**PDHonline Course C387 (3 PDH)**

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# Environmental Investigation and Remediation of a Hazardous Waste Site<br> Part 2 - Analysis of Existing Information and Regulatory Concerns

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**2020**

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# Environmental Investigation and Remediation of a Hazardous Waste Site
# Part 2 - Analysis of Existing Information and Regulatory Concerns

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## Course Content

## Introduction

For many years a Research Institute (Institute) carried out experiments using both radioactive materials and organic and inorganic chemicals in its laboratories. In order to dispose of the waste products of this research the Institute operated a shallow land burial facility for twenty years on the grounds of its research campus. The shallow land burial was accomplished by randomly placing both liquid and solid wastes, held in various types of containers, into narrow parallel trenches dug into the soil to a maximum depth of about 8 to 12 feet below the ground surface. Once a trench was filled to within 4 feet below the surface, dirt was placed over the waste, graded, fertilized and seeded. In areas where parts of older trenches subsided, due to breakage of containers or compaction of the waste, additional dirt was placed in the sunken areas and these parts were re-graded and re-seeded. The site itself slopes gently downhill, so that surface water would run off the burial area and into the woods downslope of the landfill. The site is located in a part of the U.S. that receives about 35 to 45 inches of rainfall a year.

Once the site was no longer used, it was fenced, posted and locked. Minimal grounds maintenance was done until the State Radiation Protection Agency (State RPA) notified the Institute that they were to keep the fence clear of vegetation and the area within and just outside the fence mowed and free of trees. The following photo shows the waste disposal area after the site was decommissioned and grounds maintenance started:

Figure 1: Decommissioned waste disposal site at the Institute

Importantly, shallow land burial of chemical and radioactive wastes at this site was conducted in accordance with the accepted state and federal standards during the time of operation. The Institute was never cited for improper disposal practices or other violations. Both the Institute and the regulatory agencies agreed that the site was managed and operated properly.

Since the late 1980's, however, public awareness of the dangers of contamination from landfills of all types was growing throughout the country. In response to this heightened awareness, regulatory agencies charged with the protection of public health and safety became increasingly concerned that disposal practices that were once considered acceptable may have long-term negative impacts on the groundwater, surface water and soil. The Environmental Protection Agency issued drinking water standards that specified minimum acceptable levels for a number of common industrial chemicals, including some radioisotopes. Federal and state legislation required environmental agencies throughout the U.S. to investigate operating, decommissioned and abandoned landfills of all types. The Superfund program was also initiated at the federal level to help fund cleanup of hazardous waste landfills.

Following the decommissioning of the waste disposal site by the Institute, the State RPA initiated a program of soil, vegetation and surface water sampling. Yearly testing showed no evidence of significant radioactive contamination outside the burial area. Several years later, the State RPA recommended that the Institute install a series of monitoring wells to allow sampling and testing of the groundwater. In response, the Institute, under the guidance of the State Groundwater Protection Agency (State GPA), installed five monitoring wells around the waste disposal site, as shown on the following figure.

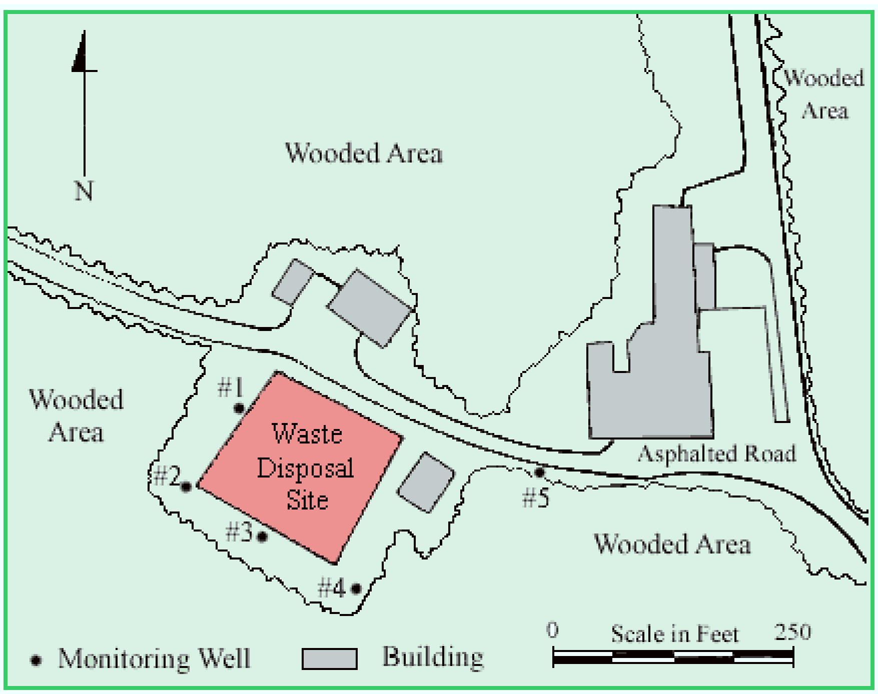


Figure 2: Location of initial monitoring wells surrounding the waste disposal site

About a month after installation, the State RPA collected groundwater samples from the five monitoring wells for radiological analysis. About a year later, one additional groundwater sample was collected from Well #3 for radiological and organic chemical analysis. The radiological analyses indicated that some of the groundwater samples in the immediate surroundings, south of the fenced area, had elevated Tritium activities. It also appeared that organic chemical contamination might be present in the groundwater in the vicinity of the disposal area. Discovery of both chemical and radiological contamination outside the fenced-in burial area prompted the State RPA to require the Institute to design and implement an extensive investigation program. The Institute issued a Request for Proposals (RFP) to environmental and engineering firms to retain the services of a qualified technical services consultant (Consultant). Part 1 of this series of courses, entitled: ***Background and History Leading to Contract Award*** summarized the actions that led to a signed contract between the Institute and the Consultant and reported on the initial meetings with the various regulatory agencies.

As part of the scope of work, the Consultant had proposed to first review existing information, develop an estimate of the inventory of the waste disposed of at the site, and evaluate existing soil, vegetation, groundwater and surface water test results. At the end of this phase of the work, the Consultant would then issue a Preliminary Site Condition Report summarizing the results of these initial studies. The results of this scope work, comments of the state agencies, and responses to those comments are presented in this course. At this point, the media also became interested in this project. The text of one of the news articles is included at the end of this course to illustrate the type of coverage that often accompanies work initiation on such hazardous waste projects.

A glossary of terms and acronyms used in this series of courses follows the summary section, at the end of this course.

## Preliminary Site Condition Report

The scope of work for the Preliminary Site Condition Report included:

- Definition of the property boundary and adjacent land uses,
- Reconstruction of the history of waste disposal at the site,
- Performance of a preliminary site reconnaissance,
- Reconstruction of the locations and geometry of the disposal trenches,
- Compilation of a radioactive waste inventory,
- Compilation of a chemical waste inventory, and
- Review of existing soil, vegetation, surface water and groundwater test results.

Each of these topics is addressed in the following subsections.

### Definition of the Property Boundary and Adjacent Land Uses

The importance of defining the property boundary with some degree of accuracy is that many of the regulations that address potential health and environmental risks are based on distance of possible receptors from the property boundary of the facility, not just from the waste disposal area. Of additional importance is the land use of the adjacent properties in order to identify potential exposure pathways.

To address these issues, the property boundary of the Institute's research campus was transferred to a topographic map and is shown on the following figure:

