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VICINITY OF BUNKER HILL COMPANY

WASTE-DISPOSAL FACILITIES

Kellogg, Shoshone County, Idaho - 1976

National Enforcement Investigations Center

Denver, Colorado

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Environmental Protection Agency
Office of Enforcement
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Jim V. Rouse

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I. INTRODUCTION

The Bunker Hill Company and its predecessors have operated a mine-mill-smelter complex in the Kellogg, Idaho area for almost a century. Initially, all liquid and solid residues from the operation were discharged into the South Fork Coeur d'Alene River. These practices gradually changed due to environmental concern and the desire to retain mill solids (tailings) for reprocessing at a later date in the event of improved recovery technology.

The first materials which were retained consisted solely of mill tailings discharged into a tailings pond, and lead smelter slag deposited on the flood plain of the South Fork Coeur d'Alene River north of the Bunker Hill facility. With time, the tailings pond received other solid waste, including byproduct gypsum from a phosphoric acid plant, together with liquid discharges such as acid mine drainage and lead smelter, zinc plant, and phosphoric acid plant effluents. The result was the gradual evolution of a 160-acre tailings pond, gypsum pond and slag pile which rises above its surroundings on the flat flood plain of the South Fork Coeur d'Alene River Valley. As the height of the tailings pond increased, the ground-water gradient between the pond and the river increased, which caused an ever-increasing rate of seepage from the pond into the stream. As the upstream receiving water quality was enhanced through pollution control measures, the effect of the seepage became increasingly apparent.

The Environmental Protection Agency (EPA) Region X office discussed this leakage with Bunker Hill Company and requested the construction of observation wells around the toe of the pond as a condition for the issuance of the Bunker Hill National Pollutant Discharge Elimination System (NPDES)* permit. The observation wells were constructed by Bunker

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* *Federal Water Pollution Control Act Amendments of 1972.*

Hill Company, as required, but they were not adequate to provide sufficient information on the seepage. Information in Company files indicated that Bunker Hill Company recognized the presence and feasibility of control for seepage as early as 1967, but none of these measures were implemented.

At the request of Region X, EPA, the U.S. Attorney for the District of Idaho filed suit in District Court on Sept. 2, 1975 to prohibit Bunker Hill from discharging unpermitted pollutants from its facilities into waters of the United States. EPA Region X requested technical support to aid in this case from the National Enforcement Investigations Center (NEIC). A meeting was held between EPA Region X and NEIC personnel on May 22, 1975, to discuss the scope of this technical support. EPA had considerable information to indicate that leakage from the tailings pond was entering the South Fork Coeur d'Alène River. Region X requested NEIC to conduct a geohydrologic investigation in the vicinity of the tailings pond and gypsum pond, to provide additional information on the areas and modes of seepage and to develop information on feasible control measures which could be employed by the Bunker Hill Company to control discharges to waters of the United States.

The U.S. Bureau of Mines and the Bunker Hill Company had announced a joint research grant to the University of Idaho to study seepage from the pond and control measures which could be applied within the pond area (internal control). Accordingly, it was decided that the NEIC investigation would address itself to leakage beyond the pond margin and would utilize, wherever practicable, information developed by the University of Idaho study on internal control measures.

NEIC personnel conducted a reconnaissance inspection of the Bunker Hill complex on October 16 and 17, 1975 [Appendix A]. A meeting was held on November 10, 1975 between the NEIC geologist in charge of the study and personnel from the University of Idaho to discuss the mutual studies and areas of overlap.

Permission was requested by EPA from Bunker Hill Company to enter its property around the tailings pond for the purpose of constructing the necessary observation wells. This permission was denied by Bunker Hill Company. The United States then filed a motion in U.S. District Court for an Order Compelling Discovery; Court-ordered entry was granted on July 16, 1976.

Arrangements were made with personnel from the Federal Highways Administration to provide a drill rig and crew. The rig and crew arrived on August 10, 1976 and concluded drilling observation wells on August 16, 1976. After construction, the wells were completed by surging and pumping. Geohydrologic data and ground-water samples were collected monthly during September, October, November, and December 1976.

II. SUMMARY AND CONCLUSIONS

1. The Bunker Hill Central Impoundment Area, gypsum pond, and slag pile receives solid and liquid waste from the Bunker Hill mine, mill, and smelter complex. The waste disposal system was not designed as such and does not represent the state of the art. Rather, the system gradually evolved over a period of years with no overall plan and no safety or geohydrologic analysis.

2. Leakage from the waste-disposal system results from improper past construction techniques that allow discharges of pollutants into the South Fork Coeur d'Alene River. Bunker Hill personnel recognized the existence and cause of the problem and the feasibility of control 10 years ago.

3. Seepage from the ponds degrades the chemical quality of underlying ground water and enters and damages the South Fork Coeur d'Alene River through discrete, identifiable sources which are subject to control.

4. Internal control measures are available to Bunker Hill Company to reduce the losses from the ponds that result in discharges to the South Fork Coeur d'Alene River.

5. External control measures are available to Bunker Hill Company to capture and treat the seepage before it is discharged to the South Fork Coeur d'Alene River. Similar measures have been employed by other mining operations through the nation for many years, and are described in open literature available to Bunker Hill Company and its consultants. Bunker Hill personnel have recognized the feasibility of such control for at least 10 years.

6. The most economical control would probably involve use of an existing gravel bed surrounding a sewer line as a linear seepage-collection well. An upgradient well in a permeable gravel section and grouting downgradient of the sewer line would assist in system operation. Water from the well and sewer-line gravel would require neutralization and metal removal in the existing Bunker Hill treatment plant before discharge.

III. RECOMMENDATIONS

1. Bunker Hill Company should immediately institute internal control measures to reduce seepage losses through internal dikes in the Central Impoundment Area and throughout the gypsum pond.

2. Bunker Hill Company should immediately begin design of external seepage measures to capture and return contaminated seepage from the ponds for treatment in the existing treatment plant, to prevent discharges of pollutants into the South Fork Coeur d'Alene River.

3. The NPDES permit re-issuance for Bunker Hill Company should include requirements for the installation and operation of external seepage control measures. The effectiveness of the measures must be monitored by Bunker Hill Company using observation wells drilled for the NEIC investigation and augmented where necessary by additional monitoring wells to be drilled by Bunker Hill Company.

   Such additional monitoring wells should be cased and completed in a manner similar to the EPA wells. No metal casings should be used. Additional observation wells should be completed by Bunker Hill Company between Bunker Creek and the gypsum pond and CIA, to evaluate seepage losses that result in discharges to Bunker Creek.

IV. SITE DESCRIPTION

Geohydrologic conditions in the vicinity of the Bunker Hill Central Impoundment Area (CIA), gypsum pond, and slag pile at Kellogg, Shoshone County, Idaho are a function of site geology, previous activities of man upstream of the site, and pond construction techniques. The ground-water movement and discharge from this facility has an impact on the receiving stream.

GEOLOGY

The geologic and geomorphic history of the area surrounding the Bunker Hill site is described in detail by Hobbs, et al. (1965).

The area is underlain by metamorphic quartzites and argillites of the Precambrian Belt Series. These rocks are generally impermeable but have been intensely deformed and fractured, resulting in the formation of secondary permeabilities along the fractures.

Rocks underlying the Bunker Hill site were intruded by younger dikes and cut by numerous faults, the most important of which is the east-west trending Osborne Fault. The present course of the South Fork Coeur d'Alene River roughly follows the trace of this fault and is probably at least partly resultant from the presence of the Osborne Fault. Most of the mineral deposits which have been exploited in the Coeur d'Alene mining district are along and associated with the Osborne Fault and its offshoots.

The present landscape in the Bunker Hill area results from the intermittent dissection of a mature upland with periods of intermittent aggradation (filling). The last period of downcutting resulted in the formation of a major broad bedrock valley along the present course of the South Fork Coeur d'Alene River at an elevation of 50 to 100 meters lower than the present stream channel.

Following the cutting of this major valley, a period of aggradation began which has resulted in the filling of the valley with alluvium of probable Quarternary age. This aggradation has resulted from the formation of Coeur d'Alene Lake and downstream features forming a base level. The lower portion of the valley fill is comprised of large boulders derived by stream action on upstream sediments. A period of relatively quiescent conditions, resulted in the deposition of an extensive silt and clay layer. Subsequent aggradation resulted in deposition of approximately 10 meters of alluvium ranging in size up to cobbles on top of the silt and clay layer. This has resulted in the formation of two separate aquifers which are probably in only limited connection and communication in the valley.

VALLEY HISTORY

The first discoveries of mineralization in the Coeur d'Alene mining region took place in 1878, followed by the discovery of placer gold deposits in the early 1880's (Koschmann and Bergendahl, 1968). Rich deposits of lead and silver were subsequently located in 1885. A railroad which promoted the mining of large amounts of lead and silver ore was completed into the area in 1887. Many of the mills continued in operation until 1933, when virtually all the mills closed. Activity began again shortly thereafter and has continued to the present.

Most of the early milling operations did not use any form of tailings pile but rather discharged tailings directly to South Fork Coeur d'Alene River and its tributaries. As a result, the stream overflowed its banks and deposited many thousands of tons of coarse jig tailings, containing zinc and other heavy metal sulfides, onto the valley floor. These deposits are easily identifiable at present by their rust-brown oxidized appearance and frequently are 1.5 to 2 meters thick. Leaching of those deposits results in the addition of some zinc and other heavy metals to the river, especially during periods of precipitation or in areas where water is ponded on the valley floor.

Bunker Hill drawing No. 1-6, dated March 31, 1918 (not reproduced in this report) shows contours along the South Fork Coeur d'Alene River valley in 1901 and 1918. These contours demonstrate the deposition of approximately 1.5 meters of tailings material along the flood plain during the intervening seventeen years. This deposition resulted, in part, from the upstream discharge of jig tailings (course gravity-separation system tailings), together with mine waste and other solid waste materials.

BUNKER HILL POND CONSTRUCTION HISTORY

Bunker Hill Company was one of the early mining companies within the Coeur d'Alene mining district to construct a tailings pond and control the discharge of solids to the stream. No good record exists of the construction of this pond; however, it is possible to reconstruct the history of construction by examination of aerial photographs taken at various times and of data from the Bunker Hill files.

1954 Conditions

It was not possible to ascertain the initial date of tailings pond construction. On September 2, 1954, when aerial photographs GS-VEJ were taken by the U.S. Geological Survey, there was a small quantity of slag deposited at the present site of the slag pile. Mill wastes were discharged from a central discharge point into a small tailings pond near the present east end of the Central Impoundment Area. A dike contained the wastes along Highway 10 [Figure 1]. The west end of the pond was formed by a dike (separating dike) which currently is under the gypsum pond. The south margin of the pond was composed of a dike along the present south dike location. According to information from the Bunker Hill files (N.J. Sather, Aug. 7, 1969) these dikes were composed of coarse tailings and stream gravel. Thus, they would be expected to be highly permeable. There are indications on the photos of seepage through the western dike. Wastes from the mine, lead smelter, and zinc plant apparently were not discharged to the tailings pond, but rather were discharged directly to the South Fork Coeur d'Alene River or its tributaries.

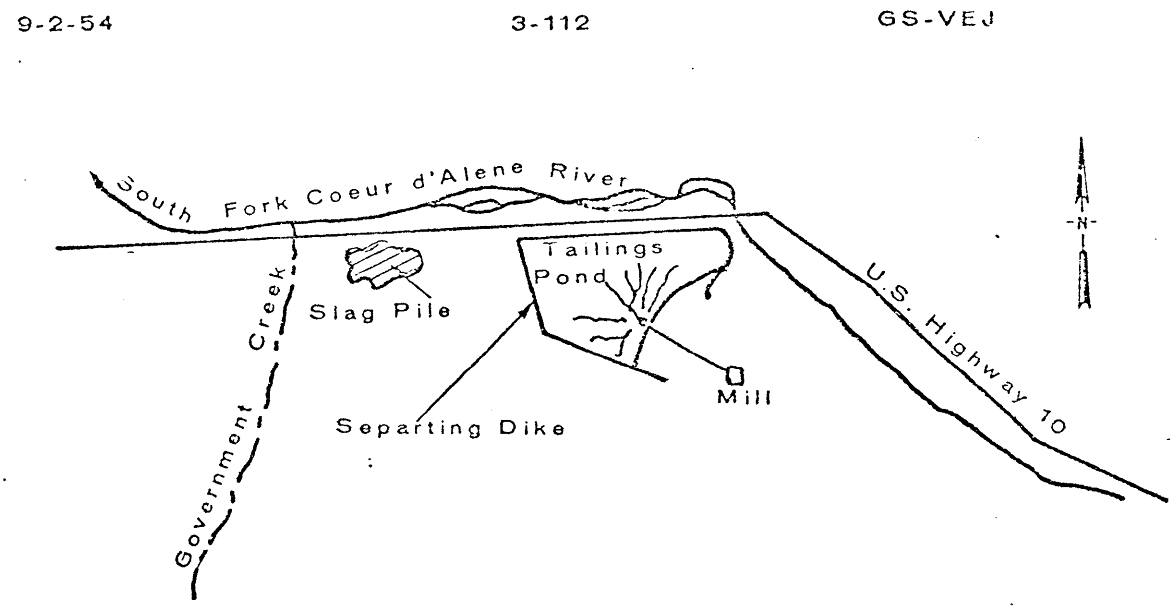

Figure 1. Sketch of Bunker Hill Facilities as shown on U.S.G.S. Airphoto, September 2, 1954

1958 Conditions

The next series of photographs examined was taken on October 25, 1958 by the Idaho Highway Department and is identified by the designation I90-1(11)48-35. This series of low altitude photographs was used in the design and construction of Interstate Highway 90 and clearly showed conditions which obtained in the tailings pond at that time. A sketch map [Figure 2] prepared from the Oct. 25, 1958 photos shows the facilities as they existed on the date of photography. The previously used tailings pond (east pond) was abandoned and was being sprinkled to prevent wind erosion. A new pond (west pond) had been created between the slag pile and the east pond. Dike construction involved the use of peripheral discharge of sand material, with a decant pipe located near the center of this pond, with decant discharge to the South Fork Coeur d'Alene River. The west end of the pond was formed by the slag pile, with tailings lapping onto the slag. The east end was formed by the separating dike. Indications are that the separating dike had been reinforced by coarse sand discharge. Effluent from the zinc plant and lead smelter apparently were discharged directly to Silver King Creek.

1964-1968 Conditions

A 1964 Bunker Hill Company drawing* indicates that the western tailings pond was in use on this date. It further indicates that a wedge shaped area had been excavated from the eastern tailings pond for use in fill in the construction of Interstate 90. The map indicates plans for the construction of a new dike along the east end of the easternmost pond, with mine water to be discharged to this pond. A decant pipe was to be constructed draining into the South Fork Coeur d'Alene River just upstream of the Interstate 90 bridge. The dike separating the eastern and western ponds was still in the original 1954 location.

A 1966 Bunker Hill Company drawing** M-23-104, portrayed the pie-shaped highway excavation in the eastern pond and indicated a

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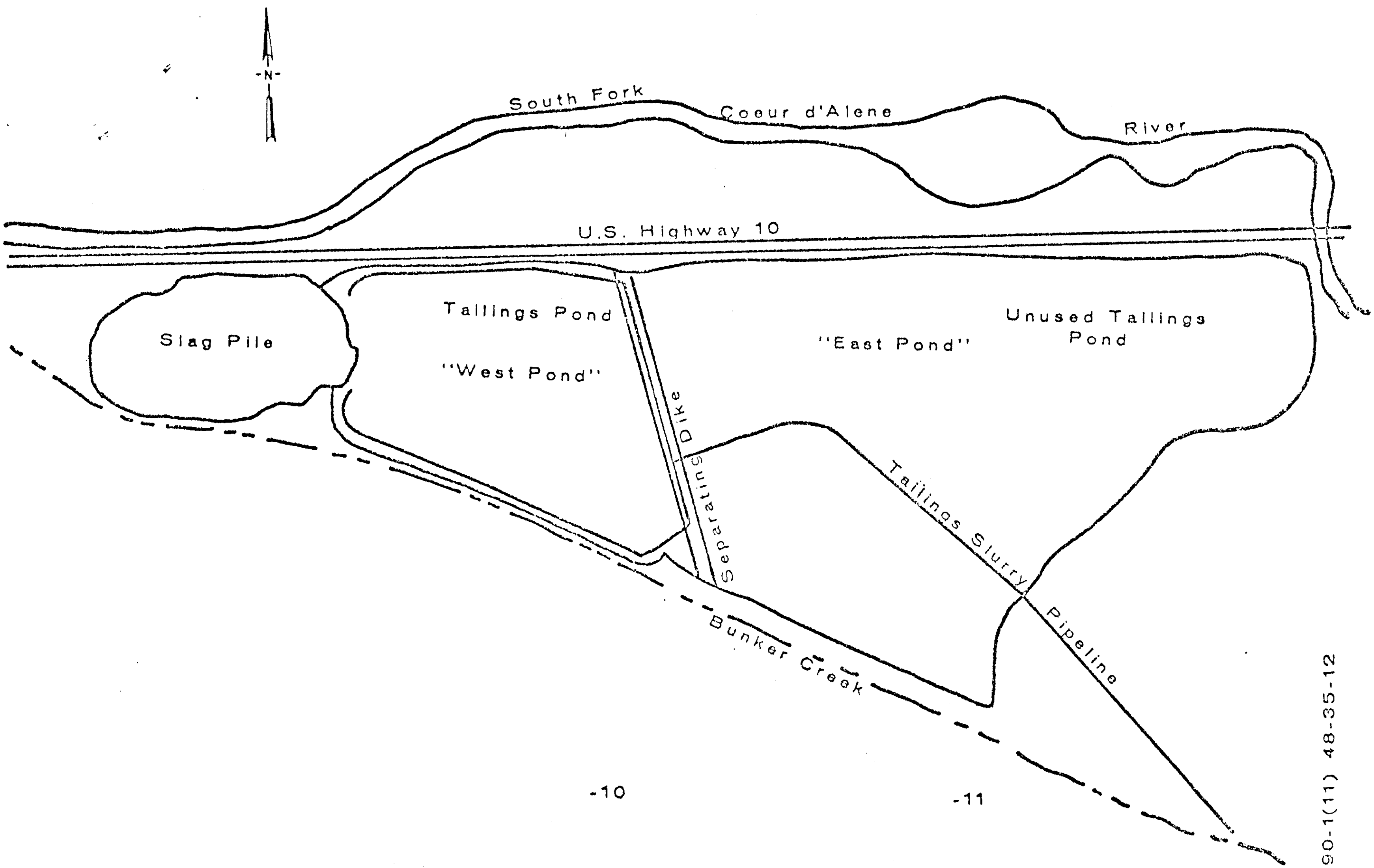
* *Drawing No. W-10-13 "General Plant Mine Area Showing Proposed Sewage, Mine Portal Water Disposal," Dec. 1, 1964.*

** *Drawing No. M-23-104 "Tailings Pond Area 1966 Proposed Expansion" June 1966.*

10-25-58



190-1(11) 48-35-12

Figure 2. Sketch Map showing Bunker Hill Pond Area October 25, 1958

north-trending decant line from the west pond, a north-trending decant pipe from the east pond, and two west-trending decant pipes from the east pond into the west pond. In addition, the decant line draining into the South Fork Coeur d'Alene River upstream of the Interstate highway bridge was shown.

