THESIS

THE DESIGN AND CONSTRUCTION
OF A RETAINING WALL
AT L'ANSE, MICH.

STANLEY R. HILL

1920

The Design and Construction of a Retaining Wall.

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE.

By

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Candidate for the degree of

Bachelor of Science.

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The Completed Wall.

Thesis 1920.

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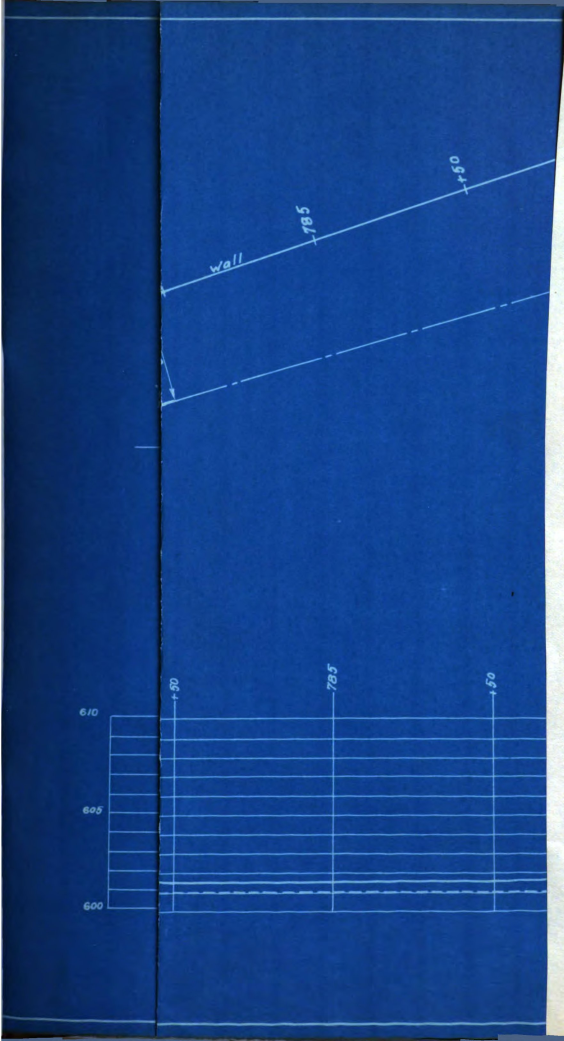
Thesis 1920.

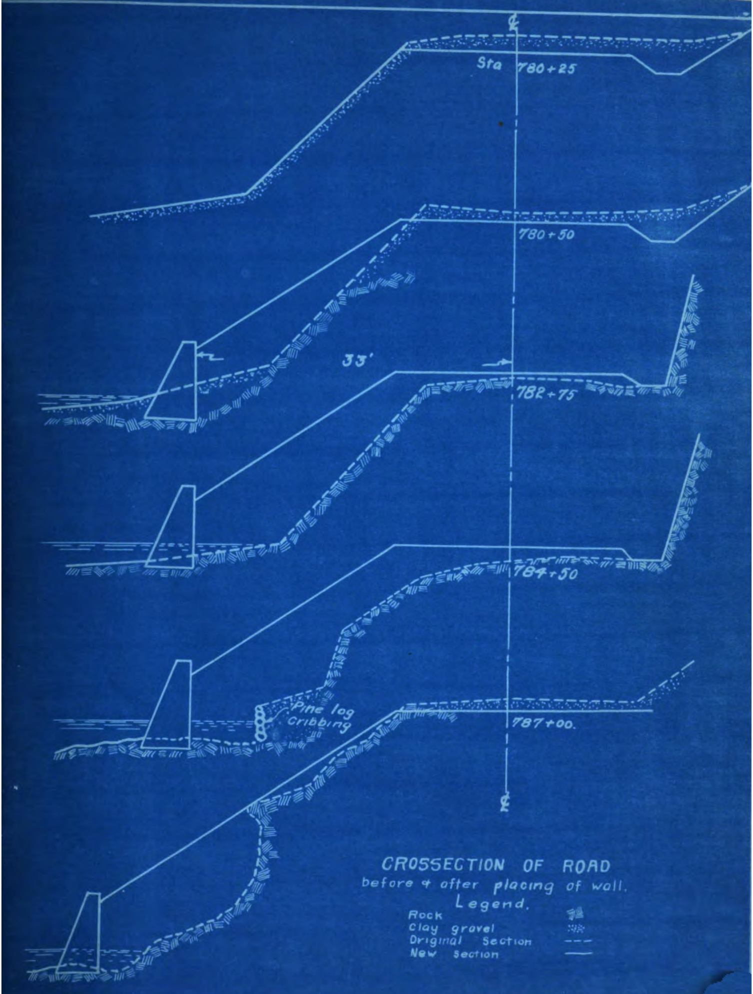
The present automotive age demands good roads, in spite of topographical barriers or other obstacles. On the Federal Aid Project #3 in Baraga County, between the villages of L'Anse and Baraga, the proposed road ran along the shore of Lake Superior and the State Highway Department was compelled to master the following situation.

The original road at the point mentioned was very narrow, due to the over-hanging cliff on one side and a steep drop to the lake on the other. To widen the road was essential and the only possible way to do it was to make a fill out in the lake and place the road on the top. The only railroad running to the Copper Country of Michigan, has its right of way directly on the top of the cliff so it was out of the question to consider removing any of the cliff, or the Red Rocks, as it is commonly called. A fill into the lake necessitated some protection from the action of the waves. The expense of building a sea wall from the lake bed to the top of the fill was prohibitive and to build a smaller wall would allow any sea that might come up, to completely go over it and wash away the fill, which would have to be made of sand.