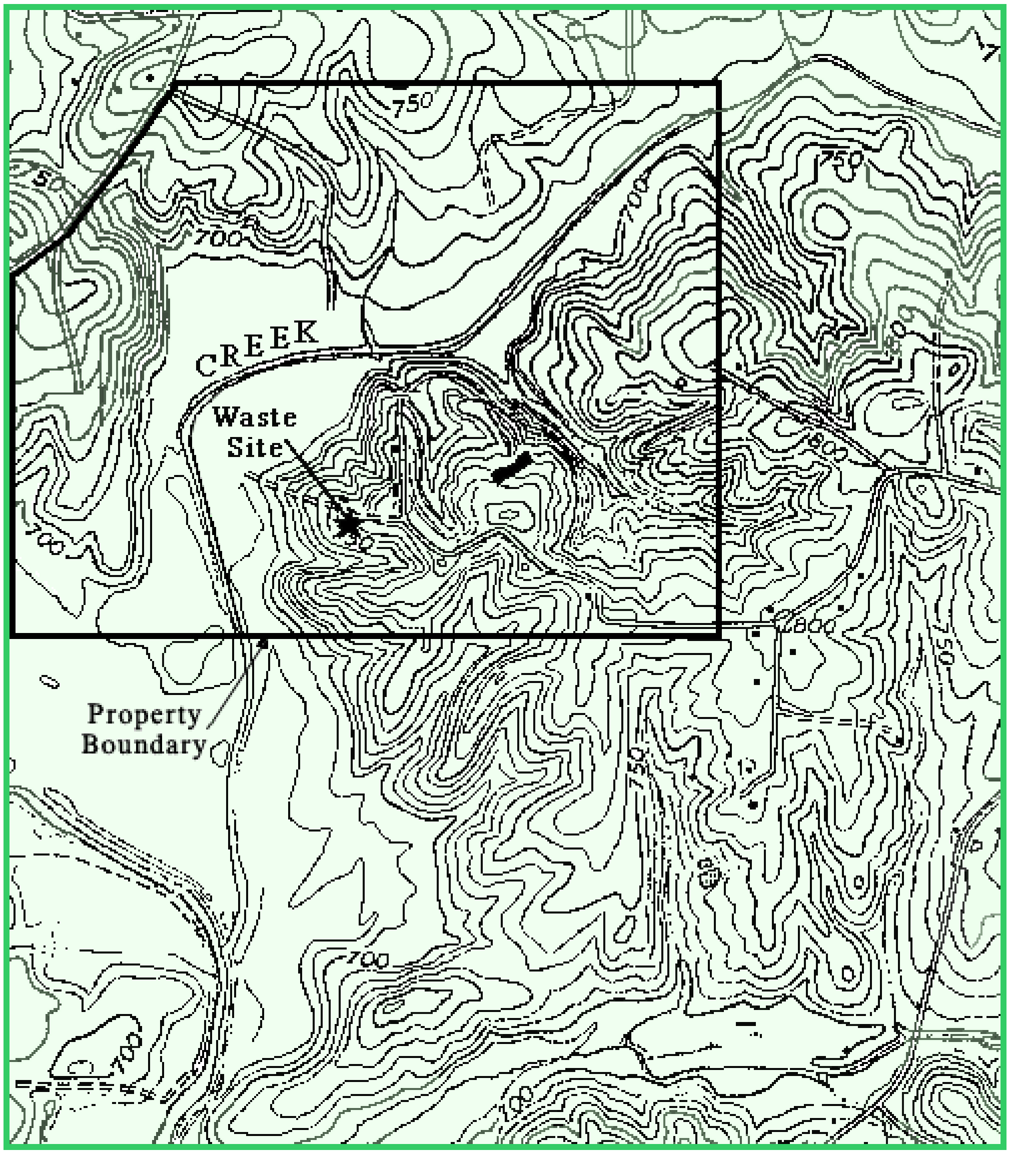


Figure 3: Map showing the property boundary of the Institute

From the map, available aerial photographs and field reconnaissance, adjacent land uses were identified. These analyses and field checks verified that three dairy farms are located along the eastern and southern boundaries of the campus and that the land on the western and northern sides of the creek was owned by the Institute and left undeveloped. The distribution of this land use is shown diagrammatically on the following sketch:

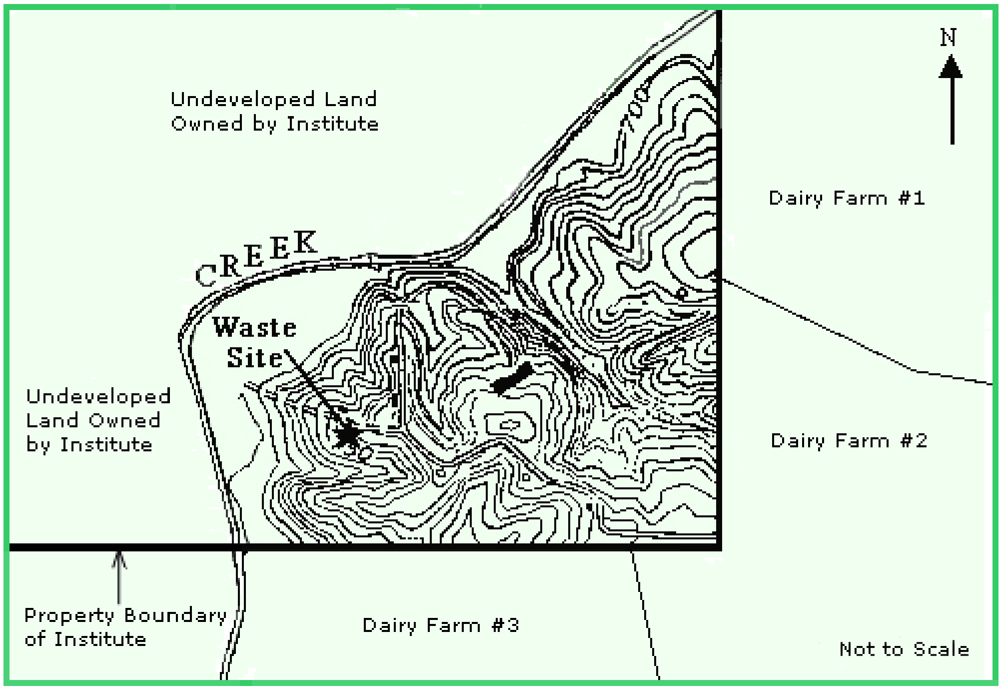


Figure 4: Sketch of land uses surrounding the property boundary of the Institute.

The Consultant also noted that a portion of the creek's eastern floodplain, at the bend of the Creek, was cultivated by the owner of dairy farm #3. The crop consisted of corn for ultimate use as cattle feed. The Institute had permitted this use as a good neighbor practice, and no compensation was paid to the Institute.

**History of Waste Disposal at the Site**

According to existing records, the Consultant determined that waste was buried at the site over a period of 20 years, from 1960 to 1980. Disposal of low-level radioactive waste was conducted under a radioactive material license issued by the State RPA. The hazardous chemicals and the radioactive wastes were usually mixed together during burial. The Institute records also indicated that large volumes of non-radioactive chemical wastes were not routinely disposed of within the burial area. No additional waste materials have been placed in the site since the end of 1980.

According to the records of the Institute and the State RPA, waste materials were accumulated in the research laboratories until sufficient volume was available to warrant mobilizing a crew for burial activities. Waste burials were usually made on a monthly basis. Solid waste materials were contained in cardboard boxes or plastic bags. Liquid wastes were contained in one-gallon glass or five-gallon metal containers. Wastes were brought to the disposal area by truck and placed directly into an open disposal trench.

No accurate records of waste volumes were kept. However, using the geometry and estimated number of trenches on site, the total volume of waste buried was likely between 30,000 to 40,000 cubic feet (about 1,000 to 1,500 cubic yards). About half of the volume was estimated to be in solid form, the rest in liquid form.

Records indicated that one disposal trench would be open at a time. Trenches were generally between 8 and 12 feet deep, 2 to 3 feet wide, and 40 to 60 feet long. The trench would be left open until the level of waste reached about 4 feet below the ground surface. At that point, the trench would be backfilled with dirt and residual soil excavated from an adjacent new trench.

The Institute's records showed that each trench would hold about 6 months worth of waste. This fact suggests that each trench would be left open for this period of time, exposing the waste directly to the rain. The open trenches also acted as pools to retain rainwater in direct contact with the waste and letting the water slowly seep into the ground. There were no records of temporary tents or covers being erected or placed over the open trenches.

No attempt was made to cap the backfilled trenches with anything more than the soil from the excavation of the next trench. If areas of the backfilled trenches subsided due to compaction of the waste or breakage or collapse of containers, additional soil was placed in the low areas which were then graded and re-seeded with grass.

Although these burial methods seem crude and improper by today's standards, it is important to note that the procedures that were used were consistent with both federal and state regulations at the time. Also, the State RPA would occasionally inspect the burial activities and found no improper or illegal activities. The burial procedures followed by the Institute were similar to the burial procedures being followed all over the U.S. at the time.

**Preliminary Site Reconnaissance**

No accurate survey information was available to determine the dimension of the burial site. At this point in the project, the Institute did not want to pay for a survey crew to generate an accurate topographic map of the area under investigation. So, the Consultant's staff determined the dimension and orientation of the fence line using a 100-foot tape and a compass in order to estimate the surface area of the waste disposal site. The measurements of the linear segments of the fence that surrounds the disposal area are:

| Fence line Segment | Length |
|---|---|
| Northern segment | 184.0 feet |
| Eastern segment | 191.6 feet |
| Southern segment | 168.0 feet |
| Western segment | 147.0 feet |

Based on these measurements, the total surface area of the disposal site is approximately 0.65 acre.

The waste disposal site is located on the south-facing slope of a small east-west trending drainage basin. The topography of the area surrounding the waste disposal site, the outline of the small drainage basin immediately south of the disposal site, and the estimated directions of surface water flow within the basin are shown on the following figure.

