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TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY OF SATURATED SEDIMENTARY ROCKS IN THE HANFORD RESERVATION

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INTRODUCTION

The Hanford Reservation (Figure 1) occupies 365,000 acres (570 square miles) of land within the Columbia Basin geologic province. This location was selected in early 1943 by the U. S. Army Corps of Engineers as the site for reactor and chemical separation facilities for the production and purification of plutonium needed in the development of nuclear weapons.[1] The Reservation is divided into the 100, 200, 300, 400, 600, 700, 1100, and 3000 Areas.

Eight graphite-moderated reactors using Columbia River water for once-through cooling and one reactor (N Reactor) using a recirculating water coolant were built along the Columbia River. Only the N Reactor is presently operating. It is being used to produce both plutonium and electricity. The reactors are located in the 100 Areas (Figure 1).

The 200 Areas (Figure 1) include all reactor fuel reprocessing and waste management facilities. The 200 West and 200 East Areas are located on a plateau south of Gable Butte and Gable Mountain and about 7 miles from the Columbia River. These facilities include "tank farms" where wastes containing high-level concentrations of radionuclides are currently stored. The tank farms include:

- One hundred forty-nine underground tanks ranging in capacity from 50,000 to 1,000,000 gallons.
- Three double-walled 1,000,000-gallon underground tanks.

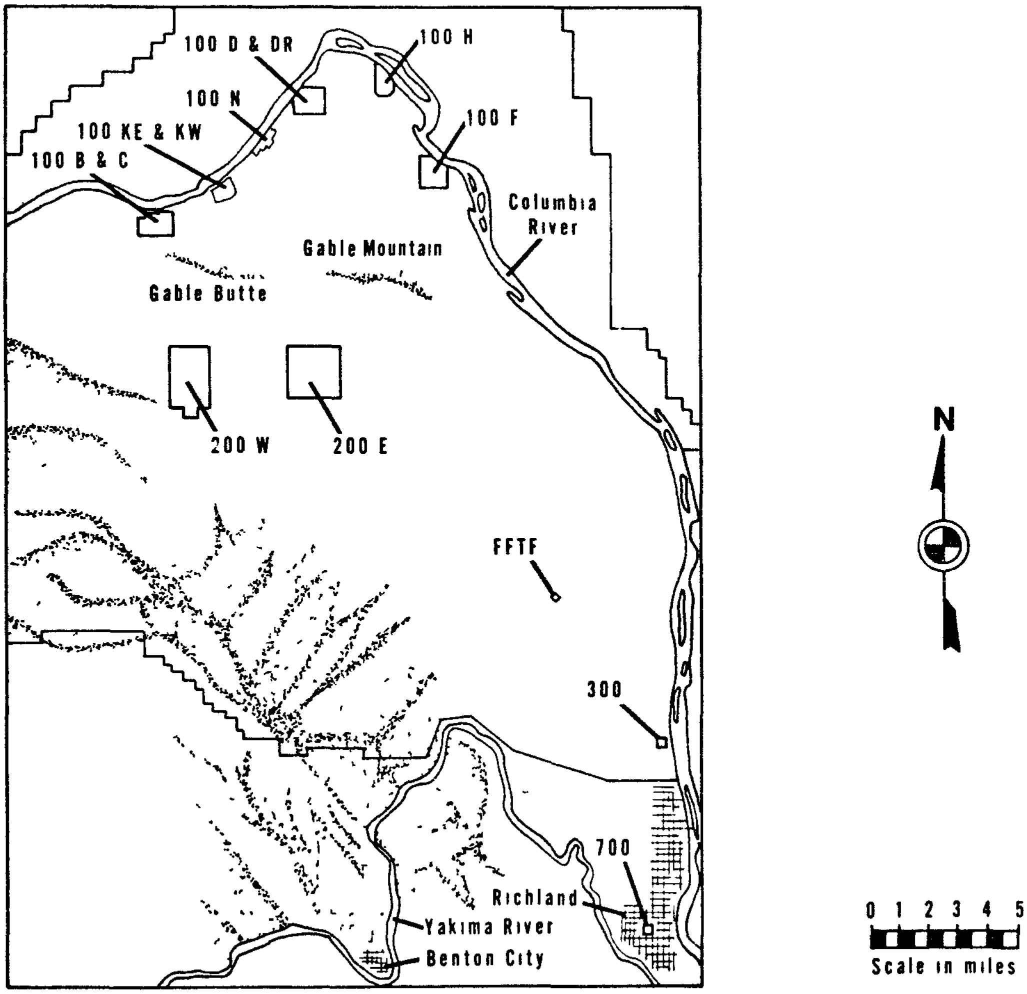

FIGURE 1
HANFORD AREA MAP

- Four double-walled 1,000,000-gallon underground tanks presently under construction.

In addition to the tank farms, the 200 Areas include:

- Four water evaporators used to convert radioactive waste into a less mobile sludge (two currently in service).
- One hundred seventy-seven cribs that have been used for the disposal of intermediate-level liquid waste.
- Ponds and ditches (covering under 400 acres) for the disposal of low-level wastes.

More than 5 million cubic feet of contaminated dry solid wastes (used equipment, paper, construction debris) are buried at Hanford in special burial trenches within and outside the 200 Areas.

The 300 Area is located just north of the city of Richland (Figure 1) and includes both the reactor fuel manufacturing facilities and the research and development laboratories.

The 400 Area is located seven miles northwest of the 300 Area and includes the Fast Flux Test Facility (FFTF) presently under construction.

The 600 Area includes all the remaining land within the Hanford Reservation. It serves as a buffer between the facility at Hanford and the nearby communities.

The 700 Area includes administration offices. The 1100 Area includes Central Stores and the bus and rail operational center for the Project. The 3000 Area includes private laboratories and Port of Benton land areas.

To adequately understand the groundwater flow regime of the Hanford Reservation, data have been gathered and tests

TABLE I

DRILLER LOG OF WELL 399-5-2

Depth, Feet		
From	To	Material Penetrated
0	3	Topsoil, boulders, sand, gravel
4	7	Boulders, sand, gravel, silt
8	15	Sand, gravel, silt
16	32	Sand, gravel
33	34	Sand, gravel, little silt
35	48	White sand, gravel
49	65	White sand, clay, gravel
66	67	Clay, gravel
68	69	Clay
70	80	Blue, brown, and yellow clay
81	89	Clay, gravel, coarse sand
90	99	Black sand, little gravel
100	105	Black sand, gravel
106	120	Sand, gravel, wood
121		Sand, gravel, clay
122	140	Sand, gravel, boulders
141	154	Sand, basalt, clay
155	160	Sand, gravel, clay
161	176	Clay
177	192	Clay, coarse sand
193	194	Clay, black sand, basalt
195	205	Sand, basalt
206	208	Basalt
209	230	Basalt, volcanic mud
231	235	Porous basalt, gravel
236	274	Hard basalt
275	279	Greenish-blue silt, sand
280	300	Bluish-greenish shale, sand
301	305	Green silt
306	310	Black mud
311	315	Porous basalt
315	319	Basalt
320	324	Shale, basalt
325	334	Basalt, shale, quartz
335	344	Basalt, green shale
345	346	Basalt, blue shale
347	359	Hard basalt
360	369	Porous basalt
370	379	Hard basalt
380	399	Hard, gray basalt
400	406	Black basalt
407	409	Hard basalt
410	419	Basalt
420	423	Hard basalt
424		Solid basalt--total depth

TABLE II

GEOLOGICAL LOG OF WELL 399-5-2

	Thickness Feet	Depth Feet
Alluvium:		
Sand, silty; about 40% quartz and 60% basalt; angular-to-subangular; poorly sorted--mostly coarse-to-fine sand with some 1/4" to 1/2" diameter gravel and a few boulders; some artificial fill in places.	3	3
Glaciofluviatile and Fluviatile Deposits:		
Gravel, sandy and bouldery; contains a small small amount of silt; basalt predominates in the gravel and coarse sand and makes up 80% of the finer sand; sand is angular-to-subangular, and gravel is rounded-to-subrounded.	12	15
Gravel, sandy and slightly silty; pebbles, averaging 1" to 3" in diameter, are subrounded-to-subangular, about 40% basalt and 60% exotic types; material is about 40% gravel, 55% medium-to-very fine sand, and 15% silt.	6	21
Gravel, sandy; gravel forms 60% of sample, sand 25%, and silt 15%; ratio of basalt-to-exotic types in gravel is about 65%:35%; sand is about 55% basalt and 45% exotics and quartz; gravel is subangular-to-subrounded and has 3" maximum diameter and 1" average diameter.	4	25
Gravel, coarse-to-fine, and coarse sand; maximum diameter of gravel 4", average diameter 2"; pebbles form about 80% of bed; basalt component of pebble gravel about 40% at 30'-depth, decreasing gradually to 20% at 50'-depth, basalt in coarse-to-medium sand decreases gradually from 30% at 30'-depth to 5% at 50' depth, almost no silt present.	25	50
Ringold Formation:		
Gravel; mostly exotic rock-types; fine-to-coarse from 1/4" to 6" in diameter, although mainly pebbles with occasional cobbles, in a medium-clean micaceous, quartzose sand matrix; upper 10' of this gravel is highly calcareous and gives strong reaction to acid; sand content	13	63