The presence of leakage from the Bunker Hill tailings pond and the feasibility of seepage control was recognized as early as August 28, 1967 by R. F. Miller, a Bunker Hill employee. An internal Bunker Hill report titled *Water Pollution* (Miller, 1967) recognized the existence of seepage from the tailings pond under the highway and discharge into the South Fork Coeur d'Alene River and recommended the installation of perforated tile and gravel in a trench between the highway and the tailings pond. Water from the tile was to be limed for metal removal.

In a Bunker Hill memorandum from N. J. Sather (August 7, 1969) to R. L. Hafner, the problem of seepage was recognized and attributed to the presence of the original north-south trending dike, previously referred to as the separating dike.

The Idaho Highway Department again photographed the Bunker Hill area on October 28, 1968. Figure 3, prepared from the photos, depicts conditions as they existed on the date of photography. Conditions at that time were similar to the conditions as portrayed on the 1964 and 1966 Bunker Hill drawings. A dike had been completed around the eastern end of the east pond, expanding it eastward to its present site. The pie-shaped wedge, previously excavated, was clearly visible. The upper surface of the east pond was extremely dark in color, indicating either slag spread on the surface to prevent wind erosion or oxidation of material due to exposure. Tailings were discharged from a pipe ending at the apex of the pie-shaped excavated area. The tailings sands flowed and formed a beach in the wedge with water ponded at the easternmost end of the section and adjacent to the eastern dike. The west pond was

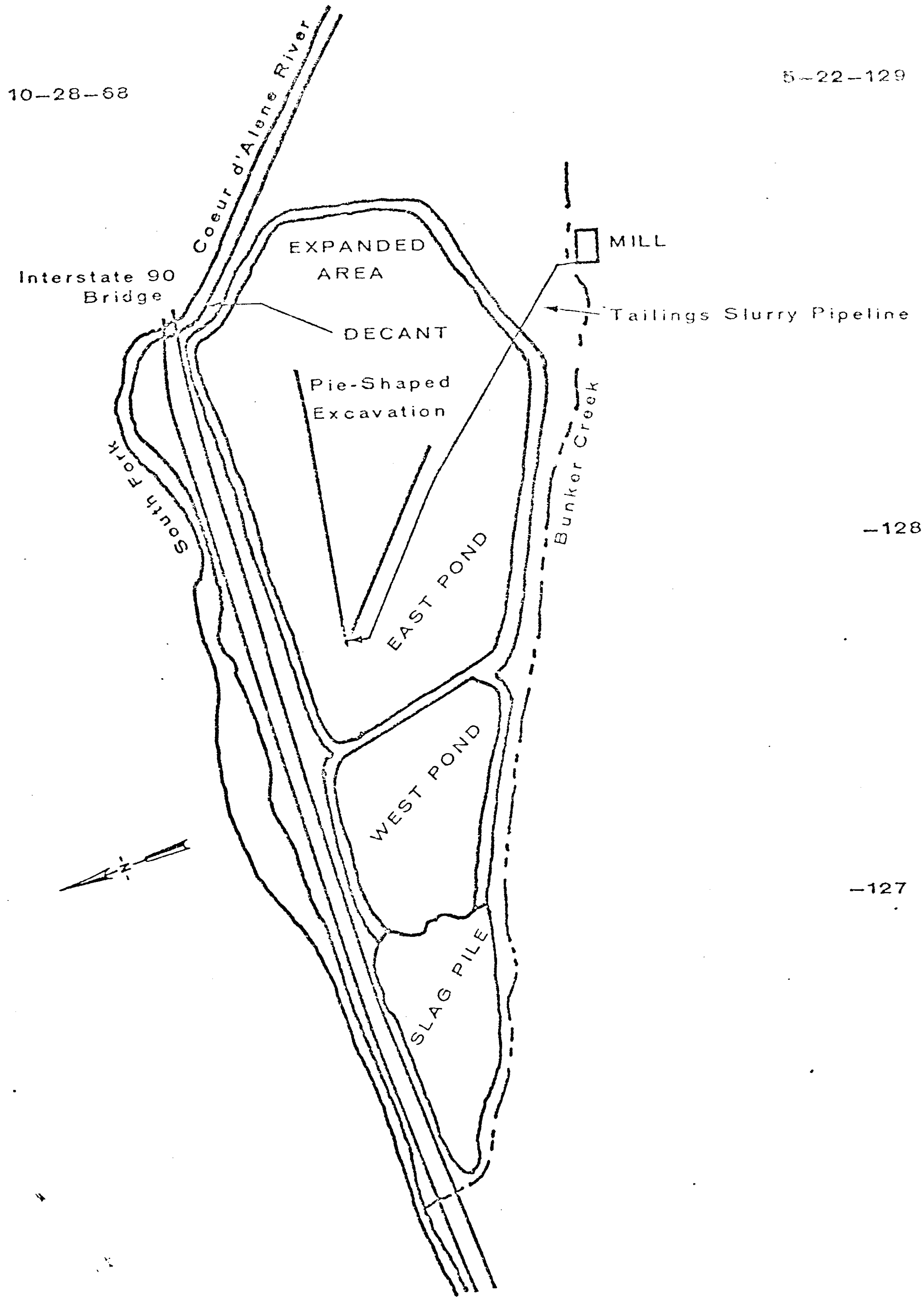


Figure 3. Sketch Map Showing Bunker Hill Pond Area
October 28, 1968

still intact, with recent evidence of raising of the dike by pushing sand up with a crawler tractor. A decant pipe drained the western pond directly into the South Fork Coeur d'Alene River while another decant pipe drained the eastern pond into the River just upstream of the Interstate 90 bridge. The new eastern dike of the eastern pond had been raised and reinforced by peripheral discharge of tailings material.

1970-1972 Conditions

A Bunker Hill Company drawing* indicates that a tailings distribution line was to be extended along the entire north face of the tailings pond, both the eastern and western portion. By this time, the mine water was being discharged to the tailings pond at its present site.

A series of photographs** taken from rather low altitudes was exposed by the consulting engineering firm of CH_2M-Hill Engineers on May 2, 1972. These show that the slag pile had grown to near its present size. Gypsum slurry, from the phosphophoric acid plant was discharged from a single pipe at a point at the west end of the tailings area, flowed in a braided pattern to the east, overlapping the separating dike. There was a slight surface indication of this dike; no indications were available that the dike had been destroyed. Mill tailings, apparently of sand size, were discharged from a tailings distribution line along the entire north flank of the pond. A major delta of sand had built up along the north dike at the point of the previous separating dike. The pie-shaped area was almost completely filled while contaminated water from the gypsum pond flowed to the extreme east end of the pond. Flow from Sweeney Pond, the lead smelter waste pond, was discharged to Government Creek (Silver King). Mine water was discharged into the eastern portion

* *Drawing M-23-123, "West Mill 12-Inch ID Wood Stave Pipe Tailings Line - North," August 25, 1970.*

** *Designated M308.01, Roll 4, Photographs 7 to 13 and retained by CH_2M-Hill in Redding, Calif.*

of the combined pond. Decant from the pond was through the previously installed pipeline which discharged into the South Fork Coeur d'Alene River a short distance upstream of the Interstate 90 bridge.

Discharge of seepage into South Fork Coeur d'Alene River is evident on the 1972 photographs, especially north of and slightly downstream of the site where the old separating dike intersected the northern dike of the present combined pond. Apparently, the dike and the delta of sand discharged at the intersection served as a sand drain for water which entered the subsurface, moved north and entered the South Fork Coeur d'Alene River.

Topographic conditions in and adjacent to the Bunker Hill tailings pond are shown on a topographic map dated July 1974 prepared for Bunker Hill Company by the consulting firm of Limbaugh Engineers Incorporated, Albuquerque, New Mexico, using photogrammetric methods. By the time the photos used in preparation of this map were taken in June 1974, a dike had been constructed separating the gypsum pond (west) and the tailings pond (east). This dike was 400 to 600 feet east of the previous separating dike. The previous dike site was completely inundated by water from the gypsum pond. At the time of photography, June 15, 1974, the gypsum pond was at an elevation of 2,308.7 feet. A beach was present around the eastern and part of the northern end of the tailings pond. Water was in direct contact with the north dike of the tailings pond (CIA) at the northwest corner and at the northeast corner of the gypsum pond.

1975 Conditions

The Idaho Highway Department again flew and photographed the Bunker Hill area on September 8, 1975. The photographs clearly documented conditions as present on the date of photography. Mine water was discharged into the tailings (east) pond. Gypsum slurry was discharged at the west end of the gypsum pond and flowed to the east. Clear water in the gypsum pond occupied approximately the eastern half of the pond, covering the site of the old separating dike. A beach of tailings slimes had been built up along the eastern and northern sides of the tailings pond (CIA). Decant from the pond was routed to the recently constructed neutralization plant, with discharge from the plant into Bunker Creek. Waste was discharged from Sweeney Pond into Government Creek. Discharge of ground water into the South Fork Coeur d'Alene River was evident, especially north of the intersection of the old separating dike with the northern dike of the gypsum pond. This discharge caused a chemical precipitate to form on the bottom of the South Fork Coeur d'Alene River and discolored the river for approximately one-half the width of the stream. The discharge appeared to be concentrated in the area just downstream of a point north of the previously mentioned dike intersection.

It was obvious from investigation of the various aerial photographs and the Bunker Hill files that the Bunker Hill tailings and gypsum ponds were not the result of a true design. Rather, they "just happened." There has been no adequate engineering safety analysis of the structural integrity of the facilities and there has been no overall plan for waste disposal or consideration of the effect of the pond on the geohydrologic conditions of the area. This approach is directly counter to all published recommendations on the design, construction and operation of a tailings pond. The Bunker Hill facility is not an engineered tailings disposal system and does not reflect the state of the art.

EFFECT ON RECEIVING WATER

The fact that the Bunker Hill CIA and gypsum pond leaks and discharges into the South Fork Coeur d'Alene River is readily apparent through visible observation of the stream. The South Fork Coeur d'Alene is clear upstream of the tailings pond. When the acid discharge, which is visible during low stream flow, enters the stream, which is at a higher pH, various metal hydroxides (most notably ferric hydroxide) precipitate on the bed and banks of the stream. This results in a severe brown to yellowish-brown to white discoloration downstream from the point of discharge seepage inflow.

In addition to the aesthetic effects, the presence and effects of the discharge have been documented by a number of studies performed by EPA Region X personnel. The metals loading due to seepage has been calculated on the basis of metals loading in the stream upstream of and downstream from the seepage inflow. Region X personnel (Ray Peterson, personal communication) calculated that a daily seepage load addition of 1,950 lb zinc, 0.5 lb cadmium, 15 lb lead, and 944 lb fluoride occurred during October 1975.

A similar study was performed during October 1976, when the daily load addition due to tailings pond seepage was calculated to have increased to 3,950 lb zinc, 3.4 lb cadmium, 15 lb lead, and 1,000 lb fluoride. It was noted that the Bunker Hill tailings pond surface elevation had been raised in an effort to prevent wind erosion of previously deposited tailings solids.

V. RESULTS OF INVESTIGATION

Upon receipt of a court order permitting access to Bunker Hill property, twenty-six observation holes were drilled and completed adjacent to the tailings pond to provide information on the quality and direction of ground-water flow. The drilling was done with an 8-inch continuous-flight, hollow-stem auger owned and operated by the Federal Highway Administration. An NEIC geologist, present continuously during the time of drilling, prepared geologic logs of the various holes. After each hole was drilled, it was cased with 1-1/2 inch inside diameter Schedule 80 PVC slotted pipe with a solid plug on the bottom. Backfill was by slumpage of the hole as the auger was retrieved. The holes were capped with a steel cap equipped with a lock. After drilling was completed, the holes were surged and pumped with a centrifugal pump to establish a clean sand filter pack. Water-table elevations were determined and ground-water samples were collected from the wells each month, September through December. Prior to sampling, each well was pumped to purge water from the surrounding voids. The water from the wells was filtered in the field through 0.45 micron filters and preserved. Chain-of-custody procedures were maintained on the samples in accordance with published NEIC procedures [Appendix B]. Samples were split with Bunker Hill personnel.

Available geologic information indicated that the South Fork Coeur d'Alene River valley floor was underlain at a depth of approximately 10 meters by a thick clay and silt layer. With some exceptions, the holes were drilled into this layer. Completion information on each hole is contained in the drilling logs [Appendix C].

STRATIGRAPHY

Findings within the area bore out previously reported geologic conditions, that is, a clay layer at a depth of approximately 5 to 10 meters overlain by poorly sorted alluvium. The clay layer tended to be more silty upstream and downstream from the tailings pond. In the tailings pond area, the layer was a tan plastic clay. Near the middle portion of the tailings pond, there was an uplift force acting on the clay, resulting in upward flowage of material into the hole as the auger plug was retrieved. This is indicative of a discharge area in the ground-water flow system. In some cases, difficulty was encountered in emplacing the total length of casing. The final completion is shown on the logs.

Most of the alluvium was a poorly sorted, silty, clayey sand containing gravel to cobble material. However, in some of the holes, clean sections of sand and gravel (an old gravel bar) were encountered. This was especially true in the middle portion of the tailings pond, holes 9 to 13 [Figure 4]. Later pumpage of some of these holes indicated that the holes were completed in an extremely clean, permeable section of alluvium. It was observed that this section of clean alluvium was immediately adjacent to the site of the previous north-south dike separating the two portions of the Bunker tailings pond. The northern extension of this clean channel of alluvium is the site of the major observed seepage into South Fork Coeur d'Alene River. The upstream portion of the channel is under the gypsum and tailings ponds. Thus, this channel serves as a conduit of ground-water flow between the pond and the river.

GROUND-WATER MOVEMENT AND CONTAMINATION

Before establishment of the Bunker Hill Central Impoundment Area and gypsum pond, ground and surface water in the area was at an equilibrium condition, with ground water generally discharging into the surface

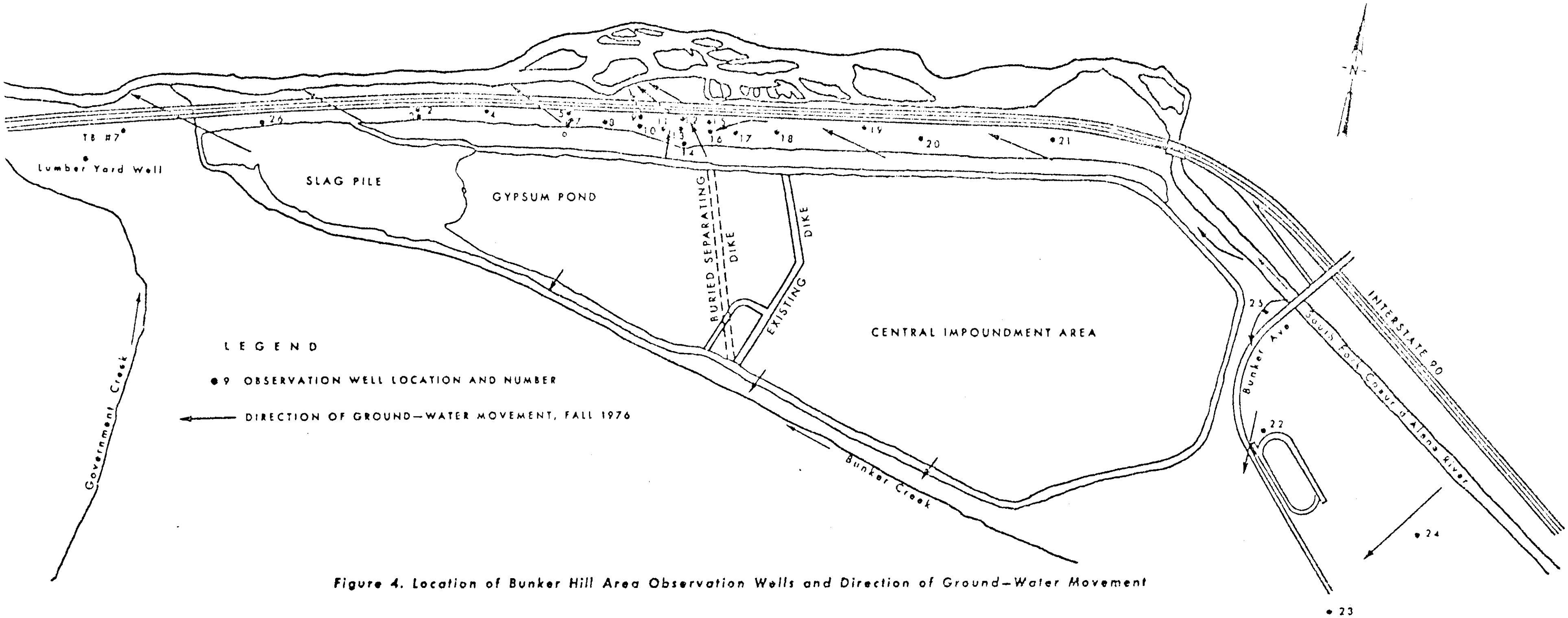


Figure 4. Location of Bunker Hill Area Observation Wells and Direction of Ground—Water Movement

streams. The activities of Bunker Hill Company have modified this equilibrium resulting in changes in ground-water movement and quality.

