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GEOLOGIC & FOUNDATION REPORT
for
CARLIN CANYON TUNNELS
near
Carlin, Elko County, Nevada

PREPARED BY

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By
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for
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near
Carlin, Elko County, Nevada

This report covers the geologic, foundation, and design recommendations for the proposed Carlin Canyon Tunnels located approximately 15 miles west of Elko, Nevada. More specifically, the project extends between Stations ±1775+00 and ±1792+50 on the new proposed alignment for Interstate Route 80.

INTRODUCTION:

Field studies for the proposed project were conducted in March and April 1964. The investigation was conducted under the terms of an engineering agreement between the Nevada State Highway Department and the consulting engineering firm of Clair A. Hill & Associates of Redding and Folsom, California.

The field work consisted of drilling four (4) wet rotary borings at the westerly portal areas, making a detailed geologic cross section map depicting anticipated geologic conditions through the proposed tunnel area, and conducting a geophysical refraction seismic survey at the easterly and westerly portals. Boring data obtained while performing the foundation studies for the approach bridges to the tunnels were also used in the analysis. (See Log of Test Borings sheet attached.)

Drilling: The borings were made by means of a wet rotary drill. Standard split spoon penetration tests were conducted in the unconsolidated sediment, and diamond cores were cut from the bedrock. These cores were examined, logged and boxed for future examination by prospective bidders and design engineers, and will be available for inspection at the District III Highway Office in Elko, Nevada. Sufficient data were obtained from the studies to permit a comprehensive evaluation of the geologic aspects pertinent to the design and construction of the proposed tunnels, and to aid in the determination of the proper location of the tunnel portals.

Geologic Mapping: Geologic mapping consisted of a general field reconnaissance and detailed underground mapping of the adjacent Southern Pacific Company's railroad tunnel. This tunnel is located approximately 250 feet south, and roughly parallel to, the proposed alignment of the eastbound Interstate Route 80 tunnel.

Appendix A comprises a stratigraphic section of the geology through the Southern Pacific railroad tunnel. A projection of this geology into the area where the highway tunnels will be made indicates that the westerly portal of the eastbound tunnel will begin in the same stratum as that located at Station 540+00 in the railroad tunnel, and the westbound portal in the same stratum as that located at Station 620+00. Structural geologic methods served as a basis for projecting the mapped geology into the area of interest where the proposed tunnels will be constructed. The detailed geology at the portal sites was determined by boring methods and geophysical studies. (See Drawing No. G-5.)

Geophysical Survey: A refraction seismic survey was conducted as part of the investigation at the easterly and westerly portal areas. The field work and interpretations were conducted by J. W. Cooksley, Jr., Geophysicist, of Redding, California. A 12 channel refraction seismic system, Electro-Tech 75-12, was used during this phase of the study.

Normal profile shooting methods were used exclusively. Four (4), one-spread traverses, employing a total of 16 shot points, were used at the westerly portals; and three (3), one-spread traverses, employing a total of 12 shot points, were used at the easterly portals. (See attached Drawing No. G-5 for profile locations.)

The purpose of the above investigations was to determine the bedrock surface to facilitate location of the tunnel portals; to assist in the determination of safe allowable design loads for tunnel footings; and to forecast expected rock loads, working conditions, and other pertinent rock and subsurface data as they affect design and construction.

The work was conducted under the supervision of the consultant's Principal Engineering Geologist, C. H. Harned, and was inspected by the State's Engineering Geologist, Stanley Mosher.

Site plans, bench marks, alignment data, proposed portal locations and desirable footing elevations were furnished by the Nevada State Highway Department. Numerous field and office conferences were held during the progress of the work, and the degree of cooperation rendered by the State Bridge Department, the U. S. Bureau of Public Roads and personnel of the Highway District Office in Elko was outstanding. Services rendered, and the highly cooperative attitude of the Southern Pacific Company's Ogden, Utah office and Carlin, Nevada division personnel was also very helpful.

GENERAL GEOLOGY:

The Carlin Canyon area, which lies in the Great Basin and Range Province, is located at the intersection of the westward-flowing Humboldt River and the West Elko Hills. These hills trend north-south and represent a northerly extension of the Pinyon Range. Typical Basin and Range Topography prevails, with normal block-faulting, and erosion by the Humboldt River being responsible for the major topographic features.

In general, rocks of Paleozoic Age, dipping steeply to the east and faulted, are overlain at the tunnel portal areas by poorly-consolidated and unconsolidated deposits of Quaternary Age, consisting of river sediment, colluvium and talus.

Tonka Formation: The oldest rocks in the tunnel area are Paleozoic rocks of Mississippian Age, and are designated the Tonka Formation. This formation consists of brown-weathering, chert-pebble conglomerate, with intercalated beds of sandstone, limey siltstone, shaly limestone and clay-shale. These latter strata are light grey, pink, grey-yellow or light brown in color and commonly display a thin bedded, wavy, laminated stratification.

The pebble conglomerate and sandstone crop out as a series of bold, dark brown or reddish-brown cliffs and ledges near the entrance to the westerly portals. The siltstone, shale and other less competent beds have been eroded more extensively and form the intervening gullies and depressions. The conglomerate and sandstone beds are well indurated and are cemented by hematite, limonite, quartz and chalcedony.

The conglomerate and sandstone beds are usually 3 to 5 feet thick, and the intervening shale and siltstone beds vary in thickness from a fraction of an inch to several inches. The stratification is generally indistinct within a unit, but may be sharp between differing lithologic units where weathering has produced a parting or separation plane parallel to the bedding.

Strathearn Formation: The Strathearn Formation,of late Pennsylvanian Age, rests unconformably upon the older Tonka Formation, as evidenced by the sharp angular unconformity exposed in the canyon wall near the tunnel site. The Strathearn is composed of medium to massive bedded limestone interbedded with flaggy calcareous shale and shaly limestone. The rocks of the Strathearn that will be encountered during tunneling operations are generally moderately to badly jointed and fractured. The strike of the Strathearn Formation varies from N17°W to N41°W, and the dip varies from 66° to 80° NE.

Quaternary Deposits: Deposits of Quaternary Age consist of old granular river sediment deposited during Pleistocene time, and Recent colluvium and talus. The Pleistocene sand and gravel is found in the vicinity of the westerly portals of the tunnels, and was first identified while conducting foundation studies for the bridge adjacent. Seismic investigations and subsequent borings delineated the extent of these deposits. Aggrading by the Humboldt River in Pleistocene time deposited the alluvium in thicknesses as great as 50 feet at the westerly portal areas, and subsequent mass wasting in geologically Recent time has covered the river sediment with a thin mantle of colluvium and talus which ranges in thickness from 0 to 20 feet. Some colluvium is intermixed with the Pleistocene alluvium as the old valley wall was quite steep and colluvium rolled or washed into the Pleistocene river channel off the steep slopes above it.

The ancestoral Humboldt River also cut a channel into the bedrock at the easterly portal areas, but this old channel is filled exclusively with colluvium and talus rather than river gravel. (See Drawings G-4 and G-5.)

GEOLOGIC STRUCTURE:

Steeply dipping beds constitute the main geologic structure at the tunnel site. Many of the less competent beds are weathered, and these rocks are soft and friable. Local bedding-plane faults are present (but not common), and the faults seem to die out within short distances along strike directions. Movement along the bedding-plane faults has been minor, and has not occurred during the last 60 years, as evidenced by observations made within the Southern Pacific railroad tunnel.

The rocks of the Tonka Formation strike quite consistently at N11° to 20°W, and dip ±85°NE. The dip and strike of the Strathearn Formation is not as consistent as that displayed by the Tonka, with the beds striking between N17°W and N41°W, and the dip varying between 66° and 80°NE. The Strathearn Formation is moderately to badly fractured, and as attested to by the variations in the strike and dip directions, is locally folded and warped. This warping is due to the close proximity of a high angle fault of considerable extent that is located north of the easterly portal area. (See geologic map attached.) This fault has raised the Tonka Formation from its normal stratigraphic position and "repeated" it in the Strathearn Formation. Effects of the faulting are seen in the limestone beds of the Strathearn Formation in the vicinity of the east portal area. Here a very high degree of fracturing, brecciation, and local strike and dip variations attest to the fault's presence. Minor parallel faults, adjacent to the main fault and within the limestone, no doubt accompanied the major faulting.

Initial observation of some of the limestone outcrops at the easterly portal site gives the impression that some of the larger outcrops are loose blocks of rock that have broken off and slid down-slope, as their attitude does not conform to the general geologic structure. Upon closer examination, however, these apparent slump blocks were found to be in-place, and their attitudes are a direct result of local warping and drag folding.

Three sets of joints were noted in the Tonka and Strathearn Formations. One set is parallel to the bedding, and the second and third sets strike N65° to 85°E and N65° to 85°W. The dips of the joints vary considerably with a SW or SE dip being the most common. Spacing of the joints in the sandstone and conglomerate is usually two (2) to five (5) feet, while joint spacing in the shale, siltstone, and shaly limestone may be as close as one (1) inch.

SEEPAGE AND DRAINAGE:

Major water problems are not expected to be encountered during construction; however, small areas of seepage were noted in the unlined Southern Pacific Company's tunnel. Since the entire length of the tunnels will require lining, weep holes and drains should be provided during design to assure proper drainage.