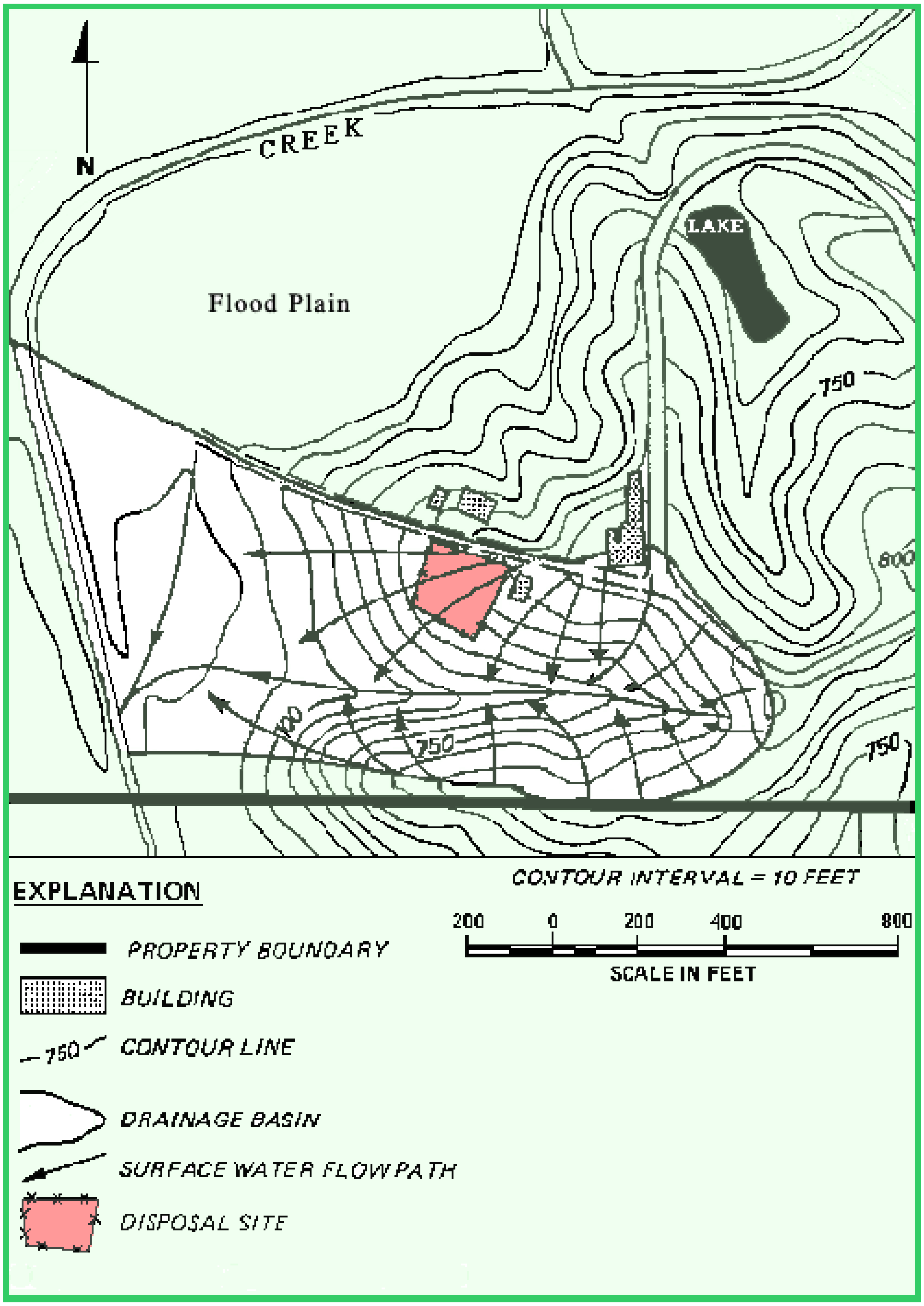


Figure 5: Disposal Site Location, Drainage Basin and direction of Surface Water flow.

The area in the immediate vicinity of the waste disposal site is shown on the next figure. The figure also shows the locations of the five monitoring wells installed by the Institute, under the guidance of the State GPA, in response to a request made by the State RPA.

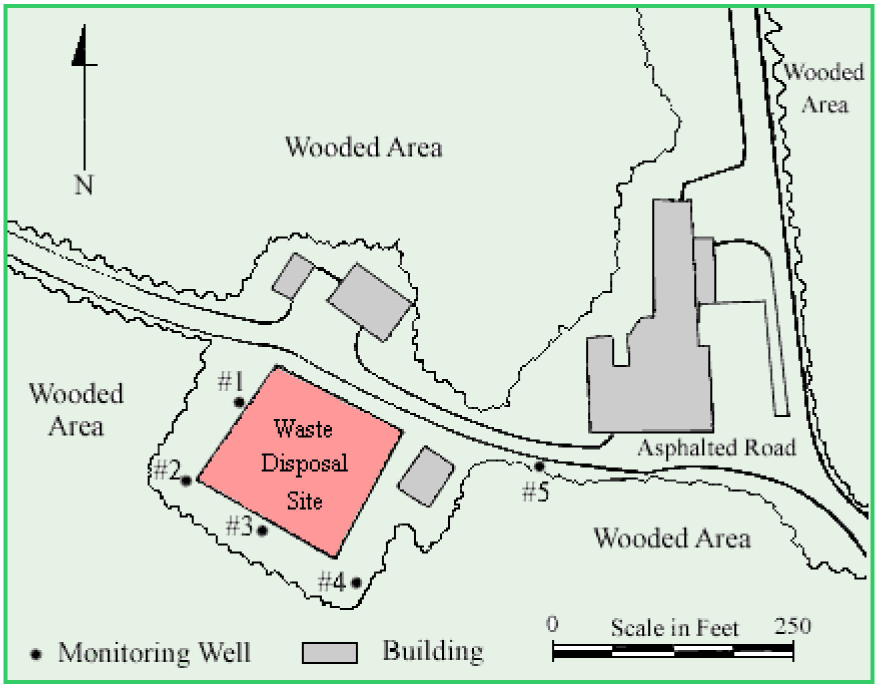


Figure 6: Site map showing the Waste Disposal Site and the Existing Five Monitoring Wells.

The Institute did not survey the monitoring well locations at the time of their installation. Since relatively accurate elevations are required to determine groundwater and surface water gradients, the Consultant needed to determine these elevations. In the absence of accurate survey information, an approximate alternative approach was used, as described in the following paragraphs.

The information on Figure 6 was transferred to the appropriate 7.5 minute topographic quadrangle map (scale of 1:24,000, contour interval: 10 ft) published by the United States Geological Survey (USGS). This composite map was then used to estimate the elevations of the five monitoring wells. Monitoring Well #5 was the closest to a contour line on the USGS map and its elevation was interpreted to be 779.0 feet.

The other four monitoring well locations fell between contour lines, so that their interpreted elevations were less certain. To improve accuracy, the elevations of the other four monitoring wells (Nos. 1 through 4) were measured with a surveying altimeter relative to Well #5. Several clockwise and counterclockwise closed traverses were made using Well #5 as the starting point. The altimeter measures elevation changes from a base point based on the fact that barometric pressure changes with elevation. In order to factor out atmospheric effects and other errors, several traverses are usually completed and the data averaged to minimize and distribute closure errors. The ground surface elevations at monitoring wells Nos.1 through 4, as calculated from the altimeter survey, and the elevation of well #5, are presented in the following table:

 

| Well Number | Elevation |
|---|---|
| Well #1 | 756.6 feet |
| Well #2 | 747.0 feet |
| Well #3 | 749.6 feet |
| Well #4 | 748.2 feet |
| Well #5 | 779.0 feet |

The highest elevation well is #5. It is considered to be the "background" or "up-gradient" monitoring well, used to determine the chemical characteristics of the groundwater before it encounters and mixes with the groundwater beneath the waste disposal area. All other wells are downgradient of the disposal area, and should therefore intercept contaminated groundwater moving away from the disposal area. Without at least one upgradient well for comparison, it would be impossible to positively link any contamination in the other remaining four wells to a provenance from the disposal area.

The topographic gradient (slope of the land) across the disposal area was calculated from the ground surface elevations at the monitoring wells. The gradient ranges from 7 percent downhill in a westerly direction (between monitoring wells #5 and #1), to 12 percent downhill in a southwesterly direction (between monitoring wells #5 and #4). This information suggests that surface water would most likely enter the disposal area from the northeast and travel across the area to the southwest.

**Locations and Geometry of Disposal Trenches**

The actual locations and dimensions of the waste burial trenches were not recorded during the period of operation. However, based on interviews with personnel involved with the disposal activities, the approximate locations and configuration of the trenches were reconstructed based on the following information:

- The fence around the waste disposal area was constructed before the digging of any trenches. Therefore, all the trenches lie within the fenced area.
- Trenches were not placed closer than 10 feet from the perimeter fence.
- A minimum of 6 feet was left undisturbed between trenches.
- Trenches were excavated with a backhoe.
- The approximate dimensions of the trenches were: 2 to 4 feet wide, 40 to 60 feet long, and 8 to 12 feet deep.

The first two trenches were thought to have been dug in the lower portion of the waste disposal area, parallel to the southern segment of the fence. However, all the remaining trenches were dug parallel to each other in a down-slope direction. No trenches were placed in the eastern third of the Site.

The Consultant estimated that it would take approximately 38 trenches laid out as shown on the following figure to satisfy all of the above geometrical constraints. The following figure shows the reconstructed layout of the trenches.

