view in Figure 4-32.

Radionuclide IHSSs in the SW027 basin originated from inadequate storage of drums and equipment, various building operations and manufacturing processes, and burning and subsequent burial of wastes. Details of some of these releases are compiled in the following paragraphs. This information is not intended to be complete, due to the number of IHSSs, but rather it is intended to be representative of the types of events that have occurred which may have led to potential contamination sources within the basin.

Drum storage areas in several buildings, including B865, B881, and B885 have led to contamination concerns within the SW027 basin (1953-present). Drums containing waste oils, waste paints, waste solvents, and low-level radioactive wastes were typically stored on concrete floors or pallets, without secondary containment or floor drains. Poor housekeeping conditions in B885 showed paint cans and drums stored haphazardly, and rainwater was allowed to flow through the building; however, there were no known or documented releases. The drum storage areas in B865 and B881 were remediated in 1995 and their IHSS status was removed.

Contamination has been suspected in areas used for equipment storage, including an area northeast of B881, where lathe parts and rolling mill parts potentially contaminated with enriched or DU were stored (1964-1966). In addition, two sites used for scrap metal storage in the SE portion of the IA may have been contaminated with uranium (Sept 1968 - Nov 1971), although one of the sites, located south of the 903 Pad, was cleaned up in December 1971 and the disturbed soil was revegetated the following spring. The other site is undergoing final closure (1997).

Table 4-3. Plutonium IHHSs in the SW027 Drainage.

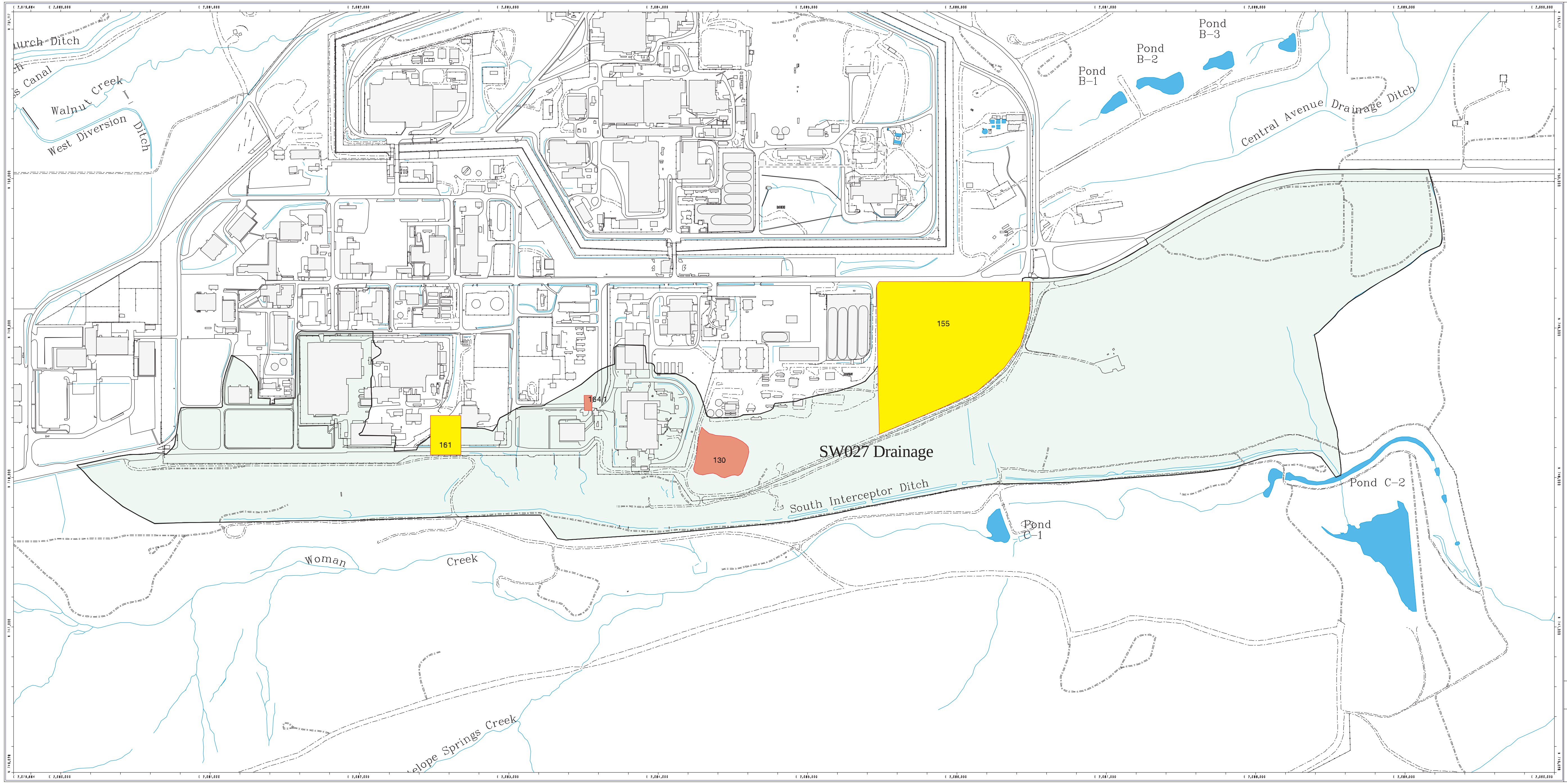
IHSS #	Location/Bldg.	Dates	Description
109	900 Area, Trench T-2	July 1954 - August 1968	The trench received sewage sludge contaminated with uranium and plutonium from the WWTP in addition to some crushed empty drums. Area was remediated in 1996 and IHSS status was removed.
111.2-111.6	NE Area, Trenches T-5 through T-9	July 1954-August 1968	The trenches all received sewage sludge contaminated with uranium and plutonium from the WWTP in addition to some flattened drums that once contained uranium-contaminated oils.
112	900 Area, 903 Pad	1955 or 1958 - June 1968	1500 drums were stored on the 903 pad beginning in 1958. By 1960, significant leaking was noticed, and 50 drums had drained entirely. Drum removal activities and heavy rains in 1967 resulted in the release and spread of plutonium. Over the course of 903 Pad operations, it has been estimated that approximately 150 g of plutonium leaked into the soil.
130	900 Area, Contaminated Soil Disposal Area E. of B881	1969-1972	Approximately 320 tons of plutonium-contaminated soil and asphalt from the May 1969 fire in B776 was buried under 1-2 feet of fill. Another 60 yards of plutonium-infiltrated soil from the removal of concrete waste tanks near B774 was placed in the same area in 1972. Area was remediated in 1997 and IHSS status was removed.
155	900 Area, 903 Lip Area	1964-1973	Contamination from the 903 drum storage area was spread by wind and rain to adjacent soil. Approximately 16 g of plutonium was distributed by wind and surface water runoff in an area exceeding 2,000 acres. Efforts in 1976 and 1978 were conducted to remove highly contaminated soil from the Lip Area.
161	600 Area, Storage Site West of B664	1971 - Present	The area west of B664 is suspected to contain low-level residual plutonium and uranium contamination resulting from punctured or leaking drums and boxes of solid and liquid wastes. Remediation efforts are presently under investigation.
164.1	600 Area, Radioactive Slab from B776	September, 1957	After the fire in B776/777, a radioactively contaminated slab from the building was placed in an area NW of B881 for temporary storage. It was thought that plutonium likely contaminated the slab. Presently, no further action is planned for remediation.

Manufacturing operations that began in 1953 within B447 may have caused infiltration of radioactive materials into the surrounding soils. Surveys performed from 1977 through 1984 of the areas outside the building could not be completed due to high-level background radioactivity. The staging of plutonium- and uranium-contaminated liquid and solid wastes in B664 are the likely residual constituents that led to elevated gamma-radiation and americium activities detected in the vicinity in 1977. Both areas are still considered to pose a contamination concern.

Trenches located at the west end of the SID, south of the IA were used for the disposal of ash from an incinerator (1959-1968). Small quantities of DU-contaminated combustibles were burned along with the general combustible plant refuse. The Original Landfill south of B460 was used as a burning pit (1952-1968). In 1965, approximately 60 kg of DU was inadvertently burned, however it was estimated that 70% of the burned material was recovered. Contractors grading a road SW of B444 uncovered a portion of the landfill and exposed a source of DU (July 1979; from HRR). A survey was performed, with three locations of DU being identified, and one box of contaminated soil was removed. No further remediation of these areas has occurred.

Figure 4-32

Plutonium IHSS's Tributary to SW027



Legend

Monitoring Location Objective*

Drainage

SW027 Drainage

Plutonium Related IHSS's

Individual Hazardous Substance Site (IHSS)

No Further Action (NFA)

Standard Map Features

Buildings and other structures

Lakes and ponds

Streams, ditches, or other drainage features

Fences and other barriers

Rocky Flats boundary

Paved roads

Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1/95

Scale = 1 : 6950
1 inch represents approximately 579 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Prepared by:

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P.O. Box 464
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MAP ID: 98-0253-Map6

November 02, 1998

/gis2/projects/fy98/98-0253/map6/sw027-ihss.aml

Site sediments in the SW027 drainage basin have a lengthy history of receiving contamination from historical releases. Of the 31 IHSSs identified within the drainage, 20 remain potential contamination sources, with the 903 Pad and Lip Area considered to pose the greatest concern. Documentation is limited regarding the fate and mobility of contaminants in the environment from a majority of the IHSSs. Activities took place concurrently with historical releases which may have affected the migration of contaminants from their point of origin. Construction and maintenance of dirt parking surfaces and roads common in the southern portion of the IA make it reasonable to expect that vehicular traffic provided a source of mobility of potentially contaminated surficial soils. Additionally, storm events, characterized by heavy rains and high winds, were frequent mechanisms for dispersion of contaminants. While future investigations take place to further characterize the above IHSSs with respect to the magnitude and extent of contamination, historical information currently supports the existence of diffuse contamination through much of the SW027 basin.

4.2.7. Groundwater Data

All groundwater data discussed in this document were retrieved from the RFSWD or from the recently completed *Draft Evaluation of Plutonium and Americium in Groundwater at the Rocky Flats Environmental Technology Site* (RMRS, 1998b). Available data was evaluated from all groundwater wells within the SW027 surface-water drainage area. All radionuclide activity results discussed are unfiltered, total radionuclide activities. Samples rejected in the data validation process were not considered. Sample results labeled as real, duplicate, and laboratory replicate were averaged as appropriate.

Groundwater Hydrology in the SW027 Drainage

The uppermost, unconfined aquifer within the SW027 drainage flows through the Rocky Flats Alluvium and Arapahoe and Laramie Formations. There is no known direct hydraulic connection between this shallow alluvial aquifer and deeper confined aquifers extending off-Site (Kaiser-Hill, 1995). In the spring and early summer, the shallow alluvial aquifer is recharged by precipitation and lateral groundwater flow. In the late summer and early fall, the Rocky Flats Alluvium and Arapahoe formations are recharged primarily by groundwater lateral flow.

