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WATER TABLE CONFIGURATION AND AQUIFER AND TAILINGS DISTRIBUTION,
COEUR D'ALENE VALLEY, IDAHO

A Thesis

Presented in Partial Fulfillment of the Requirements for the

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by

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AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

This thesis of Peter M. Norbeck for the Master of Science degree with major in Hydrology and titled "Water Table Configuration and Aquifer and Tailings Distribution, Coeur d'Alene Valley, Idaho" was reviewed in rough draft form by each Committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

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ABSTRACT

The Coeur d'Alene District has ranked high in the production of lead, zinc, silver, and antimony for the past 80 years. The published literature indicates that mining practices in the district historically have had a significant impact on the environment. Past practices have left extensive deposits of old tailings which have been reworked by man and streams, especially in the valley of the south fork of the Coeur d'Alene River. These old tailings as well as tailings from some present operations represent a potential source of pollution for ground water.

In order to gain greater insight into this potential source, the distribution of alluvium, tailings, and mixed tailings and alluvium was mapped using air photos and field observations. Seismic refraction and electrical resistivity depth soundings were utilized to interpret the thickness of the valley floor fill, which constitutes the aquifer supplying many of the wells in the area. A water-table map was prepared from water-level measurements at 88 locations. Ground-water was sampled at 49 locations, and the samples were analyzed for pH, electrical conductivity, calcium, cadmium, copper, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc.

The valley fill was found to thicken westward from 30 feet near Wallace to 414 feet near Rose Lake. The water-table map indicates that the main stem of the Coeur d'Alene River is gaining water from the ground-water system. Additional water-level measurements are needed east of Kingston before it can be determined whether the south fork is gaining or losing. High heavy-metal concentrations in the valley of the south fork can be correlated with geochemical anomalies, jig tailings deposits,

tailings ponds, and metal processing plants. Low pH, high conductivity, and high concentrations of cadmium, antimony, zinc, and several other ions were noted in industrial wells adjacent to the Bunker Hill tailings pond near Smelterville.

INTRODUCTION

Since the advent of mining in the Coeur d'Alene Mining District of north Idaho in the late 1800's, various waste products, including tailings, mine waters, and sewage, have been discharged into the streams and onto the flood plains of the area. Since 1968 most waste material, including sewage from Kellogg, has gone into tailings ponds. The effect of leakage from these tailings ponds and leaching of old jig tailings distributed on the valley floor upon ground-water quality along the Coeur d'Alene River has not been evaluated; however, several studies of the pollution of surface waters and the sources of this pollution have been conducted. This study concentrates on the ground water.

Objectives

This study is one of a series of studies concerned with ground- and surface-water pollution resulting from waste disposal practices (both industrial and domestic) in the Coeur d'Alene Mining District. The ultimate objective of these studies is to evaluate quantitatively and qualitatively the status of the pollution problem, recommend corrective measures for existing undesirable conditions and practices, and formulate guidelines to prevent their recurrence. To assist in the achievement of these objectives, this study was initiated to map the distribution of tailings, define the aquifer and water-table configuration, and provide an overview of ground-water quality.

It was hoped that correlation of these data would allow sources of ground-water pollution to be identified.

Setting

The study area is located in north Idaho and includes the valleys of the main stem and south fork of the Coeur d'Alene River from near the community of Rose Lake to the vicinity of Wallace (Plate 1, Appendix I). This area lies within the Bitterroot Range of the Rocky Mountains. Terrain is generally rugged with relief between valley floors and adjacent ridges ranging from about 1,000 to 4,000 feet. Valleys are steep sided and narrow; flats rarely exceed one mile in width. Ridge crests are generally accordant and range in altitude from approximately 4,000 feet near Rose Lake to about 6,000 feet near Wallace. The main stem and south fork of the Coeur d'Alene River and most of the larger tributary streams flow throughout the year, but many smaller streams dry up in late summer (Hobbs, et al., 1965, p. 5).

The Coeur d'Alene Mining District along the south fork of the Coeur d'Alene River in the eastern portion of the study area has ranked high in the production of lead, zinc, silver, and antimony for the past 80 years. In 1968, the district produced 57 percent of the total mineral production for the state of Idaho, and Idaho is ranked first nationally in the production of silver and antimony, second in lead, and third in zinc. In addition, there are several lumber operations in the area, although they serve mainly the mining industry (Mink, et al., 1971, p. 3).

The population of the drainage basin of the south fork is approximately 17,850, mostly in three cities and several smaller communities and housing developments. The population along the main stem to Rose Lake is about 1,000 (Mink, et al., 1971, p. 2).

Agriculture and lumber are the main industries in that portion of the area along the main stem of the Coeur d'Alene River. Much of the bottom land in the main valley and tributary valleys, as well as some of the lower ridges, is cultivated for hay and pasture for cattle.

Climate and Vegetation

The climate is highly seasonal and is generally typical of the climate of the western slope of the northern Rocky Mountains (Hobbs, et al., 1965, p. 6). Precipitation ranges from less than 30 inches in the western part of the area to more than 40 inches per year, most of which occurs as snowfall during the winter (Idaho Bureau of Mines and Geology, 1964, p. 258). Rain commonly occurs in the early fall and spring. Temperatures can range from below zero in the winter to 100°F in the summer. At higher elevations a snow cover several feet thick persists from late fall to late spring, but at the lower elevations in the western part of the area snow may melt away between storms (Hobbs, et al., 1965, p. 6).

Vegetation is abundant throughout most of the area, but the type and amount is subject to the effects of local variations (both natural and man-made) in environment. During the early years of mining, large stands of timber near the major mines were stripped for timbers and fuel. In 1910, the area was swept by a forest fire which burned much of the remaining forest cover, leaving only local patches in deep ravines. Most of the logged-off and burned-over areas are now covered by brush and second growth (Hobbs, et al., 1965, p. 6).

Slopes commonly support growths of various species of pine, fir, hemlock, larch, cedar, spruce, and aspen. Willow, cottonwood, and alder are common in the valley flats and along perennial stream courses. Thickets of alder and willow flourish on ridge slopes where the soils are moist. Several varieties of brushy plants, ranging in abundance from sparse growths on dry slopes to dense thickets in moist areas, are found throughout the area and grasses flourish in open areas.

Previous Investigations

Owing to the economic importance of the mineralization in the Coeur d'Alene District, many geologic studies of the area have been published over the past 70 years. Among the more important early studies were the works of Ransome and Calkins (1908) and Umpleby and Jones (1928). The Idaho Bureau of Mines and Geology published a study by A. L. Anderson in 1940. Like the earlier two studies, it was concerned with the geology and mineralization of the district. A Ph.D. dissertation by Dort (1954) discussed glaciation. The most comprehensive report on the geology and mineralization of the district is the work of Hobbs, Griggs, Wallace, and Campbell (1965).

In recent years several geochemical surveys have been conducted in the Coeur d'Alene District. A reconnaissance geochemical soil survey by Canney (1959) was designed to assess zinc and lead distribution, with special attention given to the detection of contamination from smelter fumes. High concentrations of lead and zinc observed near the smelter at Smelterville and the zinc plant in Government Gulch were interpreted as indicating that these plants were sources of contamination. In most cases, concentrations were higher in the upper six inches of soil than below six inches. Kennedy (1960) studied soil and botanical geochemistry in order to evaluate the feasibility of using geochemical techniques in prospecting for copper, lead, zinc, antimony, and tungsten. Sampling was limited primarily to areas where veins are known to crop out at the surface. Background concentrations were found to be 21 ppm (parts per million) lead in soil and rocks, 100 ppm zinc in soil, 44 ppm zinc in rocks, 24 ppm copper in soil, and 13 ppm copper in rocks. Average concentrations of these metals in a limited number of stream-sediment samples were observed to be 40 ppm lead, 76 ppm zinc, and 45 ppm copper. A U.S. Geological Survey open-file report by Gott, et al. (1969), contains maps showing the geochemical distribution of silver, antimony, tellurium, cadmium, copper, zinc, and arsenic in soils and rocks of the mining district. Of special note with regard to this study are anomalously high concentrations of antimony and cadmium in Belt Series rocks between Kellogg and Osburn and anomalously high values of antimony, cadmium, copper, and zinc in rocks south of the valley between Big Creek and Wallace. Anomalous concentrations of antimony, cadmium, copper, and zinc in soils reflect in a general way the patterns noted by Canney (1959) for lead and zinc. Johnson (1971) conducted a trace-element study of Belt Supergroup rocks with the objective of determining a diagnostic suite of elements for each Belt Supergroup formation. Mean concentrations of copper, manganese, lead, and zinc are summarized in Table 3 (Appendix II). In general, the highest mean concentrations of these elements are found in rocks of the Prichard, St. Regis, and Wallace formations. Rocks of these formations crop out along the north and south sides of the valley of the south fork.

The pollution of the south fork and main stem of the Coeur d'Alene River has likewise received much attention. Kemmerer, Bovard, and Boorman (1923) conducted a biological and chemical study of Coeur d'Alene Lake during the years 1911 to 1913. They noted that the silt-laden waters of the Coeur d'Alene River could be traced far out into the lake. Ellis (1940) investigated various aspects of the pollution of the Coeur d'Alene River and adjacent bodies of water by mine wastes. He found that the waters of the south fork and main stem were toxic to native varieties of fish and plankton. Extensive deposits of tailings were found in the river channels and along the banks (Ellis, 1940, pp. 10-11). Finer fractions of tailings were found deposited over areas of the valley floor subject to periodic flooding and over virtually the entire bottom of Coeur d'Alene Lake (Ellis, 1940, p. 28).

In 1962, a group consisting of various communities and mining companies in the area hired the consulting firm of Cornell, Howland, Hayes, and Merryfield (1964) to study mine, industrial, and domestic waste disposal in the basin of the south fork of the Coeur d'Alene River. The firm completed its report in 1964, outlining various sources of pollution in the area and suggesting various means of dealing with these waste materials.

The Idaho Department of Health conducted a biological survey of the Coeur d'Alene River system in 1962 and has gathered coliform bacteria data at several stations since 1968 (Mink, et al., 1971, p. 8).

A study by Mink, Williams, and Wallace published in 1971 was concerned with the effect of industrial and, to a lesser extent, domestic effluents on surface-water quality of the basin. Monthly samples were taken at 34 points selected to bracket suspected sources of pollution. In addition, ground water was sampled from four wells in the area. A concentration of 12.9 ppm zinc was observed in well 48N 4E 18ddb near Osburn and 1.1 ppm zinc was observed in well 49N 2E 32dad near Pinehurst

(Mink, et al., 1971, p. 20). See Plate 2 (Appendix I) for an explanation of the well-numbering scheme.

Galbraith (1971) presents analyses of ground water sampled from within tailings piles. The results are summarized in Table 2, Appendix II.

GEOLOGY

Geologic History

The Coeur d'Alene District lies at the intersection of an anticlinal arch of geosynclinal Belt sediments and a west-northwest trending major structural zone of weakness known as the Lewis and Clark Line. Belt sediments are Precambrian in age and consist mainly of quartzites, argillites, and dolomites deposited in a north-northwest trending geosynclinal basin which was apparently centered to the east of the mining district (Hobbs, et al., 1965, pp. 1-16). The area has probably been a positive landmass since Late Cambrian time. Belt rocks are characterized by dull tones of green, red, yellow, and gray (Hobbs, et al., 1965, p. 14). The Osburn fault can be traced from the St. Regis-Superior region of western Montana almost to Spokane, Washington, and has been reported to have 16 miles of right lateral displacement (Hobbs, et al., 1965, p. 77). The fault lies south of the valley between Osburn and Cataldo, but north of the valley to the east of Osburn and to the west of Cataldo. Due to the complex Cenozoic history of the area, the Osburn fault only partially controls the position of the major drainage channels in the Coeur d'Alene District (Hobbs, et al., 1965, pp. 73-74).

Various types of igneous rock intrude Belt Series rocks as batholithic masses, stocks, dikes, and sills in north Idaho and adjacent areas. Typical are the gem stocks trending approximately north-northeast from Wallace.

The present-day topography of the Coeur d'Alene District appears to result from the dissection of a mature land surface. The downcutting was interrupted by at least two principal periods of aggradation and numerous subperiods (Hobbs, et al., 1965, p. 63). Evidence for various periods of aggradation includes terraces and gravel deposits which are present at elevations up to about 1,100 to 1,200 feet above the present valley floor.

Alluvium

Most streams are deeply entrenched in narrow, steep-walled valleys. The valley of the Coeur d'Alene River is the main exception. The river is presently aggraded with Coeur d'Alene Lake as the base level. West of Cataldo Mission the valley reaches a maximum width of about 1½ miles.

A period of aggradation represented by a series of terraces and gravel deposits about 700 feet above the present valley may have resulted from damming of the ancient Coeur d'Alene River by Columbia River basalts (Hobbs, et al., 1965, p. 64). These basalts form the plateaus on either side of the river at its mouth on the east end of Coeur d'Alene Lake. The course of the river prior to the stage represented by these gravels and terraces lay south of the present valley from about Big Creek to Cataldo (Dort, 1954, pp. 75-79, and Hobbs, et al., 1965, pp. 66-70). The river may have followed a course north of its present course between Silverton and Osburn and between Cataldo and Rose Lake.

Evidence for shifting of the course of the river includes the numerous places where the present valley is narrow and steep walled but still aggraded. This condition results from the superposition of the stream along a new channel prior to the present period of aggradation. Examples can be found 1-3/4 river miles west of Cataldo Mission, between Kingston and Cataldo and between Pinehurst and Kingston.

Stream piracy may have been a factor in relocating stream channels in some places; for example, between Pinehurst and Kingston. Plate 3(a) (Appendix I) illustrates a hypothetical drainage pattern for the area during a period of aggradation represented by terraces and gravel deposits about 300 feet above the present valley floor. Downcutting was reactivated through lowering of the stream's base level. Instead of cutting straight downward, the river was pushed toward the north (Plate 3(b), Appendix I), due to a greater sediment load from the south. The mountains to the south of the valley are thought to have been higher and steeper than the mountains north of the valley. Due to a higher rate of erosion, more sediments would be contributed by the mountains to the south, resulting in a partial filling of the valley from that direction (Dort, 1954, pp. 75-79). Eventually through a combination of headward erosion by stream A and its tributaries and crowding of the old south fork toward the north, stream A was able to capture the Coeur d'Alene River (Plate 3(c), Appendix I). The river then abandoned its original channel in favor of stream A's channel. During periods of erosion the river continued to be crowded to the north. This process may also have occurred between Kingston and Cataldo and west of the Cataldo Mission.

Unconsolidated sediments in the area include recent alluvium, glacial deposits, and older gravels and terrace gravels. Logs of wells (Appendix III), as well as numerous exposures of alluvium in the valley, indicate that the sediments are fairly coarse grained in the eastern end of the valley and in the valley of Canyon Creek. To the west the sediments become finer grained, with a large increase in the silt-size and smaller fractions. Near Wallace, the alluvium consists of unconsolidated sand and gravel with a considerable percentage (10 to 20 percent) of rounded to subrounded cobbles and boulders. Drillers' logs of wells near Smelterville report about 25 feet of sand and gravel overlying approximately 45 feet of "blue mud" with 10 feet or more of gravel below this. The sediments become better sorted and finer grained to the west. Below Cataldo they consist predominately of very fine sand, silt, and clay, although most water wells tap gravel layers. Hobbs, et al. (1965, p. 70), reported a well at Pinehurst which was drilled to 300 feet through mostly silt without hitting bedrock. They interpreted the record as indicating that much of the alluvium west of Pine Creek was deposited in ponded water. In places a thin soil has developed upon the sediments. Tailings have been intermixed with or have covered the soil in places (Plate 4, Envelope). Soil is distinguished from underlying material by the addition of organic material (humus) resulting from the growth and decay of plants.

The by-products of milling and concentration of ore consist mainly of finely ground rock (mostly quartz grains) called tailings. During the early years of mining the particle size of tailings ranged from microscopic to one-fourth inch. Large piles of these old tailings (termed "jig tailings" after the method of concentration) accumulated in the valley of the south fork and in the valleys of Canyon Creek, Ninemile Creek, and Big Creek (U.S. Bureau of Mines, 1943, pp. 374-379, and 1948, pp. 1506-1508). In addition, some jig tailings were discharged directly to streams and subsequently deposited over much of the valley floor along the south fork of the Coeur d'Alene River.

With the introduction of flotation concentration methods in the 1930's, the average grain size of tailings was greatly reduced to silt size and smaller particles. As a result, the streams of the area could carry tailings much farther before they settled out. Ellis (1940, p. 48) found evidence indicating that pollution (in the form of finely divided tailings and ions in solution) from the mining district had reached an irrigation project taking water from the Spokane River downstream from Coeur d'Alene Lake.

The increased efficiency of flotation concentration made it profitable to rework jig tailings. From 1943 to 1948 the Osburn Tailings Plant reworked several million tons of jig tailings from a large dump at Osburn. During this period most of the mills in the district were processing tailings from deposits along Canyon Creek, Ninemile Creek, Big Creek, and along the south fork near Mullan, Wallace, Osburn, Kellogg, and Smelterville (U.S. Bureau of Mines, 1943, pp. 374-379, and 1948, pp. 1506-1508). This resulted in the removal of much of the early tailings. The equipment used in the removal operation caused the remaining jig tailings to be extensively intermixed with the upper layer of alluvium.

Prior to the introduction of tailings ponds to the district in 1968, some companies discharged mill tailings directly into streams. Since that time, most tailings and other by-products of milling have gone into tailings ponds. The present periodic turbid condition of the waters of the south fork is caused by the inadequacy of some industrial and municipal waste disposal systems, by erosion of old tailings, and by highway construction projects.

At some places along the south fork deposits of jig tailings from early operations are exposed along the river banks and in places reach a thickness of about four feet. These deposits are often covered by a layer of surficial material resulting from the weathering of jig tailings and mixing with subsequent stream deposits which may also include tailings. These materials are often difficult to distinguish from natural alluvial deposits. Rock dust comprising the finer fractions of tailings has been deposited over almost the entire floor of the valleys of the main stem and south fork during periods of high water such as spring flooding (Ellis, 1940, p. 11).

Sand and gravel layers within the alluvium comprise the aquifer which supplies water to most of the domestic, municipal, and industrial wells in the area. Tailings which have been mixed with or deposited on the upper portion of the alluvium represent a potential source of groundwater pollution due to the action of the normal downward percolating surface and meteoric waters.

No faults in the area have been proven to cut the alluvium, although a few driller's logs report passing through the Osburn fault before reaching Belt rocks. Faulting and fracturing are no doubt important in their effect on the yield of wells drilled in Belt rocks, but these relations have not been examined in this study.

HYDROLOGY

Surface Water Hydrology

The south fork of the Coeur d'Alene River below Wallace is a relatively shallow and swift-flowing stream with a gradient of about 30 feet per mile. The gradient of the main stem is only about one foot per mile, as one might expect from the broader valley flats. The main stem is relatively deep (approximately 15 feet) and slow moving. According to river pilots' reports, the river below Cataldo Mission was deeper (about 30 to 50 feet) around the turn of the century (Ellis, 1940, p. 10). As previously mentioned, the streams of the area have received a heavy silt load (mine and mill tailings) since the advent of mining some 90 years ago, accounting for the significant filling of the channels of the main stem.

Ground-Water Hydrology

Based on currently available information, the sediments of the present valley constitute one primary aquifer consisting of sand and gravel near Wallace and grading into interbedded silt, clay, and sand near Rose Lake, over a distance of 33 miles. Wells drilled anywhere in the sediments of the main valley can provide adequate quantities of water for domestic purposes, although the water may be highly mineralized.

At one time almost all homesites in the area obtained their water from wells or developed springs, but most of the communities have converted to municipal supplies. One hundred and fifty domestic wells still in use were located at the beginning of the study. There are probably about that many more which were missed due to the short time available for locating wells. The number of abandoned domestic wells is estimated to be 200. There are approximately 30 industrial and municipal wells presently in use and probably about 20 more either not presently in use or abandoned.

About 15 high-capacity industrial wells have been drilled in the alluvium between Wallace and the confluence of the north fork and south fork. Most of them have been in use for several years with no problems such as excessive drawdown, water-quality fluctuations, or decreasing yield due to the formation around the well or the well perforations becoming clogged with silt. A municipal well with a capacity of 300 to 400 gallons per minute at Cataldo has been in service for several years. However, the community of Rose Lake was unable to obtain adequate quantities of water for a municipal supply from any of several wells and as a result has developed a spring. Well yields in the Rose Lake area are usually adequate for domestic purposes, although the ground water is usually mineralized.

This writer knows of only one location within the study area where water usually cannot be found in sufficient quantities for domestic supplies; this is a very small area in the north-central portion of sec. 25, T. 49 N., R. 1 W. The sediments in this area are older gravels with a high clay content, as indicated by drillers' logs (Appendix III).

Several domestic wells within the study area have been drilled in Belt rocks, but the yields are generally low, on the order of five gpm.

METHODS OF INVESTIGATION

Mapping Alluvium and Tailings

In order to delineate the aquifer in the vally of the main stem and south fork of the Coeur d'Alene River and to evaluate the pollution potential of tailings deposits in the area, the distribution of tailings was mapped. The results are presented on Plate 4 (Envelope). The following units were differentiated: alluvium (Qal), older gravels and terrace deposits (Tog), mill tailings (Qmt), mixed alluvium and tailings (Qat), and other mine wastes (Qmw).

Stereo air-photo coverage of the entire area at a scale of 1:15,000 was acquired from the U.S. Forest Service. Photos were studied in stereo in order to map the distribution of tailings, alluvium, mixed tailings and alluvium, and, where possible, older gravels. Air-photo interpretation was augmented with field observations. Tailings are readily distinguishable on air photos by tone, texture, shape, and often lack of vegetation. The contact between alluvium and Belt rocks is generally marked by an abrupt change in slope, often accompanied by changes in vegetation and tone.

The finer fraction of tailings (which can readily be carried in suspension) has been extensively distributed over the lowlands of the valleys of both the south fork and main stem during periods of high water (Ellis, 1940, pp. 10-11). It is not presently known whether this material has been deposited in significant amounts in the valley of the main stem except on the river banks. This wide and ill-defined distribution has been further complicated by changes in the natural drainage pattern of the area due to channeling by levee construction and railroad and highway fill.

Areas which, on air photos, appeared to have been subjected to periodic flooding were assumed to be mixed alluvium and tailings. The accuracy of this assumption and the significance of these deposits is unknown without a detailed sampling program, but the large volume of tailings available for erosion during flooding lends credence to the assumption.

The distribution of the older gravels and terrace deposits was for the most part taken from Hobbs, et al. (1965, Plates 1-5), and a preliminary map by Griggs, et al. (1968).

Depth Sounding

Electrical resistivity and seismic refraction depth sounding were used to determine the depth of the alluvium and thereby define, approximately, the dimensions of the aquifer at several locations in the study area. The relation between ground-water flow (Q, gal./day), properties of the aquifer (permeability, K, gal./day/ft.^{2}), cross-sectional flow area (A, ft.^{2}), and potential gradient (dh/dl, ft./ft.) is expressed by Darcy's law:

$$Q = (K)\ (A)\ (dh/dl)$$

The gradient can be determined from water-level measurements and permeability can be determined from pump tests or estimated roughly from the grain-size distribution of the sediments.

In order to evaluate the remaining term (cross-sectional flow area, A) on the right side of the equation, a program was laid out which called for seismic refraction depth determinations at several critical points along the valley of the main stem and south fork of the Coeur d'Alene River and one determination in the valley of Canyon Creek. Seven depth determinations at six points were completed (Plate 5, Envelope). An additional depth determination was made near the Page tailings pile east of Smelterville to assist in the planning of a future study. Seismic refraction was used for five depth determinations and electrical resistivity was used for three determinations.

Seismic Investigations

A 12-channel analog portable seismograph was used for obtaining depth information. Thirty-two shots were taken for five depth determinations. Detailed descriptions of the seismic refraction method have been given by Nettleton (1940, pp. 245-279), Jakosky (1940, pp. 751-766), and several others; therefore, only a brief explanation of the procedures used in this study will be given.

The apparatus consisted of an oscillograph, 12-channel amplifier, 550-foot geophone cable, 12 geophones, and a 50-foot shooting cable (Plate 7(a), Appendix I). The geophones and cable were laid out along a line centered over the point where the depth determination was desired (hereafter referred to as the depth point). Small charges (¼ to ½ sticks of dynamite) were set off at the end of the line by means of a circuit within the apparatus, which simultaneously produced a mark on the record (Plate 7(b), Appendix I). In order to average out the effects of dipping interfaces, shots were taken at each end of the geophone array. The arrival times (time for the energy to travel from the shot point to each geophone) from each shot were plotted against the distance from the shot point to each geophone on what is called a time-distance plot (Plate 7(c), Appendix I). Velocities of the subsurface layers were determined by taking the inverse of the slopes of straight lines drawn through the arrival times.

The velocities from shots at each end of the geophone array were averaged for the depth calculations.

Depths were calculated according to the following equations:

$$Z_0 = \frac{X_{c1}}{2}\sqrt{\frac{V_1 - V_0}{V_1 + V_0}}$$

$$Z_1 = \frac{1}{2}\left(T_{i2} - 2Z_0\frac{\sqrt{V_2^2 - V_0^2}}{V_2V_1}\right)\frac{V_2V_1}{\sqrt{V_2^2 - V_1^2}}$$

Where (Plate 7, Appendix I),

Z_0 = depth to base of surface material

Z_1 = depth to base of first layer

V_0 = velocity of sound in surface material

V_1 = velocity of sound in first layer

V_2 = velocity of sound in second layer

X_{c1} = distance at which energy refracted along V_0-V_1 interface arrives at same time as direct arrivals (Plate 7(c), Appendix I)

T_{i2} = zero distance intercept time for V_2 arrivals (Plate 7(c), Appendix I)

This procedure yields an accuracy of about ±10 percent for depth calculations. Nettleton (1940, pp. 267-271), Dobrin (1960, pp. 81-83), and several other writers have described procedures which yield higher degrees of precision by taking into account such factors as lateral variations in velocity or thickness. Because of the time-consuming calcuations required to obtain higher degrees of accuracy, it was decided that 10 percent accuracy was adequate for the purpose of this study.

The maximum depth determination which can be achieved with any type of refraction shooting depends on the spread length (distance from the shot point to the last geophone) and the subsurface velocity contrasts. The spread length required is inversely proportional to the magnitude of the velocity contrasts between subsurface lithologies (i.e., a given spread length will yield information from greater depth in areas where velocity contrasts are high than in areas where contrasts are low). As a rule of thumb, the spread length should be approximately three times the anticipated depth. The equipment used in this study allowed a total spread length of about 650 feet. By using a longer shooting cable it was possible to increase the spread length and obtain data from greater depths. In order to keep the resistance in the shooting circuit down, the longest shooting cable practical was about 230 feet or a total spread length of 880 feet. This spread length permitted depth determinations to a maximum depth of 250 to 300 feet.

