

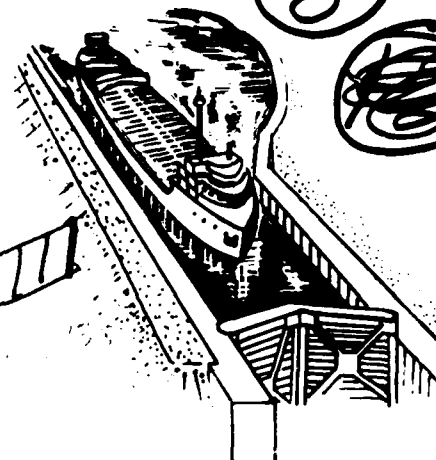


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LEVEL III



REVIEW *of* REPORTS

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LAKE ERIE - LAKE ONTARIO

WATERWAY

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APPENDIX B

GEOLOGY, SOIL, AND MATERIALS

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U.S. ARMY CORPS OF ENGINEERS  
BUFFALO DISTRICT

OCTOBER 1973

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REVIEW OF REPORTS  
ON  
LAKE ERIE - LAKE ONTARIO WATERWAY

APPENDIX B  
GEOLOGY, SOIL, AND MATERIALS

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## LAKE ERIE - LAKE ONTARIO WATERWAY GEOLOGY AND SOILS APPENDIX

### INTRODUCTION AND PURPOSE

B-1. The proposed Lake Erie-Lake Ontario Waterway lies in a general north-south direction connecting the two lakes and is divided into the overland and the Niagara River sections. The overland section connects Lake Ontario with the Niagara River near the city of North Tonawanda. This section with four 80-foot high locks has two possible alignments, A-1 and C-2. The Niagara River section is in the river and joins into Lake Erie via a lock with a 5-foot high lift and a canal at Squaw Island. Due to the foundation requirements of the two sections, emphasis will be placed on the overland section in this Appendix.

The purpose of the Appendix is to describe the geologic conditions and their effect on the canal and lock areas of the proposed waterway. The Appendix will stress the following:

- a. The characteristics of the overburden and bedrock.
- b. The geologic and soil investigations and tests performed to date.
- c. The foundation conditions at the lock sites.
- d. The sources of construction materials.

### REGIONAL GEOLOGY

#### B-2. Physiography

The region of the Lake Erie-Lake Ontario Waterway is located in

the western portion of the Erie-Ontario physiographic province of New York, which is in the northeastern portion of the Central Lowlands physiographic province of the Interior Plains, physiographic division. It is bordered on the north by Lake Ontario, on the west by Lake Erie and the Niagara River, and on the south by the Allegheny Plateau (Fig. B1). Within this region are three plains, Ontario, Huron, and Erie, separated by the east-west striking Niagara, Onondaga, and Portage Escarpments. Alignments A-1 and C-2 of the overland section are shown on Figure B2. The elevation above mean sea level of the region ranges from 244 feet at Lake Ontario to 1,500 feet along the Portage Escarpment. The relief between Lake Ontario and Lake Erie is 326 feet. Over one-half of that relief along the proposed waterway is located at the Niagara Escarpment.

### B-3. Stratigraphy

In the lowland, the age of the bedrock follows a Paleozoic sedimentary sequence and ranges from the Upper Ordovician through the Upper Devonian. This sequence is shown on a geologic map (Fig. B3). A generalized section for the pertinent formations, which are from the Upper Ordovician System through the Bertie Group of the Upper Silurian System, is shown on Plate B1. This section was based partly on data from Fisher (1960).

The Queenston Shale, which is the bedrock for the Ontario plain, is Upper Ordovician in age and 1,200 feet thick in western

New York. The interbedded shales, siltstones, and sandstones of the Medina Group are the rocks of the Lower Silurian. The Middle Silurian strata are composed of alternating beds of shale, sandstones, and limestones of the Clinton Group and dolomite-limestone and dolomites of the Lockport Group. The gypsiferous shale of the Salina Group and the shales and dolomite of the Bertie Group together with the Akron Dolomite make up the Upper Silurian strata. There are no Lower Devonian rocks in the region. The Middle Devonian rocks are made up of the Onondaga Limestone and the shales of the Hamilton Group and underlie Upper Devonian shales.

Outcrops of lowland bedrock are found along streams and along certain reaches of the shoreline of Lake Erie and Lake Ontario. The more resistant formations are exposed along the Niagara and Onondaga Escarpments. A complete sequence from the Queenston Shale of the Upper Ordovician age through the Lockport Group of the Middle Silurian age can be observed along the Niagara Gorge.

#### B-4. Geologic Structure

The strata of the bedrock in the lowlands have a general dip of approximately  $1/2^{\circ}$  to the southeast and a strike subparallel to the face of the escarpments. Only minor undulations have been found in the rocks of the area, such as along certain road cuts in western New York. Major folding, however, occurs in the Allegheny Mountains to the south. One large fault running from Clarendon to Linden, NY, which has a throw of over 100 feet, has been noted by Chadwick (1919).

This normal fault strikes in a north-south direction and dips to the west. The fault is approximately 40 miles east of the proposed waterway. Its approximate location and extent is shown on Figure B3. Numerous small thrust faults along with superficial faults caused by surface agents or the removal of salt or gypsum in the underlying bed have been reported in the region.

As of this date, there are no known recent comprehensive published reports on jointing in western New York. However, joint studies for the surrounding areas of central New York and northern Pennsylvania have been published by Parker (1942). A joint survey was conducted by the Buffalo District for the American Falls Study approximately 10 miles from where the alignment and the Niagara Escarpment intersect. The preliminary analysis indicated at least two joint sets in the Lockport Dolomite. A high angle  $N60^{\circ}E - N80^{\circ}E$  joint set appears to be a pronounced set with a secondary set trending  $N10^{\circ}W$  to  $N20^{\circ}E$ . Also at the American Falls, near vertical sheeting joints in the Rochester Shale were subparallel to the face. It can be expected that sheeting joints have developed in the Rochester Shale along the Niagara Escarpment.

Evidence of convergence and uplift in man-made cuts in the Lockport and Rochester Formations indicate that horizontal and vertical active stresses are present in the rock. A study by Rose (1951) of the Niagara Falls area reported numerous cases of rock movement in the region both east and west of the proposed

waterway. At Rochester, NY, for example, all the original bridges across the Barge Canal at the western limit of the city are known to have converged. At Lockport, NY, a 30-foot cut for the Barge Canal converged 9 inches in 25 years. Also in Lockport, NY, at the bottom of the Barge Canal, the Rochester Shale is rising, and it is necessary to remove rock every year in order to maintain the proper depth of the Canal. Near Niagara Falls, Ontario, a time dependent convergence of 4 inches was measured in a wheel pit for the Niagara Mohawk Power Plant. One hundred and fifty feet of Lockport Dolomite and 30 feet of Rochester Shale were excavated for the wheel pit. Further examples of rock movement are found in the report. Some of Rose's conclusions are:

a. Maximum stress direction appears to be in a general east-west trend in the Niagara Falls-Lockport area.

b. A much greater movement occurs in the Lockport Dolomite than in the Rochester Shale.

c. The maximum rate of rock movement probably occurs near the time of excavation and gradually diminishes.

Further examples of rock displacement as a result of load release due to excavation are reported by Hogg (1958).

Rebound of unexcavated land masses due to glacial loading and unloading are found in this region. One example of this type of uplift is the tilting of some beach ridges, indicating rebound after deposition.

#### B-5. Seismicity

The Environmental Science Service Administration (ESSA) prepared a seismic risk map in 1969 dividing the continental United States according to occurrences of earthquakes. These divisions or zones are based on intensities of earthquakes and geological considerations and are numbered 0 to 3. The Erie-Ontario lowland is in the zone 3 area, where major destructive earthquakes may occur. Epicenter locations of earthquakes in the area since 1857 have been recorded by the ESSA and others. These locations and their intensities, using the Modified Mercalli Intensity Scale of 1931, are given on Table B1 and shown on Figure B4. This scale, a local measure of seismic effects on people and objects in any affected area, is a result of the energy-release of the earthquake, the distance, the geology, and the structural properties of buildings. The scale ranges from one to twelve in intensity. The highest intensity earthquake in the region registered an eight on the scale. The shallow excavation for the overland Canal would have no appreciable effect on the occurrence of seismic disturbances. The design of the structures of the waterway should take into account the earthquake factor.

#### B-6. Geologic History

The topography of the area consists of a series of gentle rolling plains interrupted by east-west striking escarpments. The simple geologic structure and the erosional feature of the bedrock along with the complex glacial erosion and deposition produces an interesting geologic history.

The age of the bedrock ranges from Ordovician to Upper Devonian. The strata dip approximately 33 feet per mile to the southeast. The rock formations are interbedded shales, siltstones, sandstones, limestones, and dolomites of various thickness and sequence. Differential erosion left the more resistant rocks as escarpments, separating the low irregular surfaces of the more erodible rocks. The bedrock in the area has greatly influenced the Pleistocene geology.

During the Pleistocene age, the area was subjected to four major advances of glacial ice alternating with warm periods. Each advance scoured the bedrock and incorporated and rearranged the deposits of its forerunner; therefore, only the last major advance (Wisconsin) can be totally recognized. Glacial till was deposited in some areas as terminal and ground moraines covering the bedrock. The retreat of the glaciers was accompanied by vast amounts of melt-water. Huge lakes were formed in the scoured lowlands and were ancestors of the Great Lakes. Within the lakes, in some areas, silts and clays were deposited over the glacial till. The Niagara River channel drained the waters from early Lake Erie into Lake Iroquois. Further decrease in the lake levels introduced glacial Lake Tonawanda in the lowland between the Onondaga and Niagara Escarpments. It drained to the north over the Niagara Escarpment. Visible channels cut into the escarpment are found at Lockport, Gasport, Lewiston, Medina, and Holly, NY. Some buried channels may exist throughout

the escarpment. During part of the stage of Lake Iroquois, water extended to the base of the Niagara Escarpment and formed sand beach deposits. Complete and detailed discussions of the complex Pleistocene history are given in Calkin (1966), Kindle and Taylor (1913), and Spencer (1907).

#### B-7. Ground Water

The presence of ground water is dependent on the permeability of the materials involved. The aquifers in this area are in both overburden and rock. The overburden of the Ontario, Erie, and Huron plains consists primarily of glacial till and lacustrine clays, which are generally low-yielding aquifers. The Lockport, Camillus, and Onondaga Formation are the three major aquifer units in rock. The Lockport Dolomite and the Onondaga Limestone have water flowing through fractures, joints, and open bedding planes and yield as much as 100 gpm. The Camillus Shale has water flowing through solution cavities along gypsum and salt beds and yields as much as 1,200 gpm. The rest of the formations in the area is low-yielding aquifers and are considered impermeable (LaSala and others 1964).

#### INVESTIGATIONS PERFORMED

#### B-8. Field Investigations

Subsurface explorations were performed from 1963 through 1967 to determine the character and conditions of the overburden and the bedrock for the Lake Erie-Lake Ontario Waterway project. The drilling

was performed by the Detroit, Mobile, and Buffalo Districts, Corps of Engineers and by Empire Soils Investigation, Inc. These explorations included drilling and sampling in overburden with augers, undisturbed and drive samplers into rock with six-inch and NX-size core barrels. The locations of the explorations are shown on Plates B2, B3, B4, B5, and B6. The thickness of overburden, depth drilled into rock, and other pertinent data on the explorations are given on Table B2.

During the period from 1963 through 1965, a drilling program was performed along the original waterway alignments. There were 24 borings located along Alignment A of the overland section and six borings along the lock site at Squaw Island of the Niagara River section. These borings were taken to determine the characteristics and depths of the overburden, the conditions of the bedrock along the alignment, and to obtain samples for testing. In overburden, standard splitspoon drive samples were taken in 26 borings. Three-inch Shelby tube undisturbed samples were taken in five of those borings. Twenty-three borings out of the 30 that were drilled into the rock were NX-size with the remainder of the borings 6-inch size. There were 403 probings to determine the top of rock in the overland section. This was done by drilling a solid steel rod to refusal, which was assumed to be the overburden bedrock contact. A rock contour map based on these probings and supplemented by the boreholes is shown on Plate B7.

In late 1965, the overland section alignments were changed to

the existing Alignment A-1 and C-2. Initially, one 6-inch core boring was drilled along Alignment A-1. That boring revealed several soft clay zones (1.6 feet to less than 0.1 foot thick) below the assumed sound rock line in the Queenston Shale. Subsequently, a total of 15 core borings was drilled to gather data on overburden and rock. In overburden, standard splitspoon drive samples were taken in four borings, and 3-inch shelly tube undisturbed samples were taken in four borings. Of the 14 borings drilled into rock, 11 were NX-size and three were 6-inch size. Continuous Queenston Shale core was obtained to depths ranging from 85 to 135 feet in the bedrock. Pressure testing was performed in bedrock. These borings were located along the first three locks of Alignment A-1.

#### B-9. Laboratory Testing

Laboratory tests were performed on the Queenston Shale and soil samples along the overland section to determine criteria for shear, bearing, and consolidation. Tests were also performed on the Queenston Shale to determine the effects of cyclic loading due to the filling and emptying of the locks. In 1963, samples of the Queenston Shale from UDC-5A were prepared in suites, and samples from each suite were sent to NCD (North Central Division), ORD (Ohio River Division), and SWD (Southwestern Division) Laboratories. The tests performed by SWD were mainly torsional shear. Due to the difficulty of interpretation, the torsion shear test is no longer performed by SWD, and the results have not been included. In 1966,

overburden samples from RUDC 16, RUDC 17B, RUDC 28, and RUDC 29 were tested by NCD Laboratory. In 1968, consolidation, permeability, Atterbergs, and one point triaxial compression tests were performed on undisturbed samples of overburden from Borings U66502, 67511, AUC 67515, and AUC 67516. A summary of all the laboratory testing data is on Table B3. The basic laboratory test data is in Supplement one of this Appendix and is available for review at the U. S. Army Engineer District, Buffalo, upon request.

Cyclic loading tests were performed on 6-inch diameter core samples of Queenston Shale. The Concrete Division, WES (Waterways Experiment Station), performed petrographic and chemical analyses on the shale and chemical analysis of the water used during the testing. The equipment was designed by NCD Laboratory. The samples used for these tests were from Boring RC66501. The cyclic loading tests were performed on saturated samples in triaxial equipment for a year. The specimens were then tested to failure without drainage under a lateral pressure of one ton per square foot. Uncycled specimens were tested to failure by the same method. WES also performed petrographic and chemical analyses on samples of the shale and water after testing. Neither the length of the cycles nor frequency of the cycling had any apparent effect on the strength of the shale. However, based on the results of the tests, it was determined that for a factor of safety of three, the Queenston Shale should not be loaded over 33 tons per square foot. For details of the program see Davis (1970).

## LOCAL GEOLOGY

### B-10. Topography

The elevations between the Ontario plain and the Huron plain vary considerably along the proposed waterway. The Ontario plain is nearly level and has an average elevation of 250 feet above mean sea level. The surface slopes northward from elevation 400 feet near the base of the escarpment, which separates the two plains and is divided into the lower and upper escarpment along the proposed waterway, due to differential erosion of certain rock formations. The Huron plain, which slopes westward, is also nearly level and has an average elevation of 650 feet at the Niagara Escarpment to 600 feet at Squaw Island. The surface elevation of the Niagara River is about 570 feet. A geologic profile along the overland section is shown on Plates B8, B9, and B10.

### B-11. Overburden

Overburden information was obtained from field investigations and previous studies (Kindle and Taylor, 1913). The overburden of the Ontario plain along the proposed waterway is generally glacial till of the Wisconsin age. The till blankets the Queenston Shale and consists of a clay silt matrix with some sands, gravels, and boulders. Lacustrine deposits of glacial lakes Lundy and Iroquois are found in favorable localities over the till. These stratified clays and silts are found near the shores of Lake Ontario and in an irregular

four square mile area near the town of Ransomville. The Lake Iroquois beach ridge is located along Route 104 and is 10 to 30 feet above the adjacent ground surface. Data from boreholes indicate a buried basin along the base of the escarpment. The materials in the basin range from impermeable clays and silts to pervious sands and gravels. The overburden thickness of the Ontario plain along the alignment averages 30 feet and ranges from 10 feet to 120 feet.

The overburden of the Huron plain along the overland section of the waterways is mainly made up of glacial till and lacustrine deposits. The till covers most of the bedrock of the Huron plain and has generally the same characteristics as the till of the Ontario plain. Extensive deposits of lacustrine silts and clays, from both Lake Lundy and Lake Tonawanda, overlie the till and are found four miles south of the escarpment to the Niagara River. The thickness of the overburden averages 23 feet and ranges from 3 feet to 50 feet. West of Sanborn, NY, for approximately 12,000 feet along the alignment, the thickness of the overburden ranges from 3.0 to 9.0 feet. Detailed soil profiles along the overland section are shown on Plates B11 through B18.

The overburden of the Huron plain at Squaw Island of the Niagara River section has an average thickness of 65 feet. North of the International Bridge, the overburden is made up of sands and gravels and has a thickness ranging from 45 to 65 feet. South of the

bridge, the material consists of fill from the garbage dump underlain by a reddish, silty clay and has a thickness ranging from 60 to 90 feet. A soil profile along the lock at Squaw Island is shown on Plate B19.

#### B-12. Stratigraphy

The bedrock of the lowland along the proposed waterway is made up of rocks ranging in age from Upper Ordovician through Middle Devonian.

The Queenston Shale represents the Upper Ordovician strata in the Ontario plain. Although the formation is approximately 1,200 feet thick, only the upper 200 feet are visible in the lowlands. The shale which is not exposed along the alignment, weathers readily into blocky chunks when exposed to the atmosphere. The Queenston, which is technically classified as a claystone, is generally maroon in color and contains some green discontinuous bands and nodules. It has massive bedding and is soft to moderately-hard. The shale is indurated (cemented with calcareous material) and is made up chiefly of the clay minerals illite, chlorite, kaolinite, and montmorillonite with some quartz. The formation contains occasional slickenside compaction planes. Soft zones were found along the alignment down to 100 feet in the shale. The Queenston Shale will be the foundation rock for four of the locks along the waterway.

The Whirlpool Sandstone, which is the basal unit of the Medina Group and of the Lower Silurian age, overlies the Queenston Shale

unconformably. The formation outcrops at the base of the lower escarpment along the alignment and is approximately 20 feet thick. It is a light-gray to white, medium- to massive-bedded, moderately-hard, medium- to coarse-grained quartzitic sandstone. The sand grains, strongly cemented by silica, are well-rounded and frosted. There are occasional inclusions of green shale scattered throughout the sandstone.

The Power Glen Shale of the Medina Group rests on the Whirlpool conformably. The shale, which does not outcrop along the alignment, weathers quite readily when exposed. The thickness of the formation at the alignment site is approximately 35 feet. The Power Glen is a grayish-green to dark-gray, laminated, moderately-hard shale. Some siltstone beds and stringers of silty limestones and dolomite are present. The major constituents of the rock are quartz and the clay minerals, illite and chlorite.

The Grimsby Sandstone of the Medina Group overlies the Power Glen Shale conformably and is not exposed along the alignment. Although portions of the Grimsby have been used as curbstones for the city of Buffalo, it generally weathers readily upon exposure to the atmosphere. The formation along the alignment is approximately 50 feet thick and is generally a pink- to dark-red sandstone and siltstone, interbedded with shale. The sandstone is fine to medium grained and is well cemented; the siltstone and shale vary from soft to moderately hard.

The Thorold Sandstone is the uppermost unit of the Medina Group and rests conformably on the Grimsby Sandstone. The formation that outcrops along the alignment at the lower escarpment is approximately 6 feet thick. The Thorold is a light- to greenish-gray, medium- to massive-bedded, hard, very fine-grained orthoquartzitic sandstone. The sand grains are cemented with silica and are subangular to angular in shape, with green shale partings occurring throughout the sandstone.

The Neahga Shale, which is the basal unit of the Clinton Group and of Middle Silurian age, rests on the Thorold Sandstone conformably. The shale, which weathers very rapidly and is not exposed along the alignment, is approximately 6 feet thick. This greenish-gray, platy, soft, dense, shale has a waxy feel and appearance. Illite, the dominant clay mineral present with quartz, is the most abundant non-clay mineral.

The Hickory Corners Limestone Member of the Reynales Limestone in the Clinton Group overlies the Neahga Shale conformably. Although the member is resistant to weathering and is 5 feet thick, it is not exposed along the alignment. It is a light- to medium-gray, argillaceous, thin-bedded, very fine-crystalline, moderately-hard limestone. The limestone has numerous wavy shale partings and bands that produce a nodular appearance.

The Irondequoit Formation of the Clinton Group overlies the Hickory Corners Member of the Reynales Limestone unconformably.

The formation is resistant weathering and is the caprock for the lower escarpment at the alignment. It has two members, (in ascending order) the Rockway Dolomite Member and the Upper Limestone Member.

a. The Rockway Member: light- to brownish-gray, thin- to massive-bedded, argillaceous, fine-crystalline, moderately-hard interspersed with occasional gypsum nodules, thickness approximately 9 feet.

b. The Upper Member: light-gray with a pinkish tint, medium- to massive-bedded, coarse-crystalline, moderately-hard, occasional vugs, thickness approximately 9 feet.

The Rochester Shale in the upper unit of the Clinton Group overlies the Irondequoit Formation conformably. The shale, which weathers rapidly when exposed to the atmosphere, is not exposed along the alignment. The formation is a medium- to dark-gray, laminated, moderately-hard shale. The thickness of the shale at the alignment is approximately 62 feet. The major constituents of the shale are quartz and the clay mineral illite. There is a 6-foot argillaceous dolomite bed near the middle of the formation.

The Lockport Dolomite of the Lockport Group rests conformably over the Rochester Shale. The dolomite is resistant to weathering and is the caprock for the upper escarpment. It is also the bedrock for the northern area of the Huron plain of the overland section. The formation consists of five members which (in ascending order)

are named DeCew, Gasport, Goat Island, Eramosa, and Oak Orchard. The total thickness of the formation along the alignment varies due to its irregular eroded surface on the Huron plain. The general characteristics of the Lockport Dolomite members are:

a. DeCew Dolomite Member: medium- to dark-gray, thin- to medium-bedded, argillaceous, fine-crystalline, moderately-hard, angular shale partings are common, thickness approximately 10 feet.

b. Gasport Limestone Member: light- to medium-gray, massive, stylolitic shale partings, fine- to coarse-crystalline, moderately-hard, vuggy, thickness approximately 18 feet.

c. Goat Island Dolomite Member: light- to dark-gray, thin- to massive-bedded, stylolitic shale partings in middle, chert nodules in upper, fine- to coarse-crystalline, moderately-hard, pitted and vuggy, thickness approximately 26 feet.

d. Eramosa Dolomite Member: medium-gray to brown, thin- to medium-bedded, stylolitic shale partings, fine-crystalline, moderately-hard, thickness approximately 14 feet.

e. Oak Orchard Dolomite Member: medium-gray to brown, thin- to thick-bedded, stylolitic shale partings, fine-crystalline, moderately-hard, thickness approximately 14 feet.

The Camillus Shale of the Salina Group and of the Upper Silurian System overlies the Lockport Formation conformably. The shale that is not exposed at the alignment is assumed to weather readily. Its total thickness is approximately 400 feet. The

formation is the bedrock for the southern area of the overland section and most of the Niagara River section. The Camillus is predominantly a brownish-gray, thin- to massive-bedded shale with gypsum and anhydrite beds that are mined for industry. Other formations of the Salina Group are not known to be present west of Batavia, NY.

The Bertie Formation of the Upper Silurian age rests conformably on the Camillus Shale. The formation that is not exposed along the alignment has four members: the Oatka (oldest), the Falkirk, the Scajaquada, and the Williamsville. The Falkirk Member is the foundation rock of the Squaw Island Lock. The general characteristics of the members of the Bertie Formation as taken from the 1963 boreholes at Squaw Island are:

a. The Oatka Dolomite Member: light-brown to dark-gray, thin-bedded, argillaceous, shale beds, bands and parting throughout; gypsum parting, bands and nodules are found in certain beds; dense, soft- to moderately-hard, thickness approximately 23 feet.

b. The Falkirk Dolomite Member: light-brown to dark-gray, thin-bedded, very argillaceous dolomite and shale beds throughout, numerous gypsum partings, bands and nodules throughout, dense, soft to hard, thickness approximately 26 feet.

c. The Scajaquada Shale Member: bluish-gray to dark-gray and black, dolomitic, occasional calcite nodule, moderately-hard, thickness approximately 7.0 feet.

d. The Williamsville Dolomite Member: medium-gray, thin- to medium-bedded, several shale partings, very fine-crystalline, moderately-hard, thickness approximately 6 feet.

The Akron Dolomite is of the Upper Silurian System and rests conformably on the Bertie Formation. It is a thin- to medium-bedded, dense, moderately-hard, ruggy, greenish-gray to light-buff dolomite. Its thickness in the area varies from 1 to 8 feet.

The Onondaga Limestone rests unconformably on the Akron Dolomite. It is Middle Devonian and has three members in the area. These members are the Edgecliff Member, the Nedrow Member, and the Moorehouse Member. The Onondaga Limestone is generally thin- to massive-bedded, cherty, dense, moderately-hard to hard, and blue-gray in color. The total thickness of the formation is approximately 160 feet. The Akron Dolomite, Onondaga Limestone contact is south of the Squaw Island Lock near the sewage treatment plant.

#### B-13. Geologic Structure

The data on the rock structure are primarily from borings and from a few limited outcrops. There is no evidence of faulting or significant folding. The beds dip approximately 33 feet per mile in a southeasterly direction. The most significant structural features were found in the Queenston Shale. There is a fractured weathered zone at the top of rock. The Queenston also contains soft zones. Some joints and weathered zones were also found in the

overlying units.

The borings from the 1966-67 program in the Queenston Shale showed a fractured weathered zone that averaged 22 feet and ranged from 2.9 to 43 feet. The sound rock below had vertical joints up to 3 feet in length and at depths down to 150 feet from ground surface. Soft zones were also encountered in the sound rock and will be discussed in detail below.

In 1966 in borehole RC=66501, a 2.4 foot soft clay zone was found approximately 30 feet below the top of the rock. This zone consisted of angular fragments of shale in a clay matrix and is shown in Figure B4. Subsequent borings along the alignment uncovered numerous soft clay zones ranging in thickness from 0.4 feet to less than 0.05 feet. Examples of these zones are shown on Figure B5. A review of 20 borings either wholly or in part in the Queenston Shale was studied to ascertain the characteristics, position, and extent of any soft zone.

Five samples were sent to the Ohio River Division Laboratory for X-ray analysis of the soft material. The major constituents of the soft material consist essentially of quartz, illite, chlorite, kaolinite, feldspar, and hematite in decreasing order of abundance. The soft zones within the Queenston Shale are described as soft clay or plastic on the original field logs. In most cases, there are angular to subrounded shale grains in the matrix. While the size of the shale fragments varies according to the thickness of the

zone, they are totally absent in only a very few cases. In most of these clay zones, the fragments are aligned subparallel to the top and bottom of the zone.

While the majority of the zones were found within 30 to 40 feet of the top of rock, several were below 50 feet and some as deep as 100 feet (See Plates B20, B21, B22, B23). No firm correlations of the soft zones were found either along the bedding planes or subparallel to the top of rock line. This fact tends to imply that the zones are discontinuous over a distance that is not known at this time. The origin of the soft clay zones appears to be that of the shearing of the weak shale caused by the movement of the mountainous ice sheet during the glacial periods. This origin has been proposed for apparently comparable zones in different areas under similar glacial history by Knill (1968).

There were four borings drilled at the escarpment. The formations that were found in these borings ranged from the Queenston Shale to the Lockport Dolomite. Very few joints were found. Outcrops along the alignment were too poorly exposed to show the condition of the rock. Two roadcuts near the alignment were at Pekin, NY; one located at the lower escarpment exposed the Irondequoit Limestone to the Neahga Shale. The top few feet of Irondequoit were fractured and weathered. Some joints were found but only confined to particular beds. The Neahga Shale was weathered to clay. The second roadcut

in the upper escarpment exposed the Goat Island Member through the DeCew Member of the Lockport Formation. The beds showed some minor folding. The majority of the joints was in the beds of the upper Goat Island member in individual beds.

The bedrock of the Huron plain along the proposed waterway consists of the Lockport, Camillus, and Bertie Formations. Logs of the borings along the Huron plain showed a fractured zone in the upper 5 feet of the Lockport Dolomite and a few joints in the sound rock below. The boreholes at Squaw Island indicate a fractured weathered zone at the top of the Bertie Dolomite less than 15 feet thick. These boreholes also indicate a gentle dipping syncline just south of the proposed Black Rock Lock. This fold is shown on Plate B24.

#### B-14. Weathering in Bedrock

Weathering is the alteration of the rock during exposure to air, moisture, and organic matter by chemical and mechanical processes. Chemical weathering is the decomposition of rock, for example, solutioning of rock along joints and fractures. Mechanical weathering is the disintegration of rock, for example, rock fracturing due to wet-dry, freeze-thaw cycles. The two processes work in close coordination in the breaking down of sound rock. Uhl, Hall, and Rich, project engineers for the construction of the Robert Moses Power Plant

Niagara Falls, NY, conducted an experiment in 1959 on samples of shales that were exposed in the channel cut. The shale pieces were from the Queenston, Power Glen, Grimsby, Neahga, and Rochester Formations. The shales, along with a sample of gunnited Queenston Shale, were exposed to atmospheric condition for approximately three months. At the end of this period, all of the exposed shale disintegrated completely with the exception of a piece of dolomitic Rochester Shale that broke down into several pieces. The gunnited Queenston Shale did not appear to be affected by atmospheric conditions. Figure B6 illustrates the results. These samples were obtained in bedrock less than 10 miles from the proposed waterway. The weathering of the bedrock along the proposed waterway is discussed according to its physiographic location.

The Queenston Shale of the Ontario Plain weathers rapidly into blocky chunks upon exposure to the atmospheric conditions by mechanical processes and eventually into clay. The information on the depths of the fractured and weathered zone to sound rock was taken from the 1966-67 boring program. The thickness of this zone along Alignment A-1 averages 22 feet and ranges from 2.9 to 43 feet.

As the rock formations of the escarpment vary lithologically, the weathering processes of those rocks differ also. The shales and some siltstones weather rapidly, by mechanical processes, into clay and silt to unknown depths into the face of the escarpment. The more

resistant sandstones, limestones, and dolomites may weather chemically and large voids along joints, fractures, and horizontal partings by ground water solutioning.

The bedrock of the Huron plain along the proposed waterway consists of the Lockport, Camillus, and Bertie Formations.

a. The Lockport Dolomite is resistant to weathering. Boreholes along the alignment indicate a weathered zone of less than 5 feet thick.

b. The Camillus Shale weathers readily by mechanical processes. The gypsum beds located in the formation are soluble in water and can be removed by solutioning. The fractured weathered zone found in boreholes along the alignment is approximately 15 feet thick.

c. The Bertie Dolomite, the foundation rock of the Squaw Island Lock, is fairly resistant to weathering. The Dolomite found in the boreholes at Squaw Island indicates a fractured weathered zone in the formation less than 15 feet thick.

#### B-15. Ground Water

The Lockport Dolomite and the Camillus Shale are the only two high-yield aquifers in the overland section. The Lockport Dolomite generally transports the ground water by artesian flow through open joint fractures and interconnected cavities. Water wells in the dolomite along the alignment yield ground water up to 110 gpm. These wells were drilled as far down as 50 feet into the rock.

Greater amounts of ground water are expected in the lower sections of the formation. In the Niagara Falls area, seven water bearing zones are found throughout the Lockport Dolomite (Johnston 1964). These zones and possibly more may be found in the waterway area. Regionally, the Camillus Shale is known to yield up to 1,200 gpm of ground water along solution cavities; however, there is no known ground-water information in this unit along the overland section of the waterway.

There is very little information on the ground water of the Silurian rocks below the Lockport Dolomite along the overland section. Generally, the Rochester Shale which underlies the Lockport Dolomite is impermeable. The sandstone and limestone formations of the Silurian strata that are good aquifers in some areas may, in fact, be poor due to the lack of recharge of the ground water. Water well data near the alignment indicate a very low-yield in these formations.

The Queenston Shale is a low-yielding aquifer. In the 1966-67 drilling program, the sound rock of this formation was pressure tested. The rock being tested was generally not capable of transporting water. Water wells drilled into the shale are generally seated in the fractured weather zone that is found at varying thicknesses above the sound rock. This zone yields up to 40 gpm of ground water in certain areas near the alignment although it generally yields less than 5 gpm.

The overburden of the overland section is generally a low-yielding aquifer. A few water wells are found in the Ontario plain along the alignment; however, they are only used for domestic purposes. In

contrast, the overburden of Squaw Island of the Niagara River section, which is made up of sands and gravels, is highly permeable. The ground-water table is approximately at the same level as the river.

Water levels found in the borings along the alignment of the overland section and at Squaw Island are shown on Plates B11 through B19.

#### EXCAVATION

##### B-16. General

Excavation of overburden and rock will be required for all locks. Excavation of some overburden will be required for all dikes. In the canal cut from Lock 4-5 to the Niagara River, extensive removal of overburden and rock is necessary to produce the proper channel depth. Excavation for some of the guide walls will be necessary. Geologic profiles for the individual locks and its guide walls are shown on Plates B20, B21, B22, B23, and B24. Some of the excavated materials could be used for construction purposes.

##### B-17. Lock 1-5

The founding elevation for the lock walls is 175.0 feet (I.G.L.D., 1955) with a section for a conduit at an elevation of 168.0. The overburden that is generally glacial till and lacustrine silts and clays has a uniform thickness of approximately 25 feet. The bedrock of the lock area is the Queenston Shale. Approximately 90 feet of this rock is to be excavated. The average sound-rock line is at elevation 220. Excavation for the lower guide wall will be in overburden and rock to elevation 204.0. The removal of overburden to elevation 271.0

for the upper guide wall will be necessary. A preliminary estimate for the slope in the overburden cut generally will be 1V on 2H and for the shale cut 2V on 1H with berms to be provided where necessary for drainage and protection against spalling.

B-18. Lock 2-5

The founding elevation for the lock walls is 255.0. The conduit section will be as deep as elevation 245.5. The overburden, which has a thickness ranging from 30 feet on the downstream end to 60 feet on the upstream portion, is generally glacial till. Up to 40 feet of Queenston Shale must be excavated to reach the founding elevation. In the upstream end of the lock, from boring AUC-67516, the sound rock is estimated to be at elevation 242.8. This is 12.2 feet below founding elevation of the lock walls. The removal of overburden to elevation 286.7 for the lower guide wall will be required. No excavation other than stripping will be necessary for the upper guide wall. The overburden slope cut during excavation generally will vary from 2V on 5H to 1V on 5H, depending on height of cut. The cut in shale will be 4V on 1H, with a berm provided for drainage and protection against spalling.

B-19. Lock 3-5

The lock wall is founded on the Queenston Shale at elevation 328.0. The thickness of overburden varies from 10 to 20 feet and consists mainly of glacial till and sands and gravels of the ancient

beach of Lake Iroquois. The thickness of the bedrock to be excavated ranges from 30 to 35 feet. The sound-rock line is based on one hole and is at elevation 343.8. The removal of overburden for the lower guide wall to elevation 351.4 will be required. It is not necessary to excavate for the upper guide wall other than stripping. Temporary slopes during construction for the overburden cut generally will be 2V on 3H and for the rock cut generally will not exceed 2V on 1H with a berm provided for drainage and protection against spalling.

B-20. Lock 4-5

The founding elevation for the lock walls is 416.0. There were no boreholes at the actual lock site, and all data are extrapolated from boreholes along Alignment A. The overburden, which ranges from a few feet to approximately 40 feet in thickness, consists generally of glacial till. It is assumed that the lock will be founded on the Queenston Shale. Rock excavation from the upstream end of the lock probably will consist of shale, sandstone, and shaly sandstone from the Medina and Clinton Groups. The rock cut will have a 10V on 1H slope for sandstone and 2V on 1H for shale. The sound-rock line has not been determined at this site. No excavation for the lower guide wall is required. Rock excavation will be necessary in the Rochester and Irondequoit Formations to elevation 524.0 for the upper guide wall. The rock cut in the Irondequoit Limestone and the Rochester Shale will have a slope of 10V on 1H and 2V on 1H, respectively, with berms to be provided as required.

B-21. Overland Canal

The canal excavation from the end of the upper guide wall of Lock 4-5 to the beginning of the overland section at the Niagara River is to be excavated in both overburden and rock. The bottom of channel elevation is 531.0. The overburden consists generally of lacustrine silts and clays and glacial till and has a thickness varying from about 6 feet of till to about 50 feet of weak clay. The bedrock that will be excavated is from the Rochester, Lockport, and Camillus Formations. The thickness of bedrock to be excavated ranges up to 90 feet. The thickness of the overburden and rock excavation for the canal cut is shown on Plates B8 and B9. The slope of the channel cut in rock ranges from 10V on 1H in the Lockport Dolomite to 2V to 1H in the Rochester and Camillus Shale. The overburden slopes will generally vary according to depth and strength characteristics, however, for estimating purposes a 2V on 5H slopes were used, except where overburden cuts exceed 30 feet in depth and submergence was a factor. Overburden from Niagara River to approximately Station 1290+00 varies from about 30 to 50 feet of weak clay. Some excavation in the Camillus Shale can be expected. Between Sta. 1290+00 and Sta. 1420+00, there is a maximum of about 90 feet of Lockport Dolomite to be excavated along with a shallow mantle of overburden, mainly till.

B-22. Lock 5-5

The founding elevation for the lock walls is 510. The center line of the original lock site, which has six borings drilled into

rock, has been relocated about 200 feet toward the river. The rock depth and condition at the lock site can only be extrapolated from these boreholes. The overburden is a sand and gravel material that ranges from 45 to 65 feet. Considerable fill from the nearby garbage disposal plant is present. The bedrock is Bertie Dolomite and its excavation is assumed to be up to 12 feet. The sound-rock line based on one borehole outside the lock area is at elevation 514.1. Overburden removal is expected for the upper and lower guide walls. The slopes in the overburden for excavation will be determined from actual boring data and will depend on seepage and uplift pressures and other factors affecting the stability. However, for this report it is assumed that the overburden cut will be 1V on 1.5H.

B-23. Existing Canal

Deepening of the existing Black Rock Canal will be required. Upstream of the existing Black Rock Lock the required channel depth will be at El.539. Downstream of the lock the required channel depth will be at El.534. Rock excavation will be required both upstream and downstream of the lock. Upstream of Squaw Island the rock to be removed is Onondaga limestone. Downstream the rock to be removed consists of Camillus Shale. The overburden to be removed varies from silty sand to glacial till.

FOUNDATION CONDITIONS

B-24. Locks 1-5, 2-5, 3-5

The foundation conditions for Locks 1-5, 2-5, and 3-5 are

similar. The overburden for the three locks is generally glacial till with some lacustrine clays and silts. However, sand and gravel materials of the beach ridge are found on the upstream portion of Lock 3-5.

The three locks are founded on the Queenston Shale. This formation as discussed previously in Section B-13, Geologic Structures, has discontinuous soft clay zones of varying thicknesses above and below the founding elevations of the lock walls to an approximate depth of 100 feet into rock. A thickness of 10 feet of sound Queenston Shale was determined to sufficiently reduce stresses in soft zones to prevent differential settlement and plastic flow. There were no soft zones found below the founding elevations in the borings of Lock 1-5 (Pl B20). In Lock 2-5, a minimum thickness of 10.6 feet of the lock walls and the soft zones was found in borehole C-67516 (Pl B21). In Lock 3-5, a minimum thickness of 17 feet of sound rock between the founding elevation of the lock walls and the soft zones was found in borehole ARC-66508 (Pl B22). The occurrence of soft zones will require additional explorations and analysis in subsequent studies.

A weathered fractured zone located at the top of rock was found in all boreholes. The founding elevations for all of the lock walls are below this zone. Joints found in boreholes were usually tight and vertical. Ground-water seepage during construction

may occur along the weathered fractured zone in the shale and along the beach ridge in the overburden; however, it is not expected to produce any major problems. The shale, which weathers readily upon exposure to atmospheric conditions, should be protected during construction. A major grouting program for the bedrock is not expected.

B-25. Canal Dikes

The reaches of the canal dikes from Lock 1-5 to Lock 3-5 has generally the same geologic conditions. The overburden is generally a firm glacial till with lacustrine clays and silts in some areas. The rock underlying the overburden is the Queenston Shale. The canal dikes from Lock 1-5 to Lock 2-5 have a crest elevation of 331.7 and are approximately 9,000 feet long. The dikes from Lock 2-5 to Lock 3-5 have a crest elevation of 411.4 and are 12,000 feet long. Due to the length of the dikes, differential settlement may occur along these reaches.

The canal dikes from Lock 3-5 to Lock 4-5 are approximately 2,000 feet long and have a crest elevation of 491.1. The overburden of the area is made up of a sequence of clays and silts overlying semi-pervious to pervious sand and gravel material. The overburden thickness varies from 60 feet to approximately 120 feet. The sands and gravels are in a buried depression that runs along the escarpment. The bedrock is Queenston Shale.

B-26. Lock 4-5

The closest borehole to the lock site is 1,500 feet to the east.

By extrapolation, it is anticipated that the Queenston Shale will be the foundation bedrock for the lock walls. The Medina and Clinton Group will be exposed on the upstream end of the lock. Ground-water seepage can be expected and grouting should be considered.

B-27. Overland Canal

The canal cut from Lock 4-5 to the Niagara River will be in overburden and rock. The overburden for the northern half of the canal cut is firm glacial till and for the southern half is weak lacustrine clay and silt underlain by glacial till. The rock that will be excavated will be the Rochester, Lockport, and Camillus Formations. Stresses in the Rochester Shale and Lockport Dolomite may produce a convergence when the cut is made and should be considered in the design of bridges crossing the canal. The Lockport Dolomite and Camillus Shale are high-yielding aquifers, and seepage can be expected during construction.

B-28. Lock 5-5

Lock 5-5 is located partly on Squaw Island and partly in the Niagara River. The overburden of Squaw Island where the lock will be located is highly pervious. The foundation rock of the lock is the Bertie Dolomite and is fractured to a depth of 15 feet from top of rock. Seepage can be expected to be a major problem during construction. Grouting can be expected.

## DESIGN CONSTANTS

### B-29. Rock

On the basis of tests performed by NCD and ORD on the Queenston Shale, the following preliminary constants for this intact material were established:

Internal Friction	Tan $\phi$ = 0.700
Compressive Strength (Allowable)	33 tons per sq. ft. Maximum
Modulus of Elasticity, "E"	390,000 pounds psi
Unit Weight	165 pounds per cubic foot
Resistance to Sliding	Tan $\phi$ = 0.30

Initially placed, this Queenston Shale and other similar excavated shales were assumed to have the same characteristics as the dolomitic limestone to be used in the dike shell, as follows:

Angle of Internal Friction	$\phi$ = 40 degrees
Cohesion	c = 0 psf
Unit Dry Weight	w = 115.5 pcf
(based on 30 percent voids)	
Submerged Unit Weight	W <sub>sub</sub> = 72.0 pcf

A substantial amount of excavated shale will be used in toe berms on the dike sections. Most of this material weathers readily into blocky chunks when exposed to the atmosphere (refer to the Local Geology section of this report, paragraph B-12) and in most instances (over a prolonged period of time) would revert to a semigranular soil mass of its component minerals - illite, chlorite, kaolinite, and montmorillonite with some quartz, and eventually into clay.

In view of the foregoing, the following conservative preliminary design values were assigned this material for the possible ultimate

weathered condition in compacted toe load berm fills:

Angle of Internal Friction	$\phi = 10$ degrees
Cohesion	$c = 200$ psf
Unit Dry Weight	$w = 115.5$ pcf
Submerged Unit Weight	$W_{sub} = 72.0$ pcf

B-30. Overburden

From comparison of test data with blow counts, there are apparently five zones in the overburden from the Niagara Escarpment north to Lake Ontario. These zones vary considerably in thickness, and definitive drilling programs will be required to establish their extent, reach by reach.

Preliminary design constants for these zones were established by evaluating the constants determined for the in situ soils and assessing the amount of strength increase expected due to consolidation of these soils under the weight of the dikes during construction. The design constants so determined are considered to be realistic and conservative, but will require verification by appropriate test programs conducted in conjunction with final design studies.

The preliminary design constants established for the previously mentioned zones are as follows:

<u>Zone No.</u>	<u>Zone Designation</u>	<u>Cohesion "C" in Psf</u>	<u>Unit Dry Weight Pcf</u>	<u>Moisture Percent of Dry Wgt.</u>
I	Upper Clay	1,500	113.3	18.2
II	Intermediate Clay	1,000	103.8	23.5
III	Middle Weak Clay	900	89.8	33.4
IV	Lower Clay	1,500	113.3	18.2
V	Till (Presumptive Values)	$c = 1,000$ $\phi = 25$ degrees	135.0	10.0

The submerged unit weight required in the analyses performed was calculated using the foregoing values, and the specific gravity and void ratio values determined by test are shown in Table B3.

Upstream of the escarpment, from about Lockport Road to the Niagara River, the overburden changes from the thin till mantle to clay. This clay extends to 50 feet in places, and indications from Borings RUDC 28 and 29 are that it is quite weak. The preliminary design constants for this clay in situ are:

C = 125 pounds per square foot  
 Unit dry weight = 85 pounds per cubic foot  
 w = 35 percent (of the unit dry weight)

Much of this material will be utilized as core material in the impervious dikes. Obviously, considerable processing, particularly aeration to remove excess moisture, will be required to achieve the density and impermeability required in the core. It is presumed that the compacted material will have properties comparable to the best underlying soils in the major dike areas, thus the following constants were established for the clay core:

(PRESUMPTIVE VALUES)

<u>Compacted Clay Core Material*</u>	<u>Cohesion C in Psf</u>	<u>Unit Dry Wgt. Pcf</u>	<u>Moisture Percent of Dry Wgt.</u>
As Placed	1,500	105	19.0
Saturated	1,000	105	23.4

\*Angle of Internal Friction  $\phi$  = 0 in all cases.

## CONSTRUCTION MATERIALS

### B-31. Rock

The amount of rock that will be excavated during the construction of the waterway is approximately 37,113,000 cubic yards in situ. The estimated quantities of each type of material to be excavated are summarized in Table A4 in Appendix A.

Calculations indicate that sufficient durable Lockport Dolomite will be obtained from the channel cut to satisfy the requirements for riprap, rock-fill breakwater material, and coarse and manufactured fine aggregate for concrete and bedding and filter materials. During the construction of the Robert Moses Power Plant the Lockport Dolomite, with the exception of the DeCew member, was used for the coarse and fine aggregates for concrete. The stone proved excellent quality for both aggregates. The Lockport Dolomite at the waterway site is less than 10 miles east of the power plant, and its quality is assumed comparable. Other rock types, notably Camillus Shale, will be utilized for construction materials in toe load berms for dikes at many locations (refer to Table B4 which lists the rock formations that will be excavated and their possible uses).

### B-32. Overburden

The amount of overburden soil excavated during construction of the waterway will be approximately 37,960,000 cubic yards in situ. The amount of clay core material required for the impervious dikes is

calculated to be 4,787,000 cubic yards and will be selected from the most impermeable overburden soils available in the excavation areas of the waterway. Available soil boring and laboratory test data indicate most of the clay core material will be selected from deposits upstream of the escarpment from about Lockport Road to the Niagara River.

The borings taken to date indicate some superficial silty and clayey sand and gravel deposits exist in dike areas that will probably require excavation, as will those deposits occurring in the general excavation areas. These materials and all others that have soils constants comparable or superior to those values assigned disintegrated shale can be used in dike toe berms in noncritical areas, as shown in Plates A7 through A10.

The use and disposition of all excavated materials is covered more fully in Appendix A under Use and Disposal of Excavated Materials.

#### DIKE DESIGN

##### B-33. Design Procedure

The procedures followed in the investigation of the stability of dikes and dike foundations and their effectiveness against seepage losses were as follows:

- a. Since many typical sections as originally conceived were quite similar, groups of such sections were determined, and typical

sections in each group were selected for analysis. In each case the most critical section was used; i.e., for a given configuration the highest dike section founded on the deepest typical subsoil formation was chosen for evaluation.

b. All necessary computations were performed to determine additional basic data required in the analyses, such as wet density and submerged unit weights, using the preliminary design constants previously presented and the test data in Table B3.

c. Stability analyses were performed, using the Swedish slip circle method of analysis, on the typical sections, mentioned previously.

Sections found to be unstable were redesigned as required to meet acceptable factor of safety requirements.

d. Seepage analyses flow nets were prepared for typical high and low sections on rock, a typical high dike section over a thick and a thin foundation section, and a typical low dike over a thick and a thin foundation section. Average horizontal and vertical permeability factors were determined from the test data in Table B3, and these values were used for both the foundation and core. In the case of the core, it was considered very conservative to apply the same factors, since a substantial increase in permeability factors will be realized in the compacted state.

#### B-34. Stability Analysis

Most of the sections as originally conceived were found to be

unstable due to excessive dike height on weak foundation soils, when evaluated against the minimum factors of safety set forth in EM 1110-2-1902 Engineering and Design Stability of Earth and Rock Fill Dams. In these cases, the sections were redesigned to meet the required criteria using the slip circle method of analysis.

Two types of revised sections were considered, flattening slopes and adding toe load berms to the existing sections. The toe load berm method was determined the more economical means of achieving the desired results, hence this design revision method was standardized throughout.

Stability analyses were performed for various toe load berm heights on the typical sections to establish top of berm elevations required for the highest section in each (lock to lock) reach of the canal. The top of berm elevation so determined for each reach was held constant throughout that reach for practical and aesthetic reasons; thus, the safety factors for the bulk of the dikes are higher than those established for the basic critical sections.

The three basic design conditions having the most severe safety factor requirements were used in the analysis of the typical sections. These conditions and the minimum factor of safety required in each use are as follows:

End of Construction	1.4
Partial Pool with Steady Seepage	1.5
Steady Seepage with Maximum Storage Pool	1.5

These cases were evaluated for upstream and downstream slopes as appropriate. Since all other design conditions have less stringent factors of safety requirements, spot checks on selected sections for these conditions were made that verified the revised designs to be satisfactory.

Additional stability analyses were performed on the revised design sections to determine the suitability of using shale or other degradable materials with comparable physical characteristics in the toe load berms at selected locations. The locations of permissible use for these materials are designated on Plates A7 through A10.

The stability analyses were performed with the aid of an electronic computer. The locations of trial failure arcs were set manually by an experienced soils engineer to assure that the critical circle location was not influenced by the limitations of a programmed search procedure.

The location of the failure planes, used in stability analyses checks performed by the sliding wedge method of analysis, were also set manually by an experienced soils engineer. Therefore, the computer program used in this analysis also served the sole function of reducing computational effort.

#### B-35. Seepage Analysis

All of the seepage analyses performed were based upon average

horizontal and vertical permeability factors presented in Table B3. Ten sets of horizontal and vertical permeability factors determined by tests on undisturbed specimens are available. Of these 20 tests, three were obvious outliers, that is, nontypical insofar as the other 17 are concerned, and were not included in the averages. The legitimacy of these tests is not in question. However, it was felt they represented localized deposits of more permeable material that will have to be treated as separate problems when encountered during construction (refer to the Conclusions and Recommendations section which follows for a discussion of this item). The average in situ foundation soil permeability factors used in the analyses were as follows:

$$\text{Vertical Permeability Factor } K_v = 183 \times 10^{-9} \text{ cm/sec}$$

$$\text{Horizontal Permeability Factor } K_h = 310 \times 10^{-9} \text{ cm/sec}$$

These same factors were also used for the compacted dry core material, which is considered to be a conservative approximation.

To facilitate making rational seepage estimates for the various combinations of dike heights and foundation soil thickness encountered throughout the overland section, flow nets were constructed for the following general conditions:

	<u>High Core</u>	<u>Low Core</u>
Head of Water, Feet	96	26
Foundation Soil Thickness, Feet	0	0
Foundation Soil Thickness, Feet	20	12
Foundation Soil Thickness, Feet	40	25

Transformed sections were constructed, and seepage quantities per linear foot of dike were calculated for each of the above combinations.

The total computed seepage loss for the overland section of the canal, through and under the dikes, is 6,550 cubic feet per day. This is very low and reflects the relatively low permeability factors. Obviously, detailed exploration will reveal areas of much higher subsoil permeability that exist in localized locations, as indicated by the three tests deleted from the permeability factor averages. These areas when encountered will require specialized corrective action, such as excavation and replacement, extended cores, or cutoff walls.

The total computed seepage loss through and under the Niagara River section dikes is a nominal 150 cubic feet per day. However, this quantity is considered inconsequential compared to the uncertainties of inflow or outflow of groundwater in the cut sections of the canal. Reference is made to paragraph B-7 of this Appendix that indicates the Lockport Dolomite has water flowing through fractures, joints, and open bedding planes that yields as much as 100 gallons per minute (19,250 cubic feet per day), and flow through the Camillus Shale of as much as 1,200 gallons per minute (231,000 cubic feet per day). Hence, it appears highly probable that water inflow will be a far more significant factor in this section than will seepage losses through the dike.

## SUMMARY AND CONCLUSIONS

### B-36. General

As stated in the opening paragraphs, the purpose of this appendix is to describe the geologic conditions and the effect of these conditions on the canal and lock areas of the proposed waterway. Those geologic conditions have been described in considerable detail in the preceding sections of this appendix.

The objective of this final section is to summarize the salient points made and to assess their probable effects upon the design and construction of the proposed waterway.

As noted in the introduction, this appendix stressed the following:

Characteristics of the Overburden and Bedrock  
Geologic and Soil Investigations and Tests  
Foundation Conditions at Lock Sites  
Sources of Construction Materials

The conclusions and recommendations which follow also concentrate on these items and their significance to the project.

### B-37. Overburden

Substantially more geologic data are available relative to the rock formations and their characteristics than is available on overburden soils for the immediate waterway area.

Realignment of the canal after initial soils exploratory work

was performed has resulted in some of the borings being too far removed from the present line to be reliable for design purpose.

Although a substantial amount of exploratory work has been performed to date, detailed subsurface profiles beneath actual dike locations, along with substantially more laboratory test data, are required to verify the preliminary dike designs established in this study.

The overburden of the Ontario plain along the proposed waterway is generally glacial till that blankets the Queenston Shale and consists of a clay silt matrix with some sands, gravels, and boulders. The overburden thickness of the Ontario plain along the alignment averages 30 feet and ranges from 10 feet to 120 feet. These variations in thickness of overburden could be a source of significant differential settlements in dikes and guide walls and will have to be investigated further. The physical characteristics of these soil deposits have been listed in paragraph B-30, and the strata thicknesses used in the analyses were established from generalizations of the applicable soil boring test data presented in Table B-3 and the various Profiles B-8 through B-19.

The overburden of the Huron plain along the overland section is composed of glacial till and lacustrine deposits. Till covers most of this plain and generally has the same characteristics as the till of the Ontario plain.

Extensive deposits of lacustrine silts and clays overlie the till along the alignment from four miles south of the escarpment to the Niagara River. The thickness of the overburden averages 23 feet and ranges from 3 feet to 50 feet.

Selectivity of the overburden soils to be excavated in the overland section will provide all the core material required for the dikes. The remainder of the excavated soils will be disposed of as detailed in Appendix A.

Further exploration of the overburden soils in this area will be required to locate the most suitable core material and to further explore the cut stability characteristics of these in situ soils at the slopes set in this preliminary study.

The overburden of the Huron plain at Squaw Island has an average thickness of 65 feet. North of the International Bridge, the overburden is sands and gravels ranging in thickness from 45 to 65 feet. South of the bridge, the material consists of fill underlain by silty clay and is 60 to 90 feet thick.

Lock 5-5, located partly on Squaw Island and partly in the river, will be in the pervious sand and gravel area, and seepage will be a major problem during construction.

Excavation of some overburden will be required for all dikes. However, in most instances only topsoil stripping will be required

unless soft, unstable, underlying soil or highly pervious deposits are encountered.

B-38. Rock

Virtually all the overland cut section will be in rock. Evidence of convergence and uplift in the Lockport and Rochester formations indicates that horizontal and vertical active stresses are present in the rock and will present problems that must be considered.

In Lockport, NY, at the bottom of the Barge Canal, the Rochester Shale is rising, and it is necessary to remove rock every year in order to maintain the proper depth of the canal.

Numerous other examples of rock displacement as a result of load release due to excavation indicate that this is not an isolated phenomenon, and it must be considered in setting depths of cut through these formations in the final design stage.

The suitability and possible uses of excavated rock types are presented in Table B4.

In general, the best rock will be utilized in the most critical components of the structures and dikes, with the less desirable stone utilized in less critical areas.

B-39. Foundation Conditions

The foundation conditions for Locks 1-5, 2-5, and 3-5 are

similar. The overburden for the three locks is generally glacial till with some lacustrine clays and silts, with the exception of sand and gravel materials of the beach ridge found on the upstream portion of Lock 3-5. All three locks are founded on Queenston Shale. The presence of soft clay zones of varying thicknesses above and below the various founding elevations of these structures was studied in considerable detail. At this point, it is believable that these clay zones are predominantly very thin and discontinuous. A thickness of 10 feet of sound Queenston Shale overlying one of these zones was determined sufficient to reduce stresses in the zone to prevent differential settlement and plastic flow. However, frequency of occurrence of these soft zones will require additional explorations and analysis in subsequent studies.

A weathered fractured zone at the top of rock was found in all boreholes. However, since the founding elevations of all locks and lock walls are below this zone, few problems of consequence (other than seepage during construction) are expected.

Insofar as the foundation of the dikes within the reaches of the first three locks are concerned, some differential settlement may occur due to length of the dikes and the variability of subsoil characteristics and thickness beneath the dike. Additional exploration and testing will be required to facilitate estimation of the amount and variability of this settlement.

The canal dike foundation soils between Lock 3-5 and Lock 4-5 will also require additional exploration and testing to assess the implications of excessive overburden thicknesses within this reach and possible permeability problems associated with the underlying sand and gravel deposits in the buried depression along the base of the escarpment.

It is anticipated that the Queenston Shale will be the foundation bedrock for Lockwalls 4-5, and since the Medina and Clinton Group Limestone rock will be exposed on the upstream end of Lock 4-5, ground-water seepage can be expected, which may require grouting.

Foundation soils in the northern half of the Niagara River section starting above Lock 4-5 are firm glacial till. However, the southern half is weak lacustrine clay and silt (underlain by glacial till) that will present settlement and stability problems for any structures founded on these weak soils.

Further subsoil boring and testing will be required in this area at specific structure locations to facilitate proper final design of cut and dike slopes.

Lock 5-5 will be founded on Bertie Dolomite, which is fractured to a depth of as much as 15 feet below the top of rock. Seepage in this area will be a major problem during construction of the structure and grouting will probably be necessary.

B-40. Construction Materials

A favorable balance between materials available from the cuts in overland section and the dike and structure needs of the overland section was discovered. Thus, it is not anticipated that any borrow or disposal areas outside of the canal right-of-way will be required.

Sufficient Lockport Dolomite is available to provide all fine and coarse aggregate for the concrete required in all the structures, plus riprap, breakwater material, and the shells for the dikes including the toe load berms at critical locations.

Since there will be a surplus of shale excavated, most of this material will be used for toe load berms, particularly exterior berms that will not be submerged, and for interior berms at less critical locations.

The preliminary plan for use and disposition of all excavated materials, including calculated quantities, is presented in Appendix A.

As will be noted, excess material disposition will be made within the canal and surge basin limits of the overland section. It is anticipated that the locations currently indicated will be varied to more effectively increase dike toe loads to achieve greater stability where final design may indicate such needs exist.

B-41. Design Considerations

In the preliminary dike designs established herein, every

effort was made to use realistic data and rational design procedures. Final designs based on more complete data will certainly result in additions and modifications, involving such things as toe load berm height adjustments, toe berm slope adjustments (or reinforcement with limestone when shale is used), and determination of section details, such as intermediate filter layers between the clay core and shell rock. Many of these items are beyond the scope of this study. However, certain design considerations that must be resolved in future studies merit discussion.

The dike design investigation conducted for this report established a basically sound configuration well-suited to the predominant subsoil conditions. However, since it was necessary to base designs upon generalized subsurface soils profiles, additional studies must be made, based on specific data for each reach of the waterway. Such additional studies can be expected to reveal areas where added toe load berm heights will be required, areas where additional excavation of soft and unsuitable soils will be required, deposits of porous material that will require extension of the clay core into the underlying strata, bottom areas that will require blankets of impermeable material, and areas of high settlement potential that may require sand drains, etc.

Such problem areas, expected to be the exception not the rule, accentuate the need for additional comprehensive soils investigation.

As mentioned previously, blankets of intermediate size material will be required on both sides of the clay core to prevent migration of this clay into the porous shell rock. It is anticipated that this material can be manufactured from the Lockport Dolomite, as will the concrete aggregates.

It should be noted that where shale or any other degradable rock or fine grained soil is used for toe load berms on the dike exterior, such material must be underlain by a drain blanket of porous material to prevent a head buildup in the outer shell of the dike.

Further study of the physical characteristics inherent to degraded shale and other similar materials that may be used in toe load berms should be made to facilitate final design utilization of these materials. In general, extensive use of deteriorating material in critical dike toe areas, particularly on the upstream side of high dike sections, should be carefully analyzed.

The Erie-Ontario lowland is in the seismic Zone 3 area, where major destructive earthquakes may occur. The shallow excavation for the overburden canal would have no appreciable effect on the occurrence of seismic disturbance. The design of the structures of the waterway should take into account the earthquake factor.

Insofar as the dikes are concerned, design checks indicate

safety factors in excess of the required FS = 1.0 for earthquake design conditions (Case No. 7, EM 1110-2-1902).

Preliminary stability design checks utilizing the sliding wedge method were made to assess possible consequences of thin continuous strata of weak material in the subsoils. Indications are that such conditions underlying dike fills will be critical, and the possible existence of such conditions, particularly at guide wall locations, must be thoroughly investigated.

Based on the studies and analyses performed, it is concluded that construction of the proposed waterway is feasible insofar as local soils and geologic conditions are concerned. This conclusion presupposes that the available data are typical for the site as a whole and that the conditions assumed in the analysis are valid.

It is also concluded that the preliminary designs are realistic for the site and will result in maximum utilization of on-site materials with no excessive borrow or waste required.

It is further concluded that numerous localized design and construction problems will be encountered, but that these problems can be anticipated and resolved to a great extent by further field and laboratory investigations of the various in situ materials throughout the site.

Table B1 Compilation of earthquakes of western New York and vicinity

DATE	EPICENTER DATA				LOCALITY	AFFECTED AREA (SQ. MI.)	AUTHORITY
	INTENSITY: (MODIFIED: MERCALLI)	N. LAT. (DEG.)	W. LONG. (DEG.)	AREA			
1969 August 12	IV	42.8	78.2	Attica	--	NOAA	
1967 June 13	V	42.8	78.2	Attica	--	Canisius College & Dominion Observatory, Ottawa	
1966 Jan 1	VI	42.8	78.2	Attica	3,500	ESSA	
1965 Aug 29	IV	--	--	Attica	--	ESSA	
1965 July 16	IV	--	--	Attica	--	ESSA	
1962 Mar 27	V	--	--	Niagara Falls	--	Canisius College	
1958 July 21	IV	--	--	St. Catharines, Ont.	--	Canisius College	
1955 Aug 16	V	42.5	78.3	Attica	--	ESSA	
1946 Sept 20	IV	--	--	Niagara Falls	--	Canisius College	
1939 June 13	II	--	--	Niagara Falls	--	Canisius College	
1939 Mar 23	II	--	--	Niagara Falls	--	Canisius College	
1929 Aug 12	VIII	42.9	78.3	Attica	100,000	ESSA	
1879 Aug 21	V	43.2	79.2	Canada near Bflo.	1,300	ESSA	
1873 July 6	V	43.0	79.5	W. of Niagara Falls, in Ont.	30,000	ESSA	
1857 Oct 23	VI	43.2	78.6	W. New York	18,000	ESSA	

Table B2 Borehole data. Locations of boreholes taken along centerline of canal using Alignment A-1. All holes are vertical.