In the drainage to the SID, groundwater discharges as seeps which typically occur at the base of the Rocky Flats Alluvium where individual sandstone lenses become exposed to the surface (Kaiser-Hill, 1995). Major seeps were identified and mapped as part of the *Seep and Spring Analysis in Support of the Accelerated Site Action Project for Site Closure (RMRS, 1996)*. The locations of these seeps are depicted in Figure 4-33. Figure 4-33 also identifies the location of the one seep discharge measurement performed in the spring of 1995 within the drainage to the SID. Even during this time of presumably high discharge for seeps, a flow rate of less than 1 gallon per minute was recorded. Though funding for the study was cut before more discharge measurements could be collected to the south and east of the 903 pad, it is expected that the total contribution of flow by seeps to surface water in the SID is minimal. RMRS (1996) concluded that although there are a substantial number of seeps at the Site, re-infiltration to the groundwater system allows for little loss from the groundwater to the surface water.

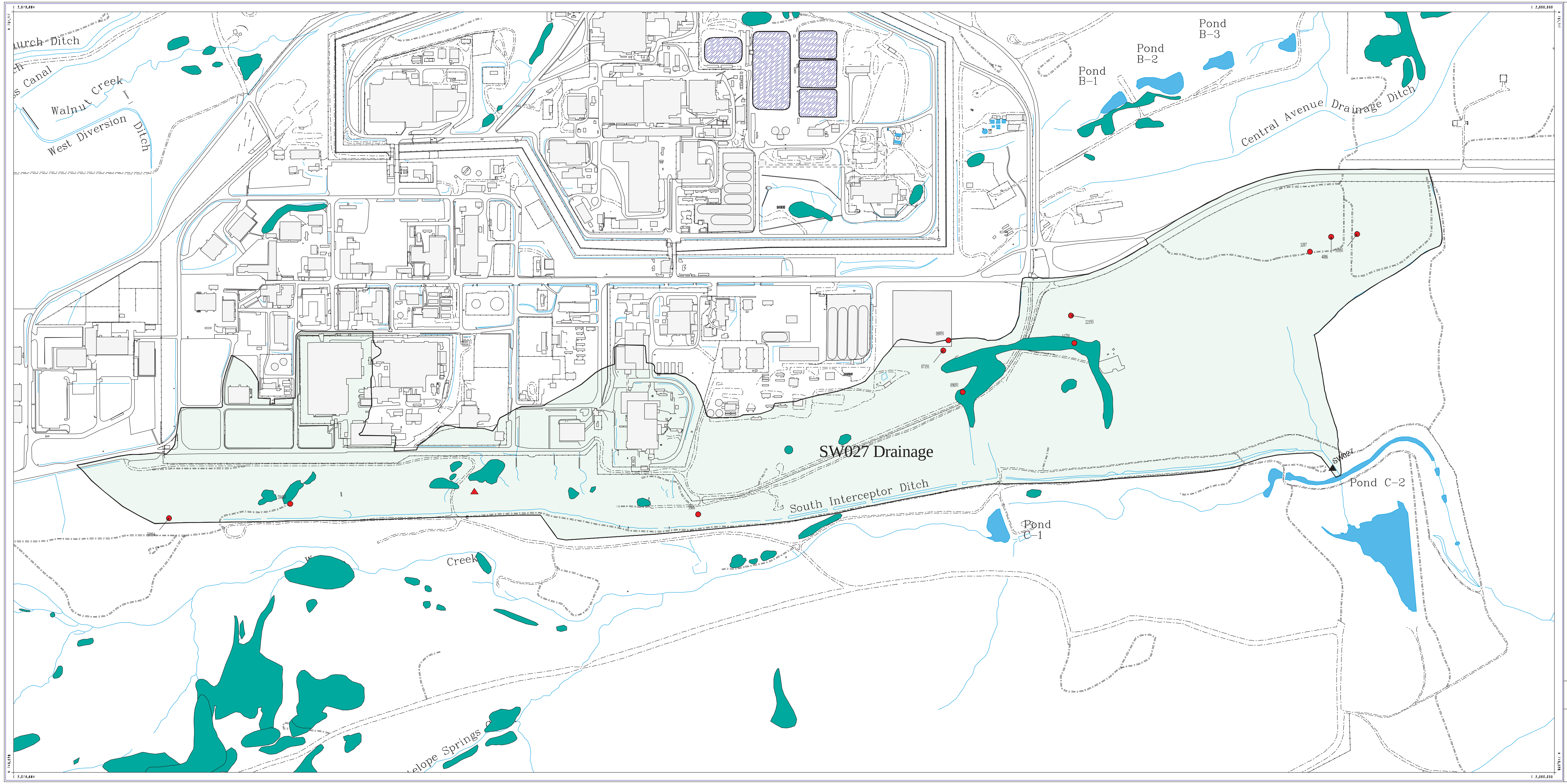
Summary of Groundwater Data

Groundwater data considered in this analysis were limited to plutonium and americium (total, unfiltered) and TSS. Complete data sets are presented for wells considered representative of frequently observed trends; however, due to the size of the historical data set, only summary values are presented for the majority of wells discussed.

Of the 66 wells in the SW027 drainage sampled intermittently since 1986 for radionuclides, eleven yielded samples with total plutonium activities greater than 0.15 pCi/L. Data from these wells are summarized in Table 4-4. Of these eleven wells, seven are in the immediate vicinity or east of the 903 Pad. The location of each well is identified in Figure 4-33.

Figure 4-33

Seeps and Selected Groundwater Monitoring Wells in the SW027 Drainage



Legend

- ▲ Surface Water Monitoring Location
- ● Groundwater Well (With historical record of total Pu > = 0.15pCi/L)
- ▲ Seep Discharge Measurement Point (Spring 1995)
- Seep Areas

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Solar evaporation ponds
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Scale = 1 : 6950
1 inch represents approximately 579 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

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P.O. Box 464
Golden, CO 80402-0464

MAP ID: 98-00253-Map7 October 28, 1998

/gis2/projects/fy98/98-0253/map7/sw027-sel-wells.aml

Table 4-4. Data Summary of Historically Sampled Groundwater Wells in the SW027 Drainage with Plutonium Activities* Greater than 0.15 pCi/L.

Well Number	Date of First Sample	Number of Samples	Max. Pu-239,240 (pCi/L)	Date of Max Pu-239,240 (pCi/L)	Average Pu-239,240 (pCi/L)
3287	March 1988	14	0.17	May 1992	0.02
4086	May 1987	6	0.24	May 1987	0.04
5986	April 1987	15	0.90	April 1987	0.06
07191	May 1992	5	15.4	May 1992	3.41
09091	May 1992	12	354.6	May 1992	94.6
09691	March 1992	10	1.1	Sept. 1993	0.326
10991	Feb. 1992	15	0.23	Feb. 1992	0.02
11791	Feb. 1992	17	23.20	May 1992	3.83
22193	June 1993	9	0.41	April 1995	0.02
59493	June 1993	10	1.04	Nov. 1993	0.10
59894	Jan. 1995	3	1.23	Jan. 1995	0.28

*All results are total, unfiltered.

It is important to note that for all of these wells, the percent difference between the maximum result and the average result for plutonium is more than 70%. Further, for eight of these eleven wells, the collection date of the maximum result is the same as or very close to the date of the first sample grab. These trends may be indicative of localized cross-contamination of the well by surface materials, resulting from installation and sampling protocols. This will be discussed further in the following sections.

Sampling results from groundwater wells 11791 and 09691 are presented in Figure 4-34 and Figure 4-35, respectively. These wells were chosen as representative of the two common trends observed in plutonium and americium data profiles for groundwater in the drainage.

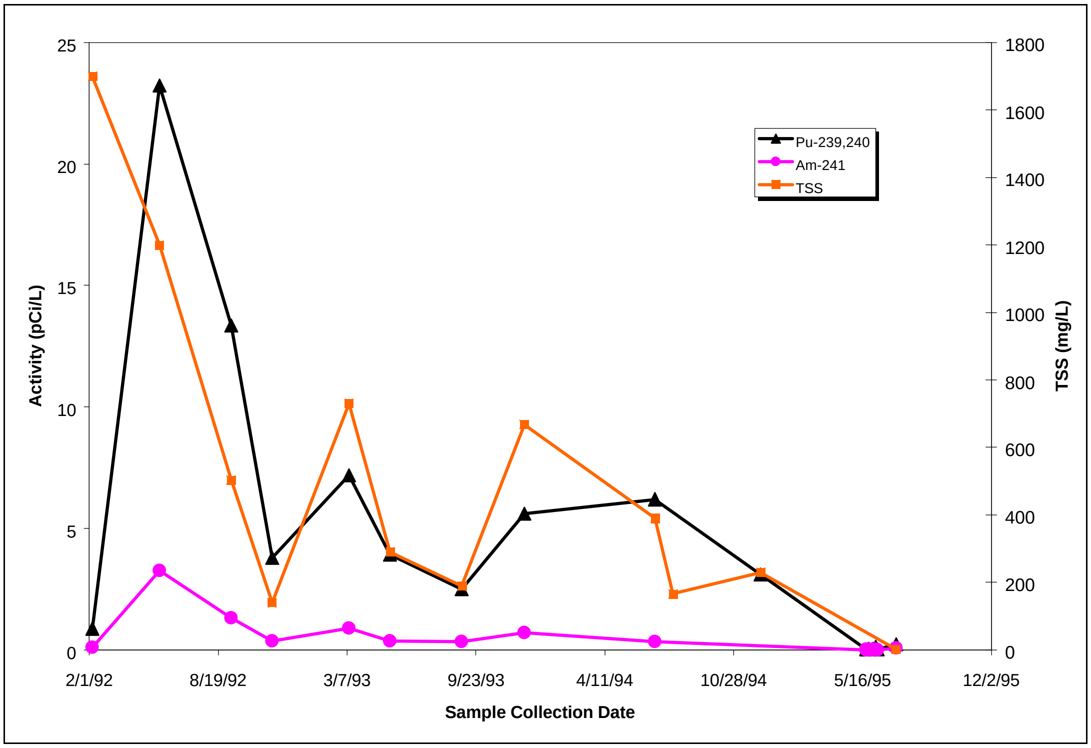


Figure 4-34. Groundwater Sampling Results for Well 11791

Figure 4-34 presents a trend of decreasing sample activity with time as observed in well 11791. Further, there is an apparent correlation between plutonium activity and TSS concentration. Of the wells identified in Table 4-4, a similar trend is observed for data from wells 4086, 5986, 07191, 09091, 10991, 11791, and 59894.

