GEOLOGY AND GEOTECHNIQUES

OF THE CARLIN CANYON TUNNELS

Interstate Highway 80
Through Carlin Canyon, Elko County, Nevada

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INTRODUCTION

In December 1962 an examination was made by the writer of three proposed routes for Interstate Route 80 through Carlin Canyon in Elko County, Nevada. The purpose of the examination was to determine the feasibility of construction and design of the three routes from a geologic point of view. The proposed routes consisted of two cut sections, both in rock; one 260 feet deep and one 220 feet deep, and two 1500-foot parallel tunnels.

Based on favorable geologic conditions and the fact that the tunnels offered the best alignment and grade, the tunnel routes were selected.

In 1964 a detailed geologic study was made of the tunnel sites and foundation studies were conducted for four parallel bridges across the Humboldt River which flows through the canyon. The purpose of the studies was to determine the following:

1. The proper location of the tunnel portals;
2. Any seepage or drainage problems;
3. Anticipated overbreak;
4. Expected rock loads;
5. Cut-slope design and excavation properties;
6. Grouting and backpacking;
7. Foundation recommendations for tunnel and retaining wall footings;
8. Foundation recommendations for all bridge piers and abutments.

This paper explains the techniques used and the results obtained from the geologic examination.

The field work consisted of drilling wet rotary borings at the portals of the tunnels, and at all bridge pier and abutment locations, making a detailed geologic cross-section map depicting anticipated geologic conditions through the proposed tunnels, making a general geologic map of the area, and conducting a geophysical refraction seismic survey at the tunnel portal areas.

Drilling: The borings were made by means of a Concore trailer-mounted rotary drill. Standard 2-inch O.D. split-spoon penetration tests were made in the unconsolidated sediment, and "BX" diamond cores were cut from the bedrock. The cores were examined, logged, and boxed for future examination by prospective bidders and design engineers, and were made available for inspection at the District Highway Office in Elko, Nevada.

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 INTERSTATE ROUTE 80.

A STRATIGRAPHIC SECTION OF THE GEOLOGY THROUGH THE SOUTHERN PACIFIC RAILROAD TUNNEL WAS MADE AND PROJECTED INTO THE AREA WHERE THE HIGHWAY TUNNELS WILL BE MADE. 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.

GEOPHYSICAL SURVEY: THE GEOPHYSICAL SURVEY CONSISTED OF A REFRACTION SEISMIC STUDY USING A 12-CHANNEL ELECTRO-TECH 75-12. NORMAL PROFILE SHOOTING WAS USED EXCLUSIVELY WITH SUFFICIENT TRAVERSES BEING MADE TO DETERMINE THE BEDROCK SURFACE TO FACILITATE IN THE PROPER LOCATION OF THE TUNNEL PORTALS.

GENERAL GEOLOGY:

THE CARLIN CANYON AREA LIES IN THE GREAT BASIN AND RANGE PROVINCE, AND 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.

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. 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.

THE STRATHEARN FORMATION OF LATE PENNSYLVANIAN AGE RESTS UNCONFORMABLY UPON THE OLDER TONKA FORMATION; THE UNCONFORMITY IS ANGULAR, AND IS 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 FORMATION THAT WILL BE ENCOUNTERED DURING TUNNELING OPERATIONS ARE GENERALLY MODERATELY TO BADLY JOINTED AND FRACTURED. THE STRIKE OF THE FORMATION VARIED FROM N 17° W TO N 41° W, AND THE DIP VARIES FROM 66° TO 80° NE.

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 MIXED 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.

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 N 11° 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 N 17° W AND N 41° 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 ARE FOUND TO BE IN-PLACE, AND THEIR ATTITUDES ARE A DIRECT RESULT OF LOCAL WARPING AND DRAG FOLDING.

THREE PROMINENT SETS OF JOINTS EXIST IN THE TONKA AND STRATHEARN FORMATIONS. ONE SET IS PARALLEL TO THE BEDDING, AND THE SECOND AND THIRD SETS STRIKE N 65° TO 85° E AND N 65° 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 2 TO 5 FEET, WHILE JOINT SPACING IN THE SHALE, SILTSTONE, AND SHALY LIMESTONE MAY BE AS CLOSE AS 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 10 PER CENT.

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 1:1, INCLUDING BENCHES WHERE NECESSARY, ARE RECOMMENDED FOR EXCAVATIONS IN THE VICINITY OF THE PORTALS. BENCHES SHOULD BE A MINIMUM OF 10 FEET 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, SINCE 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 1:1, 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 PER CENT 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 5 PER CENT. 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 10 PER CENT.

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 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 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., 3.5 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 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 WHICH WOULD EFFECT DIFFERENTIAL SETTLEMENT.

FOUNDATION RECOMMENDATIONS:

BECAUSE OF WEATHERING AND 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 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, PROVISION 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 PRESENTLY HAS 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 PRESSURE.

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 1:1 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 40:1 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.

APPENDIX A

STRATIGRAPHIC SECTION THROUGH THE SOUTHERN PACIFIC RAILROAD TUNNEL

SECTION MAPPED FROM WEST PORTAL (STATION 0) TO EAST PORTAL (STATION 1902)

