STRATIGRAPHY OF THE UNSATURATED ZONE AT THE RADIOACTIVE WASTE MANAGEMENT COMPLEX, IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO

By S.R. Anderson and B.D. Lewis

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CONVERSION FACTORS

For readers who prefer to use metric (International System) units rather than units used in this report, the following conversion factors may be used:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
cubic foot (ft^3)	0.02832	cubic meter
curie (Ci)	3.70×10^{10}	becquerel

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

A complex sequence of layered basalt flows, cinders, and sediment underlies the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory in southeastern Idaho. Wells drilled to 700 feet penetrate a sequence of 10 basalt-flow groups and 7 major sedimentary interbeds that range in age from about 100,000 to 600,000 years old. The 10 flow groups consist of 22 separate lava flows and flow-units. Each flow group is made up of from one to five petrographically similar flows that erupted from common source areas during periods of less than 200 years. Sedimentary interbeds consist of fluvial, lacustrine, and eolian deposits of clay, silt, sand, and gravel that accumulated during periods of volcanic inactivity ranging from thousands to hundreds of thousands of years. Flows and sediment are unsaturated to a depth of about 600 feet. Flows and sediment below a depth of 600 feet are saturated and make up the uppermost part of the Snake River Plain aquifer.

The areal extent of flow groups and interbeds was determined from well cuttings, cores, geophysical logs, potassium-argon ages, and geomagnetic properties. Stratigraphic control was provided by four sequential basalt flows near the base of the unsaturated zone that have reversed geomagnetic polarity and high emission of natural gamma radiation compared to other flows. Natural gamma logs were used as a primary correlation tool. Natural-gamma emissions generally are uniform in related, petrographically similar flows and generally increase or decrease between petrographically dissimilar flows of different age and source.

INTRODUCTION

The RWMC (Radioactive Waste Management Complex) is in the southwestern part of the INEL (Idaho National Engineering Laboratory) in southeastern Idaho (fig. 1). The RWMC, which is used for above-ground storage and subsurface burial of radioactive and chemical waste, is situated about 3.5 mi north of the southern boundary of the INEL and covers an area of 0.225 mi^2. The area covered in this report, the RWMC area, encompasses about 1.5 mi^2 and includes the RWMC and immediately adjacent areas in which stratigraphic information has been collected from numerous wells (fig. 2). As used in this report, a well refers to any drill hole, core hole, borehole, or water well from which geologic and geophysical information has been collected; the usage excludes shallow auger holes completed in surficial sediment.

The RWMC was established in 1952 as a controlled area for the management of solid radioactive waste. Low-level waste is buried in shallow pits and trenches excavated in sediment at the SDA (Subsurface Disposal Area) (figs. 1 and 2). Transuranic waste, which in the past also was buried at the SDA, has been stored since 1970 above ground on asphalt pads in retrievable containers at the TSA (Transuranic Storage Area) (figs. 1 and 2). From 1952 to 1986, about 6.3 million ft^3 of low-level and transuranic radioactive waste containing about 9.5 million Ci of radioactivity was buried at the RWMC. An estimated 88,400 gal of organic waste also was buried before 1970 (D.E. Kudera, EG&G Idaho, Inc., written commun., 1987). Buried organic waste includes an estimated 24,400 gal of carbon tetrachloride, about 39,000 gal of lubricating oil, and about 25,000 gal of other organic compounds such as trichloroethane and trichloroethylene.

Concern about the potential for migration of buried waste from the RWMC to the underlying Snake River Plain aquifer has prompted numerous subsurface investigations of the RWMC area (Barraclough and others, 1976; Burgus and Maestas, 1976; Humphrey and Tingey, 1978; Humphrey, 1980; U.S. Department of Energy, 1983; Rightmire, 1984; Rightmire and Lewis, 1987a, 1987b). From June 1971 to September 1988, 45 wells (fig. 2) with a composite depth of 13,880 ft were drilled to evaluate the geologic, geohydrologic and

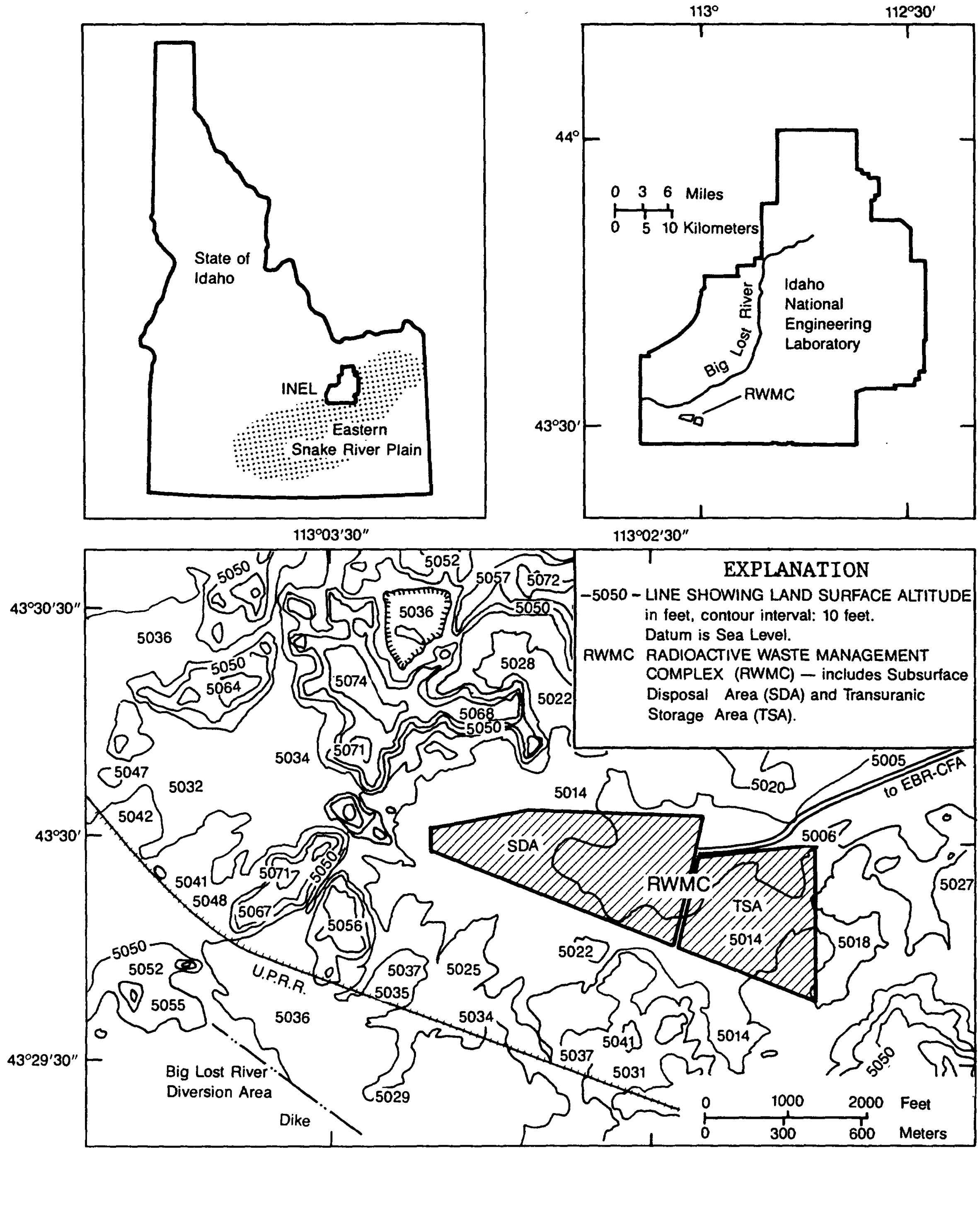

Figure 1.--Location of the Radioactive Waste Management Complex.

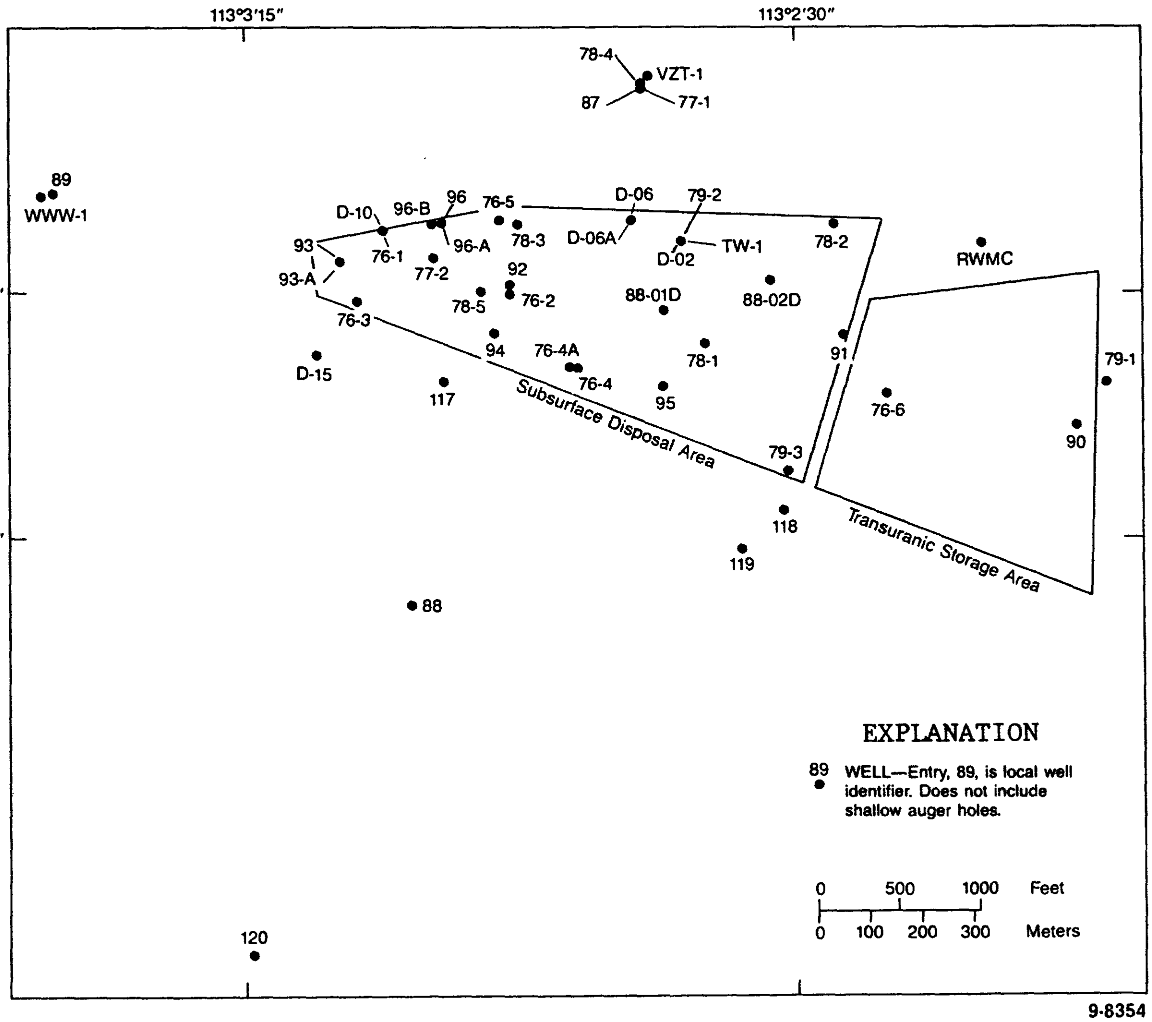

Figure 2.--Location of wells at the Radioactive Waste Management Complex.

geochemical characteristics of the unsaturated zone and aquifer. Samples from wells indicate that waste is present in the subsurface at depths greater than that of burial. Purgeable organic compounds have been detected in water from wells in and near the SDA, and radionuclides have been detected in drill cores from a depth of about 110 ft below the land surface. Additional data collection and study are needed to evaluate the potential for contamination of the unsaturated zone and aquifer. In 1988, the U.S. Geological Survey, in cooperation with the U.S. Department of Energy, began an investigation of the stratigraphy of the unsaturated zone at the RWMC. The investigation was undertaken to determine stratigraphic relations in the unsaturated zone that ultimately may affect the potential for migration of buried waste from the RWMC to the Snake River Plain aquifer.

Purpose and Scope

The purpose of this report is to describe the stratigraphic framework of the unsaturated zone in the RWMC area, using geologic and geophysical data collected from June 1971 to September 1988. Data collected for this and previous studies indicate that there are numerous basaltic lava flows and sedimentary interbeds in the subsurface at the RWMC. This report describes the stratigraphic relations between groups of related flows and major interbedded sedimentary deposits in the unsaturated zone and uppermost part of the aquifer. The stratigraphic framework described in this report is an extension of the framework first described by Kuntz and others (1980). The reader is referred to Kuntz and others (1980), Champion and others (1981), and Champion and others (1988) for information concerning the ages and physical characteristics of individual lava flows and the criteria used for subdividing volcanic and sedimentary sequences in the subsurface at the RWMC. The altitude and thickness of flow groups and sedimentary units are shown on figures 3-24 and tables 1 and 2 at the end of this report.

Approach

This report contains geologic sections, maps, and tables that describe the stratigraphic characteristics of the subsurface in the RWMC area; geologic data are referenced to altitude above sea level and depth below land surface. Geologic data shown on sections, maps, and tables were interpreted from well cuttings, cores, geophysical logs, K-Ar (potassium-argon) ages, and geomagnetic properties. Natural gamma logs were used to correlate stratigraphic units determined from detailed core descriptions, age determinations, and geomagnetic properties in 5 wells (Kuntz and others, 1980) to stratigraphic units in 40 other wells in the RWMC area. A straight-line interpolation was used to extend observed contacts from well to well on geologic sections. Map contours of altitude and thickness of stratigraphic units were interpolated between wells to the nearest 10 ft on the basis of data from multiple well clusters that indicate changes in relief of more than 5 ft in adjacent wells on many geologic surfaces. Map contours, which are considered approximate because of probable high surface relief and sparse data in places, were interpolated from data with a probable accuracy of ±2 ft. The greatest effect on accuracy of data in this report is likely a result of uncertainties concerning locations and altitudes of unsurveyed wells. Such wells, many of which have been buried, backfilled, or otherwise destroyed, were approximately located on the basis of verbal or written descriptions and assigned land-surface altitudes that are accurate to ±2 ft.

Acknowledgments

Assistance was provided during this investigation by personnel of EG&G Idaho, Inc. Steven C. Minkin and Patrick L. Laney, Environmental Monitoring, generously provided well data and assisted in efforts to compile surveyed locations and altitudes of wells at the RWMC.

GEOHYDROLOGIC SETTING

The eastern Snake River Plain is a northeast-trending structural basin about 200 mi long and 50 to 70 mi wide. The plain is underlain by a layered sequence of Tertiary and Quaternary volcanic rocks and sedimentary deposits that is thousands of feet thick (Whitehead, 1986; Mann, 1986; Rightmire and Lewis, 1987a). Volcanic rocks of this sequence consist mainly of basaltic lava flows and cinder beds in the upper part and rhyolitic ash flows and tuff in the lower part. Basalt flows are intercalated with fluvial, lacustrine, and eolian deposits of clay, silt, sand, and gravel.

Basaltic rocks and sediment are saturated at depth and together form the Snake River Plain aquifer. Depth to water in the aquifer ranges from tens to hundreds of feet across the plain and from 200 to 900 ft below land surface at the INEL. Saturated thickness of the aquifer ranges from less than 500 to more than 4,000 ft (Whitehead, 1986). Hydraulic properties of the aquifer differ considerably from place to place depending on saturated thickness and the characteristics of the basalt and sediment. In places, basalt and sediment sequences in the upper part of the aquifer yield thousands of gallons per minute of water to wells with negligible drawdown. Hydraulic data for rock units underlying the Snake River Plain aquifer are sparse, but data for a 10,365-ft test hole at the INEL indicates that deeper rocks and sediment are relatively impermeable compared to those within the aquifer (Mann, 1986).

The RWMC area is underlain by numerous basaltic-lava flows, lava-flow units, and lava-flow groups. A lava flow is a solidified body of rock that is formed by a lateral, surficial outpouring of molten lava from a vent or fissure (Bates and Jackson, 1980). The term flow is used informally in this report to include a lava-flow unit, which is a separate, distinct lobe of lava that issues from the main body of a lava flow (Bates and Jackson, 1980). A lava-flow group is a sequence of one or more petrographically similar flows or flow units that are extruded from the same vent or magma source within the course of a single eruption or multiple eruptions during a relatively short interval of time (Kuntz and others, 1980). Lava-flow groups are referred to as basalt-flow groups or flow groups in this report.

Wells drilled to a depth of 700 ft at the RWMC penetrate a sequence of basalt-flow groups that ranges in age from about 100,000 to 600,000 years old (Kuntz and others, 1980; Champion and others, 1981; Champion and others, 1988). Flow groups consist of single or multiple flows that were formed during eruption events of less than 200 years (Kuntz and others, 1980). Individual flows consist mainly of medium- to dark-gray beds of vesicular to dense, olivine basalt. Individual flows are as much as 114 ft thick, and, in places, are interbedded with cinders and thin layers of sediment.

Basalt-flow groups unconformably overlie older flow groups or are separated from older flow groups by thin to thick layers of sediment. These layers, referred to as major sedimentary interbeds, are the result of sediment accumulations across the area during long intervals of volcanic inactivity ranging from thousands to hundreds of thousands of years (Kuntz and others, 1980). Major sedimentary interbeds are as much as 40 ft thick and consist of well- to poorly-sorted deposits of clay, silt, sand, and gravel. In places the interbeds contain cinders and basalt rubble.

The general relations between basalt-flow groups, major sedimentary interbeds, and the unsaturated zone and aquifer in the upper 700 ft of the subsurface are shown in figures 3 through 6. Because most wells in the RWMC area are completed in the upper 300 ft of the unsaturated zone, relations in this zone are better defined that those between 300 and 700 ft. Basalt-flow groups and sedimentary interbeds generally are unsaturated to a depth of about 600 ft; basalt and sediment sequences penetrated by wells below a depth of 600 ft are saturated and make up the uppermost 100 ft of the Snake River Plain aquifer (figs. 3-6). In June 1988, depth to water ranged from 580 to 613 ft in seven wells that penetrate the upper 100 ft of the aquifer. Perched ground water also has been identified in numerous wells in the unsaturated zone at depths ranging from 30 to 230 ft (Rightmire and Lewis, 1987a). Zones of perched ground water occur in basalt and sediment, and may be the result of lateral movement of recharge water from diversion ponds of the Big Lost River that lie to the south of the RWMC area (Rightmire and Lewis, 1987a) (fig. 1).