Boring No.	Location Sta-Rg	Depth		Total Depth (ft)	Size: core	Date Drilling comp.
		Surf. Elev.	of (ft)			
Drillholes Prior to 1966						
RDC-1	: 1964+00-14,24ORT	: 270.2	: 26.6	: 50.2	: 76.8	: NX : 1/15/63
RDC-4	: 1909+50-12,00ORT	: 295.2	: 38.0	: 52.1	: 90.1	: NX : 1/26/63
DC-5	: 1896+10-11,48ORT	: 293.7	: 26.5	: 68.3	: 94.8	: NX : 2/5/63
UDC-5A	: 1897+40-11,52ORT	: 296.2	: 27.0	: 101.1	: 128.1	: 6" : 3/16/63
RDC-6	: 1884+00-11,24ORT	: 299.3	: 54.6	: 51.0	: 105.6	: NX : 2/14/63
RUDC-16	: 1612+00-2,60ORT	: 381.8	: 57.0	: 25.0	: 82.0	: NX : 12/4/64
RDC-16A	: 1603+10-2,30ORT	: 384.1	: 59.0	: 25.0	: 84.0	: NX : 12/7/64
RDC-16B	: 1596+70-1,60ORT	: 389.7	: 64.0	: 25.0	: 89.0	: NX : 1/25/65
RDC-17	: 1588+00-1,30ORT	: 394.2	: 79.0	: 25.0	: 104.0	: NX : 1/6/65
RDC-17A	: 1579+00-1,15ORT	: 394.7	: 98.0	: 25.0	: 123.0	: NX : 12/17/64
RUDC-17B	: 1575+00-1,00ORT	: 398.7	: 102.0	: 25.0	: 127.0	: NX : 12/18/64
RDC-18	: 1569+50-775RT	: 408.3	: 124.6	: 51.6	: 176.2	: NX : 3/29/65
DC-19	: 1563+00-55ORT	: 444.1	: 2.6	: 70.1	: 72.7	: NX : 4/4/63
DC-20	: 1553+50-70ORT	: 502.2	: 38.3	: 54.8	: 93.1	: NX : 3/15/63
RC-21	: 1541+50-88ORT	: 542.5	: 2.4	: 145.2	: 147.6	: 6" : 4/11/63
RC-22	: 1505+50-1,48ORT	: 566.8	: 48.6	: 93.0	: 141.6	: 6" : 3/28/63
RDC-23	: 1500+00-1,64ORT	: 623.0	: 7.5	: 115.5	: 123.0	: NX : 1/28/65
RC-24	: 1456+00-2,08ORT	: 644.1	: 7.6	: 53.8	: 61.4	: 6" : 4/15/63
RC-24A	: 1455+92-2,08ORT	: 644.1	: 3.0	: 209.9	: 212.9	: 6" : 4/24/63
RDC-25	: 1413+80-2,78ORT	: 651.4	: 5.0	: 146.5	: 151.5	: NX : 1/21/65
RDC-26	: 1377+00-2,10ORT	: 633.5	: 10.0	: 124.0	: 134.0	: NX : 2/11/65
DC-27	: 1328+00-1,10ORT	: 620.7	: 6.5	: 94.0	: 100.5	: NX : 4/22/65
RUDC-28	: 1223+00-100LT	: 574.9	: 25.0	: 35.0	: 60.0	: NX : 2/16/65
RUDC-29	: 1105+08-69,50ORT	: 571.9	: 25.8	: 18.9	: 44.7	: 6" : 2/17/65
SI-DC-1	: 534+78-39RT	: 569.1	: 45.1	: 50.4	: 95.5	: NX : 2/12/63
SI-DC-2	: 525+78-88RT	: 569.3	: 49.8	: 50.6	: 100.4	: NX : 2/18/63
SI-DC-2A	: 527+70-60RT	: 569.7	: 49.5	: 40.5	: 90.0	: 6" : 4/4/63
SI-DC-3	: 517+00-143RT	: 590.1	: 78.4	: 50.7	: 129.1	: NX : 2/27/63
SI-DC-4	: 502+85-80RT	: 590.0	: 91.3	: 25.6	: 116.9	: NX : 3/13/63
SI-DC-5	: 493+78-58RT	: 579.9	: 63.3	: 25.5	: 88.8	: NX : 3/6/63

Table B2 Borehole data. Locations of boreholes taken along centerline of canal using Alignment A-1. All holes are vertical.

Boring No.	Location Sta-Rg	Surf. Elev.	Depth of Overb. (ft)	Depth in Rock (ft)	Total Depth (ft)	Size: core	Drilling comp.
Drillholes 1966 - 67 Program							
RC-66501	: 1958+25-81OLT	: 258.6	: 17.7	: 137.1	: 154.8	: 6"	: 7/25/66
U 66502	: 1621+50-1,400RT	: 389.5	: 40.0	: -	: 40.0	:	: 7/26/66
RC-66503	: 1941+00-780LT	: 272.6	: 28.5	: 102.8	: 131.3	: NX	: 11/1/66
RC-66504	: 1912+00-190LT	: 297.4	: 27.3	: 123.0	: 150.3	: NX	: 10/27/66
RC-66505	: 1836+75-780LT	: 306.6	: 29.4	: 131.0	: 160.4	: NX	: 11/8/66
RC-66507	: 1647+00-900LT	: 364.6	: 15.8	: 134.3	: 150.1	: NX	: 11/23/66
ARC-66508	: 1622+50-575LT	: 388.1	: 32.9	: 102.2	: 135.1	: NX	: 12/1/66
ARC-66509	: 1784+50-200LT	: 313.8	: 48.0	: 83.7	: 131.7	: NX	: 11/14/66
ARC-66510	: 1807+90-675LT	: 312.4	: 19.5	: 111.0	: 130.5	: NX	: 11/18/66
AUC-67511	: 1692+00-800LT	: 331.7	: 22.0	: 96.0	: 118.0	: NX	: 10/25/67
ADC-67512	: 1638+75-475LT	: 367.7	: 7.5	: 103.6	: 111.1	: 6"	: 11/6/67
ADC-67513	: 1656+50-275LT	: 350.9	: 7.5	: 98.5	: 106.0	: NX	: 11/9/67
DC-67514	: 1827+75-430LT	: 307.4	: 28.5	: 94.2	: 122.7	: NX	: 11/16/67
AUDC-67515	: 1953+00-280LT	: 265.9	: 25.0	: 99.7	: 124.7	: NX	: 11/23/67
AUC-67516	: 1798+00-425LT	: 313.3	: 46.6	: 79.8	: 126.4	: 6"	: 11/29/67

Table B4 Possible uses of excavated rock

Rock Type	Thickness	Location of Excavation	Possible Use	Service Record
Lockport Dolomite:		Station 1170+00:	Coarse and manufactured	P. A. S. N. Y. Robert
Oak Orchard Mem:		to 1505+00	Fine aggregate for con-	Moses Power Plant
Bramosa Mem	+128'		crete bedding, filter	many quarries in
Goat Island Mem:			material, riprap, break-	this formation are
Gasport Mem			water material, dike fill	approved by Corps
				of Engrs for con-
				crete aggregate and
				riprap
Lockport Dolomite:		Station 1400+00:	Dike material, channel	
DeCew Mem	10'	to 1505+00	fill and waste	
				Selective placement
Clinton Group		Station 1415+00:	Breakwater material (Iron:	
	90'	to 1545+00	dequoit Limestone) Dike	
			material, channel fill	
			and waste	
				Selective quarrying
Medina Group		Lock 4-5	Breakwater material	
	122'		(Thorold and Whirlpool	
			Sandstone) Dike material,	
			channel fill and waste	
				Whirlpool Sandstone
				Selective placement
				in channel
Queenston Shale		Lock 1-5, 2-5,	Breakwater material	
	+1,200'	3-5	channel fill and waste	
				Selective placement
				in channel
Camillus Shale		Station 1160+00:	Dike material, channel	
	+400'	to 1170+00	fill and waste	
				Selective placement
				in channel
Bertie Limestone		Lock 5-5	Waste	
	65'			
Onondaga Lime-		Station	Breakwater material, Dike	
stone	160'		material	
				Quarries in this
				formation are ap-
				proved by Corps of
				Engrs for concrete
				aggregate & riprap
				Selective placement
				in breakwater & dike







# TABLE B3

BORING NO.	SAM NO	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	PL				OPT WATER %	MAX DRY D LBS/
RUDC-16	1	380.3-378.8	ORGANIC CLAY (OH)					72.3	37.3		66.8	54.7		
	2	378.8-377.3	ORGANIC CLAY (OH)					69.6	35.2	2.55				
	3	-375.8	CLAY (CL)					34.6	17.7	2.76				
	4	-374.3	CLAY (CL)					32.9	15.9	2.75				
	5	-372.8	CLAY (CL)							2.77	18.1	114.3		
								34.6	17.7	2.77	17.9	114.4		
								34.6	17.7	2.77				
	6	-371.3	CLAY (CL)					34.3	17.1	2.77				
	7	-369.8	CLAY (CL)					-	-	2.78				
	8	-368.3	CLAY (CL)					32.4	16.7	2.77				
	9	-366.8	CLAY (CL)					34.8	15.4	2.78				
	10	-365.3	CLAY (CL)					32.8	16.9	2.78				
	11	-363.8	CLAY (CL)					-	-	2.77				
	12	-362.3	CLAY (CL)					27.1	16.2	2.77				
	13	-360.8	CLAY (CL)					31.0	17.5	2.75				
	14	-359.3	CLAY (CL)					25.7	14.4	2.75				
	15	-357.8	CLAY (CL)					41.8	16.6	2.79				
	16	-356.3	CLAY (CL)					39.5	19.5	2.78				

# TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

DEPTH FEET	COMPACTION DATA			SHEAR DATA										PERMEABILITY INCHES			
	WET DENSITY LBS CU FT	WATER CONTENT %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL P	DRY DENSITY LBS CU FT	W <sub>1</sub> %	W <sub>F</sub> %	S <sub>1</sub> %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	$\sigma_m$ T SQ FT	$\sigma_1$ T SQ FT		C T SQ FT	$\phi$ DEGREES	r
0.7				1.521	63.1	58.6		98.3	TC	1.38 X 2.95	Q	0.5	1.05	0.20			
				1.552	62.4	59.6		97.9		1.39 X 2.95	Q	1.0	1.71	0.34			
				1.839	56.0	70.8		98.2		1.38 X 2.96	Q	2.0	2.93	0.41			
				1.807	56.7	70.0		98.7		1.39 X 2.96	Q	4.0	4.89	0.44	C-0.35	AVERAGE	
				0.531	112.5	19.1		99.3	TC	1.40 X 2.95	Q	0.5	2.07	0.78			
				0.516	113.2	18.8		100	TC	1.40 X 2.93	Q	0.5	2.04	0.77			
								97.9								0.512	10
0.4								96.9								0.511	39
				0.496	115.5	17.7		98.8	TC	1.38 X 2.96	Q	0.5	4.33	1.92			
				0.547	111.7	19.4		98.5	TC	1.41 X 2.94	Q	0.5	3.12				
				0.516	114.0	18.4		98.9		1.41 X 2.94	Q	1.0	3.09				
				0.523	113.5	18.7		98.9		1.42 X 2.96	Q	2.0	5.40				
				0.544	111.9	19.4		99.0		1.36 X 2.96	Q	4.0	7.10	1.40			
				0.570	110.5	20.2		98.5	TC	1.39 X 2.95	Q	0.5	2.61	1.06			
				0.636	105.7	22.7		98.9	TC	1.38 X 2.96	Q	0.5	1.89	0.70			
				0.678	103.4	23.7		97.1	TC	1.38 X 2.95	Q	0.5	0.87	0.15			
				0.566	110.8	19.7		96.8	TC	1.37 X 2.91	Q	0.5	0.94	0.22			
				0.696	101.9	24.9		99.1	TC	1.38 X 2.96	Q	0.5	1.31	0.40			
				0.682	102.8	24.3		98.7	TC	1.39 X 2.96	Q	0.5	1.10	0.30			
				0.710	100.3	25.6		99.2	TC	1.37 X 2.94	Q	0.5	0.90	0.20			
				0.652	103.8	23.6		99.5	TC	1.41 X 2.93	Q	0.5	1.01	0.26			
			1.096	83.0	38.4		97.7	TC	1.40 X 2.94	Q	0.5	0.74	0.12				
			1.047	84.7	37.6		99.9	TC	1.39 X 2.93	Q	0.5	0.72	0.11				

TC - Triaxial Compression  
UC - Unconfined Compression

DS - Direct Shear  
UU - Unconsolidate Undrained

CD - Co  
CU - Co

			PERMEABILITY		CONSOLIDATION DATA				REMARKS
$\sigma_1$ T/SQ FT	c T/SQ FT	$\phi$ DEGREES	e	$k_{20}$ FT MIN $\times 10^{-9}$	$P_0$ T/SQ FT	$P_c$ T/SQ FT	$C_c$	$t_{50}$	
.05	0.20								
.71	0.34								
.93	0.41								
.89	0.44	C-0.35	AVERAGE						
.07	0.78								
.04	0.77								
			0.512	114.2					VERTICAL
			0.511	396.2					HORIZONTAL
.33	1.92								
.12									
.09									
.40									
.10	1.40								
.61	1.06								
.89	0.70								
.87	0.16								
.94	0.22								
.31	0.40								
.10	0.30								
.90	0.20								
.01	0.26								
.74	0.12								
.72	0.11								

Direct Shear      CD - Consolidated Drained      \* Values at Pressure      T/SQ FT  
 Consolidate Undrained      CU - Consolidated Undrained

# TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	PL				OF WATER %	MAX DRY DENSITY LBS CU FT
RUDC-16	17	355.3-353.8	CLAY (CL)								28.0	94.5		
			CLAY (CL)					26.3	15.9	2.76	27.6	94.6		
	18	-352.3	SILTY CLAY (CL-ML)					22.1	16.3		21.2			
	20A	350.8-349.3	CLAY (CL)					30.5	16.2	2.76				
	21	-347.8	CLAY (CL)					26.5	16.8	2.75				
	22	-346.3	CLAY (CL)					29.3	15.8	2.76				
	23	-345.0	SILT (ML)					(N-P)						
	25	343.3-341.8	CLAY (CL)					35.3	16.8	2.77				
	26	-340.3	CLAY (CL)					34.1	15.6	2.77				
	27	-338.8	CLAY (CL)					41.4	18.9	2.79				
	28	-337.3	CLAY (CL)					32.3	16.0	2.78				
	29	-335.8	CLAY (CL)					32.6	16.1	2.76				
	30	-334.3	SILT (ML)					17.0	13.4	2.75				
	31	-333.1	CLAY (CL)					24.4	15.0					



TEST					PERMEABILITY		CONSOLIDATION DATA			REMARKS	
	$\sigma_m$ T/SQ FT	$\sigma_1$ T/SQ FT	c T/SQ FT	$\phi$ DEGREES	e	$K_{20}$ FT MIN $\times 10^{-9}$	$P_0$ T/SQ FT	$P_c$ T/SQ FT	$C_c$		$t_{50}$
					0.822	158.1					VERTICAL
					0.821	2851.4					HORIZONTAL
Q	0.5	0.95									
	1.0	1.40									
	2.0	2.52									
	4.0	4.50	0.23								
Q	0.5	0.86	0.18								
Q	0.5	0.99	0.25								
Q	0.5	0.84	0.170								
Q	0.5	0.93	0.22								
Q	0.5	0.83	0.17								
Q	0.5	0.83	0.17								
Q	0.5	0.75	0.13								
Q	1.0	3.56	1.33								
	2.0	6.43	2.22								
	4.0	10.22	3.12								
		AV.	0.45	22.36							

DS - Direct Shear      CD - Consolidated Drained      Values at Pressure      T/SQ FT  
 UU - Unconsolidated Undrained      CU - Consolidated Undrained

# TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	PL				OFT. WATER %	MAX. DRY DENSITY LBS/
RUDC-17B	1	397.2-395.7	CLAY (CL)					33.9	17.7	2.77				
EL. 398.7														
	2	-394.2	CLAY (CL)					-	-	2.77				
	3	-392.7	CLAY (CL)					31.2	15.7	2.76				
	5	391.2-389.7	CLAY (CL)					42.2	16.7	2.78				
										2.78	21.0	108.5		
										2.78	20.5	108.5		
	6	-388.2	CLAY (CL)					44.0	19.5	2.80				
	9	385.2-383.7	CLAY (CL)					42.1	17.2	2.77				
	10	-382.2	CLAY (CL)					-	-	2.77				
	11	-380.7	CLAY (CL)					43.9	20.0	2.78				
	12	-379.2	CLAY (CL)					-	-	2.78				
	13	-377.7	CLAY (CL)					42.6	19.0	2.78				
	14	-376.2	CLAY (CL)					37.9	17.4	2.78				
	15	-374.2	CLAY (CL)					-	-	2.76				
	16	-373.2	CLAY (CH)					53.3	21.7	2.79				
	17	-371.7	CLAY (CH)					-	-	2.77				
											23.6	102.9		
											26.8	97.4		
	18	-370.2	SILT (ML)					(N-P)		2.74				
	19	-368.7	CLAY (CL)					27.2	14.7	2.75				

# E B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

COMPACTION DATA			SHEAR DATA											PERMEABILITY	
PT. NO.	MAXIMUM DRY DENSITY LBS CU FT	INITIAL P	DRY DENSITY LBS CU FT	W <sub>i</sub> %	W <sub>F</sub> %	S <sub>i</sub> %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ <sub>m</sub> T SQ FT	σ <sub>1</sub> T SQ FT	C T SQ FT	φ DEGREES	e	k <sub>20</sub> FT MIN. X 10 <sup>-9</sup>
		0.504	114.9	16.4		90.2	TC	1.39 X 2.96	Q	0.5	2.56	1.03			
		0.496	115.5	16.9		94.3	TC	1.39 X 2.97	Q	0.5	3.54	1.52			
		0.547	111.3	17.5		88.3	TC	1.36 X 2.97	Q	0.5	2.36	0.93			
		0.672	103.8	21.6		89.4	TC	1.39 X 2.96	Q	0.5	1.66	0.58			
						97.6								0.599	74.2
						95.5								0.599	136.2
		0.660	105.2	22.8		96.7	TC	1.40 X 2.95	Q	0.5	2.87	1.18			
		0.724	100.3	26.1		99.8	TC	1.40 X 2.95	Q	0.5	2.44	0.97			
		0.772	97.5	27.8		99.8	TC	1.39 X 2.94	Q	0.5	1.90	0.70			
		0.798	96.5	28.5		99.3	TC	1.49 X 2.94	Q	0.5	2.00	0.75			
		0.738	99.8	26.3		99.0	TC	1.40 X 2.93	Q	0.5	2.42	0.96			
		0.868	98.9	30.9		92.9	TC	1.40 X 2.91	Q	0.5	0.64	0.07			
		0.776	97.7	27.6		98.9	TC	1.39 X 2.95	Q	0.5	1.36	0.43			
		0.766	97.5	27.3		98.4	TC	1.39 X 2.90	Q	0.5	0.75	0.12			
		1.248	77.4	44.6		99.7	TC	1.39 X 2.96	Q	0.5	1.25	0.38			
		0.941	89.0	33.7		99.2	TC	1.40 X 2.94	Q	0.5	0.93	0.22			
														0.679	304.1
														0.774	242.3
		0.595	107.2	21.0		96.8	TC	1.39 X 2.89	Q	0.5	3.36	1.43			
		0.557	110.6	19.5		96.5	TC	1.39 X 2.95	Q	1.0	1.80	0.40			
		0.588	108.5	21.1		99.1		1.38 X 2.95		2.0	2.89	0.45			
		0.591	108.2	21.3		99.5		1.38 X 2.97		4.0	5.29	0.65			
		0.563	110.2	20.2		99.0		1.39 X 2.96		6.0	7.34	0.67			
													AV. C=0.45		

TC - Triaxial Compression      DS - Direct Shear      CD - Consolidated  
 UC - Unconfined Compression      UU - Unconsolidated Undrained      CU - Consolidated Undrained

$\sigma_m$ T/SQ FT	$\sigma_1$ T/SQ FT	C T/SQ FT	$\phi$ DEGREES	PERMEABILITY		CONSOLIDATION DATA				REMARKS
				e	$k_{20}$ FT/MIN. $\times 10^{-9}$	$P_0$ T/SQ FT	$P_C$ T/SQ FT	$C_C$	$t_{50}$	
0.5	2.56	1.03								
0.5	3.54	1.52								
0.5	2.36	0.93								
0.5	1.66	0.58								
				0.599	74.2					VERTICAL
				0.599	136.2					HORIZONTAL
0.5	2.87	1.18								
0.5	2.44	0.97								
0.5	1.90	0.70								
0.5	2.00	0.75								
0.5	2.42	0.96								
0.5	0.64	0.07								
0.5	1.36	0.43								
0.5	0.75	0.12								
0.5	1.25	0.38								
0.5	0.93	0.22								
				0.679	304.1					VERTICAL
				0.774	242.3					HORIZONTAL
0.5	3.36	1.43								
1.0	1.80	0.40								
2.0	2.89	0.45								
4.0	5.29	0.65								
6.0	7.34	0.67								
		AV. C=0.45								

DS - Direct Shear

UU - Unconsolidate Undrained

CD - Consolidated Drained

CU - Consolidated Undrained

\* Values at Pressure

T/SQ FT

3

# TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	PL				OPT. WATER %	MAX. DRY DENSITY LBS CU FT
RUDC-17B	20	368.7-367.2	SILT (ML)					(N-P)	2.72					
	21	-365.7	CLAY (CL)					32.9	15.3	2.80				
	23	364.2-362.7	CLAY (CL)					-	-	2.76				
	25	361.2-359.7	CLAY (CL)					36.2	15.3	2.77				
RUDC-28	1	569.5-568.0	CLAY (CL)					47.1	21.8	2.78				
EL. 575.0	2	-566.5	CLAY (CL)					45.2	19.5	2.80				
	3	-565.0	CLAY (CL)					42.3	20.0	2.78	35.2	85.6		
											38.1	81.8		
	4	-563.5	CLAY (CL)					40.5	19.1	2.80				
	5	-562.0	CLAY (CL)					33.2	16.3	2.76				
	6	-560.5	SILTY SAND (SM) GRAVELLY	30	32	38								

# TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

AT. NO.	NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA		SHEAR DATA											
		OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL P	DRY DENSITY LBS CU FT	w <sub>1</sub> %	w <sub>F</sub> %	s <sub>1</sub> %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	$\sigma_m$ T SQ FT	$\sigma_1$ T SQ FT	c T SQ FT	$\phi$ DEGREE
				0.490	113.9	17.5		97.1	TC	1.39 X 2.93	Q	0.5	1.48	0.49	
				0.636	106.9	21.8		96.1	TC	1.40 X 2.94	Q	0.5	1.14	0.32	
				0.740	99.0	26.7		99.5	TC	1.38 X 2.95	Q	0.5	1.01	0.25	
				0.849	93.5	30.6		99.8	TC	1.37 X 2.95	Q	0.5	1.05	0.26	
				0.724	100.6	25.1		96.4	TC	1.41 X 2.94	Q	0.5	1.40	0.45	
				0.957	89.3	33.5		98.1	TC	1.39 X 2.95	Q	0.5	0.95		
				0.957	89.3	33.8		98.8		1.40 X 2.94		1.0	1.77		
				0.958	89.2	33.7		98.5		1.39 X 2.94		2.0	2.60		
				0.961	89.1	33.8		98.5		1.40 X 2.94		4.0	5.40		
													C-0.40		
				1.137	81.2	40.5		99.0	TC	1.39 X 2.95	Q	0.5	0.89	0.20	
5.2	85.8														
3.1	81.8														
				1.126	82.2	39.6		98.4	TC	1.39 X 2.95	Q	0.5	0.81	0.15	
				0.925	89.4	31.0		92.5	TC	1.41 X 2.89	Q	0.5	0.59	0.045	

TC - Triaxial Compression DS - Direct Shear  
 UC - Unconfined Compression UU - Unconsolidate Undrained

PERCENT

$\sigma_m$ T/SQ FT	$\sigma_1$ T/SQ FT	c T/SQ FT	$\phi$ DEGREES	PERMEABILITY		CONSOLIDATION DATA				REMARKS
				e	$k_{20}$ FT MIN. $\times 10^{-9}$	$P_0$ T/SQ FT	$P_c$ T/SQ FT	$C_c$	$t_{50}$ *	
0.5	1.48	0.49								
0.5	1.14	0.32								
0.5	1.01	0.26								
0.5	1.06	0.26								
0.5	1.40	0.45								
0.5	0.95									
1.0	1.77									
2.0	2.60									
4.0	5.40									
	C-0.40									
0.5	0.89	0.20		1.021	916.6					VERTICAL
				1.120	1435.6					HORIZONTAL
0.5	0.81	0.15								
0.5	0.59	0.045								

DS - Direct Shear      CD - Consolidated Drained      \* Values at Pressure      T/SQ FT  
 UU - Unconsolidate Undrained      CU - Consolidated Undrained

# TABLE B3 TEST

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	FL				OPT. WATER %	MAXIMUM DRY DENSITY LBS CU FT
RUDC-29 EL. 572.0	1	570.5-569.0	CLAY (CL)					38.7	17.0	2.73				
	2	-567.5	CLAY (CL-CH)					-	-	2.76				
	3	-566.0	CLAY (CL-CH)					48.7	21.7	2.79				
	4	-564.5								2.81	24.4	102.2		
			CLAY (CH)					56.3	22.7		23.1	104.5		
	5	-563.0	CLAY (CL)					46.7	20.9	2.80				
	6	-561.5	CLAY (CH)					52.8	23.4	2.81				
	7	-560.0	CLAY (CL-CH)					50.3	23.3	2.80				
	8	-558.5	CLAY (CL)					46.0	20.9	2.79				
	9	-557.0	CLAY (CL)					47.8	20.7	2.80				
	10	-555.5	CLAY (CL)					46.2	20.2	2.79				
	11	-554.0	CLAY (CL)					36.1	16.6	2.80				
	12	-552.5	CLAY (CL)					45.6	21.0	2.80	43.8	77.5		
											43.3	76.7		
	13	-551.0	CLAY (CL)					47.2	21.2	2.79				
	14	-549.5	CLAY (CL)					43.2	17.6	2.80				

# BLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

SOLIDITY PT	COMPACTION DATA		SHEAR DATA							PERMEABILITY						
	OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL P	DRY DENSITY LBS CU FT	w <sub>1</sub>	w <sub>F</sub>	s <sub>1</sub>	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ <sub>1</sub> T 50 FT	σ <sub>1</sub> S 50 FT	σ <sub>3</sub> T 50 FT	σ <sub>3</sub> S 50 FT	DEGREES	FT X
			0.540	110.6	18.2		92.0	TC	1.41 X 2.94	Q	0.5	2.94	1.22			
			0.536	112.1	18.6		95.7	TC	1.39 X 2.94	Q	0.5	2.08	0.79			
			0.633	106.6	22.0		96.9	TC	1.37 X 2.95	Q	0.5	2.25	0.88			
															0.716	143.
															0.678	454.
			0.714	101.9	25.1		98.4	TC	1.36 X 2.95	Q	0.5	0.74				
			0.770	98.7	26.3		95.6		1.40 X 2.94		1.0	2.01				
			0.736	100.6	26.0		99.0		1.39 X 2.94		2.0	3.14				
			0.752	99.7	25.9		96.5		1.40 X 2.95		4.0	5.13	0.50			
			0.937	90.5	32.8		98.4	TC	1.41 X 2.93	Q	0.5	1.93	0.72			
			1.043	85.5	37.1		99.6	TC	1.40 X 2.95	Q	0.5	1.48	0.49			
			1.016	86.4	36.4		100	TC	1.39 X 2.95	Q	0.5	1.13	0.32			
			1.134	81.9	40.3		99.5	TC	1.39 X 2.95	Q	0.5	0.99	0.25			
			1.220	78.4	43.6		99.7	TC	1.39 X 2.95	Q	0.5	0.75	0.12			
			1.077	84.1	37.7		98.0	TC	1.40 X 2.93	Q	0.5	0.76	0.13			
															1.254	454
															1.277	690
			1.408	72.3	50.2		99.5	TC	1.38 X 2.95	Q	0.5	0.68	0.09			
			1.254	77.5	44.4		99.2	TC	1.38 X 2.95	Q	0.5	0.71	0.10			

TC - Triaxial Compression      DS - Direct Shear      CD - Consolidated  
 UC - Unconfined Compression      UI - Unconsolidate Undrained      CU - Consolidated Undrained

$\sigma_1$	C	O	PERMEABILITY		CONSOLIDATION DATA				REMARKS
			P	K <sub>20</sub> FT MIN X 10 <sup>-9</sup>	P <sub>0</sub>	e <sub>c</sub>	C <sub>c</sub>	e <sub>s</sub>	
100 FT	100 FT	DEGREES			100 FT	100 FT			
94	1.22								
08	0.79								
26	0.88								
			0.716	143.1					VERTICAL
			0.678	454.8					HORIZONTAL
74									ULTIMATE
01									ULTIMATE
14									ULTIMATE
13	0.50								ULTIMATE
93	0.72								
48	0.49								
13	0.32								
99	0.25								
75	0.12								
76	0.13								
			1.254	454.6					VERTICAL
			1.277	690.9					HORIZONTAL
68	0.09								
71	0.10								

at Shear      CD - Consolidated Drained      \* Values at Pressure      T SQ FT  
 Consolidate Undrained      CU - Consolidated Undrained

# TABLE B3

BORING NO.	SAM NO.	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	C <sub>10</sub>	LL	PL				OFT WATER %	MAX DRY DENSITY LBS/FT <sup>3</sup>
U66502	2	383.0-381.1	SILTY SAND (SM)	7	58	36				2.71	10.2	105.3		
EL. 389.5														
	3	-379.4	SANDY CLAY (CL)								17.1	101.6		
								31	17	2.78	18.3	112.9		
	4	377.4-376.3	CLAY (CL)					33	17	2.76	19.3	109.3		
	5	374.3-372.0	CLAY (CL)					38	18	2.78				
	6	370.5-368.0	CLAY (CL)					37	16	2.78				
	7	365.6-363.6	CLAY (CL)					35	17	2.77				
	8	361.1-358.6	CLAY (CL)					37	16	2.77				
U66502	9	356.5-354.0	CLAY (CH)					52	21	2.80				
AUC67511	1	329.7-327.9	SANDY CLAY (CL)					28	18	2.72				
EL. 331.7														
	2	326.2	SANDY CLAY (CL)					28	14	2.74				
	3	-324.8	SANDY CLAY (CL-ML) GRAVELLY					19	13	2.72				
	4	324.5-322.8	SANDY CLAY (CL)					28	15	2.72				
	5	315.7-313.7	SANDY CLAY (CL)					22	13	2.73				

# TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA		SHEAR DATA											PERM e		
	OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL "	DRY DENSITY LBS CU FT	w <sub>1</sub> %	w <sub>F</sub> %	s <sub>1</sub> %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	$\sigma_m$ T SQ FT	$\sigma_1$ T SQ FT	c T SQ FT		$\phi$ DEGREES	
105.3																
101.6																
112.9																
109.3			0.562	110.2	19.8		97.2	TC	1.36 X 2.94	Q	0.5	4.49	2.00			
			0.529	113.4	19.0		99.9	TC	1.33 X 2.94	Q	0.5	4.43	1.97			
			0.654	104.9	23.4		99.5	TC	1.34 X 2.95	Q	0.5	2.71	1.10			
			0.710	101.1	25.7		100	TC	1.39 X 2.95	Q	0.5	1.56	0.53			
			0.715	100.8	25.8		100	TC	1.40 X 2.92	Q	0.5	1.18	0.34			
			1.013	86.8	35.9		99.2	TC	1.37 X 2.95	Q	0.5	0.93	0.22			
			0.624	104.5	20.2		88	TC	1.37 X 2.97	Q	0.5	1.70	0.60			
			0.406	121.6	13.5		91	TC	1.45 X 2.92	Q	0.5	3.21	1.35			
			0.353	126.3	11.4	13.1	88.3									0.35
			0.402	121.2	11.7	14.1	79.7									0.40
			0.415	119.9	11.4		74.8	TC	1.39 X 2.95	Q	0.5	1.96	0.75			
			0.424	119.2	15.2		97.5	TC	1.39 X 2.95	Q	0.5	4.97	2.24			
			0.298	131.2	10.7		98.1									

TC - Triaxial Compression      DS - Direct Shear  
 UC - Unconfined Compression      UU - Unconsolidate Undrained

TEST	$\sigma_m$ T/SQ FT	$\sigma_1$ T/SQ FT	c T/SQ FT	$\phi$ DEGREES	PERMEABILITY		CONSOLIDATION DATA				REMARKS
					e	$k_{20}$ FT MIN $\times 10^{-9}$	$P_0$ T/SQ FT	$P_c$ T/SQ FT	$C_c$	$t_{50}$	
Q	0.5	4.49	2.00								
Q	0.5	4.43	1.97				0.70	0.90	0.045		SWELLING NOTED
Q	0.5	2.71	1.10								
Q	0.5	1.56	0.53				1.59	2.0	0.196		
Q	0.5	1.18	0.34								
Q	0.5	0.93	0.22				2.15	1.6	0.640		
Q	0.5	1.70	0.60				0.10	1.7	0.08		
Q	0.5	3.21	1.35								
					0.353	77.2					VERTICAL
					0.402	141.5					HORIZONTAL
Q	0.5	1.56	0.53				0.385	0.80	0.032		
Q	0.5	4.97	2.24								
							1.1	2.9	0.0365		SWELLING NOTED

DS - Direct Shear

UU - Unconsolidate Undrained

CD - Consolidated Drained

CU - Consolidated Undrained

\*Values at Pressure

T/SQ FT

# TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	PL				OPT. WATER %	MAX. DRY DENSITY LBS/
AUDC 67515	1	264.9-262.4	SANDY CLAY (CL)					37	20	2.74				
EL. 265.9	2	-260.4	SANDY CLAY (CL)					35	19	2.75				
	3	259.9-257.7	CLAY (CL)					36	19	2.76				
AUDC 67515	4	256.9-255.9	CLAY (CL)					40	19	2.76				
	5	254.4-252.2	CLAY (CL)					39	19	2.74				
AUC 67516	1	311.3-300.4	CLAY (CL)					34	20	2.73				
EL. 313.3	2	308.8-307.3	CLAY (CL)					28	18	2.75				
	3	-305.1	SANDY CLAY (CL)					37	18	2.73				
AUC 67516	4	-302.3	CLAY (CL)					32	18	2.74				

# TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

NATURAL DENSITY γ <sub>CUFT</sub>	COMPACTION DATA			SHEAR DATA										PERME k	
	OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL P	DRY DENSITY LBS CU FT	w <sub>1</sub> %	w <sub>F</sub> %	s <sub>1</sub> %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ <sub>m</sub> T SQ FT	σ <sub>1</sub> T SQ FT	c T SQ FT		φ DEGREES
			0.725	99.1	24.4	23.9	92.2								
			0.593	107.7	19.4		89.9	TC	1.43 X 2.97	Q	0.5	1.99	0.75		
				106.2	20.3	21.7	90.7								0.616
				107.7	18.8	21.6	87.2								0.593
			0.718	100.3	24.0		92.3	TC	2.81 X 6.34	Q	0.5	2.0	0.75		
			0.654	104.1	18.4	22.8	77.5								
			0.859	92.6	30.6		98.3	TC	1.43 X 2.91	Q	0.5	1.95	0.75		
			0.837	93.1	29.9		97.9	TC	1.40 X 2.93	Q	0.5	1.25	0.35		
			0.857	91.3	31.3	24.9	100								
			0.770	96.3	25.9		91.8	TC	1.40 X 2.96	Q	0.5	1.50	0.50		
			0.603	106.3	20.1	20.9	91.0								
			0.551	110.6	18.9		94.4	TC	1.36 X 2.91	Q	0.5	2.51	1.00		
				105.2	21.5	22.6	93.5								0.432
				106.9	20.3	21.3	92.3								0.605
			0.682	101.3	25.5		100	TC	1.40 X 2.95	Q	0.5	1.77	0.64		
			0.645	103.5	23.1	22.9	97.6								
			0.643	104.1	23.4		99.4	TC	1.40 X 2.97	Q	0.5	1.92	0.71		
			0.676	102.0	24.6	23.0	99.7								

TC - Triaxial Compression      DS - Direct Shear      CD -  
 UC - Unconfined Compression      UU - Unconsolidate Undrained      CU

TEST					PERMEABILITY		CONSOLIDATION DATA			REMARKS
	$\sigma_m$ T/SQ FT	$\sigma_1$ T/SQ FT	c T/SQ FT	$\phi$ DEGREES	e	$K_{20}$ FT/MIN $\times 10^{-9}$	$P_0$ T/SQ FT	$P_c$ T/SQ FT	$C_c$	
							0.05	2.8	0.134	
	0.5	1.99	0.75							
					0.616	7358				VERTICAL
					0.593	50,490				HORIZONTAL
	0.5	2.0	0.75							
							0.31	2.8	0.055	SWELLING NOTED
	0.5	1.95	0.78							
	0.5	1.25	0.38							
							0.58	4.5	0.246	
	0.5	1.50	0.50							
							0.1	1.6	0.0684	
	0.5	2.51	1.00							
					0.632	999.9				
					0.605	1397.3				
	0.5	1.77	0.64							
							0.31	4.1	0.0963	SWELLING NOTED
	0.5	1.92	0.71							
							0.35	4.2	0.134	

DS - Direct Shear

UU - Unconsolidate Undrained

CD - Consolidated Drained

CU - Consolidated Undrained

\*Values at Pressure

T/SQ FT







# TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS				ATTERBERG LIMITS		SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION	
				GRAVEL %	SAND %	FINES %	D <sub>10</sub>	LL	PL				OFT WATER %	MAX. DRY DENSITY LBS/
C-66501	1	199.2-198.2							2.76					
	4	193.1-192.0							2.80					
	11	181.8-180.7							2.79					
	13	179.2-177.6							2.79					
	15	174.1-172.7							2.78					
	17	170.7-169.8							2.75					
	19	168.9-167.6							2.79					
	20	166.0-165.0							2.79					
	22	160.9-159.6							2.76					
	8	186.4-184.9							2.77					
	3	197.4-196.6							2.77					
	5	192.0-190.9							2.78					
	9	183.6-182.6							2.78					
	10	182.6-181.8							2.78					
	12	180.7-179.7							2.79					
	14	176.9-175.6							2.77					
	16	172.6-171.6							2.78					
	18	169.8-168.9							2.77					
	20	167.0-166.0							2.79					
	24	157.9-156.9							2.76					

# TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY - CYCLIC LOADING ON QUEENSTON SH

SPEC. NO.	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA		SHEAR DATA									
			OPT. WATER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL P'	DRY DENSITY LBS CU FT	W <sub>i</sub> %	W <sub>F</sub> %	S <sub>i</sub> %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	$\sigma_m$ T/50 FT	$\sigma_I$ T/50 FT
6					0.041	165.4	1.0	1.2	100	TC	5.84 X 10.35	SU	1.0-6.0	1.0-35.0
0					0.057	165.3	1.0						1.0-6.0	1.0-45.0
9					0.048	166.1	1.0	1.7	58.1	TC	5.86 X 12.1	SU	1.0-6.0	1.0-25.0
9					0.052	165.4	1.2	2.27	63.9	TC	5.85 X 13.27	SU	1.0-6.0	1.0-15.0
8					0.039	167.0	1.0	1.54	71.3	TC	5.88 X 12.92	SU	1.0-6.0	1.0-15.0
5					0.033	166.1	1.0	1.2	83.7	TC	5.86 X 10.55	SU	1.0-6.0	1.0-25.0
9					0.056	164.9	1.0	2.2	50.1	TC	5.89 X 13.35	SU	1.0-6.0	1.0-35.0
9					0.051	165.6	1.0	1.8	54.3	TC	5.93 X 11.58	SU	1.0-6.0	1.0-45.0
6					0.041	165.4	1.0	1.5	67.2	TC	5.84 X 13.08	SU	1.0-6.0	1.0-45.0
7					0.044	165.6	1.0	1.6	63.3	TC	5.85 X 13.20	SU	1.0-6.0	1.0-25.0
7					0.045	165.4	1.0	1.8	61.8	TC	5.82 X 8.48	SU	0	0
8					0.053	164.7	1.1	2.4	60.0	TC	5.81 X 13.14	SU	0	0
8					0.050	165.3	1.0	2.0	55.9	TC	5.85 X 11.15	SU	0	0
8					0.057	165.8	1.0	2.2	100	TC	5.86 X 8.88	SU	0	0
9					0.054	165.3	1.0	2.2	52.1	TC	5.87 X 10.35	SU	0	0
7					0.043	165.7	1.0	2.0	64.3	TC	5.87 X 10.50	SU	0	0
8					0.042	166.4	1.0	2.2	65.5	TC	5.86 X 9.84	SU	0	0
7					0.040	166.2	1.0	1.6	69.6	TC	5.86 X 9.31	SU	0	0
9					0.046	166.5	1.0	1.9	61.3	TC	5.89 X 12.05	SU	0	0
6					0.044	164.9	1.0	1.9	62.3	TC	5.87 X 10.1	SU	0	0

TC - Triaxial Compression  
UC - Unconfined Compression

DS - Direct Shear  
UU - Unconsolidate Und

CYCLIC LOADING ON QUEENSTON SHALE

NO	TEST	CYCLES			CONSOLIDATION DATA				REMARKS		
		$\sigma_m$ T/SQ FT	$\sigma_I$ T/SQ FT	C T/SQ FT	LENGTH	TOTAL	$P_o$ T/SQ FT	$P_c$ T/SQ FT		$C_c$	$t_{50}$
5	SU	1.0-6.0	1.0-35.0	237.0	10 MIN	62.472					$\sigma_m$ & $\sigma_I$ ARE THE MIN & MAX PRESSURES DURING CYCLING
		1.0-6.0	1.0-45.0		LOST IN CYCLING DUE TO POOR PREPARATION					SAMPLES WERE SHEAR- ED AT $\sigma_{II} = 1TSE$	
1	SU	1.0-6.0	1.0-25.0	192.3	10 MIN	54.437					
27	SU	1.0-6.0	1.0-15.0	123.6	10 MIN	66.071					
92	SU	1.0-6.0	1.0-15.0	202.0	10 MIN	63.342					
55	SU	1.0-6.0	1.0-25.0	135.3	10 MIN	58.740					
35	SU	1.0-6.0	1.0-35.0	207.9	10 MIN	61.452					
58	SU	1.0-6.0	1.0-45.0	160.3	10 MIN	65.364					
08	SU	1.0-6.0	1.0-45.0	161.8	10 MIN	52.212					
20	SU	1.0-6.0	1.0-25.0	192.6	26 MIN	30.876					
3	SU	0	0	167.3	0	0	SATURATED 36 DAYS				
14	SU	0	0	137.2	0	0	SATURATED 54 DAYS				
15	SU	0	0	122.3	0	0	SATURATED 45 DAYS				
0	SU	0	0	181.5	0	0	SATURATED 34 DAYS				
5	SU	0	0	205.7	0	0	SATURATED 34 DAYS				
0	SU	0	0	101.1	0	0	SATURATED 35 DAYS				
1	SU	0	0	68.3	0	0	SATURATED 38 DAYS				
0	SU	0	0	125.6	0	0	SATURATED 35 DAYS				
5	SU	0	0	118.2	0	0	SATURATED 32 DAYS				
0	SU	0	0	113.0	0	0	SATURATED 35 DAYS				

DS - Direct Shear      CD - Consolidated Drained      \* Values at Pressure      T SQ FT  
 UU - Unconsolidate Undrained      CU - Consolidated Undrained  
 SU - Slow Undrained

GENERALIZED GEOLOGIC COLUMN

SYSTEM		GENERAL DESCRIPTION			
GROUP	FORMATION	MEMBER	AVERAGE THICKNESS		
QUATERNARY					
			08	<u>TILL, LACUSTRINE, AND BEACH DEPOSITS:</u> CLAYS, SILTS, SANDS, AND GRAVELS, RED TO RED-BROWN, GRAY.	
SILURIAN	BERTIE	SCAJAQUADA	7'	Sbs	<u>SHALE:</u> THIN-BEDDED; DOLOMITIC; MODERATELY-HARD; BLUISH-GRAY TO BLACK.
		FALKIRK	26'	Sbf	<u>DOLOMITE:</u> THIN-BEDDED; VERY ARGILLACEOUS, GYPSIFEROUS, SHALE BEDS THROUGHOUT. NUMEROUS GYPSUM BAND. BEDS, AND MODULES THROUGHOUT; SOFT TO HARD; DENSE; LIGHT-BROWN TO DARK-GRAY.
		OATKA	23'	Sbo	<u>DOLOMITE:</u> THIN-BEDDED; ARGILLACEOUS, GYPSIFEROUS, SHALE BEDS THROUGHOUT; SOFT TO MODERATELY-HARD; DENSE; LIGHT-BROWN TO DARK-GRAY.
	SALINA	CAMILLUS	400'	Sc	<u>SHALE:</u> THIN-BEDDED TO MASSIVE; GYPSIFEROUS; SOFT TO MODERATELY-HARD; GRAY TO BROWNISH-GRAY.
	LOCKPORT	LOCKPORT	+140	Sl	<u>DOLOMITE AND DOLOMITE LIMESTONE:</u> THIN-BEDDED TO MASSIVE; ARGILLACEOUS TO SHALY, OCCASIONAL CALCITE AND GYPSUM PARTINGS. OCCASIONAL CARBONACEOUS AND SHALY PARTINGS, CHERT MODULES; MODERATELY-HARD TO HARD; DENSE TO FINE-CRYSTALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) THAT ARE OCCASIONALLY STAINED AND WIDENED BY SOLUTION ACTION. OCCASIONAL MINERALIZED SOLUTION PITS AND VUGS; VARIOUS SHADES OF GRAY.
	ROCHESTER	ROCHESTER	62'	Sr	<u>SHALE:</u> LAMINATED TO BLOCKY; UPPER IS SLIGHTLY CALCAREOUS WITH OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE. LOWER IS SLIGHTLY CALCAREOUS WITH BANDS AND THIN BEDS OF LIMESTONE, OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN); DARK-GRAY.
	CLINTON	IRONDEQUOIT	18'	Si	<u>LIMESTONE:</u> MEDIUM-BEDDED TO MASSIVE; OCCASIONAL SHALE PARTINGS; MODERATELY-HARD TO HARD; DENSE TO CRYSTALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) SOME WIDENED BY SOLUTION ACTION. OCCASIONAL VUGS; LIGHT-TO MEDIUM-GRAY.
	REYNALDES	REYNALDES	5'	Sre	<u>LIMESTONE:</u> THIN-BEDDED; ARGILLACEOUS, SLIGHTLY-CALCAREOUS; MODERATELY-HARD TO HARD; FINE-CRYSTALLINE TO CRYSTALLINE; GRAY.
	NEAHGA	NEAHGA	6'	Sn	<u>SHALE:</u> PLATY; SLIGHTLY-SILTY, SLIGHTLY-CALCAREOUS, WAXY, OCCASIONAL GYPSUM PARTINGS ALONG BEDDING PLANES; SOFT; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) OCCASIONALLY STAINED AND OCCASIONALLY FILLED WITH PYRITE; GREENISH-GRAY.
	MEDINA	THOROLD	THOROLD	6'	Sf
GRIMSBY		GRIMSBY	50'	Sg	<u>SILTSTONE AND SANDSTONE:</u> INTERBEDDED WITH SHALE AND SANDSTONE; MODERATELY-HARD TO HARD; FINE-TO MEDIUM-GRAINED; CONTAINS OCCASIONAL JOINTS AND FRACTURES (TIGHT TO OPEN); PINK, WHITE, OR PALE-GREEN, MOTTLED SILTSTONE OR SANDSTONE WITH RED SHALE AND RED SANDSTONE INTERBEDS.
POWER GLEN		POWER GLEN	35'	Sp	<u>SHALE:</u> LAMINATED TO PLATY; ARGILLACEOUS WITH OCCASIONAL THIN CALCAREOUS SILTSTONE BEDS; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE OCCASIONALLY SLIGHTLY STAINED AND OCCASIONALLY OPEN; GRAYISH-GREEN WITH LIGHT-TO MEDIUM-GRAY SILTSTONE.
					<u>SANDSTONE:</u> MEDIUM-BEDDED TO MASSIVE; CROSS-BEDDED; QUARTZITIC, OCCASIONAL INCLUSIONS OF GREEN SHALE; HARD;

## ABBREVIATIONS

@	at	la	low angle
alt	alternating	lam	laminated, laminae
ang	angular	lea	leached
an	anhydrite	lig	lignite
ar	argillaceous	ln	lean
bdd	bed, bedded, bedding	*ls	limestone
bdr	bedrock	lt	light
bky	blocky	lo	loose
bl	blue	L.C.	lost core
bld	boulder	L.D.W.	lost drill water
blk	black	med	medium
brcc	brecciated	mic	micaceous
brn	brown	min	mineralized
buf	buff	mod	moderate, moderately
c	coarse	mss	massive
calc	calcareous	mst	moist
carb	carbonaceous	mtl	material
cav(s)	cavity	muc	mucky
cbl	cobble	nod	nodules
*cht	chert	num	numerous
circ	circulation	occ	occasionally, occasional
cl	clay, clayey	op	open
cmtd	cemented	org	organic
col	columnar	pit	pit, pitted, pitting
conc	concretions	pl	plastic
cong	conglomerate	pla	platy
crm	crumbly	pln	plane
d	dense	ptg(s)	parting, partings
dk	dark	*qtz	quartzite, quartz
dmp	damp	rnd	round, rounded
*dol	dolomite, dolomitic	sat	saturated
ext	extremely	scat	scattered
f	fine, finely	sd	sand, sandy
fe	iron	*sh	shale, shaly
fld	filled	si	silt, silty
fm	firm	*sis	siltstone
fos	fossil, fossiliferous	sl	slightly
frac(s)	fractures	slcs	siliceous
frag	fragments	slks	slickensides
fri	friable	so	soft
fsl	fissile	ss	sandstone
gen	generally	st	stained, staining
gr	grain	stf	stiff
gra	gradation	v	very
grn	green	var	variegated
grv	gravel, gravelly	vert	vertical
gry	gray	vgy	vuggy
*gyp	gypsum	w	water
ha	high angle	w/	with
*hal	halite	wea	weathered
hd	hard	wht	white
hor	horizontal	x-bdd	cross bedded
inbd	interbedded	xin	crystalline
incl	inclusions	y	yellow
irr	irregular		
jt	joint		

HOLE NUMBER -  
\*OFFSET FROM C

ELEVATION AND

OVERBURDEN -

LOST CORE -

PERCENT CORE F

DIAMETER OF B

DATE BORING C

\*OFFSET FROM F

I KNOWN SOFT ZONE

II PROBABLE SOFT

III POSSIBLE SOFT

## UNIFIED SOIL CLASSIFICATION SYSTEM

[GW]	GRAVEL OR SANDY GRAVEL, WELL GRADED	[ML]	SILTS, SANDY SILTS, GRAVELLY SIL
[GP]	GRAVEL OR SANDY GRAVEL, POORLY GRADED	[CL]	LEAN CLAYS, SANDY CLAYS, OR GRAV
[GM]	SILTY GRAVEL, OR SILTY SANDY GRAVEL	[OL]	ORGANIC SILT, OR LEAN OR AM
[GC]	CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL	[MH]	M M LAGEOUS
[SW]	SAND OR GRAVELLY SAND, WELL GRADED	[H]	
[SP]	SAND OR GRAVELLY SAND, POORLY GRADED	[F]	
[SM]	SILTY SAND OR SILTY GRAVEL, AM	[U]	
[SC]	CLAYEY SAND OR CLAYEY SANDY SAND		

NOTE:

1 2 3 4 5 6 7 8 9 10 11 12

AD-A100 739

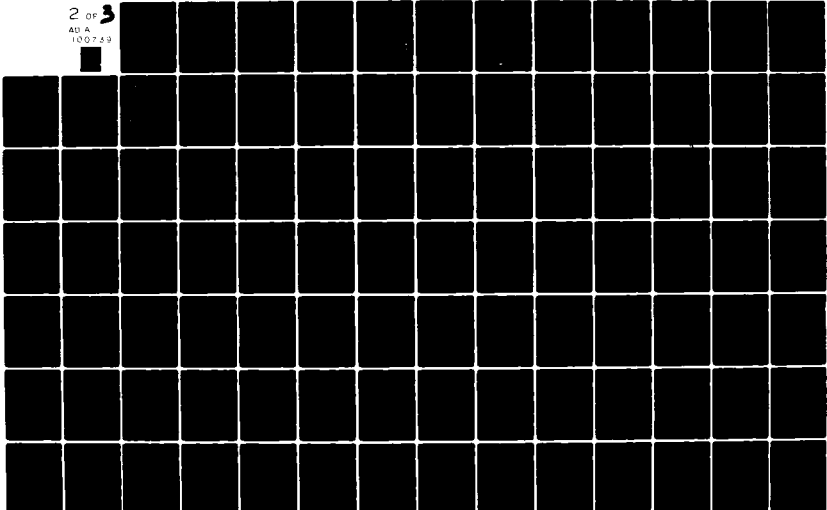
CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT  
REVIEW OF REPORTS ON LAKE ERIE-LAKE ONTARIO WATERWAY, NEW YORK.--ETC(U)  
OCT 73

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UNCLASSIFIED

NL

2 of 3  
AD A  
100739



### LEGEND FOR LOGS OF BORINGS

HOLE NUMBER	AUDC-67512
*OFFSET FROM CENTER LINE OF CANAL	100'LT
ELEVATION AND DATE WATER LEVEL OBSERVED	<div style="display: flex; align-items: center; justify-content: flex-end;"> <span style="margin-right: 5px;">▼ W</span> <div style="border: 1px solid black; padding: 2px;"> <div style="text-align: center;">10-7-60</div> </div> </div>
OVERBURDEN	<div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">OB</div>
LOST CORE	<div style="display: flex; align-items: center; justify-content: flex-end;"> <span style="margin-right: 5px;">L.C. 0.8'</span> <div style="border: 1px solid black; padding: 2px; width: 20px; height: 15px;"></div> </div>
PERCENT CORE RECOVERED IN BEDROCK	95%
DIAMETER OF BEDROCK CORE	2 1/8"
DATE BORING COMPLETED	1-16-63

\*OFFSET FROM PROFILE MAYBE RIGHT OR LEFT AS DEFINED.

### TYPE OF EXPLORATION CODE DESIGNATION

- A - AUGER HOLE - HAND OR POWER AUGER
- U - UNDISTURBED SAMPLE HOLE
- D - DRIVE SAMPLE HOLE
- C - CORE HOLE
- R - ROCK BIT HOLE
- P - PROBING
- SI - SQUAW ISLAND BORINGS
- - VERTICAL PROBINGS
- - VERTICAL BORINGS

### SOFT ZONE CLASSIFICATION

- I KNOWN SOFT ZONE - GOOD EVIDENCE OF ZONE IN CORE (I.E. RECOVERED).
- II PROBABLE SOFT ZONE - FAIR EVIDENCE OF ZONE IN CORE, BUT ZONE NOT INTACT.
- III POSSIBLE SOFT ZONE - SLIGHT EVIDENCE OF ZONE IN CORE; HOWEVER, APPARENT ROCK TO ROCK CONTACT IN MOST CASES.

### CLASSIFICATION SYSTEM

- ML** SILTS, SANDY SILTS, GRAVELLY SILTS OR DIATOMACEOUS SOILS
- CL** LEAN CLAYS, SANDY CLAYS, OR GRAVELLY CLAYS
- OL** ORGANIC SILT, OR LEAN ORGANIC CLAYS
- MI** MICACEOUS SILTS, DIATOMACEOUS SOILS OR PLASTIC SILTS
- CH** FAT CLAYS
- OH** FAT ORGANIC CLAYS
- PT** PEAT, HUMUS, AND OTHER ORGANIC SWAMP SOILS

CONFORM WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

SILURIAN	CLINTON	OATKA	23'	S <sub>bo</sub>	DOLOMITE: THIN-BEDDED; ARGILLACEOUS, GYPSIFEROUS, SHALE BEDS THROUGHOUT; SOFT TO MODERATELY-HARD; DENSE; LIGHT-BROWN TO DARK-GRAY.
		SALINA	400'	S <sub>c</sub>	SHALE: THIN-BEDDED TO MASSIVE; GYPSIFEROUS; SOFT TO MODERATELY-HARD; GRAY TO BROWNISH-GRAY.
		LOCKPORT	+140	S <sub>l</sub>	DOLOMITE AND DOLOMITE LIMESTONE: THIN-BEDDED TO MASSIVE; ARGILLACEOUS TO SHALY, OCCASIONAL CALCITE AND GYPSUM PARTINGS. OCCASIONAL CARBONACEOUS AND SHALY PARTINGS, CHERT MODULES; MODERATELY-HARD TO HARD; DENSE TO FINE-CRYSTALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) THAT ARE OCCASIONALLY STAINED AND WIDENED BY SOLUTION ACTION. OCCASIONAL MINERALIZED SOLUTION PITS AND VUGS; VARIOUS SHADES OF GRAY.
		ROCHESTER	62'	S <sub>r</sub>	SHALE: LAMINATED TO BLOCKY; UPPER IS SLIGHTLY CALCAREOUS WITH OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE. LOWER IS SLIGHTLY CALCAREOUS WITH BANDS AND THIN BEDS OF LIMESTONE, OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN); DARK-GRAY.
		IRONDEQUOIT	18'	S <sub>i</sub>	LIMESTONE: MEDIUM-BEDDED TO MASSIVE; OCCASIONAL SHALE PARTINGS; MODERATELY-HARD TO HARD; DENSE TO CRYSTALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) SOME WIDENED BY SOLUTION ACTION, OCCASIONAL VUGS; LIGHT-TO MEDIUM-GRAY.
		REYNALDES	5'	S <sub>re</sub>	LIMESTONE: THIN-BEDDED; ARGILLACEOUS, SLIGHTLY-CALCAREOUS; MODERATELY-HARD TO HARD; FINE-CRYSTALLINE TO CRYSTALLINE; GRAY.
		NEAHGA	6'	S <sub>n</sub>	SHALE: PLATY; SLIGHTLY-SILTY, SLIGHTLY-CALCAREOUS, WAXY, OCCASIONAL GYPSUM PARTINGS ALONG BEDDING PLANES; SOFT; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) OCCASIONALLY STAINED AND OCCASIONALLY FILLED WITH PYRITE; GREENISH-GRAY.
		THOROLD	6'	S <sub>t</sub>	SANDSTONE TO SILTSTONE: MEDIUM-BEDDED TO MASSIVE; QUARTZITIC WITH QUARTZ GRAINS (ANGULAR TO SUB-ANGULAR) CEMENTED WITH SILICA, OCCASIONAL SHALE AND GYPSUM PARTINGS; HARD; FINE-GRAINED; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE STAINED, SOME SLIGHTLY OPEN; LIGHT-GRAY.
		GRIMSBY	50'	S <sub>g</sub>	SILTSTONE AND SANDSTONE: INTERBEDDED WITH SHALE AND SANDSTONE; MODERATELY-HARD TO HARD; FINE-TO MEDIUM-GRAINED; CONTAINS OCCASIONAL JOINTS AND FRACTURES (TIGHT TO OPEN); PINK, WHITE, OR PALE-GREEN, MOTTLED SILTSTONE OR SANDSTONE WITH RED SHALE AND RED SANDSTONE INTERBEDS.
		POWER GLEN	35'	S <sub>p</sub>	SHALE: LAMINATED TO PLATY; ARGILLACEOUS WITH OCCASIONAL THIN CALCAREOUS SILTSTONE BEDS; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE OCCASIONALLY SLIGHTLY STAINED AND OCCASIONALLY FILLED WITH PYRITE; OPEN; GRAYISH-GREEN WITH LIGHT-TO MEDIUM-GRAY SILTSTONE.
		WHIRLPOOL	20'	S <sub>w</sub>	SANDSTONE: MEDIUM-BEDDED TO MASSIVE; CROSS-BEDDED; QUARTZITIC, OCCASIONAL INCLUSIONS OF GREEN SHALE; HARD; WELL CEMENTED WITH SILICA; MEDIUM-TO COARSE GRAINED (WELL-ROUNDED, FROSTED. QUARTZ GRAINS); OCCASIONAL JOINTS AND FRACTURES; LIGHT-GRAY TO WHITE.
		UNCONFORM			
ORDOVICIAN		QUEENSTON	+1200'	O <sub>q</sub>	SHALE: (TECHNICALLY CLASSIFIED AS A CLAYSTONE). MASSIVE; CALCAREOUS; SOFT TO MODERATELY-HARD; OCCASIONAL HIGH ANGLE JOINT SOME HEALED WITH GYPSUM; WEATHERS READILY TO BLOCKS UPON EXPOSURE TO THE ATMOSPHERE; PURPLE-RED WITH GREEN OR GRAY MOTTLING.

