GEOLOGIC REPORT -- GORGE HIGH DAM

Table of Contents

GEOLOGIC REPORT -- ILLUSTRATIONS

INTRODUCTION

Exploratory programs vary widely in their mechanics of drilling, their methods of recording the drilling progress, and in the interpretation and presentation of the sub-surface geology.

To give the reader an objective perspective regarding the value and limitations of this particular exploratory program, the following few descriptive pages are submitted. By presenting a full account of the program, we hope to help the reader avoid both excessively large and excessively small estimates.

INTRODUCTION (2)

The Gorge High Dam Site was diamond drilled and explored at two widely separated intervals.

During the first interval, 1492 to 1760 , a total of__________holes were sunk into overburden of which__________ reached and penetrated bedrock. On the accompanying maps these early holes are designated by the numbers 1 to 32 and by the symbols X-1 to X- .

During the second interval, July, 1953 to March, 1954, a total of______________holes were sunk into overburden of which ______________reached and penetrated bedrock. On the maps these later holes are designated by the single, double, and triple letters A to Z. The geology of the abutments was mapped during the second interval.

The report is the combined effort of Dr.______________ ____________________, Consultant geologist, Mr.______________ ____________________, Skagit Project____________________, and John M. Nelson and William C. Irvin, Geologist at the dam site during exploration.

MECHANICS OF DRILLING

The mechanics of drilling differ in overburden and in bedrock.

Driving pipe and casing through overburden

In most of the holes, $3\frac{1}{2}$" pipe with standard couplings is driven downward through the overburden toward bedrock. The driving is facilitated by chipping, pounding, and loosening the sand, gravel, and small boulders with a star bit mounted on drill rods which pass down through the pipe. Water is pumped down through the drill rods and star bit and then passes upward between drill rods and pipe to the surface. The water velocity is sufficient to carry medium and fine sand and minute rock chips upward to the surface and thus volumetrically make room for the pipe. In practise, the star bit pounds its way ahead of the pipe for a distance of 1 to 3 feet. The pipe is then driven downward and turned to keep the threads tight and to prevent the pipe from bending and breaking. Where necessary, dynamite charges (1 to 15 sticks of 60%) are lowered to split small boulders and loosen sand and gravel.

In some instances the pipe cannot be safely driven further because of depth, tightness, or bending. Smaller NX casing is then lowered inside the pipe and driven to greater depth.

Further reduction to AX casing is resorted to in some holes.

In a few shallow holes, six inch casing was driven with a small churn drill and cable tools. In these holes, the sand, gravel, and rock fragments are bailed out at intervals as the hole is deepened.

An inspector at each hole records the increasing depth of the casing, the relative amount and color of the water return, the relative amount and character of the recovered sand and fine rock fragments and collects samples, the depth, size, and shape of dynamite charges, changes in the driving rate, and the censored pertinent remarks of the drillers.

Generally, boulders two or more feet in diameter must be diamond drilled and the mechanics of drilling are the same as for bedrock. The boulders are then blown apart with dynamite.

Diamond drilling in bedrock

Standard drill-rods, core barrels, reamers, and diamond bits are used in the drilling. Core barrel lengths range from 2' to 10'. Drilling generally procedes until the core barrel is filled and the core is forcibly twisted loose from the rock. This practice of letting the core block instead of breaking with the core spring accounts for 1" to 18" mechanical core loss per pull. It is resorted to in this area because the competent granite gneiss cannot always be broken from bedrock with the core springs.

The recovered core is pulled from the hole at successive intervals, generally 3' to 8' in length. The core is carefully placed in a long wooden core box and the respective depths of the top and bottom of the pull are marked on the box and in the inspector's written record of the hole.

The inspector at each hole records the maximum depth and elevation of the diamond bit at the time the core breaks loose from bedrock, calculates the length of pull by subtracting the depth of the preceding pull, places the core in the box, measures the core length, calculates the core loss, notes the character of rock, the position and character of the natural joints and the drill-fractures. During the drilling the amount and character of the water return is recorded. Evident changes in the rate of drilling are recorded but a continuous inch by inch record of progress is <u>not</u> attempted.

The core boxes and the inspector's log of the hole are transferred to a field office for further study by a geologist. (See Methods of Interpretation, pages to).

METHODS OF INTERPRETATION

Recognition of Boulders and Ledges

At the Gorge Creek Dam Site the canyon is steep and narrow. Overhanging cliffs and ledges may be seen on both sides and blocks of rock and boulders may be seen in the overburden. Holes driven and drilled into the overburden may be expected to penetrate both boulder and ledge. The following criteria are used to separate the two in the geologic logs of each hole.

1. If the character of the drilled rock is foreign to the dam site area and common to the river gravels, the rock is interpreted as a boulder.

2. If the character of the drilled rock is also common to the rock types of the dam site area the rock may be either boulder or bedrock and the following criteria are used.

    a. If the attitude of the foliation, axes of minor folds in the foliation, joints, faults, striae on fault surfaces do not agree with those observed in outcrop and adjacent holes, the rock is interpreted as a boulder. If they fit, the rock is interpreted as a ledge.

Recognition of Boulders and Ledges (Continued)

b. The rock's position with respect to known bedrock topography may make it possible to give a definite boulder or ledge interpretation.

c. If the stream-scoured and etched surfaces of the rock are preserved and if the core can be rotated so that its structures fit those of the outcrops, the attitude of the surfaces may be reasonably sub-parallel to the canyon wall indicating a possible ledge interpretation. If the surfaces of the drilled rock cannot be integrated with those of the probably canyon wall, a boulder interpretation is indicated.

Where the combined evidence is not conclusive the Geologist's tentative interpretation and evidence is recorded in the log.

Orientation of Core

Commonly the core is broken along natural joints and mechanical drill-fractures into pieces that range in length from an inch or two up to several feet. When brought to the field office, the pieces of core occupy their correct position with respect to depth of hole but have a random orientation with respect to rotation around the core axis. In the field office

Orientation of Core(Continued)

the Geologist orients and describes the core.

First, the pieces of core are rotated to a common orientation for the pull. This is done by rotating the pieces of core until they "lock together" or by rotating until a continuity across the break is established for the structures, textures, and character of the rock. In similar fashion, each pull is rotated until it has a common orientation with respect to the other pulls from the same hole.

Where time has permitted a study of the attitude of structures (foliation, joints, faults, minor folds) in the nearby outcrops, the core is further rotated until its structures have the same orientation. The core is then oriented to approximately the same position that it had in place prior to drilling. In those holes in which the core has been completely oriented in this fashion, the attitude of the joints and faults has been measured and hence these structures may be projected and in many instances correlated from hole to hole.