After much study and various surveys it was decided to build a low retaining wall out in the lake and to protect the fill by a rip-rap of blue granite slabs that are quite plentiful in the vicinity. A very accurate survey was made of the location, and the nature of the sub-soil and the bearing qualification of the bed rock was determined. The lake bottom along the proposed wall was tested by means of drills. The drills were driven every ten feet and driven down far enough to determine the exact depth



Wall
785
+50
+50
785
+50
610
605
600



℄
Sta 780+25
780+50
33'
782+75
784+50
Pine log
Cribbing
787+00.
℄
CROSSECTION OF ROAD
before & after placing of wall.
Legend.
Rock
Clay gravel
Original Section
New Section

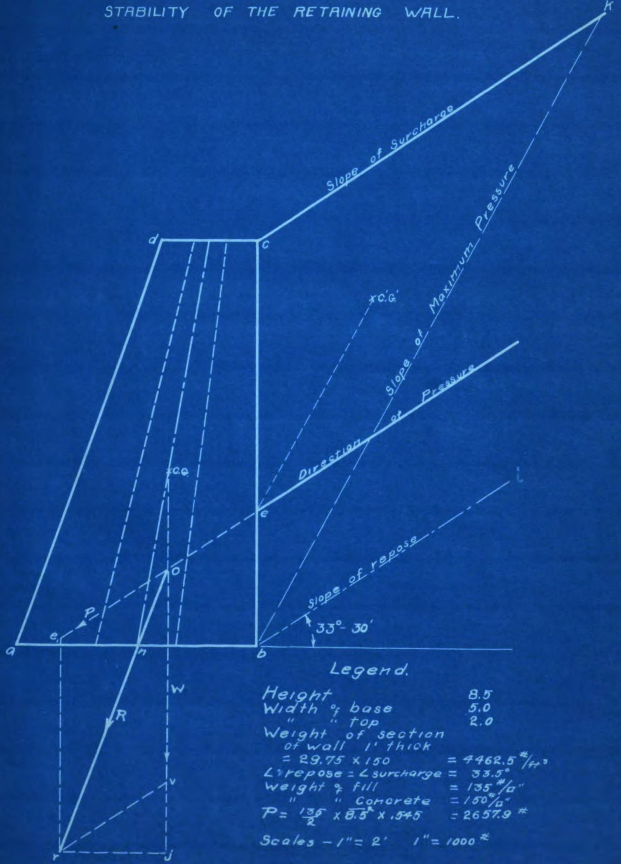
to solid rock. All soundings were recorded and then plotted as is shown on plate I. Crossections were also made and the same plotted showing both the road crossection before and after the proposed wall is in. Plate II. shows this crossection and gives some idea of the nature of the soil.

After all the preliminary surveys had been made and the plan view of the wall decided upon it was then necessary to design the wall to withstand the action of the waves, hold up the fill of sand and beheavy enough to counteract the action of frost and freezing temperature.

There are two general types of retaining walls, those that are made of plain concrete and those of reinforced concrete. The plain concrete walls depend on their weight for stability while the reinforced walls depend upon a series of lever arms for stability. For a wall to meet the three requirements enumerated I therefore decided would have to be of plain concrete, heavy enough to withstand the lifting action of the frost and with a batter on the outside to counteract the action of the waves.

The ordinary theoretical formulas are of but little value in designing retaining walls. The problem presents such conditions that cannot all be expressed in an algebraic formula. Something had to be assumed and it was much more simple to assume the thickness of the wall at once than to derive it from equations based upon a number of uncertain assumptions. The first assumption made was therefore the thickness. The American Civil Engineers Handbook recommends for designing retaining walls to be built in a country where the frost penetrates more than three

STABILITY OF THE RETAINING WALL.



Legend.

Height	8.5
Width of base	5.0
" " top	2.0
Weight of section of wall 1' thick $= 29.75 \times 150$	$= 4462.5$ #/ft³
∠ of repose = ∠ surcharge	$= 33.5°$
Weight of fill	$= 135$ #/□'
" " Concrete	$= 150$ #/□'
$P = \frac{135}{2} \times \overline{8.5}^2 \times .545$	$= 2657.9$ #

Scales – 1" = 2' 1" = 1000 #

feet in the ground, a top width of not less than two feet. The width of the base depending upon the work the wall is to perform. With a heavy surcharge such as this wall is to hold the approximate formula is x (b = .60 xh)(Page 599 ACEPB) The maximum (h) is found to be 8.5 feet and through out the rest of the design the maximum height will be used. Assuming the width of the top to be two feet and the maximum height as 8.5 feet the value of (b) will be .60 x 8.5 = 5.1 Using 5 feet. Several empirical rules have been devised by prominent engineers but the majority of them prove out about the same as the one used from Merriman. The most used formulas are those of General Fanshawe, Sir Benjamine Baker and Trautwine.

After the proposed section had been decided upon the next most important question in the design concerned the probable pressures to be exerted by the retained material and many theories have been advanced on the subject. Nearly as many theories have been advanced as there have been walls built but the ones generally accepted and solutions based on are those of Rankine and Coulomb. Both men lead to identical equations for determining the pressures existing in non-cohesive earths,

Rankine's formula was used in the general design for determining the pressures exerted. To fully determine the pressure of the filling on a retaining wall it is necessary that the resultant pressure be known (a) in amount, (b) in line of action, and (c) in point of application. In referring to Plate No.3 the graphical solution for the line of action and the point of application of the pressures is found.

In referring to the figure the outline of the wall is shown by the lines (a b c d); the line (ck) representing the surface of the surcharge or the slope of the back filling, which on the average is $1\frac{1}{2}$ horizontal to 1 vertical. The top of the filling coming to the top of the wall.

In making calculations, only 1 foot of the length of the wall and of the back filling is taken; thus, it is simply necessary to take the area of the section of the wall and the backing. The material composing the backing is assumed to be a fairly loose sandy gravel with a possibility of it becoming saturated either from excess rain or drenched from waves washing over the wall.

It is generally assumed that the maximum pressure on a retaining wall is caused by a wedge-shaped prism of earth (bck) included between the wall and the line (bk), which bisects the angle (cbi), or the angle formed by the rear face of the wall and the slope of repose of the fill. This line is called the line of maximum pressure and the prism whose crossection is (cbk) is called the prism of maximum pressures. The point of application of the pressure P was found by determining the center of gravity (c'g') of the triangle (bck) and drawing the line (c'e) parallel to the line of maximum pressure. The intersection (e) of this line with the back of the wall is the required point of application of (P). The superimposed load that might occur on the top of the fill was not considered, due to the nature of the original crossection and because of the slight difference this load would make. The maximum load that could pass over a highway would not be greater than a road roller

or some such piece of road machinery.

