THESIS

INVESTIGATION OF THE WATER SUPPLY AT NEWAYGO, MICHIGAN.

F. E. BURRELL & E. M. YOUNG

1915

This thesis was contributed by

F. E. Burrell

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

The Investigation of the Water Supply System

of

Newaygo Michigan...

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

By

[illegible] Young   F. E. Burrell

Candidates for the Degree of

Bachelor of Science

June, 1915.

THESIS

INTRODUCTION.

In this investigation we will give the prevailing conditions of the system in view of determining its adequacy for the village of Newaygo, a small town 36 miles north of Grand Rapids, and lying in a direct line north west of Lansing. The population remaining practically constant for the last 20 years, the adequacy of the system for a growing village need not be considered here.

We propose to comment freely upon the present arrangement, and suggest such changes and improvements as we see fit. Our conclusions are based on the water supply methods recognized by the best authorities.

Our references are;-"Public Water Supply", by Turneaure and Russell; " Treatise on Hydraulics", by Merriman; "Gillette's Cost Data" and Merriman's " Civil Engineers' Pocket Book".

Here we wish to thank the fire marshal and water works engineer of Newaygo for the interest they took, and also for the help given us during our invetigation.

HISTORY.

The village of Newaygo was incorporated in 1867. When in 1883 the entire town was destroyed by fire, the need of a water works system was impressed upon the people. In 1884 the town was bonded for $10,000, of which $500 was raised yearly by taxation to pay off the bonded debtedness. The wqter works system when completed, consisted of a wood stave pipe distributing system, and an equalizer or really a small air pressure tank which was situated in the pump house. The pumps consisted of 2 - 6" x 10" Walker pumps, which were driven by an old Leffel water wheel, the power being furnished by the water from Brooks Creek, a small branch of the Muskegon River, and having its origin in Ness lake, 2.5 miles distant. The fall of the creek is very rapid, and consequently in the summer this stream becomes very small. The pump house for the old system was situated up the creek about 500 feet from the present one. From the best authority we have been able to find, the old system was adequate to the needs of the people at that time. However, as the wood stave pipes became old there were leakages in the mains in the business district where the static head was the greatest. Every time a fire occurred and when extra pressure was put on, new leaks would show up and damage the streets to considerable extent. Another unsatisfactory feature of this old system was that the residences in the higher parts of the village could get no water during periods of the greatest consumption, and in the dry season during the summer months, water from the service tap was almost a luxury because of its rarity. Finally in 1912 the service became so poor that a new system was bonded for, and was entirely completed in August 1913. Our investigation follows in this thesis and is taken in the order shown:-

SOURCE.	Exhaustibility.
	Quality.
PLANT.	Pumping station.
	Water tower.
	Pipe line system.

SERVICE. Purity of water furnished.

Quantity.

Fire protection.

Waste and leakage.

FINANCES. First cost.

Method of payment.

Rates.

RECOMMENDATIONS FOR EXTENSION AND IMPROVEMENT.

Source.

Pumping.

Fire protection.

Extension of mains.

CONCLUSION.

SOURCE.

So far as we know the supply is ground water. It comes from several springs located on a side hill, this side hill being about 100 feet high and constituting one bank of Brooks Creek. The slope is very steep and wooded and the soil is of a springy and clayey nature. The business district itself is located in a basin or valley and contains several flowing wells.

These springs as before mentioned have been the source of supply as long as the systems have been in operation and have always up to the present time supplied the needs of the people. Even if the entire town were to be supplied with water from these springs, it is probable that the flow under the present system would still be large enough to perform that function.

The water as it comes from these springs is always cool and seems to remain at a fairly constant temperature. It is very clear and free from the slightest odor. There is practically no suspended matter and the taste is pleasing.

PLANT.

Pumping Station.

The pumping station is located on Brooks Creek. It is fitted with a 17 E, style 24, Samson Horizontal Turbine made by James Leffel & Company of Springfield, Ohio. It operates at a fairly high speed and under a head of 41 feet. Of course this may be varied considerably by adding more slash, or by removing some of them. The pumps, two in number, are made by the Gould company of Seneca Falls, New York. These pumps are belted to the shaft of the turbine.

The service pump is a three plunger, 8" x 8" pump, and under its rated speed tests up exactly to its rating, 100 gallons per minute. This totals up to 144,000 gallons per day, which is considerably more, taking the day as an average, than is used by the people. Of course the demand varies greatly during the day, but up to the present this pump has always been able to supply the demands of the people at all times for domestic purposes. This pump is run continuously but is slowed up during the night to prevent the stand pipe from running over, thus forming of the tower an equalizer. That is, the pump is run at all times just fast enough to maintain a constant head on the distributing system. In case the demand is greater than the supply from the pumps, the water from the tank supplies the deficiency. The drawing of the water from the tank, however, is objectionable in the hot seasons of the year for this reason:- we have found that there is one period in the day, about noon, considering the hottest days, when the pumps do not operate fast enough to supply all the water necessary. Here, the water in the tank horetofore used as an equalizer, flows in the system. This small tank allows the water to become heated up very quickly, and as a consequence, the people complain of warm water. Later in the discussion we will attempt to devise a plan by which we would eliminate the above trouble.

The fire pump is a Gould # 4, having a capacity of 500 gallons per minute. This pump was tested by us as to its capacity and was found to work almost exactly as rated. The data on the test as run is given below:-

Final gage reading on the tank ------------	6.9'
Initial gage reading ---------------------	1.8'
Difference in readings -------------------	5.1'
Time of run ------------------------------	18 minutes.
Average speed ----------------------------	315 R.P.M.
Pump pressure ----------------------------	65 #.
Diameter of tank -------------------------	17.42'

17.42 x 17.42 x .7854 x 5.1 = 1215.49 cu. ft. in 18 minutes.