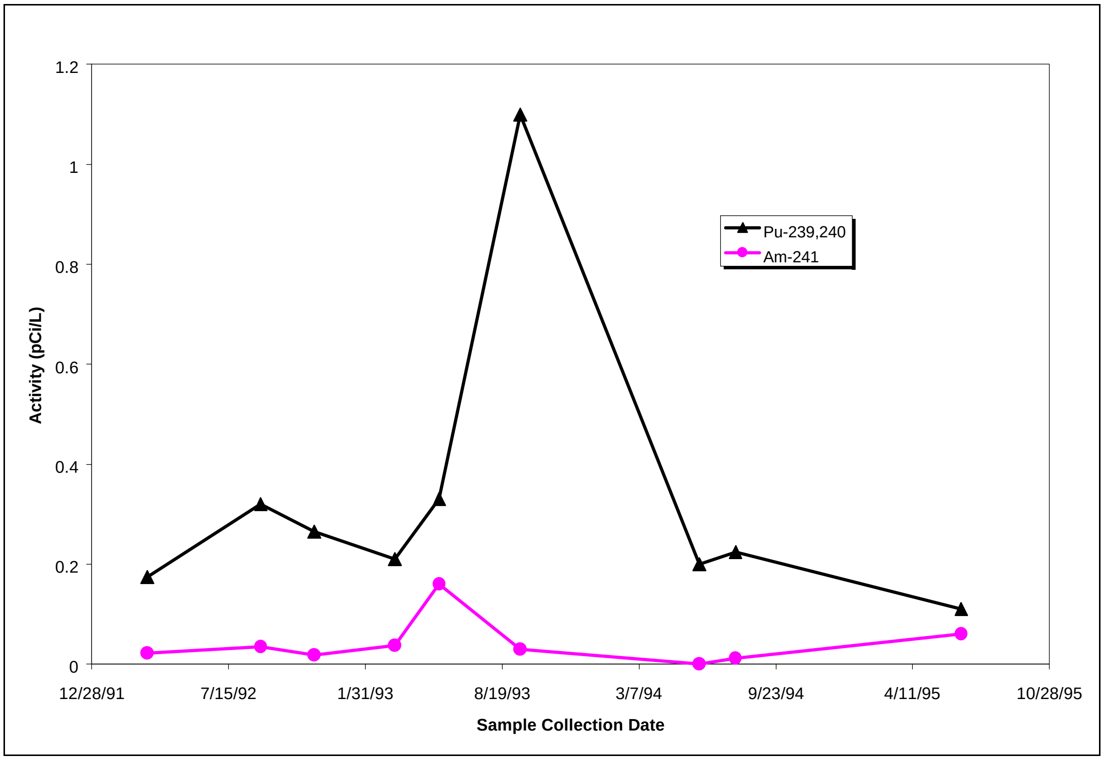


Figure 4-35. Groundwater Sampling Results for Well 09691

Figure 4-35 illustrates the second general type of data set observed. Specifically, results from a single sample appear elevated as compared to the other data points, with no consistent increasing or decreasing trend with time. TSS data was not available for this well. Of the wells identified in Table 4-4, a similar profile of results were observed for data from wells 3287, 22193, and 59493.

Two other possible profiles of activity versus time are noticeably missing among the data sets of these wells. Specifically, none of the data sets exhibit results showing increasing trends of activity versus time, or results showing both consistently elevated values with no trends with activity versus time. Again, observed results may be indicative of cross-contamination attributable to well installation or design. The representativeness of these results is discussed further in the following sections.

Analysis of Groundwater Data

The existence of both elevated groundwater sample results and groundwater seeps (although minor contributors) in the SW027 drainage is not adequate evidence to implicate groundwater contamination as a source of surface water contamination observed at SW027. This is due to the fact that there is reason to doubt the representativeness of the sampling data.

<u>Possible Sources of Observed Radionuclide Contamination in Groundwater Wells in the SW027 Drainage Area</u>

As hypothesized in RMRS (1998b), plutonium and americium contamination of groundwater at the Site may occur via three pathways: (1) non-aqueous phase liquid (NAPL) infiltration to the groundwater, (2) natural infiltration of contaminated surface soils or sediments, and (3) investigation-induced cross-contamination by contaminated surface soils. A thorough discussion of each of these pathways is presented in RMRS (1998b) and will only be summarized here.

First, plutonium-entrained NAPL in the subsurface is a potential source of plutonium in groundwater. NAPL contamination of groundwater in the drainage is likely considering the release history of the 903 Pad (DOE, 1997). Though NAPLs have not been observed in alluvial or bedrock monitoring wells near the 903 Pad, high levels of chlorinated hydrocarbons have been detected in the groundwater suggesting NAPL presence (RMRS, 1998b). Plutonium-contaminated NAPLs reaching the water table would slowly dissolve or degrade to continuously release entrained radionuclides to the groundwater. Once released from the NAPL to the groundwater, plutonium transport through the clay-rich sediments would remain dependant on facilitation by some mobile colloidal phase.

Second, incident precipitation and runoff may mobilize plutonium-contaminated surface soils or sediments and transport them to the groundwater. Transport to the groundwater would probably occur via macropores. As discussed in Section 4.2.5, significant surface soil contamination exists within the SW027 drainage. Further, migration of surface contamination through the first meter of the unsaturated zone via macropores has been observed by Litaor et al., 1994. Though direct evidence of the existence of preferential flow paths below a depth of one meter at the Site is not available; the fairly rapid response time of water levels in some wells to infiltration events may serve as indirect evidence. Again, once plutonium contamination reaches the groundwater, its continued transport through the clay-rich sediments remains unlikely without facilitation by some mobile phase.

Third, plutonium activity observed in groundwater samples may be the result of cross-contamination of wells by surface soils, attributable to installation activities or well design. Monitoring well installation activities performed through significantly contaminated surface soils can inadvertently introduce surface contamination to the sample intake point. Techniques to prevent cross-contamination and isolate the surface soils during well installation have only been used in the construction of certain wells which monitor for off-Site migration of contaminants. Well development, or purging of significant volumes of water from wells, is common practice to remove installation artifacts prior to sampling; however, the low productivity of most wells at the Site makes thorough development difficult. Wells contaminated during installation often exhibit sample activities which decrease with time due to natural, continuous purging effects and purging during sampling. Further, TSS values for such wells often follow this same trend, decreasing with time.

Surface soils may also infiltrate a monitoring well during infiltration events, effectively short-circuiting the normal path through soil horizons to the water table. This is frequently the result of well design specifications. Shallow wells with long intake casings and poorly sealed wells are often subject to short-circuiting. Such wells may exhibit apparently erratic contamination, or contamination that varies with water table variations. It should be noted that, in the case of investigation-induced cross-contamination, sample results are not representative of the true mobile load of the groundwater.

<u>Interpretation of Groundwater Data</u>

Available evidence suggests neither widespread plutonium contamination of groundwater nor significant horizontal mobility of plutonium in the aquifer. Considering the three hypothesized pathways for plutonium migration to the groundwater, investigation-induced cross-contamination seems the most likely explanation for the observed results.

To begin, NAPLs are not expected to be a significant source of plutonium in the groundwater for several reasons. First, wells which indicate significantly elevated levels of volatile organic compounds (VOCs), as might be expected in the presence of NAPL contamination, do not exhibit correspondingly elevated levels of radionuclide activities (RMRS, 1998b). Second, there is a very non-uniform distribution of plutonium-contaminated groundwater wells. Plutonium-contaminated wells are often closely interspersed with wells indicating no plutonium contamination (RMRS, 1998b). Again, this does not fit the profile of groundwater contaminated by a radionuclide-entrained NAPL plume. Third, the nature of the observed plutonium activity trends with time are contrary to what would be expected for NAPL release of radionuclides. Specifically, wells with plutonium activities decreasing rapidly with time or exhibiting extremely erratic levels do not suggest a continuously releasing NAPL source.

Significant vertical transport of surface contamination to the groundwater by incident precipitation or runoff through macropores is also questionable as a source. This phenomenon was observed by Litaor et al. (1996a) over the first meter of the soil profile near the 903 pad. Litaor et al. (1996a) also hypothesized that movement of plutonium to deeper soil horizons approaching the water table would be constrained by the decreasing number and size of macropores, preventing transport of discrete particles. Further, vertical profiles of soil activity versus depth from trenches near the 903 Pad suggest that little plutonium migration below a depth of 20 cm has occurred over the last 25 years (RMRS, 1998b).

Lateral migration of plutonium is also expected to be minimal. Plutonium and americium have high partition coefficients (K_d) for saturated Site soils (Cleveland et al., 1976 and Honeyman and Santchi, 1997b). Consequently, plutonium and americium are expected to be relatively immobile in the groundwater, sorbing strongly to the solid matrix. The potential for colloid facilitated transport has not yet been adequately quantified.

Of the three hypothesized pathways for migration of contamination to the groundwater, investigation-induced cross-contamination of wells seems the most likely for several reasons. First, installation locations and procedures suggest susceptibility to such artifacts. The wells identified with highly elevated results were all installed through very contaminated surface soils using industry standard installation protocols which do not prevent surface-contamination of the borehole. Further, development of the wells is limited by the low yielding characteristics of the system. Consequently, cross-contamination cannot be immediately removed. Second, the occurrence of uncontaminated wells directly adjacent to highly contaminated wells suggests a randomness more indicative of errors in representativeness than actual, widespread contamination. Third, the profiles of sampling results with time suggest in-well contamination or short-circuiting. The trends of decreasing plutonium and TSS with time as wells as erratic results match expected results for cross-contamination or short-circuiting and not for a slowly migrating contaminant plume.

Error attributed to cross-contamination in the borehole wall or filter pack is exacerbated by the fact that sampling is performed with bailers. Sampling with bailers, as opposed to low-flow pumps, causes significant surging in the immediate vicinity of the well casing, thereby mobilizing material into the well which would not otherwise be mobile. This effect is readily apparent in the extremely elevated TSS values observed for the groundwater samples (e.g. Figure 4-34). The correlation between TSS and plutonium activity, combined with the decreasing trend with time, may be interpreted as further evidence of cross-contamination. Frequently, elevated plutonium activities in wells with erratic record also correlate with extremely high TSS values. These elevated TSS values are clearly not representative of the true mobile load of the groundwater. This conclusion is in agreement with findings of the recent evaluation of radionuclides in groundwater performed at the Site (RMRS, 1998b).

Conclusions of Groundwater Data

Groundwater is not expected to be a significant source of the contamination observed in surface water at gaging station SW027 for the following reasons:

- Seeps into the SID drainage contribute only a minute amount of flow to the surface. Further, this flow is expected to almost exclusively re-infiltrate the soil matrix to the groundwater before mixing with surface water (RMRS, 1996).
- Lateral migration of plutonium and americium in groundwater is expected to be minimal based on high Site-specific partition coefficients reported by Honeyman and Santchi, (1997b).
- Elevated levels of plutonium and americium activity observed in groundwater samples within the drainage are not likely to be representative of the true mobile load. Instead, these data are suspected to be artifacts of well installation and design (RMRS, 1998b).

Unfortunately, definitive conclusions about the quality of the groundwater with respect to radionuclide contamination and mobility cannot be made due to the limitations on interpretation of the data. These limitations are imposed by groundwater well installation procedures and sampling protocols applied to collection of the data. To generate reliable data, future well installation protocols must be modified to prevent both initial borehole contamination and short-circuiting. Further, low-flowrate pumps should be used in place of bailers to retrieve samples.