Time has not permitted complete orientation of core in all the holes. If economically helpful to either the grouting or design groups, further mapping of structures in outcrop will in most instances permit orientation of core and the integration of the larger more continuous structures from hole to hole.

Water Return

In overburden; Changes in the amount of water returning to the surface are generally a direct reflection of the nature of the material being penetrated by the lower end of the pipe or casing. Normally, the water return will be good through the less permeable sand and lessened or absent through the more permeable gravel and boulders. Integrated with other data, the amount of water return is helpful in interpreting the type of overburden.

In bedrock: Water is forced downward through the drill-rods, out through the diamond bit, and upward between the drill-rods and the rock toward the surface again. If the hole is through rock not traversed by open joints and the pipe or casing is properly sealed to bedrock, the full amount of water will return to the surface. Where the hole intersects an open joint or fault, a decrease in the water return or a complete loss of water is commonly noted. Less commonly an increase in water return is caused by artesian flow of water from an open joint whose hydrostatic head of water is higher than the collar of the hole. The amount of change in the water return is a rough indication of the amount of throughgoing channelway in the open joints and faults.

Water Return - In bedrock (Continued)

A change in color of water from the normal "skim-milk white" of the local fresh rock to a yellow to brown is helpful in recording the exact depth of deeply weathered joints.

Core Loss

The total core length recovered is less than the length of the drilled hole. The loss is for the most part caused by mechanical grinding of the core along cross-joints during the drilling process. To a lesser extent it may represent open spaces along joints and faults. Losses of 1 to 4' are common in each pull and they are generally mechanical in origin. To the extent possible, the amount of mechanical core loss and the amount of actual open space along joints has been estimated. Such estimates are based on examination of core but it is impossible to correctly estimate the amount of grinding where the original joint surface has been completely worn away.

The measurement of core loss and its proper positioning is further complicated by a not uncommon slippage of the core spring that retains the core in the barrel. In these instances, a portion of the core remains as a stub at the bottom of the hole and an equivalent core loss is recorded for the pull. If there is no mechanical core loss or actual open space in the rock, the stub will be recovered in the next pull and be recorded as a core gain. Generally, but not always, scratches and drill markings are helpful in locating the exact base of the stub.

GLOSSARY OF TERMS

Fault: A plane or zone along which movement has occurred. Indicated in the core by offset of structures, grooving, striations, slickensides, gouge and polishing. In this area the faults are associated with chlorite alteration and iron sulphides and hence were formed at the times of igneous intrusion. No indication of recent movement has been recognized although the possibility of late movement cannot be eliminated. From a stress point of view, the faults may be considered as weak planes, lubricated with slippery chlorite, which will fail under low stress unless naturally or artificially keyed into place.

Joint: A natural break in the rock with no indication of movement other than separation. The separation may range from microns up to several inches.

Parting: An insipient joint. The rock is broken along a plane but there is no visible separation. Similar to a crack that does not entirely span a window pane. Most partings separate during the drilling.

Drill-fractures: Fractures caused by stresses incident to drilling. These fractures were not present in the rock prior to drilling. The most competent unjointed rock will commonly show more drill fractures than a jointed rock whose natural breaks permit adjustment to the drilling stresses.

Strike: The direction of the line of intersection of a planar structure and a horizontal plane. For example, if a person faces northwest and places a book flat and exactly in reading position in front of him and turns the pages, all pages that are not horizontal will in every other position strike northwest (N 45° W).

Dip: The angle of tilt between a planar structure and a horizontal plane ranging from 0° if the structure is horizontal to 90° if vertical. With the book positioned as above, a page as turned in reading would dip more and more steeply to the southwest, through vertical, and less and less steeply to the northeast.

Foliation: A planar structure common to the granite-gneisses of the Gorge Creek area. Crude discs or plates of biotite (black mica) make up 2% to 25% of the rock and it is the subparallel arrangement of the mica plates that is referred to as foliation in this area. Except where noted in the geologic logs, the strength of the rock is essentially the same in every direction (torsional fractures, created by the drill, curve both across and along the foliation without evident modification or preferential orientation).

The attitude of the foliation is primarily useful as a datum plane which permits partial or complete orientation of the core.

Rock terms: As applied to the rocks at the Gorge Creek Site.)

Granite: A Competent rock composed of feldspar, quartz, and biotite. The rock shows no foliation or banding. Not common in this area.

Gneissic Granite: A competent rock composed of feldspar, quartz, and biotite. The biotite shows some tendency toward subparallel orientation and the rock shows a slight foliation. Common but not dominant in this area.

Granite-gneiss: A competent rock composed of feldspar, quartz, and biotite. The sub-parallel orientation of the biotite is well developed and the rock shows a definite foliation. The dominant rock type in this area.

Schist: A relatively incompetent rock composed of biotite, feldspar, and quartz. The soft, black biotite makes up a large percentage of the rock and the rock has an extremely well-developed foliation. Not uncommon as small stringers and dikes in this area.

Pegmatite: A competent rock composed of feldspar, quartz, and biotite. The minerals are larger than in the other rocks (½" or more across) and the biotite content is commonly lower. Abundant as minor near-white bands and dikes in this area.

Aplite: A competent rock composed of feldspar, quartz, and biotite. The minerals are smaller than in the pegmatite and the biotite content is commonly very low. Not uncommon as minor near-white bands and dikes in this area.

Rock textures:

Coarse-grained: The size of the individual minerals in the rock averages slightly more than ¼" in diameter.

Medium-grained: The size of the minerals averages slightly less than ¼" in diameter.

Fine-grained: The size of the minerals averages 1/8" or less in diameter.

Rock minerals: Simplified description for Gorge Creek Area.

Feldspar: A competent white mineral that is harder than a nail and softer than a file. Reflects light from optically flat breaking surfaces. Reacts with and bonds well with cement during hydration. The most abundant mineral in the area.

Quartz: A competent clear or white mineral that is harder than a file. Breaks on curved planes. Reacts and bonds moderately well with cement during hydration. The second most abundant mineral in the area.

Biotite (black mica): An incompetent near-black soft mineral than can be scratched with copper wire. Breaks into thin flakes. Common in all rocks of the area but generally not abundant enough to materially weaken the rock.

Hydrothermal minerals: Those formed during and shortly after igneous activity in Tertiary or pre-Tertiary time. Found along and extending out from faults and joints; useful in dating the time at which these structures were formed.

