APPENDIX B

RIO VALENCIANO RESERVOIR GEOTECHNICAL REPORT
-BLACK AND VEATCH-

Rio Valenciano Reservoir Geotechnical Report

Black & Veatch Puerto Rico
June 30, 2000

Rio Valenciano Reservoir
Geotechnical Report

Table of Contents

1.0	GENERAL	1
	1.1 Project Description	1
	1.2 Purpose of Investigation	1
	1.3 Scope of the Report	1
	1.4 Sources of Data	1
2.0	GEOLOGY OF THE RESERVOIR AREA	2
3.0	EXPLORATION PROGRAM	3
	3.1 General	3
	3.2 Geologic Mapping	3
	3.3 Soil and Rock Borings	3
	3.4 Hydraulic Conductivity Tests	3
	3.5 Groundwater Level Monitoring	4
	3.6 Seismic Refraction Surveys	4
	3.7 Test Pits	5
	3.8 Laboratory Testing	5
4.0	GEOLOGIC CHARACTERIZATION	6
	4.1 Lithology	6
	4.1.1 Granodiorite	6
	4.1.2 Dikes	6
	4.2 Weathering Characteristics	6
	4.3 Rock Strength	7
	4.4 Rock Mass Discontinuities	8
5.0	HYDRAULIC CONDUCTIVITY	9
6.0	GEOLOGIC HAZARDS	11
	6.1 Local Fault Considerations	11
	6.2 Reservoir Induced Seismicity	11
	6.3 Landslide Potential	12
7.0	ENGINEERING CONSIDERATIONS	13
	7.1 Foundation Conditions	13
	7.2 Grouting Recommendations	13
8.0	REFERENCES	14

List of Figures

Figure 1	Geologic Map of Puerto Rico
Figure 2	Geologic Map of the Rio Valenciano Reservoir Area
Figure 3	Geotechnical Investigation Plan
Figure 4	Geologic Cross-sections
Figure 5	Stereoplot of Joint Poles
Figure 6	Photographs of Corestones
Figure 7	Distribution of Water Takes with Depth

Appendices

Appendix A Soil and Rock Boring
- A-1 Boring Logs
- A-2 Well Completion Logs

Appendix B Hydraulic Conductivity Tests

Appendix C Seismic Refraction Surveys

Appendix D Test Pits

Appendix E Laboratory Tests

1.0 GENERAL

1.1 Project Description

The Rio Valenciano Dam will be a 30-meter high dam that will close the valley of the generally north flowing Rio Valenciano at a point about 2.2 kilometers south of Juncos, PR. The reservoir has a tributary area of 38.8 square kilometers and will supply an average of 14.4 million gallons of water per day (MGD) for treatment and distribution to municipalities in east central region of Puerto Rico.

1.2 Purpose of Investigation

This geotechnical investigation was undertaken to provide basic site data for the preparation of the RFP documents for the Design-Build contract. The investigations provide geologic and geotechnical data on the foundation conditions at the proposed dam site. This data was used in the selection of the roller-compacted concrete gravity dam alternative presented in the bid documents, and to assess the seepage potential through the foundation.

The results of the investigation presented in this report are intended to be used by the Design-Build contractor to assist in bid preparation and final design. However, the type of dam to be built is not finalized, and application of the data to other dam-type alternatives can be made as appropriate. The extent of available material resources for dam construction was not investigated and is considered a responsibility of the Design-Build contractor.

1.3 Scope of the Report

The scope of this report is to:

- Present the results of the geotechnical investigation undertaken during February and March 2000,
- Discuss the engineering considerations resulting from the geotechnical investigation,
- Evaluate the likelihood of reservoir induced seismicity, and
- Evaluate the stability of the reservoir rim.

1.4 Sources of Data

Sources of data for this report included the present geotechnical investigation, which encompassed the following:

- Geologic mapping
- Air photo interpretation
- Soil and rock borings
- Field hydraulic conductivity tests
- Test pits
- Seismic refraction surveys
- Laboratory testing of soil and rock samples

In addition, relevant data was available from the Buck, Seifert and Jost investigation in 1978 along the same dam alignment as this investigation, and the Corps of Engineers investigation in 1974 where the dam alignment was 800 m downstream from the present location.

2.0 GEOLOGY OF THE RESERVOIR AREA

The Rio Valencio reservoir site lies on the northern edge of the San Lorenzo batholith (Figure 1). This granitic rock was intruded into volcanic rocks during upper Mastrichtian or lower Paleocene time. Just north of the batholith is one of two major faults crossing Puerto Rico, the northern Puerto Rico fault zone (NPRFZ) (Figures 1 and 2). This fault is only 1 to 2 km north of the dam location. The NPRFZ trends east-southeast, has left lateral strike-slip motion, and can be traced for about 50 km (Jolly et al., 1998). There are no geologic units common to both sides of the fault, therefore, 50 km is assumed to represent the minimum displacement. The major movement on the NPRFZ has been determined by Jolly (1998), based on the compositions of volcanic rocks, to have occurred about 85 million years ago (Ma) in the upper Cretaceous. However, movement on associated strike-slip faults can be seen cutting rocks as young as upper Paleocene (55 Ma) (Jolly, 1998) indicating movement took place over a prolonged period. Major movement according to Jolly (1998) would have preceded emplacement of the San Lorenzo batholith, but minor movements would have postdated it.

A fault has been postulated to cross the reservoir that would appear to be related to the NPRFZ (Figure 2). Evidence for this fault includes:

- The straight and narrow river valley segment that includes the dam location and extends for over 2 km.
- Shear zone 13.5 wide with fault gouge observed in a Corps of Engineers core boring located about 500 m downstream of the proposed dam axis.
- A sheared and/or hydrothermally altered dike in the streambed about 100 m north of the proposed dam location and trending parallel to the river.
- A suspected sheared and/or hydrothermally altered dike in boring BSJ-13 near the river on the proposed dam axis.
- A thin dike observed in boring BV-5 adjacent to the river on the dam axis.

This postulated fault most likely strikes along the course of the river to the south where it would appear to merge with a fault mapped by others parallel to the NPRFZ. To the north, there is topographic evidence from maps and air photos that this fault continues up to the broad valley north of Juncos that is the location of the NPRFZ. The orientation of this fault matches almost exactly the orientation of theoretical reverse faults forming in an area between two right-stepping, left lateral strike-slip faults such as the NPRFZ and the parallel fault mapped to the south. The entire NPRFZ system has been inactive for at least 55 million years, and therefore poses no threat as a seismic source.

The other significant fault zone on the island is the southern Puerto Rico fault zone (SPRFZ) (Figure 1). This fault has been studied in detail by Erikson et al. (1990). They were able to

conclude that the age of significant deformation along the SPRFZ is constrained to middle Eocene to early Oligocene (35 Ma). This is also clearly an inactive fault.

3.0 EXPLORATION PROGRAM

3.1 General

Field exploration and laboratory testing for the Rio Valenciano Reservoir included:

- Geologic mapping and air photo interpretation
- Soil and rock borings
- Hydraulic conductivity tests in boreholes
- Groundwater level monitoring
- Seismic refraction surveys
- Test pits
- Laboratory testing

A summary of the scope of each of these investigations is discussed in the following sections.

3.2 Geologic Mapping

Geologic mapping was undertaken to document rock types, identify lithologic contacts, obtain joint orientations, identify shear and fault zones, observe surface weathering, and evaluate geologic hazards. Mapping included the integration of previous work in the area, field checking of previous mapping efforts, and evaluation of aerial photography. The geologic map is presented in Figure 2, and a stereonet of joint orientations is shown on Figure 5.

3.3 Soil and Core Borings

Six soil and core borings were completed during this investigation (BV-1, BV-2, BV-4, BV-5, BV-7, and BV-8). Borings BV-3 and BV-6 were deleted from the original investigation plan due to schedule constraints. The borings were advanced with a hollow stem auger and sampled with a split spoon until reaching refusal. Beyond this, the borings were advanced with an NX-size double tube coring system. These borings are in addition to 17 borings drilled during the Buck, Seifert and Jost investigation in 1978. Boring logs from this investigation along with a description of the procedures used for drilling and sampling are presented in Appendix A. Boring locations are shown on Figure 3.

3.4 Hydraulic Conductivity Tests

Packer tests were conducted on the five borings drilled along the dam alignment to evaluate *in-situ* hydraulic conductivity of the bedrock. Packer tests were performed generally in intervals 11 feet long, and successive tests were overlapped by 1 foot. The boreholes were tested from the bottom of the hole to the top of competent rock.

Five-stage pressure tests were typically performed in each interval. The stages were generally as follows:

0.5	P_{BL}	
0.75	P_{BL}	
1.0	P_{BL}	
0.75	P_{BL}	
0.5	P_{BL}	where P_{BL} = baseline pressure (generally 1 psi per foot of depth)

As can be seen, the first three stages were conducted at increasingly higher pressures, and the fourth and fifth stages at the same pressure as the second and first stages, respectively. The five-stage test allowed interpretation of fracture changes during testing such as dilation, washout, and fracture filling. Test pressures were controlled to produce data most representative of intrinsic bedrock permeability and did not exceed a pressure factor of 1 psi per foot of hole measured from the ground surface to the center of the test interval, except in boreholes BV-4 and BV-5. Boreholes BV-4 and BV-5, located on the valley floor, were tested at pressures commensurate with the planned reservoir head to evaluate the potential for hydraulic jacking of the rock mass discontinuities. Packer tests were typically run for 5 minutes at each pressure step.

Water take and pressure data were used to calculate hydraulic conductivity values in centimeters per second and lugeon values for each test. Test procedures and results are included in Appendix B, and representative lugeon values from each test are presented in tabular form in Section 5.0 of this report.

3.5 Groundwater Level Monitoring

Groundwater levels were measured once during this investigation. This occurred just prior to packer testing of the borings. All borings had a minimum of two weeks to equilibrate between the cessation of drilling activities and the start of packer testing. Three of the borings (BV-1, BV-5, and BV-8) were completed as monitoring wells for future observation. Well completion logs are included in Appendix A. Water levels are shown on the dam axis cross-section in Figure 4.

3.6 Seismic Refraction Surveys

Seven seismic refraction surveys were conducted in the dam footprint area in order to estimate the depth of weathering and the seismic velocities of bedrock materials (Figure 3). Refraction lines SR-1, 2, 5, 6, 7 and 8 were essentially perpendicular to the river channel with SR-5 and 6 nearest to the dam centerline, SR-1 and 2 upstream of the dam centerline, and SR-6 and 7 downstream of the dam centerline on the right bank and left banks respectively. Line SR-3 paralleled the river on the right bank. An eighth seismic line, SR-4, intended to parallel the river on the left bank was not completed because of the highly irregular topography.

For each survey, a 140 pound hammer dropped 8 feet from a drilling tripod to a metal plate provided the seismic impulse, and the wave arrival times were recorded using a 24-channel StrataView S-24 exploration seismograph. A 10-foot geophone spacing with the shot points located about 5-feet from the end geophones in each line provided total survey line lengths of

230-feet. The time/distance data, data plots and interpretations for the completed lines are contained in Appendix C.

The data obtained from the seismic refraction lines is of limited use. Due to equipment problems Channel 12 was not recorded in several of the survey line seismograms, the geophones nearest several shot points did not detect the wave arrivals, and arrival data could only be resolved in one direction for lines SR-6 and 8. The seismic refraction method works best to resolve distinct subsurface interfaces between layers of contrasting seismic velocity. Granitic rocks such as the granodiorite underlying the dam site typically do not weather to produce distinct contrasting layers. Weathering penetrates along joints and fracture zones to produce weathered seams separating rounded but intact rock corestones with the average seismic velocity of the mass generally increasing gradually with depth. The sloping irregular topography of the dam site further complicates interpretation of the seismic refraction data.

What is highlighted by the seismic refraction surveys is the irregularity of the subsurface materials. The time/distance plots tend to be wavy and rounded without distinct breaks in slope. The data interpretations obtained from a computer software package show irregular interfaces. Several of these interpretations are clearly questionable, suggesting that the subsurface conditions are too complex to be fitted to simple models. The seismic refraction survey results generally confirm the subsurface conditions indicated by both the earlier Buck, Seifert and Jost borings and the present drilling program that the weathering profile beneath the dam site is irregular. Significant relief can be expected on the excavated foundation surface.

3.7 Test Pits

Five test pits were excavated to obtain bulk samples of the soils overlying bedrock at the site. The pits ranged from 3 to 6 feet deep and were backfilled after completion. All the pits extended down into extremely weathered and saprolitic bedrock.

The pits were excavated with a small backhoe mounted on a Caterpillar rubber tired tractor. A bench cut at about half the total depth in the deeper pits allowed examination and sketching of the side walls. Samples of the various materials encountered were stockpiled during excavation and later put into plastic buckets for delivery to the laboratory for testing. Test pit logs are presented in Appendix D, and locations are shown on Figure 3.

3.8 Laboratory Testing

Selected soil samples from drilling and test pits, and rock core samples were tested to evaluate engineering properties. This testing included:

- Sieve and hydrometer tests
- Density tests
- Moisture content
- Atterberg limits
- Standard Procter tests
- Unconfined compression tests on rock

Results of these tests are presented in Appendix E.

4.0 GEOLOGIC CHARACTERIZATION

4.1 Lithology

4.1.1 Granodiorite

The dam foundation area and the entire reservoir inundation area are underlain by the San Lorenzo batholith (Figure 2). The roughly circular surface exposure area of this intrusive body is about 17 miles in diameter (Figure 1). The age and boundary conditions of the batholith are discussed in Section 2.0 of this report.

Based on surface exposures and core from borings, the batholith is predominantly composed of granodiorite. The typical slightly weathered to fresh granodiorite is medium- to coarse-grained, gray, strong, and very hard. The major mineral constituents in order of abundance are feldspar, quartz, and hornblende. In core there appears to be some areas where the rock grades from granodiorite into granite due to an increase in the percentage of potassium feldspar at the expense of plagioclase feldspar, but there are no associated changes in the engineering characteristics of the rock. The rock is massive with no oriented fabric. A characteristic of the rock is the abundance of mafic inclusions. These inclusions are generally well-rounded bodies ranging in size from 0.25 to 3 feet in diameter, and composed of fine-grained feldspar and hornblende. They are thought to be an early crystallization product of the magma.

4.1.2 Dikes

Two different types of dikes were encountered in the exploration program. One was observed in boring BV-7 as a dark gray to black, aphanitic intrusive with black phenocrysts (pyroxene?). The total length in core was 2.2 feet, and the two contacts with the granodiorite were not parallel. Although float of similar material was observed in several areas, this type of dike was never observed in outcrop during field mapping.

The other dike was observed in outcrop just downstream of the diversion dike for the existing water treatment plant intake. This dike is granitic in composition, and could not be distinguished from the surrounding granodiorite except by the finer grain size. It was also characterized by banding caused by shearing and/or hydrothermal alteration. The dike appeared to be oriented parallel to the river, and dipping near vertical. In boring BSJ-13 a 45-foot interval of "metamorphic granitic rock" was encountered that is thought to be equivalent to this dike. The banding was probably mistaken for a planar metamorphic fabric.

4.2 Weathering Characteristics

The weathering profile observed in field exposures, cores, and test pits consistently shows a surface layer of topsoil, a clayey sand layer, a variable thickness of saprolite, and little to no intermediately weathered rock before reaching the top of sound rock. The borings drilled by

Buck, Seifert and Jost (BSJ) are in general agreement with the B&V borings, however, there are some inconsistencies in terminology and possible misidentification of materials in the saprolite and soil sections of the BSJ boring logs.

The soil section of the weathering profile is best described in the test pits, because the boring locations were all prepared by a dozer. All five test pits contained 0.5 to 1.0 feet of organic rich topsoil at the top. Below this was a layer of clayey sand to sandy clay that ranged in thickness from 0.6 to 3.0 feet, except in BVTP-4, where it was absent. The saprolite below the soil is extremely weathered and friable granodiorite with the parent rock texture still intact (for an explanation of rock weathering terms see Appendix A). The saprolite layer observed in the B&V borings ranged in thickness from 0 feet in BV-2 to 33.3 feet in BV-4. A similar range in thickness was observed in the BSJ borings. The transition from saprolite to sound rock or slightly weathered rock is very abrupt. The intervening layer of moderately weathered rock was never more than 5 feet thick in any of the 23 borings drilled. The depth from the surface to sound rock for all 23 borings ranged from 1.5 to 43 feet, and averaged 18.2 feet.

Another characteristic of weathering in the granodiorite is the formation of core stones. Core stones are relatively unweathered rock surrounded by weathered seams developed along fractures that, after exposure to the effects of erosion, will form boulders on the surface. Core stones could be observed in place in several areas around the reservoir site (Figure 6), and the residual boulders are ubiquitous throughout the area. The top of sound rock that was determined in boreholes, and shown on the sections in Figure 4, is most likely the top of core stones. Evidence of this could be seen in cores as intervals of highly weathered rock with core loss underlying the upper interval of slightly weathered rock. For instance, in boring BV-1 the top of slightly weathered rock was encountered at 13.9 feet, but weathered rock and no recovery zones at 25.6-28.5 feet and 33.2-33.9 feet probably define the boundaries of core stones. This type of weathering will produce a hummocky excavated surface with highs on the top of corestones and deeper excavation into the weathered seams separating them.

Seismic refraction surveys were performed to help determine the depth to the top of sound rock between boreholes. This data was determined to be an unreliable predictor of this interface for reasons discussed in Section 3.6 of this report.

4.3 Rock Strength

Unconfined compressive tests were run on rock core to determine the strength of the rock. A total of 31 tests were run. Results of these tests are tabulated in Appendix E. Most samples were taken from the 10 feet just below the top of sound rock. The upper sample in each boring was the first piece of core greater than 4 in long below the top of sound rock. The average strength of the 31 tests was 18,353 psi, and the range was from 2,811 to 27,241 psi. The low value was from a piece of core with a partially healed fracture with iron oxide coating the joint surfaces. The next lowest value was 8,531 psi.

4.4 Rock Mass Discontinuities

Rock mass discontinuity data was collected from surface outcrops around the dam location. All data was taken from the San Lorenzo granodiorite. Figure 5 presents the orientation data collected during field mapping. Four primary joint sets are recognized from this data set:

Joint Set	Strike	Dip
1	N14E	84 SE
2	N8W	90
3	N80E	80 NW
4	N56W	85 SW

A low angle joint set was also observed in the field with dips less than 20°. This joint set is not represented on Figure 5 because strike orientations are difficult to accurately determine on surfaces dipping this shallowly. Joint sets 1 and 2, with a difference in average strike orientation of only 22°, may represent a single joint set. If these joints do represent a single joint set, then the average strike would be very close to north-south. These joints, oriented close to perpendicular to the axis of the dam, offer the most direct route for seepage. Grout holes should be oriented to maximize intersections with these joints.

Since most of the joint sets are steeply dipping, joint spacing must be estimated from surface exposures with near horizontal surfaces rather than core. Outcrops were generally characterized by one joint set being dominant with joint spacing on this set generally 1 to 3 ft. Subsidiary joint sets had spacing in the 5 to 10 ft range.

A characteristic seen in all the cores was the presence of quartz and calcite filled discontinuities. These features were healed and tight. These were common in slightly weathered to fresh cores, and were generally 0.1 to 0.2 in wide. Comprehensive water quality sampling and testing was conducted by Black & Veatch from 12/8/99 to 12/31/99, and from 1/13/00 to 1/20/00 on raw water from the Rio Valenciano. The pH of water from these two time periods ranged from 7.70 to 8.08 and 7.76 to 8.38, respectively. Regular daily alkalinity testing of raw Rio Valenciano river water taken for the operation of the Ceiba Sur Filtration Plant from October 1998 through October 1999 had only three tests with a pH under 7.0. USGS data on the Rio Valenciano collected during the period 3/9/71 to 9/10/85 had an average pH of 7.39, a range of 6.2 to 8.3, and a standard deviation of 0.53. This data, taken together, indicates that dissolution of calcite in joints is very unlikely to occur.

Open joints observed in core had slightly rough surfaces coated with iron oxide, and were planar. Most joints, observed in outcrop and core, appeared very narrow (<0.1 in).

5.0 HYDRAULIC CONDUCTIVITY

A total of 15 packer tests were conducted in the five borings along the dam axis. All tests were below the top of slightly weathered rock. Water takes ranged from 0 to 84 lugeons, representing hydraulic conductivity values from 0 to 8.4 x 10^{-4} cm/s. Results of these tests are as follows:

Boring No.	Test Interval (depth in ft)	Hydraulic Conductivity (cm/s)	Lugeons	Test Interval Measured From Top of Sound Rock (ft)
BV-1	17 - 28	3.0 x 10^{-4}	30.4	3.1 – 14.1
	26 - 37	2.3 x 10^{-5}	2.4	12.1 – 23.1
BV-4	43 - 54	2.4 x 10^{-5}	2.4	0 – 11
	53 - 65	0	0.0	10 – 22
BV-5	22 - 33	4.8 x 10^{-4}	48.1	3 – 14
	32 - 43	4.2 x 10^{-5}	4.2	13 – 24
	42 - 53	1.9 x 10^{-4}	19.5	23 – 34
	52 - 63	2.7 x 10^{-4}	27.1	33 – 44
	62 - 74	4.6 x 10^{-5}	4.5	43 – 55
BV-7	30 - 40	2.2 x 10^{-4}	19.1	2.8 – 12.8
	40 - 50	0	0.0	12.8 – 22.8
BV-8	22 - 33	2.7 x 10^{-5}	1.5	0.5 – 11.5
	32 - 43	8.4 x 10^{-4}	84.4	10.5 – 21.5
	42 - 53	0	0.0	20.5 – 31.5
	52 - 63.5	0	0.0	30.5 – 42

As can be seen from this data, 6 out of 15, or 40%, of the tests had water takes greater than 5 lugeons. Of the 6 tests with significant water takes, 3 were in the uppermost test interval and 3 were below this. Based on this limited data, a grout curtain will be necessary to control both seepage and uplift pressures. In addition, some consolidation grouting may be necessary since the upper zone of every boring had some water take.

The Corps of Engineers conducted packer tests at a proposed dam site about 500 m downstream of the site investigated for this report. Although this site is somewhat removed, the underlying rocks are the same. Results of these tests are as follows:

Boring No.	Test Interval (depth ft)	Lugeons
CB-S1	23 - 41.5	0
	46 - 64.8	0
CB-1	22 - 68.9	2.8
CB-2	32.7 - 60.3	0
CB-3	5 - 25	56
	25 - 61.5	0
CB-4	10 - 19.2	45
	21 - 29	0
	29 - 39	0
	39 - 49	0
	49 - 59	0
	59 - 69	0
	69 - 79	0
CB-5	4 - 15	200
	17 - 27	0
	27 - 37	0
	37 - 47	4.3
	47 - 57.3	0
	57.3 - 70.7	0
CB-6	5.6 - 15.6	7.2
	15.6 - 25.6	12.6
	35 - 63.5	0
CB-7	32.9 - 43.1	0
	43.1 - 53.1	0.2
	53.1 - 63.1	0.7
	63.1 - 81.1	0

Of these tests only 5 out of 26 had water takes greater than 5 lugeons, and of these 5, four of the tests were at least partially in saprolite. Therefore, to compare these test results to those done for this investigation, the 4 tests with takes in saprolite must be eliminated. In the Black & Veatch tests 40% had takes greater than 5 lugeons versus only 5% of the tests done by the Corps. This indicates that either there is a difference in the hydraulic conductivity of the rock at the two sites, or the small number of tests does not accurately represent the statistical variation. The lugeon data from both the Black & Veatch (B&V) and the Corps of Engineers (COE) packer tests are plotted by depth on Figure 7. Each symbol is placed at the depth of the center of the tested interval.

6.0 GEOLOGIC HAZARDS

6.1 Local Fault Considerations

No Holocene faulting (evidence of movement within the past 11,000 years) is known to exist at the project site, or within the geologic block between the Northern and Southern Puerto Rico Fault Zones (NPRFZ and SPFZ) (Figure 1). Prior to this study, the closest faults mapped in the area were the faults associated with the Northern Puerto Rico Fault Zone about 2 km to the northeast of the dam axis, and a small unnamed fault mapped about 3 km to the southeast (Figure 2). Based on observations during this investigation, a fault is thought to trend along the portion of the Rio Valenciano riverbed that includes the dam location. The strike of this fault, and the proximity to faulting associated with the NPRFZ, suggests that it is related to the NPRFZ. The last documented movement of the NPRFZ was Paleocene time (55Ma). Therefore, it is anticipated that the local fault crossing the dam axis is inactive and poses no threat as a seismic source.

There are seismic considerations that must be addressed in the design if the Rio Valenciano dam due to active tectonics surrounding the island of Puerto Rico. These issues are addressed in a separate report entitled: Seismic Hazard Study, Rio Valenciano Reservoir.

6.2 Reservoir Induced Seismicity

Simpson et al. (1988) have identified two causes for reservoir induced seismicity: 1) the elastic stress due to the load of the reservoir, and 2) the gradual diffusion of water from the reservoir to hypocentral depths. Direct loading from the reservoir will cause increase shear stresses at depth, and increase pore pressures, thereby decreasing the effective normal stress across potential planes of failure. Likewise, diffusion of reservoir water will also increase pore pressure. In either case, the predominant energy released in the triggered earthquake is from preexisting tectonic strain (Yeats, et al., 1997).

Only a small percentage of reservoirs have triggered significant earthquakes. Attempts to determine the unique characteristics of those that do trigger earthquakes has produced five significant correlations:

(1) Triggered events are more likely associated with large or deep reservoirs
(2) Triggered events are more likely in areas of normal and strike-slip faulting
(3) Large events have occurred predominantly in areas of late Quaternary faulting
(4) Triggered events are more likely during periods of rapid change in water level
(5) Triggered events are more likely to occur in reservoirs on sedimentary rocks

Based on Baecher and Keeney's (1982) discussion of these characteristics, the following tabulation ranks the reservoir characteristic according to the likelihood of having reservoir triggered seismicity (RTS). Shading indicates classifications into which the Rio Valenciano Reservoir falls.

Attribute	Most Likely RTS	Intermediate RTS	Least Likely RTS
Depth	Very Deep > 150 meters	Deep 92 – 150 m	Shallow < 92 m
Volume	Very Large 10^{10} m^3	Large $0.12 - 1 \times 10^{10}$ m^3	Small $< 0.12 \times 10^{10}$ m^3
State of Stress	Shear (strike-slip)	Extensional	Compressional
Fault Activity	Active Fault Present	---	No Active Fault Present
Geology	Sedimentary	Metamorphic	Igneous

The only characteristic that the Rio Valenciano reservoir will share with reservoirs prone to reservoir induced seismicity is that it is in an area of strike-slip faulting. It is therefore very unlikely that any reservoir triggered earthquakes will be occur at this site.

6.3 Landslide Potential

The rim slopes are comprised of granodiorite covered by variable quantities of saprolite and topsoil. A review of the reservoir topography reveals that a vast majority of slopes around the rim are relatively gentle (all less than 2H:1V and most less than 4H:1V).

Aerial photographs were reviewed for areas exhibiting landslide morphology. One suspected area was identified, but upon field examination no other indications of landsliding were observed. The gentle slopes and lack of evidence for landslides make it very unlikely that any slope instability involving bedrock would occur in the reservoir slopes, even considering future saturation and possible ground shaking associated with earthquakes.

There is however a high probability of small scale surficial slumps of soil and saprolite. Evidence of this type of gravity failure was observed in the field as arcuate scarps up to 5 m long and 20 cm high with trees that had been rotated downhill. This assessment agrees with the landslide susceptibility map of Puerto Rico developed by Monroe (1979). He has mapped the reservoir site as in an area of moderate landslide susceptibility, but states that no large landslide has occurred in the intrusive rocks, only small slumps of soil and weathered rock. This type of gravity failure will constitute no danger to the reservoir or problems to the surrounding area. The only other type of failure that is foreseeable would be granitic boulders rolling downslope. The reservoir will not hasten this ongoing process.

7.0 ENGINEERING CONSIDERATIONS

7.1 Foundation Conditions

Foundation conditions are favorable for dam construction. If a gravity type dam is chosen, the soil and saprolite should be removed and the dam should be founded on sound rock. Depths to sound rock ranged from 1.5 to 43 feet (0.5 to 13 m) and averaged 18 feet (5.5 m) in the 23 borings drilled in the area of the proposed dam. The strength of the saprolite should allow stable temporary excavation slopes of 1.5H:1V, and possibly 1H:1V.

The foundation surface at the top of sound rock will be uneven due to corestones in the underlying sound granodiorite. Foundation preparation will require over excavation of the weathered material between corestones, and backfilling with dental concrete. Additional concrete to even the surface between corestones may be required prior to starting RCC placement. There is a high probability that a fault zone running perpendicular to the axis of the dam exists below the river. This will also likely require over excavation and backfill with concrete prior to starting dam construction. Depending on the depth and extent of weathering along this feature, stitch grouting may be required to sufficiently limit seepage.

If an embankment dam is built at this site the saprolite may provide sufficient strength for a foundation surface based on STP blow counts. This will need to be confirmed by additional testing in the field and laboratory. If the dam is founded on saprolite, it is recommended that a cutoff wall socketed into sound rock be included in the design.

7.2 Grouting Recommendations

The primary purpose of foundation grouting will be to limit seepage under the dam. A two-row grout curtain with shallow consolidation grouting would be acceptable for this purpose. The consolidation grouting will serve to improve the curtain grouting efficiency by limiting surface grout leakage.

All the packer tests with lugeon values over 5 were less than 45 feet (13.6 m) below the anticipated excavation surface at the top of sound rock (see table in Section 5.0). Based on these results, a grout curtain depth of 25 m will likely be sufficient to inhibit seepage under the dam. In general, a tight foundation below a depth of 45 feet was confirmed, but with limited data.

Since the foundation granodiorite is not susceptible to solution and cavern formation, the use of only neat cement grouts is anticipated.

8.0 REFERENCES

Baecher, G.B., R.L. Keeney, 1982, Statistical examination of reservoir induced seismicity, Seismological Society of America Bulletin, no. 72, p. 553-569.

Broedel, C.H., 1961, Preliminary geologic map showing iron and copper prospects in the Juncos quadrangle, Puerto Rico: USGS Miscellaneous Geologic Investigations Map I-326.

Cox, D.P. and Briggs, R.P., 1973, Metallogenic Map of Puerto Rico: USGS Miscellaneous Geologic Investigations, Map I-721.

Dolan, J.F., H.T. Mullins, D.J. Wald, 1998, Active tectonics of the north-central Caribbean: Oblique collision, strain partitioning, and opposing subducted slabs: *in* Active Strike-Slip and Collisional Tectonics of the Northern Caribbean Plate Boundary Zone, Dolan, J.F. and P. Mann, eds., Geological Society of America, Special Paper 326.

Erikson, J.P., J.L. Pindell, and D.K. Larue, 1990, Mid-Eocene-early Oligocene sinistral transcurrent faulting in Puerto Rico associated with formation of the northern Caribbean plate boundary zone, Journal of Geology, vol. 98, p. 365-384.

Houlsby, A.C., 1976, Routine Interoperation of the Lugeon Water Test, Water Resources Commission, NSW Australia.

Jolly, W.T., E.G. Lidiak, J.H. Schellekens, and H. Santos, 1998, Volcanism, tectonics, and stratigraphic correlations in Puerto Rico: *in* Tectonics and Geochemistry of the Northeastern Carribean, Lidiak, E.G. and D.K. Laure, eds., Geological Society of America, Special Paper 322.

LaForge, R.C., and Hawkins, F.F., 1999, Seismic hazard and ground motion anlaysis for Carraizo dam, Puerto Rico, Geophysics, Paleohydrology, and Seismotectonics Group, Bureau of Reclamation, Denver, CO, Seismotectonic Report 99-2.

Mann, P., G. Draper, and J.F. Lewis, 1991, Overview of the geological and tectonic development of Hispaniola: *in* Geologic and Tectonic Development of Hispaniola , P. Mann, G. Draper and J.F. Lewis, eds., Geologic Society of America, Special Paper 262.

Masson, D.G., and K.M. Scanlon, 1991, The neotectonic setting of Puerto Rico, Geological Society of America Bulletin, v. 103, p. 144-154.

McCann, W., 1994, Seismic hazard map for Puerto Rico 1994, report prepared for: The Seismic Safety Commission of Puerto Rico, by: Earth Scientific Consultants, W. McCann and Associates, Inc.