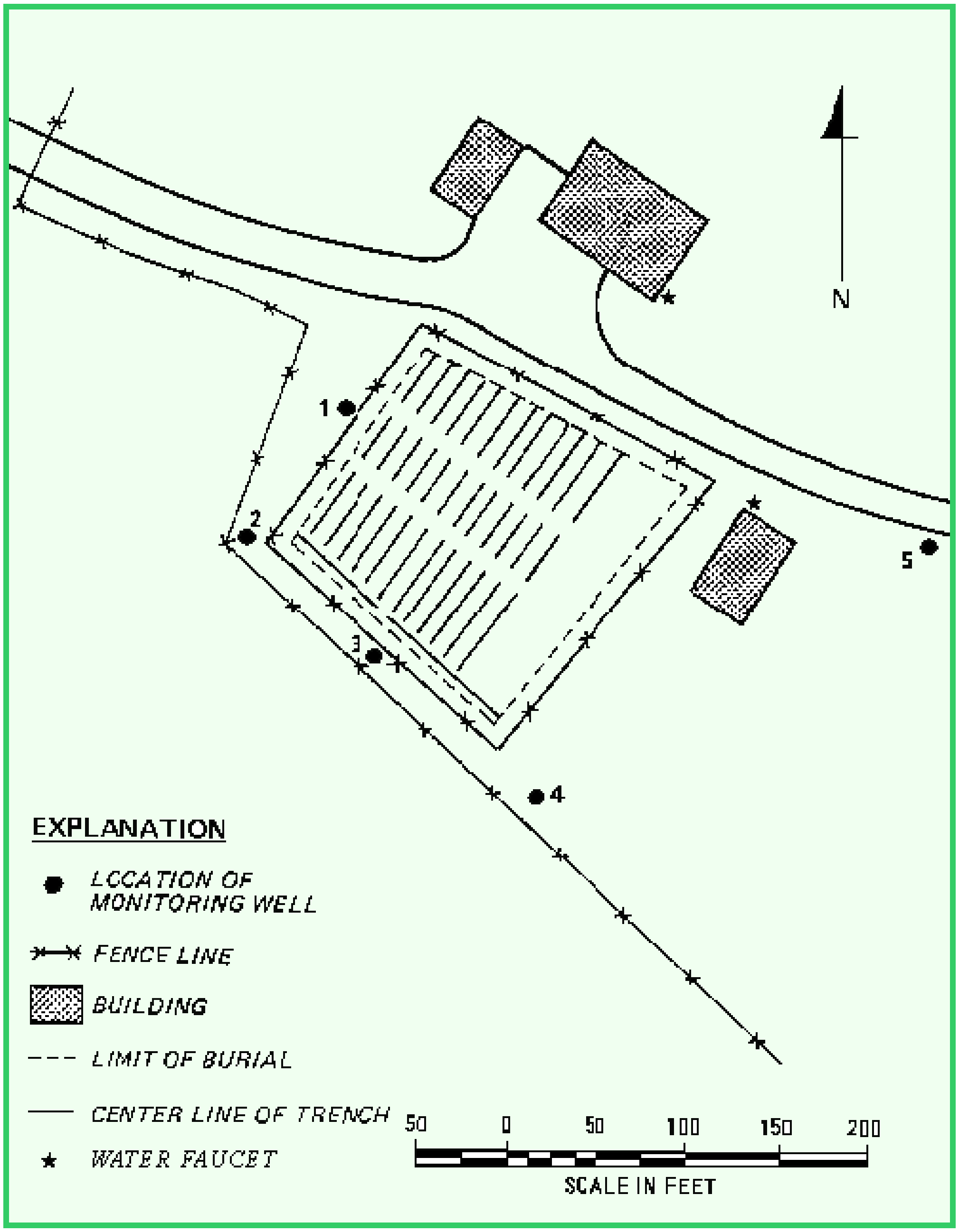


Figure 7: Reconstructed Location of Trenches within the Waste Disposal Site.

Another check on this number is provided by the Institute's estimate of the period of operation of a single trench, assumed to be on the order of 6 months. Since the waste disposal facility operated for a period of 20 years, the corresponding number of trenches is estimated by this method would be 40. This is in general agreement with the 38 trenches estimated using the geometric constraints that were spelled out above.

The Consultant had the capability and experience to actually map the subsurface distribution of the trenches using geophysical techniques, for example by using ground penetrating radar. However, the

Consultant and the Institute were both hesitant to have personnel spend time walking slowly across the entire waste disposal area with equipment since the extent of near surface contamination was not known at this point and numerous health and safety issues arose. As such, the estimated distribution discussed above was the extent of the work done to reconstruct the trench locations at this point in the project.

**Inventory of Radioactive Waste**

Records of low-level radioactive waste buried at the site were found for the following periods:

- 1960 through October 1973, and
- July 1979 through the end of 1980.

Records for the period from November 1973 through June 1979 were missing. Despite a thorough search by the Institute, these records were not found. The inventory of radionuclides at the time of burial and their decayed equivalent amounts as of January 1, 1989 for the record periods of 1960 to 1973 and 1979 to 1980 are presented in the following table, measured in milli-Curies (mCi):

**Estimated Radiological Inventory**

| **Radionuclide** | **Buried Activity** (in mCi) | **Half Life (*)** | **Decayed Activity** (as of 01/01/1989) |
|---|---|---|---|
| H-3 | 1860.832 | 12.3 years | 675.4191 |
| C-14 | 166.7247 | 5570.0 years | 166.7247 |
| Na-22 | 0.555 | 2.6 years | 0.0108 |
| P-32 | 17.562 | 14.2 days | 0 |
| S-35 | 287.0718 | 87.1 days | 0 |
| Ca-45 | 10.0022 | 164.0 days | 0 |
| Sc-46 | 1.3082 | 85.0 days | 0 |
| V-48 | 1.2551 | 161.0 days | 0 |
| Cr-51 | 222.4618 | 27.8 days | 0 |
| Co-57 | 0.0429 | 270.0 days | 0 |
| Se-75 | 0.2366 | 127.0 days | 0 |
| Sr-85 | 0.5943 | 65.0 days | 0 |
| Rb-86 | 9.1054 | 18.6 days | 0 |
| Cd-109 | 0.375 | 1.3 years | 0 |
| In-111 | 0.007 | 2.8 days | 0 |
| I-125 | 0.7896 | 60 days | 0 |
| I-131 | 90.7007 | 8.1 days | 0 |
| Xe-133 | 0.072 | 5.27 days | 0 |
| Ce-141 | 0.1395 | 32.0 days | 0 |
| Hg-197 | 0.188 | 2.7 days | 0 |
| Au-198 | 6.1837 | 2.7 days | 0 |
| Hg-203 | 0.0566 | 45.8 days | 0 |
| Ra-226 | 0.0111 | 1620.0 years | 0.0111 |

(*) Half-life is the period of time it takes for one half of the radioactive isotope to decay to a non-radioactive isotope.

As can be seen from the table, the most significant radionuclides by total activity are Tritium (H-3), Carbon-14 (C-14), Sulfur-35 (S-35), Chromium-51 (C-51), and Iodine-131 (I-131). Note that because all radioactive elements decay, the total activity decreases with time. As a rule of thumb, a radioactive element is essentially decayed to zero after 10 half lives. The last column shows the calculated decayed activity for each element as of January 1989. The effect of the half-life can readily be seen. For example, Sulfur-35 (S-35) has a half-life of 87.1 days. Five years after the site was closed S-35 would have cycled through 20 half lives. As such, the decayed activity for S-35 was essentially zero in January 1989 and it was no longer radioactive.

Tritium (H-3) had decayed to about one-third of its original activity by 1989, due to its longer half-life of 12.3 years. The Carbon-14 activity was essentially unchanged, since its half-life is over 5,000 years. Given the quantities buried and the half-lives, the two elements of greatest interest are Tritium and Carbon-14.

The issue of the missing period of records (November 1973 to June 1979) required an alternative approach to estimating the total radioactive waste inventory. The Consultant requested that the Institute conduct a review of all the radionuclide purchase orders for the period of the missing records. This search established that the quantities of radioactive materials that were purchased during the period of missing records were similar to quantities purchased during the several years immediately preceding and following the 1973 to 1979 interval. The total quantities could therefore be interpolated using this information, based on the following assumptions:

- The inventory of radionuclides during the period of missing records did not vary significantly from those held by the Institute during the periods for which waste burial records are available.
- No projects were identified that would have generated unusually large quantities of wastes during the period of missing waste burial records.
- Waste materials were buried during the time span of the missing records.
- All burial of wastes during the period of missing records was performed in the same manner as burial before and after the missing period.

Based on these assumptions, a reasonable upper estimate of radioactivity buried during the period of missing records would be an additional 1400 mCi of Tritium and 300 mCi of Carbon-14. In a letter to the State RPA, the Institute indicated that all the buried waste decayed as of January 1, 1989 can conservatively be estimated not to exceed 1400 mCi for Tritium and 400 to 500 mCi for Carbon-14. The State RPA responded verbally that these estimates were reasonable and acceptable.

### Inventory of Chemical Waste

No records were kept of the chemical waste that was buried at the site. From the type of experiments that were conducted by the Institute it was possible to infer that various amounts of organic chemicals such as chloroform, toluene, xylene, and 1,4-dioxane were buried in some of the trenches. It was not common practice by the Institute to routinely dispose of large volumes of non-radioactive organic laboratory chemicals in the trenches. The uncertainty in exactly which chemicals were disposed of and their volumes meant that the future site testing program would have to screen for numerous chemical elements and compounds.

## Review of Initial Environmental Testing

The waste disposal site operated under a broad coverage license issued by the State RPA. The State RPA performed periodic inspections during the period of operation to ensure compliance with the conditions set forth in the license and with applicable state regulations. After site decommissioning, the State RPA continued to inspect the disposal site periodically, and conducted an annual survey of existing conditions for several years following the closure of the waste disposal site. Samples of vegetation, soil and surface water were taken for radiological analysis. The locations of the sampling points are shown on the following figure.