STRATIGRAPHY OF THE UNSATURATED ZONE

The unsaturated zone and the uppermost part of the Snake River Plain aquifer in the RWMC area consist of 22 basaltic lava flows and 7 major sedimentary interbeds. The basalt and sediment sequence is overlain in most places by a thin veneer of surficial sediment. The flows can be further subdivided into 10 basalt-flow groups, assigned an informal alphabetical designation of A through I that corresponds to the stratigraphic sequence of each group from the land surface to the uppermost part of the aquifer (figs. 3-6). Flow groups A, B, C, D, E, F, and G are equivalent to flow groups A through G described by Kuntz and others (1980); flow groups FG, H, and I were identified during this investigation. Sedimentary interbeds are referred to as A-B through H-I on the basis of their relation to overlying and underlying flow groups. For example, interbed A-B lies between basalt-flow groups A and B. Sedimentary interbeds A-B, B-C, and C-D previously have been referred to as the 30, 110, and 240 ft interbeds, respectively, on the basis of average depth from land surface (Barraclough and others, 1976).

Seven flow groups and three interbeds extend across the RWMC area as shown by correlations made from well data; the remaining three flow groups and four interbeds are absent in some wells (figs. 3-6). From five to eight flow groups and from three to seven interbeds can locally be identified in wells that penetrate the unsaturated zone. The extent and thickness of interbeds are related to the surface relief of underlying flow groups.

Basalt-Flow Groups

Basalt-flow groups A through I make up about 90 percent of the 700 ft thick stratigraphic sequence that has been penetrated by wells in the RWMC area (figs. 3-6). The average thickness of individual flow groups ranges from 22 ft for flow group A to 167 ft for flow group F. Surface relief of individual flow groups ranges from 34 ft for flow group A to 99 ft for flow group G. All flow groups extend across the RWMC area with the exception of flow groups A, FG, and H. Flow groups A, B, C, D, E, F, FG and the uppermost part of G are in the unsaturated zone. Flow groups H, I, and the lowermost part of G are below the water table and make up the uppermost part of the Snake River Plain aquifer. Stratigraphic relations of flow groups A through D are better defined than those of underlying flow groups because only 12 of 45 wells penetrate below the base of flow group D.

Ages of basalt-flow groups A through I range from about 100,000 to 600,000 years old; however, the ages of flows in any one flow group probably differ by less than 200 years (Kuntz and others, 1980). Ages of flow groups A, B, C, D, E, and F are based on a compilation of ages presented in previous reports (Kuntz and others, 1980; Champion and others, 1981; Champion and others, 1988). Probable ages of flow groups FG, G, H, and I are based on tentative regional correlation of the flows to dated flows of similar stratigraphic position in a core hole 10 mi northeast of the RWMC (Champion and others, 1988).

Flow group A.--Flow group A, the youngest flow sequence in the RWMC area, consists of one to two flows that erupted from Quaking Aspen Butte and flowed down the valley of the Big Lost River in the area north and west of the RWMC (Kuntz, 1978; Kuntz and others, 1980; Kuntz and others, 1984). The age of flow group A is 95,000±50,000 years old on the basis of measured K-Ar ratios. Flow group A is confined to the northern and western parts of the RWMC area and overlies sedimentary interbed A-B and flow group B (figs. 3-9; table 1). Flows of flow group A, which locally are overlain by surficial sediment, are exposed and form a prominent ridge along the western edge of the RWMC area. Flow group A is fully penetrated by 23 wells. In these wells, the top of flow group A is at a depth of 2 to 20 ft and ranges in altitude from 4,990 to 5,024 ft. The base of flow group A is at a depth of 18 to 46 ft and ranges in altitude from 4,966 to 4,996 ft. Thickness of flow group A ranges from 0 to 43 ft, averages 22 ft, and is greatest in the northern part of the RWMC area.

Flow group B.--Flow group B consists of two to three flows that were erupted from vent 5206 about 3 mi southeast of the RWMC (Kuntz, 1978; Kuntz and others, 1980; Kuntz and others, 1984). The age of flow group B is from 95,000±50,000 to 200,000 years old based on its stratigraphic position below flow group A and on measured K-Ar ratios. Flow group B overlies sedimentary interbed B-C and flow group C (figs. 3-6 and 10-12; table 1). Flow group B is overlain by sedimentary interbed A-B and flow group A in the northern and western parts of the RWMC area and locally by surficial sediment in the southern and eastern parts. Flows of flow group B are partially or fully penetrated by 45 wells in the RWMC area. In these wells, the top of flow group B is at a depth of 3 to 55 ft and ranges in altitude from 4,962 to 5,029 ft. The base of flow group B is at a depth of 87 to 131 ft and ranges in altitude from 4,881 to 4,931 ft. Thickness of flow group B ranges from 38 to 118 ft, averages 75 ft, and is greatest in the extreme southern and eastern parts of the RWMC area.

Flow group C.--Flow group C consists of three to five flows from an unknown source probably northwest of the RWMC area. The age of flow group C is from 180,000±30,000 to 290,000±45,000 years old on the basis of measured K-Ar ratios. Flow group C overlies sedimentary interbed C-D and flow group D, and is overlain by sedimentary interbed B-C and flow group B (figs. 3-6 and 13-15; table 1). Flows of flow group C are partially or fully penetrated by 40 wells in the RWMC area. The top of flow group C is at a depth of 88 to 171 ft and ranges in altitude from 4,841 to 4,921 ft. The base of flow group C is at a depth of 218 to 253 ft and ranges in altitude from 4,759 to 4,801 ft. Thickness of flow group C ranges from 82 to 132 ft, averages 115 ft, and is greatest in the northern part of the RWMC area.

Flow group D.--Flow group D consists of one to two flows from an unknown source probably northwest of the RWMC area. Potassium-argon ratios indicate that flow group D is 230,000±85,000 years old. Flow group D overlies sedimentary interbed D-E and flow group E, and is overlain by sedimentary interbed C-D and flow group C (figs. 3-6 and 16; table 1). Flows of flow group D are partially or fully penetrated by 24 wells in the RWMC area. The top of flow group D is at a depth of 230 to 269 ft and ranges in altitude from 4,745 to 4,781 ft. The base of flow group D is at a depth of 261 to 304 ft and ranges in altitude from 4,708 to 4,752 ft. Thickness of flow group D ranges from 8 to 55 ft, averages 32 ft, and is greatest in the northeastern part of the RWMC area.

Flow group E.--Flow group E consists of one flow from an unknown source probably southeast of the RWMC area. The age of this flow is 515,000±85,000 years old on the basis of measured K-Ar ratios. Flow group E overlies sedimentary interbed E-F and flow group F, and is overlain by sedimentary interbed D-E and flow group D (figs. 3-6; table 2). Flow group E is partially or fully penetrated by 12 wells in the RWMC area. The top of flow group E is at a depth of 267 to 311 ft and ranges in altitude from 4,708 to 4,746 ft. The base of flow group E is at a depth of 359 to 403 ft and ranges in altitude from 4,609 to 4,662 ft. Thickness of flow group E ranges from 71 to 114 ft, averages 86 ft, and is greatest in the southern part of the RWMC area.

Flow group F.--Flow group F consists of four flows from an unknown source probably near the RWMC area. Potassium-argon ratios indicate that flow group F is 565,000±14,000 years old. Flow group F overlies sedimentary interbeds F-G and F-FG and flow groups G and FG; flow group F is overlain by sedimentary interbed E-F and flow group E (figs. 3-6; table 2). Flows of flow group F are partially or fully penetrated by 10 wells in the RWMC area. The top of group F is at a depth of 359 to 403 ft and ranges in altitude from 4,609 to 4,656 ft. The base of flow group F is at a depth of 487 to 578 ft and ranges in altitude from 4,432 to 4,525 ft. Thickness of flow group F ranges from 84 to 199 ft, averages 167 ft, and is greatest in the northern part of the RWMC area.

Flow group FG.--Flow group FG consists of one flow from an unknown source probably northwest of the RWMC area. The age of flow group FG is from 565,000±14,000 to 641,000±55,000 years old on the basis of its stratigraphic position between flow groups F and I. Flow group FG overlies sedimentary interbed FG-G and flow group G, and is overlain by sedimentary interbed F-FG and flow group F (figs. 3 and 4; table 2). Flow group FG is penetrated only by well 89 in the western part of the RWMC area. The top of flow group FG is at a depth of 548 ft and an altitude of 4,481 ft. The base of flow group FG is at a depth of 569 ft and an altitude of 4,460 ft. Thickness of flow group FG in well 89 is 21 ft. Flow group FG pinches out between well 89 and the eastern part of the RWMC area.

Flow group G.--Flow group G consists of two flows from an unknown source probably near the RWMC area. The age of flow group G is from 565,000±14,000 to 641,000±55,000 years old on the basis of its stratigraphic position between flow groups F and I. Flow group G overlies sedimentary interbeds G-H and G-I and flow groups H and I. Flow group G is overlain by sedimentary interbeds F-G and FG-G and flow groups F and FG (figs. 3-6; table 2). Flows of flow group G are partially or fully penetrated by nine wells in the RWMC area. The top of flow group G is at a depth of 493 to 590 ft and ranges in altitude from 4,420 to 4,519 ft. The base of flow group G is at a depth of 600 to 637 ft and ranges in altitude from 4,368 to 4,416 ft. Thickness of flow group G ranges from 40 to 123 ft, averages 81 ft, and is greatest in the southern part of the RWMC area.

Flow group H.--Flow group H consists of one flow from an unknown source probably southeast of the RWMC area. The age of flow group H is from 565,000±14,000 to 641,000±55,000 years old on the basis of its stratigraphic position between flow groups F and I. Flow group H overlies sedimentary interbed H-I and flow group I, and is overlain by sedimentary interbed G-H and flow group G (figs. 3-6; table 2). Flow group H is fully penetrated by wells 87, 117, 119, 120, and RWMC in the eastern part of the RWMC area. The top of flow group H is at a depth of 605 to 642 ft and ranges in altitude from 4,363 to 4,411 ft. The base of flow group H is at a depth of 620 to 667 ft and ranges in altitude from 4,338 to 4,396 ft. Thickness of flow group H ranges from 3 to 27 ft, averages 18 ft, and is greatest in well 120 and least in well 117. Flow group H pinches out between well 117 and the western part of the RWMC area.

Flow group I.--Flow group I is the oldest flow sequence that has been penetrated by wells in the RWMC area. Flow group I, which appears to correlate with the flows of AEC Butte 8 mi northeast of the RWMC area, consists of one flow that probably is 641,000±55,000 years old. Flow group I is overlain by sedimentary interbeds G-I and H-I and flow groups G and H (figs. 3-6; table 2). Flow group I is partially penetrated by wells 117, 119, 120, and RWMC in the southern and eastern parts of the RWMC area. The top of flow group I is at a depth of 639 to 673 ft and ranges in altitude from 4,332 to 4,374 ft. Maximum explored thickness of flow group I is 49 ft in well 120.

Surficial Sediment

Basaltic rocks in the RWMC area are overlain in most places by a thin veneer of surficial sediment that is fully penetrated by 45 wells and numerous auger holes. The surficial sediment overlies the basaltic lava flows of flow group A in the northern and western parts of the RWMC area and the flows of flow group B in the southern and eastern parts (figs. 3-6, 17 and 18; table 1). In wells, the base of surficial sediment is at a depth of 2 to 22 ft and ranges in altitude from 4,986 to 5,029 ft. Thickness of surficial sediment ranges from 0 to 22 ft, averages 10 ft, and is greatest inside the boundaries of the SDA. In this report, description of the distribution of surficial sediment is considered approximate because it excludes data from auger holes and does not reflect changes in sediment thickness that occur as a result of periodic recontouring of the land surface at the SDA. A more rigorous evaluation of surficial sediment in the RWMC area is presented by Rightmire and Lewis (1987a).

Sedimentary Interbeds

Sedimentary interbeds A-B through H-I and overlying surficial sediment make up about 10 percent of the 700 ft stratigraphic sequence that has been penetrated by wells in the RWMC area (figs. 3-6). The average thickness of individual interbeds ranges from 5 ft for interbeds A-B and E-F to 17 ft for interbed C-D. Surface relief of individual interbeds ranges from 27 ft for interbed E-F to 93 ft for interbed F-G. Interbeds C-D, F-G, and G-I extend across the RWMC area; interbeds F-G and G-I consist of laterally equivalent interbeds F-FG, FG-G, G-H, and H-I that extend above and below discontinuous flow groups FG and H. The remaining four interbeds, A-B, B-C, D-E, and E-F, are missing in places, but underlie large parts of the RWMC area. Interbeds A-B, B-C, C-D, D-E, and E-F are in the unsaturated zone. Interbeds FG, F-FG, and FG-G are partly in the unsaturated zone and partly below the water table. Interbeds G-I, G-H, and H-I are below the water table in the uppermost part of the Snake River Plain aquifer. Stratigraphic relations of interbeds A-B through C-D are better defined than those of underlying interbeds because only 12 of 45 wells penetrate below the top of interbed D-E and flow group E.

Interbed A-B.--Sedimentary interbed A-B is fully penetrated by 23 wells in the RWMC area. Interbed A-B, which is present mainly in the northern and western parts of the area, overlies flow group B and is overlain by flow group A (figs. 3-6, 9, 19, and 20; table 1). The top of interbed A-B is at a depth of 18 to 46 ft and ranges in altitude from 4,966 to 4,996 ft. The base of interbed A-B is at a depth of 22 to 55 ft and ranges in altitude from 4,962 to 4,990 ft. Thickness of interbed A-B ranges from 0 to 11 ft, averages 5 ft, and is greatest in wells D-06 and WWW-1 near the northern boundary of the SDA and extreme western part of the RWMC area, respectively.

Interbed B-C.--Sedimentary interbed B-C is partially or fully penetrated by 38 wells in the RWMC area. Interbed B-C, which is present throughout most of the RWMC area except in wells 76-1, 76-2, 78-3 and 88, overlies flow group C and is overlain by flow group B (figs. 3-6, and 21-23; table 1). The top of interbed B-C is at a depth of 87 to 131 ft and ranges in altitude from 4,881 to 4,939 ft. The base of interbed B-C is at a depth of 91 to 171 ft and ranges in altitude from 4,841 to 4,921 ft. Thickness of interbed B-C ranges from 0 to 40 ft, averages 13 ft, and is greatest in the western part of the SDA and in well 120 near the southwest edge of the RWMC area.

Interbed C-D.--Sedimentary interbed C-D is partially or fully penetrated by 35 wells in the RWMC area. Interbed C-D, which is present throughout all of the RWMC area, overlies flow group D and is overlain by flow group C (figs. 3-6, 15, 16, and 24; table 1). The top of interbed C-D is at a depth of 218 to 253 ft and ranges in altitude from 4,759 to 4,801 ft. The base of interbed C-D is at a depth of 230 to 269 ft and ranges in altitude from 4,745 to 4,781 ft. Thickness of interbed C-D ranges from 5 to 32 ft, averages 17 ft, and is greatest throughout the central part of the RWMC area.

Interbed D-E.--Sedimentary interbed D-E is partially or fully penetrated by nine wells in the RWMC area. Interbed D-E, which is present throughout most of the RWMC area except in wells 87, 90, and RWMC, overlies flow group E and is overlain by flow group D (figs. 3-6; table 2). The top of interbed D-E is at a depth of 261 to 304 ft and ranges in altitude from 4,716 to 4,752 ft. The base of interbed D-E is at a depth of 267 to 311 ft and ranges in altitude from 4,710 to 4,746 ft. Thickness of interbed D-E ranges from 0 to 9 ft, averages 6 ft, and is greatest in wells 77-1, 119, and 120.

Interbed E-F.--Sedimentary interbed E-F is fully penetrated by five wells in the RWMC area. Interbed E-F is present in wells 77-1, 87, 88, 89, and 90, and is absent in wells 117, 118, 119, 120, and RWMC. Interbed E-F overlies flow group F and is overlain by flow group E (figs. 3-6; table 2). The top of interbed E-F is at a depth of 360 to 378 ft and ranges in altitude from 4,635 to 4,662 ft. The base of interbed E-F is at a depth of 365 to 384 ft and ranges in altitude from 4,631 to 4,656 ft. Thickness of interbed E-F ranges from 0 to 6 ft, averages 5 ft, and is greatest in wells 88 and 89.

Interbeds F-G, F-FG, and FG-G.--Sedimentary interbeds F-G, F-FG, and FG-G are partially or fully penetrated by 10 wells in the RWMC area. Interbed F-G overlies flow group G and is overlain by flow group F (figs. 3-6; table 2). The top of interbed F-G is at a depth of 487 to 578 ft and ranges in altitude from 4,432 to 4,525 ft. The base of interbed F-G is at a depth of 493 to 590 ft and ranges from 4,420 to 4,519 ft. Thickness of interbed F-G ranges from 4 to 15 ft, averages 9 ft, and is greatest in well RWMC. Interbed F-FG overlies flow group FG and is overlain by flow group F. Interbed F-FG is at a depth of 540 to 548 ft and altitude of 4,481 to 4,489 ft in well 89; thickness is 8 ft. Interbed FG-G overlies flow group G and is overlain by flow group FG. Interbed FG-G is at a depth of 548 to 569 ft and altitude of 4,446 to 4,460 ft in well 89; thickness is 14 ft. Interbeds F-FG and FG-G are not present elsewhere in the RWMC area and are correlated with interbed F-G on the basis of similar stratigraphic position between flow groups F and G.

Interbeds G-I, G-H, and H-I.--Sedimentary interbed G-I, a probable interbed in the western part of the RWMC area, and interbeds G-H and H-I, which are penetrated by five and four wells, respectively, in the eastern part, lie between flow groups G and I (figs. 3-6; table 2). Evidence for interbed G-I and equivalence between interbeds G-I, G-H, and H-I is based on the relations between flow groups G, H, and I in wells 87, 88, 89, 117, 119, 120, and RWMC, which indicate a thinning and pinching out of flow group H and convergence of interbeds G-H and H-I from east to west across the RWMC area. If this interpretation is correct, interbed G-I and flow group I underlie the bottom of well 89 and base of flow group G, and interbed G-I grades into interbeds G-H and H-I east of well 89. Interbed G-H overlies flow group H and is overlain by flow group G. The top of interbed G-H is at a depth of 600 to 637 ft and ranges in altitude from 4,368 to 4,416 ft. The base of interbed G-H is at a depth of 605 to 642 ft and ranges in altitude from 4,363 to 4,411 ft. Thickness of interbed G-H ranges from 4 to more than 15 ft, averages at least 7 ft, and is greatest in well 88. Interbed H-I overlies flow group I and is overlain by flow group H. The top of interbed H-I is at a depth of 620 to 667 ft and ranges in altitude from 4,338 to 4,396 ft. The bottom of interbed H-I is at a depth of 639 to 673 ft and ranges in altitude from 4,332 to 4,374 ft. Thickness of interbed H-I ranges from 4 to more than 20 ft, averages at least 9 ft, and is greatest in well 87.