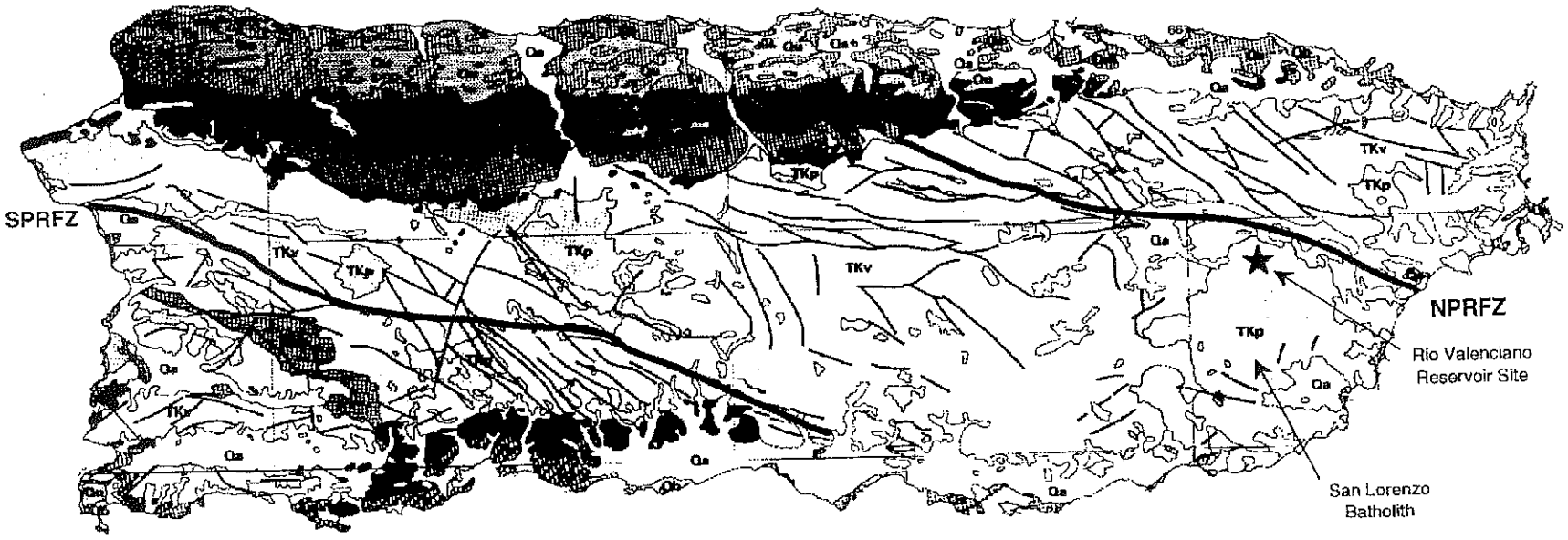
Monroe, W.H., 1979, Map showing landslides and areas of susceptibility to landsliding in Puerto Rico: USGS Miscellaneous Geologic Investigations, Map I-1148.

Miller, J.A., R.L. Whitehead, and P.G. Olcott, 1997, Ground Water Atlas of the Uniter States Segment 13, Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands: USGS, Hydrologic Investigations Atlas 730-N.

Simpson, D.W., W.S. Leith, and C.H. Scholz, 1988, Two types of reservoir-induced seismicity, Seismological Society of America Bulletin, no. 78, p. 2025-2040.

van Gestel, J., P. Mann, J.F. Dolan, and N.R. Grindlay, 1998, Structure and tectonics of the upper Cenozoic Puerto Rico-Virgin Islands carbonate platform as determined from seismic reflection studies, Journal of Geophysical Research, vol. 103, p. 30,505-30,530.

van Gestel, J., P. Mann, N.R. Grindlay, and J.F. Dolan, 1999, Three-phase tectonic evolution of the northern margin of Puerto Rico as inferred from an integration of seismic reflection, well, and outcrop data, Marine Geology, no. 161, p. 257-286.



EXPLANATION

- Qa — Alluvium
- Ql — Landslide deposits
- Qb — Beach deposits
- Qs — Swamp and marsh deposits
- Qf — Artificial fill
- Qu — Undifferentiated surficial deposits

Pliocene and Miocene rocks

- Tq — Quebradillas Limestone
- Ponce Limestone
- Aymamón Limestone
- Aguada (Los Puertos) Limestone
- Guanajibo Formation
- Cibao Formation
  - Montebello Limestone Member
  - Quebrada Arenas Limestone Member—Includes Miranda Sand Member
  - Rio Indio Limestone Member—Includes Almirante Sur Lentil
  - Guajataca Member
- Mucarabones Sand
- Juana Diaz Formation
- Lares Formation
- San Sebastián Formation

Eocene, Paleocene, and Cretaceous rocks

- TKv — Volcanic and sedimentary rocks
- TKp — Plutonic rocks—Mostly quartz diorite and granodiorite
- TKm — Metamorphic (serpentinite), sedimentary, and igneous rocks

- Fault
- Major Fault Zone

NPRFZ — Northern Puerto Rico Fault Zone

SPRFZ — Southern Puerto Rico Fault Zone

Map modified from Miller et al., 1997

Figure 1

Geologic Map of Puerto Rico

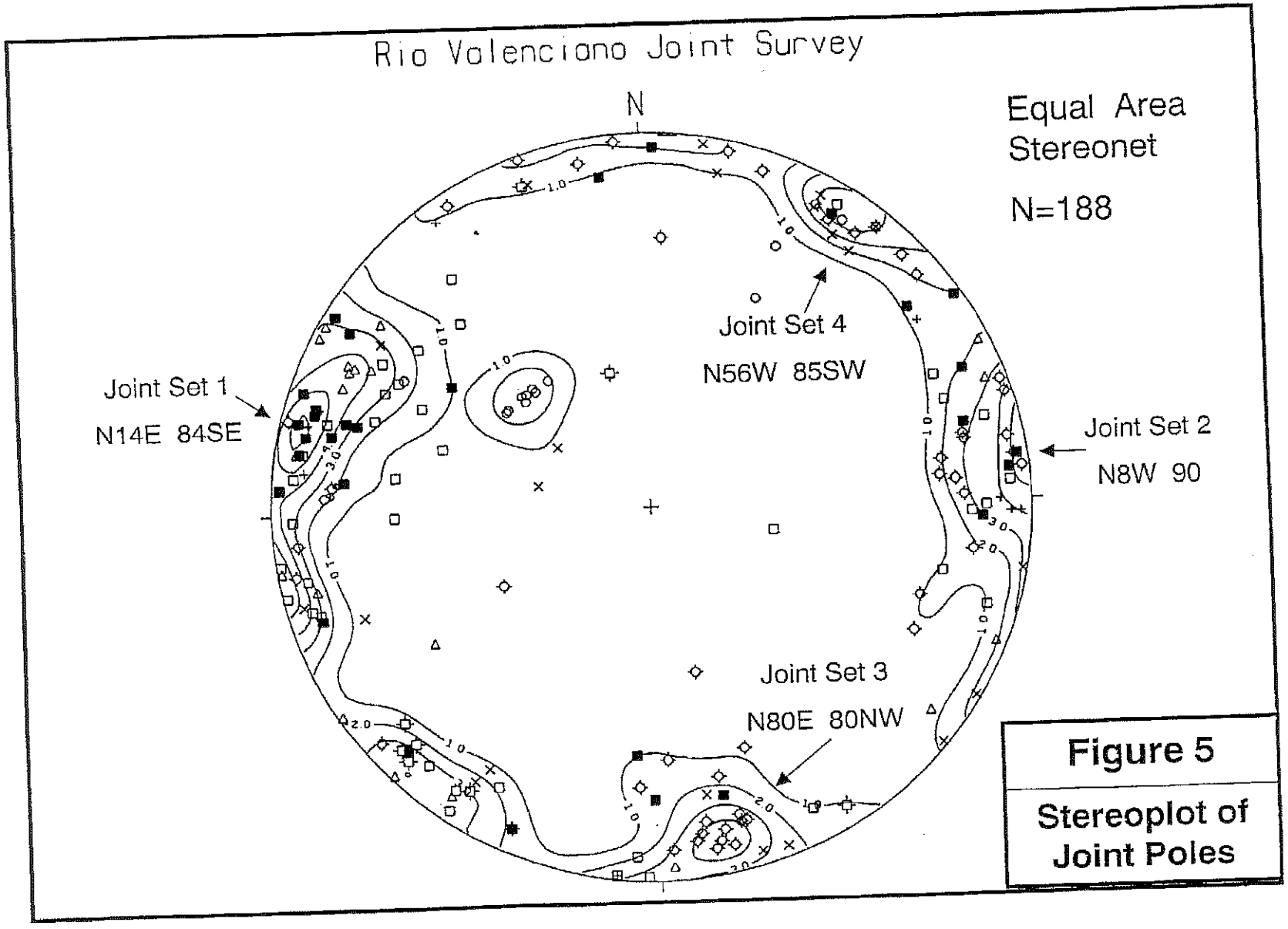


Figure 5

Stereoplot of Joint Poles

Typical weathering of granodiorite into corestones. Rounded boulders of slightly weathered to fresh rock surrounded by extremely weathered and friable saprolite. Length of hammer handle is 1 foot.

Figure 6

Photographs of Corestones

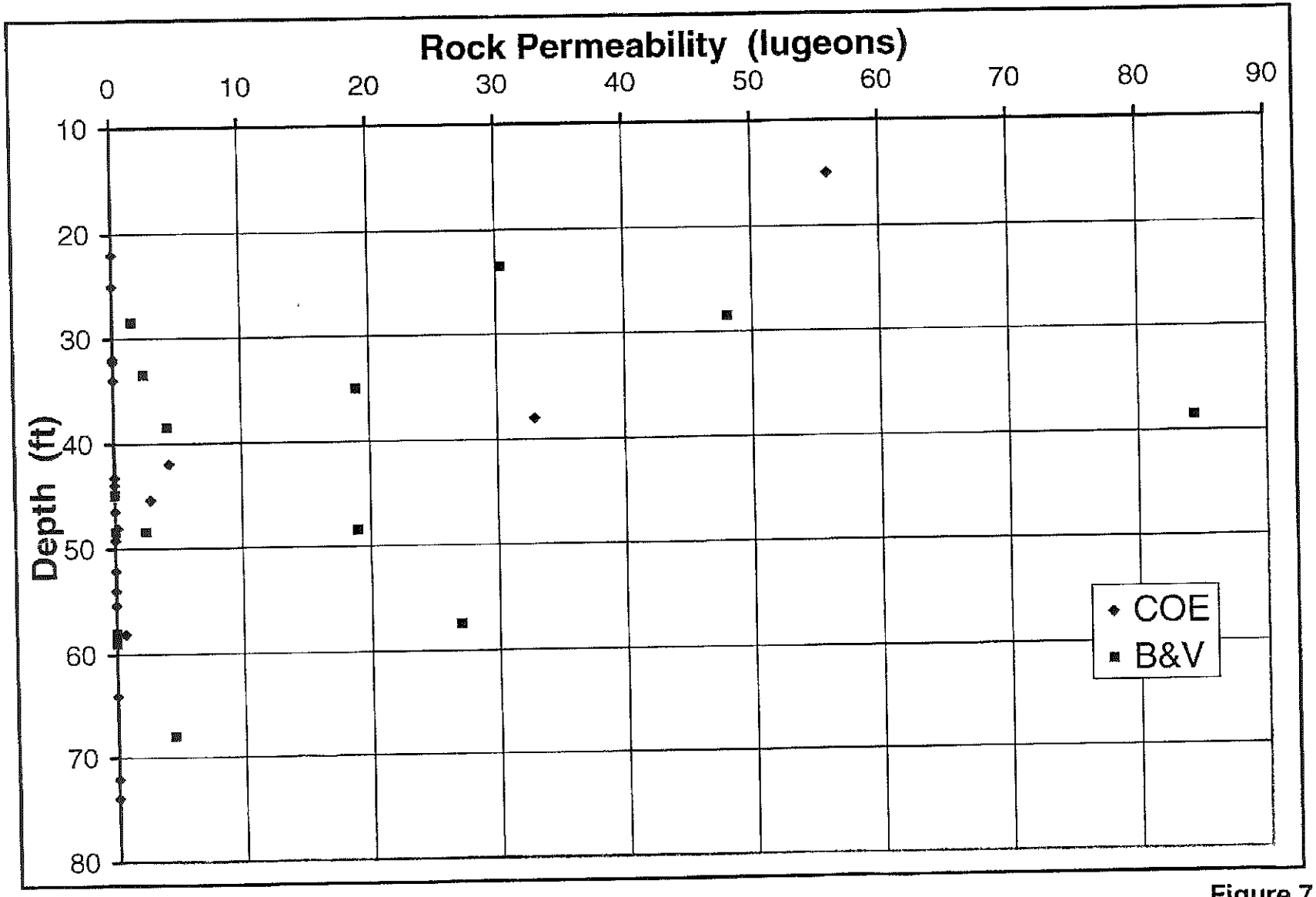


Figure 7
Distribution of Water Takes With Depth

RIO VALENCIANO RESERVOIR

GEOTECHNICAL REPORT

APPENDIX A
SOIL AND ROCK BORINGS

Rio Valenciano Reservoir
Geotechnical Report
Appendix A
Soil and Rock Borings

A.1 Introduction

Six soil and rock borings were drilled as part of this investigation. An explanation to the descriptive terms and symbols used on the boring logs is included in this appendix in Section A-1, and are followed by the boring logs in numerical sequence.

A.2 Drilling and Sampling Procedures

The drilling and hydraulic conductivity testing were performed between February 22, 2000 and March 22, 2000. All drilling, sampling, and field testing operations were supervised by a field geologist. The borings were drilled by one of two trailer-mounted CME-55 drill rigs owned and operated by GeoCim Geotechnical Testing. Each boring was advanced using Longyear NX, swivel-type core barrel. One rig was equipped with a wireline system, and the other used conventional coring techniques. Both of these systems utilize a double-tube core barrel, and a 2.0-inch inside diameter diamond-impregnated core bit. Drill fluid consisted of water and was pumped through the rods while coring to flush cuttings and cool the bit.

The inner barrel was retrieved either by wireline or by removing the drill rods after completion of each core run, which was typically drilled to a maximum length of 5 feet. The core was carefully removed and placed in the core box for detailed logging by the field geologist.

A.3 Borehole Completion

A two-inch diameter PVC monitoring well was installed in BV-1, BV-5, and BV-8. The remaining three borings were backfilled via the tremie method with a cement grout slurry. Completion logs for BV-1, BV-5, and BV-8 are included in Section A-2.

APPENDIX A-1

BORING LOGS

KEY TO DESCRIPTIVE TERMS USED ON CORE LOGS

DISCONTINUITY DESCRIPTORS

a Dip of fracture surface measured relative to a plane perpendicular to core axis

b Type:
- F - Fault
- J - Joint
- Sh - Shear
- Fo - Foliation
- V - Vein
- B - Bedding

c Aperture (inches):
- W - Wide (0.5-2.0)
- MW - Moderately Wide (0.1-0.5)
- N - Narrow (0.05-0.1)
- VN - Very Narrow (<0.05)
- T - Tight (0)

d Type of Infilling:
- Cl - Clay
- Ca - Calcite
- Ch - Chlorite
- Fe - Iron Oxide
- Gy - Gypsum/Talc
- H - Headled
- No - None
- Qz - Quartz
- Sd - Sand
- UK - Unknown

e Amount of Infilling:
- Su - Surface Stain
- Sp - Spotty
- Pa - Partially Filled
- Fi - Filled
- No - None

f Planarity:
- WA - Wavy
- Pl - Planar
- St - Stepped-
- Ir - Irregular

g Roughness of Surface:
- Slk - Slickensided [surface has smooth, glassy finish with visual evidence of striations]
- S - Smooth [surface appears and feels so to the touch]
- SR - Slightly Rough [asperities on the discontinuity surfaces are distinguishable and can be felt]
- R - Rough [some ridges and side-angle steps are evident; asperities are clearly visible, and discontinuity surface feels very abrasive]
- VR - Very Rough [near-vertical steps and ridges occur on the discontinuity surface]

h Spacing (feet):
- VW - Very Wide (>10)
- W - Wide (3-10)
- MW - Moderately Wide (1-3)
- C - Close (<0.2-1)
- VC - Very Close (<0.2)

ROCK WEATHERING/ALTERATION

Description	Recognition
Residual	Original minerals of rock have been entirely decomposed to secondary minerals, and original rock fabric is not apparent; material can be easily broken by hand
Extremely Weathered/Altered	Original minerals of rock have been almost entirely decomposed to secondary minerals, minerals, although original fabric may be intact; material can be granulated by hand
Highly Weathered/Altered	More than half of the rock is decomposed; rock is weakened so that minimum 2-inch-diameter sample can be broken readily by hand across rock fabric
Moderately Weathered/Altered	Rock is discolored and noticeably weakened, but less than half is decomposed; a minimum 2-inch-diameter sample cannot be broken readily by hand across rock fabric
Slightly Weathered/Altered	Rock is slightly discolored or dulled, but not noticeably lower in strength than fresh rock
Fresh	Rock shows no discoloration, loss of strength, or other effect of weathering/alteration, except on or immediately adjacent to joint surfaces

ROCK STRENGTH

Description	Recognition	Approximate Uniaxial Compressive Strength (psi)
Extremely Weak Rock	Can be indented by thumbnail	35 – 150
Very Weak Rock	Can be peeled by pocket knife	150 – 700
Weak Rock	Can be peeled with difficulty by pocket knife	700 – 3,500
Moderately Strong Rock	Can be indented 5 mm with sharp end of pick	3,500 – 7,000
Strong Rock	Requires one hammer blow to fracture	7,000 – 14,500
Very Strong Rock	Requires many hammer blows to fracture	14,500 – 35,000
Extremely Strong Rock	Can only be chipped with hammer blows	>35,000

SCRATCH HARDNESS

Description	Recognition
Soft	Applicable only to plastic material
Friable	Easily crumbled by hand, pulverized, or reduced to powder; too soft to be cut by pocket knife
Low Hardness	Can be gouged deeply or carved with a pocket knife
Moderately Hard	Can be readily scratched by knife blade; scratch leaves heavy trace of dust and is readily visible after powder has been blown away
Hard	Can be scratched with pocket knife only with difficulty; scratch produces little powder; traces of knife steel may be visible
Very Hard	Cannot be scratched with pocket knife; knife steel marks are left on surface

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-1

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96828

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41988.82 E 206355.51	102.5 (MSL)	44.0 FEET	03/01/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
East Abutment, grass, trees, and brush, sloping	R.Brainard/D.Marlow	03/02/00

CHECKED BY	APPROVED BY
R.Brainard	R.Brainard

SAMPLING								CORING										
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY		CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
SPT	1	2	5	9	14	1.5									1			SILT and SAND: brown; moist; medium dense; fine grained; trace clay and gravel; with roots (Topsoil)	Advance boring using 4.25' hollowstem augers, sampling soil with split spoon sampler. Sampler driven with 140 lb. hammer using a 30" drop.
															2				
SPT	2	10	30	50/5"	80+	1.3									3				
															4			SAND: brown, gray, and orange; dry; very dense; fine to coarse grained; well graded; trace clay (Saprolite-Extemely Weathered Granodiorite)	
SPT	3	50/4"			50+	0.3									5				
			5.5																
								NX	1	4.5	0.3	0	7	0	6				Auger refusal at 5.5 feet. Convert to NX size core, using water as drilling fluid.
															7			No Recovery from 5.5 to 9.7 feet	
															8				
															9				
			10.0												10			Granodiorite Boulder: gray,brown, and black; moderately weathered; hard; weak to moderately strong	
								NX	2	5.0	1.8	0	38	0	11				Intervals of no recovery interpreted as very dense, extemely weathered granodiorite washed out during coring.
															12			No Recovery from 10.0 to 13.2 feet	
															13				
															14			GRANODIORITE: light gray with black mottling; moderately to slightly weathered; hard; moderately strong; with dark gray, mafic inclusions; highly fractured and broken from 13.2 to 13.9 feet; grades to slightly weathered at 13.9 feet	
			15.0												15				
								NX	3	5.0	5.0	5.0	100	100	16				100% returns
															17				Joints:
															18				1:70-90;J;Vn;Fe+H;Su Wa;Sr-R
															19				
			20.0												20				2:10;J;Vn;Fe;Su;Pl;Sr
								NX	4	5.0	5.0	5.0	100	100	21			Joint spacing moderately wide to wide	3:80;J;Vn;Fe;Sp;Pl;R
															22				1:10-30;J;Vn;Fe;Sp;Pl; R
															23				
															24				
			25.0												25				1:0-10;J;Vn;Fe;Sp;Pl;Sr
								NX	5	5.0	2.4	1.6	48	32	26				2:70-80;J;Vn;Fe;Sp;Pl; Sr
															27			No Recovery from 25.5 to 28.1 feet.	
															28			Moderately weathered and highly fractured from 28.1 to 28.5 feet.	
															29				

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-1
SHEET 2 OF 2

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41986.82 E 206355.51	102.5 (MSL)	44.0 FEET	03/01/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
East Abutment, grass, trees, and brush, sloping	R.Brainard/D.Marlow	03/02/00

CHECKED BY	APPROVED BY
R.Brainard	R.Brainard

SAMPLING							CORING										
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
							NX	6	5.0	4.3	3.55	86	71	31				100% returns
														32				
														33			No Recovery from 33.2 to 33.9 ft.	
														34			GRANODIORITE: light gray mottled with black; fresh; very hard; fine grained; massive; very wide jointing; very strong	
										35.0				35				03/02/00
							NX	7	5.0	5.0	5.0	100	100	36				Joints:
														37				1:0-20;J;Vn;Fe;Su;Pl;Sr-R
														38				
														39				2:30;J;Vn;Fe;Su;Pl;Sr
										40.0				40				3:70-80;J;Vn;Fe;Su;Pl;R
							NX	8	2.3	2.3	2.3	100	100	41				
														42				
										42.3								
							NX	9	1.7	1.7	1.7	100	100	43				
										44.0				44				End of boring at 44.0 feet.
														45				
														46				
														47				
														48				
														49				
														50				
														51				
														52				
														53				
														54				
														55				
														56				
														57				
														58				
														59				

BLACK & VEATCH — LOG OF BORING

BORING NO. BV-2
SHEET 1 OF 2

CLIENT: Infrastructure Financing Authority (AFI)	PROJECT: Rio Valenciano Dam		PROJECT NO. 96628
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41935.43 E 206517.80	ELEVATION (DATUM): 124.8 (MSL) / TOTAL DEPTH: 60.0 FEET	DATE START: 02/25/00
SURFACE CONDITIONS: East Abutment; grass, trees, and brush; sloping	LOGGED BY: R.Brainard/D.Marlow		DATE FINISH: 03/01/00
	CHECKED BY: R. Brainard	APPROVED BY: R. Brainard	

SAMPLING							CORING										
SAMPLE TYPE	SAMPLE NUMBER	SET 0 INCHES	2ND 0 INCHES	3RD 0 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
SPT	1	3	8	6	14	1.5								1			SILT and SAND; reddish brown; medium dense; moist; fine to medium grained; poorly graded; trace clay; with roots (TOPSOIL)	Boring advanced using 4.25 hollowstem augers. Samples taken using SPT sampler driven with 140 lb. hammer using a 30 inch drop.
SPT	2	50/5"	-	-	50+	0.4								2				
			3.0				NX	1	2.0	1.0	0	50	0	3			Granodiorite Boulder; gray and black; moderately weathered; hard	
														4				
			5.0				NX	2	3.0	3.0	2.5	100	83	5			No Recovery from 4.0 to 5.0 feet.	Auger refusal at 2.9 feet. Install 3" I.D. casing to 3.0 feet. Convert to NX size core with diamond bit using water as drilling fluid.
														6			GRANODIORITE; gray, white, and black; slightly weathered; very hard; fine grained; massive; with occasional healed joints; very strong	
														7				
			8.0				NX	3	2.0	2.0	2.0	100	100	8				
														9				
			10.0				NX	4	5.0	5.0	4.7	100	94	10			Grading fresh 8.0 feet.	60 to 70% returns
														11				100% returns
														12			Occasional dark gray, fine grained mafic inclusions up to 2" diameter	
														13				
														14			Joint Spacing is wide to very wide	Joints:
			15.0				NX	5	5.0	5.0	4.9	100	98	15				1.50-60;J;N;Fe;Su;Pl;S
														16				2.90;J;Vn;Fe;Su;Pl;S
														17				1.40-50;J;Vn;Fe;Su;Pl;S
														18				1.40-50;J;Vn;Fe;Sp;Pl;S
														19				2.40-50;J;Vn;No;Sp;Pl;S
			20.0				NX	6	5.0	5.0	5.0	100	100	20				
														21				1.40-50;J;Vn;No;No;Pl;S
														22				
														23				
														24				
			25.0				NX	7	5.0	5.0	5.0	100	100	25				02/29/00
														26				
														27			Core breaks preferentially along 40-50 degree joint set; joints healed with white unknown.	1.0-10;J;Vn-N;Sd;Sp+Fe;Pl;SR
														28				
														29				

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-2
SHEET 2 OF 2

CLIENT: Infrastructure Financing Authority (AFI)	PROJECT: Rio Valenciano Dam		PROJECT NO. 96628
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41935.43 E 206517.90	ELEVATION (DATUM): 124.8 (MSL) / TOTAL DEPTH: 60.0 FEET	DATE START: 02/25/00
SURFACE CONDITIONS: East Abutment; grass, trees, and brush; sloping		LOGGED BY: R.Brainard/D.Marlow	DATE FINISH: 03/01/00
	CHECKED BY: R. Brainard	APPROVED BY: R. Brainard	

SAMPLING: SAMPLE TYPE	SAMPLE NUMBER	SET 0 INCHES	2ND 0 INCHES	3RD 0 INCHES	N VALUE	SAMPLE RECOVERY	CORING: CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
							NX	8	5.0	5.0	5.0	100	100	31, 32, 33, 34, 35			GRANODIORITE; gray, black, white and pink; fresh; very hard; fine grained; very strong; occasional healed joints at 40-50 degrees	100% returns Joints: 1.0;J;Vn-N;No;Su+Fe;Pl;Sr 2.40-50;J;N;No;Su+Fe;Pl;S 3.60-70;J;sh;Cl;Fi;Pl;Sr 4.40-50;J;Vn;No;Su+Fe;Pl;S
							NX	9	5.0	35.0 5.0	5.0	100	100	36, 37, 38, 39, 40				
							NX	10	5.0	40.0 5.0	5.0	100	100	41, 42, 43, 44, 45				03/01/00 Joint: 1.10-30;J;Vn;No;Su+Fe;Wa;Sr
							NX	11	4.5	45.0 4.5	4.5	100	100	46, 47, 48, 49				
							NX	12	5.5	49.5 5.5	5.0	100	91	50, 51, 52, 53, 54, 55				Return water turned brown at 53.0 feet.
							NX	13	5.0	55.0 5.0	5.0	100	100	56, 57, 58, 59				End of boring at 60.0 feet.

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-4

CLIENT: Infrastructure Financing Authority (AFI)	PROJECT: Rio Valenciano Dam		PROJECT NO.: 96628
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41922.18 E 206270.96	ELEVATION (DATUM): 83.1 (MSL) / TOTAL DEPTH: 65.0 FEET	DATE START: 03/02/00
SURFACE CONDITIONS: East of River; grass and trees, sloping		LOGGED BY: R.Brainard/D.Marlow	DATE FINISH: 03/03/00
	CHECKED BY: R. Brainard	APPROVED BY: R. Brainard	

SAMPLING: SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORING: CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	CLASSIFICATION OF MATERIAL	REMARKS
SPT	1	2	2	3	5	1.5								1–2	Sandy CLAY; brown mottled with orange; firm; moist; low plasticity ; some silt; with roots (TOPSOIL)	Advance boring with 4.25" I.D. hollowstem augers using SPT sampler driven with 140 pound hammer using a 30" drop.
SPT	2	2	7	10	17	1.5								3–4	Clayey SAND; light brown; medium dense; moist; fine to medium grained; poorly graded; trace silt (Residual Soil of Granodiorite)	
SPT	3	11	15	21	36	1.5								5–6		
SPT	4	50/5"	-	-	50+	0.3								7–8	SILT and SAND; gray, brown, and orange; dense; moist; fine to coarse grained; well graded; trace clay (Extremely Weathered Granodiorite - Saprolite)	
SPT	5	30	50/5"	-	50+	0.9								9–11	Grading very dense and dry	
SPT	6	28	50/5"	-	50+	0.9								12–16		
SPT	7	27	50/5"	-	50+	0.9								17–21		
SPT	8	34	50/5"	-	50+	0.9								22–26		
														27–29		

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-4

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96828

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41922.18 E 206270.96	83.1 (MSL)	65.0 FEET	03/02/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
East of River; grass and trees, sloping	R.Brainard/D.Marlow	03/03/00

CHECKED BY	APPROVED BY
R. Brainard	R. Brainard

SAMPLING																							
SAMPLE TYPE	SAMPLE NUMBER	SET 0 INCHES	2ND 0 INCHES	3RD 0 INCHES	N VALUE	SAMPLE RECOVERY	CORING							DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
							CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD					
SPT	9	40	50/4"	-	50+	0.8								31 32 33 34			Grading wet with vertical parting	Auger refusal at 35.2 feet. Install 35 feet of casing. Convert to NX size core with diamond bit using water as drilling fluid.
SPT	10	50/2"	-	-	50+	0.2								35				
			35.2															
							NX	1	5.0	4.5	0.75	90	15	36 37 38 39			GRANODIORITE; gray, orange, and white; highly weathered; soft to moderately hard; friable; fine to medium grained; iron stained; with occasional fine grained dark gray mafic inclusions; very weak	No Recovery 38.4-38.6 ft and 38.8 to 39.0 ft.
			40.0											40				
							NX	2	5.0	5.0	2.6	100	51	41 42 43 44			Grading moderately weathered, moderately hard, moderately strong,	Joints: 1.50-60;J;N;No;Su+Fe;Pl;S
																	Grading slightly weathered with iron stained joint surfaces; massive; very hard; very strong	2.70;J;Vn-N;No;Su+Fe;Pl;S
			45.0											45				
							NX	3	4.3	4.3	4.3	100	100	46 47 48 49				2A.70;J;N;Ca+Fe;Fi;Pl;Sr 3.J;50-60;N;No;Su+Fe;Pl;S 1.40;J;N;No;Su;Pl;S
			49.3															
							NX	4	0.7	0.7	0.7	100	100					2.40-50;J;N;No;Su;Pl;S
			50.0											50				
							NX	5	5.0	5.0	5.0	100	100	51 52 53 54			Grading Fresh; with occasional joints surfaces with surface iron stain	100% returns 1.40;J;Vn;No;Su+Fe;S
			55.0											55				
							NX	6	5.0	5.0	5.0	100	100	56 57 58 59				03/03/00 1.70-80;J;Vn;Fe;Su;Pl;Sr 2.80-90;J;Vn;Fe;Su;Ir;R

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-4

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41922.18 E 206270.96	83.1 (MSL)	65.0 FEET	03/02/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
East of River; grass and trees, sloping	R.Brainard/D.Marlow	03/03/00

CHECKED BY	APPROVED BY
R. Brainard	R. Brainard

SAMPLING											CORING										
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
							NX	7	5.0	4.1	4.1	82	82	61				Left 0.9 feet of core in bottom of borehole, could not recover.
														62				
														63				
														64			No Recovery 64.1-65.0 ft.	
										65.0				65				End of boring at 65.0 feet.
														66				
														67				
														68				
														69				
														70				
														71				
														72				
														73				
														74				
														75				
														76				
														77				
														78				
														79				
														80				
														81				
														82				
														83				
														84				
														85				
														86				
														87				
														88				
														89				

BLACK & VEATCH — LOG OF BORING

BORING NO. BV-5
SHEET 1 OF 3

CLIENT: Infrastructure Financing Authority (AFI)	PROJECT: Rio Valenciano Dam		PROJECT NO. 96828
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41891.91 E 206229.91	ELEVATION (DATUM): 77.7 (MSL) / TOTAL DEPTH: 74.0 FEET	DATE START: 02/25/00
SURFACE CONDITIONS: Grass, trees, sloping		LOGGED BY: R.Brainard/D.Marlow	DATE FINISH: 02/28/00
		CHECKED BY: S.Brand	APPROVED BY: R.Brainard