Rankine's theory assumed that the pressure is always parallel to the earth slope; but this does not seem reasonable since the direction of the pressure should be the same as that of the motion of the sand. Experiments have shown that the surcharge has little or no effect upon the lateral pressure and that the direction of the pressure is parallel to the slope of repose. The equation for finding the value of (P) when the angle of surcharge and the slope of repose are the same is ($P = \frac{1}{2} wxh^2 \cos O$), where (w) is the weight of the filling in pounds per cubic foot, (h) the depth of the wall in feet, (O) is the angle of repose of the filling and (P) the resultant pressure on the wall in pounds. The resultant pressure will be at an angle of $33^\circ - 40'$. Solving the equation

$$P = \frac{1}{2} \times 135 \times \overline{8.5}^2 \times .545 =$$

$$P = 2657.9\#.$$

The weight of the wall is found by the equation $W = \frac{1}{2}\, a + b \times hxw$ where (w) is the weight of a cubic foot of concrete found in the table on page 153 ACEPB to be 150# per cubic foot, (a) is the width of the top and (b) is the width of the base, h being the altitude. Solving the equation for a section 1 foot thick

$$W = \frac{1}{2}\, 2 + 5 \times 8.5 \times 150.$$

$$W = 4462.5\#.$$

The direction the weight (w) is on the vertical line through the center of gravity (CG) of the wall section, the total pressure (R), acting on the base of the wall is then the resultant of the pressure (P) and the weight (W) of the wall.

Its magnitude and line of action are determined by the parallelogram (oe'rv), in which (oe' =P) and ov' =W), the point (o) being the intersection of the line of action of (P) with a vertical through the center of gravity of the wall.

If both the wall and the foundation are absolutely incompressible and incapable of fracture or crushing, the wall will be safe from overturning for the point where the line of action of (R) meets the base is well within the middle-third section of the base. Practical considerations require that, under ordinary conditions, the point (n) should fall within the middle third. This can be greatly reduced if the foundation is perfectly rigid and the masonry of the best. In the present problem weather conditions make it necessary to design the wall heavy enough to withstand the action of a 40° below zero weather in the winter.

To test for stability against sliding the total pressure (R) on the base is resolved into a vertical component (oj) and a horizontal thrust (jr) the latter tending to produce sliding on the base. This thrust must not exceed the product of the normal pressure (oj) and the coefficient of friction between the wall and its foundation. The coefficient of friction between concrete and blue granite is considered by dependable authorities to be .65 with an angle of friction equal to 35° 00'. The value of (oj) is 2.95 and the value of (rj) is 1.1

oj x coefficient of friction

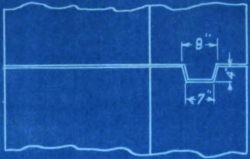
2.95 x .65 = 1.92.

The value obtained is much greater than the value of (rj) which proves that the wall is safe from sliding but a-s a further factor of safety iron tie rods of 1½ round were used to anchor the wall to the foundation. The method of doing this will be explained later.

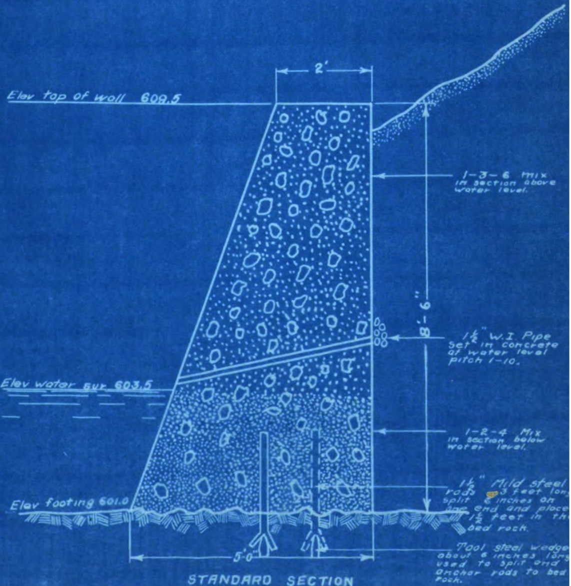
As a rule, it is customary to assume that the only load upon the base of the wall is the weight of the masonry, and also to assume that the center of pressure is to be kept within the middle third of the base, and that consequently the maximum pressure is not more than twice the mean. Computed in this way there is no likelihood that the masònry of an ordinary retaining wall will fail by crushing. Little or no attention is therefore given in the design of a retaining wall to the factor of safety against crushing.

After the wall had been proved safe from overturning, sliding and crushing the next thing to design was the joint to be placed at the end of a days pour. In any kind of a joint the only force to act on it would be the force of pressure in the direction already described, and it would act in shear. Concrete of a 1:3:5 mix has a shearing strength of 1180 lbs. per sq.in. With such a high shearing strength any joint that would extend the total height of the wall would have sufficient strength. The joint chosen is 6" wide running the full depth of the wall and projecting about 4" into the next section. This design was changed slightly while on the actual construction in order to make the removing of the forms more convenient.

The completed design was sent to the State Highway Depart-



KEY EXPANSION JOINT
To be placed at end of days pour.



STANDARD SECTION
Scale ½" = 1'

ment for approval where specifications were drawn up and the contract let. The contract was awarded to "The Smith Sparks Construction Company" of Houghton, Michigan, and the price named was $14.00 a cubic yard of concrete, the State to prepare the foundation for the wall.

The following extracts were taken from the specifications prepared for the concrete wall.

Materials.

Cement - The cement shall be Portland and shall meet the requirements of the State Highway Department.

Concrete Aggregate - The fine aggregate shall consist of stamp sand obtained from the Isle Royal Stamp mill and the large aggregate shall all pass through a screen with 2½ inch mesh. The large aggregate to be obtained from the Champion Sand and Gravel Company and shall consist of pit run crushed to pass through a 2½ screen but to be retained on a ¼ screen.

Lumber - The lumber for the forms shall have a thickness of 1 inch, shall be matched and finished on one side. The studding to be made of 2 x 6 material.

Excavation- The excavation shall all be done by the State but the contractor shall see that the foundation is cleared of all loose gravel and that the concrete is poured on a solid foundation.

Concrete- The concrete shall be machine mixed and of such consistency that it will flow into the forms without the separation of the coarse aggregate from the mortar. All concrete shall be deposited in horizontal layers and shall be compacted by tamping with a straight shovel until the surplus water has risen to the surface.

Forms - Forms shall be substantial and unyielding and built so that the concrete will conform to the design and dimensions, and so constructed that there will be no leakage of mortar but have gates provided for the escape of the water that will rise to the top. The forms are not to be removed within 36 hours of the time of pouring.

Proportioning- For portion of the wall from the water level to the foundation, one (1) part of cement, two (2) parts stamp sand, and four (4) parts of large aggregate. For the portion from the water line to the top of the wall, one(1) part of cement, three (3) parts stamp sand and six (6) parts of large aggregate.