OVERBREAK:

The rocks that will be encountered during tunnel excavation dip from 65° to near vertical, and are herein classified as medium to massive, moderately jointed to moderately blocky and seamy to very blocky and seamy. The blocks between joints and fractures are generally interlocked or secondarily cemented. Where the joints are closely spaced (as they will be in certain portions of the tunnel), the amount of overbreak will largely be dependent upon the distance between the working face and the supported roof. The bridging action or "stand up" capacity of the rock is moderately good, and, with proper construction procedures with respect to blasting, it is estimated that the average overbreak will not exceed ten per cent (10%).

Where excessively blocky or seamy ground is encountered, the length of time which elapses between the removal of the natural roof support by blasting and the installation of the steel supports should be as short as possible. It should be anticipated that where the tunnel passes abruptly from a rock formation with a long bridge-action period (such as in the massive conglomerate), into a formation with a short bridge action (such as in the clay-shale or siltstone beds), local but excessive overbreak conditions should be anticipated.

ROCK LOADS AND SIDE PRESSURES:

Rock loads and pressures will vary considerably with lithological and structural variations within the beds. As definite boundaries cannot be established between the occurrence of moderately jointed and blocky and seamy rock, prior to construction, rock load and side pressure computations have been based on the following rock conditions:

1. Portal Sections: Saturated, blocky, fractured and seamy rock, with moderate side pressure.
2. Interior Sections: Moist, medium to massive bedded, moderately blocky and jointed, with little or no side pressure.

Since the strength, lithologic, and structural characteristics of the rock will change abruptly in this sequence of sedimentary beds, it is recommended that an experienced tunnel engineer be available during the construction period.

For design purposes, the first 200 feet of the tunnels at the westerly ends, and the first 250 feet at the easterly ends should be designed using a vertical rock load of 10,000 pounds per square foot of projected cross section. The expected maximum horizontal pressure acting on the vertical supports is 3,500 pounds per square foot.

The interior section of the tunnels should be designed for an expected vertical load of 3,000 pounds per square foot of projected cross section. The maximum horizontal pressure acting on the vertical supports will be 1,000 pounds per square foot.

Load computations were based on the assumption that during the spring thaw periods,and abnormally long wet seasons, rocks in the tunnels are likely to be saturated; therefore, design computations based upon dry conditions were disregarded.

CUT-SLOPE DESIGN AND EXCAVATION:

Open cutting will be necessary at the tunnel portals before the actual tunnel headings begin. Overall cut slopes of 1 to 1, including benches where necessary, are recommended for excavations in the vicinity of the portals. Benches should be a minimum of ten feet (10') wide and sloped at 40 to 1 toward the back of the cuts. Provision should be made for transporting water from the benches to minimize ponding. The possibility of ponded water occurring on the benches should be avoided. The recommended maximum vertical distance between benches is 50 feet.

Stability problems are not expected in the colluvial soils at the westerly tunnel portals. However, talus, in a semi-cohesionless state, forms a veneer over the bedrock at the easterly portals. The talus in this area lies on a slope of approximately 1 to 1, and is resting at, or very nearly at, its maximum angle of repose. This talus occupies a depression formed by erosion of less competent limestone beds in the Strathearn Formation, and has washed or rolled down-slope from higher positions.

To minimize excavation problems at the easterly portals, when starting the tunnel bores, it is recommended that the talus first be removed. It is estimated that approximately 8,500 cubic yards of material will be involved in this stripping operation. This quantity of stripping is in excess of the minimum excavation required for the proposed design cut slopes at the easterly portals.

For design purposes, it is estimated that 100 cubic yards of rock excavated from the tunnels will make 110 cubic yards of embankment (10% swell). The colluvium and alluvium at the west portal is classified as common excavation and is compact to very dense. The shrinkage factor for this material is estimated at five (5) percent. The colluvium and talus at the east portal is also classified as common excavation, and as it has a consistency of loose to compact, shrinkage of this material when placed in embankment is estimated at ten (10) percent.

GROUTING AND BACKPACKING:

In order to keep rock loads to a minimum, the tunnel supports should be placed and backpacked as soon as possible after shooting, and the area between the spring lines and the apex of rock arches should be cement grouted.

PORTAL LOCATION AND FOOTING FOUNDATION ELEVATIONS:

It is recommended that the westerly portals on both the eastbound and westbound lanes be located at Station 1777+40. The easterly portals should be located at Station 1792+10 for the eastbound lanes and Station 1791+75 for the westbound lanes. Footing elevations at the westerly portals should be 4966.0 for the eastbound lanes and 4976.0 for the westbound lanes. Easterly portal footings can be founded at elevations 4969.5 and 4979.5 for eastbound and westbound lanes respectively.

The base of the footing block should be placed approximately three and one-half feet ($3\frac{1}{2}$') below the finished tunnel grade, and the footing block concrete poured against unformed and undisturbed in-place bedrock to assure maximum bonding and friction effects. Provisions should be made in the specifications and contract documents to lower the footings in the portal areas as much as five (5) feet at contract prices, in the event in-place bedrock is not encountered at the recommended footing elevations. The footings will then require being stepped up to the maximum allowable footing grade (i.e. 3½ feet below finished tunnel grade) for the necessary vertical and horizontal distances.

Recommended footing elevations for the retaining walls at the east and west tunnel portals are the same as the footing elevations for the portals. The retaining wall footing will protrude out approximately ten (10) feet from the face of the portal and should be founded on in-place bedrock, with the footing concrete poured against unformed and undisturbed rock. Provisions should be made to raise or lower the footing during construction to assure placing on in-place bedrock at the most economic elevation. Careful inspection should be made by the Resident Engineer to assure that the footings are not placed partially on bedrock and partially on alluvial or colluvial soils.

FOUNDATION RECOMMENDATIONS:

Because of weathering, and/or fracturing at the tunnel portals, design loads for footing foundations for the first 200 feet at the westerly ends of the tunnel and 250 feet at the easterly ends of the tunnel should not be greater than ten (10.0) tons per square foot. The interior section of the tunnels, or that portion that remains, excluding the 450 feet of portal sections, may be designed for footing pressure loads to 15.0 tons per square foot.

LEGAL ASPECTS & DAMAGE:

It is not expected that blasting within the proposed highway tunnels will damage the Southern Pacific railroad tunnel, but the Highway Department should provide for the necessary agreements and legal requirements needed for protection against alleged claims of damage due to blasting.

If the railroad tunnel remains unlined, except for the portal areas, as is presently the case, provisions should be made for constant observation, or warning devices, within the railroad tunnel during times of blasting in the highway tunnels adjacent.

The Southern Pacific Company presentlyhas plans for lining their tunnel with concrete. If the lining is completed prior to the construction of the highway tunnels, it is recommended that photographs be taken of the lining for the entire tunnel length prior to highway construction. These photographs should show all leaks or cracks in the lining with specific delineation, and verification should be required by representatives of the Southern Pacific Company.

Damage to the concrete placed in the eastbound tunnel may occur in the event the contractor does not conduct his tunneling operations in such a fashion as to keep the headings of the tunnels and the order of work in the parallel tunnels at uniform rates of progress. It is possible that forces exerted by the footing loads of the westbound tunnel might affect the lining and footing concrete in the eastbound tunnel. Stress relaxation within the rock may also affect the adjacent tunnel if headings are not kept as near uniform as possible.

SUMMARY OF DESIGN RECOMMENDATIONS:

1. Ground water is not expected to be encountered except as minor amounts of seasonal seepage.
2. Since the tunnels will require concrete lining, weep holes and drains should be provided to handle small amounts of anticipated seasonal seepage.
3. It is believed that overbreak will not be greater than an average of 10 per cent, but excessive overbreak can be expected in the shale and siltstone, unless careful construction practices with regard to blasting are followed.
4. Vertical rock loads of 10,000 pounds per square foot, and horizontal loads of 3,500 pounds per square foot should be used for design computations in the first 200 feet of tunnels at the westerly ends and 250 feet at the easterly ends.
5. The interior portion of the tunnel should be designed using vertical loads of 3,000 pounds per square foot, and 1,000 pounds per square foot horizontal pressures.
6. The westerly portals of the eastbound and westbound lanes should be located at Stations 1777+40, and footings should be founded at elevations 4966.0 and 4976.0 for the eastbound and westbound lanes respectively.

7. The easterly portals of the eastbound lanes should be located at Station 1792+10 and Station 1791+75 for the westbound lanes. Footings should be founded at elevations 4969.5 and 4979.5 for the eastbound and westbound lanes respectively.

8. Safe allowable footing loads to 10.0 tons per square foot may be used in the first 200 feet at the westerly tunnel ends and 250 feet at the easterly tunnel ends. An allowable load to 15.0 tons per square foot may be used for footings founded on rock throughout the remaining length of the tunnel.

9. Design loads to 10.0 tons per square foot may be used for retaining wall footings (maximum toe pressure) founded on fractured bedrock.

10. Overall cut slopes of 1 to 1 are recommended for excavation in the vicinity of the portals. Benches should be used to separate cuts that are greater than 50 feet in height. Benches should be at least 10 feet wide and slope at approximately 40 to 1 back toward the cut slope.

11. The loose 8,500 cubic yards of talus in the vicinity of the easterly portals should be removed prior to beginning the tunnel bores. This quantity is in excess of the minimum excavation required for the proposed design cut slopes at the easterly portals.