TABLE II (continued)

	Thickness Feet	Depth Feet
increases to 55% of sample in 57' to 60' zone, remainder being gravel.		
Gravel, exotic-type, subrounded-to-subangular; has thin slit and clay zones in bottom foot of bed.	4	67
Clay, light-tan; contains a few 1/2" angular pebbles.	5	72
Clay, light-tan, finely micaceous, slightly silty.	9	81
Clay, light-tan, slightly silty, has a few 1/6" to 1/4" diameter rounded-to subrounded indurated claystone nodules.	3	84
Gravel, granule and pebble, in a silty clay clay matrix; approximate percentages: granule gravel, 75; pebble gravel, 15; silty clay, 10; rock particles are about half exotic and half basalt, all rounded-to-subrounded.	3	87
Siltstone, light-tan, clayey, very finely micaceous.	4	91
Sand, quartzose and micaceous, medium-to-fine, well-sorted, over 90% siliceous, and gravel mainly of dark exotic-types mostly about 1/2" to 1-1/2" in diameter; gravel about 30% of sample in 91'- to 96'-zone increasing to 50% in the 96'- to 99'-zone.	8	99
Sand, silty and clayey, and gravel; gravel, maximum diameter 1", forms approximately 20% of sample; rude 1/8"-thick weathering rind on basalt pebbles.	3	102
Sand, quartose and micaceous, and gravel, as in 91'- to 96'-zone; good weathering rind on basalt.	4	106
Gravel, sandy as in 91'- to 99'-foot bed except that gravel component has increased to 80% of sample; gravel in lower 6' increases in size to maximum diameter of 4" and average diameter of 2-1/2"; larger gravel is about 20% basalt having weathering rinds.	10	116

TABLE II (continued)

	Thickness Feet	Depth Feet
Sand, quartzitic and micaceous, medium-to-fine, well-sorted, medium-to-heavy response to acid test.	4	120
Siltstone, gravelly and slightly clayey; gravel of 1/4" diameter forms 40% of bed in 120'- to 123'-zone, is absent in 123'- to 126'-zone and increases to 50% of the sample in 126'- to 130'-zone, where the maximum diameter is 3", gravel is mainly exotic types, and sand is siliceous.	10	130
Sand, silty; contains about 3% subrounded granule gravel.	6	136
Gravel, sandy and bouldery; gravel forms about 80% of bed, is 50% granules, and is composed mainly of dark exotic rocks; cemented sand coatings on pebbles and excellent 1/8"-thick rinds on basalts.	5	141
Sand, fine-to-medium, micaceous, about 90% clear angular-to-subangular quartz, about 2% basalt, and estimated 1% calcareous grains; very reactive to acid test; a sand interbed in gravel of 136'- to 165'-unit.	3	144
Gravel, pebble and boulder, in a clayey sand; subrounded gravel, mainly of exotic types, forms 50% of bed in 144'- to 156'-zone and increases to 80% in 156'- to 165'-zone.	21	165
Gravel, boulder, cobble, and pebble; pebble gravel is mainly 1/2" to 1" in diameter.	6	171
Silt, clayey, gray-tan; contains about 5% angular granules--both exotics and basalt; fewer rock particles in lower half of bed than in upper half.	6	177
Clay, silty, gray-tan, has thin laminae of fine gray-white volcanic ash near bottom of bed.	13	190
Clay, blue-gray, has some greenish laminae.	2	192
Sand, basaltic; sand is 80% coarse-to-fine black basalt, with 10% quartz and 10% calcareous cement; some basalt and cemented fragments are 1/4" in diameter; pyrite occurs as rare vesicle filling in basalt pebbles; water-bearing.	2	194

TABLE II (continued)

	Thickness Feet	Depth Feet
Basalt of the Columbia River Group:		
Basalt, black, dense-to-vesicular; contains about 30% khaki banded and botryoidal opaline vesicle fillings, together with some clear feldspar and rounded and frosted quartz vesicle fillings; secondary minerals abundant in upper part of basalt; basalt is weathered and clayey in upper part but fresh and hard below 200' depth.	18	212

PENETRATION-RATE LOGS[9]

Foundation engineers commonly sample rocks by driving a split-spoon sampler into the ground with a standard weight dropped a standard distance (typically 140 pounds dropped 30"). The blows required to drive the sample 1' describe the rock's penetration resistance. Soft, unconsolidated rocks are penetrated rapidly (only a few blows per foot). Penetration-rate logs show the penetration rate at various depths. In addition, they usually show the water content of the split-spoon sample as percent of the dry weight. Penetration logs are available for the Fast Flux Test Facility (FFTF) and Nuclear Reactor areas.

BOREHOLE GEOPHYSICAL STUDIES

Borehole geophysical studies, sometimes called electric logs or wire-line logs, are obtained by lowering one or more sensors on a cable and recording their output at the surface. The Geohydrology Section, Research Division, College of Engineering, Washington State University, obtained 110 log suites from 82 wells and test holes in and around the Hanford Reservation.[10-13] Log suites by commercial logging companies have been obtained from some deep test holes.

LABORATORY TESTS

Some rocks and soil samples collected during the drilling of wells and test holes are taken into a laboratory where selected properties are measured. The properties measured that contribute directly to our understanding of the flow continuum include grain-size distribution, relative density, permeability, porosity, and the elastic moduli.

Several hundred grain-size analyses have been made of samples from the 200 Areas. McHenry[14] reported the grain-size distribution, pH, $CaCO_3$ content, and cation exchange capacity of 504 samples from 38 wells distributed over the north half of the Hanford Reservation.

PUMPING TESTS

Pumping tests consist of (1) pumping a well and measuring the discharge and water-level drawdown both in the pumping well and in nearby observation wells and (2) turning off the pump and measuring the water-level recovery. By 1974 the results of 124 such tests had been reported for the wells in the Reservation or for wells near the Reservation.[4,6]

Drill-stem tests and injection tests have been conducted in a few wells.

HYDROGRAPHS

Hydrographs are the records of the water level in wells and test holes as a function of time or the record of river stage as a function of time. Kipp and Mudd[15] reported the hydrographs of wells on the Hanford Reservation for which more than two water-level measurements have been taken since 1944.

ELASTIC-WAVE DATA

Elastic-wave data consist of measurements of the velocity with which shear and compressional energy travel from a source to a receiver. Elastic energy radiates outward from the source as distinct waves. The compressional or "P" wave has small displacements along the direction of propagation of the wave; the shear or "S" wave has small displacements in a plane perpendicular to the direction or propagation of the wave. Compressional waves travel faster than the shear waves. In general wave velocities in dense, well-indurated rocks are faster than the wave velocities through softer, more porous, unconsolidated rocks.

Elastic-wave data for rocks of the Hanford Reservation derive from three types of measurements:

1. Measurements in one bore hole. The energy source and the receiver are suspended in the same hole or the energy source is in the hole and the receiver is at the surface nearby.
2. Measurements between holes. The energy source is in one drill hole and the receiver is at the same depth (usually) in another hole.
3. Refraction seismic surveys. The source transmits energy from a point at the surface or from a drill hole that is received by a number of receivers set up on the ground along a line radiating from the source. Arrival times and distance from the source are then used to interpret the velocities of the various beds through which the wave passes.

Brown and Raymond[16] described the results of refraction surveys conducted through 1964. Elastic-wave investigations have been conducted at each of the W.P.P.S.S.

nuclear project sites and are included as part of the *Preliminary Safety Analysis Reports.*

GEOLOGY

A large amount of information is available regarding the general sequence and lithology of the rocks in the Pasco Basin.[7,17-23] In an earlier report[8] the authors included a recent stratigraphic column.* This stratigraphic column differs from earlier interpretations[7] in that the Ellensburg Formation is excluded. Consequently, the Beverly members and Saddle Mountain Basalt members are also excluded.

From older-to-younger we find in the Pasco Basin the Yakima Basalt Formation, the Ringold Formation, Quaternary Glaciofluviatile Sands and Gravels, and unconsolidated Holocene deposits and ash beds. Each of these is discussed below.

YAKIMA BASALT FORMATION

This formation is the uppermost formation in the Columbia River Basalt group. The Pasco Basin is a synclinal basin that developed when the basalts folded. The upper surface of the Yakima Basalt formation thereby provided the floor upon which the sediments were deposited.

The Yakima Basalt Formation consists of relatively thick basalt flows separated by beds of tuffs and tuffaceous sandstones. These interbeds also included beds of sand and gravel, clay, diatomaceous material, and shale. Where the top of the formation consists of sedimentary rocks, they may be confused with the overlying sediments. Brown and

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*Prepared by R. K. Ledgerwood (ARHCO).

Haney[19] show clearly in a cross-section that the overlying sediments rest on interbeds at Wells 699-61-66, 65-60B, 53-55, 37-42, 31-31, and 15-15.