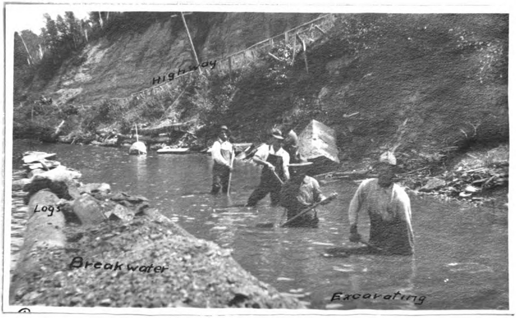
The firm of Smith and Sparks sub-let the building of the wall to a concrete construction company of Menominee,Michigan. The price named being $11.00 a cubic yard, Smith and Sparks to supply all necessary equipment and handle the buying of the material for them. The difference of $3.00 being estimated as the value of depreciation on the equipment loaned to the Carlson Company.

During the wrangling over contract letting and sub-letting, two rod men and myself staked out the wall preparatory to the excavation. The instrument was first set up at the shore end 53 feet to the left of station 780 - 59.2 and a temporary line run parallel to the center line of the road, wooden stakes being driven at intervals of twenty feet along the line. The instrument was then moved to a point 42 feet to the left of station 787 - 00, or the point at which the wall would end. The crown of the road at this station is 25.5 feet above the surface of the lake and with a road width of 24 feet and a slope of the fill 1 to 1½ it was necessary to place the inside of the wall at a point 42 feet to the left of the center line of the road, thus allowing the fill to come within six inches of the top of the wall. A point was then chosen on the line previously found at station 783 - 98.6, this point being taken as the (PI) for the curve of the wall. Stakes were driven along this line at intervals of twenty feet. The curve data determined for the wall is as follows:

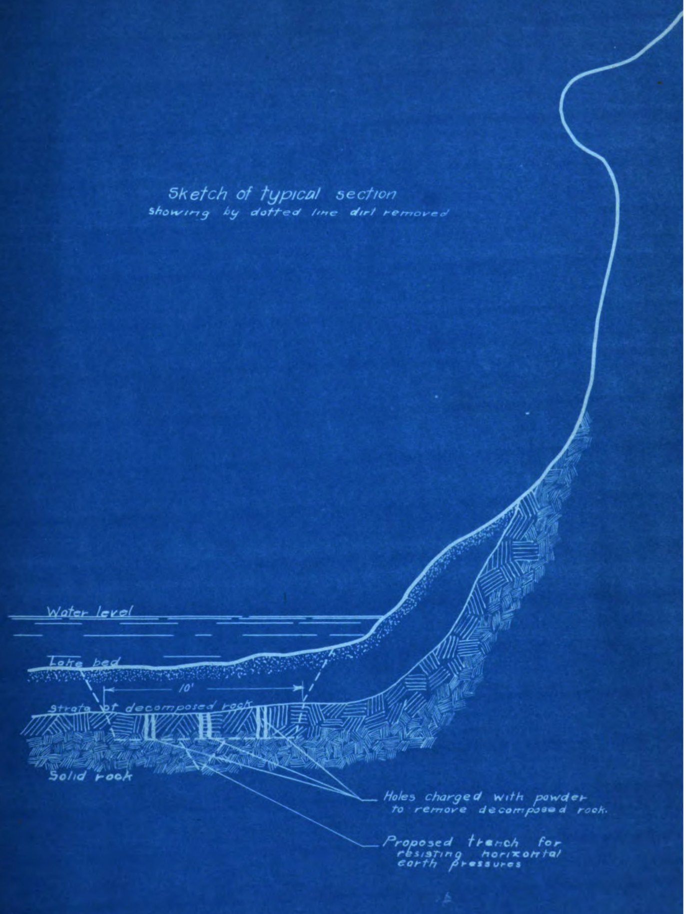
Δ	18° .44'
E	4.1'
EI^{o}	77.42
D	19°
T	49.7'
Ti^{o}	945.1
L	98.6
PI	783 - 98.6
PC	783 - 48.9
PT	784 - 46.5

After the curve data had been determined the wooden stakes were removed on the first line run and 1½" gas pipe inserted. In order to run the curve it was necessary to take the instrment in the water and place it over the (PC) station 783 - 48.9. The points on the curve were at intervals of ten feet and were marked by gas pipe driven into the lake bed.

In the excavation for the foundation of the wall, it was necessary to conduct the work on a State Force Account Basis. The material to be removed was composed mostly of beach sand and large loose rocks. To remove this material eight men were employed as shovelers and two men employed to blast away the larger of the rocks. The work of excavating began July 29th, 1919. The dirt removed being used to form a breakwater to protect the trench from the action of the water. As the work progressed, it was found necessary to build a more permanent form of breakwater. This was accomplished by chaining two or more logs together and sinking them in the desired position by means of rock, removed from the trench. The accompanying photographs show more clearly how this was accomplished, and the conditions under which the men worked.



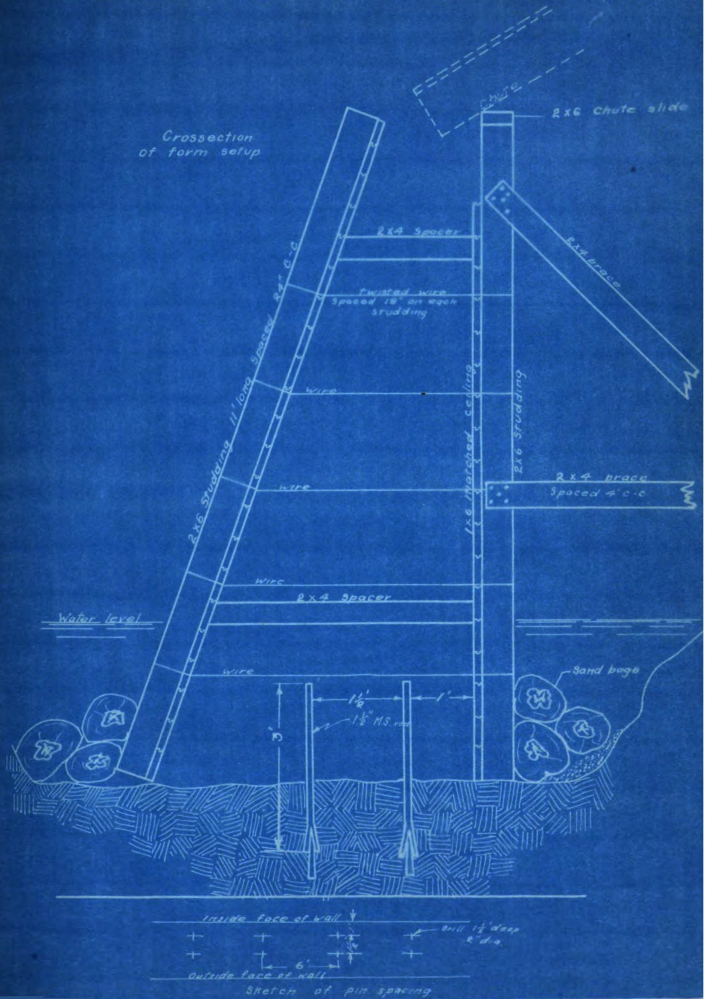
Due to the depth of the lake at the site the men were unable to wear boots or any other form of protection but worked in the water at times up to their arm-pits. Extremely bad weather made the work of excavating very slow and but thirty feet of the work was accomplished during the first week.