12. An experienced tunnel engineer should be available during construction.

Should additional questions arise during the design or construction of the tunnels, please feel free to call upon us for assistance.

Respectfully submitted,
CLAIR A. HILL & ASSOCIATES

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APPENDIX A

STRATIGRAPHIC SECTION THROUGH THE SOUTHERN PACIFIC RAILROAD TUNNEL

Section Mapped from West Portal (Station Zero) to East Portal (Station 1902)

	Station	Description
TONKA FORMATION	0 - 200	Tonka Formation and colluvium, covered by concrete lining, probably weathered and soft and exerting horizontal pressures.
	200 - 245	Shale, grey, calcareous. Beds strike N11°W and dip 85°NE. Beds are 2 inches to 1 foot thick with flaggy partings. Joints strike and dip N11°W, 85°NE; N83°E, 47°SE and N85°E, 63°NW. Estimated overbreak is 15 percent and is due to breaking of shale along bedding planes. In some zones, slaking is common. Timber backpacking is loose--taking no apparent lateral stress. Fragments up to 4 feet in diameter and 1.5 feet in thickness have broken loose from the wall.
	245 - 300	Sandstone, buff, calcareous, fine to medium grained, beds up to 4 feet thick with intercalated pebble conglomerate beds to 3 inches thick. Beds strike N10° to 15°W and dip 84°NE. Joints strike and dip N10° to 15°W, 84°NE and N85°W, 35°NE. Estimated overbreak 5 percent. Slaking very minor and no apparent lateral pressures. No backpacking has been used.
	300 - 360	Limestone and shale, buff, beds are from 1 to 3 feet thick. Beds strike N12°W and dip 80°NE. Some beds of thin wavy laminated siltstone are intercalated. Joints strike and dip N12°W, 80°NE; N80°W, 67°SE and N85°W, 45°NE. Estimated overbreak is 5 to 10 percent.
	360 - 365	Siltstone, tan, argillaceous and soft. Beds strike N11°W and dip 81°NE.
	365 - 410	Limestone, silty, buff to grey, generally massive but with some thin laminated beds. Jointing is insignificant.
	410 - 450	Siltstone and shale, vari-colored. Beds strike N11°W and dip 79°NE. Joints strike and dip N11°W, 79°NE; N26°E, 28°NW and N70°E, 47°SE. Estimated overbreak varies from 5 to 15 percent.

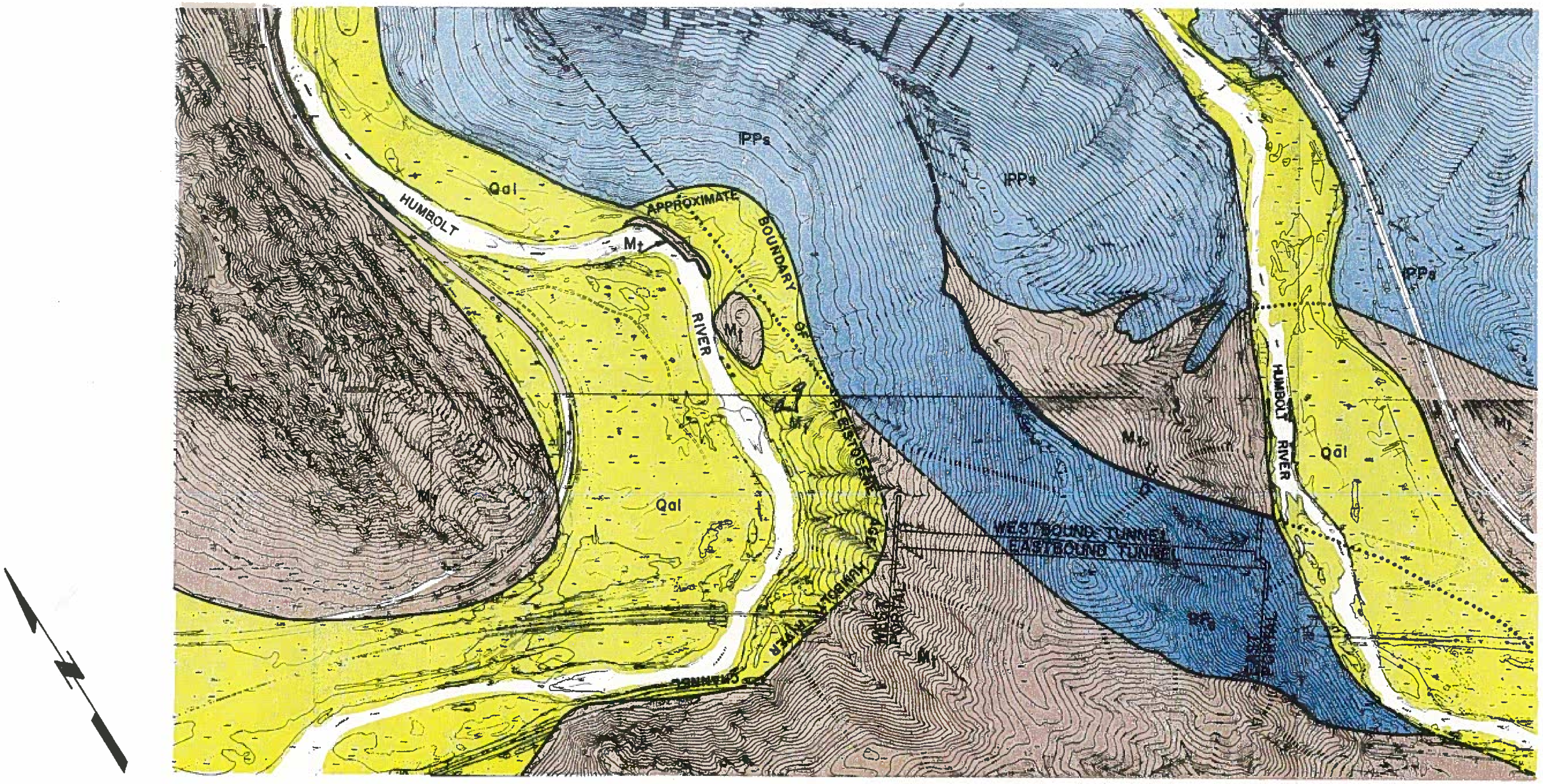
TONKA FORMATION	450 - 700	Conglomerate, intercalated with beds of sandstone and limestone with a few thin siltstone and shale beds. Overbreak less than 5 per cent. All beds are generally massive except for the siltstone and shale beds. Beds strike N23°W and dip 86°NE. Water drips from the arch between Stations 612 and 615--possible shear zone. The tunnel is lined from invert to apex of arch from Station 500 to 700 with timber lining.
	700 - 750	Pebble conglomerate, friable and weathered, with one (1) foot beds of sandstone and silty limestone. Beds strike N21°W and dip 87°SW. Estimated overbreak 10 per cent.
	750 - 775	Sandstone and siltstone, fine to medium grained, all highly calcareous. Estimated overbreak 5 per cent. Railroad tunnel is lined to apex of arch with timber lining.
	775 - 830	Sandstone, medium to coarse grained, buff colored. Beds strike N30°W and dip 83°NE. Joints strike and dip N30°W, 83°NE and N80°E, 87°SE. Estimated overbreak 10 to 15 per cent.
	830 - 870	Pebble conglomerate, very coarse grained, up to one (1) inch pebbles, beds strike N15°W and dip 78°NE and are generally massive, from 1 to 3 feet thick. Overbreak less than 5 per cent.
	870 - 915	Limestone, shaly and silty, grey. Beds strike N17°W and dip 87°NE.
	915 - 960	Shaly limestone, sandstone and pebble conglomerate with beds of shale and siltstone. Beds strike N17°W and dip 87°NE. Overbreak as high as 25 per cent in some areas.
	960 - 980	Pebble conglomerate, coarse grained and massive with some soft weathered stratum. Beds strike N13°W and dip 84°NE. Joints strike and dip N13°W, 84°NE and N77°E, 67°SE. Estimated overbreak is 15 per cent in the soft weathered pebble conglomerate.
	980	Minor and local shear zone, strikes N12°W and dips 50°SW.
	980 - 1000	Shale, calcareous, reddish.
	1000 - 1010	Sandstone, fine grained and calcareous, strikes N25°W and dips 82°SW.

TONKA FORMATION	1010 - 1045	Pebble conglomerate, massive bedded, estimated overbreak 5 to 10 per cent.
	1045 - 1065	Shale, calcareous, reddish. Beds strike N25°W and dip 88°NE, and joints strike and dip N25°W, 88°NE and N65°E, 83°SE.
	1065 - 1100	Pebble conglomerate, weathered, massive beds from 1 to 4 feet thick. Estimated overbreak 5 per cent. Some fine sandy siltstone interbeds to ½ foot thick.
	1100 - 1150	Conglomerate, very coarse and very massive, overbreak less than 5 per cent.
	1150 - 1175	Pebble conglomerate and shale, weathered and soft, estimated overbreak 10 per cent. Beds strike and dip N17°W, 88°NE.
	1175 - 1225	Conglomerate, massive beds to five (5) feet thick, overbreak less than five (5) per cent.
	1225 - 1230	Siltstone, greyish white, overbreak 5 to 10 per cent.
	1230 - 1250	Shale, siltstone, sandstone and limestone, vari-colored, overbreak 10 to 15 per cent.
	1250 - 1270	Conglomerate, argillaceous and massive, overbreak less than five (5) per cent. Beds strike N8°W and dip near vertical, some local movement along bedding and jointing planes.
	1270 - 1280	Siltstone and shale, vari-colored, estimated overbreak 15 per cent. Beds strike and dip N35°W, 85°SE.
	1280 - 1290	Sandstone and quartzite, pink to buff, estimated overbreak five (5) per cent. Beds strike and dip N10°W, 78°NE. Joints strike and dip N10°W, 78°NE; N25°E, 38°NW and N65°E, 85°NW.
	1290 - 1300	Sandstone, argillaceous, buff. Estimated overbreak 5 to 10 per cent.
	1300 - 1350	Conglomerate, massive, estimated overbreak less than five (5) per cent.