Iron Sulphides (sulphides): Pyrite, marcasite, and pyrrohotite, the "brass-like" minerals, are unevenly distributed in and near many of the joints and faults. Volumetrically they make up perhaps only 1/100% of the rock but locally they are concentrated and may constitute 1/10 to 1% of the rock. (see weathering)

Chlorite: A soft, green mineral formed in some joints and also as an alteration product of biotite near some joints and faults. The chlorite acts as a lubricant on joints and faults. Unless otherwise noted in the geologic logs, the presence of chloritized biotite does not materially weaken the rock.

Sericite: A soft, white, talc-like mica occurring in the same way as chlorite above. Lubricates joints and faults but generally does not materially weaken the rock.

Minerals related to weathering:

Limonite and other iron oxides: Yellow, brown, and red soft, earthy minerals resembling the common rust formed on iron. The relatively insoluble residual product formed by the weathering of pyrite and other iron sulphides.

Clay: Light-colored, earthy residual product formed by the weathering of feldspars and biotite.

Gypsum (selenite): Clear to white mineral softer than a fingernail formed along some open joints and faults, a calcium sulfate. A secondary mineral whose components are derived from the weathered feldspars and iron sulphides.

Melanterite: Soft, yellow mineral formed along some open joints and faults, an iron sulphate. A secondary mineral formed during the weathering of iron sulphides.

Weathering: The process of oxidation, hydration, and carbonization of the rock caused by downward moving water charged with air and organic acids. Present at the surface and extending downward along joints and other open spaces. Except where iron sulphides are present, the weathering is slight in this area and does not materially decrease the strength of the rock.

Iron sulphides are unevenly distributed in the rocks at the Gorge High Dam. These are easily oxidized by surface and downward percolating waters with the production of sulfuric acid. The sulfuric acid attacks the rocks and may weather them for distances up to several inches on both sides of the joints.

Where joints are closely spaced and sulphides are abundant, the strength of the rock may be seriously reduced in zones up to several feet in width.

In the geologic logs the weathering along joints is described as follows:

Upper Zone

1. Weathered X inches into rock: where weathering penetrates the rock for distances ranging from 1/32" to several inches the observed distance is recorded. If the weathering is measured in inches, the strength of the rock may be lowered and the presence of open space is highly probable.

2. Iron-oxide coated: The presence of a coating and its thickness is a rough indication of the minimum possible open space along the joint.

Lower Zone

3. Iron-oxide stained: The joint is in the zone of weathering and may or may not be appreciably open.

4. Slightly weathered: The weathering is less than 1/32" in thickness and the joint may be either open or tight.

5. Very slightly weathered: Esentially unweathered but enough to indicate that the break is a natural joint and not a drill-fracture. A very slightly weathered joint is generally tight if in the weathering zone but may be open if near the bottom of the weathering zone.

Sulphates

6. Gypsum, selenite, or melanterite coated: Generally unweathered and the thickness of the coating is a rough measure of the minimum open space along the joint.

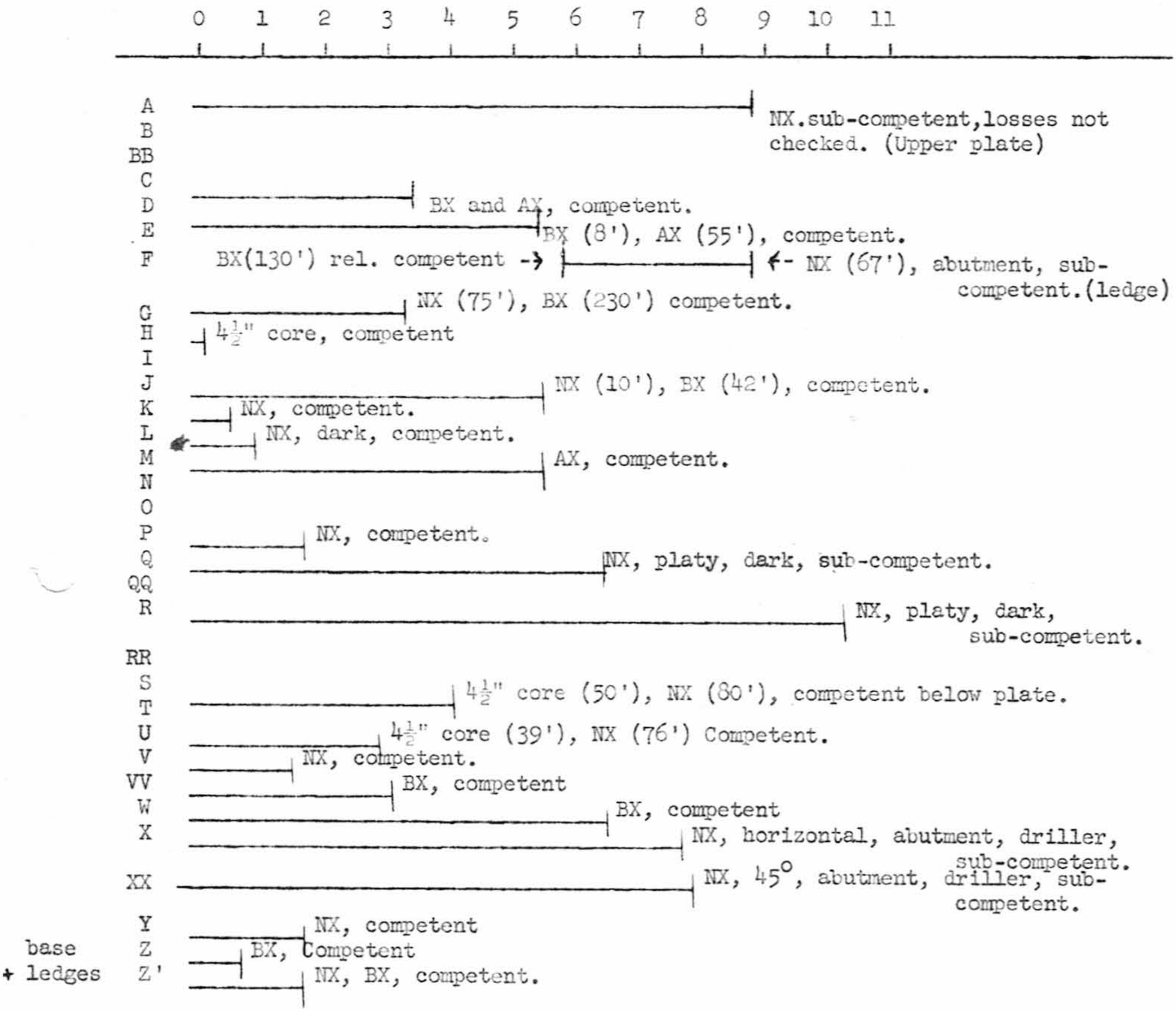
The weathering at the Gorge Creek site follows a common pattern. At and near the surface the iron sulphides are oxidized to hydrous iron oxides and the rock shows maximum weathering out from the joints. At greater depth, some of the iron sulphides are oxidized to the hydrous iron oxides and some remain fresh and unaltered.