4.2.8. Assessment of Radiochemistry Quality Assurance

Verification of Elevated Analytical Results

All data returned to date from the subcontracted analytical laboratories have met the required QA/QC criteria, and no requests for re-runs of "questionable" data have been required. Data packages for the three samples contributing to the reportable measurement from SW027 have been reviewed, including case narratives, minimum detectable activity (MDA) confirmation, and tracer recovery acceptability. Based on this review of each case narrative for all three samples, there were no deviations from the prescribed Statement of Work (SOW) requirements. The analytical MDA for isotopic plutonium in water is 0.03 pCi/L or less and the MDA for the three samples was $\leq$ 0.03 pCi/L. Acceptable tracer recovery for isotopic plutonium in water is $\geq$20% but $\leq$110%. For the samples dated 4/20/98, 4/30/98 and 5/8/98 the tracer recoveries were 86.9%, 85.3%, and 50.9% respectively. Only one sample, dated 4/20/98, has been verified to date. The remaining two samples are expected to be verified after receipt of an acceptable Electronic Data Deliverable (EDD). Verification is to be performed on all analytical samples, but is not initiated until the lab has submitted an acceptable EDD to the Site's Analytical Services group.

Analytical Data Validation

None of the three samples detailed in this report have been selected for data package validation, which is performed on 25% of all analytical measurements generated by sub-contracted laboratories. For FY98, funding issues concerning all levels of validation were evaluated throughout the year.

4.3. Evaluation of Watershed Improvements on Plutonium Transport in the South Interceptor Ditch Basin

4.3.1. Background of Watershed Improvements Implemented at the Site

Erosion control measures were implemented at the Site during FY96 and FY97 in an effort to stabilize and entrap soils and sediments likely to be transported from a watershed by stormwater runoff. Implementation of these measures was based on studies that indicate radionuclides associate with solids suspended in stormwater (US DOE, 1996; Little and Whicker, 1978; Hanson, 1980; Hakonson and Watters, 1981; Webb et al., 1983; Honeyman and Santschi, 1997b). Stormwater data collected at the Site between 1991 and 1996 support this conclusion (DOE, 1996). Based on these characteristics of radionuclides and stormwater, removing particulate material from stormwater runoff should reduce radionuclide loading to the water. Drainage areas targeted for control measures were those locations identified as most likely to contribute material that could provide a transport mechanism for radionuclides in Site runoff.

Although watershed improvements were implemented at various locations on the Site, only those improvements implemented within the SID drainage basin will be discussed in this report.

4.3.2. Selection of Watershed Improvement Locations

Several sources of information, in conjunction with walk-downs of the Site, were used to determine locations where watershed improvements should be implemented. These information resources are listed below:

- Surface-water monitoring data;
- Gamma spectroscopy data;
- IA sediment quality data;
- IA soils data; and
- HRR information.

Items of concern noted during Site walk-downs included the following items:

- Areas of concentrated fine sediments in drainage pathways;
- Areas of exposed dirt susceptible to erosion (e.g., steep dirt roads, barren hillsides, etc.);
- Erosion on radionuclide-contaminated IHSSs; and
- Position of radionuclide-contaminated IHSSs in relation to stormwater drainage pathways.

Results of the various investigative surveys were used in conjunction with findings from Site walk-downs to identify areas to target for watershed improvements. Specific types of improvement measures implemented within the SID drainage basin are discussed in the following section.

4.3.3. Types of Watershed Improvements Implemented in the South Interceptor Ditch Basin

Two types of watershed improvement measures were implemented in the SID drainage basin during FY96 and FY97. Brief descriptions of these two hydraulically-applied erosion control products are provided below:

- TopSeal® was applied at areas of the Site targeted for erosion control where revegetation was not practical, such as dirt roads. This acrylic copolymer emulsion product is mixed with water and sprayed on using a water truck. It dries within several hours to seal and bind the soil together and does not pose a threat to water quality.
- SoilGuard® was hydraulically applied at Site locations targeted for erosion control where revegetation was beneficial, such as exposed dirt hillsides. A combination of wood fibers mixed with fertilizers and a guar gum tackifier, it acts to stabilize the soil and encourage revegetation. SoilGuard® is applied by a certified contractor using a hydroseeding truck. The product can be used strictly as a soil stabilizer, without seed, or sprayed as a fixative on top of planted seeds. It dries within several hours to form a bonded fiber matrix, can withstand heavy rainfall while protecting the top layer of soil, and does not degrade water quality. New vegetative growth can protrude through the matrix without disrupting the surrounding sealed area.

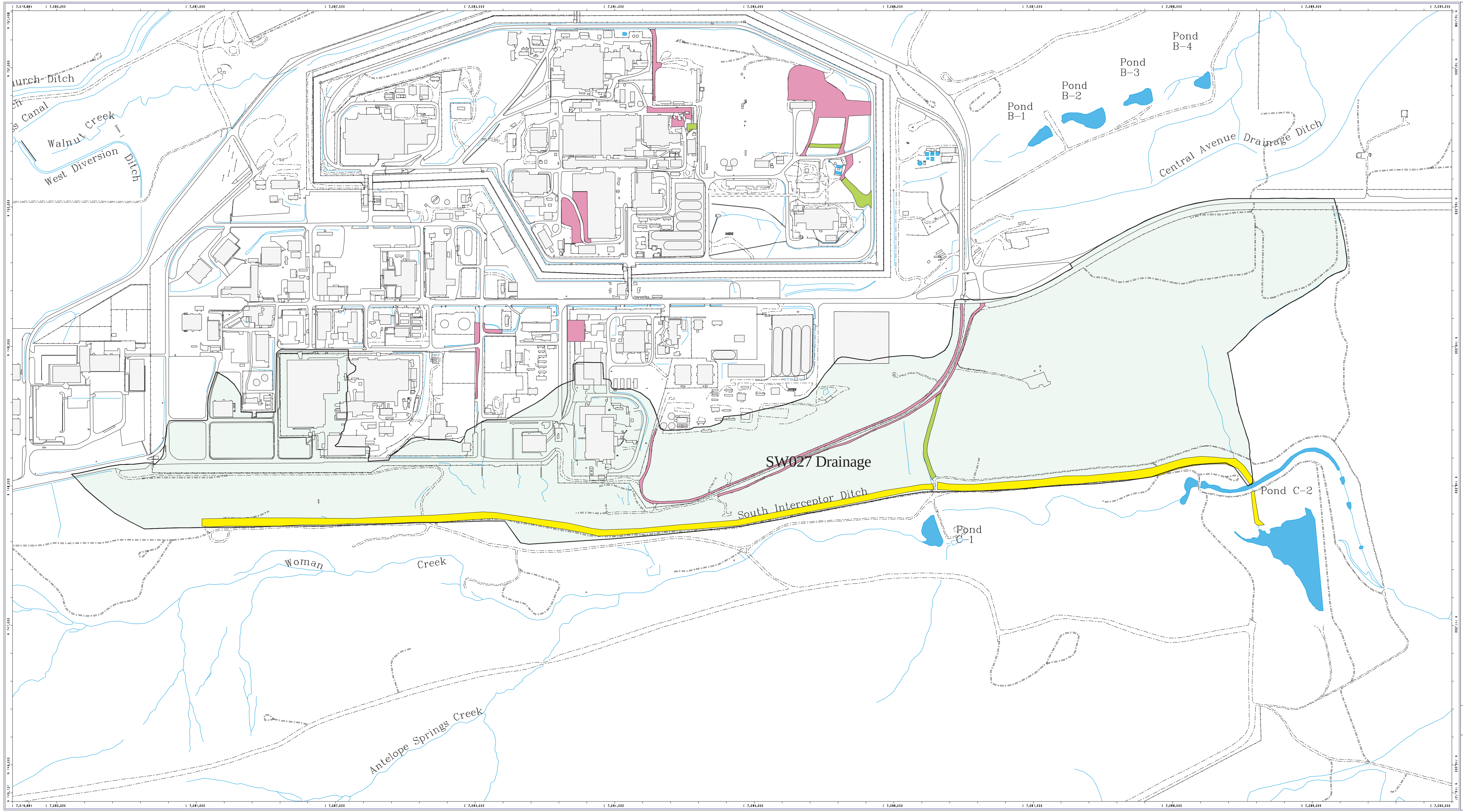
4.3.4. Impacts of Watershed Improvements on Plutonium Transport in the South Interceptor Ditch Basin

This section provides an analysis of the water quality impacts of watershed improvements implemented in the past in the SID drainage basin as monitored at station SW027. The following watershed improvements were implemented in the SW027 drainage basin on the dates shown and are shown in Figure 4-36:

- The road leading from the 903 Pad Lip Area downhill toward Pond C-1 was permanently closed and SoilGuard® was hydraulically applied as an interim measure to prevent transport of sediments down the hillside (completed on 5/28/96).
- The same road leading down to Pond C-1 was revegetated using imported topsoil, native grass seed mix and a cover layer of SoilGuard® to protect the planted area from wind and water erosion while the grasses became established (completed 9/17/96).
- TopSeal® soil sealant was applied to the dirt roads on the south and east sides of the 903 Pad north of the security fence (completed 9/30/96).
- Appproximately 180 trees were removed from the SID. This improvement was implemented in order to enhance the capacity of the channel to convey runoff, versus being intended to impact the mobility of radionuclides in the drainage basin (completed 11/7/96).
- TopSeal® soil sealant was applied to the dirt roads on the south and east sides of the 903 Pad on the south side of the security fence (completed 4/16/97).

Figure 4-36

Locations of Watershed Improvements Implemented in the SW027 Basin



Legend

Watershed Improvements

- Top Seal
- Revegetation/Soil Guard
- Drainage Maintenance

Drainage

- SW027 Drainage

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr., EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

Scale = 1 : 6870
1 inch represents approximately 573 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Prepared by:

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MAP ID: 98-0253-Map8

November 09, 1998

/gis2/projects/fy98/98-0253/map8/wat-shd-imp.aml

Figure 4-37 shows a plot of plutonium activity versus time at monitoring station SW027 from 1/1/94 through 10/1/98. From 1/1/94 until the time that watershed improvements were first implemented in the basin (5/28/96), plutonium activity in samples collected at SW027 ranged from 0.001 pCi/L to 2.3 pCi/L. Since watershed changes were first implemented, plutonium activity in samples at this location ranged from 0.005 pCi/L to 0.80 pCi/L. More significantly, perhaps, is the absence of seasonal increases in plutonium measured during the summers of 1996 (the year that the majority of the improvements were implemented) and 1997. A seasonal increase in plutonium values was observed in 1998. While data in Figure 4-35 do not reflect variations in the flow rate at the time the samples were collected, they do suggest that the average plutonium activity during the periods of seasonal high runoff declined for more than one year following the implementation of watershed changes. If further analysis supports the value of watershed improvements, the Site will consider reapplication is selected areas.