RINGOLD FORMATION

In the Hanford area the Ringold Formation usually contains three units.[20-23] These are the lower clays, the middle conglomerates, and the upper silts and sands. In many areas at Hanford there is evidence that the lowermost beds of the Ringold Formation have been tilted.

The three-unit division cannot be applied indiscriminately at Hanford since it is an oversimplification.

1. Lower clay unit. The lower clay unit is not exposed. It is known only from wells. It consists of blue- and green-colored silts and clayey silts. Some beds of gravel and sand are interbedded with the blue clays and in some places are the predominant rocks. These rocks appear to be lacustrine sediments. Newcomb[24] believed they accumulated below altitudes of 290'. However, driller logs of some wells (*e.g.*, 699-32-62) suggest that the clays may have filled the basin to altitudes higher than 400'. Wells in a north-south strip near the White Bluffs have penetrated two conglomerates either of which could be the middle unit. They also penetrate two blue-clay sequences which fit the description of the lower unit. Wells near Rattlesnake Hills penetrate a conglomerate that overlies the Yakima Basalt Formation.

2. Middle conglomerate unit. The conglomerate unit extends from a variable altitude of about 290' upward for about 165'. According to Newcomb,[24]

the conglomerate occurs in a line or strip about 10 miles wide and 50 miles long, between Sentinel Gap and Wallula Gap and running through the Hanford Reservation. It is a rather uniform aggregation of well-rounded pebbles and cobbles and some small boulders. The space between the pebbles and cobbles and some small boulders are almost completely filled by a matrix of medium-to-fine subrounded and angular-siliceous sand. The pebbles and cobbles are about 65% quartz and other metamorphic, granite, and porphyritic volcanic rocks and 35% basaltic rocks. The sand is largely quartzose. Sand lenses and beds are common while lenses of sandy silt are rare.

The position, shape, thickness, and lithology of the conglomerate unit indicates that it represents a river-laid train of gravel in which quiet-water sediments had been deposited and which were removed in part before deposition of the coarse-clastic sediment began.

Laterally (northwest and southwest) with respect to the main body of the conglomerate, its stratigraphic interval is occupied by fine-grained deposits.

3. Upper silts and sands. The upper portion of the Ringold Formation does not contain a marked lithology type. It consists of intergraded layers of fine sandstone, siltstone, and claystone, some zones of which attain thicknesses of 20 to 40'. Newcomb[24] believed these sediments were laid down in a large lake. These upper silts and sands are capped in certain areas by a caliche layer.

PALOUSE SOIL

In portions of the Hanford Reservation between the Ringold Formation and the overlying glaciofluviatile sediment lies a layer of soil developed upon the eroding surface of the Ringold Formation. For the most part it is a calcareous sand and silt derived from the Ringold Formation. In places it is an eolian deposit of well-sorted angular-to-subangular, slightly frosted, buff-colored silt that is as much as 70' thick. Newcomb[25] named similar eolian deposits in the Walla Walla and Umatilla River Basins the Palouse Formation.

GLACIOFLUVIATILE DEPOSITS

The glaciofluviatile deposits are divided into the Pasco Gravels and the Touchet Silts. The Touchet Silts appear to be a quiet water facies of the Pasco Gravels.

The Pasco Gravels were deposited by an aggrading stream. They are predominantly coarse-grained gravels, cobbles, and sands with cut-and-fill structure. The Touchet Silts are fine-grained deposits including some clays and fine sand deposited in slowly moving water or perhaps in temporary lakes. Both the Pasco Gravels and the Touchet Silts are unconsolidated. Cement is rare in both of them. The gravels contain a predominance of basalt fragments.

HOLOCENE DEPOSITS AND ASH BEDS

With the exception of the eolian deposits and ash falls, the land surface of the Hanford area has been degrading since the deposit of the Touchet Silts, and in all probability erosion has removed considerable material. As a consequence, Holocene deposits consist of alluvium along the Columbia River, talus and fan deposits along Rattlesnake

Hills, Gable Mountain, and Gable Butte. Extensive areas of dunes mark the eolian deposits.

Three layers of volcanic ash have been recognized in outcrops around the Hanford Reservation, but none have been specifically detected at a well site.

HYDRAULIC CONCEPTS

POROSITY

The porosity of a material is defined as the ratio of the volume of the void space (U_v) to the bulk volume (U_b) of the porous medium; this is,

$$\text{porosity} = f = \frac{U_v}{U_b} = \frac{1-U_s}{U_b}$$

where U_s is the volume of solids within U_b.

From the standpoint of flow through a porous medium one is concerned only with those pores that are interconnected. The above concept of porosity involves the sum total of all pore space. A more useful quantity in flow studies is the concept of effective porosity f_e which is defined as the ratio of interconnected pore volume $(U_v)_e$ to the total volume of the medium; that is,

$$f_e = \frac{(U_v)_e}{U_b}$$

STORAGE COEFFICIENT

The storage coefficient indicates the relationship between the changes in the quantity of water stored in an aquifer and the corresponding changes in water table or piezometric surface elevation. It can be defined as the volume of water released from storage, or taken into storage, per unit of surface area of aquifer per unit change in water table elevation or piezometric head. In confined aquifers the storage coefficient involves the interplay of two elastic effects--compression of the aquifer and expansion of the contained water--when the head is reduced during pumping. In unconfined aquifers the storage coefficient represents the result of dewatering of interconnected pores and thus in the limit approaches the effective porosity.

HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of a flow continuum is a measure of the capacity of the interconnected pores to transmit water. These pores include the intergranular space between particles and the space generated when the rock mass fractures. The effective porosity of unconsolidated rocks derives from the intergranular space, whereas the effective porosity of indurated rocks derives primarily from fractures.

In general the hydraulic conductivity of an unconsolidated mass decreases as the mass compacts. It is further decreased when cement fills the voids. When the rocks fracture, the hydraulic conductivity of the rock mass increases. In fine-grained deposits the hydraulic conductivity due to fracture porosity may be orders of magnitude greater than that due to intergranular porosity.

The sediments of the Pasco Basin range from loose, unconsolidated masses that will not hold an unsupported vertical face, to well-indurated, cemented rocks that form cliffs and stand open in drill holes without support.

TRANSMISSIVITY

Transmissivity (T) is a measure of an entire lithologic entity's (formation, part of a formation, group of formations) capacity to transmit water horizontally under a unit hydraulic gradient. In an isotropic homogeneous porous medium with thickness (b) and the horizontal component of hydraulic conductivity (K), the transmissivity of any vertical column of saturated rock is

$$T = Kb$$

For rocks with multiple layers each of thickness b_i and having different hydraulic conductivities (K_i)

$$T = \sum_{1=1}^{n} K_i b_i .$$

If we know T and b or $\sum_{1=1}^{n} b_i$, then we may compute the mean horizontal hydraulic conductivity ($\overline{K}$).

LABORATORY AND FIELD DETERMINATIONS OF HYDRAULIC PROPERTIES

As noted previously in this report much is known about the geology and hydraulic characteristics of the sediment underlying the Hanford Reservation. This section of the report was prepared by compiling, condensing, and interpreting results from all tests conducted on the sediment overlying the top surface of the basalt. From a hydrologic standpoint this zone between the top of the basalt and the water table is usually termed the Hanford unconfined aquifer.

POROSITY

Porosity measurements in sediments underlying the Hanford Reservation are not abundant. The effective porosity of the glaciofluviatile sediments is usually less than 10%. Lithologic differences suggest that the rocks of the Ringold Formation should have a lower porosity than those of the glaciofluviatile deposits. The elastic-wave velocity contrast between the Ringold Formation and the glaciofluviatile deposits also suggests that the porosity of the rocks that make up the Ringold Formation must be appreciably smaller.

HYDRAULIC CONDUCTIVITY

The hydraulic conductivity has been measured in the laboratory for a few samples collected from wells or test holes. A few constant-head injection tests have also been conducted in wells to determine hydraulic conductivity. The results can be summarized as follows:

Material	K (ft/day)
Sandy gravel and gravels	250 -4000
Sand	1 - 250
Clay	0.004- 1

The areal distribution of the horizontal hydraulic conductivity has been computed using data from 48 pumping tests. These data were processed using the Transmissivity Iterative Routine (TIR) developed by Battelle Pacific Northwest Laboratories to obtain a Transmissivity distribution. This distribution was used in conjunction with aquifer thickness data (aquifer thickness = depth to aquifer bottom-depth to water) to obtain a hydraulic conductivity distribution. The depth to the bottom of the aquifer (Figure 2) was obtained from driller logs and then a