In and below this lower zone of partial oxidation is a zone of sulphate precipitation, commonly in the form of white gypsum or selenite (calcium sulphate) and less commonly as yellow melanterite (iron sulphate). Weathering is absent or minor in this sulphate zone.

The depths of weathering vary widely and may be determined for each hole by a study of the individual geologic logs.

GORGE HIGH DAM UPPER SITE

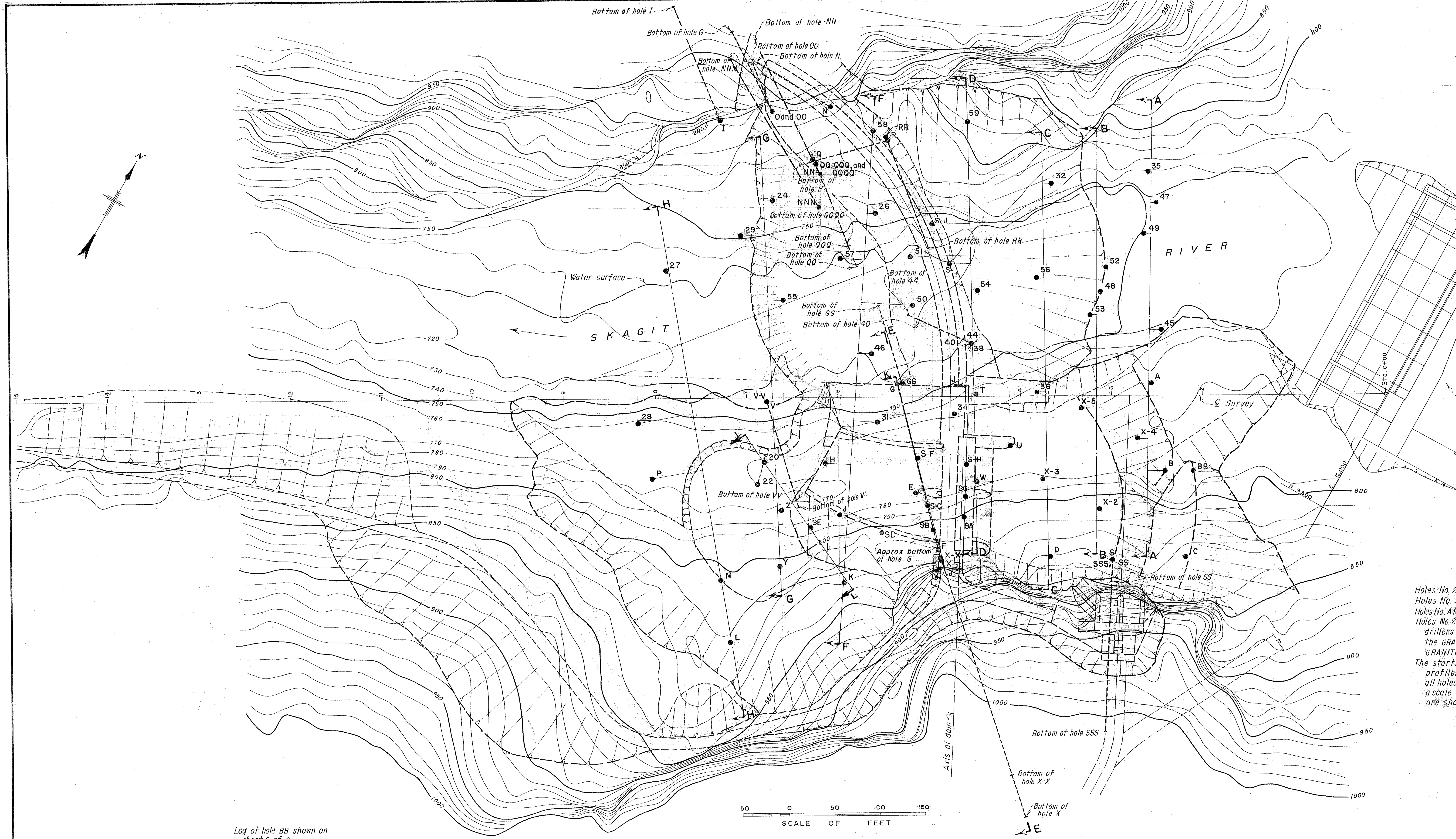
Percent Core Loss



All core from the Gorge High Dam Site is boxed and stored for current and future reference. It is recognized that problems may develop at any time that require exhaustive re-examination of a few feet of core and that such intensive study of all core would defeat the immediate objective of presenting a simple objective picture of the sub-surface geology in this area.