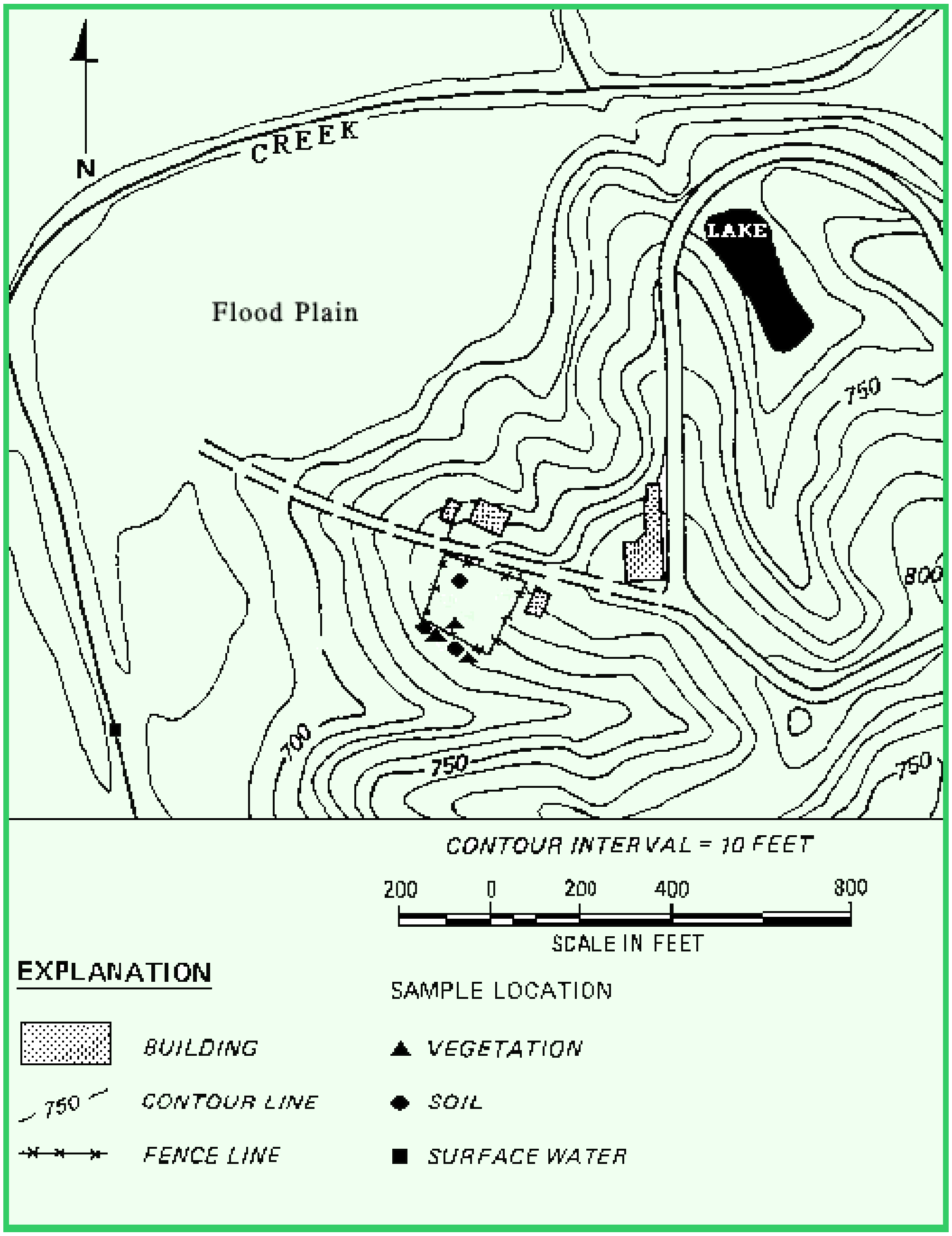


Figure 8: Location and Type of Samples collected by the State Radiation Protection Agency

The results of the radiological analyses of the surface water, soil and terrestrial vegetation samples completed by the State RPA are presented in the following sections.

**Results of Initial Surface Water Sampling and Testing**

The following table indicates the results of yearly surface water sampling from the creek just downstream of the waste disposal site.

**Table-1: Summary of Surface Water Testing from the Creek**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error (*) |
|---|---|---|---|---|---|---|---|---|
| Alpha(*) | 1.81 | 3.66 | 3.45 | 1.87 | 1.22 | | | +/- 1 |
| Beta(*) | 2.32 | 3.65 | 6.67 | 3.49 | 1.08 | | | +/- 1 |
| *Tritium | 975.00 | 318.01 | 711.45 | 245.43 | | 155.34 | 0.00 | +/- 850 |
| Sn-113 | | | | | 5.11 | | | +/- 4 |
| *Ra-226 | | | | | 1.33 | | | +/- 4 |
| K-40 | | | | | | 90.36 | 41.41 | +/- 54 |
| *Hg-203 | | | | | | | 3.62 | +/- 2 |
| ***Notes:** All results are given in pico-Curies/Liter (piC/L). Alpha (*) = total alpha particles from all sources, Beta (*) = total beta particles from all sources. Error (*) is approximate resolution of each test for each element in piC/L. A pico-Curie (piC) is 10E-12 Curies. Isotopes that are starred (*) were identified in the inventory of buried waste. | | | | | | | | |

For reference, the EPA water quality standards specify the following limits for the average annual gross particle activity: 15 piC/L for total alpha emitters and 50 piC/L for total beta emitters. The maximum average annual activity level for tritium shall not exceed 20,000 piC/L.

Also, the error range for the Tritium test (+/- 850 piC/L) is larger than most of the readings. As such, these Tritium concentration results are suspect. Note that the inventory compiled by the Consultant indicates that no Potassium-40 (K-40) was disposed of in the burial site. Therefore, The K-40 identified in surface water in years 6 and 7 likely represents fertilizer runoff from farms and/or the leaching of natural radioactive potassium in the soils (K-40 has a half life of 1.3 billion years). Also, the error range for the K-40 test (+/- 54) is high relative to the test results. Importantly, no upstream samples were taken to determine the background chemistry of the surface water before its possible contamination by any site effluent. Therefore, as a whole, it is not possible to positively assign the measured radioactivity to contamination from the Institute’s waste disposal site.

**Results of Initial Soil Sampling and Testing**

Soil samples from three locations were also tested every year. The results are presented in the following three tables. Location S-1 was inside the fenced area. The other two (S-2 and S-3) are just south of the waste disposal area.

**Table Soil-1: Results of Yearly Radiological Analysis of Soils from Location S-1**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error(*) |
|---|---|---|---|---|---|---|---|---|
| Alpha | 23.94 | 14.26 | 14.71 | 17.50 | 31.44 | 39.31 | 28.35 | +/- 15 |
| Beta | 28.92 | 29.89 | 48.90 | 22.48 | 70.61 | 46.31 | 43.01 | +/- 20 |
| Mn-54 | 0.039 | 0.051 | | 0.047 | | | | +/- .01 |
| Cs-137 | | | | | | 0.039 | 0.181 | +/- .03 |
| K-40 | 26.89 | 24.05 | 31.30 | 23.75 | 23.40 | 23.08 | 26.79 | +/- .5 |
| *Ra-226 | 1.25 | 0.951 | 0.975 | 1.270 | 1.380 | 1.290 | | +/- .05 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| U-235 | 0.166 | 0.144 | | | | | | +/- .07 |
| Th-232 | 3.920 | 3.810 | 3.470 | 4.42 | 3.890 | 3.800 | | +/- .1 |
| Th-234 | | | | | | | 0.431 | +/- .06 |
| Sr-90 | 0.00 | 0.00 | 0.00 | 0.161 | 0.00 | 0.189 | | +/- .3 |
| Sr-89 | 0.580 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | +/- .3 |
| Be-7 | | | 0.105 | | | | | +/- .2 |
| *I-131 | | .0123 | | | | | | +/- .02 |
| Co-60 | | | 0.029 | | | | | +/- .02 |
| *Co-57 | | | 0.020 | | | | | +/- .01 |
| *Hg-203 | | | | 0.226 | | | | +/- .02 |
| *Notes: All results are given in pico-Curies/Gram (pCi/gr.). Error is approximate resolution of each test in piC/gr. Isotopes that are starred (*) were identified in the inventory of buried waste. | | | | | | | | |

**Table Soil-2: Results of Yearly Radiological Analysis of Soils from Location S-2**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error(*) |
|---|---|---|---|---|---|---|---|---|
| Alpha | 34.33 | 31.66 | 16.83 | 0.00 | 33.03 | 28.19 | 38.17 | +/- 15 |
| Beta | 46.89 | 34.57 | 40.38 | 61.62 | 45.74 | 42.86 | 47.20 | +/- 20 |
| Mn-54 | 0.025 | 0.078 | 0.048 | 0.066 | | | 0.038 | +/- .01 |
| Cs-137 | 0.151 | 0.209 | 0.328 | 0.125 | 0.191 | 0.177 | | +/- .03 |
| K-40 | 30.60 | 24.75 | 25.70 | 25.15 | 27.02 | 27.52 | 25.00 | +/- .5 |
| Ra-224 | | | | | | 72.79 | | +/- 6 |
| *Ra-226 | 1.270 | 0.970 | 1.020 | 1.270 | 1.310 | 1.440 | | +/-.05 |
| Ra-228 | | | | | | 4.280 | | +/- .2 |
| U-235 | 0.202 | 0.153 | | | | | | +/- .07 |
| Th-228 | | | | | | 4.35 | | +/- .05 |
| Th-232 | 2.060 | 3.490 | 3.620 | 3.460 | 3.360 | 3.140 | | +/- .1 |
| Th-234 | | | | | | | 0.466 | +/- .06 |
| Sr-90 | 0.060 | 0.00 | 0.090 | 0.156 | 0.00 | 0.00 | | +/- .3 |
| Sr-89 | 1.280 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | +/- .3 |
| Be-7 | | 0.183 | | | | | | +/- .2 |
| *Hg-203 | | | | | | 0.129 | | +/- .02 |
| Ba-140 | | | | | 0.595 | | | +/- .5 |
| *Cd-109 | | | | | | 5.750 | 10.09 | +/- 1 |
| *Note: all results are given in pico-Curies/Gram (pCi/gr.). Error is approximate resolution of each test in piC/gr. Isotopes that are starred (*) were identified in the inventory of buried waste. | | | | | | | | |