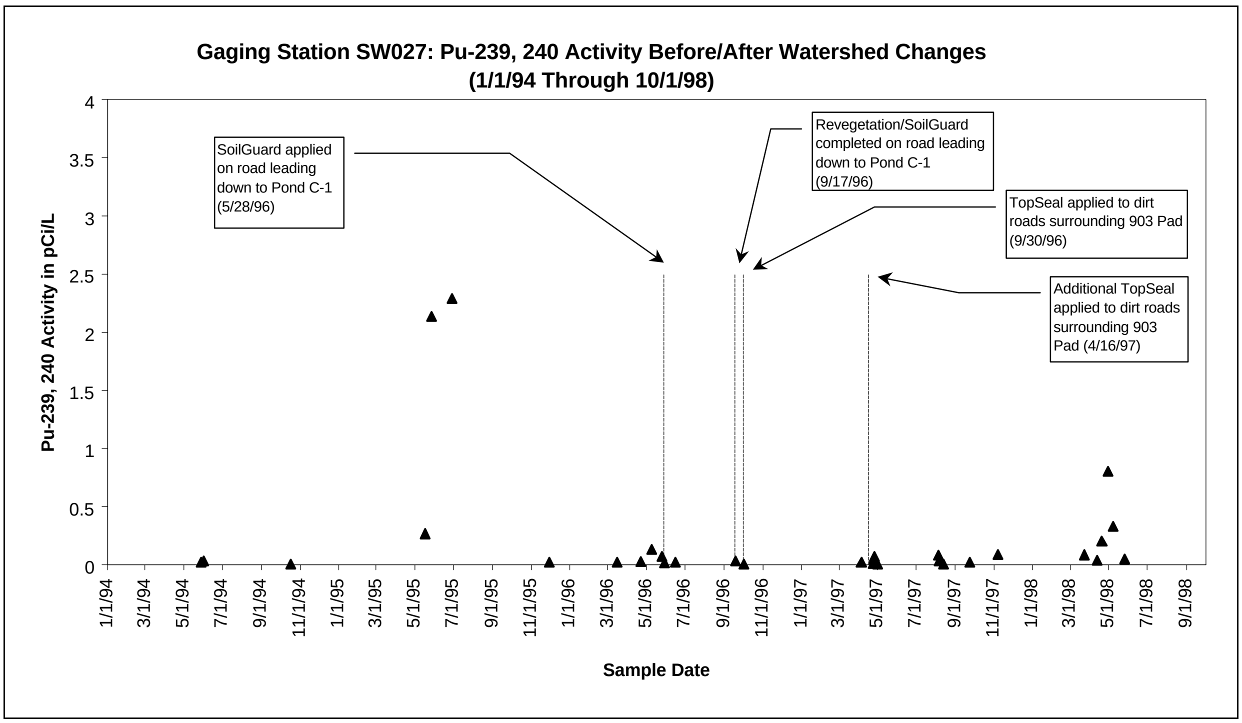

Figure 4-37. Gaging Station SW027: Plutonium Activity Before/After Watershed Changes.

Figure 4-38 shows a plot of plutonium activity versus flow rate for samples collected at SW027 from 1986 through the present. If surface water transport of plutonium is assumed to be associated with particulate matter, then an increase in plutonium activity is anticipated with a rise in flow rate if the physical flushing mechanism of particulate matter increases. Trendlines of this plot indicate that, following watershed changes, the amount of plutonium transported from the SW027 basin for a given flow rate was reduced by - perhaps - nearly two-thirds. However, statistical correlations for these trendlines are weak and need further evaluation.

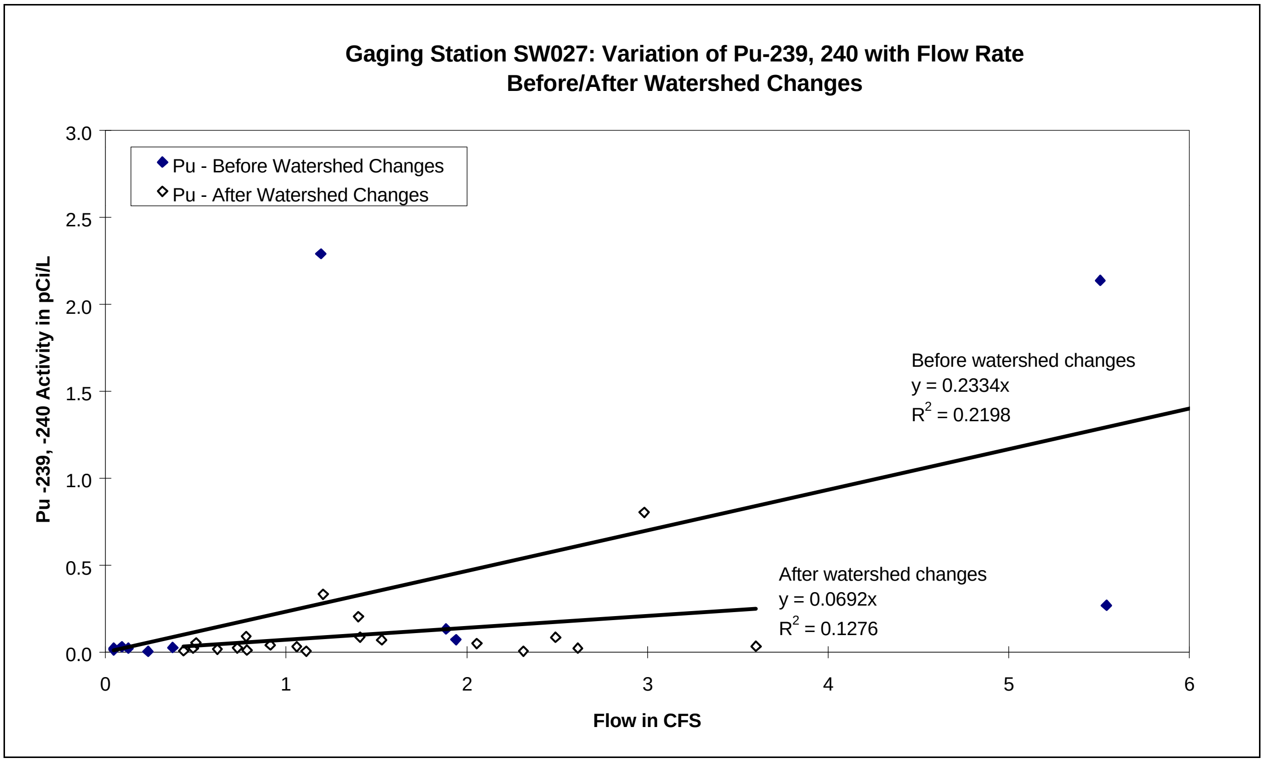

Figure 4-38. Gaging Station SW027: Variation of Plutonium Activity with Flow Rate Before/After Watershed Changes.

5. SW027 SOURCE LOCATION ANALYSIS: HYPOTHESES AND CONCLUSIONS

In the following section, a discussion of source hypotheses for SW027 is presented. To date, a singular localized source of contamination measured at SW027 can not be identified, although the 903 Pad appears to be the primary source of distributed contamination in the drainage.

5.1. Widespread Soil and Sediment Contamination in the SW027 Drainage

<u>Soil Contamination and Suspended Solids in Surface Water</u>

Site soils and sediments have a history of contamination from historical releases. The section on historical releases (Section 4.2.6) identifies various events and practices from the Site's production era which introduced radioisotopes to Site drainages through both airborne and surface-water runoff pathways. In Section 4.2.5, a review of existing soil/sediment data indicate widespread plutonium contamination of surface-soils and sediments throughout the SW027 drainage. Higher-level contamination is particularly evident southeast of the 903 Pad (Figure 4-29). As stated previously, plutonium forms strong associations with particulate matter. During high-intensity (heavy) precipitation events, with increased raindrop impact, greater quantities of solids are transported in overland flow, especially during periods with high soil-moisture conditions. When particles are transported in surface water, then so is any associated plutonium. Under these conditions in the SID drainage, distributed plutonium contamination that was initially spread as airborne particles could be transported to SW027.

Section 4.2.2 shows that there are numerous surface-water sampling locations with average activities above 0.15 pCi/L. Several of these locations measured surface-water in sub-drainages that are known to occasionally contribute flow to the SID. Accordingly, these sub-drainages would also be contributing plutonium load that originated as distributed contamination mobilized in overland runoff.

Surface-soil activities for samples in the drainage show a range of several orders of magnitude (see Section 4.2.5). The average areal surface-soil activity is approximately 130 pCi/g.[13] Assuming that plutonium is associated with soil solids measurable as TSS, and that TSS represents a uniform suspension of all soil fractions (i.e. TSS maintains the same particle size and composition ratios as the surface soils), surface water activity could be calculated directly from soil activity for a given TSS concentration. The average TSS value measured at SW027 is 54 mg/L, with a maximum to date of 500 mg/L. With a TSS of 0.5 g/L and assuming uniform suspension of surface-soils, a surface-soil with 0.3 pCi/g could yield activities of 0.15 pCi/L. Given the soil activities in the drainage, the recent elevated activities at SW027 are possible based on this analysis. Specifically, Table 5-1 shows the calculated surface water sample activities at SW027 which would result from a given basin soil activity, assuming uniform suspension of surface soils as TSS and complete association of plutonium with TSS in solution.

Table 5-1. Calculated Surface Water Activities Assuming Uniform Soil Suspension and Complete Association of Plutonium with Suspended Solids for SW027.

	Total Suspended Solids (TSS)	
Basin Soil Activity Ranges (pCi/g)	**54 mg/L (Average)**	**500 mg/L (Maximum)**
10-100	0.54 to 5.4 pCi/L Pu-239,240	5.0 to 50.0 pCi/L Pu-239,240
200 to 500	10.8 to 27.0 pCi/L Pu-239,240	100 to 250 pCi/L Pu-239,240

Contamination transported through airborne mechanisms would result in a distribution based on prevailing winds, with levels diminishing further from sources such as the 903 Pad (Figure 4-29). The movement of contaminated soils and sediments in runoff could result in locally contaminated deposits if suspended solids were to settle to ditch beds. These deposited sediments could then be re-suspended by subsequent events to provide plutonium activity at SW027. This phenomena could result in intermittently high activities at SW027 or a lag time between overland loading of plutonium to the SID and measurement of elevated activities at SW027.

Data collected from future Source Location monitoring locations (see Section 6.1.2) would further determine the proportions of plutonium load that each monitored sub-basin may be contributing. If a certain sub-basin is determined to be contributing a significant proportion of the load at SW027, that basin could be further characterized through soil/sediment sampling; and watershed improvements could be targeted to mitigate further transport. These types of watershed improvements have been effective for this drainage and other locations around the Site (see Section 4.3).

<u>Fractionation Effects on Surface-Water Activities</u>

Fractionation of both soils in surface water runoff and radionuclides in soils is undoubtedly occurring in the drainage. As stated previously, the conceptual model of uniform suspension of surface soils as TSS is an over-simplification. Both mechanical and physiochemical suspension mechanisms suggest preferential suspension of certain fractions of the surface soil in stormwater runoff. Fractionation may occur as a function of particle size, density, and/or surface chemistry. Furthermore, plutonium may associate preferentially with certain fractions of the soil based on surface area and/or surface chemistry. The net results may be a drastically different specific activity of suspended material in the surface water as compared to specific activity of the surface soils.

[13] Based on an areal average using the estimated distribution contours in Figure 4-29.