SAMPLING							CORING							DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
SAMPLE TYPE	SAMPLE NUMBER	SET 0 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD					
SPT	1	2	5	9	14	1.5								1			SILT; brown; moist; nonplastic; with organics (TOPSOIL)	Advance boring using 2.0"I.D. hollowstem auger sampling with SPT sampler driven with 140 pound hammer using a 30" drop.
SPT	2	5	6	10	16	1.5								2, 3, 4			Silty SAND; brown; medium dense; moist; fine grained; poorly graded	
SPT	3	8	18	32	50	1.5								5, 6, 7			SAND and SILT; gray, brown, and orange; very dense; moist; fine to medium grained; (Extremely Weathered Granodiorite-Saprolite)	
SPT	4	18	50	–	50+	1.0								8, 9				Auger refusal at 14.0 feet. Advance casing to 14 feet. Convert to NX size core with diamond bit using water as drilling fluid.
SPT	5	26	32	44	76	1.5								10, 11, 12, 13				
							NX	1	5.0	14.0 / 2.7	0	54	0	14, 15, 16, 17, 18			GRANODIORITE; light gray, white, and black; mod. to highly wthrd; mod. hard; fine to med. grained; with occ. small mafic inclusions; mod. strong No Recovery 16.7–19.0 ft.	100% returns Joints: 1.0–20;J;N;Fe+Cl;Sd;Fl+Su;Pl;Sr 2.40–50;J;N;Fe+Cl+Sd;Fl+Su;Pl;Sr
							NX	2	5.0	19.0 / 5.0	4.1	100	82	19, 20, 21, 22, 23			Grades to slightly weathered Grades to fresh, very hard and strong, massive	3.0–20;J;N;Fe+Cl+Sd;Fl+Su;Pl;Sr 1.75;J;Vn;Fe;Su;Pl;Sr 2.70;J;N;Cl+Fe;Fl;Pl;Sr
							NX	3	5.0	24.0 / 5.0	4.9	100	98	24, 25, 26, 27, 28				3.0–20;J;Vn;Fe;Su;Pl;Sr 1.35;J;Vn;Fe;Su;Pl;Sr–R 2.15;J;T;H+Qz;Fl;Pl;Sr 3.60;J;T;H+Qz;Fl;Pl;Sr
										29.0				29				

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-5
SHEET 2 OF 3

CLIENT: Infrastructure Financing Authority (AFI)	PROJECT: Rio Valenciano Dam		PROJECT NO. 9662B
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41891.91 E 206229.91	ELEVATION (DATUM): 77.7 (MSL) / TOTAL DEPTH: 74.0 FEET	DATE START: 02/25/00
SURFACE CONDITIONS: Grass, trees, sloping		LOGGED BY: R.Brainard/D.Marlow	DATE FINISH: 02/28/00
		CHECKED BY: S.Brand	APPROVED BY: R.Brainard

SAMPLING: SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORING: CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
																		Joints:
														31			Grades moderately weathered	1.30-50;J;Vn;Fe;Su;Pl;Sr
														32				2.90;J;N;Fe+Qz;Fi;Pl;Sr
														33			Grades highly to extemely weathered	3.50-70;J;Vn;Fe;Su;Wa;Sr
										34.0				34				
							NX	5	5.0	2.9	1.55	58	31	35			No Recovery 32.8-36.1 ft.	
														36			Grades moderately weathered	
														37				
														38			Grades slightly weathered to fresh	
										39.0				39				
							NX	6	5.0	4.3	3.2	86	64	40				1.80;J;Vn;Fe;Su;Ir;Vr
														41				2.20-30;J;Vn;Fe;Su;Pl;Sr
														42				
														43				
										44.0				44			No Recovery 43.3-44.65 ft.	02/26/00;02/27/00;
							NX	7	5.0	4.35	3.5	87	70	45				02/28/00
														46				1.15;J;N;Qz+GrnUnk;Fi; Pl;Sr
														47				
														48				2.10-20;J;Vn;Fe;Sp;Pl;R
														49				3.50;J;Vn;Fe;Su;Pl;Sr
										49.0				50				
							NX	8	5.0	3.4	-	68	-	51				1.80;J;Vn;Fe;Su;Wa;R
														52				2.50;J;Vn;Fe;Su;Pl;R
														53			No Recovery 52.4-54.0 ft.	
										54.0				54				
							NX	9	5.0	5.0	4.65	100	93	55				1.70-90;J;N;Fe+GrnUnk+Q ;Fi;Wr;R
														56				
														57				
														58				1.10;J;Vn;Fe;Su;Pl;R
										59.0				59				

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-5

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41891.91 E 206229.91	77.7 (MSL)	74.0 FEET	02/25/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
Grass, trees, sloping	R.Brainard/D.Marlow	02/28/00

CHECKED BY	APPROVED BY
S.Brand	R.Brainard

SAMPLING							CORING							DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD					
										60.5							No Recovery 60.5-60.75 ft.	Joints:
							NX	11	3.5	3.25	1.2	93	34	61			Grades moderately weathered	1.0-90;J;Vn;Fe;Sp;Pl;Sr
														62				
														63			Grades slightly weathered to fresh	
										64.0				64				
							NX	12	5.0	5.0	5.0	100	100	65				1.35;J;Vn;No;No;Pl;R
														66				2.45;J;Vn;Fe;Su;Pl;Sr
														67				
														68				
										69.0				69				
							NX	13	5.0	5.0	4.0	100	80	70			Grades moderately weathered	1.10-90;J;Vn;Fe;Sp;Pl;Sr
														71			Grades slightly weathered to fresh	
														72				
														73				
										74.0				74			Grades highly to extremely weathered	End of boring at 74.0 feet.
														75			Grades slightly weathered to fresh	
														76				
														77				
														78				
														79				
														80				
														81				
														82				
														83				
														84				
														85				
														86				
														87				
														88				
														89				

BLACK & VEATCH — LOG OF BORING

BORING NO. BV-7
SHEET 1 OF 2

CLIENT: Infrastructure Financing Authority (AFC)		PROJECT: Rio Valenciano Dam		PROJECT NO. 96628
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41864.79 E 206194.16	ELEVATION (DATUM): 80.2 (MSL)	TOTAL DEPTH: 50.0 FEET	DATE START: 02/22/00
SURFACE CONDITIONS: West Abutment; grass and trees, sloping		LOGGED BY: R.Brainard/D.Marlow		DATE FINISH: 02/24/00
		CHECKED BY: S.Brand	APPROVED BY: R.Brainard	

SAMPLING										CORING											
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	CLASSIFICATION OF MATERIAL	REMARKS
SPT	1	4	11	10	21	1.3	1										Clayey SAND; yellowish orange; medium dense; moist; fine grained	Boring advanced with 2"I.D. hollowstem augers and sampling with SPT sampler driven with 140 pound hammer using a 30" drop.
							2											
SPT	2	11	19	31	50	1.5	3										Silty SAND; yellowish orange; very dense; moist; fine grained (Residual Soil of Granodiorite)	
							4											
							5											
SPT	3	14	50	-	50+	1.0	6											
							7											
SPT	4	32	39	50	89	1.5	8											
							9											
							10											
SPT	5	23	50	-	50+	1.0	11											Auger refusal at 11.0 feet. Install casing to 11.0 feet. Convert to NX size core with diamond bit using water as drilling fluid. 02/23/00
			11.0															
NX	1	4.0	1.9	-	22	-	12										GRANODIORITE; yellow, brown, orange, white; extremely weathered; soft and friable; fine grained; saprolitie	
							13											
							14										No Recovery 11.0-14.1 ft.	
							15											
			15.0															
NX	2	5.0	3.0	-	60	-	16										Highly fractured; joint surfaces heavily iron stained; filling between fragements is clay with occasional roots (Boulder/Cobbles)	Joints: 1.10-30;J;N;Fe+Sd+Cl; Su+Fi;Pl;Sr
							17											
							18											
							19										No Recovery 15.0-17.0 ft.	
							20											
			20.0															
NX	3	5.0	1.9	-	38	-	21										Highly fractured; highly weathered; soft; friable; heavy iron stain with clay filling with occasional roots (Boulder/Cobbles)	2.70;J;N;Fe+Cl+Sd; Su+Fi;Pl;Sr
							22											
							23										No Recovery 20.0-23.1 ft.	
							24										Highly fractured; highly weathered; iron stained; with clay and roots	3.15;J;Vn;Fe;Sp;Pl;R
							25											
			25.0															
NX	4	5.0	5.0	3.3	100	66	26										GRANODIORITE; gray, white, black; moderately weathered; mod. hard; fine to med. grained; weak	4.80;J;Vn;Fe+WhUnk; Sp;Pl;R
							27											
							28											
							29										Grading slightly weathered; mod. hard; mod. strong	

BLACK & VEATCH — LOG OF BORING

BORING NO. BV-7
SHEET 2 OF 2

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFC)	Rio Valenciano Dam	96628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41864.79 E 206194.16	80.2 (MSL)	50.0 FEET	02/22/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
West Abutment; grass and trees, sloping	R.Brainard/D.Marlow	02/24/00

CHECKED BY	APPROVED BY
S.Brand	R.Brainard

SAMPLING / CORING													
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD
NX	5		5.0	5.0	100	100			5.0	5.0	100	100	
NX	6		5.0	5.0	100	100			5.0	5.0	100	100	
NX	7		5.0	4.8	100	96			5.0	5.0	4.8	100	96
NX	8		5.0	-	26	-			5.0	1.3	-	26	-

DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
31, 32, 33, 34, 35				1.60;J;Vn;Fe+GrnUnk; Su;Pl;Sr 2.30;J;Vn;Fe;Sp;Pl;R 3.60;J;Vn;Fe+WhUnk; Su;Pl;Sr
36, 37, 38, 39, 40			Several healed joints filled with quartz and green unknown.	4.75;J;T;H;Fe;Pl;Sr 02/23/00 1.70;J;Vn;Fe+GrnUnk; Sp;Pl;Sr
41, 42, 43, 44, 45			INTRUSIVE DIKE: dark gray; aphanitic with black phenocrysts; very hard; very strong GRANODIORITE: gray,black,and white; slightly weathered to fresh; very hard; fine to medium grained; massive; very strong	1.0-10;J;Vn;Fe;Su;Pl;R 2.70;J;N;Fe+Cl;Su;Pl;Sr 3.20;J;Vn;Fe;Sp;Pl-Ir R-Vr
46, 47, 48, 49, 50			No Recovery 46.3-50.0 ft.	1.60;J;Vn;Fe;Sp;Pl;Sr Left 3.7 feet of core in borehole, attempted retrieval but failed.
51, 52, 53, 54, 55, 56, 57, 58, 59				End of Boring at 50.0 feet.

BLACK & VEATCH — LOG OF BORING

BORING NO. BV-8
SHEET 1 OF 3

CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 41837.95 E 206158.53	102.23 (MSL)	63.0 FEET	02/22/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
Grass and trees, sloping	R.Brainard/D.Marlow	02/24/00

CHECKED BY	APPROVED BY
R.Brand	R.Brainard

SAMPLING							CORING									CLASSIFICATION OF MATERIAL	REMARKS
SAMPLE TYPE	SAMPLE NUMBER	SET 0 INCHES	2ND 0 INCHES	3RD 0 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	
SPT	1	3	14	12	26	1.5								1			SILT and SAND; brown; dry; fine grained; poorly graded; with roots (TOPSOIL)
SPT	2	50	-	-	50+	0.4								3			SAND; gray, brown, and black; medium dense; dry; fine to medium grained; iron stained; trace to some silt; friable (Extremely Weathered Granodiorite - Saprolite)
SPT	3	50/5"	-	-	50+	0.4								5			Grading very dense
			5.4				NX	1	4.6	0	-	0	-	6			No Recovery 5.4-10.0 ft.
			10.0				NX	2	5.0	1.65	-	33	-	10			No Recovery 10.0-13.35 ft.
			15.0				NX	3	5.0	3.35	-	67	-	15			GRANODIORITE; highly weathered; firm; very weak (Boulder)
														16			No Recovery 15.0-16.65 ft.
			20.0				NX	4	5.0	4.65	2.5	93	50	20			GRANODIORITE; light gray and black; moderately weathered; moderately hard; medium grained; iron stained; strong
			25.0				NX	5	5.0	3.0	-	60	-	25			Grading slightly weathered; hard and strong
														26			No Recovery 24.65-25.0 ft.
														28			No Recovery 27.0-28.0 ft. and 29.0-30.7 ft.

Auger Refusal at 5.4 feet. Convert to NX size core with a diamond bit using water as drilling fluid.

100% returns

Joints:
1.60-90;J;T;Fe;Su;Pl;S
1.90;J;T;H;Wa;Sr
2.0-70;J;T;Fe;Su;Pl-S
3.0-30;J;Vn;Fe;Sp;Ir;Sr-R
1.90;J;H;Unk;Fe;Sp;S-Sr
1.50-60;J;T;Fe;Sp;Pl;S

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-8
SHEET 2 OF 3

CLIENT: Infrastructure Financing Authority (AFI)	PROJECT: Rio Valenciano Dam		PROJECT NO. 96628
PROJECT LOCATION: Juncos, Puerto Rico	COORDINATES: N 41837.95 E 206158.53	ELEVATION (DATUM): 102.23 (MSL) / TOTAL DEPTH: 63.0 FEET	DATE START: 02/22/00
SURFACE CONDITIONS: Grass and trees, sloping	LOGGED BY: R.Brainard/D.Marlow		DATE FINISH: 02/24/00
CHECKED BY: R.Brand	APPROVED BY: R.Brainard		

SAMPLING							CORING											CLASSIFICATION OF MATERIAL	REMARKS
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG			
							NX	6	5.0	4.3	2.8	86	56	31, 32, 33, 34, 35					02/23/00 1.60-70;J;T;H;Fi; Pl;S
							NX	7	5.0	35.0 4.0	2.3	80	46	36, 37, 38, 39, 40				Slag from burned up bit	Lost circulation 36.0-37.0 ft. 1.60-70;J;Vn;Fe; Su;Pl;S
							NX	8	5.0	40.0 5.0	5.0	100	100	41, 42, 43, 44, 45					02/24/00 2.40-50;J;Vn;Fe+Mg; Su;Pl;S 50;J;Vn;H;Fi;Pl;S Approx. 85% returns
							NX	9	3.5	45.0 3.5	3.5	100	100	46, 47, 48				GRANODIORIE; gray, black, and white; fresh; hard; medium to coarse grained; massive; with occ. mafic inclusions	1.60-70;J;Vn;Unk; Pa;Wa;S-Sr
							NX	10	1.5	48.5 1.2	0.3	80	20	49, 50					1.60-70;J;Vn;Unk; Pa;Wa;S-Sr
							NX	11	4.8	50.0 4.4	4.4	92	92	51, 52, 53, 54					1.40;J;T;Ukn;Fi;Pl ;S
							NX	12	2.6	54.8 2.5	2.0	96	80	55, 56, 57					1.0-40;J;Vn-N;Fe; Su+Sp;Pl;Sr
							NX	13	3.2	57.3 3.2	3.2	100	100	58, 59					

BLACK & VEATCH

LOG OF BORING

BORING NO. BV-8

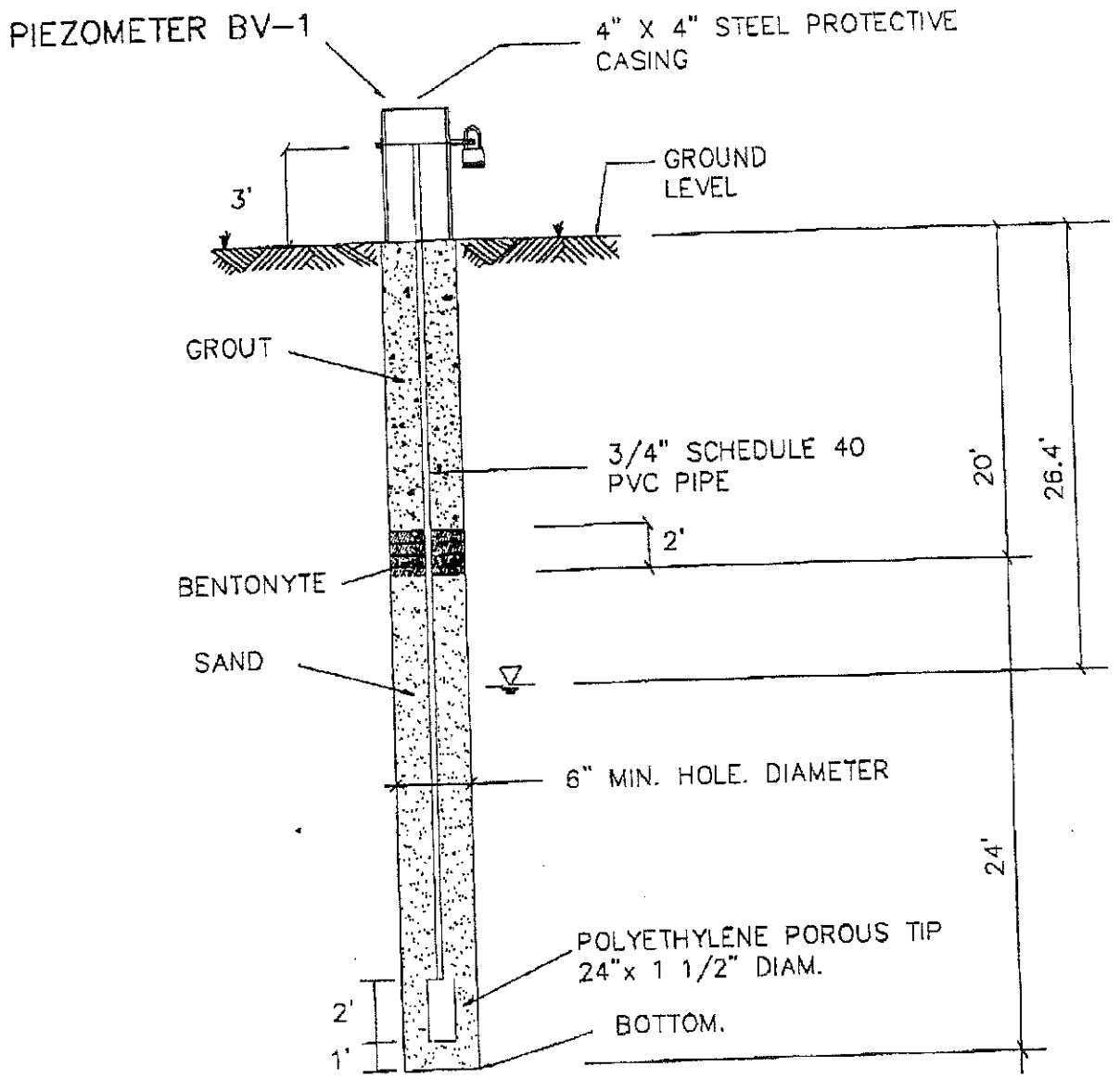
CLIENT	PROJECT	PROJECT NO.
Infrastructure Financing Authority (AFI)	Rio Valenciano Dam	96628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE START
Juncos, Puerto Rico	N 418 37.95 E 208158.53	102.23 (MSL)	63.0 FEET	02/22/00

SURFACE CONDITIONS	LOGGED BY	DATE FINISH
Grass and trees, sloping	R.Brainard/D.Mariow	02/24/00

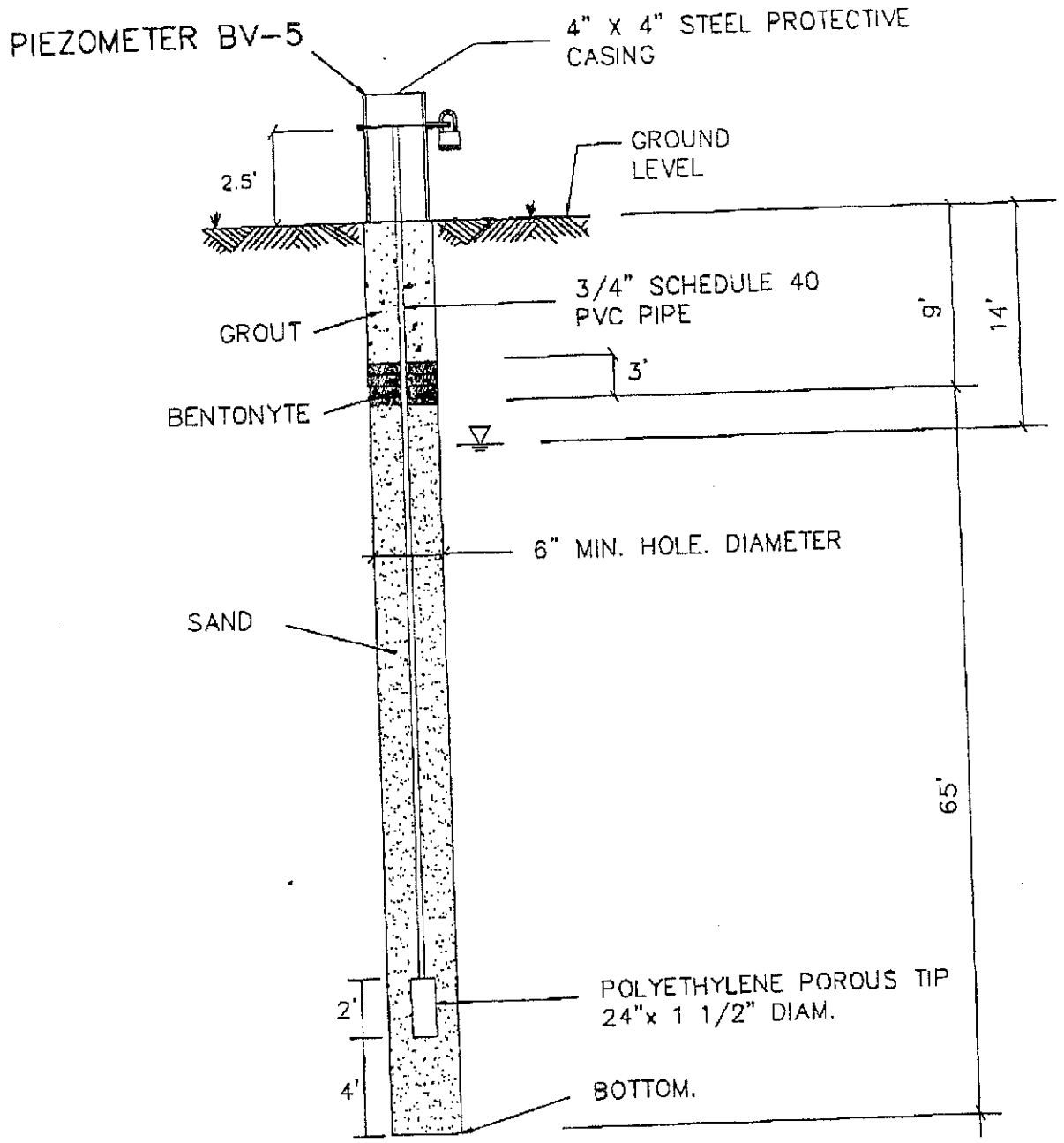
CHECKED BY	APPROVED BY
R.Brand	R.Brainard

SAMPLING							CORING											
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD	DEPTH IN FEET	SAMPLE TYPE	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	REMARKS
										60.5								
							NX	14	2.5	2.2	-	88	-	61				I.10-20;J;Vn;H;Fi; Pl;S
														62				
										63.0				63			Left 0.3'of core in borehole could not recover.	
														64				End of Boring at 63.0 feet.
														65				
														66				
														67				
														68				
														69				
														70				
														71				
														72				
														73				
														74				
														75				
														76				
														77				
														78				
														79				
														80				
														81				
														82				
														83				
														84				
														85				
														86				
														87				
														88				
														89				



TYPICAL PIEZOMETER INSTALLATION DETAIL

GeoCim	EAST CENTRAL REGIONAL AQUEDUCT - JUNCOS P.R.					
	DATE: 3/28/2K	DRW. BY: G.O.G.	CKD. BY: M.R.Q.T.	JOB. NO: 2431-99	SCALE: N.T.S.	FIG. NO: 1

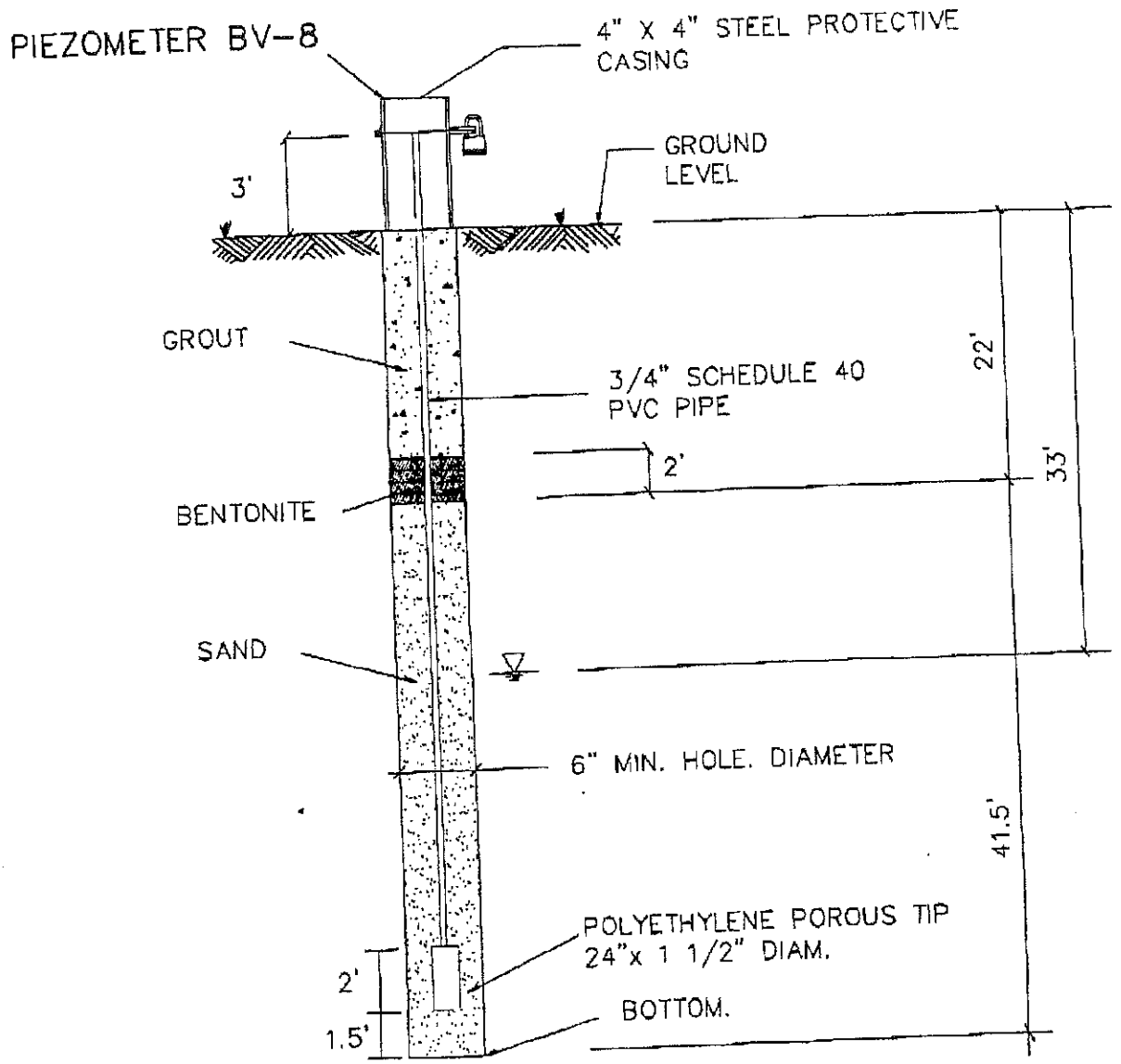


TYPICAL PIEZOMETER INSTALLATION DETAIL

GeoCim

EAST CENTRAL REGIONAL AQUEDUCT - JUNCOS P.R.

DATE:	DRW. BY:	CKD. BY:	JOB. NO:	SCALE:	FIG. NO:
3/28/2K	G.O.G.	M.R.Q.T.	2431-99	N.T.S.	1



TYPICAL PIEZOMETER INSTALLATION DETAIL

GeoCim	EAST CENTRAL REGIONAL AQUEDUCT - JUNCOS P.R.					
	DATE: 3/28/2K	DRW. BY: G.O.G.	CKD. BY: M.R.Q.T.	JOB. NO: 2431-99	SCALE: N.T.S.	FIG. NO: 1

RIO VALENCIANO RESERVOIR

GEOTECHNICAL REPORT

APPENDIX B

HYDRAULIC CONDUCTIVITY TESTS

Rio Valenciano Reservoir
Geotechnical Report
Appendix B
Hydraulic Conductivity Tests

B.1 Introduction

Water pressure tests (packer tests) were conducted in the five borings drilled along the dam axis to provide data for assessing the *in-situ* hydraulic conductivity characteristics of the bedrock. In general, the test involves injecting water into a discrete borehole interval at a series of different (increasing and then decreasing) pressures. The results of the test provide for interpretations of foundation permeability and flow patterns, and are useful for developing seepage remediation design. The test data were reduced to yield average field hydraulic conductivity values in cm/s and water takes in lugeons.

B.2 Methodology

B.2.1 Equipment

The standard packer testing equipment included a water-supply tank, water pump, vibrating-wire pressure transducer and readout-box, flow meter, the borehole packer assembly and compressed nitrogen bottle. Double pneumatic packers with a 10-foot, perforated-pipe test section were used to test the majority of the borehole. The pressure transducer sensing tube was placed midway between the packers to monitor water pressure at the center of the test section. The bottom portion of the boring was tested with a single packer at the top of the test interval.

B.2.2 Test Procedures

Borings were tested by lowering the packer assembly, via 1-inch diameter galvanized pipe, to the desired test interval. The packers were usually inflated to a pressure of at least 50 psi over the anticipated maximum test pressure. Water was then pumped down the pipe string and into the sealed test interval.

The test was begun by increasing the flow to the lowest required test pressure. In general, a series of 5 consecutive test steps, at increasing and then decreasing pressures, was performed in each interval. The pressures were selected as a factor (F) of a baseline pressure (P_{BL}), defined as 1 psi per foot of depth from ground surface to the center of the test interval. Each of the two decreasing pressure steps was performed at approximately the same pressure as the initial, increasing step to determine if the hydraulic conductivity of the rock was either temporarily or permanently changed as a result of higher pressure testing. The typical series of test pressures is as follows:

Step	F
1:	0.5 P_{BL}
2:	0.75 P_{BL}
3:	1.0 P_{BL}
4:	0.75 P_{BL}
5:	0.5 P_{BL}

The last two steps were commonly omitted when no recorded flow occurred during the first three pressure steps.

Readings of pressure and flow rate were recorded at 1-minute increments after a steady flow rate was achieved at the desired pressure. Each test step was run for a minimum of 5 minutes after consistent flow and pressure measurements were attained.

Each boring was typically tested upward at 10-foot increments, with each test interval overlapping the upper foot of the preceding interval. The bottom interval was tested with a single packer. Packer testing was completed within each boring to the top of sound rock, which is the approximate depth of surface casing in the borehole.

B.3 Data Reduction

The hydraulic conductivity of the rock in each tested interval was calculated in Système International units (cm/s) using the formula shown below. The formula is generally considered valid where the length of the test section is more than 10 times the radius of the boring. This requirement was met for all tests conducted for this investigation.

$$k = \frac{Q}{2\pi LH}\ln\left(\frac{L}{r}\right)x30.48$$

where:
k = hydraulic conductivity, cm/s
Q = constant rate of flow in the hole, ft^3/s
L = length of the test section, ft
H = differential head on the test section, ft
r = radius of the hole, ft
and 30.48 is the conversion factor from feet to centimeters.

A standardized water take of 1 lugeon is defined as a water take of 1 liter per minute per meter of test interval at a pressure of 1 MPa. Calculations shown on the attached data reduction sheets were made by the following formula:

$$\text{Water take in lugeons} = \frac{Q}{L} \cdot \frac{1801.27}{P}$$

where: Q = Constant rate of flow from the borehole in gallons/minute

L = Length of test interval in feet
P = Pressure in the test interval in psi
1801.27 is a conversion factor

B.4 Interpretation

Representative lugeon values were selected based on the method described by Houlsby (1976) for each test interval.