Preliminary investigations with a single channel hammer seismograph indicated velocities in the alluvium of less than 1,000 feet/second above the water table and 3,000 to 8,000 feet/second below the water table, as compared to bedrock velocities greater than 6,000 feet/second. The lowest bedrock velocity encountered was 5,800 feet/second on a fresh (although highly fractured) exposure at a road cut. Bedrock velocities at the locations where depth determinations were made ranged from 11,400 feet/second to 17,500 feet/second, which is higher than the velocity noted above because at each depth point the bedrock was below the water table and probably less weathered.

Resistivity Investigations

At two locations (A-A' and B-B', Plate 5, Envelope) where the depth of the alluvium was found to be in excess of the working limit of the seismic equipment (approximately 250 feet), electrical resistivity was used. Various electrode configurations have been proposed by Wenner, Schlumberger, Lee, and others (Dobrin, 1960, pp. 349-352). For this study the Schlumberger configuration was used (Plate 8, Appendix I). The method has been described by Orellana and Moody (1966, pp. 1-8) who have also published master curves for various subsurface resistivity distributions and structural stituations.

Plate 5 (Envelope) shows diagrammatically the field layout used. The potential electrodes are kept at a constant spacing and apparent resistivity readings are taken at various current electrode spacings. The apparent resistivities thus obtained can then be plotted on logarithmic paper (6.35 cm/cycle), the resulting curve is matched with the appropriate master curve and the depth determined according to the procedure given by Orellana and Moody (1966, pp. 20-33).

Due to time considerations it was not possible to check the two methods (seismic and resistivity) against each other or against a known point, such as a well known to have bottomed in bedrock. Both methods, however, have been widely used and accepted for many years.

Water-Level Measurements

At the beginning of the study 150 wells and ponds in the area were located. Care was taken to eliminate developed springs and to select only ponds whose water level was representative of ground-water levels (no surface inflow or outflow). Some of these could not be relocated and some could not be measured owing to various reasons, including lack of access to the well for measurement or the owner changing his mind. A total of 86 water-level determinations were made.

The elevation of a reference point (usually a mark on the top of the casing) was determined by leveling from U. S. Geological Survey or Highway Department bench marks. Most lines were closed, either back to the starting point or to another bench mark, but time did not permit closing all traverses.

Water levels were measured in 86 wells and ponds during the last week in August 1971. Locations are shown on Plate 5 (Envelope, see Plate 2, Appendix I for well location scheme). Forty-six wells or ponds were in the main valley (valley of the south fork and main stem of the Coeur d'Alene River) and 36 were in tributary valleys. Two wells in tributary valleys and two ponds in the main valley were dry at the time the measurements were made.

A steel tape was used to measure the water levels with respect to the reference point. The measurements were converted to elevations and plotted on a map for contouring. Wells which were pumping at the time they were measured or which were known to have pumped sometime during the day are designated by the letter "P" following the water level. Water level contours were drawn, assuming that equipotential lines meet impermeable boundaries at right angles and that the alluvium and valley fill of the study are contained within impermeable valley sides and floor. This assumption must be made because of the paucity of data for an area of this size. The water level will be higher under areas of high elevation. Ground-water flow rates are low, so it takes considerable time for the water table under mountainous areas to reach equilibrium. Many years with no precipitation would be required for an area such as the Coeur d'Alene District to reach equilibrium.

Ground-Water Sampling and Analysis

Ground water was sampled to determine the ground-water quality of the area and to determine its relationship to any sources of pollution.

One-liter samples were taken from 49 of the 86 wells and ponds in which the water level was measured. The locations are shown on Plate 5 (Envelope). Most of the 37 wells and ponds which could not be sampled were swamps or industrial wells which had no tap or other provision for sampling. A few uncased abandoned wells and some ponds in the coarse sediments of the eastern part of the area were sampled.

Electrical conductivity (EC) and pH were measured in the field. In order to save time in setting up the instruments, five to 10 samples were collected and analyzed at the same time. To prevent the precipitation of some of the ions (such as iron) before a complete analysis could be run, 25 ml of nitric acid was added to each sample. The samples were analyzed for calcium, cadmium, copper, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc using the method of atomic absorption spectrometry.

RESULTS AND DISCUSSION

Alluvium and Tailings

The distribution of tailings and alluvium is presented on Plate 4 (Envelope). Alluvium (Qal) consists of stream-deposited sand, gravel, and silt. Older gravels and terrace deposits (Tog) are partially indurated stream deposits from prior periods of aggradation. Mill tailings (Qmt) include tailings ponds and tailings disposal sites which are still in use or which have been abandoned. Areas on which tailings have been deposited by streams are designated as mixed alluvium and tailings (Qat). Other mine wastes (Qmw) are mainly the waste rock dumps near mine portals.

The distribution of mixed alluvium and tailings is difficult to assess due to the effects of weathering and periodic reworking of the valley floor by flood waters. In addition, railroad and highway fill, communities, and farming have had a definite (but poorly understood) effect on these processes. Railroad and highway fill act as levees and alter the natural drainage pattern. Buildings, streets, lawns, etc., associated with communities cover any surface material which was not removed prior to construction. Plowing and irrigation of crops tend to redistribute the soil. Large areas of the valley floors of Canyon Creek, Ninemile Creek, and the South Fork of the Coeur d'Alene River are blanketed with jig tailings. In the valley of the main stem, tailings are evident on the river banks and some lowland areas.

A more detailed sampling program is needed to determine precisely the full extent and significance of mixed tailings and alluvium. Such a program should include augering with samples taken at various depths. The maximum sampling depth required would probably be about six feet adjacent to the river. Away from the river much shallower samples would be adequate. The samples should be analyzed geochemically and petrographically.

Results of Depth Soundings

Depth soundings yielded the following depths to bedrock:

Location (see Plate 5, Envelope)	Seismic (ft.)	Resistivity (ft.)
A-A' (see Plate 2, Appendix I)		414
C-C'	161	
D-D' (north of river)	196	
D-D' (south of river)		73
E-E'	156	
F-F'	36	
G-G'		90
I-I' (SE-NW)	29	
I-I' (NE-SW)	32	

Cross sections of the valley were constructed according to the following procedure: The depth point was plotted on a map; a line was drawn through the depth point at a right angle to the axis of the valley; elevations along this line of the valley sides (where Belt rocks crop out in every case), valley floor, and the depth from the valley floor to the base of the alluvium determined by depth sounding were plotted on graph paper; a curve (concave upward) was drawn between the valley sides in such a manner that it passed through the computed depth to the base of the alluvium at the depth point. The curve was also drawn so that it was consistent with any information about the configuration of the valley which had been reported by previous workers. The resultant cross sections are presented in Appendix I, Plates 9-17.

The seismic and resistivity field data are presented in Appendix I, Plates 31-41. These data are in the form of time-distance plots for the seismic data and resistivity master curves from Orellana and Moody (1966) superimposed on a plot of the field data for the resistivity soundings.

Depth points were located as near the center of the valley as possible. In some cases this was not feasible because of highways, railroads, swamps, or the river (for example, E-E' and G-G', Plate 5, Envelope).

Section A-A' (Plate 9, Appendix I) is located just off the western edge of Plate 5a (Envelope, for location of section A-A' see Plate 1, Appendix I) at a point approximately two miles west of the community of Rose Lake. Seismic depth sounding at location A-A' proved unsuccessful due to the spread length limitation to a maximum of 880 feet. Time-distance plots (Plate 31, Appendix I) yielded a velocity of about 1,000 feet/second to a depth of about seven feet (which is also the height of the bank above the river level) and 5,500 feet/second below that using a spread length as great as 880 feet. Resistivity sounding yielded a depth of 414 feet (Plates 32 and 9, Appendix I).

Location B-B' (Plate 5, Envelope) might be described as a gentle saddle located about two miles north of the Coeur d'Alene River between Rose Lake and Cataldo. Depth information was desired at that location to test the hypothesis that the Pre-Wisconsin river may have flowed through this area. In that case the old channel might be an aquifer and dissolved constituents could possibly enter and pass through the area. With an 880-foot spread, velocities of 5,500 feet/second and 7,450 feet/second were obtained. The maximum velocity obtained by shooting in the opposite direction was 5,980 feet/second (Plate 33, Appendix I). At location C-C' two miles to the southwest, an average bedrock velocity of 11,400 feet/second was obtained (Plate 34, Appendix I). At location D-D' three miles to the east, an average bedrock velocity of 16,700 feet/second was obtained (Plate 35, Appendix I). Based on these velocities the maximum velocity (7,450 feet/second) obtained at location B-B' was assumed to represent alluvium rather than Belt rocks. The velocity of 7,450 feet/second indicates that the alluvium in this area may consist of dense clay. This is consistent with drillers' logs for the area (see logs of wells 49N 1W 24ccc and 24dcc, Appendix III).

The writer was unable to obtain the landowner's permission to attempt a sounding in the field away from the fence along the edge of the Highway Department right-of-way. Resistivity cannot be used in the proximity of conductors such as wire fences, so no further information could be obtained. Although a depth estimate was not obtained, the results of the seismic investigations indicate that the depth to bedrock is in excess of 250 feet. This is more than 200 feet below the elevation of the water table in the main valley (about 2,130 feet, Plate 6, Envelope). Therefore, if an aquifer were present, ground water from the main valley could enter the area. Two wells in the area encountered Belt rocks at 68 feet (well 49N 1W 24ccc) and 40 feet (well 49N 1W 24dcc). These wells are located on the north flank of the saddle. There are no wells located properly to confirm the presence or absence of an aquifer. Although water level control is limited, the direction of the flow indicated by the water table contours (Plate 6, Envelope) is to the southeast and to the southwest away from the saddle. Therefore, contamination of the ground water of the area by way of ground water from the main valley is unlikely.

Section E-E' (Plate 12, Appendix I) at the mouth of Pine Creek indicates a constriction in the cross-sectional area of the aquifer, as compared with sections G-G' and L-L' (Plates 13 and 14, Appendix I). According to Darcy's Law (p. 16), the total flow (Q) through a porous medium is proportional to the product of permeability (K), cross-sectional area (A), and hydraulic gradient (dh/dl). Therefore, the constriction in the valley fill at Pine Creek will cause a reduction in ground-water flow past that point. This reduction in flow will cause the water level to rise upgradient from the constriction. The rise in water level above the constriction will increase the gradient across the constriction, thereby increasing the flow unless the water level intercepts the ground surface. If the water level intercepts the ground surface (as is the case for the valley of the south fork above Pine Creek), ground water will be discharged to springs, seeps, swamps, or streams. The swamps at either end of the Page tailings pond between Pine Creek and Smelterville are an expression of ground-water discharge caused by the restricted valley cross section at Pine Creek. Ground water is also discharged to the river.

Drillers' logs (see Appendix II) were available for most of the wells in the valley of the south fork immediately east of the Page Mine tailings pond near Smelterville. The log of well 49N 2E 34dac, which was drilled to bedrock, was used to construct section L-L' (Plate 14, Appendix I). For additional subsurface control, well 49N 2E 34dcd (not known to have reached bedrock) was projected about 1,000 feet east into the section.

Sections J-J' and K-K' (Plate 16, Appendix I) were drawn utilizing logs of test borings from a tailings pond foundation study (Dames and

Moore, 1971). The location of these borings is shown in Plate 5 (Envelope).

At location I-I' (Plate 5, Envelope) a 220-foot seismic spread oriented parallel to the valley yielded a bedrock depth of 32 feet which was much shallower than expected. A second spread, perpendicular to the first, was shot as a check, but it yielded a depth of 29 feet (Plates 17, 40, and 41, Appendix I). Bridge abutments in the constriction of the valley of Canyon Creek at the mouth of the valley are set on bedrock. This gives a bedrock depth of about five feet and a cross-sectional area of about 1,000 square feet for the valley fill. The cross-sectional area of the valley fill at section I-I' is about 50,000 square feet. Because of the restricted cross section at the mouth of the valley, almost all the ground-water flow in the aquifer (valley fill) is discharged to Canyon Creek.

Water Table Map

Water-table elevations were determined from water-level measurements in 86 wells and ponds and two stream gages. The elevations and water-table contours are presented on Plate 6 (Envelope). It is obvious that many more wells are needed to define precisely the water table in an aquifer with a configuration such as that of the valleys of the south fork and main stem of the Coeur d'Alene River. The aquifer is narrow and sinuous except for the relatively broad (up to 1½ miles wide) flats at Mission Flats west of the community of Cataldo and at Rose Lake. Somewhat narrower flats are found near Osburn, Kellogg, and Smelterville.

Wells which were pumping or which had been pumped on the day they were measured (designated by the letter "P" following the water level) are not included in the water table contours. In spite of leaving out these wells, the configuration of the 2,200-foot contour reflects the effect of pumping wells in the area.

More water-level control is needed to determine whether the south fork and main stem east of Cataldo are gaining or losing water with respect to the ground-water system. The water-table contours indicate the main stem west of Cataldo and the north fork near the confluence area are gaining (i.e., a component of the ground-water gradient is toward the river). Most of the ground-water flow toward the main stem is ground water from tributary valleys.

Water Quality

Ground water was sampled from 43 wells and six ponds (Plate 5, Envelope). The samples were analyzed for pH and electrical conductivity (EC) in the field, and for calcium, cadmium, copper, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc by means of atomic absorption spectrometry. Four of these wells were abandoned. Ion concentrations in the unused wells and ponds in the main valley (indicated by squares) fall within the range of concentrations found in the wells which are presently in use. The results of the analyses of these 49 samples are presented in Table 1 (Appendix II). Plates 18 through 30 (Appendix I) are plots of values of pH and electrical conductivity (EC) and concentrations of calcium, cadmium, copper, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc against distance (river miles above the river mouth at Harrison). pH, electrical conductivity (EC), and zinc concentration values are also plotted next to the well locations on Plate 5 (Envelope).

Seepages at several tailings accumulations in the area were sampled by Mink (Williams, 1972). Results of the analyses of these samples are presented in Table 2 (Appendix II). Table 3 (Appendix II) presents mean concentrations of various ions in Belt rocks of the Coeur d'Alene District which were reported by Johnson (1971, pp. 65-91). Recommended drinking-water standards as defined by the U.S. Public Health Service (American Water Works Association, 1971, pp. 45-47) are presented in Table 4 (Appendix II). Effluent limitations (U.S. Environmental Protection Agency, 1973) for discharge from the Bunker Hill complex at Smelterville and the Crescent Mine on Big Creek are given in Table 5 (Appendix II). Values in Table 5 are typical of limitations proposed for other operations in the district.

pH

Water for domestic, municipal, and most industrial uses should have a pH value near neutral (pH of 7.0). Acidic (low pH) or basic (high pH) waters are corrosive and unpalatable and require treatment for most uses. pH ranges for industrial uses may vary widely, depending on the type of process, plant design, and other variables. The U.S. Environmental Protection Agency (1973) has proposed limiting values of pH within the range of 6.0 to 8.5 (Table 5, Appendix II) for water discharged to the south fork of the Coeur d'Alene River.

The average value of pH is about 6.5 for ground water from the main valley and from tributary valleys (Plate 18, Appendix II). Mink (Williams, 1972) obtained values of 7.98 from a seepage at the Sunshine tailings pond at Big Creek, 5.20 and 3.69 at two seepages at the Bunker Hill tailings pond between Kellogg and Smelterville, 6.39 and 6.37 at seepages at the Page tailings pond (no longer in use) east of Smelterville, and 6.70 from a seepage at the large tailings accumulation at Mission Flats (Table 2, Appendix II). A value of 5.6 has been reported for ground water in tailings at the Mission Flats tailing piles (Galbraith, 1971, p. 52). High pH values at Big Creek are attributable to the effluent of an antimony plant, while the low values at the Bunker Hill pond are attributable to mine drainage (pH 3.33) and the effluent from a phosphoric acid plant which enters the tailings pond (pH 2.57) (Williams, 1972). Referring to Plate 18 (Appendix I), the pH values of about 5.4 at 41 miles are from heavily pumped industrial wells (48N 2E 1aad and 48N 2E 1aac, see Plate 5, Envelope) located near the discharge end of the Bunker Hill tailings pond. No reason is known for the high values at 29 and 33 miles. The value of 7.53 at 33 miles is from a flowing well one mile west of Kingston (49N 1E 35adc) and the values of 7.50 and 7.41 are from irrigation and stock wells in Hardy Gulch (49N 1E 19cac and 49N 1E 19cda).

Electrical Conductivity

Electrical conductivity (EC, expressed in micromhos at 25°C) is plotted against distance in Plate 19 (Appendix I). Total dissolved solids (TDS) can be estimated from EC by the formula

$$TDS = 0.7\ (EC)$$

where TDS is in parts per million and EC is the conductivity in micromhos at 25°C (Davis and Dewiest, 1966, p. 84). The recommended upper limit of TDS for drinking-water supplies is 500 ppm (Table 4, Appendix II) corresponding to a conductivity of 714 micromhos.

Conductivity decreases from an average value of 260 micromhos near Wallace to about 228 micromhos at Rose Lake. Anomalously high values are noted near Kellogg, Smelterville, and Cataldo. From Mission Flats eastward tailings accumulations and other by-products of mining and milling operations in addition to natural sources of ions contribute to the higher values of EC. Jig tailings are much in evidence east of Pine Creek. The heaviest deposits seem to be concentrated in the east end of the valley near Osburn. These tailings ranged in size up to one-fourth inch in diameter and thus settled out rapidly. Due to the inefficiency of the jig table concentration process, those tailings that have not been reworked contain significant amounts of metal ions.

Wells adjacent to the Bunker Hill tailings pond exhibit highest values of EC. These values may indicate that water from the tailings pond is entering the ground-water flow system.

The value of 9,320 micromhos was observed in an industrial well (48N 2E 34dcc) one-half mile west of the center of Smelterville, in an area of heavy ground-water pumping (Plate 6, Envelope). The most probable sources of dissolved constituents which cause the high values of EC are the Page tailings pond, a two- to three-foot layer of jig tailings covered by a few inches of surface material which is exposed in river banks along this section of the valley, leakage from the Bunker Hill pond, and infiltration of water draining from the zinc plant.

Another possible source of contamination for ground water in the valley of the south fork considered by Canney (1959, pp. 205-210) is smelter fumes, which he has shown to have affected the soil of the Coeur d'Alene District. Water percolating downward through this material may carry some of the ions contained in the fumes into the ground-water system

(Canney, 1959, pp. 208-209). The rise in electrical conductivity east of Osburn correlates with geochemical anomalies in Belt rocks south of the river which were reported by Gott, et al. (1969).

A value of 2,900 micromhos was obtained from a well (48N 1E 3bab) drilled in old gravels 2,300 feet south-southeast of the community of Cataldo. Although the well is located on a terrace about 16 feet above the valley floor, the water level in the well is compatible with the water table in the valley.

Reasons for the decline in EC from east to west include dilution by ground water from tributary valleys, filtration, ion exchange, and the restricted cross section at Pine Creek which causes ground water to discharge at this point. In the eastern end of the area where sediments are coarse and ground-water flow rates are relatively high, the decline in EC is fairly rapid. To the west, where the alluvium consists of finer material resulting in slower flow rates, the decline is much less pronounced.

Ion Centrations

Ion centrations in parts per million (ppm) plotted against distance for calcium, cadmium, copper, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc are presented in Plates 20 to 30 (Appendix I). Like EC (Plate 19, Appendix I), ion concentrations in general decrease from east to west. Exceptions are iron, no change; manganese, no recognizable trend; and sodium, which increases downstream. Cadmium, copper, lead, and antimony were detected at only a few locations throughout the area. Concentrations of ions in solution in ground water ordinarily increase with flow path length; i.e., the reverse of the situation in the Coeur d'Alene valley, except for sodium.

Considering only the main valley, anomalies for all the ions monitored in this study occur between Osburn and Pinehurst. Geochemical studies of the Coeur d'Alene Mining District by Johnson (1971, pp. 65-91), Gott, et al. (1969), and Canney (1959) have indicated above-normal concentrations of cadmium, copper, manganese, lead, antimony, zinc, and other ions in soils and rocks at several locations along the valley of the south fork. These geochemical anomalies may contribute ions to ground water.

Jig tailings have been deposited over much of the valley floor along the south fork. These tailings range in diameter up to one-fourth inch and still contain appreciable quantities of ore. Some of the ions contained in the ore may be leached by water percolating downward through the tailings toward the water table. It is interesting to note that all but three wells in the valley of the south fork between the east end of Osburn and Pine Creek contain high concentrations of zinc. Two wells with relatively low zinc concentrations are located at the mouths of tributary valleys (48N 3E 11bdd at the mouth of Prospect Gulch and 48N 3E 4ccc at the mouth of Elk Creek). Ground water from the fill of the tributary valleys may be entering these wells.

There are also three tailings ponds along the south fork which could contribute ions to ground water. These are the Sunshine tailings pond on Big Creek (48N 3E Sec 10), the Bunker Hill tailings pond between Kellogg and Smelterville (48N 2E Sec 1, 49N 2E Sec 35 and 36), and the Page Mine tailings pond one mile west of Smelterville (no longer in use, 48N 2E Sec 3 and 4, and 49N 2E Sec 33 and 34). The leaching potential of tailings has been demonstrated by several investigations (see Galbraith, 1971, p. 52, for example). Galbraith collected samples 10 feet below the surface of the Page pond and the tailings accumulation at Mission Flats.

Representative analyses of these samples are presented in Table 2, Appendix II. Sodium, calcium, and potassium compounds are among the reagents used in concentrating ores (Ellis, 1940, p. 35). Since these materials are not recovered, anomalous concentrations of them can be considered to be indicators of leaching of tailings or infiltration of mill waste water if no other sources are present. High concentrations of these ions are noted in ground water downgradient (west) of the Bunker Hill tailings pond (49N 2E 34dac1 north of Smelterville and 49N 2E 34dcc at the west end of Smelterville) and near the discharge (east) end of the pond (48N 2E 1aad and 48N 2E 1aac).

Sediments in much of the valley of the south fork are coarse grained, resulting in relatively high ground-water flow rates. Precipitation and surface water as well as water percolating downward from tailings may readily enter the ground-water system. Ground-water contamination is indicated by high concentrations of calcium, potassium, magnesium, sodium, manganese, and zinc in heavily pumped industrial wells. Generally high concentrations in samples collected in the valley of the south fork may be the result of tailings ponds, jig tailings, geochemical anomalies in the area, smelter fumes, or a combination of these. The latter seems most likely.

Tailings deposited by flood waters over much of the valley flats in the vicinity of Cataldo constitute a potential source of ground-water pollution. One well (49N 1E 33dcb, one-half mile west of Cataldo) sampled might confirm this hypothesis. The analysis of water from this well yielded high concentrations of calcium, magnesium, and zinc. More samples throughout the area are needed to determine the exact source of these and other ions.

Wells 48N 1E 3bab (2,300 feet south-southeast of the community of Cataldo), 49N 1E 5aac (3,000 feet south of the Cataldo Mission), 49N 1W 36cbb (3,600 feet northeast of the community of Dudley), 49N 1W 33cdd (1,800 feet north of the community of Rose Lake, along Highway 3), and 48N 1W 4baa (1,000 feet north of the community of Rose Lake, along Highway 3) were drilled in old gravels or Belt rocks. Even though the water levels in these wells represent the water table of the valley, the samples reveal that the water may be dissimilar to and supplied by a source separate from the ground water of the main valley. Owners of most of these wells have voiced complaints about the taste of the water and stained plumbing fixtures.

Only three wells (49N 1E 5aac, 3,000 feet south of the Cataldo Mission; 49N 1E 29dbd, at the mouth of Whiteman Gulch; and 49N 1W 23dca, one mile east of the Rose Lake junction) known to be drilled in the Belt rocks were sampled. Although they contain various ions, no correlation between wells could be made.

Ground water from several wells drilled in old gravels yielded 10 to 20 ppm sodium. Calcium, copper, iron, magnesium, antimony, and zinc were each noted in various wells in old gravels, but no pattern could be observed.

Comparison of the data in Table 1 (Appendix II) with recommended drinking water standards given in Table 4 (Appendix II) indicates that many wells in the study area have concentrations of various ions which exceed recommended maximum values. Some of these are industrial wells near potential pollution sources such as tailings ponds, but some are in the western part of the area in tributary valleys where pollution from mine or industrial wastes seems unlikely. Concentrations of iron and manganese in excess of the recommended limits are found in many domestic wells in the area. The observed concentrations of some of these ions may cause taste, odor, and staining of plumbing fixtures, but will probably not cause health problems. A high concentration of zinc (5.8 ppm) was found in well 49N 1W 34cba, one mile northeast of the community of Rose Lake. A filter designed to remove iron and other metal ions has been installed between the pressure tank and the house, but the sample was taken from a tap on the pump outlet in order to obtain a sample representative of ground water. In only one domestic well was there found a concentration of any ion in excess of the mandatory limits given in Table 4 (Appendix II). A concentration of 0.02 ppm cadmium was found in well 48N 3E 13bbb1, 1,300 feet west of the mouth of Terror Gulch. The owner (who claims to be in perfect health) was informed of the problem, but it is not known whether he has done anything about it.

Anomalously high concentrations of calcium, cadmium, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc are found in industrial wells (48N 4E 18ddb at Osburn, 48N 2E 1aad and 48N 2E 1aac at the southwest corner of the Bunker Hill tailings pond, and 49N 2E 34dcc at the west end of Smelterville) in the valley of the south fork. These wells contain concentrations of iron, manganese, or zinc exceeding recommended drinking-water standards and concentrations of lead and cadmium exceeding mandatory drinking-water standards. Ground water from industrial wells in the valley of the south fork is used for process water by various plants in the area and is of suitable quality for this use.

Ion concentrations in water from wells in tributary valleys, in general, follow the same trends that are observed in the main valley. Sufficient geochemical data are not available to permit correlation of high ion concentrations in ground water of tributary valleys with geochemical anomalies in soils and rocks. East of Pine Creek, considerable geochemical data exist but too few wells in tributary valleys were sampled to permit any conclusions to be drawn. Table 3 (Appendix II) contains mean concentrations of various ions for the formations of the Belt Supergroup rocks (Johnson, 1971, pp. 65-91). These data represent samples from just the mining district and may not be representative of the entire area of this study.

Wells in tributary valleys contained various ions, including potassium, iron, magnesium, manganese, sodium, and calcium. The source of this mineralization is apparently the aquifer material, whether it be soil, sediments, or weathered or fractured Belt rocks, in which the water is stored and transported.

Zinc Mass Transport

A computation was made of the amount of zinc transported by ground water through section L-L' at Smelterville (Plate 14, Appendix I). The section shows approximately 20 feet of sand and gravel overlying 35 to 55 feet of clay and a layer of sand, gravel, and boulders below this. Water levels in the near-surface sand and gravel layer (measured at 49N 2E 34dacl and 49N 2E 3bbd) are the same as water levels in the lower sand and gravel layer (49N 2E 34dbd, 34dbc, 34cbd, 34cda, 34cca, and 34dcc). This indicates an interconnection between the layers, possibly along the edges of the valley.