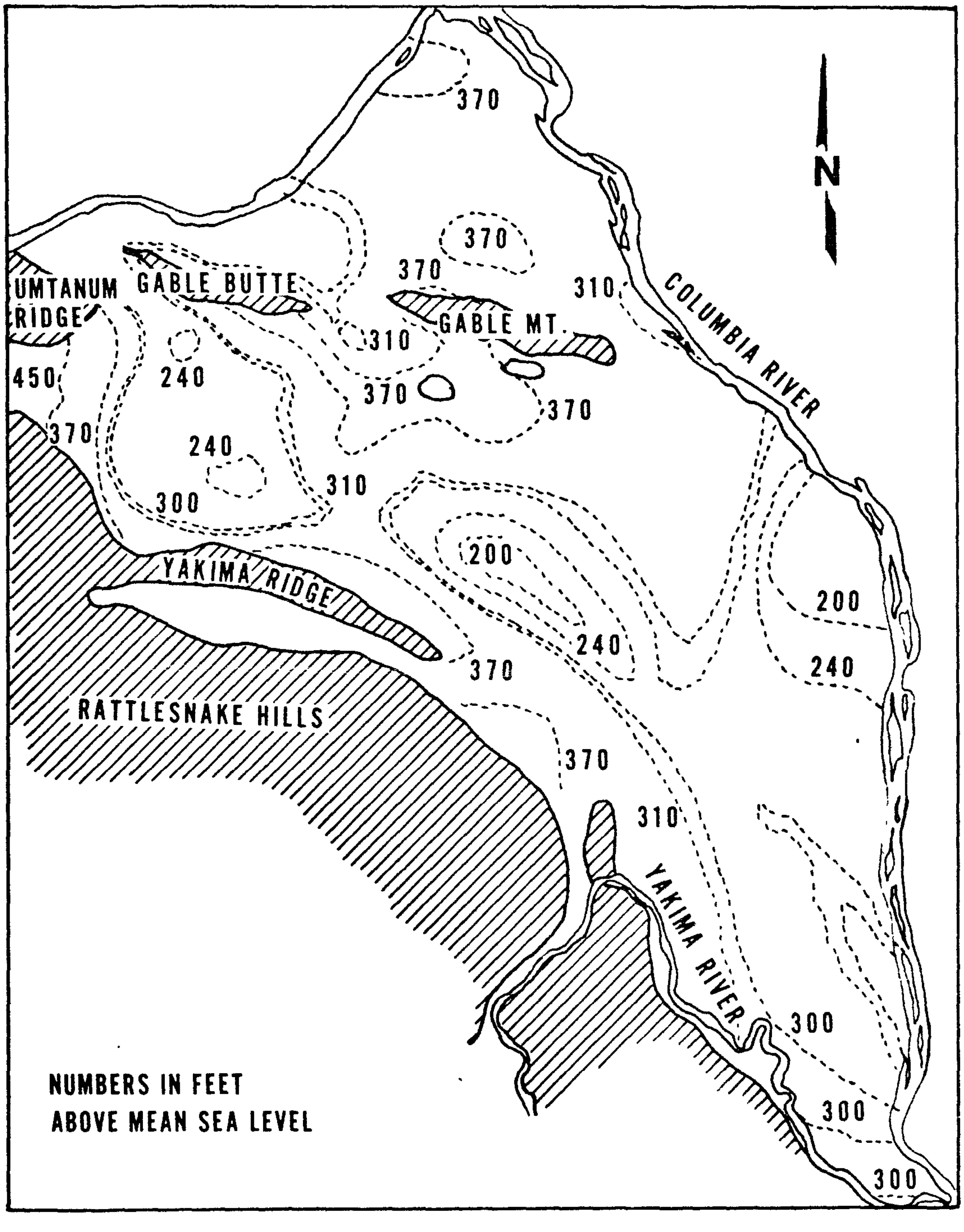

FIGURE 2

COMPUTER-GENERATED MAP OF THE BOTTOM
OF THE UNCONFINED AQUIFER

contour map was generated using a computer. The areal distribution of hydraulic conductivity obtained by this technique (Plate 1) is not representative of average hydraulic conductivities in the unconfined aquifer but represents the hydraulic conductivity of the intervals pump tested. Table III lists the wells used in preparing Plate 1.

TRANSMISSIVITY VALUES

Transmissivity values can be obtained by using the hydraulic conductivity values measured in the laboratory and assuming a saturated thickness for the aquifer. Such a procedure is not very accurate. This is especially true when we are dealing with values measured in the Ringold Formation. Since we believe that the Ringold Formation is fractured, the low values obtained in many laboratory tests reflect only the intergranular pores and therefore do not reflect the true value of the hydraulic conductivity of the flow continuum.

Two reports[26,27] show the transmissivity as determined by analyses of the relationships between river-level-stage changes and the change of water levels in wells near the river. The transmissivity values reported are summarized in Table IV.

Transmissivity data obtained from 48 pumping tests were fed to the TIR Model to obtain a Transmissivity distribution (Plate 2). The wells used are those shown in Table III.

STORAGE COEFFICIENT

Storage coefficient must be determined from pumping tests. Unfortunately, the techniques and necessary input data for the calculation of storage coefficient distribution for the unconfined aquifer have not yet been developed.

TABLE III

WELLS USED IN PREPARING PLATE 1

Well No.	K (ft/day) Range from Pump Tests	K (ft/day) Input Data	Comments
199-D2 -5	370- 2900	500	
199-D8 -3	1400- 2000	1700	
199-K -10	39- 53	53	
199-N -14	92- 150	100	
199-N -15	590- 1100	590	
199-F7 -1	530	530	Very low-quality data, no range determined.
299-W21-1	27- 50	27	
399-8 -2	190	190	Very low quality.
699-S12-3	6- 7	7	
699-S8 -19	100- 300	300	
699-S1 -7A	36- 40	40	Very low quality.
699-S1 -7B	13- 18	18	Low quality.
699-2 -3	130- 630	200	
699-1 -18	60- 100	100	
699-8 -17	130- 150	140	
699-8 -32	10- 35	20	
699-10 -54	30	30	Low quality.
699-15 -26	155- 190	320	Input value adjusted by factor of 2 for reference line fit.
699-17 -5	5- 11	11	
699-17 -47	18- 58	18	
699-29 -20	290- 320	300	
699-26 -15	40- 170	140	
699-26 -89	5	5	
699-31 -31	1200- 1400	1200	
699-31 -53B	120- 500	310	
699-32 -77	20- 260	20	
699-33 -56	228- 233	230	
699-35 -9	30- 950	40	
699-36 -61A	7- 800	700	
699-40- 53	9- 13	9	
699-41 -23	220- 410	410	
699-42 -12	950- 2100	750	
699-43 -89	6- 82	13	
699-43 -104	5	5	Low quality.
699-43 -35	36	36	
699-47 -60	27- 85	50	
699-55 -60A	8500-15000	8500	
699-61 -66	500- 510	500	
699-62 -43	1500- 2700	1600	

TABLE III (continued)

Well No.	K (ft/day) Range from Pump Tests	K (ft/day) Input Data	Comments
699-63 -90	310- 480	480	
699-65 -50	190- 200	200	
699-69- 45	0.8- 1	5	Low quality, uncertainty factor of 5.
699-71 -30	3- 7	5	
699-71- 52	96	96	
699-71- 77	84	84	
699-77 -54	68- 770	500	
699-87 -55	60- 180	60	
399-49- 16	1200	1200	

TABLE IV

TRANSMISSIVITIES FROM RIVER-STAGE FLUCTUATIONS

Reach of Columbia	Formula	Transmissivity ft^2/d	Ref. Source
100 N Area	Glaciofluviatile	4000 to 8000	26
North of Gable Mountain	Glaciofluviatile	81000 to 310000	3
North of Gable Mountain	Glaciofluviatile Ringold	17000 to 32000	3
Town of Hanford	Ringold	2000 to 35000	3
West boundary to 100 K	Glaciofluviatile	27000	27
100 K-100 H Areas	Glaciofluviatile Ringold	1300	27
100 H Area-Ringold	Ringold (?)	6100	27
Ringold-Richland	Glaciofluviatile	160000	27

Values for the storage coefficient at Hanford are few and not of great accuracy. They range from 0.00007 to 0.2 (Table V).

For the purposes of groundwater flow and radionuclide transport simulation modeling, the effective porosity over

TABLE V

STORAGE COEFFICIENT VALUES (S) DETERMINED FROM PUMPING TESTS AT THE HANFORD RESERVATION

Well No.	Number of Observed Wells	b (ft)*	S	Investigator
199-K -10	1	86	0.04	Deju
		85	0.00007	Bierschenk
		88	0.0002	Newcomb *et al.*
699-31-53	1	127	-	Deju
		120	0.06	Bierschenk
699-36-61	1	65	-	Deju
		67	0.007-0.10 average 0.54	Kipp and Mudd
699-43-89	1	220	0.01 -0.21 average 0.016	Kipp and Mudd
699-55-50B	1	65	0.07	Deju
		45	0.20	Bierschenk
699-62-43	13	30	0.06	Bierschenk
		31	0.03	Honstead *et al.*

*b = saturated thickness tested according to analyst.

the saturated thickness of the unconfined aquifer is assumed to be equal to the storage coefficient.

TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY FROM DRILLER LOGS

Transmissivity and hydraulic conductivity values can be obtained from an examination of driller logs. This is the procedure we used:

1. On the drillers' logs we recognized five relative permeability units. To these units were assigned relative numbers (N1) as follows:

N1	Lithology from Drillers' Logs
10^4	Cobbles, coarse gravel, pebbles
10^3	Gravel, sand and gravel
10^2	Sand
10	Fine sand, sand and silt
1	Clay, clay and silt, sandy clay

2. We then color-coded each driller's log to show the number N1 for each interval described by the driller.

3. For each well location the January 1973 water-table elevation was obtained from the water-table map. This elevation was used to determine the upper limit of saturation.