Rio Valenciano Reservoir
Packer Test Data

Boring Number: BV-1	Tested By: GeoCim	Groundwater Depth:	26.8 feet
Date Started: 3/18/00	Total Tests: 2	Inclination:	0 degrees
Date Completed: 3/18/00	Hole Diam: 2.93 inches	Surface Elevation:	336.2 feet

Test Interval			Footage to Transducer	Stage No.	Transducer Pressure		Net Pressure		Rate of Injection		Hydraulic Conductivity	Water Take
Footage		Length										
top	bottom	feet			feet	psi	feet	psi	ft^3/min	gpm	cm/s	lugeons
26.0	37.0	11.0	33.5	1	26	11	19	8	0.0	0.0	0.0E+00	0.0
26.0	37.0	11.0	33.5	2	55	24	48	21	0.0	0.2	1.8E-05	1.9
26.0	37.0	11.0	33.5	3	78	34	72	31	0.1	0.7	3.9E-05	3.9
26.0	37.0	11.0	33.5	4	58	25	51	22	0.0	0.4	2.6E-05	2.6
26.0	37.0	11.0	33.5	5	28	12	21	9	0.0	0.1	2.3E-05	2.4
17.0	28.0	11.0	23.5	1	32	14	32	14	0.3	2.6	3.0E-04	30.4
17.0	28.0	11.0	23.5	2	46	20	46	20	0.5	3.8	3.1E-04	31.0
17.0	28.0	11.0	23.5	3	62	27	62	27	0.9	6.9	4.2E-04	42.0
17.0	28.0	11.0	23.5	4	48	21	48	21	0.4	3.1	2.4E-04	24.2
17.0	28.0	11.0	23.5	5	28	12	28	12	0.2	1.4	1.9E-04	18.9

Rio Valenciano Reservoir
Packer Test Data

Boring Number: BV-4	Tested By: GeoCim	Groundwater Depth:	27.0 feet
Date Started: 3/20/00	Total Tests: 2	Inclination:	0 degrees
Date Completed: 3/20/00	Hole Diam: 2.93 inches	Surface Elevation:	272.4 feet

Test Interval			Footage to Transducer	Stage No.	Transducer Pressure		Net Pressure		Rate of Injection		Hydraulic Conductivity	Water Take
Footage		Length										
top	bottom	feet			feet	psi	feet	psi	ft^3/min	gpm	cm/s	lugeons
53.0	65.0	12.0	59.0	1	85	37	53	23	0.0	0.1	5.0E-06	0.5
53.0	65.0	12.0	59.0	2	127	55	95	41	0.0	0.0	0.0E+00	0.0
53.0	65.0	12.0	59.0	3	152	66	120	52	0.0	0.0	0.0E+00	0.0
53.0	65.0	12.0	59.0	4	87	38	55	24	0.0	0.0	0.0E+00	0.0
53.0	65.0	12.0	59.0	5	81	35	49	21	0.0	0.0	0.0E+00	0.0
43.0	54.0	11.0	48.5	1	81	35	60	26	0.0	0.4	2.3E-05	2.3
43.0	54.0	11.0	48.5	2	123	53	101	44	0.1	0.6	2.1E-05	2.1
43.0	54.0	11.0	48.5	3	167	72	146	63	0.1	1.0	2.7E-05	2.7
43.0	54.0	11.0	48.5	4	121	53	100	43	0.1	0.6	2.4E-05	2.4
43.0	54.0	11.0	48.5	5	82	36	61	26	0.1	0.4	2.3E-05	2.3

Rio Valenciano Reservoir
Packer Test Data

Boring Number: BV-5
Date Started: 3/21/00
Date Completed: 3/22/00

Tested By: GeoCim
Total Tests: 5
Hole Diam: 2.93 inches

Groundwater Depth: 14.4 feet
Inclination: 0 degrees
Surface Elevation: 255 feet

Test Interval Footage top	Test Interval Footage bottom	Test Interval Length feet	Footage to Transducer	Stage No.	Transducer Pressure feet	Transducer Pressure psi	Net Pressure feet	Net Pressure psi	Rate of Injection ft^3/min	Rate of Injection gpm	Hydraulic Conductivity cm/s	Water Take lugeons
62.0	74.0	12.0	68.0	1	78	34	25	11	0.0	0.0	0.0E+00	0.0
62.0	74.0	12.0	68.0	2	123	53	69	30	0.1	0.7	3.7E-05	3.7
62.0	74.0	12.0	68.0	3	162	70	109	47	0.1	1.1	3.5E-05	3.4
62.0	74.0	12.0	68.0	4	123	54	70	30	0.1	0.7	3.6E-05	3.6
62.0	74.0	12.0	68.0	5	87	38	34	15	0.1	0.4	4.6E-05	4.5
52.0	63.0	11.0	57.5	1	66	28	22	10	0.0	0.0	0.0E+00	0.0
52.0	63.0	11.0	57.5	2	99	43	56	24	0.4	2.8	1.9E-04	18.8
52.0	63.0	11.0	57.5	3	128	55	84	37	0.5	3.8	1.7E-04	16.8
52.0	63.0	11.0	57.5	4	102	44	59	25	0.4	2.9	1.8E-04	18.5
52.0	63.0	11.0	57.5	5	68	29	25	11	0.2	1.8	2.7E-04	27.1
42.0	53.0	11.0	48.5	1	54	23	20	8	0.0	0.0	0.0E+00	0.0
42.0	53.0	11.0	48.5	2	90	39	55	24	0.3	2.1	1.4E-04	14.2
42.0	53.0	11.0	48.5	3	115	50	81	35	0.4	3.3	1.5E-04	15.2
42.0	53.0	11.0	48.5	4	89	39	55	24	0.3	2.4	1.6E-04	16.2
42.0	53.0	11.0	48.5	5	60	26	26	11	0.2	1.3	1.9E-04	19.5
32.0	43.0	11.0	38.5	1	59	26	35	15	0.0	0.4	4.0E-05	4.0
32.0	43.0	11.0	38.5	2	85	37	61	26	0.1	0.7	4.2E-05	4.3
32.0	43.0	11.0	38.5	3	114	49	90	39	0.1	1.0	4.0E-05	4.0
32.0	43.0	11.0	38.5	4	87	38	63	27	0.1	0.7	4.0E-05	4.0
32.0	43.0	11.0	38.5	5	59	26	35	15	0.1	0.5	4.8E-05	4.9
22.0	33.0	11.0	28.5	1	58	25	44	19	0.3	2.0	1.7E-04	17.4
22.0	33.0	11.0	28.5	2	85	37	71	31	0.5	4.1	2.2E-04	21.8
22.0	33.0	11.0	28.5	3	108	47	94	41	1.3	9.9	4.0E-04	39.9
22.0	33.0	11.0	28.5	4	87	38	73	32	1.0	7.7	3.9E-04	39.7
22.0	33.0	11.0	28.5	5	50	22	36	16	0.6	4.6	4.8E-04	48.1

Rio Valenciano Reservoir
Packer Test Data

Boring Number: BV-7
Date Started: 3/22/00
Date Completed: 3/22/00

Tested By: GeoCim
Total Tests: 2
Hole Diam: 2.93 inches

Groundwater Depth: 28.7 feet
Inclination: 0 degrees
Surface Elevation: 297.6 feet

Test Interval Footage top	Test Interval Footage bottom	Test Interval Length feet	Footage to Transducer	Stage No.	Transducer Pressure feet	Transducer Pressure psi	Net Pressure feet	Net Pressure psi	Rate of Injection ft^3/min	Rate of Injection gpm	Hydraulic Conductivity cm/s	Water Take lugeons
40.0	50.0	10.0	45.0	1	56	25	42	18	0.0	0.0	0.0E+00	0.0
40.0	50.0	10.0	45.0	2	77	33	60	26	0.0	0.0	0.0E+00	0.0
40.0	50.0	10.0	45.0	3	102	44	86	37	0.0	0.0	0.0E+00	0.0
30.0	50.0	20.0	36.5	1	47	20	39	17	0.2	1.8	1.1E-04	9.7
30.0	50.0	20.0	36.5	2	69	30	61	27	0.4	2.7	1.1E-04	9.2
30.0	50.0	20.0	36.5	3	87	38	79	34	0.5	3.9	1.2E-04	10.4
30.0	50.0	20.0	36.5	4	69	30	62	27	0.4	2.9	1.1E-04	9.7
30.0	50.0	20.0	36.5	5	44	19	36	16	0.2	1.5	1.0E-04	8.7

Note: Because there was no take in the 1st test, all takes in the 2nd test occured over a 10 ft interval. Therefore, actual lugeon values are double what is shown in the table.

Rio Valenciano Reservoir
Packer Test Data

Boring Number: BV-8	Tested By: GeoCim	Groundwater Depth:	33.9 feet
Date Started: 3/20/00	Total Tests: 2	Inclination:	0 degrees
Date Completed: 3/20/00	Hole Diam: 2.93 inches	Surface Elevation:	335.3 feet

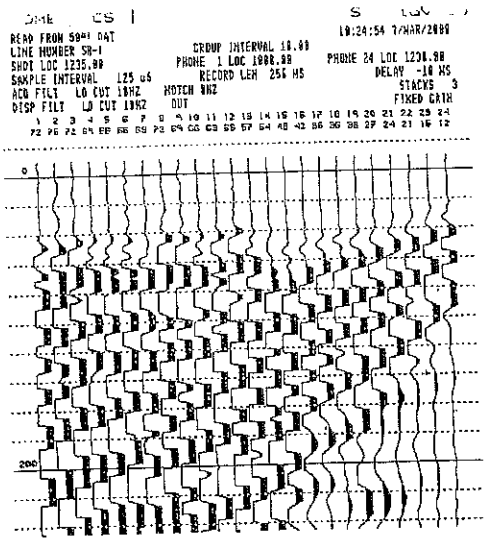
Test Interval Footage top	Test Interval Footage bottom	Test Interval Length feet	Footage to Transducer	Stage No.	Transducer Pressure feet	Transducer Pressure psi	Net Pressure feet	Net Pressure psi	Rate of Injection ft^3/min	Rate of Injection gpm	Hydraulic Conductivity cm/s	Water Take lugeons
52.0	63.5	11.5	58.0	1	72	31	48	21	0.0	0.0	0.0E+00	0.0
52.0	63.5	11.5	58.0	2	104	45	80	35	0.0	0.0	0.0E+00	0.0
52.0	63.5	11.5	58.0	3	135	58	111	48	0.0	0.0	9.2E-07	0.1
52.0	63.5	11.5	58.0	4	111	48	87	38	0.0	0.0	0.0E+00	0.0
42.0	63.5	21.5	48.5	1	52	23	38	16	0.0	0.0	0.0E+00	0.0
42.0	63.5	21.5	48.5	2	86	37	72	31	0.0	0.0	0.0E+00	0.0
42.0	63.5	21.5	48.5	3	123	54	109	47	0.0	0.0	0.0E+00	0.0
42.0	63.5	21.5	48.5	4	61	27	47	20	0.0	0.0	0.0E+00	0.0
32.0	43.0	11.0	38.5	1	59	26	54	24	1.6	12.1	8.4E-04	84.4
32.0	43.0	11.0	38.5	2	49	21	44	19	0.9	6.6	5.5E-04	55.9
22.0	33.0	11.0	28.5	0	34	15	34	15	0.0	0.0	0.0E+00	0.0
22.0	33.0	11.0	28.5	0	52	22	52	22	0.0	0.0	0.0E+00	0.0
22.0	33.0	11.0	28.5	0	65	28	65	28	0.0	0.3	3.7E-05	1.6
22.0	33.0	11.0	28.5	0	52	22	52	22	0.0	0.2	2.7E-05	1.5
22.0	33.0	11.0	28.5	0	34	15	34	15	0.0	0.0	0.0E+00	0.0

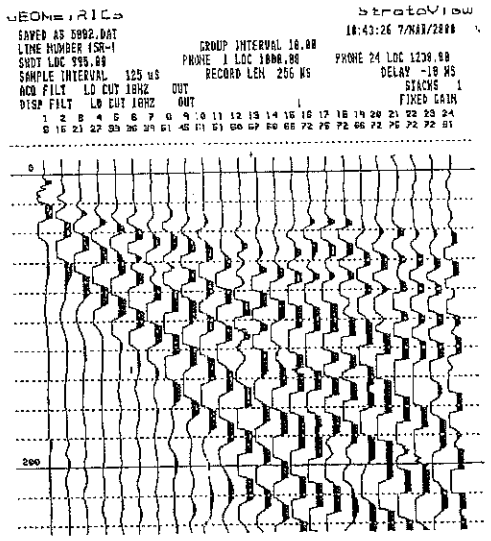
RIO VALENCIANO RESERVOIR

GEOTECHNICAL REPORT

APPENDIX C

SEISMIC REFRACTION SURVEYS





THE SPREAD FILE D:\E51.LPK WAS MADE FROM THE FILES
5991.SPK
5992.SPK

SIPDC V-4.0 For Quality Control of GS-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, Y-Loc, etc., and re-run on SIPT2.

TITLE: LINE NUMBER SR-1 FILE851.LPK

DATE: 3-08-2000 TIME: 9:48

Spread A contains 2 Shotpoints and 24 Geophones. Distance units: feet.

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0
B	.0	1235.0	.0	.0

Arrival Times T and Layers L

Geo	Elev	X-Loc	Y-Loc	SP A T	SP A L	SP B T	SP B L
1	.0	1000.0	.0	.0	0	40.3	0
2	.0	1010.0	.0	2.5	1	41.0	2
3	.0	1020.0	.0	4.4	1	35.4	0
4	.0	1030.0	.0	6.0	1	35.0	2
5	.0	1040.0	.0	9.5	1	38.6	0
6	.0	1050.0	.0	13.3	1	40.5	2
7	.0	1060.0	.0	16.6	1	40.0	2
8	.0	1070.0	.0	17.5	1	39.1	2
9	.0	1080.0	.0	19.5	1	38.0	2
10	.0	1090.0	.0	22.4	1	37.4	2
11	.0	1100.0	.0	24.3	1	37.0	2
12	.0	1110.0	.0	24.3	2	36.1	2
13	.0	1120.0	.0	25.0	2	34.8	2
14	.0	1130.0	.0	26.5	2	34.0	2
15	.0	1140.0	.0	27.0	2	34.0	2
16	.0	1150.0	.0	27.3	2	33.4	2
17	.0	1160.0	.0	27.0	2	32.5	2
18	.0	1170.0	.0	27.0	2	31.1	2
19	.0	1180.0	.0	28.5	2	29.3	2
20	.0	1190.0	.0	29.0	2	25.3	1
21	.0	1200.0	.0	30.1	2	22.3	1
22	.0	1210.0	.0	31.5	2	19.3	1
23	.0	1220.0	.0	33.0	0	15.0	1
24	.0	1230.0	.0	32.4	2	14.0	1

Depths of layers directly beneath Shotpoints and Geophones for Spread A:

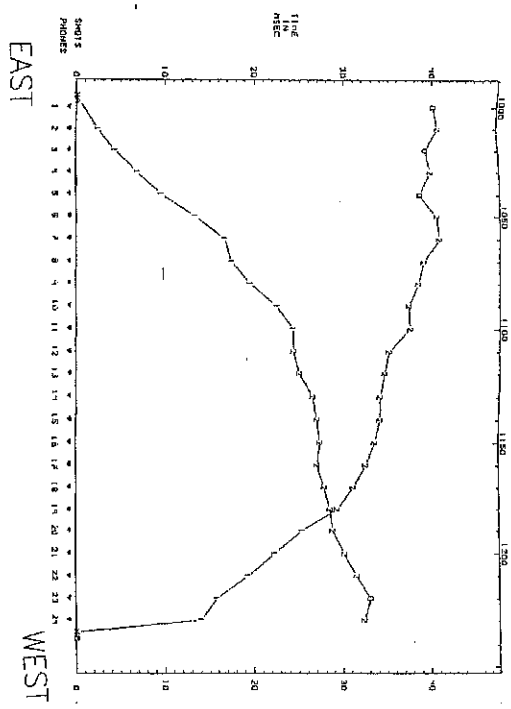
SP	X-Loc	Layer 2
A	995.0	32.1
B	1235.0	36.0

Geo		
1	1000.0	32.5
2	1010.0	39.5
3	1020.0	41.5
4	1030.0	44.6
5	1040.0	47.6
6	1050.0	45.2
7	1060.0	50.0
8	1070.0	52.4
9	1080.0	53.5
10	1090.0	51.0
11	1100.0	43.6
12	1110.0	42.0
13	1120.0	40.5
14	1130.0	40.3
15	1140.0	40.0
16	1150.0	39.5
17	1160.0	39.5
18	1170.0	38.7
19	1180.0	37.7
20	1190.0	35.0
21	1200.0	33.4
22	1210.0	35.2
23	1220.0	36.1
24	1230.0	37.1

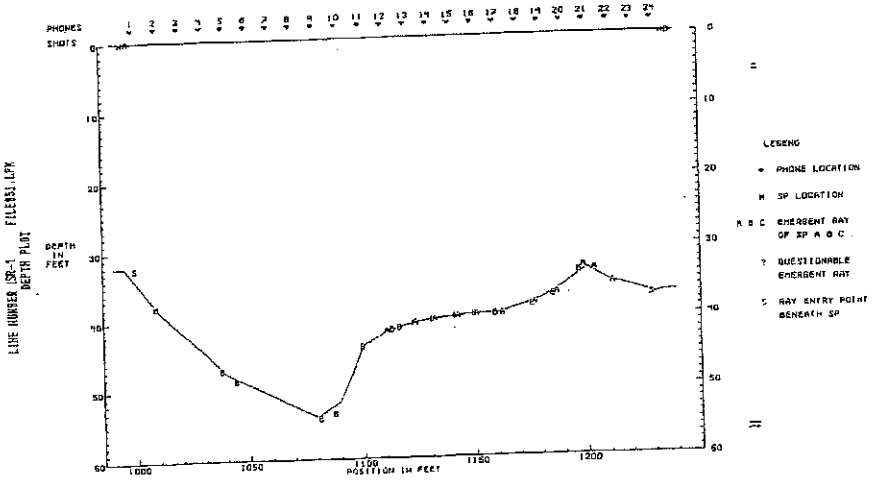
Velocities used:

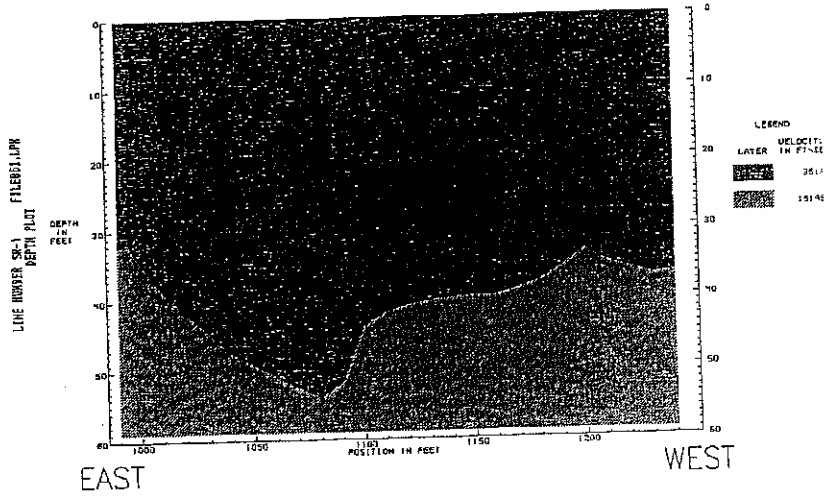
Layer 1	Layer 2
3518.	15190. ft/s

LINE NUMBER SR-1 FILE851.LPK
TIME - DISTANCE PLOT



Seismic Refraction Line SR-1


LINE NUMBER SR-1 FILE851.LPK
DEPTH PLOT
PHONES
SHOTS
DEPTH IN FEET
POSITION IN FEET
LEGEND
PHONE LOCATION
SP LOCATION
A B C EMERGENT RAY OF SP A B C
? QUESTIONABLE EMERGENT RAY
S RAY ENTRY POINT BENEATH SP


LINE NUMBER SR-1 FILE861.LPK
DEPTH PLOT
DEPTH IN FEET
POSITION IN FEET
LEGEND
LAYER
EAST
WEST

THE SPREAD FILE D:\B1.LPK WAS MADE FROM THE FILES
1992.BPK
1992.BPK

SIPRE V-4.0 For Quality Control of ES-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, Y-Loc, etc., and re-run on SIPT2.

TITLE: LINE NUMBER SR-2 FILEB1.LPK

DATE: 3-08-2000 TIME: 5:13

Spread A contains 2 Shotpoints and 24 Geophones. Distance units: feet

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0
B	.0	1235.0	.0	.0

Arrival Times T and Layers L

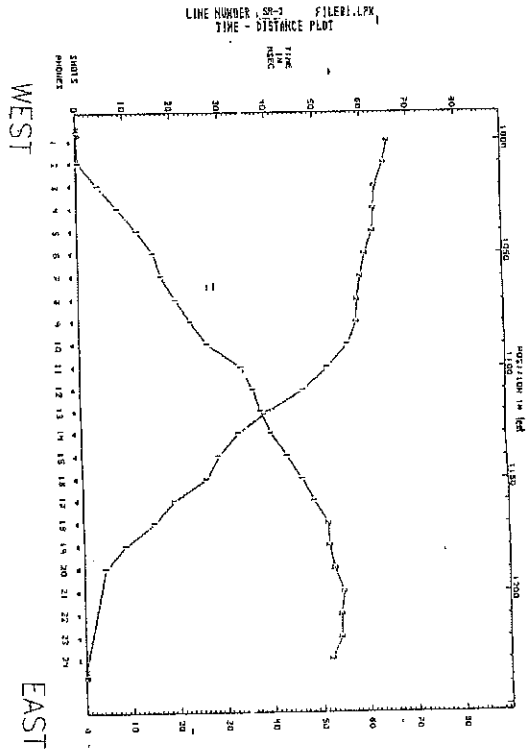
Geo	Elev	X-Loc	Y-Loc	SP A T	SP A L	SP B T	SP B L
1	.0	1001.0	.0	.0	0	65.0	2
2	.0	1010.0	.0	.5	1	64.0	2
3	.0	1020.0	.0	4.5	1	62.0	2
4	.0	1030.0	.0	8.5	1	62.5	2
5	.0	1040.0	.0	12.5	1	62.3	2
6	.0	1050.0	.0	16.0	1	60.5	2
7	.0	1060.0	.0	17.6	1	59.5	2
8	.0	1070.0	.0	20.5	1	58.5	2
9	.0	1080.0	.0	23.5	1	58.3	2
10	.0	1090.0	.0	27.0	1	56.3	1
11	.0	1100.0	.0	34.0	1	52.0	1
12	.0	1110.0	.0	36.5	1	47.0	1
13	.0	1120.0	.0	38.0	1	39.0	1
14	.0	1130.0	.0	40.1	1	33.0	1
15	.0	1140.0	.0	43.3	1	28.0	1
16	.0	1150.0	.0	45.3	1	25.3	1
17	.0	1160.0	.0	49.5	1	19.3	1
18	.0	1170.0	.0	51.4	2	15.0	1
19	.0	1180.0	.0	51.5	2	8.9	1
20	.0	1190.0	.0	52.6	2	4.5	1
21	.0	1200.0	.0	54.4	2	.0	0
22	.0	1210.0	.0	53.9	2	.0	0
23	.0	1220.0	.0	53.0	2	.0	0
24	.0	1230.0	.0	51.0	2	.0	0

Depths of layers directly beneath Shotpoints and Geophones for Spread A:

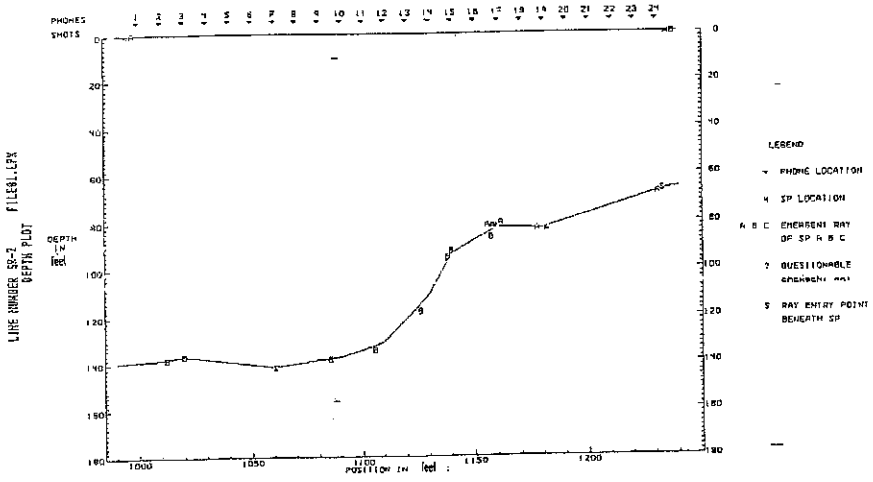
SP	X-Loc	Layer 2
A	995.0	139.2
B	1235.0	66.7
Geo		
1	1000.0	135.0
2	1010.0	138.0
3	1020.0	136.6
4	1030.0	137.0
5	1040.0	131.0
6	1050.0	140.2
7	1060.0	141.4
8	1070.0	140.0
9	1080.0	138.5
10	1090.0	137.2
11	1100.0	134.1
12	1110.0	131.0
13	1120.0	128.8
14	1130.0	110.7
15	1140.0	93.4
16	1150.0	87.9
17	1160.0	82.4
18	1170.0	82.7
19	1180.0	83.1
20	1190.0	80.0
21	1200.0	77.0
22	1210.0	74.0
23	1220.0	71.0
24	1230.0	68.2

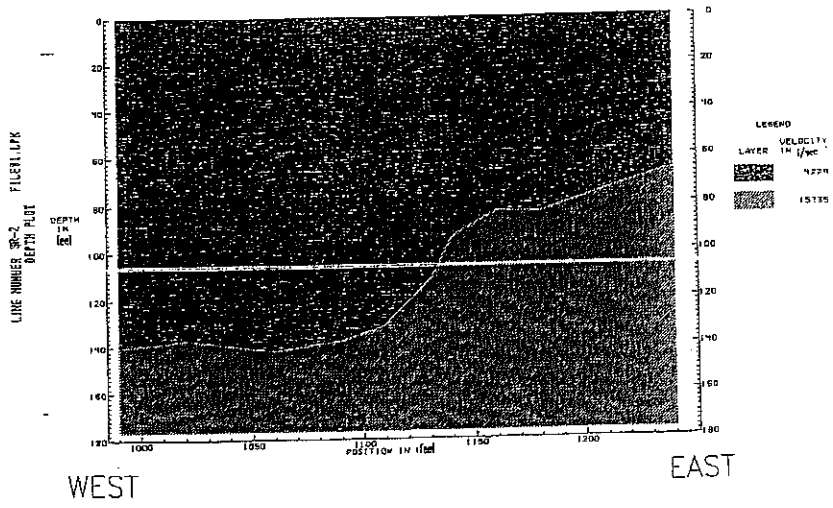
Velocities used:

Layer 1	Layer 2
4779.	16385. f/s

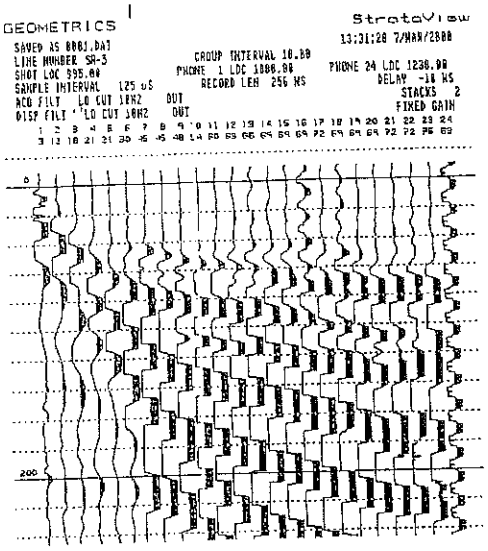


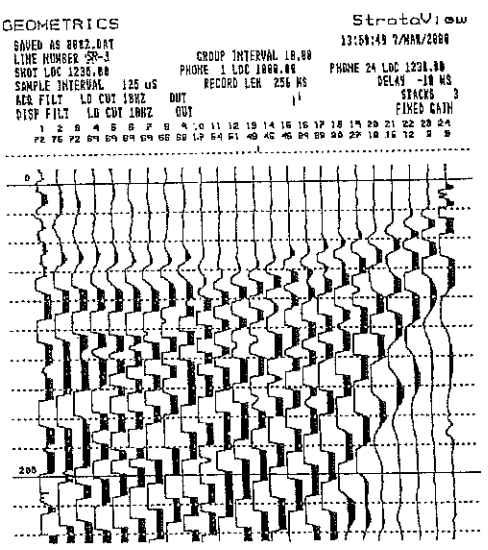
Seismic Refraction Line SR-2





NOTE: EFFECTIVE EXPLORATION DEPTH IS 70' (FEET).





THE SPREAD FILE D:\00.LPK WAS MADE FROM THE FILES
0001.DPK
0002.DPK

SIPOC V-4.0 For Quality Control of ES-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, Y-Loc, etc., and re-run on SIPT2.

TITLE: LINE NUMBER SR-3 FILE00.LPK

DATE: 3-09-2000 TIME: 10:27

Spread A contains 2 Shotpoints and 24 Geophones. Distance units: feet.