Walton (1962, pp. 67-68) reports a permeability of 8,100 gpd/ft.^{2} for a sand and gravel aquifer in Illinois. The permeability of the sediments in the valley of the south fork is probably slightly lower due to poorer sorting (larger fractions of fine material, cobbles, and boulders).

Therefore, the permeability of the sand and gravel layers in section L-L' was estimated to be 7,000 gpd/ft^2. The concentration of zinc was about 19 ppm in water sampled from the shallow gravel layer (49N 2E 34dacl) and 1.2 ppm in water sampled from the deeper gravel (49N 2E 34dcc). The cross-sectional flow area of the sand and gravel aquifers was estimated from section L-L' to be 87,000 square feet for the upper aquifer and 115,000 square feet for the lower aquifer. From Plate 6 (Envelope), the hydraulic gradient was estimated to be 0.0033 ft/ft. Substituting these figures in Darcy's Law (p. 16), the computed zinc mass transport through section L-L' was approximately 330 pounds/day at a total flow of 3,250,000 gallons/day in late August, 1971.

SUMMARY AND CONCLUSIONS

Alluvium, tailings, mine waste, terrace gravels, and mixed tailings and alluvium were mapped using air photos and field observations. Precise delineation of areas overlain by mixed tailings and alluvium is impossible without an expensive detailed sampling program, which would involve geochemical and petrographic analysis.

To determine the thickness of the valley fill, seismic refraction and electrical resistivity depth soundings were made at Canyon Creek 1½ miles above the mouth of the canyon, in the valley of the south fork at the mouth of Polaris Gulch, at the west end of the Page tailings pond west of Smelterville, at the mouth of Pine Creek, in the valley of the main stem one-half mile southwest of the community of Cataldo, one mile west of the mouth of Latour Creek, and two miles west of the community of Rose Lake. Depths to bedrock ranged from 30 feet near Wallace to 414 feet near Rose Lake. Depth information from these soundings and drillers' logs were used to construct cross sections of the valley.

Water levels were measured in 86 wells and ponds during the last week of August, 1971. A water-table map was drawn using water table elevations determined from these measurements and from two stream-gaging stations.

Ground-water samples from 49 locations were analyzed for pH, electrical conductivity (EC), calcium, cadmium, copper, iron, potassium, magnesium, manganese, sodium, lead, antimony, and zinc. pH, EC, and concentrations of these ions were plotted against distance (river miles above the mouth of the main stem at Harrison) so that concentration trends and sources of pollution could be recognized.

High concentrations of cadmium, copper, manganese, lead, antimony, and zinc in ground water from the valley of the south fork can be correlated with geochemical anomalies noted by previous workers (Johnson, 1971, Gott, et al., 1969, and Canney, 1959). West of Pine Creek, insufficient geochemical data exist to permit any conclusions to be drawn.

Extensive deposits of jig tailings which have been intermixed with alluvium in places are also found in the valley of the south fork. These deposits can contribute ions to ground water when they extend below the water table or come in contact with downward percolating meteoric water. High zinc concentrations in ground water from the valley of the south fork may be due to contamination from these old tailings deposits. More work needs to be done to assess the full pollution potential of mixtures of tailings and alluvium in the valleys of the south fork and main stem of the Coeur d'Alene River.

Several tailings ponds are presently in use in the valley of the south fork or in tributary valleys. Tailings are no longer being accumulated in the Page pond west of Smelterville or at Mission Flats west of Cataldo Mission. Wells adjacent to the Bunker Hill tailings pond at Smelterville exhibited low pH, high conductivity, and anomalously high concentrations of calcium, cadmium, potassium, magnesium, manganese, and zinc. The source of these ions could be seepage from the pond, pollution from jig tailings, or infiltration of waste water from the zinc plant (although the ditch carrying zinc-plant wastes past these wells was dry when they were sampled). A previous investigation (Galbraith, 1971) has shown that the extensive tailings deposit at Mission Flats has a deleterious effect on ground-water quality. Water-table contours indicate ground-water flow in the Mission Flats area is toward the river, so that domestic supplies are probably not affected.

Results of the depth sounding indicate that ground-water flow through the valley fill of the south fork will be limited by constricted valley cross sections west of Osburn and at the mouth of Pine Creek. Much of the ground-water flow through the relatively broad valley flats at Osburn, Kellogg, and Smelterville will be discharged to the south fork. The amount of zinc carried by ground water through a valley cross section at Smelterville was computed to be 330 pounds/day.

Water-table contours indicate the main stem and the north fork at Enaville are receiving ground water. The source of this recharge is ground-water flow from tributary valleys. Ion concentrations in ground water show a tendency to decrease from east to west, due to dilution by ground-water flow from tributary valleys and ground-water discharge to the river at points where the valley cross section is restricted.

Results of the analyses of 49 samples indicate that ground water from the valley of the south fork is unsuitable or of low quality for domestic use. Ground water from valleys tributary to the south fork is generally of good quality. Ground water from the valley of the main stem and valleys tributary to it is generally suitable for domestic use, although the water may be hard and may cause staining of plumbing fixtures.

REFERENCES

American Water Works Association, Inc., 1971, Water Quality and Treatment: New York, McGraw-Hill Book Company, Inc., 654 p.

Canney, F. C., 1959, Geochemical Study of Soil Contamination in the Coeur d'Alene District, Shoshone County, Idaho: A.I.M.E., S.M.E., Mining Engineering, Vol. II, No. 2, pp. 205-210.

Cornell, Howland, Hayes, and Merryfield, 1964, Mine, Industrial, and Domestic Waste Disposal Study for the South Fork Coeur d'Alene River: Engineers and Planners, Corvallis, Oregon, 102 p.

Dames and Moore, 1971, Report of Foundation Investigation Proposed Galena Tailings Dam Near Wallace, Idaho, for the American Smelting and Refining Company: Consulting Engineers in the Applied Earth Sciences, Seattle, Washington, 2 p.

Davis, S. N., and R. J. M. DeWiest, 1966, Hydrogeology: New York, John Wiley and Sons, Inc., 463 p.

Dobrin, M. B., 1960, Introduction to Geophysical Prospecting: New York, McGraw-Hill Book Company, Inc., 446 p.

Dort, Wakefield, Jr., 1954, Glaciation of the Coeur d'Alene District, Idaho: Stanford University, Ph.D. Thesis, 106 p.

Ellis, M. M., 1940, Pollution of the Coeur d'Alene River and Adjacent Waters by Mine Wastes: Special Scientific Report 1, U.S. Bureau of Fisheries, 61 p.

Galbraith, J. H., 1971, A Study of Mine Tailings and Associated Plants and Ground Water in the Coeur d'Alene District, Idaho: University of Idaho, M.S. Thesis, 138 p.

Gott, G. B., J. M. Botbol, T. M. Billings, and A. P. Pierce, 1969, Geochemical Abundance and Distribution of Nine Metals in Rocks and Soils of the Coeur d'Alene District, Shoshone County, Idaho: U.S. Geological Survey Open-File Report, 3 p.

Griggs, A. B., D. W. Baker, N. T. Zilka, and R. T. Tracy, 1968, Geologic Map of the Northeast Part of the Spokane 2° Quadrangle, Idaho and Montana: U.S. Geological Survey Open-File Map, 1 sheet.

Hobbs, S. W., A. B. Griggs, R. E. Wallace, and A. B. Campbell, 1965, Geology of the Coeur d'Alene District, Shoshone County, Idaho: U.S. Geological Survey Prof. Paper 478, 137 p.

Idaho Bureau of Mines and Geology, 1964, Mineral and Water Resources of Idaho: Committee on Interior and Insular Affairs, U.S. Senate, Special Report No. 1, 335 p.

Jakosky, J. J., 1940, Exploration Geophysics: Newport Beach, California, Trija Publishing Company, 1195 p.

Johnson, J. B., 1971, Geochemistry of Belt Supergroup Rocks, Coeur d'Alene District, Shoshone County, Idaho: University of Idaho, Ph.D. Thesis, 673 p.

Kemmerer, George, J. F. Bovard, and W. R. Boorman, 1923, Northwestern Lakes of the United States: Biological and Chemical Studies with Reference to Possibilities in Production of Fish: Bulletin of the Bureau of Fisheries, Washington, U. S. Government Printing Office, Vol. 39, No. 944, 138 p.

Kennedy, V. C., and S. W. Hobbs, 1961, Geochemical Studies in the Coeur d'Alene District, Shoshone County, Idaho: Washington, D. C., U. S. Government Printing Office, U. S. Geological Survey Bulletin 1098-A, 55 p.

Mink, L. L., R. E. Williams, and A. T. Wallace, 1971, Effect of Industrial and Domestic Effluents on the Water Quality of the Coeur d'Alene River Basin: Moscow, Idaho, Idaho Bureau of Mines and Geology Pamphlet 149, 130 p.

Nettleton, L. L., 1940, Geophysical Prospecting for Oil: New York, N. Y., McGraw Book Company, Inc., 444 p.

Orellana, Ernesto, and H. M. Moody, 1966, Master Tables and Curves for Vertical Electrical Sounding over Layered Structures: Madrid, Spain, Interciencia, 125 p.

U. S. Bureau of Mines, 1943, Minerals Yearbook: U. S. Department of the Interior, 1626 p.

U. S. Bureau of Mines, 1948, Minerals Yearbook: U. S. Department of the Interior, 1652 p.

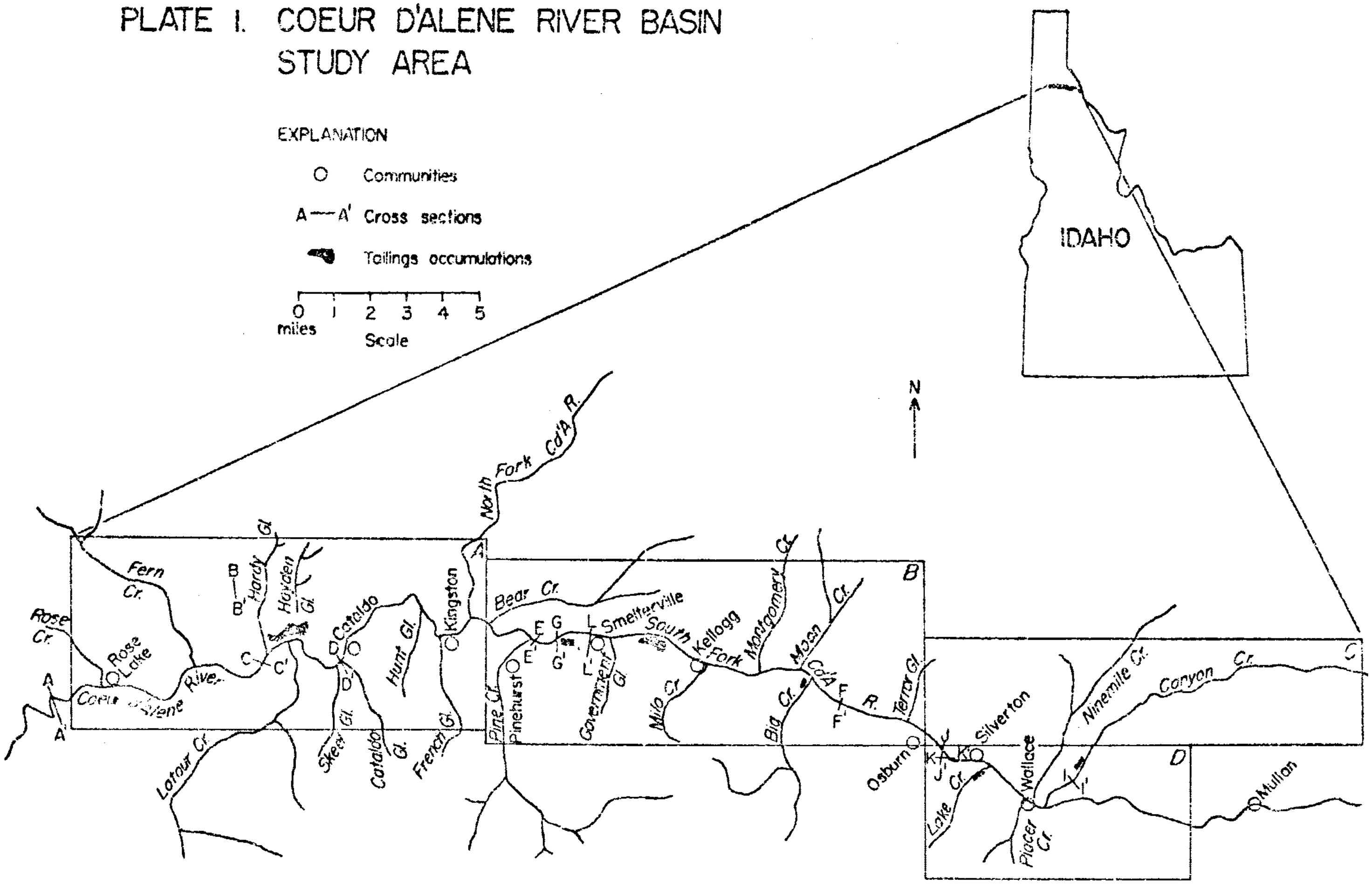
U. S. Environmental Protection Agency, 1973, Fact Sheet--Application for National Pollutant Discharge Elimination System (NPDES) Discharge Permit, Application No. ID-000007-8, The Bunker Hill Company, 11 p.

Walton, W. C., 1962, Selected Analytical Methods for Well and Aquifer Evaluation: Illinois State Water Survey Bulletin 49, 81 p.

Williams, R. E., 1972, The Role of the Mine Tailings Ponds in Reducing the Discharge of Heavy Metal Ions to the Environment: Completion Report of Contract H0110088 for U. S. Bureau of Mines.

APPENDIX I, PLATES

PLATE I. COEUR D'ALENE RIVER BASIN STUDY AREA



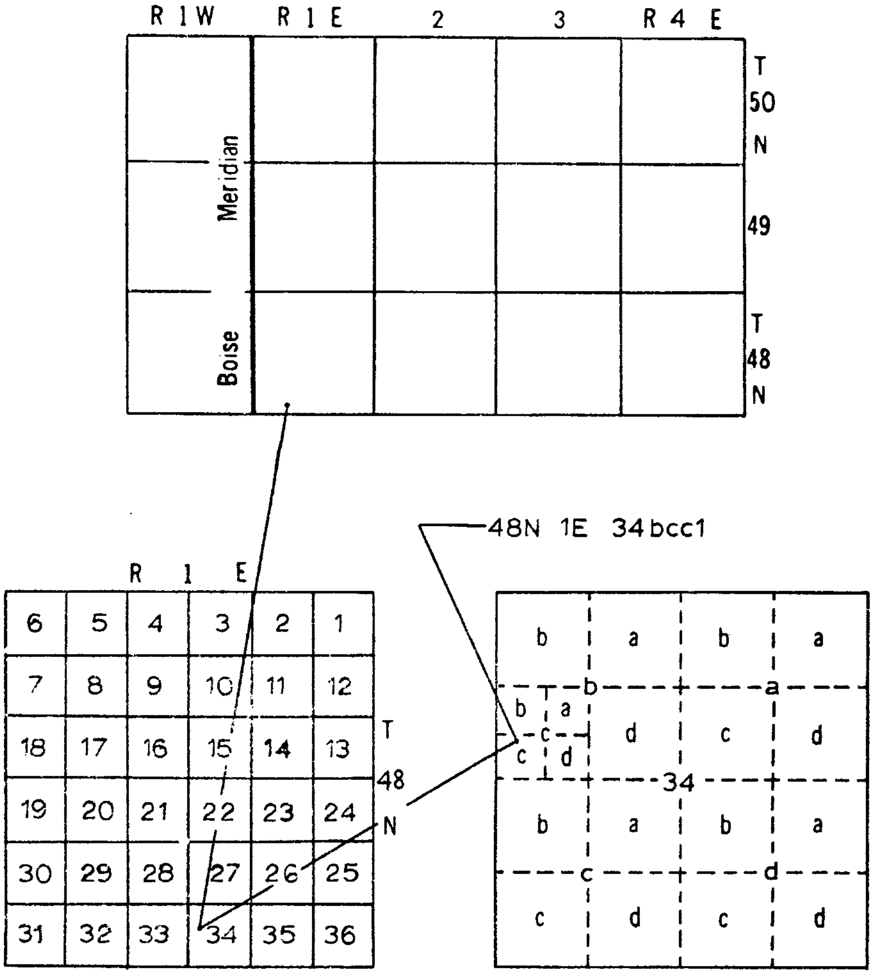
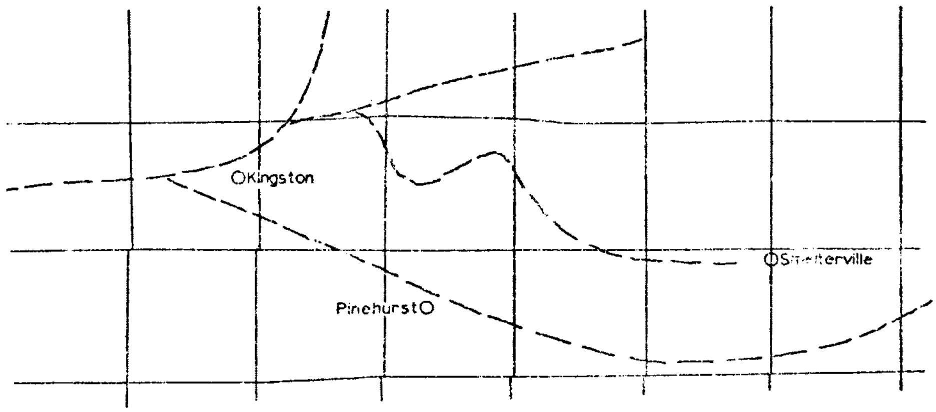
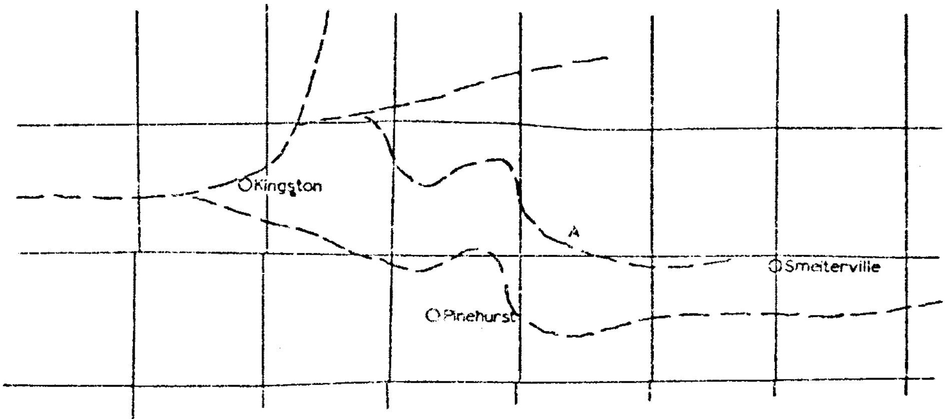


Plate 2. Well-numbering system used in Idaho. The system indicates the locations of wells and springs within the official rectangular subdivision of the public lands of the United States. In this State, all lands are referenced to the Boise Meridian and base line. The first two segments of a number designate the township and range (48N - 1E). The third segment gives the section number followed by two or three letters (48N-1E-34bcc). Quarter sections are lettered a, b, c, and d, in counterclockwise order, from the northeast quarter of each section. Within each quarter section, the 40-acre tracts are labeled in the same manner, and the 40-acre tracts may be divided into 10-acre tracts in the same way. Thus, well 48N-1E-34bcc1 is in the SW 1/4 of the SW 1/4 of the NW 1/4 of Section 34, Township 48 north, Range 1 east, Boise Meridian and base line and is the first well visited in that tract.

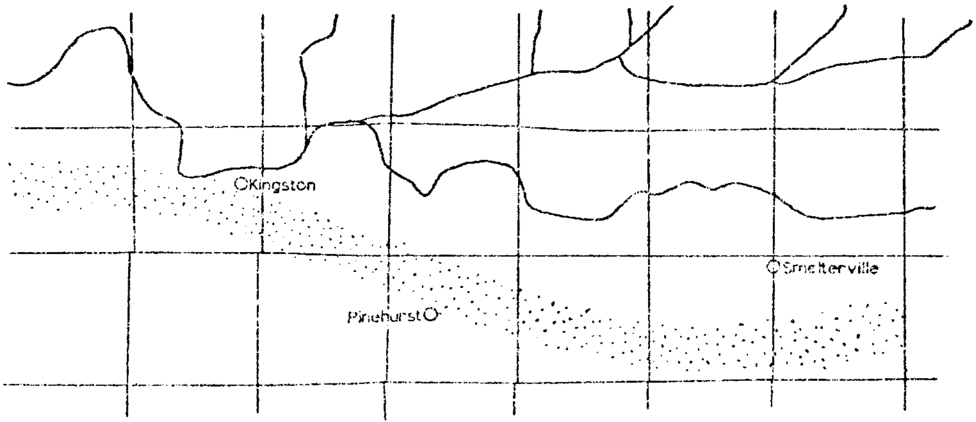
PLATE 3. POSSIBLE HISTORY OF DRAINAGE PATTERN NEAR PINEHURST.



(a) Location of ancestral drainage during period of aggradation represented by terrace gravels approximately 300' above present valley floor.

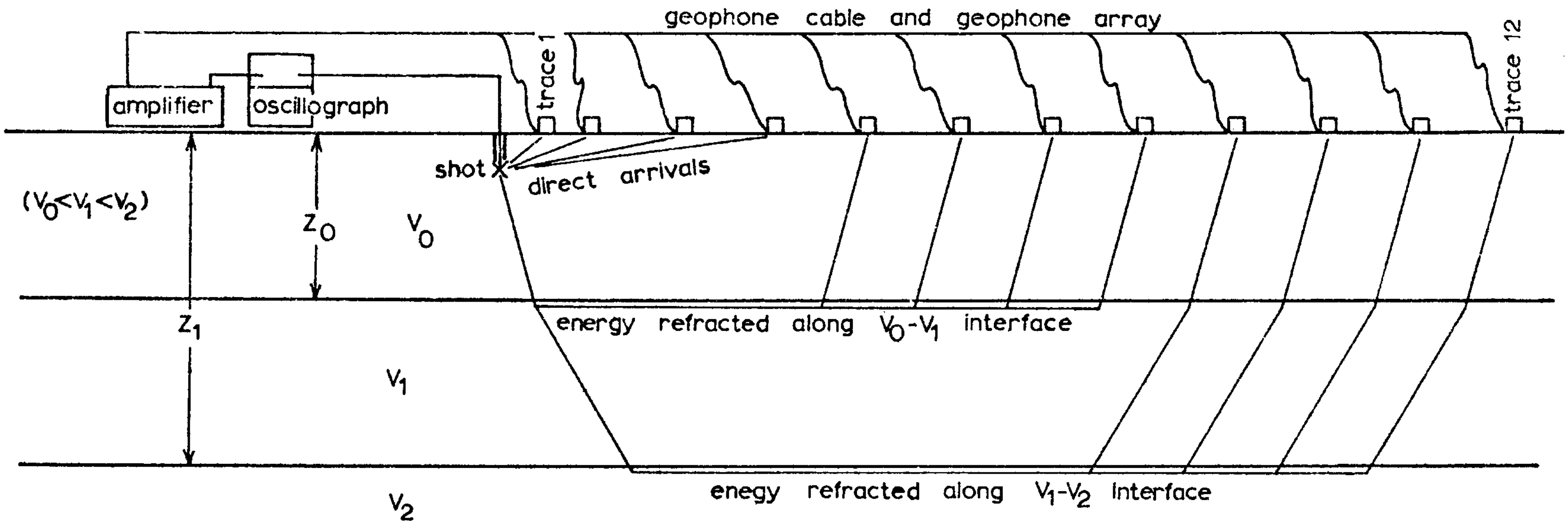


(b) Location of drainage following reactivation of downcutting, but prior to captivation of major drainage by stream 'A'.

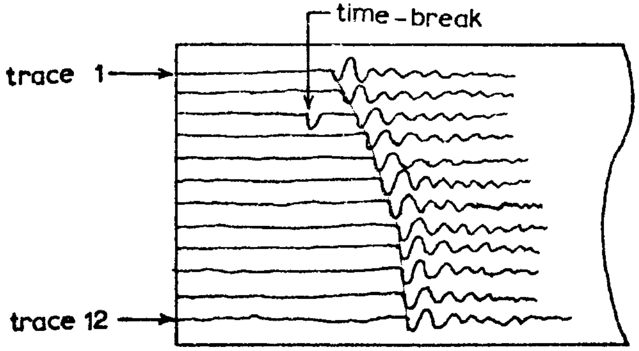


(c) Location of present drainage and distribution of terrace gravels (stippled areas represent terrace gravels).

PLATE 7. (a) Representative siesmic refraction spread and subsurface configuration.