1215.49 x 7.48 = 9091.9 gallons in 18 minutes.

$\frac{9091.9}{18}$ = 505.1 gallons per minute.

The above test was made by us on April 15, 1915. We shut off the water from the village at 12:00 midnight as the water is least used at about that time. We then read accurately the gage on the tank after the fire pumps had gotten up to full speed and recorded the time. We allowed the pumps to run 18 minutes at full speed and again read the gage on the tank.

In connection with these pumps, the turbine may also be used to drive a generator of the following description:- 480 volt, 4[illegible].1 amperes, 3 phase, with a frequency of 25 and a speed of 375 R.P. . This generator is made by the Allis-Chalmers company, of Milwaukee, Wisconsin.

During the hot season when the overflow from the lake is small and the rainfall is slight, the head in the pond can not be kept up. This forces the generator out of business as there is not enough power to run both generator and pump. Commercially, therefore, this generator is of no importance, except that it might be used to light the residence of the water works engineer, public library, pumping station, school house and the park buildings.

The arrangement of the pumping station is shown on the blueprint, plate # [illegible] in the pocket of this thesis.

Water Tower.

The water tank is a circular one holding 30,000 gallons. It is 17.4[illegible] feet in diameter, and 18 feet 10 inches deep. It is made of 3 inch timber and rests upon a tower of steel 60 feet high, the legs of which are raised 5 feet from the ground and supported by concrete blocks spaced 20 feet center to center. These blocks are 3 feet 8 inches square at the top, and are 9 feet square at the bottom, and are set in the ground about 5 feet on hard clay foundation. Each leg is fastened by two bolts to the block.

The water tank is nearly 200 feet above the lowest fire hydrant giving a static pressure of about 86 #, and about 77 feet above the hightest hydrant giving a static pressure of 33.4 #.

Pipe Line System.

The tank may be shut off entirely from the system, and the pumps used to force the water directly into the mains. By so doing these pressures may be greatly increased. Flowing and static pressures due to the head of water in the tank, and flowing and static pressures due to pumping pressure, pumping directly into the mains with the fire pumps were taken by us. The apparatus used for taking these pressures consisted of a 2 inch pipe, 3.5 feet long. A hydrant coupling was placed on one end, and 1[illegible] inches from this was placed a nipple in the pipe to which was screwed a pressure gage. The other end contained a nozzle coupling and also was threaded for a cap so static pressures could be read at the same period. A 1 inch nozzle was used to take the flowing pressures. All pressure readings taken by us are tabulated below, gage readings as shown are corrected later in the computations.

Hydrant #	Static.	Flowing.	Fire Pressure Flowing.	Tank Head.
1.	5[illegible] #	51 #		15.0'
2.	73		95 #	17.0'
3.	74 #			16.5'
4.	[illegible] #		*105 #	16.5'
5.	[illegible]7 #			16.0'
6.	6[illegible].5 #			16.[illegible]'
7.	75	40.[illegible] #	64 #	15.0'
8.	60 #			16.0'
9.	No test. Hydrant broken.			
10.	6[illegible]	40 #		15.[illegible]'

Hydrant #	Static.	Flowing.	Fire Pressure Flowing.	Tank Head.
11.	82 #			15.5'
12.	86 #	49 #	61 #	15.0'
13.	33 #			15.0'
14.	No test.	Hydrant broken.		
15.	35 #			15.0'
16.	35.5 #			15.0'
17.	24 #	16 #	28 #	14.0'
18.	35 #	24.5 #	44 #	14.5'

* Fire pressure static.

In hydrant # 7, stone in nozzle caused gage to read 62 # under flowing pressure, and in hydrant # 17, stone in nozzle caused gage to read 64 # under fire pressure flowing.

The level notes on the present and proposed systems are given on the following blueprints. The location of these hydrants, the pipe line system, and proposed extension may be found on the blueprint, plate # 1, in the pocket of this thesis.

4,850 feet of 6 inch pipe, and 12,100 feet of 4 inch pipe comprise the greater part of the present distributing system. There are 18 fire hydrants, all of which are connected to the mains by 4 inch pipe. They are all 2 way, and are 5 feet long.

The profiles and hydraulic gradients of all pipe lines are shown on plate # 2. Plate # 1 also shows the layout of the town, location of the tank, pump house, reservoirs, springs, and possible sources of contamination.

March 30, 1915
Weather: Cold, clear
Young + Burrell.

Level Notes. (Copy)

Point	B.S.	H.I.	F.S.	Elev.	Desc.
T.P. Walk int.	10.875	60.875		50	Depot
Hyd #1			9.540	51.335	Flange
End of line			9.606	51.3	State Road
Pt. 1			4.100	56.8	State Rd. + River
T.P. Hyd #2	8.579	67.534	1.920	58.955	Flange
Pt. 2			1.800	65.7	
T.P. 3	11.793	77.514	1.813	65.721	X side walk
Hyd. #3			8.624	68.9	Near line down hill
Pt. 3			1.350	76.2	Near Hyd. # 4
T.P. 4	8.830	84.529	1.815	75.699	Int. S.W.
Hyd #4			6.650	77.9	In line with Park St.
T.P. 5	6.535	87.747	3.317	81.212	Int. S.W.
Hyd. #5			3.894	83.9	Quarter Line + State Rd.
Pt. 4			5.550	82.2	"
Pt. 5			7.330	80.4	
T.P. Hyd. #6	0.192	80.387	7.552	80.195	State Rd. + Wood
Pt. 6			2.680	77.7	"
Pt. 7			10.150	70.2	Mid-block
T.P. 7	1.093	69.996	11.484	68.903	House S.W.
Pt. 8			6.960	63.0	State Rd. + Water
T.P. Hyd. #7	12.020	75.772	6.244	63.752	"
Pt. 9			9.000	66.8	
T.P. 8	10.679	84.496	1.955	73.817	X side walk
Hyd. #8			8.033	76.5	Justice + Water
Pt. 10			10.350	74.1	"
Pt. 11			9.900	74.6	"
Pt. 12			2.600	81.9	
Pt. 13			0.920	83.6	Justice + Wood
T.P. 9	8.458	92.006	0.948	83.548	Over pipe S.W.
Pt. 14			2.800	89.2	Wood + Fair
T.P. 10 ①	7.423	98.322	1.107	90.899	Int. S.W.
Hyd. #9			0.600	97.7	Droom + Wood
Pt. 15			4.000	94.3	"
Pt. 16			1.800	96.5	Service Tap
Pt. 17			2.800	95.5	"

March 30, 1915
Weather:- Cold, Clear.
Young & Burrell.