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0
B	.0	1235.0	.0	.0

Arrival Times T and Layers L

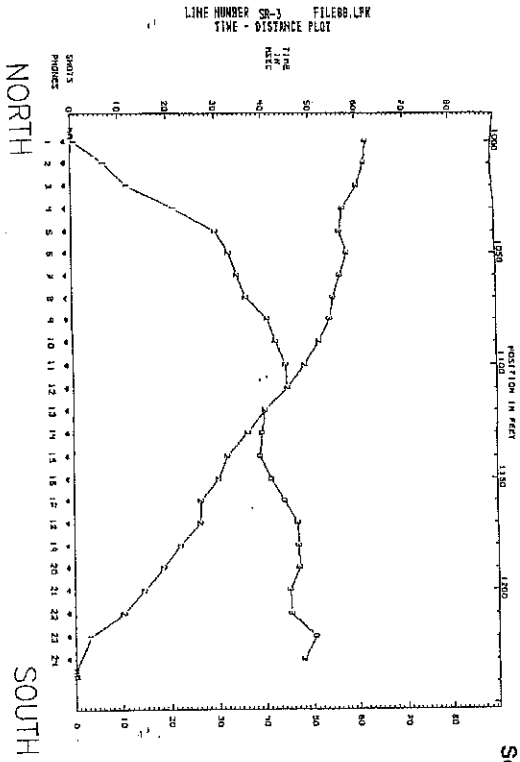
Geo	Elev	X-Loc	Y-Loc	SP A T	SP A L	SP B T	SP B L
1	.0	1000.0	.0	.0	1	62.6	3
2	.0	1010.0	.0	7.0	1	62.3	3
3	.0	1020.0	.0	11.0	1	60.4	3
4	.0	1030.0	.0	21.3	1	57.0	3
5	.0	1040.0	.0	30.0	2	56.1	3
6	.0	1050.0	.0	32.0	2	57.0	3
7	.0	1060.0	.0	34.6	2	55.1	3
8	.0	1070.0	.0	35.3	2	54.4	3
9	.0	1080.0	.0	40.0	2	54.0	3
10	.0	1090.0	.0	42.6	2	51.6	2
11	.0	1100.0	.0	44.5	2	48.6	2
12	.0	1110.0	.0	44.0	0	44.0	2
13	.0	1120.0	.0	40.0	0	40.0	2
14	.0	1130.0	.0	35.4	0	36.3	2
15	.0	1140.0	.0	35.0	0	32.6	2
16	.0	1150.0	.0	41.3	0	30.1	2
17	.0	1160.0	.0	44.0	0	26.4	2
18	.0	1170.0	.0	46.7	3	26.3	2
19	.0	1180.0	.0	46.5	3	22.0	2
20	.0	1190.0	.0	47.0	3	18.4	2
21	.0	1200.0	.0	45.0	3	14.4	2
22	.0	1210.0	.0	45.3	3	10.3	2
23	.0	1220.0	.0	50.4	0	3.3	1
24	.0	1230.0	.0	48.0	3	.0	0

Depths of layers directly beneath Shotpoints and Geophones for Spread A:

SP	X-Loc	Layer 2	Layer 3
A	995.0	7.3	89.3
B	1235.0	8.2	10.4
Geo			
1	1000.0	7.3	89.3
2	1010.0	7.7	99.3
3	1020.0	7.9	101.5
4	1030.0	8.0	107.0
5	1040.0	8.0	109.3
6	1050.0	8.0	105.7
7	1060.0	8.0	110.0
8	1070.0	8.0	111.5
9	1080.0	8.0	112.9
10	1090.0	8.0	110.6
11	1100.0	8.0	107.6
12	1110.0	8.0	104.6
13	1120.0	8.0	101.6
14	1130.0	8.0	98.6
15	1140.0	8.0	95.4
16	1150.0	8.0	91.5
17	1160.0	8.0	69.2
18	1170.0	8.0	42.0
19	1180.0	8.0	20.3
20	1190.0	8.0	17.3
21	1200.0	8.0	14.5
22	1210.0	8.0	14.6
23	1220.0	8.1	19.6
24	1230.0	8.2	10.0

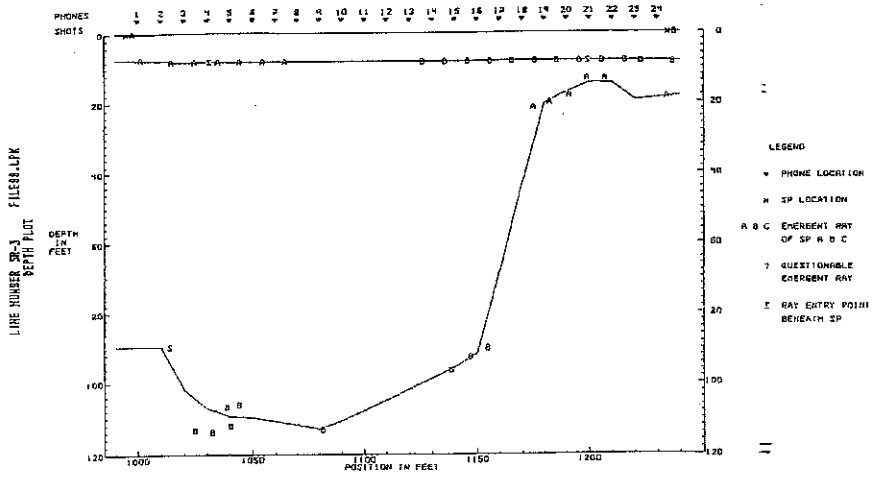
Velocities used:

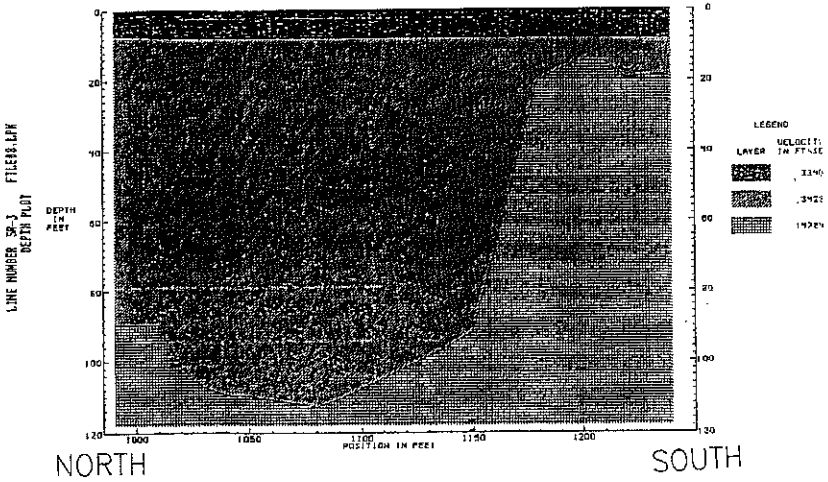
Layer 1	Layer 2	Layer 3

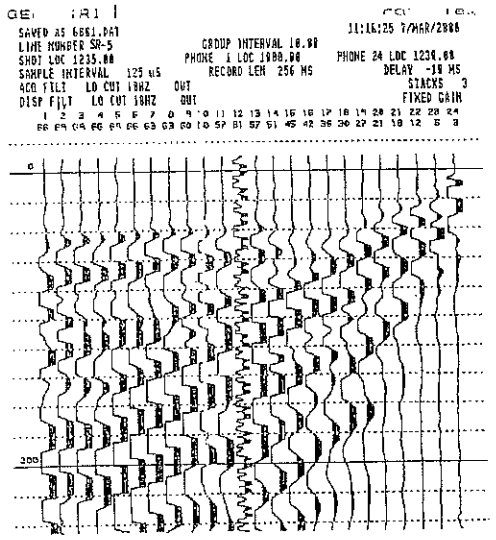


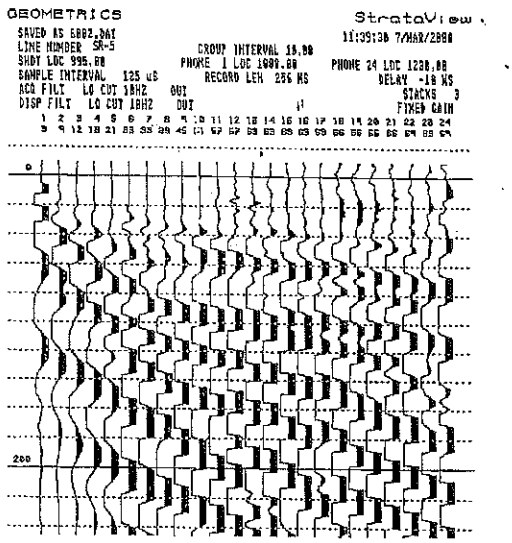
Seismic Refraction Line SR-3

NOTE: EFFECTIVE EXPLORATION DEPTH IS 70' (FEET).









THE SPREAD FILE D:\86.LPK WAS MADE FROM THE FILES
6861.DPK
6862.DPK

SIPRE V-4.0 For Quality Control of ES-2401, SmartSeis & StrataView field data.

(C) Copyright Rinrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, Y-Loc, etc., and re-run on SIPT2.

TITLE: LINE NUMBER SR-5 FILE86.LPK

DATE: 3-08-2000 TIME: 18:07

Spread A contains 2 Shotpoints and 24 Geophones. Distance units: feet.

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0
B	.0	1235.0	.0	.0

Arrival Times T and Layers L

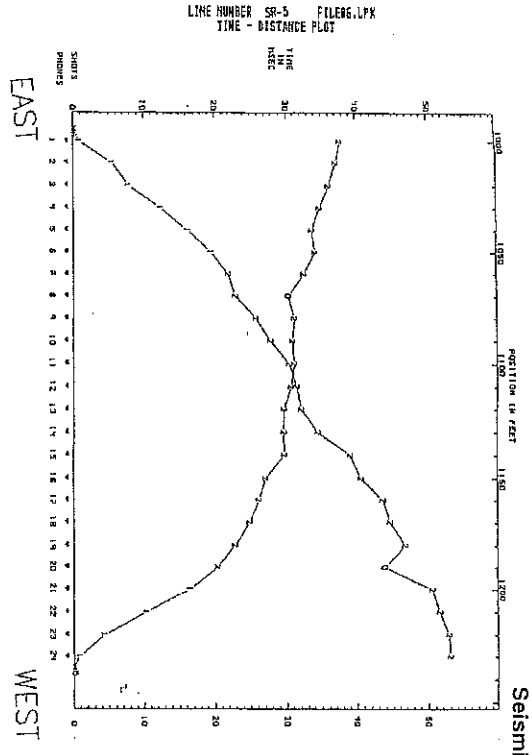
Geo	Elev	X-Loc	Y-Loc	SP A T	SP A L	SP B T	SP B L
1	.0	1000.0	.0	.0	1	37.5	2
2	.0	1010.0	.0	5.4	1	36.0	2
3	.0	1020.0	.0	7.0	1	35.0	2
4	.0	1030.0	.0	12.3	1	34.5	2
5	.0	1040.0	.0	16.0	1	33.5	2
6	.0	1050.0	.0	19.4	1	34.0	2
7	.0	1060.0	.0	21.9	2	32.5	2
8	.0	1070.0	.0	23.0	2	30.3	0
9	.0	1080.0	.0	25.0	2	31.1	2
10	.0	1090.0	.0	27.0	2	30.0	2
11	.0	1100.0	.0	30.3	2	31.0	2
12	.0	1110.0	.0	31.3	2	30.5	2
13	.0	1120.0	.0	32.0	2	29.6	2
14	.0	1130.0	.0	34.3	2	29.5	2
15	.0	1140.0	.0	39.0	2	29.5	2
16	.0	1150.0	.0	40.5	2	27.0	2
17	.0	1160.0	.0	43.0	2	26.1	2
18	.0	1170.0	.0	44.5	2	24.0	2
19	.0	1180.0	.0	46.7	2	22.5	2
20	.0	1190.0	.0	49.0	0	20.4	2
21	.0	1200.0	.0	50.5	2	16.4	1
22	.0	1210.0	.0	51.5	2	10.3	1
23	.0	1220.0	.0	52.0	2	4.3	1
24	.0	1230.0	.0	53.0	2	.0	1

Depths of layers directly beneath Shotpoints and Geophones for Spread A:

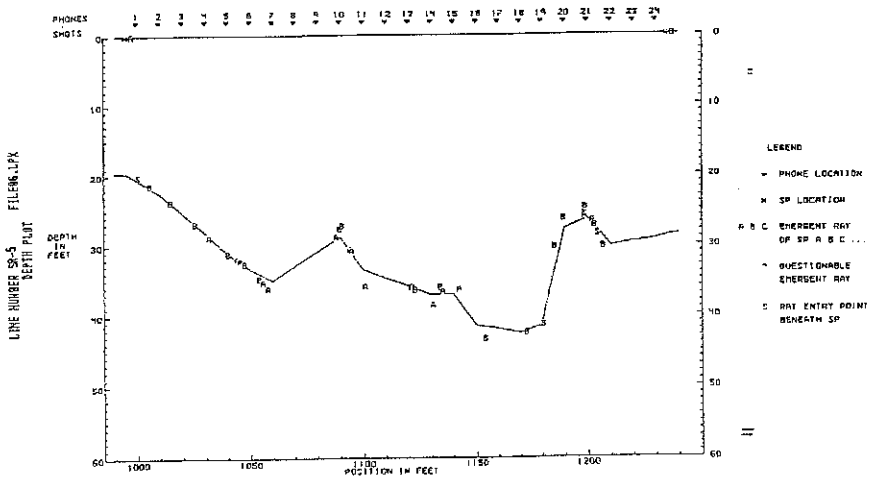
SP	X-Loc	Layer 2
A	995.0	19.5
B	1235.0	20.0
Geo		
1	1000.0	20.0
2	1010.0	22.4
3	1020.0	25.3
4	1030.0	28.2
5	1040.0	31.0
6	1050.0	33.4
7	1060.0	35.0
8	1070.0	32.9
9	1080.0	30.0
10	1090.0	28.7
11	1100.0	33.5
12	1110.0	34.7
13	1120.0	35.0
14	1130.0	37.0
15	1140.0	36.5
16	1150.0	41.4
17	1160.0	41.5
18	1170.0	42.5
19	1180.0	41.4
20	1190.0	27.0
21	1200.0	26.3
22	1210.0	30.2
23	1220.0	29.7
24	1230.0	29.3

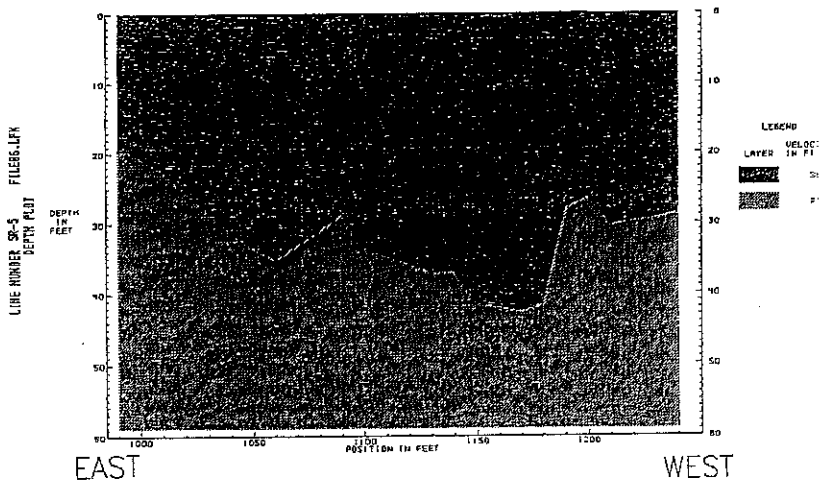
Velocities used:

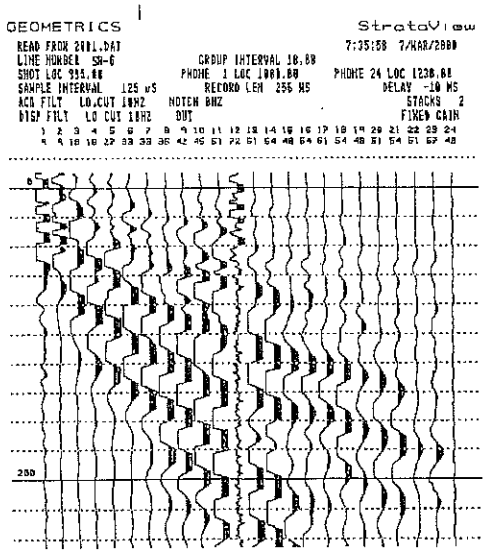
Layer 1	Layer 2
3503.	7356. ft/s

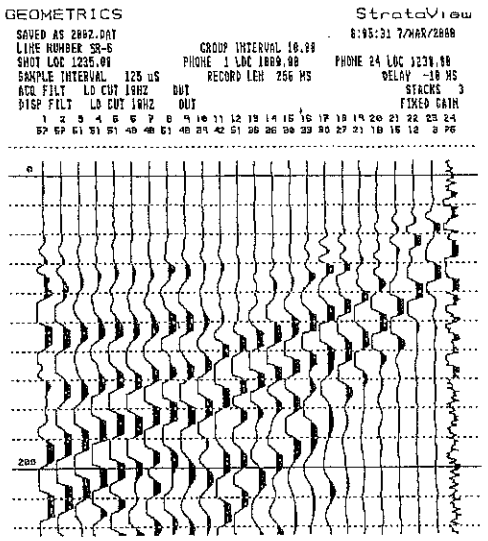


Seismic Refraction Line SR-5


PHONES
SHOTS
LINE NUMBER SR-5
DEPTH PLOT
FILE86.LPK
DEPTH IN FEET
POSITION IN FEET
LEGEND
PHONE LOCATION
SP LOCATION
EMERGENT RAY OF SP A B C ...
QUESTIONABLE EMERGENT RAY
RAY ENTRY POINT BENEATH SP


LINE NUMBER SR-5
DEPTH PLOT
FILE86.LPK
DEPTH IN FEET
POSITION IN FEET
LEGEND
LAYER
EAST
WEST





THE SPREAD FILE D:\821.LPK WAS MADE FROM THE FILES
2002.DPK

SIPT2 V-4.0 For Quality Control of ES-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, V-Loc, etc., and re-run on SIPT2.

TITLE: LINE NUMBER SR-6 FILE821.LPK

DATE: 3-00-2000 TIME: 9:27

Spread A contains 1 Shotpoints and 24 Geophones. Distance units: feet

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	1235.0	.0	.0

Arrival Times T and Layers L

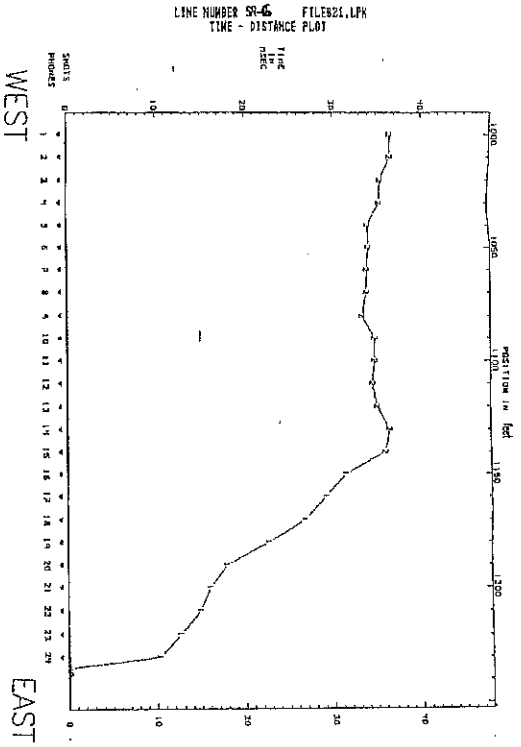
Geo	Elev	X-Loc	Y-Loc	SP A T	L
1	.0	1000.0	.0	36.5	2
2	.0	1010.0	.0	36.5	2
3	.0	1020.0	.0	36.5	2
4	.0	1030.0	.0	36.5	2
5	.0	1040.0	.0	34.0	2
6	.0	1050.0	.0	34.0	2
7	.0	1060.0	.0	33.0	2
8	.0	1070.0	.0	33.0	2
9	.0	1080.0	.0	33.3	2
10	.0	1090.0	.0	34.0	2
11	.0	1100.0	.0	34.0	2
12	.0	1110.0	.0	34.5	2
13	.0	1120.0	.0	35.0	2
14	.0	1130.0	.0	35.3	2
15	.0	1140.0	.0	35.0	2
16	.0	1150.0	.0	31.4	1
17	.0	1160.0	.0	29.1	1
18	.0	1170.0	.0	26.0	1
19	.0	1180.0	.0	22.7	1
20	.0	1190.0	.0	17.9	1
21	.0	1200.0	.0	16.0	1
22	.0	1210.0	.0	14.0	1
23	.0	1220.0	.0	12.6	1
24	.0	1230.0	.0	10.3	1

Depths of layers directly beneath Shotpoints and Geophones for Spread A:

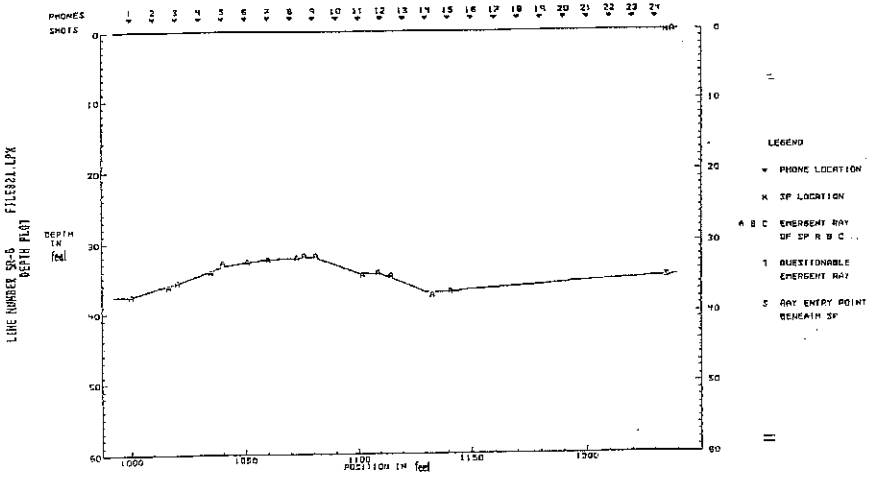
SP	X-Loc	Layer 2
A	1235.0	35.0
Geo		
1	1000.0	37.5
2	1010.0	36.6
3	1020.0	35.8
4	1030.0	34.6
5	1040.0	33.4
6	1050.0	32.8
7	1060.0	32.4
8	1070.0	32.3
9	1080.0	32.1
10	1090.0	33.2
11	1100.0	34.4
12	1110.0	34.6
13	1120.0	35.0
14	1130.0	37.1
15	1140.0	37.1
16	1150.0	36.8
17	1160.0	36.5
18	1170.0	36.4
19	1180.0	36.2
20	1190.0	35.5
21	1200.0	35.2
22	1210.0	35.5
23	1220.0	35.3
24	1230.0	35.0

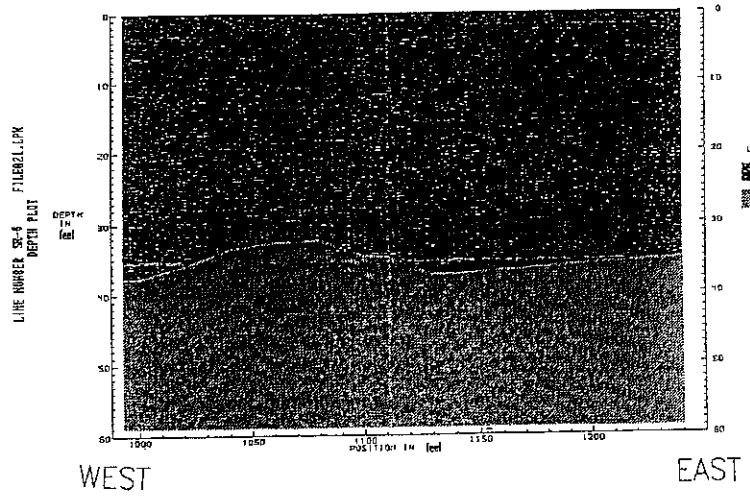
Velocities used:

Layer 1	Layer 2	
2022.	387692.	f/s



Seismic Refraction Line SR-6


LINE NUMBER SR-5 FILE021.LPK
DEPTH PLOT
PHONES
SHOTS
DEPTH IN feet
POSITION IN feet
LEGEND
PHONE LOCATION
SP LOCATION
A B C EMERGENT RAY OF SP A B C ..
? QUESTIONABLE EMERGENT RAY
S RAY ENTRY POINT BENEATH SP


LINE NUMBER SR-4 FILE021.LPK
DEPTH PLOT
DEPTH IN feet
POSITION IN feet
LEGEND
LAYER
VELOCITY IN ft/sec
WEST
EAST

THE SPREAD FILE D:\82.LPK WAS MADE FROM THE FILES
2881.BPK

SIPOC V-4.0 For Quality Control of ES-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final interpretation, add Elev, Y-Loc, etc., and re-run on SIPTZ.

TITLE: LINE NUMBER SR-6 FILE82.LPK

DATE: 3-08-2008 TIME: 9:26

Spread A contains 1 Shotpoints and 24 Geophones. Distance units: feet

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0

Arrival Times T and Layers L

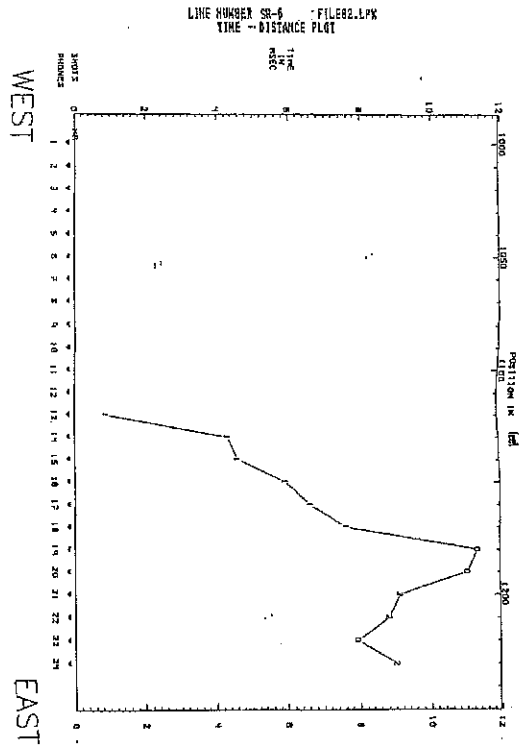
Geo	Elev	X-Loc	Y-Loc	SP A ---T--L
1	.0	1005.0	.0	.0 0
2	.0	1018.0	.0	.0 0
3	.0	1028.0	.0	.0 0
4	.0	1038.0	.0	.0 0
5	.0	1048.0	.0	.0 0
6	.0	1058.0	.0	.0 0
7	.0	1068.0	.0	.0 0
8	.0	1078.0	.0	.0 0
9	.0	1088.0	.0	.0 0
10	.0	1098.0	.0	.0 0
11	.0	1108.0	.0	.0 0
12	.0	1118.0	.0	.0 0
13	.0	1128.0	.0	.0 0
14	.0	1138.0	.0	4.3 1
15	.0	1148.0	.0	4.6 1
16	.0	1158.0	.0	5.9 1
17	.0	1168.0	.0	6.6 1
18	.0	1178.0	.0	7.6 1
19	.0	1188.0	.0	11.3 0
20	.0	1198.0	.0	11.8 0
21	.0	1208.0	.0	9.1 2
22	.0	1218.0	.0	8.0 2
23	.0	1228.0	.0	7.1 0
24	.0	1238.0	.0	9.1 2

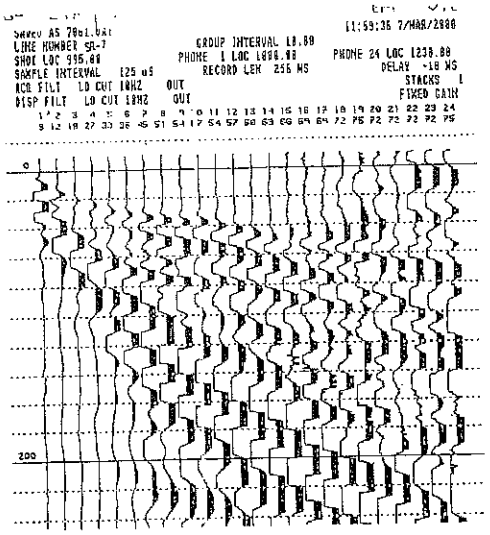
Depths of layers directly beneath Shotpoints and Geophones for Spread A:

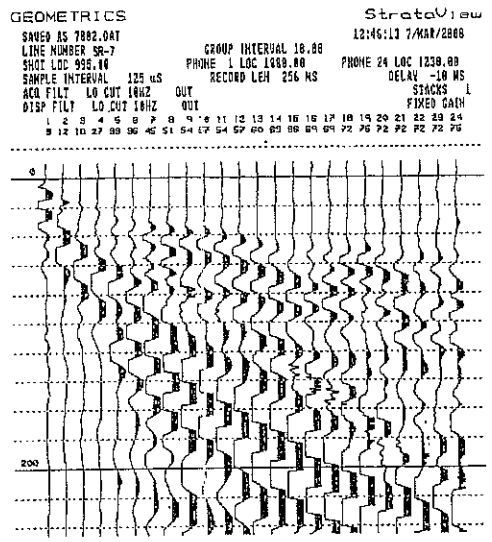
SP	X-Loc	Layer 2
A	995.0	216.6
Geo		
1	1005.0	214.9
2	1018.0	213.6
3	1028.0	212.3
4	1038.0	211.0
5	1048.0	209.7
6	1058.0	208.3
7	1068.0	207.0
8	1078.0	205.7
9	1088.0	204.4
10	1098.0	203.1
11	1108.0	201.8
12	1118.0	200.4
13	1128.0	199.1
14	1138.0	197.8
15	1148.0	196.5
16	1158.0	195.2
17	1168.0	193.8
18	1178.0	192.5
19	1188.0	191.2
20	1198.0	189.9
21	1208.0	188.6
22	1218.0	187.3
23	1228.0	185.9
24	1238.0	183.4

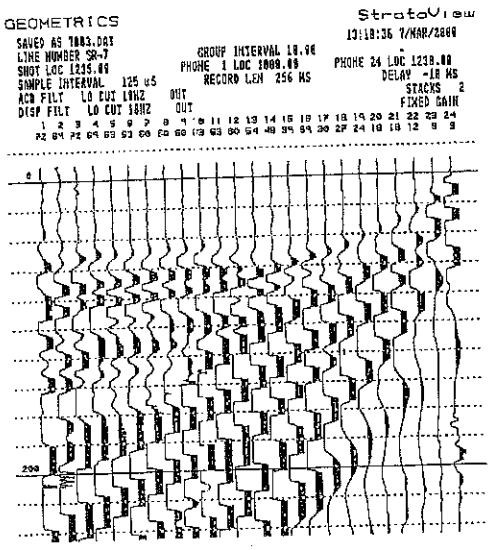
Velocities used:

Layer 1	Layer 2
4681.7	7881.35 f/s









THE SPREAD FILE D:\07.LPK HAS MADE FROM THE FILES
7001.DPK
7003.DPK

SIPQC V-4.0 For Quality Control of ES-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, Y-Loc, etc., and re-run on SIPI2.

TITLE: LINE NUMBER SR-7 FILE07.LPK

DATE: 3-08-2000 TIME: 10:16

Spread A contains 2 Shotpoints and 24 Geophones. Distance units: feet.