(b) Record



(c) Time-distance plot

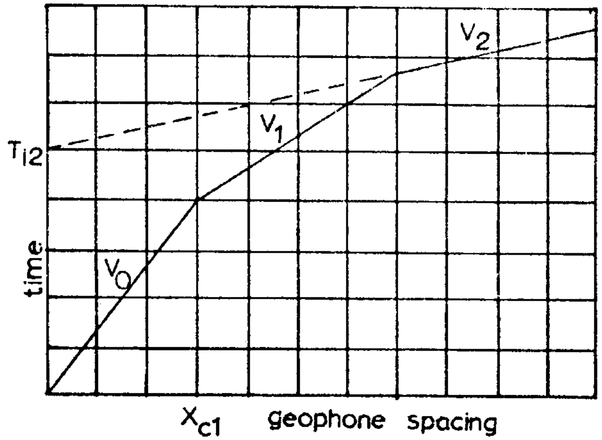
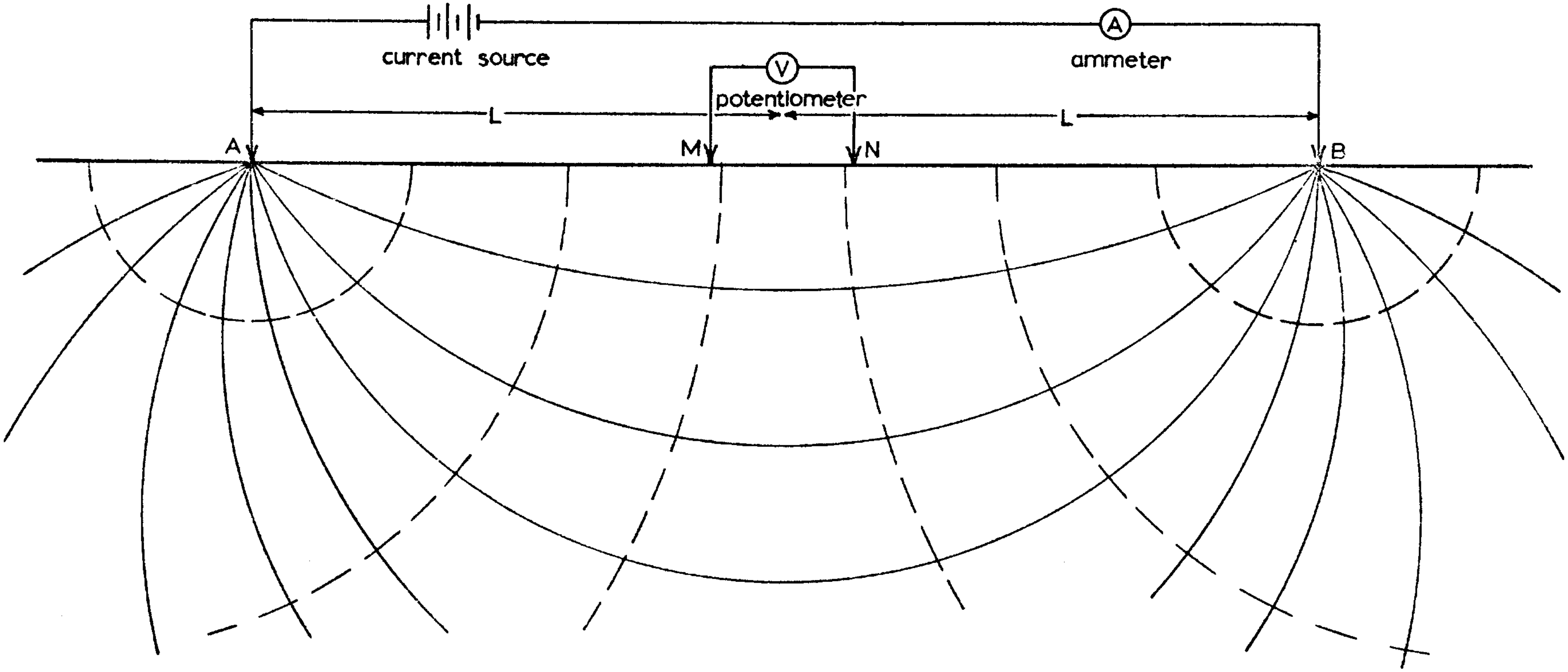
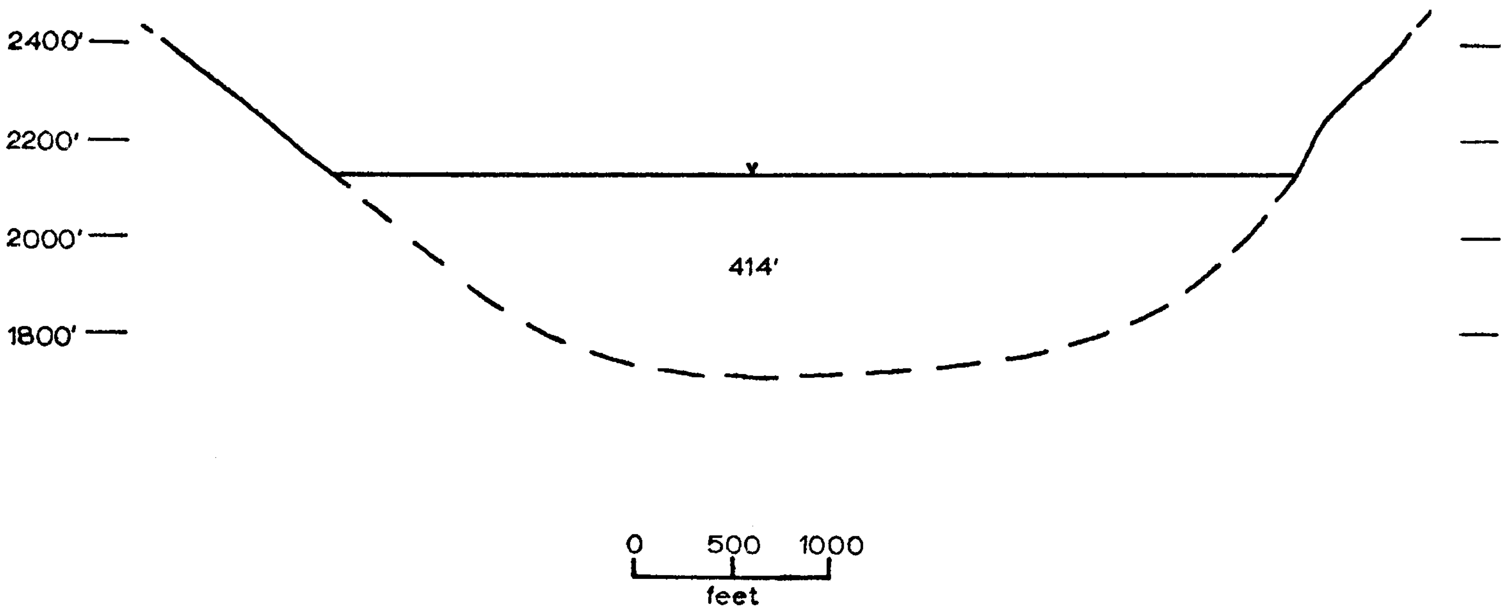


PLATE 8. SCHLUMBERGER ELECTRODE CONFIGURATION FOR ELECTRICAL RESISTIVITY DEPTH SOUNDING



M,N	Potential electrodes
A,B	Current electrodes
—	Lines of current flow
- -	Equipotential lines
L	Distance from center of configuration to current electrodes (A,B)

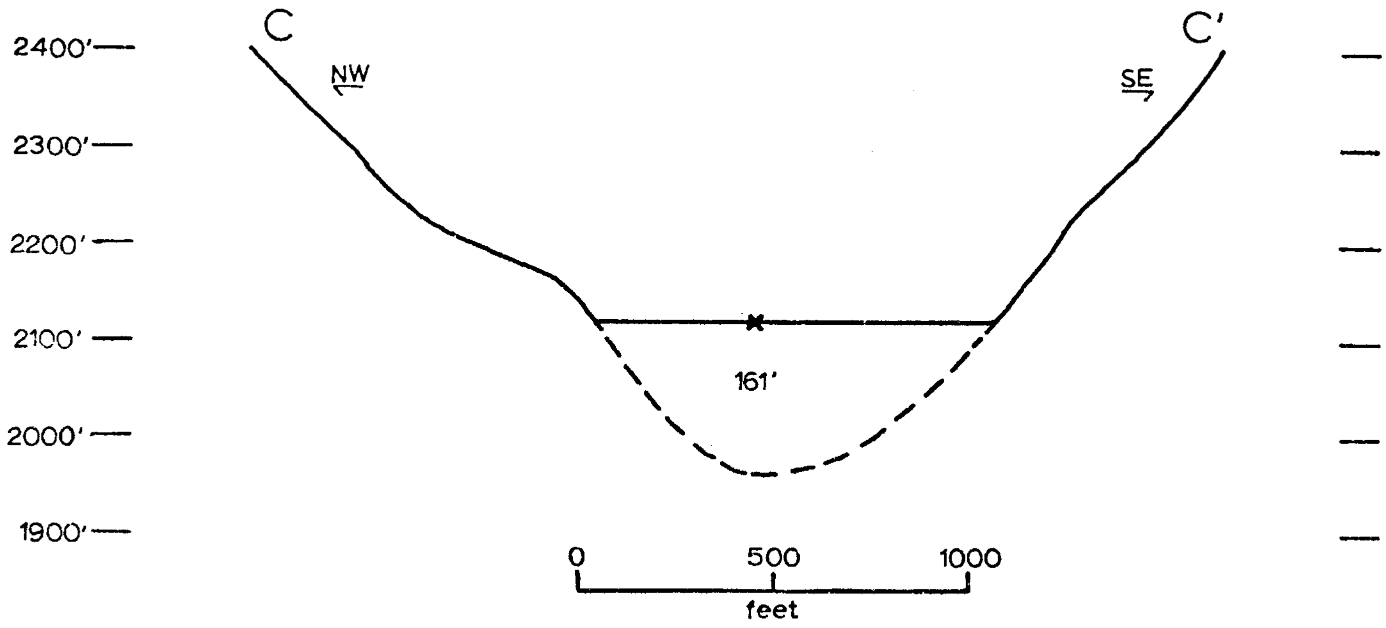
PLATE 9. VALLEY CROSS SECTION $2\frac{1}{2}$ MILES WEST OF ROSE LAKE — A - A'



2.5 : 1 Vertical Exageration

—x— Resistivity Depth Point

PLATE 10. VALLEY CROSS SECTION 4 MILES WEST OF CATALDO — C - C'



2.5 : 1 Vertical Exageration

—✕— Seismic Depth Point

PLATE II - VALLEY CROSS SECTION AT CATALDO — D-D'

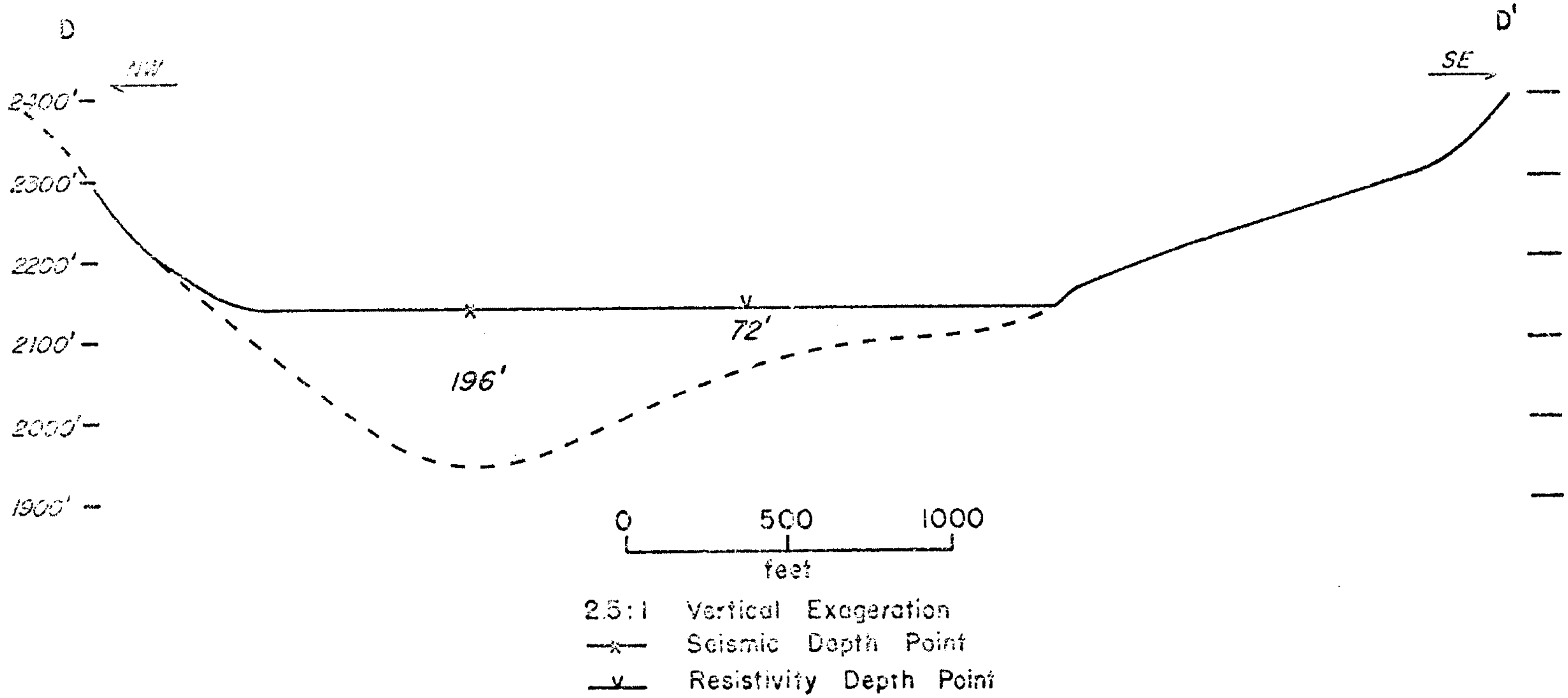


PLATE 12. VALLEY CROSS SECTION AT PINE CREEK — E-E'

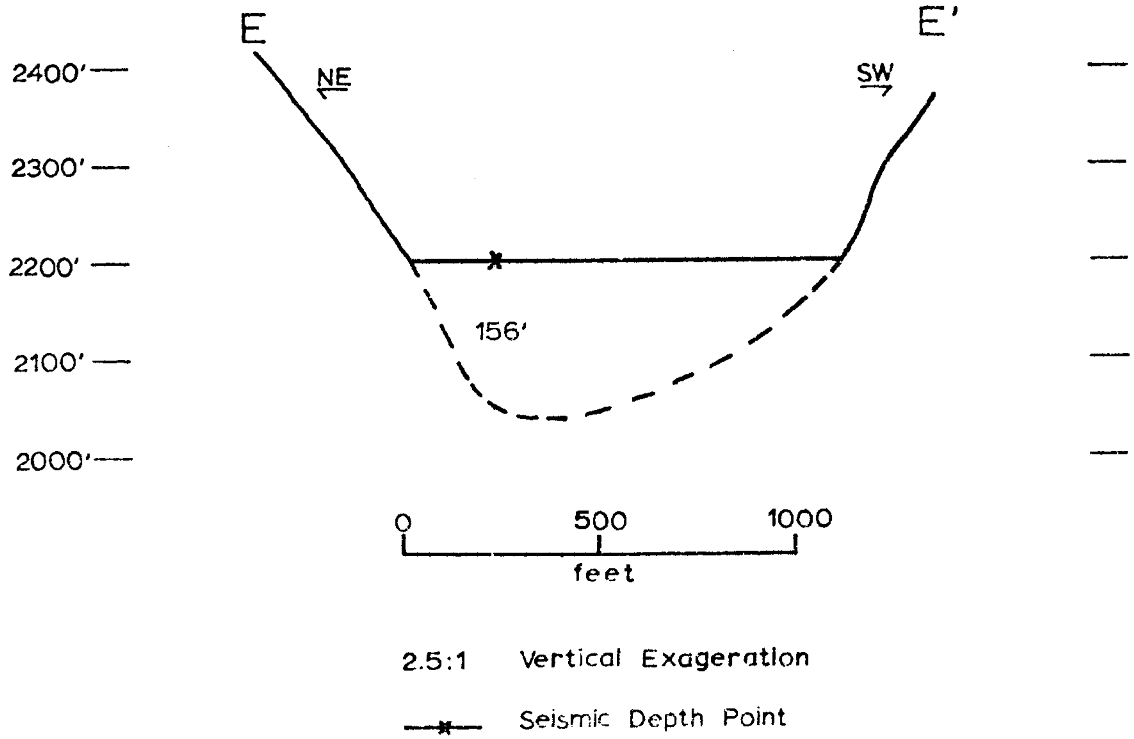


PLATE 13. VALLEY CROSS SECTON AT EAST END OF PAGE POND — G-G′

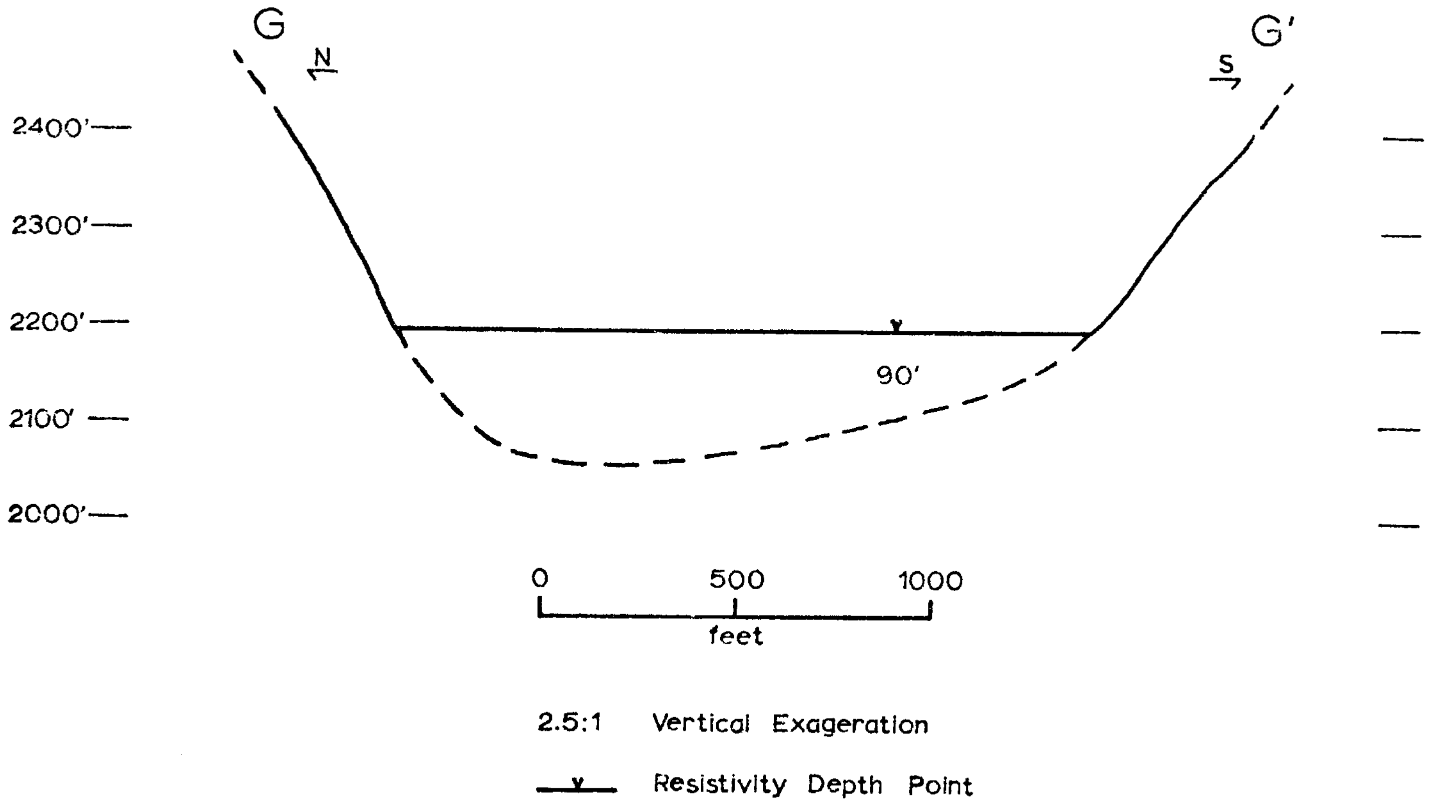


PLATE 14. VALLEY CROSS SECTION AT SMELTERVILLE, L-L'

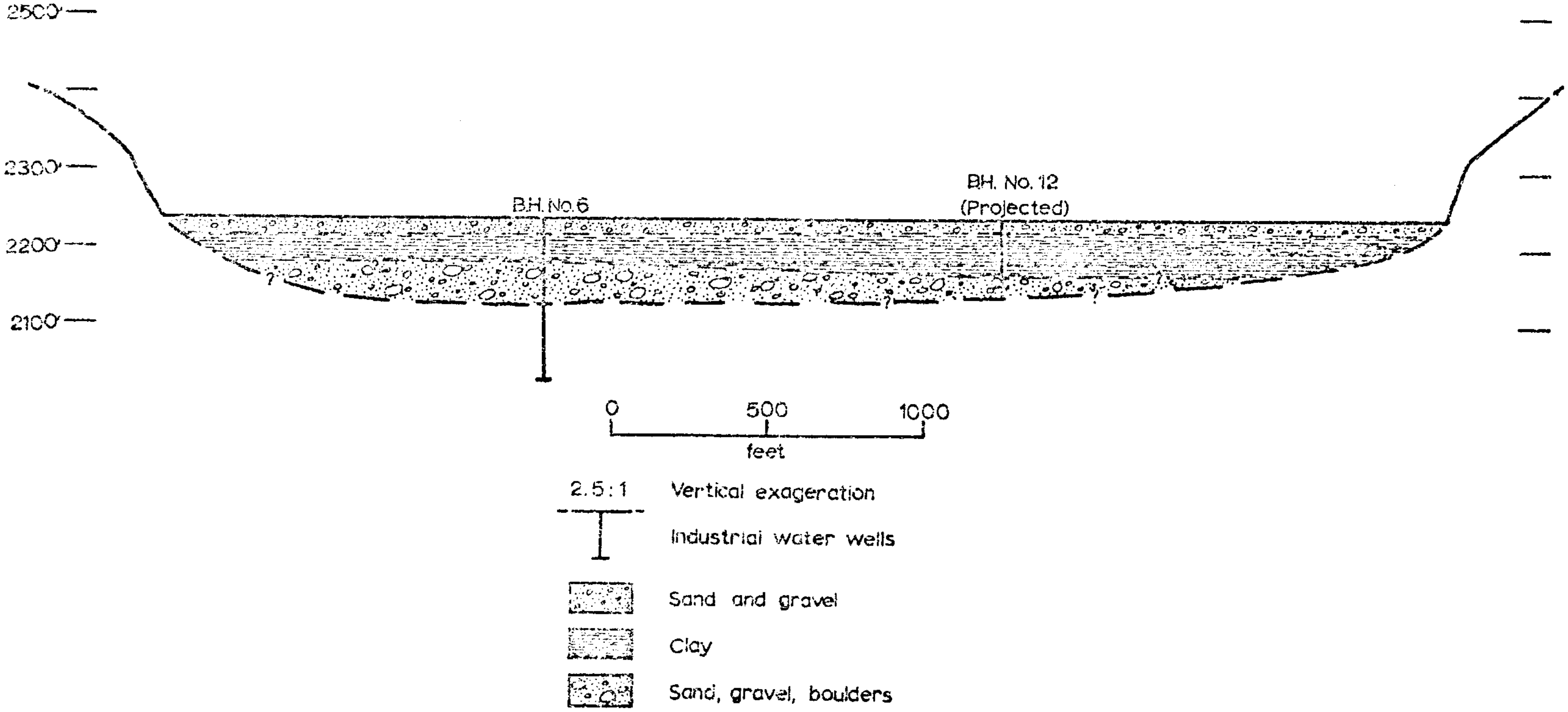


PLATE 15. VALLEY CROSS SECTION $\frac{3}{4}$ MILE EAST OF BIG CREEK — F - F'

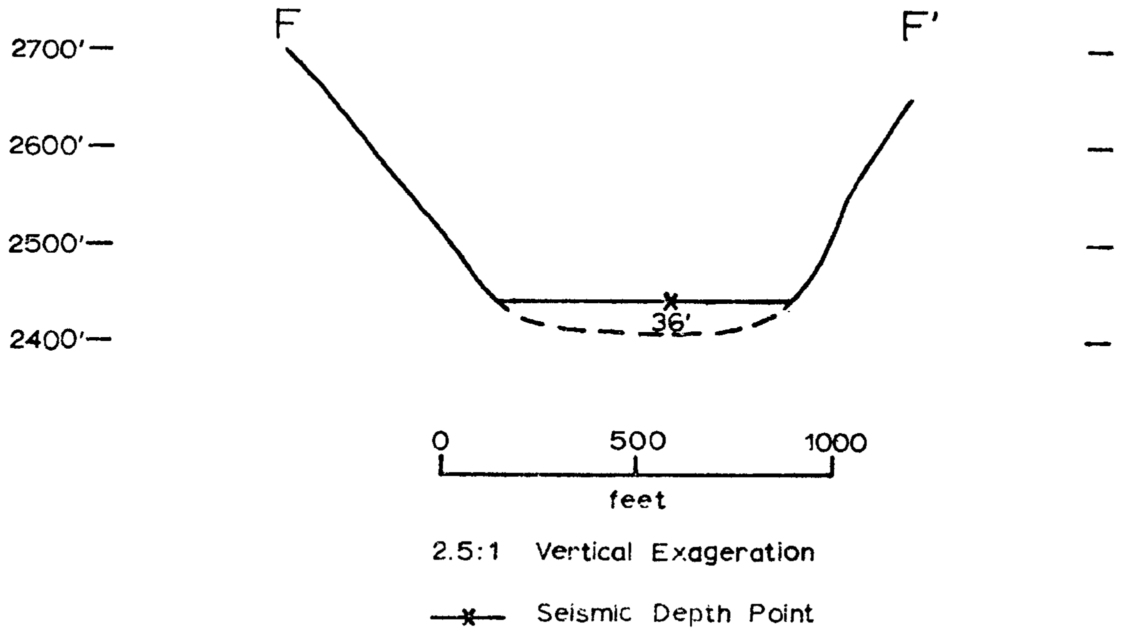


PLATE 16. VALLEY CROSS SECTIONS EAST OF OSBURN — K-K' & J-J'

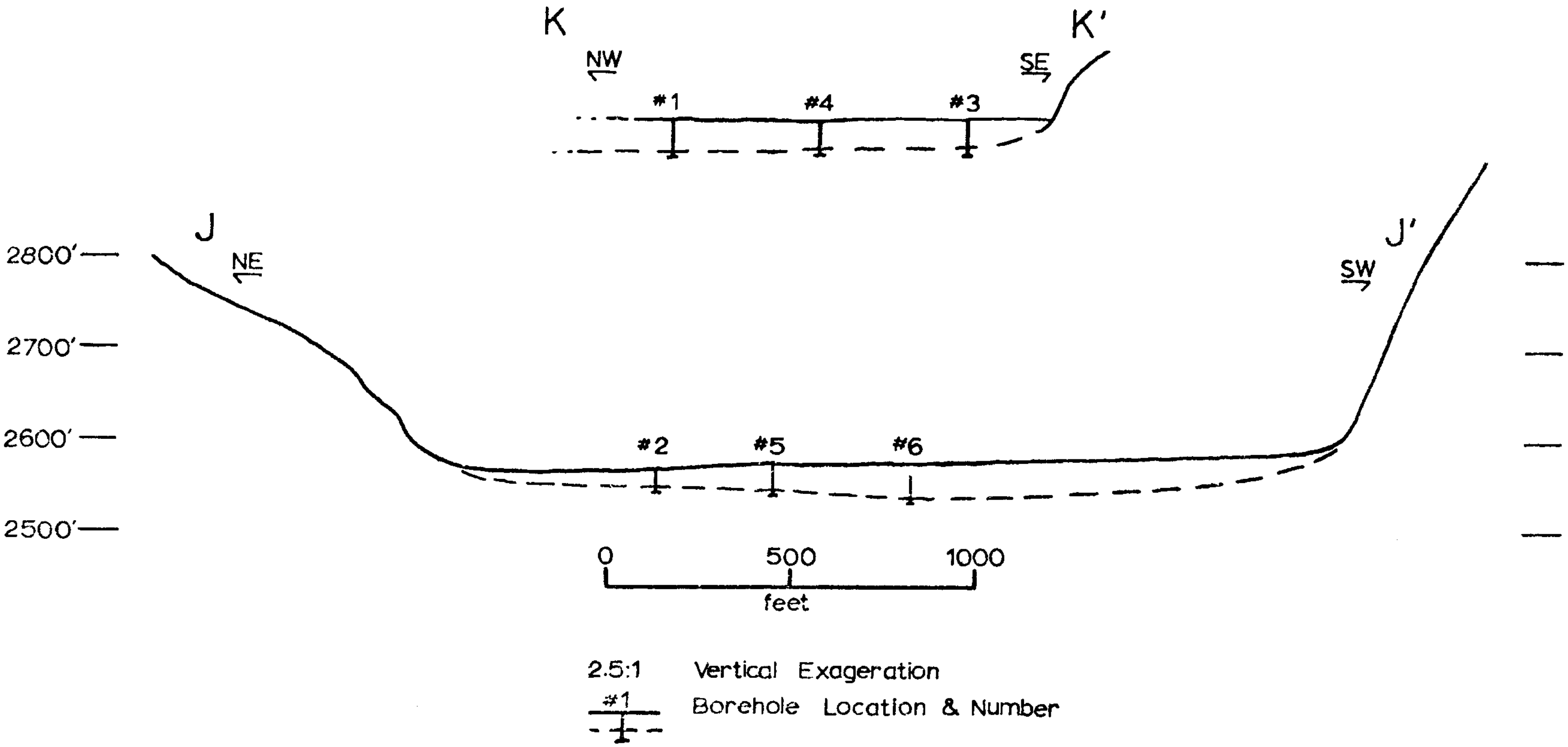


PLATE 17 - VALLEY CROSS SECTION AT CANYON CREEK — I-I'