Level Notes. (Copy)

Point	B.S.	H.I.	F.S.	Elev.	Desc.
T.P. 10 ②	1.750	92.649		90.899	Int. S.W.
Pt. 18			7.250	85.4	Service Tap
Pt. 19			7.630	85.0	"
Pt. 20			9.000	83.6	"
Pt. 21			6.700	85.9	"
T.P. 10 ③	10.100	100.999		90.899	Int. S.W.
T.P. 11 ①	12.282	111.001	2.280	98.719	Quarter Line & Fair
T.P. 12	8.516	118.322	1.915	109.806	x stone
Pt. 22			4.900	113.4	Quarter Line & Broom
Pt. 23			11.500	106.8	Service Tap
T.P. 11 ②	3.530	102.249		98.719	
Hyd. #10			2.950	99.3	Quarter Line & Fair
Valve 1			2.750	99.5	"
T.P. 13	3.098	92.787	12.560	89.689	x-sidewalk
Pt. 24			5.400	87.4	Quarter Line & Justice
T.P. Hyd. #6	1.269	81.464		80.195	Wood & State Rd.
Valve 2			4.400	77.1	"
Pt. 25			10.800	70.7	Angle of Wood
T.P. 14	0.849	70.028	12.285	69.179	x side walk
Pt. 26			6.500	63.5	x stone
T.P. 15	0.896	57.924	13.000	57.028	"
T.P. Hyd. #11	0.750	49.924	8.750	49.174	Wood & Water
T.P. 16	4.150	43.911	10.163	39.761	x stone
T.P. 16a	4.540	42.073	6.378	37.533	"
Hyd. #12			2.318	39.8	End of line
T.P. 11 ③	11.734	110.453		98.719	Quarter Line & Fair
T.P. 17	12.894	123.177	0.170	110.283	Stones in road
T.P. 18	12.284	134.721	0.740	122.437	"
T.P. 19	12.666	147.287	0.100	134.621	"
T.P. 20	12.666	159.618	0.335	146.952	"
T.P. 21	10.229	168.777	1.170	158.548	"
Pt. 27			8.000	160.8	Main & Clay
Pt. 28			5.140	163.6	Post & Clay

March 30, 1915
Weather: Cold, clear
Young & Burrell

Level Notes. (Copy)

Point	B.S.	H.I.	F.S.	Elev.	Desc.
T.P. Hyd. #13	2.745	167.952	3.570	165.207	Post & Clay
Pt. 29			4.310	163.6	Wash. & Clay.
T.P. Hyd. #14	5.488	169.671	3.762	164.183	"
Pt. 30			5.860	163.8	Wash. & Scott
T.P. Hyd. #15	3.864	169.371	4.164	165.507	" & Ewing
Valve 4			5.900	163.5	"
Pt. 31			5.400	164.0	"
Pt. 32			4.100	165.3	Wash. & John
Pt. 33			2.250	167.1	Service tap
Pt. 34			3.300	166.1	"
T.P. Hyd. #16	2.789	170.620	1.540	167.831	Wash. & John
Pt. 35			5.940	164.7	Jefferson & "
T.P. 22	0.713	165.004	6.329	164.291	X Stone
Pt. 36			3.100	161.9	Quarter Line & Jefferson
Pt. 37			7.400	157.6	" & Brooks
T.P. 23	6.425	163.883	7.546	157.458	X Stone
Hyd. #17			3.520	160.4	Quarter Line & Third
Pt. 38			5.380	158.5	End of line
T.P. Hyd. #14 ②	3.523	167.706		164.183	Wash & Clay.
Pt. 39			5.050	162.7	" & Park
Pt. 40			12.940	154.8	Service Tap
T.P. 24 ①	6.171	168.095	5.782	161.924	Catch basin
Pt. 41			3.840	164.3	Post & Park
Pt. 42			4.320	163.8	Service Tap
T.P. 24 ②	4.318	166.242		161.924	Catch basin
Pt. 43			3.925	162.317	Base of Tower

March 31, 1913
Weather: Cold, clear
Young & Burrell.

Level Notes (Copy)

Point	B.S.	H.I.	F.S.	Elev.	Desc.
T.P. 24 ③	3.277	165.201		161.924	Catch basin
x stone T			8.271	156.930	Base of Tower
T.P. 25	5.432	169.190	1.443	163.758	x stone
Pt. 44			3.000	166.2	Post & Stake
T.P. Hyd #18	1.990	159.060	12.120	157.070	Main & "
Pt. 45			5.000	154.1	"
Pt. 46			8.620	150.4	Service tap
Pt. 47			3.500	155.6	"
Pt. 48			6.100	153.0	Turn on hill
x stone T	0.602	157.532		156.930	Base Tower
T.P. 26	1.575	146.334	12.773	144.759	Stone on hill
T.P. 27	0.973	134.803	12.504	133.830	"
T.P. 28	0.650	123.075	12.378	122.425	"
T.P. 29	0.380	110.873	12.582	110.493	"
T.P. 30	0.778	99.208	12.443	98.430	"
T.P. 31	7.650	94.098	12.760	86.448	"
Pt. 49			10.340	83.758	Pump House Floor
Top Penstock			6.440	87.658	Ent. Pump House
T.P. 1	12.318	106.116	0.300	93.798	Stone on hill
T.P. 2	12.758	118.573	0.301	105.815	"
T.P. 3	10.800	128.713	0.660	117.913	"
Pond			3.900	124.8	Water Level

(Copy)

Weather, – Windy

Level Notes for Proposed Extension.