Stratigraphic Relations

Stratigraphic relations in the unsaturated zone and uppermost part of the aquifer are the result of 10 major cycles of volcanism and sediment deposition during the past 600,000 years. Brief volcanic eruptions from at least 10 different source vents resulted in periodic inundation of the area by basaltic lava flows and cinders. Long intervals of volcanic inactivity were marked by the accumulation of sediment in stream channels, floodplains, playas, and dunes. Although the past 600,000 years were dominated by sedimentary processes, the cumulative depositional volume of basalt and cinders was much greater than that of sediment, resulting in a stratigraphic sequence made up largely of volcanic rocks.

Figures 3 through 24 illustrate known and inferred stratigraphic relations in the subsurface of the RWMC area on the basis of data collected through September 1988. General relations indicate a relatively consistent pattern of alternating volcanic and sedimentary layers with depth. Most flow groups extend across the area and overlie and are overlain by sediment. Most sediment layers are continuous in extent but are thickest where they coincide with localized depressions in underlying flow surfaces. Unique stratigraphic relations in the RWMC area include: the depositional relations between flow groups A and B and interbed A-B; the depositional relations between flow group C and interbed B-C; the comparatively large thickness and wide areal extent of interbed C-D; and the depositional relations between flow groups F, FG, G, H, and I. Stratigraphic control was provided by the flows of flow group F, which are uniquely characterized by reversed geomagnetic polarity and high emission of natural gamma radiation compared to other flows.

The depositional relations between flow groups A and B and sedimentary interbed A-B were first described by Kuntz (1978); Kuntz and others (1980); and Kuntz and others (1984). Flows of flow group B, which erupted from vent 5206 about 3 mi southeast of the RWMC, underlie all of the RWMC area. Interbed A-B and the younger flows of flow group A, which erupted from Quaking Aspen Butte about 12 mi southwest of the RWMC, were deposited over the flows of flow group B within the valley of the Big Lost River generally north and west of the RWMC (Kuntz, 1978; Kuntz and others, 1980; Kuntz and others, 1984; this report, figs. 3-9, 19 and 20). The southern limit of flow group A and sedimentary interbed A-B is inside the boundaries of the SDA but is not well defined because of the complexity of depositional contacts. The southern limit of flow group A and interbed A-B may extend to the southeast corner of the SDA on the basis of observations made in pit excavations.

The depositional relations between flow group C and sedimentary interbed B-C are characterized by abrupt changes in sediment thickness that coincide with numerous depressions and ridges in the top of the underlying flows of flow group C (figs. 3-6, 13, 14, 22, and 23). These relations are most evident in the western part of the SDA where they may be enhanced by a high density of wells. Sediment of interbed B-C, which is absent in wells

76-1, 76-2, 78-3, and 87, thickens abruptly to 22, 24, 25, 25, and 27 ft in wells 96-A, 76-3, 96-B, 78-5, and 96, respectively. Data indicate that sediment of interbed B-C in the western part of the SDA was deposited in a closed depression bounded by ridges. Data suggest similar deposition in closed depressions in the extreme northern and eastern parts of the RWMC area, but the data are insufficient to adequately define the complex geometry between flow group C and interbed B-C. Interbed B-C consists largely of clay and silt that may have been deposited in a shallow lake or playa. The top of interbed B-C is relatively flat and slopes to the east at an average rate of about 20 ft/mi (Barraclough and others, 1976; this report, fig. 21).

The comparatively large thickness and wide areal extent of sedimentary interbed C-D is one of the most prominent stratigraphic features in the RWMC area. Interbed C-D is similar in composition to interbed B-C, but generally is thicker and more widespread. Interbed C-D is penetrated by all 35 wells completed below the base of flow group C. Thickness of interbed C-D ranges from 5 to 32 ft and exceeds 20 ft in more than 50 percent of the area (figs. 3-6, 15, 16, and 24). The thickest deposits of interbed C-D are in a northeast-trending depression in the top of flow group D that extends across the central part of the area. Interbed C-D consists largely of clay and silt that may have been deposited in a shallow lake or playa. The top of interbed C-D is relatively flat and slopes to the east at an average rate of about 25 ft/mi (Barraclough and others, 1976, this report, fig. 15).

The depositional relations between flow groups F, FG, G, H, and I are a common characteristic of basalt flows across the INEL and eastern Snake River Plain. The relations, which are similar to those between flow groups A and B, are a consequence of depositional overlap of flows caused by changes in basalt source areas through time. Flows of flow groups FG and H are interpreted as flows or flow units that, like those of flow group A, extended only partly across the RWMC area before cooling. Flow groups FG and H, like flow groups F, G, and I, overlie and are overlain by sediment, suggesting a long interval of time between the deposition of each flow group. Although the source and areal extent of flows that make up flow groups FG and H are uncertain, the flows, like those of flow groups A and B, probably originated from different vents located relatively near the RWMC. Flows of flow group B, and probably those of flow groups C, E, F, and G, erupted from vents located less than 5 mi from the RWMC. Flows of flow group A and probably those of flow groups D and I are from vents located 10 mi or less from the RWMC. On the basis of tentative subsurface correlations and observed extent of surficial flows, all basalt flows underlying the RWMC probably extend less than 15 mi from their source.

Flow group F extends across the RWMC area and also is present in the subsurface of the INEL 10 mi northeast of the RWMC (Champion and others, 1988). Flows of flow group F are uniquely characterized by reversed geomagnetic polarity and are assigned to the Big Lost Reversed Polarity Subchronozone and Subchron (Champion and others, 1988). Flows of flow group F, which also are characterized by a high emission of natural gamma radiation compared to other flows, were correlated from well to well on the basis of gamma-log signatures and provided stratigraphic control near the base of the unsaturated zone.

Hydrologic Implications

Stratigraphic relations in the unsaturated zone ultimately may affect the potential for migration of buried waste from the RWMC to the Snake River Plain aquifer. Although impermeable in places, basalt flows contain numerous fractures that may provide unrestricted avenues for vertical and horizontal flow of contaminated water. Sediment layers may facilitate or retard vertical flow depending on grain size and sorting characteristics. Lateral flow and perching of water may take place along some clay and silt layers, and discontinuous layers may divert flow toward underlying or adjacent basalt flows. Interbed C-D, which is at a depth of about 240 ft, may retard vertical flow because of its high clay-silt content and large thickness. However, the potential for lateral flow away from the RWMC along the east-sloping surface of interbed C-D may be high.

Additional evaluation of rock and sediment characteristics are needed to determine the potential for migration of buried waste from the RWMC to the Snake River Plain aquifer. Factors that need further evaluation include: the lithology and distribution of individual lava flows and minor interflow sedimentary beds; the distribution and characterization of individual flow contacts, fractures, and vesicles; the lithology of major sedimentary interbeds; and the distribution of basalt and sediment hydraulic properties. Determination of hydraulic properties by direct measurement and extrapolation of properties by indirect methods, such as kriging, need to coincide with observed stratigraphic boundaries because log signatures of induced gamma radiation indicate numerous, layer-dependent density differences with depth.

CONCLUSIONS

Wells drilled to 700 ft in the RWMC area penetrate a complex sequence of layered basalt flows, cinders, and sediment that ranges in age from about 100,000 to 600,000 years old. Ten basalt-flow groups consisting of 22 separate lava flows and flow-units make up the sequence. Each flow group is made up of from one to five petrographically similar flows that erupted from common source areas during periods of less than 200 years. Seven major sedimentary interbeds in the sequence consist of fluvial, lacustrine, and eolian deposits of clay, silt, sand, and gravel that accumulated during periods of volcanic inactivity ranging from thousands to hundreds of thousands of years. Flows and sediment are unsaturated to a depth of about 600 ft. Flows and sediment below a depth of 600 ft are saturated and make up the uppermost part of the Snake River Plain aquifer.

The areal extent of flow groups and interbeds was determined from well cuttings, cores, geophysical logs, potassium-argon ages, and geomagnetic properties. Natural gamma logs were used as a primary correlation tool. Natural-gamma emissions generally are uniform in related, petrographically similar flows and generally increase or decrease between petrographically dissimilar flows of different age and source. Flows of flow group F, which are characterized by reversed geomagnetic polarity and high emission of natural gamma radiation compared to other flows, provided stratigraphic control near the base of the unsaturated zone. Flows of flow group F also are present in the subsurface 10 mi northeast of the RWMC and may facilitate the evaluation of stratigraphic relations in other areas of the INEL and eastern Snake River Plain.

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EXPLANATION

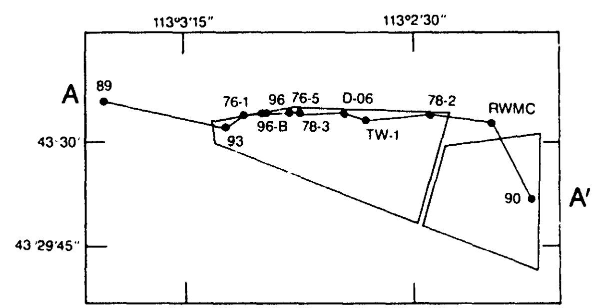
B BASALT — Basalt-flow group composed of one or more related flows. Letter, B, indicates sequence of group from top to bottom of section. Locally includes cinders and thin layers of sediment

CLAY, SILT, SAND, AND GRAVEL — Major sedimentary interbed between volcanic flow groups. Locally includes cinders and basalt rubble

GEOLOGIC CONTACT — Queried where uncertain

89 WELL — Entry, 89, is local well identifier. Arrow indicates water level in aquifer in June, 1988. Water level in well RWMC not measured

Location of Section



9-8478

Figure 3.--Geologic section A-A' at the Radioactive Waste Management Complex.

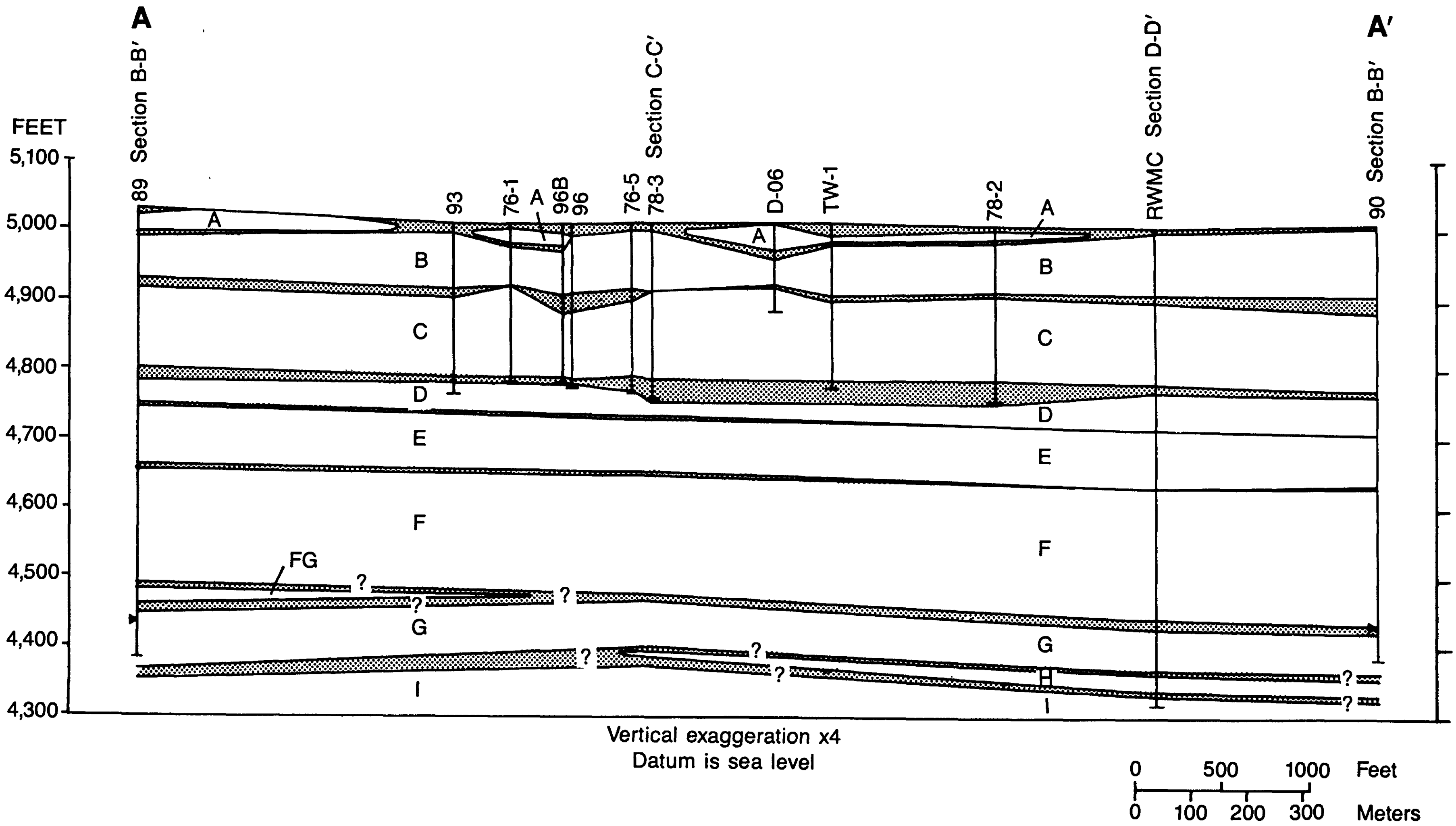


Figure 3.--Geologic section A-A′ at the Radioactive Waste Management Complex, continued.

9-8482

EXPLANATION

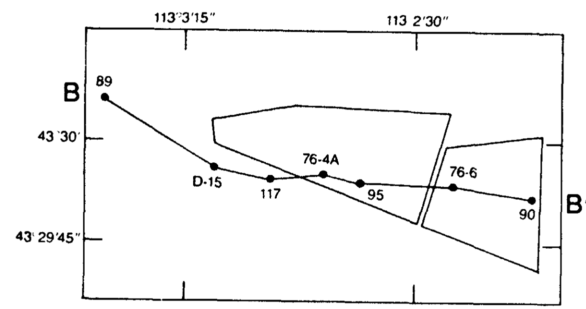
BASALT — Basalt-flow group composed of one or more related flows. Letter, B, indicates sequence of group from top to bottom of section. Locally includes cinders and thin layers of sediment

CLAY, SILT, SAND, AND GRAVEL — Major sedimentary interbed between volcanic flow groups. Locally includes cinders and basalt rubble

GEOLOGIC CONTACT — Queried where uncertain

WELL — Entry, 89, is local well identifier. Arrow indicates water level in aquifer in June, 1988

Location of Section



9-8477

Figure 4.--Geologic section B-B' at the Radioactive Waste Management Complex.

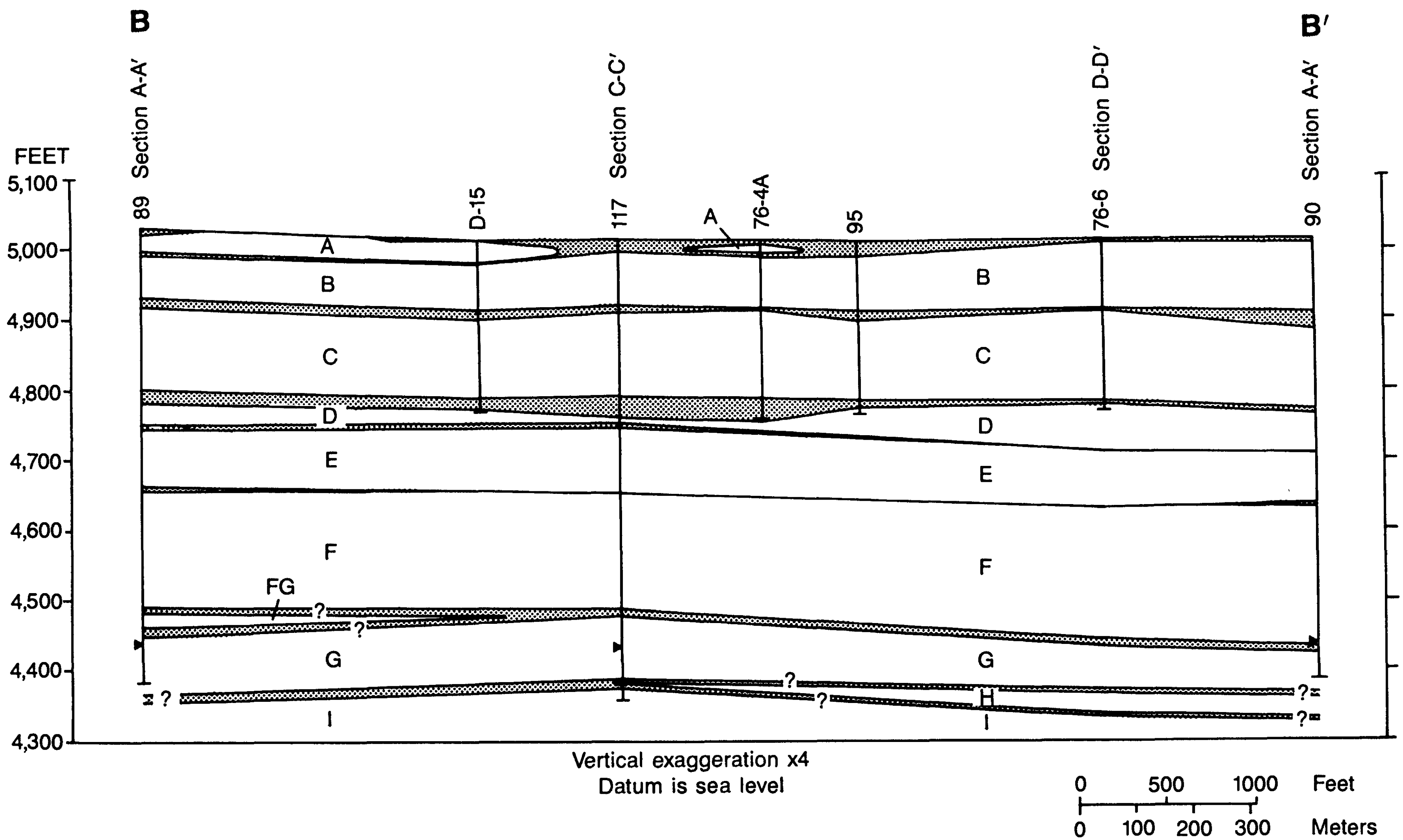


Figure 4.--Geologic section B-B′ at the Radioactive Waste Management Complex, continued.