Sketch of typical section
showing by dotted line dirt removed
Water level
Lake bed
10'
Strata of decomposed rock
Solid rock
Holes charged with powder to remove decomposed rock.
Proposed trench for resisting horizontal earth pressures

The excavation consisted in removing all the beach sand and loose rock from a trench about ten feet wide, digging until solid bed rock was reached (sketch on previous page). After all of the loose material had been removed holes were drilled in the rock about one foot deep and light charges of powder set off. These charges removed all decomposed rock and made a firm foundation for the wall. At first it was thought best to blast a V shaped trench in the middle of the larger one to help resist the horizontal thrust of the earth pressure but all blasts tended to raise too large an area of rock. Iron rods were then used to anchor the wall to its foundation. Two holes, $1\frac{1}{2}$ feet deep and 2 inches in diameter were drilled 1 foot and $2\frac{1}{2}$ feet respectively from the inside edge of the wall at intervals of six feet. The method of anchoring these rods was to split them at one end about six inches, insert a tempered steel wedge and place in the holes provided. By driving the rods with a heavy mallet the wedge, resting on the bed rock, would force the split end apart and the rod would become firmly held in the rock. The rods were made of mild steel $1\frac{1}{2}$ inches in diameter and 3 feet long. The following photo shows the method in which the rods were placed and the conditions the men worked under.

After the first week the work of excavating and placing of the tie rods just kept ahead of the construction company but at no time during the making of the wall were the forms setters hindered by lack of space in which to place the forms. During high winds it was necessary to keep a man with the form setters to clean out what dirt would wash in the trench. The breakwater helped considerably in protecting the excavation from the action of moderate waves but whenever a storm arose the low breakwater was of little value. Photo No.5 shows how just a light wind made the waves come in, and several times the wind was strong enough to drive the water as high as the road level.

During the week that the excavation work was begun the construction company had arrived on the job with their equipment and had set up their camp, which consisted of a sleeping tent, cook shanty, stables and cement shed. The first work they did toward the actual construction of the wall was to build the forms. The lumber used for these forms was of pine ceiling six inches wide and ten feet long. Ten sets, consisting of a front face, rear face and necessary braces, were made before any forms were set in place. While the carpenters were making the forms it was necessary to be constantly on the job to see that they were made according to specifications. The slightest variation in the dimension of an inside brace, although seemingly small, would make a great deal of differance in the amount of concrete the forms would hold.


Crossection
of form setup
Chute
2x6 Chute slide
2x4 Spacer
2x4 brace
Twisted wire
Spaced 18" on each
Studding
2x6 Studding 11' long Spaced 24" C-C
wire
wire
1x6 matched ceiling
2x6 Studding
2x4 brace
Spaced 4' c-c
wire
2x4 Spacer
Water level
wire
Sand bags
$1\frac{1}{2}$'
1'
3'
$1\frac{1}{2}$" M.S. rod
Inside face of wall
Drill $1\frac{1}{2}$' deep
2" dia.
6'
Outside face of wall
Sketch of pin spacing

In setting up the forms care was taken to have the rear face perpendicular. The inside braces were then nailed on and the outside face put in place. The form for the rear was braced firmly to the shore by means of a two by four bracing. The front form was held in place by twisting wire from the studding on the front face to the studding on the rear face. The wires were placed eighteen inches apart along the length of the studding and twisted tight enough to resist the weight of the wet concrete. After the forms had been firmly wired together cement bags full of sand were placed along the base on the outside to prevent any leakage of mortar while the forms were being filled. The weight of the sand also helped resist the lifting action of the water on the forms.

The following photos show clearly how the forms were set up and how the bracing was accomplished. The studs were placed two feet apart and the braces used to hold the sections apart were of two by four lumber.


Forms

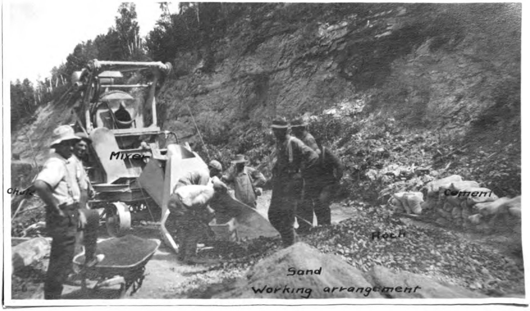
As soon as enough forms were in place the contractor would estimate the amount of concrete they could pour in the days run and the end board would be put in accordingly. This end board not only served to keep the concrete from running out of the forms but it also was built to carry the form for the expansion joint, as shown on the plates. Before any concrete was allowed to enter the forms it was necessary to measure up the volume of concrete it would hold. To do this I took cross sections every five feet along the length of the forms my rodman holding the rod at three different points at the five foot section. The average height was in this way determined and the average area determined for each

CONSTRUCTION DATA SHEET.						
DATE	AVER H'T	AVER XSECT	LENGTH	CU. YD.	CEMENT	W.I. PIPE in feet
Aug 5	6.32	19.7	32.9	24.0	100	14
Aug 6	6.82	21.8	30.2	24.4	106	7
Aug 7	7.55	25.1	38.2	35.6	161	3.5
Aug 8	Pump not working					
Aug 9	7.9	26.8	53.0	52.6	269	10.5
Aug 11		No sand				
Aug 12	7.9	26.8	51.8	51.5	221	7
Aug 13		Rain				
Aug 14	8.0	27.4	62.0	63.0	232	7
Aug 15		Rain – setting forms				
Aug 16	8.1	27.8	60.4	62.2	252	7
Aug 18		Setting	forms			
Aug 19		" "	" "			
Aug 20	8.1	27.8	65.6	67.6	271	7
Aug 21	8.4	29.2	48.1	52.0	214	7
Aug 22		Setting	forms			
Aug 23	8.3	28.8	65.8	70.2	306	10.5
Aug 25		Setting	forms			
Aug 26	8.6	30.3	62.0	69.6	259	7
Aug 27	8.4	29.2	52.2	56.5	245	7
Aug 28	7.9	26.8	42.3	42.0	181	7
Totals			664.5	671.2	2817	101.5

Stanley A. Hill Plate No IX

section. Plate No.8 shows the amount of concrete poured during each day's work and also shows the amount of cement and wrought iron pipe used. The notes for the cross sectioning are to be found in ~~the pocket in~~ the back of this book.