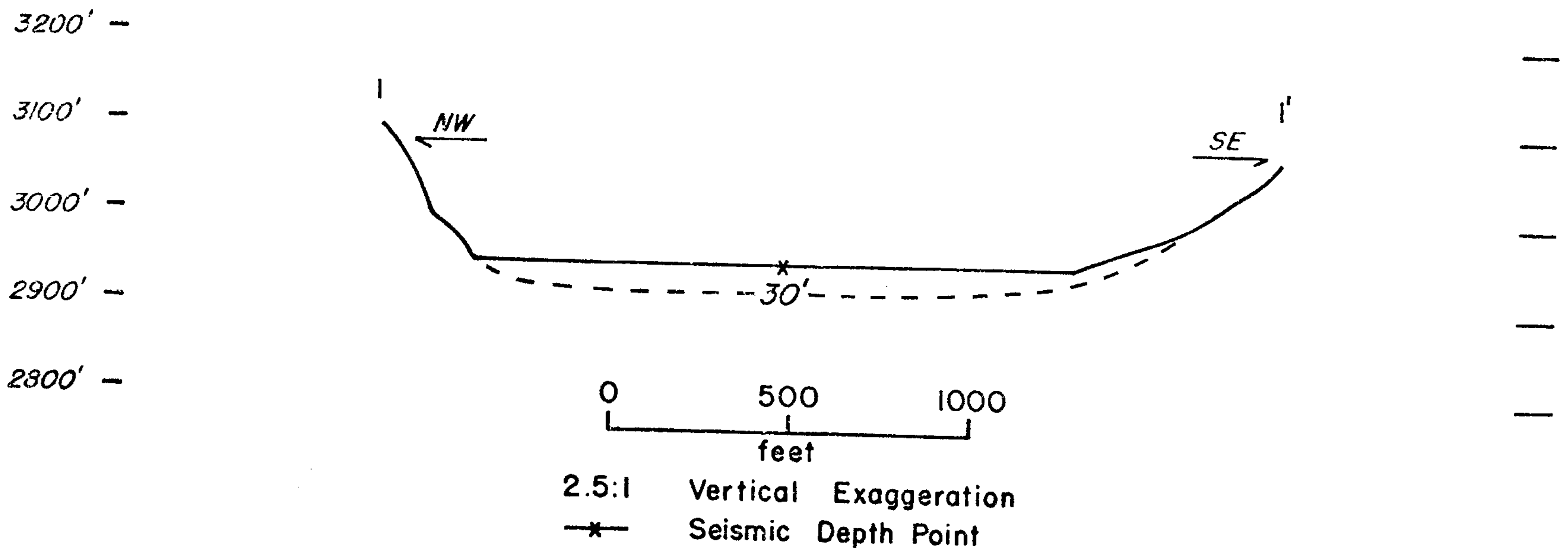


PLATE 18. pH VS. DISTANCE

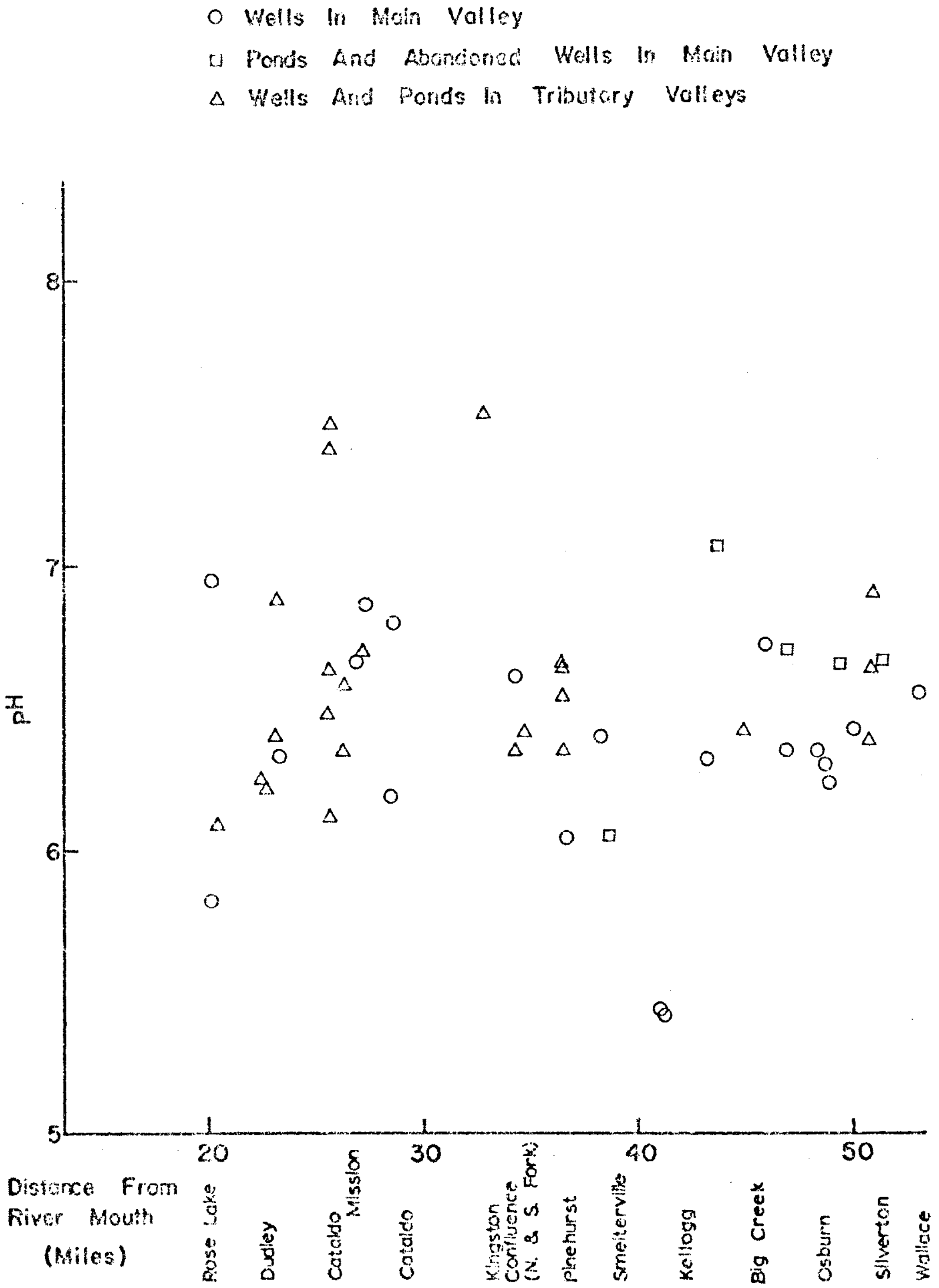


PLATE 19. CONDUCTIVITY VS. DISTANCE

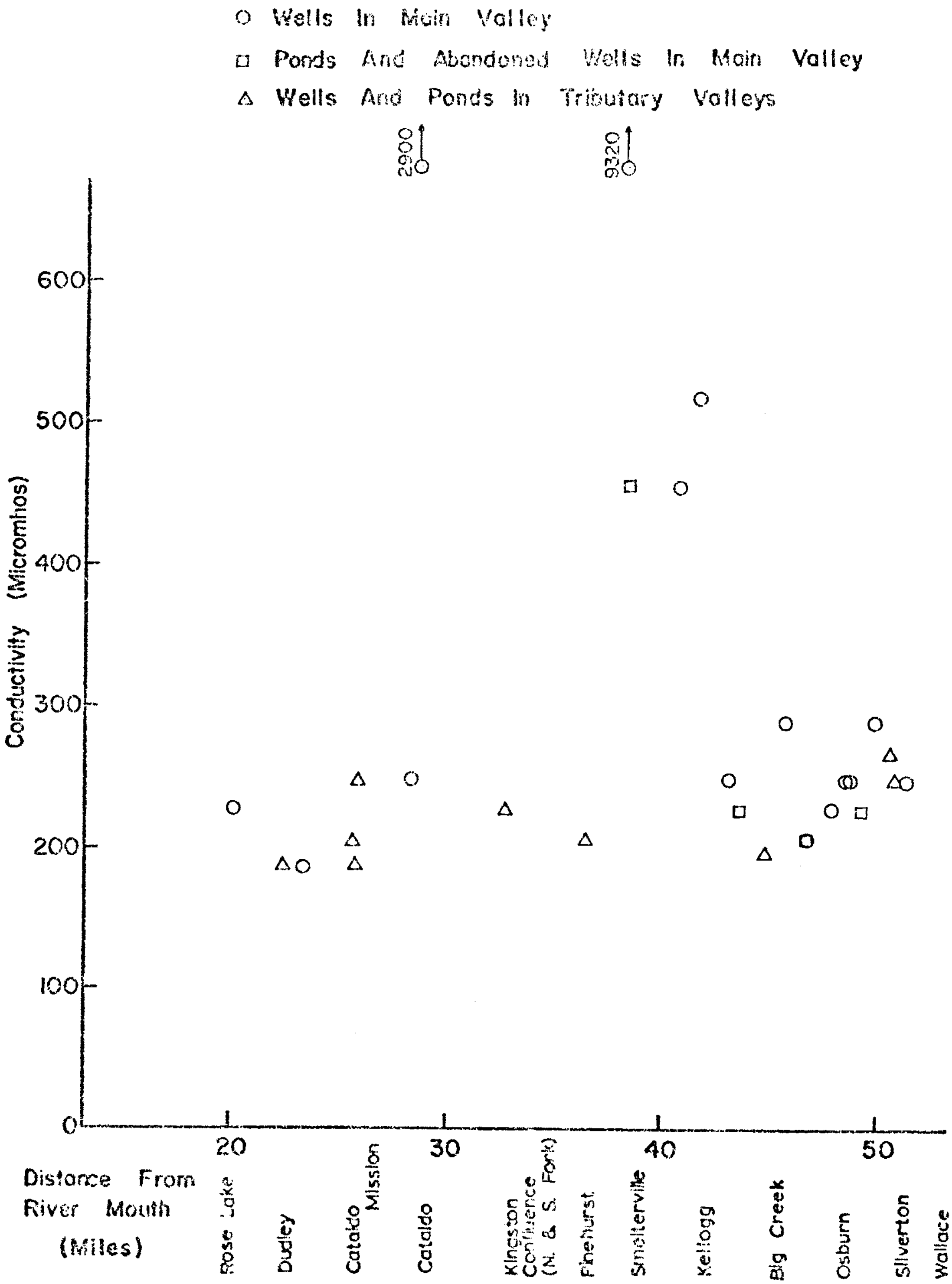


PLATE 20. CALCIUM CONCENTRATION VS. DISTANCE

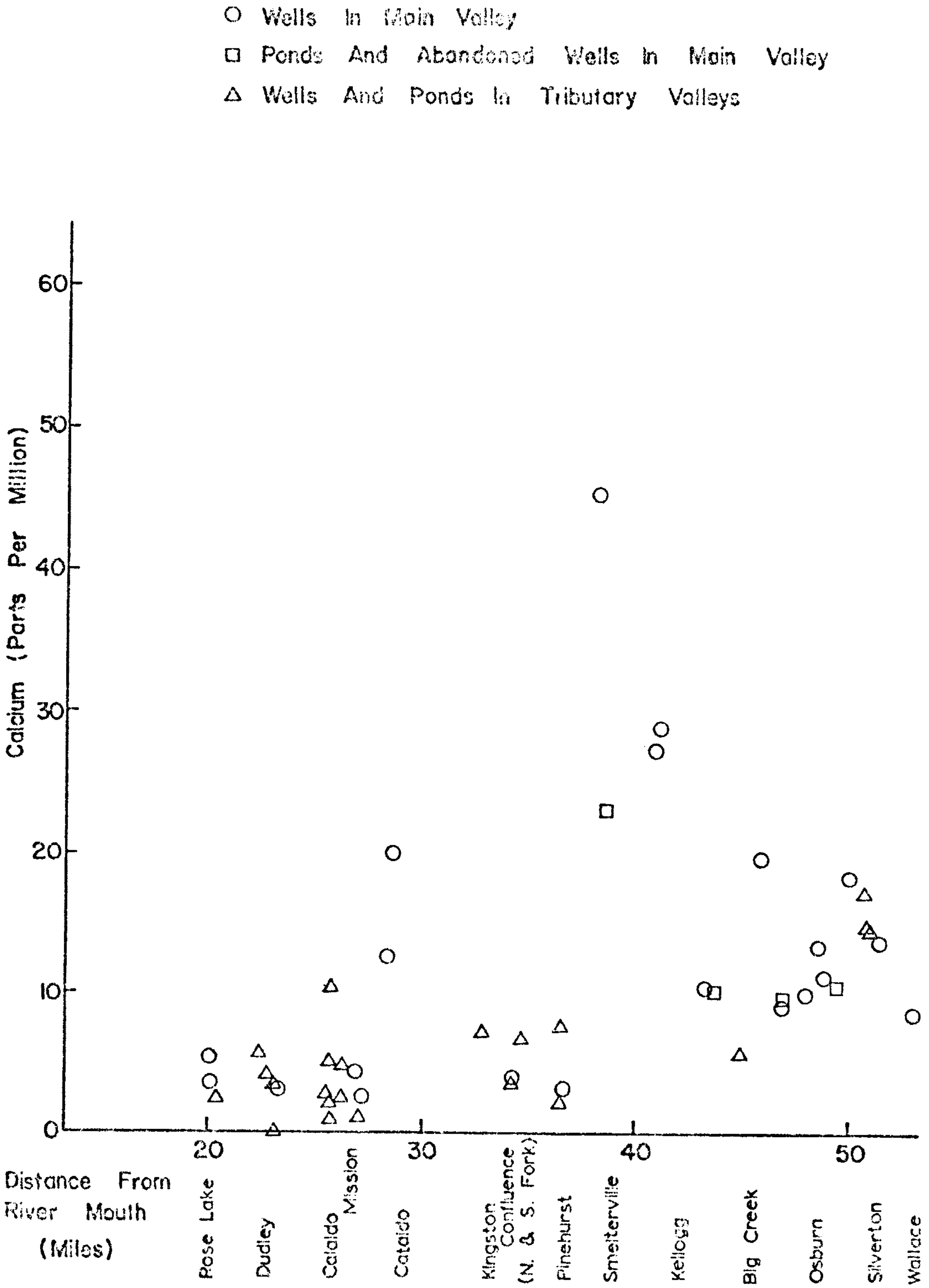


PLATE 21. CADMIUM CONCENTRATION VS. DISTANCE

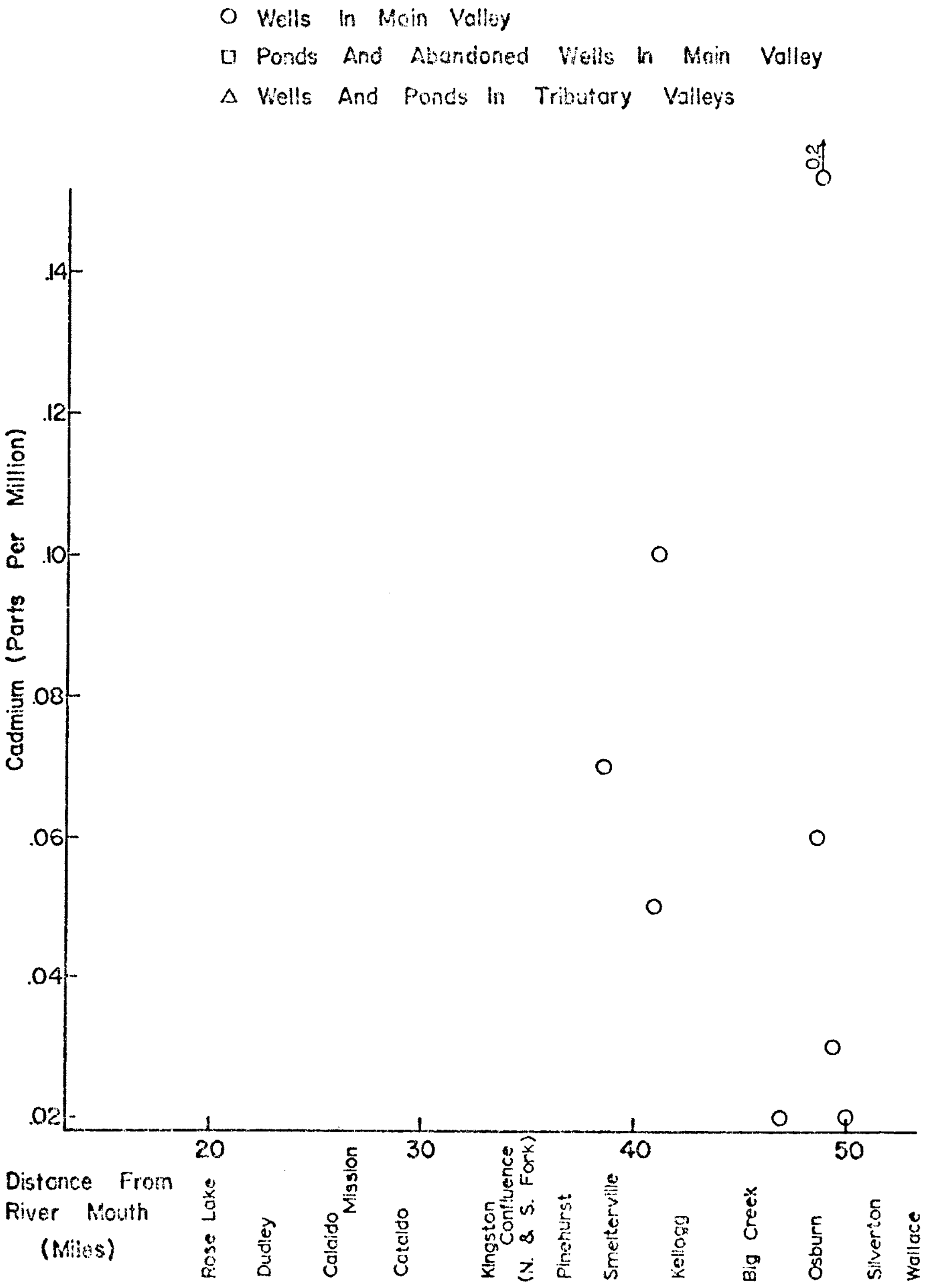


PLATE 22. COPPER CONCENTRATION VS. DISTANCE

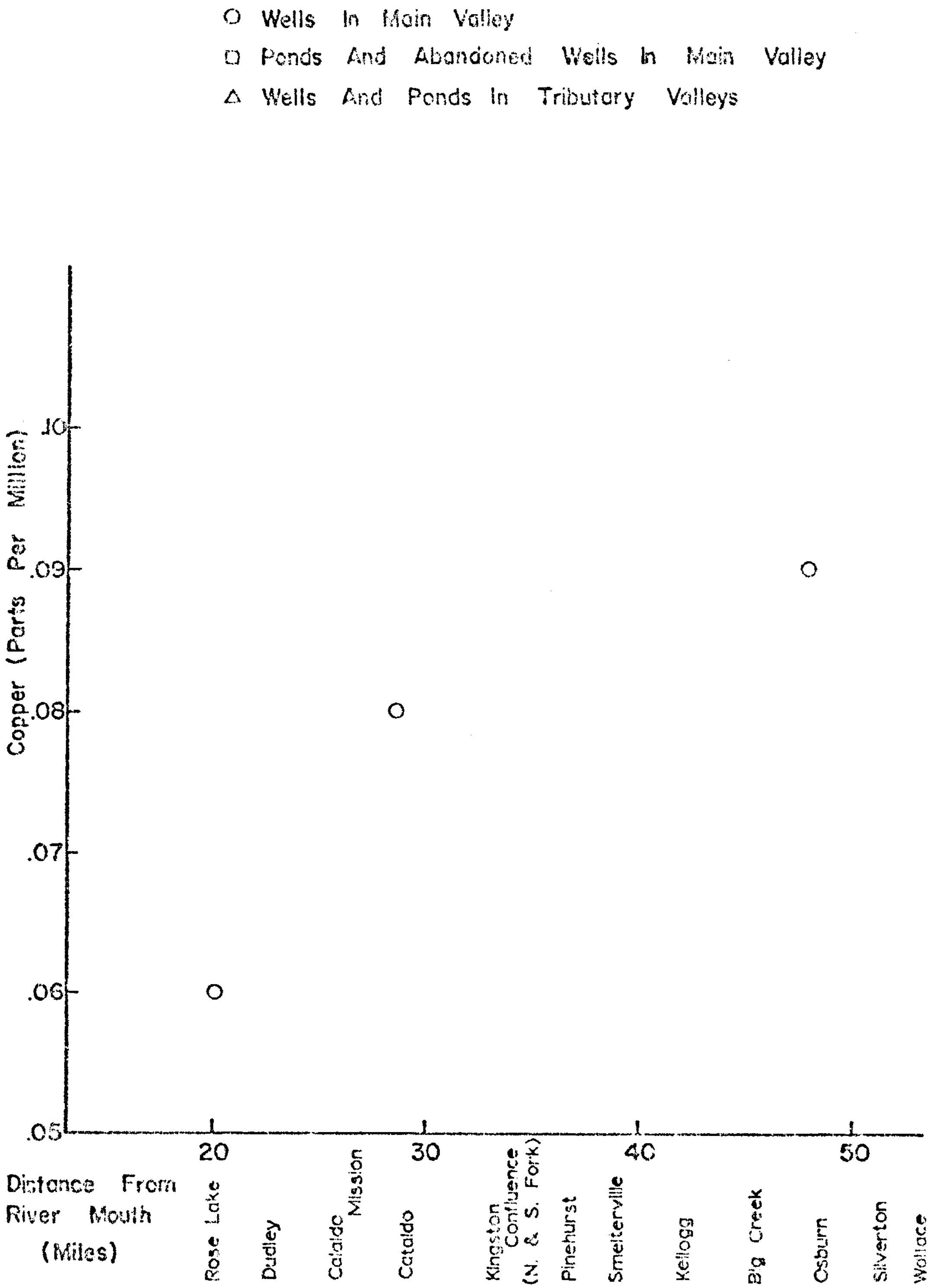


PLATE 23. IRON CONCENTRATION VS. DISTANCE

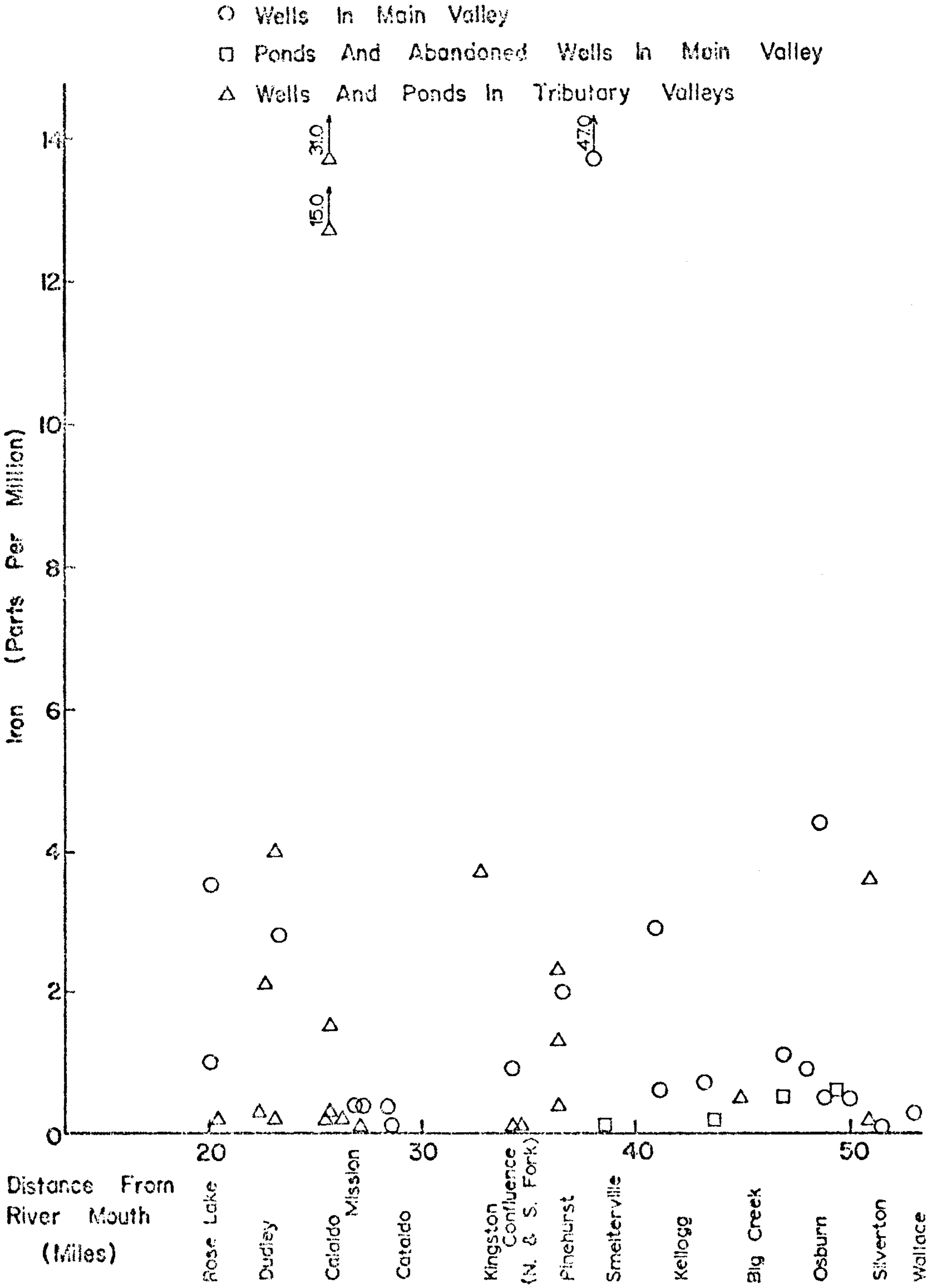


PLATE 24. POTASSIUM CONCENTRATION VS. DISTANCE