Sample results from Performance Monitoring Location, GS27[14] (Figure 5-1), provide a good example of this fractionation phenomenon. GS27 is an excellent test case because it has a very small drainage basin, approximately one acre of pavement and exposed soils, and stormwater runoff activities are significantly higher than the detection limits for plutonium. Soil activities in this area range from 0.1 to 10 pCi/g. Measured TSS concentrations at this location range from 12 to 1,650 mg/L. For a plutonium activity of 10 pCi/g in the soil and a sample with 1,650 mg/L TSS, the surface-water suspended activity would be 16.5 pCi/L, assuming uniform suspension. With actual observed plutonium activities of 30 to 75 pCi/L and a maximum of 90 pCi/L, the data may suggest that plutonium is preferentially suspended in surface water, perhaps associated with a preferentially suspended fraction of the surface soils. Figure 5-1 shows a comparison of sample-specific activity with TSS, where sample activity is normalized to solids concentration in the sample.

No clear correlations are apparent in Figure 5-1, however, the elevated values of specific activity at low sample TSS concentrations dispute a simplified conceptual model of uniform association and suspension. If plutonium associated uniformly with suspended material in a simple mass to mass ratio, the relationship would fit a horizontal line. In other words, in the event of no preferential sorption, the activity of the samples normalized to mass of solids would show no correlation with solids concentration (TSS). Instead, there is significant variation from a mean activity to mass ratio, particularly for the low TSS samples.

Similar indications of preferential suspension of plutonium and/or plutonium-associated solids are apparent when considering data from across the SID drainage (see Section 6.3). Approximate basin soil activities are compared to maximum observed TSS activities for various monitoring location sub-basins in Table 5-2.

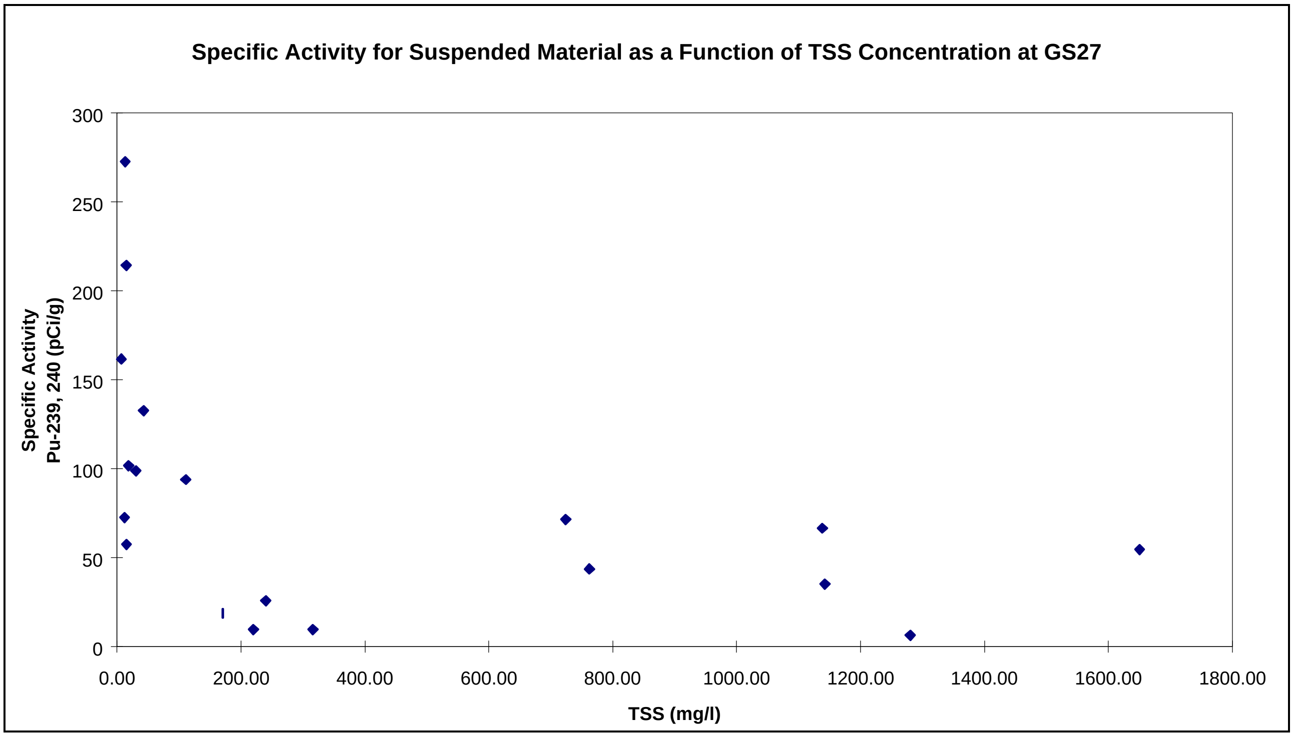

Figure 5-1. Specific Activity of Suspended Material as a Function of TSS Concentration in Stormwater Samples from GS27.

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[14] GS27 monitors a small sub-basin in the 800 Area tributary to Central Avenue Ditch and GS10. A more detailed treatment of GS27 is included in the Walnut Creek Source Evaluation Progress Reports.

Table 5-2. Calculated Activities of Suspended Material in Surface Water Samples for Gaging Stations SW027, GS03, GS10, SW093, SW022, and GS27.

Monitoring Location	Approximate Basin Soil Activity (pCi/g)	Maximum TSS Activity* (pCi/g)
SW027	130 (<10.0 for IA sub-drainages)	30.93
GS03	< 1.0	3.29
GS10	1.0	7.0
SW093	1.0	11.83
SW022	1.0	27.27
GS27	5.0	272.3

*TSS activities were calculated from total sample activities and suspended solids concentrations. It was assumed that all plutonium in the surface water samples is associated with suspended material measured as TSS.

In all cases except for SW027, the maximum calculated TSS activity is dramatically higher than the approximate basin soil activity, which may indicate both selective association of plutonium with a certain fraction of the soil and preferential suspension of that fraction by surface water runoff. Results from the AMS support this hypothesis (Section 6.3).

The fact that SW027 TSS activities are not higher than the basin average is likely due to the two different flow sources for SW027. As discussed in Section 4.2, flows reaching SW027 originate from the IA under most conditions (approximate sub-basin activity <10.0 pCi/g plutonium). However, during certain extreme conditions (spring 1995), overland runoff occurs from areas east of the 903 Pad with significantly higher plutonium activities.

Various hypotheses about the mechanisms of suspension, association, and subsequent transport of plutonium in surface water can be formulated from these data. Relevant variables may include particle size and surface area as well as the nature of mineral and organic coatings. Consultation with the AMS scientists is in progress in an effort to resolve some of these uncertainties and identify any relationships which may lead to a greater understanding and ability to predict and control radionuclide transport. Specifically, the AMS continues to evaluate soil/sediment and surface-water TSS speciation and the associated radionuclide activities to provide additional insight into transport of plutonium in surface water.

5.2. Groundwater Sources

One hypothesis to explain the elevated levels of plutonium and americium observed at SW027 is groundwater contamination of surface water. This hypothesis is supported by the existence of groundwater seeps at the base of the Rocky Flats Alluvium and the record of significantly contaminated groundwater samples collected within the SW027 drainage. Careful consideration of the available data, however, does not support this hypothesis.

Groundwater is not expected to be a significant source of the contamination observed in surface water at gaging station SW027 for the following reasons:

- Seeps into the SID drainage contribute only a minute amount of flow to the surface. Further, this flow is expected to almost exclusively re-infiltrate the soil matrix to the groundwater before mixing with surface water (RMRS, 1996).
- Lateral migration of plutonium and americium in groundwater is expected to be minimal based on high Site-specific partition coefficients reported by Honeyman and Santchi, (1997b).
- Elevated levels of plutonium and americium activity observed in groundwater samples within the drainage are not likely to be representative of the true mobile load. Instead, these data are suspected to be artifacts of well installation and design (RMRS, 1998b).

Unfortunately, definitive conclusions about the quality of the groundwater with respect to radionuclide contamination and mobility cannot be made due to the limitations on interpretation of the data. These limitations are imposed by suspected artifacts of groundwater well installation procedures and sampling protocols applied to collection of the data. To generate reliable data, future well installation protocols must be modified to prevent both initial borehole contamination and short-circuiting. Further, low flow-rate pumps should be used in place of bailers to retrieve samples.

5.3. Potential Issues with Laboratory Results

Issues with the quality of analytical laboratory results must also be considered when interpreting off-normal radioanalytical data. Variations in analytical data at SW027 naturally cause reevaluation of results from a data quality perspective. Factors to consider which might contribute to variation include changes in sample collection protocols (flow-paced composites vs. grabs, as previously described), use of newly subcontracted analytical labs (three sub-contracted labs have been used since December 1995 versus one on-site lab), variability in sample preparation and handling (currently, one subcontracted staff person is assigned to RFCA sample preparation and handling), and general analytical variability for radiochemistry samples at or near the level of detection. All subcontracted labs are required to perform to the same quality standard and should therefore produce the same quality data. Lab-to-lab variability, especially for the low-level radionuclide measurements, may be one of the more likely sources of sample result variability.

All data that contributed to the reportable values at SW027 have met the required QA/QC criteria and no requests for re-runs of “questionable” data have been required (see Section 4.2.8). None of the three samples detailed in this report have been selected for data package validation, which is performed on 25% of all analytical measurements generated by contract labs. Data validation, as described in the Site’s *General Guidelines for Data Verification and Validation*, DA-GR01-v1, 12/3/97, is a process designed to determine the extent to which the subcontract laboratory accurately and completely reported all sample and quality control results and their adherence to the specific Module contractual requirements. Validation does not assess or measure the variability that laboratories may introduce as part of their unique analytical processes. Factors such as laboratory staff experience, ambient laboratory conditions, and variation in analytical methods, as well as method-specific variability can, and do, contribute to sample result variability, especially at the very low radioactivity levels being measured. As long as all data are reported accurately and the specific Module requirements, such as detection level or sample preparation, are met, then data are considered valid. The change from Site analytical laboratories, which had demonstrated good analytical comparability at environmental levels of radionuclides of interest, to off-Site commercial laboratories may have introduced a measure of analytical variability that cannot be accurately assessed. These laboratories were originally contracted because the single laboratory was not capable of handling the large number of samples routinely collected for analysis. The availability of multiple subcontracted laboratories also provides alternatives in the event that one laboratory cannot perform analyses due to any number of problems such as equipment failure. The use of periodic, Site-prepared blind samples to test laboratory accuracy is currently being considered.

6. SOURCE EVALUATION PROGRAM STATUS: ISSUES AND HIGHLIGHTS

6.1. Automated Surface-Water Monitoring

6.1.1. Continuous Flow-Paced Sampling

As part of the source evaluation, and in accordance with RFCA, continuous flow-paced sampling has continued as specified in the IMP for SW027. Start and completion dates of samples for which analytical data has not yet been returned from the laboratory are presented in Table 6-1.

Table 6-1. Log of Recent SID Composite Samples.

Gaging Station	Sample Start Date	Sample Collection Date
SW027	9/10/98	Sampling In Progress

Upon receipt of laboratory results, 30-day moving average calculations will be updated as appropriate, and data will be made available.

Laboratories have been instructed to run TSS analysis on any samples which have not, by virtue of the sample collection duration, exceeded the maximum hold time of seven days. Collection of TSS information will aid in the determination of transport mechanisms for plutonium.