To place the concrete in the forms the mixer was placed on the road above and the concrete conveyed by troughs to the forms. The pump for forcing the water up to the mixer was placed on the shore of the lake and a one inch pipe laid along the road to a point about a thousand feet from the mixer where a section of pipe about twenty feet in length was raised into the air. To get water taps were provided along the pipe at convenient places. The object of the raised pipe was to give the mixer a uniform pressure and the length of pipe acting as a reservoir. The materials for mixing were arranged around the mixer as shown in the following photo.



Working arrangement

The next photo shows the relative position of the mixer forms and pump when at work. The angle of the chute changes for each location of the mixer.

In order to take care of the seepage of water $1\frac{1}{2}$" wrought iron pipes were placed at intervals of 20 feet. The pipe was laid on a 10% slope, the lower end of the pipe being about six inches above the mean water level. Surface water is assumed to be taken care of by flowing over the top of the wall.

Much trouble was at first encountered in the pouring of the concrete to get the mix into the forms at the proper constituency because of the slope at which the chutes were set. With the chutes set at a steep angle the large aggregate would come down first followed by the fine mortar. To remedy this leather strips were placed at angles to each other in the troughs, thus causing the concrete to flow more slowly and not disintegrate into a fine mortar and coarse aggregate. The first section poured showed results of this separation but although not as compact as it should have been the wall did not seem to be weakened because of it. Care was taken during future pourings that the concrete came into the forms in a more uniform condition and that the puddling was done more thoroughly.

In order to have the concrete poured in horizontal layers the chute was placed in the middle of the section and the concrete from here spread by hand.

One of the big problems that confronted us during the course of construction occurred at a point where the original roadway is very narrow and the drop to the lake very steep. The mixer with its materials for mixing occupied considerable space and it was impossible to maintain traffic and mix at the same time. This obstacle was overcome by holding up traffic while a batch was mixed and poured, then allowing traffic to proceed. Although this hindered the speed of construction it was much less expensive than building a staging out over the cliff.

The forms were removed about 48 hours after the concrete was poured, care being taken that they were not damaged and that the corners of the wall were not broken. In removing the forms the sand bags were taken away from the base of the forms then the wires were cut and the forms easily came off. The braces were used over again, as well as the rest of the forms, they being removed from their position as the concrete filled the section.

Work on the rest of the wall progressed very rapidly after the first week and very few delays were encountered. Lack of sand or rain were the only things that did delay us but even then for not more than a day at a time. The largest yardage for any one day was on August 23, 1919 when they filled a section 65.8 feet long with a yardage of 70.2 of concrete. During the entire construction of the wall it was necessary to always be on the job in order that the wall be placed on the proper line and that the proper elevation be given for the top of the wall. An inspector was employed to be with the mixer to watch the mix and report any inferior material being used.

The total time required to complete the wall was 30 days of which 5 were the extra number of days used to start the excavating, 13 days of actual pouring and 12 days in laying of forms and cleaning up the debris after the job was completed. The only finishing necessary was to brush the face of the wall, remove all wires and clean away all signs of construction equipment. The breakwater was destroyed as the completion of the work warranted by first removing the log and allowing the wave action to take care of the sand and rock


Complete wall

The following estimate is only an approximate one due to the fact that the contractor was unwilling to give me the exact prices paid for material. The prices quoted are those obtained from dealers in the vicinity of the work.

671.2 cubic yards of concrete were poured which at the contract price of $14.00 per cubic yard amounts to $9,396.80. The sub-let contract price was for $11.00 per cubic yard or $7,383.20, the difference of $2,013.60 representing the depreciation and loan of equipment.

Contract Price			$9396.80
Depreciation and loan of equipment.		$2013.60	

Labor.

No.	Title	Rate	
1	Foreman	$10.00	$10.00
2	Puddlers	7.00	14.00
2	Carpenters	8.00	16.00
1	Chute man	5.00	5.00
1	Engineer	6.00	6.00
2	Rock wheelers	5.00	10.00
2	Sand wheelers	5.00	10.00
1	Cement man	5.00	5.00
	Total per day -		$76.00

Material.

Total labor for 21 days	76.00 x 21	1596.00
705 barrels of cement including sacks	3.00	2115.00
308 yards of stamp sand	.75	231.00
620 yards gravel ½"-2½"	1.50	930.00
2400 board feet 1 x 6 spruce matched ceiling	90.00	216.00
1200 board feet 2 x 6 lumber	65.00	78.00
1200 board feet 2 x 4 lumber	65.00	78.00
10 bundles form wire #9	5.00	50.00
Various kinds of nails		10.00
Miscellaneous expenses		100.00
100 gallons gasoline	.20	20.00
660 feet 1½ round M.S.6#/ft.	.05	198.00
200 feet 1½ x 1 T.S. for wedges 5#/ft.	.10	100.00
		7735.60
Profit for sub-contractor not deducting office expenses -		1661.21

The work which the State did took 30 days and the expense outside of the engineering is as follows:

8	Shovelers	@ $6.00 per day	$48.00
2	Drill men	@ 6.50	13.00
1	Team and driver	9.00	9.00
1	Foreman	8.00	8.00
1	Inspector and timekeeper	4.00	4.50
		Total expense per day	$82.50

Total expense for the 30 days work

30 x 82.50 = $2475.00

The high cost of excavating was due to the fact that the men had to work at all times in water up to their arm pits. The high wage paid the men was necessary in order to keep them on the job and working under the conditions mentioned.

The Contractor

The Engineer.