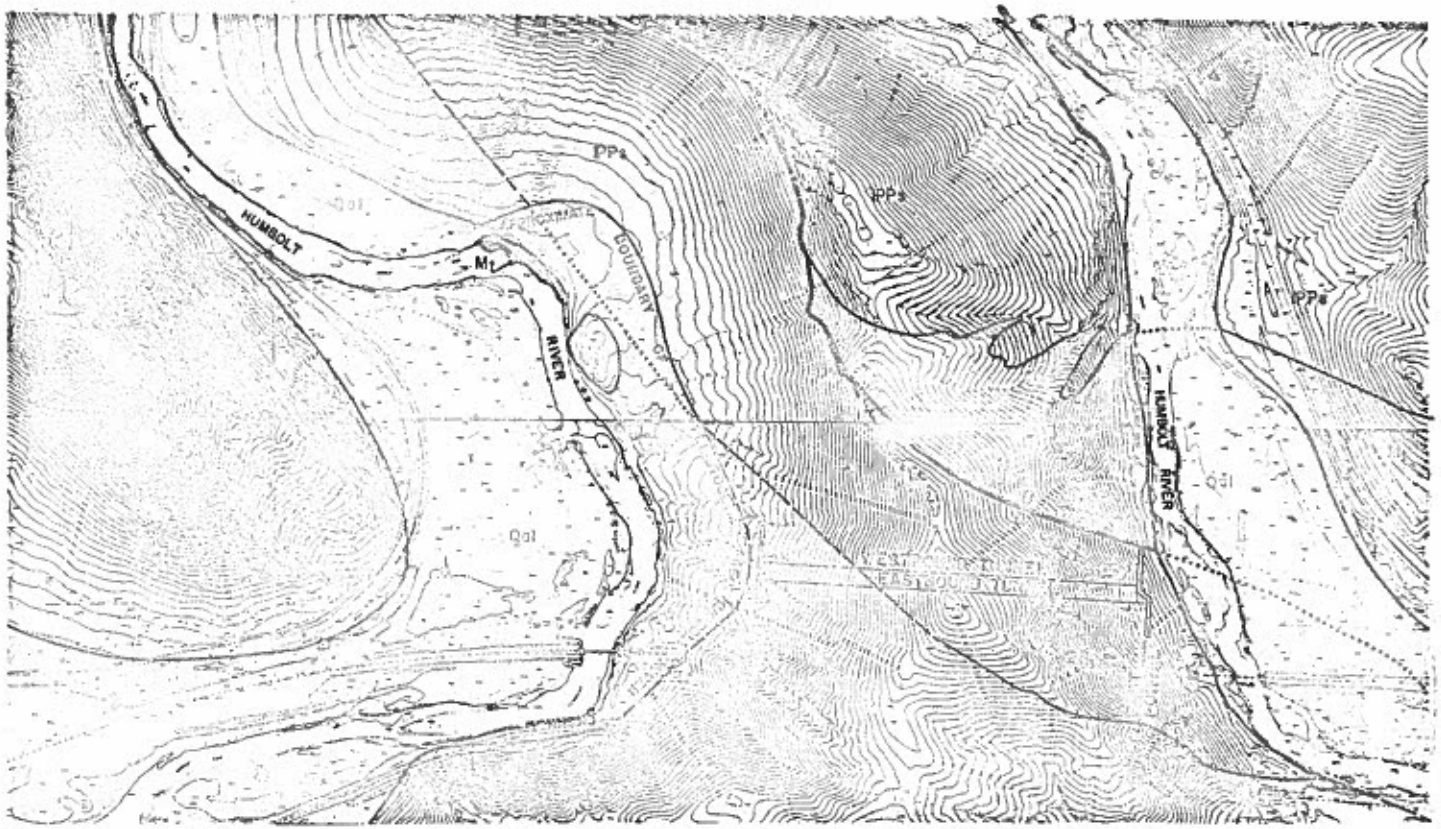
STATION	DESCRIPTION
0-200	TONKA FORMATION AND COLLUVIUM, COVERED BY CONCRETE LINING, PROBABLY WEATHERED AND SOFT, AND EXERTING HORIZONTAL PRESSURES.
200-245	SHALE, GREY, CALCAREOUS. BEDS STRIKE N 11°W AND DIP 85° NE. BEDS ARE 2 INCHES TO 1 FOOT THICK WITH FLAGGY PARTINGS. JOINTS STRIKE AND DIP N 11°W, 85° NE; N 83°E, 47°SE, AND N 85° E, 63° NW. ESTIMATED OVERBREAK IS 15 PER CENT 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 N 10° TO 15° W AND DIP 84° NE. JOINTS STRIKE AND DIP N 10° TO 15°W, 84°NE, AND N 85°W, 35° NE. ESTIMATED OVERBREAK 5 PER CENT. SLAKING VERY MINOR AND NO APPARENT LATERAL PRESSURES. NO BACK-PACKING HAS BEEN USED.
300-360	LIMESTONE AND SHALE, BUFF, BEDS ARE FROM 1 TO 3 FEET THICK. BEDS STRIKE N 12°W AND DIP 80°NE. SOME BEDS OF THIN WAVY LAMINATED SILTSTONE ARE INTERCALATED. JOINTS STRIKE AND DIP N 12°W, 80°NE; N 80°W, 67°SE, AND N 85°W, 45°NE. ESTIMATED OVERBREAK IS 5 TO 10 PER CENT.
360-365	SILTSTONE, TAN, ARGILLACEOUS AND SOFT. BEDS STRIKE N 11°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 N 11°W AND DIP 79°NE. JOINTS STRIKE AND DIP N 11°W, 79°NE; N 26°E, 28°NW, AND N 70°E, 47°SE. ESTIMATED OVERBREAK VARIES FROM 5 TO 15 PER CENT.
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 N 23°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-FOOT BEDS OF SANDSTONE AND SILTY LIMESTONE. BEDS STRIKE N 21°W AND DIP 87°SW. ESTIMATED OVERBREAK 10 PER CENT.

TONKA FORMATION

STATION	DESCRIPTION
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 N 30°W AND DIP 83°NE. JOINTS STRIKE AND DIP N 30°W, 83°NE, AND N 80°E, 87°SE. ESTIMATED OVERBREAK 10 TO 15 PER CENT.
830-870	PEBBLE CONGLOMERATE, VERY COARSE GRAINED, UP TO ONE-INCH PEBBLES, BEDS STRIKE N 15°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 N 17°W AND DIP 87°NE.
915-960	SHALY LIMESTONE, SANDSTONE AND PEBBLE CONGLOMERATE WITH BEDS OF SHALE AND SILTSTONE. BEDS STRIKE N 17°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 N 13°W AND DIP 84°NE. JOINTS STRIKE AND DIP N 13°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 N 12°W AND DIPS 50°SW.
980-1000	SHALE, CALCAREOUS, REDDISH.
1000-1010	SANDSTONE, FINE GRAINED AND CALCAREOUS, STRIKES N 25°W AND DIPS 82°SW.
1010-1045	PEBBLE CONGLOMERATE, MASSIVE BEDDED, ESTIMATED OVERBREAK 5 TO 10 PER CENT.
1045-1065	SHALE, CALCAREOUS, REDDISH. BEDS STRIKE N 25°W AND DIP 88°NE, AND JOINTS STRIKE AND DIP N 25°W, 88° NE, AND N 65°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 1/2 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 N 17° W, 88°NE.
1175-1225	CONGLOMERATE, MASSIVE BEDS TO FIVE FEET THICK, OVERBREAK LESS THAN 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 5 PER CENT. BEDS STRIKE N 8°W, AND DIP NEAR VERTICAL, SOME LOCAL MOVEMENT ALONG BEDDING AND JOINTING PLANES.