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0
B	.0	1235.0	.0	.0

Arrival Times T and Layers L

Geo	Elev	X-Loc	Y-Loc	SP A T	SP A L	SP B T	SP B L
1	.0	1000.0	.0	1.5	1	50.0	3
2	.0	1010.0	.0	6.0	1	56.6	3
3	.0	1020.0	.0	11.6	1	54.0	3
4	.0	1030.0	.0	13.6	1	52.3	3
5	.0	1040.0	.0	19.0	2	51.0	3
6	.0	1050.0	.0	21.4	2	51.6	3
7	.0	1060.0	.0	24.1	2	51.9	3
8	.0	1070.0	.0	25.4	2	50.6	3
9	.0	1080.0	.0	28.0	2	50.6	3
10	.0	1090.0	.0	28.1	2	49.4	3
11	.0	1100.0	.0	30.1	2	50.3	3
12	.0	1110.0	.0	32.0	2	49.0	3
13	.0	1120.0	.0	36.5	2	46.7	2
14	.0	1130.0	.0	41.0	2	46.3	2
15	.0	1140.0	.0	42.0	2	45.0	2
16	.0	1150.0	.0	43.6	2	43.0	2
17	.0	1160.0	.0	44.0	2	40.5	2
18	.0	1170.0	.0	46.0	2	33.3	1
19	.0	1180.0	.0	49.0	2	27.3	1
20	.0	1190.0	.0	52.5	2	23.4	1
21	.0	1200.0	.0	54.6	2	18.0	1
22	.0	1210.0	.0	56.0	2	13.0	1
23	.0	1220.0	.0	58.0	2	6.5	1
24	.0	1230.0	.0	59.5	2	1.5	1

Depths of layers directly beneath Shotpoints and Geophones for Spread A:

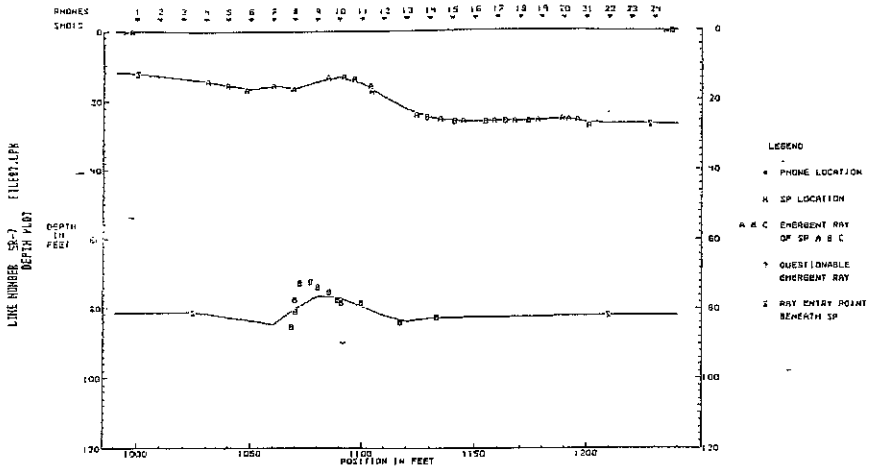
SP	X-Loc	Layer 2	Layer 3
A	995.0	11.9	81.4
B	1235.0	26.9	81.9
Geo			
1	1000.0	12.1	81.4
2	1010.0	12.8	81.4
3	1020.0	13.5	81.4
4	1030.0	14.2	81.5
5	1040.0	15.4	82.3
6	1050.0	16.0	83.4
7	1060.0	16.8	84.7
8	1070.0	16.6	86.1
9	1080.0	14.6	76.4
10	1090.0	13.3	76.8
11	1100.0	15.1	75.5
12	1110.0	18.0	82.1
13	1120.0	22.4	83.8
14	1130.0	24.7	82.9
15	1140.0	25.6	82.6
16	1150.0	25.0	82.5
17	1160.0	25.9	82.4
18	1170.0	25.7	82.3
19	1180.0	25.6	82.2
20	1190.0	25.2	82.1
21	1200.0	26.5	82.0
22	1210.0	26.6	81.9
23	1220.0	26.7	81.9
24	1230.0	26.9	81.9

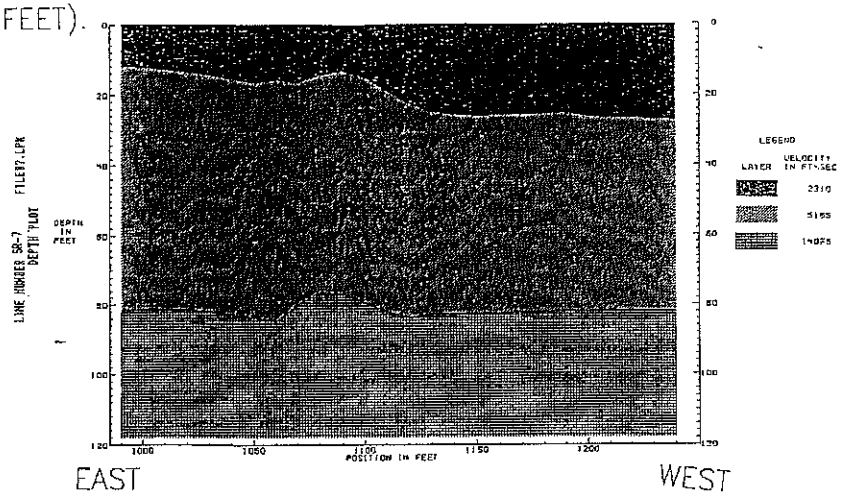
Velocities used:

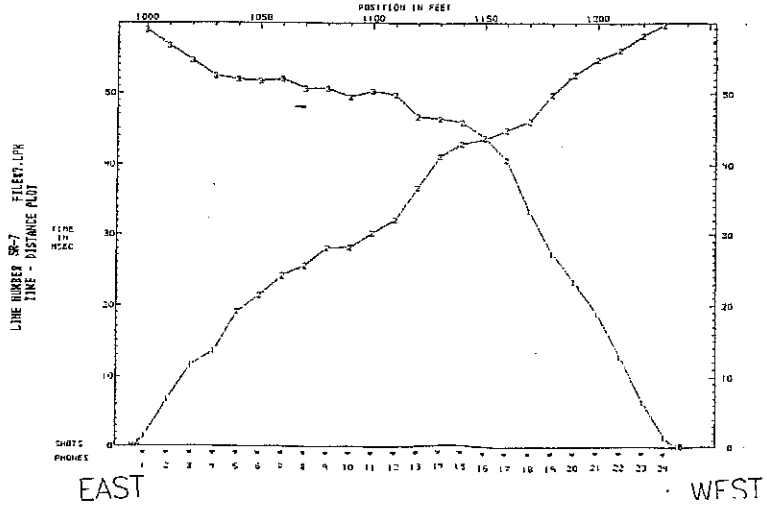
Layer 1	Layer 2	Layer 3
2310.	5165.	14876. ft/s

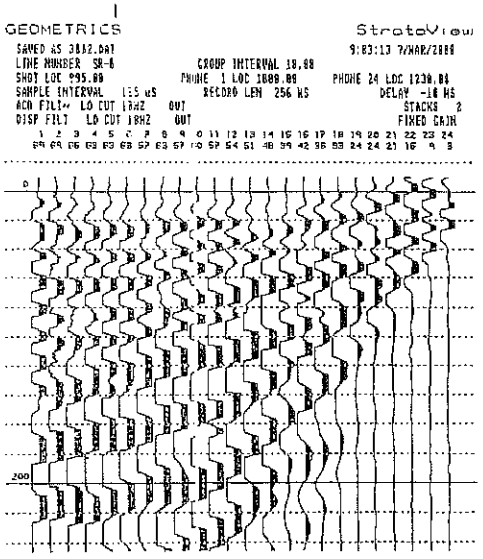
Seismic Refraction Line SR-7

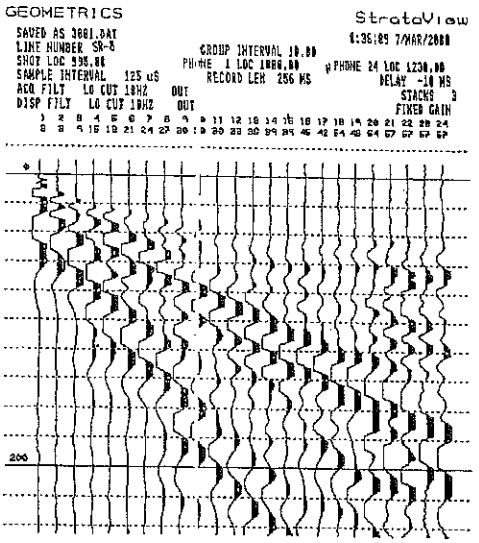
NOTE: EFFECTIVE EXPLORATION DEPTH IS 70' (FEET).











THE SPREAD FILE 0:\83.LPK WAS MADE FROM THE FILES
3881.BPK
3882.BPK

SIPRC V-4.0 For Quality Control of EG-2401, SmartSeis & StrataView field data.

(C) Copyright Rimrock Geophysics, Inc. 1991-1993

For Final Interpretation, add Elev, Y-Loc, etc., and re-run on SIPT2.

TITLE: LINE NUMBER SR-8 FILE83.LPK

DATE: 3-08-2000 TIME: 9:36

Spread A contains 2 Shotpoints and 24 Geophones. Distance units: feet

SP	Elev	X-Loc	Y-Loc	Depth
A	.0	995.0	.0	.0
B	.0	995.0	.0	.0

Arrival Times T and Layers L

Geo	Elev	X-Loc	Y-Loc	SP A T	SP A L	SP B T	SP B L
1	.0	1000.0	.0	.5	1	11.0	2
2	.0	1010.0	.0	4.0	1	13.9	2
3	.0	1020.0	.0	7.3	1	13.6	2
4	.0	1030.0	.0	11.9	1	12.0	2
5	.0	1040.0	.0	13.9	1	12.0	2
6	.0	1050.0	.0	15.1	1	11.0	2
7	.0	1060.0	.0	17.9	1	11.0	2
8	.0	1070.0	.0	21.1	1	10.0	2
9	.0	1080.0	.0	24.0	1	8.0	2
10	.0	1090.0	.0	28.5	1	9.3	2
11	.0	1100.0	.0	30.6	1	9.0	2
12	.0	1110.0	.0	34.0	2	9.6	2
13	.0	1120.0	.0	35.3	2	7.6	2
14	.0	1130.0	.0	36.0	2	7.1	2
15	.0	1140.0	.0	37.4	2	6.5	2
16	.0	1150.0	.0	36.5	2	7.1	2
17	.0	1160.0	.0	39.9	2	1.3	2
18	.0	1170.0	.0	40.9	2	.0	0
19	.0	1180.0	.0	40.9	2	.0	0
20	.0	1190.0	.0	41.6	2	.0	0
21	.0	1200.0	.0	40.0	2	.0	0
22	.0	1210.0	.0	40.5	2	.0	0
23	.0	1220.0	.0	40.3	2	.0	0
24	.0	1230.0	.0	40.3	2	.0	0

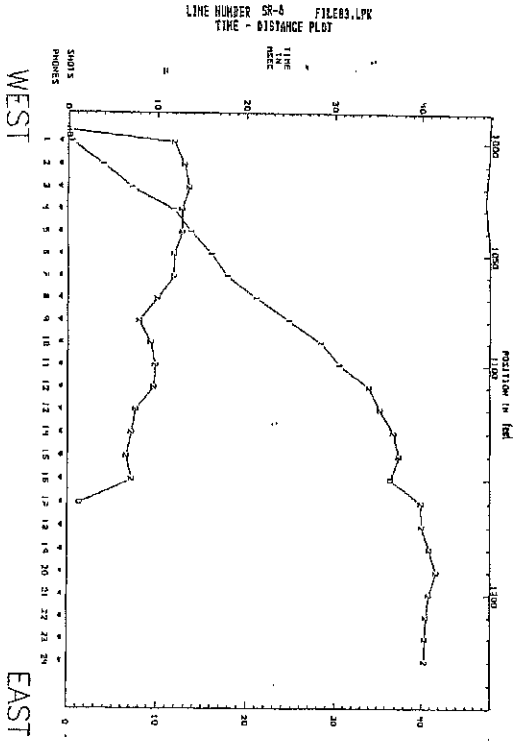
Depths of layers directly beneath Shotpoints and Geophones for Spread A:

SP	X-Loc	Layer 2
B	995.0	18.5

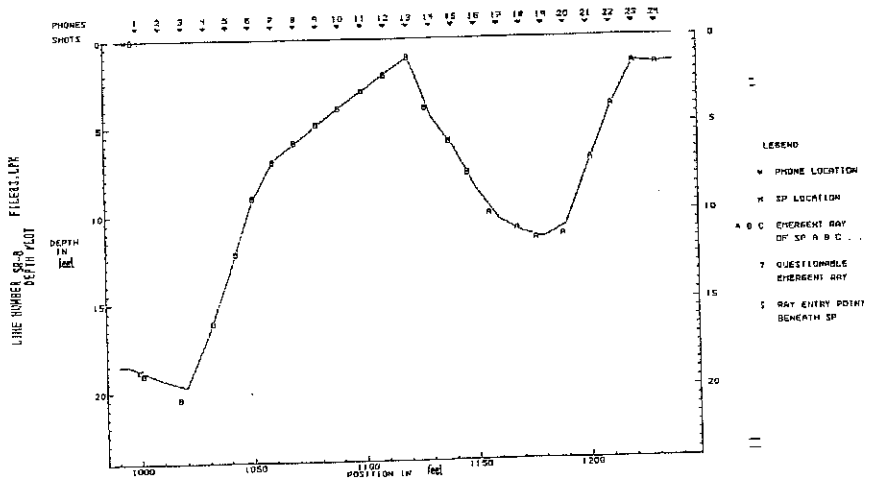
Geo		
1	1000.0	18.0
2	1010.0	15.3
3	1020.0	19.7
4	1030.0	16.0
5	1040.0	13.3
6	1050.0	9.3
7	1060.0	5.9
8	1070.0	6.9
9	1080.0	4.9
10	1090.0	3.9
11	1100.0	3.0
12	1110.0	2.0
13	1120.0	1.1
14	1130.0	4.5
15	1140.0	6.3
16	1150.0	9.7
17	1160.0	10.4
18	1170.0	11.1
19	1180.0	11.5
20	1190.0	10.0
21	1200.0	7.4
22	1210.0	4.3
23	1220.0	1.5
24	1230.0	1.6

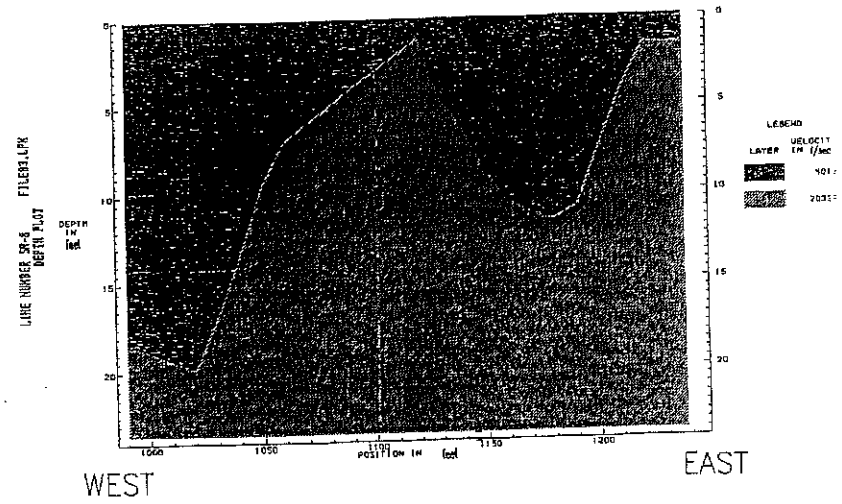
Velocities used:

Layer 1	Layer 2
4013.	20332. f/s



Seismic Refraction Line SR-8


PHONES
SHOTS
LINE NUMBER SR-8
DEPTH PLOT
FILE03.LPK
DEPTH IN feet
POSITION IN feet
LEGEND
PHONE LOCATION
SP LOCATION
A B C EMERGENT RAY OF SP A B C . .
? QUESTIONABLE EMERGENT RAY
RAY ENTRY POINT BENEATH SP


LINE NUMBER SR-5
DEPTH PLOT
FILE03.LPK
DEPTH IN feet
POSITION IN feet
LEGEND
LAYER
VELOCITY IN f/sec
WEST
EAST

RIO VALENCIANO RESERVOIR

GEOTECHNICAL REPORT

APPENDIX D

TEST PITS

BLACK & VEATCH
CONSULTING ENGINEERS

LOG OF TEST PIT

TEST PIT NO. 1
SHEET 1 OF 2

CLIENT	PROJECT	PROJECT NO.
AFI	Rio Valenciano	096628

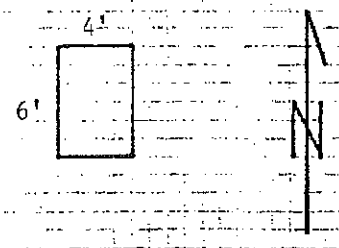
PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE
1.4 km south of Juncos,PR	Not surveyed		6 ft	03/07/00

SURFACE CONDITIONS	INSPECTOR
Undisturbed natural slope	Norm Holst

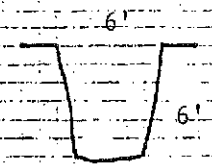
METHOD OF EXCAVATION
Small backhoe mounted on Cat rubber tired tractor

CHECKED BY	APPROVED BY

PLAN VIEW SKETCH, DIMENSIONS, AND NORTH ARROW

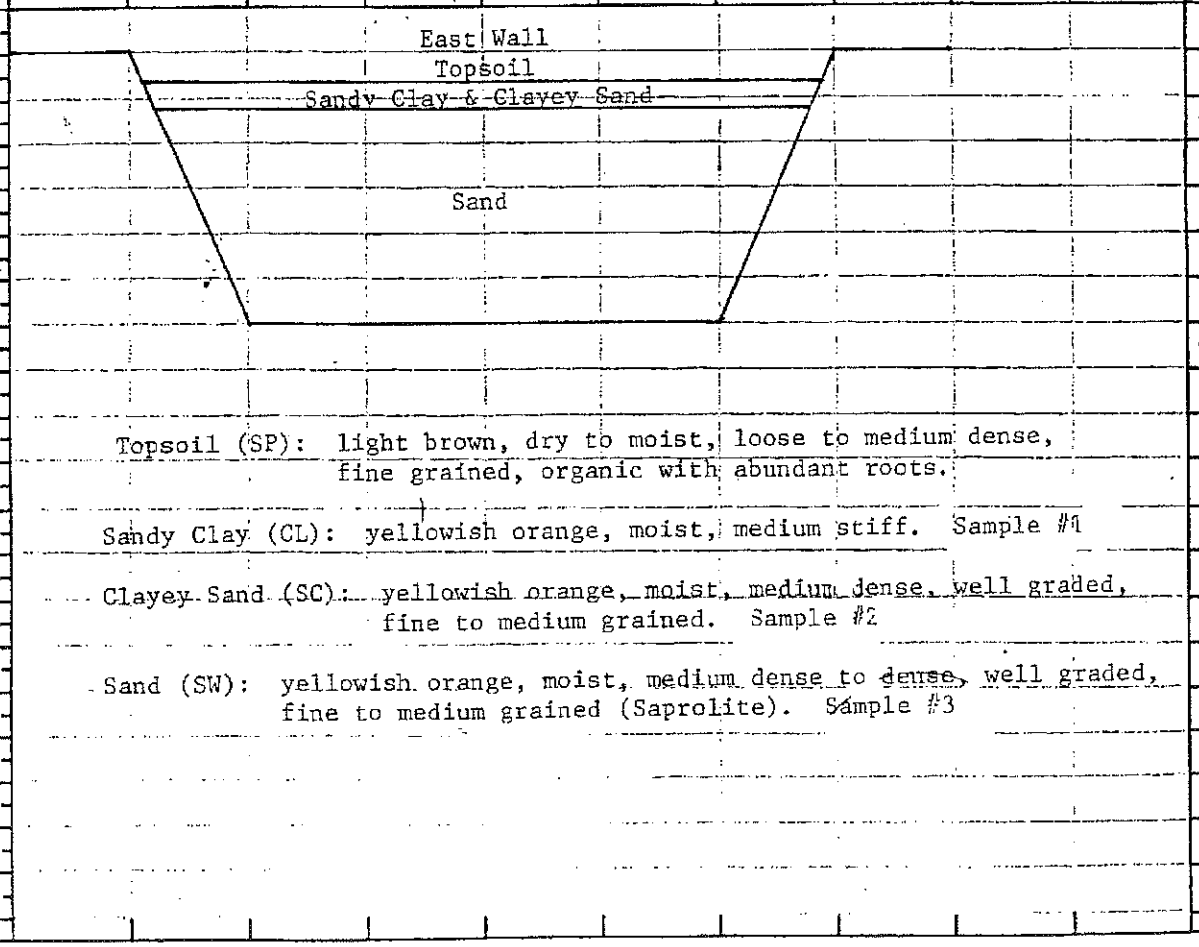


PROFILE VIEW SKETCH AND DIMENSIONS



SAMPLE TYPE AND NUMBER	DEPTH IN FEET	CLASSIFICATION AND DESCRIPTION OF MATERIAL
Bulk #1&2	0–1	Topsoil
	1–2	Sandy Clay & Clayey Sand
Bulk #3	2–6	Sand

STATION INTERVALS



Topsoil (SP): light brown, dry to moist, loose to medium dense, fine grained, organic with abundant roots.

Sandy Clay (CL): yellowish orange, moist, medium stiff. Sample #1

Clayey Sand (SC): yellowish orange, moist, medium dense, well graded, fine to medium grained. Sample #2

Sand (SW): yellowish orange, moist, medium dense to dense, well graded, fine to medium grained (Saprolite). Sample #3

REMARKS:
Located approximately 70 ft bearing S 35 E of BV - 4
Photos #21 & #22 with scale in NW corner

P-ST-038A

BLACK & VEATCH
CONSULTING ENGINEERS

LOG OF TEST PIT

TEST PIT NO. 1
SHEET 2 OF 2

CLIENT	PROJECT	PROJECT NO.
AFI	Rio Valenciano	096628

PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE
1.4 km south of Juncos,PR	Not surveyed		6 ft	03/07/00

SURFACE CONDITIONS	INSPECTOR
Undisturbed natural slope	Norm Holst

METHOD OF EXCAVATION
Small backhoe mounted on Cat rummer tired tractor

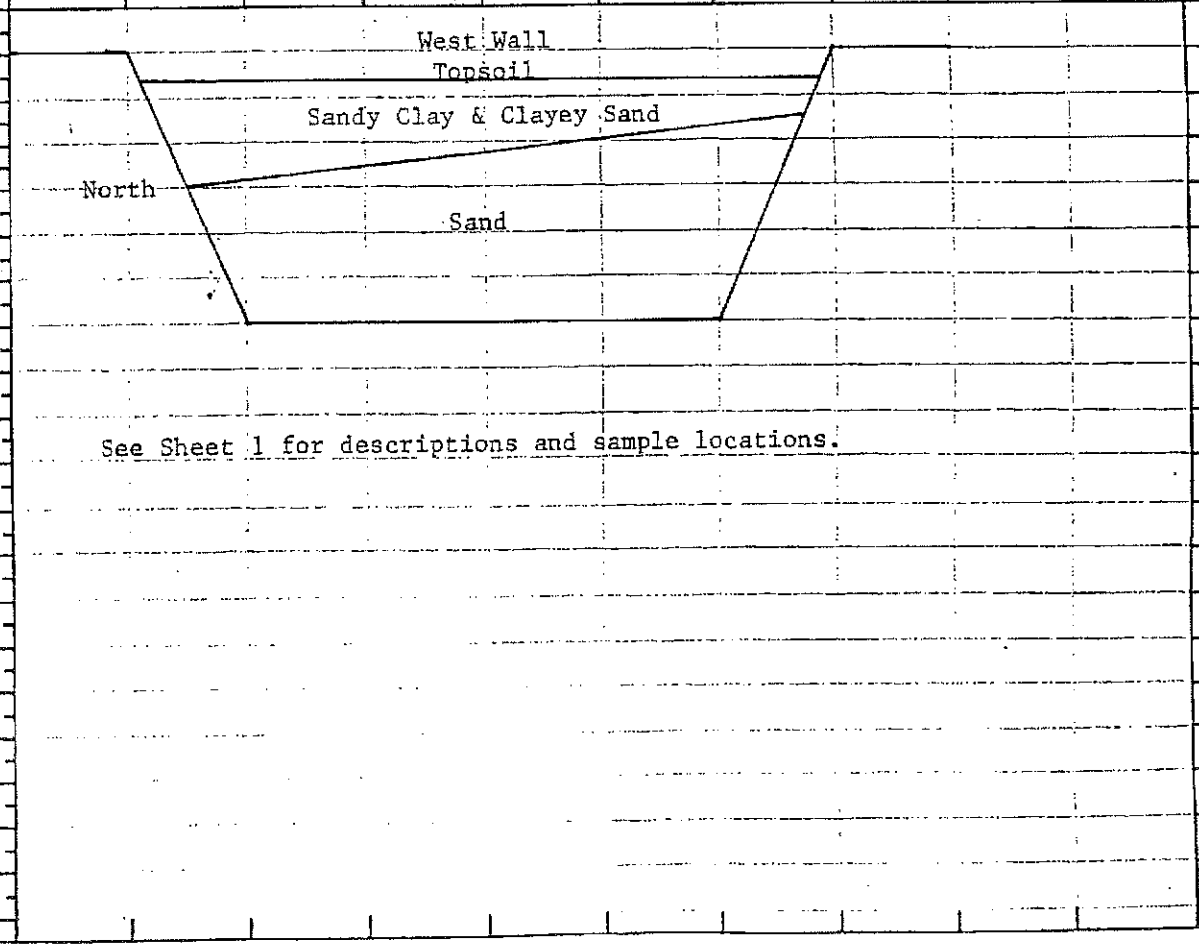
CHECKED BY	APPROVED BY

PLAN VIEW SKETCH, DIMENSIONS, AND NORTH ARROW

PROFILE VIEW SKETCH AND DIMENSIONS

SAMPLE TYPE AND NUMBER	DEPTH IN FEET	CLASSIFICATION AND DESCRIPTION OF MATERIAL	DEPTH

STATION INTERVALS



See Sheet 1 for descriptions and sample locations.

REMARKS:
Located approximately 70 ft bearing S 35 E of BV - 4
Photos #21 & #22 with scale in NW corner

P-ST-038A

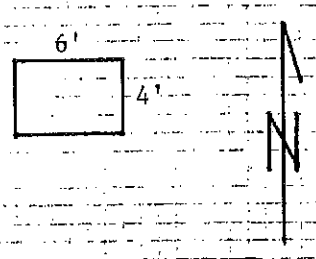
BLACK & VEATCH
CONSULTING ENGINEERS

LOG OF TEST PIT

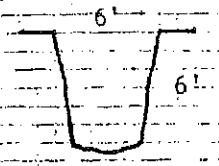
TEST PIT NO. 2
SHEET 1 OF 1

CLIENT: AFI	PROJECT: Rio Valenciano		PROJECT NO.: 096628
PROJECT LOCATION: 1.4 km south of Juncos,PR	COORDINATES: Not surveyed	ELEVATION (DATUM):	TOTAL DEPTH: 6 ft / DATE: 03/07/00
SURFACE CONDITIONS: Undisturbed natural slope		INSPECTOR: Norm Holst	
METHOD OF EXCAVATION: Small backhoe mounted on Cat rubber tired tractor			
CHECKED BY:		APPROVED BY:	

PLAN VIEW SKETCH, DIMENSIONS, AND NORTH ARROW



PROFILE VIEW SKETCH AND DIMENSIONS



SAMPLE TYPE AND NUMBER	DEPTH IN FEET	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	0	South Wall Topsoil
	1	
Bulk #1	2	Clayey Sand
	3	
	4	Sand with Silt
Bulk #2	5	
	6	

STATION INTERVALS

DEPTH

Topsoil (SW): light brown, dry to moist, loose to medium dense, well graded, fine to medium grained, organic with abundant roots.

Clayey Sand (SC): mottled yellowish orange and red, moist, medium stiff, well graded, fine to medium grained. Sample #1

Sand with Silt (SW-SM): yellowish orange, moist, medium dense to dense, well graded, fine to medium grained (Saprolite). Sample #2

REMARKS: Located approximately 8 ft NE of BV - 3 location

Photos #19 & #20 with scale in SW corner

P-ST-038A

BLACK & VEATCH
CONSULTING ENGINEERS

LOG OF TEST PIT

TEST PIT NO. 3
SHEET 1 OF 1

CLIENT	PROJECT	PROJECT NO.
AFI	Rio Valenciano	096628

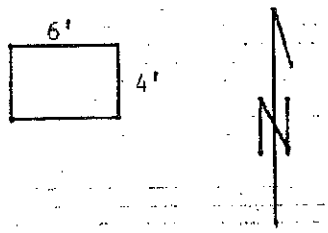
PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE
1.4 km south of Juncos,PR	Not surveyed		6 ft	03/07/00

SURFACE CONDITIONS	INSPECTOR
Undisturbed natural slope	Norm Holst

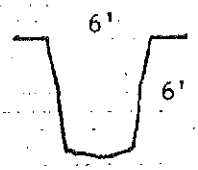
METHOD OF EXCAVATION
Small backhoe mounted on Cat rubber tired tractor

CHECKED BY	APPROVED BY

PLAN VIEW SKETCH, DIMENSIONS, AND NORTH ARROW



PROFILE VIEW SKETCH AND DIMENSIONS



SAMPLE TYPE AND NUMBER	DEPTH IN FEET	CLASSIFICATION AND DESCRIPTION OF MATERIAL
		STATION INTERVALS
	0	South Wall
	1	Topsoil
Bulk #1	2	
	3	Clayey Sand
	4	
Bulk #2	5	Sand
	6	

Topsoil (SW): light brown, dry to moist, loose to medium dense, well graded, fine to medium grained, organic with abundant roots.

Clayey Sand (SC): mottled yellowish orange and light brown, moist, medium dense, well graded, fine to medium grained. Sample #1

Sand (SW): yellowish orange, moist, medium dense to dense, well graded, fine to medium grained (Saprolite). Sample #2

REMARKS: Located approximately 10 ft south of initial BV - 2 location

Photos #17 & #18 with scale in SW corner

P-ST-038A

BLACK & VEATCH
CONSULTING ENGINEERS

LOG OF TEST PIT

TEST PIT NO. 4
SHEET 1 OF 1

CLIENT	PROJECT	PROJECT NO.
AFI	Rio Valenciano	096628

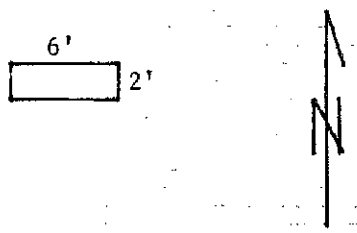
PROJECT LOCATION	COORDINATES	ELEVATION (DATUM)	TOTAL DEPTH	DATE
1.4 km south of Juncos,PR	Not surveyed		3 ft	03/07/00

SURFACE CONDITIONS	INSPECTOR
Ground stripped of vegetation	Norm Holst

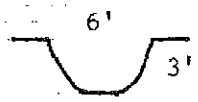
METHOD OF EXCAVATION
Small backhoe mounted on Cat rubber tired tractor

CHECKED BY	APPROVED BY

PLAN VIEW SKETCH, DIMENSIONS, AND NORTH ARROW



PROFILE VIEW SKETCH AND DIMENSIONS



SAMPLE TYPE AND NUMBER	DEPTH IN FEET	CLASSIFICATION AND DESCRIPTION OF MATERIAL (STATION INTERVALS)	DEPTH
Bulk #1	0	Topsoil	
	1	Sand	
	2		
	3		

Topsoil (SW - SM): light brown, dry to moist, loose to medium dense, well graded, fine to medium grained sand with some silt, organics and abundant roots.

Sand (SW): yellowish orange, moist, medium dense, well graded, fine to medium grained (Saprolite). Sample #1

REMARKS: Located approximately 70 ft east of BV - 8

Photos #1 & #2 of south & north walls respectively

P-ST-038A

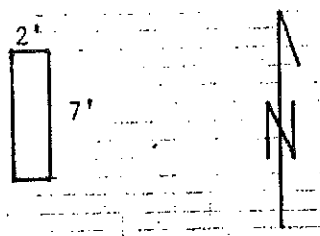
BLACK & VEATCH
CONSULTING ENGINEERS

LOG OF TEST PIT

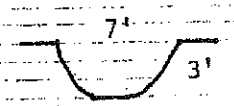
TEST PIT NO. 5
SHEET 1 OF 1

CLIENT: AFI	PROJECT: Rio Valenciano		PROJECT NO.: 096628
PROJECT LOCATION: 1.4 km south of Juncos,PR	COORDINATES: Not surveyed	ELEVATION (DATUM):	TOTAL DEPTH: 3' / DATE: 03/07/00
SURFACE CONDITIONS: Ground stripped of vegetation		INSPECTOR: Norm Holst	
METHOD OF EXCAVATION: Small backhoe mounted on Cat rubber tired tractor			
CHECKED BY:		APPROVED BY:	

PLAN VIEW SKETCH, DIMENSIONS, AND NORTH ARROW



PROFILE VIEW SKETCH AND DIMENSIONS



SAMPLE TYPE AND NUMBER	DEPTH IN FEET	CLASSIFICATION AND DESCRIPTION OF MATERIAL (STATION INTERVALS)	DEPTH
		West Wall	
	0	Topsoil	
Bulk #1	1	North — Sand with Clayey Lenses	
Bulk #2	2	Sand	
	3		
		East Wall	
	0	Topsoil	
	1	North — Sand with Clayey Lenses	
	2	Sand (Bottom hard)	
	3		

Topsoil (SP - SM): light brown, dry to moist, loose to moderately dense, poorly grade, mostly fine with some medium grained, some silt, organic with abundant roots.

Sand with Clayey Lenses: sand (SW) with few lenses (to 2 inch thick) of clayey sand (SC), mottled yellowish orange to light brown, moist, moderately dense, well graded, fine to medium grained. Sample #1

Sand (SW): yellowish orange, moist, medium dense to dense, well graded, fine to medium grained (Saprolite). Sample #2

REMARKS: Located approximately 60 ft south of BV - 5

Pictures #3 & #4 of west & east walls respectively

1-ST-D38Y

APPENDIX A-2

MONITORING WELL COMPLETION LOGS

APPENDIX C

MEMORANDUM ON
DESIGN OF PROPOSED DAM AND RESERVOIRON THE RIO VALENCIANO
–BUCK, SEIFERT, AND JOST-

PUERTO RICO AQUEDUCT AND SEWER AUTHORITY

MEMORANDUM
ON
DESIGN OF
PROPOSED DAM AND RESERVOIR
ON THE
RIO VALENCIANO

JULY 16, 1971

BUCK, SEIFERT AND JOST
Consulting Engineers
429 Sylvan Avenue
Englewood Cliffs, New Jersey

GEORGE H. BUCK CHARLES F. JOST EDWIN H. HARTMAN DOMENIC J. PULICE

ASSOCIATE ENGINEERS
HARD N. AUMILLER
JOHN J. CANNIZZO
RAMON CORTEGUERA
JUAN R. de TORRES
ROBERT J. DI PALMA
BENJAMIN FELDMAN
BARTON JONES
L. A. LEYENBERGER
J. RICHARD TOMPKINS
GUIDO VON AUTENRIED

BUCK, SEIFERT AND JOST
CONSULTING ENGINEERS
429 SYLVAN AVENUE
ENGLEWOOD CLIFFS, N.J. 07632

SAN JUAN, PUERTO RICO

CABLE ADDRESS - BUSEJOS
NEW JERSEY 201-567-8990
NEW YORK 212-563-5181

WATER SUPPLY
DAMS, FILTRATION AND PUMPING STATIONS
SANITARY AND HYDRAULIC INVESTIGATIONS
WATER POWER AND FLOOD CONTROL
SEWAGE AND INDUSTRIAL WASTES DISPOSAL
VALUATION AND RATES

LABORATORIES FOR:
ANALYSIS OF WATER
ANALYSIS OF SEWAGE
TESTING OF SAND
TESTING OF GRAVEL

MEMORANDUM ON DESIGN OF PROPOSED DAM AND RESERVOIR ON THE RIO VALENCIANO

Mr. Wilfredo Vivoni, Executive Director
Puerto Rico Aqueduct and Sewer Authority
Post Office Box 7066
Barrio Obrero Station
San Juan, Puerto Rico 00916

Dear Mr. Vivoni:

This memorandum is prepared to summarize our analysis of the design of the proposed dam on the Rio Valenciano, to describe briefly the type of structure selected with its design criteria, and to present our latest estimate of construction cost of the dam and intake.