TONKA FORMATION	1350 - 1370	Siltstone and sandstone, vari-colored, estimated overbreak 10 to 15 percent.
	1370 - 1420	Conglomerate, massive, with interbeds of quartzite and sandstone. Estimated overbreak 5 percent. Beds strike N15°W and dip vertical. Joints strike and dip N15°W, with vertical dips and N65°W, 55°SW.
	1420 - 1440	Shale and conglomerate, shear zone. Beds strike N30°W and dip 75°NE.
	1440 - 1465	Conglomerate, massive, estimated overbreak 5 percent.

-------------ANGULAR UNCONFORMITY---------------

STRATHEARN FORMATION	1465 - 1510	Limestone, massive, beds up to 4 feet thick, with beds of conglomerate to 1 foot thick. Beds strike N17°W and dip 66°NE. Joints strike and dip N17°W, 66°NE and N78°W, 55°SW. Estimated overbreak less than 5 percent.
	1510 - 1535	Limestone, shaly, tan. Estimated overbreak 5 to 10 percent. Beds strike N41°W and dip 80°NE. Joints strike and dip N41°W, 80°NE and N75°W, 61°SW.
	1535 - 1560	Limestone, medium bedded, tan to grey.
	1560 - 1680	Limestone, shaly, medium to massive bedded. Beds strike and dip N30°W, 70°NE. Joints strike and dip N30°W, 70°NE; N80°E, 37°SE and N75°W, 62°SW.
	1680 - 1750	Limestone, fractured, no lateral pressure on backpacking. Estimated overbreak 5 percent.
	1750 - 1902	Limestone, tunnel concrete lined to apex of roof, assumed to be fractured with caving and horizontal pressures.



LEGEND

QUATERNARY	Qal	INCLUDES RECENT & PLEISTOCENE COLLUVIUM AND RIVER DEPOSITED ALLUVIUM
LOWER PERMIAN - UPPER PENNSYLVANIAN STRATHEARN FORMATION	IPPs	MEDIUM TO MASSIVE BEDDED LIMESTONE WITH INTERBEDS OF CHERT-GRANULE AND PEBBLE CONGLOMERATE, SILTSTONE AND SHALE
LOWER PENNSYLVANIAN UPPER MISSISSIPPIAN TONKA FORMATION	Mt	CHERT-PEBBLE CONGLOMERATE WITH INTERBEDS OF SANDSTONE, QUARTZITE CALCAREOUS SILSTONE, ARGILLACEOUS LIMESTONE AND SHALE

———	DEFINITE CONTACT
— — —	APPROXIMATE CONTACT
········	CONCEALED CONTACT (APPROXIMATE LOCATION)
U / D	HIGH ANGLE FAULT, RELATIVE MOVEMENT - U, UP AND D, DOWN

SCALE: 1"=450'

DWN. J.C.V.
CHK. T.C.
DATE SEPT.64

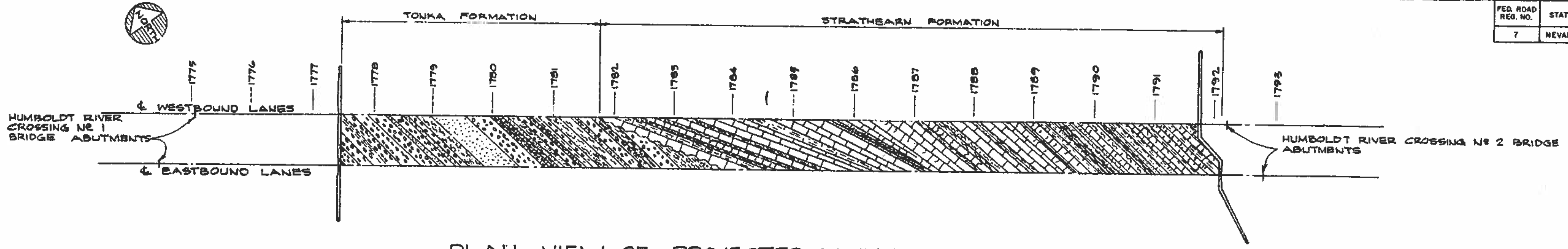
Clair A Hill
REG. CIVIL ENG. NO. 1158
Tom
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1626 COURT STREET REDDING, CALIFORNIA

GENERAL GEOLOGIC MAP
STATE OF NEVADA
CARLIN CANYON TUNNELS

DWG. NO. G-1
C-2005.19

FED. ROAD REG. NO.	STATE	PROJECT NO.	COUNTY	CONTROL SECTION	STATE ROUTE	SHEET NO.	TOTAL SHEETS
7	NEVADA		ELKO				

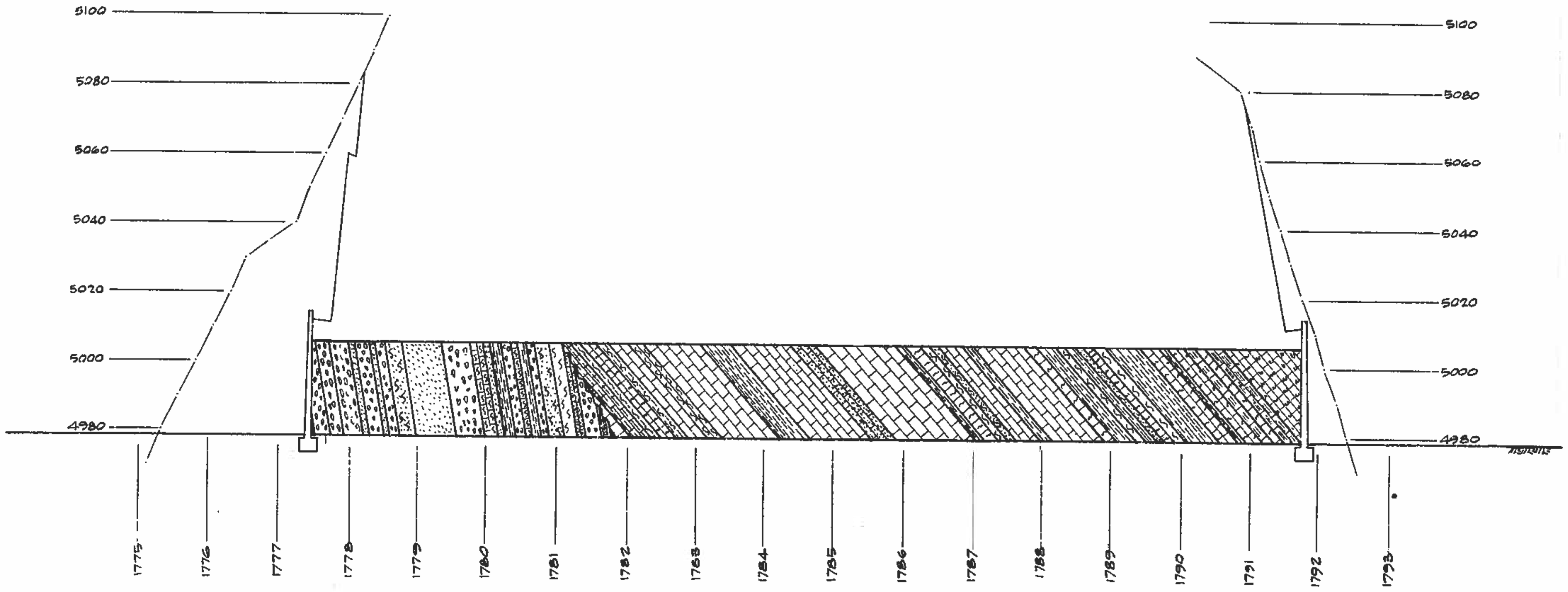


PLAN VIEW OF PROJECTED TUNNEL GEOLOGY
PORTAL TO PORTAL, BETWEEN ℄'s @ GRADE LEVEL
SCALE: 1"=100'

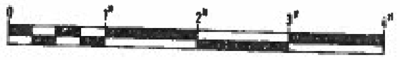
LEGEND

- ▩ CONGLOMERATE
- ▥ SHALE
- ▨ SILTSTONE
- ░ SANDSTONE OR QUARTZITE.
- ▦ LIMESTONE
- ▦ FRACTURED LIMESTONE
- 〰 ANGULAR UNCONFORMITY.