Young + Burre

Point	B.S.	H.I.	F.S.	Elev.	Desc.
T.P. 1	3.095	165.019		161.924	Catch basin
T.P. 2	1.692	160.663	6.048	158.971	Park + Barton
T.P. 3	5.247	160.738	4.722	155.941	Mary + "
1			7.854	152.884	Wash. + Mary
2			3.880	156.858	Jefferson + "
3			5.090	155.648	Brooks + "
4			9.152	151.586	Mill + Wash.
T.P. 4	4.923	159.965	5.696	155.042	Jeff. + Eliza
5			4.811	155.154	Brooks + State
6			3.230	156.735	Barton + "
7			3.950	156.015	Jeff. + "
T.P. 5	1.654	150.776	10.843	149.122	Wash. + "
8	1.795	141.148	11.423	139.353	Patt. + Kritzer
T.P. 6	0.968	135.362	6.754	134.394	Water Trough
9			2.725	132.637	Eckhard + Kritzer
T.P. 7	0.694	123.577	12.479	122.883	x Stone
10			2.204	121.373	Eckhard + Duffy
11			9.302	114.275	Line " "
T.P. 8	0.308	110.930	12.955	110.622	Main + State
T.P. 9	0.302	98.381	12.851	98.079	Top steady grade
T.P. 10	0.330	85.780	12.931	85.450	x stone
T.P. 11	1.568	74.478	12.870	72.910	"
T.P. 12	1.063	62.611	12.930	61.548	Bridge + State Rd.
12			11.550	51.061	West end of Bridge.

Computations for sizes of pipe.

In computing the sizes of pipe necessary to supply a certain district or town, the maximum average consumption must be assumed or obtained.

According to past records the tank is emptied on an average of three times each day, making a total of 90,000 gallons per day. This has been the average consumption since the installment of the system two years ago. There are now 130 service taps in use. Taking an average of 5 people per tap, we have 650 people using 90,000 gallons per day. This makes 138.4 gallons per capita per day. Actual consumption tests totaling 24 hours, with readings practically every hour, were taken by us during several different days. We performed these tests by filling the tank, then shutting off the pumps, noting time and gage reading of the tank. The test could not be a continuous one as it was necessary to fill the tank at intervals. The data of these tests as run is given below:-

Date.	Time.	Gage Reading.	
April 1.	6:00 P.M.	14.40'	
"	8:30 P.M.	9.40'	
"	12:00 Midnight.	1.90'	
	Difference in elevation ---------------		12.50'
April 2.	12:00 Midnight.	16.25'	
"	1:00 A.M.	14.40'	
"	2:00 A.M.	12.70'	
"	3:00 A.M.	11.30'	
"	4:00 A.M.	9.90'	
"	5:00 A.M.	7.70"	
	Difference in elevation ---------------		8.55'

Date.	Time.	Gage Reading.
April 3.	5:50 A.M.	5.75'
"	6:50 A.M.	4.00'
"	7:50 A.M.	1.60'
	Difference in elevation -----------	4.15'
April 4.	7:50 A.M.	12.40'
"	8:50 A.M.	10.50'
"	9:50 A.M.	8.50'
"	10:50 A.M.	6.50'
"	11:50 A.M.	4.60'
"	11:40 A.M.	4.00'
	Difference in elevation -----------	8.40'
April 5.	11:40 A.M.	10.50'
"	12:40 P.M.	8.50'
"	1:40 P.M.	6.63'
"	2:50 P.M.	5.75'
	Difference in elevation -----------	4.75'
April 7.	2:50 P.M.	16.63'
"	3:50 P.M.	14.50'
"	4:50 P.M.	12.30'
"	5:50 P.M.	9.90'
"	6:00 P.M.	7.50'
	Difference in elevation -----------	9.13'

Total depth of water used ------------------- 47.48'

17.48 x 17.48 x 47.48 x .7854 = 11, 310 cu. ft. per day.

11, 310 x 7.48 = 84,710 gallons per day.

From this test we see that the above quantity checks very closely with the average consumption for the past two years. [illegible]4,750 gallons per day amounts to 130 gallons per capita per day, considering the number of people actually using water from the taps, and not the entire population.

Since more water is used about noon of every day, and on Mondays as wash day, the rate of flow will be considerably higher. Practice has determined this rate as 175% of the maximum average daily consumption per capita to cover the largest possible demands. The pipe must also be designed to furnish "n" fire streams at one time, where "n" is obtained by the formula, $n = 2.8\sqrt{x}$, given on page 74[illegible] of "Public Water Supply" by Turneaure and Russell. In this formula, x = the population of the town in thousands. Each fire stream will give an amount depending on the size of pipe, size of hose, and the pressure.

Morrison gives the following formulae:-

$$v = \sqrt{\frac{2gh}{m + \frac{fl}{d} + \left(\frac{1}{c_1}\right)^2 \times \left(\frac{d}{D}\right)^4}}$$

$$V = \left(\frac{d}{D}\right)^2 v \qquad \text{and} \qquad Q = .7854\, D^2 V$$

Where,- v = velocity in hose. V = velocity in nozzle.

Q = quantity of discharge.

m = coefficient for loss at entrance.

f = coefficient of friction.

h = pressure at hydrant.

d = diameter of hose.

D = diameter of nozzle.

l = length of hose.

c_1 = coefficient of velocity for nozzle.