TONKA FORMATION

	STATION	DESCRIPTION
TONKA FORMATION	1270-1280	SILTSTONE AND SHALE, VARI-COLORED, ESTIMATED OVERBREAK 15 PER CENT. BEDS STRIKE AND DIP N 35°W, 85°SE.
	1280-1290	SANDSTONE AND QUARTZITE, PINK TO BUFF, ESTIMATED OVERBREAK 5 PER CENT. BEDS STRIKE AND DIP N 10°W, 78°NE. JOINTS STRIKE AND DIP N 10°W, 78°NE; N 25°E, 38°NW AND N 65°E, 85°NW.
	1290-1300	SANDSTONE, ARGILLACEOUS, BUFF. ESTIMATED OVERBREAK 5 TO 10 PER CENT.
	1300-1350	CONGLOMERATE, MASSIVE, ESTIMATED OVERBREAK LESS THAN 5 PER CENT.
	1350-1370	SILTSTONE AND SANDSTONE, VARI-COLORED, ESTIMATED OVERBREAK 10 TO 15 PER CENT.
	1370-1420	CONGLOMERATE, MASSIVE, WITH INTERBEDS OF QUARTZITE AND SANDSTONE. ESTIMATED OVERBREAK 5 PER CENT. BEDS STRIKE N 15°W AND DIP VERTICAL. JOINTS STRIKE AND DIP N 15°W, WITH VERTICAL DIPS AND N 65°W, 55°SW.
	1420-1440	SHALE AND CONGLOMERATE, SHEAR ZONE. BEDS STRIKE N 30°W AND DIP 75°NE.
	1440-1465	CONGLOMERATE, MASSIVE, ESTIMATED OVERBREAK 5 PER CENT.
		ANGULAR UNCONFORMITY
STRATHEARN FORMATION	1465-1510	LIMESTONE, MASSIVE, BEDS UP TO 4 FEET THICK, WITH BEDS OF CONGLOMERATE TO 1 FOOT THICK. BEDS STRIKE N 17°W AND DIP 66°NE. JOINTS STRIKE AND DIP N 17°W, 66°NE, AND N 78°W, 55°SW. ESTIMATED OVERBREAK LESS THAN 5 PER CENT.
	1510-1535	LIMESTONE, SHALY, TAN. ESTIMATED OVERBREAK 5 TO 10 PER CENT. BEDS STRIKE N 41°W AND DIP 80°NE. JOINTS STRIKE AND DIP N 41°W, 80°NE, AND N 75°W, 61°SW.
	1535-1560	LIMESTONE, MEDIUM BEDDED, TAN TO GREY.
	1560-1680	LIMESTONE, SHALY, MEDIUM TO MASSIVE BEDDED. BEDS STRIKE AND DIP N 30°W, 70°NE. JOINTS STRIKE AND DIP N 30°W, 70°NE; N 80°E, 37°SE, AND N 75°W, 62°SW.
	1680-1750	LIMESTONE, FRACTURED, NO LATERAL PRESSURE ON BACKPACKING. ESTIMATED OVERBREAK 5 PER CENT.
	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	PPs	MEDIUM TO MASSIVE BEDDED LIMESTONE WITH INTERBEDS OF CHERT-GRANULE AND PEBBLE CONGLOMERATE, SILTSTONE AND SHALE
LOWER PENNSYLVANIAN UPPER MISSISSIPPIAN TONKA FORMATION		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'

J.C.V. T.C. SEPT.6

CLAIR A. HILL & ASSOCIATES
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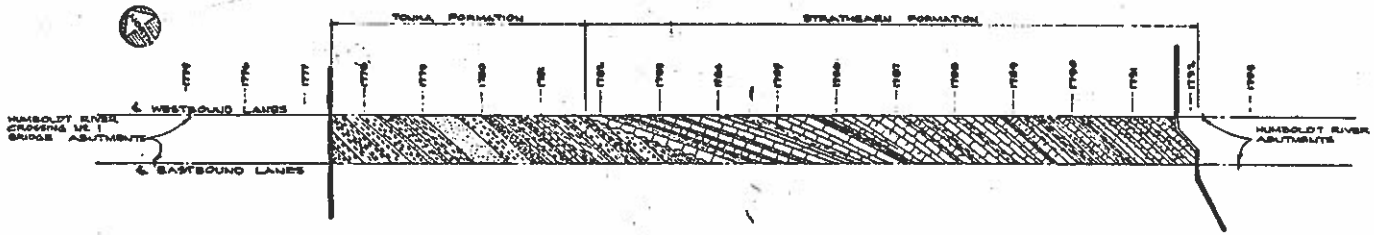
GENERAL GEOLOGIC MAP
STATE OF NEVADA
CARLIN CANYON TUNNELS