**Table Soil-3: Results of Yearly Radiological Analysis of Soils from Location S-3**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error(*) |
|---|---|---|---|---|---|---|---|---|
| Alpha | 31.36 | 0.00 | 17.05 | 8.970 | 19.54 | 29.90 | 23.53 | +/- 15 |
| Beta | 44.89 | 28.44 | 54.14 | 12.07 | 48.12 | 41.55 | 31.00 | +/- 20 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mn-54 | 0.072 | 0.046 | | | 0.034 | | | +/- .01 |
| Cs-137 | 0.052 | 0.247 | 0.480 | 0.166 | 0.106 | 0.308 | 0.100 | +/- .03 |
| K-40 | 23.44 | 27.20 | 30.89 | 25.74 | 29.20 | 27.43 | 29.03 | +/- .5 |
| *Ra-226 | 1.190 | 1.060 | 1.330 | 1.300 | 0.139 | 1.290 | | +/- .05 |
| U-235 | | 0.097 | | | | | | +/- .07 |
| Th-232 | 3.610 | 3.350 | 2.860 | 3.460 | 2.600 | 2.650 | | +/- .1 |
| Th-234 | | | | | | | 0.559 | +/- .06 |
| Sr-90 | 0.00 | 1.910 | 0.370 | | 0.00 | 0.00 | | +/- .3 |
| Sr-89 | 0.410 | 0.00 | 0.00 | | 0.00 | 0.00 | | +/- .3 |
| Be-7 | 0.373 | | | | | | | +/- .2 |
| *Co-57 | | | 0.016 | 0.019 | | | | +/- .01 |
| *Hg-203 | | | | | 0.042 | | | +/- .02 |
| *Cd-109 | | | | | | | 7.720 | +/- 1 |
| Rb-103 | | | | | | | 0.030 | +/- .02 |
| *Note: all results are given in pico-Curies/Gram (pCi/gr.). Error is approximate resolution of each test in piC/gr. Isotopes that are starred (*) were identified in the inventory of buried waste. | | | | | | | | |

All three locations provided essentially the same results, although some elements were not tested for in all samples. For example, all three locations showed consistent Potassium-40 (K-40) concentrations (as did the surface water samples). Since no K-40 exists in the inventory of waste buried in the disposal site, these numbers most likely represent leftover potassium from earlier farming and fertilizer use on the Institute's property and/or natural potassium in the soils. Measurable concentrations of other long half-life isotopes not used by the Institute, such as Cesium-137 (Cs-137), Thorium-232 (Th-232), and Strotium-90 (Sr-90) are most likely fallout from the numerous above-ground nuclear tests conducted by the U.S., the former Soviet Union and other countries from the mid 1940's to the early 1960's. It has been well documented that numerous radioactive isotopes were dispersed into the highest levels of the atmosphere during these tests and remained in the atmosphere long enough (months to years) to be distributed around the world. It should be noted that the amounts of radioactivity in all these samples was considered low by the State RPA and were not considered a cause for concern.

**Results of Initial Vegetation Sampling and Testing**

Vegetation from three locations was also sampled every year by the State RPA. One sampling location (V-1) was just inside the southern fence line of the disposal area, and the other two (V-2 and V-3) were just outside the southern fence line. Vegetation is sampled since it tends to concentrate radioisotopes that are absorbed through the roots. The results of the vegetation analyses are shown on the following three tables.

**Table Veg-1: Results of Yearly Radiological Analysis of Vegetation from Location V-1**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error(*) |
|---|---|---|---|---|---|---|---|---|
| Alpha | 0.3700 | 0.290 | 0.130 | 0.890 | 0.00 | 1.940 | | +/- 1 |
| Beta | 1.460 | 5.630 | 4.250 | 1.710 | 2.590 | 11.23 | | +/- 2 |
| Mn-54 | | 0.032 | | | | | | +/- .02 |
| K-40 | 3.580 | 6.360 | 4.890 | 7.320 | 6.440 | 8.220 | 8.13 | +/- .5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Th-232 | 0.446 | 0.456 | | | | | | +/- .1 |
| Be-7 | 1.380 | 3.490 | 0.292 | 0.181 | 2.520 | | 3.010 | +/- .2 |
| *I-131 | | | | | | 0.114 | | +/- .06 |
| Ce-144 | | | | | | 0.372 | | +/- .2 |

*Note: all results are given in pico-Curies per gram (piC/gr.). Error is approximate resolution of each test in piC/gr. Isotopes that are starred (*) were identified in the inventory of buried waste.

**Table Veg-2: Results of Yearly Radiological Analysis of Vegetation from Location V-2**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error(*) |
|---|---|---|---|---|---|---|---|---|
| Alpha | 2.880 | 0.110 | 2.460 | 0.00 | 0.00 | 0.240 | | +/- 1 |
| Beta | 7.860 | 2.430 | 6.010 | 4.620 | 5.440 | 5.000 | | +/- 2 |
| Cs-137 | 0.018 | | 0.021 | | | | | +/- .03 |
| K-40 | 2.170 | 4.350 | 5.520 | 6.270 | 6.730 | 7.350 | 5.11 | +/- .5 |
| Th-232 | 0.338 | 0.165 | 0.370 | | 0.2550 | | | +/- .1 |
| Sr-90 | 2.480 | | | | | | | +/- .02 |
| Sr-89 | 0.00 | | | | | | | +/- .02 |
| *Sr-85 | | | | 0.115 | | | | +/- .04 |
| Be-7 | 0.351 | 2.160 | 1.430 | | 1.530 | | 2.470 | +/- .2 |
| *Hg-203 | | | | 0.065 | | | | +/- .05 |
| Zn-65 | | | 0.034 | | | | | +/- .06 |
| Ru-106 | | | | | | 0.322 | | +/- .01 |

*Note: all results given in pico-Curies per gram (piC/gr.). Error is approximate resolution of each test in piC/gr. Isotopes that are starred (*) were identified in the inventory of buried waste.

**Table Veg-3: Results of Yearly Radiological Analysis of Vegetation from Location V-3**

| Test(*) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Error(*) |
|---|---|---|---|---|---|---|---|---|
| Alpha | 0.860 | 0.00 | 0.940 | 0.00 | 0.00 | 0.320 | | +/- 1 |
| Beta | 3.070 | 4.510 | 5.520 | 3.370 | 1.480 | 7.510 | | +/- 2 |
| Cs-137 | 0.020 | 0.048 | | | | | | +/- .03 |
| K-40 | 2.100 | 5.170 | 6.740 | 9.270 | 7.130 | 5.370 | 9.680 | +/- .5 |
| Th-232 | 0.512 | 0.329 | 0.397 | 0.471 | | | | +/- .1 |
| Th-234 | | | | | | | 0.156 | +/- .05 |
| Sr-90 | | 0.080 | | | | | | +/- .09 |
| Sr-89 | | 0.020 | | | | | | +/- .09 |
| Be-7 | 0.307 | 2.090 | 1.850 | | 3.630 | 3.920 | 2.220 | +/- .2 |
| Nb-95 | | | 0.030 | 0.076 | | 0.068 | | +/- .02 |
| Ce-139 | | | | | 0.011 | | | +/- .02 |

*Note: all results given in pico-Curies per gram (piC/gr.) Error is approximate resolution of each test in piC/gr. Isotopes that are starred (*) were identified in the inventory of buried waste.

The results of the vegetation sampling generally mimic the soil sampling results. Many of the same elements were identified, including Potassium-40 (K-40) and the nuclear fallout isotopes such as Th-232.

One interesting observation is the measurable amount of Beryllium-7 (Be-7) in the vegetation samples. Be-7 was not part of the inventory of materials used by the Institute. It also has a relative short half-life of 53 days. This means that even if it was disposed of, it would have decayed to near zero in about a year and a half (10 half lives). The identification of measurable amounts of Be-7 in the vegetation samples year after year for 9 years after decommissioning of the site is a bit of a mystery and may be the result of laboratory contamination or the result of a misidentification.