Substituting in the above formula:-

for 400 feet of 2.5 inch hose, with 1 inch nozzle; hydrant pressure of 75 #; f = .02; c_1 = .072.

v = 10.54 feet per second.

V = 65.9 feet per second.

Q = 0.36 cu. ft. per second, or 161 gallons per minute.

For 100 feet of hose under the same conditions,

v = 14 feet per second.

V = 87.6 feet per second.

Q = 215 gallons per minute.

Therefore, from the above, we will assume 200 gallon fire streams. As the town is one of very slow, if any growth, we assume from the curve that in 1940, a year probably far beyond the life of the system, the population will not exceed 1,300. Therefore we deem it safe to use such a number for that future time. [illegible], when first incorporated, was a lumbering town and was most prosperous when lumber was not so scarce as it is now. The town proper depends mainly upon three factories for its maintenance.

The total number of fire streams to be concentrated at any one time = $2.8\sqrt{1.3}$ = 3.19. Say 3 fire streams. 3 x 200 = 600 gallons per minute for fire purposes.

Assuming from our test a maximum average consumption of 1[illegible] gallons:- 175 % of 1[illegible] = 242 gallons per capita per day. We assume that for the practical length of life of this system the town will not exceed 1,000 people using water, as at present there are only 650. Therefore the total consumption will not exceed 242 x 1,000 = 242,000 gallons per day, or 168 gallons per minute. This makes a total of [illegible] gallons per minute.

From the diagram for calculating cast iron pipe, given on page 243 of "Public Water Supply" by Turneaure and Russell, we get only 97 gallons per minute from a 4" pipe, allowing a 10' loss of head per 1,000 feet. From a 6" pipe with the same loss we get 300 gallons per minute, making a total of 397 gallons per minute. This shows that the present mains are not big enough for emergencies.

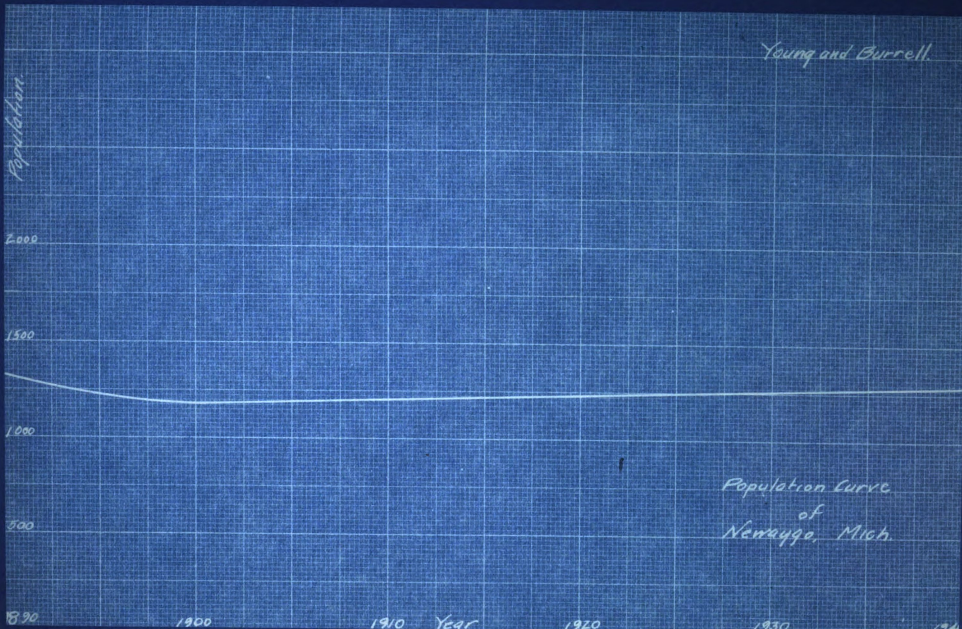
Below is given the data from which we plotted the population curve.

Date		Population.
1890	---------------------	1,[illegible]0
1900	---------------------	1,178
1905	---------------------	1,195
1910	----------------------	1,[illegible]07

The population is given as plotted on the following sheet.

To show graphically the loss of head at various points of the system, profiles of each street are plotted, elevations being referred to a zero datum plane. From the same datum we plotted the actual flowing pressures at the hydrants, after reducing to a zero level. By connecting these pressures we obtained a curve known as the hydraulic gradient, which is the line to which the water level would rise if piezometer tubes were inserted at certain points along the line. These gradients are shown on blue print, plate # 8.

Because of the wide range in elevation we found it convenient in plotting profiles to refer everything to a zero



Young and Burrell.
Population.
2000
1500
1000
500
1890
1900
1910
Year
1920
1930
194
Population Curve
of
Newaygo, Mich.

datum plane. To correct our elevations from level notes we subtracted 37 from the given elevation to get the point. This brings our lowest point only 0.5 of a foot above this zero reference plane.

To get points on the gradient we first reduced our hydrant elevation to its corresponding height above datum, then changed our gage readings from pounds per square inch to an equivalent head in feet of water, by multiplying by the conversion factor, 2.304. The sum of the two gives the point on the gradient.

Before using our pressure gage readings we corrected them according to the amounts shown necessary in the following calibration test of the instrument used, made by us on April 7, 1915.

Calibration of 200 # gage.

Standard pressure #/sq. in.	Gage Reading Up	Gage Reading Down
0	0.0	0.0
5	6.0	6.0
10	11.0	11.0
15	16.0	16.0
20	21.0	21.0
25	26.0	26.0
30	31.0	31.0
35	36.0	36.0
40	40.5	40.5
45	46.0	46.0
50	51.0	51.0

Standard Pressure	Gage Reading	
#/sq. in.	Up	Down
55	56.0	56.0
60	61.0	61.0
65	65.0	65.0
70	70.0	70.0
75	75.0	75.0
80	80.0	80.0
85	85.0	85.0
90	90.0	90.0
95	95.0	95.0
100	100.0	100.0
105	105.0	105.0
110	110.0	110.0

Elevation of water level in the tower above datum.