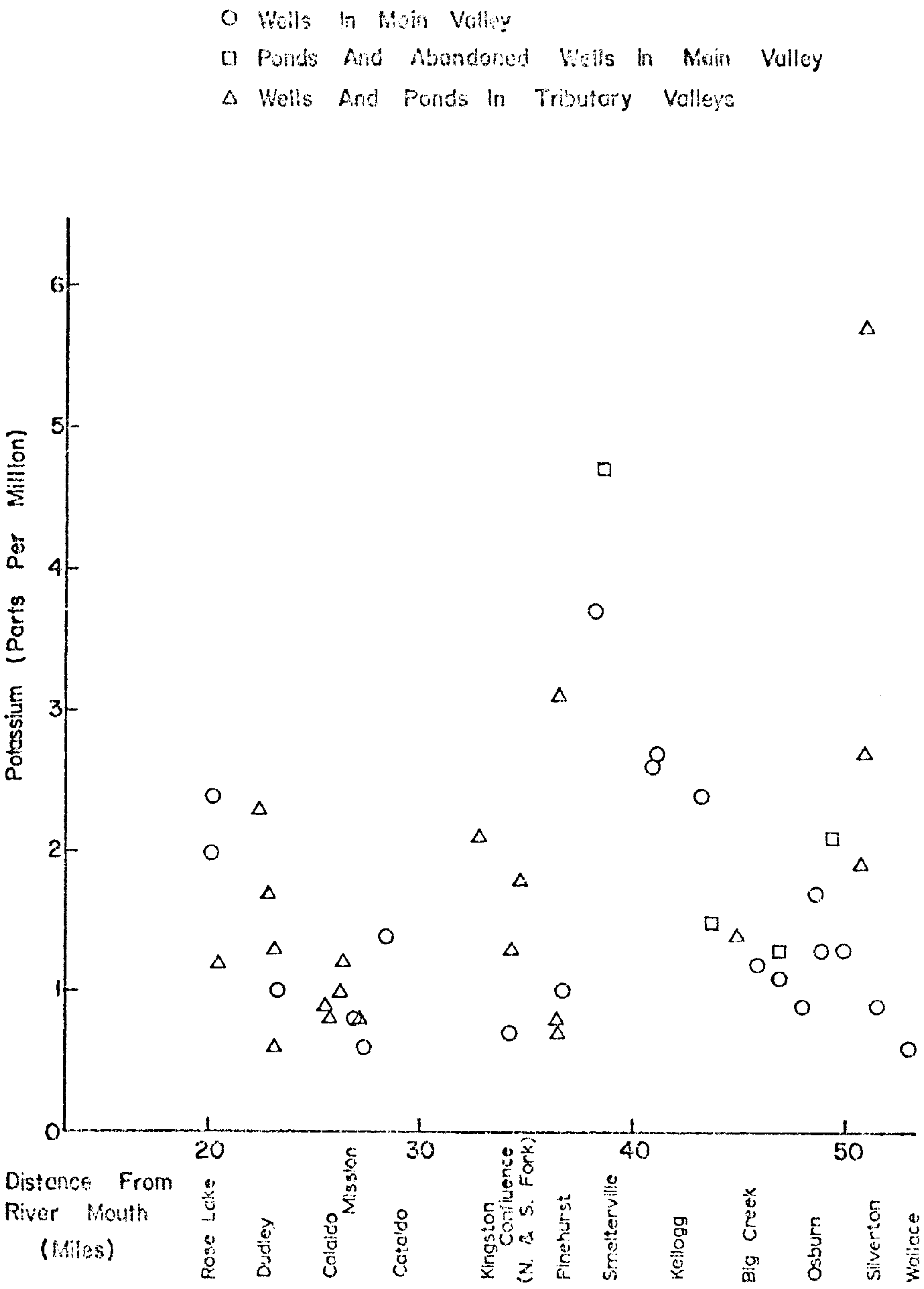


PLATE 25. MAGNESIUM CONCENTRATION VS. DISTANCE

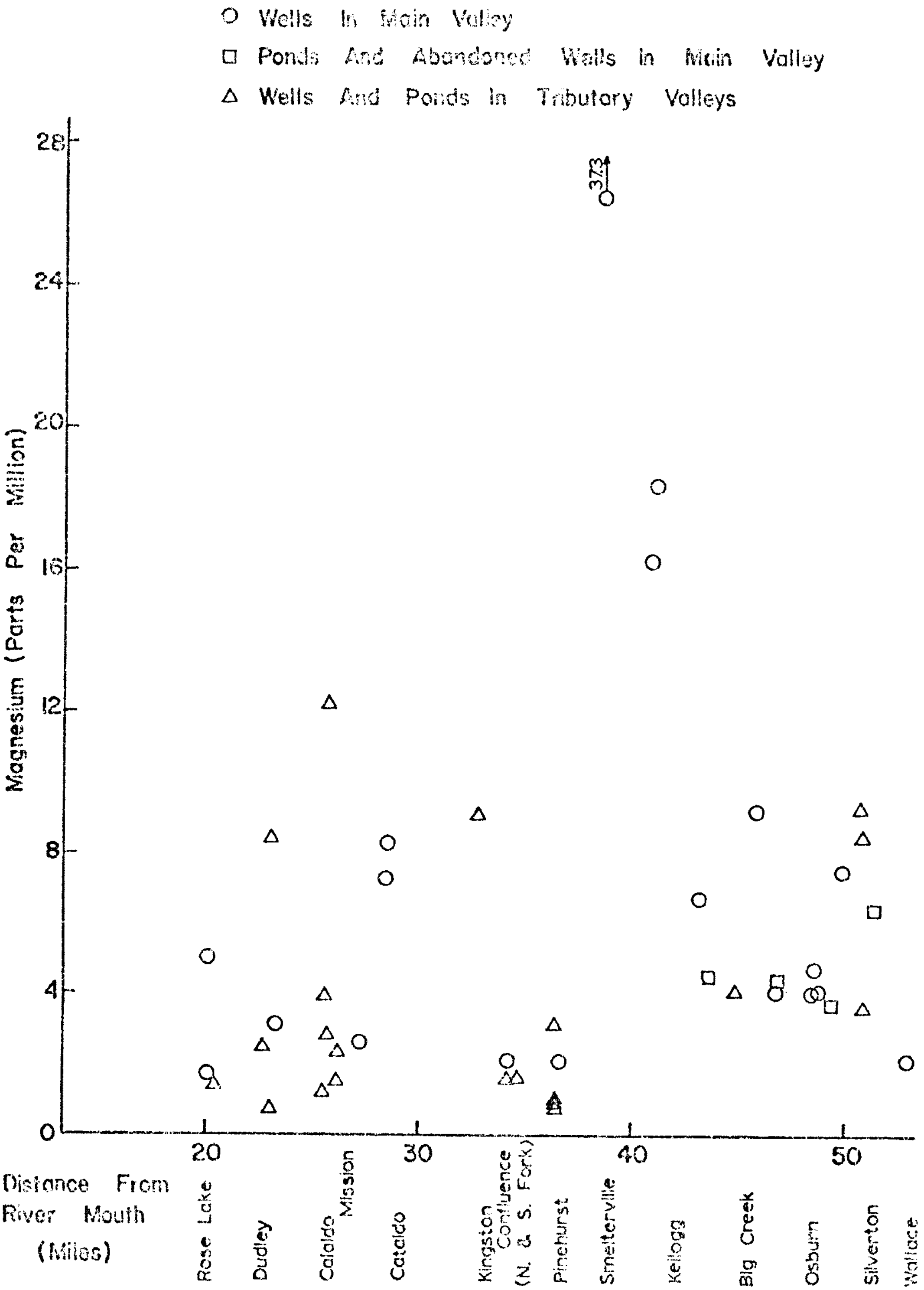


PLATE 26. MANGANESE CONCENTRATION VS. DISTANCE

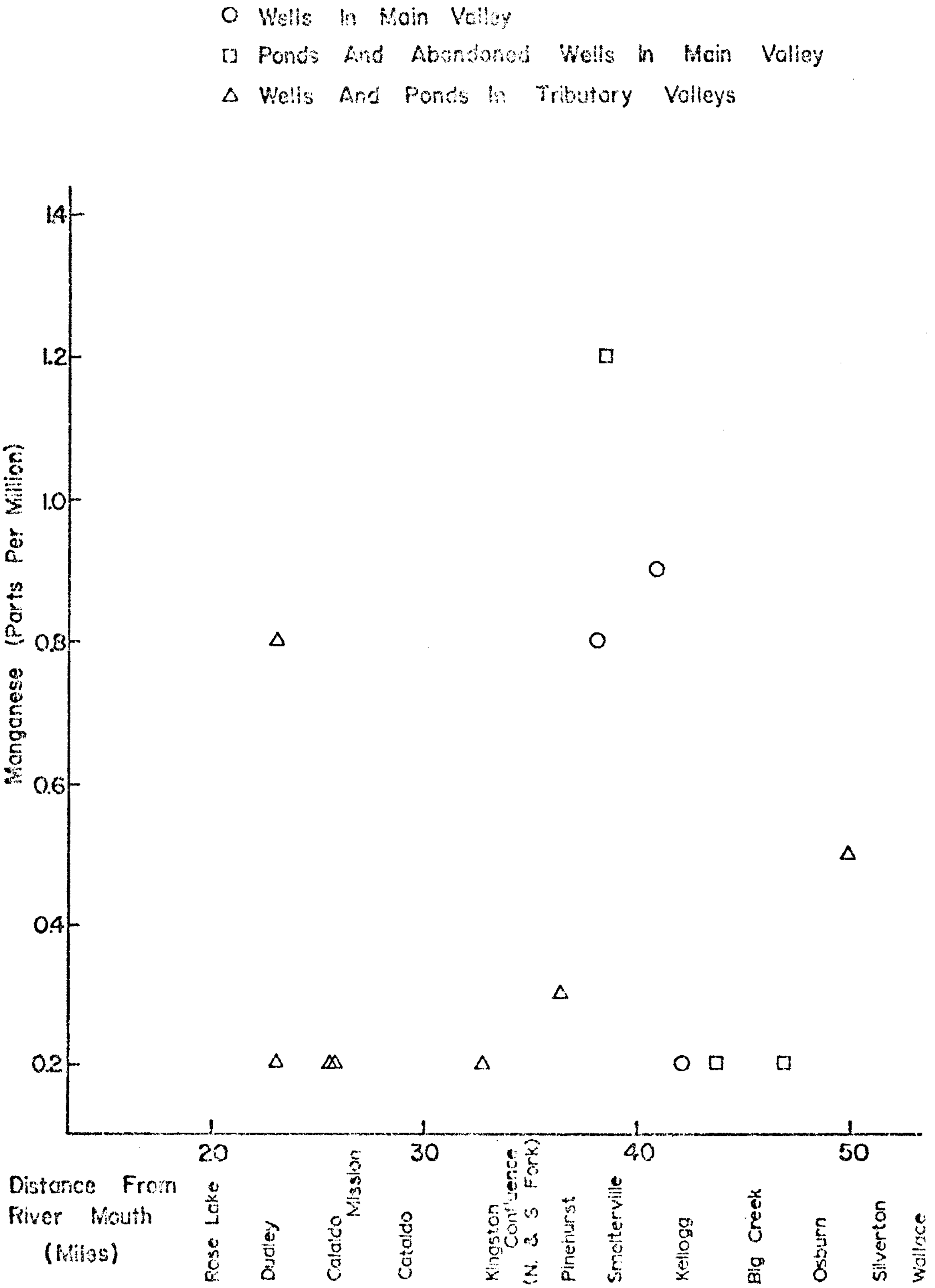


PLATE 27. SODIUM CONCENTRATION VS. DISTANCE

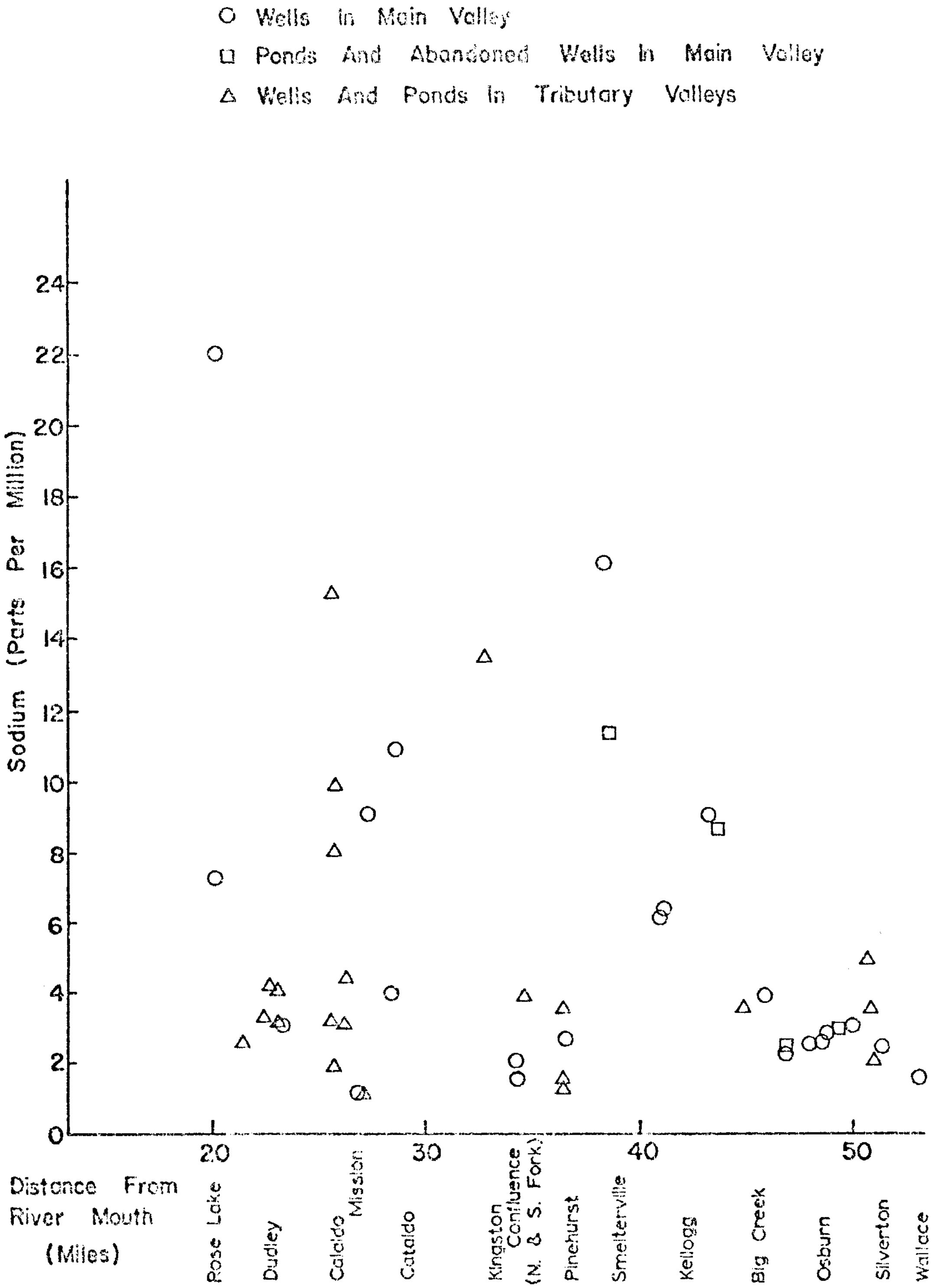


PLATE 28. LEAD CONCENTRATION VS. DISTANCE

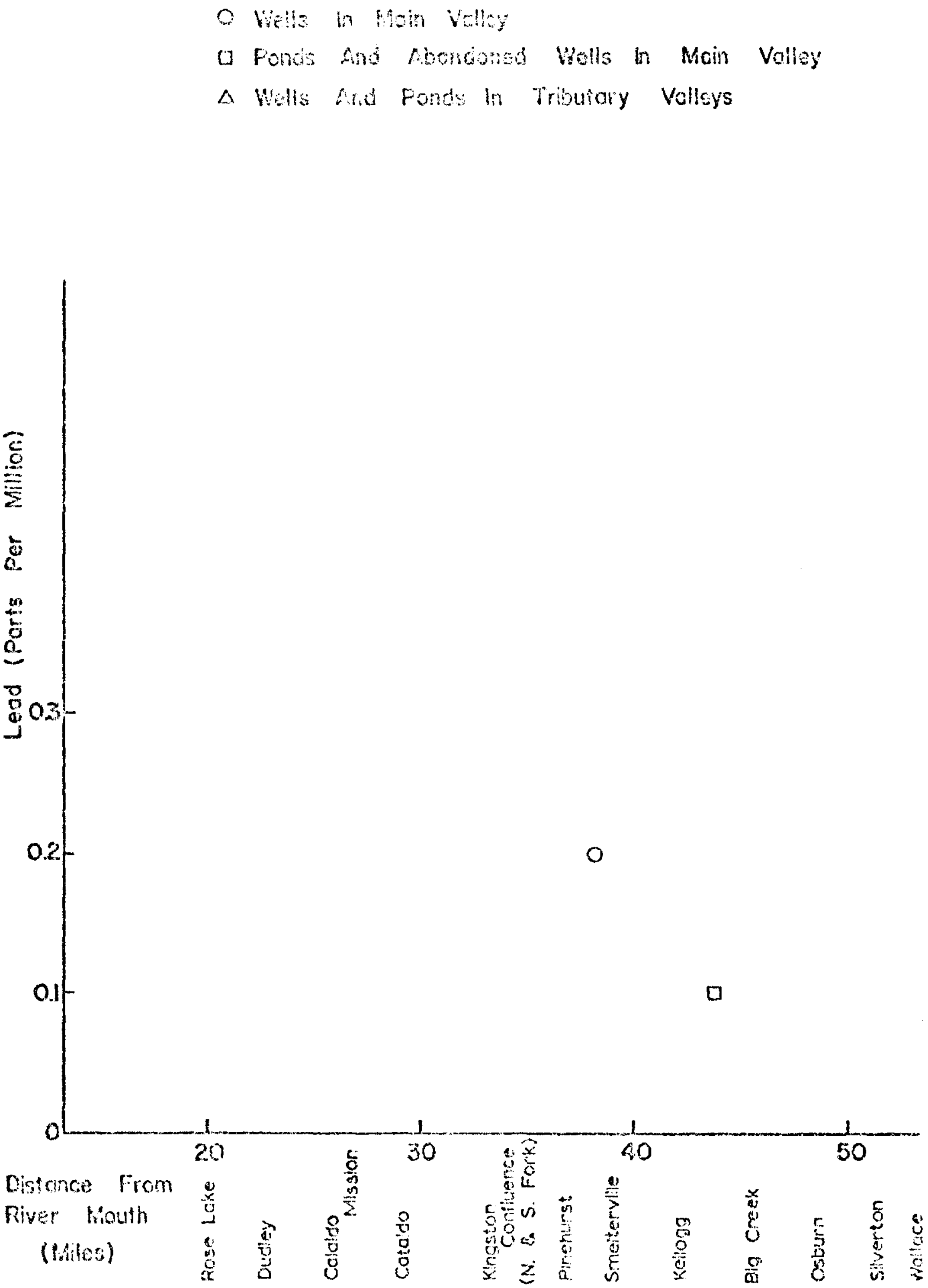


PLATE 29. ANTIMONY CONCENTRATION VS. DISTANCE

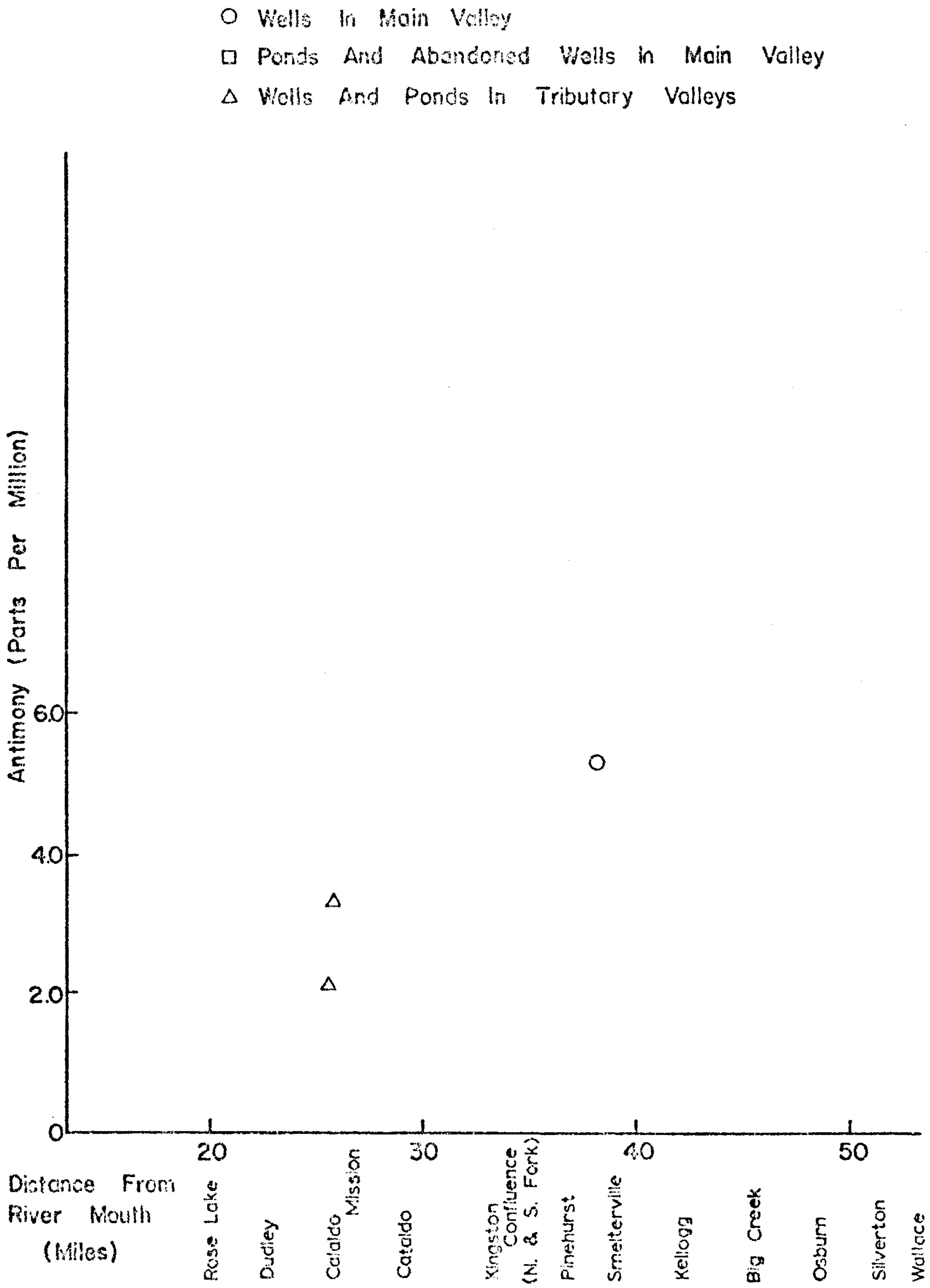


PLATE 30- ZINC CONCENTRATION vs. DISTANCE

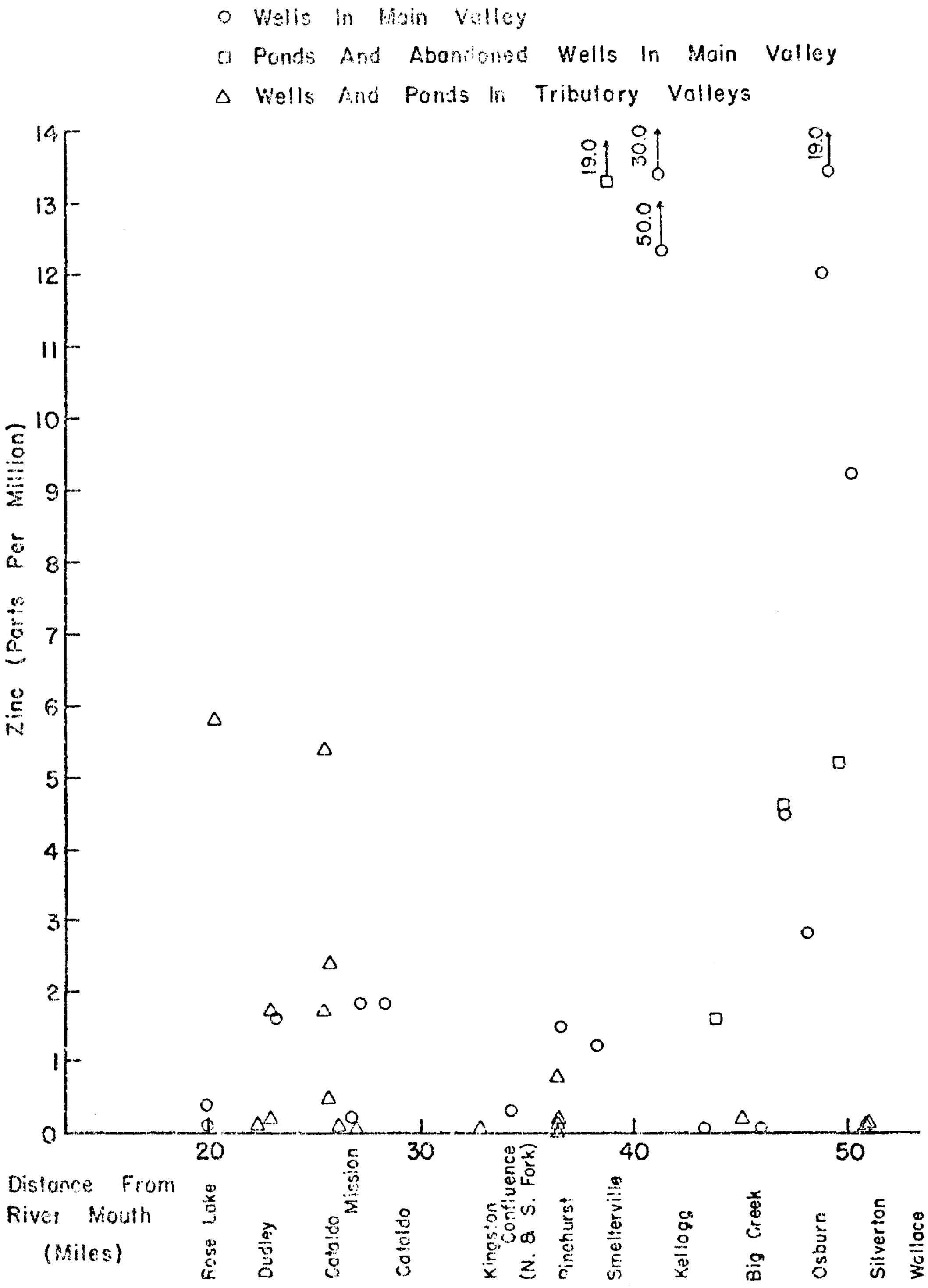


PLATE 31. TIME-DISTANCE PLOT, A-A'