REVISIONS

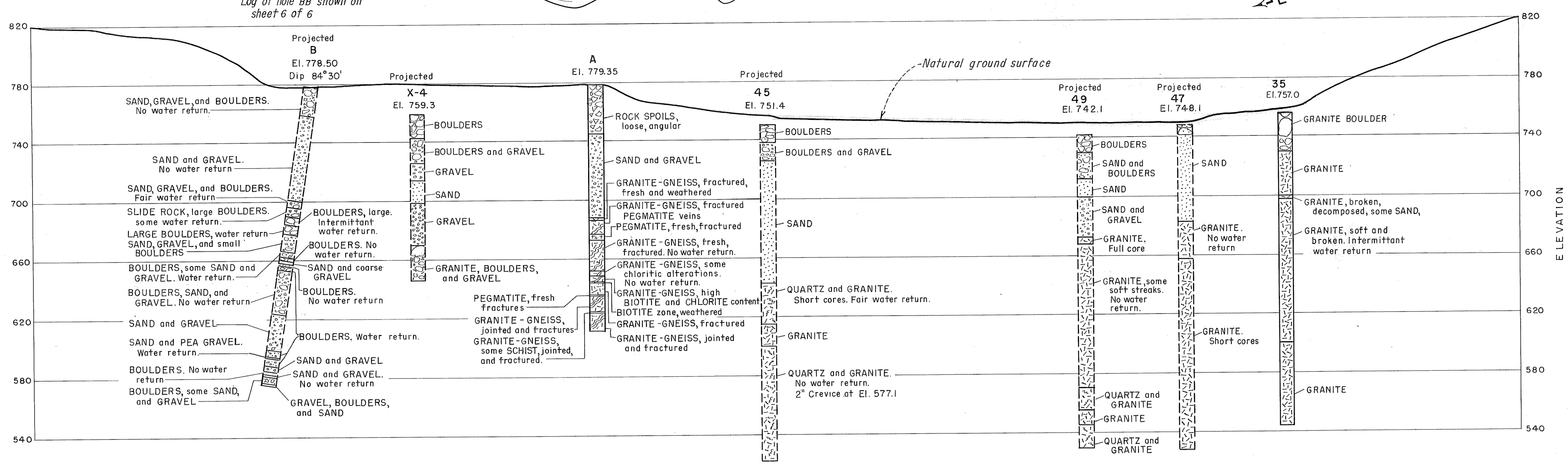
MARK	MADE BY	CKD. BY	DESCRIPTION	DATE	APPD.
1	M.F.	A.T.L.	Training wall alinement	10-2-54	J.L.S.
2	A.O.	A.T.L.	Revised limits of upstream excavation	12-7-54	C.E.S.
3	W.F.	C.T.R.	Added drill holes SA thru SG and Sections JJ-KK-LL.	12-11-57	C.E.S.
4	L.L.M.	E.J.D.	Corrected horizontal bearings of drill holes NN and NNN	6-30-59	
5	B.I.W.	G.G.S.	Added drill holes SI & SJ	10-8-59	



NOTES

Holes No. 20 to 59 incl., drilled and logged in 1918 and 1919.
Holes No. X-2 to X-5 incl., drilled and logged in 1923.
Holes No. A to Z incl., drilled and logged in 1953 and 1954.
Holes No. 20 to 59 incl., and X-2 to X-5 incl., were logged by drillers inexperienced with rock types and therefore the GRANITE indicated on these old logs should be GRANITE-GNEISS.
The starting point of all holes have been located on the profiles with scale of 20 feet = 1 inch. The depths of all holes, vertical, angular, or horizontal are plotted with a scale of 40 feet = 1 inch. All angular holes on Sections are shown in their projected lengths.

Log of hole BB shown on sheet 6 of 6



SECTION A-A

20 0 20 40 60
HORIZONTAL SCALE OF FEET (For Section A-A)

40 0 40 80 120
VERTICAL SCALE OF FEET (For Section A-A)

CITY OF SEATTLE - LIGHTING DEPARTMENT
PAUL J. RAVER - SUPERINTENDENT
SKAGIT PROJECT - GORGE DEVELOPMENT

GORGE HIGH DAM
LOCATION AND LOGS OF EXPLORATIONS

JOHN M. NELSON — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

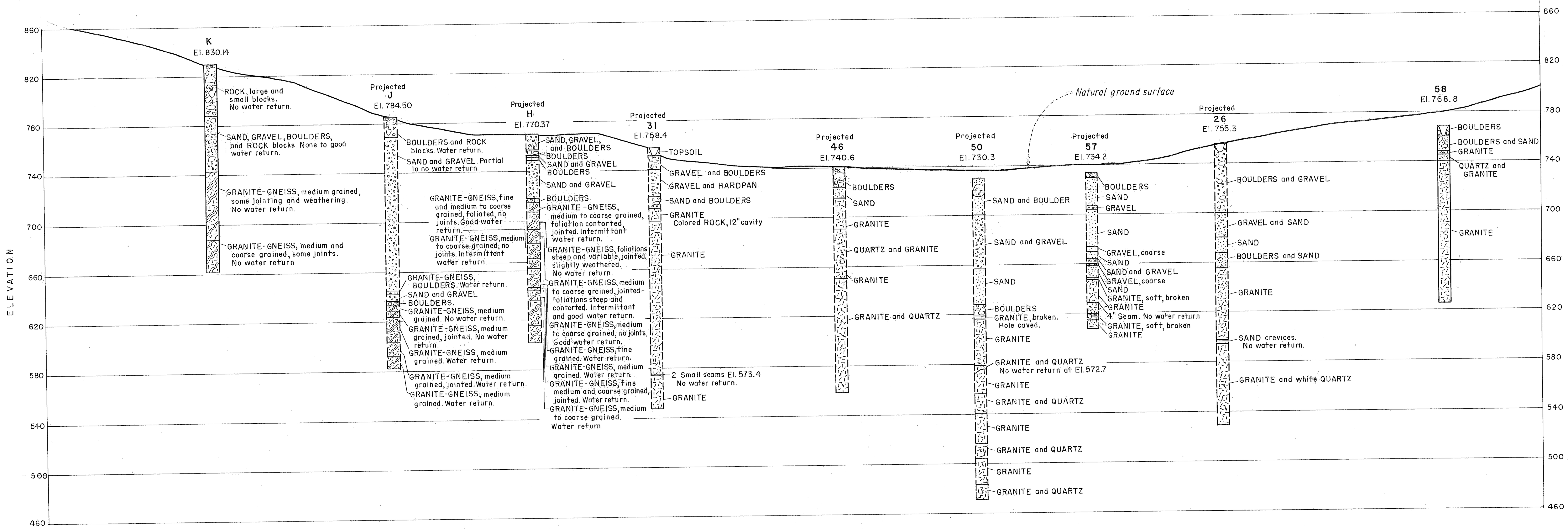
APPROVED BY THE BOARD OF PUBLIC WORKS AUG 18 1954, SEATTLE, WASH. ATTEST: E. B. Henry, SECY.; CHAIRMAN

Approved J. L. Savage, CONSULTING ENGINEER

DR. BY W.M.S.	PASSED	SUBMITTED C. R. Hoisted	ORD.
TR. BY W.M.S.		RECOMMITTED C. E. Shorling	SCALE As shown
CH. BY J.J.H.	8-8-4	APPROVED John M. Nelson	DATE 3-20-54