G-1
C-2005.19



PLAN VIEW OF PROJECTED TUNNEL GEOLOGY

PORTAL TO PORTAL, BETWEEN ℄'s @ GRADE LEVEL

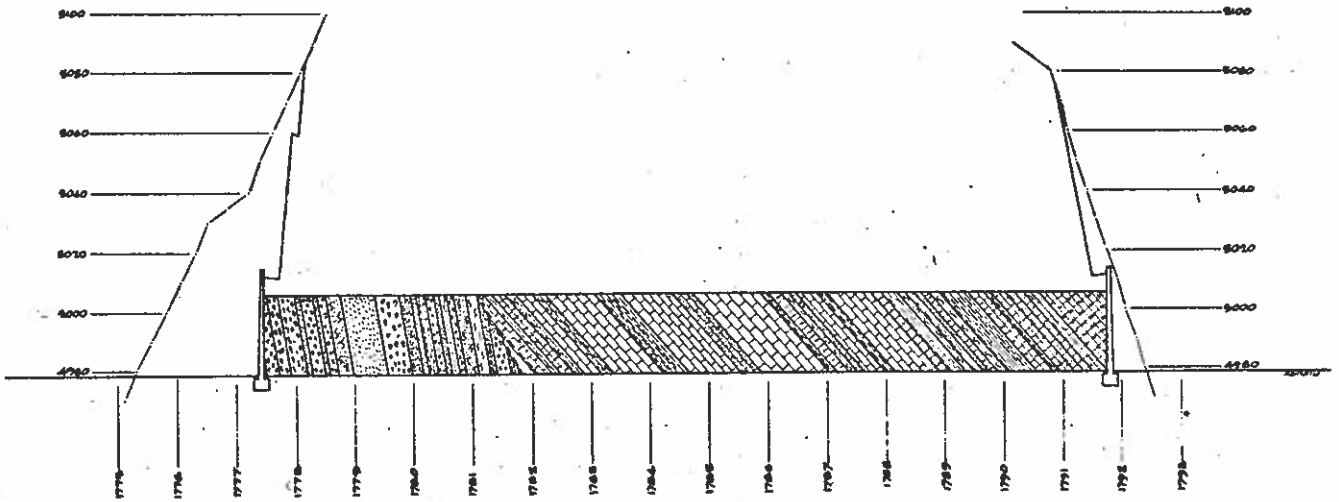
SCALE: 1"=100'

LEGEND

- CONGLOMERATE
- SHALE
- SILTSTONE
- SANDSTONE OR QUARTZITE.
- LIMESTONE
- FRACTURED LIMESTONE
- ANGULAR UNCONFORMITY.

NOTE

THIS GEOLOGY IS PROJECTED, AND DOES NOT NECESSARILY 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

SCALES: HORIZ. 1"=100'
VERT. 1"= 20'

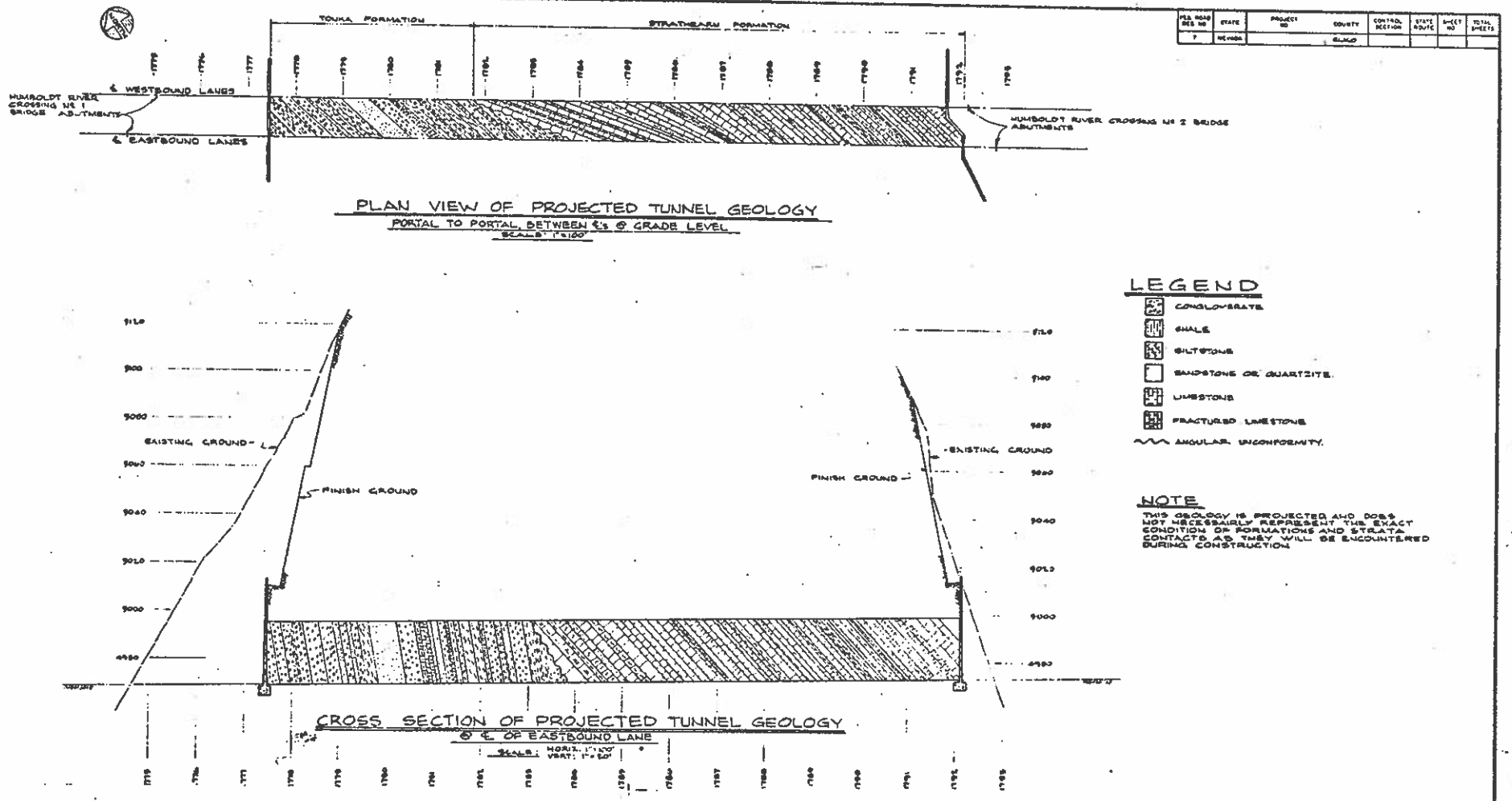
FED. ROAD REG. NO.	STATE	PROJECT NO.	COUNTY	CONTROL SECTION	STATE ROUTE	SHEET NO.	TOTAL SHEETS
7	NEVADA		ELKO				