NOTE
THIS GEOLOGY IS PROJECTED AND DOES NOT NECESSAIRLY REPRESENT THE EXACT CONDITION OF FORMATIONS AND STRATA CONTACTS AS THEY WILL BE ENCOUNTERED DURING CONSTRUCTION



CROSS SECTION OF PROJECTED TUNNEL GEOLOGY
@ ℄ OF WESTBOUND LANE
SCALE: HORIZ. 1"=100'
VERT. 1"= 20'



REDUCED PLAN

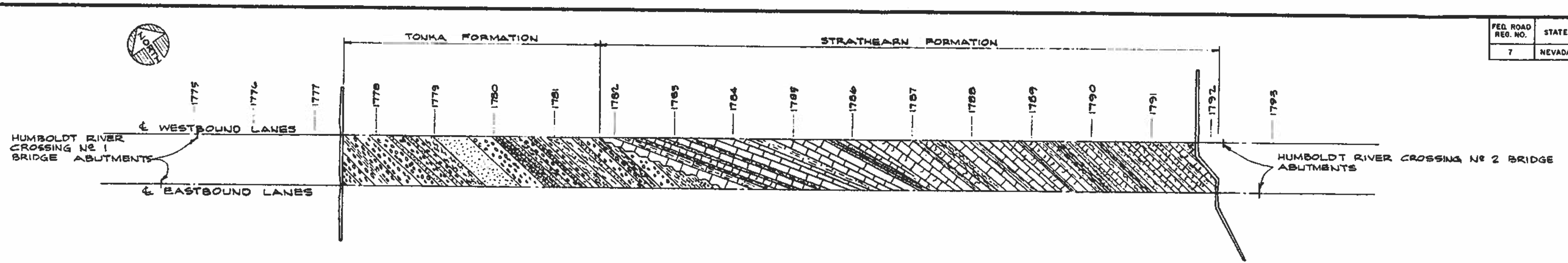
DWN. ROHL	Clair A. Hill REG. CIVIL ENG. NO. 1138	
CHK. T. C.		
DATE: SEPT. 1964	Tom Cordova ENGINEERING GEOLOGIST	

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1525 COURT STREET
REDDING, CALIFORNIA

GEOLOGIC CROSS SECTIONS
STATE OF NEVADA
CARLIN CANYON TUNNELS

DWG. No. C-2005.19
G-2

FED. ROAD REG. NO.	STATE	PROJECT NO.	COUNTY	CONTROL SECTION	STATE ROUTE	SHEET NO.	TOTAL SHEETS
7	NEVADA		ELKO				



PLAN VIEW OF PROJECTED TUNNEL GEOLOGY

PORTAL TO PORTAL, BETWEEN ℄'s @ GRADE LEVEL

SCALE: 1"=100'

LEGEND

⁘	CONGLOMERATE
▥	SHALE
⁙	SILTSTONE
░	SANDSTONE OR QUARTZITE.
▦	LIMESTONE
▩	FRACTURED LIMESTONE
〰	ANGULAR UNCONFORMITY.

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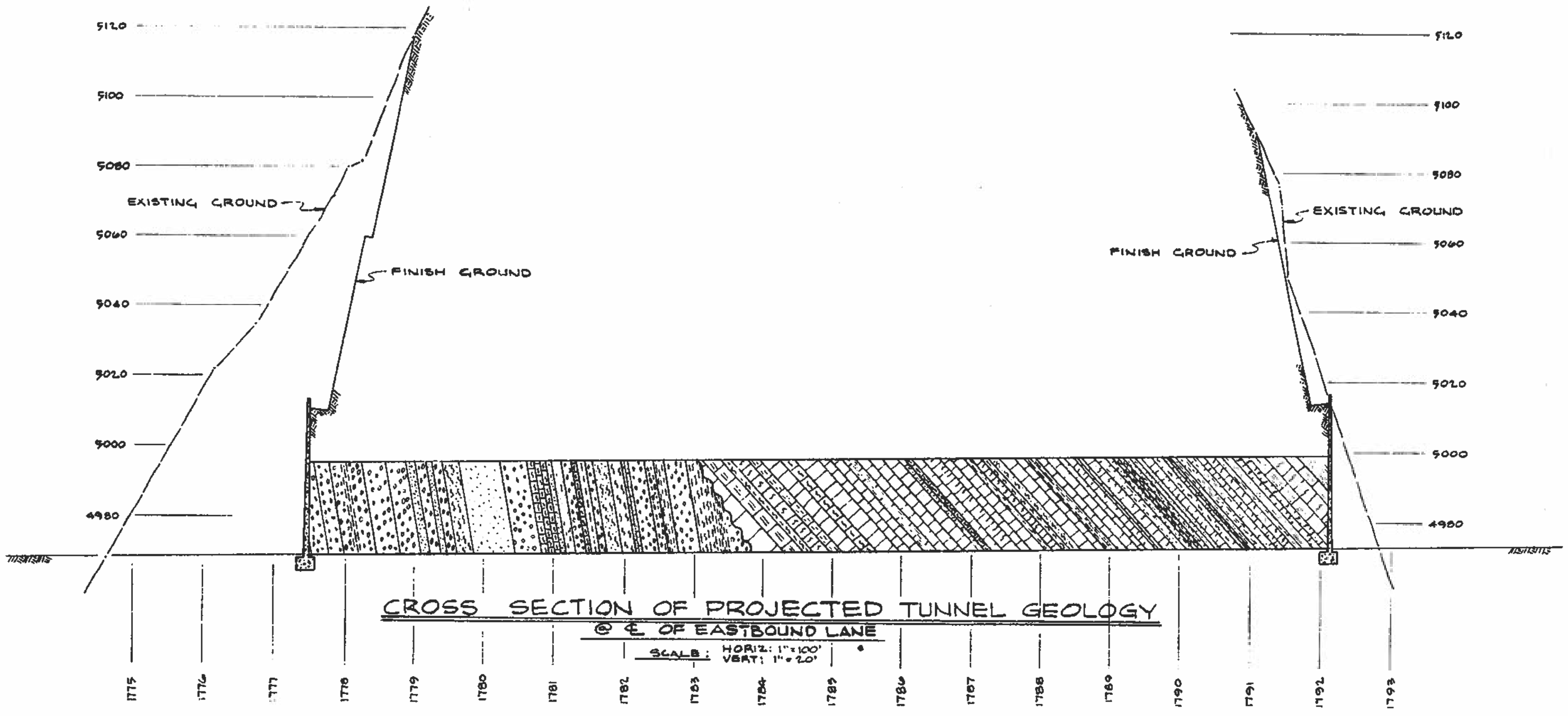

CROSS SECTION OF PROJECTED TUNNEL GEOLOGY

@ ℄ OF EASTBOUND LANE

SCALE: HORIZ: 1"=100'
VERT: 1"=20'

DWN. L.C.
CHK. T.C.
DATE: SEPT. 1964

Clair A. Hill
REG. CIVIL ENG. NO 1138
Tom Cordova
ENGINEERING GEOLOGIST

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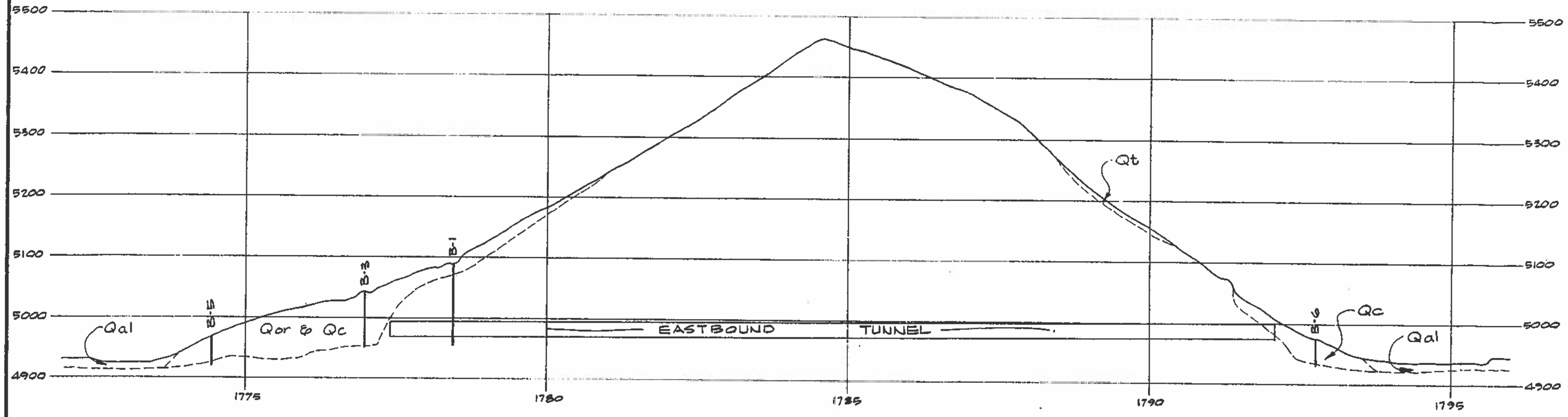
1626 COURT STREET REDDING, CALIFORNIA