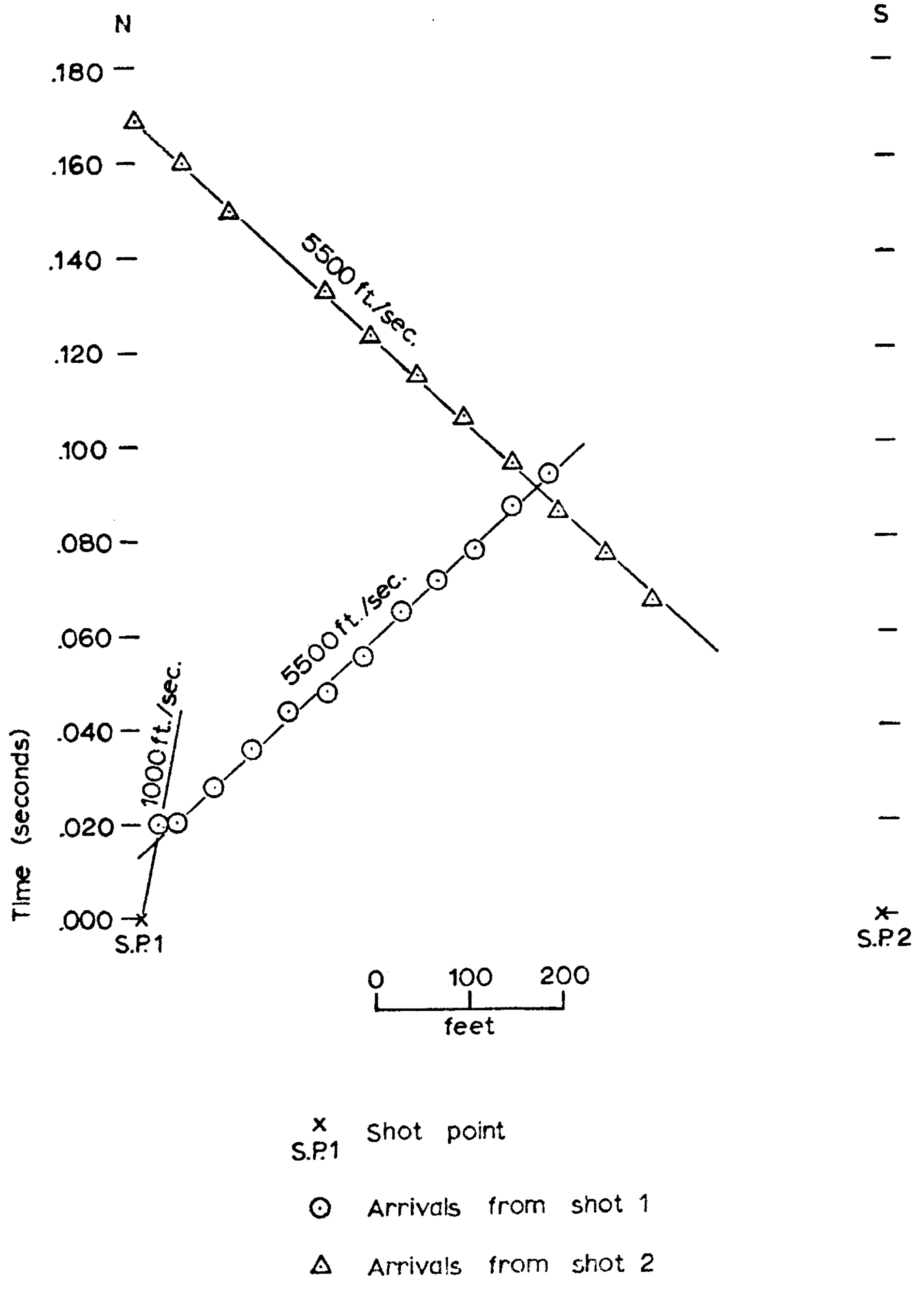
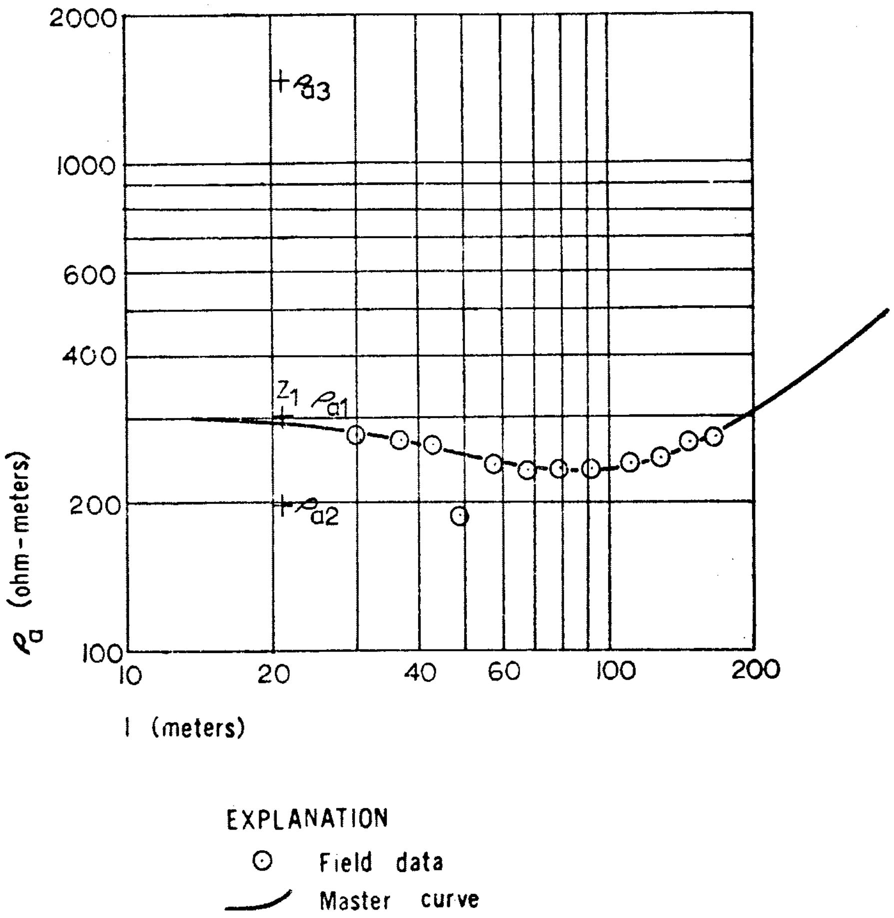


PLATE 32. RESISTIVITY FIELD CURVE & MASTER CURVE, A-A'



INTERPRETATION

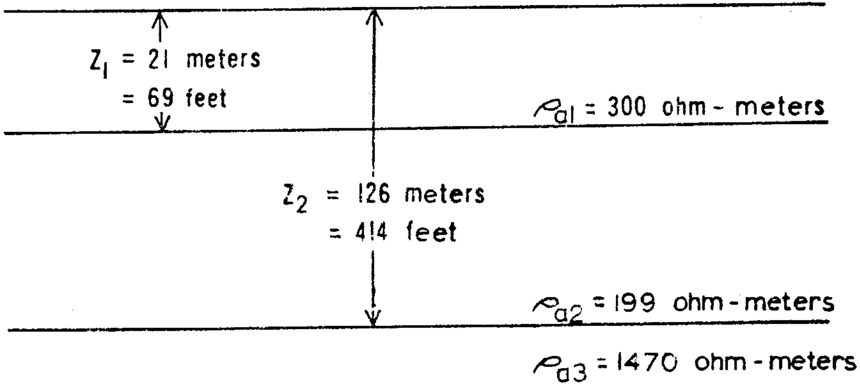


PLATE 33. TIME - DISTANCE PLOT, B - B'

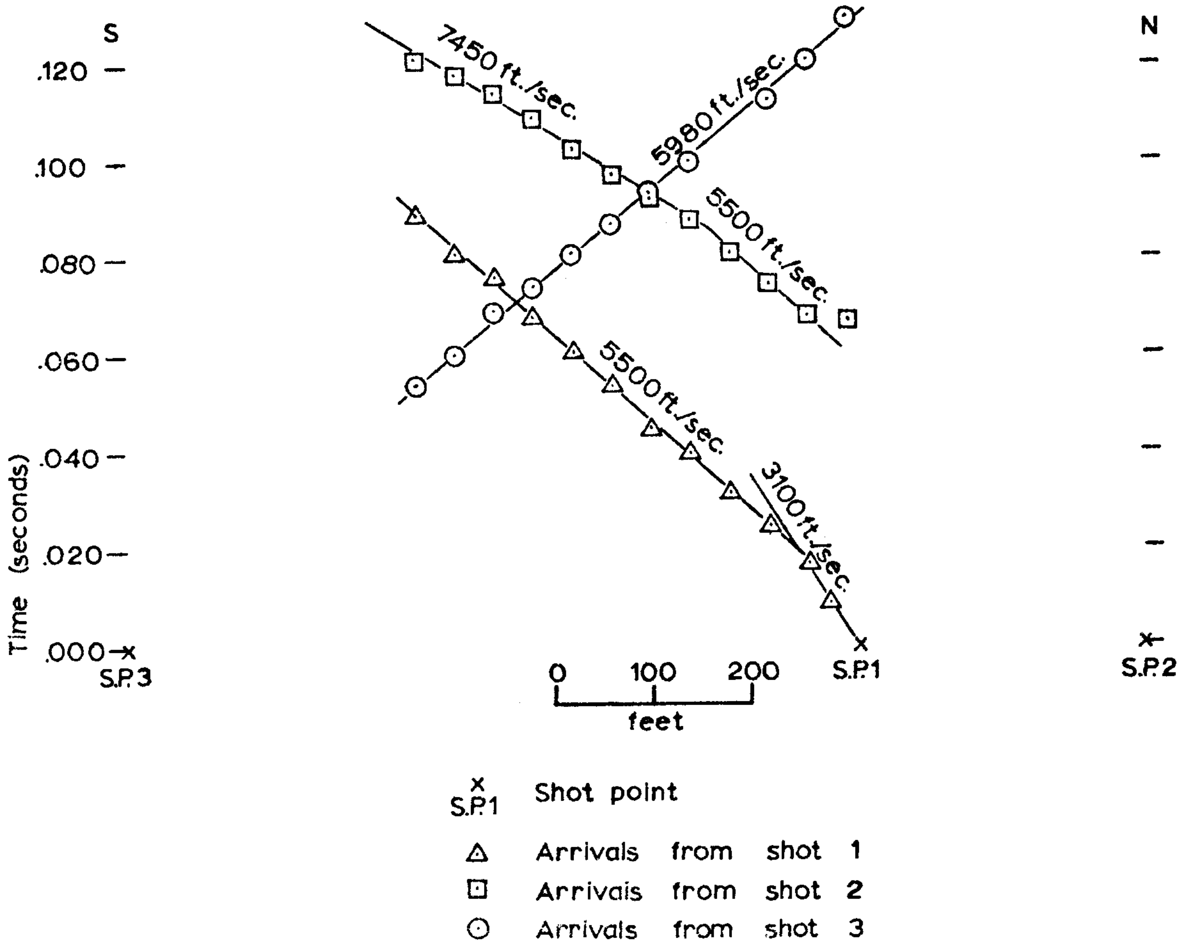


PLATE 34. TIME - DISTANCE PLOT, C - C'

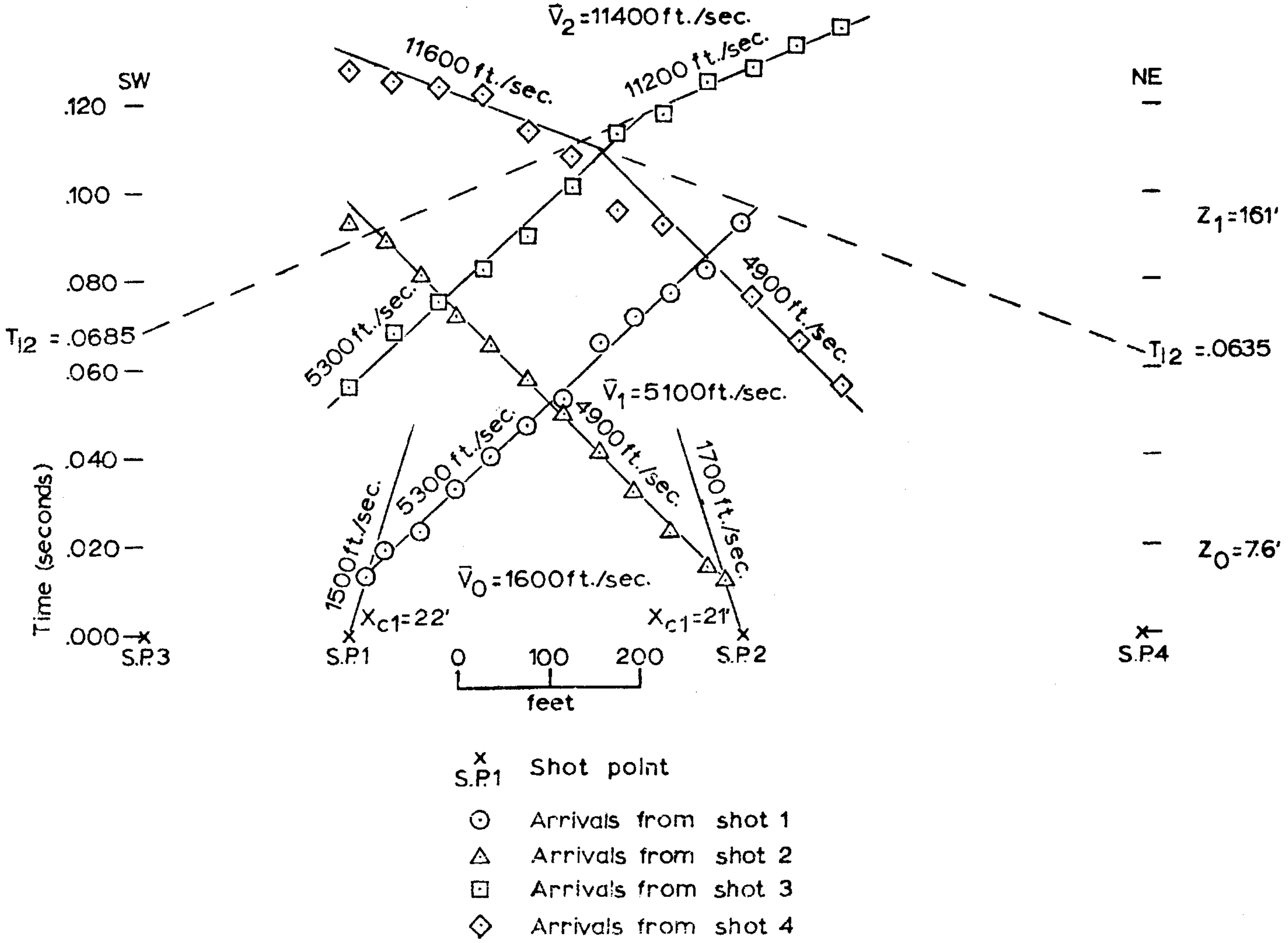


PLATE 35. TIME - DISTANCE PLOT, D-D'

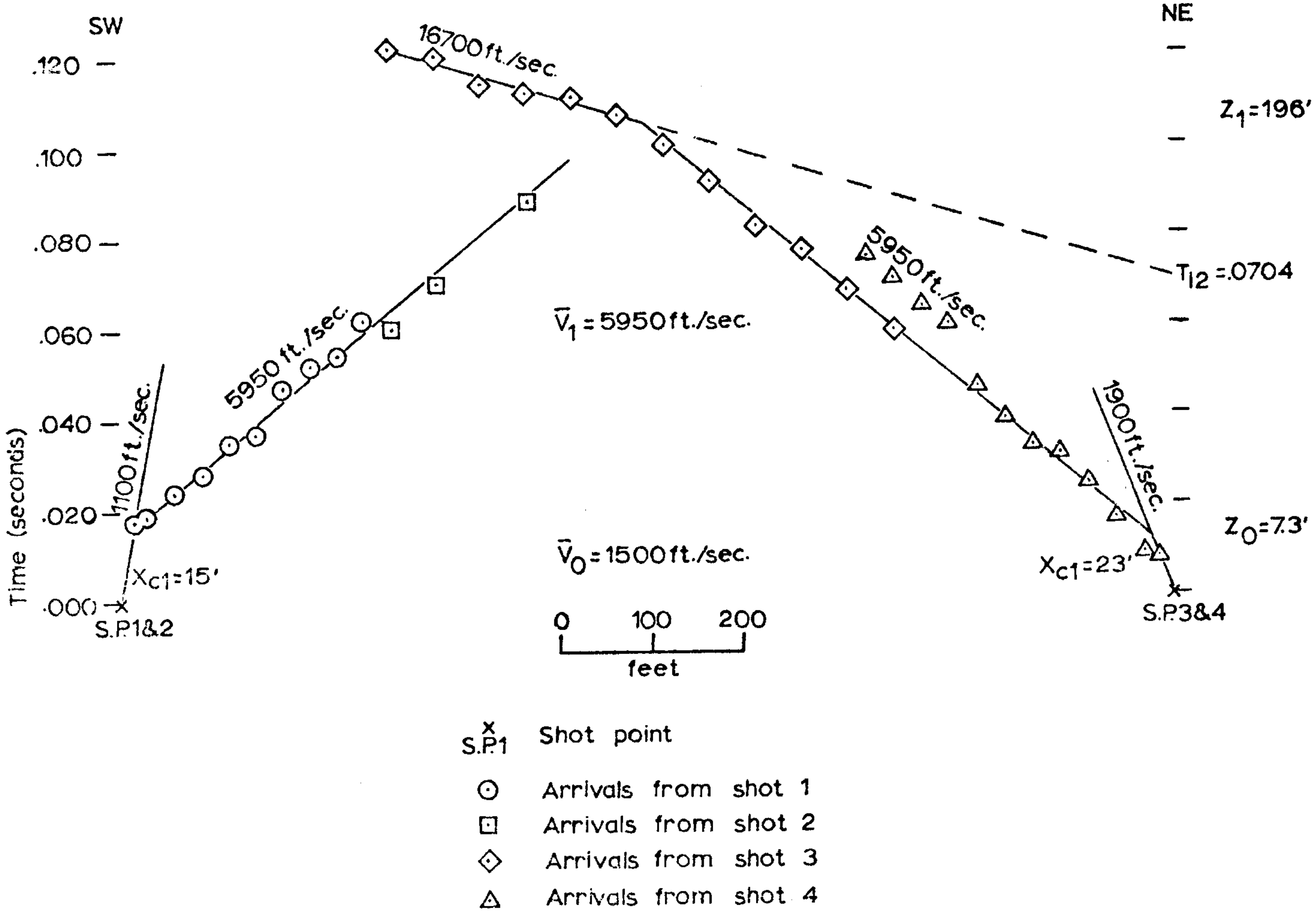
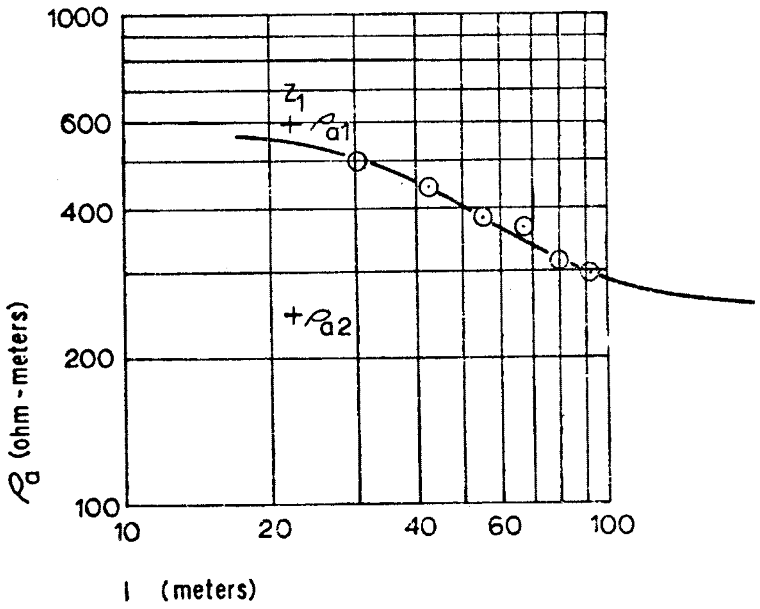


PLATE 36. RESISTIVITY FIELD CURVE & MASTER CURVE, D-D′



EXPLANATION

⊙ Field data

—— Master curve

INTERPRETATION

Z_1 = 22.2 meters
= 73 feet

ρ_{a1} = 600 ohm-meters

ρ_{a2} = 245 ohm-meters

PLATE 37. TIME-DISTANCE PLOT, E-E'

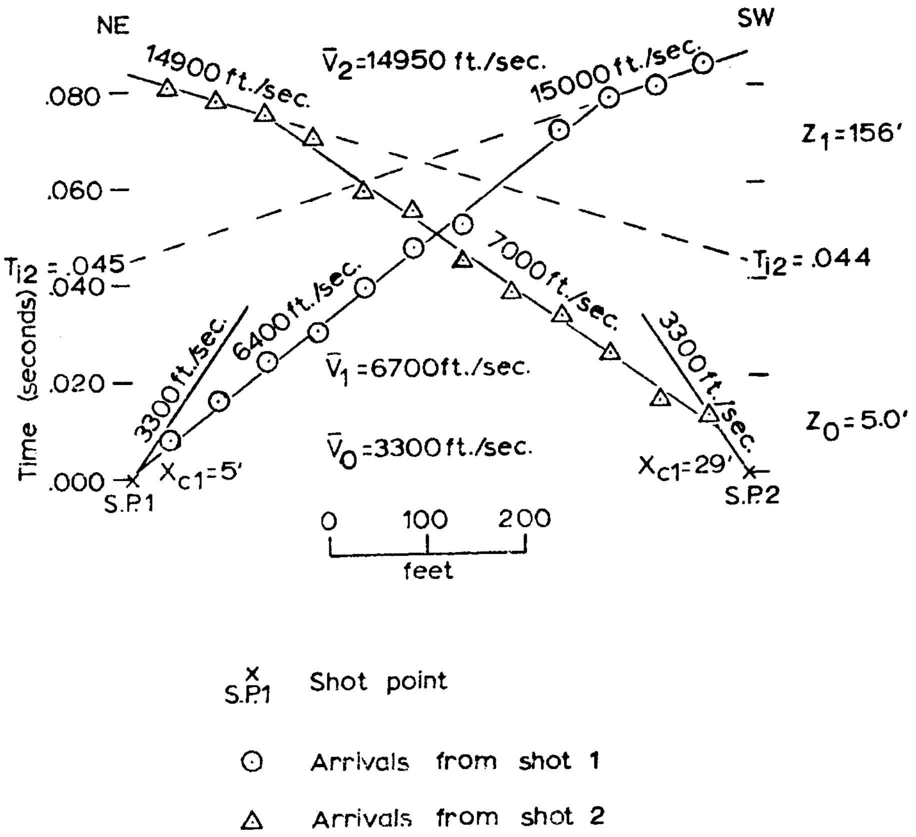
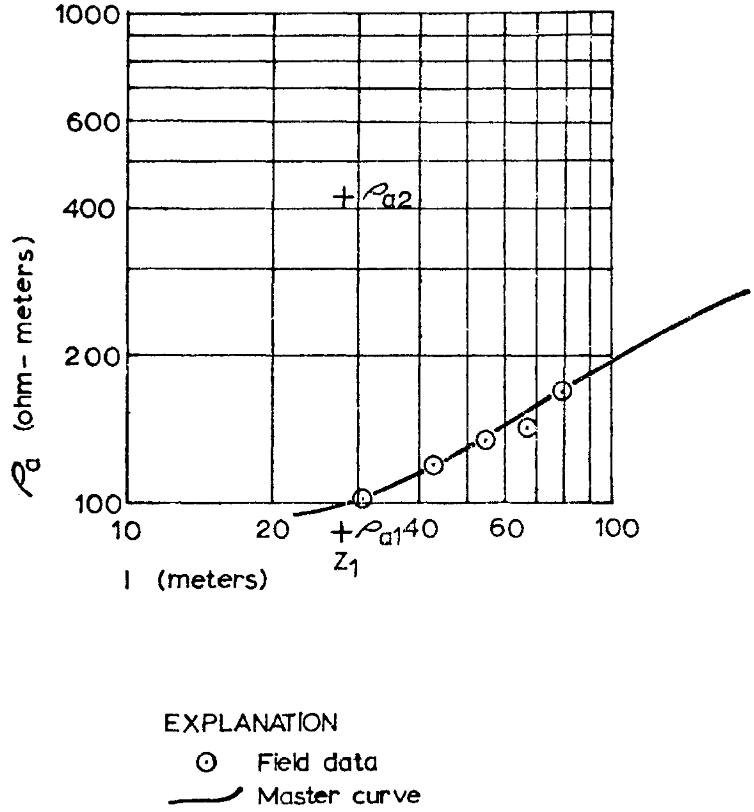


PLATE 38. RESISTIVITY FIELD CURVE & MASTER CURVE, G-G'



INTERPRETATION

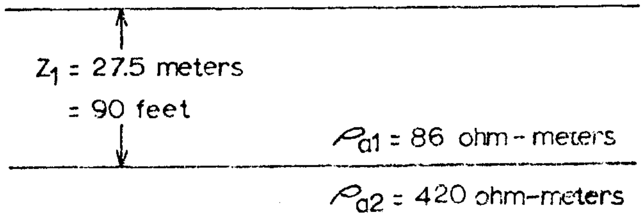


PLATE 39. TIME - DISTANCE PLOT, F - F'