D-18501

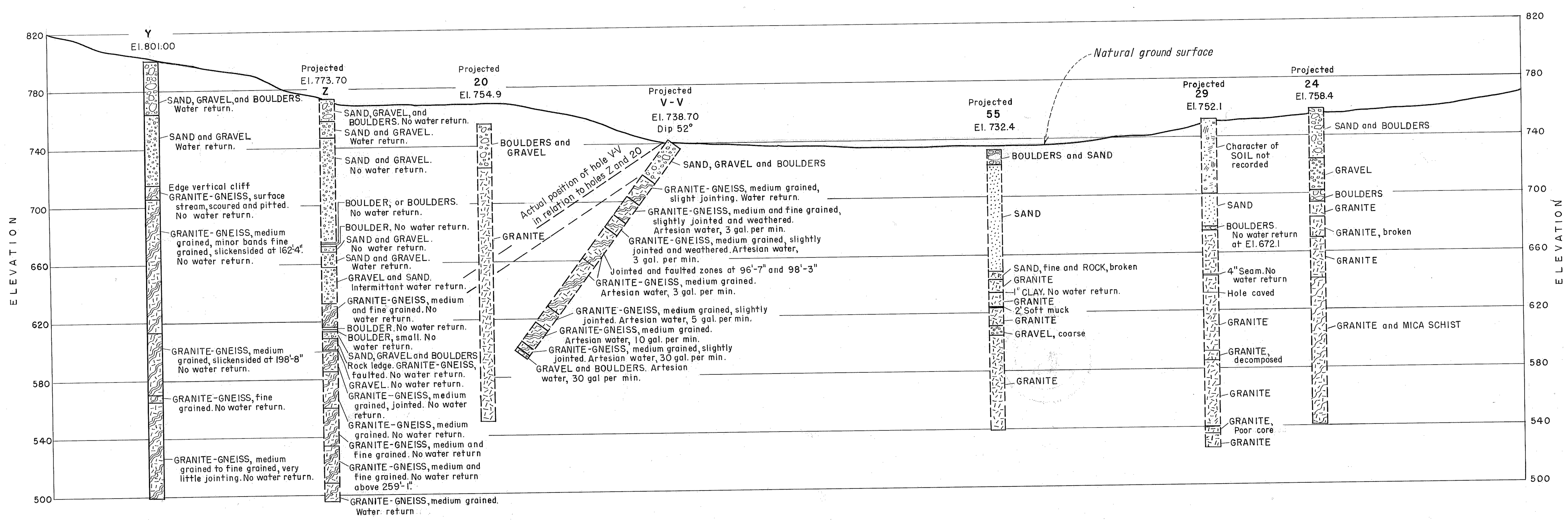
REVISIONS						
MARK	MADE BY	CKD BY	DESCRIPTION	DATE	APPD.



SECTION F-F

20 0 20 40 60
HORIZONTAL SCALE OF FEET

40 0 40 80 120
VERTICAL SCALE OF FEET



SECTION G-G

NOTE

For location of drill holes and Notes see Dwg. D-18501.

DRAWING CONVERTED BY:
Vendor: PIM, CITY/ARA
other:
Date:

SHEET 4 OF 6

JOHN M. NELSON — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

CITY OF SEATTLE - LIGHTING DEPARTMENT
PAUL J. RAVER - SUPERINTENDENT

SKAGIT PROJECT - GORGE DEVELOPMENT

GORGE HIGH DAM
LOGS OF EXPLORATIONS

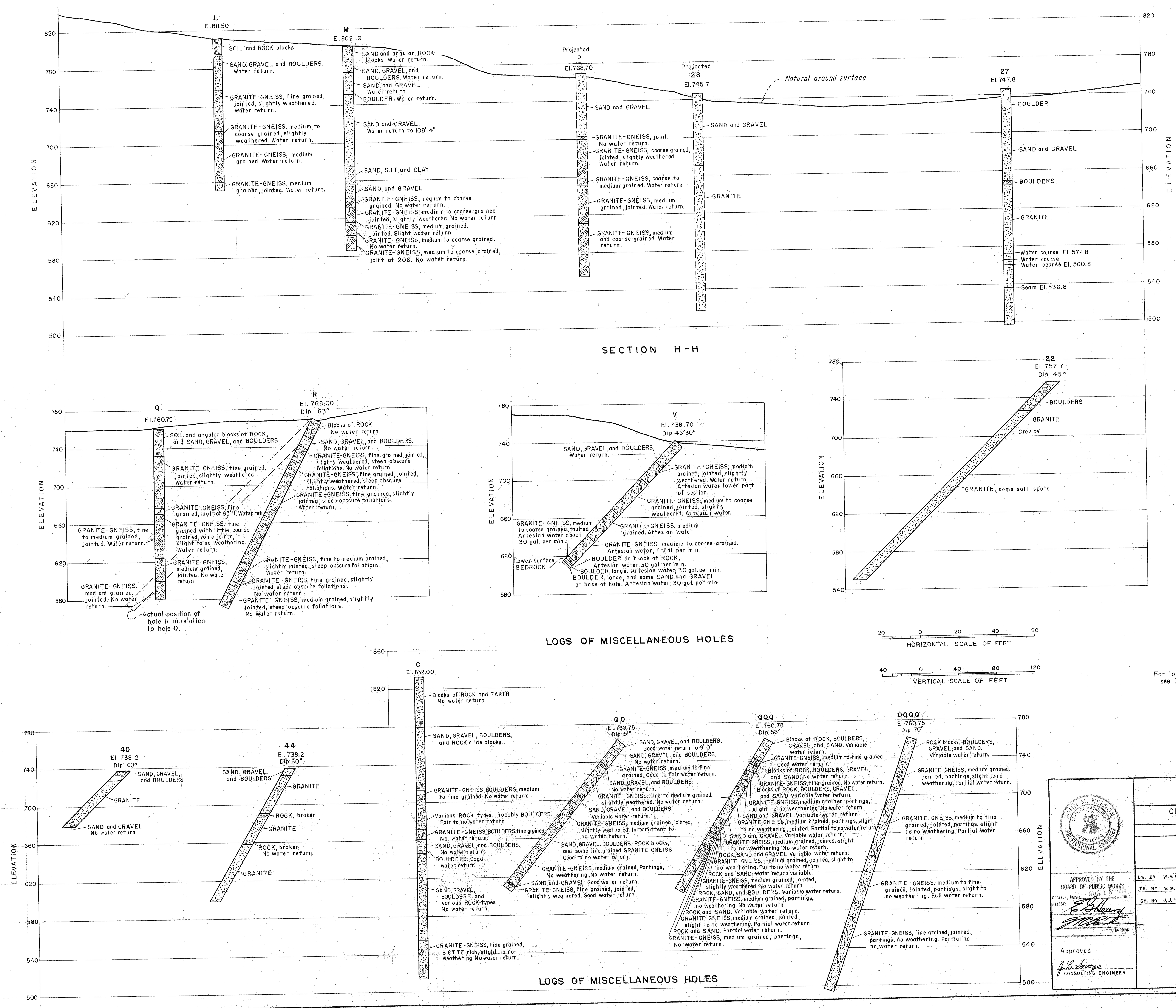
APPROVED BY THE BOARD OF PUBLIC WORKS
SEATTLE, WASH. AUG 18 1954
ATTEST: [signature] SECY.
[signature] CHAIRMAN

Approved
J. L. Savage
CONSULTING ENGINEER

DR. BY W.M.S.	PASSED	SUBMITTED [signature]	ORD.
TR. BY W.M.S.		RECOMMENDED [signature]	SCALE As shown
CH. BY J.J.H.	88-H.	APPROVED John M. Nelson	DATE 3-20-54

D-18504 MF

REVISIONS					
MARK	MADE BY	CKD. BY	DESCRIPTION	DATE	APP'D.