#### JOINT CLASSIFICATION AND DEFINITIONS

HORIZONTAL JOINT	0° TO ±10° FROM THE HORIZONTAL
LOW ANGLE JOINT	±10° TO ±45° FROM THE HORIZONTAL
HIGH ANGLE JOINT	±45° TO ±85° FROM THE HORIZONTAL
VERTICAL JOINT	±85° TO ±90° FROM THE HORIZONTAL

A  
U  
D  
C  
R  
P  
S  
I

...DENSE;

...CITE AND GYPSUM  
...DENSE TO FINE-CRYSTAL-  
...ED BY SOLUTION

...LAMINAE, LOWER  
...LAMINAE:

...TO CRYSTALLINE;  
...LIGHT-TO

...ALLINE TO

...ING PLANES; SOFT;  
...PYRITE:

...B-ANGULAR)  
...ONAL JOINTS

...TO MEDIUM-GRAINED,  
...SILTSTONE OR SANDSTONE

...LY-SOFT TO  
...ED AND OCCASIONALLY

...SHALE: HARD;  
...ASIONAL JOINTS

...UNIFORMITY

...CCASIONAL HIGH AND  
...HERE; PURPLE-

cong	conglomerate	pla	platy
crm	crumbly	pln	plane
d	dense	ptg(s)	parting, partings
dk	dark	qtz	quartzite, quartz
dmp	damp	rnd	round, rounded
*dol	dolomite, dolomitic	sat	saturated
ext	extremely	scat	scattered
f	fine, finely	sd	sand, sandy
fe	iron	*sh	shale, shaly
fld	filled	si	silt, silty
fm	firm	*sis	siltstone
fos	fossil, fossiliferous	sl	slightly
frac(s)	fractures	slcs	siliceous
frag	fragments	slks	slickensides
fri	friable	so	soft
fsl	fissile	ss	sandstone
gen	generally	st	stained, staining
gr	grain	stf	stiff
gra	gradation	v	very
grn	green	var	variegated
grv	gravel, gravelly	vert	vertical
gry	gray	vgy	vuggy
*gyp	gypsum	w	water
ha	high angle	w'	with
*hal	halite	wea	weathered
hd	hard	wht	white
hor	horizontal	x-bdd	cross bedded
inbd	interbedded	xin	crystalline
incl	inclusions	y	yellow
irr	irregular		
jt	joint		

I KNOWN SOFT ZONE -

II PROBABLE SOFT ZONE

III POSSIBLE SOFT ZONE

\*WHEN USED AS LOG SYMBOL  
FIRST LETTER IS CAPITALIZED

UNIFIED SOIL CLASSIFICATION SYSTEM

- |   |  |
|---|--|
| <b>[GW]</b> GRAVEL OR SANDY GRAVEL, WELL GRADED   | <b>[ML]</b> SILTS, SANDY SILTS, GRAVELLY SILTS OR  |
| <b>[GP]</b> GRAVEL OR SANDY GRAVEL, POORLY GRADED | <b>[CL]</b> LEAN CLAYS, SANDY CLAYS, OR GRAVELLY   |
| <b>[GM]</b> SILTY GRAVEL, OR SILTY SANDY GRAVEL   | <b>[DL]</b> ORGANIC SILT, OR LEAN ORGANIC CLAYS    |
| <b>[GC]</b> CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL  | <b>[MH]</b> MICACEOUS SILTS, DIATOMACEOUS SOILS OR |
| <b>[SW]</b> SAND OR GRAVELLY SAND, WELL GRADED    | <b>[CH]</b> FAT CLAYS                              |
| <b>[SP]</b> SAND OR GRAVELLY SAND, POORLY GRADED  | <b>[OH]</b> FAT ORGANIC CLAYS                      |
| <b>[SM]</b> SILTY SAND OR SILTY GRAVELLY SAND     | <b>[PT]</b> PEAT, HUMUS, AND OTHER ORGANIC SWAMP   |
| <b>[SC]</b> CLAYEY SAND OR CLAYEY GRAVELLY SAND   |  |

NOTE:  
DUAL CLASSIFICATIONS, WHERE USED, ARE IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION

TERMS FOR STRENGTH OF  
SOILS AND HARDNESS OF BEDROCK

CONSISTANCY	ESTIMATED STRENGTHS	
	UNCONFINED COMPRESSIVE STRENGTH (TONS PER SQUARE FOOT)	
VERY SOFT	0.25	
SOFT	0.25-0.5	
MEDIUM	0.5-1.0	
STIFF	1.0-2.0	
VERY STIFF	2.0-4.0	
HARD	4.0	

BEDROCK  
SCALE OF HARDNESS

VERY SOFT OR PLASTIC	CAN BE INDENTED EASILY WITH THUMB.
SOFT	CAN BE SCRATCHED WITH FINGERNAIL.
MODERATELY HARD	CAN BE SCRATCHED EASILY WITH KNIFE.
	CANNOT BE SCRATCHED WITH FINGERNAIL.
HARD	DIFFICULT TO SCRATCH WITH KNIFE.
VERY HARD	CANNOT BE SCRATCHED WITH KNIFE.

LAKE ERIE

GEOLOG

U. S. ARMY EN

TO ACCOMPAN

0

TYPE OF EXPLORATION  
CODE DESIGNATION

- A - AUGER HOLE - HAND OR POWER AUGER
- U - UNDISTURBED SAMPLE HOLE
- D - DRIVE SAMPLE HOLE
- C - CORE HOLE
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- - VERTICAL PROBINGS
- - VERTICAL BORINGS

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CLASSIFICATION SYSTEM

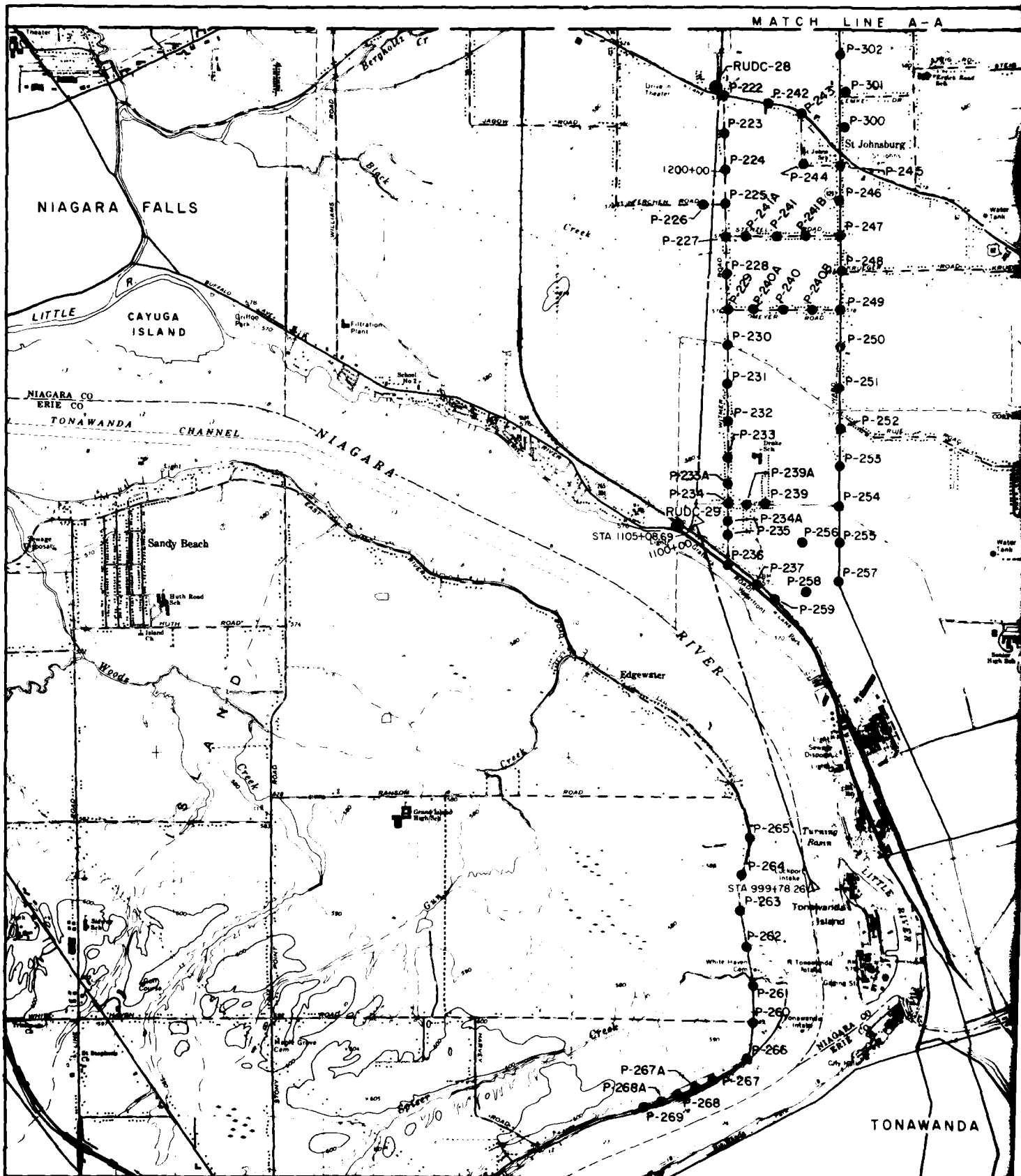
- ML SILTS, SANDY SILTS, GRAVELLY SILTS OR DIATOMACEOUS SOILS
- CL LEAN CLAYS, SANDY CLAYS, OR GRAVELLY CLAYS
- OL ORGANIC SILT, OR LEAN ORGANIC CLAYS
- MH MICACEOUS SILTS, DIATOMACEOUS SOILS OR PLASTIC SILTS
- CH FAT CLAYS
- OH FAT ORGANIC CLAYS
- PT PEAT, HUMUS, AND OTHER ORGANIC SWAMP SOILS

ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

LAKE ERIE-LAKE ONTARIO WATERWAY

LEGEND FOR  
GEOLOGIC INVESTIGATIONS

U. S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973



# HURON PLAIN

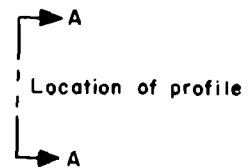


### SHEET INDEX

SEE PLATE B5
SEE PLATE B4
SEE PLATE B3
THIS PLATE B2

### NOTES:

For profiles of locks see plates B20, B21, B22, B23 and B24.  
For legend of borings see plate B1.



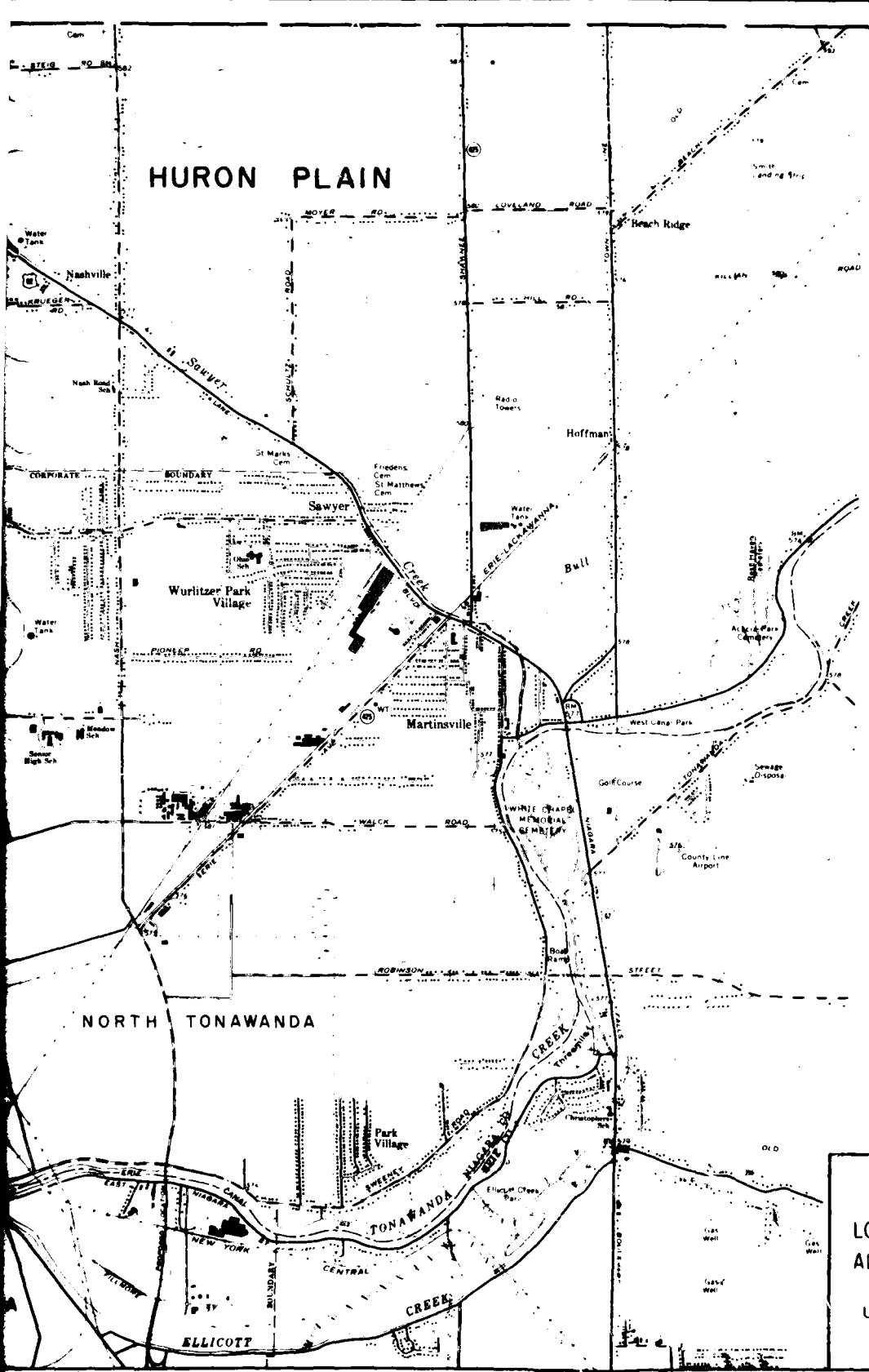
### SCALE OF FEET



### LAKE ERIE-LAKE ONTARIO WATERWAY

LOCATION OF SUBSURFACE EXPLORATIONS  
ALONG OVERLAND SECTION (SHEET 1 OF 4)

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973



MATCH LINE B-B

LOWER NIAGARA ESCARPMENT

UPPER NIAGARA ESCARPMENT

TUSCARORA

INDIAN RESERVATION

HURON PLAIN

Colonial Village

US MIL RES Falcon Manor

NIAGARA FALLS AIR FORCE BASE

NIAGARA FALLS INTERNATIONAL AIRPORT

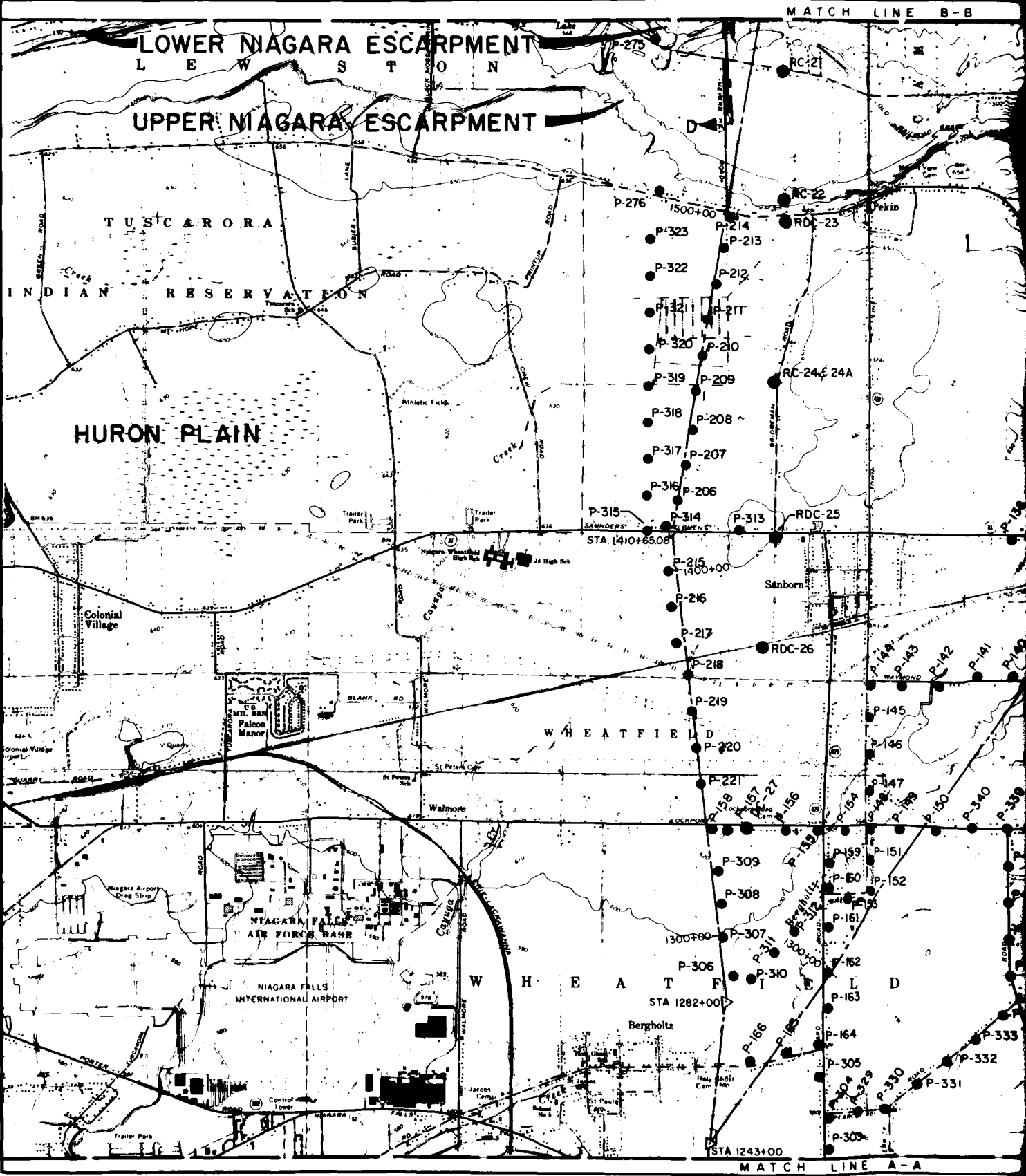
WHEATFIELD

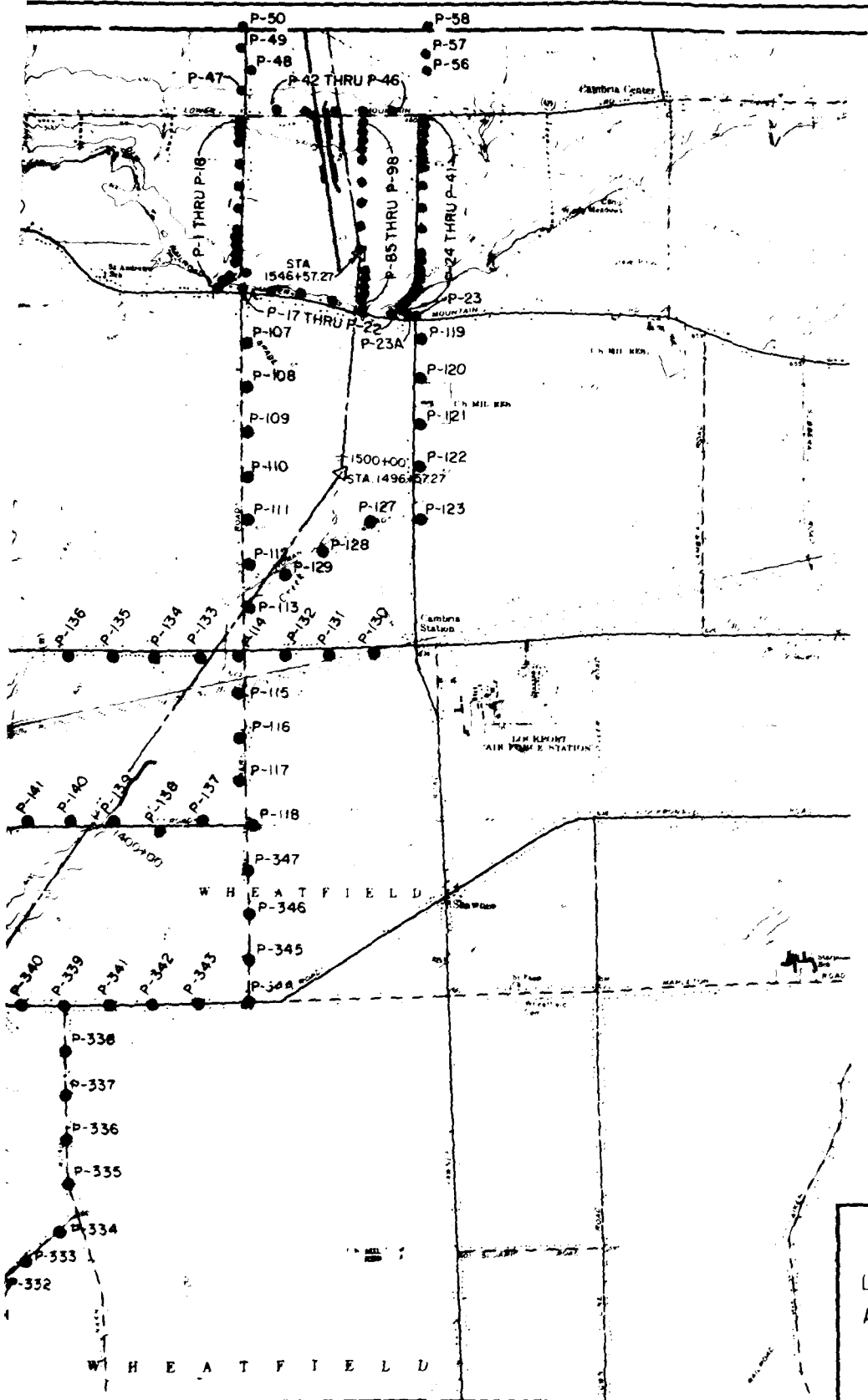
WHEATFIELD

Bergholtz

STA 1243+00

MATCH LINE A-A



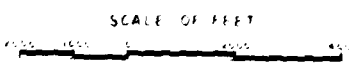
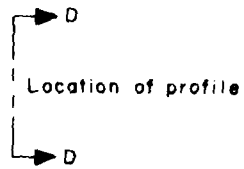


SHEET INDEX

SEE PLATE B5
SEE PLATE B4
THIS PLATE B3
SEE PLATE B2

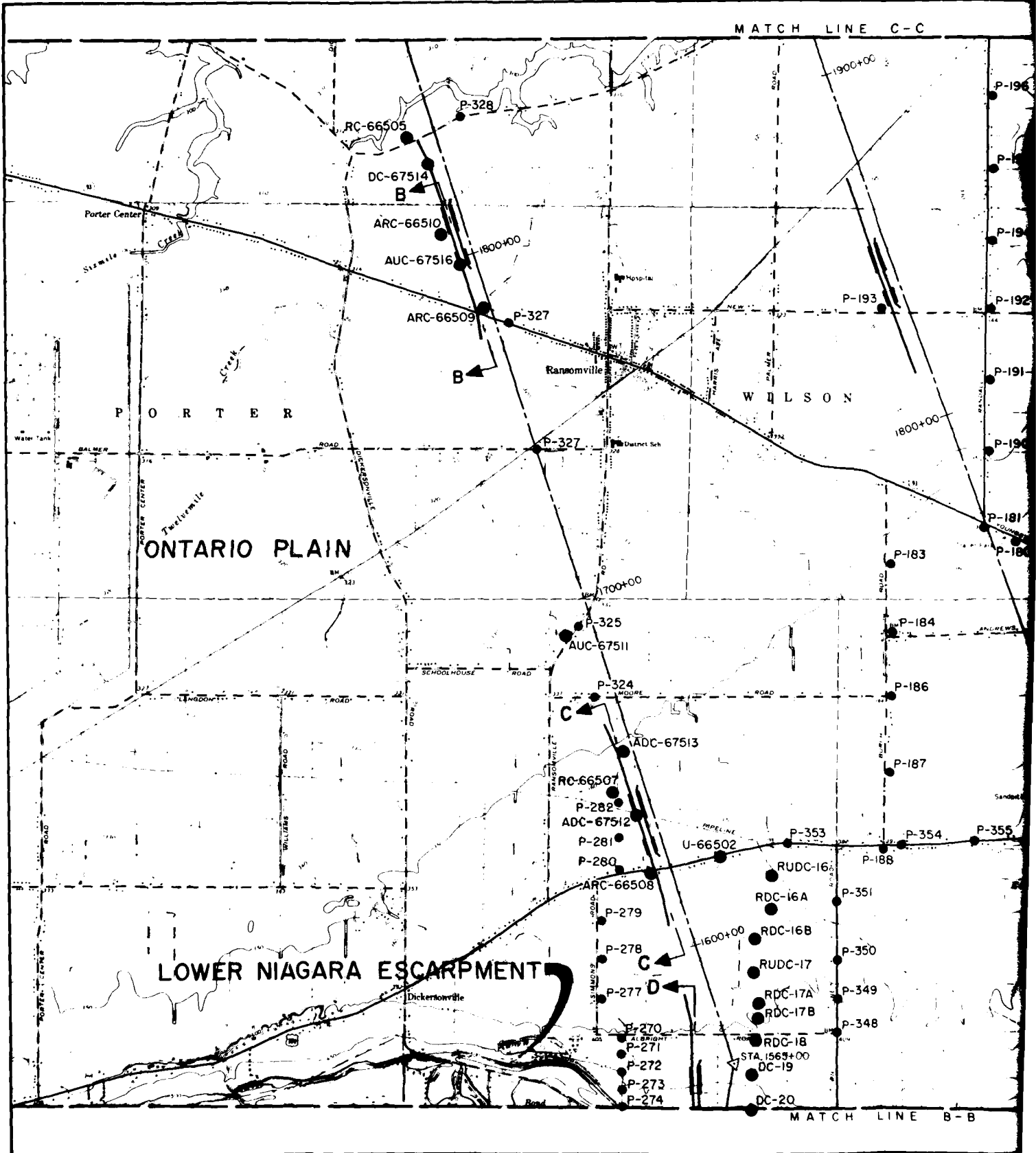
**NOTES:**

For profiles of locks see plates B20, B21, B22, B23 and B24  
 For legend of borings see plate B1



LAKE ERIE-LAKE ONTARIO WATERWAY  
 LOCATION OF SUBSURFACE EXPLORATIONS  
 ALONG OVERLAND SECTION (SHEET 2 OF 4)  
 US ARMY ENGINEER DISTRICT, BUFFALO  
 TO ACCOMPANY REVIEW OF REPORTS  
 OCTOBER 1973

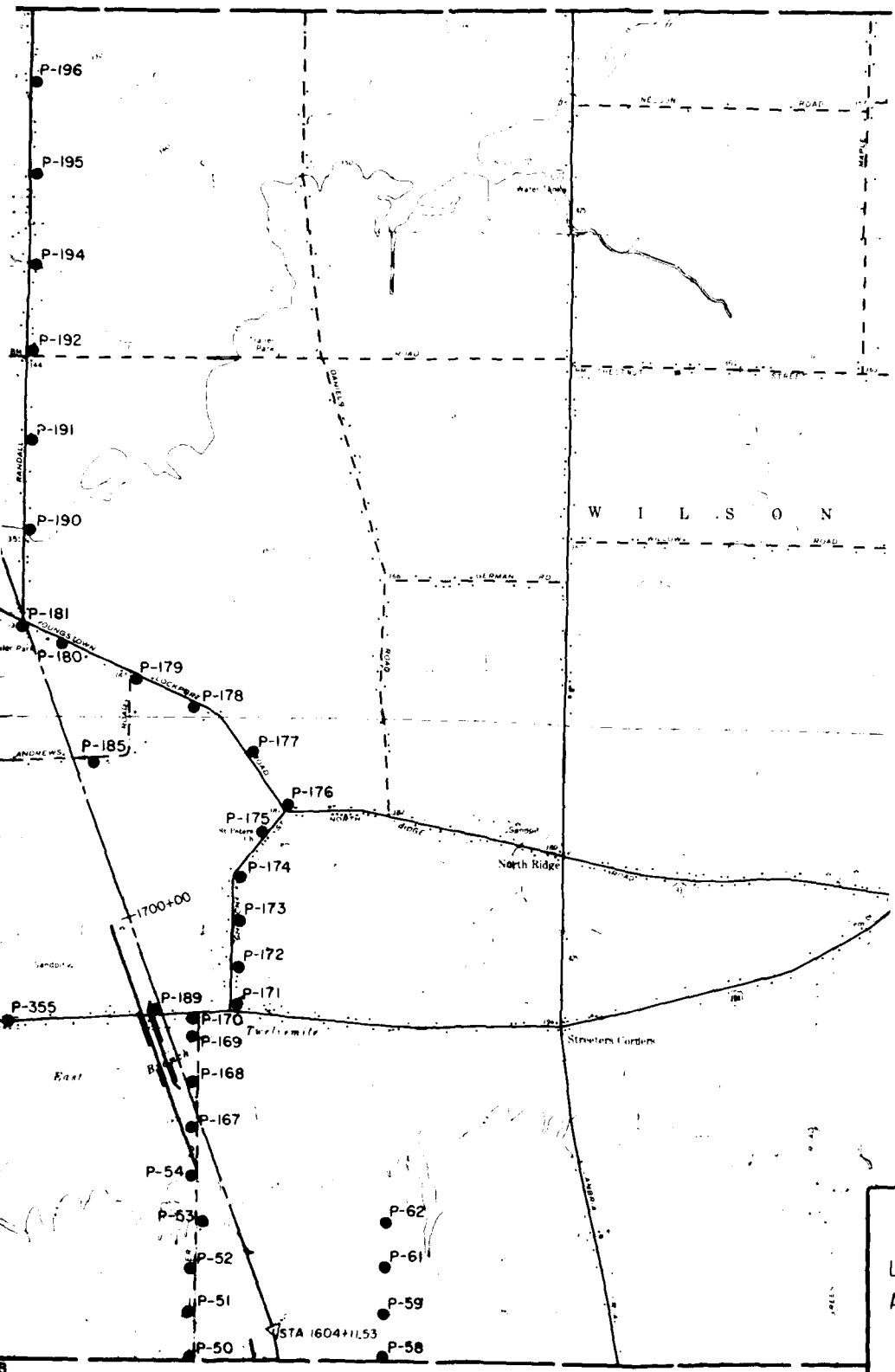
MATCH LINE C-C



ONTARIO PLAIN

LOWER NIAGARA ESCARPMENT

MATCH LINE B-B

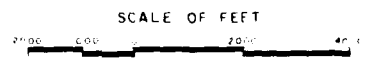
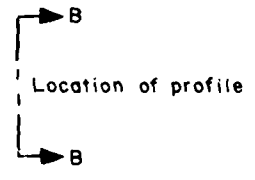


SHEET INDEX

SEE PLATE B5
THIS PLATE B4
SEE PLATE B3
SEE PLATE B2

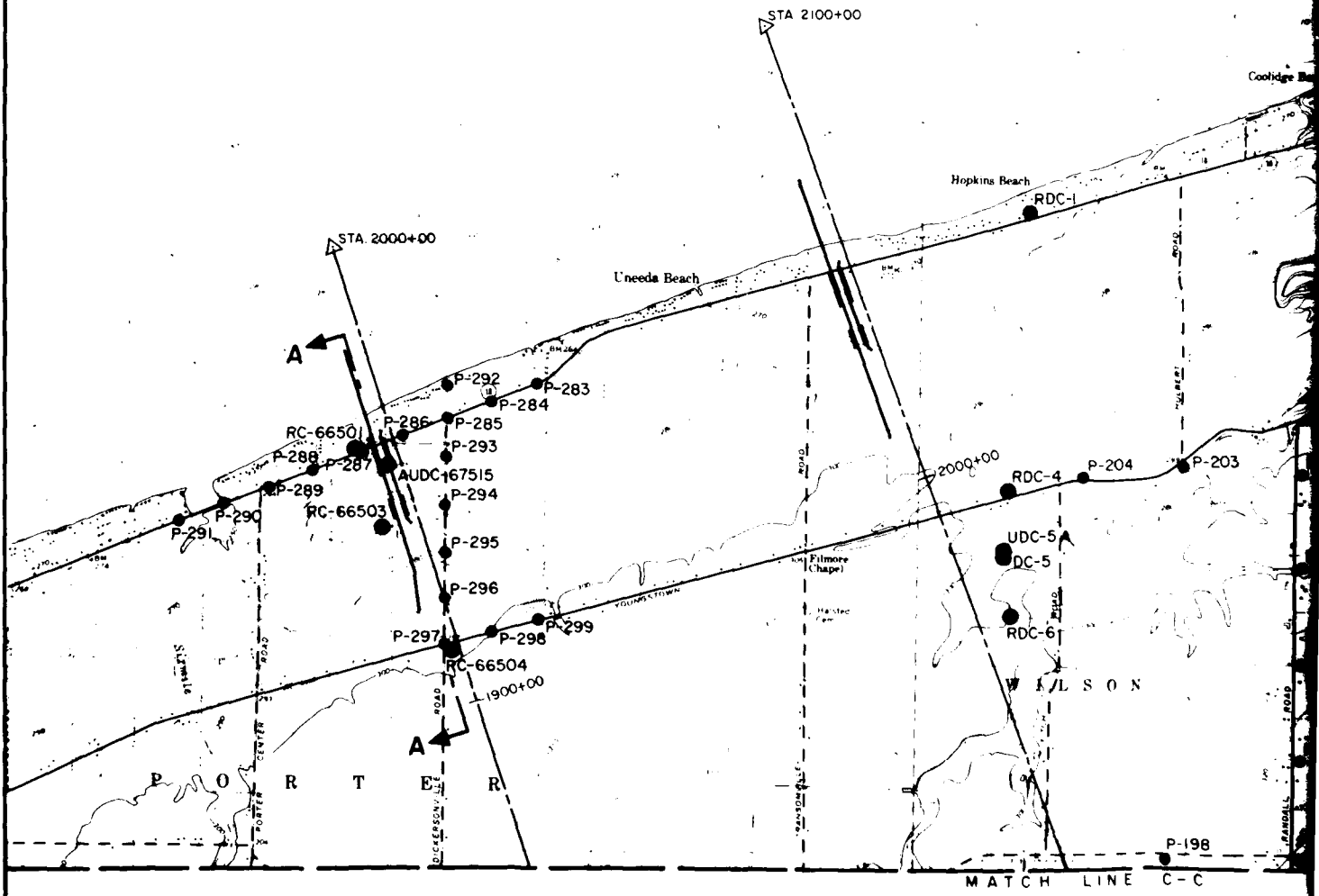
NOTES:

For profiles of locks see plates B20, B21, B22, B23 and B24.  
For legend of borings see plate B1.



LAKE ERIE-LAKE ONTARIO WATERWAY  
LOCATION OF SUBSURFACE EXPLORATIONS  
ALONG OVERLAND SECTION (SHEET 3 OF 4)  
U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

L A K E O N T A R I O





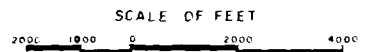
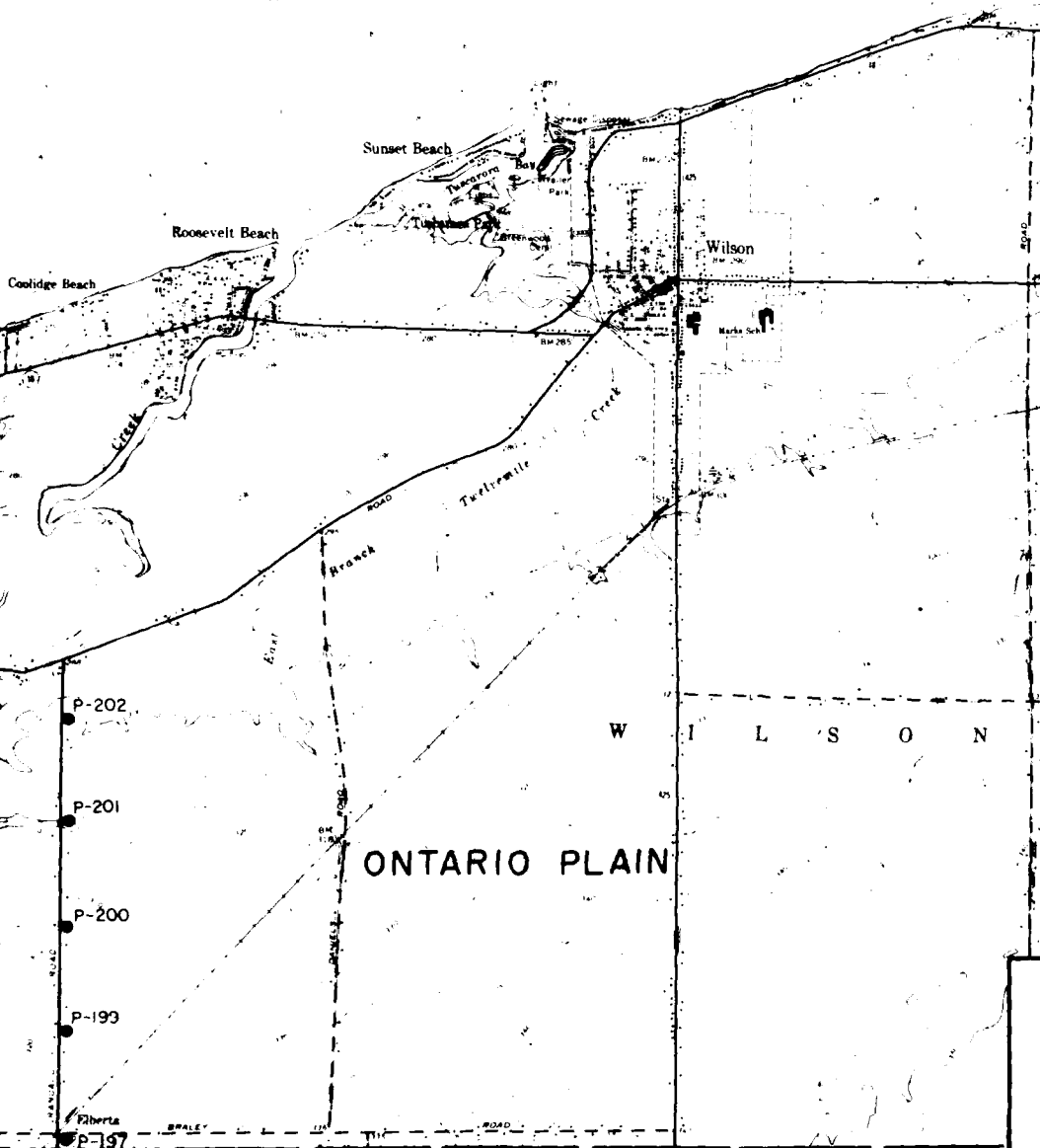
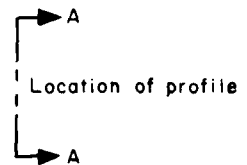
SHEET INDEX

THIS PLATE B5
SEE PLATE B4
SEE PLATE B3
SEE PLATE B2

NOTES:

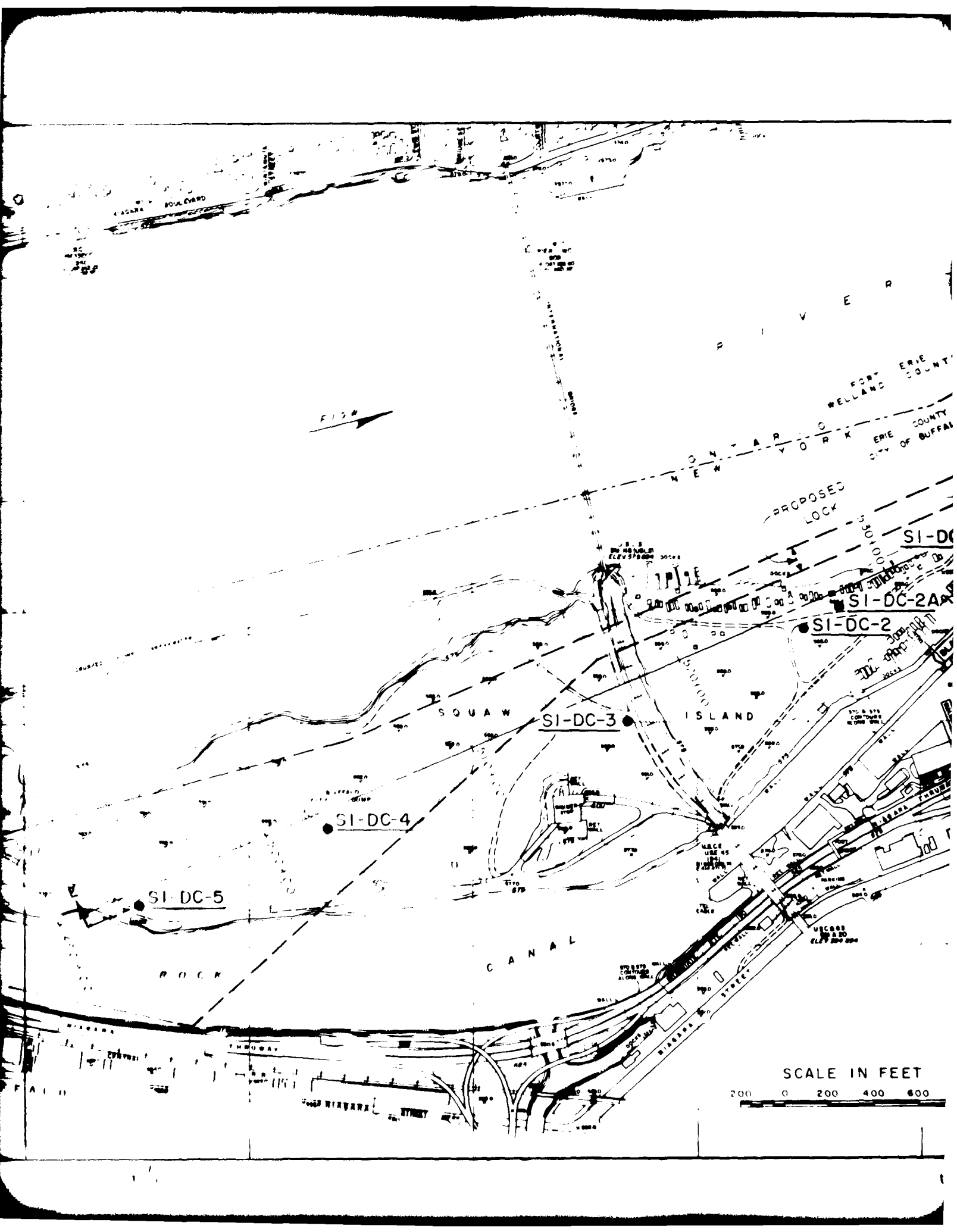
For profiles of locks see plates B20  
B21, B22, B23 and B24.

For legend of borings see plate R1.

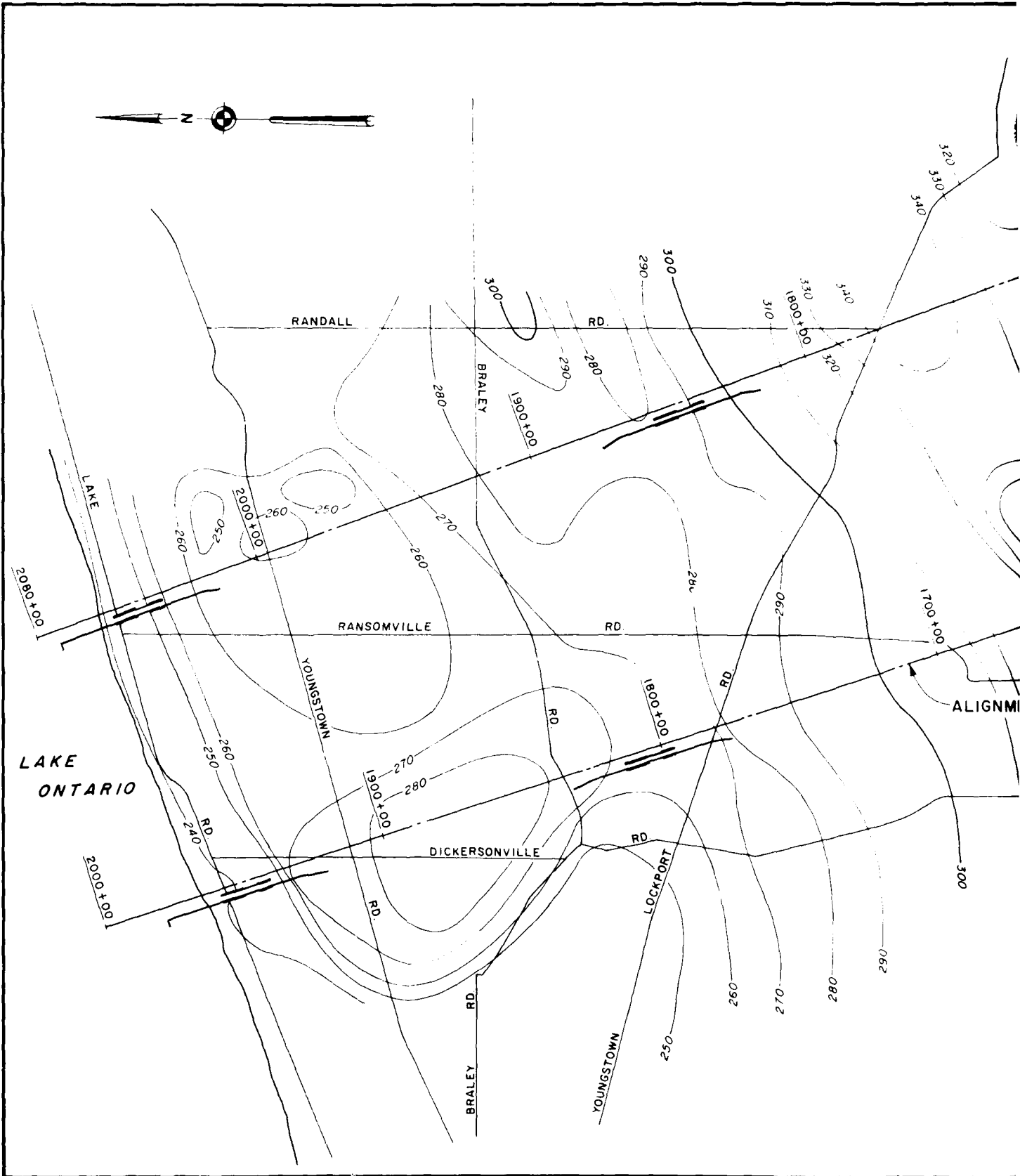


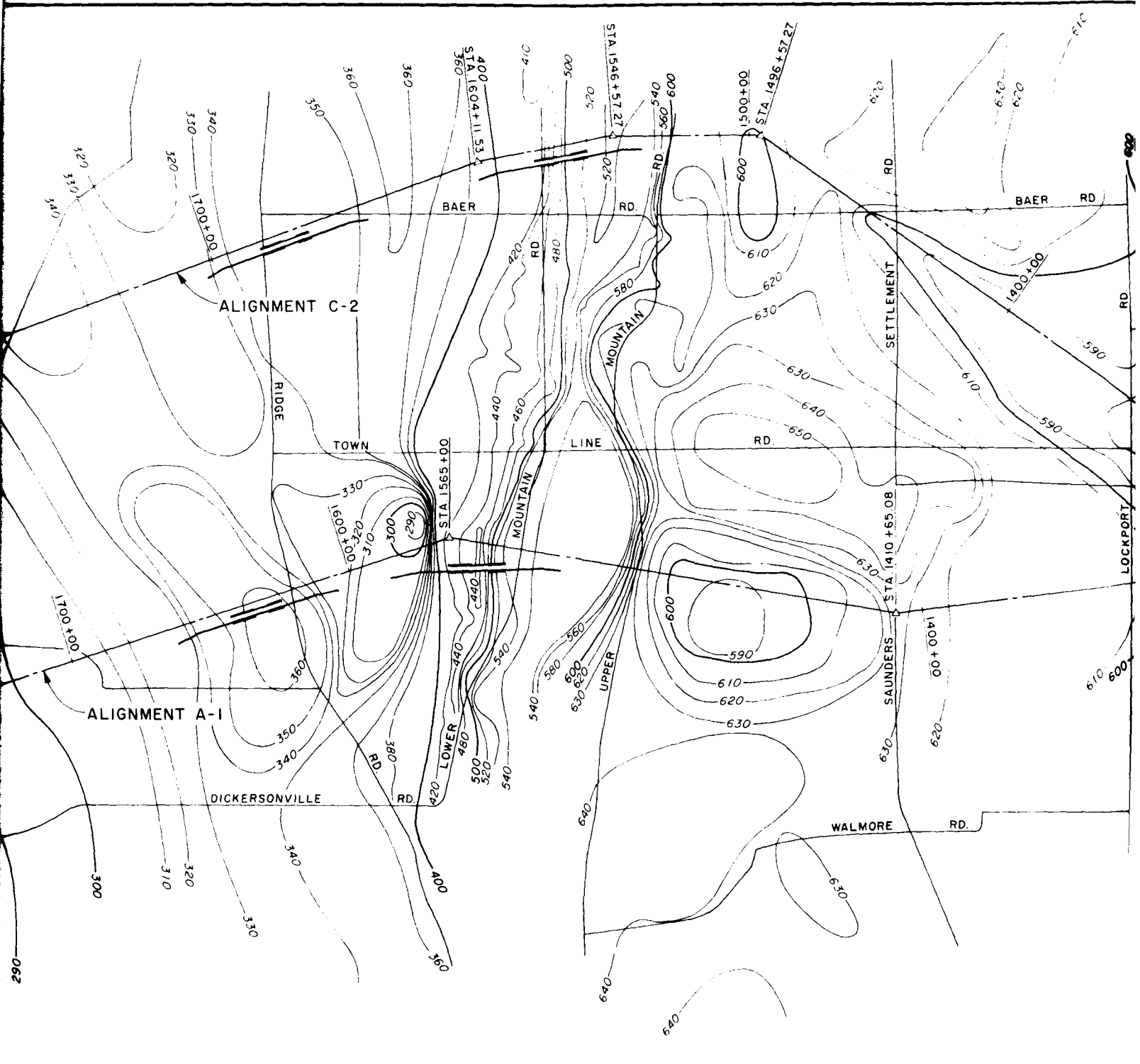
LAKE ERIE-LAKE ONTARIO WATERWAY  
LOCATION OF SUBSURFACE EXPLORATIONS  
ALONG OVERLAND SECTION (SHEET 4 OF 4)  
U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973





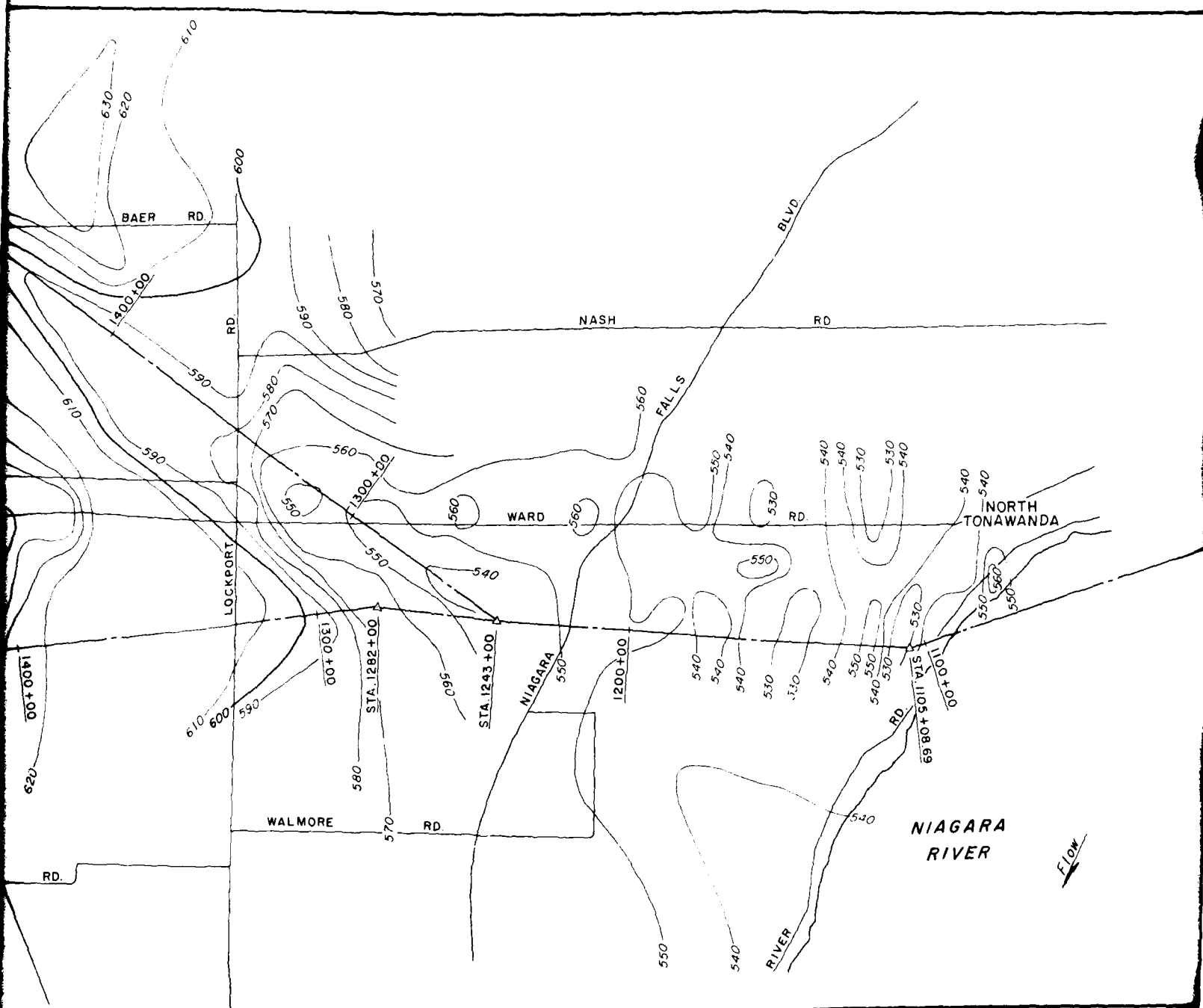






290

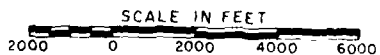
1. 2.



**NOTES:**

TOP OF ROCK CONTOURS ARE BASED MAINLY ON DATA FROM PROBINGS SUPPLEMENTED WITH DATA FROM BOREHOLES DRILLED INTO ROCK.

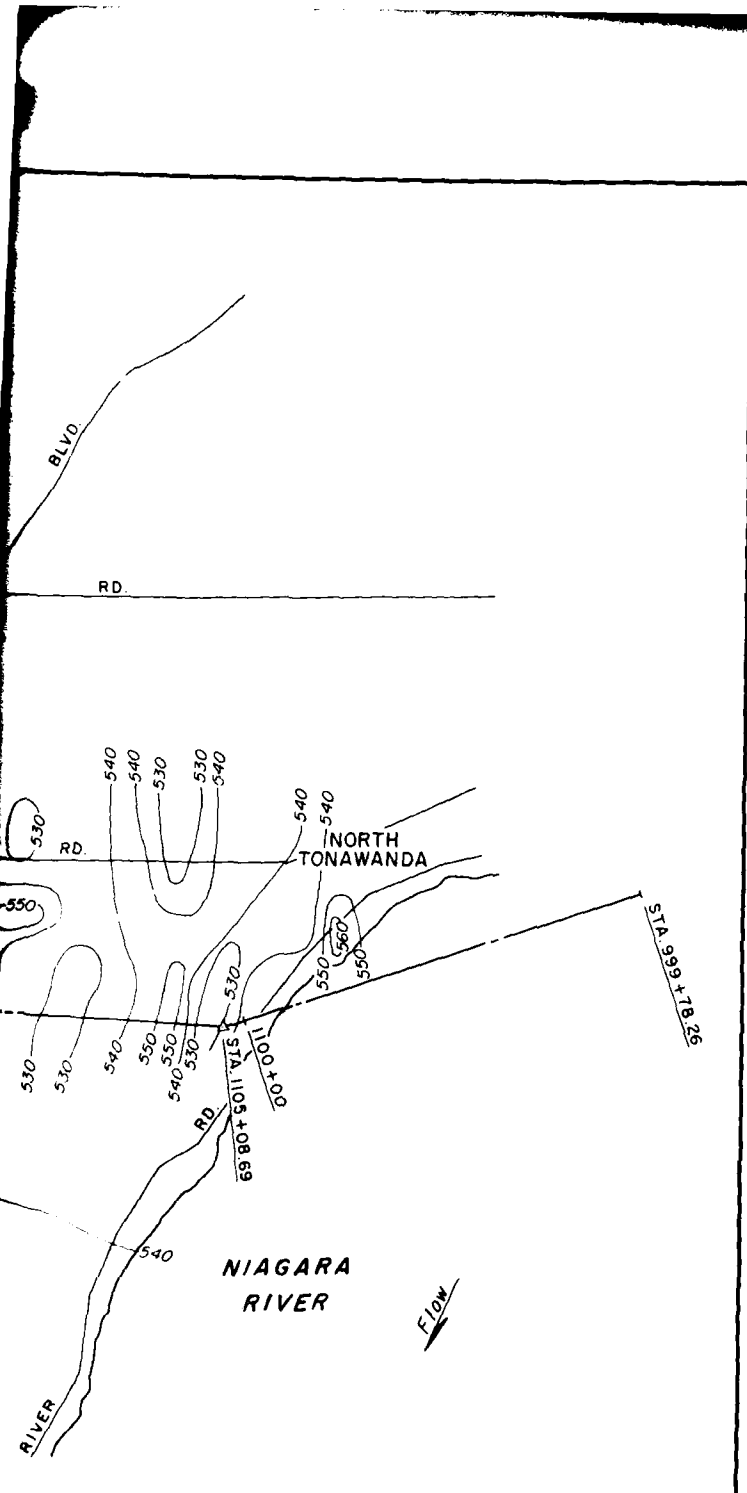
LOCATIONS OF THE SUBSURFACE EXPLORATIONS ARE SHOWN ON PLATES B2, B3, B4 AND B5.