LOCATION

The site for the proposed dam across the Rio Valenciano is at a narrow place in the river valley, approximately 1.4 kilometers upstream from the bridge over the Rio Valenciano at Juncos. The selection of this site was covered in our Memorandum on Rio Valenciano Impounding Reservoir dated May, 1969.

The watershed tributary to the site of the proposed Rio Valenciano dam is 14.85 square miles.

VOLUME OF STORAGE AND YIELD

Only a few stream flow measurements were made at the dam site by the Authority during 1966 and 1967. Daily stream flow records for the period beginning in 1959 are available for the recording stream flow stations maintained by the U.S. Geological Survey on the Rio Gurabo, 4.9 miles downstream from the mouth of the Rio Valenciano and on the Rio Grande de Loiza at Caguas. These records were used to develop a synthesized record of probable monthly average flow at the dam site for the same period.

Based on our study of these records, we have determined the yield in addition to the natural flow of the stream when operated in conjunction with the Carraizo Reservoir downstream is as follows:

Drought Period	MGD Increase
5 Months	21.9
6 Months	18.3
7 Months	15.6
8 Months	13.7

SILTATION

Siltation is a problem in most reservoirs in Puerto Rico and must be considered in determining the total volume of storage required for the Rio Valenciano Reservoir. Siltation rates for some of the reservoirs in Puerto Rico have been as follows:

Reservoir	Original Capacity Per Square Mile of Watershed In Million Gallons	Siltation in Million Gallons Per Year Per Square Mile
Guayabal	72.5	1.18
Coamo	16.9	0.27
Carite	390.	0.36
Patillas	18.8	0.22
Comerio	12.1	0.38
Loiza	31.6	0.50

The rate for the proposed reservoir probably will be about 7 million gallons per year.

FLOW LINE OF RESERVOIR

The capacity of the proposed reservoir basin and the corresponding flooded area are shown in Diagram No. 1. These were computed from aerial maps at a scale of 1:2000 with contours at 2 meter intervals.

We have selected a flow line at elevation 100.0 meters as the most appropriate for the development. At this elevation, without siltration, the capacity of the reservoir will be about 3,750 million gallons. The excess storage of some 350 million gallons will be adequate to maintain the yield as stated on Page 2 with the siltation anticipated to occur over 50 years.

QUALITY OF WATER

Sampling and analysis by the USGS of the samples collected on the Rio Valenciano at Juncos and the Rio Gurabo at Gurabo were made between 1958 and 1963. A total of 31 samples at Juncos and 322 at Gurabo were collected and analyzed. The results of these analyses are summarized in Table No. 1. Although the analyses were made in the prior decade, there has been no development within the watershed that would have a major effect on water quality.

Based on the average results obtained for these samples, it appears the natural raw water of the stream is moderately turbid and colored. The chemical balance of the alkalinity, free carbon dioxide and pH value indicate the water is not inclined to be corrosive. The iron content is below that known to cause difficulties with staining problems. Tests for manganese content were not made. The chloride content and hardness are normal. The water is not greatly different from that now entering the Loiza Reservoir and is entirely suitable for treatment by standard filtration methods.

FLOOD FLOWS

In connection with the design of the dam, it is necessary to determine the magnitude of floods that are likely to be experienced. This was done and discussed in our Memorandum on Rio Valenciano Impounding Reservoir of May, 1969 and will not be repeated herein. It is sufficient for the purposes of this memorandum to state that a flood with a peak discharge of about 40,000 cubic feet per second, a magnitude expected to occur about once in 100 years, was adopted as the recommended flood for preventing damage to private property along the reservoir shores, generally property lying above elevation 101.00. The recommended probable maximum flood for use in design of the structures against failure, to prevent damage to downstream settlements, was estimated to be of the general magnitude of 60,000 cubic feet per second.

GEOLOGY

The geology in the vicinity of the dam site indicates the bedrock formations are relatively young and the region does not have a long and complex geological history. It is probable that no buried gorges underlie the stream and that bedrock lies at shallow depth beneath the river. The bedrock is generally hard, sound and impermeable.

A visual inspection of the site shows that the rock, principally granite, outcrops near the top of the proposed dam on the left bank.

Boring data indicate a fault crosses the dam at about a 45 degree angle near the base of the valley and bears northwesterly downstream. Data obtained from borings leads to the opinion the fault does not constitute a zone of weakness since there is no indication of the presence of a weak or deeply-decayed crushed zone. The fault will be sealed by pressure grouting to prevent seepage from the reservoir.

A series of test borings were made at the site, one line on the proposed centerline of the dam, one line approximately 25 meters upstream from the centerline and a third line approximately 25 meters downstream from the centerline. The line of borings upstream and downstream from the centerline were made to determine if any erratic changes occur in the level of the top of sound bedrock.

The test borings indicated layers of soil, sands and gravel overlay rock in the valley and extend up the valley sides. The borings confirm the fact that the bedrock is of granite. It has adequate strength to support any

dam structure that reasonably might be placed on it. The bedrock itself is not soluble nor is it characterized by solution channels or cavernous conditions. Jointing in upper surficial part of the bedrock indicates that the foundation should be grouted to prevent underseepage.

The maximum thickness of sands, gravels, clays and decayed rock over the bedrock is approximate feet.

TYPE OF DAM

It would be possible to construct an earth-fill type of dam at the site. The clay and sands in the valley are adequate for the mass sections of such a dam. However, this type of dam would require additional land for a side channel spillway and would introduce difficult design and construction problems in providing the necessary spillway capacity. This would increase the cost of this type of construction materially.

The valley is too wide for a thin arch type of dam. Massive abutments would be required on both sides.

A combination concrete gravity overflow and intake section with earth fill abutments was selected as the least costly type of structure. This type of dam appears well adapted to pass flood flows and provide selectivity of regulated discharge through the intake structure. Consequently, we have adopted the concrete gravity-type dam for the overflow and intake section and earth fill type abutments at both the right and left banks of the valley.

ARRANGEMENT OF SPILLWAY

Only one spillway arrangement has been considered for the gravity-type concrete and earth fill abutments dam due to limitations of crest length and the need to control maximum pool level at flood flows.

To overcome the objections of the Tainter gate and wheel gate spillways as determined in the studies for the Rio de la Plata Dam, a bascule type of gate for installation in each spillway bay has been adopted. This type of gate is constructed of structural steel and steel plate. It is hinged at the bottom, at the crest of the spillway, and is raised or lowered by hydraulic cylinders located in the dam section. When the gate is in its fully lowered position it is recessed within the dam and forms a part of the ogee surface for the spillway. The operation can be manually controlled or can be automatically controlled by sensing the elevation of the water in the reservoir. The automatic controls would be set to maintain the water surface in the reservoir at elevation 100.0 under all normal conditions, the gate raising or lowering to permit water to pass over the top or to be impounded in the reservoir as required. This type of gate would require four spillway bays, each 15.24 meters wide. Since the height of this type of gate is limited, the crest of the spillway would be at elevation 96.00 meters. The maximum flow line at the spillway crest would be elevation 101.4 meters with the maximum estimated flood of 60,000 cubic feet per second passing over the spillway. The top of the dam would be at elevation 103.0 meters.

With the bascule type of gate installed with the reservoir at elevation 100.0 meters, the reservoir will impound almost 3,750 million gallons, with safe yields as set forth on Page 2.

TYPE OF SPILLWAY SELECTED

An ungated spillway gives excellent operation under adverse conditions but is the most expensive to construct. Also, it requires the purchase of much more land, the relocation of greater lengths of highways and the acquisition of more houses.

The bascule type gate is favorable for operation under adverse conditions but is not possible of unwatering except if a floating caisson is provided. This is not considered necessary for this type of gate since the operating mechanisms are within the dam structure and are accessible at all times and under all conditions. These gates, being low in height, have a much greater chance of the elevation of the reservoir being at or below the crest of the spillway, when they can be examined, repaired and maintained.

A curve showing the capacity of the spillway section proposed is shown in Diagram No. 2. The plan, downstream elevation and sections of the dam as proposed are shown in Diagrams Nos. 3, 4 and 5 respectively.

INTAKE AND FLOW REGULATION

As previously mentioned, the intake forms an integral part of the dam, being a part of the non-overflow section of the dam, located near the center of the existing stream. The bascule gates control mechanisms, intake discharge control valves and tunnel dewatering equipment also will be housed in this section.

Three 48-inch diameter intake ports are provided in the upstream face of the intake chamber, spaced about eight meters apart vertically

between elevation 80.0 and 96.25 meters. Each intake port is to be protected on the outside with a fabricated wrought iron trash rack and controlled on its inside face by a 48-inch diameter butterfly valve, hand wheel operated. The flow from the intake chamber passes through a 48-inch pipe, through a 48-inch butterfly valve, and discharges to atmosphere through a 48-inch Howell Bunger valve. The Howell Bunger valve provides discharge flow regulation. The 48-inch pipe from the intake chamber, through a tee immediately upstream of the 48-inch butterfly valve, is extended to the left bank of the river for direct connection to a future filtration plant.

BACKWATER CURVES

Studies of the probable elevations of the backwater curves for the maximum flood of 60,000 cubic feet per second and for the 100 year flood of 40,000 cubic feet per second have been made. The profiles of these two floods are shown on Diagram No. 6. Reference to the diagram indicates that, with the reservoir, the elevation of the backwater curve for the maximum flood will be at elevation 101.4 meters over the spillway section and will intersect the normal backwater curve without the construction of the dam some 4.5 kilometers upstream from the dam. The backwater curve for the design flood, which is anticipated will have a 100 year occurrence, will be at elevation 100.4 meters over the spillway crest. It will intersect the normal backwater curve without the construction of the dam about 4.3 kilometers upstream from the dam.

These elevations are based on free flow over the spillway crest, with the gates in their lowest position, making available the maximum

capacity of the spillway. In actual operation, the gates will operate to control the elevation of the water surface and maintain it at 100.0 meters.

CONSTRUCTION COST

Our estimate of the construction cost of the Rio Valenciano Dam is shown in Table No. 2. We estimate that the cost, including an allowance for contingencies, is $5,800,000.

Respectfully submitted,

BUCK, SEIFERT AND JOST

Edwin H. Hartman

Edwin H. Hartman

July 16, 1971

ENR CCI

1971 $ 5,800,000 → 1581 × 4.865

3/2006 $ 28,217,000 ← 7692

Table No. 2 was not found

B & V comment 8/2006

TABLE NO. 1

CHEMICAL ANALYSES BY U. S. G. S.
1958 TO 1963

	Rio Valenciano at Juncos				Rio Gurabo at Gurabo			
	No. of Obs.	Min	Max	Median	No. of Obs.	Min	Max	Median
Alkalinity	7	62	150	91	58	25	160	118
Hardness	7	50	69	60	56	24	114	90
pH	7	6.9	7.8	7.5	58	6.9	8.1	7.4
Iron	1	-	-	.02	46	.00	.04	.00
Chloride	7	15	22	18	58	6	26	20
Sulfate	2	8.4	8.8	-	46	7.6	22	16

The water is moderately hard, contains sufficient alkalinity for normal treatment processes, and is not greatly different from that of the Rio Gurabo now entering Loiza Reservoir.

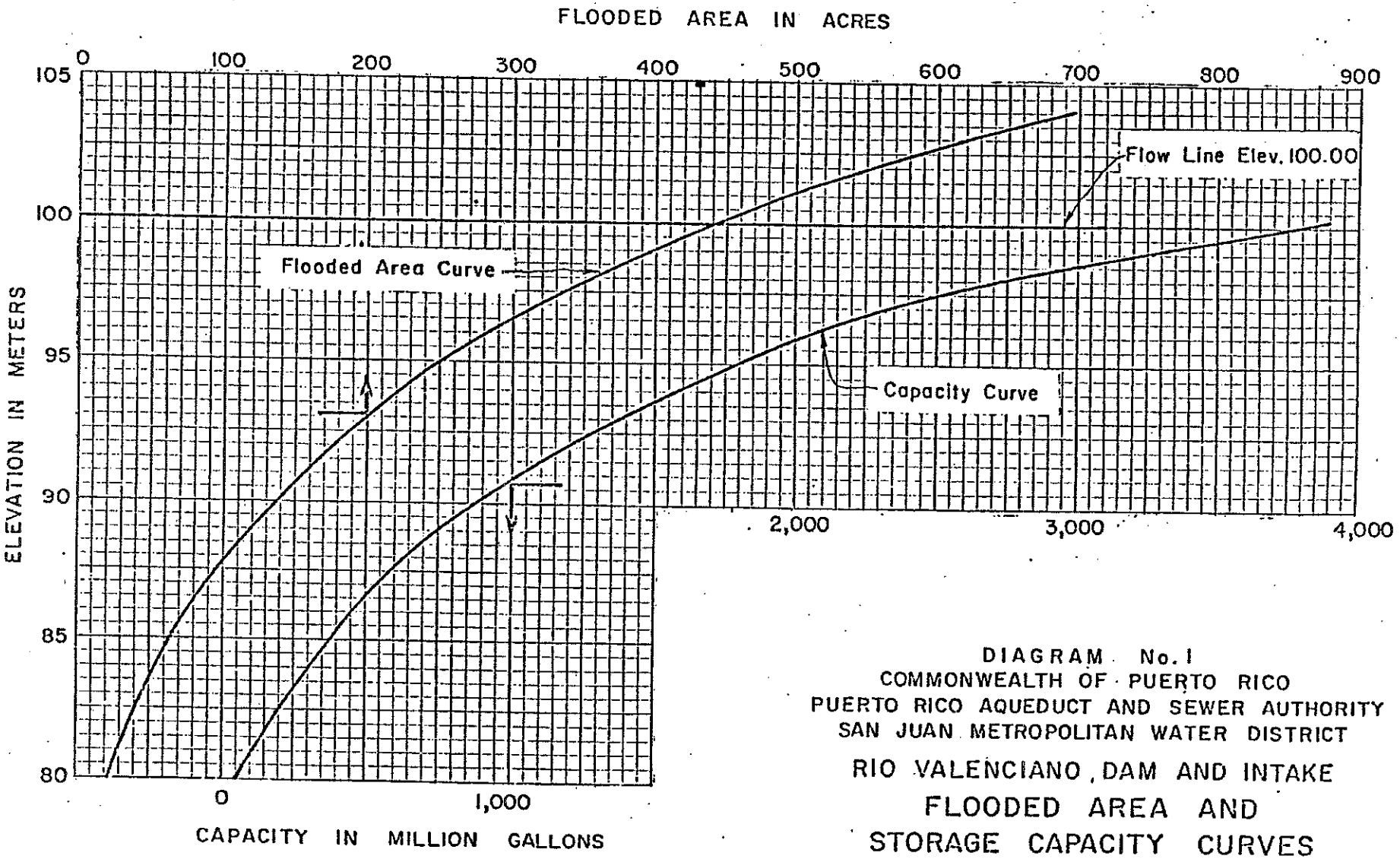


DIAGRAM No. I
COMMONWEALTH OF PUERTO RICO
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY
SAN JUAN METROPOLITAN WATER DISTRICT

RIO VALENCIANO, DAM AND INTAKE

FLOODED AREA AND
STORAGE CAPACITY CURVES

Buck, Seifert and Jost
Consulting Engineers
Englewood Cliffs, N.J. – San Juan, P.R.
January, 1971

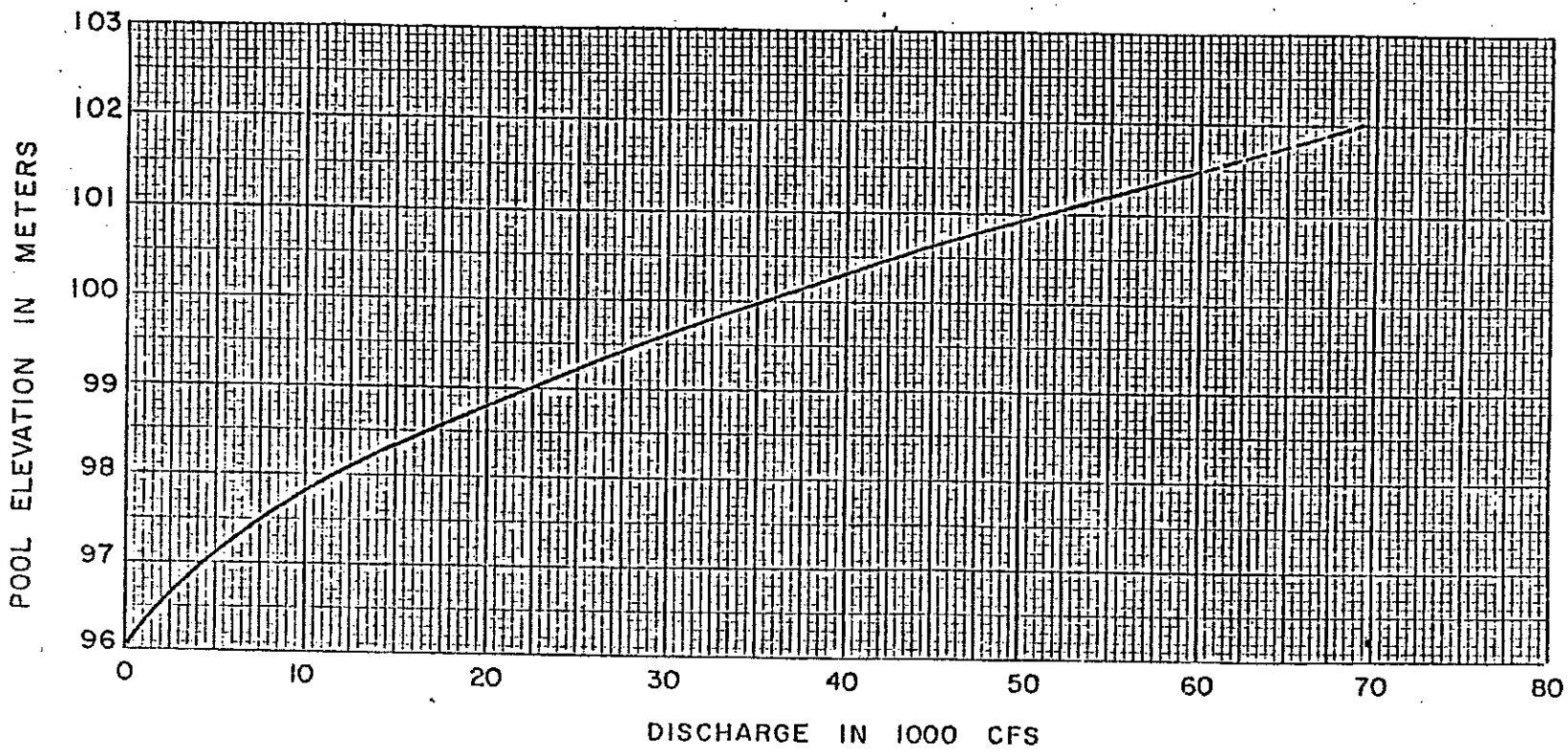
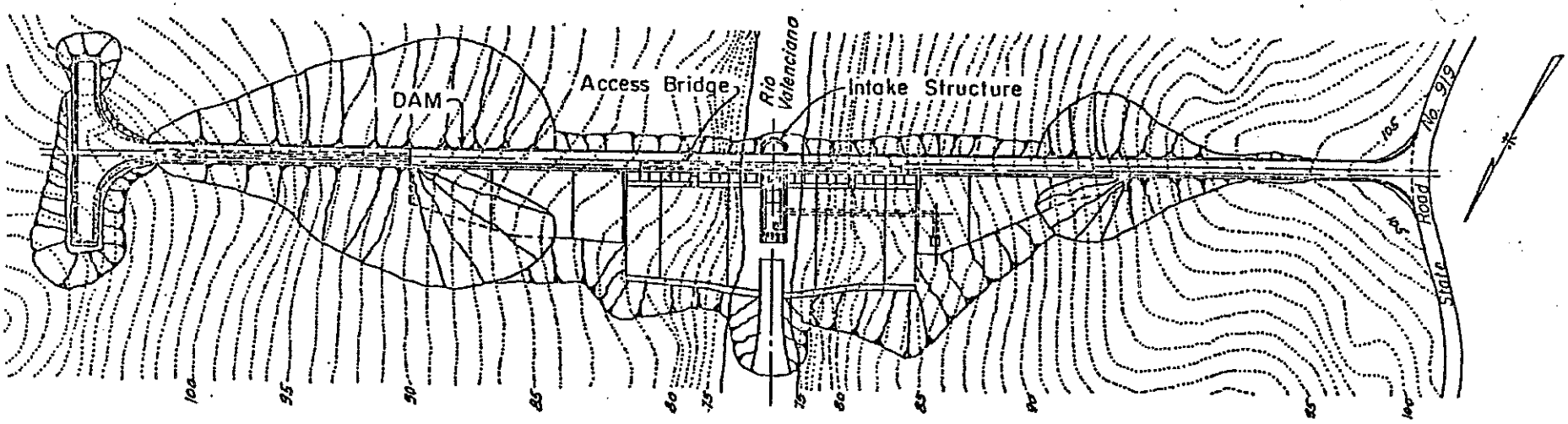


DIAGRAM No. 2
COMMONWEALTH OF PUERTO RICO
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY
SAN JUAN METROPOLITAN WATER DISTRICT

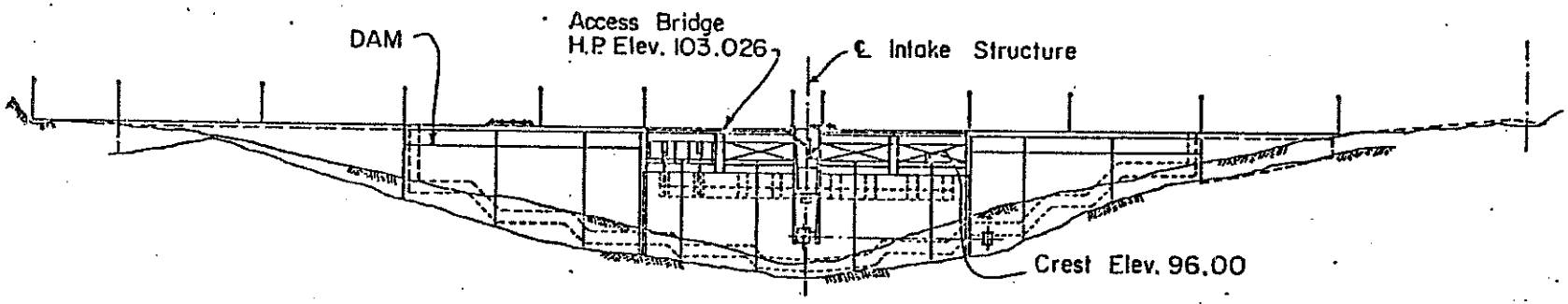
RIO VALENCIANO DAM AND INTAKE

RATING CURVE WITH GATES IN LOWERED POSITION

Buck, Seifert and Jost
Consulting Engineers
Englewood Cliffs, N. J. – San Juan, P. R.
January, 1971



PLAN



ELEVATION

DIAGRAM No. 3
COMMONWEALTH OF PUERTO RICO
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY
SAN JUAN METROPOLITAN WATER DISTRICT

RIO VALENCIANO DAM AND INTAKE

PLAN AND ELEVATION

Buck, Seifert and Jost
Consulting Engineers
Scale: 1:1,500 Englewood Cliffs, N. J. – San Juan, P. R. January, 1971

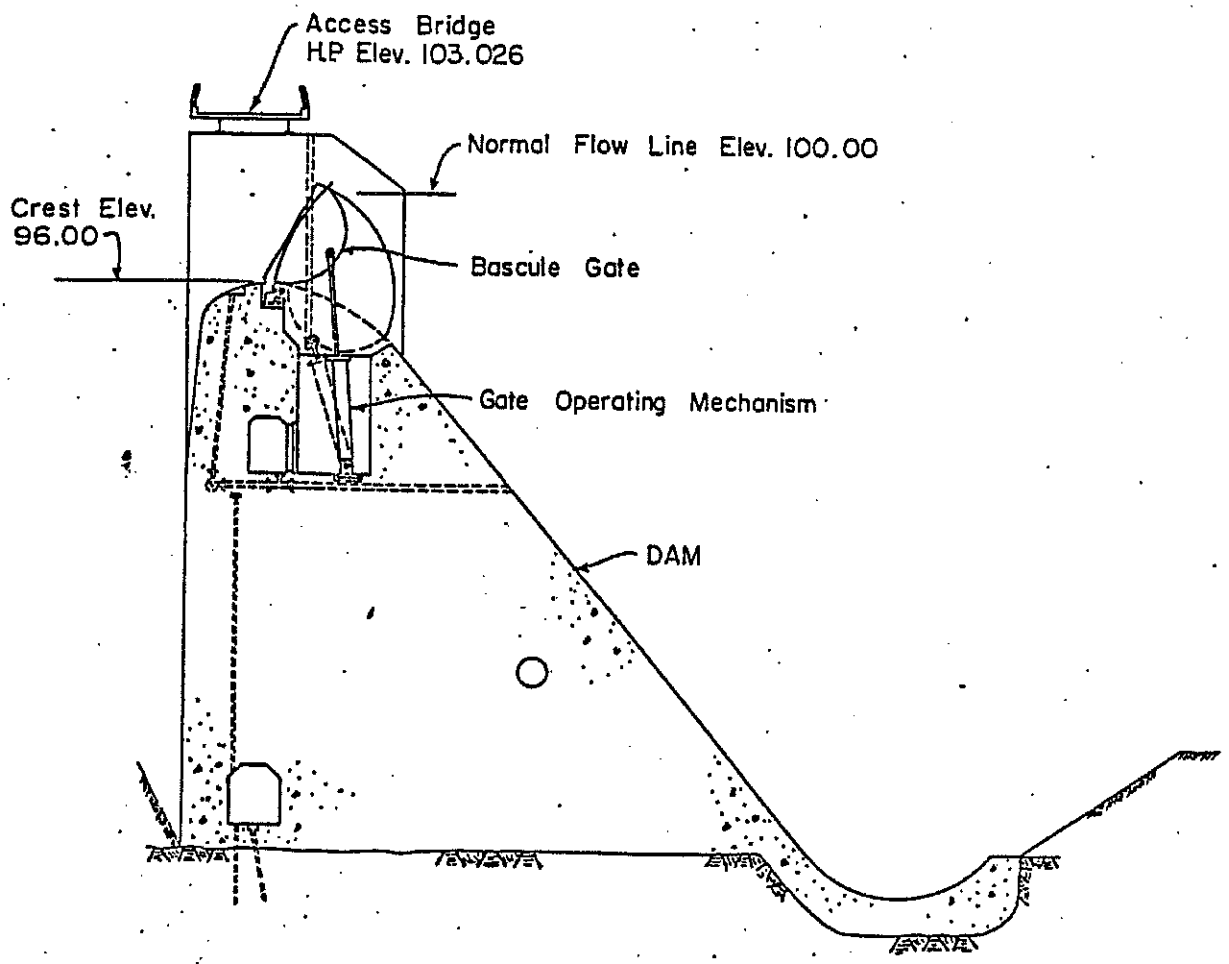
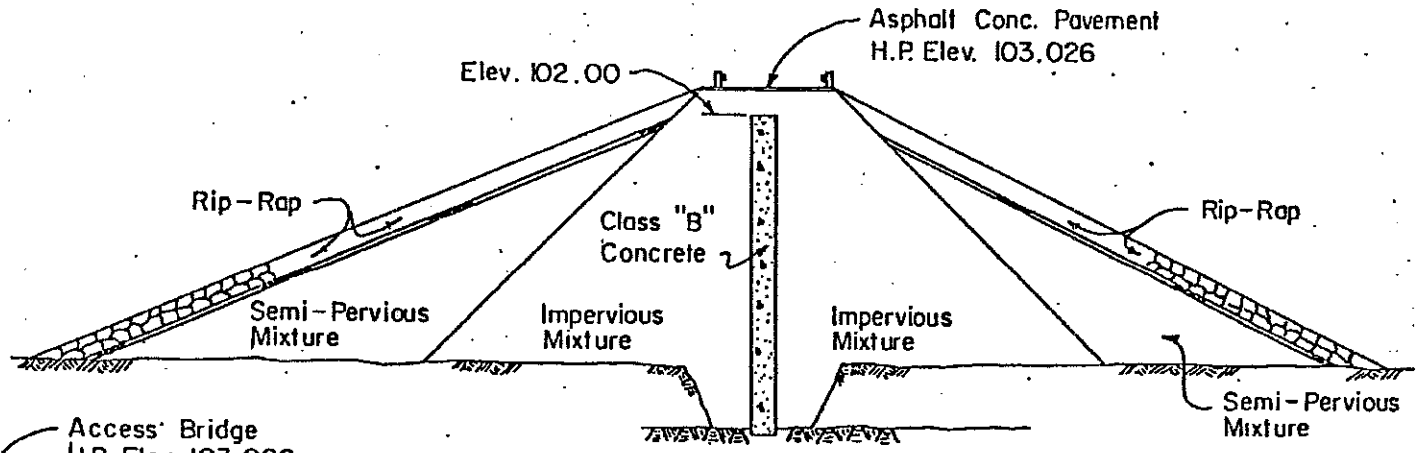


DIAGRAM No. 4
COMMONWEALTH OF PUERTO RICO
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY
SAN JUAN METROPOLITAN WATER DISTRICT

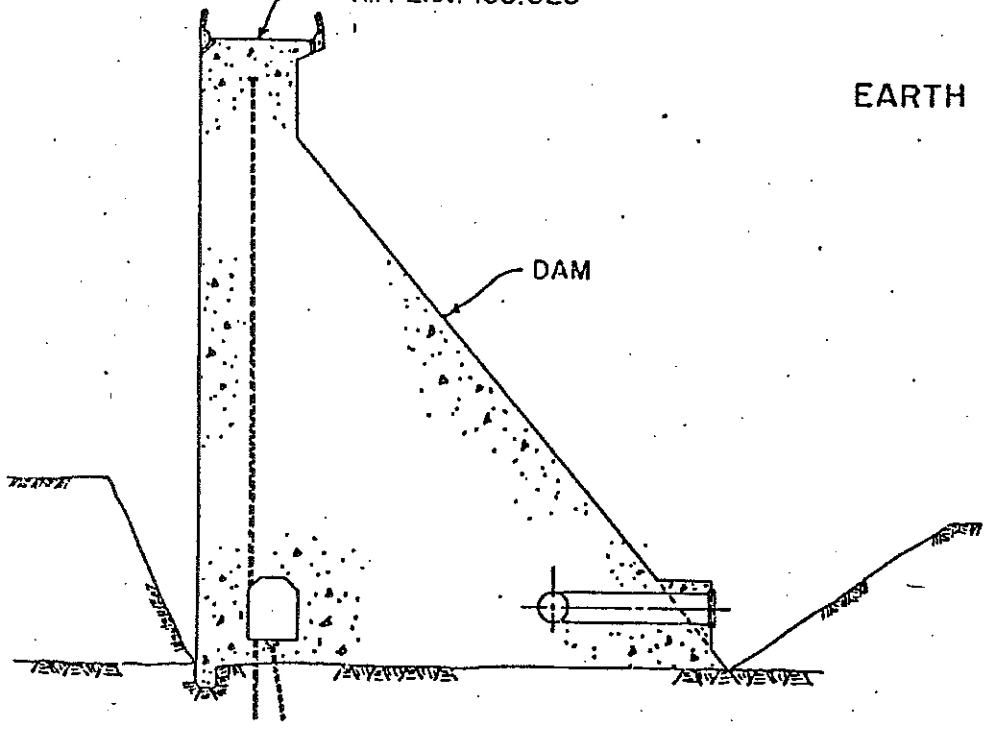
RIO VALENCIANO DAM AND INTAKE

TYPICAL OVERFLOW SECTION

Buck, Seifert and Jost
Consulting Engineers



EARTH FILL SECTION



TYPICAL NON-OVERFLOW SECTION

DIAGRAM No. 5
COMMONWEALTH OF PUERTO RICO
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY
SAN JUAN METROPOLITAN WATER DISTRICT