9-8481

EXPLANATION

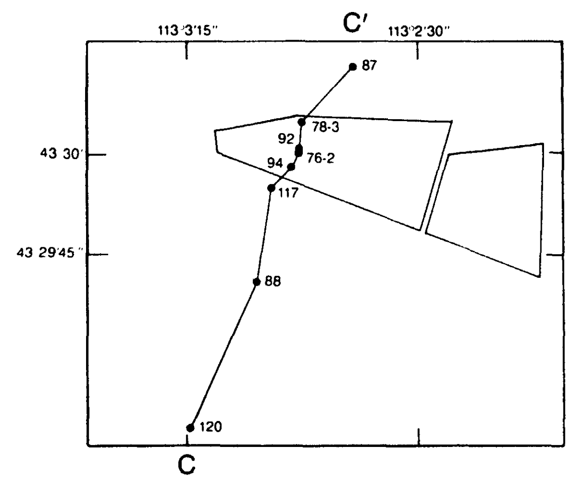
BASALT — Basalt-flow group composed of one or more related flows. Letter, B, indicates sequence of group from top to bottom of section. Locally includes cinders and thin layers of sediment

CLAY, SILT, SAND, AND GRAVEL — Major sedimentary interbed between volcanic flow groups. Locally includes cinders and basalt rubble

GEOLOGIC CONTACT — Queried where uncertain

WELL — Entry, 88, is local well identifier. Arrow indicates water level in aquifer in June, 1988

Location of Section



9-8476

Figure 5.--Geologic section C-C' at the Radioactive Waste Management Complex.

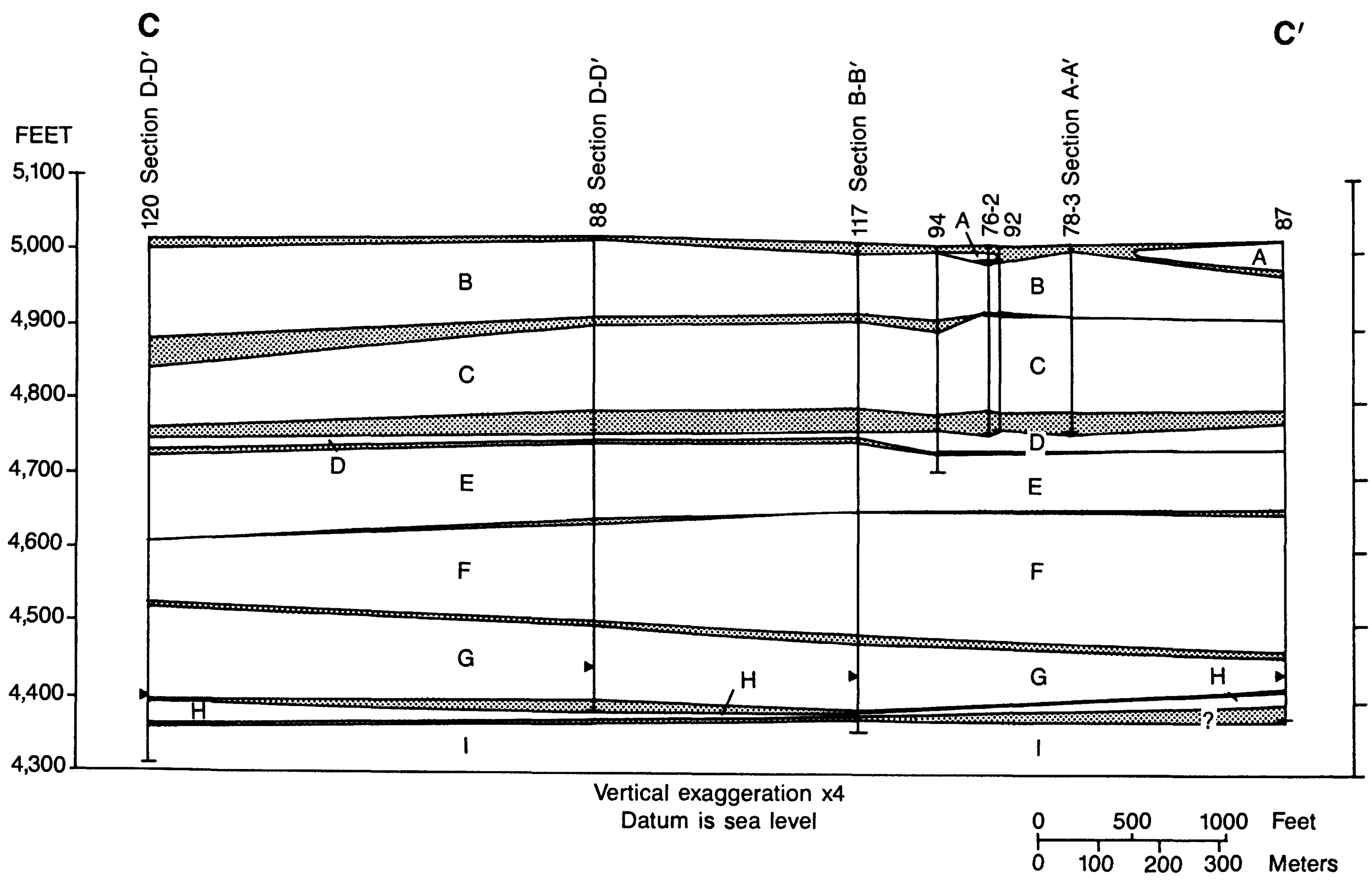


Figure 5.--Geologic section C-C′ at the Radioactive Waste Management Complex, continued. 9-8483

EXPLANATION

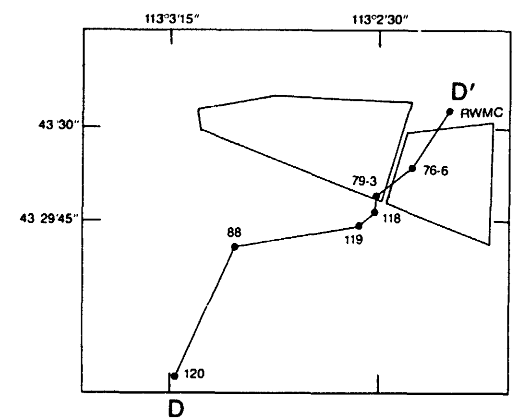
BASALT — Basalt-flow group composed of one or more related flows. Letter, B, indicates sequence of group from top to bottom of section. Locally includes cinders and thin layers of sediment

CLAY, SILT, SAND, AND GRAVEL — Major sedimentary interbed between volcanic flow groups. Locally includes cinders and basalt rubble

GEOLOGIC CONTACT — Queried where uncertain

WELL — Entry, 88, is local well identifier. Arrow indicates water level in aquifer in June, 1988. Water level in well RWMC not measured

Location of Section



9-8479

Figure 6.--Geologic section D-D′ at the Radioactive Waste Management Complex.

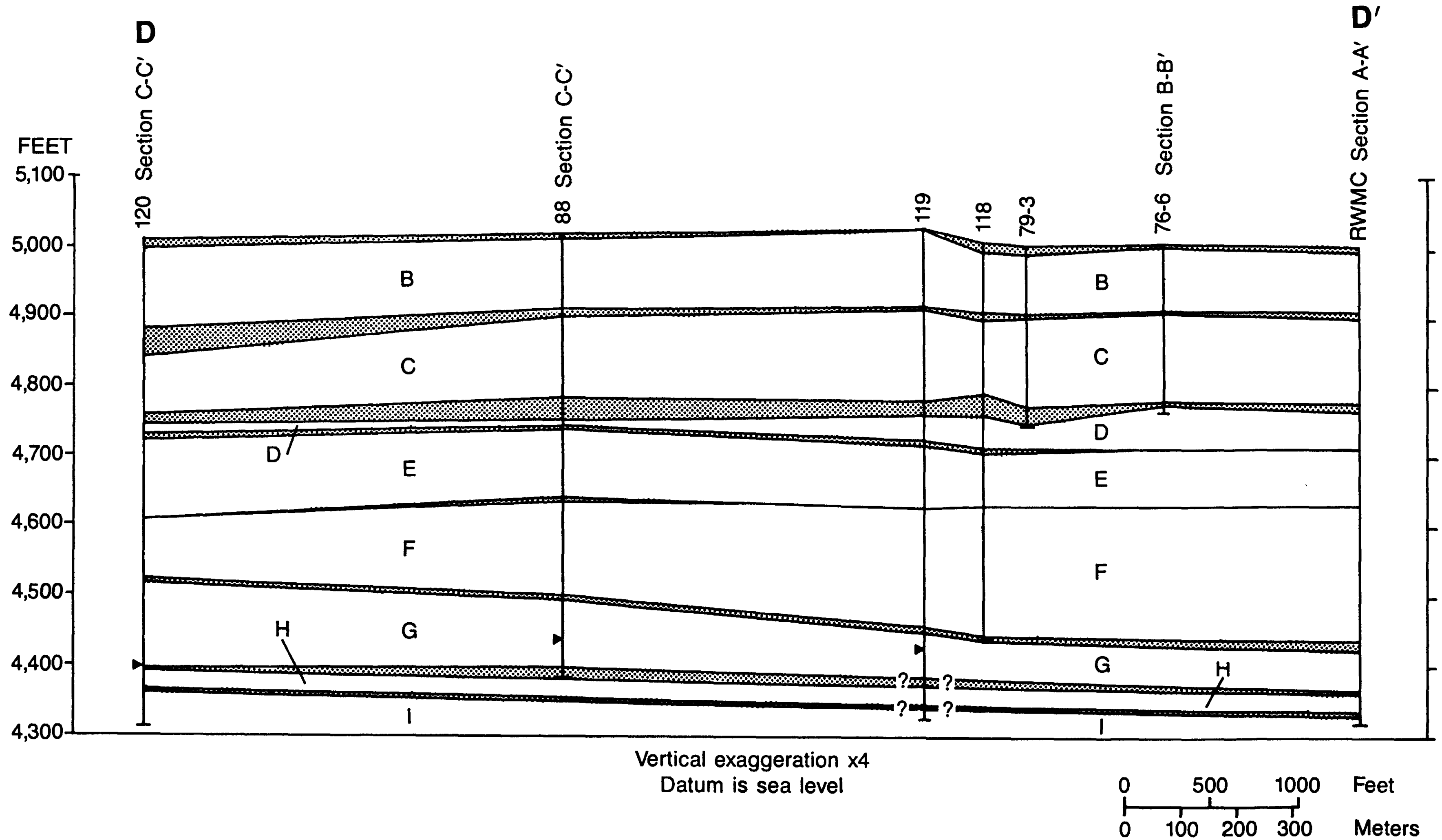


Figure 6.--Geologic section D-D′ at the Radioactive Waste Management Complex, continued.

9-8480

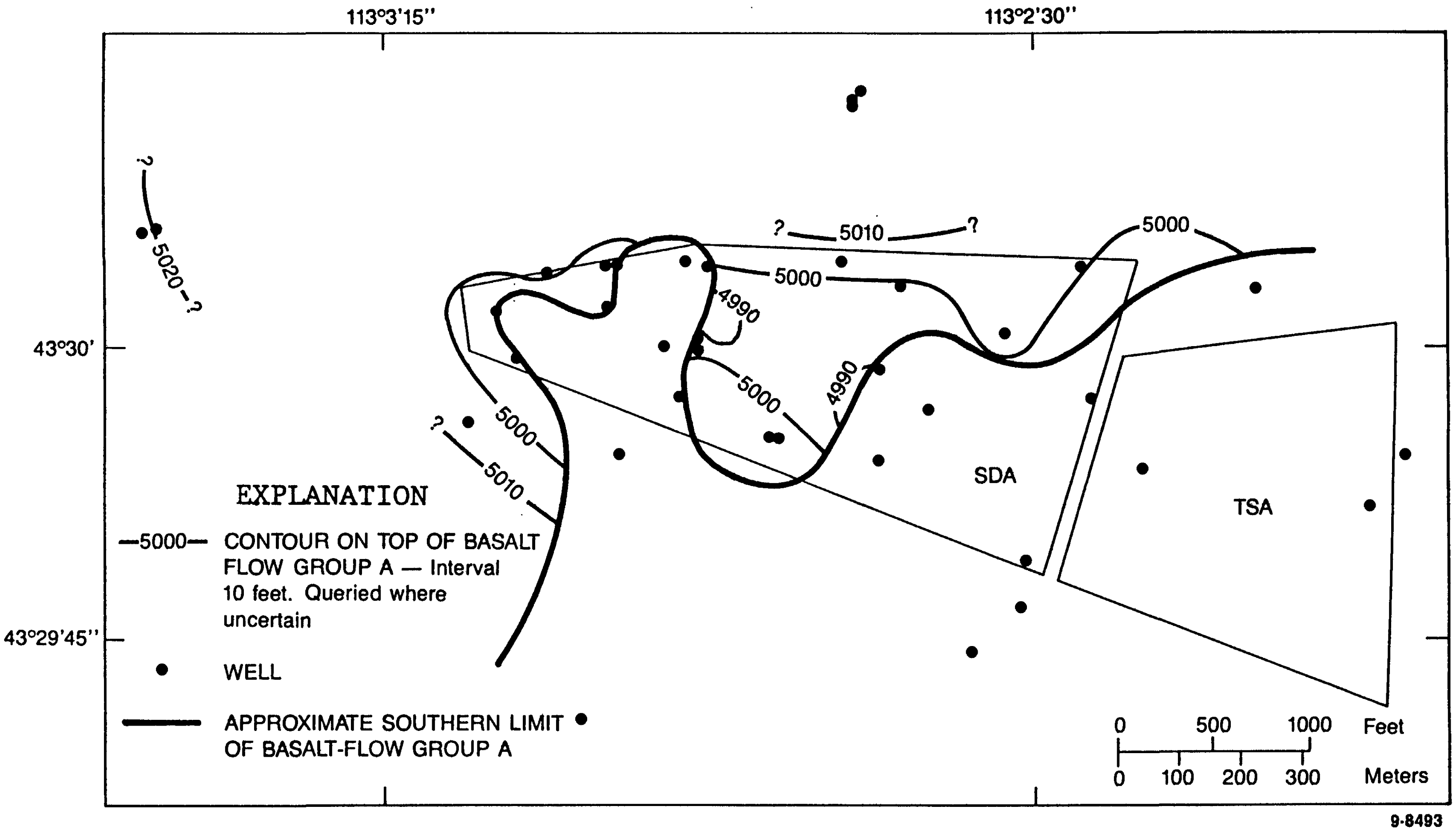


Figure 7.--Altitude of the top of basalt-flow group A at the Radioactive Waste Management Complex.

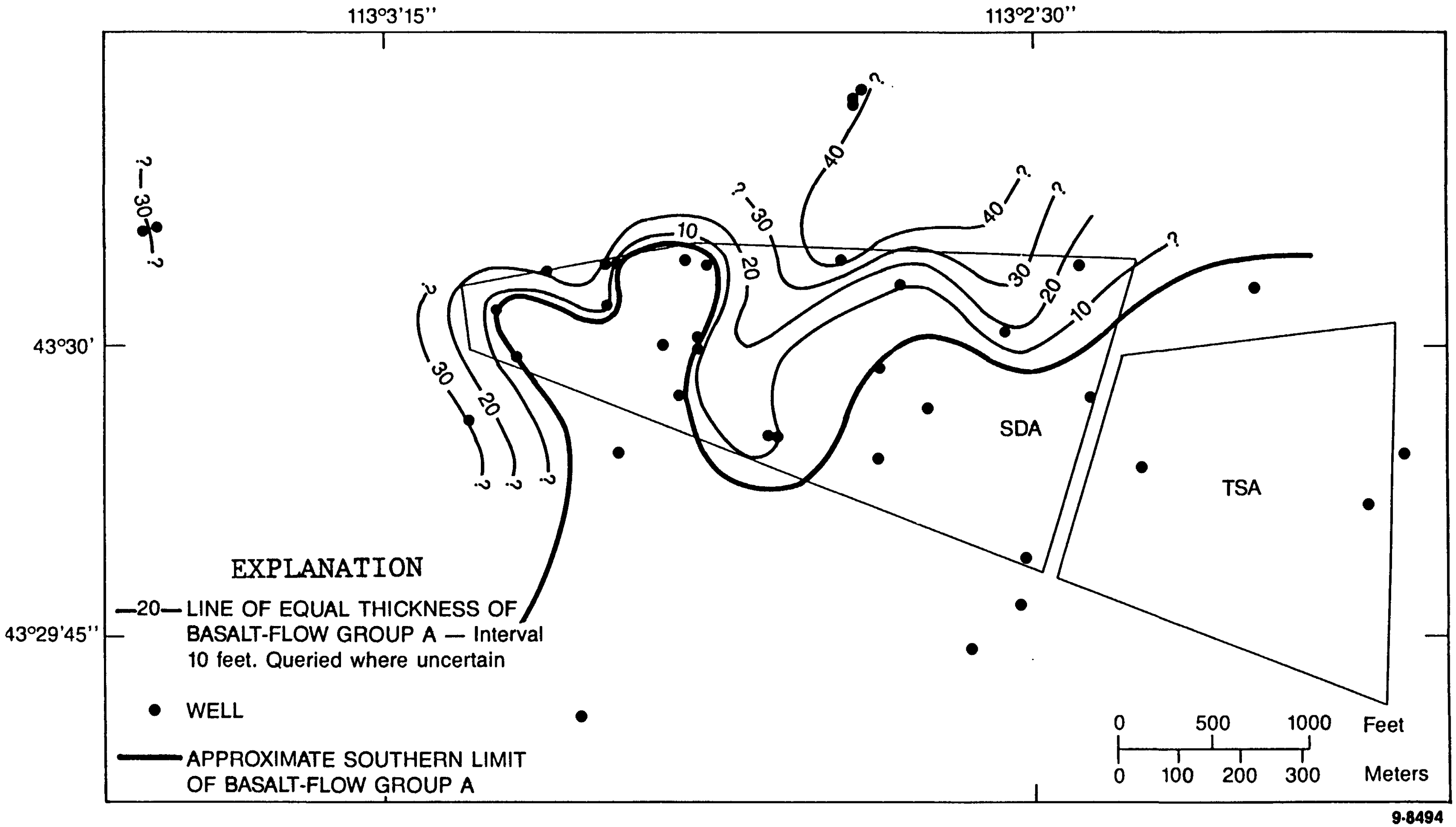


Figure 8.--Thickness of basalt-flow group A at the Radioactive Waste Management Complex.