During the course of the study, measurements were made of ground water elevations in the various observation wells around the Bunker Hill pond [Table 1]. By plotting these elevations and preparing ground-water contour maps, it is possible to deduce the direction of ground-water movement. The following discussion is based on such information.

Pumpage of ground water by Bunker Hill Company from deep alluvium aquifers in the Bunker Hill water-supply wells south and east of the Central Impoundment Area has reduced the water level in the deep aquifer with subsequent leakage from the shallow aquifer through the confining clay layer. As a result, upstream of the Central Impoundment Area in the vicinity of the Junior High School grounds, water moves from the stream to the south, as shown by the arrows on Figure 4. Much of this leakage may be around the casing of the supply wells or through old, unplugged wells as well as through fracturing induced by seismic activity.

Seepage from the Central Impoundment Area and the gypsum pond has created a mound on the ground-water surface, resulting in the discharge of ground water into the South Fork Coeur d'Alene River and probably into Bunker Creek. The flow into the South Fork Coeur d'Alene River is along the entire north dike of the Central Impoundment Area and the gypsum pond, as well as from the slag pile. The flow is in a saturated zone extending upward from the underlying clay layer to the water table, a thickness of 4 to 7 meters. Ground-water direction of movement is generally at a bearing of approximately 300°, or a 30° angle to the Interstate Highway.

The direction of ground-water movement is locally affected by differences in alluvium permeability. This is most pronounced in the area of an old buried gravel bar, observed near observation well 9.

Table 1

GROUND-WATER DEPTH AND ELEVATIONS
BUNKER HILL OBSERVATION WELLS
1976

Hole No. or Site	Casing Top Elevation	Aug. 17-18 Depth ft	Aug. 17-18 Elev.	Sept. 7-9 Depth ft	Sept. 7-9 Elev.	Sept. 10 Depth ft	Sept. 10 Elev.	Oct. 5-6 Depth ft	Oct. 5-6 Elev.	Nov. 10-11 Depth ft	Nov. 10-11 Elev.	Dec. 8-9 Depth ft	Dec. 8-9 Elev.
01	2,229.1	16.92	2,212.2	17.42	2,211.7	-	-	17.73	2,211.4	-	-	18.28	2,210.8
02	2,249.8	12.48	2,237.3	12.19	2,237.6	12.10	2,237.7	12.75	2,237.1	13.54	2,236.3	11.82	2,238.0
03	2,248.2	10.78	2,237.4	9.43	2,238.8	10.36	2,237.8	11.25	2,237.0	11.83	2,236.4	10.03	2,238.2
04	2,251.6	12.27	2,239.3	12.19	2,239.4	12.19	2,239.4	12.60	2,239.0	12.84	2,238.8	12.33	2,239.3
05	2,249.8	8.67	2,241.1	8.92	2,240.9	9.00	2,240.8	9.17	2,240.6	9.31	2,240.5	9.18	2,240.6
06	2,251.4	9.67	2,241.7	4.93	2,246.5	4.63	2,246.8	6.08	2,245.3	9.55	2,241.8	9.90	2,241.5
07	2,250.6	9.31	2,241.3	9.46	2,241.1	9.36	2,241.2	9.60	2,241.0	9.85	2,240.8	9.62	2,241.0
08	2,251.0	8.44	2,242.6	8.50	2,242.5	8.33	2,242.7	8.78	2,242.2	8.91	2,242.1	8.78	2,242.2
09	2,254.1	10.54	2,243.6	10.74	2,243.4	10.71	2,243.4	10.72	2,243.3	10.95	2,243.1	10.92	2,243.2
10	2,254.2	10.33	2,243.9	9.72	2,244.5	9.7	2,244.5	9.81	2,244.4	10.61	2,243.6	10.48	2,243.7
11	2,254.6	9.92	2,244.7	9.91	2,244.7	10.00	2,244.6	10.00	2,244.6	10.30	2,244.3	10.20	2,244.4
12	2,256.4	11.58	2,244.8	11.71	2,244.7	11.70	2,244.7	11.77	2,244.6	12.00	2,244.4	11.96	2,244.0
13	2,255.6	10.17	2,245.4	10.36	2,245.2	10.34	2,245.3	10.40	2,245.2	10.75	2,244.8	10.28	2,245.3
14	2,259.4	11.25	2,248.2	11.60	2,247.8	10.34	2,249.1	10.70	2,248.7	9.95	2,249.4	9.52	2,249.9
15	2,256.5	10.42	2,246.1	10.60	2,245.9	10.54	2,246.0	10.58	2,245.9	10.87	2,245.6	10.80	2,245.7
16	2,255.0	8.77	2,246.2	8.96	2,246.0	8.90	2,246.1	8.95	2,246.0	9.31	2,245.7	9.15	2,245.8
17	2,256.0	8.46	2,247.5	8.60	2,247.4	8.58	2,247.4	8.57	2,247.4	9.00	2,247.0	8.78	2,247.2
18	2,256.6	7.78	2,248.8	7.84	2,248.8	7.90	2,248.7	7.80	2,248.8	8.28	2,248.3	8.05	2,248.6
19	2,260.0	7.38	2,252.6	7.60	2,252.4	-	-	7.43	2,252.6	8.13	2,251.9	8.00	2,252.0
20	2,262.3	7.50	2,254.8	7.74	2,254.6	7.70	2,254.6	7.45	2,254.9	8.25	2,254.1	8.15	2,254.1
21	2,271.9	14.06	2,257.8	14.24	2,257.7	-	-	14.01	2,257.9	15.18	2,256.7	15.00	2,255.9
22	2,277.3	17.42	2,259.9	-	-	-	-	19.60	2,257.7	22.95	2,254.3	23.58	2,253.7
23	2,282.2	21.67	2,260.5	-	-	-	-	Silted	-	-	-	Silted	-
24	2,286.5	24.42	2,262.1	-	-	-	-	30.30	2,256.2	-	-	29.38	2,257.1
25	2,276.5	9.52	2,267.0	11.23	2,265.3	-	-	11.95	2,264.5	14.98	2,261.5	15.62	2,260.9
26	2,241.6	9.44	2,232.2	8.94	2,232.7	10.28	2,231.3	9.76	2,231.8	10.65	2,231.0	9.73	2,231.9
TB#7	2,240.8	-	-	-	-	-	-	13.10	2,227.7	13.43	2,227.4	13.15	2,227.6
Lumber Yard Well	2,240.2	13.09	2,227.1	13.49	2,226.7	-	-	13.42	2,226.8	13.76	2,226.4	13.38	2,226.8

This area of increased permeability serves as a ground-water drain, lowering the water table and hence functioning as a sink for ground-water movement from the south and east. This modifies the direction of ground-water flow as shown on Figure 4. It further serves to drain ground water recharged from seepage through the buried separating dike which is located to the south, under the existing gypsum pond. The fact of this movement is shown not only by ground-water contours but by evidences of ground-water contamination.

High concentrations of fluoride are not indigenous to ground or surface waters in the South Fork Coeur d'Alene River Valley. Large amounts of fluoride are imported to the area in the phosphate rock which serves as a raw material in the fertilizer plant. A large percentage of this fluoride is discharged to the gypsum pond along with the gypsum slurry. A sample of water collected on December 9, 1976 from the clarified water at the northeast corner of the gypsum pond was found to contain 840 mg/l fluoride. Fluoride is mobile and not easily precipitated in an acid media; therefore, it serves as an excellent tracer of Bunker Hill ground-water contamination.

Gypsum from the phosphate plant previously overflowed the entire area of the Bunker Hill gypsum pond and Central Impoundment Area before the existing dike was constructed between the two ponds. Hence, gypsum underlies the Central Impoundment Area sediments and could reasonably be expected to be present in the seepage from both ponds.

Fluoride has been found to be beneficial when present in small quantities in potable drinking water supplies. High concentrations of fluoride are detrimental, damaging the teeth of those drinking the water.* The maximum concentration of fluoride permitted in the water supply is a function of temperature, decreasing with increasing temperature. Concentrations over approximately 2.5 mg/l are not acceptable at any temperature. Fluoride can be removed to concentrations of approximately 15 mg/l by lime addition.

As shown in Figure 5, the background ground water has approximately 0.2 mg/l of fluoride. This is greatly modified as a result of seepage from the Bunker Hill ponds. All the ground water to the north and northwest of the ponds exhibited abnormally high fluoride levels, ranging up to 170 mg/l in one sample collected from observation well 9. As shown in Table 2, the highest values are present in wells 9 and 10, in the old buried gravel channel. This tongue of high concentrations of fluoride probably connects with the old separating dike between the two original tailings ponds. The data indicates there is a direct hydrologic connection from the gypsum pond through the separating dike, through the old gravel bar, and directly into the South Fork Coeur d'Alene River.

Zinc is present in high concentrations in the Bunker Hill ore, mostly in the form of zinc sulfide which readily oxidizes to yield dissolved zinc in a sulfuric acid solution. During the early days of milling operations in the South Fork Coeur d'Alene Valley, zinc was not recovered; hence, the jig tailings within the area tend to be extremely high in zinc sulfide. Even today, zinc recovery is not complete, with the result that zinc sulfide is present in tailings discharged to the Bunker Hill tailings pond. Zinc is present in liquid waste discharged to the CIA from the zinc plant.

Zinc is highly toxic to aquatic organisms at low concentrations. The toxic concentration is a function of water hardness but generally is less than 1 mg/l. It can be removed by the addition of lime to form zinc hydroxide. Further zinc removal can be achieved by the addition of inorganic sulfide ions to form zinc sulfides.

Zinc is relatively mobile as a heavy metal in ground water, especially in acid conditions. It will adsorb to some extent on the rocks forming an aquifer, and is one of the last heavy metals to be removed by pH adjustment.

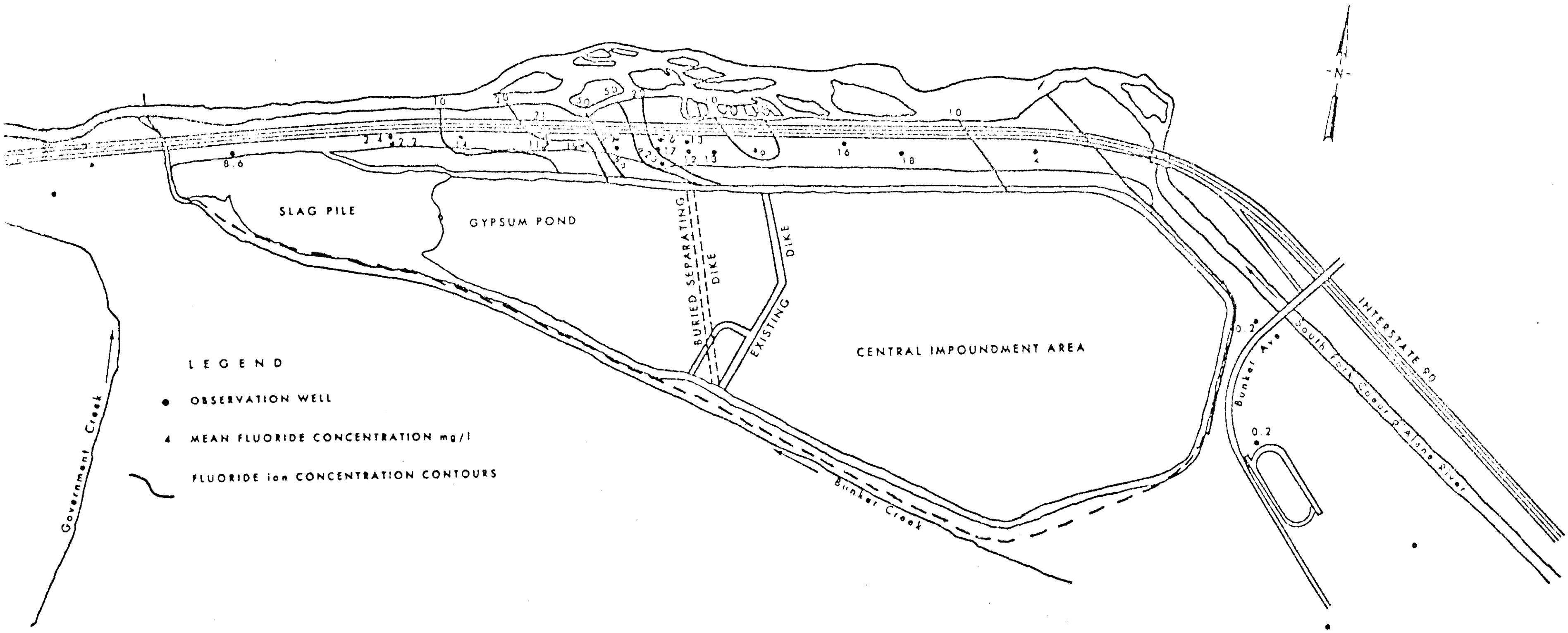


Figure 5. Mean Fluoride Concentrations in Bunker Hill Observation Wells, Sept–Dec, 1976

Table 2

RESULTS OF FLUORIDE ANALYSES
BUNKER HILL OBSERVATION WELL SAMPLES
1976

Observation Well No.	Sept. 10 mg/l	Oct.5-6 mg/l	Nov. 10-11 mg/l	Dec. 8-9 mg/l	Mean/Std.Dev.
1	-	-	-	-	-
2	1.4	3.6	2.7	2.1	2.4/0.9
3	1.5	4.0	1.4	2.0	2.2/1.2
4	8.8	22	10	15	14/6
5	11	34	17	21	21/10
6	-	-	-	-	-
7	2.2	30	6.0	6.1	11/13
8	11	31	15	20	19/9
9	29	170	78	94	93/58
10	29	120	92	102	86/40
11	12	41	16	22	23/13
12	10	25	13	17	16/6
13	11	23	15	18	17/5
14	-	-	13	-	
15	9	17	12	14	13/3
16	10	13	8.2	15	12/3
17	9.3	21	8.3	14	13/6
18	6.5	15	4.9	9.6	9/4
19	-	22	8.9	16	16/7
20	10	32	10	20	18/10
21	-	12	0.5	0.7	4/7
22	-	0.3	0.2	-	-
23	-	-	-	-	-
24	-	-	-	-	-
25	-	0.3	0.1	0.3	0.2/0.1
26	1.6	30	0.8	1.9	8.6/14.3

\- No sample

Analyses of samples collected from the various observation wells [Table 3] indicate that zinc is present in relatively high concentrations in the ground water in the shallow alluvium of the South Fork Coeur d'Alene Valley due to leaching from jig tailings which cover the floor of the South Fork Valley. Despite the relatively high values (approximately 1 mg/l) which comprise background levels, the effect of the Bunker Hill tailings pond leakage was clearly demonstrated in the abnormally high concentrations of zinc in the observation wells. As shown in Table 3, values of zinc as high as 180 mg/l were observed in observation wells along the north side of the dike. By way of comparison, a sample collected December 9 from the clear water in the western end of the Bunker Hill CIA was found to contain 220 mg/l zinc. The highest average values of zinc in the observation wells were present in wells 11, 13, and 15, along the eastern side of the old gravel bar [Figure 6]. This probably reflects a conduit effect from the separating dike and from within the Central Impoundment Area moving into this channel. Zinc is probably also present in seepage from the gypsum pond as a result of leaching of zinc from old tailings which underlie the gypsum pond.

Cadmium behaves similarly to zinc but is somewhat less mobile. The only wells which exhibited high cadmium values were in wells 2 and 3, adjacent to the east end of the slag pile and the point of discharge of gypsum and in wells 9 and 10 in the old gravel bar [Table 4]. The high values in wells 2 and 3 probably reflect acid leaching of slag as acid water moves from the point of gypsum discharge downward through the slag and thence into the ground water. Wells 9 and 10 represent the relatively rapid movement of ground water through the permeable gravel bar with little chance for metal adsorption.

Lead does not generally tend to be mobile in a ground-water environment. The only wells containing significant quantities of lead were wells 2 and 3, adjacent to the slag pile and the point of gypsum discharge, and wells 9 and 10 in the old gravel bar section [Table 5]. The explanation for the presence of lead in these wells is similar to that for cadmium.