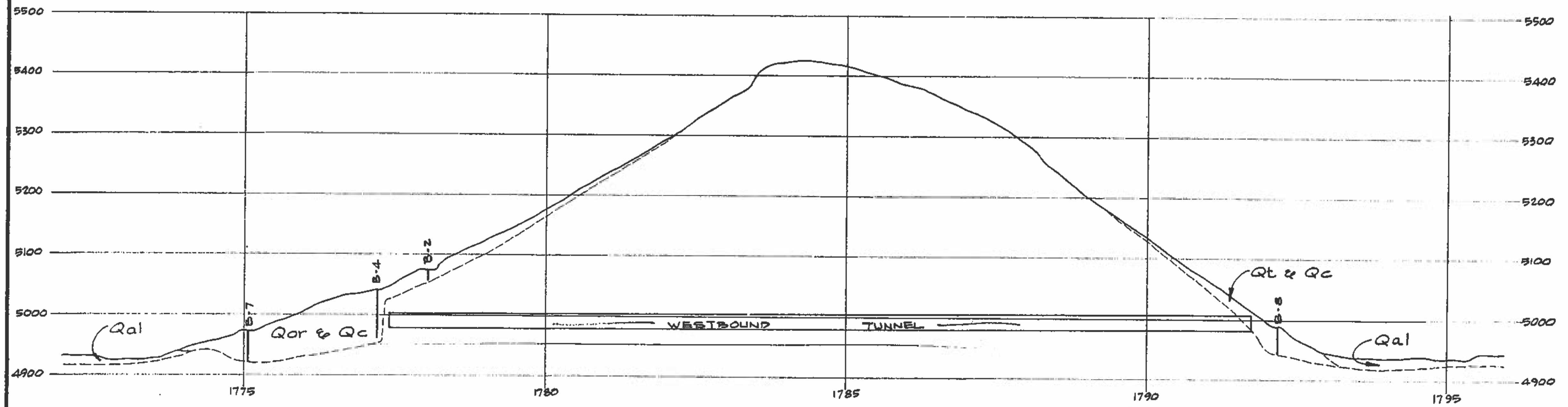
GEOLOGIC CROSS SECTIONS
STATE OF NEVADA
CARLIN CANYON TUNNELS

DWG. NOC-2005.19
G-3



EASTBOUND LANE PROFILE

SCALE: 1" = 100' HORIZ. & VERT.



WESTBOUND LANE PROFILE

SCALE: 1" = 100' HORIZ. & VERT.

LEGEND

QUATERNARY	RECENT	Qt	TALUS (LOOSE SURFICIAL ROCK FRAGMENTS).
		Qc	COLLUVIUM (TALUS, SOIL & LOCAL WASH).
		Qal	GEOLOGICALLY RECENT ALLUVIUM, INCLUDES SILT, SAND & GRAVEL DEPOSITED BY HUMBOLDT RIVER.
	PLEISTOCENE	Qor	OLDER RIVER DEPOSITED SAND & GRAVEL, INCLUDES SOME COLLUVIUM, SEMI-CEMENTED IN PLACES.

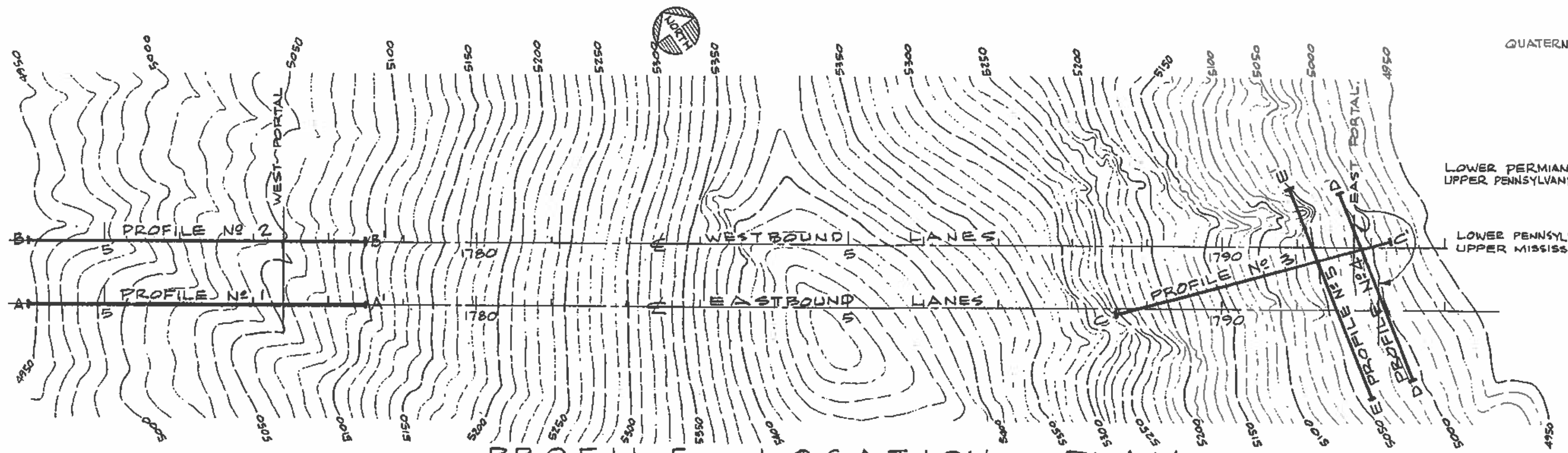
DWN. ROHL
CHK. T. C.
DATE: SEPT. 1964

Clair A Hill
REG. CIVIL ENG. NO. 1138
Tom Cordova
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1825 COURT STREET REDDING, CALIFORNIA

SURFICIAL GEOLOGY CROSS-SECTIONS
STATE OF NEVADA
CARLIN CANYON TUNNELS

DWG. NO. C-2005.19
G-4



PROFILE LOCATION PLAN

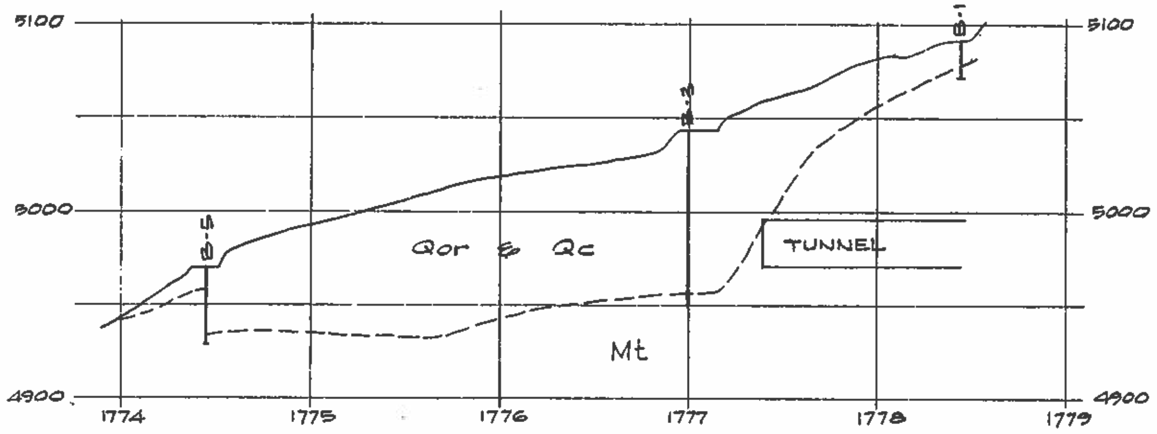
SCALE: 1" = 100'
CONTOUR INT. = 10'

LEGEND

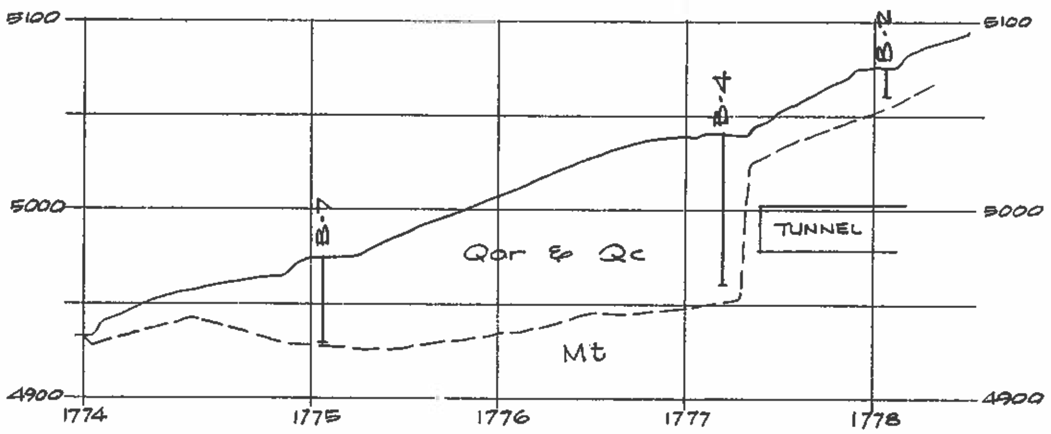
QUATERNARY
- RECENT
  - Qt TALUS (LOOSE SURFICIAL ROCK FRAGMENTS).
  - Qc COLLUVIUM (TALUS, SOIL & LOCAL WASH).
- PLEISTOCENE
  - Qor OLDER RIVER DEPOSITED SAND & GRAVEL, INCLUDES SOME COLLUVIUM, SEMI-CEMENTED IN PLACES.