This was used as the high point for the hydraulic gradients.

Average tank reading ------ 14.7 feet.

Height of tower ----------- 60.0 "

Elevation base above datum-125.3 "

Elevation of water level - 200.0 "

Elevations along streets from which profiles were drawn:-

Profile # 1.

Point	Location	Elevation	Elev. above datum.
x	Stone Base of tower.	156.0	111.0
28	Washington and Park.	162.7	125.7
29	" " Clev.	163.6	126.6
30	" " Scott.	163.8	126.8
31	" " Ewing.	164.0	127.0

Point	Location	Elev.	Elev. above datum.
32	Washington and John.	165.3	128.3
35	Jefferson and John.	164.7	127.7
36	" " Quarter Line.	161.9	124.9
37	Brooks " "	157.6	120.6
38	End of line.	158.5	121.5
	Profile # 2.		
44	Post and State.	166.2	129.2
45	Main " "	154.1	117.1
48	Turn before hill.	153.0	116.0
2	Hit State Road.	65.7	28.7
	Profile # 3.		
4	State Road and Quarter Line.	82.2	45.2
24	Justice " "	87.4	50.4
Valve # 1	Fair " "	99.5	62.5
	Profile # 4.		
6	Wood and State Road.	77.7	40.7
25	Angle of Wood.	70.7	33.7
26	115 feet down hill.	63.5	26.5
T.P. 16	Near cement plant.	39.8	2.8
T.P. 16a	" " "	37.5	0.5
Hyd. 12	End of line.	39.8	2.8
	Profile # 5.		
End of line on State Road.		51.3	14.3
1	State Road and River.	56.8	19.8
2	50' left of pipe down hill.	65.7	28.7
3	Near hydrant # 4.	76.2	39.2

Point	Location	Elev.	Elev. above datum.
4	State Road and Quarter Line.	82.8	45.8
5	100 feet from corner.	80.4	43.4
6	State Road and Wood.	77.7	40.7
7	Middle of block.	70.8	33.8
8	State Road and Water.	63.0	26.0
9	160 feet from State Road.	66.8	29.8
10	50 feet from Justice.	74.1	37.1
11	Water and Justice.	74.6	37.6
12	110 feet from Water.	81.9	44.9
13	Wood and Justice.	83.6	46.6

Profile # 6.

29	Washington and Clay.	163.6	126.6
28	Post " "	163.6	126.6
27	Main " "	160.8	123.8
Valve # 1	Main and Weir.	99.5	62.5
14	Wood and Weir.	89.9	52.9
16	End of line.	94.3	57.3

Computations for points on Gradient.

Hydrant # 1. Pressure 51 #. Elevation 13.5 feet.

2.304 x 51 plus 13.5 = 131.0

Hydrant # 7. Pressure 48 #. Elevation 26.3 feet.

2.304 x 48 plus 26.3 = 136.9

Hydrant # 10. Pressure 39 #. Elevation 61.8 feet.

2.304 x 39 plus 61.8 = 151.6

Hydrant # 16.   Pressure 48 #.   Elevation 8.3 feet.

2.304 x 48 plus 8.3 = 118.9

Hydrant # 17.   Pressure 15 #.   Elevation 122.9 feet.

2.304 x 15 plus 122.9 = 157.5

Hydrant # 18.   Pressure 23.5 #.   Elevation 119.6 feet.

2.304 x 23.5 plus 119.6 = 173.6

Computations for points on Gradients where pressures were not taken.

We first computed the quantity of water flowing and from that obtained the velocity. From the velocity and length of pipe we computed the losses. Merriman gives the following formulae for discharge from nozzle, velocity in pipe, and loss:-

$$q = 19.65\,D^2 \sqrt{\frac{p}{\left(\frac{1}{c}\right)^2 - \left(\frac{D}{d}\right)^4}} \quad \text{gallons per minute.}$$

$$v = \frac{q}{a} \qquad \text{and loss} = f\frac{l}{d'}\frac{v^2}{2g}.$$

Where, q = discharge from nozzle, in gallons per minute.

D = diameter of nozzle in inches.

d = diameter of pipe to which nozzle is attached, in inches.

c = coefficient of discharge for 1 inch nozzle.

v = velocity of water in main.

f = coefficient of friction.

a = cross sectional area of main.

d' = diameter of main.

l = length of main.

p = gage pressure at entrance to nozzle.

Computations for loss from hydrant # 3 to hydrant # 1. From the ratio of flowing to static pressures at the hydrants where both pressures were taken, we assumed that an average condition existed at hydrant # 3. We found this average to be

$$\frac{\text{static pressure}}{\text{flowing pressure}} = 1.5.$$

Hydrant # 3. Static pressure = 74 #.

$$\frac{74}{1.5} = 49.3 \text{ \# flowing pressure.}$$

Elevation = 68.9 - 37.5 = 31.4 feet.

2.304 x 49.3 plus 31.4 = 144.9 which is the last point on gradient # 6, and also establishes the second point on gradient # 5.

From hydrant # 7 we computed the loss back to # 6 where the pipe changes size. From formula given above:-

q = 207 gallons per minute, or 0.46 cu. ft. per second.

v = 5.27 feet per second.

Loss = 29.8 feet, on single pipe, or 7.45 feet on a gridiron system. This gives a loss of 4.5 feet in the distance from hydrant # 6 to # 7. 136.8 plus 4.5 = 141.3.

From hydrant # 7 to Wood Street, a distance of 1,000 feet, the loss shown above is 7.45 feet.

136.8 - 7.5 = 129.3 point at end of gradient # 5.