RCHL
T.C.
SEPT. 1964

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1000 COURT STREET REDDING, CALIFORNIA

GEOLOGIC CROSS SECTIONS
STATE OF NEVADA
CARLIN CANYON TUNNELS

DWG NO. C-6008(10)
G-2



PLN. PROJ. SEC. NO	STATE	PROJECT NO	COUNTY	CONTROL SECTION	STATE ROUTE	SHEET NO	TOTAL SHEETS
7	NEVADA		ELKO				

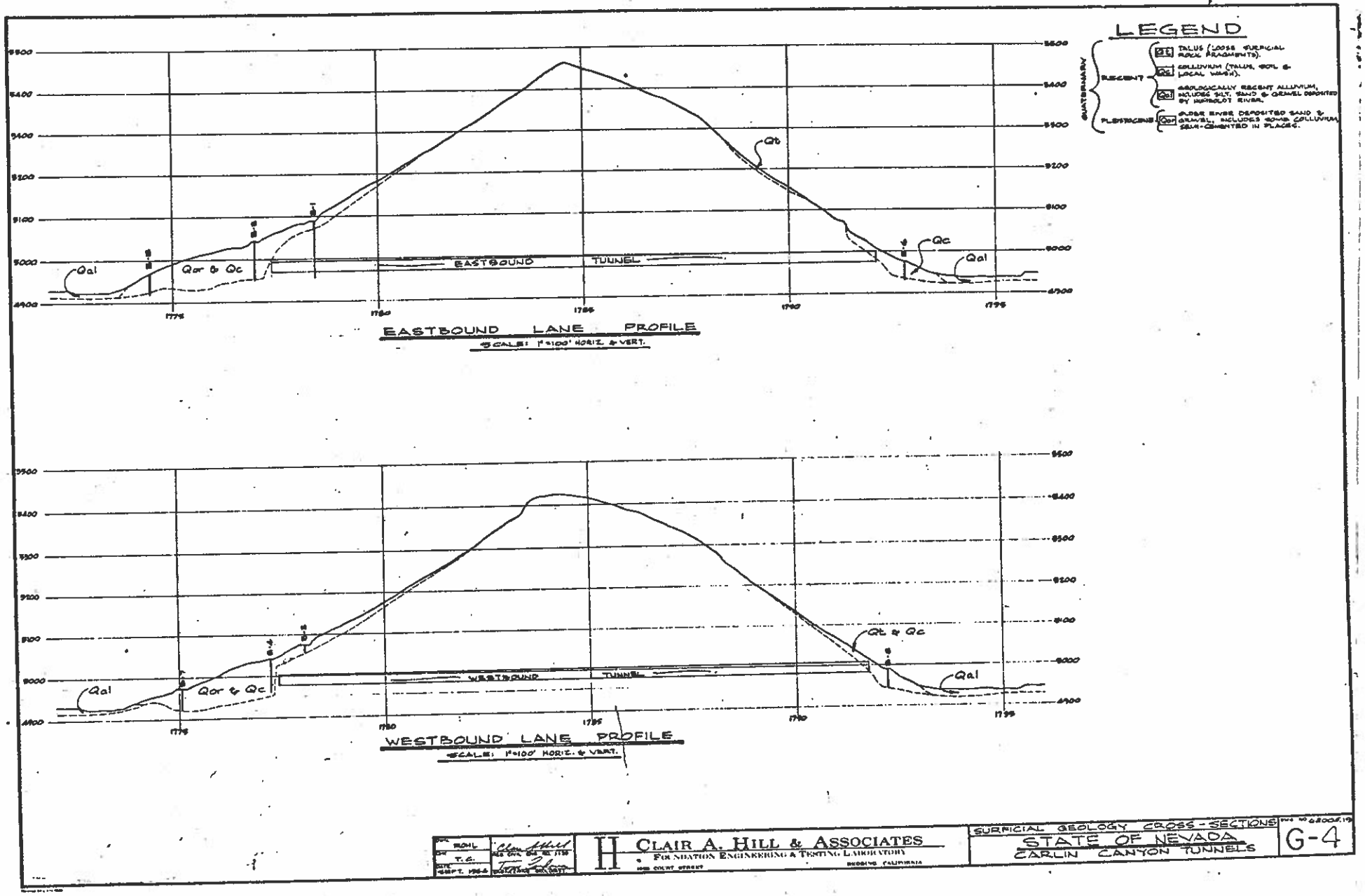
L.G.	
T.C.	
DATE	1964

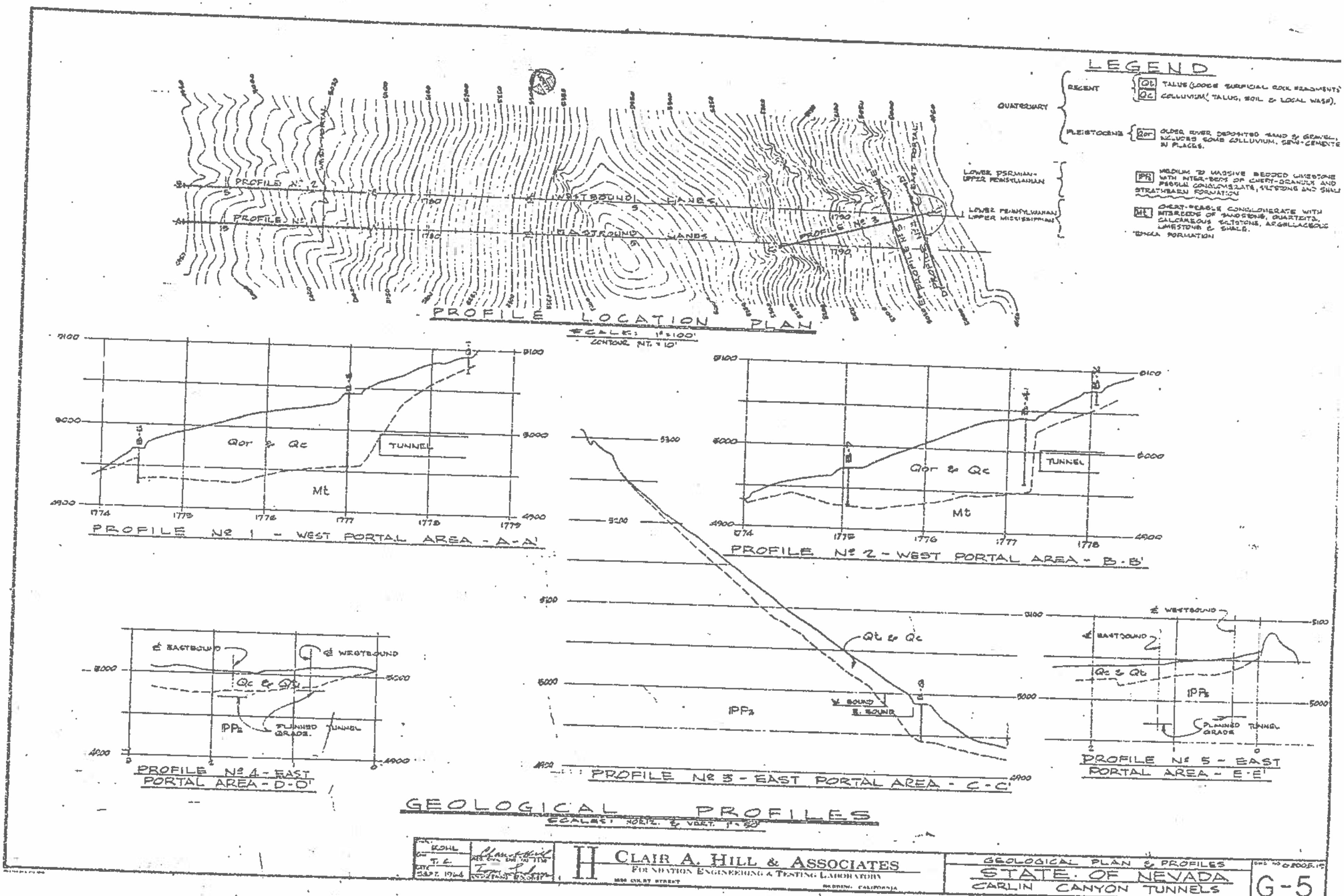
CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORIES

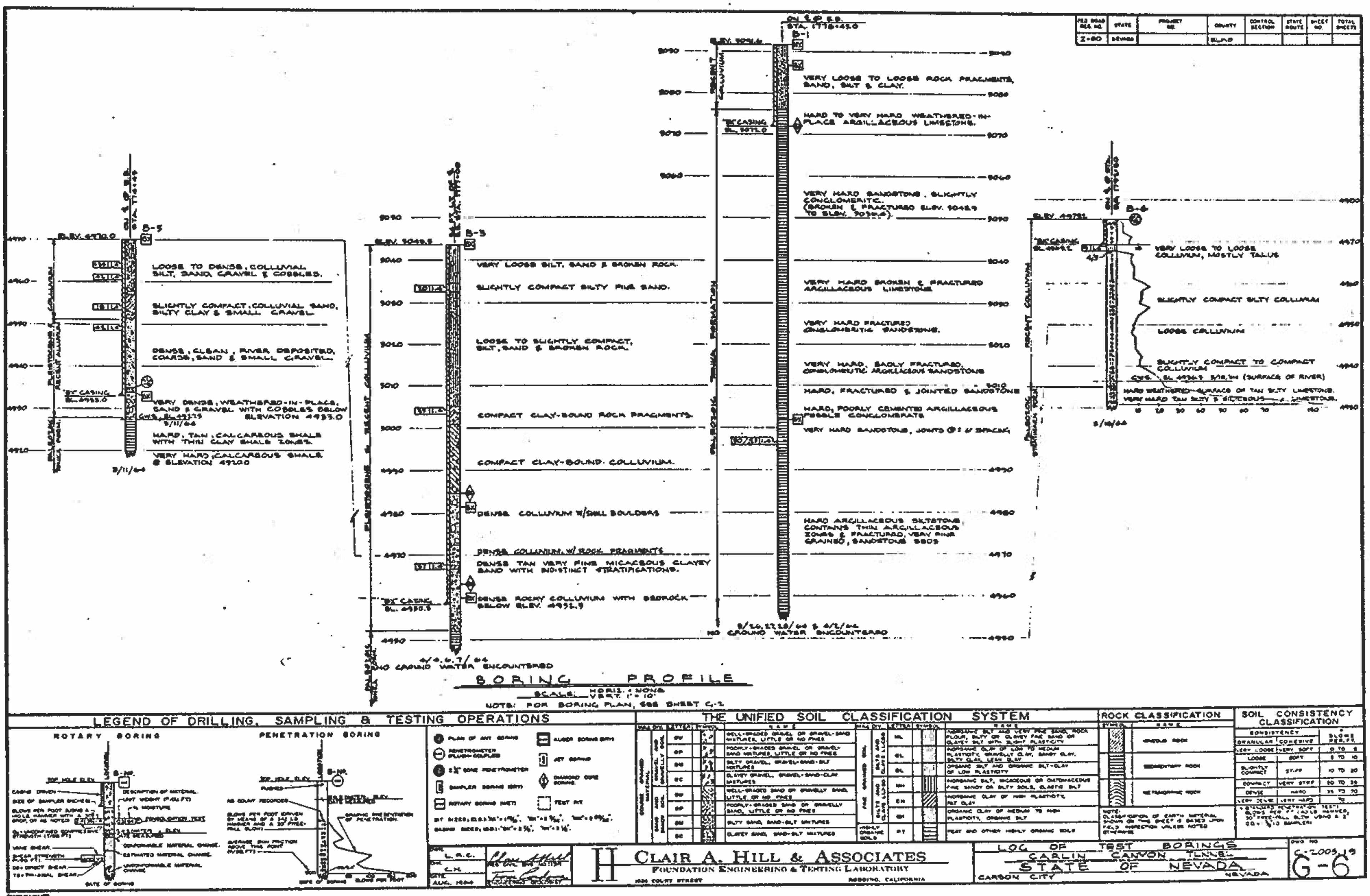
GEOLOGIC CROSS SECTIONS
STATE OF NEVADA
CARLIN CANYON TUNNELS

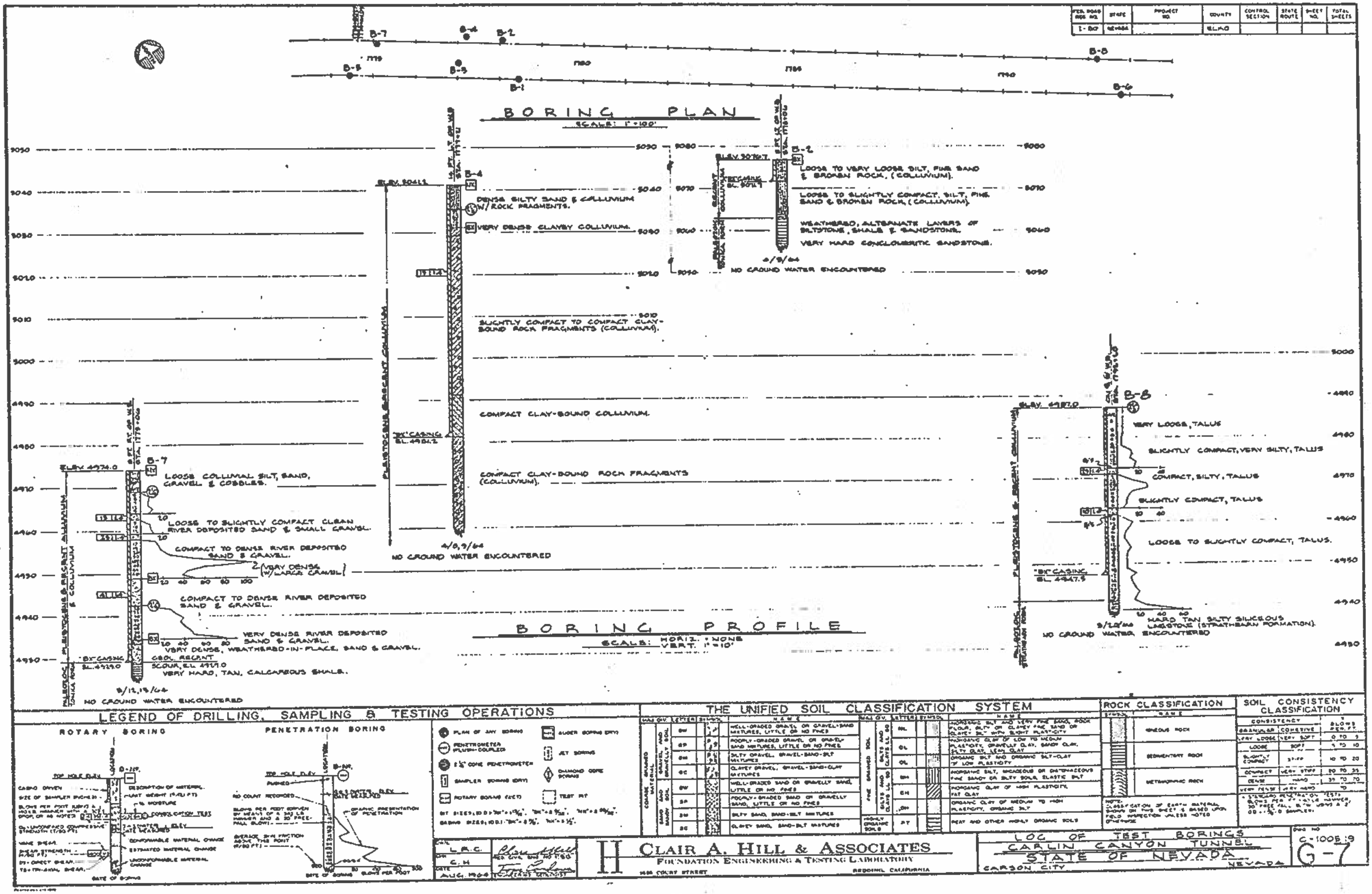
RC-2503(9)

G-3


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.
Qt
Qc
Qal
Qor & Qc
EASTBOUND TUNNEL
EASTBOUND LANE PROFILE
SCALE: 1"=100' HORIZ. & VERT.
Qt & Qc
WESTBOUND TUNNEL
WESTBOUND LANE PROFILE
SCALE: 1"=100' HORIZ. & VERT.
CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
SURFICIAL GEOLOGY CROSS-SECTIONS
STATE OF NEVADA
CARLIN CANYON TUNNELS
G-4


LEGEND
RECENT
QUATERNARY
PLEISTOCENE
Qt TALUS (LOOSE SURFICIAL ROCK FRAGMENTS)
Qc COLLUVIUM (TALUS, SOIL & LOCAL WASH)
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 2
PROFILE Nº 1
WESTBOUND LANES
EASTBOUND LANES
PROFILE Nº 3
PROFILE LOCATION PLAN
SCALE: 1"=100'
CONTOUR INT. = 10'
Qor & Qc
TUNNEL
Mt
PROFILE Nº 1 - WEST PORTAL AREA - A-A'
PROFILE Nº 2 - WEST PORTAL AREA - B-B'
Qt & Qc
W. BOUND
E. BOUND
IPPs
PROFILE Nº 3 - EAST PORTAL AREA - C-C'
℄ EASTBOUND
℄ WESTBOUND
Qc & Qt
PLANNED TUNNEL GRADE
PROFILE Nº 4 - EAST PORTAL AREA - D-D'
PROFILE Nº 5 - EAST PORTAL AREA - E-E'
GEOLOGICAL PROFILES
SCALES: HORIZ. & VERT. 1"=50'
SEPT. 1964
CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
REDDING, CALIFORNIA
GEOLOGICAL PLAN & PROFILES
STATE OF NEVADA
CARLIN CANYON TUNNELS
G-5