LOWER PERMIAN-UPPER PENNSYLVANIAN
- IPPs MEDIUM TO MASSIVE BEDDED LIMESTONE WITH INTER-BEDS OF CHERT-GRANULE AND PEBBLE CONGLOMERATE, SILTSTONE AND SHALE. STRATHEARN FORMATION

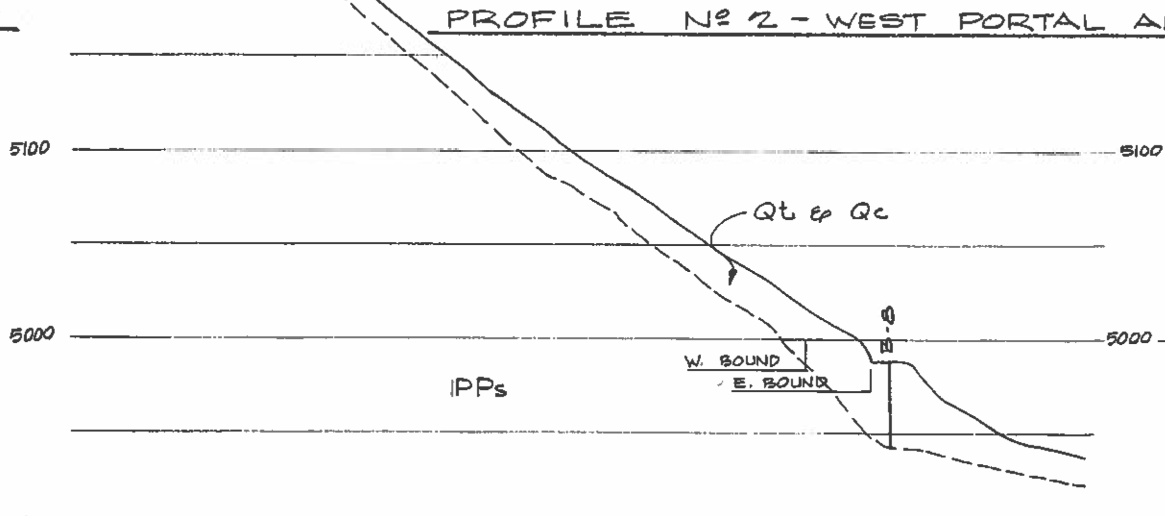
LOWER PENNSYLVANIAN UPPER MISSISSIPPIAN
- Mt CHERT-PEBBLE CONGLOMERATE WITH INTERBEDS OF SANDSTONE, QUARTZITE, CALCAREOUS SILTSTONE, ARGILLACEOUS LIMESTONE & SHALE. TONKA FORMATION



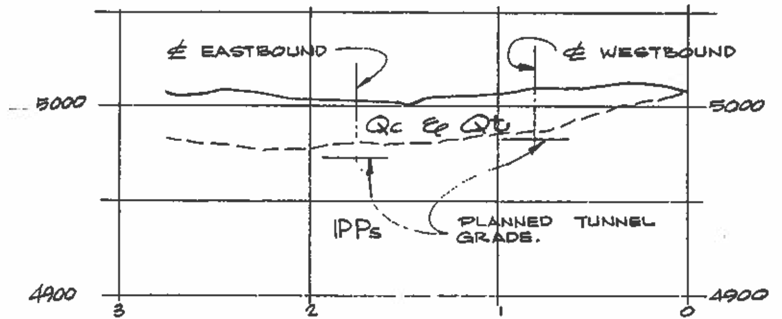
PROFILE Nº 1 - WEST PORTAL AREA - A-A'



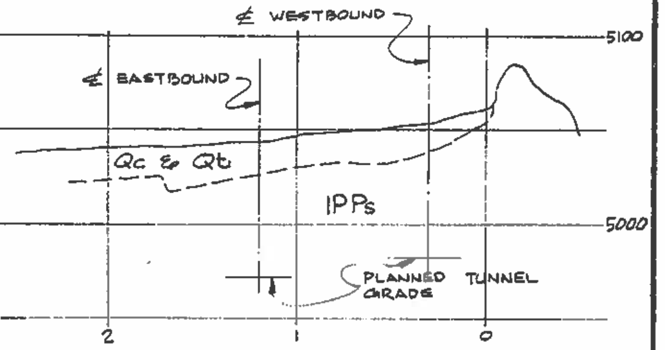
PROFILE Nº 2 - WEST PORTAL AREA - B-B'



PROFILE Nº 3 - EAST PORTAL AREA - C-C'



PROFILE Nº 4 - EAST PORTAL AREA - D-D'



PROFILE Nº 5 - EAST PORTAL AREA - E-E'

GEOLOGICAL PROFILES

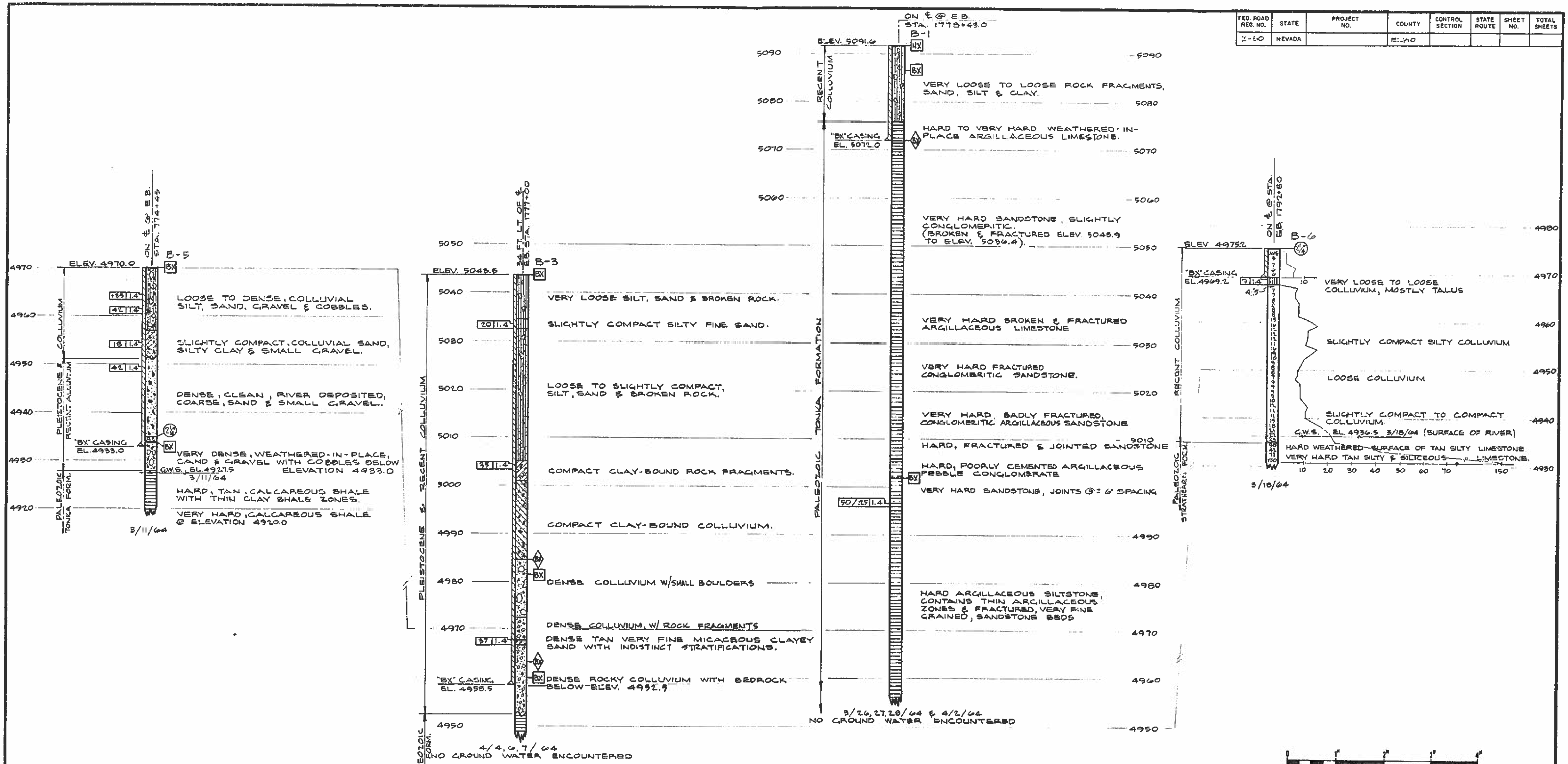
SCALES: HORIZ. & VERT. 1" = 50'

0 1" 2" 3" 4"
REDUCED PLAN

DWN. ROHL CHK. T. C. DATE: SEPT. 1964	Clair A. Hill REG. CIVIL ENG NO. 1138 Tom Cordova ENGINEERING GEOLOGIST	**CLAIR A. HILL & ASSOCIATES** FOUNDATION ENGINEERING & TESTING LABORATORY 1525 COURT STREET REDDING, CALIFORNIA	GEOLOGICAL PLAN & PROFILES STATE OF NEVADA CARLIN CANYON TUNNELS

DWG. NO. G 2005.19
G-5

FED. ROAD REG. NO.	STATE	PROJECT NO.	COUNTY	CONTROL SECTION	STATE ROUTE	SHEET NO.	TOTAL SHEETS
I-80	NEVADA		ELKO				



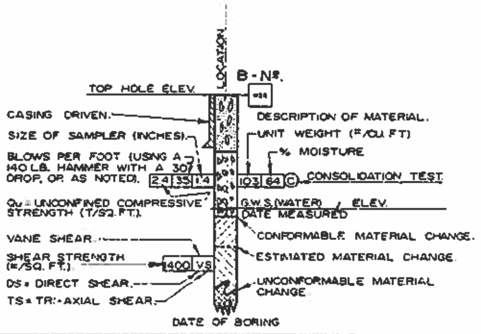
BORING PROFILE

SCALE: HORIZ. = NONE
VERT. 1" = 10'

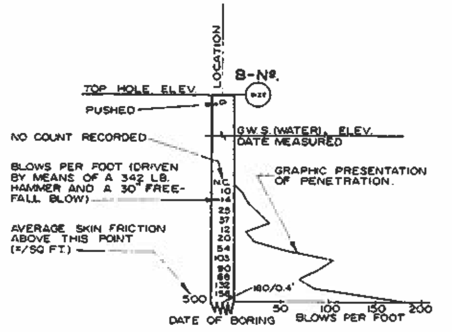
NOTE: FOR BORING PLAN, SEE SHEET G-2

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS

ROTARY BORING



PENETRATION BORING



● PLAN OF ANY BORING

○ PENETROMETER (FLUSH-COUPLED)

◉ 2 1/4" CONE PENETROMETER

▯ SAMPLER BORING (DRY)

▭ ROTARY BORING (WET)

▣ AUGER BORING (DRY)

⬚ JET BORING

◇ DIAMOND CORE BORING.