From hydrant # 10 to hydrant # 9 at the end of gradient # 6, we computed the loss as follows:-

q from hydrant # 10 = 190 gallons per minute = 0.42 cu. ft. per second. v = 4.88 feet per second. Loss = 27.4 feet per 1,000 feet of pipe. From hydrant # 10 to Wood Street, a gridiron system is used. This means a loss of 4.11 feet.

151.6 - 4.1 = 147.5 feet elevation of gradient at corner of Wood and Fair Streets. In going 500 feet from Wood Street to hydrant 9, the loss is 13.7 feet. 147.5 - 13.7 = 133.8 feet. point on gradient at hydrant No.

SERVICE.

Purity of Water Furnished.

The water for all purposes except fire is taken from springs. These springs are located on a wooded hillside and there are but few sources of contamination, within the 600 foot radius, which are required to be recorded by the State Board of Health. These sources of contamination are shown on the map of the system, plate # 1. This shows 12 privy vaults within that distance, none of them being less than 275 feet from any spring.

We will here give parts of the law relative to water works and sewerage systems. Act 98, Public Acts 1913.

An act providing for the supervision and control by the State Board of Health over water works systems and sewage disposal systems, and providing for the appointment, duties, salary and expenses of a State sanitary engineer, and providing penalties and defining liabilities for violations of this act.

Section 6. It shall be the duty of the mayor of each city, the president of each village and of all private corporations, partnerships or individuals now or hereafter operating water works systems in this state, to file with the State Board of Health a true and correct copy of the plans and specifications of the entire system owned or operated by such corporation, partnership or individual, including such filtration or other purification plant as may be operated by them in connection therewith, and also plans and specifications of all alterations, additions, or improvements to such systems which may be made from time to time. The plans and specifications herein referred to shall, in addition to all other things, show all the sources through or from which the water is or may be at any time pumped or otherwise permitted or caused to enter into such systems. Such plans and specifications shall be certified by the mayor and city engineer of city corporations, by the president and engineer, if one is employed, for village corporations, and by such proper officer and the engineer employed by a private corporation for private corporations, and by some individual member of a partnership, or by the individual owner in case of water works owned and operated by partnerships or individuals, including the engineer employed, if any.

In accordance with section 3, part of which is given above, the State Board of Health have adopted certain rules and regulationsccovering the preparation and submission of plans of public water supplies, purification works, and extensions and alterations of the same.

One of these rules is:- "The location of all streams, outlets of sewers and other possible sources of contamination within 5 miles of the water works intake must be shown with reference to the intake or source of supply." This refers to large cities or those cities taking water from lakes or rivers. One which applied to the village of Newaygo, but upon investigation we found it was not printed on the list of miles, due to an oversight, was to the effect that all possible sources of contamination located within a 600 foot radius of the source of water supply must be marked plainly and accurately upon a drawing to be filed with the State Board of Health.

From the springs the water is carried to two concrete reservoirs through 8 inch pipes. One of these reservoirs is square, has a capacity of 5,000 gallons and is fed by three springs. The other is circular, 24 feet in diameter, has a 60,000 gallon capacity, and is fed by 5 springs in the bottom and at the sides. A 6 inch spiral riveted pipe connects the pump with the springs and the water is pumped directly into the mains and water tower on the hill.

This water is cold ground water of the best quality, and so far there have been no water borne diseases contracted from the use of water supplied by the system.

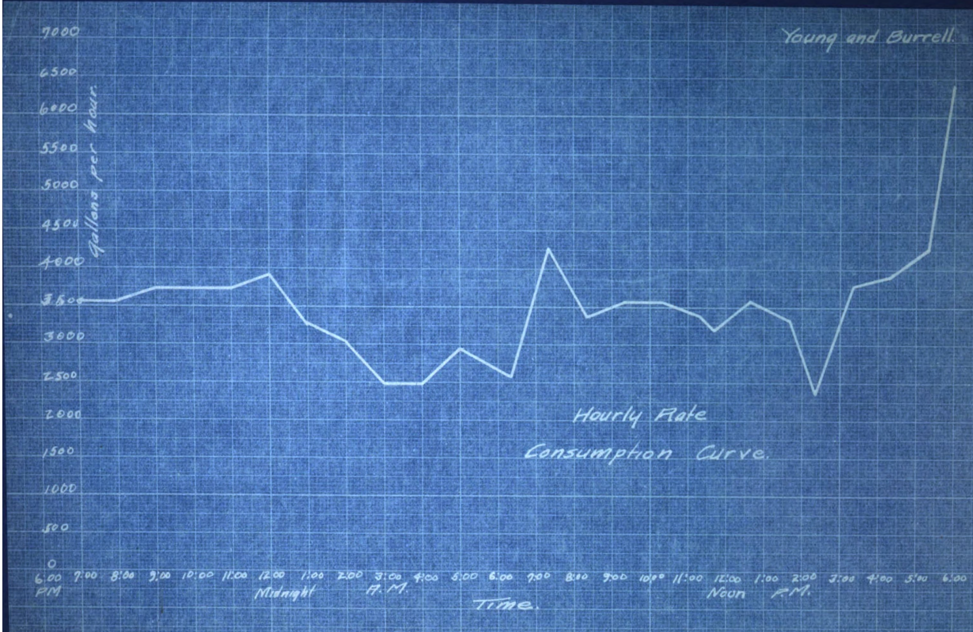
Quantity.

To the present date these springs have furnished an ample supply of water for all common needs of the town, and all indications are that a much larger quantity could be secured from the same source.

At this point we shall put the computations for plotting hourly consumption curve, also give data hourly as from test.