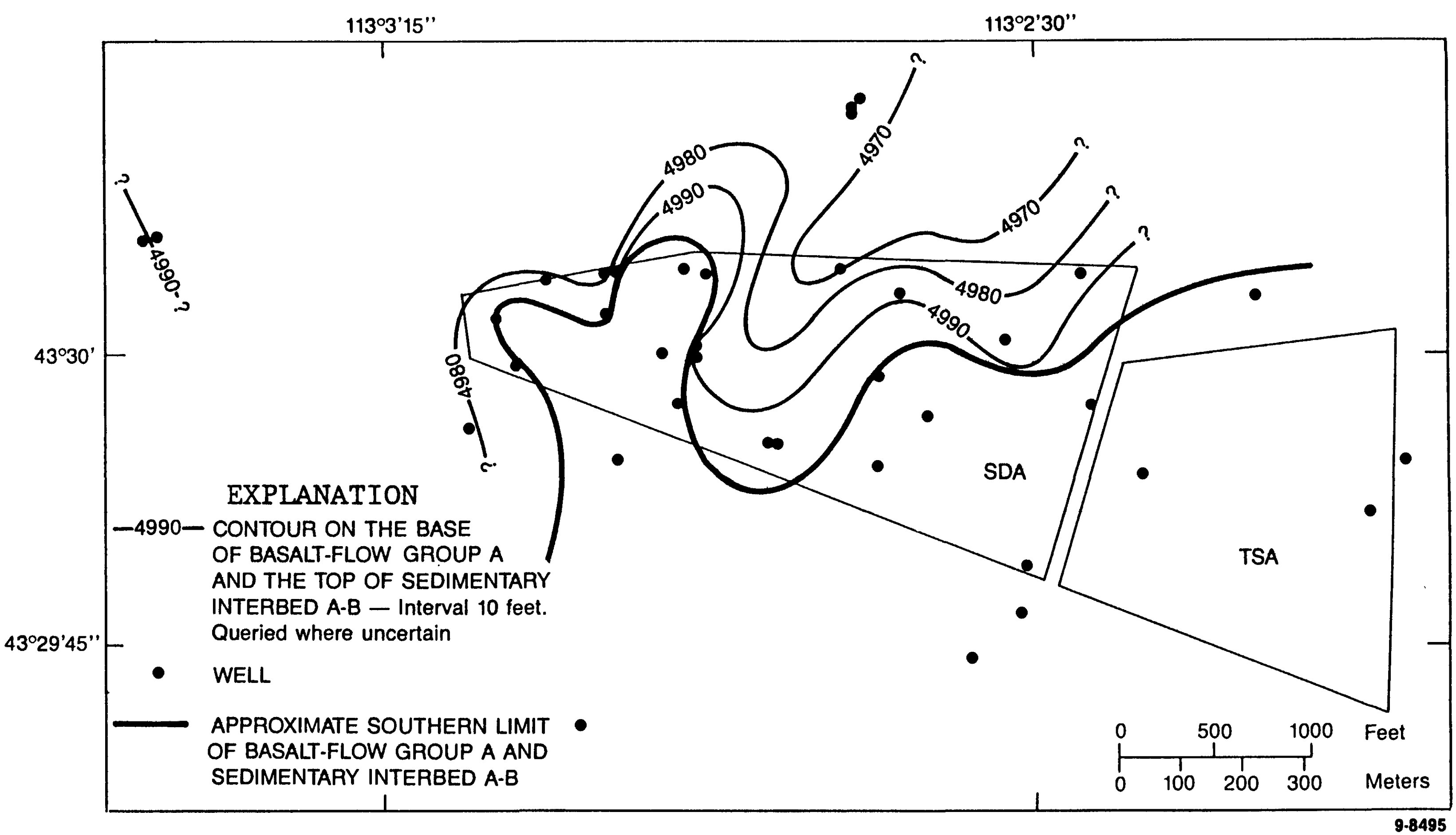


Figure 9.--Altitude of the base of basalt-flow group A and the top of sedimentary interbed A-B at the Radioactive Waste Management Complex.

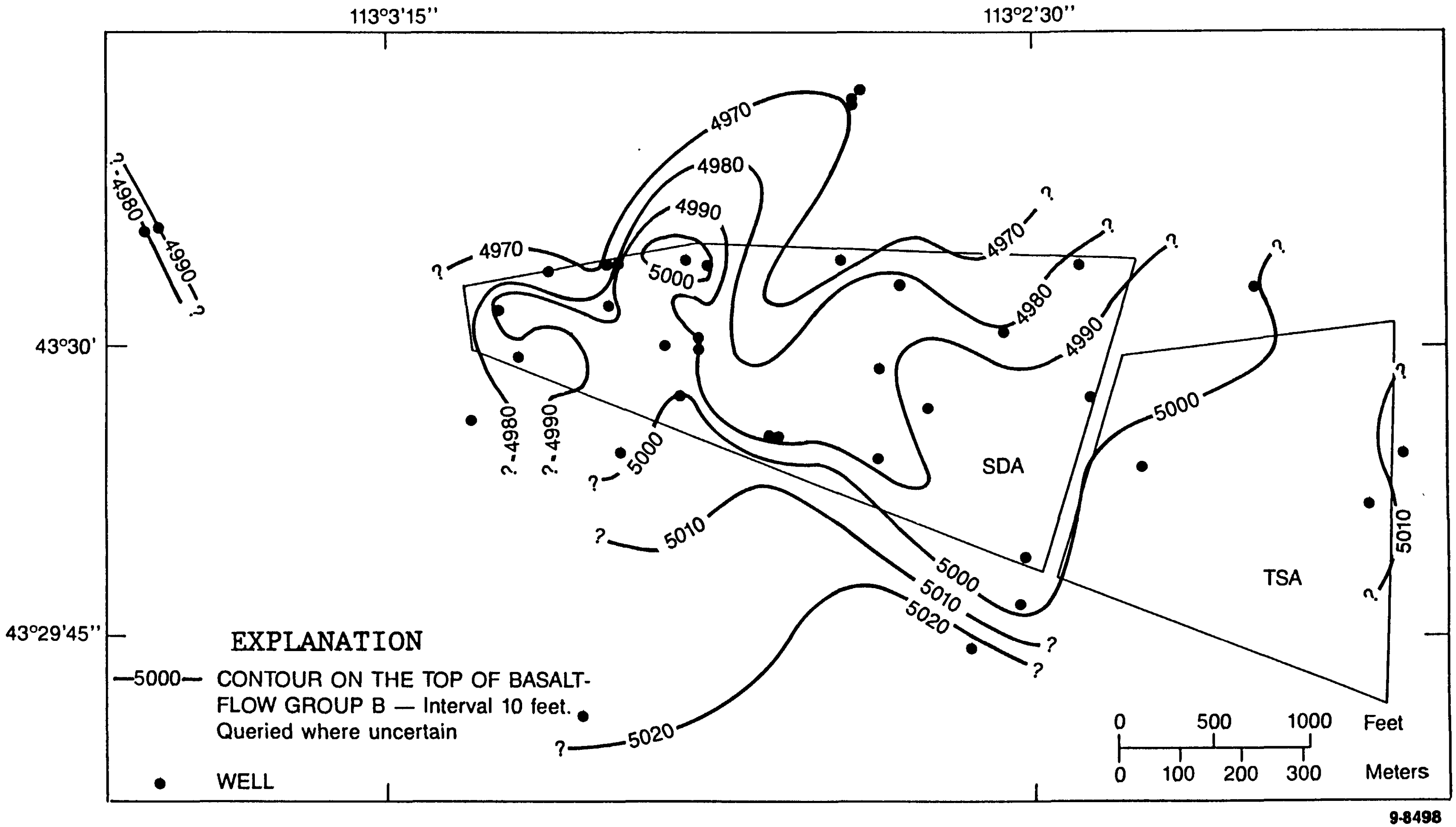


Figure 10.--Altitude of the top of basalt-flow group B at the Radioactive Waste Management Complex.

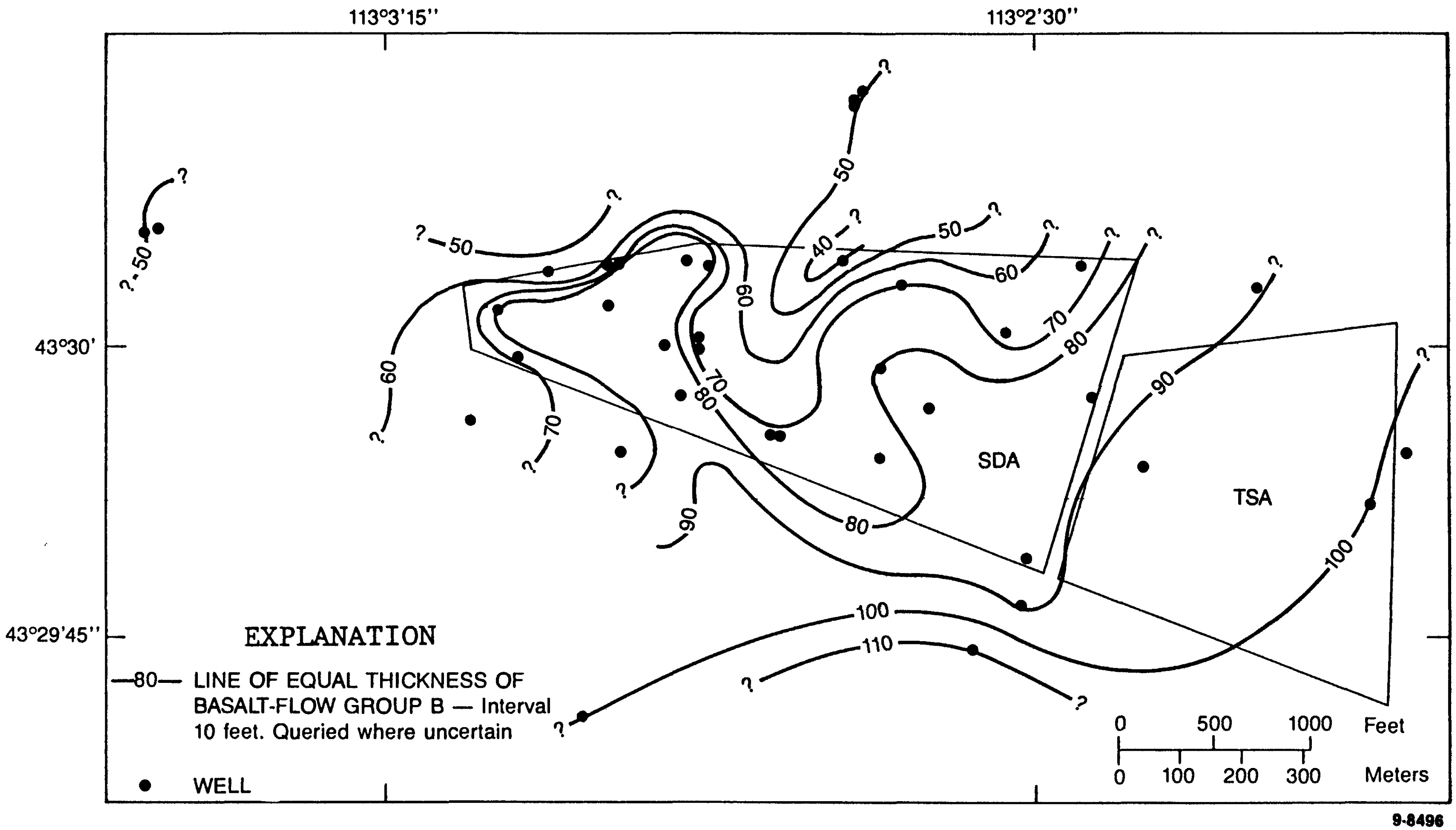


Figure 11.--Thickness of basalt-flow group B at the Radioactive Waste Management Complex.

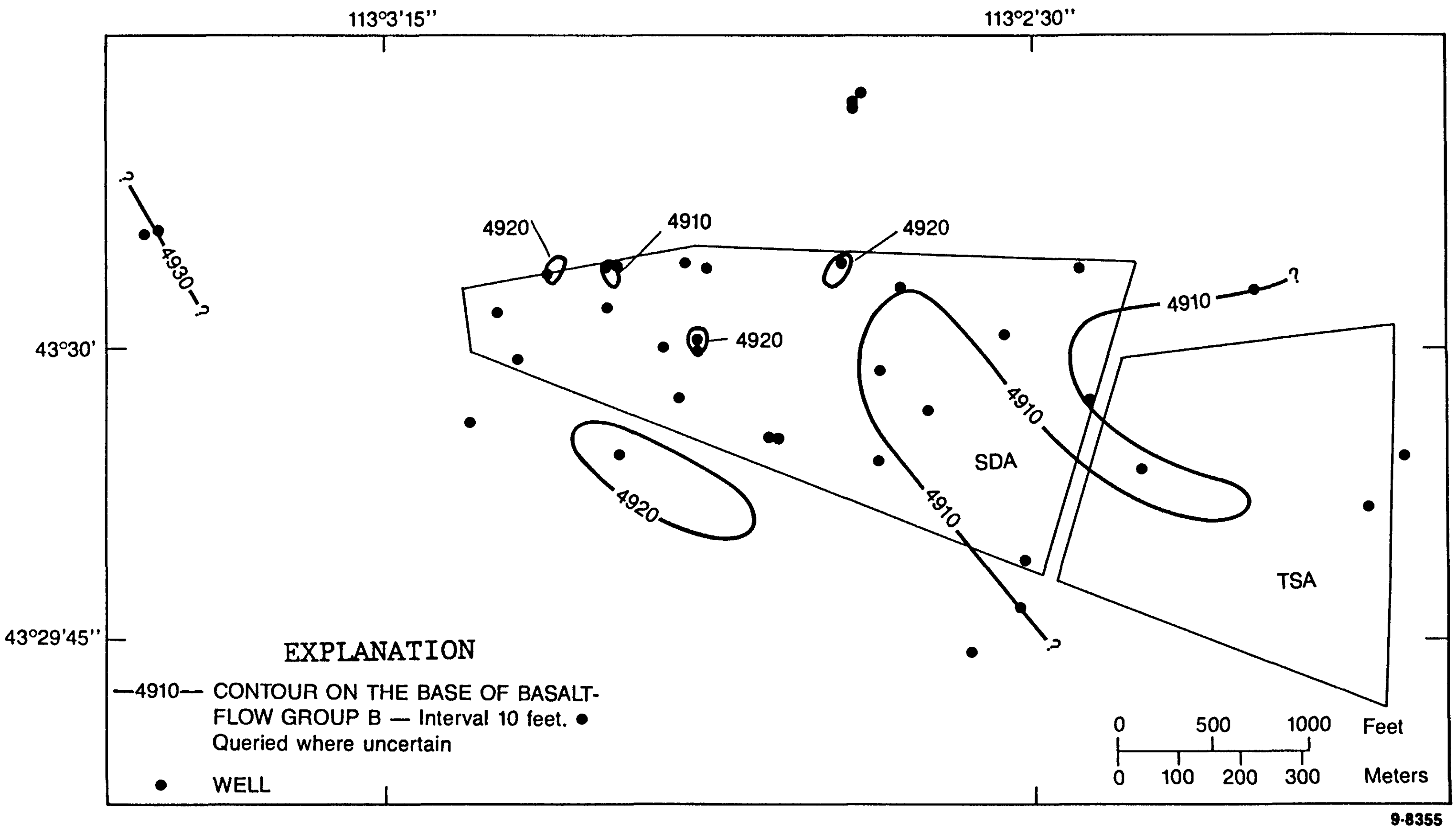


Figure 12.--Altitude of the base of basalt-flow group B at the Radioactive Waste Management Complex.

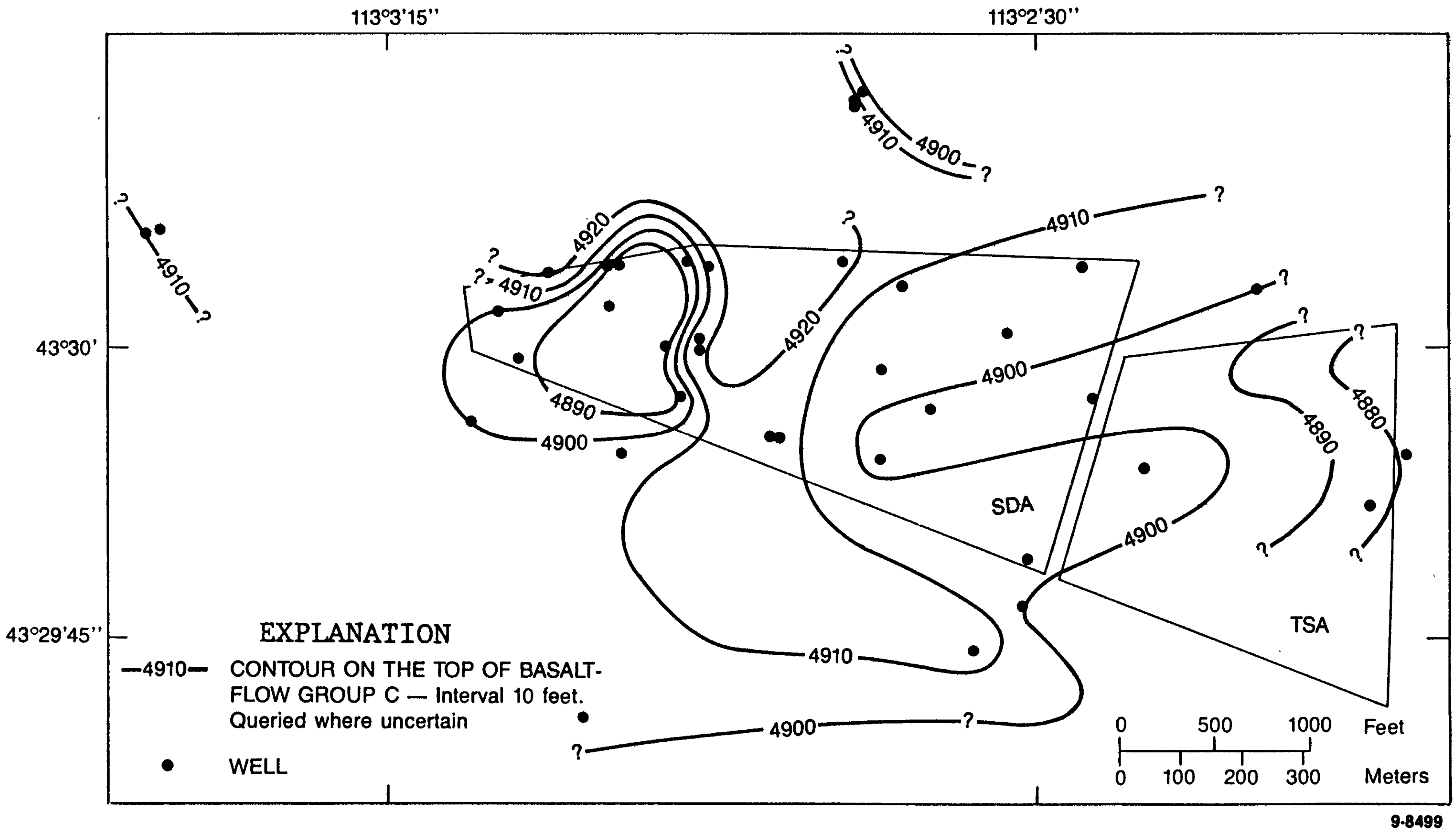


Figure 13.--Altitude of the top of basalt-flow group C at the Radioactive Waste Management Complex.