RIO VALENCIANO DAM AND INTAKE

SECTIONS

Buck, Seifert and Jost
Consulting Engineers
Scale: 1:300 · Englewood Cliffs, N.J. – San Juan, P. R. January, 1971

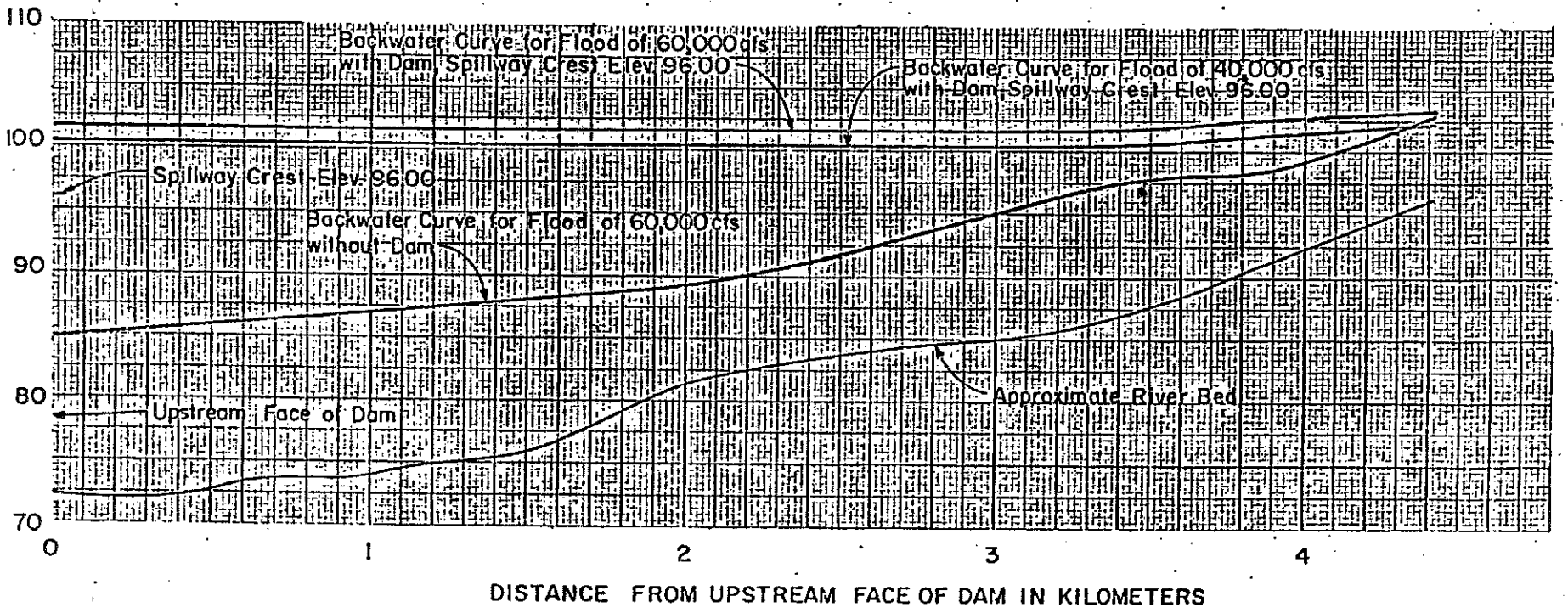


DIAGRAM No. 6
COMMONWEALTH OF PUERTO RICO
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY
SAN JUAN METROPOLITAN WATER DISTRICT

RIO VALENCIANO DAM AND INTAKE

BACKWATER CURVE

Buck, Seifert and Jost
Consulting Engineers
Englewood Cliffs, N. J. – San Juan, P. R.
June, 1971

APPENDIX D

RIO VALENCIANO STUDY, FOUNDATION AND MATERIALS, TECHNICAL APPENDIX B
–U.S. ARMY CORPS OF ENGINEERS-

RIO VALENCIANO STUDY

FOUNDATION AND MATERIALS

TECHNICAL APPENDIX B

900 M downstream
of
BSJ site

TABLE OF CONTENTS

Title	Page
Geologic Report	1-16
Fault Zone Map, Figure 1	Following 3
Boring Notes	17
Boring Logs	Appendix "A"
Laboratory Test Results	Appendix "B"
Core Boring Location Map	Plate 1
Geologic Profile	Plate 2
Geologic Map	Plate 3

GEOLOGIC REPORT

1. INTRODUCTION. A considered dam on the Rio Valenciano has been studied by the U. S. Army Corps of Engineers as a flood control project with secondary benefits to be derived from water storage for municipal use and as a recreational area. The Rio Valenciano Dam site is located approximately 1.1 km south of the town of Juncos in the eastern part of Puerto Rico. The Rio Valenciano is a tributary of the Rio Gurabo which in turn is a tributary of the Rio Grande De Loiza. Though the drainage area of the Rio Valenciano is relatively small, just over 15 square miles, it can contribute significantly to flooding downstream on the Rio Grande De Loiza. In the flood of September 6, 1960, the Rio Valenciano runoff was 37,100 c.f.s. The foundation exploration program conducted by the Corps of Engineers was for a dam to have a crest elevation of 109.5 meters and a spillway elevation of 104.8 meters with the base of the dam at an elevation of approximately 71 meters.

2. Regional geology. a. Geologic setting. The Island of Puerto Rico, with an area of 3,400 square miles, is the smallest and most easterly of the Greater Antilles. The Island is just under 110 miles long by 40 miles wide with the longitudinal axis running east-west. A central backbone of mountains rising to a maximum altitude of 4,398 feet extends east-west through the Island. Extending north and south of the mountain range are foothills and the coastal plains, both of which are much broader on the north side of the Island as the crest of the watershed lies nearer the south coast.

b. Geologic history. The oldest rocks of Puerto Rico are Jurassic age agglomerates composed of both intrusive and extrusive rocks cemented by andesite porphyritic material. Rocks of Cretaceous age rest conformably upon the Jurassic agglomerates. The Cretaceous was a period of volcanic activity with the deposition of great thickness of pyroclastics, and lava flows. Also, advances of the sea allowed the formation of some limestones and shales.

Orogenic disturbances and active plutonism occurred between the end of the Cretaceous and Lower Eocene producing a mountainous terrain which was rapidly eroded down into hilly terrain by Middle Eocene time. The San Lorenzo batholith, which is the major geologic feature in the project area, is a product of this period of plutonism. Late Eocene through Lower Oligocene was a period of volcanism and marine advances which produced a series of limestones and shales intermingling with pyroclastic rocks. Igneous activity had ceased by the end of Lower Oligocene time.

Puerto Rico was raised and tilted by a series of uplifts occurring during Middle Miocene, Early Pliocene and at the end of Pliocene time. This brought about erosional cycles which produced landforms that are evident today. The Quaternary was a period of gentle uplift and tilting to the north and east along with fluctuations of sea level. The Quaternary was predominantly a period of erosion.

c. Structure. In Puerto Rico, as throughout most of the West Indies, the broad structural elements are clear but the details are obscure. The general structural framework of the Islands is a core of extensively folded pyroclastics and some sediments, with intrusions and lava flows. The core is unconformably flanked to the north and south by tilted Tertiaries, progressively younger towards the coasts. Detailed structural interpretations are made difficult or impossible because, in the Cretaceous and older Tertiary rocks, strike and dip readings are scarce and unreliable. Within an area of a square mile strikes can swing through 180° and dips fluctuate greatly without any apparent reason.

d. Regional faulting. The rocks in Puerto Rico, not being brittle, tend to fold rather than fault when subjected to diastrophism. The large faults which do occur are usually of the normal fault type or strike slip type. Evidence of faulting, such as sudden change in strike and dip or offsetting of topographic features, can be detected in the field. However, interpretation of data obtained from seismic and geophysical records has provided the best picture of faulting on the island and adjacent submarine areas. In January 1973, the Puerto Rico Water Resources Authority commissioned an extensive and comprehensive study to identify areas suitable for nuclear power plant siting. Onshore geologic mapping and

PUERTO RICO FAULT ZONE MAP

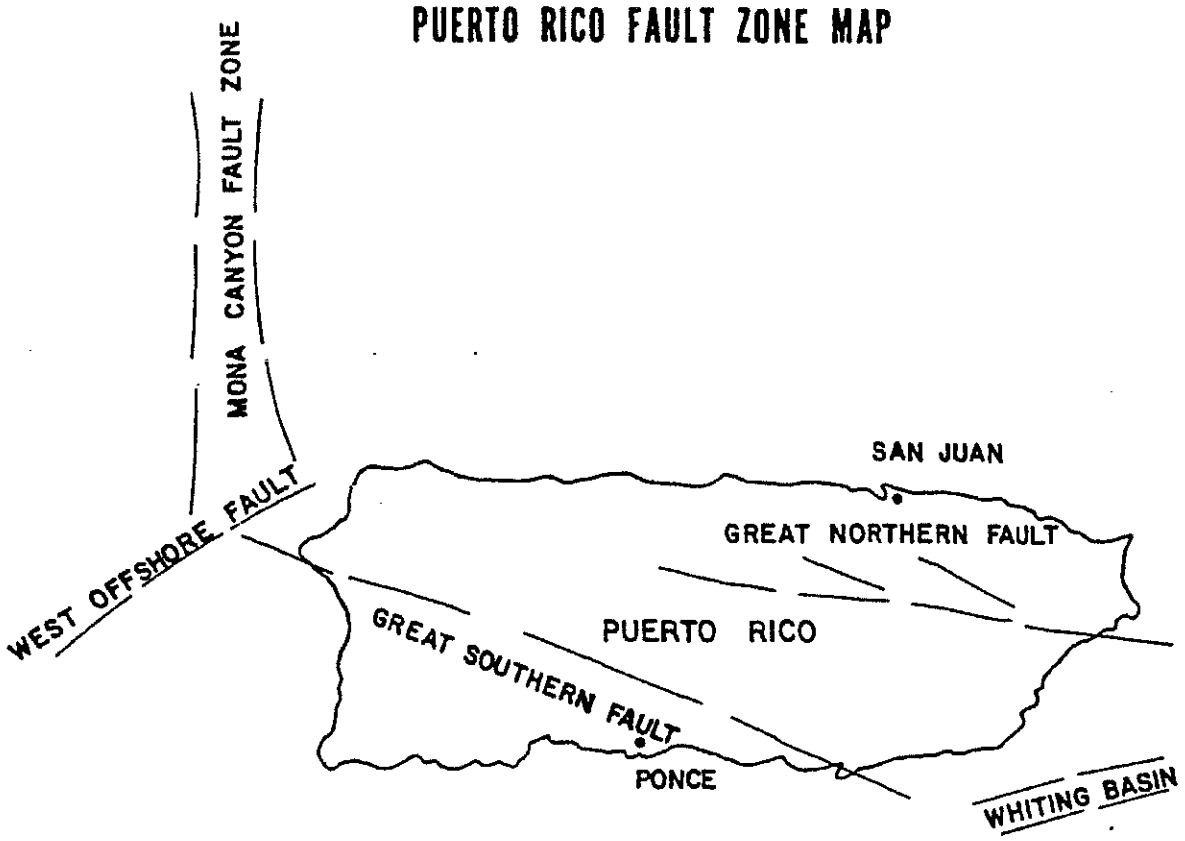


FIGURE I

engineering studies were conducted by Fugro Inc. Western Geophysical Company was commissioned to conduct offshore seismic reflection and magnetometer surveys to locate faults and to relate them to the tectonic and seismic history of Puerto Rico. On the island, two major fault zones have been delineated. They are The Great Northern Puerto Rico Fault Zone and The Great Southern Puerto Rico Fault Zone (see figure 1). The Great Southern Fault, which has been traced for a total length of about 180 km., has been intermittently active since early Cretaceous. Both vertical and left lateral movement has occurred. The lateral displacement may be as much as 60 km. Grabens and horsts occur within the fault zone. There is no evidence on land that indicates this fault zone is presently active capable but inactivity has not been conclusively demonstrated. Inactivity, is indicated in the following evidence: (1) It is terminated on the northwest and southeast by northeast-southwest trending high angle faults; (2) The last known age of movement is Niocene; (3) Nowhere does the zone offset Quaternary sediments; (4) There are no historic or recorded seismic events associated with any of the faults in the zone.

The Great Northern Fault Zone which is closer to the project site has similar characteristics to the southern fault. However, it is definitely considered to be inactive. It is overlain by a thick sequence of middle to late Tertiary strata which is unbroken across the fault zone. It should not affect the project.

e. Folds. Although folding is present everywhere in the Cretaceous and older Tertiary rocks there are few indications of an intense degree of folding. Few folds are symmetric, but recumbent folding is not common. The symmetric folds have their axial surfaces inclined southward with steeper limbs to the north, indicative of thrusting from the south.

f. Flexures. Several broad, low warps can be detected, both in the younger Tertiaries and the older rocks. The general trend of these warps is north-south but they vary from north-northwest to north-northeast. A large broad downwarp can be traced across the Island from near Quebradillas to near Ponce.

g. Unconformities. Several unconformities are known to exist in Puerto Rico. Undoubtedly, the most pronounced is between the Upper Cretaceous and the younger Tertiaries. Other known unconformities do not show the same marked difference between the rocks in juxtaposition.

h. Seismology. (1) Historical seismicity. Plate boundary movement, epicenter records, and historical data were analyzed by Western Geophysical Company and Fugro, Inc., in the previously mentioned study for the Puerto Rico Water Resources Authority. It is from their report that the following information is derived. The seismic pattern shows an arcuate band of earthquakes along the Lesser Antilles Island Arc and scattered earthquakes along the coast of Venezuela. Many shallow-focus earthquakes have occurred in the Puerto Rico Trench, in Mona Passage, under Hispaniola and a few along the Cayman Trough. A few intermediate-focus earthquakes (70-140 km) occur along the western margin of the Lesser Antilles Belt and beneath eastern Hispaniola. Focal-mechanism determinations substantiate the general regional interpretation of left lateral movement along the Puerto Rico Trench and Cayman Trough, right lateral movement along the El Pilar fault of Venezuela and underthrusting beneath the Lesser Antilles.

On Puerto Rico, only three or four low-magnitude earthquakes have been recorded with hypocenters beneath the island. Depth of focus for these

events is greater than 30 km, which is the reported crustal thickness. However, because solutions do not exist for these earthquakes, the nature of the fault motion producing them is unknown.

Unlike on or beneath the island, the large number of earthquakes in the Puerto Rico Trench, the Anegada Gap and Mona Passage clearly reveal that the Puerto Rico-Virgin Island crustal block is bounded by active zones of movement. However, just south of Puerto Rico, the Muertos Trough has had only three small recorded earthquakes. The area around Mona Canyon off the northwest coast is particularly active. It was in this region that a magnitude 7.5 earthquake took place in 1918. This earthquake produced a tsunami that did some damage and resulted in several deaths along the northwest coast. The epicenter for this event, as well as those from other smaller events in the Mona Canyon area and along the south side of the Puerto Rico Trench, is located adjacent to fault zones mapped from the seismic reflection profiles by Western Geophysical Co.

Although the earthquake activity along the Puerto Rico Trench lies along the plate boundary, the activity in Mona Canyon and along the west side of Mona Passage does not. This may suggest that the Caribbean Plate, which is rather small is under strain along lineations other than its boundaries from the much larger plates around it; and some rotation may be involved.

Recently the United States Geological Survey has established a "Puerto Rico Seismic Program" on behalf of the Puerto Rico Water Resources Authority. For the period of August 16, 1974 through June 30, 1975, the five seismograph stations operating in the Puerto Rico Seismic Program reported a total of twenty minor tremors located in and around Puerto Rico. The strength

of the tremors was mild with only three reported as being "felt." The time and location of the tremors can be found in the U.S.G.S. Seimological Data Report - Open File Report 76-369. To date, the U.S.G.S. has not compiled enough data to make a reliable prediction as to the frequency or strength of tremors which could affect the area.

Overall, the seismic history indicates the island will experience occasional shocks of slight to moderate intensity from submarine seismic activity in the area west and northwest of the island and 10 to 60 miles offshore. Though seismic shocks have also been recorded in an area off of the eastern coast of Puerto Rico, they occur infrequently.

(2) Seismic instrumentation. Installation of a microseismic instrument at the damsite should be installed so data can be compiled before, during, and after construction. The early records will provide a basis for comparison with the records obtained as the lake fills up. Upon completion of construction three surface type accelerographs and one peak accelerograph should be installed in accordance with EM 1110-2-1908.

i. Economic geology. In Puerto Rico there are metallic mineral occurrences, but in seemingly small quantities, and therefore mining has not offered attractive possibilities. Gold occurs in the Island and was actively exploited by the Spaniards who extracted a total 4 million dollars of placer gold. Silver extraction has been almost nil. In recent years base metals have become more important that the precious metals. In modern time, only iron, manganese, and most recently copper have been seriously considered by mining personnel in Puerto Rico. Unlike the metalliferous deposits in Cuba, the bauxite in Jamaica and oil in Trinidad, Puerto Rico has offered little attraction to the mining industry.

(1) Gold. Placer gold was produced from the Fajardo, Luquillo, Mameyes, Grande, and Sabana Grande Rivers. All of these rivers are on the north side of the Island.

(2) Manganese. Manganese deposits are widely scattered throughout the interior of the Island but only the deposits at Juana Diaz have undergone intensive study and development. Here the ore, psilomelane, pyrolusite, and manganite occurs in solution-enlarged fissures in the Guayabal limestone. The deposit was mined from 1915 to 1939 with 80,000 tons averaging 60 percent manganese produced.

(3) Iron. In Puerto Rico iron occurs as magnetite and limonite. To date only the magnetite has been worked. The best known magnetite deposits are in the Juncos-Las Piedras district, near Humacao, Arroyo, Adjuntas, and Ponce. The Juncos-Las Piedras district contains the largest known deposits and the only one which has been developed. This deposit, the keystone mine, also called La Mina, La Esperanza or the Juncos mine, lies a few miles north of the Rio Valenciano Project Site. The mineralization occurs as lenticular deposits in an altered limestone which crops out just north of the San Lorenzo batholith. The ore bodies are metasomatic replacements of the limestone lenses. The principal ore mineral is magnetite but hematite and a little malachite, azurite and chrysocolla are present. The chief gangue minerals are garnet, epidote and unidentified calc-silicate minerals. Studies between 1904 and 1951 indicated an estimated reserve of 850,000 long tons of direct shipping ore and concretrates could be obtained by open pit mining. Between 1951 and 1953 the deposit was mined by the West Indies Mining Company which shipped approximately 220,000 tons of ore reported to contain a minimum of 60 percent iron. The keystone mine consists of an open pit 30 by 170 meters and a small

open cut 40 meters east of the main pit. The mineralization extends 750 meters eastward from the keystone mine.

(4) Copper. In recent years a porphyry copper deposit near the Rio Vivi in the western central part of the Island has been extensively studied. The deposit is reportedly of sufficient size and grade to be profitable exploited but has not been developed due to ecological concern.

3. Geologic Investigations. a. Previous Investigations. A geologic map showing the iron and copper prospects in the Juncos Quadrangle, Puerto Rico was prepared by Carl H. Broedel of the USGS in 1961. This map provides the basic geologic information for the dam site and reservoir area.

The Puerto Rico Aqueduct and Sewer Authority has investigated a possible dam site located approximately 2,500 feet upstream from the site of this investigation. This upstream site was for a smaller dam impounding considerably less water than called for in the present plans. In 1970 seventeen borings

were drilled at the upstream site utilizing a standard split spoon in the overburden and a NX core barrel in rock. The borings varied in depth from 22 feet to 110 feet with an average depth of 48 feet. These borings encountered "granitic" rock beneath the overburden and decomposed rock layer which averaged 17 feet in thickness.

The Jacksonville District conducted a field reconnaissance investigation of the proposed dam site in January 1970. The geologist who conducted the investigation wrote a brief but comprehensive report which concluded the site was a favorable location for a dam.

b. Present investigation. Present geologic investigations included a review of the available geologic literature, previous field reconnaissance report, and the Aqueduct and Sewer Authority's core boring logs. A general reconnaissance of the dam site, reservoir area and borrow area was made.

Due to the availability of area geologic maps, no geologic mapping of the reservoir area was deemed necessary. However, in the rocks outcropping at the dam site, the strikes and dips of the fractures were checked. The geology of the area is shown on Plate 3, the Geologic Map.

Twelve borings were drilled at selected locations to obtain data relative to the dam foundation, spillway section and borrow area. Eight core borings were drilled at the dam site, six were along the centerline of the dam, one on the tieback dike and one in the spillway area. The borings were drilled using a standard split spoon in the overburden and 4 x 5-1/2" and NX core barrels in the rock. Where possible, the borings were pressure tested. The pressure test results are shown on the core logs. Overburden samples from four of the core borings were sent to the South Atlantic Division Laboratory for analysis. The boring logs and laboratory test results are shown in Appendix "A" and "B". The

core boring locations are shown on Plate 1. The boring data is graphically depicted on the geologic cross section Plate 2. The cores are stored at the Corps of Engineers office in San Juan, Puerto Rico. Four auger borings were drilled in the proposed borrow area and representative samples of the material were sent to the South Atlantic Division Laboratory for analysis. The borrow area boring logs and laboratory test results are included. The borrow area boring locations are shown on Plate 3.

A possible alternate dam alinement, approximately 1,000 feet upstream from the present alinement, and alternate borrow areas located within the reservoir area approximately two miles upstream from the dam site were visually examined in the field but were not studied.

c. Future investigations. Future investigations should include additional core borings at the dam and spillway sites to more completely determine subsurface conditions and the rock and overburden characteristics.

An alternate dam alinement, approximately 1,000 feet upstream from the present site, should be studied, as it would eliminate the necessary expensive acquisition of a large building. Core borings would be needed to determine subsurface conditions along the alternate alinement.

In the borrow area sufficient auger borings will be necessary to delineate the material to be excavated. Bulk samples of the impervious borrow material will be collected for testing. Possible alternate borrow areas, located within the reservoir area two miles above the dam site, will also be investigated.

It will be necessary to construct a test embankment section to check the material characteristics and compaction under field conditions.

A small section of the natural embankment midway up the east side of the reservoir consists of a low narrow ridge. Investigation of this area, possibly including core borings, will be necessary to determine leakage probability and corrective measures if needed.

4. Project Geology. a. Location and topography. The project area is located near the town of Juncos in eastern central Puerto Rico. The proposed impervious borrow areas lies on the eastern edge of town in an alluvial terrace area which has been used for sugar cane farming. The dam site is located in hilly terrain approximately 3/4 of a mile south of town with the reservoir extending about 3-1/2 miles farther south. The area is mostly open pasture used for cattle grazing. At the dam site the valley is narrow and the hills forming the east abutment are very steep while on the west abutment the slopes are moderate near the river and gentle away from the river. Upstream from the dam site the valley broadens and flattens somewhat. Throughout the reservoir area the river has a moderate gradient. The slope of the hilly terrain is generally moderate to gentle though steep slopes are found adjacent to some drainages. Scattered rock outcrops occur along the steeper streams and slopes. Residual boulders are scattered throughout the area.

b. Lithology. The dam site and reservoir area is entirely underlain by the San Lorenzo batholith, a large mass of plutonic rock, predominantly granodiorite which in some areas grades locally into quartz diorite. The batholith is cut by irregular dikes of dark gray volcanic rock which are readily observed in the core but are obscure at the surface. Bordering the batholith to the north of the town of Juncos are metamorphosed volcanic rocks and impure limestones, probably of cretaceous age, into which the batholith intruded. The

plutonism probably took place at the close of the Cretaceous. The Cretaceous volcanics and limestones which occur a few miles north of the project site are locally mineralized with iron and some copper mineralization. The plutonic rocks underlying the project site are barren of mineralization. The proposed borrow area, located on the east side of Juncos, though very close to the mineralized area, is in alluvial terrace deposits barren of mineralization.

Field identification of core samples at the dam site indicate the rock is mostly granodiorite though some appeared to be quartz diorite. Differentation between the two rock types is dependent upon the amount of K feldspar present and visual classification is sometimes questionable. Precise identification is only of academic importance since physical character of the two rock types are the same. The fresh rock is gray in color, very hard, medium grained and composed of quartz, feldspar and ferro-magnesian minerals. The ferro-magnesian minerals, which appears to compose about 15 percent of the rock, consist of hornblende and biotite with the hornblende predominant.

c. Soils. At the dam site the rock is overlain by a thick layer of saprolite capped with a thin layer of topsoil. The topsoil layer is generally less than 18 inches thick, however, the total section of soft materials classified as soil, saprolite, and decomposed or intensely weathered rock averages about 18.5 feet thick reaching a maximum thickness of 26.3 feet in boring RVD-CB-2 and a minimum of 10.7 feet in RVD-CB-3. A very noticeable feature is the abrupt change from the intensely weathered zone into sound rock with little or no intermediate weathered zone. The decomposed rock and weathered rock is brown to gray brown in color due to iron stain from the decomposed ferro-magnesian minerals. In the borrow area both saprolitic soils and locally transported soils of terrace deposits were encountered. For rock weathering

definitions refer to the sheet of core boring notes.

The soils were classified according to the Unified Classification System. Classifications of the borrow area material is according to test results from the South Atlantic Division Laboratory. Lab tests shown in Appendix "B". Soils samples at the dam site were classified by visual observation and supplemented by laboratory tests of representative samples.

d. Fractures. In the weathered zone the core is broken along numerous natural fracture planes. These fractures are generally steeper than 45° from the horizontal and some are near vertical. Few fractures show signs of solutioning however, where present, it was most apparent on the near vertical fractures and at shallow depths. The fracture frequency varied from several per foot in the upper part of the borings to several feet apart deeper in sound rock. Pressure test results indicate very little or no water loss in the zones of sound rock even though fractures were present. Where the highly fractured weathered zone was tested water loss was less than expected. Though fractured, the rock is strong. Where it crops out it forms natural cliffs and cuts excavated in the rock should hold up on vertical or near vertical slopes.

Joints observed in the rock outcrops in the river just downstream from the dam centerline show a pattern of primary and secondary joints whose strikes differ about 80°. Near the dam the major joint pattern strikes NE and dips about 54° NW, however, a few hundred feet downstream the strike shifts to N, dips 72° to 82° NW. The secondary joint pattern strikes near east and dips steeply to the south. It is expected that the strike of joints will vary from place to place. Fault gouge and a shear zone was observed in borings RVD-CB-3, which is located in the river. No signs of this fault were observed at the

surface. Study of aerial photos show no alinement or offset of surface features which would indicate major faulting.

5. Site suitability. Construction materials. Construction materials are readily available. Rock for dam construction would be quarried from the spillway section and if needed the adjacent hilltop. Large quantities of impervious fill are available within a few miles of the dam site. Only sand for making concrete is not readily available and would probably have to be purchased from local sources.

b. Foundation conditions. Foundation conditions are favorable for dam construction. Weathering does not extend to a great depth. Strong, sound rock is generally encountered above a depth of 25'. The weathered section consists mostly of decomposed rock of sandy clay or clayey sand character though field identification shows some sandy clayey silt in boring RVD-CB-1. This residual material should present no excavation problems and is strong enough to stand with moderately steep slopes. Under the embankment section it will be necessary to strip off the topsoil and overburden to the depth that the vegetation root system extends. A cutoff trench along the centerline should extend down to sound rock. Pressure test water loss in the sound rock section was minor and an exploratory grout curtain on 10 ft. centers extending 25 feet into sound rock would be included in foundation design.

Excavation or tunneling in the sound rock should not present any major problems. Though the rock is fractured, the fractures are tight and support or rock bolting, if needed, should be minor.

c. Seismic considerations. The seismic history of Puerto Rico indicate tremors are to be expected but should be minor. Seismic tremors must be taken into consideration in the dam design.

5. Conclusions. The Rio Valenciano site studied is a good dam site. There are no known conditions which would make it unfavorable.

CORE BORING NOTES

1. BORING LOCATIONS ARE SHOWN ON PLATE 1.

2. BLS/0.5 FT. REFERS TO THE NUMBER OF HAMMER BLOWS REQUIRED TO ADVANCE A SPLIT-SPOON (1-3/8" I.D. X 2" O.D.) ONE-HALF FOOT. THE SPOON IS 2.0 FEET LONG AND DRIVEN CONTINUOUSLY ONE AND ONE-HALF FEET WHERE POSSIBLE.

3. (SP) AND (SM) ETC., REFERS TO THE CORPS OF ENGINEERS UNIFIED SOILS CLASSIFICATION SYSTEM. CLASSIFICATION OF MATERIALS IS BASED ON VISUAL EXAMINATION.

4. GROUND WATER ELEVATIONS WERE OBSERVED ON THE COMPLETION DATES OF THE BORINGS AND ARE SUBJECT TO FLUCTUATIONS. WHERE GROUND WATER ELEVATIONS WERE NOT OBSERVED OR NOT RECORDED, IT DOES NOT NECESSARILY INDICATE THAT GROUND WATER WILL NOT BE ENCOUNTERED AT THE LOCATION AND THROUGHOUT THE DEPTH OF THE HOLE.

5. ROCK HARDNESS IS DEFINED BY THE FOLLOWING:

   SOFT - CAN BE SCRATCHED WITH FINGERNAIL.

   MEDIUM HARD - CAN BE SCRATCHED EASILY WITH KNIFE; CANNOT BE SCRATCHED WITH FINGERNAIL.

   HARD - DIFFICULT TO SCRATCH WITH KNIFE.

   VERY HARD - CANNOT BE SCRATCHED WITH KNIFE.

6. D.T. 14 MIN. ETC., REFERS TO THE TIME IN MINUTES, REQUIRED TO DRILL THROUGH THE VERTICAL REACH SHOWN.

7. H.P. 50 P.S.I. ETC., REFERS TO THE HYDRAULIC PRESSURE, IN POUNDS PER SQUARE INCH, APPLIED TO THE DRILL BIT WHILE DRILLING THROUGH THE VERTICAL REACH SHOWN.

8. PRESSURE TESTS WERE CONDUCTED IN THE FOLLOWING MANNER: WHERE CONDITION OF THE ROCK PERMITTED,AN INFLATABLE PACKER WAS SET TO SEAL OFF THE PORTION OF THE BORING TO BE TESTED AND WATER WAS PUMPED INTO THE TEST ZONE. PUMP PRESSURE WAS REGULATED SO THE PUMP PRESSURE PLUS THE PRESSURE OF THE STATIC HEAD OF THE COLUMN OF WATER ABOVE THE WATER TABLE WOULD EQUAL 1 POUND PER FOOT OF DEPTH AT THE TOP OF THE TEST ZONE. A WATER METER WAS USED TO MEASURE THE FLOW OF WATER INTO THE TEST ZONE. WATER LOSS OVER THE INTERVAL TESTED IS SHOWN IN GPM/PSI.

9. ROCK WEATHERING DEFINED. THE CRITERIA USED TO IDENTIFY THE DEGREE OF WEATHERING INDICATED ON THE CORE BORING LOGS AND GEOLOGIC SECTIONS ARE DEFINED AS FOLLOWS:

   INTENSELY WEATHERED - BREAKS DOWN ALMOST COMPLETELY INTO SOIL UNDER LIGHT HAMMER BLOWS OR COMPACTION EQUIPMENT. EASILY EXCAVATED WITH POWER EQUIPMENT. LITTLE OR NO TRACE OF ORIGINAL CRYSTALLINE ROCK STRUCTURE REMAINS. SCATTERED RESIDUAL BOULDERS OF LESS WEATHERED ROCK MAY BE PRESENT.

   WEATHERED - PARTLY BREAKS DOWN INTO SOIL UNDER HEAVY HAMMER BLOWS OR WITH SHEEPS FOOT ROLLER. EXCAVATION REQUIRES USE OF A SINGLE TOOTH RIPPER AND A BULLDOZER OF D-8 POWER CAPABILITY. STAINED THROUGHOUT, PARTIALLY DECOMPOSED ALONG FRACTURES. SIGNS OF ORIGINAL CRYSTALLINE STRUCTURE PRESENT EXCEPT ALONG FRACTURES.

   SOUND - NO SOIL PRODUCED UNDER HEAVY HAMMER BLOWS OR COMPACTION EQUIPMENT. EXCAVATION REQUIRES BLASTING. MINOR STAINING MAY BE PRESENT ALONG FRACTURES.