**Significance of Initial Radiological Testing of Surface Water, Soil and Vegetation**

Although measurable amounts of a number of radioisotopes were found in the surface water, soil and vegetation samples from the site, the concentrations were all actually quite low. No concerns were ever raised by the State RPA about the possibility of health risks due to the levels of radioactive elements discovered. Furthermore, the elements with the highest concentrations, such as K-40, could not be attributed to contamination from the waste disposal area. Therefore, as of this point in the history of the site, the data are interesting, but not a cause for alarm. The correlation of some of the analyses to radioactive materials known to be buried in the site, however, prompted the State RPA to request the Institute to install the five groundwater monitoring wells discussed above. About a month after installation, the State RPA sampled all five wells. The results of these analyses are presented in the following sections.

## Installation of Monitoring Wells and Groundwater Testing

At the request of the State RPA, the Institute installed five monitoring wells around the perimeter of the waste disposal site. The locations of these wells are shown on Figure 6, above. The background (up gradient) monitoring well #5 was installed to a depth of 60 feet and the other four monitoring wells, on the west and south side (down gradient) of the site, were installed to a depth of 50 feet. All wells were constructed with 4 inch PVC casing and are believed to have 10-foot slotted PVC well screens near the bottom of the well. Unfortunately, no well completion diagrams were prepared during the installation and no geologic information was recorded from the borings. The Institute, however, indicated that the State GPA had selected the locations of the wells and had provided general well installation instructions.

**Initial Groundwater Sampling and Analytical Results of Radiological Testing**

Groundwater samples were collected by the State RPA from all five wells about a month after well installation. These samples were analyzed for radionuclides. One sample from Well #3 was taken about a year later to re-test for radionuclides as well as for volatile organic chemicals. The results of the radiological analyses are presented on the following table.

**Table GW-1: Results of Radiological Analysis of Initial Groundwater Samples**

| Test(*) | Well #1 | Well #2 | Well #3 | Well #3* | Well #4 | Well#5 | Error(*) |
|---|---|---|---|---|---|---|---|
| Alpha | 9.530 | 139.9 | 139.2 | | 2.21 | 0.520 | +/- 5 |
| Beta | 15.96 | 67.00 | 62.70 | | 5.37 | 7.91 | +/- 3 |
| *H-3 | 5390.0 | 13910.0 | 41640.0 | 13355.0 | 7.83 | 0.00 | +/- 200 |
| *C-14 | | | | 24114.0 | | | +/-1000 |
| Mn-54 | | | | | | 3.73 | +/- 1 |
| Cs-137 | 16.46 | | | | | | +/- 5 |
| *Ra-226 | 0.990 | 1.62 | 0.00 | | | | +/- 1 |
| Sr-89 | 0.00 | 0.00 | 0.00 | | | | +/- 2 |
| Sr-90 | 0.00 | 1.22 | 0.00 | | | | +/- 2 |
| *Cr-51 | | 215.9 | | | | | +/- 8 |
| Zn-65 | | 9.87 | | | | | +/- 4 |
| *I-131 | | 117.0 | | | | | +/- 200 |
| U (total) | | 0.100 | 0.520 | | | | +/- 0.5 |
| K-40 | | | | | 88.81 | | +/- 130 |
| Xe-131 | | | | 372.0 | | | +/- 200 |
| Zr-97 | | | | 4.320 | | | +/- 200 |
| *Cd-109 | | | | 265.8 | | | +/- 35 |
| Mo-99 | | | | 3.970 | | | +/- 1 |
| *Notes: All results are presented as pico-Curies/Liter (piC/L). Error is the approximate resolution of each test in piC/L. Isotopes that are starred (*) were identified in the inventory of buried waste. The first column for Well #3 represents the first round of sampling. The second column for Well #3 is the radiological analyses performed a year later. | | | | | | | |

A number of interesting observations can be made from the data in this table. First, Well #5, which was located upgradient of the disposal area, appears to be uncontaminated, as expected. However, Well #4, which is just southeast of the southeast corner of the disposal area, is also uncontaminated (since the error term is larger than the reported results for H-3 and K-40). This observation supports the concept that groundwater is moving in a generally southwestward direction. Well #4 can, therefore, be considered up gradient of the waste disposal site.

There is a close correlation between the radionuclides in the waste inventory (the starred elements in the table) and those which were found in concentrations well above the error value in wells #1, 2 and 3. These radio nuclides are Tritium (H-3), Carbon-14 (C-14), Chromium-51 (Cr-51), and Cadmium-109 (Cd-109).

The test results for Radium-226 (Ra-226) are just about the same as the error value, although Ra-226 was buried at the site and has a half-life of 1620 years. However, a review of the inventory indicates that a very small quantity of Ra-226 was buried (about 0.01 milli-Curies).

The test results for Iodine-131 (I-131) are actually lower than the error value (suggesting little to no actual I-131). A check of the inventory shows that over 90 milli-Curies of I-131 were buried at the site. However, I-131 has a half-life of only 8.1 days. As such, it essentially decayed to zero within 81 days (10 half-lives) of being buried.

Finally, there are two suspect analyses in the table. The first is the 41,640 piC/L reading for Tritium (H-3) in the first round of sampling for Well #3. As Tritium emits beta particles, the corresponding beta measurement should have been much higher. Instead, the beta measurement is about the same as Well #2, which had an H-3 concentration of 13,910 piC/L. Interestingly, the second round of sampling of Well #3 yielded an H-3 concentration of 13,355, which is more consistent with the earlier beta measurement. Nonetheless, there was no argument that a significant amount of Tritium existed in the groundwater sampled from Wells #1, #2 and #3.

The second suspect analysis is the Carbon-14 (C-14) measurement from the second round of sampling of Well #3. The estimated error of +/-1,000 piC/L is high, and the State RPA had questioned the validity of this result. Well #3 was re-sampled again and half the water sample was sent to the Institute's lab and the other half to an Environmental Protection Agency lab. The results of these re-analyses are presented below:

| **Test(*)** | **EPA Result** | **Institute Result** |
|---|---|---|
| Tritium (H-3) | 12,380 piC/L | 9,240 piC/L |
| Carbon-14 (C-14) | 240 piC/L | 153 piC/L |

These values should be compared to the EPA drinking water standards in effect at that time. The EPA drinking water standard was set at 20,000 piC/L, for Tritium and 2,000 piC/L, for Carbon-14. Therefore, although the values measured were well above the background levels, they still were not considered a health risk to humans.

**Significance of Initial Radiological Testing of Groundwater**

The initial radiological testing of groundwater from Wells #1, #2 and #3 revealed a correlation between the test results and the characteristics of the buried waste. Importantly, however, with the exception of Tritium and Carbon 14, all of the test results indicated very low concentrations. Even the Tritium and Carbon-14 values from these three wells, although well above background levels, were still below the EPA drinking water standards in effect at that time. Therefore, the State RPA expressed little concern about radioactive elements in the groundwater. They, and other state agencies, however, were also interested in the chemical contamination, as addressed in the following subsections.

**Initial Groundwater Sampling and Analytical Results of Chemical Testing**

The second sample from Well #3 was also analyzed by the State RPA for volatile organic compounds. The identified volatile organic compounds and their reported concentrations were:

| **Compound** | **Concentration** |
|---|---|
| 1,4-dioxane | 12,261 ug/L |
| chloroform | 3,812 ug/L |
| diisopropyl ether | 166 ug/L |
| carbon tetrachloride | 3 ug/L* |
| * Tentative identification, recorded concentration is below the detection limit of the analytical method. Concentrations are all given in micro-grams per Liter (ug/L). | |

The State RPA noted that both the 1,4-dioxane and the chloroform concentrations exceeded the state groundwater quality standards. As a result, they notified the State Waste Management Agency, Superfund Section, and the State Groundwater Protection Agency of these findings. At this point, these two other agencies became interested in investigating conditions at the site.

## Submittal of the Preliminary Site Condition Report

With the compilation of the existing site data presented above, the Consultant prepared and submitted the Preliminary Site Condition Report. Submittal of this report to the Institute formally ended Task 1 of the Consultant's contract. Task 2 entailed the development of project procedures for additional sampling and testing and preparation of Health and Safety and Quality Assurance Plans. These activities are covered in the next course in this series, entitled ***Part 3: Preparation of Project Plans and Procedures***.

The Preliminary Site Condition Report was submitted to the Institute in multiple copies. The Institute forwarded copies to the State RPA, the State WMA, Superfund Section, and the State GPA. These agencies submitted written comments to the Institute based on their reviews of the document. Their comments and the Consultant's written responses are presented in the following section.

## Comments from State Regulatory Agencies and the Consultant's Responses

Written comments were prepared by the State Regulatory Agencies that received the Preliminary Site Condition Report. The State GPA and the State WMA submitted their comments to the State RPA for forwarding to the Institute. In the letter transmitting all the written comments, the State RPA wrote "... you (the Institute) must address these concerns to satisfy all the agencies involved..." leaving little doubt that additional investigations would be required.

The comments and the Consultant's written responses are presented in the following subsections.

### State Groundwater Protection Agency Review

In a letter to the State RPA, the Head of the State GPA expressed the view of his staff as follows:

- The study did not adequately characterize the hydrogeology of the site. No drilling logs were included and apparently none were filed with our office.

- In a memo to the head of the agency, a staff member expressed himself as follows: "the report does not assess sufficiently the horizontal and vertical extent (of contamination), aquifer characteristics, and subsurface stratigraphy, particularly when there are no drilling logs available. More work in this direction is necessary before remediation can be considered".