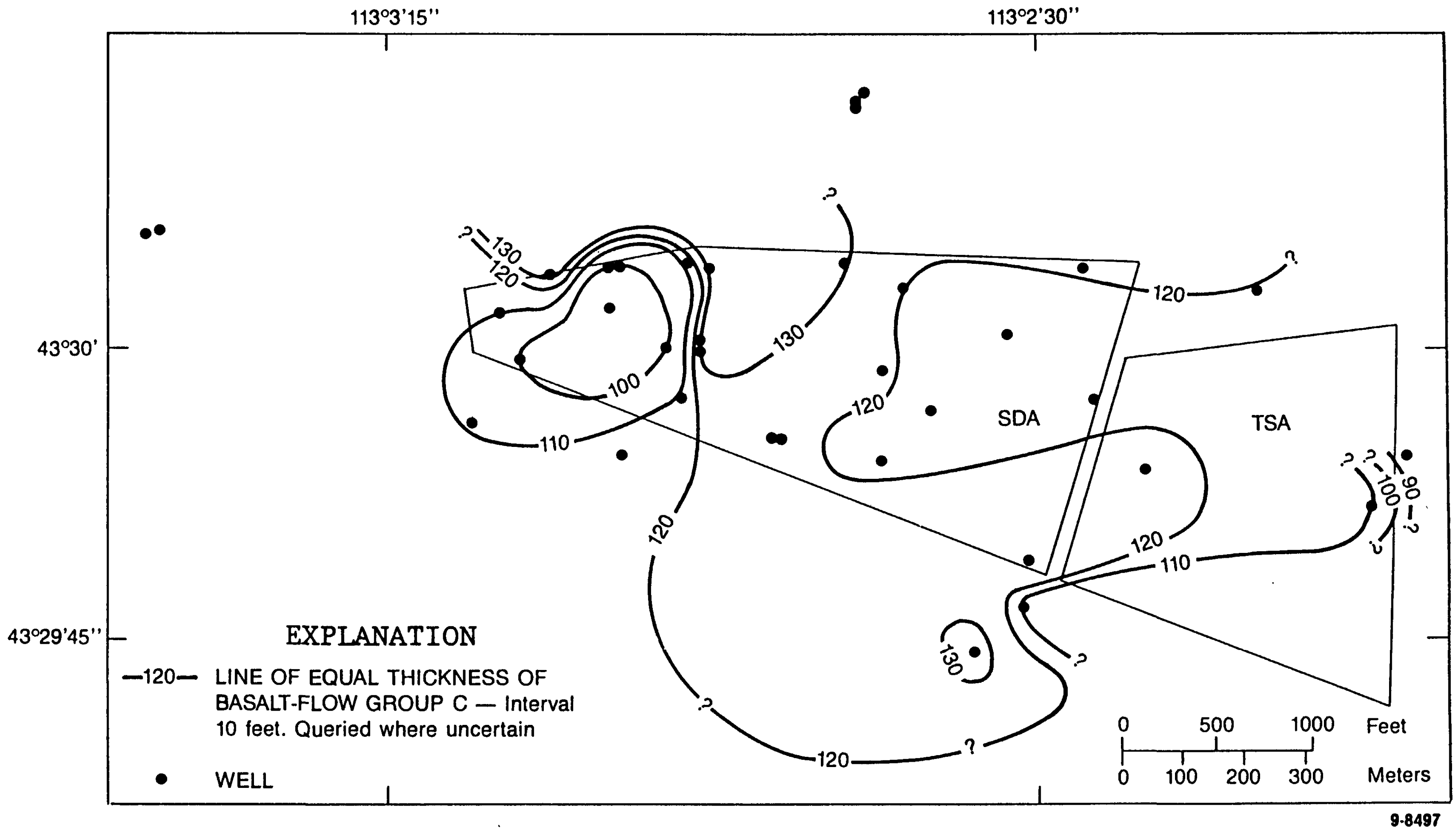


Figure 14.--Thickness of basalt-flow group C at the Radioactive Waste Management Complex.

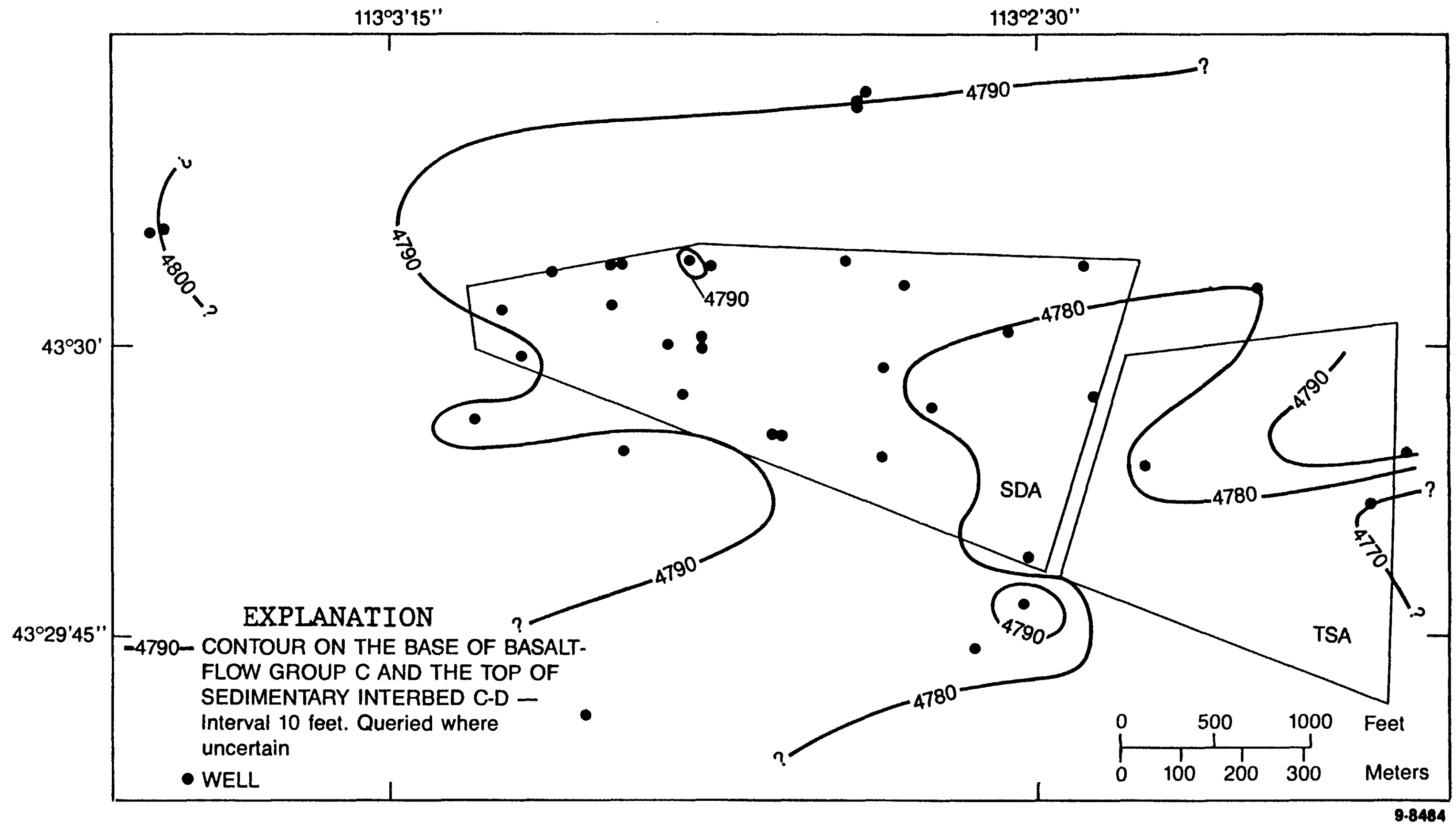


Figure 15.--Altitude of the base of basalt-flow group C and the top of sedimentary interbed C-D at the Radioactive Waste Management Complex.

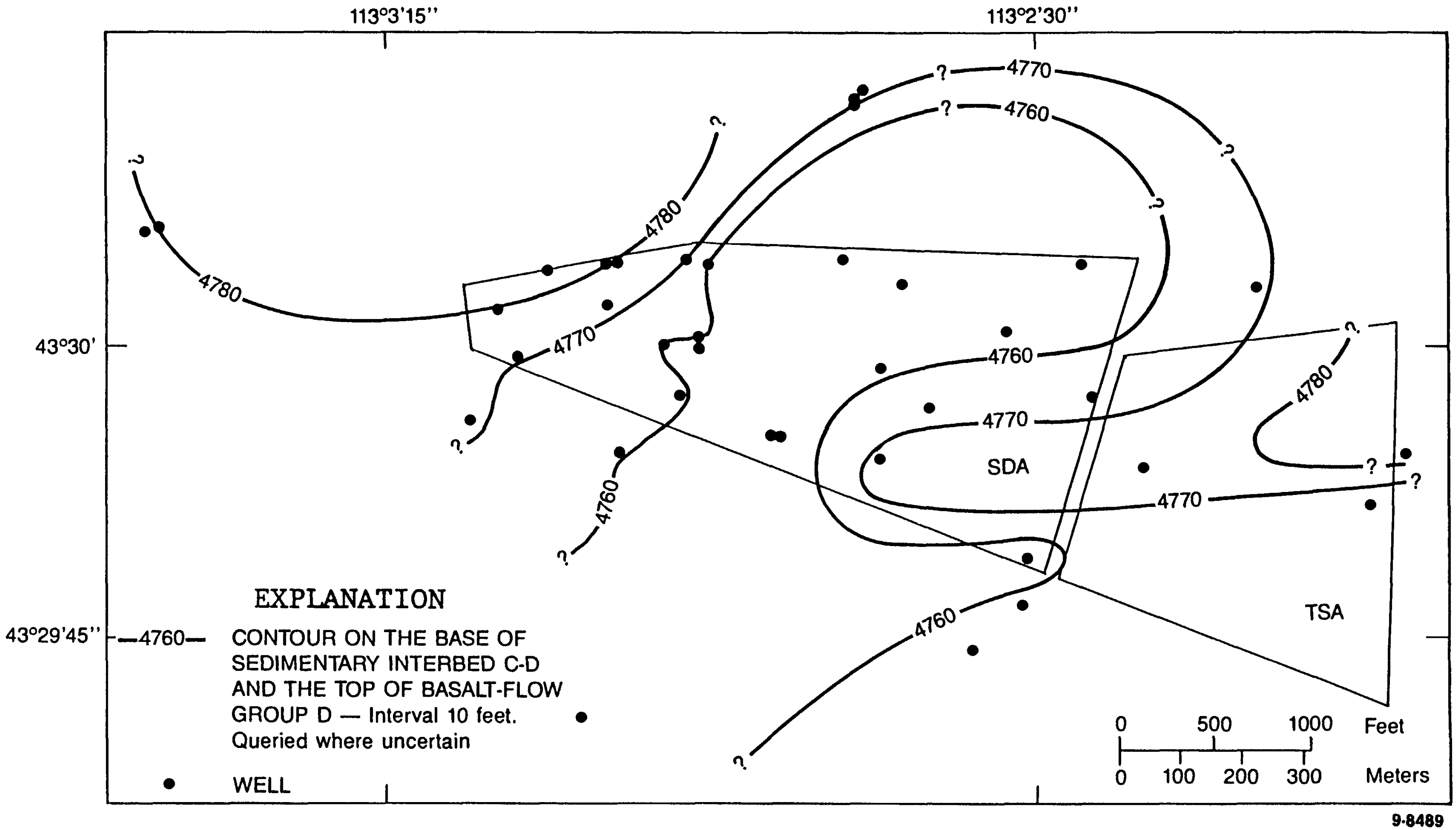


Figure 16.--Altitude of the base of sedimentary interbed C-D and the top of basalt-flow group D at the Radioactive Waste Management Complex.

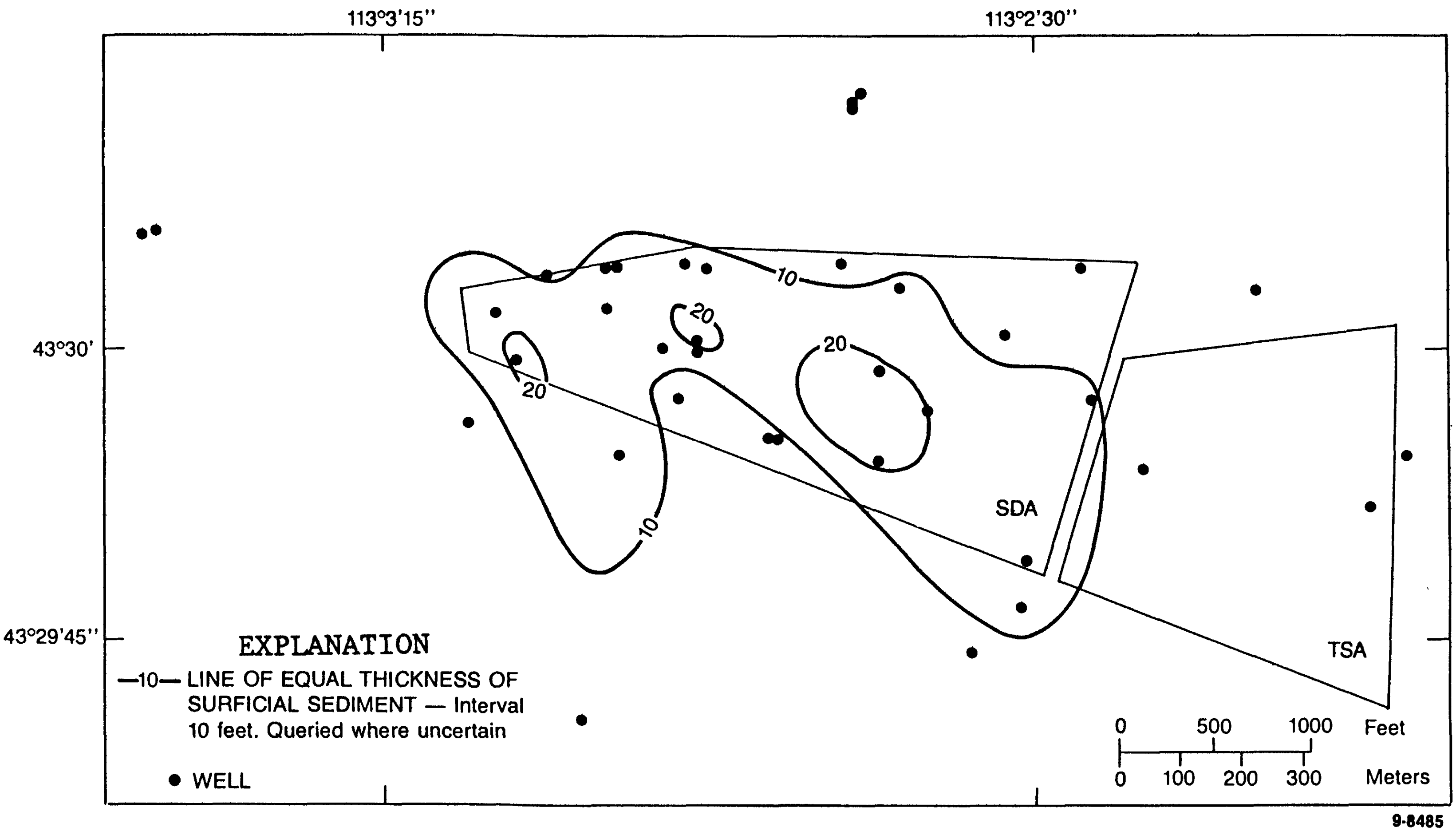


Figure 17.--Thickness of surficial sediment at the Radioactive Waste Management Complex.

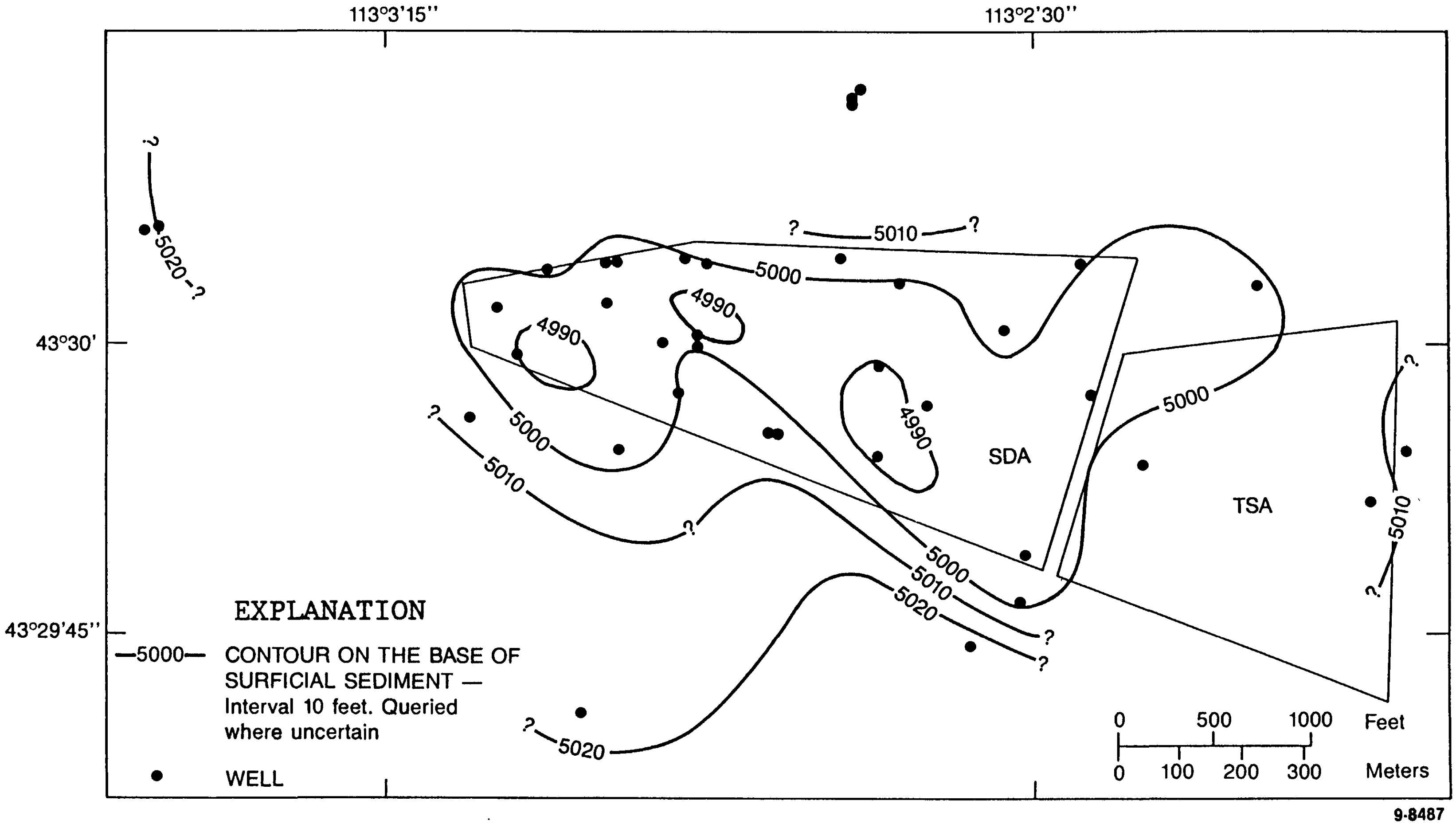


Figure 18.--Altitude of the base of surficial sediment at the Radioactive Waste Management Complex.