In summarizing, the problem is divided into three parts; the design, the construction, and the cost of construction.

The wall could have been much more economically designed if exact data as to the nature of the fill dirt had been obtained. At the time that the design was made no definite filler had been chosen but there was a possibility of either having a fill of beach sand or one of a wet clay aggregate. The design was made on the assumption that the filler with the greatest horizontal component, beach sand, would be used, and so the wall is over safe from the overturning and crushing forces of the fill.

The force of the frost can only be assumed and it remains to be seen just what the action of an extremely cold winter will have on it. The present winter has seen the temperature at 40° below zero, much lower than has ever been previously noted in that territory. The foundation for the wall is, I believe, plenty low enough to be very little affected by the frost.

The only criticism that can be offered in regard to the construction is the inadequate machinery used. With a larger mixer and a more effective means of obtaining water the work could have been completed much sooner, and in a better manner. Delays caused by the lack of sand were due entirely to the negligence of the foreman. Orders for the stamp sand used were

required to be in at least three days in advance and near the end of the job the foreman attempted to make what little there was on hand last the rest of the job.

It is practically impossible to compare the cost of the wall with anything else that the State Highway has built. At no time previous have they built anything that compares with it either in design or the conditions under which it was constructed. The price of $14.00 per yard seems like a very reasonable price for concrete work put in under the prevailing conditions and although the work was put in just after the war I do not think that the pre-war prices would have been much less. The cost of constructing concrete highways in the vicinity is about $12.50 per cubic yard and this does not include any reinforcements or drainage. The fact that the wall had to be poured under water and that the mix was of two different proportions easily licenses the difference between the prices for roads and of that for the wall.

[illegible]

Level Notes.

+ S	H. I.	− S	El	Sta	Date	T	C	H
12.52	635.95		623.43					
.62	629.84	6.73	629.22					
3.70	627.54	6.00	623.84					
4.1	620.08	11.56	615.98					
1.37	608.65	12.80	607.28					
							Water level	
							5.2 / 603.75	
							5.7 / 603.2	
							7.01 / 601.7	
							6.[illegible] / [illegible]	
							6.[illegible] / 602.1	
							7.2 / 601.7	
							7.[illegible] / 601.7	
							7.7 / 601.3	
							6.7 / 602.[illegible]	
2.03	609.9	1.37	607.28					
2.63			607.28				0.4	
			618.7				El of tape 609.3	
2.93	611.23		607.3					
				0.0	Aug.5		7.57 / 5.86	
				5.0			5.13 / 5.42	
				10.0			8.38 / 5.67	
				15.0			5.2 / 5.5	
				20.0			5.7 / 5.5	
				25.0			[illegible].3 / 5.5	
				30.0			5.25 / [illegible]	
				35.0			5.5 / 5.5	
				40.0			8.65 / 5.84	
				45.0			[illegible].38 / [illegible].97	
				50.0			5.7 / 7.5	
				55.0			[illegible].55 / [illegible].97	
				60.0			5.72 / [illegible]	

+ S	H.I.	- S	El	Sta	Date	T	C	H
3.62	610.9	3.93	607.28	0	Aug 7		8.42 / 7.03	
				5			8.8 / 7.2	
				10			8.6 / 7.2	
				15			8.75 / 7.23	
				20			8.88 / 7.46	
				25			8.75 / 7.25	
				30			8.95 / 7.55	
				35			9.10 / 7.70	
				38			9.38 / 7.98	
0.68	610.16	0.42	609.48	0	Aug 8		8.3 / 7.64	
				5			8.58 / 7.22	
				10			8.56 / 7.70	
				15			8.37 / 7.71	
				20			8.31 / 7.55	
				25			8.27 / 7.71	
				30			8.40 / 7.74	
				35			9.62 / 8.03	
5.23	614.71	0.68	609.48	40	Aug 9		12.5 / [illegible]	
				45			12.12 / 7.98	
				50			12.34 / 8.15	
				55			12.5 / 8.29	
4.15	613.63		609.48	0	Aug 11	12.4 / 7.8	11.9 / 7.8	11.7 / 7.6
				5		12.7 / 8.0	12.0 / 7.9	12.0 / 7.9
				10		12.4 / 7.4	12.1 / 8.0	12.2 / 8.1
				15		12.4 / 7.8	12.3 / 8.2	12.0 / 7.9
				20		[illegible] / 12.6	[illegible] / 7.8	11.6 / 7.5
				25		12.5 / 7.7	[illegible] / [illegible]	11.6 / 7.7
				30		12.4 / 7.8	12.1 / 8.0	11.9 / 7.6

- S	H.I.	- S	EL	Sta	Date	T	C	H
4.10	613.58		609.48	35	Aug 11	12.6/8.0	12.1/8.0	12.0/7.9
				40		12.5/7.9	12.1/8.0	11.9/7.8
				45		12.3/8.2	12.2/8.1	12.0/7.9
				50		12.4/7.6	11.9/7.6	11.7/7.6
2.25	611.72		609.48	0	Aug 12	10.4/7.7	10.1/7.9	10.0/7.8
				5		10.4/7.7	10.1/7.9	10.0/7.8
				10		10.5/7.6	10.4/8.0	9.9/7.7
				15		10.6/7.8	10.2/8.0	10.0/7.8
				20		10.5/7.8	10.4/8.2	10.1/7.9
				25		10.7/8.0	10.3/8.1	10.0/7.8
				30		10.5/7.8	10.0/7.8	9.8/7.6
				35		10.4/7.7	10.5/8.3	10.2/8.0
				40		10.5/7.8	9.8/7.6	9.6/7.4
				45		10.8/8.1	10.6/8.4	10.2/8.0
				50		10.5/7.8	10.4/8.2	10.2/8.0
				55		10.6/7.8	10.5/8.3	10.1/7.9
				60		10.7/8.0	10.3/8.1	9.9/7.7
				65		10.7/8.0	10.0/7.6	9.9/7.8
2.0	611.5		609.5	0	Aug 16	10.5/8.0	10.0/8.0	9.9/7.9
				5		10.5/8.0	10.0/8.0	9.9/7.9
				10		10.6/8.3	10.1/8.1	9.9/7.9
				15		10.[illegible]/8.3	10.1/8.1	9.9/7.9
				20		10.9/8.3	10.3/8.3	10.3/8.3
				25		10.9/8.3	10.1/8.1	10.1/8.1
				30		10.8/8.3	1[illegible].3/8.3	10:3/8.3
				35		10.8/8.3	1[illegible].1/8.1	10.1/8.1
				40		10.9/8.3	9.8/7.8	10.0/8.0
				45		10.7/8.2	10.1/8.1	10.0/8.0