⬚ TEST PIT

BIT SIZES; (O.D.): "AX" = 1 13/16", "BX" = 2 9/32", "NX" = 2 29/32".

CASING SIZES; (O.D.): "BX" = 2 7/8", "NX" = 3 1/2".

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	SYMBOL	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW	▨	WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP	▨	POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GM	▨	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC	▨	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES.
	SAND AND SANDY SOIL	SW	▨	WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP	▨	POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM	▨	SILTY SAND, SAND-SILT MIXTURES.
		SC	▨	CLAYEY SAND, SAND-SILT MIXTURES.
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML	▨	INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL	▨	INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL	▨	ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH	▨	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT.
		CH	▨	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY.
		OH	▨	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
HIGHLY ORGANIC SOILS		PT	▨	PEAT AND OTHER HIGHLY ORGANIC SOILS

ROCK CLASSIFICATION

SYMBOL	NAME
▨	IGNEOUS ROCK
▤	SEDIMENTARY ROCK
≋	METAMORPHIC ROCK

NOTE: CLASSIFICATION OF EARTH MATERIAL SHOWN ON THIS SHEET IS BASED UPON FIELD INSPECTION UNLESS NOTED OTHERWISE

SOIL CONSISTENCY CLASSIFICATION

CONSISTENCY		* BLOWS PER. FT.
GRANULAR	COHESIVE	
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT. (140 LB HAMMER, 30" FREE-FALL BLOW USING A 2" OD × 1 3/8" ID SAMPLER).

DWN. L. R. C.
CHK. C. H.
DATE: AUG. 1964

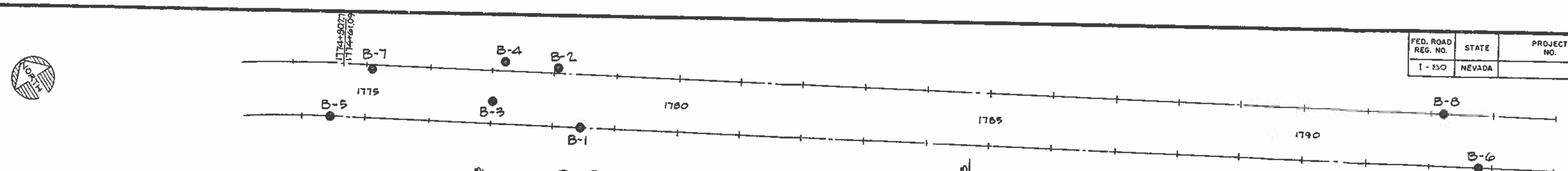
Clair A Hill
REG. CIVIL ENG. NO 1136
Tom Cordova
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1625 COURT STREET
REDDING, CALIFORNIA

LOG OF TEST BORINGS
CARLIN CANYON TUNNEL
STATE OF NEVADA
CARSON CITY NEVADA

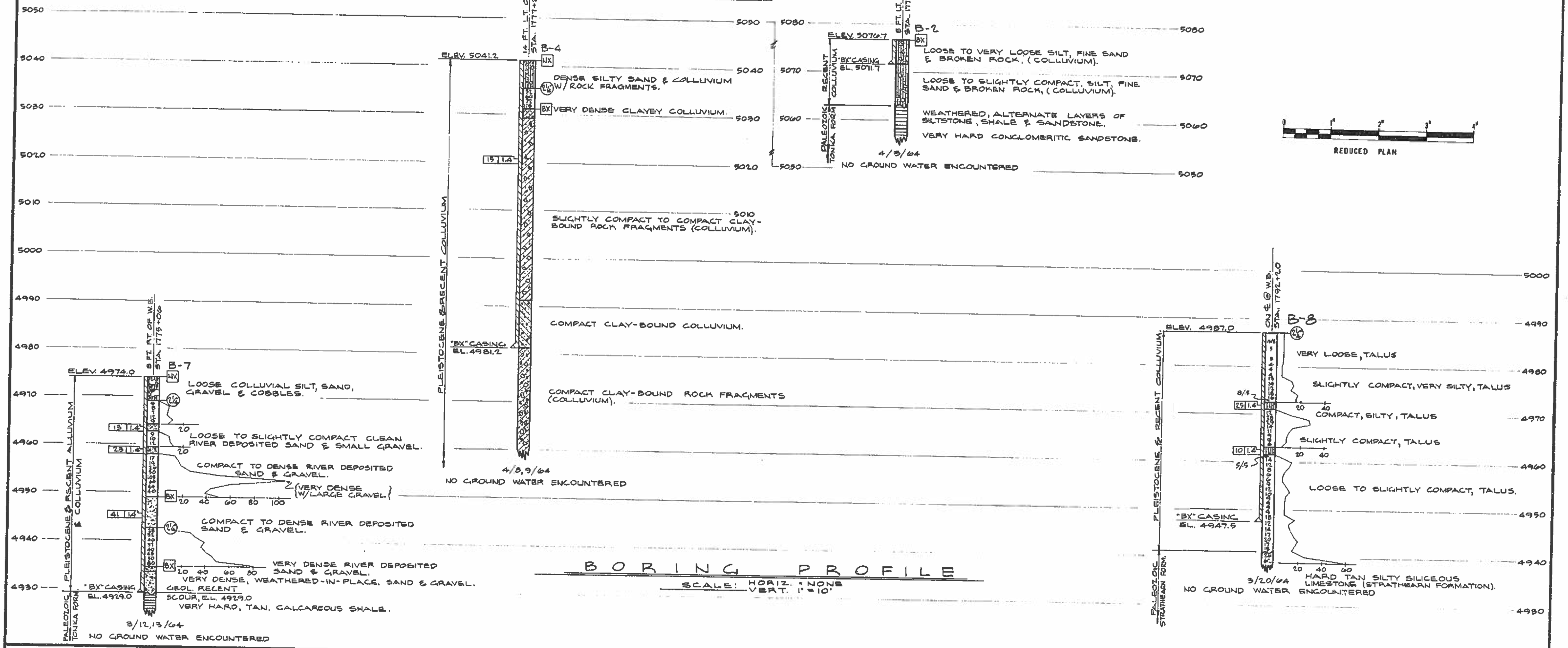
DWG. NO.
C-2035.19
G-6

FED. ROAD REG. NO.	STATE	PROJECT NO.	COUNTY	CONTROL SECTION	STATE ROUTE	SHEET NO.	TOTAL SHEETS
I - 80	NEVADA		ELKO				

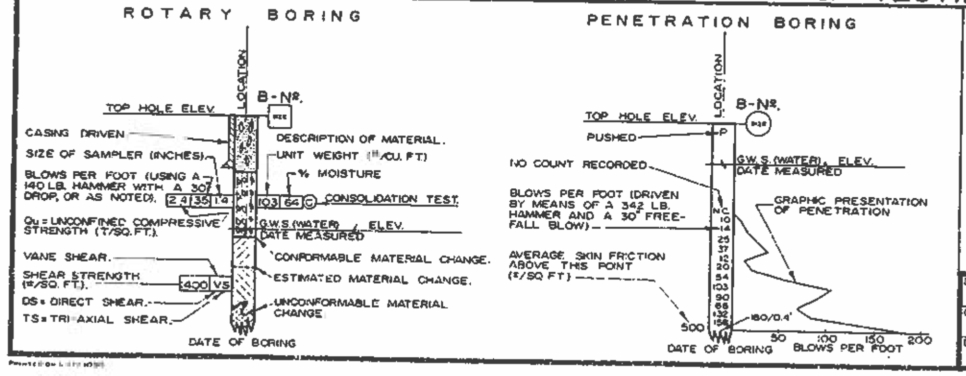


BORING PLAN

SCALE: 1" = 100'



LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS



● PLAN OF ANY BORING
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	SILTS AND CLAYS LL 50	MH	▥	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT
		CH	▨	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY.
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LOG OF TEST BORINGS
CARLIN CANYON TUNNEL
STATE OF NEVADA
CARSON CITY
NEVADA

DWG. NO.
C-1005.19
G-7