The Consultant responded to these comments as follows:

**Comment**: The study did not adequately characterize the hydrogeology of the site. No drilling logs were included and apparently none were filed with our office.

**Response**: The five monitoring wells in question were installed prior to the Consultant's involvement in the study. No information such as drilling logs, monitoring well installation diagrams or geologic descriptions were recorded during the installation of these wells. This type of information will be generated during follow-up investigations as new monitoring wells are installed by the Consultant and hydrologic testing is performed to determine the range of permeabilities at the site. The scope of the present investigation was limited to establishing a common base of information from existing records about the site that all involved parties could use with confidence.

**Comment**: the report does not assess sufficiently the horizontal and vertical extent (of contamination), aquifer characteristics, and subsurface stratigraphy, particularly when there are no drilling logs available. More work in this direction is necessary before remediation can be considered.

**Response**: The Preliminary Site Condition Report was primarily based on the evaluation of existing information. The report was also used to identify additional data needs. The Consultant will develop site-specific stratigraphic information from the logs of new monitoring wells that will be installed as part of the next phases of work. Aquifer characteristics will also be derived from permeability measurements and will be used to support the selection of an appropriate remedial strategy.

**State Waste Management Agency Review**

This agency offered the following comments:

- Information on procedures used to clean sampling equipment and containers, the type of containers used, and the type and amount of sample preservatives used was not provided in the report or in any previous documentation our office received on the site. These procedures will impact the validity of samples.

- The Institute needs to obtain information on the installation and construction of the on-site monitoring wells. The State GPA and/or the driller may have this information.

The Consultant responded to these comments as follows:

**Comment**: Information on procedures used to clean sampling equipment and containers, the type of containers used, and the type and amount of sample preservatives used was not provided in the report or in any previous documentation our office received on the site. These procedures will impact the validity of samples.

**Response**: The sampling and testing that was reported in the Preliminary Site Condition Report was conducted for several years by the State RPA. The Consultant was not involved with this site at that time. The Consultant has assumed that the State RPA followed appropriate procedures to ensure data quality and validity. However, there is no specific information about the procedures that were actually followed.

The Consultant will develop Health and Safety and Quality Assurance Plans and Sampling and Testing Procedures before implementing new field work at the Site. These plans and procedures will be available for review and comment before use.

**Comment**: The Institute needs to obtain information on the installation and construction of the on-site monitoring wells. The State GMA and/or the driller may have this information.

**Response**: The Consultant reviewed the available information that was filed with the State GMA about the wells installed at the site. The only information pertaining to the installation of the wells was found to be an application for a drilling permit that was granted by the State GMA.

In addition, the Consultant conducted a telephone interview with the drilling contractor that installed the wells in question and understood that the only information they had on file was a copy of the drilling permit. The driller recalled that the wells went down to bedrock but no other information about the construction of the wells or the geology was recorded by the driller, the State GMA or the Institute. The Consultant will obtain this type of information when additional wells are installed at the site under its supervision, as part of the follow-up investigations.

## Media Reporting

Following the submittal of the Preliminary Site Condition Report, the press became aware of the work being done at the site. A reporter from the local daily newspaper contacted and interviewed a spokesperson from the State RPA. The reporter also reviewed a copy of the Preliminary Site Condition Report. The article that was subsequently published in the newspaper is presented below. A summary of the article was also aired on the local TV morning news.

**Waste Buried by the Institute is Moving**

Hazardous and low-level nuclear waste, buried in the county over 25 years ago, is moving towards a creek that flows through the property of the Institute, state records show.

State officials from three agencies say that the waste - buried in 40 unlined trenches up to 60 feet long and 12 feet deep - does not pose an immediate health threat, but they are directing the Institute to produce plans to block the waste plume or clean up the site.

"There is no threat to the community at this time," said a representative of the State RPA."They're working on plans to control the migration, and we're going to see what they've got."
An engineering report prepared by the Institute’s consultant shows that a few radioactive isotopes and some hazardous chemicals used in research have seeped beneath the fenced boundary of a 0.65 acre dump site.

No pollution from the site has been detected in the stream, and five monitoring wells are being used to gauge the waste's movement, state officials say. The engineering report projects that the waste has spread through ground water south of the dump site.

A representative of the Institute said: "We are proceeding as quickly as we think is prudent." The representative of the State RPA added: “If it starts moving off the property, then they could have to remove the materials.”

State records show that waste was buried at the Institute’s site from 1960 to 1980. The dump includes waste that may have come from other research institutions, as well.

The waste - which originally included at least 23 different radioactive isotopes, most of which have decayed to non-threatening levels - were placed in cardboard boxes, plastic bags, and 1- and 5-gallon metal cans, thrown into the ditches and covered with 4 feet of dirt.

(End of article)

## Summary

This course addressed the collection and analysis of available data about the waste disposal site. The information was reviewed and interpreted in order to share the results with the client and the appropriate regulatory agencies. This was done in order to bring all concerned parties to a common level of understanding and generate a general consensus about the thrust of the initial phase of new field work.

After disposal ceased, the State Radiation Protection Agency continued to inspect the disposal site periodically, and conducted an annual survey of existing conditions. The results of these inspections are presented and include: sample types, locations and analytical results. As a follow-up, and at the request of the regulatory agencies, five monitoring wells were installed around the waste disposal site. Groundwater samples from these wells were collected and analyzed. The results of these analyses indicated that, although there is clearly some radioactive contamination from the waste, concentrations are low and well below the safe drinking water limits in place at that time. The State RPA was more concerned about the identified chemical contamination, especially in those compounds which did exceed the state regulated concentration standards.

The Preliminary Site Condition Report was submitted to the Institute by the Consultant at the end of the compilation and analysis of existing information. The Institute forwarded copies to the State RPA, the State GPA and the State WMA. Their written comments and the Consultant’s written responses were presented and the ensuing Press coverage of this report was also included.

This course emphasized the importance of conducting a thorough review and analysis of existing information before implementing new work. Critically evaluating this information for reasonableness is an important step in the planning of follow-up work.

## Glossary of Terms and Acronyms used in this Course Series

| | |
|---|---|
| 1,4-Dioxane | para-Dioxane (p-Dioxane), a hazardous chemical |
| AEC | Atomic Energy Commission |
| adsorption coefficient | measure of adherence of ions in solution to the surface of solids with which they come in contact |
| alluvial soil | a young soil on flood plains that is being actively deposited |
| ASTM | American Society for Testing and Materials |
| bailer | cylindrical container designed to remove water from a well |
| C-14 | Carbon-14, a radioactive form of carbon |
| CFR | Code of Federal Regulations |
| cm/sec | centimeter/second |
| Curie | A unit of measurement of radioactivity, which is approximately equal to the decay rate of one gram of pure radium. |
| DOT | Department of Transportation |
| Down-gradient | A direction towards which groundwater is likely to flow |
| draw | A small natural watercourse or gully, also a dry streambed whose water results from periodic rainfall. |
| EPA | Environmental Protection Agency |
| ft. | feet |
| GC/MS | Gas Chromatograph/Mass Spectrometer |
| H&S | Health and Safety |
| HASP | Health and Safety Plan |
| H2SO4 | Chemical formula of sulfuric acid |
| H-3 | tritium, a radioactive form of hydrogen |
| HCL | Chemical formula of hydrochloric acid |
| HNO3 | Chemical formula of nitric acid |
| in. | inches |
| mafic rock | igneous rock composed mainly of dark-colored minerals |
| mCi | milli-Curie, scale for the measurement of radioactivity |
| my | million years |
| NaOH | Chemical formula of sodium Hydroxide |
| OVA | organic vapor analyzer |
| pCi/L | pico-Curie/liter, scale for the measurement of radioactivity in liquids |
| pCi/gr | pico-Curie/gram, scale for the measurement of radioactivity in solids |
| permeability | capacity of a porous rock to transmit a fluid, ease of fluid flow |
| pH | hydrogen-ion activity in solution, a measure of acidity |
| pluton | A geologic igneous intrusion |
| potentiometric surface | a surface representing the total head of water in an aquifer |
| ppb | parts per billion |
| ppm | parts per million |
| purging | volume of water extracted from a well prior to sampling |
| QA/QC | Quality Assurance/Quality Control |
| Saprolite | A thoroughly decomposed rock, formed in place by the weathering of igneous, sedimentary or metamorphic rocks. |

| | |
|---|---|
| SCS | Soil Conservation Service |
| State RPA | State Radiation Protection Agency |
| State EPA | State Environmental Protection Agency |
| State GPA | State Groundwater Protection Agency |
| State WMA | State Waste Management Agency |
| Superfund | Acronym referring to the resources allocated by Federal or State Agencies for the clean-up of decommissioned waste disposal sites. The funds are disbursed by priority based on the degree of hazard |
| total head | the height of a column of water above a datum plane |
| ug/L | micro-gram/Liter |
| ug/kg | micro-gram/kilogram |
| uS/cm | microsiemens per centimeter, a measure of specific conductivity |
| Up-gradient | A direction opposite to that in which groundwater is likely to flow |
| USDA | United States Department of Agriculture |
| US-DOT | United States Department of Transportation |
| USEPA | United States Environmental Protection Agency |
| USNRC | United States Nuclear Regulatory Commission |
| USGS | United States Geological Survey |
| well screen | section of well casing perforated or slotted to allow water inflow |
| | |
| | |