Table 3

RESULTS OF ZINC ANALYSES
BUNKER HILL OBSERVATION WELL SAMPLES
1976

Observation Well No.	Sept. 10 mg/l	Oct.5-6 mg/l	Nov. 10-11 mg/l	Dec. 8-9 mg/l	Mean/Std.Dev.
1	-	-	-	-	-
2	16	19	61	50	36/22
3	44	23	36	54	39/13
4	101	105	110	120	109/8
5	118	150	120	120	127/15
6	-	-	-	-	-
7	83	130	96	92	100/21
8	81	170	120	130	125/37
9	100	150	110	110	118/22
10	115	150	110	110	121/19
11	160	170	140	130	150/18
12	83	150	120	120	118/27
13	103	150	120	120	123/20
14	-	-	120	-	-
15	180	150	110	110	138/34
16	86	150	120	110	116/26
17	130	150	120	12	103/62
18	104	140	90	85	105/25
19	-	77	78	79	78/1
20	55	70	65	70	65/7
21	-	29	5.5	13	16/12
22	-	19	20	-	20
23	-	-	-	-	-
24	-	-	-	-	-
25	-	1.0	0.9	0.8	0.9/0.1
26	16	8.2	7.0	5.7	9.0/4.6

\- No sample

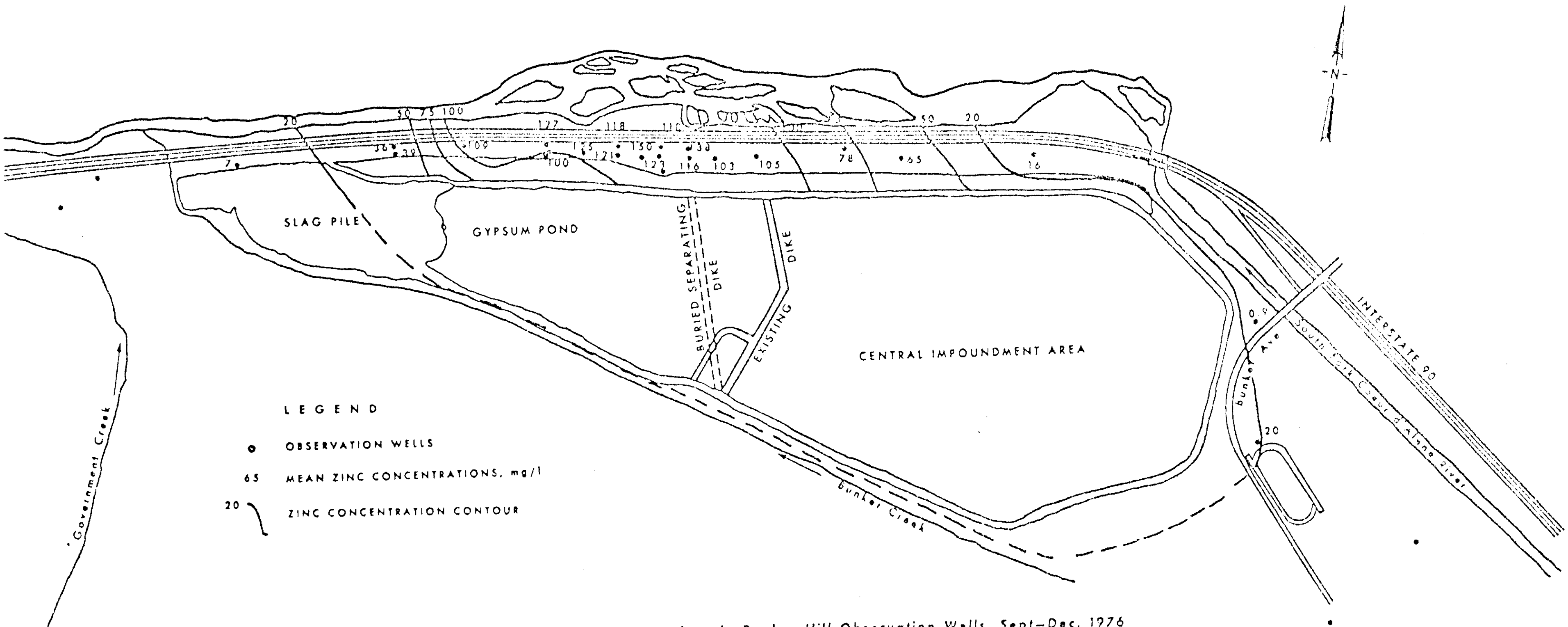


Figure 6. Mean Zinc Concentrations In Bunker Hill Observation Wells, Sept–Dec, 1976

Table 4

RESULTS OF CADMIUM ANALYSES
BUNKER HILL OBSERVATION WELL SAMPLES
1976

Observation Well No.	Sept. 10 mg/l	Oct.5-6 mg/l	Nov. 10-11 mg/l	Dec. 8-9 mg/l	Mean/Std.Dev.
1	-	-	-	-	-
2	0.07	0.07	0.15	0.27	0.14/0.09
3	0.14	0.08	0.16	0.37	0.19/0.13
4	0.03	*	*	*	
5	0.02	*	*	*	
6	-	-	-	-	
7	0.04	0.02	*	*	
8	*	0.02	*	*	
9	0.25	0.35	0.37	0.35	0.33/0.05
10	0.39	0.38	0.52	0.43	0.43/0.06
11	*	*	*	*	
12	*	0.02	*	*	
13	*	*	*	*	
14	-	-	1.8	-	
15	0.03	*	*	*	
16	0.02	0.02	*	*	
17	0.04	0.04	*	*	
18	*	0.04	*	*	
19	-	0.02	*	*	
20	*	*	*	*	
21	-	*	*	0.15	
22	-	0.07	0.13	-	
23	-	-	-	-	
24	-	-	-	-	
25	-	*	*	*	
26	*	*	*	*	

- No sample
* Less than MQDC

Table 5

RESULTS OF LEAD ANALYSES
BUNKER HILL OBSERVATION WELL SAMPLES
1976

Observation Well No.	Sept. 10 mg/l	Oct.5-6 mg/l	Nov. 10-11 mg/l	Dec. 8-9 mg/l	Mean/Std.Dev.
1	-	-	-	-	
2	0.17	0.5	0.9	1.3	0.7/0.5
3	0.21	1.0	1.1	1.8	1.0/0.6
4	*	0.3	*	*	
5	*	*	*	*	
6	-	-	-	-	
7	*	*	*	*	
8	*	*	*	*	
9	0.04	0.8	*	*	
10	0.04	0.4	0.4	*	
11	*	*	*	*	
12	*	*	*	*	
13	*	*	*	*	
14	-	-	2.9	-	
15	*	*	*	*	
16	*	*	*	*	
17	0.04	0.3	*	*	
18	*	*	*	*	
19	-	*	*	*	
20	*	*	*	*	
21	-	*	*	*	
22	-	*	*	-	
23	-	-	-	-	
24	-	-	-	-	
25	-	*	*	*	
26	*	*	*	*	

- No sample
* Less than MQDC

Iron and manganese tend to be associated with the tailings solids discharged by Bunker Hill Company and are easily mobilized following sulfide oxidation. While iron is removed at a relatively low pH, manganese is the last common heavy metal to be removed. Hence, a comparison in the behavior between the two indicates the ground-water response as a result of seepage from the ponds.

Wells which constitute background sampling stations (wells 22 and 25) generally contained no detectable iron [Table 6] and only low levels of manganese [Table 7]. All of the wells to the north and northwest of the Bunker Hill ponds contained abnormally high concentrations of both metals, indicative of contamination by acid seepage from the two Bunker ponds. These metals are responsible for much of the visual degradation in the South Fork Coeur d'Alene River where the acid seepage enters the stream and forms brown metal hydroxide precipitates on the rocks which comprise the bed and banks of the stream. Again, the highest values of iron and manganese tended to be in and adjacent to the old stream channel, which serves as a main conduit for discharge from the Bunker ponds into the South Fork Coeur d'Alene River.

A pond of seepage water has collected along the north toe of the gypsum pond dike. A pipe was observed to have been installed between the pond and a nearby highway drain, with flow from the highway drain into the South Fork Coeur d'Alene River. During the monthly visits August through December 1976, this pipe was observed to be continuously discharging into the highway drain. A sample of this water, collected from the discharge end of the 4-inch PVC pipe on September 10, 1976 was found to contain 2.6 mg/l fluoride, 0.02 mg/l cadmium, 2.2 mg/l iron, 21 mg/l manganese, 0.04 mg/l lead, and 4.7 mg/l zinc. The water and its pollutants reach the South Fork Coeur d'Alene River. This discharge is not authorized by the existing NPDES permit.

Table 6

RESULTS OF IRON ANALYSES
BUNKER HILL OBSERVATION WELL SAMPLES
1976

Observation Well No.	Sept. 10 mg/l	Oct.5-6 mg/l	Nov. 10-11 mg/l	Dec. 8-9 mg/l	Mean/Std.Dev.
1	-	-	-	-	-
2	16	26	81	40	41/29
3	25	16	19	2.6	16/9
4	140	150	140	140	142/5
5	210	180	180	180	188/15
6	-	-	-	-	-
7	9.2	100	73	40	56/39
8	140	170	160	170	160/14
9	270	290	310	330	300/26
10	270	310	320	320	305/24
11	130	180	180	180	168/25
12	160	190	190	190	182/15
13	160	180	190	190	180/14
14	-	-	*	-	
15	140	170	150	150	152/13
16	170	190	190	160	178/15
17	170	180	170	150	168/13
18	110	150	130	120	128/17
19	-	95	130	130	118/20
20	50	80	89	88	77/18
21	-	7.1	*	*	
22	-	*	*	-	
23	-	-	-	-	
24	-	-	-	-	
25	-	*	*	*	
26	17	9.4	11	9.5	12/4

- No Sample
* Less than MQDC

Table 7

RESULTS OF MANGANESE ANALYSES
BUNKER HILL OBSERVATION WELL SAMPLES
1976

Observation Well No.	Sept. 10 mg/l	Oct.5-6 mg/l	Nov. 10-11 mg/l	Dec. 8-9 mg/l	Mean/Std.Dev.
1	-	-	-	-	-
2	50	32	49	54	46/9
3	28	16	23	44	28/12
4	72	62	64	56	64/7
5	69	56	57	54	59/7
6	-	-	-	-	-
7	102	79	88	87	89/10
8	57	56	56	55	56/1
9	58	59	61	60	60/1
10	68	63	66	61	64/3
11	54	54	53	50	53/2
12	63	60	57	57	59/3
13	57	54	56	56	56/1
14	-	-	87	-	
15	60	57	52	52	55/4
16	63	58	61	54	59/4
17	75	60	56	52	61/10
18	62	66	56	53	59/6
19	-	48	50	46	48/2
20	41	40	52	52	46/7
21	-	220	9.2	85	105/107
22	-	1.5	3.7	-	
23	-	-	-	-	
24	-	-	-	-	
25	-	1.1	0.7	0.9	0.9/0.2
26	14	6.4	8.1	6.6	8.8/3.6

\- No Sample
* Less than MQDC

Much of the previous discussion on contaminant movement has revolved around the function of the old gravel bar adjacent to wells 9, 10, 11, 12, and 13 as a ground-water drain. This gravel bar serves to collect ground water moving from the south and east and discharge it directly into the South Fork Coeur d'Alene River. Apparently, the old gravel bar is in almost direct ground-water connection with the old separating dike. This dike was constructed of river gravel and jig tailings and serves as a drain under much of the gypsum pond. Thus, the dike and old gravel bar serve the purpose of a French drain, or ground-water conduit, for seepage from much of the Bunker Hill pond to discharge into the South Fork Coeur d'Alene River by a confined and discrete conveyance, which could be easily controlled and collected.

As shown in Figures 5 and 6, the quality of ground water north and northwest of the Bunker Hill tailings pond has been appreciably degraded below the quality of natural ground water. The contamination involves a zone of saturated alluvium 4 to 7 meters thick between the underlying clay layer and the water table, along the north portion of the tailings pond and the gypsum pond, a distance of approximately 1.5 km. When viewed on the regional scale of the South Fork Coeur d'Alene River valley alluvium, this is an extremely small portion of the total volume. It comprises a rectangular prism 4 to 7 meters thick by 1.5 km long. This constitutes a discernible, confined, and discrete conveyance of contaminated seepage from the Bunker Hill ponds discharging to the South Fork Coeur d'Alene River. Techniques are available to capture and control such seepage.

VI. TAILINGS DAM TECHNOLOGY

In the early mining days, tailings, or waste solid material from milling operations, were something to be disposed of as inexpensively as possible, usually by direct discharge into nearby streams. Later operations began to use tailings dams, constructed as inexpensively as possible by self-constructing techniques. The use of tailings dams resulted from two factors: downstream effects on the receiving water, and the hope that future technology would permit recovery of additional values from the tailings.

The first significant literature on tailings dam construction techniques was a series of eight articles by Walter B. Lenhart (1949, 1950, 1951), which appeared in the journal "Rock Products." In this series, the dam construction methods used at various Arizona copper mills were described. Copies of these articles were found to be a part of the Bunker Hill Environmental Department files during discovery proceedings March 18-19, 1976.

After the "Rock Products" articles, several other journal articles appeared describing improved techniques. Some of the first and most significant quantitative investigations of tailings dam construction and the effects of the dams on ground water were done by the University of Idaho and the Spokane Mining Research Laboratory, U.S. Bureau of Mines. Much of this work was done under the supervision of, or in conjunction with, Dr. Roy Williams, a frequent consultant to the Bunker Hill Company.

Continuing interest in the field of tailings disposal was indicated by a four-day International Tailings Symposium in Tucson, Arizona in the latter part of 1972 under the direction of the Journal "World Mining." Proceedings of this symposium were published under the title "Tailings Disposal Today" (Aplin and Argall, 1973). A total of thirty-four papers described tailings disposal techniques. The Bunker Hill Company, in response to government interrogatories, stated this to be the authoritative work on tailings disposal technology.

Two papers from the book "Tailings Disposal Today" are of special interest. In the first, C. O. Brawner and D. B. Campbell (1973) of the consulting firm of Golder, Brawner and Assoc., Ltd., address "The Tailings Structure and its Characteristics -- A Soils Engineer's Viewpoint." This firm has done work on tailings disposal throughout the world. In speaking of seepage control, the authors state "if the seepage water contains contaminant constituents, the volume of seepage must be determined to evaluate the influence on adjacent land and water sources. If potential contamination is above allowable limits, the design must incorporate procedures to prevent leakage, to maintain it within tolerable limits, or to remove the contaminants." They continue, "if the seepage through a foundation or abutments exceeds the amount allowable, it must be reduced or if deleterious substances such as radioactive materials or poisonous chemicals are involved, total control of seepage is necessary. With the present knowledge and experience available in soil mechanics, this is feasible."

In another paper, James R. Swaisgood and George C. Tolland (1973), of the firm of Dames and Moore, address "The Control of Water in Tailings Structures." In this paper, the authors describe seepage-control techniques which can be applied to existing tailings dams. These include the use of drainage wells to intercept seepage flow or the use of an interception trench, coupled with the construction of a dike of impermeable material downgradient from the tailings pond. The authors state "drainage wells can also be used to aid in controlling seepage outflow. This system has been successfully used by Cities Service Company to control seepage in a tailings embankment in Miami, Arizona."

As can be seen by the foregoing, technology does exist for tailings dam construction and seepage control and is available to the mining industry in the form of consultants, literature and experience on the part of mining personnel. As will be discussed, such technology has been applied at a number of mining operations throughout the nation.

The volume of seepage leaving a tailings pond or flowing through permeable media is directly proportional to the permeability of the material through which the seepage is flowing, the cross-sectional area of permeable media and the gradient, or slope, of the water table. Reductions in seepage flow can be accomplished by reducing any of these variables.

Measures can be taken within a tailings pond to reduce the total amount of seepage from the pond by varying the permeability or the hydraulic gradient. Bunker Hill Company has attempted a small amount of this type of control by the construction of slime beaches, or beaches composed of material less than 200-mesh grain size, around the internal margin of the dikes. This has the dual effect of reducing the permeability of the bottom material of the tailings pond and increasing the horizontal distance between the free water surface and the point of potential discharge, thereby reducing the hydraulic gradient serving to drive the ground water to the potential discharge point. These measures have not been taken along the dike between the tailings pond and the gypsum pond, within the gypsum pond area, or along internal dikes in the CIA.

The gypsum crystal slurry filling the gypsum pond has a very high permeability and can be expected to recharge water to the subsurface unless measures are taken to reduce the permeability. The rate of seepage could be reduced by the discharge of slime beaches around internal dikes within the tailings pond, and around the interior face of the gypsum pond dike. If problems would result from mixing of the liquid within the gypsum pond with liquid from the tailings pond, it would be possible to utilize the addition of drilling mud or other clay material. It should be noted that the gypsum beach, which laps onto the lower portion of the slag pile, has an almost infinite permeability, with the result that much of the water moves vertically down through the gypsum beach before entering the free-water pond. A layer of slimes or drilling mud built up on the gypsum beach would greatly reduce this seepage loss.

Many mining operations and solar evaporation operations have used liners to reduce seepage. Such liners are extremely expensive but can be used to greatly reduce the amount of seepage leaving a pond. In general, such installations are not recommended in existing ponds due to possible structural problems. However, significant reduction in the leakage from the gypsum pond could be realized by a partial lining of the gypsum beach, coupled with external control measures.

Internal control measures can be very effective in reducing the permeability of a tailings pond bottom and sides, thereby reducing the seepage loss from the pond. However, no internal measures can be completely effective at stopping seepage loss. Their greatest use is as an adjunct to external control measures. In this way, the internal measures serve to reduce pumping and treatment costs of the external control systems. External control measures are designed to alter one or more of the variables controlling permeable media flow, that is, the permeability, hydraulic gradient, and cross-sectional area.

Grouting has been used along and downstream of the toe of tailings dams and water supply reservoirs to reduce the permeability of material under the dam. This generally is best accomplished downgradient of the pond to prevent problems of potential erosion (piping) and structural failure. This has been carried to its ultimate in a number of operations where slurry trenches or actual subsurface dams composed of plastic sheet have been used to render the permeability as nearly zero as is possible. Plastic sheeting, coupled with collection wells, has been used by Allied Chemical Company at a trona mine in southwestern Wyoming.

The hydraulic gradient tending to drive water toward the point of discharge can be modified by the use of injection wells between the pond and the discharge point, reversing or lessening the hydraulic gradient. Such techniques are commonly employed in the prevention of sea water intrusion into potable aquifers.

Most commonly employed seepage control measures in the mining industry attempt to capture the seepage by wells, ditches, or other techniques for pumping back into the pond or directly to the treatment systems. Because of the acid nature of the ground-water seepage and the high metals concentration present, it would be necessary to treat this intercepted water before allowing its discharge to receiving streams. The treatment could be achieved by discharging back to the tailings pond, with flow through the pond into the treatment plant, or by piping the collected seepage directly to the treatment plant. Since the seepage would have very low suspended solids concentrations, certain advantages could be achieved by a direct piping of the discharge to the treatment plant. Metals recovered from the seepage could be reclaimed, offsetting a part of the cost.

According to Bunker Hill personnel (Crosser, 1976), the existing Bunker Hill treatment plant is now operating at less than the hydraulic design capacity. If, however, the treatment plant does not have sufficient hydraulic capacity to treat this intercepted seepage, a reduction in flow to the plant could be achieved by the installation of mine infiltration control measures such as are recommended by Bunker Hill consultants (Williams, 1975). These techniques would greatly reduce the amount of acid mine drainage and metals being discharged to the tailings pond and hence would have the effect of reducing the operating costs for the treatment plant. The measures would further provide excess hydraulic capacity within the treatment plant to treat the intercepted seepage. Metals discharge from the plant is regulated by the existing Bunker Hill NPDES permit.