LAKE ERIE-LAKE ONTARIO WATER

**ROCK CONTOUR MAP**

U S ARMY ENGINEER DISTRICT, B  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973



LAKE ERIE-LAKE ONTARIO WATERWAY

ROCK CONTOUR MAP

U. S. ARMY ENGINEER DISTRICT, BUFFALO  
 TO ACCOMPANY REVIEW OF REPORTS  
 OCTOBER 1973

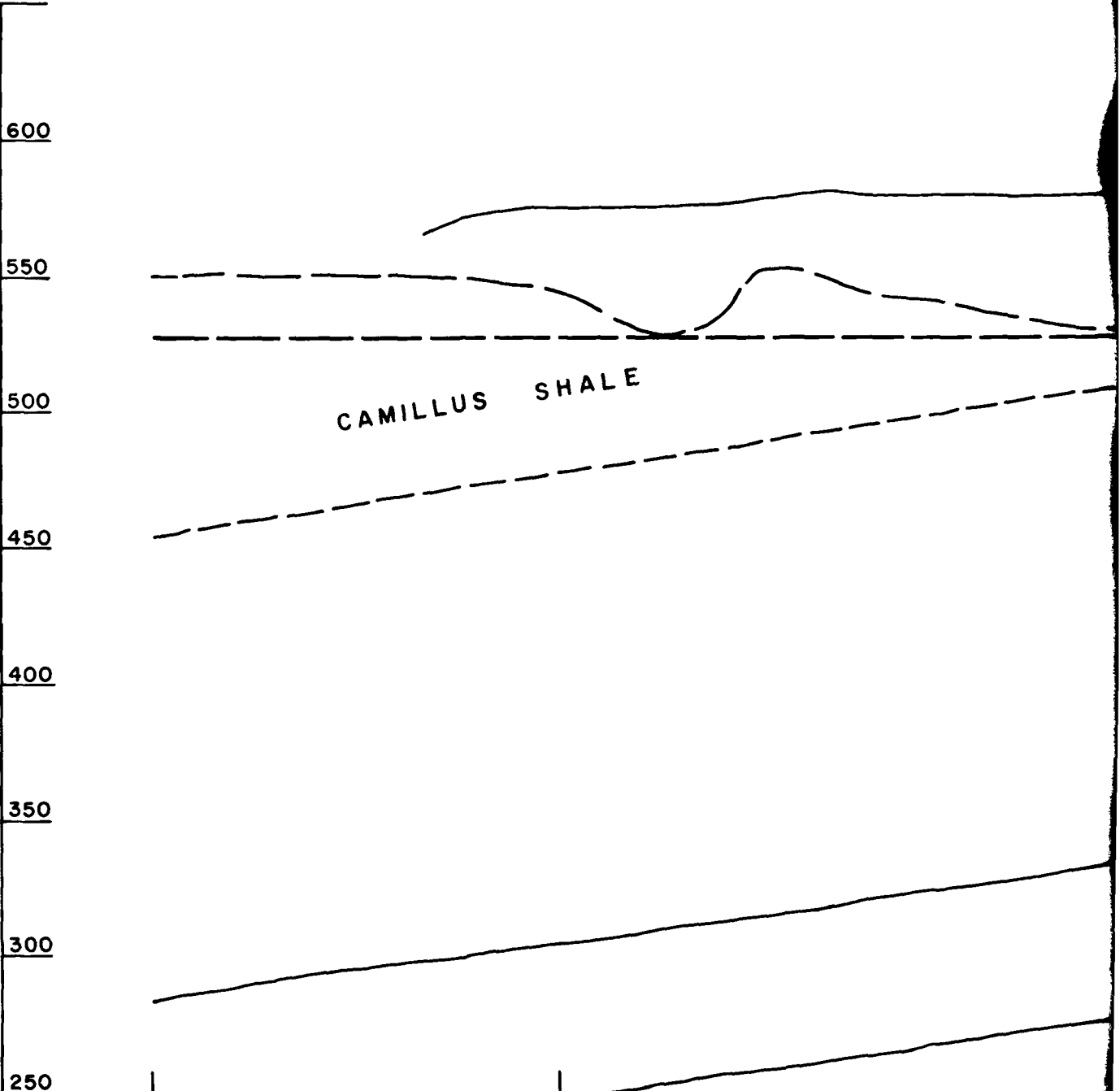
ELEVATION IN FEET I.G.L.D. (1955)

600  
550  
500  
450  
400  
350  
300  
250

1070+00

1100+00

CAMILLUS SHALE



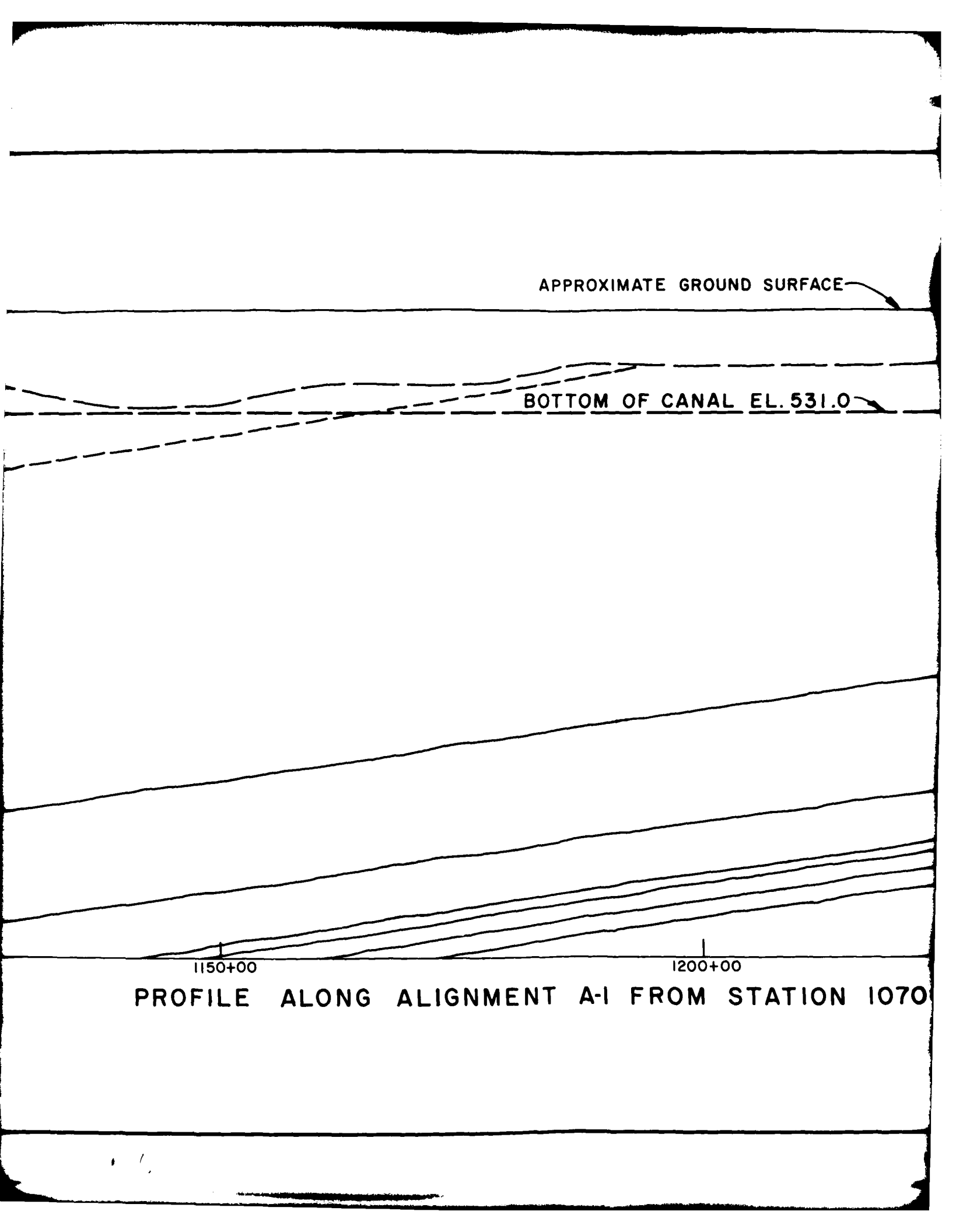
APPROXIMATE GROUND SURFACE

BOTTOM OF CANAL EL. 531.0

1150+00

1200+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1070



RFACE

531.0

APPROXIMATE TOP OF ROCK

LOCKPORT DOLOMI

ROCHESTER SH

REYNALES LIMESTONE

IRONDEQUOIT LIN

THOROLD SAND

GRIMSBY SAND

POWER GLEN S

1250+00

1300+

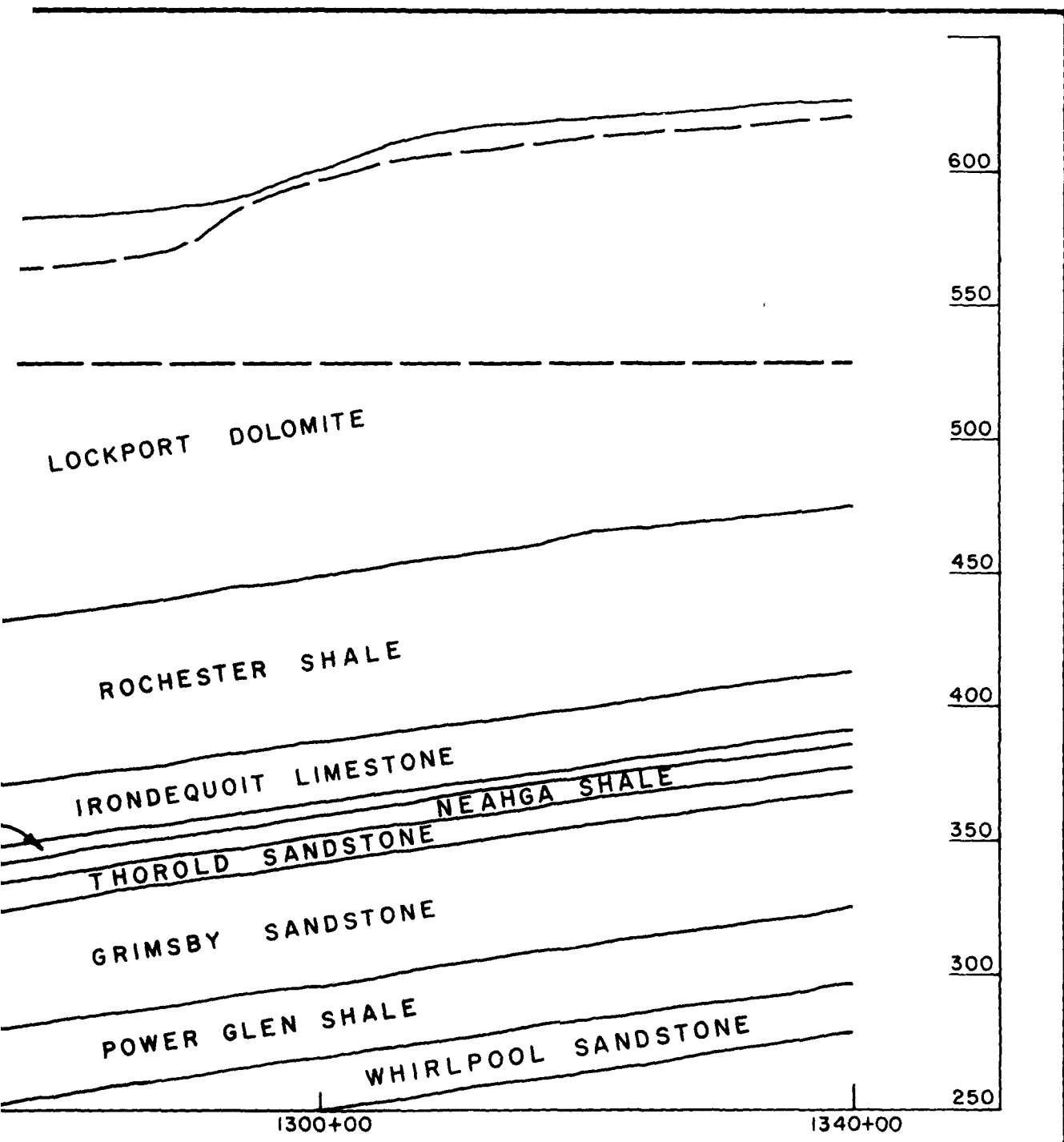
ATION 1070+00 TO 1340+00

SHEET INDEX

THIS PLATE B8	SEE PLATE B9	SEE PLATE B10
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NOTE:

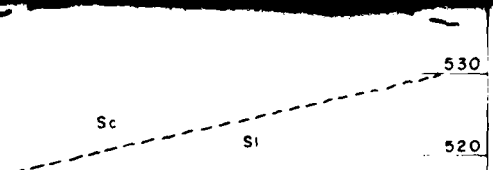
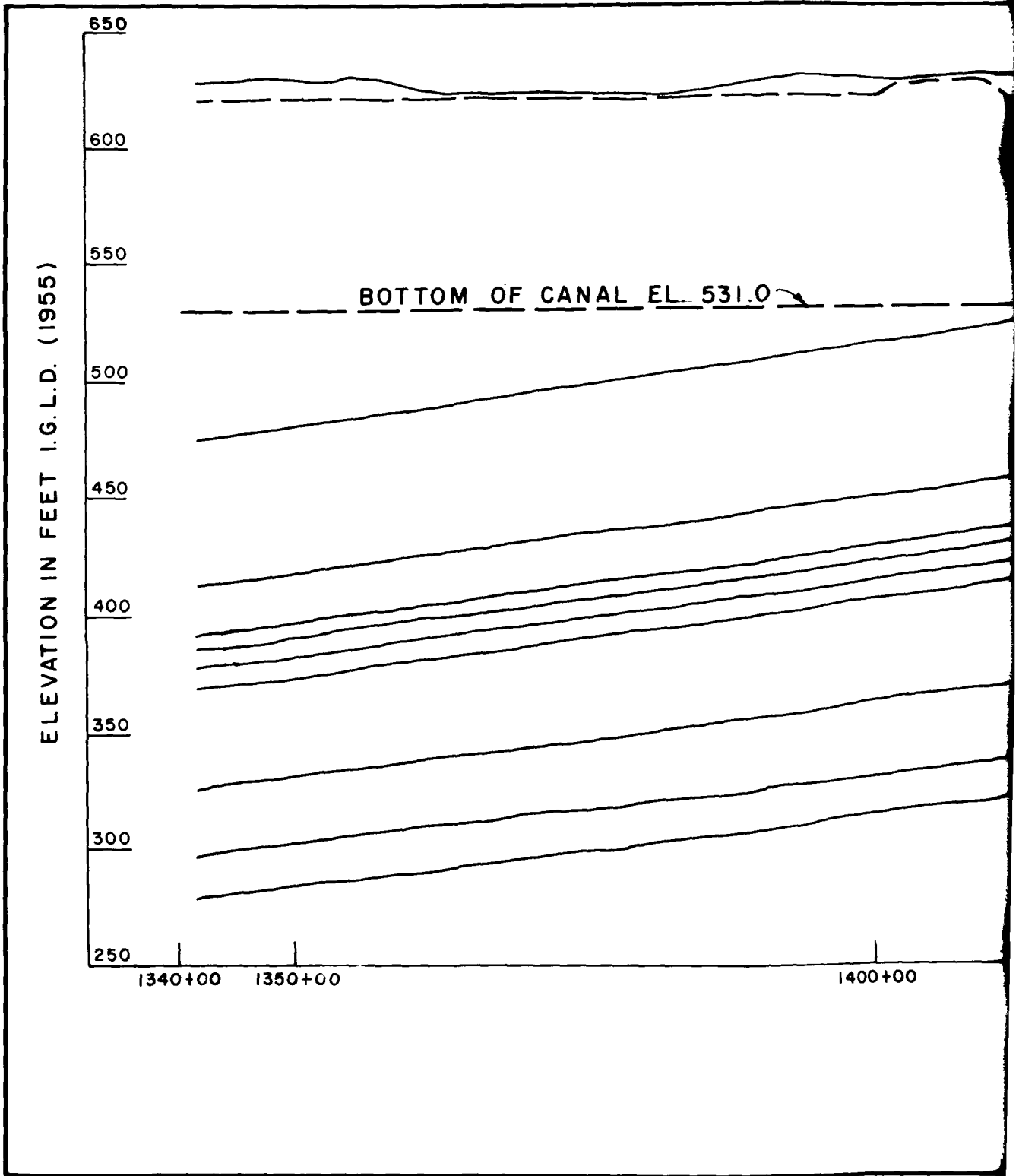
TOP OF  
FROM I  
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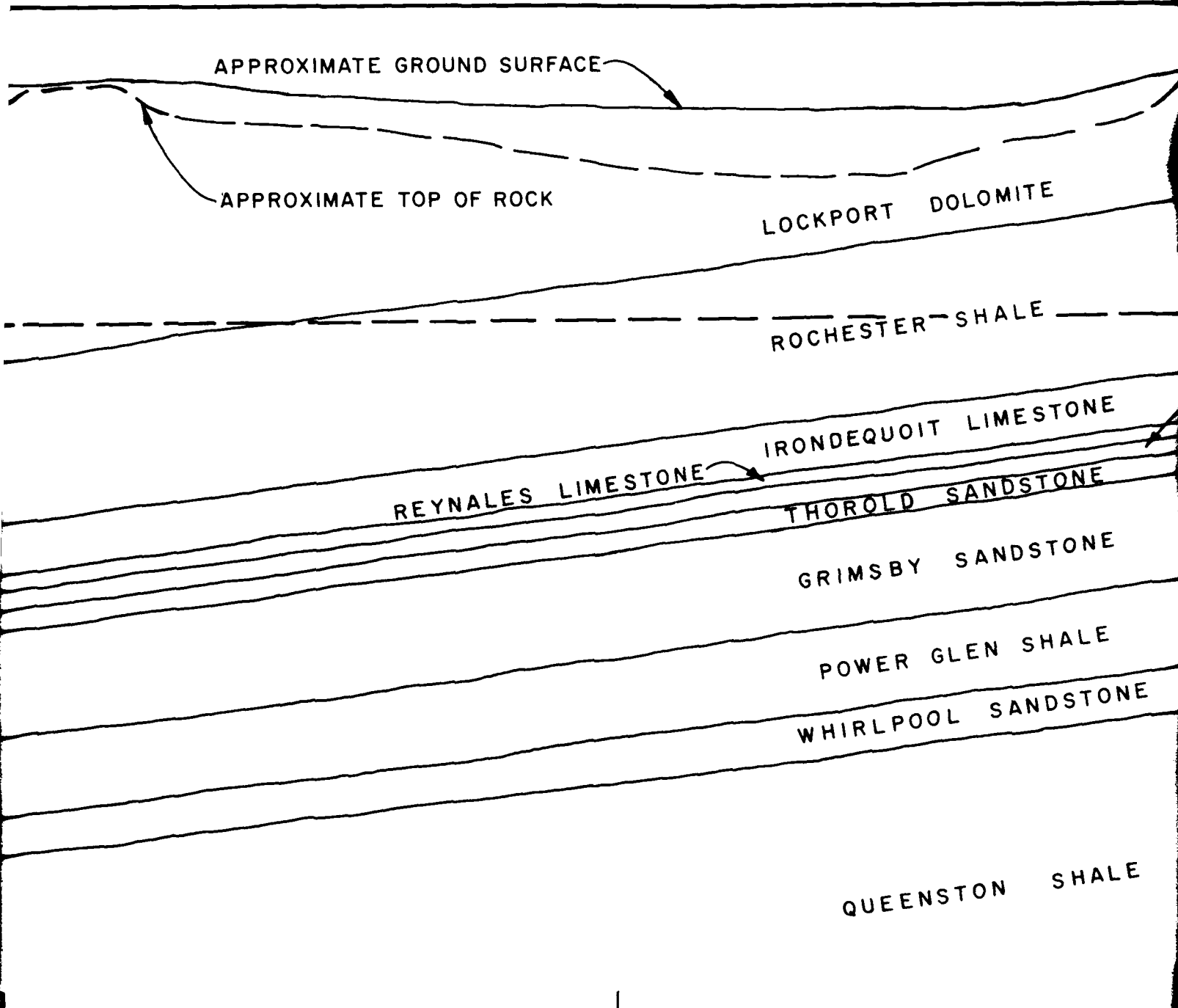


INDEX  
SEE PLATE  
B10

**NOTES:**  
TOP OF ROCK LINE DERIVED  
FROM PLATE B7  
FOR GENERALIZED GEOLOGIC  
COLUMN SEE PLATE B1

LAKE ERIE-LAKE ONTARIO WATERWAY  
**GEOLOGIC PROFILE  
ALONG OVERLAND SECTION**  
U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

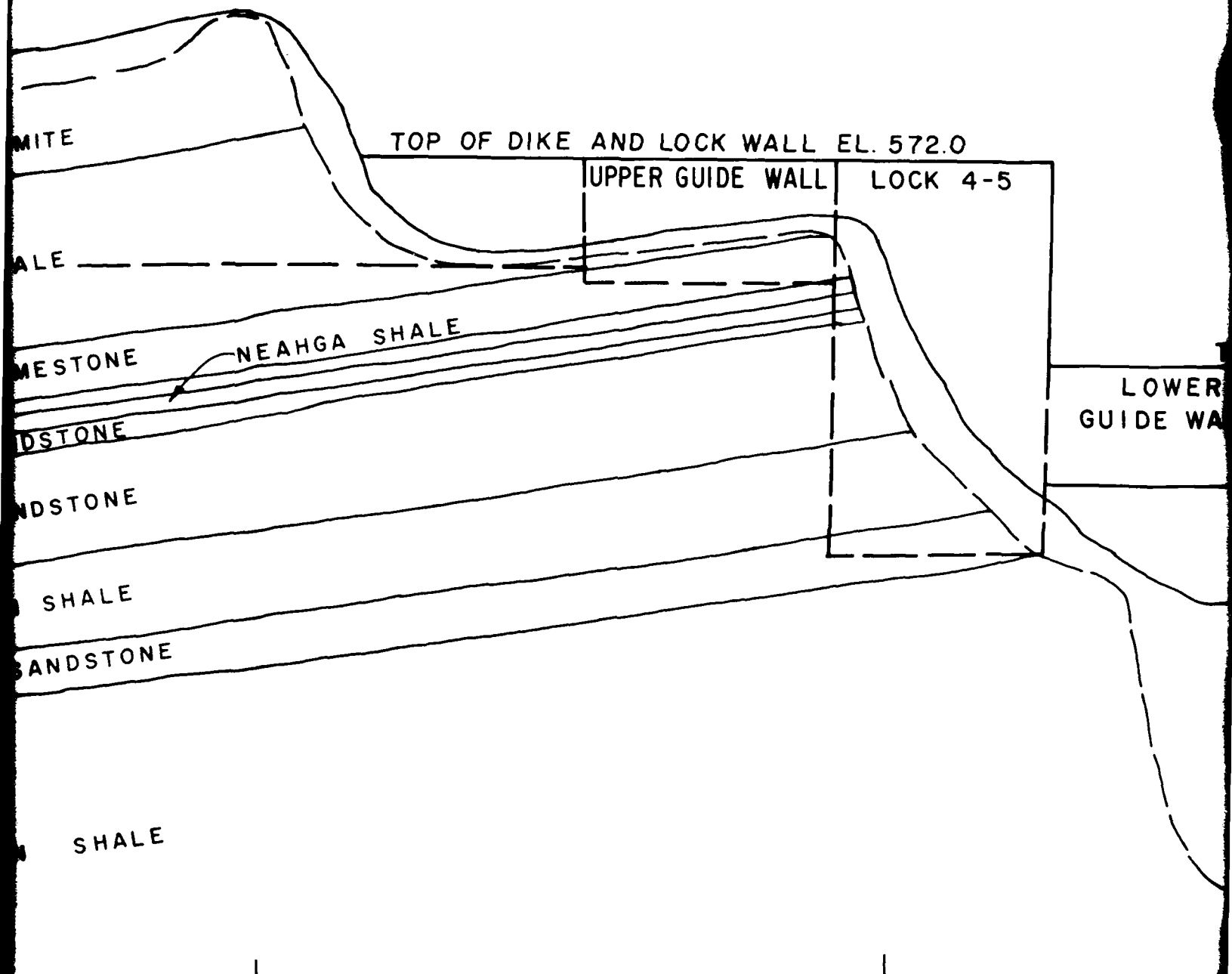




0+00

1450+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION



1500+00

1550+00

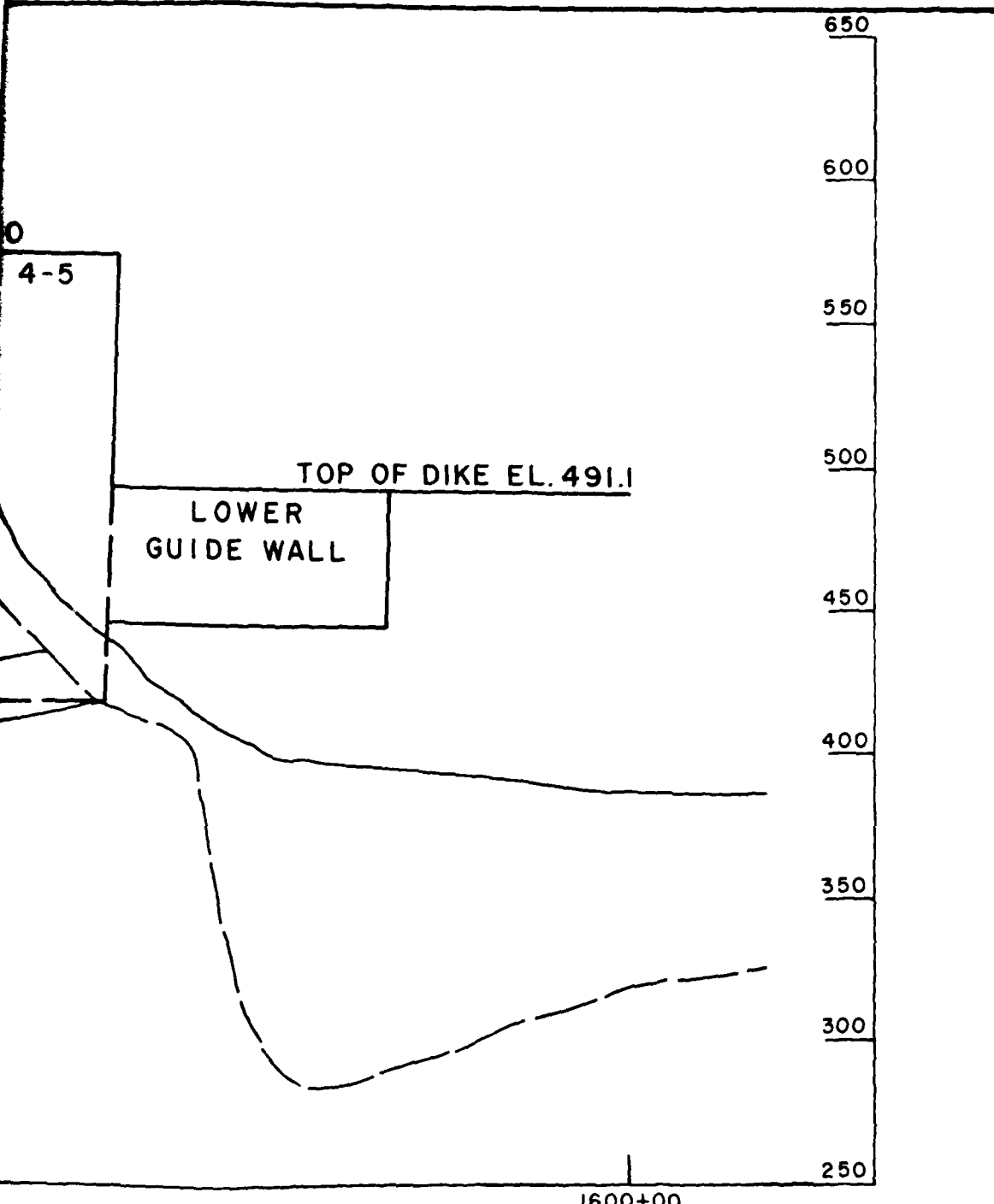
STATION 1340+00 TO 1600+00

SHEET INDEX

SEE PLATE 88	THIS PLATE 89	SEE PLATE 810
-----------------	------------------	------------------

NOTES:

TOP OF ROCK  
 FROM PLATE  
 FOR GENERAL  
 COLUMN SEE



**NOTES:**

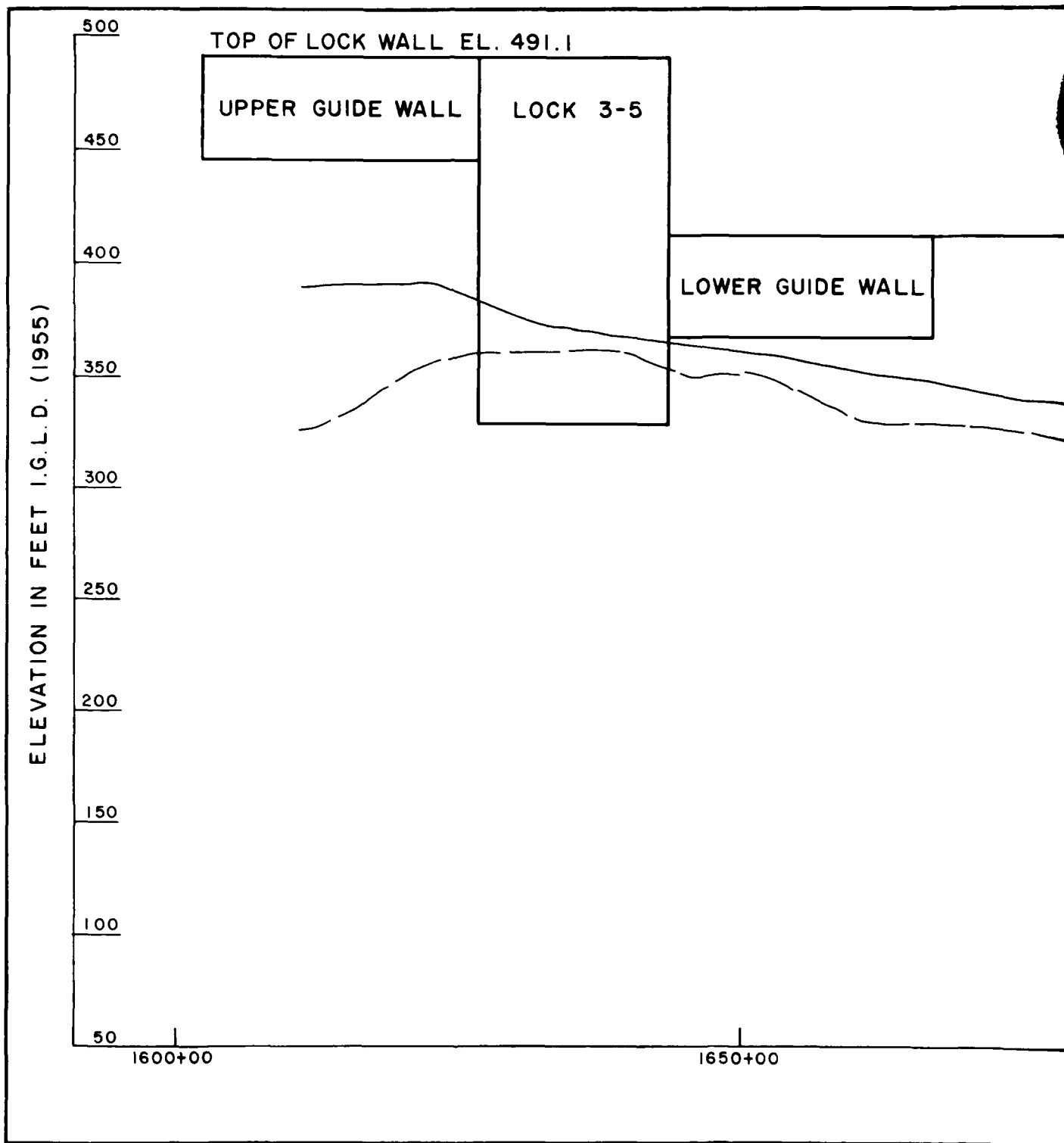
TOP OF ROCK LINE DERIVED FROM PLATE B7

FOR GENERALIZED GEOLOGIC COLUMN SEE PLATE B1

LAKE ERIE-LAKE ONTARIO WATERWAY

**GEOLOGIC PROFILE  
ALONG OVERLAND SECTION**

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973



TOP OF DIKE AND LOCK WALL EL. 411.4

APPROXIMATE GROUND SURFACE

1700+00

1750+00

PROFILE ALONG ALIGNM

4

UPPER GUIDE  
WALL

LOCK 2-5

LOWER GUIDE WALL

APPROXIMATE TOI

QUEENSTON SHALE

0

1800+00

1850+00

ALONG ALIGNMENT A-1 FROM STATION 1600+00 TO 1977+00

TOP OF DIKE AND LOCK WALL EL. 331.7

UPPER GUIDE  
WALL

LOCK 1-5

ESTIMATE TOP OF ROCK

1900+00

SHEET INDEX

SEE PLATE  
B8

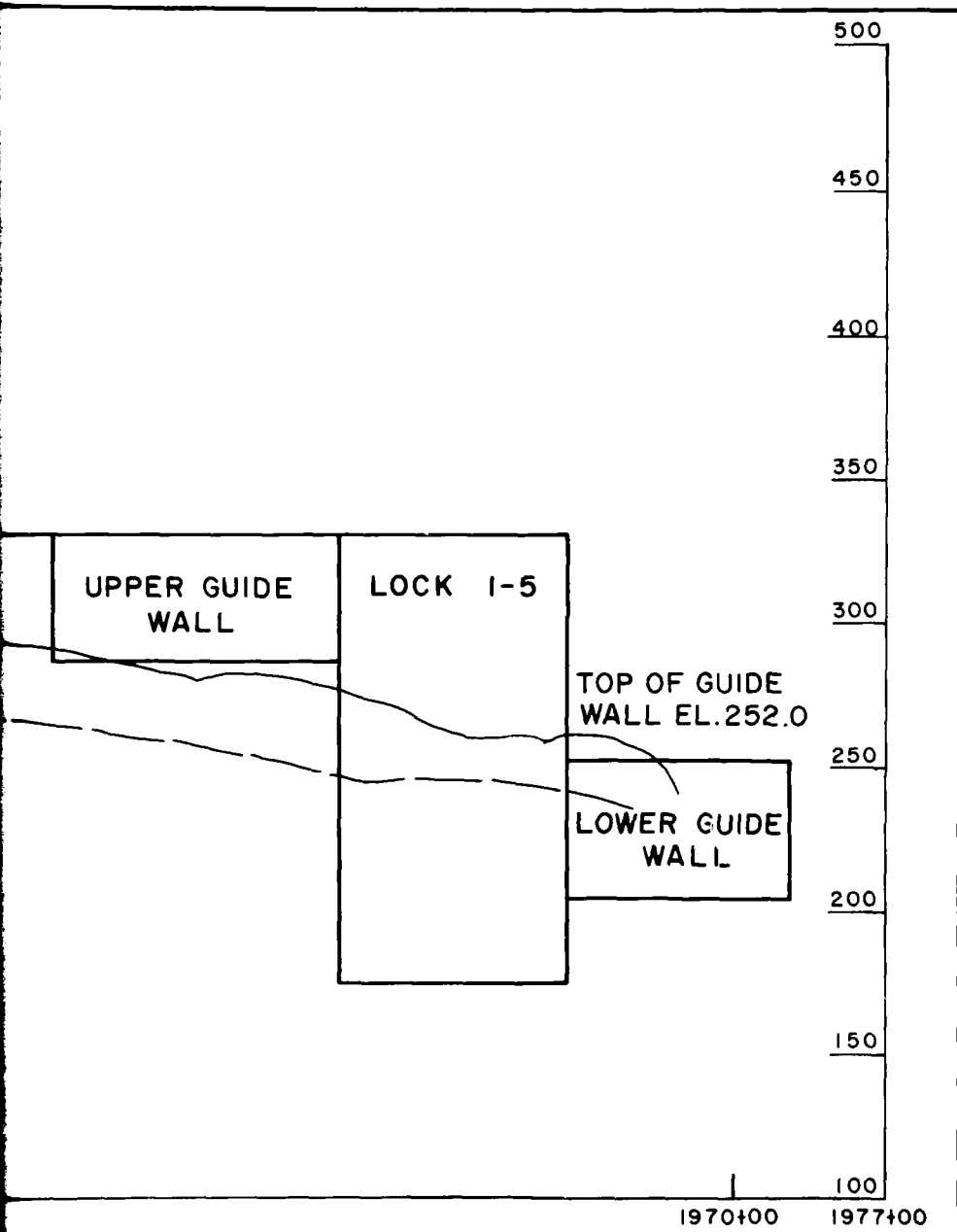
SEE PLATE  
B9

THIS PLATE  
B10

NOTES:

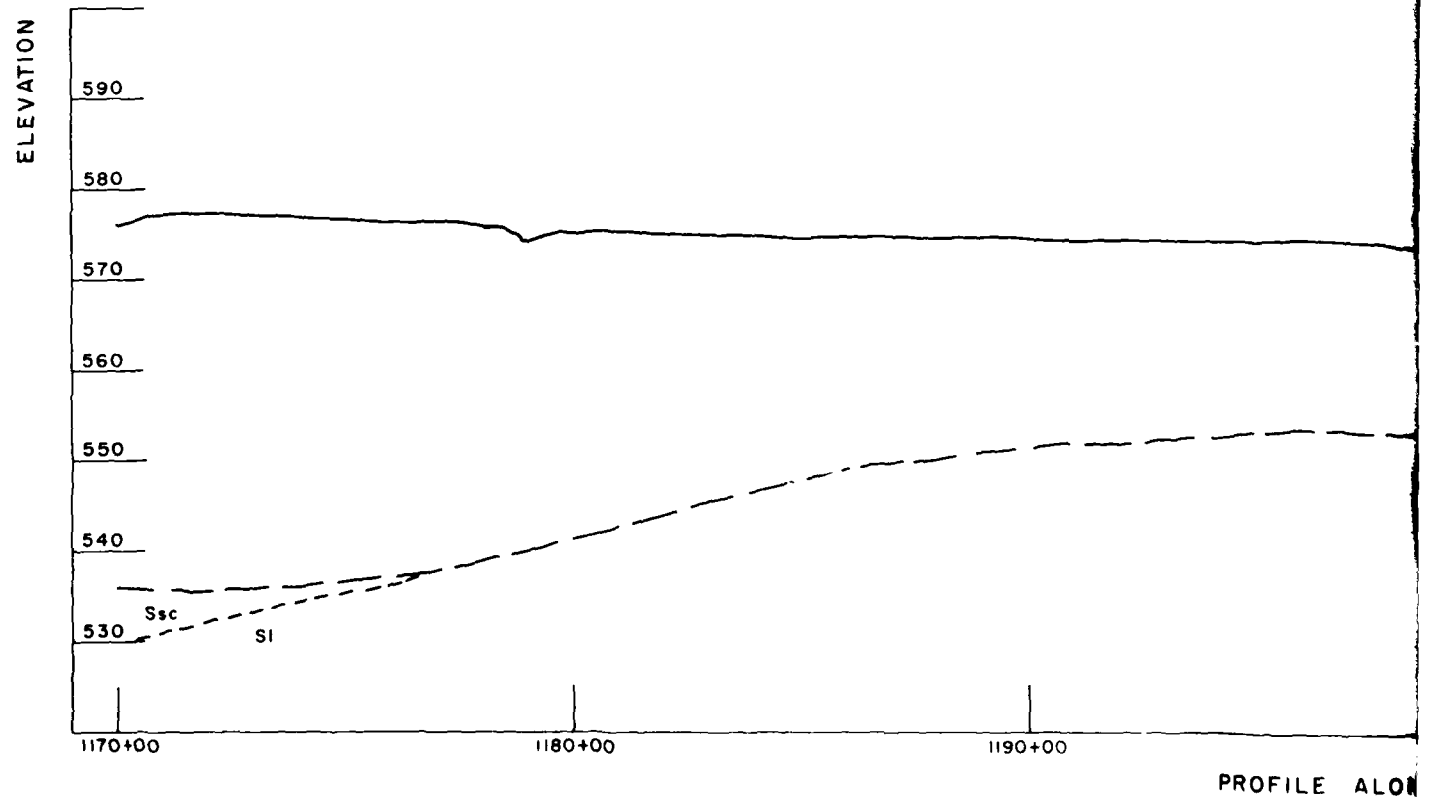
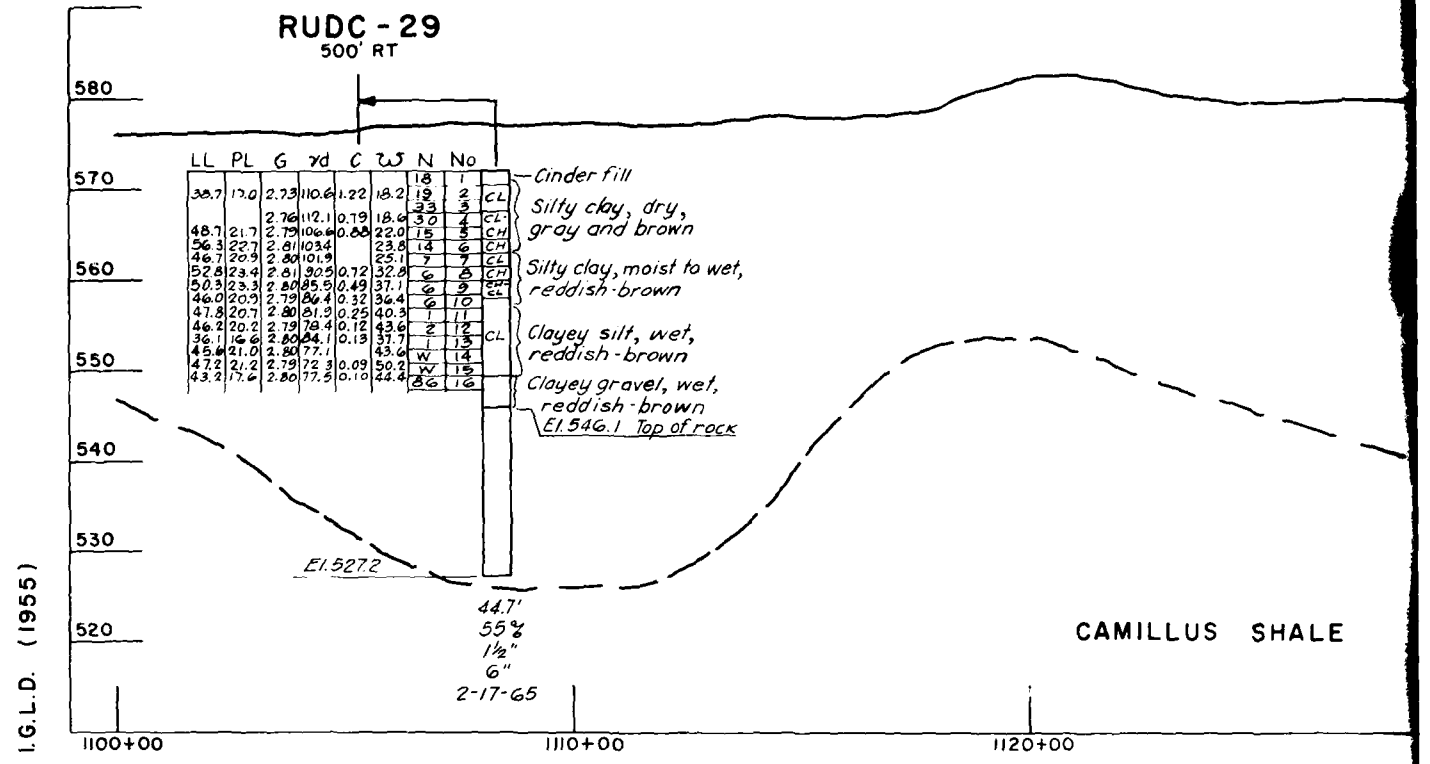
TOP OF ROCK LINE DERIVED  
FROM PLATE B7  
FOR GENERALIZED GEOLOGIC  
COLUMN SEE PLATE B1

LA  
A  
U.  
TC



**NOTES:**  
 TOP OF ROCK LINE DERIVED FROM PLATE B7  
 OR GENERALIZED GEOLOGIC PROFILE FROM SEE PLATE B1

LAKE ERIE-LAKE ONTARIO WATERWAY  
**GEOLOGIC PROFILE  
 ALONG OVERLAND SECTION**  
 U.S. ARMY ENGINEER DISTRICT, BUFFALO  
 TO ACCOMPANY REVIEW OF REPORTS  
 OCTOBER 1973



**LEGEND FOR LOGS OF BORINGS FOR SOIL PROFILES**

BORING NUMBER AND DESIGNATION \_\_\_\_\_ RUDC - 28  
 OFFSET FROM CENTERLINE CANAL \_\_\_\_\_ 100' RT

12

APPROXIMATE GROUND SURFACE

APPROXIMATE TOP OF ROCK

ILLINOIS SHALE

1130+00

1140+00

1150+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1100+00 TO 1170+00

RUDC-28  
100' LT

APPROXIMATE GROUND SURFACE

APPROXIMATE TOP OF ROCK

LOCKPORT DOLOMITE

1200+00

1210+00

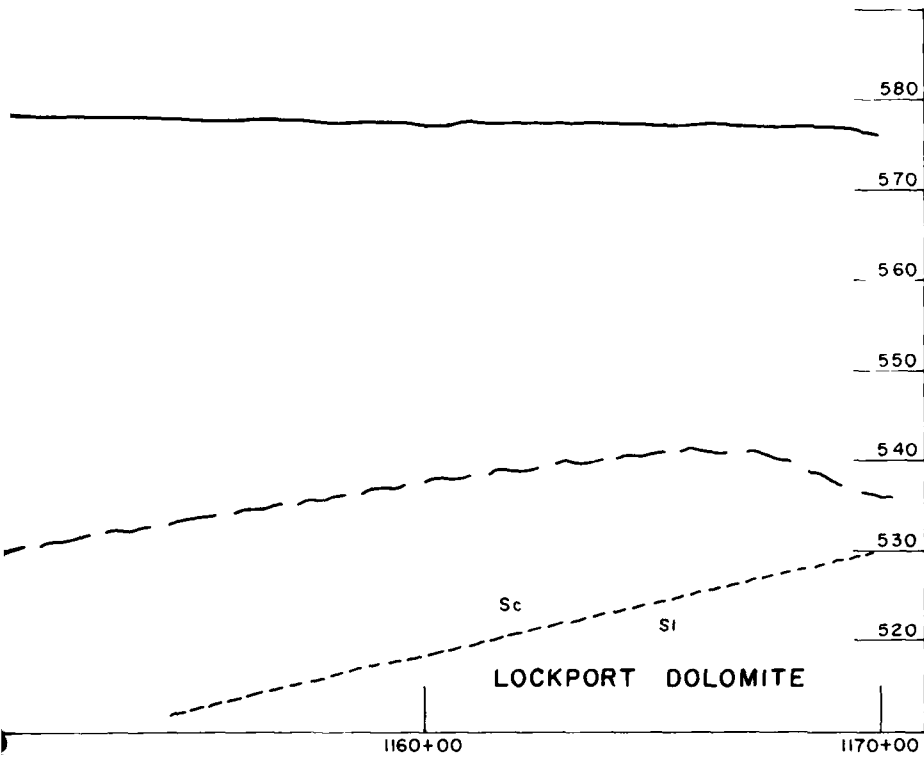
1220+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1170+00 TO 1240+00

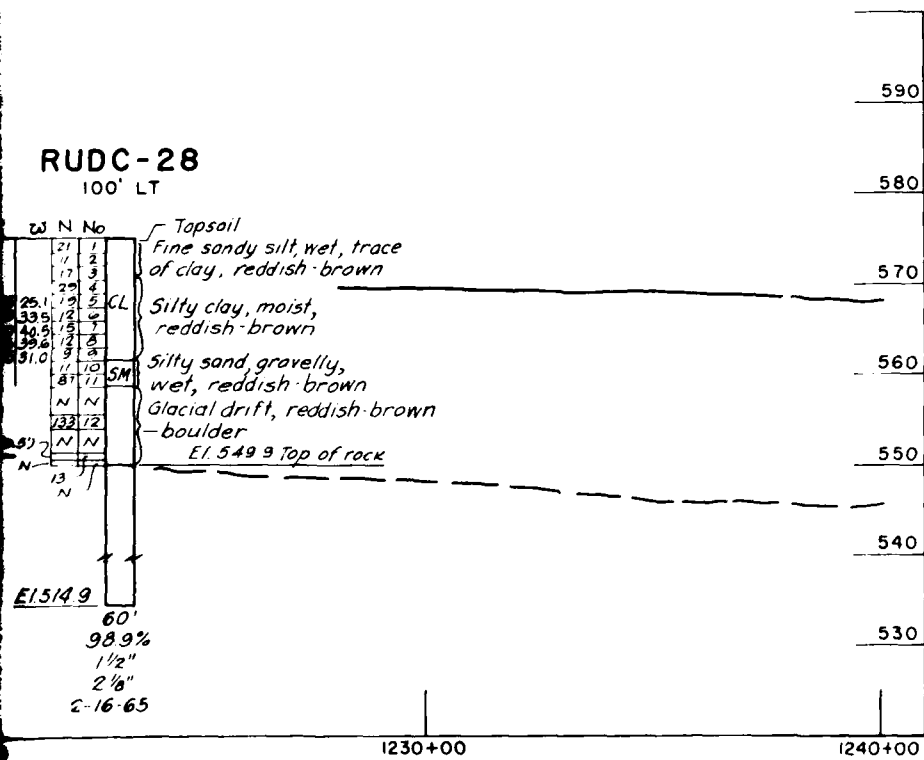
Station	Depth (ft)	Soil Description	Notes
1170+00	0	Topsoil	
1170+00	1	fine sandy silty clay	reddish-brown
1170+00	2	Silty clay, moist	reddish-brown
1170+00	3	Silty sand, gravelly	wet, reddish-brown
1170+00	4	gravelly silt, red	boulder
1170+00	5	Lockport Dolomite	49 ft top

**NOTES:**

FOR LOCATION OF BORINGS SEE PLATE B5.  
FOR UNIFIED SOIL CLASSIFICATION SYSTEM AND



**RUDC-28**  
100' LT





APPROXIMATE TOP OF ROCK

S SHALE

1130+00

1140+00

1150+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1100+00 TO 1170+00

RUDC-28  
100' LT

APPROXIMATE GROUND SURFACE

APPROXIMATE TOP OF ROCK

LOCKPORT DOLOMITE

LL	PL	G	yd	C	W	N	No	
							21	1
							7	2
							17	3
							29	4
47.1	21.8	2.78	100.6	0.45	25.1	19	5	CL
45.2	19.5	2.80	89.3	0.40	33.5	12	6	Silty clay, moist, reddish-brown
42.3	20.0	2.79	81.2	0.20	40.5	15	7	
40.5	19.1	2.80	82.2	0.15	39.6	12	8	
33.2	16.3	2.76	89.4	0.045	31.0	9	9	
						17	10	SM
						87	17	
						N	N	
						133	12	
						N	N	
						N	N	
						221(0.5)		
						N	N	
						13		
						N		

Topsoil  
 Fine sandy silt, wet, tr of clay, reddish-brown  
 Silty clay, moist, reddish-brown  
 Silty sand, gravelly, wet, reddish-brown  
 Glacial drift, reddish-boulder  
 E1.549.9 Top of rock  
 E1514.9  
 60'  
 98.9%  
 1 1/2"  
 2 1/8"  
 2-16-65

1200+00

1210+00

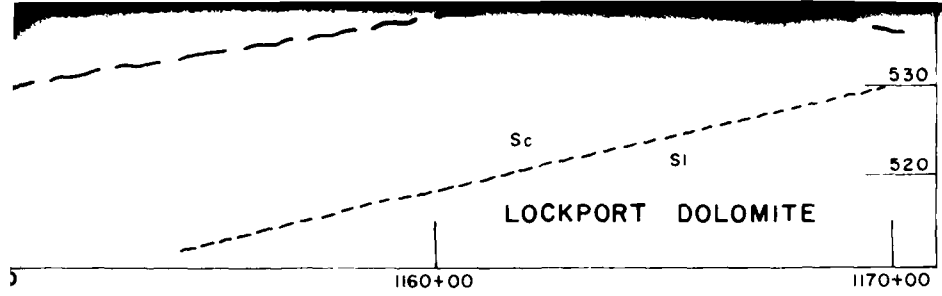
1220+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1170+00 TO 1240+00

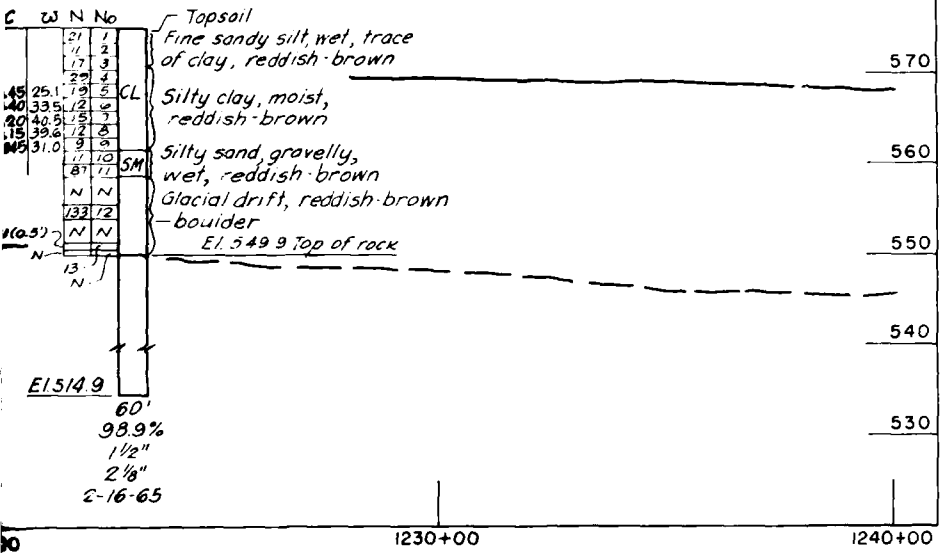
**NOTES:**

- FOR LOCATION OF BORINGS SEE PLATE B5.
- FOR UNIFIED SOIL CLASSIFICATION SYSTEM AND BORING DESIGNATIONS SEE PLATE B1.
- ALL DRIVE SAMPLES WERE OBTAINED WITH A 1 1/2" I.D. STANDARD SPLIT SPOON SAMPLER ADVANCED BY A 140 LB. HAMMER FALLING 30".
- BLOW COUNTS INDICATE THE RELATIVE RESISTANCE OF THE SOIL TO PENETRATION BY THE SAMPLER.
- TOP OF ROCK LINE DERIVED FROM PLATE B7.
- ROCK CORE INFORMATION FROM BOREHOLES WITHIN STATIONING OF LOCKS AND THEIR GUIDE WALLS ARE GIVEN ON PLATES B20, B21, B22, B23 AND B24.
- COMPLETE TEST DATA SUMMARY FOR UNDISTURBED SAMPLES ARE GIVEN ON TABLE B3.

SO  
ST



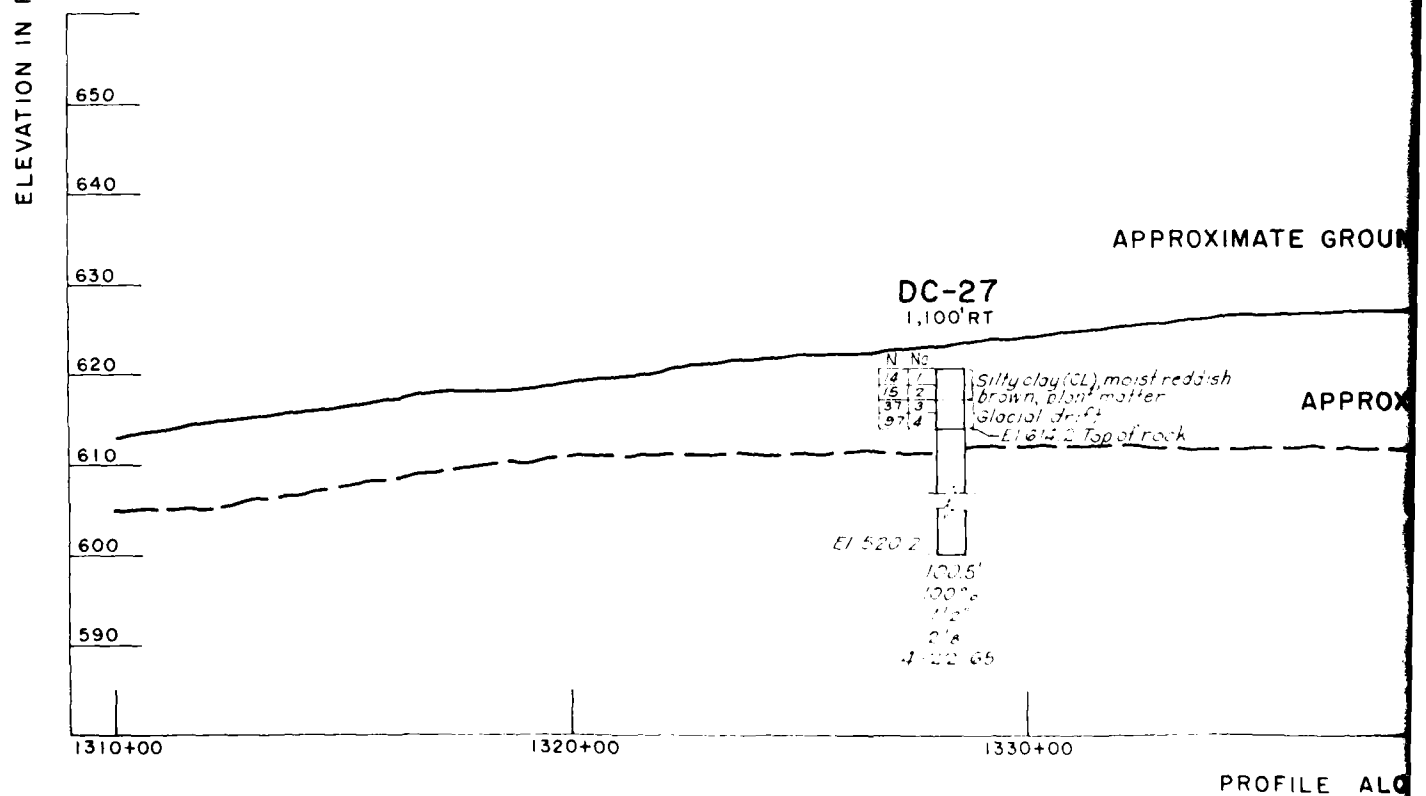
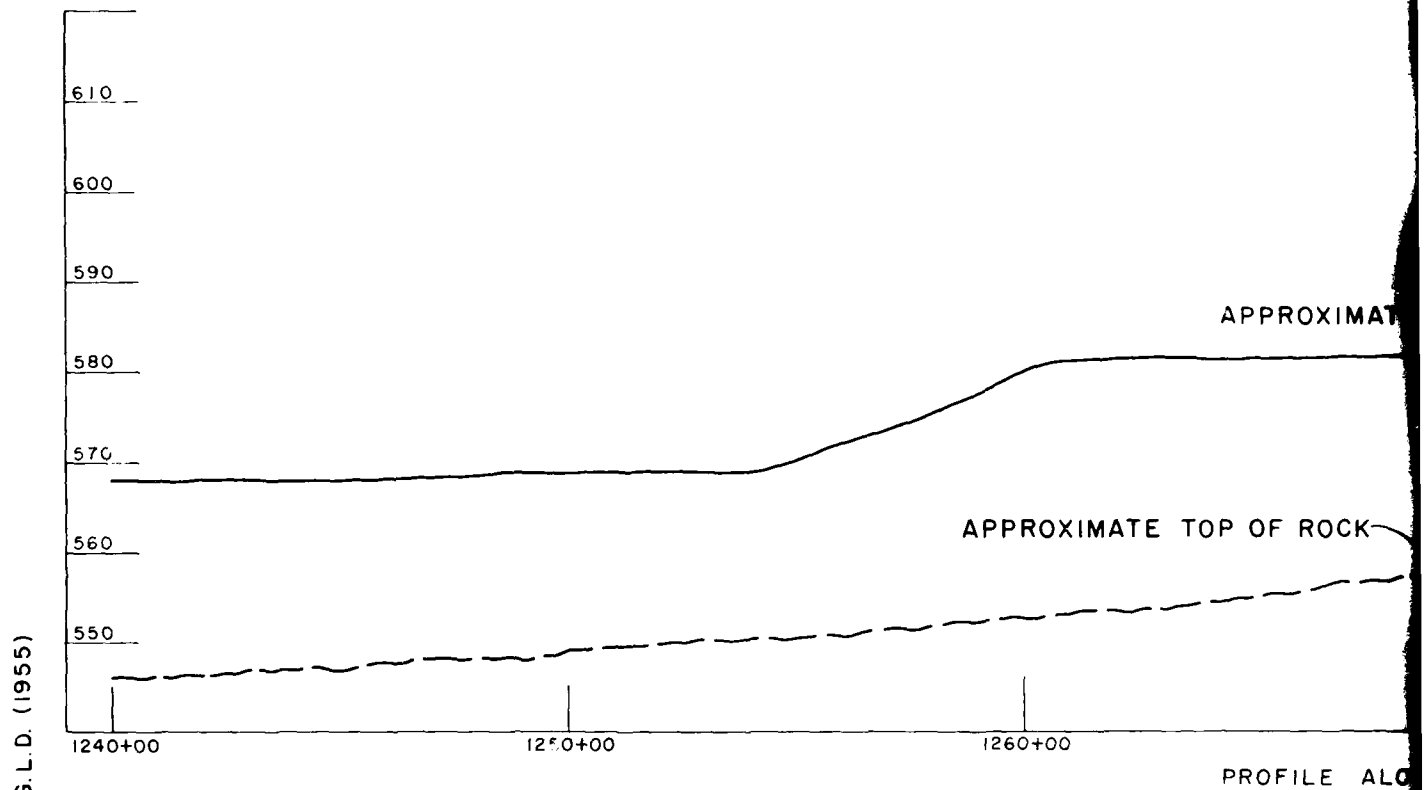
**RUDC-28**  
100' LT



LAKE ERIE-LAKE ONTARIO WATERWAY

**SOIL PROFILE OF OVERLAND SECTION  
STATION 1100+00 TO 1240+00 & CANAL**

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973



APPROXIMATE GROUND SURFACE

APPROXIMATE TOP OF ROCK

1270+00

1280+00

1290+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1240+00 TO 1310+00

APPROXIMATE GROUND SURFACE

*moist reddish  
mudstone  
top of rock*

APPROXIMATE TOP OF ROCK

1340+00

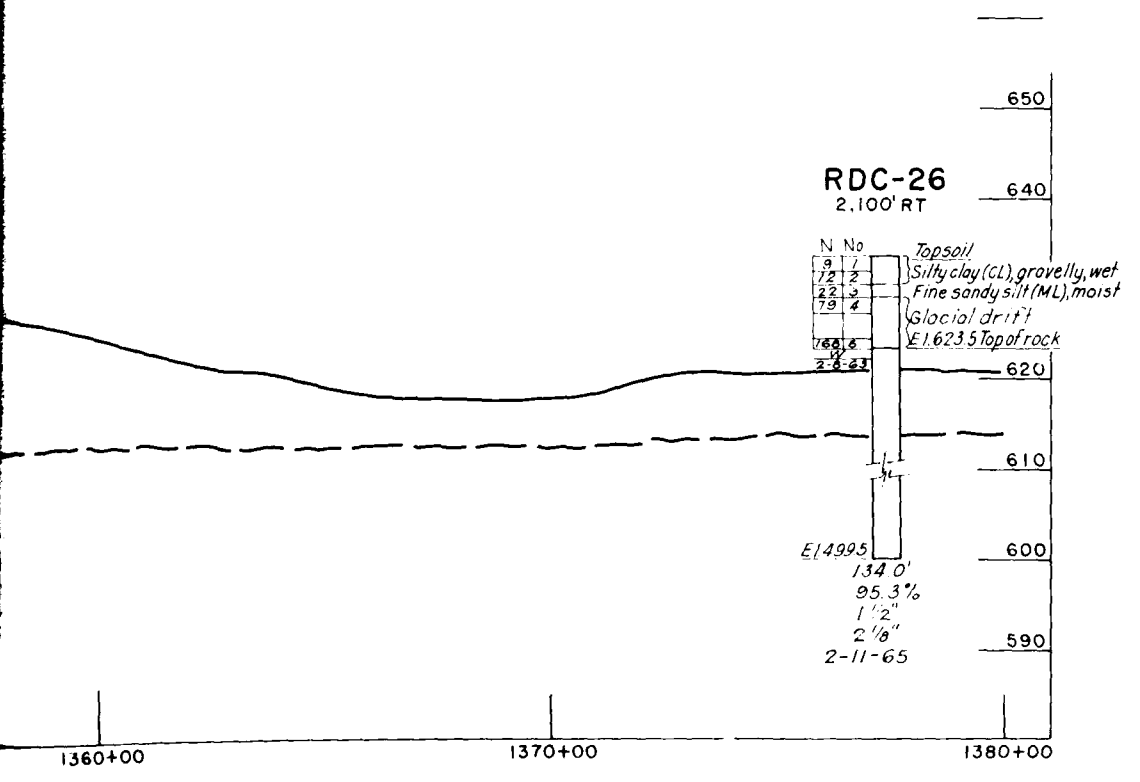
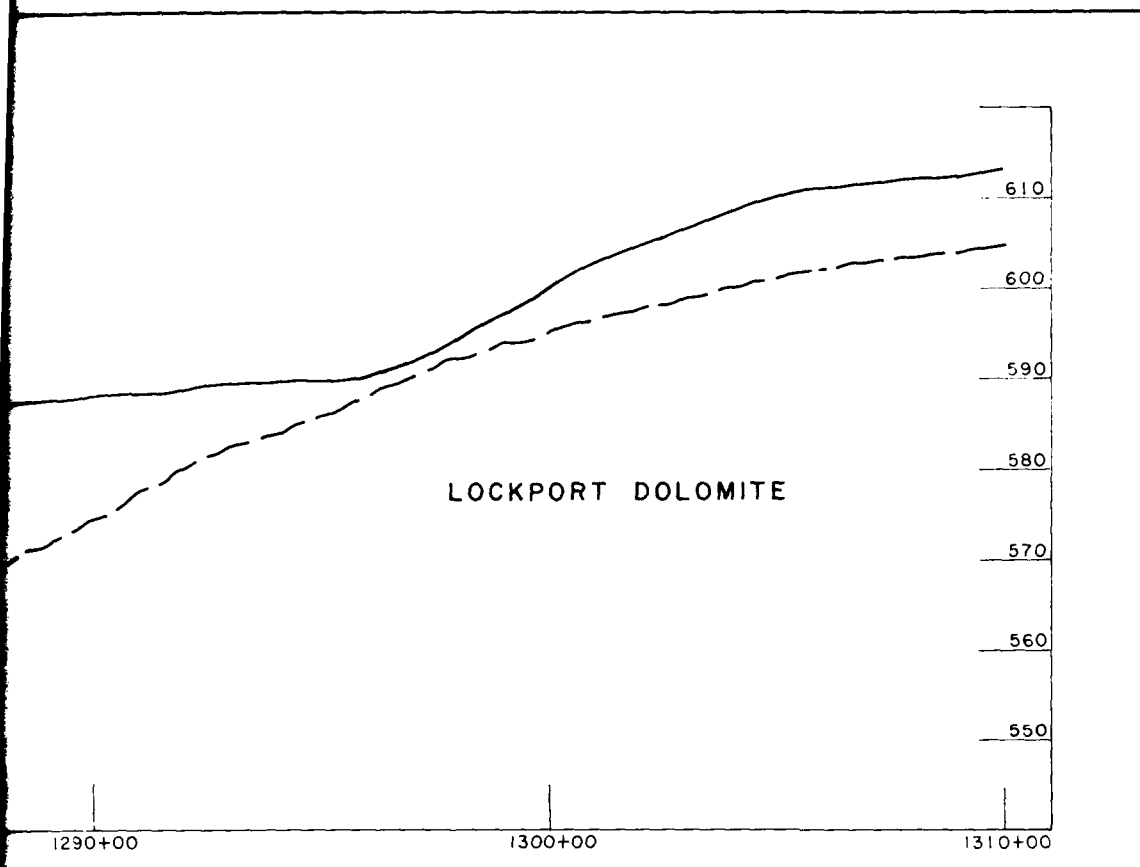
1350+00

1360+00

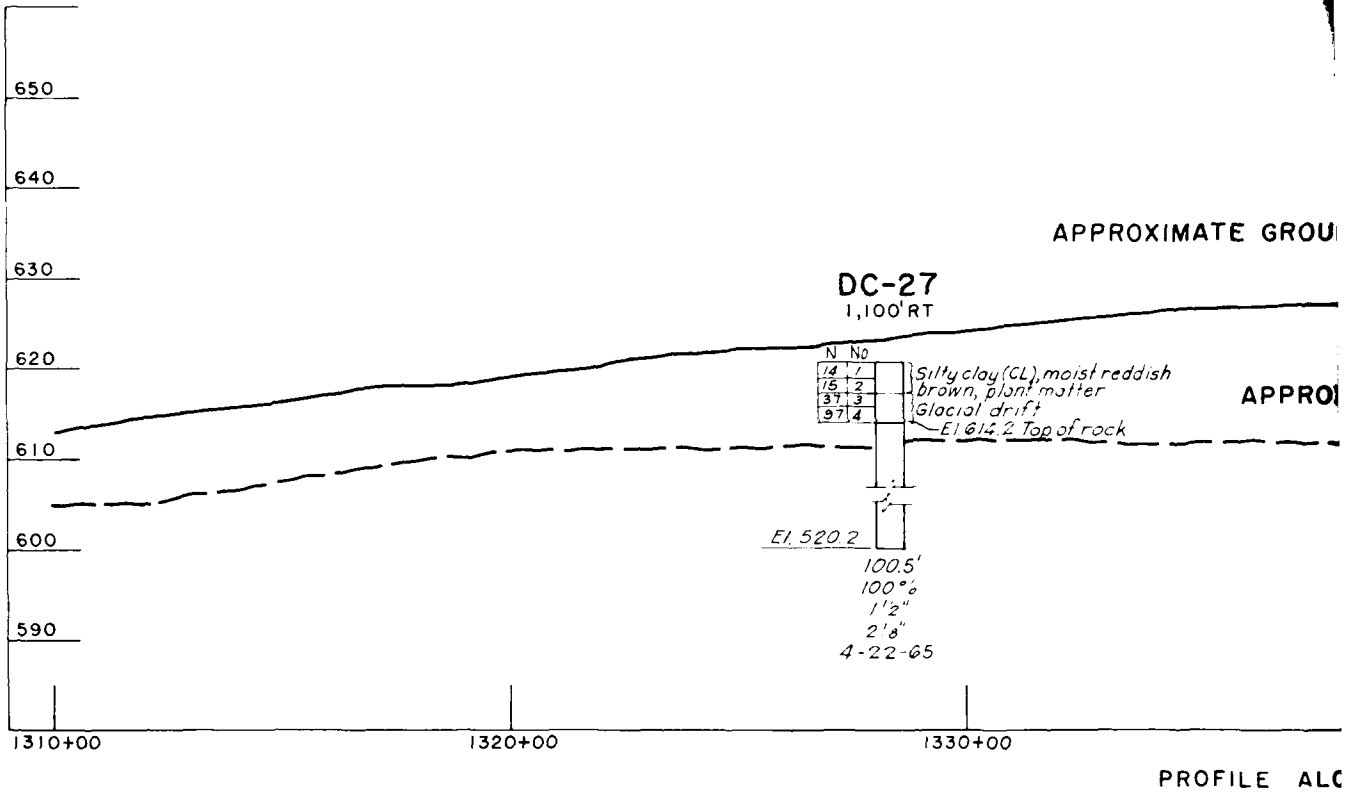
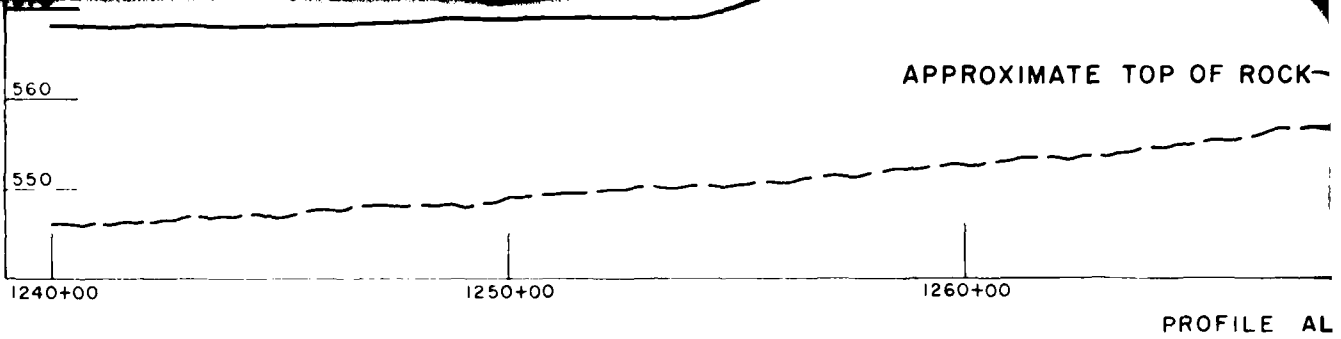
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1310+00 TO 1380+00