NOTE

For location of drill holes and Notes see Dwg. D-18501.

DRAWING CONVERTED BY:
Vendor: PIM, CIT, (SARA)
other:
Date:

SHEET 5 OF 6

CITY OF SEATTLE - LIGHTING DEPARTMENT
PAUL J. RAVER - SUPERINTENDENT
SKAGIT PROJECT - GORGE DEVELOPMENT

GORGE HIGH DAM
LOGS OF EXPLORATIONS

JOHN H. NELSON — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

APPROVED BY THE BOARD OF PUBLIC WORKS AUG 13 1954
SEATTLE, WASH. ATTEST: SECY. CHAIRMAN

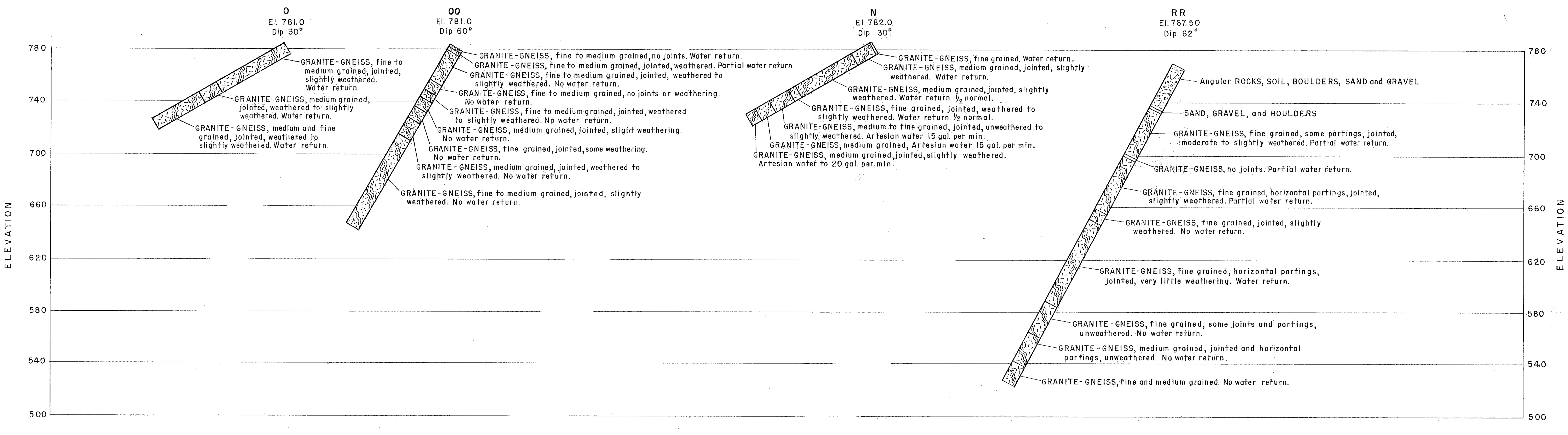
Approved
J. L. Savage
CONSULTING ENGINEER

DW. BY W.M.S.	PASSED	SUBMITTED C. R. Hoidal
TR. BY W.M.S.		RECOMMENDED C. E. Dieckerling
CH. BY J.J.H.	JJH	APPROVED John H. Nelson