4. For the saturated interval the number N1 of each interval described by the driller was multiplied by the interval's thickness. These products were then summed to produce another number (N2) representing the relative transmissiveness of the saturated sedimentary rocks described by the driller. Table VI contains the values of N2 thus obtained.

TABLE VI

SATURATED THICKNESS, RELATIVE NUMBER N2, AND ESTIMATED TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY BASED ON DRILLERS' LOGS

	Saturated Thickness				Estimated Transmissivity from Drillers' Logs		
	Total Feet		Penetrated by Well			Estimated	
Well No.	From Log	Estimated from Map	ft	%	N2 x 1000	"T" (ft^2/d) x 1000	Estimated "K" (ft/d)
199-D2 -5	-	290	30	10	180+	35+	1200
199-F5 -6		310	161	52	9.4+	1.9+	12
199-H4 -2	227		227	100	3.7	7.2	32
299-E26-1	9		9	100	9.0	1.7	190
299-E28-9	-	80	60	75	75+	15+	250
299-W11-2	255	-	255	100	87	17	67
299-W22-14	-	268	18	7	68+	13+	720
699-S31-1	102	-	102	100	66	12	120
699-S30-E15A	-	150	27	18	86+	16+	590
699-S29-E12	-	150	40	20	40+	8.0+	300
699-S23-26	-	100	29	29	70+	14+	480
699-S19-E13	-	150	32	21	50+	10+	310
699-S19-11	-	80	25	31	25+	4.9+	200
699-S18-E2	170	-	170	100	130	25	150
699-S14-20	64	-	64	100	64	15	230
699-S12-3	-	200	52	26	52+	10+	190
699-S12-29	108	-	108	100	4.9	0.95	8.8
699-S6 -E14A	157	-	157	100	110	21	130
699-S6 -E4C	264	-	264	100	14	2.7	10
699-1 -18	-	320	213	71	980+	200+	940
699-2 -33	296	-	296	100	53	10	34
699-3 -45	5	-	5	100	5.0	0.95	190
699-8 -17	-	340	57	19	5.7+	1.1+	19
699-9 -E2	361	-	361	100	290	60	170

TABLE VI (continued)

	Saturated Thickness				Estimated Transmissivity from Drillers' Logs		
	Total Feet		Penetrated by Well				
Well No.	From Log	Estimated from Map	ft	%	N2 x 1000	Estimated "T" (ft^2/d) x 1000	Estimated "K" (ft/d)
699-10 -E12	-	330	315	95	210+	41+	140
699-14 -E6 (Q&T)	-	340	295	87	1800+	300+	1000
699-14 -38	316	-	316	100	72	14	44
699-15 -15A	400	-	400	100	190	38	95
699-15 -26	-	390	225	58	780+	260+	1200
699-17 -5	-	390	43	11	28+	4.5+	100
699-20 -E5P	-	320	175	55	1200+	220+	1300
699-20 -20	-	450	66	15	160+	31	470
699-20 -39	208	-	208	100	980	190	910
699-24 -1P	283	-	283	100	65	13	46
699-24 -33	-	450	51	11	34+	6.5+	130
699-24 -46	383	-	383	100	210	42	110
699-25 -70	-	350	276	79	120+	23+	83
699-26 -15	-	480	160	33	200+	40+	250
699-26 -89	295	-	295	100	660	130	440
699-27 -8	457	-	457	100	170	22	48
699-28 -40	315	-	315	100	470	93	300
699-28 -52	413	-	413	100	100	20	48
699-29 -78	314	-	314	100	950	19	61
699-31 -31	502	-	502	100	1200	220	440
699-31 -53B	-	290	127	44	89+	1.7+	13
699-31 -65	-	330	209	63	87+	1.6+	7.7
699-32 -22	-	440	65	15	6.5+	1.3+	20
699-32 -62	-	260	224	86	25+	4.0	18
699-32 -70	-	320	142	44	59+	12+	85
699-32 -72	362	-	362	100	1500	280	770
699-32 -77	-	280	116	41	40+	8.0+	69

TABLE VI (continued)

	Saturated Thickness				Estimated Transmissivity from Drillers' Logs		
	Total Feet		Penetrated by Well				
Well No.	From Log	Estimated from Map	ft	%	N2 x 1000	Estimated "T" (ft^2/d) x 1000	Estimated "K" (ft/d)
699-33 -56	-	250	114	46	130+	25+	220
699-34 -39A	-	270	36	13	7.2+	0.14+	3.9
699-34 -41	-	250	13	5.2	0.94+	0.18+	14
699-34 -42	-	280	47	17	47+	7.3+	160
699-34 -51	-	240	61	25	57+	1.1+	18
699-34 -88	477	-	477	100	130	25	52
699-35 -9	-	400	61	15	12+	2.3+	38
699-35 -66	-	200	89	45	6.1+	0.12+	1.3
699-35 -70	-	200	93	47	44+	8.5+	91
699-35 -78	-	270	101	37	59+	11+	110
699-36 -46R	-	260	82	32	280+	56+	680
699-36 -61A	-	210	54	26	5.4+	1.0+	19
699-36 -61O	-	210	198	94	80+	16+	81
699-36 -93	490	-	490	100	110	21	43
699-37 -43	-	250	237	95	510+	100+	420
699-37 -82A	269	-	269	100	230	34	130
699-38 -65	150	-	150	100	93	18	120
699-38 -70	135	-	135	100	160	22	160
699-39 -39	-	210	86	41	0.086+	0.016+	0.19
699-39 -79	-	210	98	47	460+	91+	93
699-40 -1	231	-	231	100	97	19	82
699-40 -33	-	220	179	81	300+	60+	335
699-40 -62	-	230	42	18	0.042+	0.008+	0.44
699-41 -23	-	220	54	25	260+	51+	940
699-42 -12	152	-	152	100	63	12	79
699-42 -42	118	-	118	100	300	60	510
699-43 -42	-	110	19	17	1.9+	0.38	20

TABLE VI (continued)

	Saturated Thickness				Estimated Transmissivity from Drillers' Logs		
	Total Feet		Penetrated by Well				
Well No.	From Log	Estimated from Map	ft	%	N2 x 1000	Estimated "T" (ft^2/d) x 1000	Estimated "K" (ft/d)
699-43 -89	-	420	139	33	14+	2.8+	20
699-44 -64	123	-	123	100	470	95	770
699-45 -69	83	-	83	100	6.3	1.2	14
699-46 -21	-	220	205	93	590+	120	580
699-47 -35	28	-	28	100	200	30	110
699-47 -60	40	-	40	100	13	2.5	63
699-48 -71	-	75	67	89	400	80	1200
699-49 -28	-	130	32	25	11+	2.1+	66
699-49 -55	12	-	12	100	120	23	1900
699-49 -57	18	-	18	100	110	22	1200
699-49 -79	58	-	58	100	58	9.5	160
699-50 -28B	-	110	27	25	2.7+	0.52+	19
699-50 -30	190	-	190	100	400	80	420
699-50 -85	304	-	304	100	720	120	390
699-51 -63	-	40	21	53	210	41	2000
699-51 -75	180	-	180	100	760	150	830
699-53 -47	14	-	14	100	140	27	1900
699-53 -53	127	-	127	100	210	41	320
699-54 -42	85	-	85	100	3	0.58	6.8
699-54 -45	-	20	13	65	0.013+	0.0025+	0.19
699-55 -50A	52	-	52	100	280	46	880
699-55 -76	44	-	44	100	22	4.3	98
699-55 -89	-	180	60	33	60+	12+	200
699-55 -95	95	-	95	100	4.5+	0.85	8.9
699-57 -83	175	-	175	100	54	8.5	49
699-58 -24	-	250	10	4	1.0+	0.19+	19
699-59 -58	-	100	15	15	1.5+	0.29+	19

TABLE VI (continued)

	Saturated Thickness				Estimated Transmissivity from Drillers' Logs		
	Total Feet		Penetrated by Well				
Well No.	From Log	Estimated from Map	ft	%	N2 x 1000	Estimated "T" (ft^2/d) x 1000	Estimated "K" (ft/d)
699-71 -52	-	300	97	32	3.1+	0.61+	6.3
699-71 -77	-	300	238	79	150+	30+	130
699-72 -73	-	300	30	10	0.030+	0.006+	0.20
699-72 -92	-	300	145	48	640+	130+	900
699-74 -44	100	-	100	100	0.60	0.12	1.2
699-74 -48	-	300	63	21	120+	22+	350
699-74 -60	-	300	24	8	24+	4.8+	200
699-77 -36	-	300	131	44	150+	30+	230
699-77 -54	-	300	73	24	130+	26+	360
699-78 -62	-	300	93	31	170+	35+	380
699-80 -43C	-	300	40	13	50+	9.8+	250
699-81 -58	-	300	120	40	180+	36+	300
699-83 -47	-	300	117	39	75+	15+	130
699-84 -35A	350	-	350	100	40	8	23
699-86 -60	417	-	417	100	370	75	180
699-89 -35	-	300	65	22	120+	23+	350
699-96 -49	-	300	65	22	37+	7.3+	110
699-97 -43	-	300	60	20	3.5+	0.65	11
Han-6	-	200	39	20	20+	4.0+	100
Han-9	-	200	72	36	20+	4.0+	56
Han-19	-	200	34	17	66+	13+	380

To obtain a relation between the relative number N2 and transmissivity determined by pumping tests the following procedure was followed:

1. A table (Table VII) was prepared listing the measured transmissivities at wells for which number (N2) had also been determined.
2. For each well the number (N3) where N3 is the equivalent of N2 for the interval screened or perforated during the test was obtained and entered in the table as were the numbers for the entire saturated thickness penetrated (N2).
3. The number (N3) was plotted versus the measured transmissivity obtained from the pumping test. Figure 3 shows that a distinct relationship exists between the measured transmissivity and the relative number for the screened or perforated interval (N3).
4. To estimate the transmissivity of the entire saturated thickness penetrated by the well we used the relationship reflected by the line shown on Figure 3 to conservatively estimate the transmissivity (T) from the number (N2). These estimates are given in Plate 3.