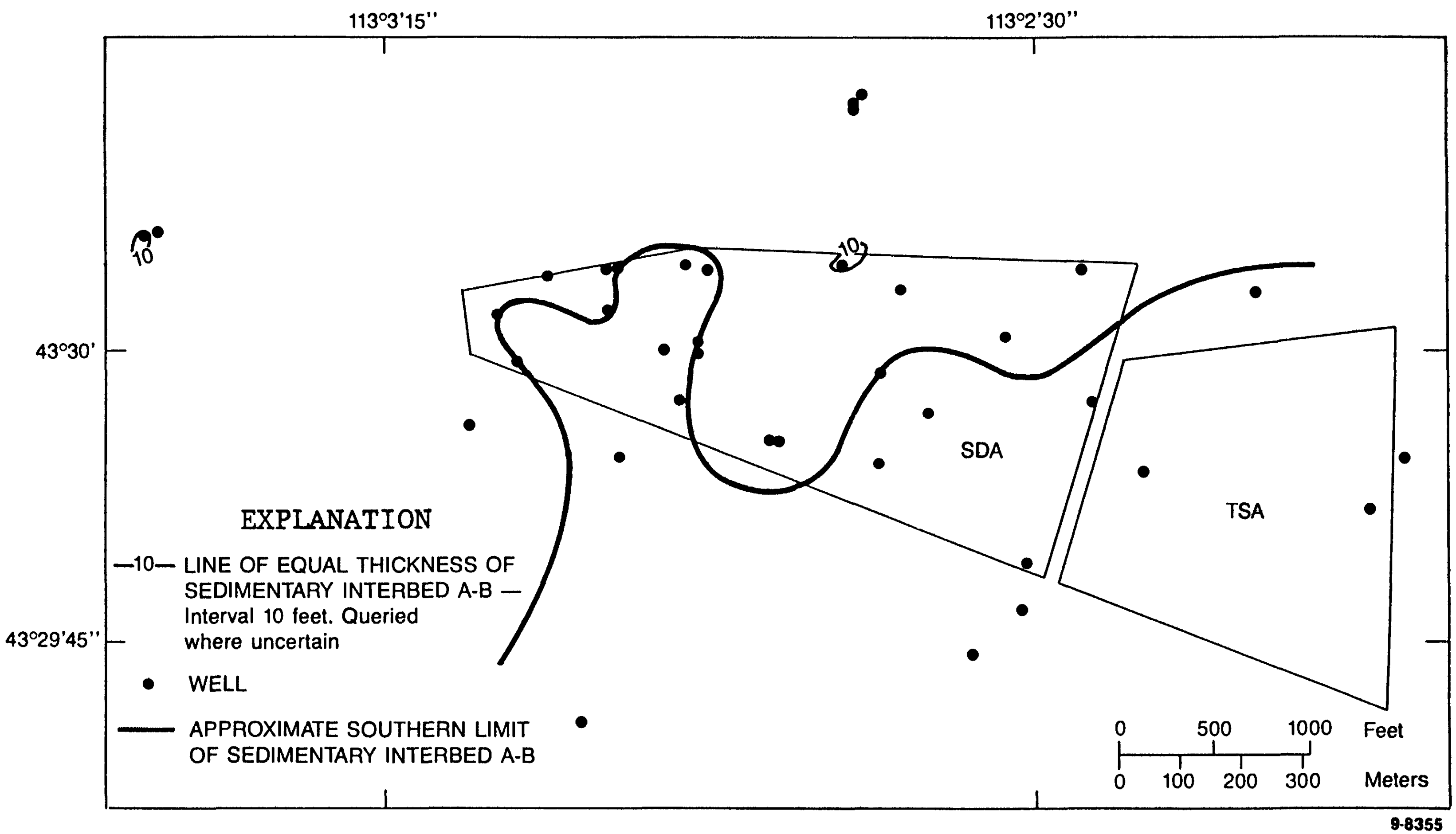


Figure 19.--Thickness of sedimentary interbed A-B at the Radioactive Waste Management Complex.

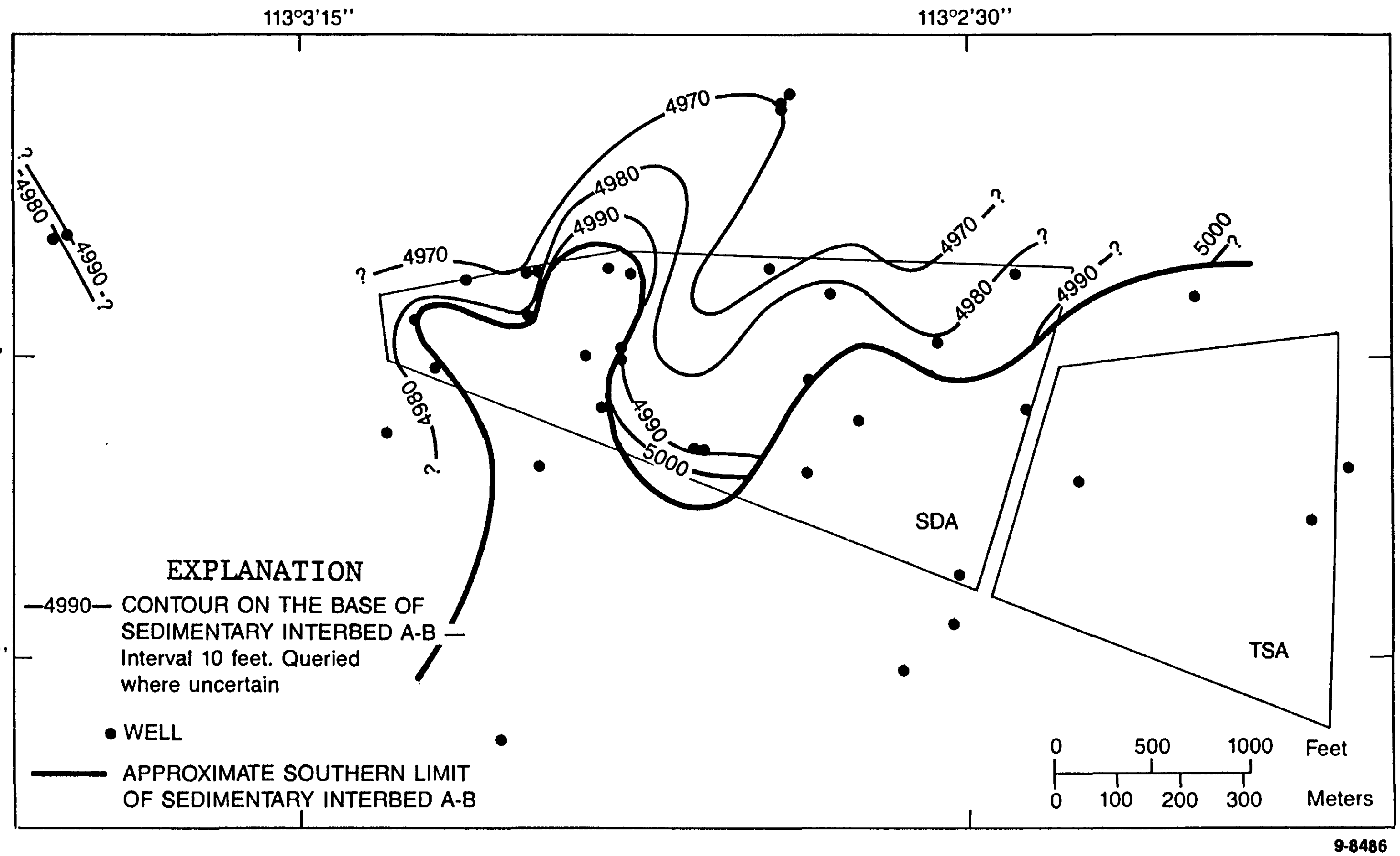


Figure 20.--Altitude of the base of sedimentary interbed A-B at the Radioactive Waste Management Complex.

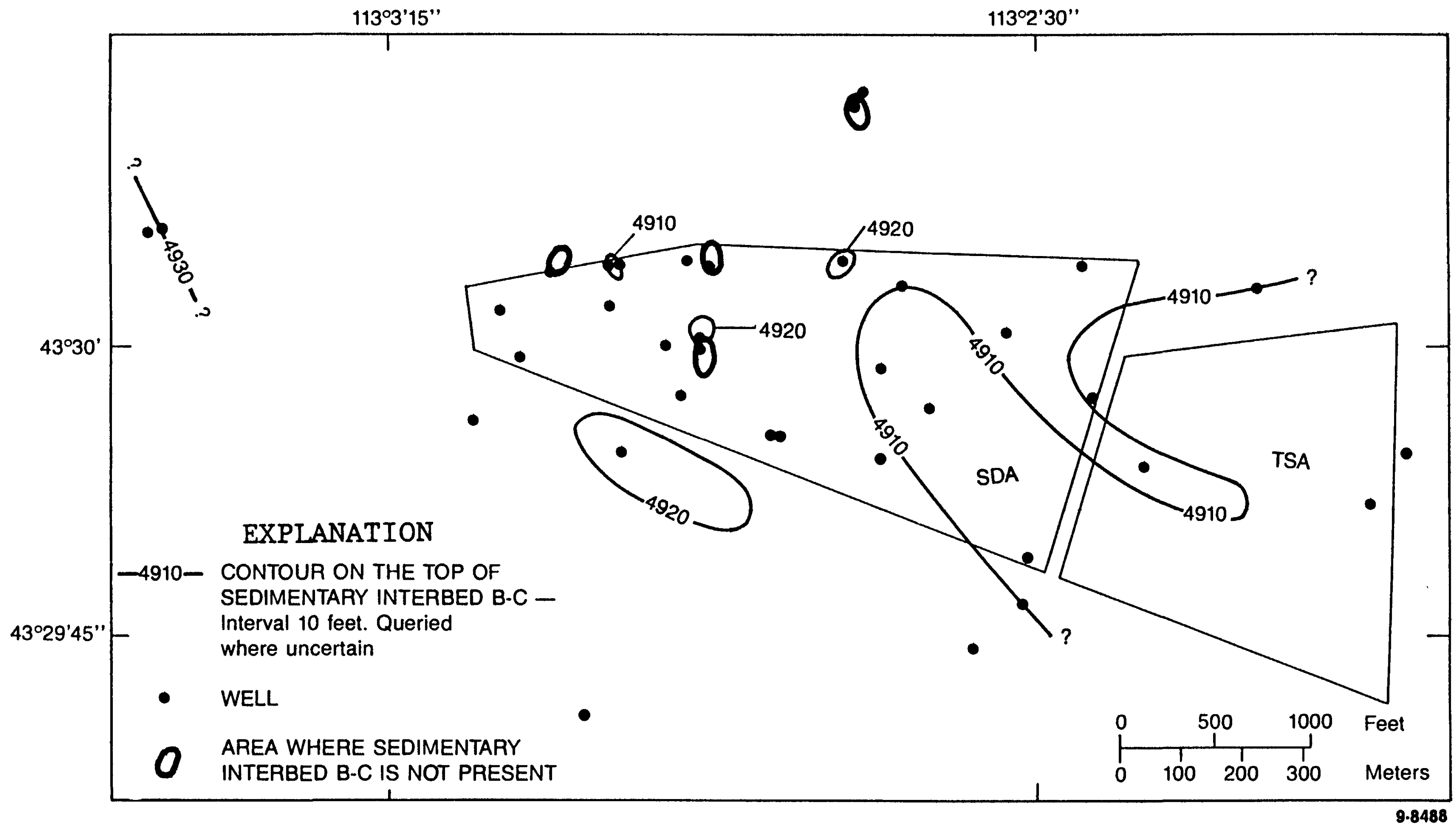


Figure 21.--Altitude of the top of sedimentary interbed B-C at the Radioactive Waste Management Complex.

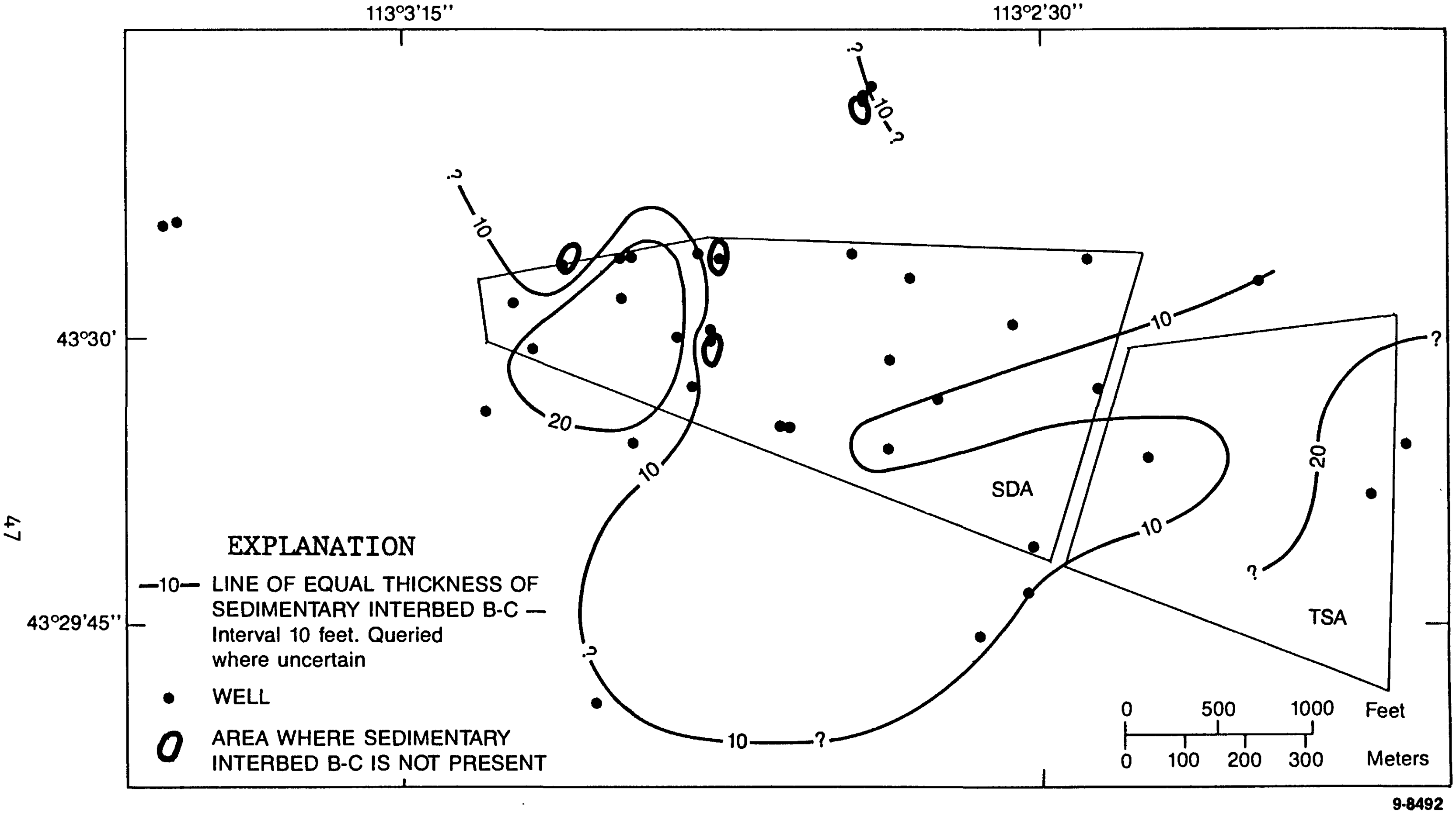


Figure 22.--Thickness of sedimentary interbed B-C at the Radioactive Waste Management Complex.

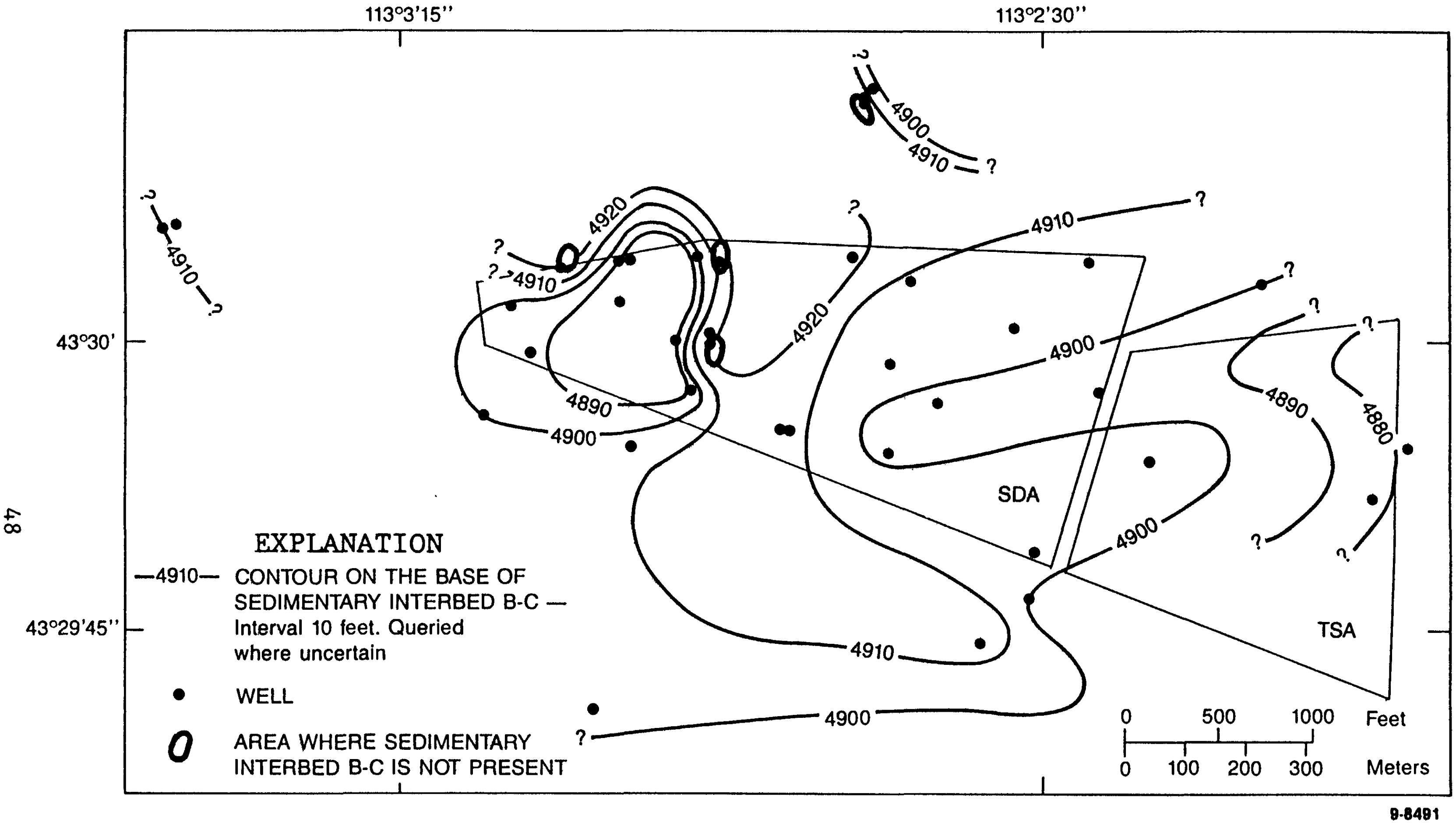


Figure 23.--Altitude of the base of sedimentary interbed B-C at the Radioactive Waste Management Complex.