6.1.2. Installation of Source Location Monitoring Locations

Tributary to SW027

No source location monitoring locations are currently scheduled for installation in the SW027 drainage area. Should future reportable values be measured at SW027, source location monitoring locations may be installed upstream from SW027 in an effort to better characterize contributions to the SID from selected tributary subdrainages. Specifically, the Site is considering a location on the ditch downstream of sampling location SW055, and on the SID on the reach near SW068, SW069, and SW070 (see Figure 4-22). These locations would be installed to support the Source Location decision, as specified in the IMP. Collection of flow record and continuous flow-paced samples for laboratory analysis at these locations will facilitate loading calculations to determine which tributaries may be sources of contamination.

Gaging station GS42 (see Figure 2-1) is located on the unnamed tributary to the east end of the SID. This station is an IMP Ad Hoc Monitoring Station. Flow is monitored continuously to measure water discharged from a small sub-basin that headwaters on the East Access Road and flows through the East Spray Field Interceptor Ditch, and then discharges to a natural gully on the hillside north of the SID. This station collects samples for plutonium, americium, and TSS using flow-paced, storm event sampling. Flow at this location is event-driven (there is no baseflow), and sample pacing is selected to sample an entire runoff hydrograph. The data will be used to help calibrate the Watershed Erosion Prediction Project (WEPP) erosion model for the AMS (see Section 6.3.2). Costs for selected pieces of equipment and sample chemical analyses are provided by the USEPA. Data from this location will also be used to calculate plutonium loads to the SID from this sub-drainage.

The flow measurement device at GS42 is a 3-inch Parshall flume, capable of measuring flow rates up to approximately 1 cfs. GS42 is equipped with an electronic flow meter to collect 5- and 15-minute flow record and an automated sampler. Supplied power is solar with battery backup. Operational protocols currently applied to maintain all RFCA surface-water monitoring locations are also be applied to GS42. Construction and instrumentation of GS42 was completed on June 23, 1998, and the location was immediately operational. To date no composite samples have been collected, and the location has measured no flow.

6.2. Soil and Sediment Sampling

6.2.1. New Locations Tributary to SW027

Additional surface-soil and sediment samples may be collected from the drainage tributary to SW027 should future reportable water-quality values be measured. However, surface-soils in this drainage are already well characterized, and additional data will not likely add value. Locations of any new samples would be determined based on the analysis of the existing data. Particular attention will be given to the results of the loading analysis for existing stations and any installed Source Location stations (see Section 6.1.2). These sediment/soil locations would be sited to indicate spatial activity variations and to fill any gaps in existing data. Summary statistics for these new values would be evaluated against historical results in the area to indicate changes. Additionally, these values would be compared to surface-water radionuclide activities in a loading context.

6.3. Actinide Migration Studies in the SID Watershed

The AMS at the Site have focused on the SID watershed due to the relative abundance of actinide contamination in the drainage. A majority of the AMS work pertains to general actinide mobility characteristics that can be applied pervasively at the Site and elsewhere. Work completed to date in the SID watershed includes:

- Analysis of surface soil and sediment samples by sequential extraction techniques at Colorado School of Mines (CSM) to investigate the phase distribution (e.g. exchangeable, organic, sesquioxide-bound, etc.) and forms of plutonium and americium in the soil;
- Analysis of sediment samples for total plutonium and americium activity to estimate actinide inventories in Pond C-2;
- Soil aggregate size analyses and actinide distribution among the soil aggregates to determine the particle-size distribution of the actinides;
- Analysis of historical flow and water-quality data to estimate runoff coefficients, actinide and solids loading, and overall erosion of the SID watershed soils; and
- Preliminary watershed erosion modeling using the WEPP model.

Additional work in progress includes a study funded by the USEPA at CSM that will characterize:

- The materials that bind primary soil particles into secondary (i.e. larger) aggregate particles;
- The particle-size distribution of the actinides for dispersed soil aggregates;
- The size-distribution of the actinides in soils that undergo freezing/thawing cycles and wetting/drying cycles; and
- The chemical and mineralogical characteristics of the soils.

6.3.1. Loading Analysis Results

The *Loading Analysis for the Actinide Migration Studies at the Rocky Flats Environmental Technology Site* (RMRS, 1998d) presents results of TSS and actinide loads and runoff coefficients for SID monitoring stations. Table 6-2 is reproduced from this report. The data analyzed indicate that approximately 2,654 kg of TSS, 447 µg plutonium and 78 µg americium are discharged to the SID annually. The plutonium flux to Pond C-2 was estimated by Honeyman and Santschi (1997a) to be between 0.06 and 0.32 mCi/yr. The lower end of this range is supported by the loading analysis results (0.03 mCi/yr).

The annual average plutonium yields from IA sources draining to gaging stations GS21, GS22, GS24, and GS25 are two orders of magnitude lower than the yield measured at SW027. Therefore, the likely source of plutonium loading to the SID lies east (i.e. downgradient) of the B881 Hillside. These results are consistent with knowledge about soil and sediment contamination in the 903 Pad and Lip area, which is downgradient from the B881 Hillside.

The results in Table 6-2 imply that suspended solids sampled at SW027 have an average activity of 12 pCi/g. Total SID bed sediment activities from CSM and Operable Unit investigations show that the average activity is closer to 1 to 3 pCi/g (refer to Section 4.2.5). However, the aggregate size distribution of the actinides in six soil samples, from the eastern quarter of the SID watershed, show that the 2 to 10 mm size aggregates have activities several times higher than their corresponding bulk sample activities (Figure 6-1). The smaller aggregates are more likely to be mobile and remain suspended in surface water. Therefore, it is concluded that suspended solids at SW027 have an average activity of approximately 10 pCi/g, which means that a suspended solids concentration of only 15 mg/L could produce RFCA reportable water-quality values for plutonium and americium.

Table 6-3 (RMRS, 1998d) shows the calculated runoff coefficients for the SID watershed. The runoff coefficient describes the percentage of applied precipitation that runs off and is measured at the watershed outlet. Runoff coefficients for undisturbed areas on the Site are very low (e.g. less than 0.2). Impervious sub-basin drainage areas increase runoff coefficients due to decreased surface infiltration of the precipitation in those areas. The entire SID watershed (upstream from SW027) is characterized by a runoff coefficient of 0.14.

Table 6-2. Summary of Actinide and TSS Annual Total Yields for the SID.

Based on the Data Obtained 1991 - 1997
[Pu = Plutonium-239,240, Am = Americium-241, U = Total Uranium, TSS = Total Suspended Solids, pCi = picocuries, cm = centimeters]

SOUTH INTERCEPTOR DITCH GAGING STATION	CONSTITUENT	ESTIMATED ANNUAL TOTAL YIELD (Pu & Am in µg U in g & TSS in kg)	ESTIMATED ANNUAL TOTAL YIELD / ACRE (Pu & Am in µg / acre, U in g/acre & TSS in kg / acre)	ESTIMATED ANNUAL SOIL EROSION DEPTH IN DRAINAGE BASIN (cm)
GS21	Pu	1	0.47	
IA Runoff from Cactus and 7th	Am	1	0.31	
Near Bldg. 664	U	2	1	
Drainage Area: 2.66 Acres	TSS	271	102	0.002
GS22	Pu	4	0.25	
Bldg. 460 Runoff and Footing Drain	Am	12	1	
Discharge to SID	U	34	2	
Drainage Area: 14.1 Acres	TSS	5,657	401	0.01
GS24	Pu	1	0.22	
Bldg. 881 and 850 Runoff to	Am	0	0.07	
881 Hillside	U	1	0.22	
Drainage Area: 5.84 Acres	TSS	333	57	0.001
GS25	Pu	1	0.18	
East Bldg. 881 and 891 Hillside	Am	1	0.10	
Runoff with 881 Sump Flows	U	7	1	
Drainage Area: 6.7 Acres	TSS	401	60	0.001
SW027	Pu	447	2	
South Interceptor Ditch (SID)	Am	78	0.42	
at Inflow to Pond C-2	U	250	1	
Drainage Area: 186 Acres	TSS	2,654	14	0.0002

6.3.2. Erosion and Associated Actinide Transport Modeling

Currently, the AMS is conducting an erosion and sediment transport modeling study using the WEPP model. The WEPP model developed by the United States Department of Agriculture (USDA) and other cooperators, is a new generation of process-oriented, computer implemented erosion prediction technology, based on modern hydrologic and erosion science. The WEPP model is a distributed parameter, continuous simulation computer program, which predicts:

- Soil loss and sediment deposition from overland flow on hillslopes;
- Sediment loss and deposition from concentrated flow in channels;
- Sediment deposition in impoundments; and
- Sediment leaving the watershed by channel flow.

The model computes spatial and temporal distributions of soil loss and deposition. It estimates when and where on a hillslope or watershed channel the erosion and deposition occur. The watershed module estimates flow and sediment transport for ephemeral and intermittent flow channels for watershed areas up to 60 km^2.

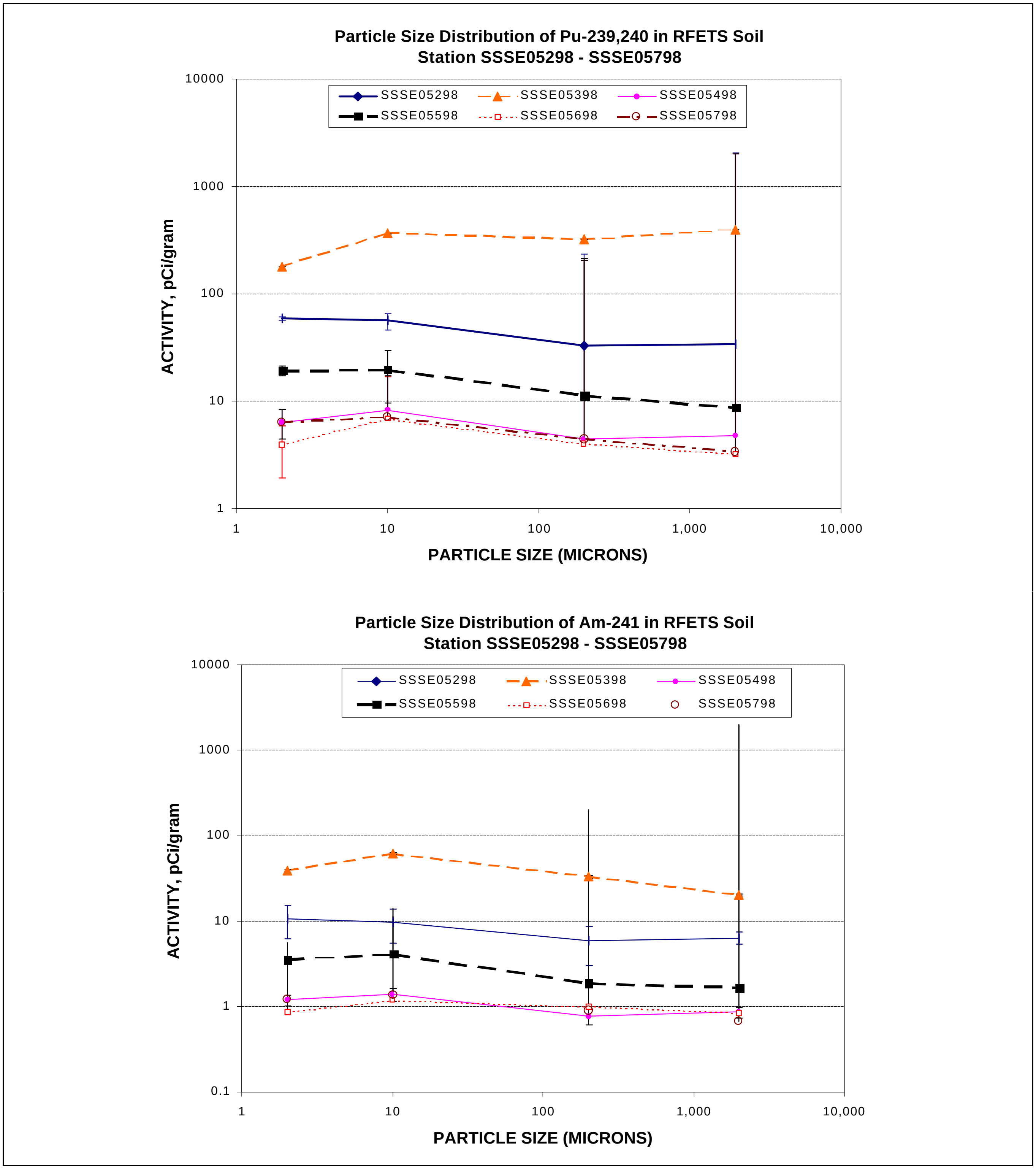

Figure 6-1. Aggregate Size Distribution of Pu and Am in Eastern SID Watershed Soils.