We estimated the average hydraulic conductivity ($\overline{K}$) given in Table VI and Plate 4 by dividing the estimated transmissivity by the saturated interval penetrated by the well.

TABLE VII

COMPARISON OF RELATIVE NUMBERS N2 AND N3 AND MEASURED TRANSMISSIVITY

N2 is based on entire well.
N3 is based on screened interval.

	Transmissivity		Relative Numbers	
Well No.	Source	ft^2/d	N2	N3
199-H4 -2	1	3	3.7×10^{4}	15
299-W11-2	1	104	8.7×10^{4}	26
699-S18-E12	1	2	1.3×10^{5}	7
699-S12-3	1	350	5.2×10^{4}+	400
	2,4	280		
699-S6 -E4C	1	1.9×10^{3}	1.4×10^{4}	-
699-1 -18	2,4	1.0×10^{4}	9.8×10^{4}	8.1×10^{4}
699-8 -17	1	3.5×10^{4}	5.7×10^{4}	3.1×10^{3}
	2	1.0×10^{5}		
	4	1.0×10^{4}		
699-10 -E12	1	210	2.1×10^{5}+	1.5×10^{3}
699-14 -38	1	424	7.2×10^{4}	-
699-15 -26	2	3.1×10^{4}	7.8×10^{5}	7.5×10^{4}
699-17 -5	2	750	2.8×10^{4}	600
	4	1.1×10^{3}		
699-20 -E5P	1	430	1.2×10^{6}	-
699-20 -20	2	3.0×10^{4}	1.6×10^{5}	6.5×10^{4}
	4	3.2×10^{4}		
699-20 -39	1	8	9.8×10^{4}	100
699-24 -1P	1	90	6.5×10^{4}	100
699-24 -33	2	4.5×10^{5}	3.4×10^{4}	6×10^{4}
	4	3.9×10^{5}		
699-26 -15	1	9.5×10^{3}	2.0×10^{5}	4.3×10^{4}
	2	9.3×10^{3}		
	4	8.9×10^{3}		
699-26 -89	1	530	6.6×10^{5}	5.5×10^{5}
699-31 -53B	1	2.1×10^{4}	8.9×10^{4}	8.2×10^{4}
	2,4	1.4×10^{4}		

TABLE VII (continued)

	Transmissivity		Relative Numbers	
Well No.	Source	ft^2/d	N2	N3
699-33 -56	1	2.2×10^{4}	1.3×10^{5}	1.1×10^{5}
	2,4	2.1×10^{4}		
699-35 -9	1	2.3×10^{3}	$1.2 \times 10^{4+}$	2.0×10^{3}
	2	6.3×10^{3}		
	4	7.2×10^{3}		
699-36 -61A	1	2.8×10^{3}	5.4×10^{3}	3.1×10^{3}
699-40 -33	2	290	3.0×10^{5}	400
	4	210		
699-42 -12	2	6.0×10^{4}	6.3×10^{4}	6.3×10^{4}
	4	8.6×10^{4}		
699-47 -35	2,4	400	2.0×10^{5}	2.0×10^{5}
699-47 -60	1	3.3×10^{3}	1.3×10^{4}	1.2×10^{4}
699-55 -50A	2,3,4	4.0×10^{5}	2.8×10^{5}	2.1×10^{5}
699-61 -66	1	4.0×10^{4}	5.6×10^{5}	2.0×10^{5}
	2	5.1×10^{4}		
699-62 -43F	2	5.0×10^{4}	2.8×10^{5}	2.0×10^{5}
	3,4	5.1×10^{4}		
	5	1.9×10^{5}		
699-65 -50	2,4	6.4×10^{4}	7.4×10^{5}	2.5×10^{5}
699-70 -68	4	3.2×10^{4}	$3.4 \times 10^{4+}$	$3.4 \times 10^{4+}$
699-71 -52	2,4	4.0×10^{3}	$3.7 \times 10^{3+}$	2.9×10^{3}
699-77 -54	1	7.0×10^{3}	$1.3 \times 10^{5+}$	4.0×10^{3}
	2,4	4.3×10^{4}		
699-84 -35A	1	4	4.0×10^{4}	25

1 - Deju 1974,
2 - Kipp and Mudd 1973,
3 - Bierschenk 1957,
4 - Bierschenk 1959,
5 - Honstead *et al.* 1955.

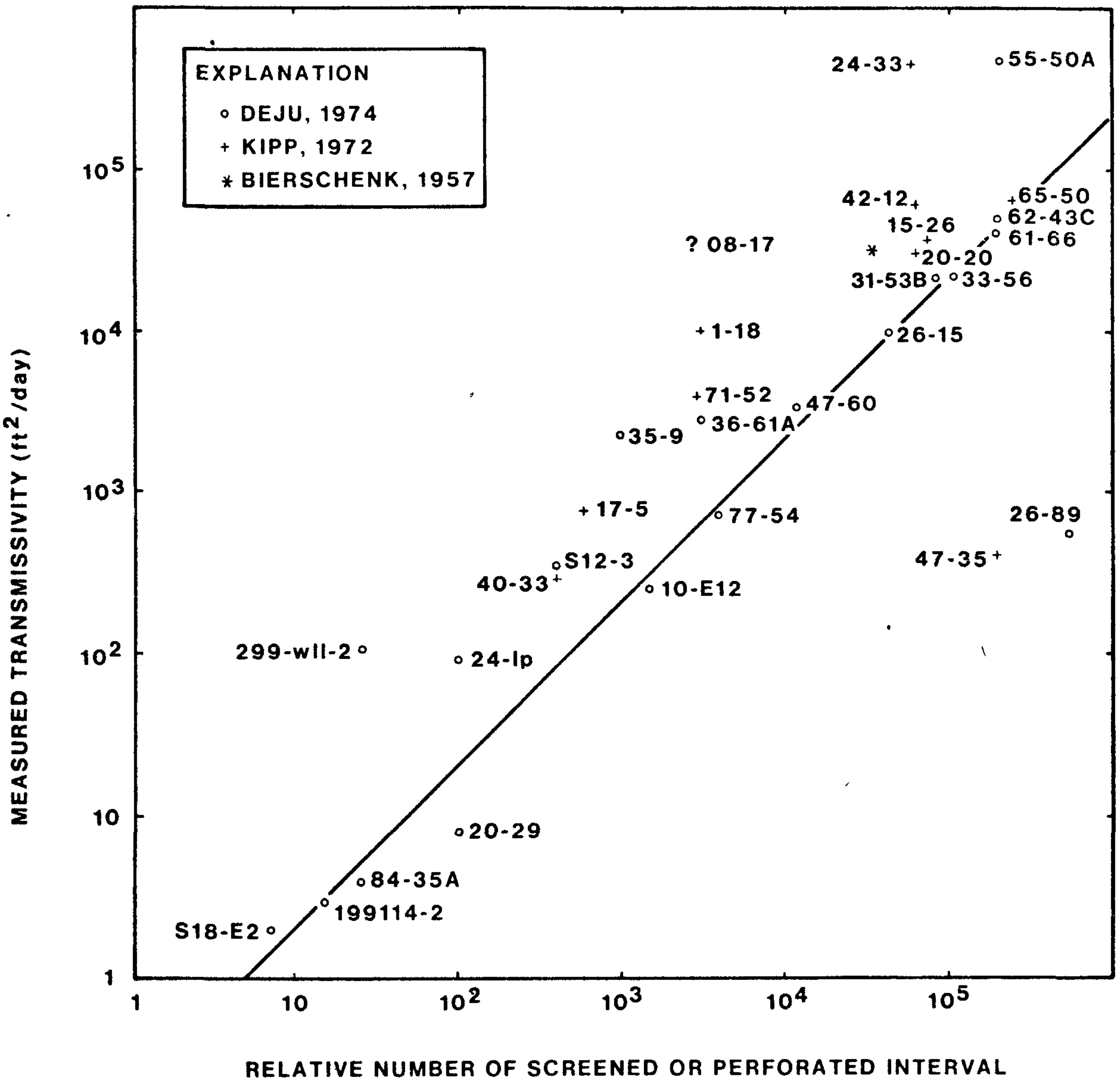

FIGURE 3

RELATION BETWEEN MEASURED TRANSMISSIVITY AND N3

On Plate 4 we included for each data point the approximate percentage of the saturated sedimentary rocks sampled by each well. The following example illustrates the reason for this practice. Consider a point on the map where the thickness consists of 10' of Pasco gravels with a hydraulic conductivity of 10,000 ft/d and 90' of lower Ringold Formation with hydraulic conductivity of 10 ft/d. The transmissivity is