LOCKPORT DOLOMITE

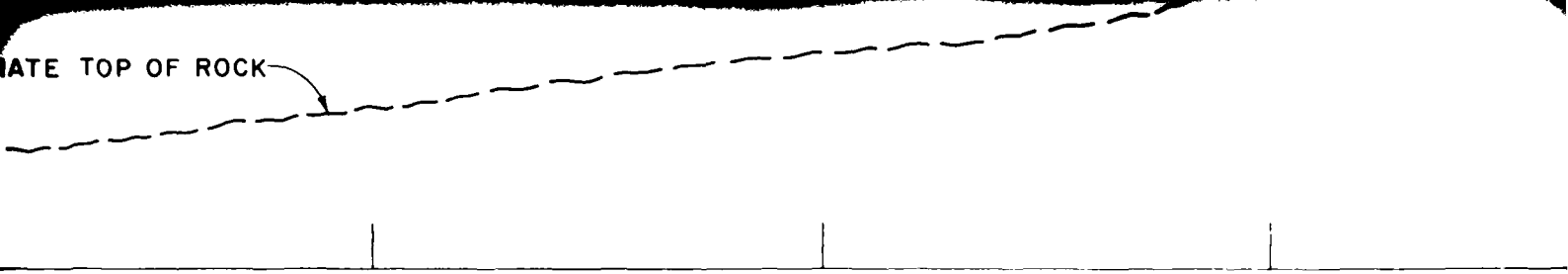
NOTES:



ELEVATION IN FEET I.G.L.D. (1955)



APPROXIMATE TOP OF ROCK



1270+00

1280+00

1290+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1240+00 TO 1310+00

APPROXIMATE GROUND SURFACE



APPROXIMATE TOP OF ROCK

moist reddish  
matter  
of rock

LOCKPORT DOLOMITE

1340+00

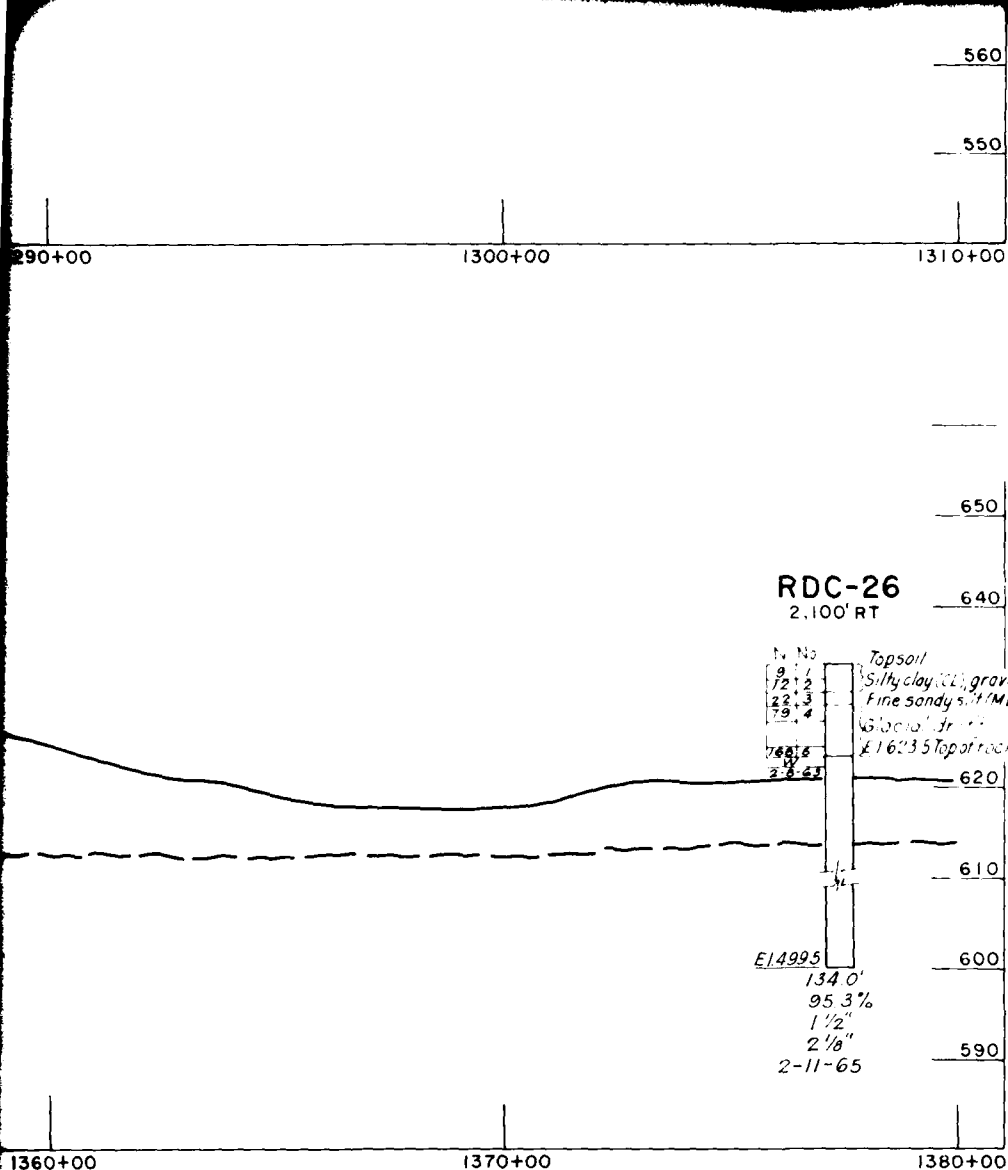
1350+00

1360+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1310+00 TO 1380+00

**NOTES:**

FOR LOCATION OF BORINGS SEE PLATE B3.  
FOR LEGEND OF SOIL PROFILES AND NOTES  
FOR LOGS OF BORINGS SEE PLATE B11

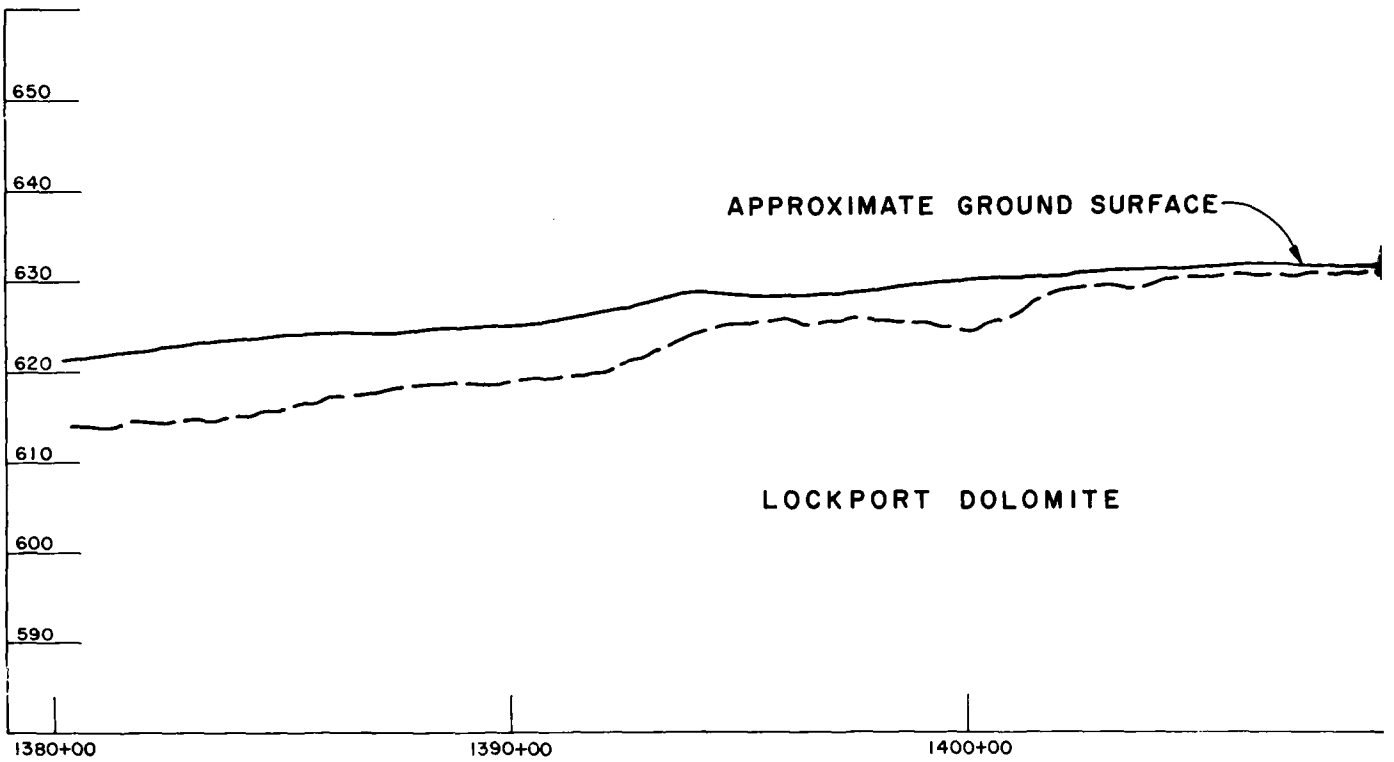


LAKE ERIE-LAKE ONTARIO WATERWAY

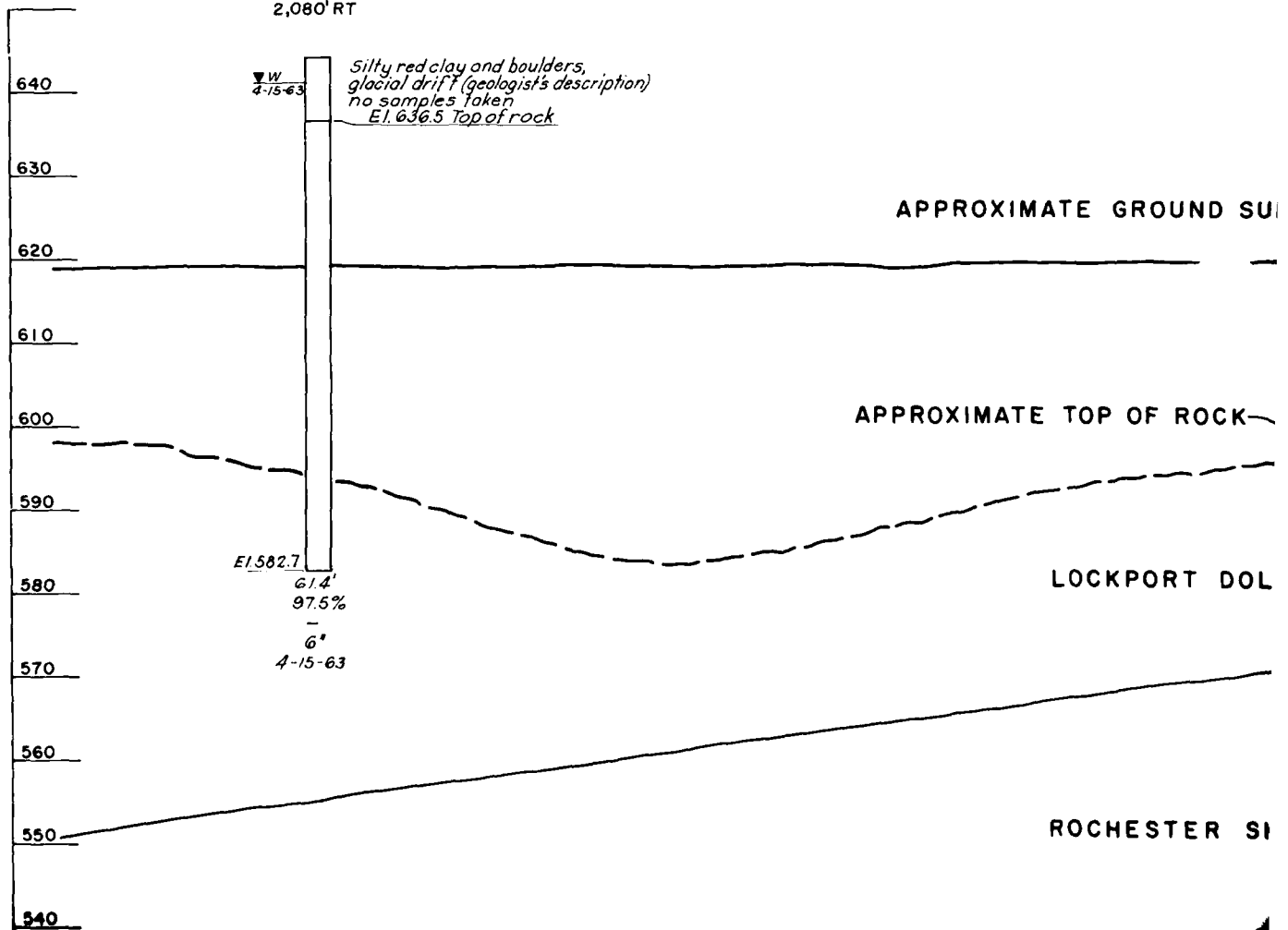
**SOIL PROFILE OF OVERLAND SECTION  
STATION 1875+00 TO 1980+00 & CANAL**

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

ELEVATION IN FEET I.G.D.A. (1955)



RC-24  
2,080' RT



**RDC-25**  
2,780' RT

N No.	Topsoil
77 1	Fill, sand, gravel, cobbles
77 2	
N N	El. 646.4 Top of rock

W  
1-14-65

El. 399.9  
151.5'  
98.2%  
1 1/2"  
2 1/8"  
1-21-65

SURFACE

APPROXIMATE TO

1410+00

1420+00

1430+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1380+00 TO 1450+00

APPROXIMATE GROUND SURFACE

APPROXIMATE TOP OF ROCK

LOCKPORT DOLOMITE

ROCHESTER SHALE

640

630

620

610

600

590

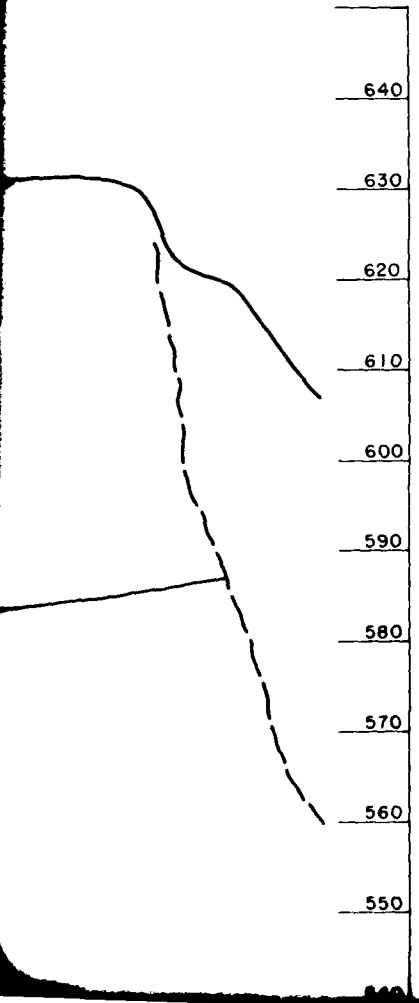
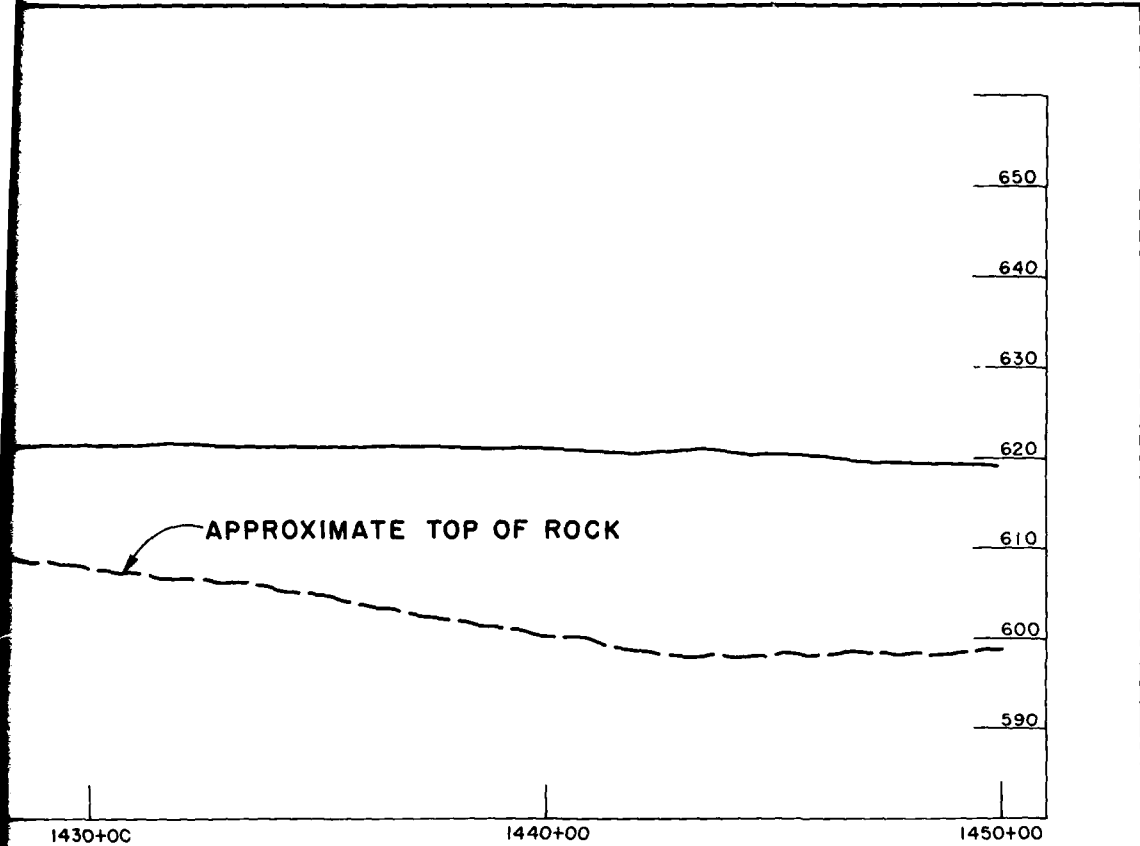
580

570

560

550

540



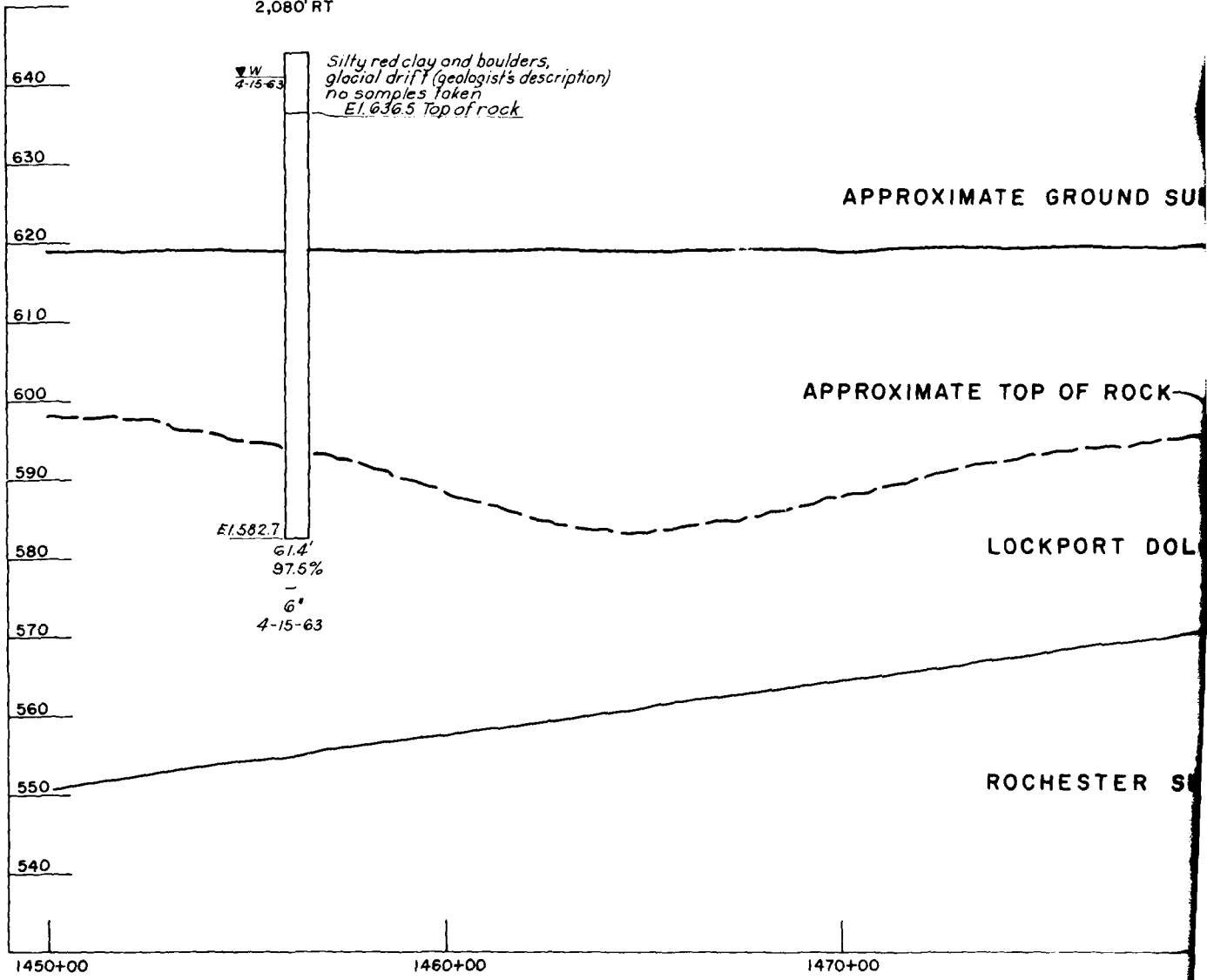
LOCKPORT DOLOMITE

ELEVATION IN FEET I.G.D.A. (1955)



PROFILE ALONG

RC-24  
2,080' RT



PROFILE ALONG ALIGNMENT A-1 FROM

E/399.8

151.5'  
98.2%  
1 1/2"  
2 1/8"  
1-21-65

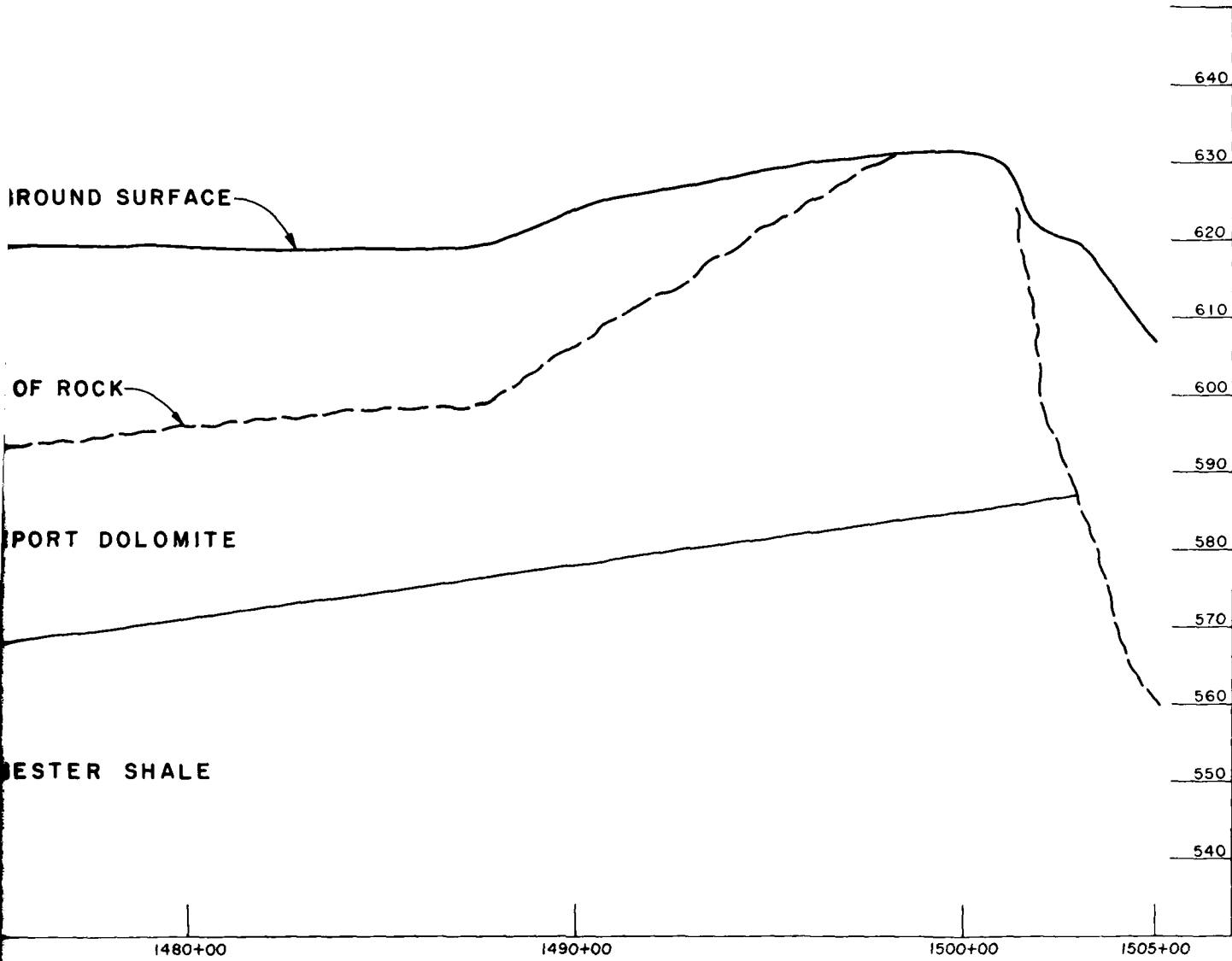
1410+00

1420+00

1430+00

1440+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1380+00 TO 1450+00



GROUND SURFACE

TOP OF ROCK

TOP OF PORT DOLOMITE

TOP OF WESTER SHALE

1480+00

1490+00

1500+00

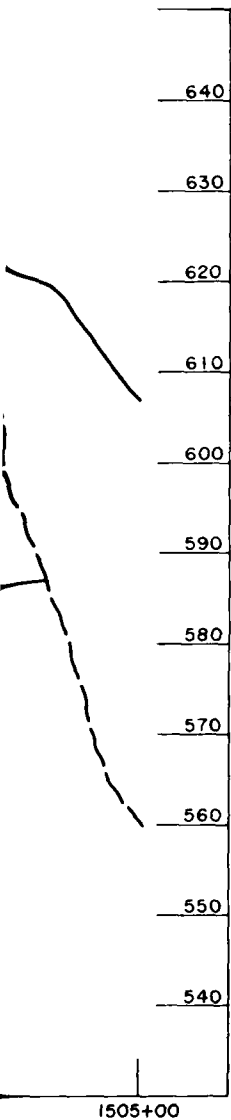
1505+00

PROFILE ALONG ALIGNMENT A-1 FROM STATION 1450+00 TO 1505+00

**NOTES:**

FOR LOCATION OF BORINGS SEE PLATE B3.  
FOR LEGEND OF SOIL PROFILES AND NOTES  
FOR LOGS OF BORINGS SEE PLATE B11.

LAK  
SOIL P  
STATION  
U. S. A  
TO AC

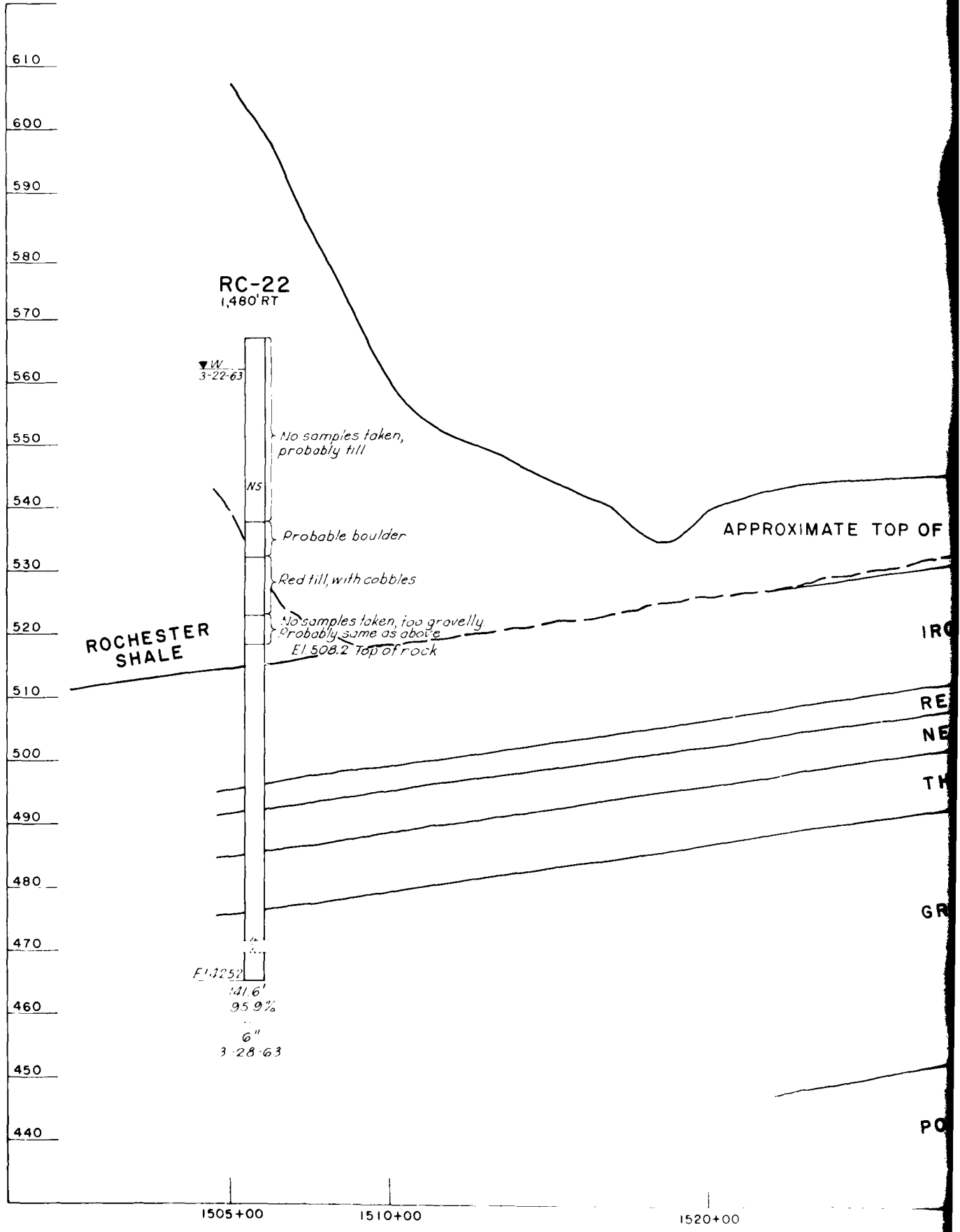


LAKE ERIE-LAKE ONTARIO WATERWAY

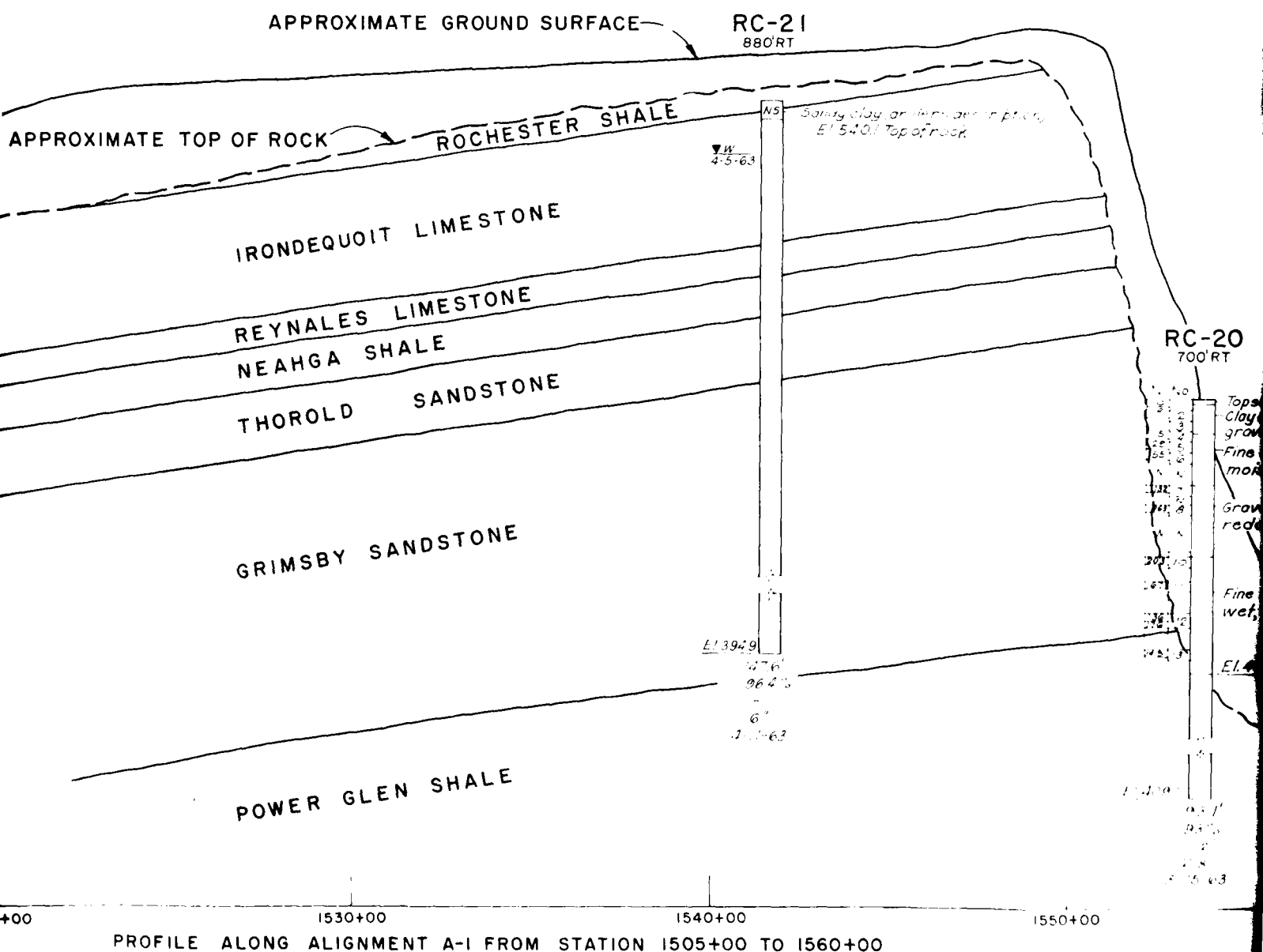
**SOIL PROFILE OF OVERLAND SECTION  
STATION 1380+00 TO 1505+00 & CANAL**

U. S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

ELEVATION IN FEET I.G.L.D. (1955)



PROFILE ALO





ELEVATION IN FEET I.G.L.D. (1955)

570  
560  
550  
540  
530  
520  
510  
500  
490  
480  
470  
460  
450  
440

W  
3-22-63

No samples taken,  
probably till

NS

Probable boulder

Red till, with cobbles

No samples taken, too gravelly  
Probably same as above  
El. 508.2 Top of Rock

ROCHESTER  
SHALE

APPROXIMATE TOP OF ROCK

IRONDEQUOIT

REYNOLDS

NEAUGUSSETT

THOROLD

GRIMSBY

EL. 465.2  
141.6'  
95.9%  
6"  
3-28-63

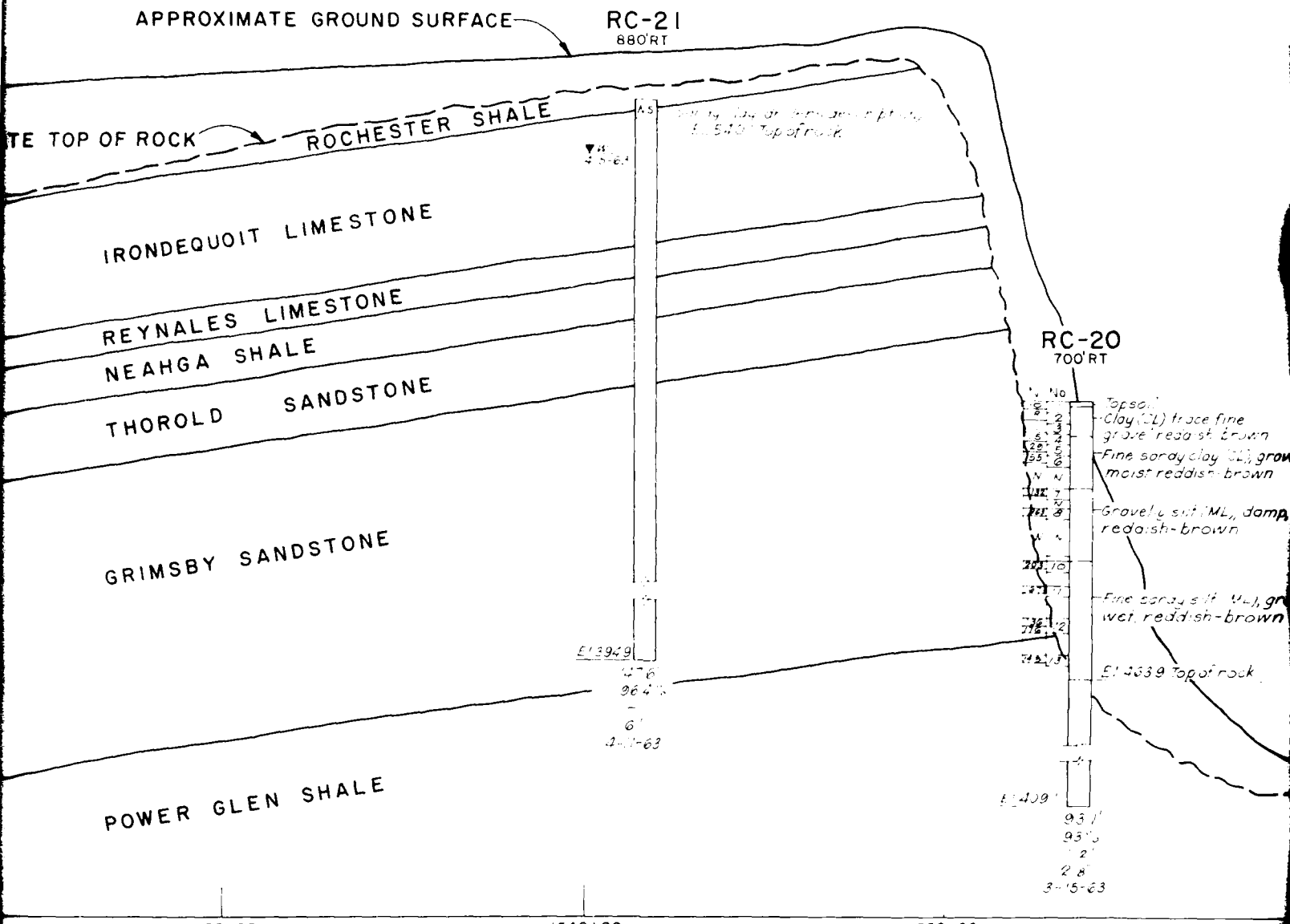
POWER

1505+00

1510+00

1520+00

PROFILE ALONG AL

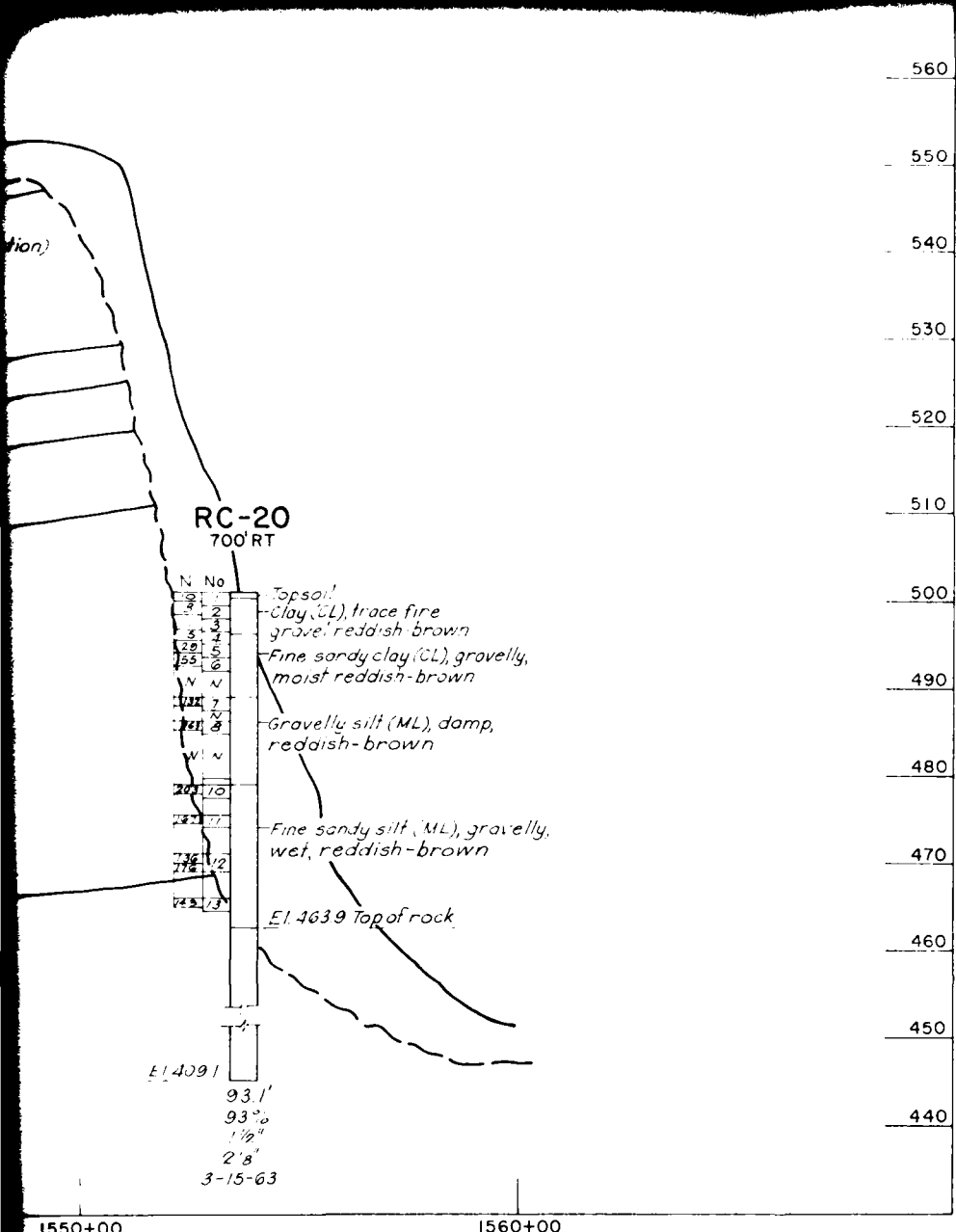


PROFILE ALONG ALIGNMENT A-I FROM STATION 1505+00 TO 1560+00

**NOTES:**

FOR LOCATION OF BORINGS SEE PLATES B3 AND B4.  
 FOR LEGEND OF SOIL PROFILES AND NOTES  
 FOR LOGS OF BORINGS SEE PLATE B11.

LAK  
 SOIL PR  
 STATION  
 U.S. AR



LAKE ERIE-LAKE ONTARIO WATERWAY

**SOIL PROFILE OF OVERLAND SECTION  
STATION 1505+00 TO 1560+00 & CANAL**

U.S. ARMY ENGINEER DISTRICT, BUFFALO

OCTOBER 1973



7A

RDC-17  
1,300' RT

RDC-16B  
1,600' RT

RDC-16A  
2,300' RT

RUDC-16  
2,600' RT

APPROXIMATE GROUND SURFACE

Topsoil  
Clayey silt (ML), gray, brown, rootlets  
Silty clay (CL-CH), dry, yellowish, brown  
Silty clay (CL-CH), dry, reddish brown, trace of gravel  
Fine sandy silt (ML), wet, yellowish brown, trace of gravel  
Silty clay (CL-CH), moist, reddish brown, thin seams fine gravel  
Silty clay (CL), wet, gray  
Fine gravel  
Sandy seam  
Clayey silt (ML), wet, red  
Gravelly  
Silty clay (CL-CH), moist  
Reddish brown, trace of gravel  
Clayey silt (ML), wet, red  
Silty clay (CL-CH), moist, reddish brown, thin seams of fine sand, trace of gravel  
Clayey silt (ML), wet, red  
Interbedded silt and clay, wet, reddish brown  
Sand seams  
Silty clay (CL-CH), moist, reddish brown, trace of gravel  
Seams of fine shale fragments, wet  
Clayey silt (ML), wet, red, with seams of gray clay  
Silty gravel (GM), wet, red  
Gravelly silt (ML), moist, red, with sand seams  
Sand, silt and gravel (GM), wet, red  
Gravelly medium sand (SP-SM), wet, trace of silt  
Boulder  
Sand, clay & gravel (GC), moist, red  
Clay & silt shale fragments, wet, red  
El. 296.7 Top of rock

N	No	Description
7	1	Topsoil silty clay (CL), gray and brown, with plant matter
8	2	Silty clay (CL-CH), damp, brown
9	3	Silt seams
10	4	Silty clay (CL-CH), moist to wet, brown
11	5	Silty clay (CL), wet, brown
12	6	Trace of gravel
13	7	Clayey silt (ML), reddish brown, with fine gravel fragments
14	8	Silty clay (CL-CH), moist, brown
15	9	Clayey silt (ML), wet, reddish brown
16	10	Clay (CL), wet, soft, brown
17	11	Silt (ML) and clayey medium sand (SC), gravelly, wet, reddish brown
18	12	Clayey silt (ML), moist, light brown, trace gravel
19	13	Indurated clay and silt, moist, reddish brown, trace of gravel
20	14	Clayey silt (ML), wet, reddish brown
21	15	Indurated clay, silt and gravel, moist, reddish brown
22	16	Clayey silt (ML), red, FW
23	17	Clayey fine to medium sand (SC), with fine gravel, wet, red
24	18	El. 315.2 Top of rock

N	No	Description
53	2	Topsoil
54	3	Silty clay (CL) moist, brown, rootlets, thin seams of sand
55	4	Silty clay (CL-CH) moist, brown, thin silt seams
56	5	Silty clay (CL-CH), moist, reddish brown
57	6	Trace of gravel
58	7	Clayey silt (ML), moist to wet, reddish brown
59	8	Interbedded clay and silt
60	9	Silty clay (CL), moist, brown, trace of gravel, chips
61	10	Silt (ML), moist, reddish brown
62	11	Silty clay (CL-CH), moist, brown
63	12	Wet
64	13	Clayey silt (ML), wet, reddish brown with weathered green shale fragments
65	14	Trace of gravel
66	15	Silty clay (CL-CH) dry, hard, reddish brown
67	16	Wet
68	17	Clayey silt (ML), reddish brown
69	18	El. 325.7 top of rock

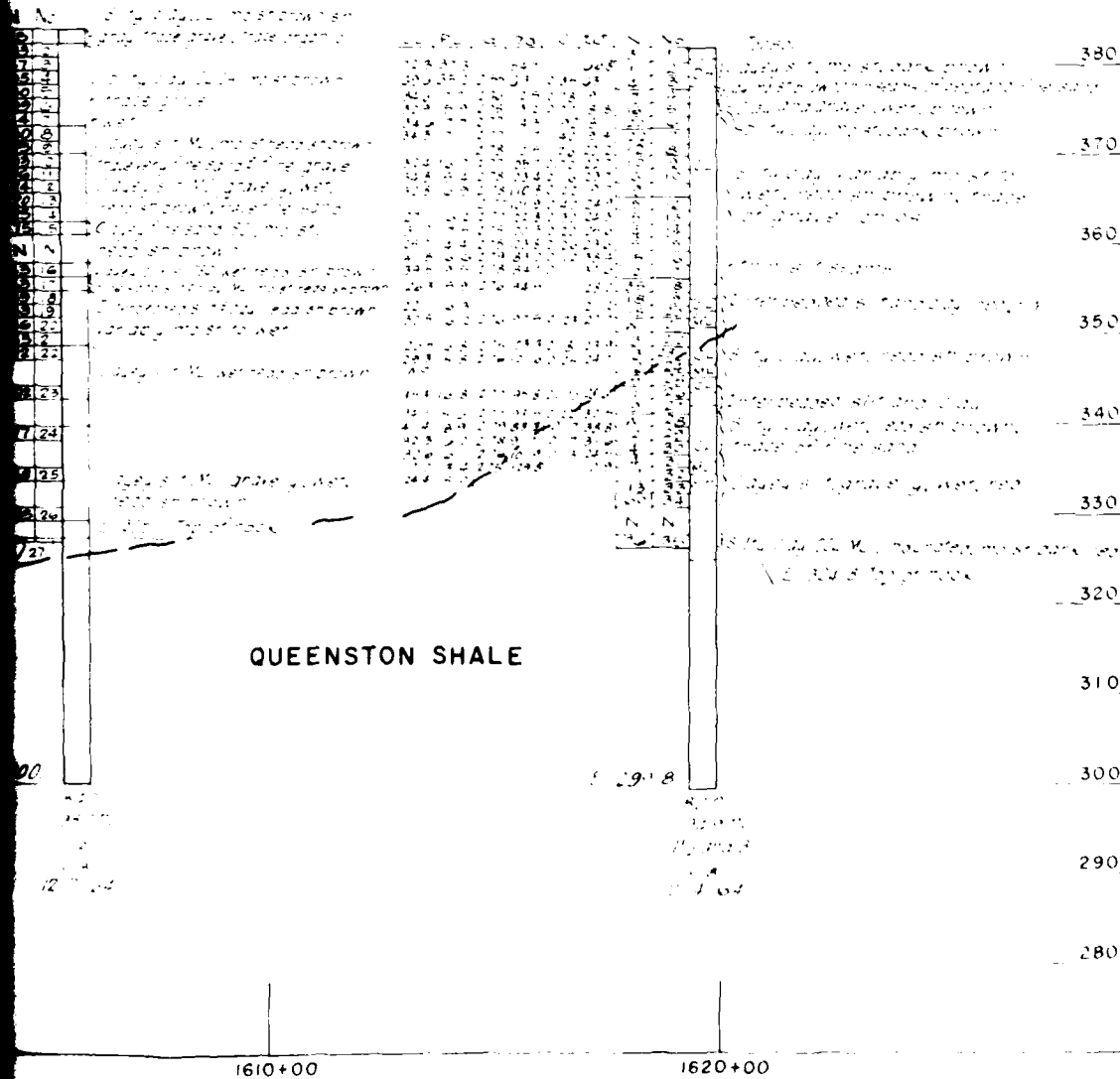
N	No	Description
13	1	Silty clay (CL) moist, brown, gray, trace gravel, trace organic
14	2	Silty clay (CL-CH) moist, brown, trace gravel
15	3	Wet
16	4	Clayey silt (ML), moist, reddish brown, trace very fine sand & fine gravel
17	5	Clayey silt (ML), gravelly, wet
18	6	Sand (SC), moist
19	7	Sand (SC), moist, brown
20	8	Clayey silt (ML), wet, reddish brown
21	9	Clayey silt (ML), moist, reddish brown
22	10	Clayey silt (ML), moist, reddish brown
23	11	Clayey silt (ML), moist, reddish brown
24	12	Clayey silt (ML), moist, reddish brown
25	13	Clayey silt (ML), moist, reddish brown
26	14	Clayey silt (ML), moist, reddish brown
27	15	Clayey silt (ML), moist, reddish brown
28	16	Clayey silt (ML), moist, reddish brown
29	17	Clayey silt (ML), moist, reddish brown
30	18	Clayey silt (ML), moist, reddish brown
31	19	Clayey silt (ML), moist, reddish brown
32	20	Clayey silt (ML), moist, reddish brown
33	21	Clayey silt (ML), moist, reddish brown
34	22	Clayey silt (ML), moist, reddish brown
35	23	Clayey silt (ML), moist, reddish brown
36	24	Clayey silt (ML), moist, reddish brown
37	25	Clayey silt (ML), moist, reddish brown
38	26	Clayey silt (ML), moist, reddish brown
39	27	Clayey silt (ML), moist, reddish brown
40	28	Clayey silt (ML), moist, reddish brown
41	29	Clayey silt (ML), moist, reddish brown
42	30	Clayey silt (ML), moist, reddish brown
43	31	Clayey silt (ML), moist, reddish brown
44	32	Clayey silt (ML), moist, reddish brown
45	33	Clayey silt (ML), moist, reddish brown
46	34	Clayey silt (ML), moist, reddish brown
47	35	Clayey silt (ML), moist, reddish brown
48	36	Clayey silt (ML), moist, reddish brown
49	37	Clayey silt (ML), moist, reddish brown
50	38	Clayey silt (ML), moist, reddish brown
51	39	Clayey silt (ML), moist, reddish brown
52	40	Clayey silt (ML), moist, reddish brown
53	41	Clayey silt (ML), moist, reddish brown
54	42	Clayey silt (ML), moist, reddish brown
55	43	Clayey silt (ML), moist, reddish brown
56	44	Clayey silt (ML), moist, reddish brown
57	45	Clayey silt (ML), moist, reddish brown
58	46	Clayey silt (ML), moist, reddish brown
59	47	Clayey silt (ML), moist, reddish brown
60	48	Clayey silt (ML), moist, reddish brown
61	49	Clayey silt (ML), moist, reddish brown
62	50	Clayey silt (ML), moist, reddish brown
63	51	Clayey silt (ML), moist, reddish brown
64	52	Clayey silt (ML), moist, reddish brown
65	53	Clayey silt (ML), moist, reddish brown
66	54	Clayey silt (ML), moist, reddish brown
67	55	Clayey silt (ML), moist, reddish brown
68	56	Clayey silt (ML), moist, reddish brown
69	57	Clayey silt (ML), moist, reddish brown
70	58	Clayey silt (ML), moist, reddish brown
71	59	Clayey silt (ML), moist, reddish brown
72	60	Clayey silt (ML), moist, reddish brown
73	61	Clayey silt (ML), moist, reddish brown
74	62	Clayey silt (ML), moist, reddish brown
75	63	Clayey silt (ML), moist, reddish brown
76	64	Clayey silt (ML), moist, reddish brown
77	65	Clayey silt (ML), moist, reddish brown
78	66	Clayey silt (ML), moist, reddish brown
79	67	Clayey silt (ML), moist, reddish brown
80	68	Clayey silt (ML), moist, reddish brown
81	69	Clayey silt (ML), moist, reddish brown
82	70	Clayey silt (ML), moist, reddish brown
83	71	Clayey silt (ML), moist, reddish brown
84	72	Clayey silt (ML), moist, reddish brown
85	73	Clayey silt (ML), moist, reddish brown
86	74	Clayey silt (ML), moist, reddish brown
87	75	Clayey silt (ML), moist, reddish brown
88	76	Clayey silt (ML), moist, reddish brown
89	77	Clayey silt (ML), moist, reddish brown
90	78	Clayey silt (ML), moist, reddish brown
91	79	Clayey silt (ML), moist, reddish brown
92	80	Clayey silt (ML), moist, reddish brown
93	81	Clayey silt (ML), moist, reddish brown
94	82	Clayey silt (ML), moist, reddish brown
95	83	Clayey silt (ML), moist, reddish brown
96	84	Clayey silt (ML), moist, reddish brown
97	85	Clayey silt (ML), moist, reddish brown
98	86	Clayey silt (ML), moist, reddish brown
99	87	Clayey silt (ML), moist, reddish brown
100	88	Clayey silt (ML), moist, reddish brown
101	89	Clayey silt (ML), moist, reddish brown
102	90	Clayey silt (ML), moist, reddish brown
103	91	Clayey silt (ML), moist, reddish brown
104	92	Clayey silt (ML), moist, reddish brown
105	93	Clayey silt (ML), moist, reddish brown
106	94	Clayey silt (ML), moist, reddish brown
107	95	Clayey silt (ML), moist, reddish brown
108	96	Clayey silt (ML), moist, reddish brown
109	97	Clayey silt (ML), moist, reddish brown
110	98	Clayey silt (ML), moist, reddish brown
111	99	Clayey silt (ML), moist, reddish brown
112	100	Clayey silt (ML), moist, reddish brown

LL	PL	G
12.3	2.3	2.55
23.6	2.2	2.16
44.9	2.1	2.15
66.2	2.1	2.17
87.5	2.1	2.17
108.8	2.1	2.17
130.1	2.1	2.17
151.4	2.1	2.17
172.7	2.1	2.17
194.0	2.1	2.17
215.3	2.1	2.17
236.6	2.1	2.17
257.9	2.1	2.17
279.2	2.1	2.17
300.5	2.1	2.17
321.8	2.1	2.17
343.1	2.1	2.17
364.4	2.1	2.17
385.7	2.1	2.17
407.0	2.1	2.17
428.3	2.1	2.17
449.6	2.1	2.17
470.9	2.1	2.17
492.2	2.1	2.17
513.5	2.1	2.17
534.8	2.1	2.17
556.1	2.1	2.17
577.4	2.1	2.17
598.7	2.1	2.17
620.0	2.1	2.17
641.3	2.1	2.17
662.6	2.1	2.17
683.9	2.1	2.17
705.2	2.1	2.17
726.5	2.1	2.17
747.8	2.1	2.17
769.1	2.1	2.17
790.4	2.1	2.17
811.7	2.1	2.17
833.0	2.1	2.17
854.3	2.1	2.17
875.6	2.1	2.17
896.9	2.1	2.17
918.2	2.1	2.17
939.5	2.1	2.17
960.8	2.1	2.17
982.1	2.1	2.17
1003.4	2.1	2.17
1024.7	2.1	2.17
1046.0	2.1	2.17
1067.3	2.1	2.17
1088.6	2.1	2.17
1109.9	2.1	2.17
1131.2	2.1	2.17
1152.5	2.1	2.17
1173.8	2.1	2.17
1195.1	2.1	2.17
1216.4	2.1	2.17
1237.7	2.1	2.17
1259.0	2.1	2.17
1280.3	2.1	2.17
1301.6	2.1	2.17
1322.9	2.1	2.17
1344.2	2.1	2.17
1365.5	2.1	2.17
1386.8	2.1	2.17
1408.1	2.1	2.17
1429.4	2.1	2.17
1450.7	2.1	2.17
1472.0	2.1	2.17
1493.3	2.1	2.17
1514.6	2.1	2.17
1535.9	2.1	2.17
1557.2	2.1	2.17
1578.5	2.1	2.17
1599.8	2.1	2.17
1621.1	2.1	2.17
1642.4	2.1	2.17
1663.7	2.1	2.17
1685.0	2.1	2.17
1706.3	2.1	2.17
1727.6	2.1	2.17
1748.9	2.1	2.17
1770.2	2.1	2.17
1791.5	2.1	2.17
1812.8	2.1	2.17
1834.1	2.1	2.17
1855.4	2.1	2.17
1876.7	2.1	2.17
1898.0	2.1	2.17
1919.3	2.1	2.17
1940.6	2.1	2.17
1961.9	2.1	2.17
1983.2	2.1	2.17
2004.5	2.1	2.17
2025.8	2.1	2.17
2047.1	2.1	2.17
2068.4	2.1	2.17
2089.7	2.1	2.17
2111.0	2.1	2.17
2132.3	2.1	2.17
2153.6	2.1	2.17
2174.9	2.1	2.17
2196.2	2.1	2.17
2217.5	2.1	2.17
2238.8	2.1	2.17
2260.1	2.1	2.17
2281.4	2.1	2.17
2302.7	2.1	2.17
2324.0	2.1	2.17
2345.3	2.1	2.17
2366.6	2.1	2.17
2387.9	2.1	2.17
2409.2	2.1	2.17
2430.5	2.1	2.17
2451.8	2.1	2.17
2473.1	2.1	2.17
2494.4	2.1	2.17
2515.7	2.1	2.17
2537.0	2.1	2.17
2558.3	2.1	2.17
2579.6	2.1	2.17
2600.9	2.1	2.17
2622.2	2.1	2.17
2643.5	2.1	2.17
2664.8	2.1	2.17
2686.1	2.1	2.17
2707.4	2.1	2.17
2728.7	2.1	2.17
2750.0	2.1	2.17
2771.3	2.1	2.17
2792.6	2.1	2.17
2813.9	2.1	2.17
2835.2	2.1	2.17
2856.5	2.1	2.17
2877.8	2.1	2.17
2899.1	2.1	2.17
2920.4	2.1	2.17
2941.7	2.1	2.17
2963.0	2.1	2.17
2984.3	2.1	2.17
3005.6	2.1	2.17
3026.9	2.1	2.17
3048.2	2.1	2.17
3069.5	2.1	2.17
3090.8	2.1	2.17
3112.1	2.1	2.17
3133.4	2.1	2.17
3154.7	2.1	2.17
3176.0	2.1	2.17
3197.3	2.1	2.17
3218.6	2.1	2.17
3239.9	2.1	2.17
3261.2	2.1	2.17
3282.5	2.1	2.17
3303.8	2.1	2.17
3325.1	2.1	2.17
3346.4	2.1	2.17
3367.7	2.1	2.17
3389.0	2.1	2.17
3410.3	2.1	2.17
3431.6	2.1	2.17
3452.9	2.1	2.17
3474.2	2.1	2.17
3495.5	2.1	2.17
3516.8	2.1	2.17
3538.1	2.1	2.17
3559.4	2.1	2.17
3580.7	2.1	2.17
3602.0	2.1	2.17
3623.3	2.1	2.17
3644.6	2.1	2.17
3665.9	2.1	2.17
3687.2	2.1	2.17
3708.5	2.1	2.17
3729.8	2.1	2.17
3751.1	2.1	2.17
3772.4	2.1	2.17
3793.7	2.1	2.17
3815.0	2.1	2.17
3836.3	2.1	2.17
3857.6	2.1	2.17
3878.9	2.1	2.17
3900.2	2.1	2.17
3921.5	2.1	2.17
3942.8	2.1	2.17
3964.1	2.1	2.17
3985.4	2.1	2.17
4006.7	2.1	2.17
4028.0	2.1	2.17
4049.3	2.1	2.17
4070.6	2.1	2.17
4091.9	2.1	2.17
4113.2	2.1	2.17
4134.5	2.1	2.17
4155.8	2.1	2.17
4177.1	2.1	2.17
4198.4	2.1	2.17
4219.7		

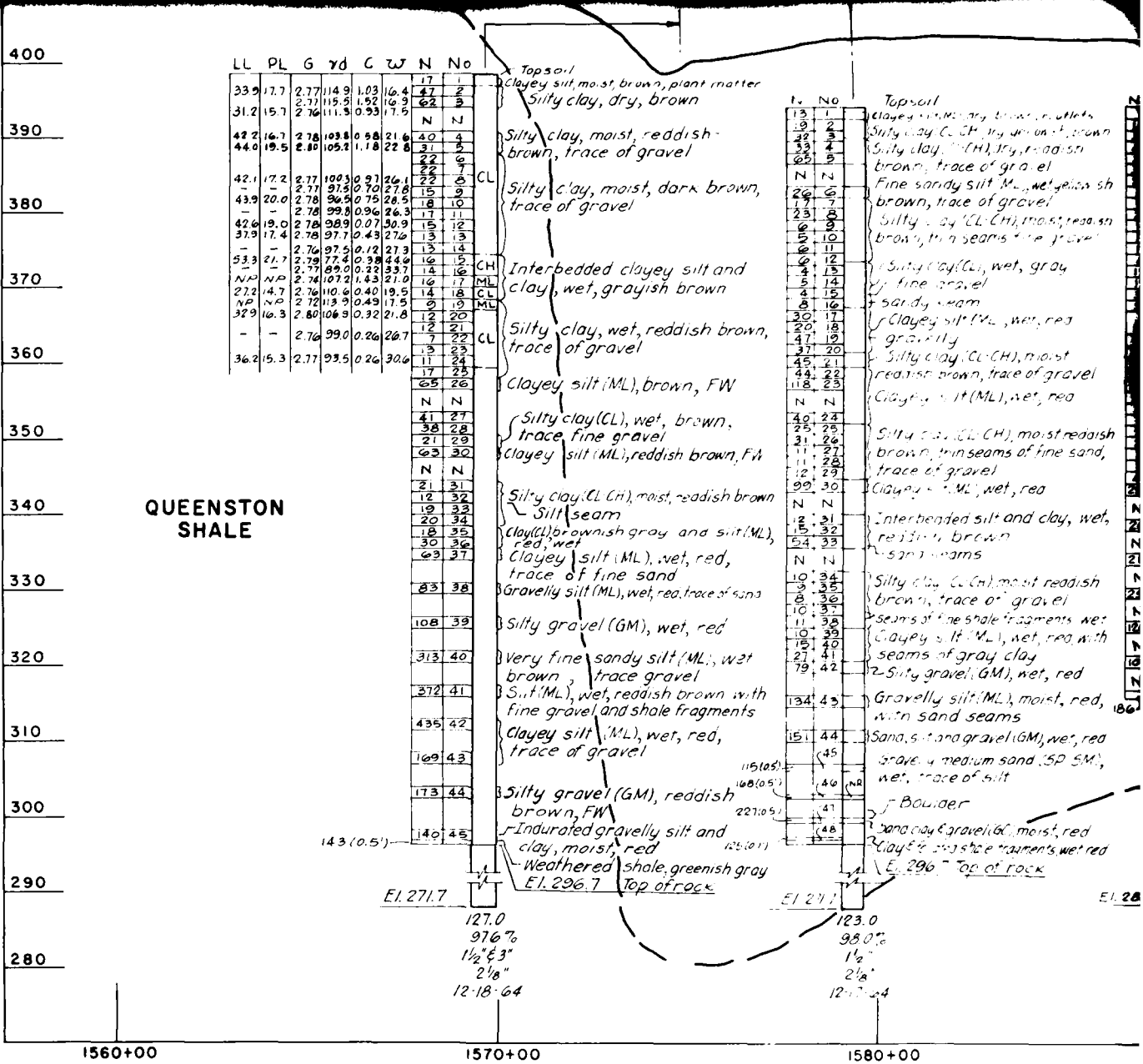
A  
T

RUDC-16  
2,600 RT

DATE GROUND SURFACE



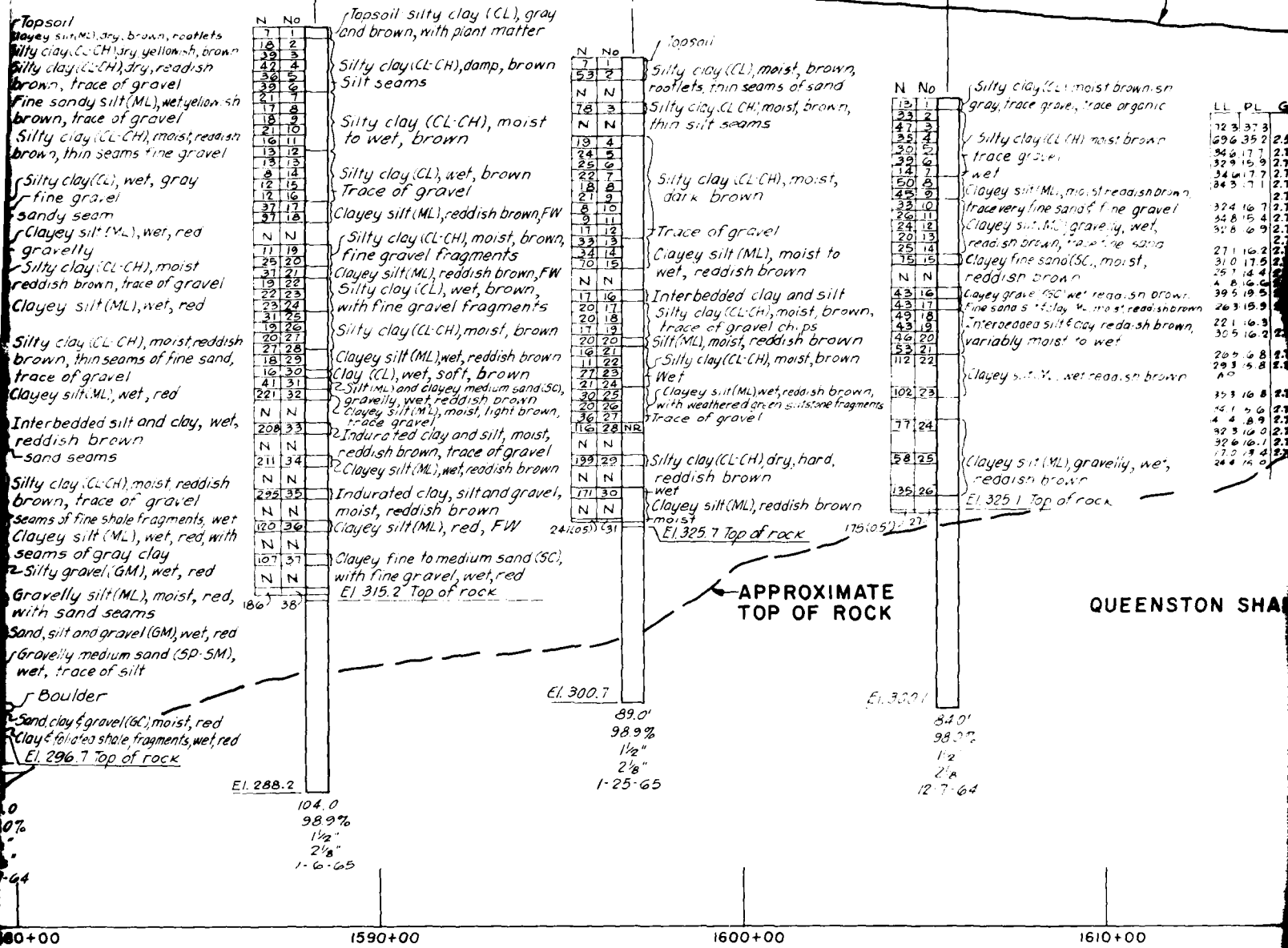
ELEVATION IN FEET I.G.L.D. (1955)



QUEENSTON SHALE

PROFILE ALONG

APPROXIMATE GROUND SURFACE



**NOTES:**

FOR LOCATION OF BORINGS SEE PLATE B4.  
 FOR LEGEND OF SOIL PROFILES AND NOTES  
 FOR LOGS OF BORINGS SEE PLATE B11.