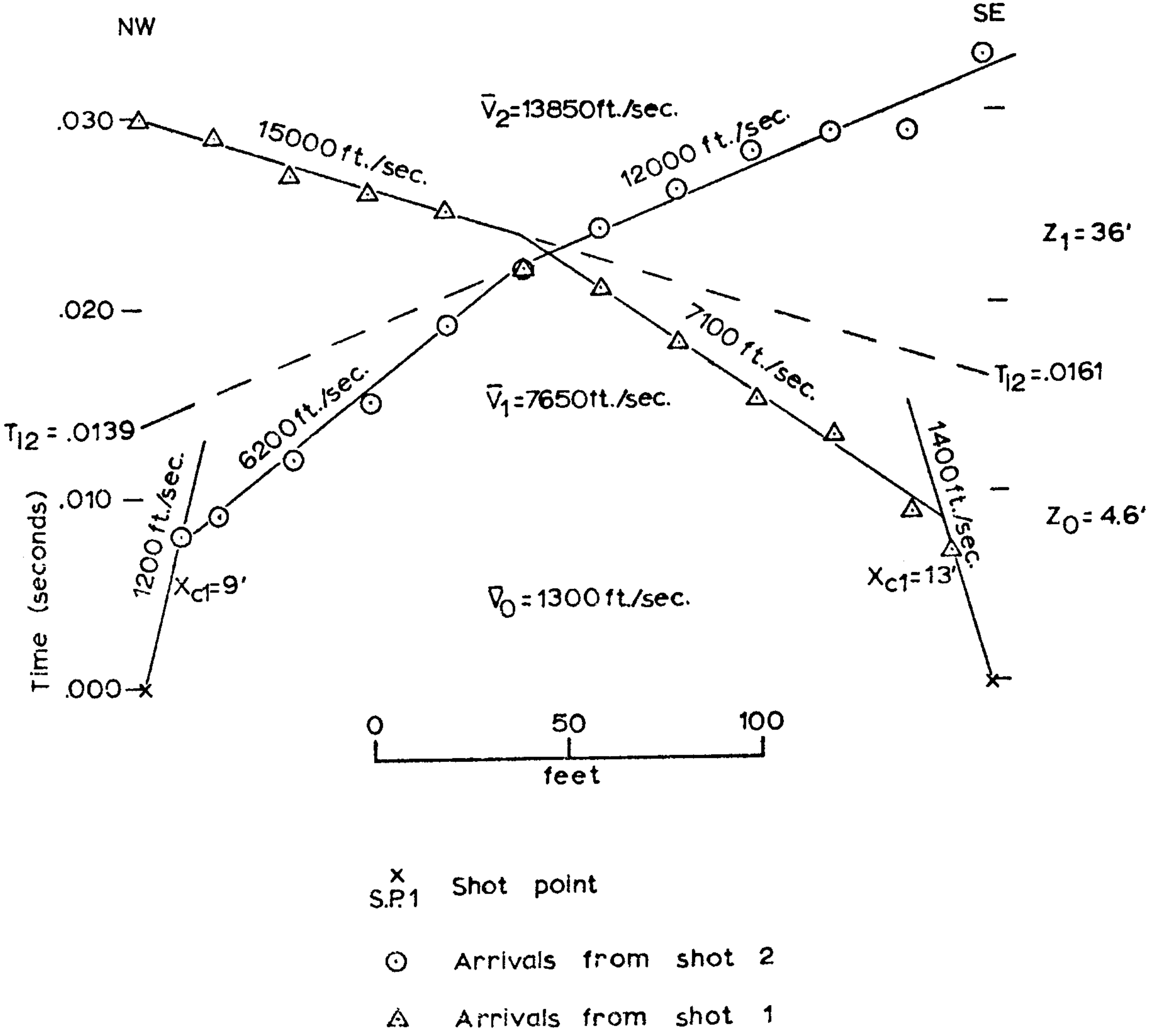


PLATE 40. TIME-DISTANCE PLOT, I-I' (SE-NW)

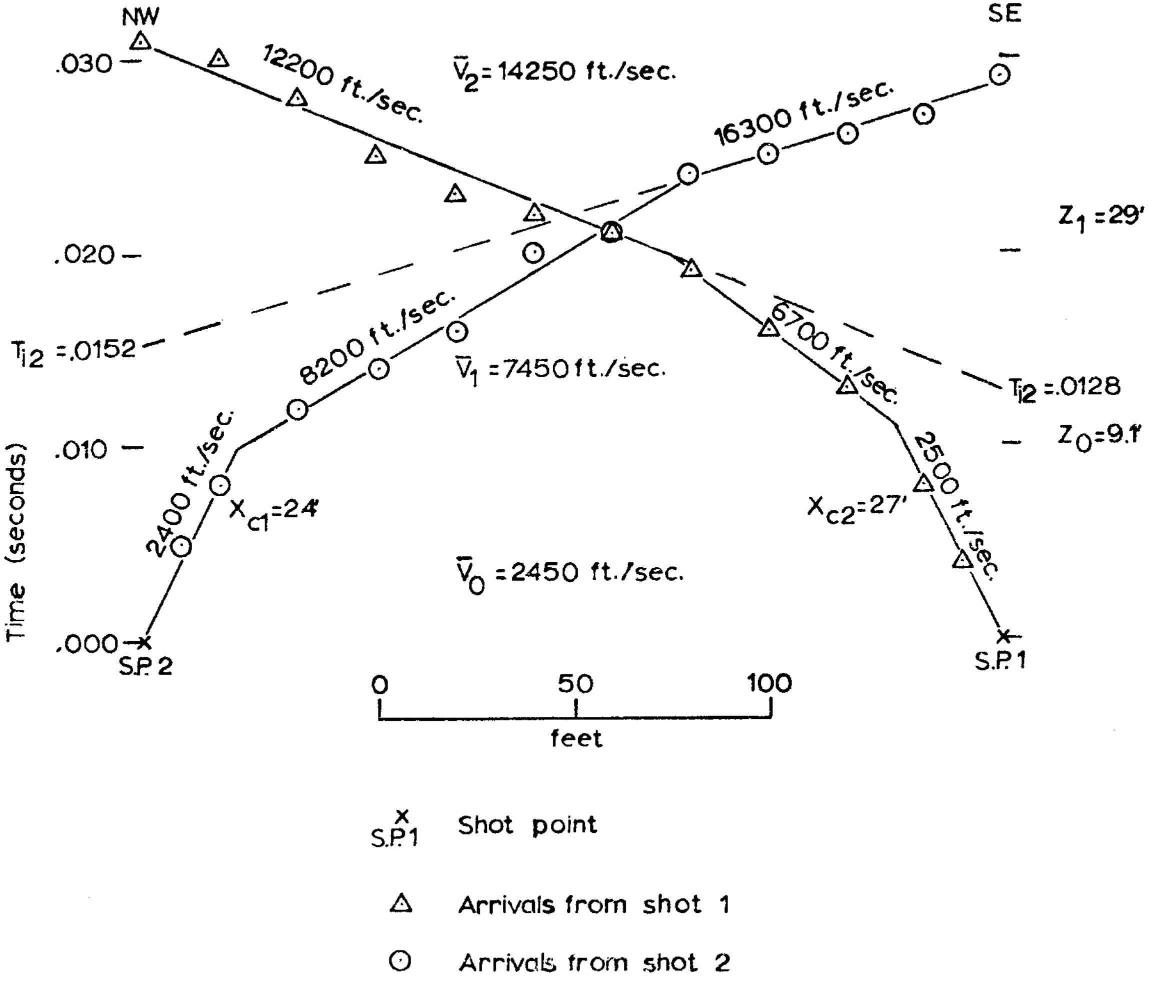
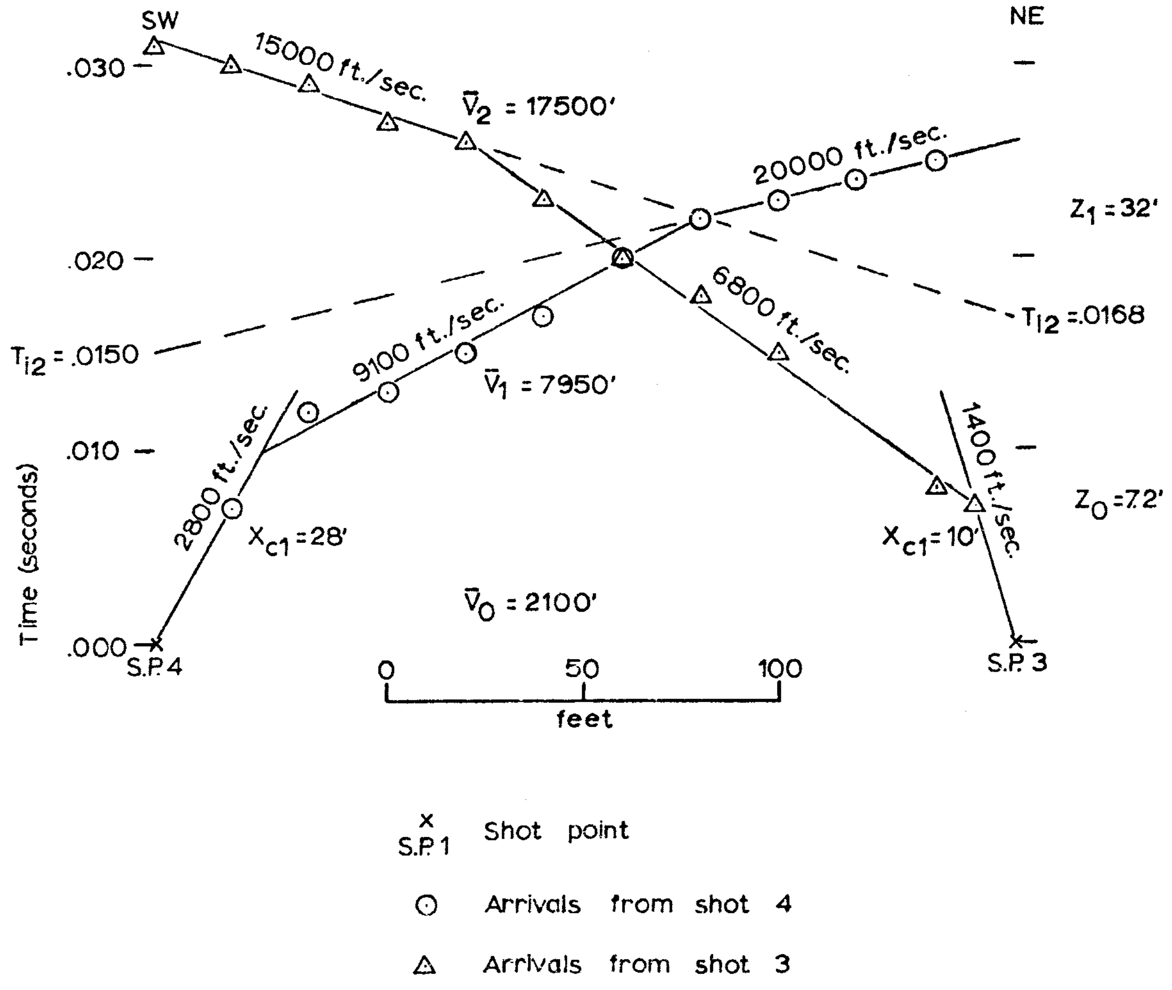


PLATE 41. TIME-DISTANCE PLOT, I-I' (NE-SW)



APPENDIX II, TABLES

TABLE 1. GROUND-WATER ANALYSIS

Well location	pH	Ec micro-mhos	Ca ppm	Cd ppm	Cu ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Na ppm	Pb ppm	Sb ppm	Zn ppm	Well use
48N 4E 34aab	6.55	<188	8.8	<0.02	<0.05	0.3	0.6	2.1	<0.1	1.7	<0.1	<2.0	<0.05	cooling
48N 4E 21dcd	6.67	249	13.9	<0.02	<0.05	0.1	0.9	6.4	<0.1	2.5	<0.1	<2.0	<0.05	abandoned
48N 4E 21bdc	6.90		14.6	<0.02	<0.05	3.6	5.7	3.6	0.5	2.1	<0.1	<2.0	0.1	drain
48N 4E 21cba1	6.64	249	14.8	<0.02	<0.05	0.2	2.7	8.5	<0.1	3.6	<0.1	<2.0	0.09	lawn
48N 4E 21cba2	6.38	269	17.1	<0.02	<0.05	<0.1	1.9	9.3	<0.1	5.0	<0.1	<2.0	0.07	domestic
48N 4E 20cab	6.42	290	18.2	0.02	<0.05	0.5	1.3	7.5	<0.1	3.1	<0.1	<2.0	9.2	business
48N 4E 20bab	6.65	228	10.6	0.03	<0.05	0.6	2.1	3.7	<0.1	3.0	<0.1	<2.0	5.2	pond
48N 4E 18ddb	6.23	249	11.2	0.2	<0.05	0.5	1.3	4.1	<0.1	2.9	<0.1	<2.0	19	industrial
48N 4E 18dbd	6.30	249	13.5	0.06	<0.05	4.4	1.7	4.7	<0.1	2.7	<0.1	<2.0	12	municipal
48N 4E 18bcc	6.35	228	10.0	<0.02	0.09	0.9	0.9	4.0	<0.1	2.6	<0.1	<2.0	2.8	trailer park
48N 3E 13bbb2	6.70	207	9.7	0.02	<0.05	0.5	1.3	4.4	0.2	2.5	<0.1	<2.0	4.6	pond
48N 3E 13bbb1	6.35	207	9.1	0.02	<0.05	1.1	1.1	3.7	<0.1	2.3	<0.1	<2.0	4.5	domestic
48N 3E 11bdd	6.72	290	19.7	<0.02	<0.05	<0.1	1.2	9.2	<0.1	4.0	<0.1	<2.0	0.05	business
48N 3E 3dbd	6.42	188	5.7	<0.02	<0.05	0.5	1.4	4.1	<0.1	3.6	<0.1	<2.0	0.2	abandoned
48N 3E 4cdd	7.07	228	10.1	<0.02	<0.05	0.2	1.5	4.5	0.2	8.7	0.1	<2.0	1.6	pond
48N 3E 4ccc	6.32	249	10.4	<0.02	<0.05	0.7	2.4	6.7	<0.1	9.1	<0.1	<2.0	0.05	lawn
48N 2E 1aad	5.41	518	28.9	0.1	<0.05	0.6	2.7	18.3	0.2	6.4	<0.1	<2.0	50	industrial
48N 2E 1aac	5.43	456	27.2	0.05	<0.05	2.9	2.6	16.2	0.9	6.2	<0.1	<2.0	30	industrial
49N 2E 34dac1	6.05	456	23.0	0.07	<0.05	0.1	4.7	19.5	1.2	11.4	<0.1	<2.0	19	pond
49N 2E 34dcc	6.40	9320	45.3	<0.02	<0.05	47	3.7	37.3	0.8	16.1	0.2	5.3	1.2	industrial
49N 2E 32dad	6.04	<188	3.3	<0.02	<0.05	2.0	1.0	2.1	<0.1	2.7	<0.1	<2.0	1.5	roadside park
48N 2E 6dad	6.54	<188	2.2	<0.02	<0.05	0.4	0.7	0.9	<0.1	1.8	<0.1	<2.0	0.1	pond
49N 2E 32dcc	6.65	<188	2.2	<0.02	<0.05	<0.1	0.8	0.8	<0.1	1.6	<0.1	<2.0	0.2	pond
49N 2E 32dac	6.64	<188	2.2	<0.02	<0.05	1.3	0.7	1.0	<0.1	1.6	<0.1	<2.0	0.8	domestic
49N 2E 30dca	6.42	<188	6.7	<0.02	<0.05	0.1	1.8	1.6	<0.1	3.9	<0.1	<2.0	<0.05	business
49N 2E 31bab	6.61	<188	4.0	<0.02	<0.05	0.9	0.7	2.1	<0.1	1.6	<0.1	<2.0	0.3	industrial
49N 2E 30ccd	6.35	<188	3.5	<0.02	<0.05	0.1	1.3	1.6	<0.1	2.1	<0.1	<2.0	<0.05	domestic
49N 2E 31dcc	6.35	207	7.6	<0.02	<0.05	2.3	3.1	3.1	0.3	3.6	<0.1	<2.0	0.07	abandoned
49N 1E 35adc	7.53	288	7.2	<0.02	<0.05	3.7	2.1	9.1	0.2	13.5	<0.1	<2.0	0.05	abandoned

TABLE 1. GROUND-WATER ANALYSIS--CONTINUED

Well location	pH	micro-mhos	Ca ppm	Cd ppm	Cu ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Na ppm	Pb ppm	Sb ppm	Zn ppm	Well use
48N 1E 3bab	6.80	2900	20.0	<0.02	0.08	0.1	0.5	8.3	<0.1	10.9	<0.1	<2.0	<0.05	domestic
49N 1E 33dcb	6.19	249	12.6	<0.02	<0.05	0.4	1.4	7.3	<0.1	4.0	<0.1	<2.0	1.8	domestic
48N 1E 5aac	6.87	<188	3.6	<0.02	<0.05	0.4	0.6	2.6	<0.1	9.1	<0.1	<2.0	1.8	domestic
48N 1E 5bda	6.70	<188	1.1	<0.02	<0.05	0.1	0.8	<0.5	<0.1	1.2	<0.1	<2.0	0.05	domestic
48N 1E 5bab	6.67	<188	4.3	<0.02	<0.05	0.4	0.8	<0.5	<0.1	1.2	<0.1	<2.0	0.2	domestic
49N 1E 29dbd	6.58	<188	4.9	<0.02	<0.05	0.2	1.2	2.3	<0.1	4.5	<0.1	<2.0	0.1	domestic
49N 1E 29bdb	6.35	<188	2.6	<0.02	<0.05	<0.1	1.0	1.5	<0.1	3.1	<0.1	<2.0	<0.05	stock and irrigation
49N 1E 30acb	6.12	188	2.1	<0.02	<0.05	31	0.8	2.8	0.2	8.1	<0.1	3.3	2.4	domestic
49N 1E 19cdd	7.41	188	1.0	<0.02	<0.05	0.3	0.8	<0.5	<0.1	1.9	<0.1	<0.0	<0.05	stock and irrigation
49N 1E 19cac	7.50	249	10.4	<0.02	<0.05	1.5	0.8	12.2	0.2	9.9	<0.1	<2.0	0.5	lawn
49N 1W 25bad	6.63	207	5.1	<0.02	<0.05	15	<0.5	3.9	0.2	15.3	<0.1	2.1	5.4	business
49N 1W 25cda	6.48	<188	2.9	<0.02	<0.05	0.2	0.9	1.2	<0.1	3.2	<0.1	<2.0	1.7	domestic
49N 1W 36cbb	6.33	<188	3.1	<0.02	<0.05	2.8	1.0	3.1	<0.1	3.1	<0.1	<2.0	1.6	domestic
49N 1W 23dca	6.40	<188	<0.5	<0.02	<0.05	4.0	0.6	0.7	0.2	3.2	<0.1	<2.0	1.7	domestic
49N 1W 23adb	6.88	188	3.4	<0.02	<0.05	0.2	1.3	8.5	0.8	4.1	<0.1	<2.0	0.2	domestic
49N 1W 27aac	6.23	<188	4.1	<0.02	<0.05	2.1	1.7	2.5	<0.1	4.2	<0.1	<2.0	<0.05	domestic
49N 1W 34ddb	6.25	188	5.7	<0.02	<0.05	0.3	2.3	3.1	<0.1	3.3	<0.1	<2.0	0.1	domestic
49N 1W 34cba	6.09	<188	2.5	<0.02	<0.05	0.2	1.2	1.4	<0.1	2.6	<0.1	<2.0	5.8	domestic
49N 1W 33cdd	5.82	<188	3.5	<0.02	<0.06	1.0	2.4	1.7	<0.1	7.3	<0.1	<2.0	0.4	domestic
48N 1W 4baa	6.95	228	5.3	<0.02	<0.05	3.5	2.0	5.0	<0.1	22.0	<0.1	<2.0	0.1	lawn

TABLE 2. QUALITY OF GROUND WATER FROM TAILINGS ACCUMULATIONS

	pH	EC micro-mhos	Ca ppm	Cd ppm	Cu ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Na ppm	Pb ppm	Sb ppm	Zn ppm
Page pond, seep #1 (1)	6.39	2117	182		0.09	0.44	29.3	35.1	20.8	12.4	0.20		19.9
Page pond, seep #2 (1)	6.37	1585	159		0.07	1.58	16.2	59.1	5.9	16.9	0.12		19.1
Page pond, 10 ft. level (2)			260		0.03	0.7	40	95	40	25	0.3		40
Bunker Hill pond, seep #1 (1)	5.20	1675	130	0.15	0.08	13.4	18.6	45.6	35.5	44.3	0.21	1.99	44.2
Bunker Hill pond, seep #2 (1)	3.69	3459	221	0.26	1.13	35.2	29.1	40.1	34.3	78.4	1.26	2.75	36.3
Sunshine pond, seep (1)	7.98	1063	9.63	0.01	0.06	0.78	7.4	3.37	2.13	243	0.11	2.29	0.07
Cataldo tailings pile, seep (1)	6.7		120				4.7	60.8	60	6.8			157
Cataldo tailings pile, ground water (2)	5.6		167		0.02	0.03	8	108	31	28	0.8		52

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(1) Mink, unpublished data

(2) Galbraith, 1971, p. 52

TABLE 3. MEAN CONCENTRATIONS OF Cu, Mn, Pb, and Zn IN BELT SERIES ROCKS (Johnson, 1971, pp. 65-91).

	Cu ppm.	Mn ppm.	Pb ppm.	Zn ppm.	Generalized Lithology
Prichard formation	41.1	468	39.6	102	argillite
Burke formation	5.0	451	18.7	26.2	green, gray, & brown quartzite
Revett formation	7.1	17.2	1.0	0.0	white & green quartzite
St. Regis formation (except upper)	4.1	976	2.0	20.0	purple, green, & gray argillite brown quartzite
St. Regis formation (upper)	35.6	310	65.7	73.5	green argillite
Lower Wallace formation	20.8	269	20.9	244	gray argillite
Upper Wallace formation	18.1	554	3.6	59.4	orange & gray argillite
Striped Peak formation	20.2	167	1.3	5.0	brown argillite quartzite

TABLE 4. U.S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS (American Water Works Association, 1971).

The following chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgement of the reporting agency and the certifying authority, other more suitable supplies are or can be made available.

Substance	Concentration (ppm.)
Alkyl benzene sulfonate (ABS)	0.5
Arsenic (AS)	0.01
Chloride (Cl)	250.0
Copper (Cu)	1.0
Carbon chloroform extract (CCE)	0.2
Cyanide (CN)	0.01
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45.0
Phenols	0.001
Sulphate (SO_4)	250.0
Total dissolved solids (TDS)	500.0
Zinc (Zn)	5.0

The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply.

Substance	Concentration (ppm.)
Arsenic (AS)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Cr^{6+})	0.05
Cyanide (CN)	0.2
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

TABLE 5. EFFLUENT LIMITATIONS FOR WATER DISCHARGED TO THE SOUTH FORK OF THE COEUR D'ALENE RIVER BY THE BUNKER HILL COMPANY (U.S. Environmental Protection Agency, 1973, P. 4)

Parameters	Discharge limitations
Total zinc	7.28 lbs/day
Total lead	1.36 lbs/day
Suspended solids	30 ppm
pH	Within the range 6.0 - 8.5

Visible foam and visible floating solids prohibited.

APPENDIX III, WELL LOGS

Owner: Woodland Park Water Company

Location: 48N 4E 24cc

From (feet)	To (feet)	Material
0	2	sand and topsoil
2	12	coarse gravel, boulders
12	40	sand and coarse gravel
40	90	bedrock

Owner: Marvin Hopkins

Location: 48N 4E 21cb

From (feet)	To (feet)	Material
0	2	topsoil
2	11	coarse gravel, boulders
11	34	sand, gravel, and clay
34	38	brown shale

Owner: Hecla Mining Company

Location: 48N 3E 13bcc

From (feet)	To (feet)	Material
0	23	red clay, some sand
23	38	brown clay and gravel
38	41	gravel, some clay
41	51	gravel, hard packed
51	69	tight gravel
69	71	blue slate

Owner: Sullivan Mining Company

Location: 49N 2E 35dcl

From (feet)	To (feet)	Material
0	30	sand and gravel
30	60	yellow hard clay
60	86	cemented gravel
86	88	bed rock

Owner: Sullivan Mining Company

Location: 49N 2E 34

From (feet)	To (feet)	Material
0	19	sand and gravel
19	72	blue clay
72	75	gravel, some silt
75	81	gravel

Owner: Ray Shutt

Location: 48N 2E 5aa

From (feet)	To (feet)	Material
0	20	coarse gravel
20	85	gravel, some clay
85	95	hard clay
95	107	fine sand

Owner: Julius Hegman

Location: 49N 1E 36dc1

From (feet)	To (feet)	Material
0	16	tan clay
16	17	sand and gravel
17	42	tan clay
42	43	gravel
43	78	tan clay
78	80	hard clay
80	82	gravel

Owner: Walter Hussa

Location: 49N 1E 34bc

From (feet)	To (feet)	Material
0	7	brown clay topsoil
7	16	yellow clay, some gravel
16	17	sand and gravel
17	18	cemented sand
18	39	gravel and tan clay
39	77	pink, gray, and tan clay
77	78	red-brown clay
78	81	conglomerate
81	87	sand and gravel
87	91	fine sand and gravel

Owner: Joe Jenicek

Location: 48N 1E 5aac

From (feet)	To (feet)	Material
0	3	topsoil
3	19	tan clay, some gravel
19	23	gray clay, some gravel
23	32	red-brown clay, some gravel
32	49	tan clay
49	65	brown clay, gravel, and cobbles
65	93	yellow clay
93	121	cemented coarse sand and gravel
121	152	brown clay, some coarse gravel
152	161	light brown slate
161	206	orange and brown clay, sand, and gravel
206	210	gray slate
210	230	brown clay (hard) and gravel

Owner: Mrs. Ailie Koski

Location: 49N 1W 36bd

From (feet)	To (feet)	Material
0	3	topsoil
3	6	gravel and boulders
6	17	tan clay
17	49	hard clay
49	56	white clay
56	66	tan cemented sand
66	82	tan cemented gravel
82	88	gray slate

Owner: Don Sverdsten

Location: 49N 1W 24dcc

From (feet)	To (feet)	Material
0	2	topsoil
2	15	brown clay
15	40	green clay, gravel
40	100	hard green slate
100	110	white slate
110	148	gray slate

Owner: Edward Sverdsten

Location: 49N 1W 24ccc

From (feet)	To (feet)	Material
0	4	sandy clay backfill
4	8	topsoil
8	30	brown sandy clay
30	32	firm brown clay
32	47	gray sandy clay
47	51	dark green fine sand
51	56	gray sand, some gravel
56	68	gray sand and gravel
68	82	fractured gray slate

Owner: Schneberger

Location: 49N 1W 27aac

From (feet)	To (feet)	Material
0	5	topsoil
5	6	sand and gravel
6	24	gray clay
24	28	compact clay and gravel
28	30	sand and gravel

Owner: G. Stoddard

Location: 49N 1W 33aa

From (feet)	To (feet)	Material
0	10	topsoil
10	52	clay
52	58	sand and clay
58	82	clay

Owner: John Strobel

Location: 48N 1W 4baa

From (feet)	To (feet)	Material
0	6	topsoil
6	45	compact clay and gravel
45	70	sand and silt
70	76	gravel, some silt
76	84	coarse gravel, some silt