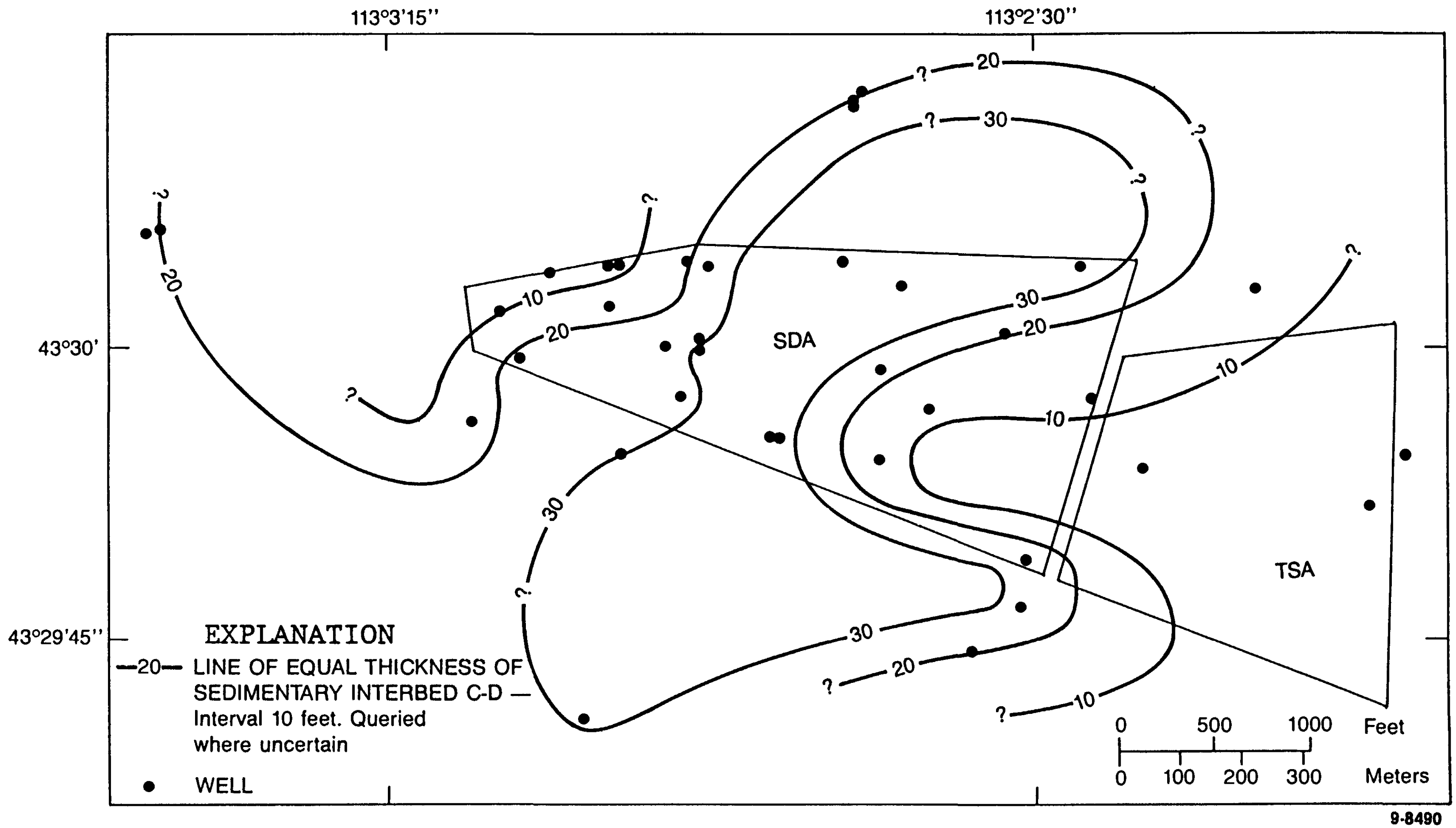


Figure 24.--Thickness of sedimentary interbed C-D at the Radioactive Waste Management Complex.

Table 1.--Thickness and altitude of the top and base of basalt flow groups and major sedimentary interbeds from land surface to the base of basalt flow group D at the Radioactive Waste Management Complex [Numbers rounded to the nearest foot and accurate to ± 2 feet. --Indicates no data; < indicates less than; > indicates greater than]

	Surficial Sediment		Basalt flow group A			Sedimentary interbed A-B		
Well	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
76-1	7	5002	5002	20	4982	4982	6	4976
76-2	11	4999	4999	10	4989	4989	4	4985
76-3	20	4990	4990	2	4988	4988	3	4985
76-4	8	5003	5003	10	4993	4993	4	4989
76-4A	6	5005	5005	12	4993	4993	5	4988
76-5	11	5000	--	0	--	--	0	--
76-6	5	5006	--	0	--	--	0	--
77-1	4	5013	5013	36	4977	4977	8	4969
77-2	18	4996	4996	10	4986	4986	3	4983
78-1	19	4991	--	0	--	--	0	--
78-2	6	5001	5001	14	4987	4987	4	4983
78-3	11	5000	--	0	--	--	0	--
78-4	3	5015	5015	39	4976	4976	5	4971
78-5	12	4998	--	0	--	--	0	--
79-1	5	5013	--	0	--	--	0	--
79-2	13	4998	4998	11	4987	4987	3	4984
79-3	13	4995	--	0	--	--	0	--
87	2	5014	5014	38	4976	4976	8	4968
88	6	5014	--	0	--	--	0	--
88-01D	21	4989	--	0	--	--	0	--
88-02D	6	5003	5003	19	4984	4984	3	4981
89	9	5020	5020	24	4996	4996	6	4990
90	5	5005	--	0	--	--	0	--
91	11	4995	--	0	--	--	0	--
92	20	4988	--	0	--	--	0	--
93	15	4995	--	0	--	--	0	--
93-A	16	4994	--	0	--	--	0	--
94	8	5000	--	0	--	--	0	--
95	22	4986	--	0	--	--	0	--
96	16	4993	--	0	--	--	0	--
96-A	13	4994	4994	19	4975	4975	2	4973
96-B	13	4996	4996	18	4978	4978	7	4971
117	16	4997	--	0	--	--	0	--
118	15	4998	--	0	--	--	0	--
119	3	5029	--	0	--	--	0	--
120	13	4999	--	0	--	--	0	--
D-02	13	4999	4999	11	4988	4988	4	4984
D-06	3	5009	5009	36	4973	4973	11	4962
D-06A	3	5009	5009	43	4966	4966	2	4964
D-10	9	5005	5005	23	4982	4982	7	4975
D-15	2	5009	5009	30	4979	4979	3	4976
RWMC	7	4998	--	0	--	--	0	--
TW-1	17	4994	4994	9	4985	4985	4	4981
WWW-1	5	5024	5024	39	4985	4985	11	4974
VZT-1	4	5014	5014	39	4975	4975	7	4988

Table 1.--Thickness and altitude of the top and base of basalt flow groups and major sedimentary interbeds from land surface to the base of basalt flow group D at the Radioactive Waste Management Complex [Numbers rounded to the nearest foot and accurate to ± 2 feet. --Indicates no data; < indicates less than; > indicates greater than]--Continued

	Basalt flow group B			Sedimentary interbed B-C			Basalt flow group C		
Well	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
76-1	4976	55	4921	--	0	--	4921	132	4789
76-2	4985	65	4920	--	0	--	4920	131	4789
76-3	4985	69	4916	4916	24	4892	4892	100	4792
76-4	4989	72	4917	4917	5	4912	4912	>116	<4796
76-4A	4988	72	4916	4916	4	4912	4912	124	4788
76-5	5000	82	4918	4918	17	4901	4901	110	4791
76-6	5006	93	4913	4913	4	4909	4909	126	4783
77-1	4969	50	4919	4919	6	4913	4913	124	4789
77-2	4983	>56	<4927	--	--	--	--	--	--
78-1	4991	>63	<4928	--	--	--	--	--	--
78-2	4983	69	4914	4914	7	4907	4907	123	4784
78-3	5000	85	4915	--	0	--	4915	129	4786
78-4	4971	53	4918	4918	5	4913	4913	123	4790
78-5	4998	86	4912	4912	25	4887	4887	100	4787
79-1	5013	108	4905	4905	28	4877	4877	86	4791
79-2	4984	71	4913	4913	5	4908	4908	>120	<4788
79-3	4995	87	4908	4908	7	4901	4901	125	4776
87	4968	56	4912	--	0	--	4912	124	4788
88	5014	101	4913	4913	11	4902	4902	116	4786
88-01D	4989	81	4908	4908	5	4903	4903	122	4781
88-02D	4981	66	4915	4915	8	4907	4907	>27	<4880
89	4990	59	4931	4931	14	4917	4917	116	4801
90	5005	97	4908	4908	23	4885	4885	115	4770
91	4995	86	4909	4909	16	4893	4893	116	4777
92	4988	67	4921	4921	5	4916	4916	130	4786
93	4995	78	4917	4917	13	4904	4904	115	4789
93-A	4994	83	4911	4911	12	4899	4899	111	4788
94	5000	88	4912	4912	16	4896	4896	113	4783
95	4986	75	4911	4911	14	4897	4897	112	4785
96	4993	81	4912	4912	27	4885	4885	100	4785
96-A	4973	62	4911	4911	>22	<4889	--	--	--
96-B	4971	62	4909	4909	25	4884	4884	96	4788
117	4997	77	4920	4920	11	4909	4909	117	4792
118	4998	88	4910	4910	10	4900	4900	108	4792
119	5029	110	4919	4919	5	4914	4914	131	4783
120	4999	118	4881	4881	40	4841	4841	82	4759
D-02	4984	70	4914	4914	5	4909	4909	120	4789
D-06	4962	38	4924	4924	3	4921	4921	>35	<4886
D-06A	4964	>2	<4962	--	--	--	--	--	--
D-10	4975	56	4919	4919	>0	<4919	--	--	--
D-15	4976	63	4913	4913	14	4899	4899	110	4789
RWMC	4998	88	4910	4910	10	4900	4900	120	4780
TW-1	4981	71	4910	4910	7	4903	4903	118	4785
WWW-1	4974	50	4924	4924	14	4910	4910	112	4798
VZT-1	4968	50	4918	4918	18	4900	4900	>16	<4884

Table 1.--Thickness and altitude of the top and base of basalt flow groups and major sedimentary interbeds from land surface to the base of basalt flow group D at the Radioactive Waste Management Complex [Numbers rounded to the nearest foot and accurate to ± 2 feet. --Indicates no data; < indicates less than; > indicates greater than]--Continued

	Sedimentary interbed C-D			Basalt flow group D		
Well	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
76-1	4789	>8	<4781	--	--	--
76-2	4789	>31	<4758	--	--	--
76-3	4792	>22	<4770	--	--	--
76-4	--	--	--	--	--	--
76-4A	4788	>31	<4757	--	--	--
76-5	4791	20	4771	4771	>5	<4766
76-6	4783	6	4777	4777	>10	<4767
77-1	4789	22	4767	4767	30	4737
77-2	--	--	--	--	--	--
78-1	--	--	--	--	--	--
78-2	4784	>30	<4754	--	--	--
78-3	4786	>26	<4760	--	--	--
78-4	4790	20	4770	4770	38	4732
78-5	4787	>27	<4760	--	--	--
79-1	4791	5	4786	4786	>12	<4774
79-2	--	--	--	--	--	--
79-3	4776	25	4751	4751	>5	<4746
87	4788	17	4771	4771	35	4736
88	4786	32	4754	4754	8	4746
88-01D	4781	>4	<4777	--	--	--
88-02D	--	--	--	--	--	--
89	4801	20	4781	4781	31	4750
90	4770	7	4763	4763	55	4708
91	4777	13	4764	4764	>13	<4751
92	4786	24	4762	4762	>1	<4761
93	4789	9	4780	4780	>16	<4764
93-A	4788	10	4778	4778	>1	<4777
94	4783	21	4762	4762	28	4734
95	4785	12	4773	4773	>11	<4762
96	4785	6	4779	4779	>6	<4773
96-A	--	--	--	--	--	--
96-B	4788	>8	<4780	--	--	--
117	4792	32	4760	4760	8	4752
118	4792	29	4763	4763	47	4716
119	4783	20	4763	4763	35	4728
120	4759	14	4745	4745	14	4731
D-02	4789	>20	<4769	--	--	--
D-06	--	--	--	--	--	--
D-06A	--	--	--	--	--	--
D-10	--	--	--	--	--	--
D-15	4789	17	4772	4772	>5	<4767
RWMC	4780	12	4768	4768	53	4715
TW-1	4785	>12	<4773	--	--	--
WWW-1	4798	21	4777	4777	>6	<4771
VZT-1	--	--	--	--	--	--

Table 2.--Thickness and altitude of the top and base of basalt flow groups and major sedimentary interbeds from the top of sedimentary interbed D-E to the base of basalt flow group I at the Radioactive Waste Management Complex. [Numbers rounded to the nearest foot and accurate to ± 2 feet. -- Indicates no data; > indicates greater than; < indicates less than. Well 119 not logged below a depth of 584 feet.]

	Sedimentary interbed D-E			Basalt flow group E			Sedimentary interbed E-F		
Well	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
77-1	4737	9	4728	4728	71	4657	4657	5	4652
78-4	4732	4	4728	4728	>53	<4675	--	--	--
87	--	0	--	4736	80	4656	4656	5	4651
88	4746	4	4742	4742	100	4642	4642	6	4636
89	4750	6	4744	4744	82	4662	4662	6	4656
90	--	0	--	4708	73	4635	4635	4	4631
94	4734	4	4730	4730	>24	<4706	--	--	--
117	4752	6	4746	4746	92	4654	--	0	--
118	4716	6	4710	4710	78	4632	--	0	--
119	4728	7	4721	4721	92	4629	--	0	--
120	4731	8	4723	4723	114	4609	--	0	--
RWMC	--	0	--	4715	83	4632	--	0	--

	Basalt flow group F			Sedimentary interbed F-FG			Basalt flow group FG		
Well	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
77-1	4652	189	4463	--	--	--	--	--	--
78-4	--	--	--	--	--	--	--	--	--
87	4651	185	4466	--	--	--	--	--	--
88	4636	133	4503	--	--	--	--	--	--
89	4656	167	4489	4489	8	4481	4481	21	4460
90	4631	199	4432	--	--	--	--	--	--
94	--	--	--	--	--	--	--	--	--
117	4654	167	4487	--	--	--	--	--	--
118	4632	186	4446	--	--	--	--	--	--
119	4629	169	4460	--	--	--	--	--	--
120	4609	84	4525	--	--	--	--	--	--
RWMC	4632	191	4441	--	--	--	--	--	--

	Sedimentary interbed FG-G			Sedimentary interbed F-G			Basalt flow group G		
Well	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
77-1	--	--	--	4463	4	4459	4459	>42	<4417
78-4	--	--	--	--	--	--	--	--	--
87	--	--	--	4466	10	4456	4456	40	4416
88	--	--	--	4503	6	4497	4497	97	4400
89	4460	14	4446	--	--	--	4446	>63	<4383
90	--	--	--	4432	12	4420	4420	>36	<4384
94	--	--	--	--	--	--	--	--	--
117	--	--	--	4487	12	4475	4475	89	4386
118	--	--	--	4446	>3	<4443	--	--	--
119	--	--	--	4460	9	4451	4451	>3	<4448
120	--	--	--	4525	6	4519	4519	123	4396
RWMC	--	--	--	4441	15	4426	4426	58	4368

Table 2.--Thickness and altitude of the top and base of basalt flow groups and major sedimentary interbeds from the top of sedimentary interbed D-E to the base of basalt flow group I at the Radioactive Waste Management Complex. [Numbers rounded to the nearest foot and accurate to ± 2 feet. -- Indicates no data; > indicates greater than; < indicates less than. Well 119 not logged below a depth of 584 feet.]--Continued

	Sedimentary interbed G-H			Basalt flow group H			Sedimentary interbed H-I		
Well	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base	Altitude of top	Thickness	Altitude of base
77-1	--	--	--	--	--	--	--	--	--
78-4	--	--	--	--	--	--	--	--	--
87	4416	5	4411	4411	15	4396	4396	>20	<4376
88	4400	>15	<4385	--	--	--	--	--	--
89	--	--	--	--	--	--	--	--	--
90	--	--	--	--	--	--	--	--	--
94	--	--	--	--	--	--	--	--	--
117	4386	4	4382	4382	3	4379	4379	5	4374
118	--	--	--	--	--	--	--	--	--
119	--	--	--	--	--	--	--	--	--
120	4396	4	4392	4392	27	4365	4365	4	4361
RWMC	4368	5	4363	4363	25	4338	4338	6	4332

	Basalt flow group I		
Well	Altitude of top	Thickness	Altitude of base
77-1	--	--	--
78-4	--	--	--
87	--	--	--
88	--	--	--
89	--	--	--
90	--	--	--
94	--	--	--
117	4374	>16	<4358
118	--	--	--
119	--	--	<4327
120	4361	>49	<4312
RWMC	4332	>12	<4320