Table 6-3. Summary of Calculated Runoff Coefficients for Woman Creek Gaging Stations.

WATER YEAR	GAGING STATION	DRAINAGE AREA (AC)	MEASURED TOTAL ANNUAL PRECIPITATION (FT)	ESTIMATED POTENTIAL TOTAL ANNUAL YIELD (AF)	MEASURED ANNUAL YIELD (AF)	ESTIMATED RUNOFF COEFFICIENT
1993	GS01+ GS02		0.88	1,365	90	0.07
1994	GS01+ GS02	1545	0.91	1,400	58	0.04
1995	GS01+ GS02		1.48	2,283	905	0.40
1996	GS01	1364	1.02	1,396	34	0.02
1997	GS01		1.20	1,631	284	0.17
					AVERAGE:	**0.08**
1993	GS14		0.88	789	*73*	*0.09*
1994	GS14		0.91	809	122	0.15
1995	GS14	893	1.48	1,319	401	0.30
					AVERAGE:	**0.12**
1993	GS07		0.88	712	186	0.26
1994	GS07	806	0.91	730	135	0.18
1995	SW029		1.48	1,191	1238	1.04
1996	SW029		1.02	825	152	0.18
					AVERAGE:	**0.21**
1993	GS16		0.88	119	35	0.29
1994	GS16		0.91	122	28	0.23
1995	GS16	135	1.48	199	103	0.51
1996	GS16		1.02	138	66	0.48
1997	GS16		1.20	161		
					AVERAGE:	**0.33**
1994	GS18	501	0.91	454	46	0.10
1995	GS18		1.48	740	*161*	*0.22*
					AVERAGE:	**0.10**

Notes:
1) Values in Italics based on partial record at GS14, GS18.
2) AVERAGE runoff coefficient values do not include water year 1995 data due to extreme hydrologic conditions in spring of 1995.

WEPP Results

Evaluation of the preliminary WEPP model output indicates that erosion is predominantly predicted on disturbed and/or steeply sloped areas, and deposition is predicted on flatter and/or well-vegetated areas. Evaluation of the results indicates that disturbed areas such as unimproved roads have the largest erosion rates.

Table 6-4 shows the preliminary results for a 100-year WEPP simulation for the SID watershed. Using the hillslope module, WEPP predicted runoff and sediment yields that closely match the monitoring data. However, WEPP tended to underestimate runoff and potentially overestimate the sediment yields. These results are consistent with sensitivity analyses and validation studies by others.

Table 6-4 Comparison of Preliminary WEPP Model Output to Loading Analysis Calculations[*]

Parameter	WEPP Output Value	Loading Analysis Value
Annual Average Soil Erosion (kg/acre)	65	15
Annual Total Soil Transport to SID (kg)	11,778	2,654
Annual Average Runoff (Acre-Feet)	10	Range: 15.5 – 63 (63 AF is for 1995 flood)
SID Watershed Runoff Coefficient	0.08	0.14 (RC = 0.08 in Water Year 1996)

[*] WEPP output value is computed as the total sediment/runoff reaching the SID. Loading Analysis Value is computed from the sediment/runoff leaving the SID outlet.
Note: Runoff Coefficient is the fraction of precipitation that reaches watershed outlet.

6.3.3. Future AMS Work

All erosion modeling and associated actinide transport estimates will be completed in FY99; culminating in a final report for the study. Specific supporting activities are as follows:

- WEPP will be used to simulate runoff and erosion for individual storms, such as the flood that occurred on May 17, 1995;
- Erosion and actinide mobility will be mapped using GIS technology; GIS will be used to combine the WEPP output with the spatial distribution of soil activity to produce actinide mobility maps;
- Field measurements of runoff and erosion at two newly installed rangeland gaging stations will continue for WEPP calibration; and
- A CSM study on Site soil aggregation characteristics is anticipated to be completed in calendar year 1998. Results from this study will complement the WEPP model results to make conclusions about the fate of actinides mobilized by erosion and sediment transport processes.

6.3.4. Previous Runoff and Erosion Modeling Studies

Investigation of overland flow processes and their potential to transport radionuclides to the SID were done by EG&G (1993) and by Zika (1996). EG&G used the Revised Universal Soil Loss Equation to predict approximately 83 tons of sediment transport to the SID annually, of which about 90 percent was estimated to be deposited in the SID channel. Although the magnitudes of these estimates are suspected to be high, the results are qualitatively consistent with large-scale sediment deposition, bank slumping, vegetation growth, and decreased hydraulic efficiency observed in the SID over the past several years.

Zika calibrated the WEPP model to field measurements of overland flow generated by rain simulators on small plots in Operable Unit 2. Zika noted that runoff only occurred for extreme hydrologic events (e.g. 1-hour, 100-year precipitation event) occurring with high antecedent moisture conditions (Zika, 1996). These results indicate that runoff is part of the normal hydrologic cycle for undisturbed surfaces in the SID watershed, and that runoff would be expected to occur during spring and early summer when antecedent moisture content of the soil is highest, and intense thunderstorms can occur. Therefore, the potential for sediment and actinide transport to the SID is greatest during the spring and other wet periods.

Zika collected runoff samples for a precipitation event on June 29, 1995 in Operable Unit Number 2 (i.e. approximately 800 feet east of the 903 Pad) at a time when the soils were saturated from extreme hydrologic conditions, including a 15-year precipitation event on May 17, 1995. The natural runoff had average activities of 12.9 pCi/L plutonium and 2.3 pCi/L americium. Runoff collected from a 42-minute, 10-year event (7.1 cm) rain simulation experiment on July 7, 1995 yielded average activities of 20 pCi/L plutonium and 3.82 pCi/L americium. These activities are up to two orders of magnitude higher than RFCA reportable levels (0.15 pCi/L). Zika concluded that on average, runoff and overland flow processes can significantly remobilize and redistribute radionuclides every 25 to 50 years, or that every two years there is a 2 to 4 percent chance that significant remobilization will occur.

6.3.5. Phase Distribution and Transport of Actinides

Research by Litaor and Ibrahim (1996) and by Honeyman and Santschi (1997b) on the phase distribution of the plutonium and americium in the soils and sediments in the SID watershed investigates how actinides are bound to soils and sediments. Sequential extraction experiments by these authors indicate that the actinides are predominantly in sesquioxide, organic, and residual (i.e. not extractable) forms. Plutonium and americium exists as extremely insoluble oxides with distribution coefficients (K_d) of 10^{-4} to 10^{-5} L/Kg (Honeyman and Santschi, 1997b). The distribution coefficient describes the distribution of the elements between aqueous (0.45 micron filtrate) and particulate phases. For example, if one pCi of plutonium was mobilized in the environment, then 0.0001 to 0.00001 pCi of the plutonium would be transported as a "dissolved" species, and 0.9999 to 0.99999 pCi would be transported on a solid material (e.g. sediment). In other words, the low K_d values obtained for plutonium and americium indicate that transport of the elements occurs predominantly on solid materials. Therefore, erosion and sediment transport controls would likely be most effective for impeding transport.

7. SUMMARY AND CONCLUSIONS

Site personnel have completed their initial source evaluation for potential cause(s) of reportable 30-day moving averages for plutonium at the POE monitoring location SW027. Site personnel completed an extensive evaluation of historical data and assessed Site activities and monitoring programs. To date, only distributed contamination from the 903 Pad has been identified as a possible cause of these reportable values. Site personnel conclude that the likely source of the reportable 30-day moving averages for plutonium at SW027 was diffuse radionuclide contamination from past Site operations released to the environment through events and conditions over past years, particularly from the 903 Pad. Based on the evaluation, Site personnel conclude that no specific remedial action(s) is indicated at this time, other than scheduled remedial actions for the 903 Pad, as the source investigations have identified no other localized source(s) of contamination.

Site personnel are continuing the surface-water source investigation using the existing monitoring program. Enhancements in monitoring activities may be implemented to provide improved resolution should any future reportable 30-day moving averages be measured at SW027.

This Report contains no specific recommendations for source control due to the reportable values measured at SW027. The recommended course of action in this report will not compromise protection of human health and the environment since the vast majority of the plutonium measured at SW027 was removed through settling in Pond C-2.

The Site's proposed course of action includes: (1) continuing observation (routine monitoring and special sampling, of the surface water as appropriate), and (2) continuing progress on the AMS. Effective best management practices, such as the use of the existing terminal ponds in batch or flow-through mode to clarify stormwater of potentially-contaminated sediment and particulate matter, should be continued. Specifically, the Site proposes the following actions as the path forward:

- Continued observation (routine monitoring and special sampling, as appropriate to the evaluation) and ongoing data interpretation to provide better understanding of actinide transport directly related to the operation of the Site automated surface-water monitoring network. This monitoring and the associated evaluations will be invaluable should reportable values be measured in the future.
- Continued progress on the AMS as a longer-term technical study to provide understanding of actinide migration to eventually provide insights about the cause(s) and possible prevention of reportable radionuclide water-quality measurements. This multi-disciplinary study and the associated watershed modeling initiative is key to understanding water-quality variation on the Site, and will eventually describe the extent, and conditions under which plutonium and americium move in the Rocky Flats environs. Site personnel expect these efforts will provide insights about the cause(s) and possible prevention of reportable radionuclide water-quality measurements.
- Continued use of the existing detention ponds in batch or flow-through mode to clarify stormwater of potentially contaminated sediment and particulate matter as an effective best management practice.
- Continued stakeholder participation in the formulation of mitigating responses to these reportable values through the Water Working Group as outlined in Appendix 5 of RFCA.
- Provide progress reporting through AMS reports, Quarterly RFCA Reports, Quarterly State Exchange Meetings, and informal status/flash briefs.

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