LATE GROUND SURFACE

N No  
 13 1  
 53 2  
 47 3  
 55 4  
 50 5  
 52 6  
 44 7  
 50 8  
 45 9  
 33 10  
 26 11  
 24 12  
 20 13  
 25 14  
 15 15  
 N N  
 43 16  
 43 17  
 49 18  
 43 19  
 46 20  
 43 21  
 112 22  
 102 23  
 77 24  
 58 25  
 135 26  
 27

Silty clay (CL), moist brownish gray, trace gravel, trace organic  
 ✓ Silty clay (CL-CH), moist brown trace gravel  
 wet  
 Clayey silt (ML), moist reddish brown, trace very fine sand & fine gravel  
 Clayey silt (ML) gravelly, wet, reddish brown, trace fine sand  
 Clayey fine sand (SC), moist, reddish brown  
 Clayey gravel (SC), wet, reddish brown  
 Fine sand silt clay (ML), moist, reddish brown  
 Interbedded silt & clay, reddish brown, variably moist to wet  
 Clayey silt (ML), wet, reddish brown  
 Clayey silt (ML), gravelly, wet, reddish brown  
 E. 325.1 Top of rock

LL	PL	G	7d	C	W	N	No
12.3	37.3		54.7		66.8	3	1
69.6	35.2	2.55	63.1	0.35	63.1	4	2
34.6	17.7	2.16	112.5	0.78	19.1	7	3
32.9	19.9	2.25	113.2	0.77	18.8	16	5
34.6	17.7	2.77	114.3	1.92	18.1	20	6
34.3	17.1	2.77	111.7	1.40	19.4	22	7
37.4	16.7	2.77	105.7	0.70	22.7	10	9
34.8	16.4	2.78	103.4	0.16	23.7	6	10
32.8	16.9	2.78	110.8	0.22	19.7	9	11
		2.77	101.9	0.40	24.9	5	12
27.1	16.2	2.77	102.8	0.30	24.3	5	13
31.0	17.5	2.75	100.3	0.20	25.6	4	14
25.7	14.4	2.75	103.8	0.26	23.6	5	15
41.8	16.6	2.79	83.0	0.12	38.4	5	16
39.5	19.5	2.78	84.7	0.11	37.6	2	17
26.3	15.9	2.76	94.5		28.0	35	18
22.1	16.3				21.2	18	19
30.5	16.2	2.76	97.5	0.23	27.7	15	20
26.5	16.8	2.75	103.3	0.18	23.9	3	22
29.3	15.8	2.76	101.6	0.25	24.7	2	24
17.0						9	27
35.3	16.8	2.77	95.8	0.170	28.6	11	28
34.1	15.6	2.77	93.5	0.22	30.5	17	28
41.4	18.9	2.79	83.3	0.17	38.8	2	29
32.3	16.0	2.78	91.7	0.17	31.6	4	30
32.6	16.1	2.76	101.9	0.13	24.5	4	31
17.0	13.4	2.75	109.8		10.9	13	32
24.4	15.0					60	34

Topsoil  
 Clayey silt, moist, dark brown  
 Clay, moist brown, thin seams of peat and fine sand  
 Clay and gravel, wet, brown  
 Silty clay, moist, dark brown  
 Silty clay, variably moist to wet, reddish brown, trace of gravel chips  
 thin silt seams  
 Interbedded silt and clay, red, FW  
 Silty clay, wet, reddish brown  
 Interbedded silt and clay  
 Silty clay, wet, reddish brown, trace of fine sand  
 Clayey silt, gravelly, wet, red  
 Silty clay (CL-ML), indurated, moist, dark red  
 E1. 324.8 Top of rock

400  
 390  
 380  
 370  
 360  
 350  
 340  
 330  
 320  
 310  
 300  
 290  
 280

QUEENSTON SHALE

1610+00

1620+00

34.0'  
 98.7'  
 1/2  
 2 1/8  
 12-7-64

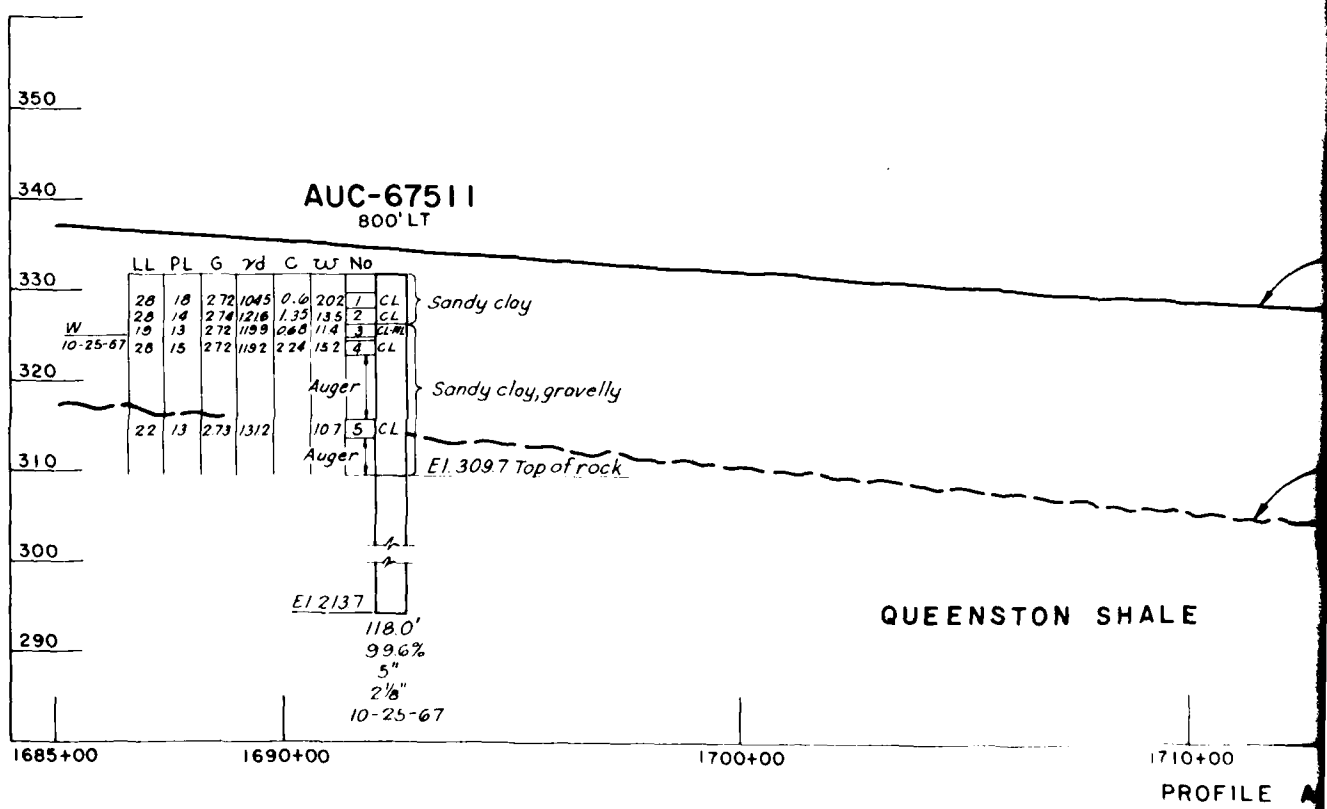
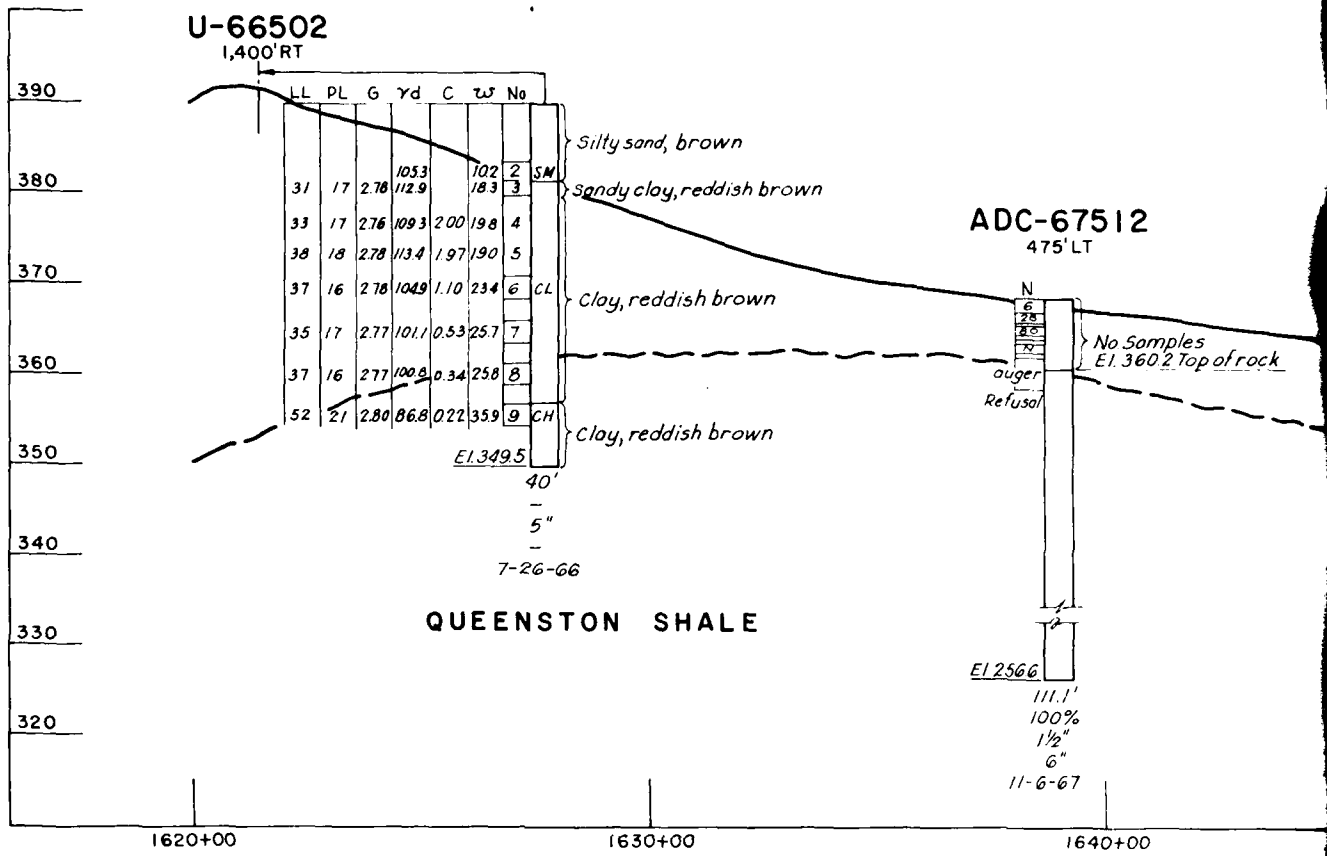
32.0'  
 94.97'  
 1 1/2' and 3"  
 2 1/8"  
 12-4-64

E1. 299.8

SEE PLATE B4.  
 LES AND NOTES  
 TE B11.

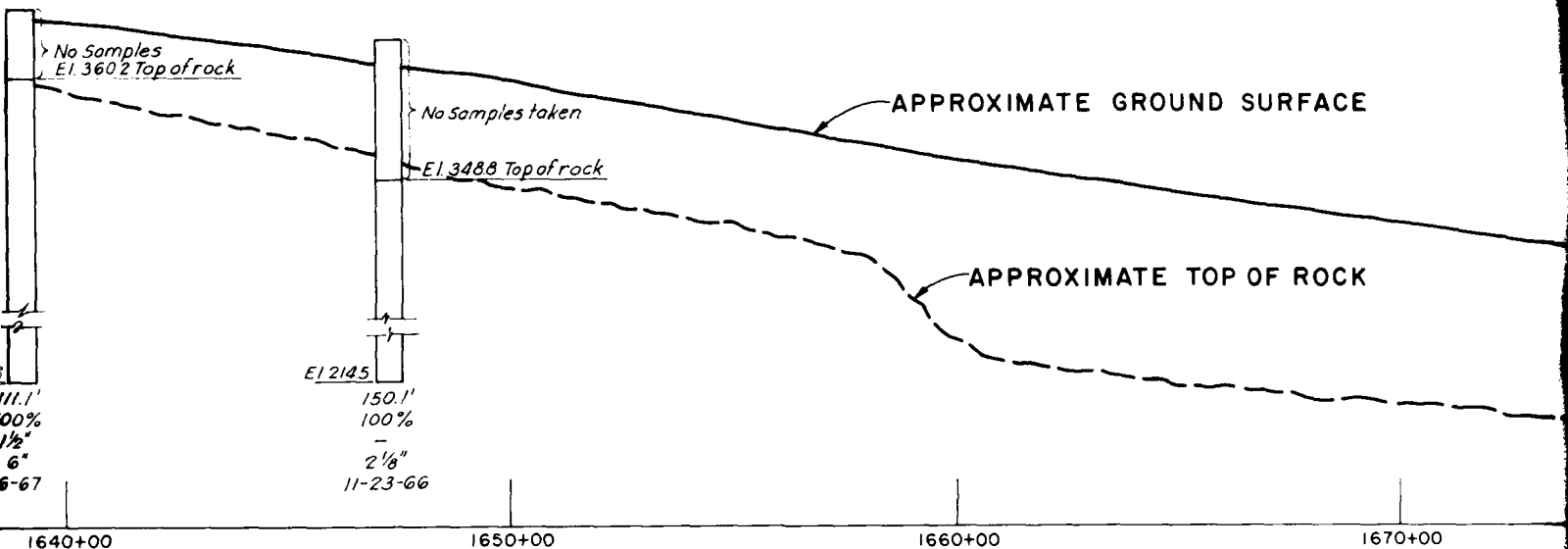
LAKE ERIE-LAKE ONTARIO WATERWAY  
 SOIL PROFILE OF OVERLAND SECTION  
 STATION 1560+00 TO 1620+00 & CANAL  
 U.S. ARMY ENGINEER DISTRICT, BUFFALO  
 TO ACCOMPANY REVIEW OF REPORTS  
 OCTOBER 1973

ELEVATION IN FEET I.G.L.D. (1955)

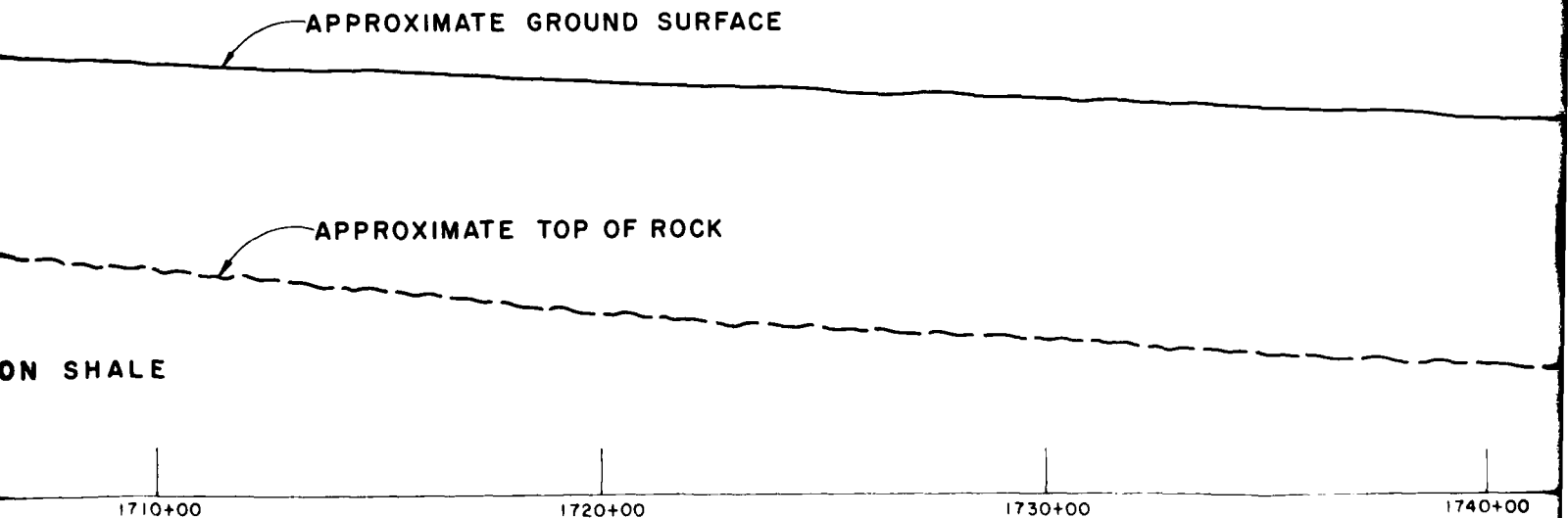


67512  
15' LT

RC-66507  
900' LT

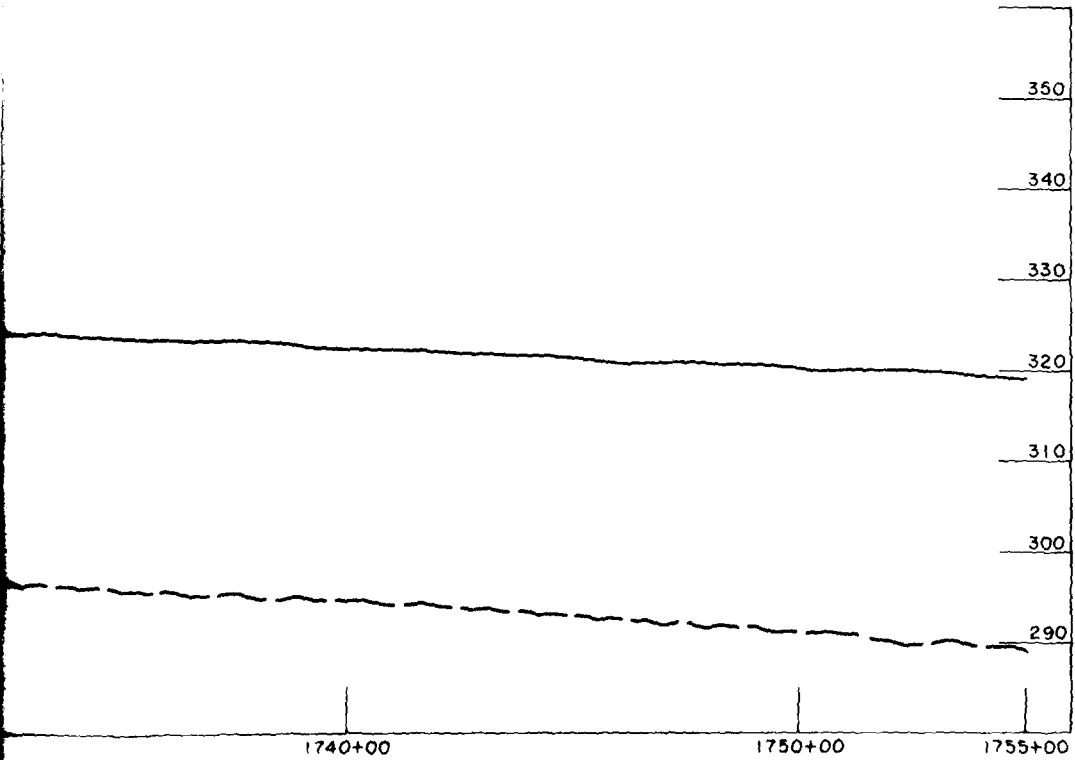
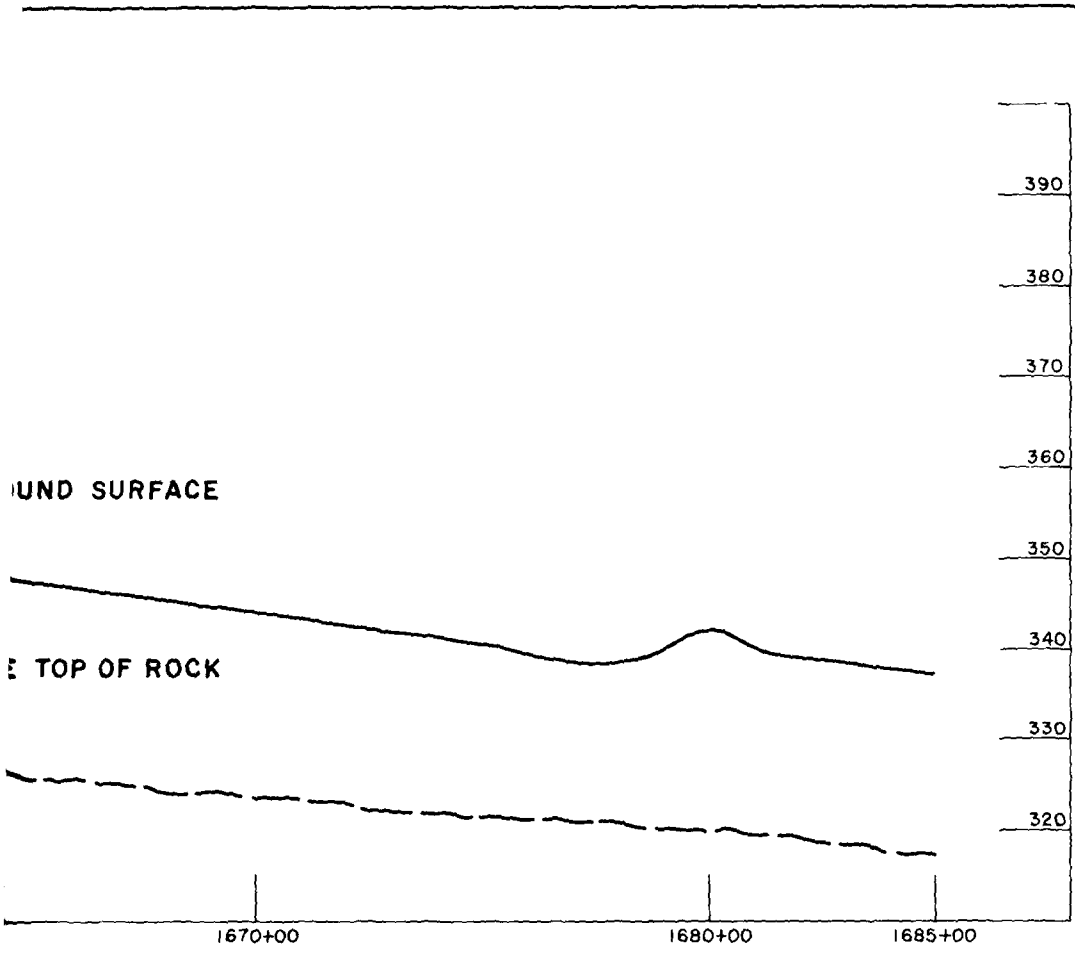


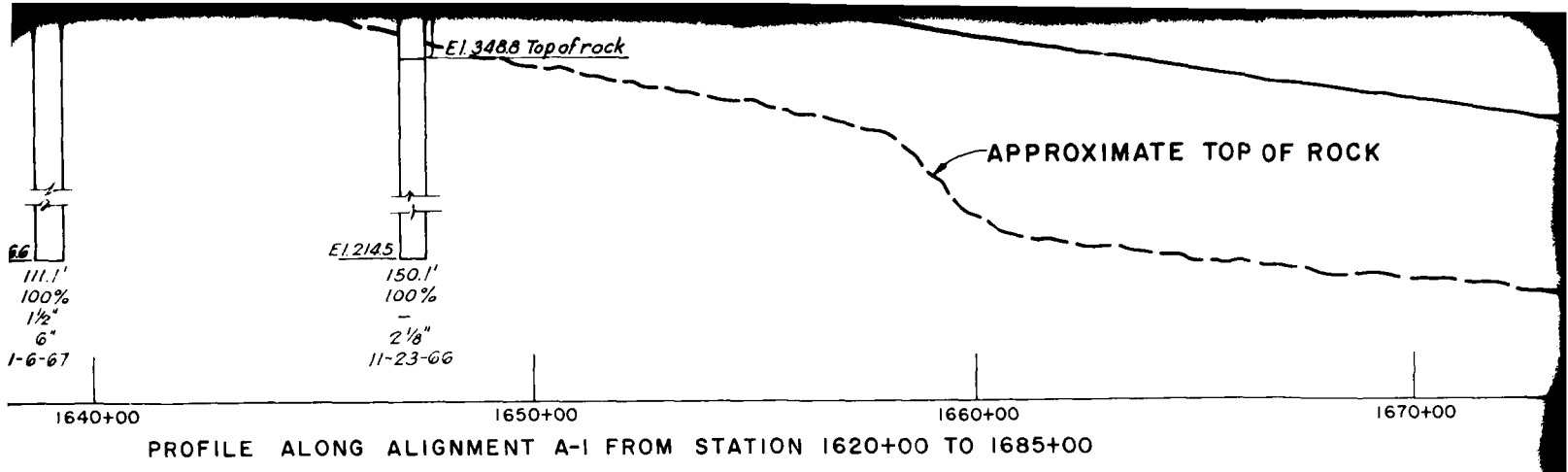
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1620+00 TO 1685+00



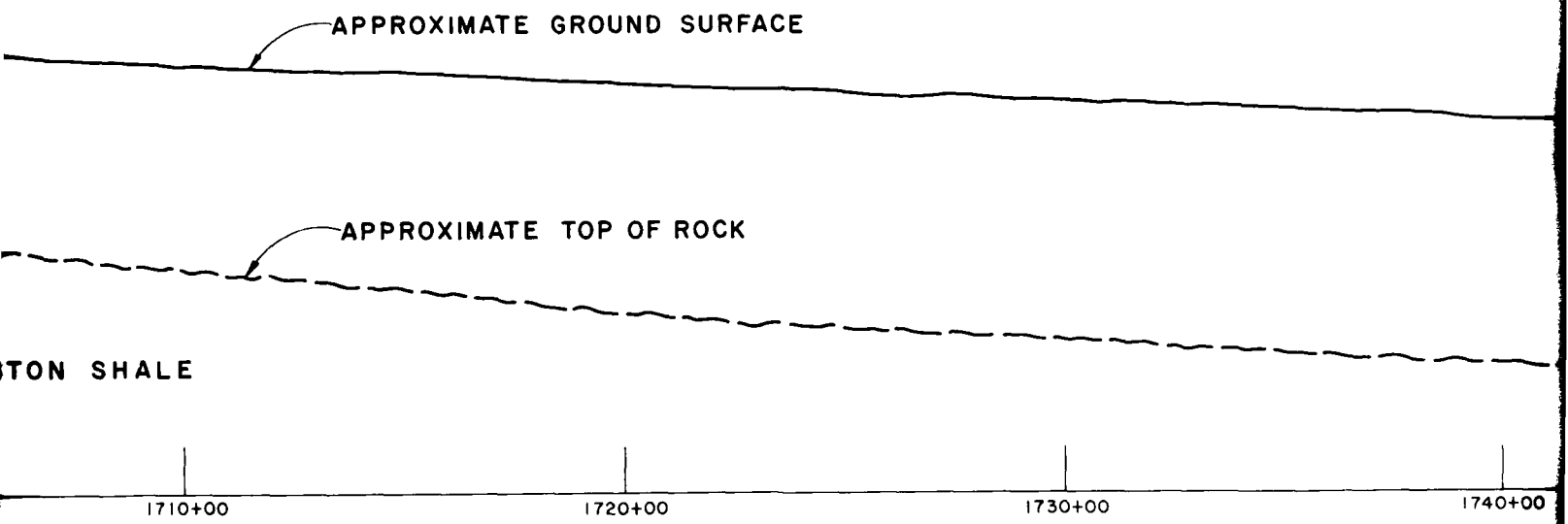
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1685+00 TO 1755+00

1.6





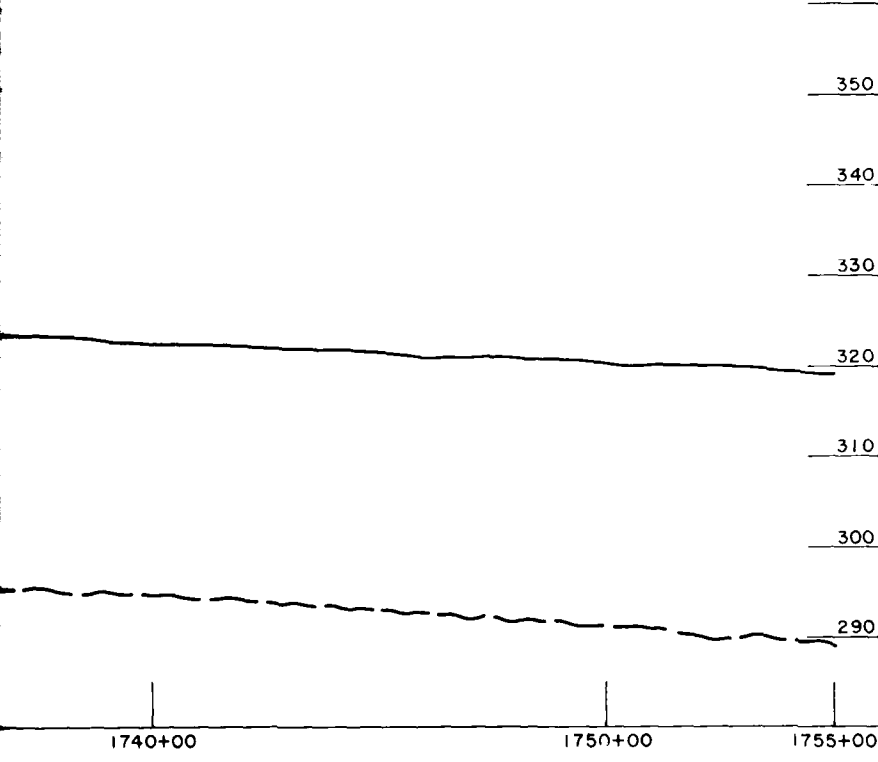
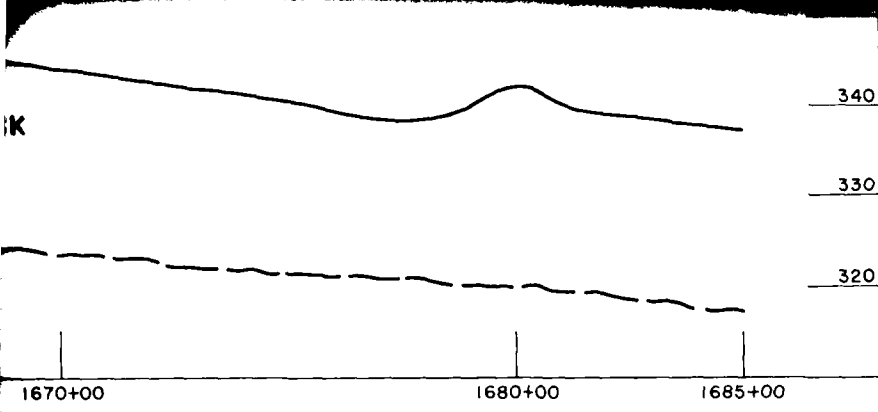
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1620+00 TO 1670+00



PROFILE ALONG ALIGNMENT A-1 FROM STATION 1685+00 TO 1755+00

**NOTES:**

FOR LOCATION OF BORINGS SEE PLATE B4.  
 FOR LEGEND OF SOIL PROFILES AND NOTES  
 FOR LOGS OF BORINGS SEE PLATE B11.

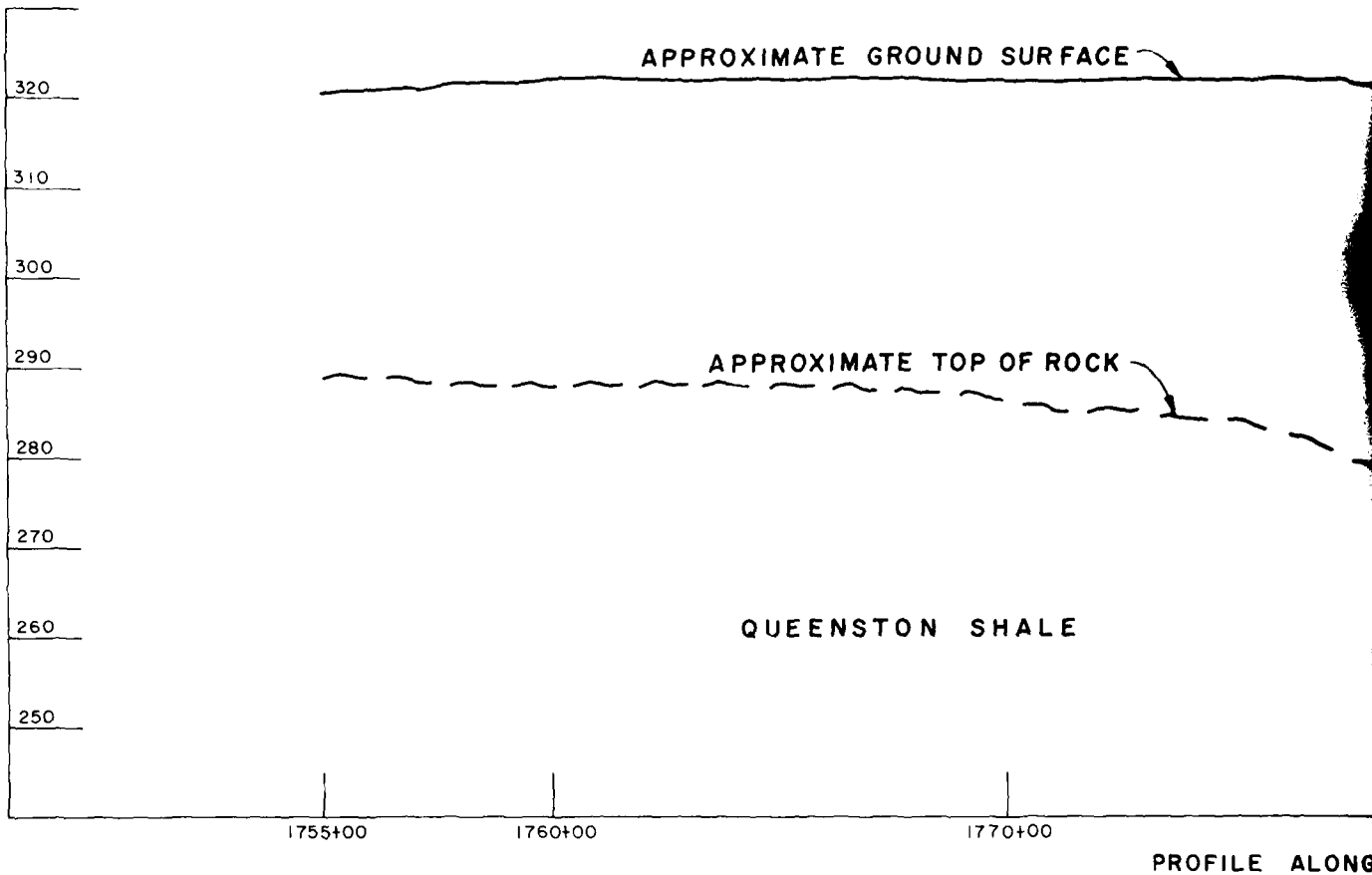


LAKE ERIE-LAKE ONTARIO WATERWAY

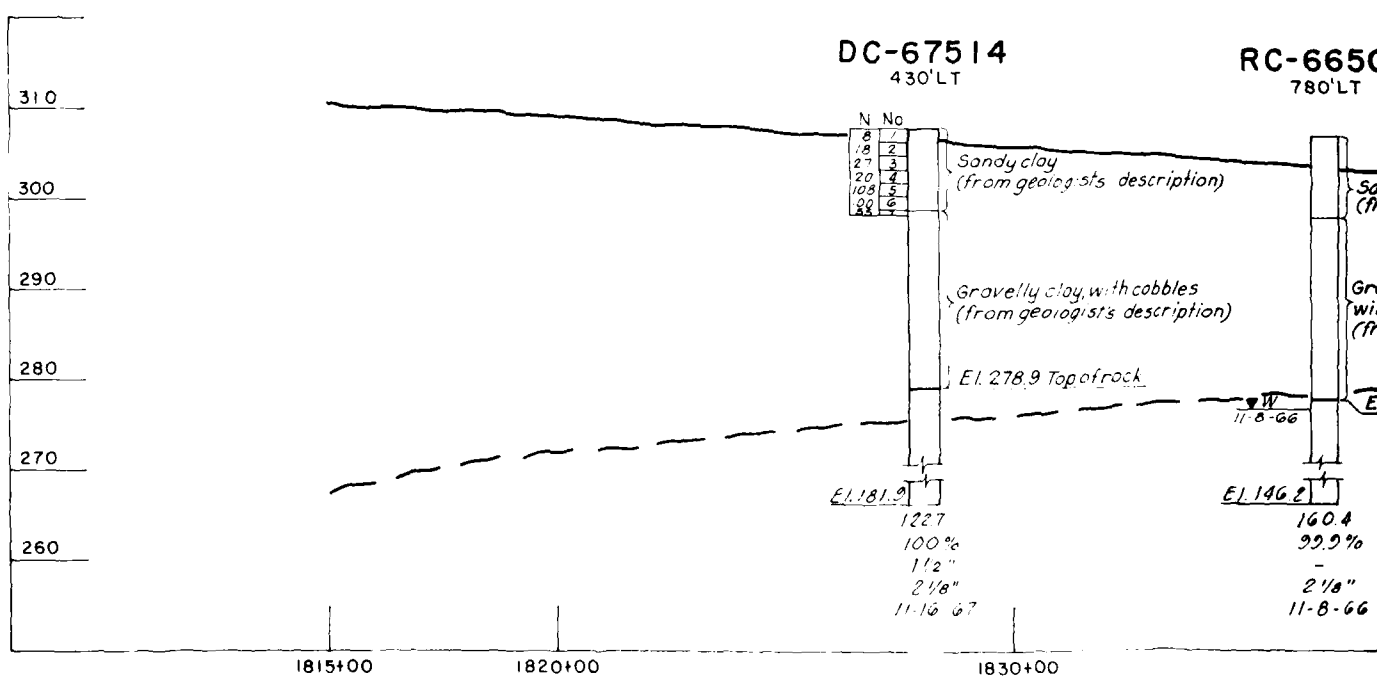
SOIL PROFILE OF OVERLAND SECTION  
STATION 1620+00 TO 1755+00 & CANAL

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

ELEVATION IN FEET I.G.L.D. (1955)



PROFILE ALONG



PROFILE ALONG

DC-67514  
430' LT

RC-6650  
780' LT

N No

18	1
19	2
20	3
108	4
20	5
20	6
20	7

Sandy clay  
(from geologists description)

Gravelly clay with cobbles  
(from geologists description)

EI. 278.9 Top of rock

EI. 181.2  
122.7  
100%  
1 1/2"  
2 1/8"  
11-16-67

W  
11-8-66

EI. 146.2  
160.4  
99.9%  
-  
2 1/8"  
11-8-66

GROUND SURFACE

ARC-66509  
200'LT

AUC-67516  
425'LT

LL PL G Yd C W No

34 20 2 3.963 050 21927

28 18 275406 100 18972

32 18 274104 1071 23473

Sandy clay

Auger

Auger refused

DATE TOP OF ROCK

Sandy clay, gray  
(from geologist's description)

Sandy clay, gray  
with cobbles

Sandy clay, gravelly, reddish brown  
(from geologist's description)

El. 266.7 Top of rock

El. 265.8 Top of rock

QUEENSTON SHALE

El. 182.1  
131.7  
98.7%  
2 1/8"  
11-14-66

El. 186.9  
126.4  
98.7%  
5"  
6"  
11-22-67

1770+00 1780+00 1790+00 1800+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1755+00 TO 1815+00

DC-67514  
430'LT

RC-66505  
780'LT

N	No
18	7
21	2
27	3
20	4
109	5
108	6

Sandy clay  
(from geologist's description)

Sandy clay, dark gray  
(from geologist's description)

Gravelly clay, with cobbles  
(from geologist's description)

Gravelly clay, reddish brown,  
with cobbles and boulders  
(from geologist's description)

El. 278.9 Top of rock

El. 277.2 Top of rock

El. 181.9  
12.7  
100%  
1 1/2"  
2 1/8"  
11-16-67

El. 146.2  
160.4  
99.9%  
2 1/8"  
11-8-66

QUEENSTON SHALE

1830+00 1840+00 1850+00 1860+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1815+00 TO 1875+00

NOTES:

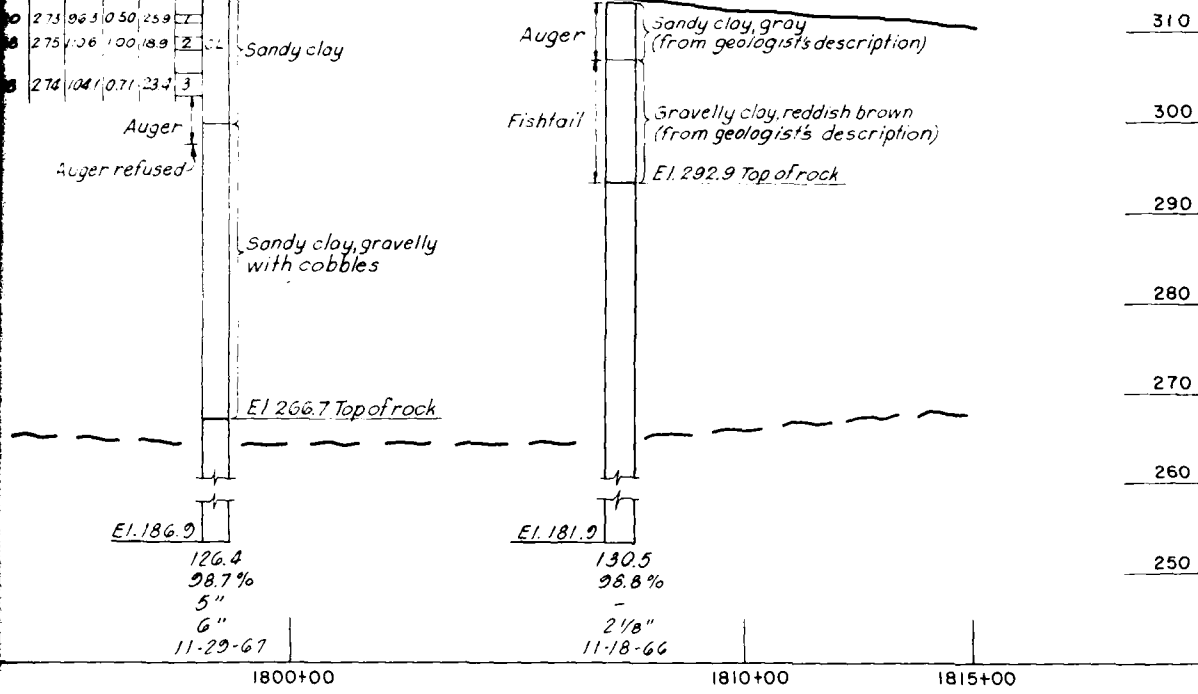
SEE LOCATION OF BORINGS SEE PLATE BA

**AUC-67516**  
425'LT

**ARC-66510**  
675'LT

Log No

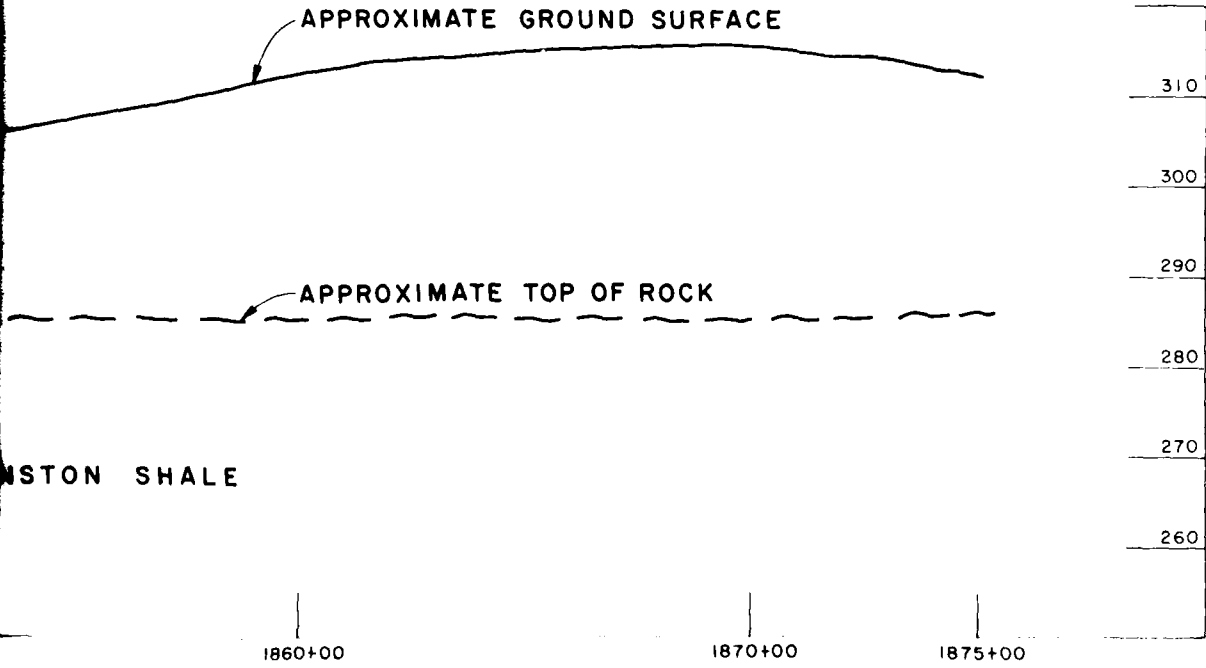
273	063	1050	259	1
275	056	100	189	2
274	104	1071	234	3



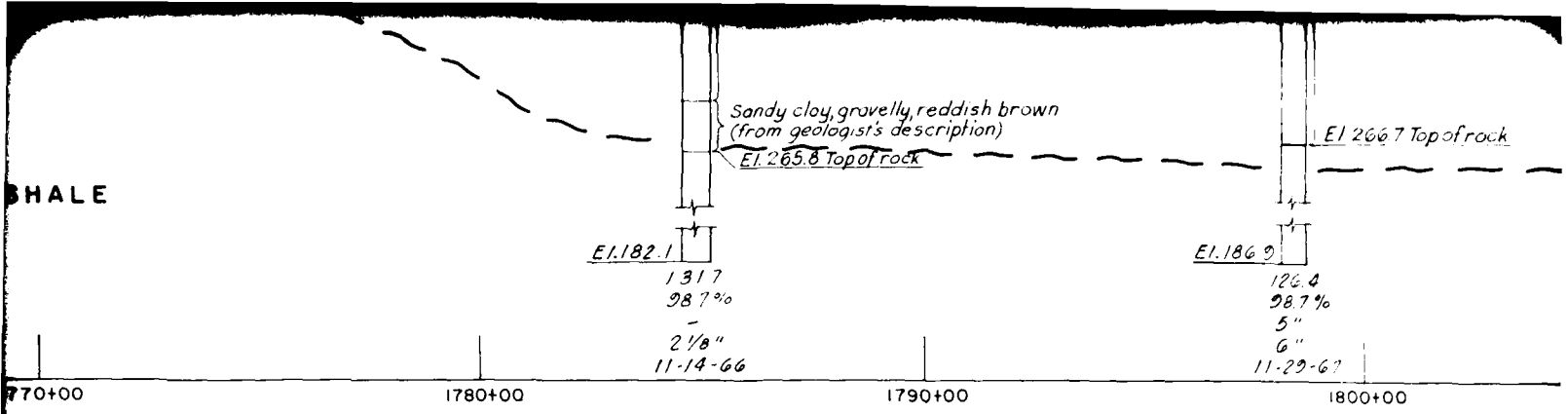
APPROXIMATE GROUND SURFACE

APPROXIMATE TOP OF ROCK

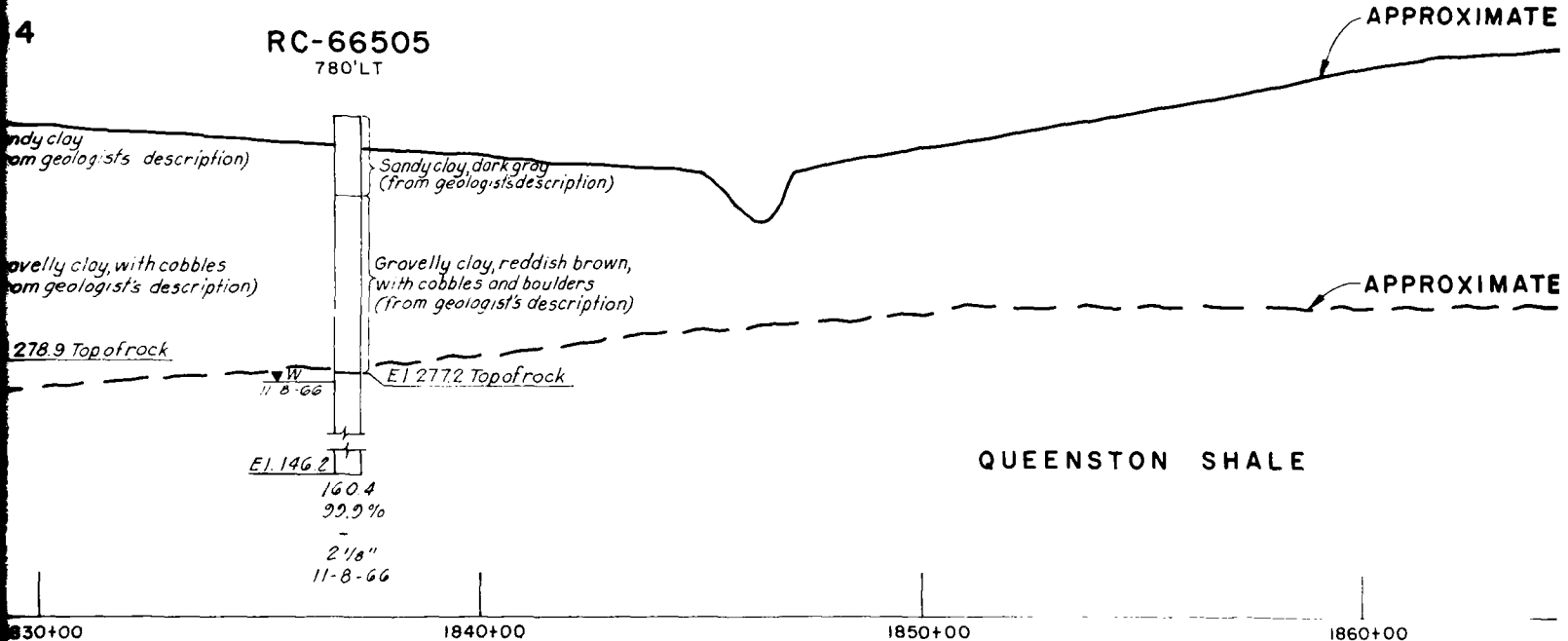
WILSON SHALE



6+00



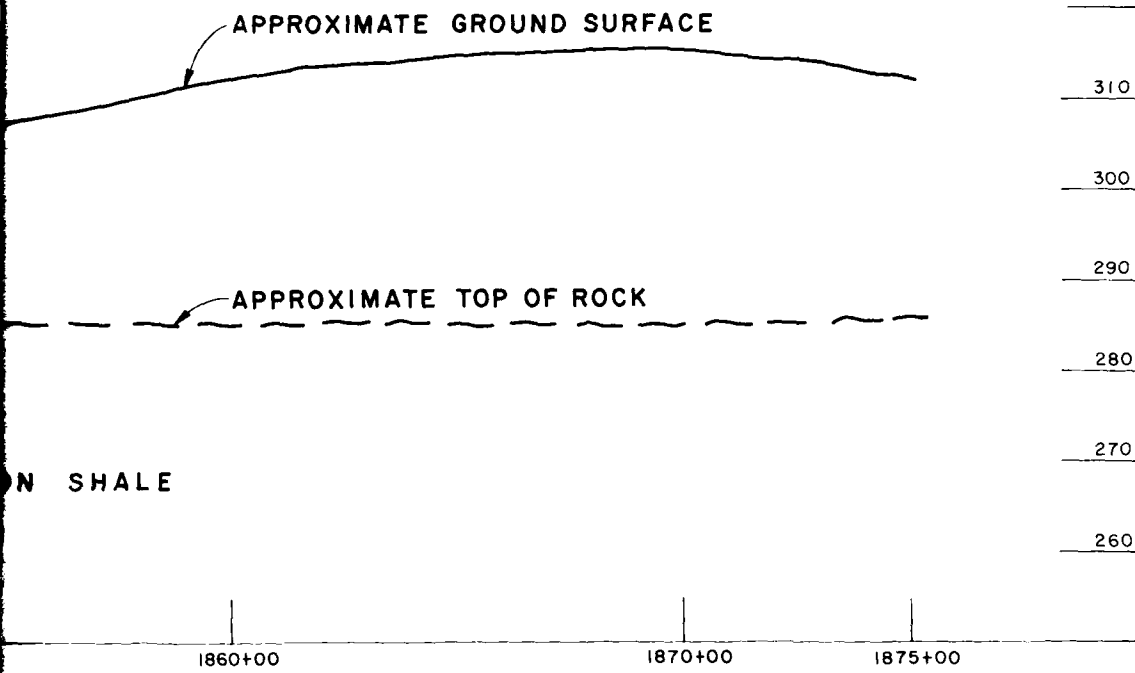
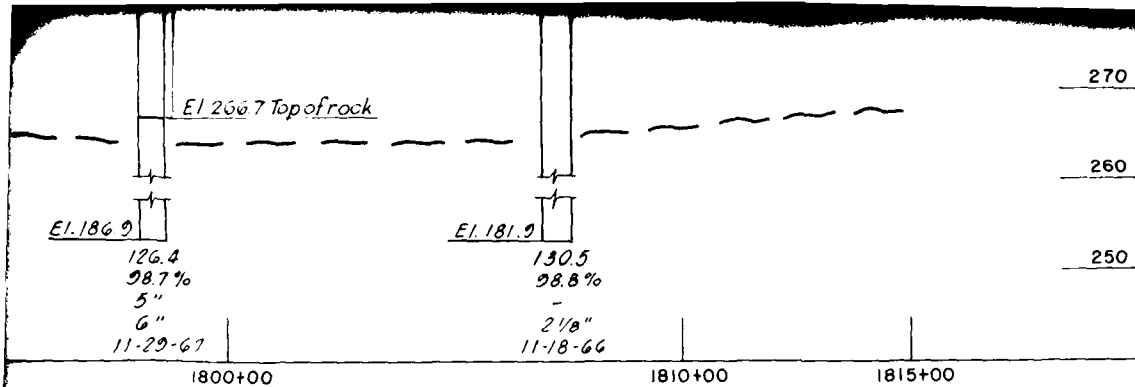
PROFILE ALONG ALIGNMENT A-I FROM STATION 1755+00 TO 1815+00



PROFILE ALONG ALIGNMENT A-I FROM STATION 1815+00 TO 1875+00

**NOTES:**

- FOR LOCATION OF BORINGS, SEE PLATE B4.
- FOR LEGEND OF SOIL PROFILES AND NOTES FOR LOGS OF BORINGS, SEE PLATE B11.