The aim of all of the external control measures is to capture seepage before it enters the river but at the same time prevent the movement of water from the river through the alluvium back to the seepage-collection facility. To do this, it will be necessary to lower the water table at the point of seepage interception to an elevation equal to that of the stream directly downgradient. If the water level is lowered more than this, it will induce flow from the river back to the seepage collection system. If the ground-water level is not lowered to the stream level, some of the seepage will bypass the collection facility and discharge to the stream. Prevention of movement from the stream back to the interception facility can be effected by a number of techniques, including grouting of the permeable media, installation of plastic dams in a trench, installation of slurry trenches or reinjecting treated effluent into a line of reinjection wells. This latter system has been chosen for a seepage collection and ground-water rehabilitation system downgradient of the Homestake Partners uranium mill at Grants, New Mexico. The plastic sheet technology has been utilized by Allied Chemical Company in Green River, Wyoming. Slurry trench technology is widely practiced in the construction industry.

Most seepage collection measures which have been installed at existing tailings ponds involve the use of vertical collection wells, drilled in a line parallel to and downgradient from the tailings pond toe. In the case of the Bunker Hill situation, this would involve a number of wells between the toe of the dike and the Interstate highway. Because of the variability of the alluvium, it would be necessary to vary the spacing and/or pumpage rates as a function of the aquifer permeability. Each of the wells would be approximately 10 meters deep, bottoming in the clay layer which underlies the site. Pumping rates and spacing would have to be designed on the basis of more extensive sampling and geophysical investigations. It is obvious that a large percentage of the pumping capacity would have to be in the buried alluvial channel, north of the old separating dike. This is in the area of observation wells 9 through 13. For purposes of preliminary cost estimation, it was assumed that a total of 50 wells, each 10 meters deep, would be required. Such wells could be drilled, cased, and equipped with a suitable pump for less than $1,000/well, or a total of $50,000. A system including liquid-level controls and piping could be installed for less than $100,000.

Because of the low pumping lifts involved, pumping costs for the system would not be excessive, certainly minor in terms of the present ground water pumping by Bunker Hill.

The old Miami Copper Company operation at Miami, Arizona had a tailings pond very similar in geohydrologic conditions to the Bunker Hill situation. In this operation (described in the "Rock Products" series available in the Bunker Hill files) a drift (horizontal tunnel) was driven in the underlying clay confining layer, and churn-drill holes were drilled into the drift from the surface to permit the vertical drainage of seepage into the drift. Infiltration to the drift was then pumped out and returned to the processing plant. Such a system would be very effective in collecting the seepage; however, it would be extremely capital intensive in this day of high labor costs.

Leakage could be collected and prevented from discharging to the stream by constructing an open ditch to below the ground-water level, between the Interstate and the toe of the dike. Such ditch collection techniques are widely utilized in the phosphate industry in southern Florida and are described in the recently released book by Dr. Roy Williams (Williams 1975, pg. 167). In the case of the Bunker Hill operation, this would involve an open ditch approximately 4 meters deep. If need be, the trench could be filled with gravel, with sumps along the ditch, to permit better control of ground-water levels to correspond to stream levels. The gravel could serve to provide enough flow resistance to provide an east-west slope corresponding to the stream gradient.

A system very similar to the open, gravel-filled ditch is already available to Bunker Hill Company. The main interceptor sewer for the South Fork Coeur d'Alene Sanitation District lies between the tailings pond and the Interstate. This ditch is constructed beneath the water table. The sewer line is bedded in slag or in gravel between 1 and 1.5 inch diameter. During the construction of the ditch, many problems were encountered due to ground-water infiltration. The existing ground-water level covers the sewer pipe, with evidence that infiltration of ground water into the sewer line is occurring. It would be relatively easy to convert the gravel bedding of this sewer line to a gravel-filled "French drain." All that would be required would be installation of pumps at intermittent locations along the sewer line. It would be possible to install a sump and pump at each manhole, with provision for pumping ground water as required to maintain the ground-water level in the sewer ditch at the elevation of the adjacent river. This would require lowering the water a maximum of approximately 1.1 meters. This would prevent movement either from or toward the river and would effectively prevent any leakage from the Bunker Hill tailings pond from being discharged into the South Fork Coeur d'Alene River. In the case of the clean gravel bar encountered adjacent to the old separating dike, it may be necessary to install one large capacity well and pump upgradient between the sewer line and the tailings pond to capture a portion of the seepage before it flows into the gravel, thus overwhelming the carrying capacity of the gravel jacket surrounding the pipe.

Such a system, utilizing the existing gravel drain would, of course, require approval by the South Fork Sanitation District and would require special easements to be granted by the Idaho Highway Department. However, such requirements do not appear beyond the realm of possibility.

The use of the sewer-bedding gravel as an interceptor would appear to be the least costly technique for solving the problem of the ground-water seepage, that results in a discharge to the South Fork Coeur d'Alene River with a cost appreciably less than the use of wells. Water pumped from the sumps would require neutralization and metals removal. To ease the problems of maintaining water level in the sewer line trench at the stream level, grout could be injected in the gravel section between the sewer line and the river in the vicinity of observation well 9, and a large-capacity well could be drilled and completed in the gravel bar upgradient of the sewer line. Water from the well and from the sewer-line gravel sumps could be pumped into the CIA for eventual flow to the existing treatment plant or could be piped directly to the treatment plant, thereby eliminating the mixing of the clear ground water with turbid pond water.

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APPENDIX A

Reconnaissance Visit of
Bunker Hill Company

October 16 and 17, 1975

RECONNAISSANCE VISIT OF
BUNKER HILL COMPANY MINE, MILL & SMELTER COMPLEX
KELLOGG, IDAHO

FACILITY ADDRESS: The Bunker Hill Company, P.O. Box 29, Kellogg, Idaho 83837

DATE OF VISIT: October 16 and 17, 1975

PARTICIPANTS:

Gene Baker, Vice President, Environmental Affairs Division, Bunker Hill Company
Ralph Crosser, Manager of Environmental Affairs, Bunker Hill Company
Merv Aiken, Environmental Technician, Bunker Hill Company
William Boyd, Attorney, Brown, Peacock, Keane, and Boyd
Robert Borman, Superintendent, Mill Concentrator
Joe Acree, Superintendent, Phosphate Plant
Jim Rouse, EPA, NEIC
Robert Harp, EPA, NEIC
Ray Peterson, S&A Division, Region X, EPA
Ken Brooks, S&A Division, Region X, EPA (October 16)
Jack Sceva, S&A Division, Region X, EPA

The purpose of our visit was to conduct a facility reconnaissance and inspection to determine what unit operations are being conducted and what wastes can be expected. Based on this information, sampling and flow measurement locations would be identified for the Second Phase Survey. Basically, we needed to: a) define geohydrologic conditions in the vicinity of the Central Impoundment Area (CIA); and b) to discuss and evaluate the sources, quantities and qualities of wastewaters entering the CIA. To better accomplish these goals, we asked Messrs. Crosser and Baker if process flow and piping diagrams, waste sewer piping maps, and technical documents on the various operations might be obtained. Mr. Baker first indicated he saw no difficulty in providing this type information but in view of the legal actions being taken against the company he felt it necessary to discuss our request with Mr. William Boyd, who represents Bunker Hill in all legal actions. In our subsequent meeting, Mr. Boyd showed us a copy of a letter dated September 18, 1975 written by Mr. Paul L. Westberg, U. S. Attorney, Boise, Idaho to Mr. Boyd regarding our visit (a copy of Mr. Westberg's letter was not available to NEIC prior to our visit). Mr. Boyd emphasized that our request for information, in his opinion, went beyond that indicated in Mr. Westberg's letter. To determine if there was a misunderstanding, he called Mr. Westberg who, from our end of the conversation, apparently agreed with Mr. Boyd's interpretation. Mr. Boyd stated that it would be no problem for us to have a tour of the plants, but no flow diagrams, no details on process operations, and no detailed technical information would be provided. This information would need to be requested in writing. Mr. Boyd indicated he expected his clients would have to answer technical questions and provide technical documents at a later date but it could not be now. He stated the Bunker Hill Company employees accompanying us through the plants could answer general questions.

The following is a discussion of the information received and of our observations during the plant survey.

GENERAL

The Bunker Hill Company operates an integrated mining, milling and smeltering complex near Kellogg, Idaho [Figure 1]. Ore from mines owned by the Company is mined through the Kellogg tunnel and other smaller workings and milled in the Bunker Hill concentrator where flotation concentrates of lead and zinc sulfide are prepared. These concentrates, together with concentrates purchased from outside sources, are fed into a lead smelter and a zinc plant to produce lead and zinc metals. By-product metals of cadmium, gold, silver and copper are also recovered. Sulfuric acid from the metallurgical operations is used to produce phosphoric acid and phosphate fertilizer at a phosphate complex operated as a joint venture between Bunker Hill Company and Stauffer Chemical Company. Details on the various process operations are discussed herein.

PROCESS OPERATIONS

Mining

Mining activities are conducted over a vertical distance of approximately one mile along the Bunker Hill ore body. Mining is conducted on approximately 23 levels generally spaced 200 feet apart vertically. Haulage is predominantly through the Kellogg Tunnel (No. 9 level) which is the main haulage level for the mine. The lowest active level is about 1600 feet beneath sea level. Mine production at the rate of 2900 tons/day of ore takes place 5 days/week with weekends being devoted primarily to repair work. The mine consists of about 500 miles of drift of which approximately 200 miles are active. Other minor haulage is done through a portal in the Wardner area, where zinc ore which has previously been placed as "gob" in old silver workings is recovered. Silver ore is mined in the Crescent Mine upstream of Kellogg [Figure 1].

There appears to be a change in type of ore above and below Level 9, i.e., the Kellogg Tunnel level. The ore above Level 9 has high zinc and low lead content, while ore beneath the Kellogg Tunnel level is predominantly lead, with lower zinc content. About 1000 tons/day of high grade lead ore are mined.

Various mining techniques are employed in the Bunker Hill mine, depending on the strength of the rock and the over-burden pressure. Most of the mining is with cut-and-fill vertical stopping, utilizing "Bunker Hill square sets" with sand back-fill for subsidence prevention. Sand is derived from the sand fraction of the Bunker Hill mill tailings and is hydraulically transported and placed in the mine.

The Bunker Hill mine is the only mine in the Coeur d' Alene district having significant water inflows, i.e., continuous pumping is required.

According to company officials, it appears that most of this water inflow is in the area of old workings immediately under Milo Creek. A recent technical paper* discusses how Bunker Hill plans to prevent and intercept infiltration before it contacts mineralized rocks in the old stopped areas. Company officials did not provide any information on the implementation of these plans.

Wastewater from the mining activities originate from two sources: 1) the mine water inflow which is pumped from sumps to gravity drainage through the Kellogg portal; and 2) the water used in transporting the sand portion of the tailings back to the mine. This latter wastewater should be similar in chemical composition to that water discharged from the mill into the Central Impoundment Area (CIA). The wastewater leaving the Kellogg portal by gravity drainage enters a closed conduit and flows by gravity to the CIA where it enters through a port located in the center of the pond. The only access to the mine drainage channel is at the mouth of the Kellogg Tunnel. Company officials indicated there should be no other inflows into this line between the tunnel and the CIA. The flow from the tunnel varies in accord with weather conditions. Estimated flows of 2000-3000 gpm were given.

Milling

The Bunker Hill Company mill has a 2500 ton/day rated capacity. Mined ore is conveyed to primary crushers and thence into secondary crushers. Crushing takes place on two of the three shifts. Following crushing the material goes into storage and from there it is fed to the concentrator or flotation mill [Figure 1]. Further crushing is necessary and this is accomplished by grinding in four sections of 8' x 10' ball mills with spiral classifiers used to remove oversized particles. The fine particles are mixed with water into a slurry called pulp of approximately 50% solids.

Pulp from the spiral classifiers is first sent to lead flotation cells. Soda ash, sodium cyanide, zinc sulfate and xanthate are added and the lead sulfide particles floated out of the pulp. The company has a meter on the lead flotation circuit to monitor pH which is controlled with lime or soda ash. At the time of the tour, this circuit was being operated at a pH slightly less than 7.

The lead sulfide froth is concentrated in a thickener with the thickener underflow going to vacuum filters. The filtered lead concentrate with about 9% moisture is conveyed to railroad cars for transport to the lead smelter.

The underflow from the lead flotation cells is conditioned with copper sulfate and lime and pumped into zinc flotation cells. The froth collects zinc sulfide minerals which are floated off and then enters a thickener from which the underflow goes to a vacuum filter. The filtered zinc

*Trexler, B. D., Jr.; Ralston, D. R.; Renison, W. R.; and Williams, R. E., July 1, 1974, "The Hydrology of an Acid Mine Drainage Problem" provided at the American Water Resources National Symposium on Water Resource Problems Related to Mining, Colorado School of Mines, July 1-3, 1974.

concentrate, with about 12% moisture, subsequently is conveyed to railroad cars and to the zinc plant for further processing.

The underflow from the zinc flotation cells flow to a series of four cyclones. These cyclones make a size separation of approximately 200 mesh. The sand fraction is returned to the Kellogg Tunnel as a 50% slurry for backfilling operations. According to company officials the Bunker Hill Mine is one of the few mines in the district which has excess sandfill because only the lower stopes are backfilled. Slimes from the cyclones drop to a sump and are pumped to discharge ports around the periphery of the CIA.

Water from the flotation air compressors and from cooling serves as the primary source for milling operations. This compressor and cooling water is obtained from wells along the South Fork of the Coeur d' Alene River and from a spring known as Miners Slough. The make-up water for the concentrator, approximately 1/2 gallon/minute/ton of ore, is obtained from the Central Treatment Plant (CTP) located adjacent to the CIA.

Waste from the concentrator consists of the slimes, sand, concentrate filtrate and concentrate thickener overflows. There is approximately a 50% split of slimes and sand in the cyclone with the latter material as mentioned previously being pumped to the mine. The slimes are conveyed to the CIA using concentrator tailings water and discharged with thickener overflows. During sandfilling operations the flow from the concentrator building to the CIA was given as 450 gpm increasing to 800 gpm when sandfilling is not in progress. The company analyzes the slimes to ascertain the loss of metals values but, according to company officials, no attempt is made to determine exact volumes of slimes or thickener overflows. The only point of access for representative sampling of the combined wastewater flow appeared to be the peripheral discharge into the CIA.

Lead Smelter

The Bunker Hill lead smelter operations were described by company officials as being typical. The smelter has a rated capacity of 130,000 tons of metallic lead. Concentrate from the Bunker Hill concentrator discussed above and concentrates purchased on a custom basis from sources within and outside the United States are the feed stock for the smelter. The concentrates are blended to achieve a uniform mixture. A charge, consisting of concentrate, crushed ore, ferric flux and limestone is prepared and pelletized. This mixture is conveyed to a sintering plant for sulfur removal and for agglomeration. In the first phase of sintering a high strength SO_2 gas (estimated volume of 35,000 cfm) is formed. This gas is fed to the sulphuric acid plant. Low strength SO_2 gas of similar volume is produced in the final phase of sintering. This gas is discharged directly to the environment after wet scrubbing.

Following sintering, the material is mixed with coke and conveyed to the top of the Bunker Hill blast furnaces. The oxygen enriched blast furnace has a rated capacity of 400 tons/day with the final product being generally in the form of 100 lb/ingots. Lead bouillon is continuously tapped off the furnace with intermittent tapping of the slag for subsequent zinc fuming and recovery.

The lead bouillon is refined through a number of steps to produce pure lead metal and to remove other valuable metals. The first step is cooling, which causes the copper to rise to the surface where it is skimmed off as a copper dross for further smelting in a reverberatory furnace.

After removal of the copper dross, arsenic and antimony are removed through oxidation in the next skimming. Electric furnaces treat this material to produce an arsenical-antimonical lead known as hard lead, which is sold to ammunition, battery and chemical manufacturers.

Gold and silver, in the form of gold and silver drosses, are then removed through the addition of zinc metal. These drosses are refined with the zinc being recovered and returned to the circuit. Pure gold and silver are sold as by-products. The final step in lead purification is vacuum dezincing, in which zinc is evaporated from the lead and deposited as metallic zinc on a condenser.

Primary water uses in the smelter are cooling waters for the blast furnace (jacket cooling water), fuming plant and the acid plant and gas scrubber waters.

Little information was furnished on the water pollution aspects of the lead smelter. A small lime treatment plant treats water from the lead smelter. This facility was not visited during the reconnaissance. From the lime plant, wastewaters are discharged into Sweeney Pond which is an irregular-shaped settling basin, an estimated 300 feet in length and 40 to 50 feet wide [Figure 1]. The overflow from this pond is recycled to the smelter or pumped directly to the CIA through a 12" PVC pipeline.

Flow from Sweeney Pond is over a concrete wall about 6" thick into a wet well. Four pumps (capacity 1250 gpm each) are available to handle the Sweeney Pond effluent. Effluent is pumped to the smelter as required, with the remainder going into the CIA. The estimated average rate of flow to the CIA was stated to be 3500 gpm.

The company monitors the Sweeney Pond discharge for process control purposes using a continuous sampling device. Samples are analyzed for lead, zinc and cadmium and the pH is determined.

In the recent past, excess flows from Sweeney Pond entered a concrete channel and flowed several hundred feet to discharge into Silver King Creek (Government Gulch). This discharge known as Outfall 003 has been "eliminated". However, it was learned that Sweeney Pond effluent has discharged through this outfall line on a number of occasions the past year. At the time of the reconnaissance, it was observed that the downstream end of this discharge line was full of debris. Flow through this line is still possible and, in the event of pump failure, could occur.

Zinc Plant

The zinc plant receives both zinc concentrates from the Bunker Hill concentrator and concentrates purchased from other sources, including foreign concentrates. Processing within the zinc plant starts with a sulfuric acid leach of those zinc concentrates containing sufficient dolomitic material (magnesium-calcium carbonate) to require magnesium or calcium removal before zinc recovery. The treated concentrates and other low-carbonate zinc concentrates are then comingled and sent to roasters. Bunker Hill operates four flash roasters and one suspended bed roaster. The company has two acid plants at the zinc plant. One acid plant treats the effluent from the four flash roasters; the other treats the discharge from the suspended bed roaster. Each acid plant has the capacity of producing 350 tons/day of sulfuric acid.

The calcine from the roasters is cooled in water-jacketed screw conveyors. This cooled calcine is then leached with spent electrolite from the zinc cell electrowinning rooms and the leach solution is filtered through Burt* Filters. Residue from the leach solution contains lead, gold and silver, which is shipped to the lead smelter for further refining.