$$T = [10 \times 10{,}000 + 90 \times 10]\ \mathrm{ft}^2/\mathrm{day} = 100{,}900\ \mathrm{ft}^2/\mathrm{day},$$

and the average hydraulic conductivity is

$$K = T/b = \frac{100{,}900}{100} \text{ or } 1009\ \mathrm{ft/d}$$

The Pasco Gravels control the transmissivity. So, if a pumping test is conducted in a well that penetrated only the gravels measures the transmissivity of the Pasco Gravels, it also measures the transmissivity of the entire thickness to a first approximation. However the average hydraulic conductivity of the saturated section is 10 times less than the hydraulic conductivity of the Pasco gravels.

Plates 5 and 6 are cross-sections through the Reservation. These cross-sections represent intersecting vertical slices onto which nearby reference wells were projected. The land surface, water table, and basalt surface were taken from maps of these features. These cross-sections were constructed using existing driller logs. In these logs we recognized three intervals illustrated on the plates: (1) the unsaturated zone, (2) the upper dominantly coarse-clastic part of the zone of saturation, and (3) the lower dominantly fine-clastic part of the zone of saturation.

The unsaturated zone contains both fine and coarse clastics and if the water table were to rise another 50', this simple three-part subdivision would be inappropriate. Fortunately the zone of saturation that we must deal with divides conveniently into the upper, coarse-grained part and the lower, fine-grained parts. The upper part consists of the Pasco Gravels and the Middle Ringold Conglomerate. In some places only one of the conglomerates was eroded away and the entire interval is composed of Pasco Gravels. In other places the Pasco Gravels are above the water table.

By reporting both T and $\overline{K}$, the cross-sections show where relatively small thicknesses of material with large hydraulic conductivities have a pronounced influence on T, whereas $\overline{K}$ increases only slightly. In general the largest T and K values (100,000 ft^2/d and 500 ft/d) occur where the saturated thickness of the Pasco Gravels is largest. Intermediate values (10,000 ft^2/d and 100 ft/d) occur where the Pasco Gravels are relatively thin or absent and the Middle Ringold Conglomerates are thick. Lower values (1,000 ft^2/d and 10 ft/d) occur when the Middle Ringold Conglomerate is thin. The minimum values (100 ft^2/d and 1 ft/d) occur where only the lower fine-grained part (Lower Ringold Formation) of the zone of saturation is present or where the saturated thickness thins to zero.

CONCLUSIONS

The sedimentary rocks of the Pasco Basin include glaciofluviatile deposits and the Ringold Formation. They may also include sedimentary rorks interbedded with the basalts. In terms of the ground-water flow continuum these rocks are divided into the unsaturated zone, the upper dominantly coarse-clastic part of the zone of saturation and the lower dominantly fine-grained part of the zone of saturation.

The effective porosity of the glaciofluviatile deposits that make up the upper coarse-clastic zone is no more 3 or 4%. The effective porosity of the Ringold coarse clastics and fine clastics of the lower part has not been adequately measured--but is undoubtedly smaller.

Drillers' logs combined with pumping tests were used as shown on this report to estimate and map the transmissivity and mean hydraulic conductivity of the saturated sedimentary rocks. They show that the largest values of transmissivity and mean hydraulic conductivity in the unconfined aquifer occur where the saturated thickness of the Pasco Gravels is largest. Intermediate values occur where the Pasco Gravels are thinnest and the Middle Ringold Conglomerates are thick. Low values occur where the Middle Ringold Conglomerate is thin, the Pasco Gravels are non-existent, and the Lower Ringold makes up the bulk of the saturated section.

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Prepared by BNW
Verified by R. A. Deju
Drafted by VITRO
Date March 15, 1975

PLATE I

EXPLANATION

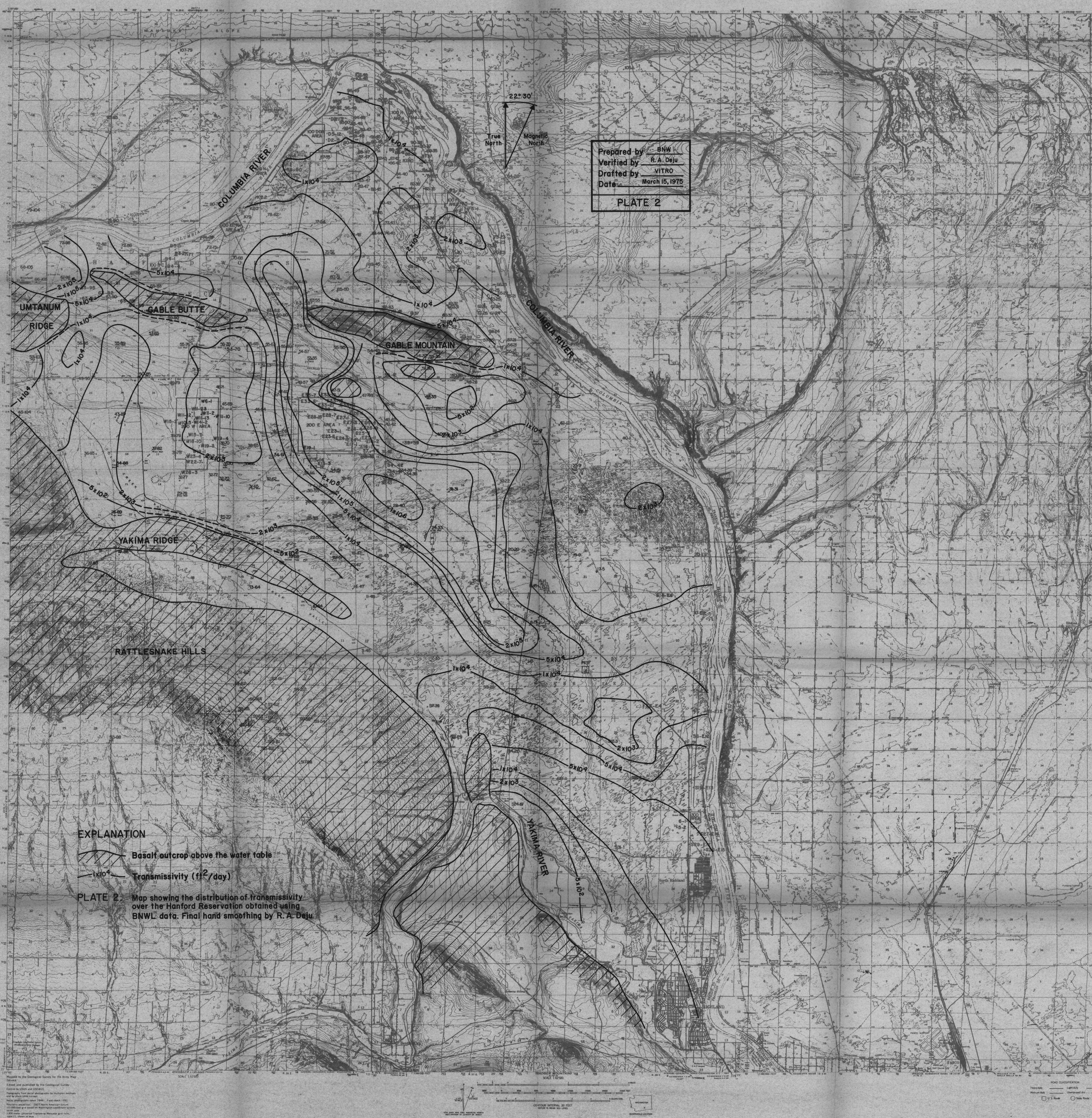
▨ Basalt outcrop above the water table

—100— Hydraulic Conductivity (ft/day)

PLATE I. Map showing the distribution of hydraulic conductivity over the Hanford Reservation obtained using BNWL data processed through the TIR Program by BNWL and smoothed. Final smoothing is shown by dashed lines. (R. A. Deju)

ARH-C-00007

ARH-C-00007
Plate # 1



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Date March 15, 1975

PLATE 2

EXPLANATION

Basalt outcrop above the water table

1x10⁴ Transmissivity (ft²/day)

PLATE 2. Map showing the distribution of transmissivity over the Hanford Reservation obtained using BNWL data. Final hand smoothing by R. A. Deju

ARH-C-00007

ARH-C-00007
Plate #2

PLATE 4. Map showing the mean hydraulic conductivity of the saturated sedimentary rock of the Hanford Reservation, Washington, as deduced from driller's logs. Based on January 1973 water table.