- S	H.I.	- S	El	Sta	Date	T	C	H
2.0	611.5		609.5	50	Aug 16	9.8 / 7.4	10.0 / 8.0	9.9 / 7.9
				55		10.3 / 8.1	10.0 / 8.0	9.8 / 7.8
				60		10.7 / 8.2	10.0 / 8.0	9.8 / 7.8
4.84	614.33		609.48	0	Aug 19	13.5 / 8.2	12.8 / 8.0	12.8 / 8.0
				5		13.1 / 7.8	12.7 / 7.9	12.7 / 7.9
				10		13.3 / 8.0	12.7 / 7.9	12.7 / 7.9
				15		13.4 / 8.1	12.6 / 7.8	12.6 / 7.8
				20		13.5 / 8.2	12.7 / 7.9	12.8 / 8.0
				25		13.6 / 8.3	12.8 / 8.0	12.7 / 7.9
				30		13.5 / 8.2	13.0 / 8.2	12.6 / 7.8
				35		13.6 / 8.3	12.9 / 8.1	12.7 / 7.9
				40		13.5 / 8.2	12.8 / 8.0	12.7 / 7.9
				45		13.5 / 8.2	12.7 / 7.9	12.5 / 7.7
				50		13.8 / 8.5	13.0 / 8.2	12.6 / 7.8
				55		13.9 / 8.5	13.0 / 8.2	12.7 / 7.9
				60		14.0 / 8.7	12.8 / 8.0	12.6 / 7.8
2.75	612.23		609.48	0	Aug 21	11.5 / 8.3	10.9 / 8.2	10.9 / 8.2
				5		11.6 / 8.4	10.9 / 8.2	10.9 / 8.2
				10		11.5 / 8.3	11.0 / 8.3	10.8 / 8.1
				15		11.9 / 8.6	11.0 / 8.3	10.9 / 8.2
				20		11.9 / 8.6	11.3 / 8.6	11.1 / 8.4
				25		11.7 / 8.5	11.3 / 8.6	11.1 / 8.4
				30		11.9 / 8.6	11.2 / 8.5	11.1 / 8.4
				35		12.0 / 8.7	11.2 / 8.5	11.1 / 8.4
				40		11.8 / 8.6	11.3 / 8.6	11.1 / 8.4
				45		11.8 / 8.6	11.1 / 8.4	11.2 / 8.5
				46		12.0 / 8.7	11.2 / 8.5	11.0 / 8.3

- S	H.I.	- S	El	Sta	Date	T	C	H
3.1	612.5	-	609.48	0	Aug 22	11.9 / 8.4	11.2 / 8.2	10.9 / 7.9
				5		11.8 / 8.3	11.1 / 8.1	11.0 / 8.0
				10		11.9 / 8.4	11.0 / 8.0	11.0 / 8.0
				15		11.7 / 8.2	11.2 / 8.2	11.3 / 8.3
				20		11.9 / 8.6	11.3 / 8.3	11.3 / 8.3
				25		11.8 / 8.3	11.5 / 8.2	11.3 / 8.3
				30		12.1 / 8.6	11.3 / 8.3	11.2 / 8.2
				35		12.2 / 8.6	11.4 / 8.4	11.4 / 8.4
				40		12.2 / 8.6	11.3 / 8.3	11.2 / 8.2
				45		12.2 / 8.6	11.2 / 8.2	11.4 / 8.4
				50		12.1 / 8.6	11.3 / 8.5	11.4 / 8.4
				55		12.1 / 8.6	11.4 / 8.4	11.4 / 8.4
				60		12.2 / 8.6	11.2 / 8.2	11.4 / 8.4
				65		12.1 / 8.6	11.2 / 8.2	11.4 / 8.4
1.35	610.83		609.48	0	Aug 25	10.7 / 8.8	10.0 / 8.7	1[illegible].1 / 8.8
				5		1[illegible].6 / 8.7	9.9 / 8.6	10.0 / 8.7
				10		10.4 / 8.6	9.8 / 8.5	10.0 / 8.7
				15		10.7 / 8.8	10.1 / 8.8	10.2 / 8.9
				20		10.6 / 8.7	10.2 / 8.9	10.2 / 8.9
				25		10.6 / 8.7	9.9 / 8.6	9.8 / 8.5
				30		10.5 / 8.6	9.8 / 8.5	9.9 / 8.6
				35		10.[illegible] / 8.7	9.8 / 8.5	9.8 / 8.5
				40		11.5 / 9.4	10.3 / 9.0	10.2 / 8.9
				45		10.6 / 8.7	10.0 / 8.7	10.0 / 8.7
				50		10.7 / 8.8	9.9 / 8.6	9.9 / 8.6
				55		10.7 / 8.5	9.9 / 8.6	9.9 / 8.6
				60		10.4 / 8.6	9.7 / 8.4	9.8 / 8.5

- S	H.I.	- S	El	Sta	Date	T	O	R
1.4	610.6	1.62	609.48	0	Aug 26	10.3/8.6	9.6/8.5	9.2/8.1
				5		10.1/8.5	9.6/8.5	9.8/8.7
				10		10.4/8.7	9.6/8.5	9.8/8.7
				15		10.1/8.5	9.5/8.4	9.8/8.7
				20		10.0/8.4	9.6/8.5	9.6/8.5
				25		9.9/8.3	9.5/8.4	9.6/8.5
				30		9.9/8.3	9.5/8.4	9.6/8.5
				35		10.0/8.4	9.5/8.5	9.4/8.3
				40		10.0/8.4	9.5/8.4	9.5/8.3
				45		9.9/8.3	9.5/8.4	9.4/8.3
				50		9.9/8.3	9.3/8.3	9.5/8.4
				55		9.9/8.3	9.3/8.2	9.3/8.3
				0	Aug 28	8.0/7.6	7.6	7.5
				5		8.0/7.6	7.6	7.5
				10		8.0/7.6	7.6	7.3
				15		8.0/7.6	7.6	7.2
				20		8.2/7.7	7.5	7.3
				25		8.3/7.8	7.7	7.5
				30		8.9/8.4	8.1	8.0
				35		9.1/8.6	8.4	8.2
				40		9.3/8.8	8.7	8.6

The last 8 stations were read off direct without the aid of an instrument.