The Burt Filter filtrate is treated by zinc dust for removal of cadmium, cobalt, nickel, antimony and arsenic. Following each stage of zinc dust addition, the solution is filtered. Residue from the first two filtrations is processed through the cadmium plant. Residues from the other stages are returned to the first purification stage. The cadmium-rich residue is leached with spent electrolyte and copper is filtered out. Cadmium is precipitated with zinc dust and redissolved. A pure cadmium metal is recovered by electrolysis.

The purified zinc solution is pumped to the cell room, where zinc is recovered on aluminum cathodes. These cathodes are mechanically pulled and the zinc is stripped. The stripped zinc is then sent to primary melting furnaces for casting of 99.99+% pure zinc metal.

Wastewaters generated during zinc plant operations are piped to a settling pond located on the opposite side of Silver King Creek. This pond is an estimated 150 feet long by 75 feet wide. The origin of all wastewaters entering this pond was not disclosed but probably is largely from pretreatment operations in the zinc plant. The pond surface was covered with what appeared to be zinc sulfide concentrate and the discharge from the pond contained high concentrations of solids. The pond discharge, which is piped to the CIA, represents the major input of zinc to the CIA and the biggest single metallurgical loss to the company. Sludge from the settling pond is recycled back to the zinc plant.

*Trade name.

According to company officials, all electrolytic solutions are recycled within the zinc plant. However, there are a number of floor drains which can receive wastes and spills from these operations.

The SO_2 gas resulting from the zinc roasters is captured and cleaned with Peabody scrubbers and is then converted to sulfuric acid. The wastewaters from the scrubbers discharge into a drop basin at the end of the zinc settling pond. The scrubber waters mix with the pond overflow and both are carried in a closed conduit to the CIA, discharging freely into the latter through a 12" PVC pipe. According to a company official, the Peabody scrubber wastes have a SO_2 concentration of about 2.5%. An estimate of the scrubber flows was stated as 100-150 gpm. The flow leaves the pond over a broad-crested rectangular weir about 2 feet in width with side contractions of about 3 inches. Just downstream of the weir is a fiberglass bar-screen. No flow figures or monitoring data were provided by the company during the visit.

Silver King Creek flows through the plant property and for a distance of several hundred yards the channel is covered with heavy timber. The channel is 4 feet deep by about 5 feet wide. During the time of the reconnaissance, the flow in Silver King Creek was very small. Most of Silver King Creek water is diverted into the main company reservoir about 3/4 of a mile upstream. Waste flows, if any, enter Silver King Creek under the covered section and were not determined during the visit. Studies by EPA, Region X, have shown increases in zinc, cadmium and copper in this reach of the stream from a point above the covered channel to just above Outfall 004. According to a company official, there are no longer any discharges into Silver King Creek, except for those permitted (i.e., Outfall 004).

There was ample physical evidence that highly corrosive wastes had been discharged to the concrete lined Silver King Creek channel in the past. Heavy rust-colored stains were also in evidence along the channel bottom.

The company has placed a rectangular, broad-crested weir across Silver King Creek just upstream of Outfall 004. This flow measurement device was required by a Section 308 request dated February 20, 1975 which, in addition, required heavy metals sampling and flow measurement at numerous locations and discharge points along Silver King Creek upstream and downstream of the zinc plant.

Cooling water from the sulfuric acid production facilities is the only NPDES permitted discharge from the zinc plant. Permit limitations on this discharge allow no increase in the lead and zinc concentrations across the heat exchangers (i.e., cooling towers). The cooling waters flow through a series of drop manholes to eventually discharge to Silver King Creek. It was noted during the reconnaissance that other flows described by a company official as cooling water enters the discharge line. However, no data on the quality and quantity of these other inputs were available.

At the point where the discharge line (004) enters Silver King Creek, a weir box approximately 36 inches wide has been constructed of 2 inch lumber. The wastewater passes over a rectangular broad-crested suppressed weir which is used to measure the flow continuously.

The 004 discharge is also the subject of an EPA Compliance Order dated September 17, 1974, in which the company was ordered to locate and measure the total quantities of flow and heavy metals contributing to the 004 discharge line. The order emphasized that all contaminated wastewaters formerly going to Outfall 004 were to be eliminated by May 1, 1974. A subsequent order dated October 21, 1974, ordered the company to segregate the contaminated wastewaters from 004 and discharge these to the CIA by October 31, 1974. In a letter dated February 13, 1975*, the company stated that waters entering Outfall 004 included blowdown from the acid plant cooling towers (flows vary from 200-900 gpm); mill water tank overflow and hillside runoff; overflow from the blowdown surge storage (20 gpm); runoff waters from grounds and building roofs (5 gpm estimated); roaster floor drains (approximately 50 gpm); cooling water overflows from the flash roaster calcine screw conveyors (100-200 gpm); leach floor drain (75 gpm); road drain which diverts storm water; cooling water from zinc coating operations (average 20 gpm); #5 roaster cooling water (average 50 gpm); rectifier cooling waters (200-300 gpm); and groundwater inflow into an older section of existing concrete line. The company in a subsequent letter dated April 28, 1975, described its plan for eliminating zinc containing wastewaters from Outfall 004. However, the EPA review of the plan pointed out that the plan did not address itself to a reduction of other heavy metals, particularly cadmium. The 004 discharge has been found to be the major point source of cadmium into the South Fork of the Coeur d' Alene River.

Phosphate Plant

The phosphate plant is located immediately downstream of the zinc plant on Silver King Creek. The plant operates three shifts and is presently operating a 10-days on, 4-days off schedule. Approximately 50 people are employed over the three-shift period. The primary products from this operation are phosphoric acid and pellet-type fertilizers of varying mixtures of nitrogen and phosphorus. Phosphate rock, anhydrous ammonia and sulfuric acid are the chief raw materials.

In the production of phosphoric acid, the sulfuric acid produced at the zinc plant is reacted with phosphate rock shipped from Southern Idaho or Wyoming. The reaction products, consisting of phosphoric acid and by-product gypsum, are separated by filtration on a tilting-pan filter. Gypsum is rinsed in a countercurrent flow with the strong rinse water used for sulfuric acid dilution. The gypsum slurry is transported to a closed portion of the CIA, utilizing contaminated water for slurry transport.

*Letter dated February 13, 1975, Mr. G. M. Baker, Vice President, Environmental Affairs Division, The Bunker Hill Company to Mr. Leonard A. Miller, Director, Enforcement Division, Region X, U. S. EPA.

The contaminated water is returned to the fertilizer plant for reuse in slurrying and as feed for evaporators and barometric condensers in the phosphoric acid circuit. Fresh water for the phosphate mill comes from the reservoir supplied directly by North Fork and South Fork Coeur d' Alene wells.

About 90% of the wastewaters generated in the phosphate plant come from the filter building, according to the plant superintendent. This includes condenser waters and other contaminated waters. The company's attempt to measure wastewater flow from the filter building using a Parshall flume proved unsuccessful because of the high velocity and turbulence at the point of attempted measurement.* Monitoring for process control is conducted on the discharge to the gypsum pond. At the monitoring point, all wastewaters, including sanitary wastes, are combined. The specific parameters monitored were not disclosed. The estimated flow figure provided was 1500 gpm to the gypsum pond.

The NPDES permit allows no discharges directly to Silver King Creek from the phosphate plant. Immediately downstream from the phosphate plant, wastewaters described as being from the sulfuric acid storage area enter a concrete box about 4 feet by 4 feet. Flow into the box is through a 26 inch concrete pipe, which showed evidence of carrying corrosive wastes as did the concrete box. Wastewater exits from the box through a 6 inch pipe, which discharges downstream into the closed conduit carrying zinc plant settling pond and Peabody scrubber wastewaters. Past surveys by EPA, Region X, indicated overflows from the concrete box have contributed zinc, cadmium and copper to Silver King Creek.

WASTE TREATMENT SYSTEM

Central Impoundment Area

As discussed earlier, wastewaters of varying quality and quantity from mining and milling operations, zinc plant operations after settling, phosphate plant operations and the lead smelter after lime treatment and settling (via Sweeney Pond) are discharged to the Central Impoundment Area at various locations. The CIA is constructed on the alluvium of the South Fork Coeur d' Alene River flood plain. The dikes are constructed of mine waste rock with a peripheral discharge of concentrator slimes intended as a sealant. Initially the CIA was constructed to settle concentrator solids, but other process wastes now enter it. A portion of the CIA has been diked off and serves as a closed system for settling phosphate plant wastes, i.e., primarily gypsum solids. The decanted contaminated water is returned to the phosphate plant.

---

*Open portion of the discharge channel just outside the filter building. The open channel is at the bottom of a dry well about 20 feet by 5 feet covered with heavy planking. The well is about 8 feet deep. A fiberglass Parshall flume was placed just downstream from the discharge pipe leaving the building. Approach conditions proved unsatisfactory for this device.

The CIA was originally constructed to discharge directly to the South Fork of the Coeur d' Alene River through two decant structures. This practice was discontinued when the Central Treatment Plant was constructed to treat the CIA decant. A visible examination of the toe of the CIA embankment, adjacent to and parallel to the South Fork Coeur d' Alene River, showed that leakage or piping around the two abandoned decant lines is highly probable. An investigation of these probable seepage areas should be undertaken to determine the quality and quantity of seepage from the CIA.

Little is known about the presence and amount of radioactivity and fluorides contained in the wastewaters generated at Bunker Hill. Ground waters in the vicinity of the CIA and wells along the South Fork of the Coeur d' Alene River downstream need to be examined for these pollutants and their ultimate fate.

The CIA is also the site of ferric oxide flux quarrying. The quarrying site is east of the phosphate pond and is protected from flooding by dikes.

Smelter slag is conveyed in slurry form to waste piles located on the west end of the CIA. At the time of this reconnaissance, there were no surface discharges apparent from the slag waste pile area. Surface discharges from the slag pile have been observed and monitored during EPA, Region X, surveys.

Central Treatment Plant

The decant from the CIA is piped to the Central Treatment Plant (CTP) located southeast of the CIA, adjacent to the mill concentrator building. The decant is first mixed with lime slurry to aid precipitation. This process is followed by aeration for iron oxidation. Provision has been made for flocculation immediately following aeration, but this process was not in operation at the time of the reconnaissance. The present flow pattern is from the aeration tank to the larger thickener (4.5 million gallons) and then to a large concrete basin. Solids collected in the thickeners are presently returned to the tailings pond. Effluent leaves the concrete basin over a 6-1/2 foot sharp-crested rectangular weir. Solids, presumably metal precipitates, were observed going over the weir.

The company monitors the CTP influent and effluent continuously for pH and flow. Continuous composite samples are collected at both locations.

Two small discharges were observed entering Bunker Creek from the south side upstream of the CTP discharge. The discharge furthest upstream of the latter discharge (about 300 yards) was oily and milky, similar in color to coolant liquids used in machine shops. The next discharge was clear and described by a company official as only hill drainage.

NPDES MONITORING REQUIREMENTS

The NPDES permit (issued September 30, 1973, expiration date June 30, 1976) contains effluent limitations [Table 1] on the following discharges:

1. CIA - Discharge from the Central Treatment Plant*;

2. 004 - Cooling water discharges from the primary smelting and refining of zinc; and

3. 008 - Discharge to Silver King Creek (Government Gulch) of excess water from the company reservoir. This is a three-basin reservoir supplied by wells located along the North and South Forks of the Coeur d' Alene River. The outside basins are supplied only with North Fork well water described as being of excellent quality. The outer basins overflow into the center basin which receives South Fork well water high in metals. The overflow to Silver King Creek is from the center basin and varies in quality depending on how much South Fork well water is pumped. The company plans to put the South Fork wells on standby, thus the overflow from the reservoir will be essentially North Fork well water.

The permit requires that drainage from the slag pile be blended with the CIA effluent prior to its discharge into the South Fork of the Coeur d' Alene River. Waste streams from the slag pile flow to Bunker Creek downstream of the CIA discharge, but upstream about 1/4 mile of the Bunker Creek mouth. The permit contains no limitations on the blended waste flows.

EPA COMPLIANCE MONITORING ACTIVITIES

Numerous receiving water and point source studies have been conducted since the issuance of the NPDES permit. These studies have revealed a number of unpermitted discharges contributing heavy metals to the South Fork of the Coeur d' Alene River. The studies have also shown heavy metal increase due to seepage in that reach of the South Fork Coeur d' Alene River running parallel to the Central Impoundment Area. Moreover, the studies have shown that the discharge from 004 is still contaminated and therefore was and still is in violation of the permit compliance schedule requiring all contaminated wastewaters to be removed from the 004 discharge by May 1, 1974. These study findings have been the basis for compliance orders, 308 requests and more recently, the filing of civil action against the Bunker Hill Company.

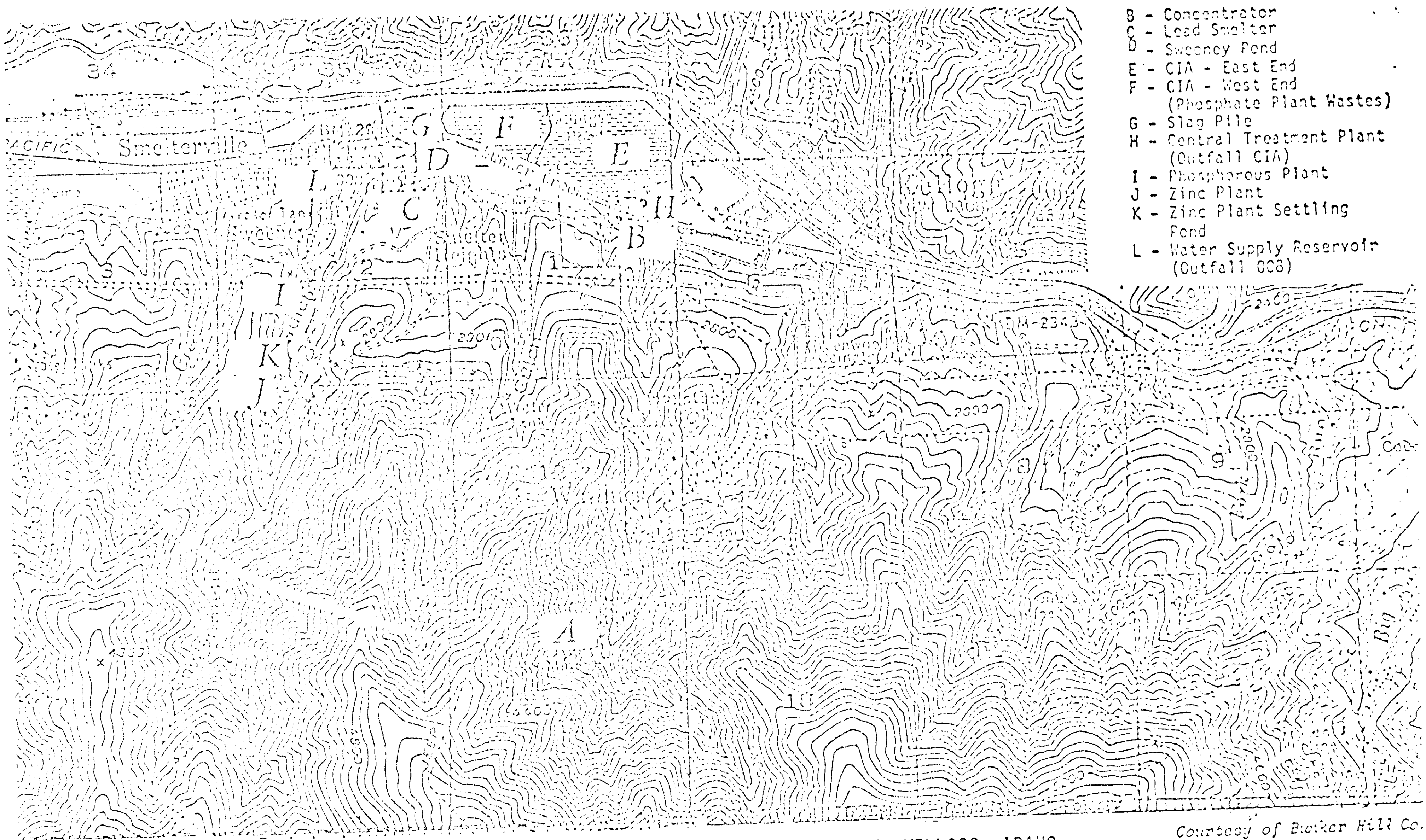
*The CIA outfall is defined to include a composite of all discharges from former discharge points designated as Outfalls 002, 003, 005, 006, 007 and the contaminated portion of the effluent formerly discharged through 004.

TABLE 1
Final Effluent Limitations for
NPDES Permitted Discharges, Bunker Hill Company
Kellogg, Idaho

		Discharge Limitation		Monitoring Requirements	
utfalls	Effluent Characteristic[1]	Daily Average	Daily Maximum	Measurement Frequency	Sample Type
CIA	Flow	40,500 cu m/d (10.7 MGD)	60,600 cu m/d (16.0 MGD)	Continuous	-
	Dissolved Zinc	0.85 mg/l (35 kg/day)	1.7 mg/l (70 kg/day)	Twice Weekly	24-hr composites
	Dissolved Cadmium) Dissolved Copper) Dissolved Lead)	Combined total not to exceed 1.0 mg/l (40.5 kg/day)	Combined total not to exceed 1.5 mg/l (60.7 kg/day)	Twice Weekly	24-hr composites
	Total Mercury	0.23 kg/day (0.5 lbs/day)	0.34 kg/day (0.75 lbs/day)	Twice Weekly	24-hr composites
	Suspended Solids	40 mg/l (1,620 kg/day)	60 mg/l (2,430 kg/day)	Daily	Grab
	Total Phosphorus	1.0 mg/l (40.5 kg/day)	1.5 mg/l (60.7 kg/day)	Twice Weekly	24-hr composites
14, 008	Flow	--	--	Monthly	-
	Dissolved Zinc[2])	No net increase above back-		Monthly	Grab
	Dissolved Lead)	ground		Monthly	Grab
	Temperature (004 only)	--	--	Monthly	Grab

he pH shall not be less than 6.0 nor greater than 9.0. The pH of the CIA discharge all be monitored continuously.

o net increase above background is interpreted to mean no increase in dissolved nc and lead across the heat exchanging unit. Samples to be taken at the inlet and tlet of unit for determining compliance.