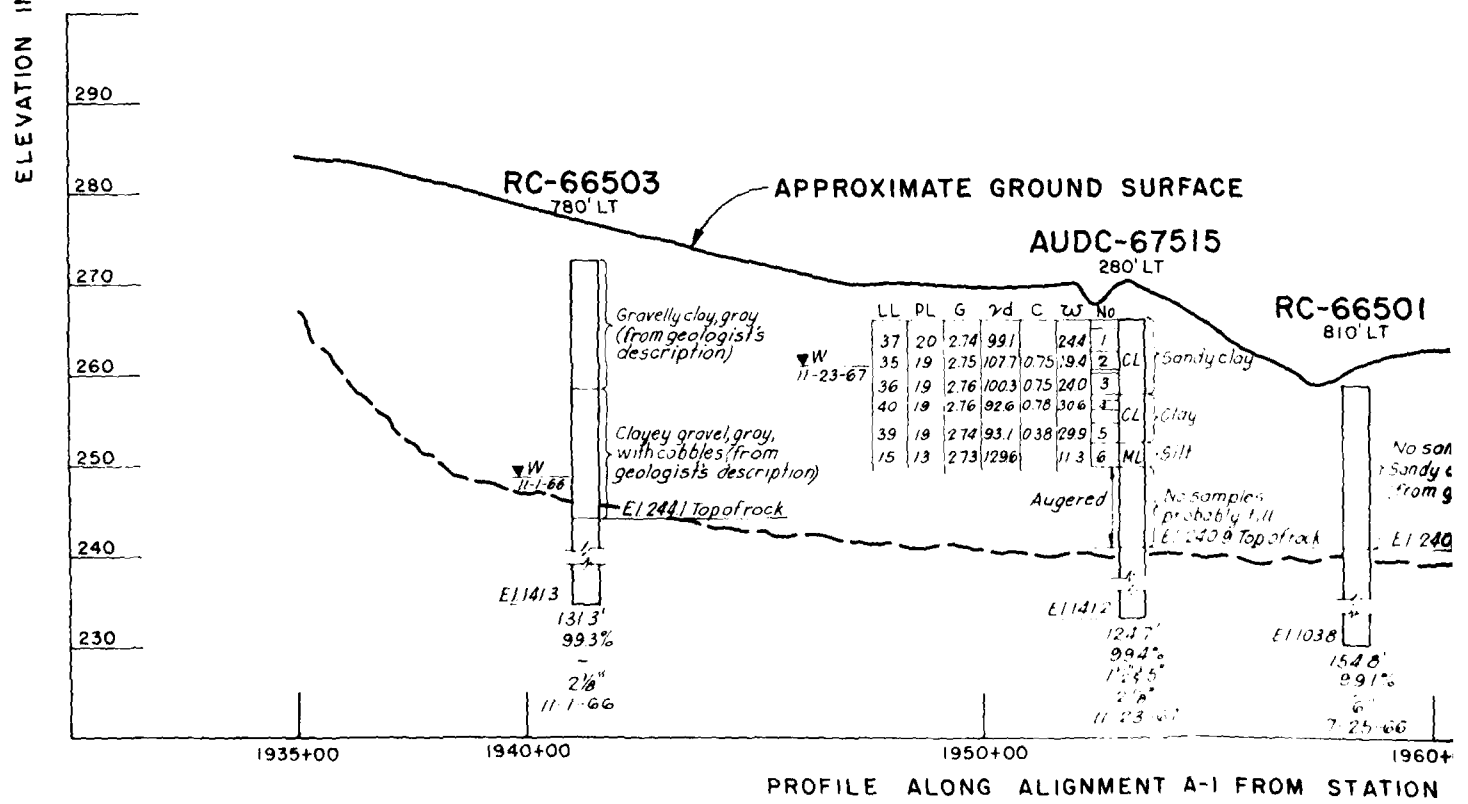
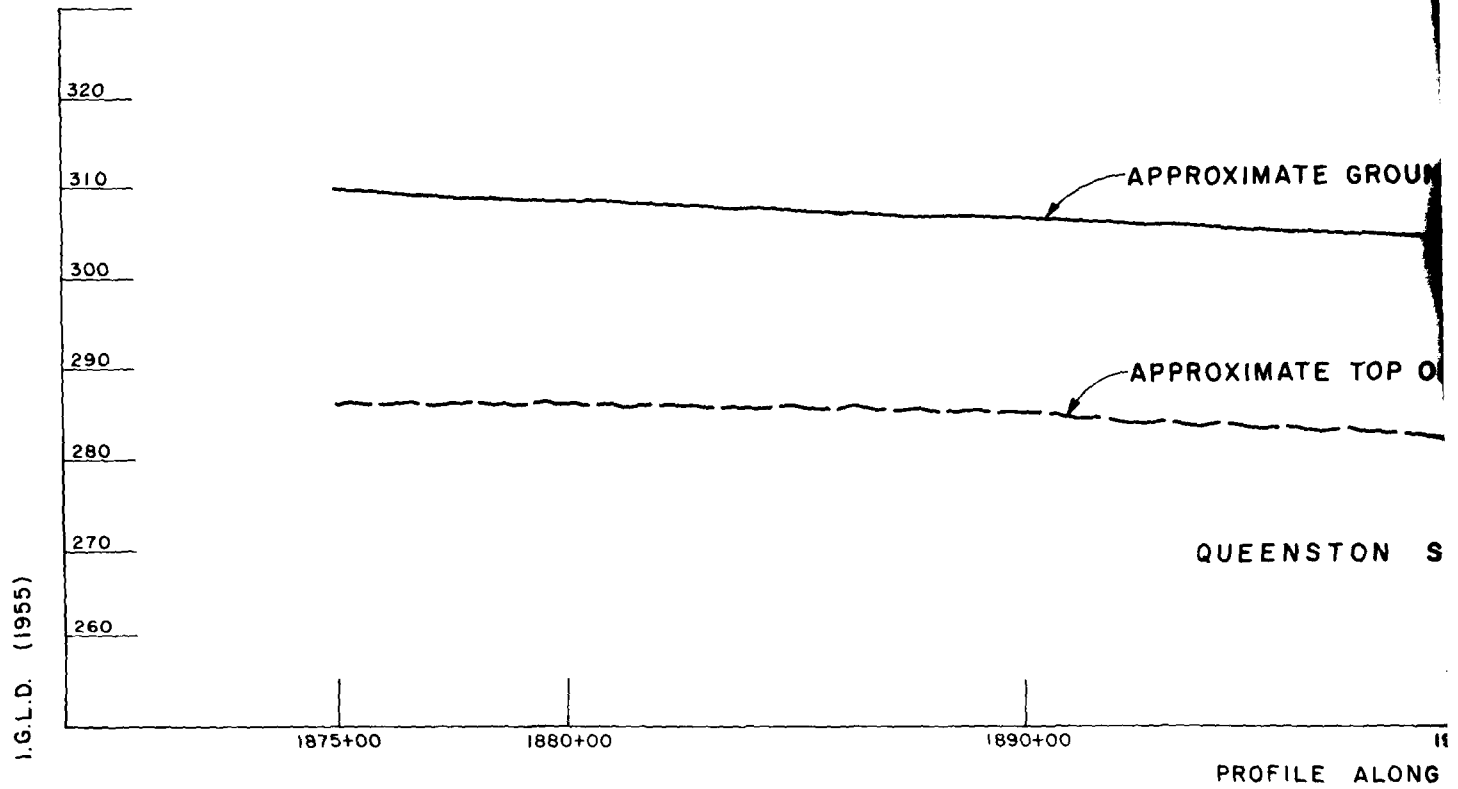


E B4.  
NOTES

LAKE ERIE-LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION  
STATION 1755+00 TO 1875+00 & CANAL

U. S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973



12  
1  
MATE GROUND SURFACE

RC-66504  
190' LT

MATE TOP OF ROCK

▼ W  
10-27-66

No samples taken;  
Sandy clay, gray (from geologist's description)

ENSTON SHALE

No samples taken;  
Sandy clay with thin hard seams, red, possibly  
weathered shale (from geologist's description)

El 270.1 Top of rock

El 142.1

150.3'  
99.9%  
-  
2 1/8"  
10-27-66

1900+00

1910+00

1920+00

1930+00

PROFILE ALONG ALIGNMENT A-I FROM STATION 1875+00 TO 1935+00

RC-66501  
810' LT

No samples taken  
Sandy clay and silt  
(from geologist's description)

LAKE ONTARIO

El 240.9 Top of rock

El 103.8

154.0'  
99.1%  
-  
6'  
7-25-66

QUEENSTON SHALE

290

280

270

260

250

240

230

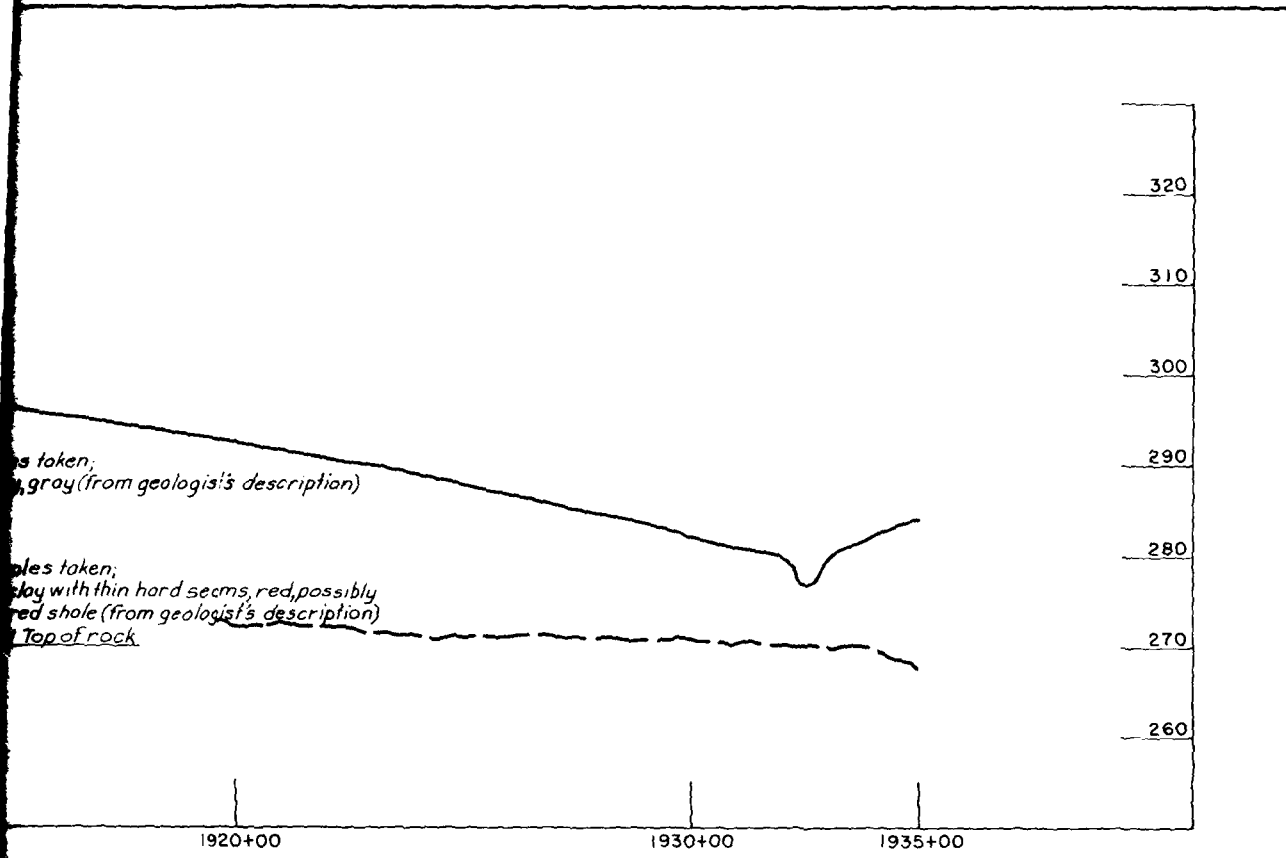
1960+00

1970+00

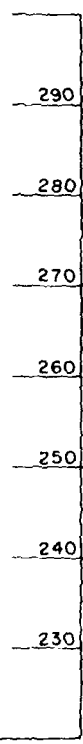
1980+00

PROFILE FROM STATION 1935+00 TO 1980+00

13



00



1980+00

QUEENSTON SHALE

No samples taken;  
Sandy clay with thin hard seams, red, possibly  
weathered shale (from geologist's description)  
E1 270.1 Top of rock

E1 142.1  
150.3'  
99.9%  
2 1/8"  
10-27-66

PROFILE ALONG ALIGNMENT A-I FROM STATION 1875+00 TO 1935+00

GROUND SURFACE

AUDC-67515  
280' LT

RC-66501  
810' LT

C	WT	No	Soil Type
75	244	1	CL
75	194	2	CL
75	240	3	CL
70	306	4	CL
70	299	5	ML
70	11.3	6	ML

Augered  
No samples - probably till  
E1 240.9 Top of rock

No samples taken  
Sandy clay and silt  
(from geologist's description)  
E1 240.9 Top of rock

LAKE ONTARIO

QUEENSTON SHALE

E1 141.2  
124.7'  
99.4%  
1 1/2" & 5"  
2 1/8"  
11-23-67

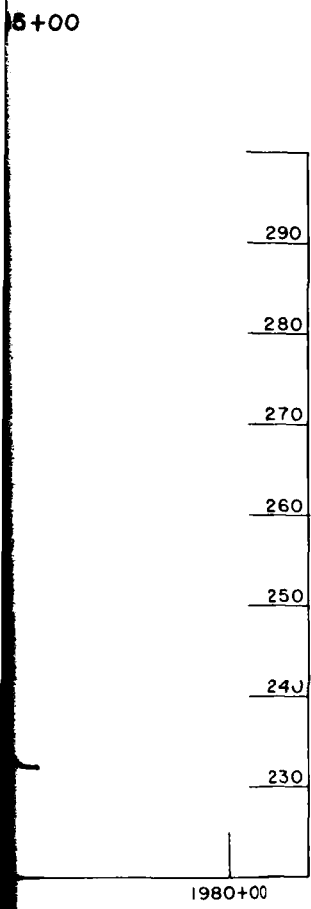
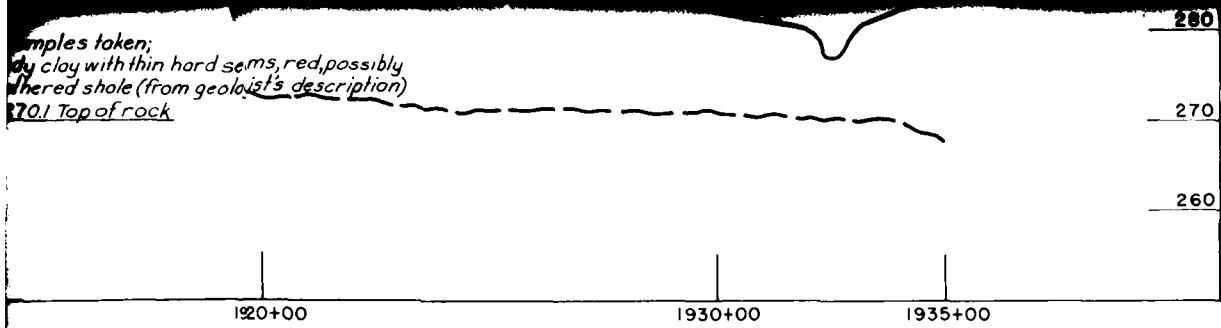
E1 103.8  
154.8'  
99.1%  
6"  
7-25-66

ALIGNMENT A-I FROM STATION 1935+00 TO 1980+00

NOTES:

- FOR LOCATION OF BORINGS SEE PLATE B5
- FOR LEGEND OF SOIL PROFILES AND NOTES
- FOR LOGS OF BORINGS SEE PLATE B11

samples taken;  
dry clay with thin hard seams, red, possibly  
weathered shale (from geologist's description)  
170.1 Top of rock



B5  
NOTES

LAKE ERIE-LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION  
STATION 1875+00 TO 1980+00 & CANAL

U. S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

PLATE B10

1 5

ELEVATION IN FEET I.G.L.D. (1955)



SI-DC-4  
80' RT.

APPROXIMATE  
GROUND SURFACE

SI-DC-5  
58' RT.

UPPER BLACK  
ROCK CANAL

N	No
69	1
100	2
	N
27	3
31	4
32	5
28	6
31	7
33	8
40	9
41	10
42	11
10	12
27	13
43	14
37	15
25	16
37	17
43	18
26	19
35	20
39	21
41	22
26	23
28	24
39	25
26	26
28	27
39	28
26	29
39	30
26	31
31	32
24	33
33	34
51	35
13	36
18	37
18	38
21	39
17	40
24	41
24	42
4	43

Fill, rubbish, stone, bricks,  
cinders, wood, etc.

Fill, -cinders, sand, clay  
and gravel

Clay (CL-CH), gravelly, wet,  
reddish brown.

Fine sandy clay (CL), gravelly,  
moist, reddish brown

Clay (CL) reddish brn. alt  
with clayey fine sand (so) moist,  
brn.

Silty clay (CL) gravelly, moist,  
reddish brown

Clayey silt (ML) gravelly,  
wet, reddish brown

Silty clay (CL), gravelly,  
wet, reddish brown

Clayey silt (ML), gravelly,  
wet, reddish brown

Silty clay (CL) gravelly, wet,  
reddish brown

Clay (CL) very stiff, red

Clay (CL), red, alt with fine  
sandy silt (ML), grayish  
brown, wet

El. 516.6 Top of rock

70 (0.5')  
Refusal

El. 491.1

88.8  
96.5 %  
1 1/2"  
2 1/8"

N No

N	No
35	1
36	NR
35	NR
36	4
35	NR
36	6
41	7
41	8
31	9
33	10
19	11
24	12
34	13
15	14
23	15
24	16
21	17
19	18
21	19
15	20
18	21
20	22
22	23
19	24
16	25
25	26
28	27
17	28
25	29
26	30
31	31
19	32
24	33
33	34
51	35
13	36
18	37
18	38
21	39
17	40
24	41
24	42
4	43

Fill, sand, clay, stone, concrete,  
wood, rubbish

Fill, wood, organic matter, brick, cinders, etc.

Fill, sand, organic matter, slag, gravel, etc.

Fill, silty sand (SM), dark gray, FW

Fill, sand and fine gravel (GP) traces of iron  
etc., dark gray, FW

Fill, sandy gravel (GP), bits of iron and slag  
dark gray, FW

Clayey sand and gravel (GC), wet brownish gray

Clay (CL-CH), trace gravel, wet, red

Silty clay (CL-CH), gravelly, wet, red

Clay (CL-CH), trace gravel, wet, red

Clay, (CL-CH), wet, red

Trace gravel

Clay (CL-CH), gravelly, wet, red

Clayey sand & gravel (GC), wet, gray  
El. 498.7 Top of rock

70 (0.7')

El. 473.1

600

APPROXIMATE  
GROUND SURFACE

SI-DC-3  
143' RT

N No

71 1  
29 2  
42 3  
45 4  
33 5  
35 6  
34 7  
36 8  
43 9  
45 10  
43 11  
37 12  
34 13  
34 14  
53 15  
101 16  
121 17  
100 18  
N N  
72 20  
38 21  
60 22  
N N  
62 23  
23 24  
65 24  
N N  
59 25  
71 26  
72 27  
103 27  
7 28  
20 29  
63 30  
N N  
37 31  
40 32  
45 33

Rubbish fill, including cinders  
sand, wood, brick, stone and  
concrete slabs

stone, concrete,  
sh

organic matter, brick, cinders, etc

organic matter, slag, gravel, etc  
sand (SM), dark gray, FW

fine gravel (GP) traces of iron,  
py, FW

gravel (GP), bits of iron and slag,  
FW

and gravel (GC), wet brownish gray

trace gravel, wet, red

CL-CH), gravelly, wet, red

trace gravel, wet, red

wet, red

gravelly, wet, red

gravel (GC), wet, gray

rock

El. 461.0

129.1  
98%

SI-DC-2  
88' RT

N No

9 1  
12 2  
17 3  
32 4  
57 5  
55 6  
58 7  
56 8  
46 9  
49 10  
27 11  
25 12  
25 13  
25 14  
19 15  
23 16  
25 17  
24 18  
23 19  
38 20  
23 21  
N  
28 22  
N  
90 23  
N  
32 24  
67 25  
N  
39 26  
27 27

Clay (CL-CH), moist, red with  
trace organic  
Organic silt (OL), black with  
sand seams

Silty sand (SM), wet, brown

Fine to medium sand and  
gravel (GP), wet, brown, trace of  
silt.

Silty fine sand (SM), gray,  
moist, trace of shells

Silty fine sand (SM), wet, dark  
gray, trace gravel

Silty sand and gravel (GM),  
wet, gray

El. 519.5 Top of rock

El. 468.9

100.4  
85.5%  
1 1/2"

SI-DC-1  
39' RT

N No

24 1  
15 2  
14 3  
11 4  
17 5  
28 6  
35 7  
41 8  
54 9  
35 10  
17 11  
14 12  
7 13  
34 4  
21 5  
31 6  
63 7  
17 8  
27 9  
27 20  
25 21  
23 22  
19 23  
21 24  
25 25  
7 26  
28 27  
71 28  
73 29  
35 30  
27 31

Clay (CL-CH) gravelly, wet, red

Clay, silty sand (slag, ms), reddish brown

Organic silt (OL), plant matter, blk

Clay (CL), ms, dk gray, w/sand seam

Silty fine sand (SM), wet, brown

Fine sandy silt (ML), wet, dark gray

Silty, fine sand (SM), gravelly, w

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

Silty fine to medium sand (SM),  
gravelly, wet, dark gray

BERTI

El. 463.6

45.5  
98%  
1 1/2"

**-DC-1**  
39' RT

EXISTING GUIDE WALL

EXISTING BLACK ROCK CANAL

No.	Description
1	Clay (CL-CH) gravelly, wet, red
2	Clay, silty sand & slag, moist, reddish-brown
3	Organic silt (OL) plant matter, blk
4	Clay (CL) moist, dk gray, w/sand seam
5	Silty fine sand (SM), wet, brown
6	Fine sandy silt (ML), wet dark gray, trace organic
7	
8	
9	Silty, fine sand (SM), gravelly, wet brown
10	
11	
12	
13	Sand and gravel (GP), wet
14	
15	
16	Silty fine to medium sand (SM), gravelly, wet, dark gray.
17	
18	
19	
20	Silty sandy gravel (GM), wet, gray
21	
22	
23	
24	
25	Clayey silt (ML-CL), grayish-brown, wet, with sand seams.
26	
27	
28	
29	Silty sandy gravel (GM), moist, dark gray (till)
30	
31	El 524.0 Top of rock

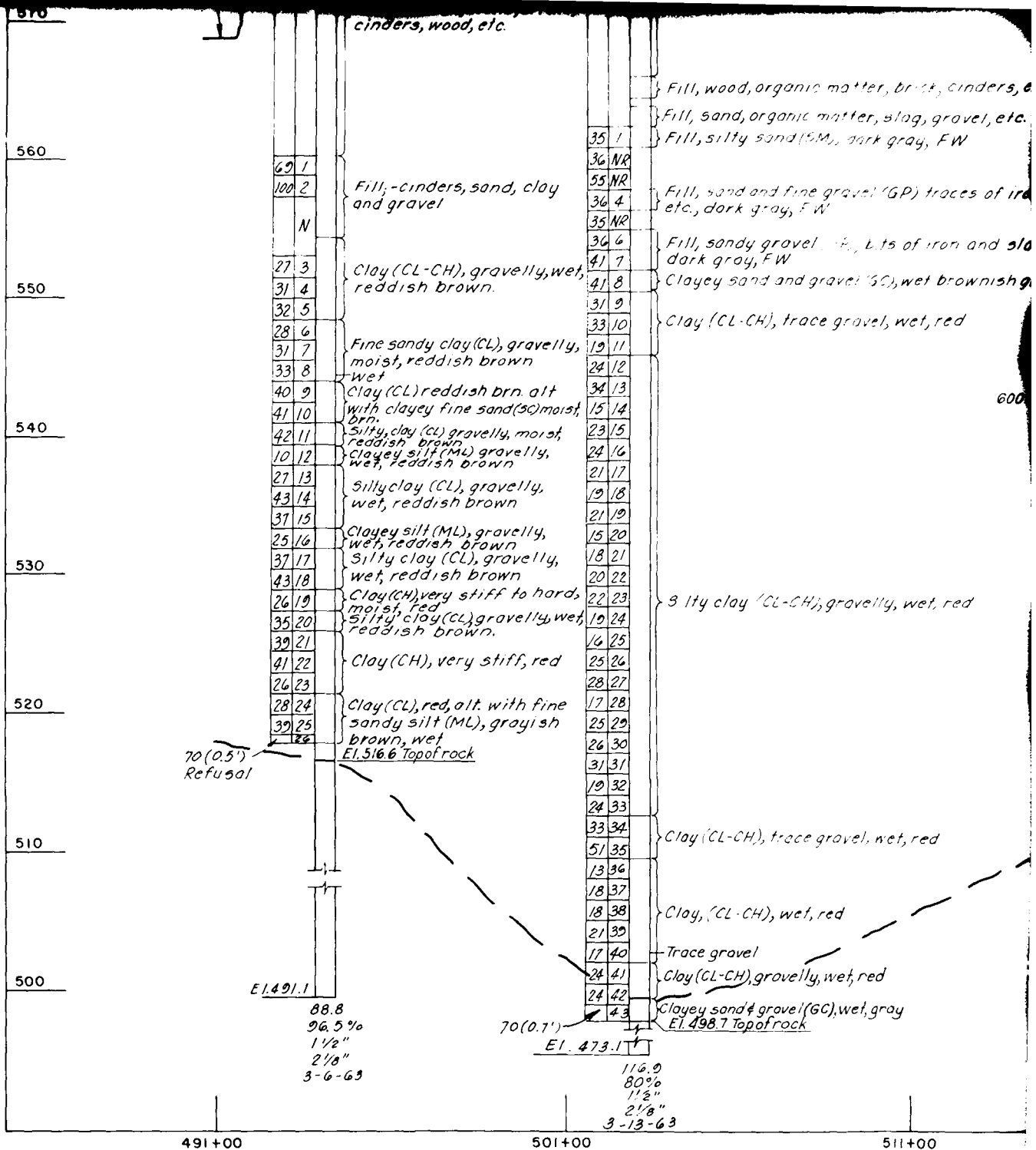
APPROXIMATE TOP OF ROCK

BERTIE LIMESTONE

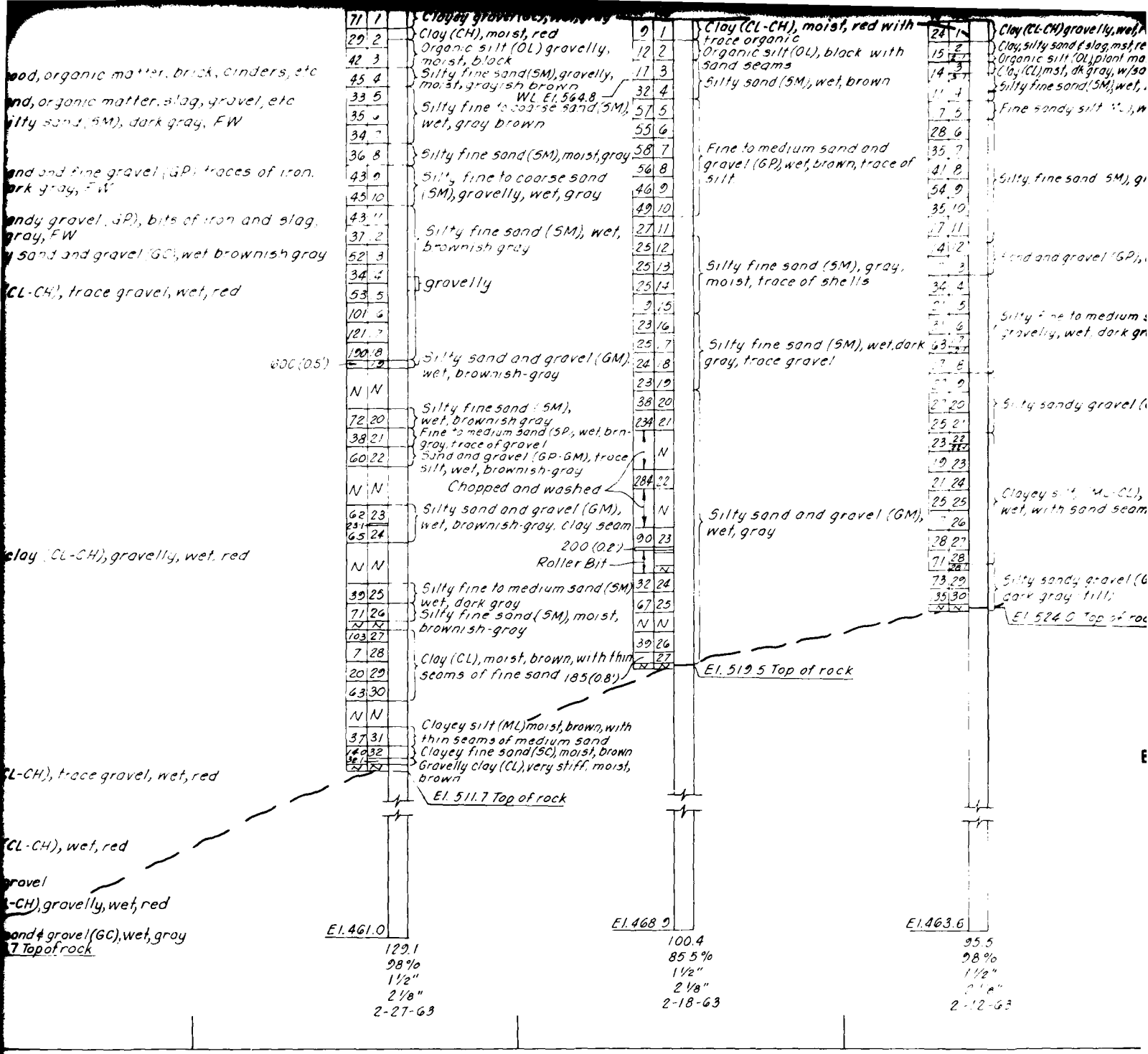
590  
580  
570  
560  
550  
540  
530  
520  
510  
500

163.6  
95.5  
98%  
1 1/2"  
2 1/2"

ELEVATION IN FEET I.G.L.D. (1955)

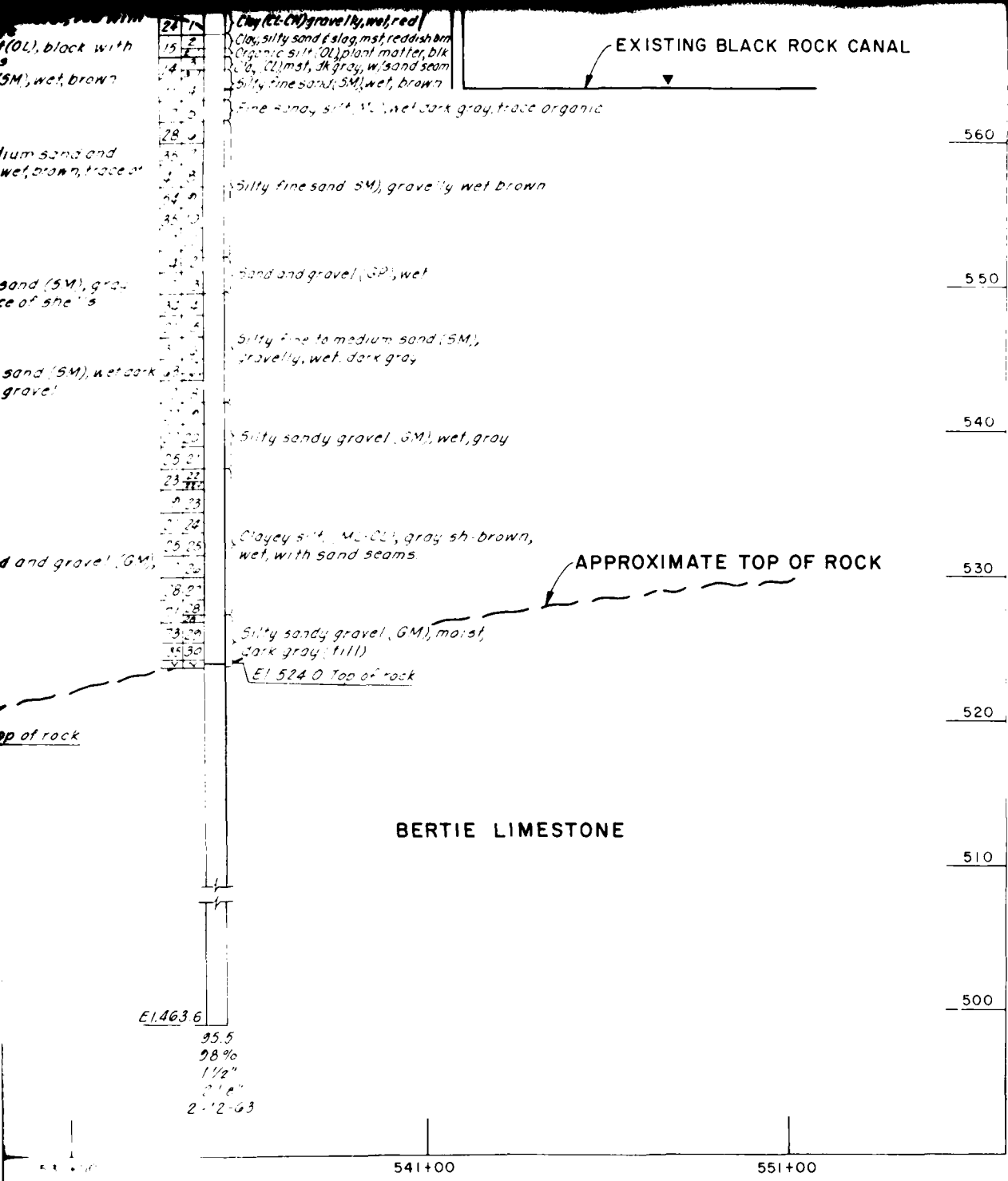


PROFILE ALONG ALIGNMENT A-1 FR



SECTION ALONG ALIGNMENT A-I FROM STATION 491+00 TO 551+00

**NOTES:**  
 FOR LOCATION OF BORINGS, SEE PLATE B6.  
 FOR DETAILED DESCRIPTION OF ROCK CORE FOR LOCK 5-5,  
 SEE PLATE B24.  
 FOR LEGEND OF SOIL PROFILES AND NOTES FOR LOGS OF BORINGS,  
 SEE PLATE B11



LAKE ERIE-LAKE ONTARIO WATERWAY

**SOIL PROFILE  
LOCK 5-5**

ARMY ENGINEER DISTRICT, BUFFALO

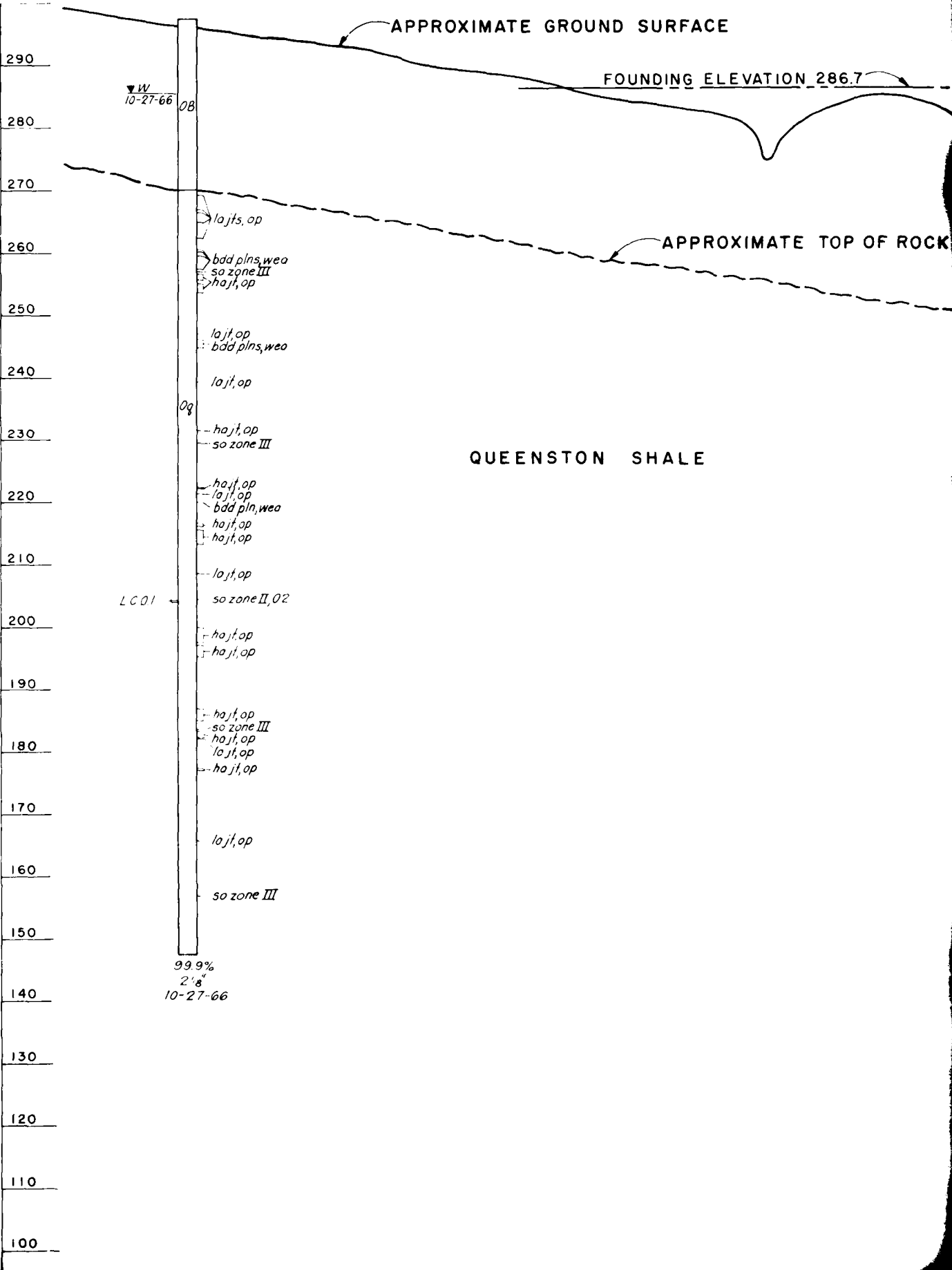
MEANY REVIEW OF REPORTS  
OCTOBER 1973

RC-66504

190' LT

UPPER GUIDE WALL

ELEVATION IN FEET I.G.L.D. (1955)



APPROXIMATE GROUND SURFACE

FOUNDING ELEVATION 286.7

APPROXIMATE TOP OF ROCK

QUEENSTON SHALE

W  
10-27-66

OB  
Og

LC01

99.9%  
2' 8"  
10-27-66

la jt, op  
bdd plns, wea  
so zone III  
ha jt, op

la jt, op  
bdd plns, wea

la jt, op

ha jt, op  
so zone III

ha jt, op  
la jt, op  
bdd pln, wea  
ha jt, op  
ha jt, op

la jt, op  
so zone II, 02

ha jt, op  
ha jt, op

ha jt, op  
so zone III  
ha jt, op  
la jt, op  
ha jt, op

la jt, op

so zone III

290  
280  
270  
260  
250  
240  
230  
220  
210  
200  
190  
180  
170  
160  
150  
140  
130  
120  
110  
100



NOTE: TOP OF LOCK WALL ELEVATION IS 331.7

LOWER GUIDE WALL

290

280

270

260

250

LAKE ONTARIO

240

230

so zone I, 01

so zone I, 01

hor jt, wea

QUEENSTON SHALE

220

so zone I, 19, pass shear zone

210

so zone I, 02

FOUNDING ELEVATION 204.0

so zone I, 01

vert jt, op

so zone I, 005

200

190

hor jt, op

180

170

160

hor jt, op

hor jt, op

150

hor jt, op

hor jt

140

130

120

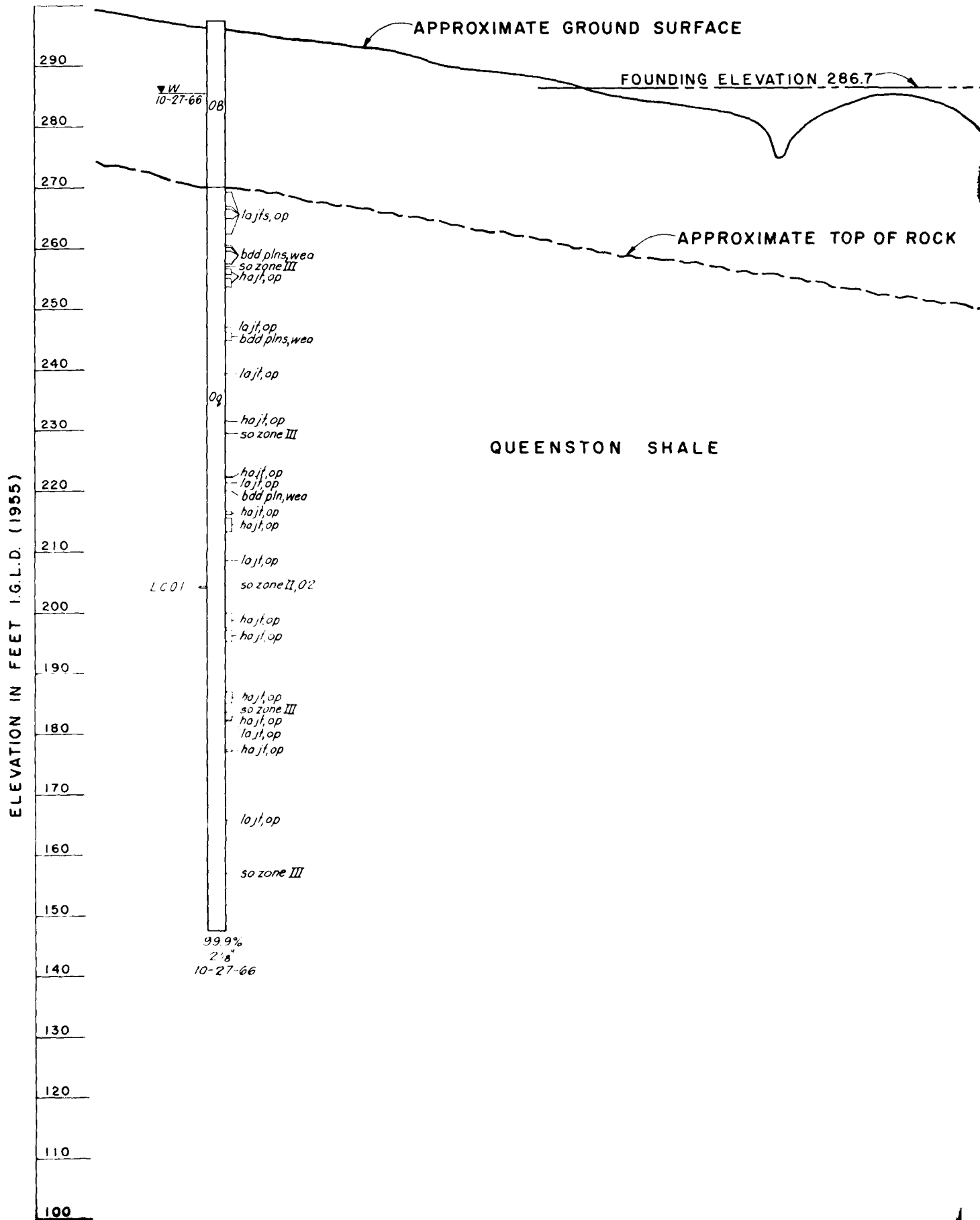
110

100

0.1%

RC-66504  
190' LT

UPPER GUIDE WALL



GUIDE WALL

LOCK I-5

NOTE: TOP OF LOCK WALL

STATION 286.7

RC-66503  
780' LT

AUDC-67515  
280' LT

RC-66501  
810' LT

DATE TOP OF ROCK

OB

▽W 1-1-66

LC04

LC04

LC04

so zone I,008  
so zone III  
so zone I,005  
so zone I,001  
so zone III,001  
so zone III,001  
so zone II,001  
so zone II  
so zone II  
so zone III  
hor jt,op,wea,num  
so zone III  
ho jt,op  
hor jt,sl,wea  
ho jt,op  
ho jt,op  
ho jt,op  
ho jt

09

ho jt,op  
ho jt  
ho jt,op

ho jt,op  
so zone I,005  
so zone I,002  
ho jt  
so zone II,001  
ho jt,op  
so zone I,004  
hor jt,wea  
FOUNDING ELEVATION 175.0  
ho jt,op

ho jt,op  
ho jt,op  
ho jt,op

ho jt  
ho jt

ho jt,partly op

▽W 11-23-67

LC02  
LC05

OB

▽W 7-25-66

LC04  
LC06

LC02

LC05

so zone I  
so zone II  
so zone III  
so zone II,005  
so zone III  
so zone III  
hor jt,sl,wea  
so zone I,009  
so zone II,002  
so zone III  
09  
ho jt,op  
so zone III  
so zone III  
so zone III  
so zone III  
ho jt,op  
so zone III  
hor jt,wea  
ho jt,op  
so zone II  
vert jt,op  
vert jt

▽W 7-25-66

OB

so zone I,01  
so zone I,01  
hor jt,wea  
so zone I,01,pass shear zone  
so zone I,02  
so zone I,01  
vert jt,op  
so zone I,005  
ho jt,op  
ho jt,op

QUE

FOUNDING ELE

EL. 165.8

99.3%  
2 1/8"  
11-1-66

99.4%  
2 1/8"  
11-22-67

99.1%

NOTE: TOP OF LOCK WALL ELEVATION IS 331.7

LOWER GUIDE WALL

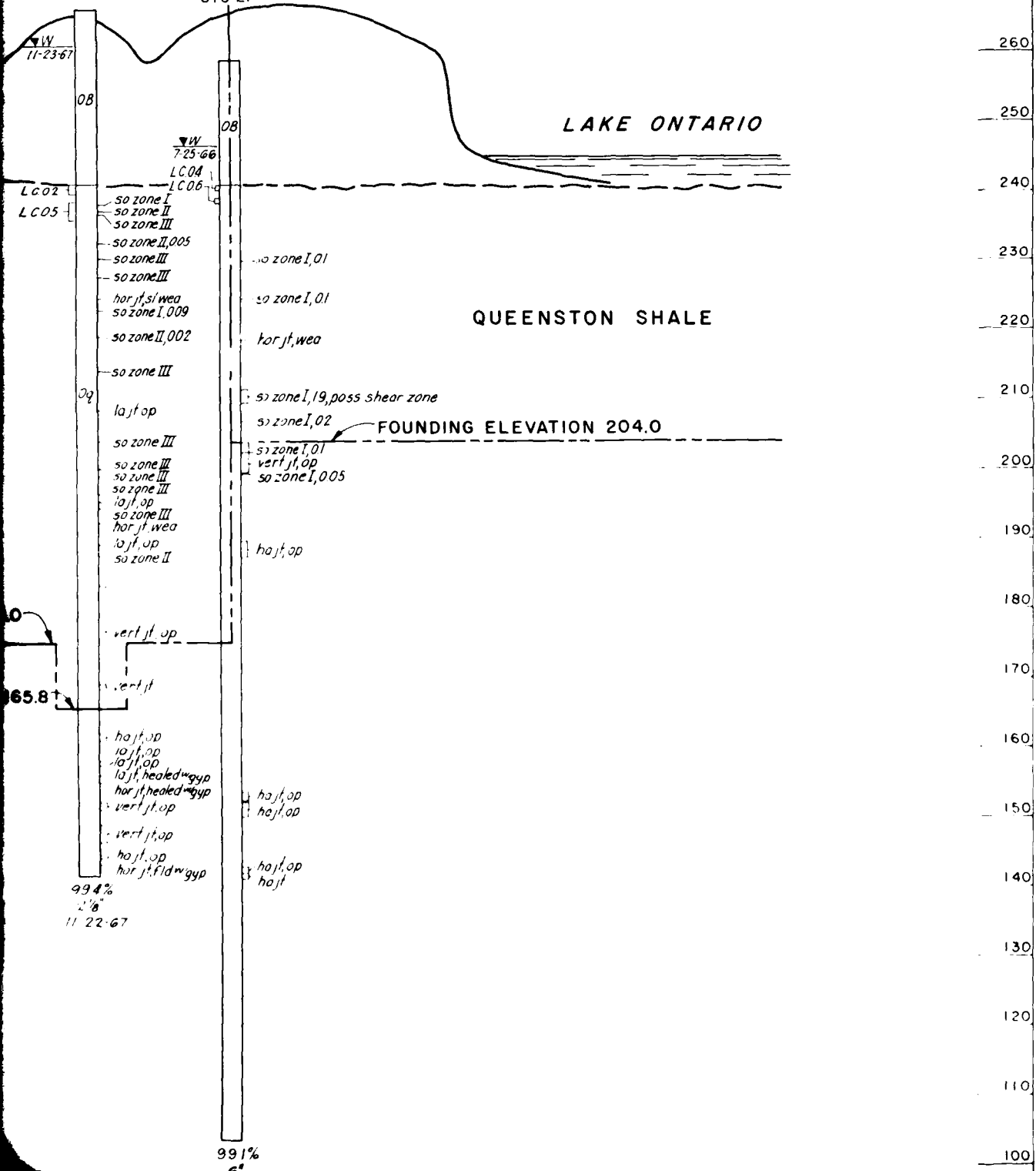
AUDC-67515  
280' LT

RC-66501  
810' LT

LAKE ONTARIO

QUEENSTON SHALE

FOUNDING ELEVATION 204.0



11-23-67

7-25-66

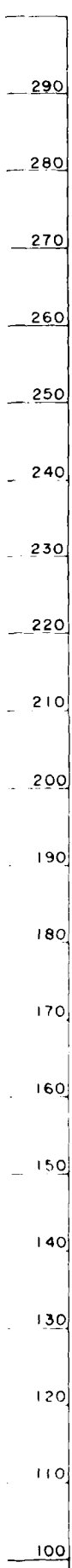
LC 02  
LC 05

LC 04  
LC 06

65.8

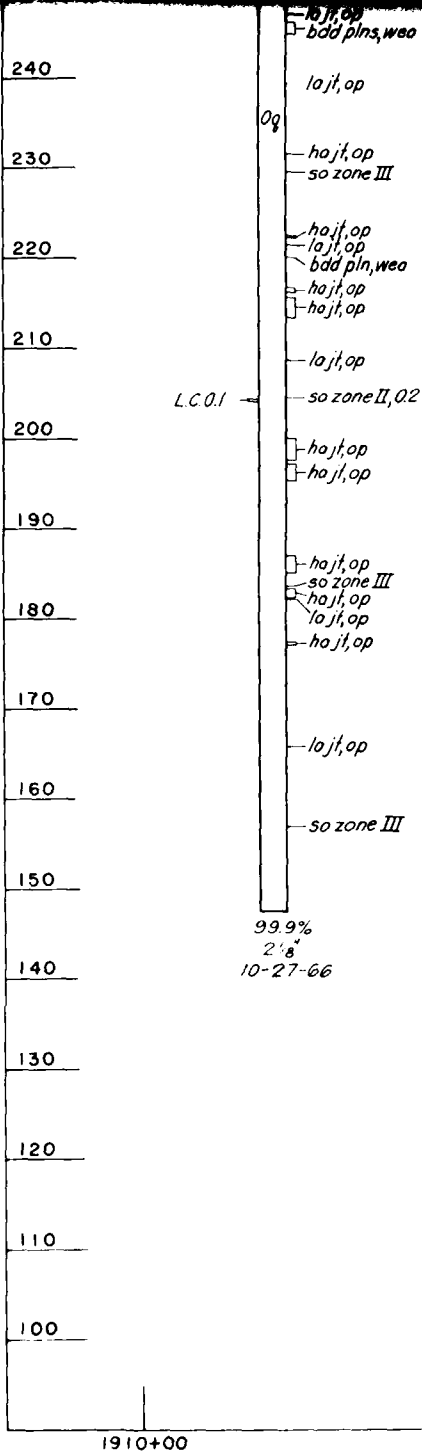
99.4%  
2 1/8"  
11-22-67

99.1%

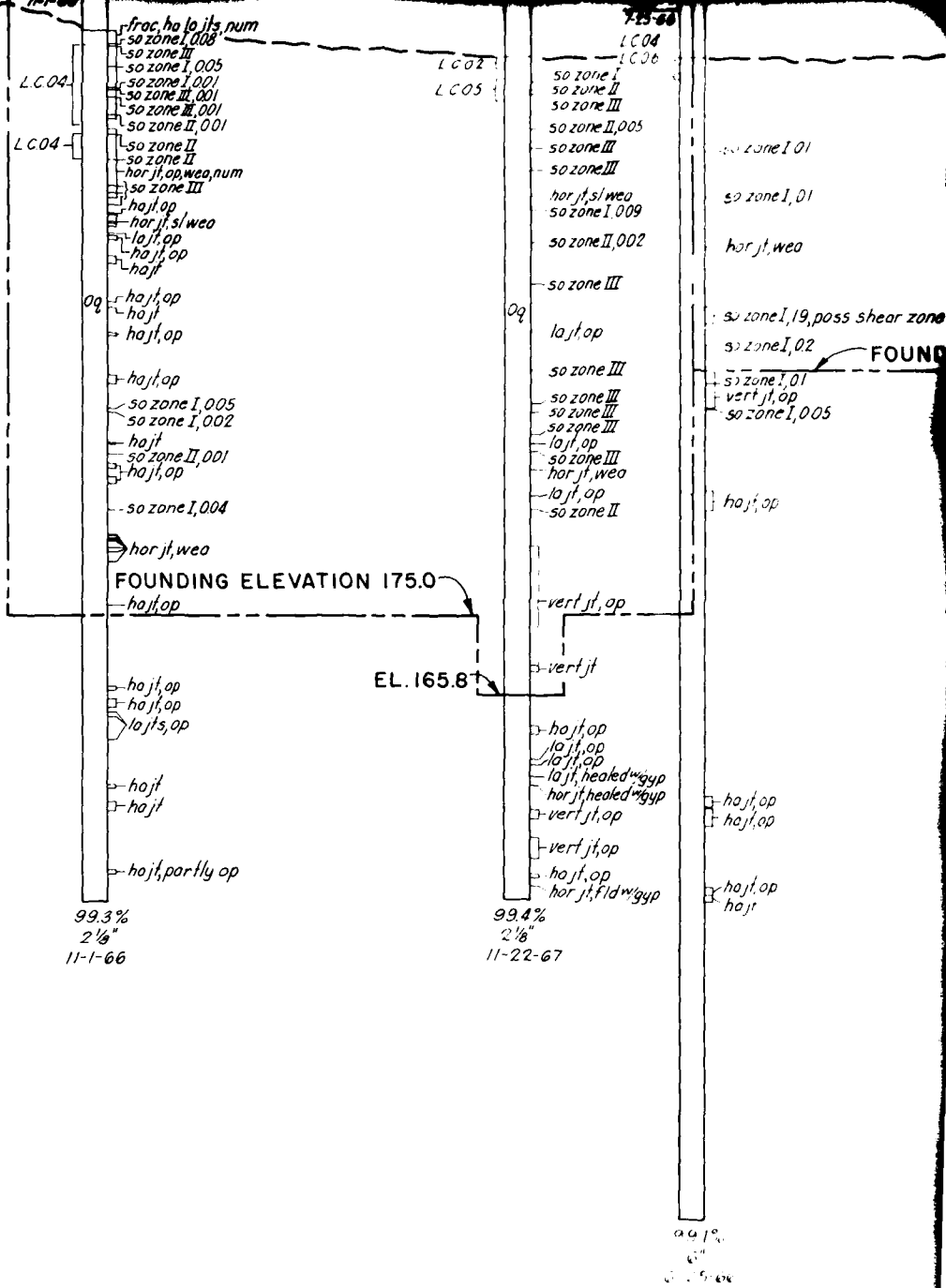


QUEENSTON SHALE

ELEVATION IN FEET I.G.L.D. (1955)



E



PROFILE A-A

**NOTES:**  
 FOR LOCATION OF PROFILE AND BORINGS, SEE PLATE B5.  
 FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS, JOINT CLASSIFICATIONS AND SOFT ZONE CLASSIFICATION SEE PLATE B1.  
 FOR DETAILED DESCRIPTION OF OVERBURDEN SEE PLATE B1B.

W  
7-25-66  
LC 04  
LC 06

202  
 205  
 so zone I  
 so zone II  
 so zone III  
 so zone II,005  
 so zone III  
 so zone III  
 hor jt, sl wea  
 so zone I, 009  
 so zone II, 002  
 so zone III  
 Oq  
 la jt, op  
 so zone III  
 so zone III  
 so zone III  
 so zone III  
 la jt, op  
 so zone III  
 hor jt, wea  
 la jt, op  
 so zone II  
 vert jt, op  
 vert jt  
 ho jt, op  
 la jt, op  
 la jt, op  
 la jt, healed w/gyp  
 hor jt, healed w/gyp  
 vert jt, op  
 vert jt, op  
 ho jt, op  
 hor jt, fld w/gyp  
 99.4%  
 2 1/8"  
 11-22-67

so zone I, 01  
 so zone I, 01  
 hor jt, wea  
 so zone I, 19, pass shear zone  
 so zone I, 02  
 so zone I, 01  
 vert jt, op  
 so zone I, 005  
 ha jt, op  
 ha jt, op  
 ha jt, op  
 ha jt, op  
 ha jt, op  
 ha jt, op  
 ha jt

QUEENSTON SHALE

FOUNDING ELEVATION 204.0

240  
 230  
 220  
 210  
 200  
 190  
 180  
 170  
 160  
 150  
 140  
 130  
 120  
 110  
 100

99.1%  
6"  
6-25-66

1960+00

1970+00

1980+00

LAKE ERIE-LAKE ONTARIO WATERWAY

GEOLOGIC PROFILE  
LOCK 1-5

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

B5.  
GIC  
NS  
PLATE B18.