B-5
ELEV. 4970.0
LOOSE TO DENSE, COLLUVIAL SILT, SAND, GRAVEL & COBBLES.
SLIGHTLY COMPACT, COLLUVIAL SAND, SILTY CLAY & SMALL GRAVEL.
DENSE, CLEAN, RIVER DEPOSITED, COARSE, SAND & SMALL GRAVEL.
VERY DENSE, WEATHERED-IN-PLACE, SAND & GRAVEL WITH COBBLES BELOW ELEVATION 4933.0
HARD, TAN, CALCAREOUS SHALE WITH THIN CLAY SHALE ZONES.
VERY HARD, CALCAREOUS SHALE @ ELEVATION 4920.0
B-3
ELEV. 5049.5
VERY LOOSE SILT, SAND & BROKEN ROCK.
SLIGHTLY COMPACT SILTY FINE SAND.
LOOSE TO SLIGHTLY COMPACT, SILT, SAND & BROKEN ROCK.
COMPACT CLAY-BOUND ROCK FRAGMENTS.
COMPACT CLAY-BOUND COLLUVIUM.
DENSE COLLUVIUM W/SMALL BOULDERS
DENSE COLLUVIUM W/ ROCK FRAGMENTS
DENSE TAN VERY FINE MICACEOUS CLAYEY SAND WITH INDISTINCT STRATIFICATIONS.
DENSE ROCKY COLLUVIUM WITH BEDROCK BELOW ELEV. 4952.9
NO GROUND WATER ENCOUNTERED
B-1
VERY LOOSE TO LOOSE ROCK FRAGMENTS, SAND, SILT & CLAY.
HARD TO VERY HARD WEATHERED-IN-PLACE ARGILLACEOUS LIMESTONE.
VERY HARD SANDSTONE, SLIGHTLY CONGLOMERITIC.
VERY HARD BROKEN & FRACTURED ARGILLACEOUS LIMESTONE
VERY HARD FRACTURED CONGLOMERITIC SANDSTONE.
VERY HARD, BADLY FRACTURED, CONGLOMERITIC ARGILLACEOUS SANDSTONE
HARD, FRACTURED & JOINTED SANDSTONE
HARD, POORLY CEMENTED ARGILLACEOUS PEBBLE CONGLOMERATE
VERY HARD SANDSTONE
HARD ARGILLACEOUS SILTSTONE, CONTAINS THIN ARGILLACEOUS ZONES & FRACTURED, VERY FINE GRAINED, SANDSTONE BEDS
NO GROUND WATER ENCOUNTERED
B-6
VERY LOOSE TO LOOSE COLLUVIUM, MOSTLY TALUS
SLIGHTLY COMPACT SILTY COLLUVIUM
LOOSE COLLUVIUM
SLIGHTLY COMPACT TO COMPACT COLLUVIUM
HARD WEATHERED SURFACE OF TAN SILTY LIMESTONE.
VERY HARD TAN SILTY & SILICEOUS LIMESTONE.
BORING PROFILE
NOTE: FOR BORING PLAN, SEE SHEET C-2
LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS
ROTARY BORING
PENETRATION BORING
THE UNIFIED SOIL CLASSIFICATION SYSTEM
ROCK CLASSIFICATION
SOIL CONSISTENCY CLASSIFICATION
CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
LOG OF TEST BORINGS
CARLIN CANYON TUNNEL
STATE OF NEVADA
CARSON CITY
NEVADA
G-6


BORING PLAN
SCALE: 1" = 100'
B-7
B-4
B-2
B-8
B-5
B-3
B-1
B-6
ELEV. 5041.2
DENSE SILTY SAND & COLLUVIUM W/ROCK FRAGMENTS.
VERY DENSE CLAYEY COLLUVIUM.
SLIGHTLY COMPACT TO COMPACT CLAY-BOUND ROCK FRAGMENTS (COLLUVIUM).
COMPACT CLAY-BOUND COLLUVIUM.
COMPACT CLAY-BOUND ROCK FRAGMENTS (COLLUVIUM).
4/8,9/64
NO GROUND WATER ENCOUNTERED
LOOSE TO VERY LOOSE SILT, FINE SAND & BROKEN ROCK, (COLLUVIUM).
LOOSE TO SLIGHTLY COMPACT, SILT, FINE SAND & BROKEN ROCK, (COLLUVIUM).
WEATHERED, ALTERNATE LAYERS OF SILTSTONE, SHALE & SANDSTONE.
VERY HARD CONGLOMERITIC SANDSTONE.
4/9/64
NO GROUND WATER ENCOUNTERED
ELEV. 4974.0
LOOSE COLLUVIAL SILT, SAND, GRAVEL & COBBLES.
LOOSE TO SLIGHTLY COMPACT CLEAN RIVER DEPOSITED SAND & SMALL GRAVEL.
COMPACT TO DENSE RIVER DEPOSITED SAND & GRAVEL.
VERY DENSE W/LARGE GRAVEL
COMPACT TO DENSE RIVER DEPOSITED SAND & GRAVEL.
VERY DENSE RIVER DEPOSITED SAND & GRAVEL.
VERY DENSE, WEATHERED-IN-PLACE, SAND & GRAVEL.
VERY HARD, TAN, CALCAREOUS SHALE.
NO GROUND WATER ENCOUNTERED
BORING PROFILE
SCALE: HORIZ. = NONE VERT. 1" = 10'
VERY LOOSE, TALUS
SLIGHTLY COMPACT, VERY SILTY, TALUS
COMPACT, SILTY, TALUS
SLIGHTLY COMPACT, TALUS
LOOSE TO SLIGHTLY COMPACT, TALUS.
HARD TAN SILTY SILICEOUS LIMESTONE (STRATHEARN FORMATION).
NO GROUND WATER ENCOUNTERED
LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS
ROTARY BORING
PENETRATION BORING
THE UNIFIED SOIL CLASSIFICATION SYSTEM
ROCK CLASSIFICATION
IGNEOUS ROCK
SEDIMENTARY ROCK
METAMORPHIC ROCK
SOIL CONSISTENCY CLASSIFICATION
CLAIR A. HILL & ASSOCIATES
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REDDING, CALIFORNIA
LOG OF TEST BORINGS
CARLIN CANYON TUNNEL
STATE OF NEVADA
CARSON CITY
NEVADA
C-1005:19
G-7
AUG. 1964