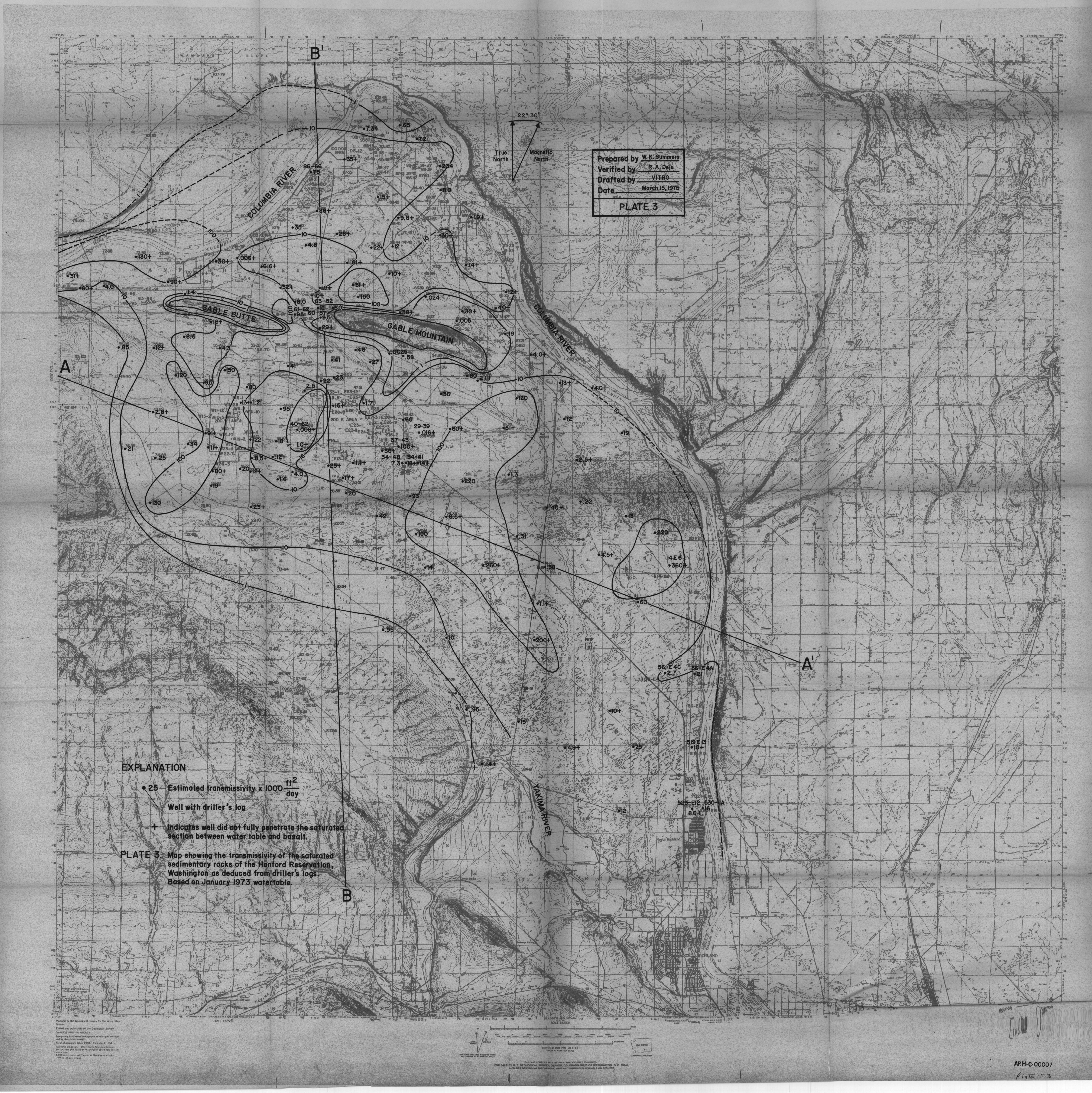
Prepared by W. K. Summers
Verified by R. A. Deju
Drafted by VITRO
Date March 15, 1975

PLATE 4

Mapped by the Geological Survey for the Army Map Service
Edited and published by the Geological Survey
Control by USGS and USC&GS
Topography from aerial photographs by multiplex methods and by plane table surveys
Aerial photographs taken 1948. Field check 1951
Polyconic projection. 1927 North American datum
10,000-foot grid based on Washington coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 11, shown in blue

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225 OR WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

Plate #4



Prepared by W. K. Summers
Verified by R. A. Deju
Drafted by VITRO
Date March 15, 1975

PLATE 3

EXPLANATION

● 25 — Estimated transmissivity x 1000 $\frac{ft^2}{day}$

— Well with driller's log

\+ Indicates well did not fully penetrate the saturated section between water table and basalt.

PLATE 3. Map showing the transmissivity of the saturated sedimentary rocks of the Hanford Reservation, Washington as deduced from driller's logs. Based on January 1973 watertable.

Plate #3

PLATE 5. CROSS SECTION A - A' SHOWING HYDROLOGIC DIVISIONS OF THE SEDIMENTARY ROCKS OF THE PASCO BASIN

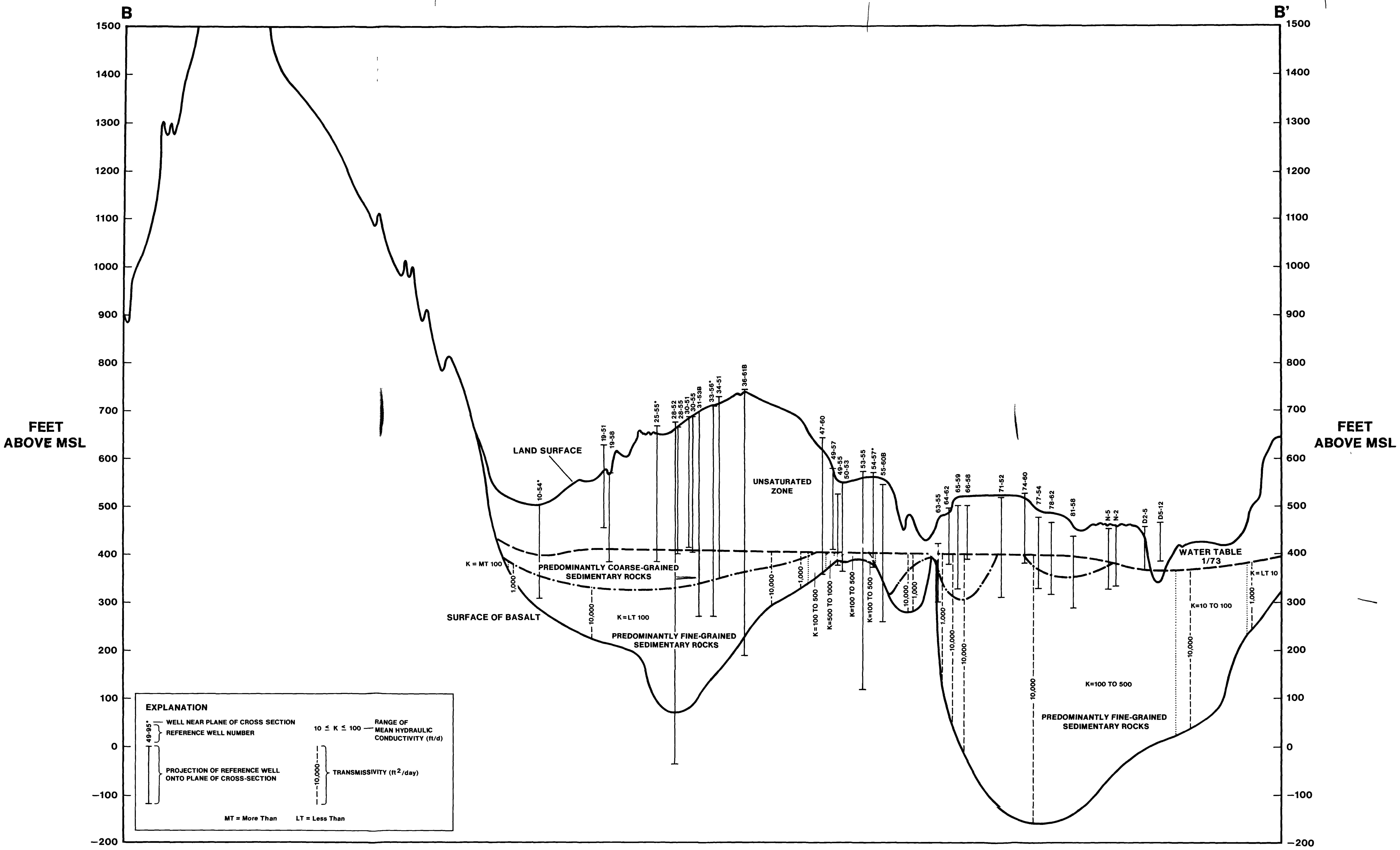


PLATE 6. CROSS SECTION B - B' SHOWING HYDROLOGIC DIVISIONS OF THE SEDIMENTARY ROCKS OF THE PASCO BASIN