UPPER GUIDE WALL

FOUNDING ELEVATION 366.4

ARC-66509  
200' LT

AU

ELEVATION IN FEET I.G.L.D. (1955)

310  
300  
290  
280  
270  
260  
250  
240  
230  
220  
210  
200  
190  
180  
170  
160  
150  
140

▼ W  
11-14-66

08

APPROXIMATE TOP OF ROCK

L.C. 0.6  
L.C. 0.3  
L.C. 0.2

so zone I, 0.05  
so zone I, 0.1  
so zone II, 0.1  
so zone I, 0.02  
so zone I, 0.03  
la jt, ap  
hor jt, sl wea  
la jt, ap  
hor jt, ap  
ha jt  
ha jt, ap  
so zone I, 0.02

QUEENSTON SHALE

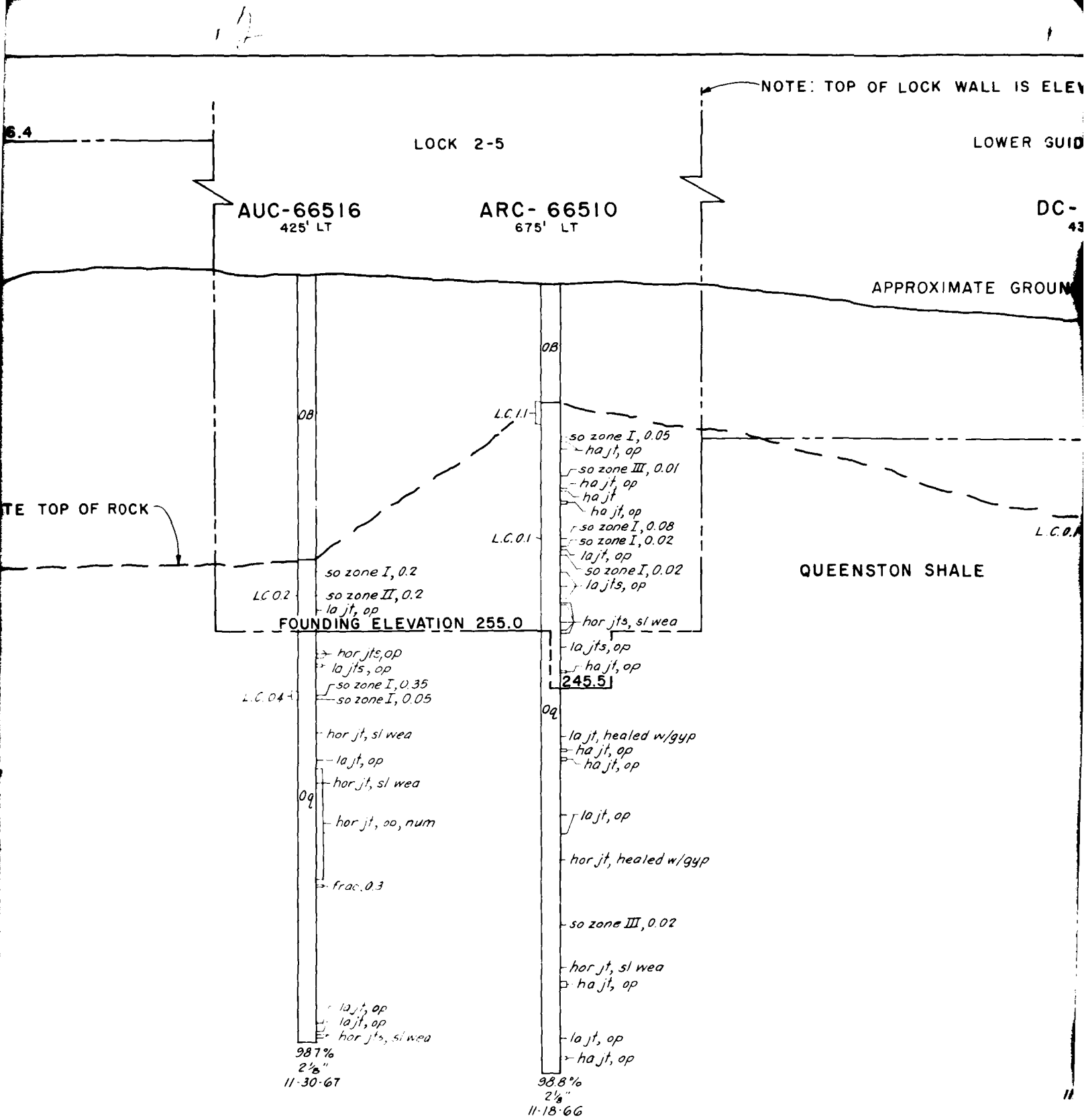
09  
hor jts, sl wea  
so zone I, 0.02  
so zone II, 0.01  
so zone I, 0.05

so zone I, 0.02  
ha jt, ap  
la jts, ap

la jt, ap

so zone III  
la jt, ap  
hor jt, sl wea  
la jt  
hor jt, sl wea

98.7%  
2 1/8"  
11-14-66



NOTE: TOP OF LOCK WALL IS ELEVATION 411.4

LOWER GUIDE WALL

DC-67514  
430' LT

RC-66505  
780' LT

APPROXIMATE GROUND SURFACE

310

300

290

FOUNDING ELEVATION 286.7

280

270

260

250

240

230

220

210

200

190

180

170

160

150

140

QUEENSTON SHALE

OB

OB

L.C.0.1

L.C.0.4

Oq

Oq

99.9%  
2 1/8"  
11-15-66

99.9%  
2 1/8"  
11-8-66

ha jt, op  
so zone I, 0.1

la jts, op  
hor jt, healed w/gyp

hor jt, sl wea

hor jt, healed w/gyp

la jt, op  
la jt, op

ha jt, op  
la jt, op  
ha jt, op  
la jt, op  
la jt, op  
ha jt, op

hor jt, healed w/gyp

so zone I, 0.02

hor jt, sl wea  
la jts, op  
hor jt, sl wea

so zone II

so zone I, 0.1  
hor jt, sl wea

ha jt  
ha jt, op  
la jt, op  
so zone III  
la jt, op  
hor jts, sl wea

la jt, op  
ha jt, op

hor jt, wea

so zone III  
hor jt, wea  
la jt, op

hor jt, wea

ha jt, op  
hor jt, wea  
ha jt, op  
so zone III

hor jt, wea

hor jt, op  
hor jt, wea

hor jt, wea

so zone III

hor jt, wea

la jt, op

ELEVATION IN FEET I.G.L.D. (1955)

290  
280  
270  
260  
250  
240  
230  
220  
210  
200  
190  
180  
170  
160  
150  
140

QUEENSTON SHALE

APPROXIMATE TOP OF ROCK

L.C. 0.6  
L.C. 0.3  
L.C. 0.2

so zone I, 0.05  
so zone I, 0.1  
so zone II, 0.1  
so zone I, 0.02  
so zone I, 0.03  
la jt, op  
hor jt, sl wea  
la jt, op  
hor jt, op  
na jt  
ha jt, op  
so zone I, 0.02  
hor jts, sl wea  
Oq  
so zone I, 0.02  
so zone II, 0.01  
so zone I, 0.05  
so zone I, 0.02  
ha jt, op  
la jts, op  
la jt, op  
so zone III  
la jt, op  
hor jt, sl wea  
la jt  
hor jt, sl wea

98.7%  
2 1/8"  
11-14-66

1768+00

1778+00

1788+00

AD-A100 739

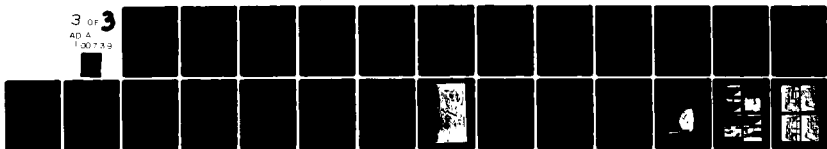
CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT  
REVIEW OF REPORTS ON LAKE ERIE-LAKE ONTARIO WATERWAY, NEW YORK.--ETC(U)  
OCT 73

F/8 13/2

UNCLASSIFIED

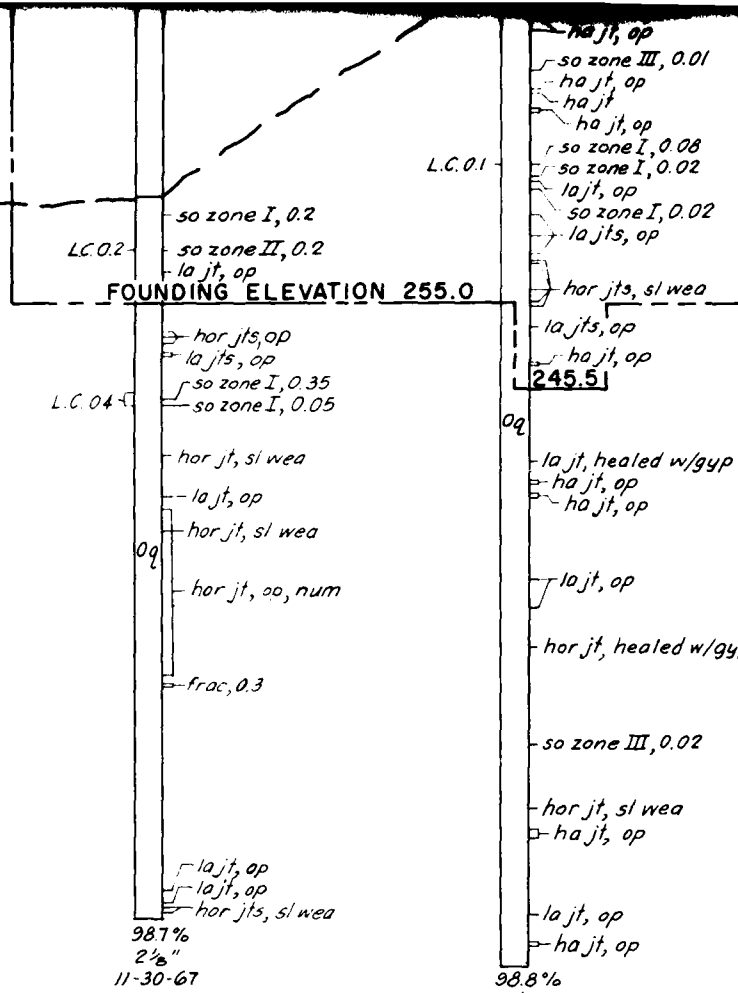
NL

3 of 3  
AD 4  
100739



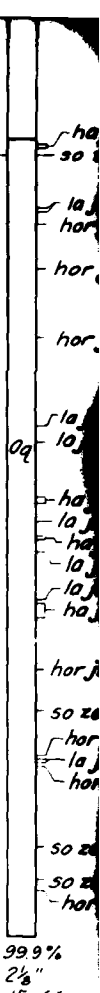
END  
DATE  
FILMED  
7-81  
DTIC

OF ROCK



QUEENSTON SHALE

L.C.01



1798+00

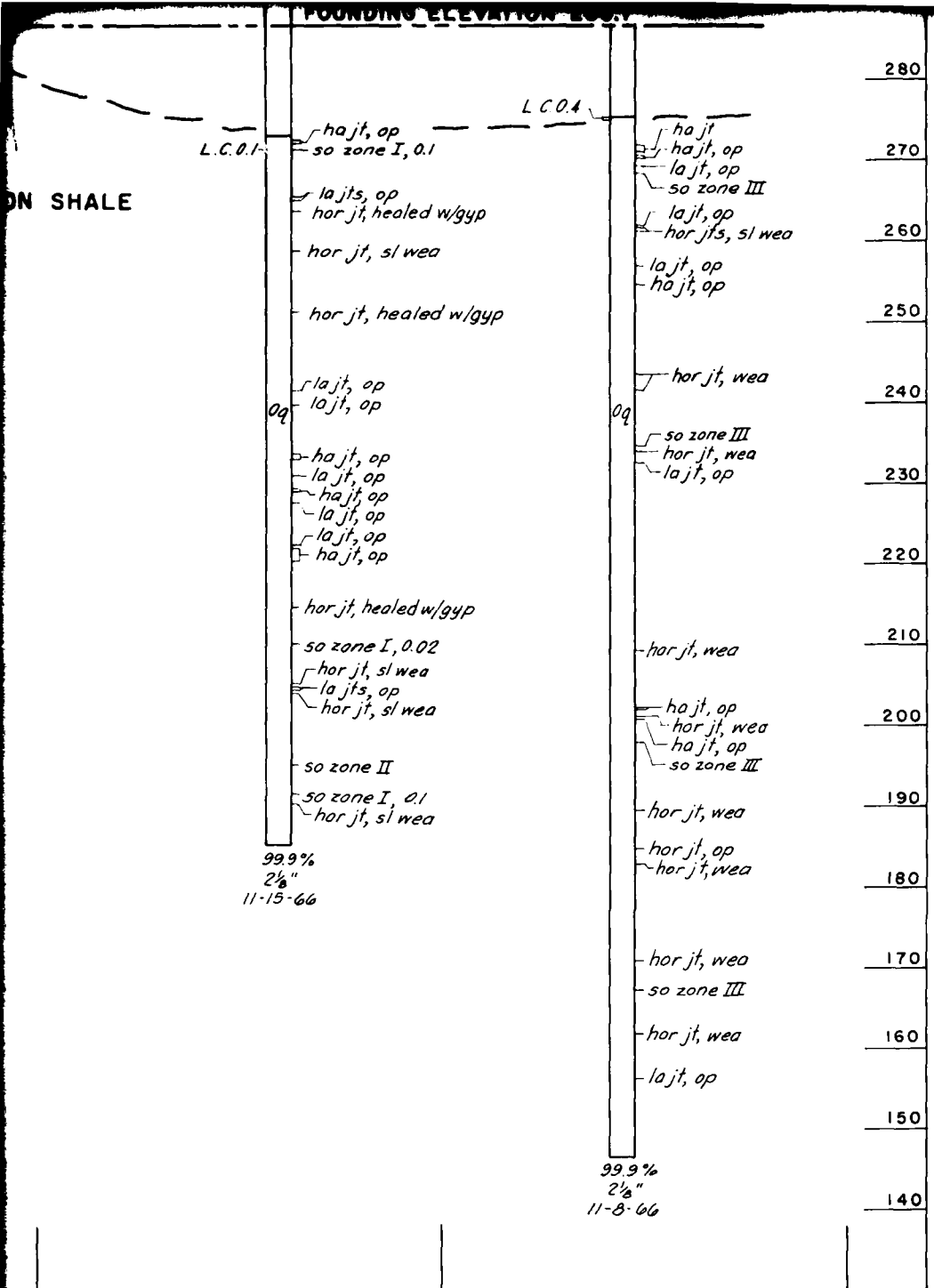
1808+00

1818+00

PROFILE B-B

NOTES:

FOR LOCATION OF PROFILE AND BORINGS SEE  
 PLATE B4.  
 FOR LEGEND OF EXPLORATIONS, GENERALIZED  
 GEOLOGIC COLUMN, LIST OF ABBREVIATIONS, SOFT  
 ZONE CLASSIFICATION SEE PLATE B1.  
 FOR DETAILED DESCRIPTION OF OVERBURDEN  
 SEE PLATE B17.



LAKE ERIE-LAKE ONTARIO WATERWAY

**GEOLOGIC PROFILE**

**LOCK 2-5**

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS

OCTOBER 1973

NO BORINGS SEE  
GENERALIZED  
VIATIONS, SOFT  
BI.  
OF OVERBURDEN

16



17

1

NOTE: TOP OF LOCK WALL IS ELEVATION 491.1

508

LOCK 3-5

LOWER GUID

ADC-67512  
475' LT

RC-66507  
900' LT

APPROXIMATE GROUND

ADC-67513  
275' LT

FOUNDING ELEVATION 328.0

- la jt, op
- so zone II, 02'
- la jts, op
- ha jt, op
- la jt, op
- la jts
- so zone III, 005' on bdd pl
- la jt, op
- ha jt, op
- la jt, op
- so zone III, 005'
- so zone II, 01'
- ha jt, op

- ha jt, op
- ha jt, op
- ha jt, op
- la jts, op
- wea zone, on bdd pl
- la jt, op
- ha jt, op
- ha jt, op
- la jts, op
- so zone I, 001'
- ha jt, op
- la jt, op
- wea zone, 02'
- ha jt, healed w/gyp
- la jt, op
- ha jt, op
- la jts, op
- so zone III, 001' on bdd pl
- so zone I, 001' on bdd pl
- so zone I, 008' on bdd pl
- so zone I, 007'
- ha jt, op
- la jts, op si wea
- la jt, healed w/gyp
- frac zone 01'
- ha jt, op
- la jt, op
- ha jt, op
- so zone II, 022'
- so zone II, 021'
- ha jt, wea on bdd pl
- la jt, 001' healed w/gyp
- la jt, op
- ha jt, some si wea
- la jts, op
- la jt, healed w/gyp

- 08
- hor jt, st
- so zone II, 001'
- frac zone 07'
- la jt, op
- so zone I, 08' cl # sh in bdd in 16' interval
- la jts
- ha jts

- 09
- la jt, op
- so zone I, 002'
- so zone I, 03'
- so zone I, 001'
- ha jt, 001' healed w/gyp
- hor jt, 001' healed w/gyp
- wea zone, 02' along bdd pl
- so zone I, 001'
- la jt
- ha jt

- hor jt, si wea
- ha jt
- la jt
- ha jt

100%  
6"  
11-6-67

- 08
- la jt, op
- ha jt, op
- wea zone, 1.3'
- la jt, op
- hor jts, wea
- so zone I, 002'
- hor jts, wea
- so zone III
- hor jts, wea
- so zone I, 003'
- wea zones, num
- ha jt, op
- la jt
- wea zones, num
- hor jts, healed w/gyp, num

- 09
- wea zones, num
- so zone I, 002'
- so zone I, 003'
- ha jt, partly healed w/gyp
- ha jt, wea
- so zone II
- hor jts, wea
- ha jt, op
- la jt, healed w/gyp
- so zone III
- ha jt
- wea zones, num
- hor jts & bdd plns, healed w/gyp, num

- ha jts, op
- ha jt
- so zone III
- wea zone num
- ha jt, op

- la jts, wea, healed w/gyp
- ha jt, healed w/gyp
- hor jts, healed w/gyp
- ha jt

100%  
2' 8"  
11-23-67

- LC 15'
- frac zone, 01'
- so zone II, 001'
- so zone I, 001'
- so zone I, 001'
- so zone I, 001'
- so zone I, 001'
- so zone I, 001'
- so zone I, 001'
- wea bdd pl
- so zone I, 001'
- so zone II, 001'
- so zone I, 001'
- so zone I, 001'
- la jt

- so zone III
- la jt, op
- frac zone 01'
- ha jt, op
- wea zones, num
- hor jts & bdd plns, healed w/gyp, num
- ha jts, op
- ha jt
- so zone III
- wea zone num
- ha jt, op

- la jts, wea, healed w/gyp
- ha jt, healed w/gyp
- hor jts, healed w/gyp
- ha jt

- ha jts, op
- ha jt, op
- ha jt
- la jt
- la jts, op
- ha jts, op
- ha jt
- ha jt

- ha jts, op
- ha jt
- ha jt

- ha jts, op
- ha jt
- ha jt

- ha jts, op
- ha jt
- ha jt

- ha jts, op
- ha jt
- ha jt

WALL IS ELEVATION 491.1

LOWER GUIDE WALL

APPROXIMATE GROUND SURFACE

ADC-67513  
275' LT

FOUNDING ELEVATION 366.4

APPROXIMATE TOP OF ROCK

LC 15'

frac zone, 13', so zones, ha & la jts

so zone II, 001'

so zone I, 002'

so zone I, 001'

so zone I, 002'

so zone I, 004'

so zone I, 005'

so zone I, 015'

so zone II, 005'

weo bdd plns, ha & la jts, num

so zone I, 002'

so zone II, 001'

so zone I, 04'

so zone I, 02'

la jt

la jt

so zone III

la jts, op

0q

frac

ha jt, op

la jts, op

vgys, fld w/gyp

hor jts, healed w/gur

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

la jts, op

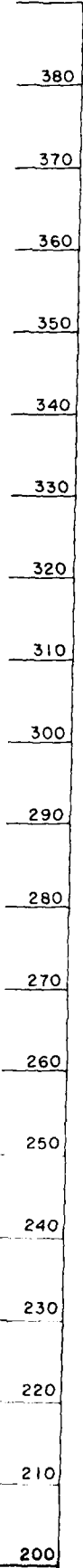
la jts, op

la jts, op

la jts, op

98.3%  
2 1/8"  
11-9-67

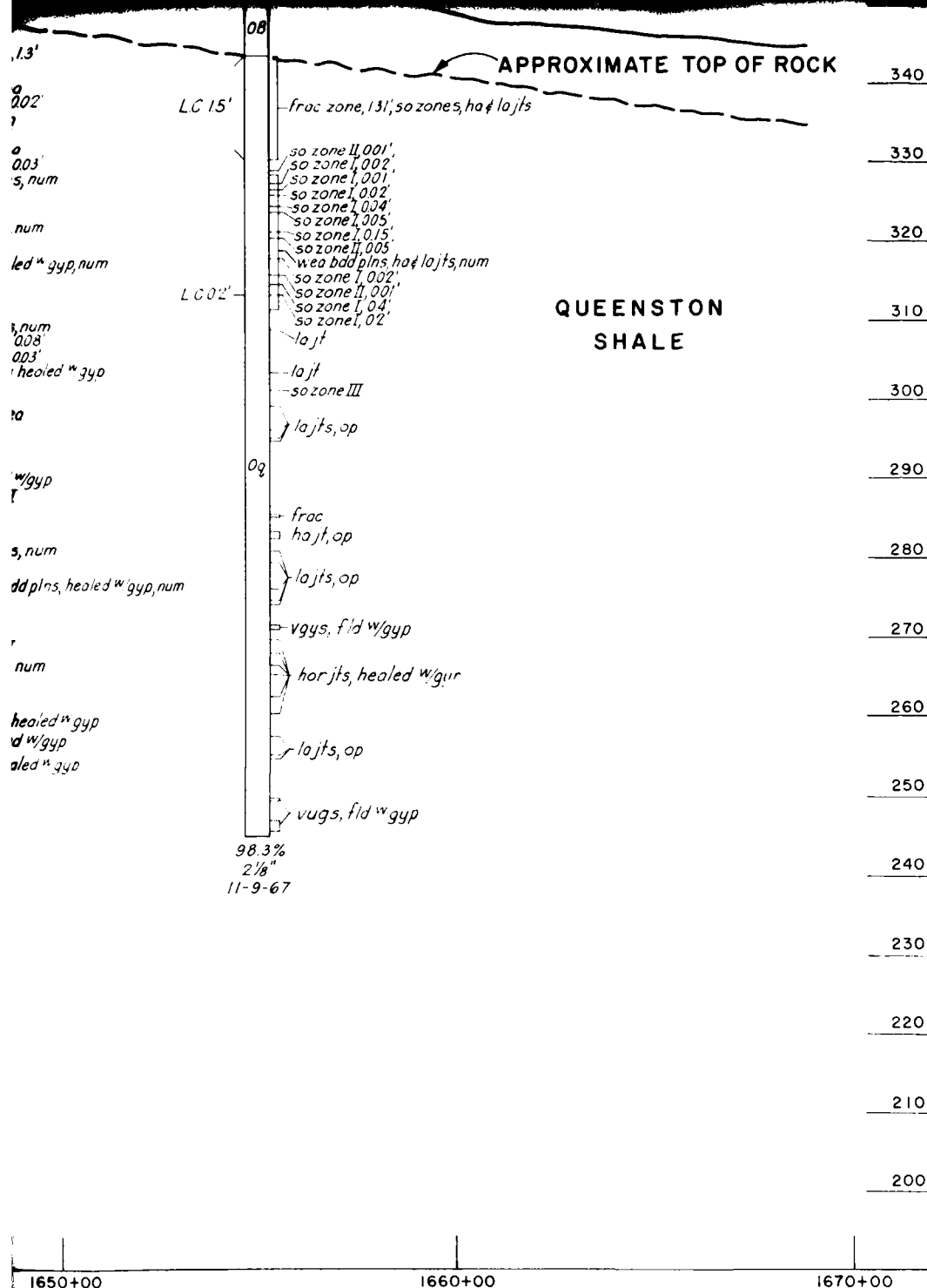
QUEENSTON  
SHALE



gyp, num  
healed w/gyp  
p  
um  
plns, healed w/gyp, num  
m  
healed w/gyp  
w/gyp  
d w/gyp







LAKE ERIE-LAKE ONTARIO WATERWAY

GEOLOGIC PROFILE  
LOCK 3-5

U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

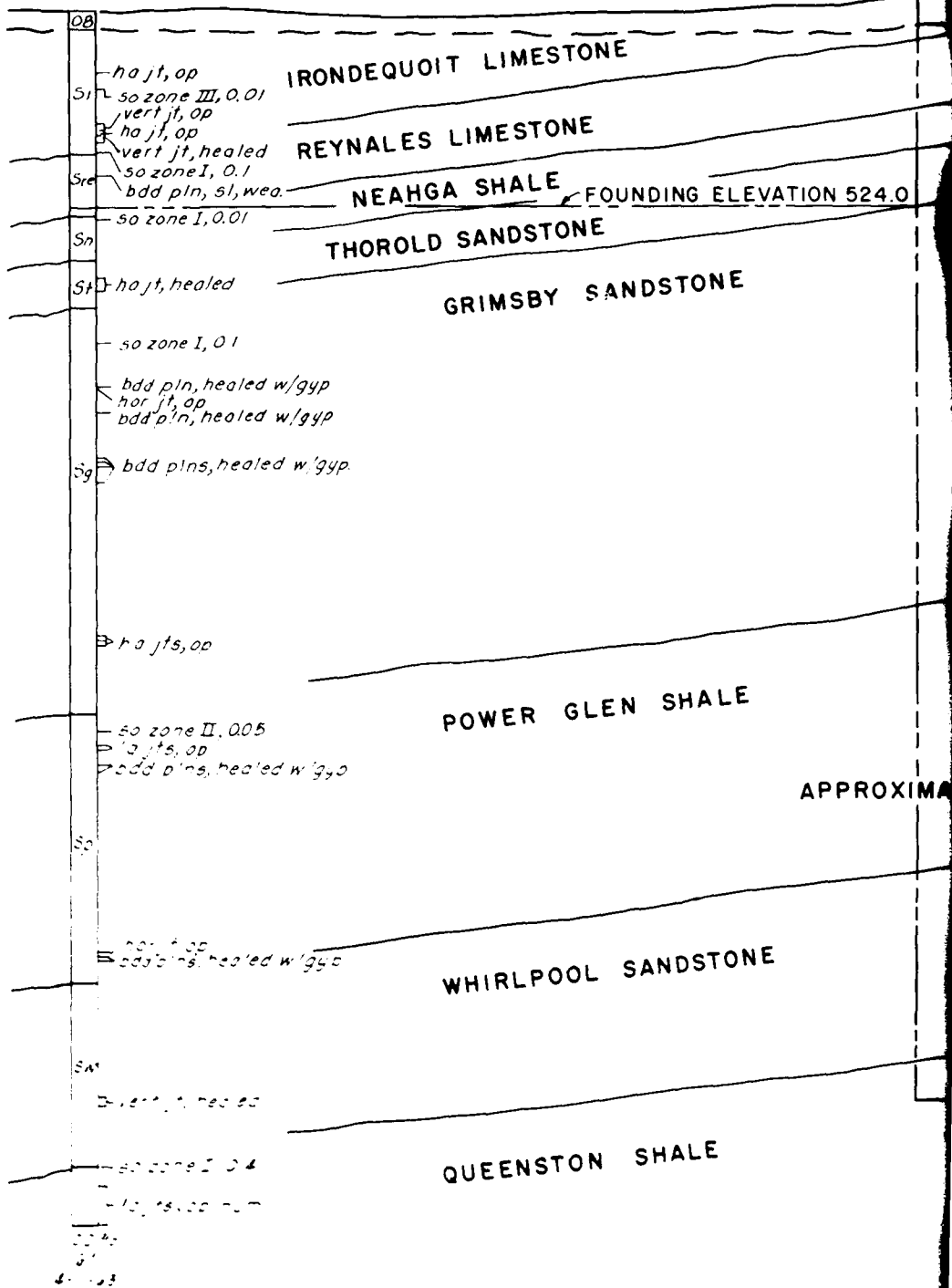
FILE AND BORINGS SEE  
RATIONS, GENERALIZED  
ABBREVIATIONS JOINT  
ONE CLASSIFICATION SEE  
TION OF OVERBURDEN

RC-21  
880'RT

UPPER GUIDE WALL

ELEVATION IN FEET IGLD. (1955)

550  
540  
530  
520  
510  
500  
490  
480  
470  
460  
450  
440  
430  
420  
410  
400  
390  
380  
370  
360



LOCK 4-5

NOTE: TOP OF LOCK WALL ELEVATION

ING ELEVATION 524.0

STONE

APPROXIMATE GROUND SURFACE

SHALE

LOWER G

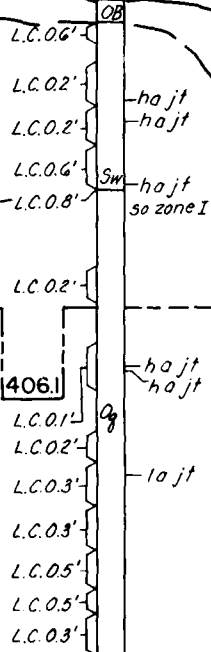
APPROXIMATE TOP OF ROCK

DC-19  
550'RT

FOUNDING ELEVATION 446.0

NDSTONE

FOUNDING ELEVATION 416.0



94.3%  
2 1/8"  
4-4-63

RDC-18  
775'RT

HALE

OB

OB

-NOTE TOP OF LOCK WALL ELEVATION IS 572.0

550  
540  
530  
520  
510  
500  
490  
480  
470  
460  
450  
440  
430  
420  
410  
400  
390  
380  
370  
360  
350  
340  
330  
320  
310  
300  
290  
280

IRFACE

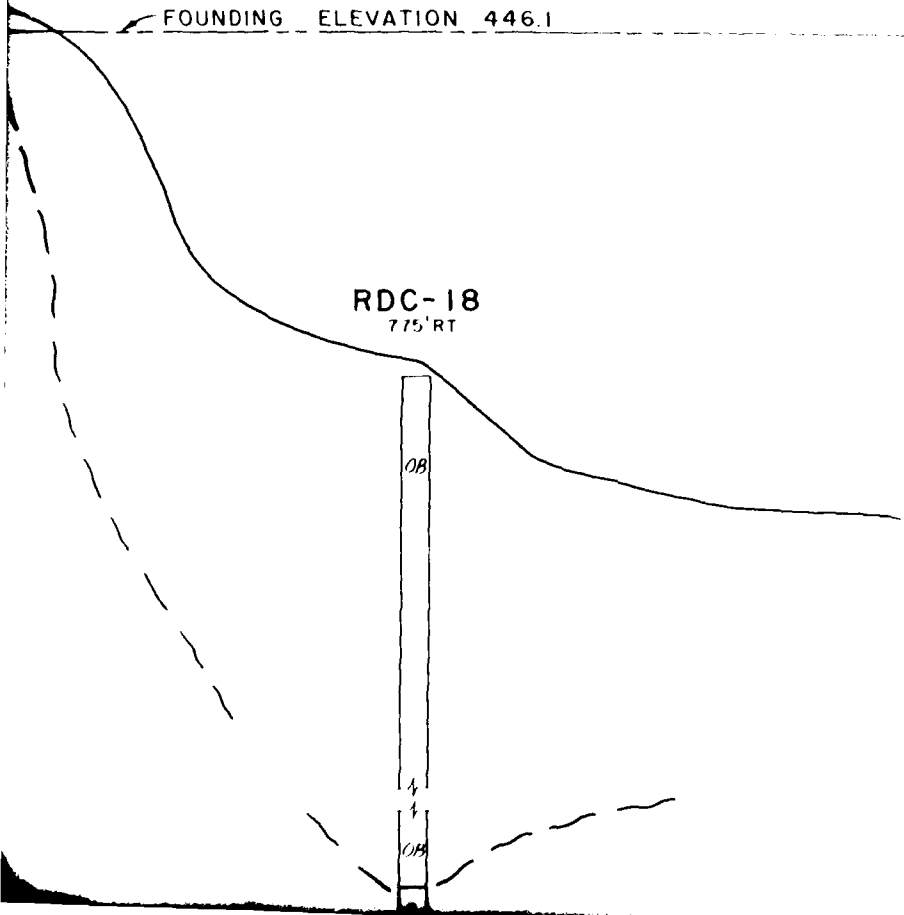
LOWER GUIDE WALL

FOUNDING ELEVATION 446.1

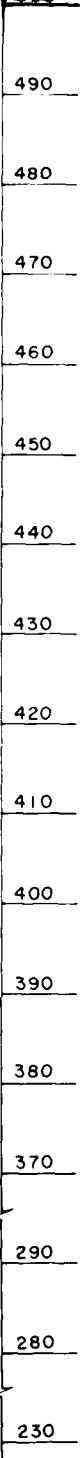
RDC-18  
775' RT

OB

OB



ELEVATION IN FEET I.G.L.D. (1955)



bdd pln, healed w/gyp

Sg bdd plns, healed w/gyp

ha jts, op

so zone II, 0.05  
la jts, op  
bdd plns, healed w/gyp

Sp

hor jt op  
bdd plns, healed w/gyp

Sw

vert jt, healed

so zone I, 0.4  
la jts, op, num

100%  
6"  
4-11-63

POWER GLEN SHALE

APPROXIMATE

WHIRLPOOL SANDSTONE

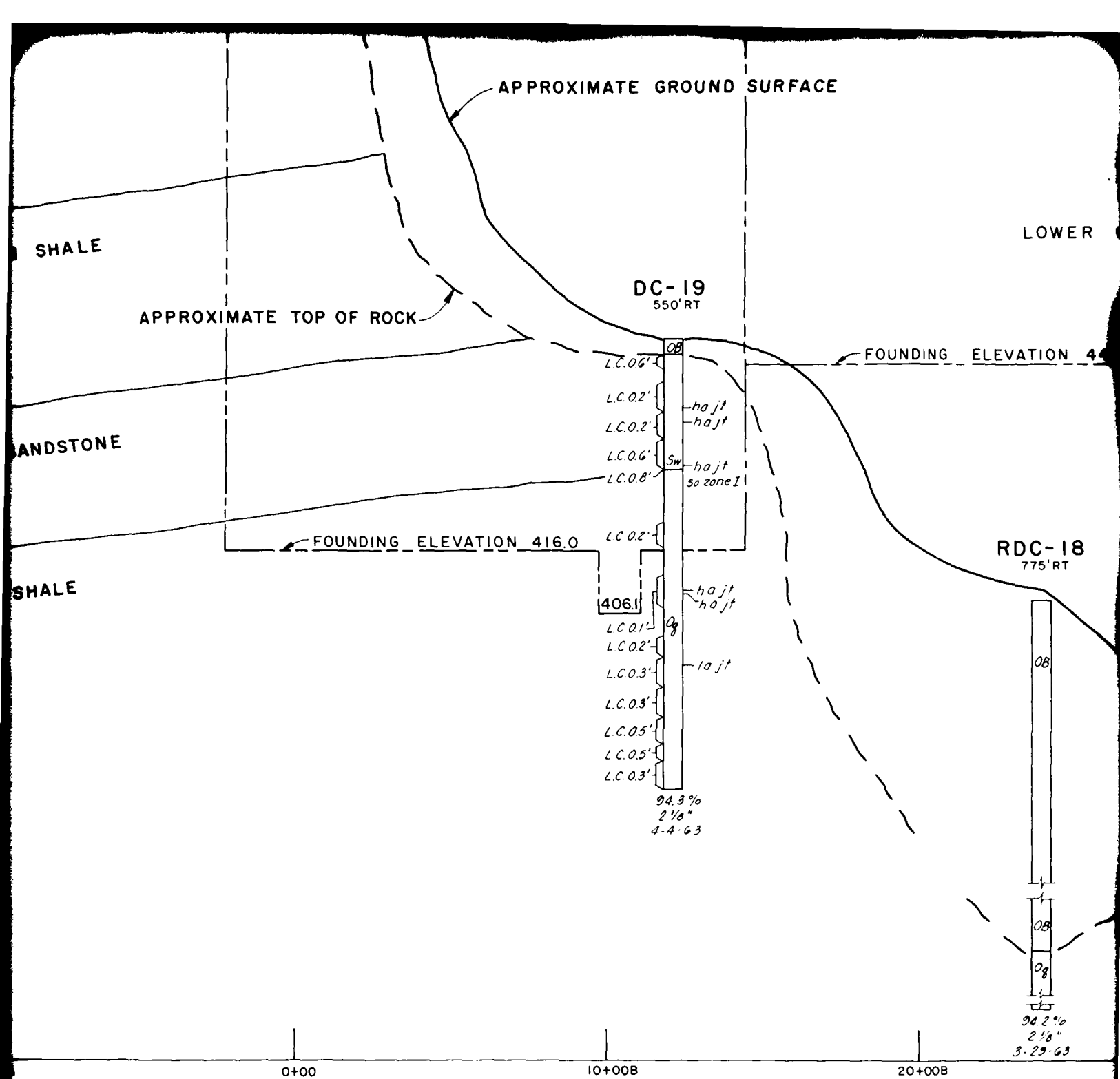
QUEENSTON SHALE

LOCK STATION 27+42.22A  
CANAL STATION 1521+06.33

20+00A

10+00A

PROFILE D-D



PROFILE D-D

NOTES:

- HOLES RC-21 AND DC-19 HAVE BEEN PROJECTED AT RIGHT ANGLES TO LOCK CENTERLINE. CORRECTIONS ARE 5.6' UP FOR RC-21 AND 6.0' UP FOR DC-19.
- FOR LOCATION OF PROFILE AND BORINGS, SEE PLATE B3 AND B4.
- FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS, JOINT CLASSIFICATIONS, AND SOFT ZONE CLASSIFICATION, SEE PLATE B1.
- FOR DETAILED DESCRIPTION OF OVERBURDEN, SEE PLATES B14 AND B15.
- LOCK STATIONING ALONG THE PROFILE WAS USED DUE TO THE BEND OF THE CANAL ALIGNMENT ALONG LOCK 4-5.
- DETAIL INFORMATION ON BORING RDC-18 HAS NOT BEEN SHOWN ON THIS SHEET.

490  
480  
470  
460  
450  
440  
430  
420  
410  
400  
390  
380  
370  
290  
280  
230

LOWER GUIDE WALL

ENDING ELEVATION 446.1

RDC-18  
775' RT



94.2%  
2 1/8"  
3-29-63

20+00B

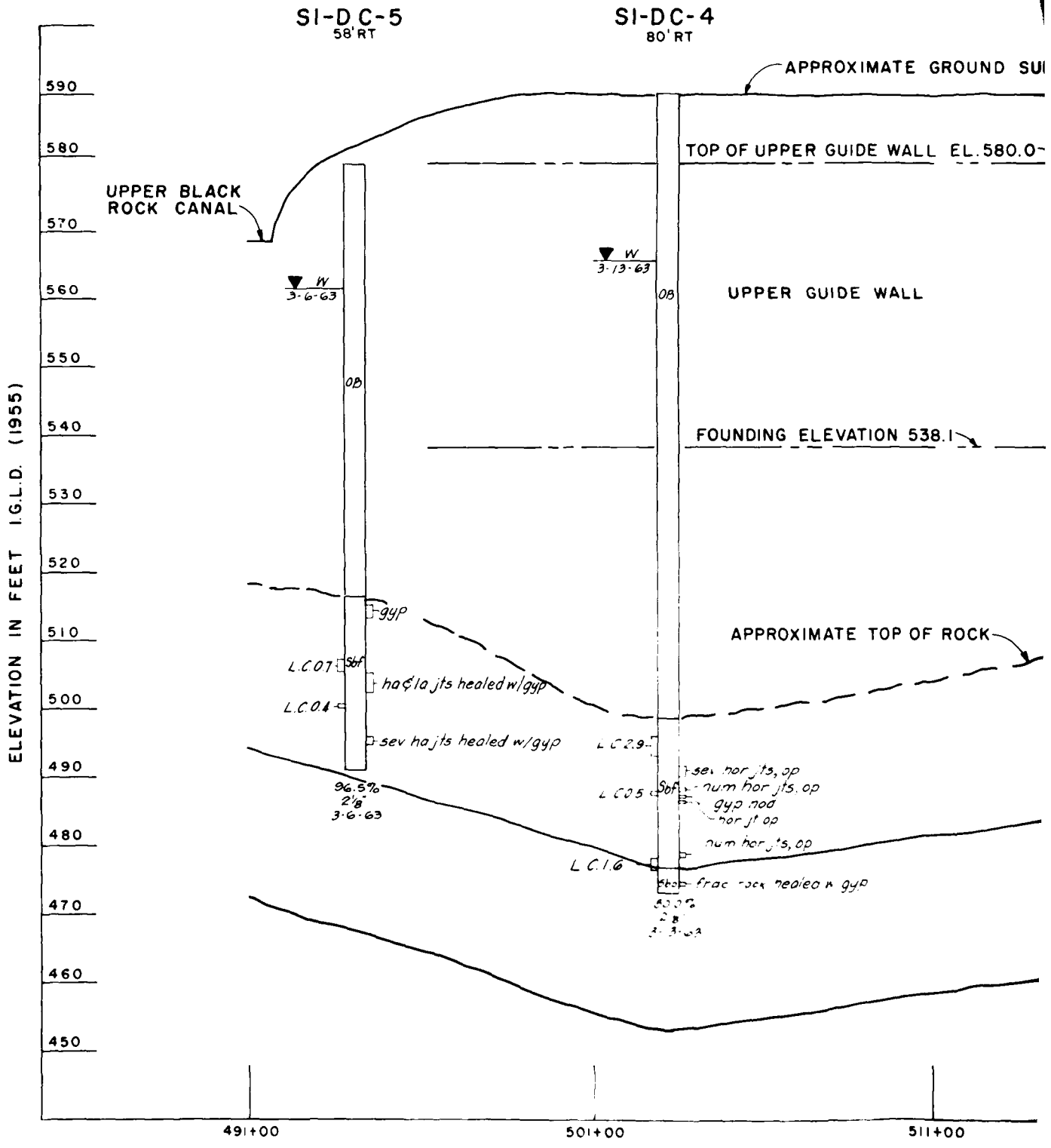
30+00B

36+00B

TERLINE. CORRECTIONS ARE  
REVIATIONS, JOINT CLASSI-  
ANAL ALIGNMENT ALONG  
ET.

LAKE ERIE-LAKE ONTARIO WATERWAY  
  
GEOLOGIC PROFILE  
LOCK 4-5  
  
U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
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16



16

SI-DC-3  
143'RT

SI-DC-2  
88'RT

SI-DC-1  
39'RT

NATE GROUND SURFACE

WALL EL. 580.0

TOP OF LOCK WALL EL. 580.0

LOCK 5-5

TOP OF LOWER G

WALL

W  
2-27-63

W  
2-18-63

W  
2-12-63

BLACK

ON 538.1

LOWER GUIDE W.

FOUNDING ELEVATIO

BERTIE LIMESTONE  
SCAJAQUADA  
MEMBER

BERT

TOP OF ROCK

FOUNDING ELEVATION 510.0

la jt healed w/gyp  
hor frags healed w/gyp  
gyp nod  
gyp nod  
gyp nod  
sev hor jts, some op  
la & hor jts, healed w/gyp  
hor jt, op  
hor jt, sl op  
hor jt, op

L.C. 2.1  
L.C. 1.3  
L.C. 4.8  
L.C. 0.3

hor jt, op  
3 gyp bands  
sev hor jts, some op  
sev hor jts  
sev gyp ptgs & bands  
la jt  
ha jt  
ha jt

85.5%  
2 1/8"  
2-18-63

frac rock  
hor jt, op  
hor jt, op  
hor jt, op  
gyp nod  
hor jt  
2 gyp nods  
gyp nod  
num gyp ptgs  
hor jts, op  
gyp nod  
ha & la jts, healed w/gyp

L.C. 1.0

98.0%  
2 1/8"  
2-12-63

CAMIL

511+00

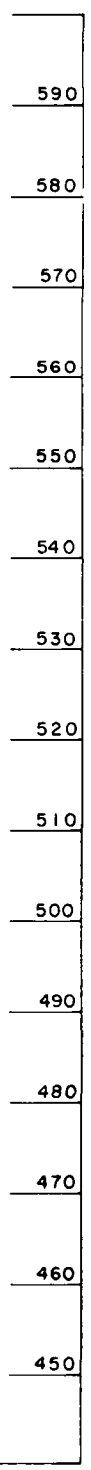
521+00

531+00

541+00

PROFILE E-E

-DC-1  
9'RT



TOP OF LOWER GUIDE WALL EL. 575.0

BLACK ROCK CANAL EL. 563.7

LOWER GUIDE WALL

FOUNDING ELEVATION 533.7

BERTIE LIMESTONE  
FALKIRK MEMBER

OATKA MEMBER

CAMILLUS SHALE

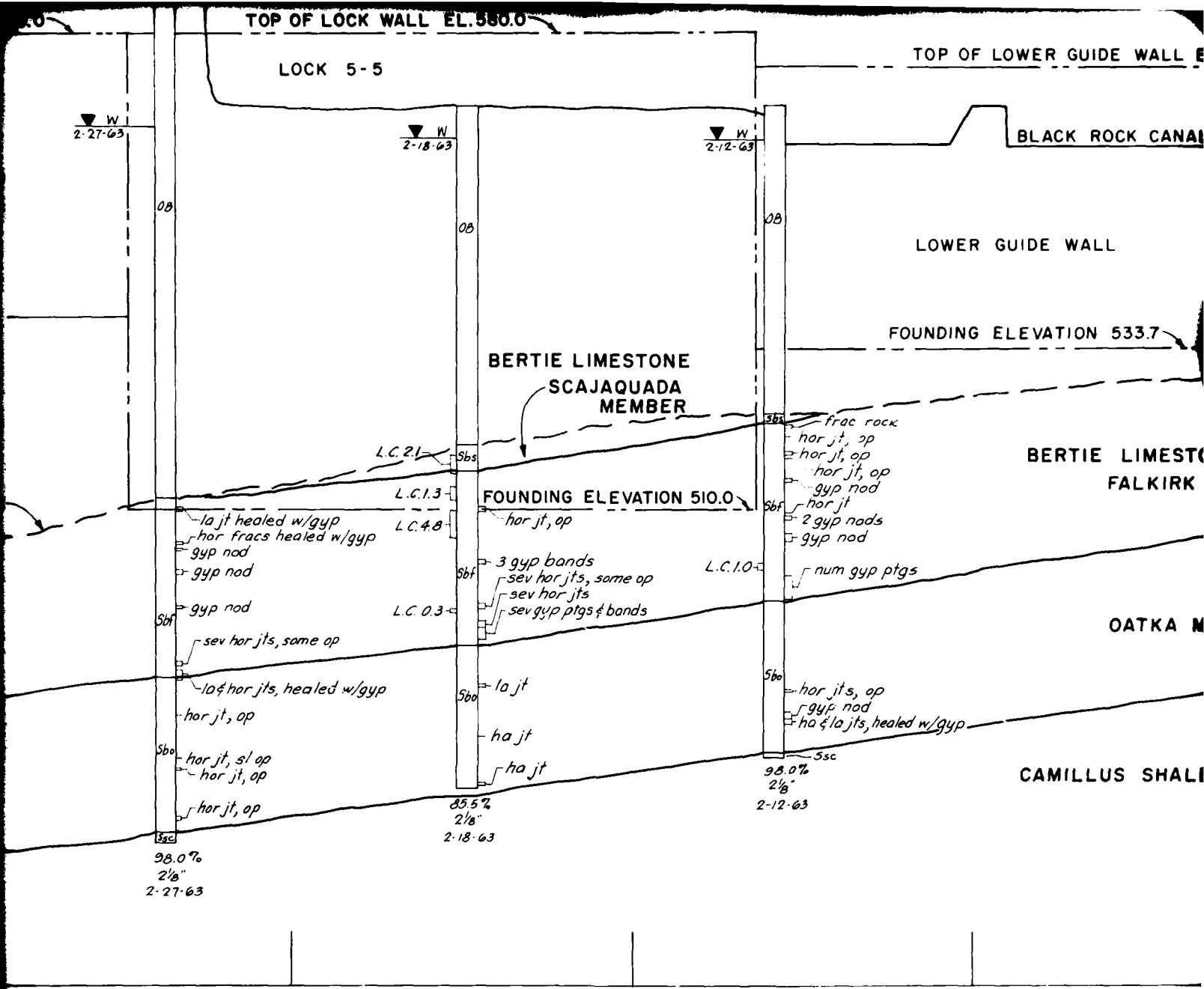
- frac rock
- nor jt, op
- nor jt, op
- nor jt, op
- gyp nod
- nor jt
- 2 gyp nads
- gyp nod
- num gyp ptgs

- nor jts, op
- gyp nod
- no & lo jts, healed w/gyp

5sc  
08.0%  
2 1/2"  
-12-63

541+00

551+00



521+00 531+00 541+00  
 PROFILE E-E

**NOTES:**  
 FOR LOCATIONS OF PROFILES AND BORINGS SEE PLATE B6.  
 FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS AND JOINT CLASSIFICATIONS SEE PLATE B1.  
 FOR DETAILED DESCRIPTION OF OVERBURDEN SEE PLATE B19.

LAKE EI  
 G  
 U.S. ARMY  
 TO ACCOMI

TOP OF LOWER GUIDE WALL EL. 575.0

BLACK ROCK CANAL EL. 563.7

LOWER GUIDE WALL

FOUNDING ELEVATION 533.7

BERTIE LIMESTONE  
FALKIRK MEMBER

OATKA MEMBER

CAMILLUS SHALE

580

570

560

550

540

530

520

510

500

490

480

470

460

450

541+00

551+00

*frac rock*  
*hor jt, op*  
*hor jt, op*  
*hor jt, op*  
*gyp nod*  
*hor jt*  
*2 gyp nods*  
*gyp nod*  
*num gyp ptgs*

*hor jts, op*  
*gyp nod*  
*ho & la jts, healed w/gyp*

*5sc*

ND BORINGS

GENERALIZED  
VIATIONS AND  
BI.  
OVERBURDEN

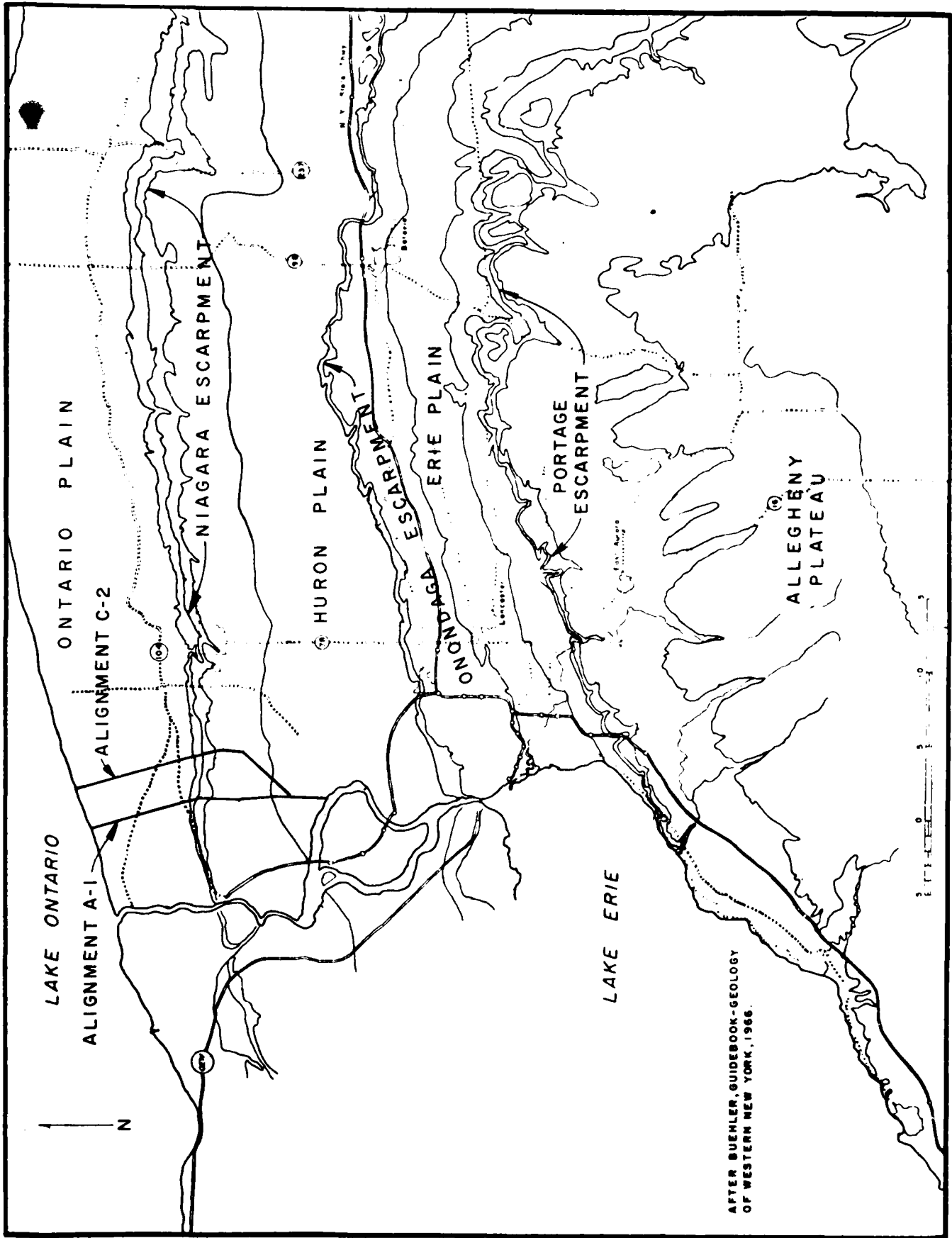
LAKE ERIE-LAKE ONTARIO WATERWAY  
  
GEOLOGIC PROFILE  
LOCK 5-5  
  
U.S. ARMY ENGINEER DISTRICT, BUFFALO  
TO ACCOMPANY REVIEW OF REPORTS  
OCTOBER 1973

PLATE B24

5



Figure B1 - View of area just west of the overland section of the proposed waterway.



AFTER BUEHLER, GUIDEBOOK-GEOLOGY OF WESTERN NEW YORK, 1966.

Figure B2 - Physiographic map of western New York.

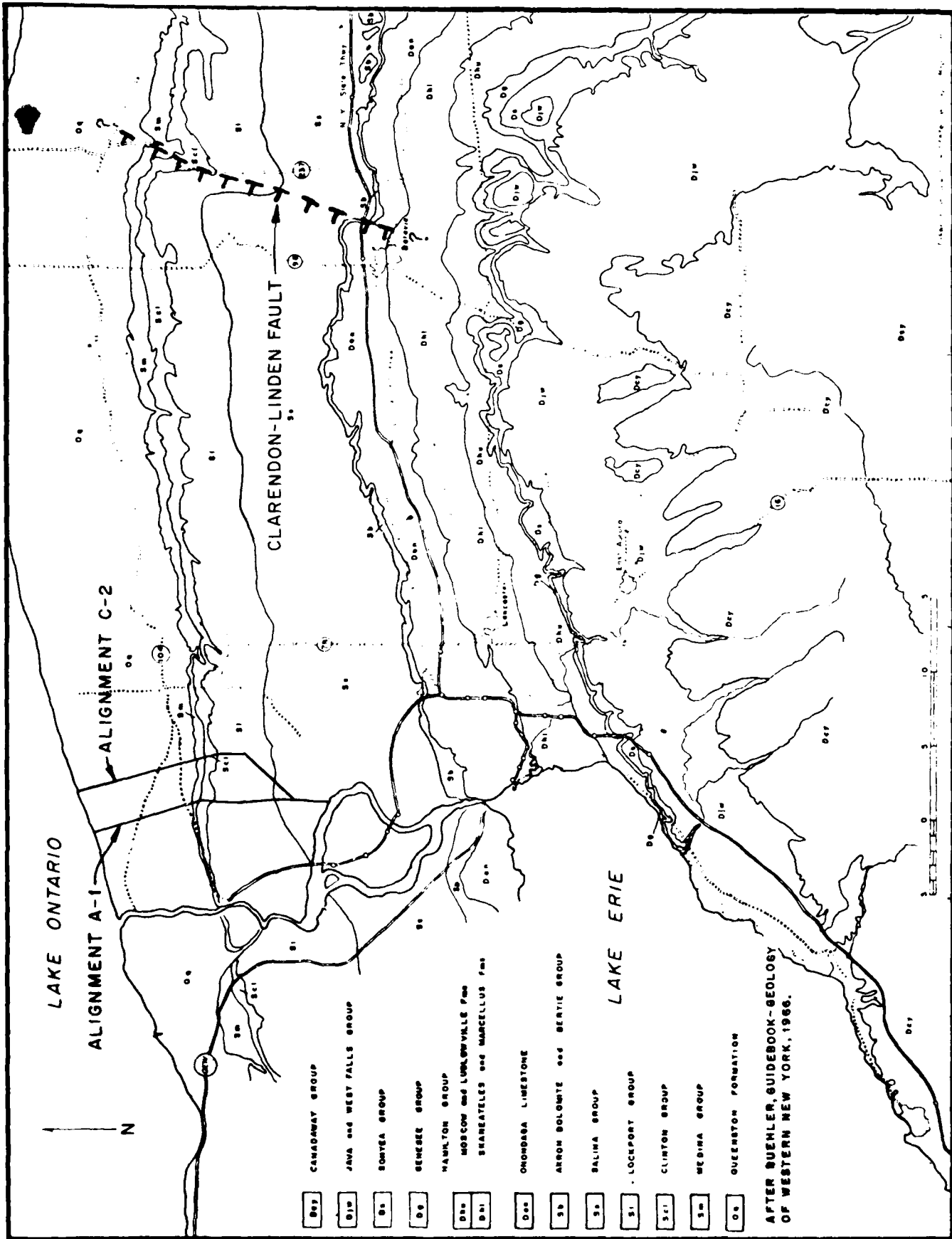
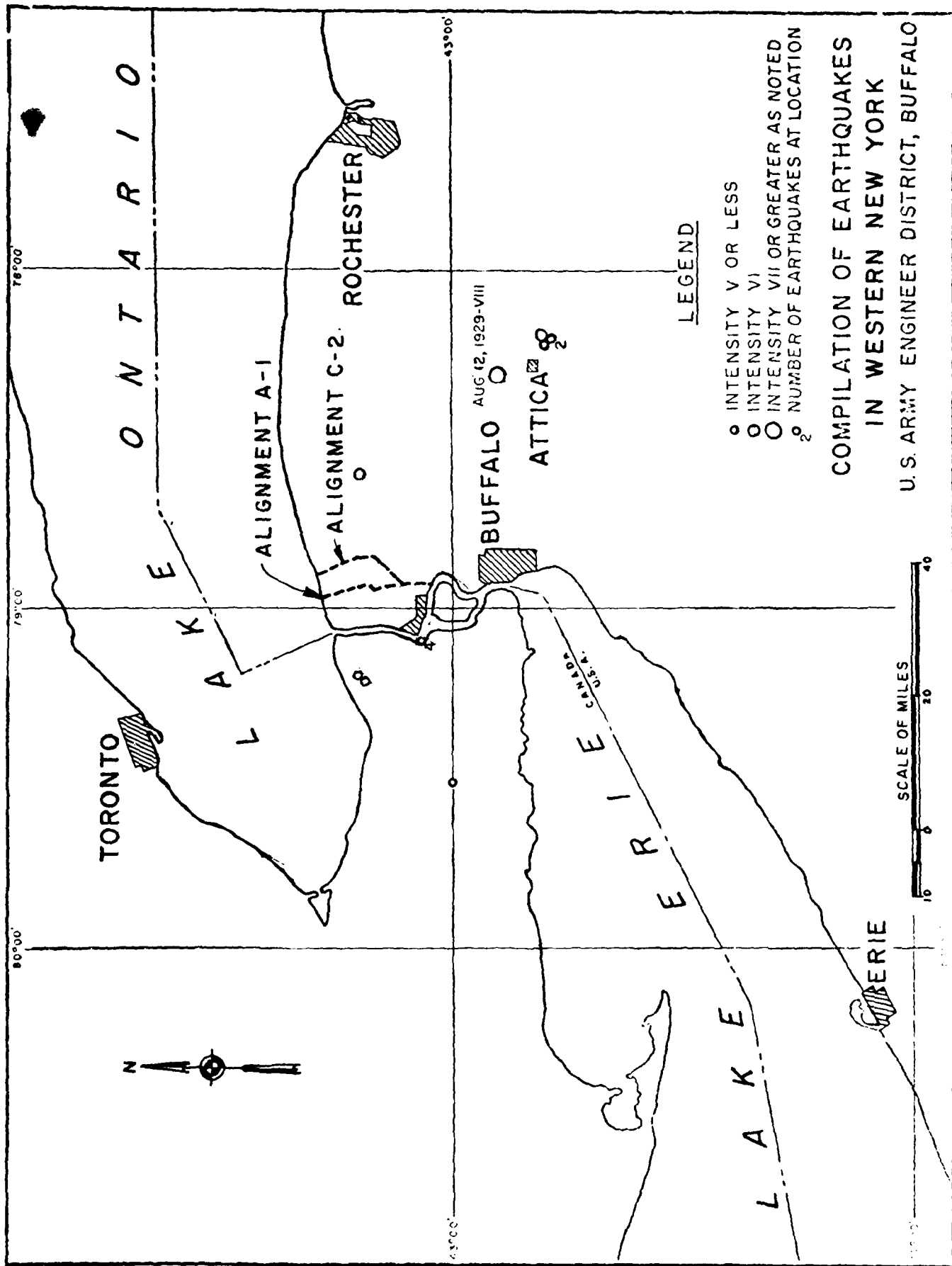


Figure B3 - Geologic map of western New York.



LEGEND

- INTENSITY V OR LESS
- INTENSITY VI
- INTENSITY VII OR GREATER AS NOTED
- NUMBER OF EARTHQUAKES AT LOCATION

COMPILATION OF EARTHQUAKES  
 IN WESTERN NEW YORK  
 U.S. ARMY ENGINEER DISTRICT, BUFFALO

Figure B4



Figs B5 - Soft zone and shale fragments found in core of Queenston Shale.

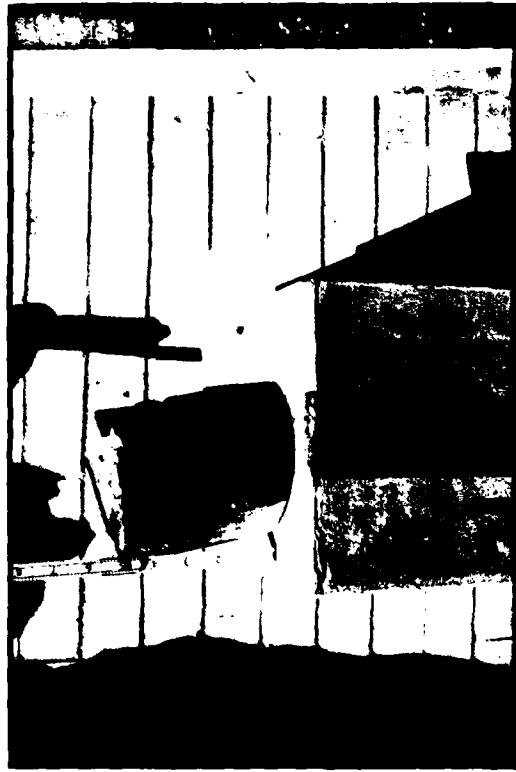
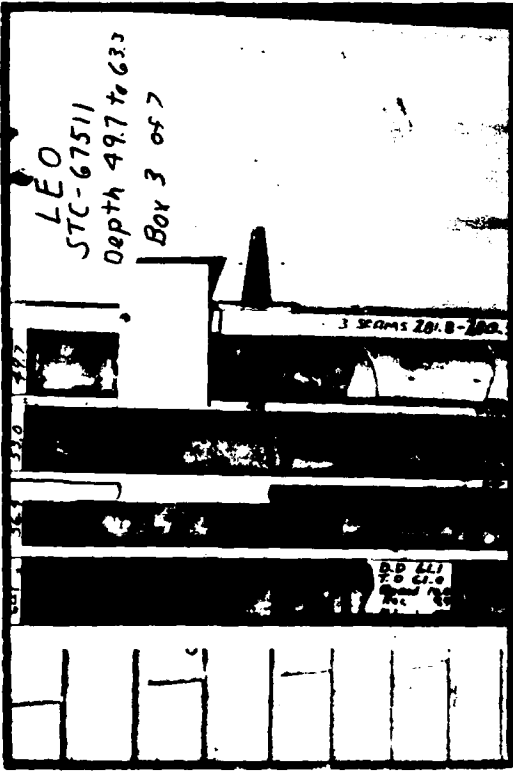
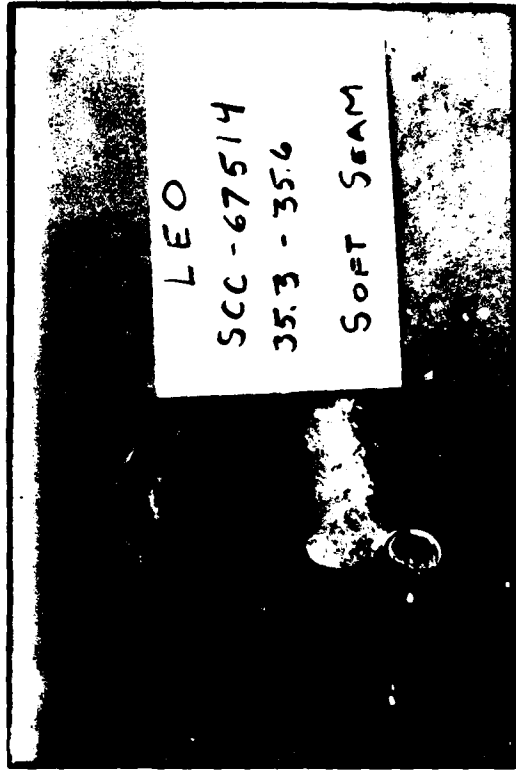


Figure B6 - Typical soft zones found in core of Queenston Shale.

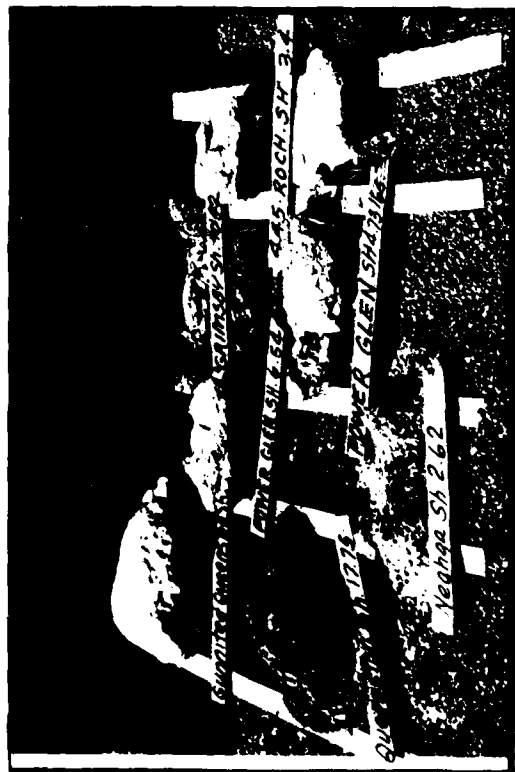
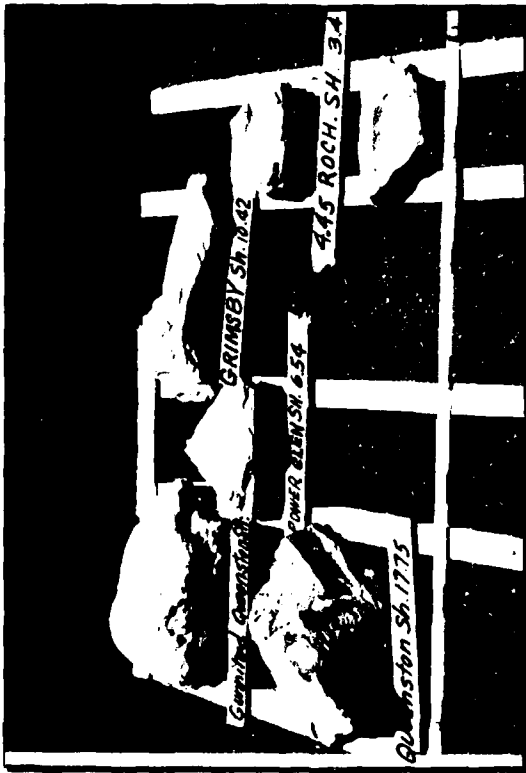


Figure B7 - Shale weathering test - Breakdown of exposed shale formations due to atmospheric conditions. (Note dates on blackboard)

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