Courtesy of Bunker Hill Co.

FIGURE 1. LOCATION MAP - BUNKER HILL COMPANY, KELLOGG, IDAHO

APPENDIX B

Chain of Custody Procedures

ENVIRONMENTAL PROTECTION AGENCY
Office Of Enforcement
NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
Building 53, Box 25227, Denver Federal Center
Denver, Colorado 80225

July 24, 1974

CHAIN OF CUSTODY PROCEDURES

General:

The evidence gathering portion of a survey should be characterized by the minimum number of samples required to give a fair representation of the effluent or water body from which taken. To the extent possible, the quantity of samples and sample locations will be determined prior to the survey.

Chain of Custody procedures must be followed to maintain the documentation necessary to trace sample possession from the time taken until the evidence is introduced into court. A sample is in your "custody" if:

1. It is in your actual physical possession, or
2. It is in your view, after being in your physical possession, or
3. It was in your physical possession and then you locked it up in a manner so that no one could tamper with it.

All survey participants will receive a copy of the survey study plan and will be knowledgeable of its contents prior to the survey. A pre-survey briefing will be held to re-appraise all participants of the survey objectives, sample locations and Chain of Custody procedures. After all Chain of Custody samples are collected, a de-briefing will be held in the field to determine adherence to Chain of Custody procedures and whether additional evidence type samples are required.

Sample Collection:

1. To the maximum extent achievable, as few people as possible should handle the sample.
2. Stream and effluent samples shall be obtained, using standard field sampling techniques.
3. Sample tags (Exhibit I) shall be securely attached to the sample container at the time the complete sample is collected and shall contain, at a minimum, the following information: station number, station location, date taken, time taken, type of sample, sequence number (first sample of the day - sequence No. 1, second sample - sequence No. 2, etc.), analyses required and samplers. The tags must be legibly filled out in ballpoint (waterproof ink).

Sample Collection (Continued)

4. Blank samples shall also be taken with preservatives which will be analyzed by the laboratory to exclude the possibility of container or preservative contamination.

5. A pre-printed, bound Field Data Record logbook shall be maintained to record field measurements and other pertinent information necessary to refresh the sampler's memory in the event he later takes the stand to testify regarding his action's during the evidence gathering activity. A separate set of field notebooks shall be maintained for each survey and stored in a safe place where they could be protected and accounted for at all times. Standard formats (Exhibits II and III) have been established to minimize field entries and include the date, time, survey, type of samples taken, volume of each sample, type of analysis, sample numbers, preservatives, sample location and field measurements such as temperature, conductivity, DO, pH, flow and any other pertinent information or observations. The entries shall be signed by the field sampler. The preparation and conservation of the field logbooks during the survey will be the responsibility of the survey coordinator. Once the survey is complete, field logs will be retained by the survey coordinator, or his designated representative, as a part of the permanent record.

6. The field sampler is responsible for the care and custody of the samples collected until properly dispatched to the receiving laboratory or turned over to an assigned custodian. He must assure that each container is in his physical possession or in his view at all times, or locked in such a place and manner that no one can tamper with it.

7. Colored slides or photographs should be taken which would visually show the outfall sample location and any water pollution to substantiate any conclusions of the investigation. Written documentatation on the back of the photo should include the signature of the photographer, time, date and site location. Photographs of this nature, which may be used as evidence, shall also be handled recognizing Chain of Custody procedures to prevent alteration.

Transfer of Custody and Shipment:

1. Samples will be accompanied by a Chain of Custody Record which includes the name of the survey, samplers signatures, station number, station location, date, time, type of sample, sequence number, number of containers and analyses required (Fig. IV). When turning over the possession of samples, the transferor and transferee will sign, date and time the sheet. This record sheet

allows transfer of custody of a group of samples in the field, to the mobile laboratory or when samples are dispatched to the NFIC - Denver laboratory. When transferring a portion of the samples identified on the sheet to the field mobile laboratory, the individual samples must be noted in the column with the signature of the person relinquishing the samples. The field laboratory person receiving the samples will acknowledge receipt by signing in the appropriate column.

2. The field custodian or field sampler, if a custodian has not been assigned, will have the responsibility of properly packaging and dispatching samples to the proper laboratory for analysis. The "Dispatch" portion of the Chain of Custody Record shall be properly filled out, dated, and signed.

3. Samples will be properly packed in shipment containers such as ice chests, to avoid breakage. The shipping containers will be padlocked for shipment to the receiving laboratory.

4. All packages will be accompanied by the Chain of Custody Record showing identification of the contents. The original will accompany the shipment, and a copy will be retained by the survey coordinator.

5. If sent by mail, register the package with return receipt requested. If sent by common carrier, a Government Bill of Lading should be obtained. Receipts from post offices and bills of lading will be retained as part of the permanent Chain of Custody documentation.

6. If samples are delivered to the laboratory when appropriate personnel are not there to receive them, the samples must be locked in a designated area within the laboratory in a manner so that no one can tamper with them. The same person must then return to the laboratory and unlock the samples and deliver custody to the appropriate custodian.

<u>Laboratory Custody Procedures:</u>

1. The laboratory shall designate a "sample custodian." An alternate will be designated in his absence. In addition, the laboratory shall set aside a "sample storage security area." This should be a clean, dry, isolated room which can be securely locked from the outside.

2. All samples should be handled by the minimum possible number of persons.

3. All incoming samples shall be received only by the custodian, who will indicate receipt by signing the Chain of Custody Record Sheet

accompanying the samples and retaining the sheet as permanent records. Couriers picking up samples at the airport, post office, etc. shall sign jointly with the laboratory custodian.

4. Immediately upon receipt, the custodian will place the sample in the sample room, which will be locked at all times except when samples are removed or replaced by the custodian. To the maximum extent possible, only the custodian should be permitted in the sample room.

5. The custodian shall ensure that heat-sensitive or light-sensitive samples, or other sample materials having unusual physical characteristics, or requiring special handling, are properly stored and maintained.

6. Only the custodian will distribute samples to personnel who are to perform tests.

7. The analyst will record in his laboratory notebook or analytical worksheet, identifying information describing the sample, the procedures performed and the results of the testing. The notes shall be dated and indicate who performed the tests. The notes shall be retained as a permanent record in the laboratory and should note any abnormalities which occurred during the testing procedure. In the event that the person who performed the tests is not available as a witness at time of trial, the government may be able to introduce the notes in evidence under the Federal Business Records Act.

8. Standard methods of laboratory analyses shall be used as described in the "Guidelines Establishing Test Procedures for Analysis of Pollutants," 38 F.R. 28758, October 16, 1973. If laboratory personnel deviate from standard procedures, they should be prepared to justify their decision during cross-examination.

9. Laboratory personnel are responsible for the care and custody of the sample once it is handed over to them and should be prepared to testify that the sample was in their possession and view or secured in the laboratory at all times from the moment it was received from the custodian until the tests were run.

10. Once the sample testing is completed, the unused portion of the sample together with all identifying tags and laboratory records, should be returned to the custodian. The returned tagged sample will be retained in the sample room until it is required for trial. Strip charts and other documentation of work will also be turned over to the custodian.

11. Samples, tags and laboratory records of tests may be destroyed only upon the order of the laboratory director, who will first confer with the Chief, Enforcement Specialist Office, to make certain that the information is no longer required or the samples have deteriorated.

EXHIBIT I

EPA, NATIONAL ENFORCEMENT INVESTIGATIONS CENTER

Station No.	Date	Time	Sequence No.

Station Location

_______ Grab

_______ Comp.

_______ BOD

_______ Solids

_______ COD

_______ Nutrients

_______ Metals

_______ Oil and Grease

_______ D.O.

_______ Bact.

_______ Other

Remarks/Preservative:

Samplers:

Front

ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

NATIONAL ENFORCEMENT INVESTIGATIONS CENTER

BUILDING 53, BOX 25227, DENVER FEDERAL CENTER

DENVER, COLORADO 80225

Back

EXHIBIT II

R ______________________________ SURVEY, PHASE ______, DATE ______________

PE OF SAMPLE ______________________

					ANALYSES REQUIRED																		
TATION UMBER	STATION DESCRIPTION	TOTAL VOLUME	TYPE CONTAINER	PRESERVATIVE	NUTRIENTS	BOD	COD	TOC	TOTAL SOLIDS	SUSPENDED SOLIDS	ALKALINITY	DO	pH*	CONDUCTIVITY*	TEMPERATURE*	TOTAL COLIFORM	FECAL COLIFORM	TURBIDITY	OIL AND GREASE	METALS	BACH	PESTICIDES	HERB

ARKS

Samplers: ______________________
____
____
____

FIELD DATA RECORD

STATION	NUMBER	DATE	TIME	TEMPERATURE °C	CONDUCTIVITY μmhos/cm	pH S.U.	D.O. mg/l	Gage Ht. or Flow Ft. or CFS

EXHIBIT IV

ENVIRONMENTAL PROTECTION AGENCY
Office Of Enforcement
NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
Building 53, Box 25227, Denver Federal Center
Denver, Colorado 80225

CHAIN OF CUSTODY RECORD

URVEY	SAMPLERS: (Signature)

STATION NUMBER	STATION LOCATION	DATE	TIME	SAMPLE TYPE: Water Comp.	SAMPLE TYPE: Water Grab.	SAMPLE TYPE: Air	SEQ. NO.	NO OF CONTAINERS	ANALYSIS REQUIRED

Relinquished by: (Signature)	Received by: (Signature)	Date/Time
Relinquished by: (Signature)	Received by: (Signature)	Date/Time
Relinquished by: (Signature)	Received by: (Signature)	Date/Time
Relinquished by: (Signature)	Received by Mobile Laboratory for field analysis: (Signature)	Date/Time
Dispatched by: (Signature) Date/Time	Received for Laboratory by:	Date/Time

Method of Shipment:

APPENDIX C

Drill Logs of
Bunker Hill Area
Observation Wells

EPA Na..onal Enforcement Investigation. Center
Drill Log

ect Number: 14-C
Number: C1
l Method: 8" hollow auger

Project: Bunker Hill C/A
Location: 10' W of ROW marker, SE Cor. Smelterville I 9[illegible]
Drill Crew: FHWA
Geologist: [illegible]
Date: 8/10/197[illegible]

th	Log	Water	Description
0			Started 0940
			Sand, gravelly, clayey, dark brown (tailings)
			Gravel, sandy, rounded to subrounded
			Sand, with some gravel, rounded to subrounded, clay
5			
			– includes cobbles @ 9' and deeper, as show
10			
			Tighter drilling, cemented, Broke sheer keys on [illegible]
			Boulder, drilling tight
15		16.4'	softer drilling, mostly sand, few cobbles
20		Perforated 1½" PVC	
			soft drilling
25			Sand, silty, med to fine, tan, rnd to subrnd.
30			

Set 20' of 1½" perf. PVC sched 80 &
10' of 1½" blank PVC

Surface Elev 2229.1'

EPA Na..onal Enforcement Investigations ..enter
Drill Log

..ject Number: 14-6 | Project: Bunker Hill C/A
..e Number: 02 | Location: 27' N. of Manhole # 26
..ll Method: 8" Hollow stem | Drill Crew: FI/WN | Geologist: [illegible]
Date: 5/10/1978(?)

Start 1450

..th	Log	Water	Description
..eet 0–5			Sand, gravelly, silty, clayey, brown (old tailings) [illegible] Old asphalt, fill
5–10			Sand and cobbles, silty, clayey, brown, subrounded gravel to (Main cobbles at depths as shown)
10–15		12.5' 3/4"	Softer@[illegible]
15–20			
20–25			Softer@2[illegible]
25–30			Few gravel[illegible]
30–35			Sand, fine, silty, tan to brown, clayey
..5–			

Perforated 1 1/2" PVC

Surface Elev. 2249.8'

EPA National Enforcement Investigations Center
Drill Log

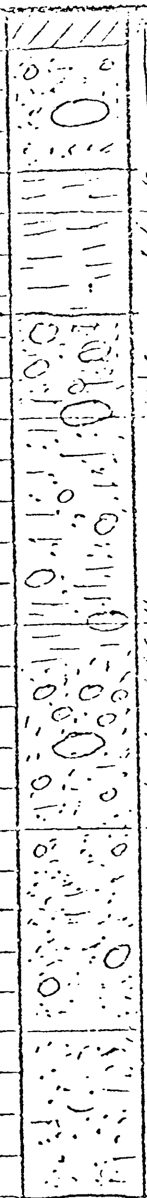
Project Number: 146
Hole Number: 03
Drill Method: 8" Hollow stem auger
Drill Crew: [illegible]

Project: Bunker Hill C/A
Location: 185' of manhole 26 S. of I-90
Geologist: [illegible]
Date: 8/10/1976
Start 1630

Depth	Log	Water	Description
Feet			Sand, gravelly, silty, clayey, brown, sub A to sub round.
5		blank	less gravel, more silt, darker brown (larger material @ depths as shown)
10		10' 8 3/4"	
15		perforated 1½"	
			Softer @ 17'6"
20			Set 10' perforated 1½" PVC sched 80 & 10' blank 1½" PVC
			Surface Elevation 2249.2

EPA National Enforcement Investigations Center
Drill Log

(Pro)ject Number: 146
(Hol)e Number: 04
(Dri)ll Method: 8" Hollow stem
Project: Bunker Hill CIA
Location: 325'N of manhole 21, S of I-90
Drill Crew: F11wd
Geologist: Rouse
Date: 8/11/1976
Start 0900 Finish 1015



(Dep)th	Log	Water	Description
0 ft		blank	Asphalt, subgrade of old highway
			Sand, silty, gravelly, clayey, brown, old tailings, large cobble; Gravel sub ∢, becomes subrnd.
5			Clay, silty, brown plastic, wet appears to include old tailings
			Gravel and cobbles, sandy, silty, clayey, tig
10		12 3/4" ▽	Material would have relatively lower permeability than similar layers in previous (01-03) holes. Less gravel with depth, more clay
15		Perforated 1½" csg	Gravel, round to subrnd, silty, sandy with occasional cobbles, some clay.
20			Sand, silty, clayey, with occasional gravel becoming less frequent with depth none below 24'
25			Sand, fine silty, tan, slightly clayey
=29			
30			Set 20' of perf. & 9' of 1½" PVC sched 80 csg.
			Surface elev. 2251.6'

EPA National Enforcement Investigations Center
Drill Log

Project Number: 146
Hole Number: 05
Drill Method: 8" hollow-stem auger
Project: Bunker Hill C/A
Location: 62.5' N. of Manhole 28
Drill Crew: FWHA
Geologist:
Date: 5/11/1978
Start 1030

Depth	Log	Water	Description
1			Silt, dark brown, clayey, sandy, gravelly, includes old tailings.
5			Sand & gravel, subrnd, clayey, silty, dark brown
10		5'	
			Tight
15			Softer @ 16'
20			Sand, fine, tan
25		Perforated 1½" PVC	
30			
35			
			Silt, greenish, tight
			Surface Elev 2247.3'

EPA National Enforcement Investigations Center
Drill Log

oject Number: 140
le Number: 06
ill Method: 8" Hollow stem
Drill Crew: FMWA
Project: Bunker Hill CIA
Location: 10' S. of manhole 28
Geologist: [illegible]
Date: 5/11/1978

pth	Log	Water	Description
feet			Silty, sandy, gravelly, clayey, dark brown includes old tailings.
5			Sand and gravel, silty; yellowish brown
9= 10		9'8"	
			Set perforated 1½" PVC csg.
			Standing water on surface in cattails, 10' South of hole.
			Surface Elev. 2250.4'

EPA National Enforcement Investigations Center
Drill Log

t Number: 146 | Project: Bunker Hill C/M
umber: 07 | Location: 55' S. of manhole 128
Method: 8" Hollow stem | Drill Crew: EMWR | Geologist: Rivas | Date: 8/11/1975

Depth	Log	Water	Description
			Sand & gravel, silty, clayey, dark brown includes old tailings near surface
			includes concrete from manhole fill
10		9 3/4"	
15		Blank	Softer @ 16 1/2'
			Silt, clayey, plastic tan to green
20		Perforated	
25			Set 10' perf & 17' blank 1 1/2" Sched 80 PVC
TD=29			Surface Elev 2250.6'
30			

EPA National Enforcement Investigations Center
Drill Log

ject Number: 146
e Number: 08
ll Method: 8" Hollow-stem
Project: Bunker Hill CIA
Location: 37.5' N. of steel fence post between [illegible]
Drill Crew: [illegible]
Geologist: [illegible]
Date: 8/11/197[illegible]

th	Log	Water	Description
		Blank	Silty, sandy, gravelly, clayey, dark brown, contains old tailings
5			
		"Slotted"	Clay; silty, blu-gray, plastic.
10			Sand & gravel, subrnd, silty, clayey, dark brown to gray.
15			
			Silt, sandy, tan — Set csg @ 17' no go[illegible]
20		Perforated	grades to
			silt, greenish, plastic
25			Hole filled to 17'; redrilled, set 20' perf & 8' blank 1½" csg
29			
30			Surface Elev 2251.0'

EPA Na..onal Enforcement Investigation. .enter
Drill Log

ject Number: 14C
e Number: 09
ll Method: 5" Yellowstone

Project: Bunker Hill C/A
Location: 52' N of Manhole 64, South of I-90
Drill Crew: FHWA
Geologist: Reece
Date:

th	Log	Water	Description
			Silt, clayey, sandy, gravelly, contains old tailings
5			
			Clay; dark gray, plastic
10		10	6½" Sand & gravel, silty, clayey, rnd to subrnd grave
15			
			[No gravel] Sand
20			
		perforated	Sand & gravel, clean, sand med to crs, subang
			Sand, fine, silty, tan
25			grading to
			silt, greenish
29 30			Hole flowed closed to 15', shook down, installed 20' perf. & 8' blank 1½" PVC
			Surface Elev 2254.1'

EPA National Enforcement Investigations Center
Drill Log

ject Number: 146
e Number: 10
ll Method: 8" Hollow-stem   Drill Crew: Ehwa

Project: Bunker Hill E/A
Location: 9' East manhole 29, S. of I-90
Geologist: Rowe
Date: 8/12-11/??