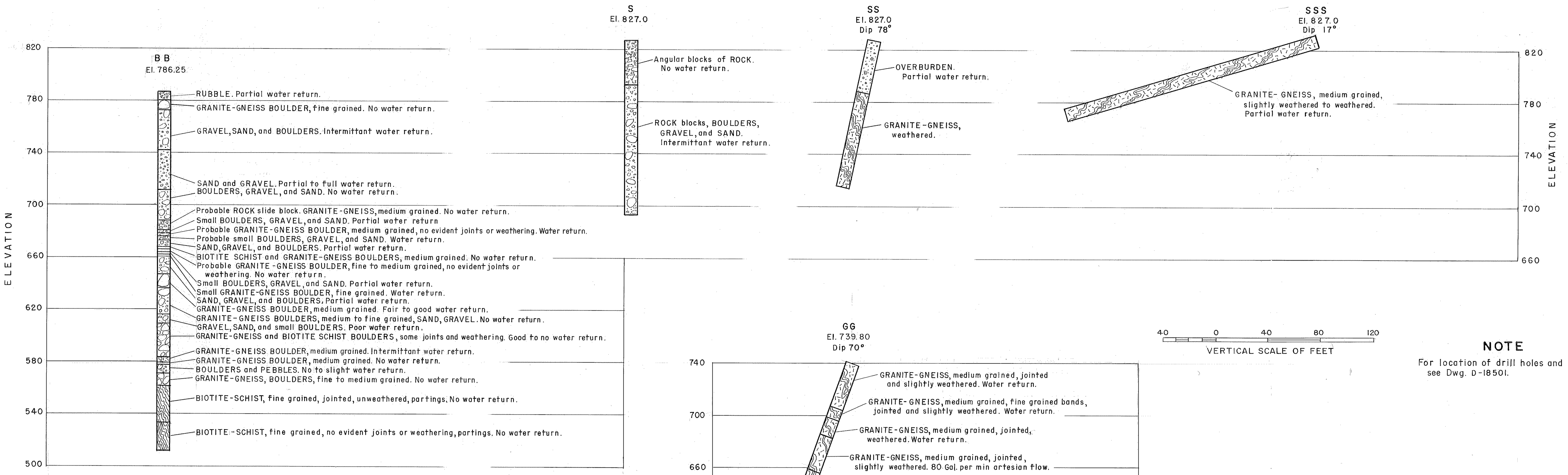
ORD.
SCALE As shown
DATE 3-22-54

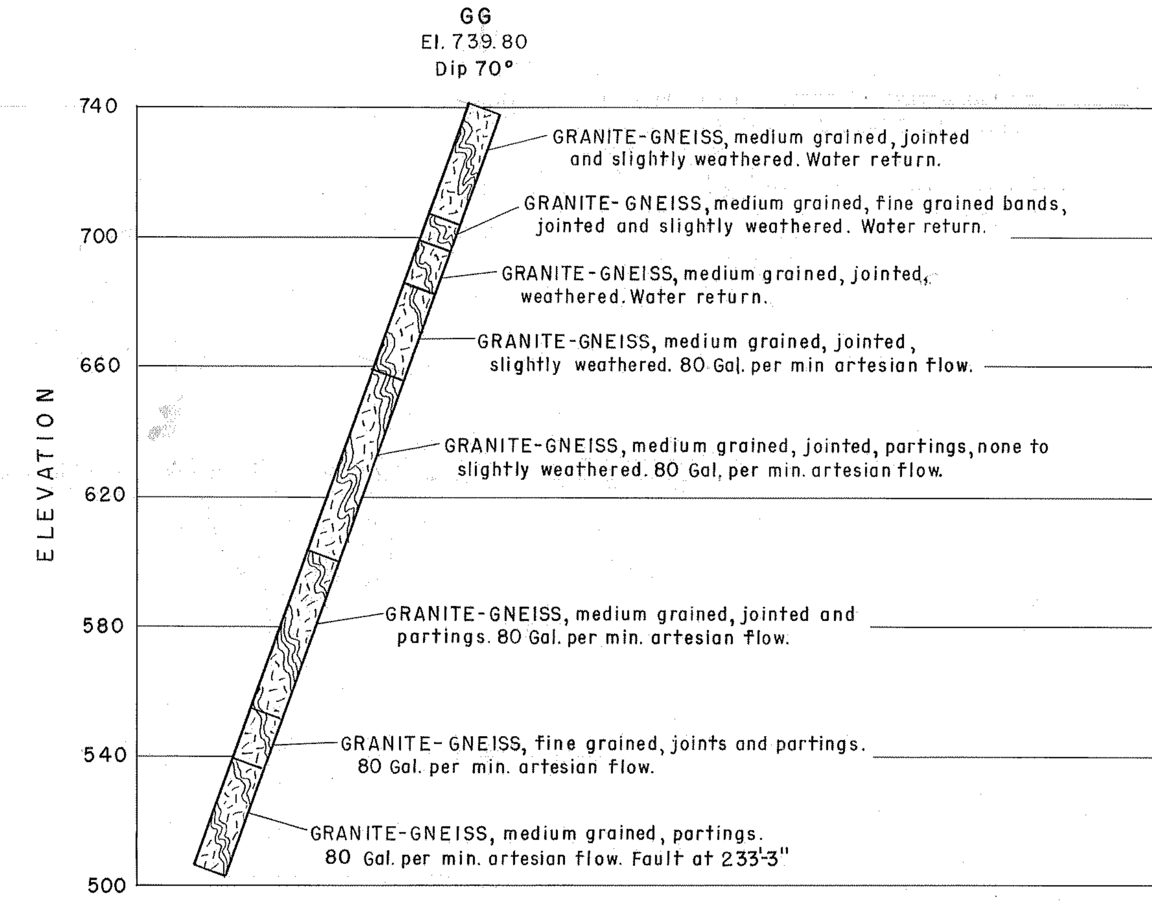
D-18505

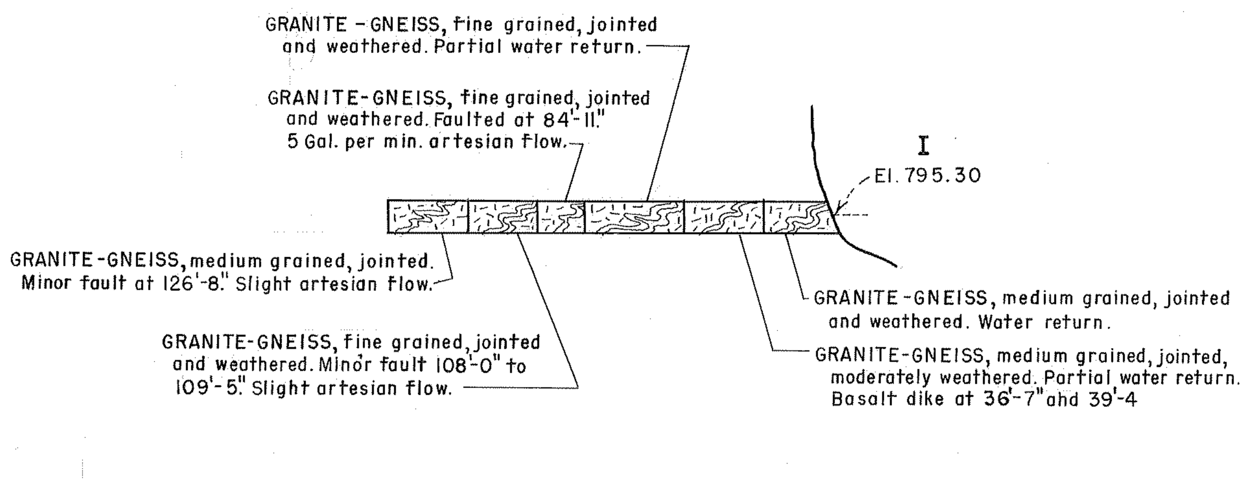
REVISIONS					
MARK	MADE BY	CKD BY	DESCRIPTION	DATE	APPD.



LOGS OF MISCELLANEOUS HOLES







LOGS OF MISCELLANEOUS HOLES

40 0 40 80 120
VERTICAL SCALE OF FEET

NOTE

For location of drill holes and Notes see Dwg. D-18501.

SHEET 6 OF 6

JOHN M. NELSON — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

APPROVED BY THE BOARD OF PUBLIC WORKS
SEATTLE, WASH. AUG 18 1954
ATTEST: [signature] SECY.
[signature] CHAIRMAN

Approved
J. L. Savage
CONSULTING ENGINEER

CITY OF SEATTLE - LIGHTING DEPARTMENT
PAUL J. RAVER - SUPERINTENDENT

SKAGIT PROJECT - GORGE DEVELOPMENT

GORGE HIGH DAM
LOGS OF EXPLORATIONS

DR. BY W.M.S.	PASSED	SUBMITTED [signature]	ORD.
TR. BY W.M.S.		RECOMMENDED [signature]	SCALE As shown
CH. BY J.J.H.	[initials]	APPROVED [signature]	DATE 3-22-54

DRAWING CONVERTED BY:
Vendor: PIM, CIT, SARA,
other:
Date:

D-18529