th	Log	Water	Description
et			Silt, sandy, clayey, gravelly, dark brown, contains old tailings
			Sand and gravel, silty, clayey, gravel subrnd, sand med to crs, subang
5			wet, with dark gray clay stringer, less gravel below 6.5'
			dark gray clay stringer
10		10'	cobbles
			Silt, dark gray, sandy, with rnd. gravel
15			
19.5'			~~Clay~~ tan, silty, fine sand, plastic
20			

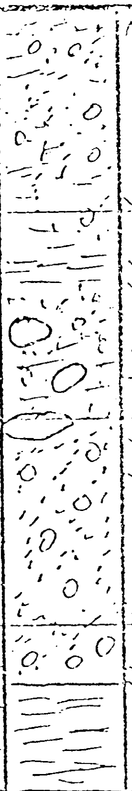
Set 9' of blank over 10' of perf. 1½" PVC, with 3 slots cut oppo. sand @ 5-6'

Surface Elev 2254.2'

EPA National Enforcement Investigations Center
Drill Log

Project Number: 146
Hole Number: 11
Drill Method: 8" Hollow stem

Project: Bunker Hill C/A
Location: on property line Rev. [illegible] E. of Hole 10
Drill Crew: [illegible]
Geologist: Reese
Date: 5/12/1976

Depth feet	Log	Water	Description
			Silty, sandy, gravelly, dark brown, inc old tailings
5		blank	
			Clay, dark gray, silty
			Sand and gravel, cobbles, slightly silty, gray gravel subrnd
		9'10"	
10			Becomes cleaner with depth
15		perforated	
			Clay, tan, plastic
=19			
20			Set 10' perf. & ~~10'~~ 9' blank 1½" PVC
			Surface Elev. 2254.6'

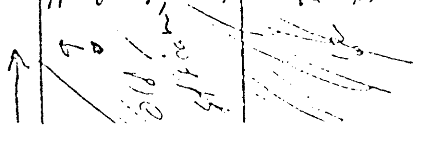
EPA National Enforcement Investigations Center
Drill Log

Project Number: 146
Hole Number: 12
Drill Method: 8" Hollow stem
Project: Bunker Hill CR
Location: 15' E. of S. end of [illegible]
Drill Crew: [illegible]
Geologist: [illegible]
Date: [illegible]

Between MI 296 14/30

Depth	Log	Water	Description
0		blank	Silt, sandy, gravelly, clayey, dark brown
			Clay, silty, tan Cobbles, fill?
			Clay, silty (old tailings, rust brown)
			Silt, sandy, with gravel & cobbles dark gray.
10		11.7' ▽	Sand & gravel, slightly silty, med sand
15			
20		Perforated	Clay, tan, slighty silty, plastic. softer @ 21'
25			
29			Set 20' perf. & 9' blank 1½" PVC
30			Surface Elev 2236.9'

Appears to be old stream channel thru holes 11 & 9, with banks marked by 10 & 12

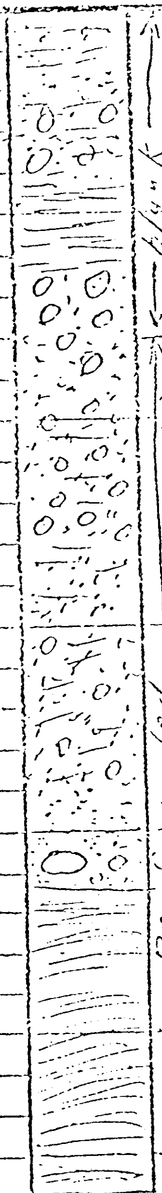


EPA Na onal Enforcement Investigation Center
Drill Log

ject Number: 14C
Number: 13
Method: 8" Hollow stem

Project: Bunker Hill CIA
Location: E of Steel Conc pst ... & Ilway ...
Drill Crew: FHWA
Geologist: Roc...
Date: 8/12/19..

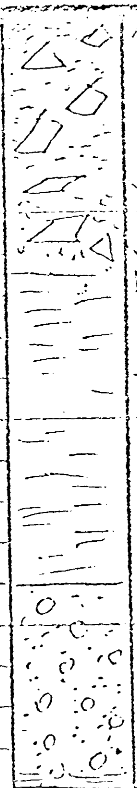
Depth (ft)	Log	Water	Description
ft			Silty, dark brown, sandy, clayey, old tailings, gravel
			silty, gravelly, sandy, dark brown
5		blank	Clay, dark gray, plastic
			Gravel, subrnd, sandy, slightly silty
10		12"	
			Sand, silty, dark gray — [Fast Drilling
15			with occas. gravel & cobbles as shown
20		perforated	[Easy Drill. — smear @ 21.5'
			Clay, tan, plastic, slightly silty
25			
29			Set 20' perf. & 8' blank 1½" csg PVC
30			Surface Elev 2235.6'



EPA Na onal Enforcement Investigations Center
Drill Log

ect Number: 14-6
Number: 19
l Method: 8" [illegible]

Project: Bunker Hill C/M
Location: At toe of C/M, South of highway [illegible]
Drill Crew: FWMA
Geologist: [illegible]
Date: 8/12/1976

h	Log	Water	Description
1		Blank	Fill; 4. cobbles to boulders in sand & gravel
			silt, clayey, sandy, very soft, wet dark gray. Flows like wet concrete
10		11.3' ∇	
15		Perforated	sand & gravel, silty
19			clay, tan, silty soft 18-19'
20			Set 10' perf & 9' blank 1½" sched 80 PVC csg.
			Surface Elev 2259.4

EPA Na onal Enforcement Investigations Center
Drill Log

ject Number: 146
e Number: 15
ll Method: 8" hollow stem

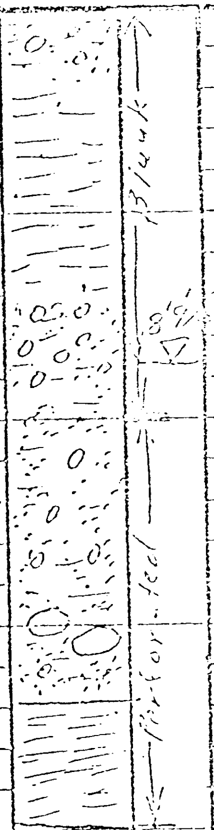
Project: Bunker Hill CIA
Location: 59' N of Washele 30, east of highway
Drill Crew: FHWA
Geologist: [illegible]
Date: 8/12/[illegible]

th	Log	Water	Description
?			Silt, sandy, gravelly, clayey, dark gray with cobbles as shown
5			Sand, red, rust brown, old tailings
			Clay, dark gray, plastic, silty, wet
10			Gravel, silty, sandy & Silty dark gray, sandy, with some round to subrnd gravel to cobbles.
15			Silt, gray, slightly sandy, clayey wet, plastic, flows like wet concrete
20		perforated	grades to clay, tan, plastic, very wet, slightly silty.
25			
29			Set 20' perf & 10' blank 1½" PVC csg. sank 1' below TD
30			
			Surface Elev 2256.5'

EPA Na onal Enforcement Investigations Center
Drill Log

ject Number: 146
Number: 16
ll Method: 8" Hollowstem
Project: Bunker Hill CIA
Location: 6' S of manhole 38
Drill Crew: FMWR
Geologist: Reese
Date:

th	Log	Water	Description
4			silty, gravelly, sandy, clayey
			Silt, dark gray, clayey, plastic
5			
			Sand & gravel, silty, dark gray
10			
15			
			Clay, tan, plastic
20			Set 10' perf. + 10' blank 1½" PVC csg
			Surface Elev 2255.0'



EPA National Enforcement Investigations Center
Drill Log

ject Number: 196
e Number: 17
ll Method: 8" Billerstan

Project: Bunker Hill CIA
Location: On ROW line, between MM 30 & 31 East of MM30

Drill Crew: FHWA

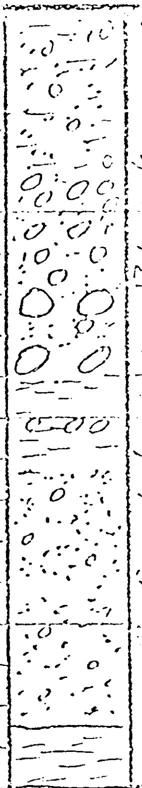
Geologist: [illegible]
Date: 5/12/1986

Depth	Log	Water	Description
1			Silty, sandy, gravelly, clayey, dark brown, inc. old tailings
5		8.5'	
			Clay, silty, light gray
10			Gravel and sand, lt. gray, silty, sand is med to crs, subang; gravel is subrnd stringers of gravel & sand interbedded
15			
			Clay, tan, plastic
19			
20			Set 10' perf & 9' blank 1½" PVC csg
			Surface Elev 2256.0'

Blank | Perf

EPA National Enforcement Investigations Center
Drill Log

Project Number: 146
Hole Number: 18
Drill Method: 8" Hollow-stem
Drill Crew: [illegible]
Project: Bunker Hill CIA
Location: 61' S. of manhole 31
Geologist: [illegible]
Date: 8/13/19[illegible]

Depth	Log	Water	Description
feet			Silt, dark brown, clayey, gravelly, sandy, contains old tailings
5			Gravel, sandy, slightly silty, subround; more cobbles w/ depth
		7' 8 3/4"	
10			silt, clayey, yellowish brown, sandy, with some gravel
			Sand, with some gravel, slightly silty, med to crs, sub [illegible]
15			
			Clay, tan, plastic
19			
20			Set 10' perf & 9' blank 1 1/2" PVC
			Surface Elev. 2256.6'
25			
30			

EPA Na onal Enforcement Investigations Center
Drill Log

ect Number: 14C
Number: 19
l Method: 8" Hollowstem
Drill Crew: Ellwk

Project: Bunker Hill CIA
Location: 27' N & 10' west of M132, 15' west edge
Geologist: Rouse
Date: 8/17/1976

h	Log	Water	Description
1		Blank	Sand, gravelly, silty, yellowish brown
			Silt, gray (old tailings)
			Gravel, sandy, silty
5		7' 4½"	Silt, gray, slightly sandy & gravelly
10		Perforated	Sand & gravel, silty, lt. brn. gravel subrnd, sand med - crs, sub ✓ to ✓
15			
20			Clay, tan, plastic, very soft
25			
30			Set 20' perf & 10' blank 1½" PVC csg
			Surface Elev 2260.0'

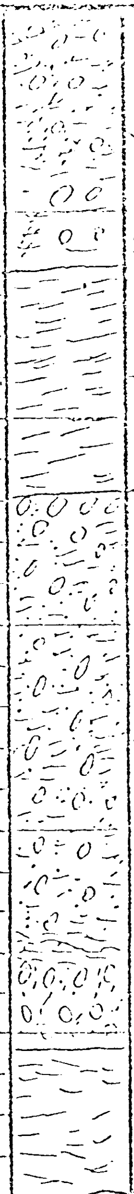
EPA Na. onal Enforcement Investigations enter
Drill Log

ject Number: 146
e Number: 20
ll Method: 8" Hollow-stem
Project: Bunker Hill C/A
Location: 8' S. of MH 33
Drill Crew: FHWA
Geologist: [illegible]
Date: 5/13/[illegible]

th	Log	Water	Description
0			Fill, silty, gravelly
			Silt, clayey, yellow, inc. old tailings
5			Clay, silty, dark gray, plastic
		Blank 7'6"	
10			Gravel, sandy, silty, subrnd
15			
			silt & sand stringers
20			
		Perforated	Clay, tan, plastic, very soft
25			
T.D.=29			
30			Set 20' perf & 9' blank 1½" PVC csg
			Surface Elev 2262.3'

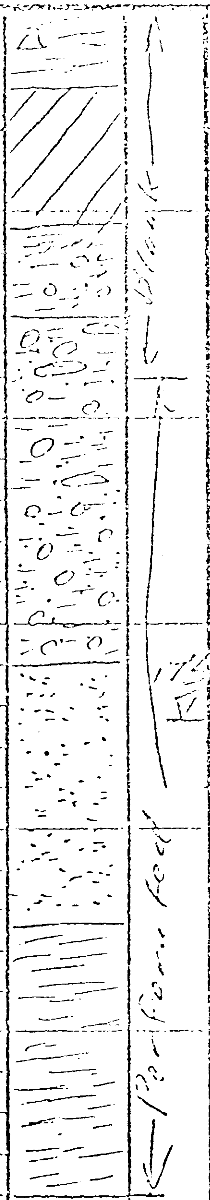
EPA Na onal Enforcement Investigations Center
Drill Log

ject Number: 14C
e Number: 21
ll Method: 8" Hollow-stem
Project: Bunker Hill CIA
Location: [illegible] N. of MH 35, NW of Bunker [illegible]
Drill Crew: TH[illegible]
Geologist: [illegible]
Date: 8/13/1980

th	Log	Water	Description
1		Blank	Silty, sandy, gravelly, clayey, brown
5			
			Silt, sandy, rust brown (old tailings)
10			
		14 3/4	Gravel, sandy, silty, subrnd.
		17	
15			
20		perforated	
			Silt stringer
25			
			Clay, tan, plastic, very soft
29			
30			Set 20' perf. & 9' blank 1½" PVC csg.
			Surface Elev 2271.9'

EPA National Enforcement Investigation Center
Drill Log

Project Number: 146
Hole Number: 22
Drill Method: [illegible]
Project: Bunker Hill Co.
Location: NW end of football field 5th [illegible] on ℄ of field, 2 posts SW of double-bar post.
Drill Crew: EMWA
Geologist: [illegible]
Date: 5/13/1986

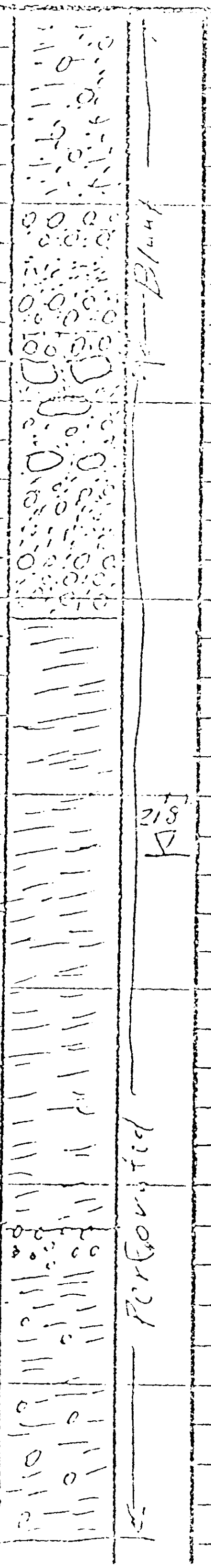
Depth (Feet)	Log / Water	Description
0		Fill; gravel, old tailings; silt
		Wood
5		
		Silt, dark brown, gravelly, clayey, sandy
		Gravel, sandy, silty, subrnd
10		
15		
		Sand, med to crs, sub ∡
20		grades to
		fine sand, tan
		Clay, tan, plastic, very soft — softer
25		
D=29		
30		Set 20' Perf & 9' blank 1¼" PVC
		Surface Elev 2277.3'

EPA National Enforcement Investigations Center
Drill Log

Project Number: 14-C
Hole Number: 23
Drill Method: 8" Hollowstem
Drill Crew: FHWA

Project: Bunker Hill CIA
Location: N. of old Bunker obs. well, near W.117
Geologist: Reese
Date: 8/13/86

Depth | Log | Water | Description



0 — Silty, gravelly, sandy; rust brown, old tailings

5 — Gravel, sandy, silty, brown, subround.
sand stringer
Cobbles as shown

10

sand stringer

15 — Silty, tan, clayey, plastic, with fine sand.

20

25

30 — Gravel, no recovery

35

Surface Elev 2232.2'

40

[illegible]

EPA Na onal Enforcement Investigations enter
Drill Log

oject Number: 146
e Number: 24
ll Method: [illegible]
Project: Bunker Hill C/A
Location: Bearing 325° from power pole behind * yellow house, 10 Diamond St.
Drill Crew: FHWA
Geologist: [illegible]
Date: 5/14/1976

th	Log	Water	Description
1		Blank	Fill
			Silt, sandy, gravelly, old tailings, wood
5			
			Gravel, sandy, silty, subround
10			
			Tight drilling
15			
			Sand, very fine, silty, tan, slightly clayey
20			
		24'5" SL	
25			Clay, silty, tan, plastic, soft
		perforated	
30			
			Gravel, no return
35			
			Cobbles, no return
			Surface Elev 2286.5'

EPA Na .onal Enforcement Investigation. Center
Drill Log

roject Number: 146
e Number: 25
ll Method: 5" Hollow-stem

Project: Bunker Hill CIA
Location: Bearing 240° towards 65 Gage
Drill Crew: FHWA

Geologist: Kane
Date: 8/14/1986

th	Log	Water	Description
eet			Fill; glass, wood, cans, etc
5		Blank	Gravel, silty, sandy, dark brown
10		9.6' ▽	
15		Perforated	Sand, med to crs, subR, with granules Grades into sand & gravel
=19' 20			Set 10' Perf & 9' Blank 1½" PVC
			Surface Elev 2276.5

EPA Na[illegible]onal Enforcement Investigation Center
Drill Log

[illegible]ect Number: 146
[illegible] Number: 2C
[illegible] Method: 5" [illegible]
west of slag pile, on S. edge of old road

Project: Bunker Hill C/R
Location: In line [illegible] 38' N. of [illegible] Bunker [illegible]
Drill Crew: [illegible]
Geologist: [illegible]
Date: 5/14/[illegible]

Depth	Log	Water	Description
1			Fill, silt, slag, etc.
			Gravel, silty
			Slag, black
5		Blank	
			Clay, dark gray, plastic, oily
			Gravel, sandy, silty, dark gray
		9.5'	
10			grades to
			Sand, med to crs, sub R, w/ occas. gravel
15			grades back to
			Sand & gravel, slightly silty
			gravel subrnd, sand med to crs, sub R
20		Perforated	
			Sand, fine, silty, tan
			grades to
25			slightly Silt, clayey, tan
29			
30			Set 20' Perf. & 8.5' Blank 1½" PVC [illegible]
			Surface Elev. 2241.6'