Time	Gage Rdg.	Diff. in Elev.	Gallons	Interval
6:00 P.M.	14.4'	0.0'	0000.0	0 hours
7:00 (Approx)	12.4'	2.0'	3,565.5	1 "
8:00 "	10.4'	2.0'	3,565.5	1 "
9:00 "	8.3'	2.1'	3,743.8	1 "
10:00 "	6.2'	2.1'	3,743.8	1 "

Time	Gage Rdg.	Diff. in Elev.	Gallons	Interval.
11:00 (Approx)	4.1'	2.1'	3,743.9	1 hour.
12:00 Midnight.	1.9'	2.2'	3,922.1	1 "
12:00 "	16.25'			
1:00 A.M.	14.4'	1.85'	3,299.1	1 "
2:00 A.M.	12.7'	1.7'	3,030.7	1 "
3:00 A.M.	11.3'	1.4'	2,495.9	1 "
4:00 A.M.	9.9'	1.4'	2,495.9	1 "
5:00 A.M.	7.7'	2.2'	3,922.1	1.3 "
5:20 A.M.	5.75'			
6:20 A.M.	4.0'	1.75'	2,585.0	1 "
7:20 A.M.	1.6'	2.4'	4,278.6	1 "
7:20 A.M.	12.4'			
8:20 A.M.	10.5'	1.9'	3,387.2	1 "
9:20 A.M.	8.5'	2.0'	3,565.5	1 "
10:20 A.M.	6.5'	2.0'	3,565.5	1 "
11:20 A.M.	4.6'	1.9'	3,387.2	1 "
11:40 A.M.	4.0'	0.6'	1,069.7	0.33"
11:40 A.M.	10.5'			
12:40 P.M.	8.5'	2.0'	3,565.5	1 "
1:40 P.M.	6.63'	1.87'	3,333.7	1 "
2:20 P.M.	5.75'	0.88'	1,568.9	0.66"
2:20 P.M.	16.63'			
3:20 P.M.	14.5'	2.13'	3,797.3	1 "
4:20 P.M.	12.3'	2.2'	3,922.1	1 "
5:20 P.M.	9.9'	2.4'	4,278.6	1 "
6:00 P.M.	7.5'	2.4'	4,278.6	0.66"


Young and Burrell.
Hourly Rate
Consumption Curve.
Gallons per hour.
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
6:00 PM
7:00
8:00
9:00
10:00
11:00
12:00 Midnight
1:00
2:00
3:00 A.M.
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00 Noon
1:00
2:00 P.M.
3:00
4:00
5:00
6:00
Time.

The number of gallons was found by multiplying the difference in elevation by the constant of the tank which is 1782.75. This constant was found in the following manner:-

Diameter of tank = 17.42'   7.48 gallons = 1 cu. ft.

17.42 x 17.42 x .7854 x 7.48 = 1782.75.

We will here insert a table taken from page 23 of "Public Water Supply" by Turneaure and Russell, which shows the consumption of water in American cities and towns for the year 1905.

City	Population 1900	Per cent of Taps Metered	Consumption per Inhabitant Daily
Chicago	1,698,600		200 gal.
Philadelphia	1,293,700	1	230 "
St. Louis	575,200	7	92 "
Boston	560,900	5	151 "
Cleveland	381,800	68	137 "
Buffalo	352,400	3	324 "
San Francisco	342,800	21	96 "
Cincinnati	325,900	12	130 "
Detroit	285,700	9	183 "
Milwaukee	285,300	80	91 "
Louisville	204,730	8	81 "
Minneapolis	202,720	47	76 "
Providence	175,600	86	68 "
Indianapolis	169,160	10	82 "
Kansas City	163,750	38	73 "
St. Paul	163,065	38	56 "

City	Population 1900	Percent of Taps Metered	Consumption per Inhabitants daily
Rochester	162,600	41	88 gal.
Toledo	131,820	70	75 gal.
Columbus	125,560	76	110 "
Worcester, Mass.	118,420	95	75 "
Fall River, Mass.	104,860	97	42 "
Memphis, Tenn.	102,320	20	100 "
Lowell, Mass.	94,970	69	59 "
Atlanta, Ga.	89,870	100	65 "
Dayton, Ohio.	85,333	70	70 "
Nashville, Tenn.	80,870	52	148 "
Camden, N.J.	75,940	3	155 "
Yonkers, N.Y.	47,930	99	115 "
Newton, Mass.	33,587	86	59 "
Madison, Wis.	19,164	97	46 "
Middleborough, Mass.	6,885	47	78 "
Foxborough, Mass.	3,266	46	63 "
Melrose, Mass.	12,962	3	112 "

From the above data we can see that the use of water in Newaygo, 172 gallons per capita per day, is not excessive for a town that is wholly unmetered. In case the town is metered it is certain that the springs can furnish water, even for a large extension of the system.

Fire Protection.

In case of fire the water tower is shut off and the water is pumped directly into the mains, partly from the springs and partly from Brooks Creek. In this way, poluted water might get into the pipes, but as the creek is fed principally by springs and very little water would remain in the pipes, there is not likely to be any trouble from this source.

The fire protection is not the best. As has been shown there should be at least 3 fire streams available at one time, and assuming 200 gallon streams, this would mean a supply of 600 gallons per minute. As the fire pump is rated at and tested out a maximum capacity of 500 gallons, there is a deficiency of 100 gallons.

Newaygo has 18 fire hydrants, which if placed rightly would be sufficient. They are 2.5" two way hydrants, many of which are placed on only 4" mains. These mains would not be large enough for the concentration of the required three streams.

There have been two large fires in the town since the present system was installed. In the month of November, 1914, the stock room and electrical shop of the Newaygo Portland Cement Company burned to the ground at a loss of $48,600. There were two hydrants within easy reach, both at the lowest point in the system where static head from elevation of the tank alone was about 86 pounds. With fire pump working there should have been a higher pressure. The main here is only 4" and fire hydrants were so clogged with stones that no pressure was available when needed.

Again in the last week of April, 1915, the plant of the Henry Rowe Manufacturing Company burned and sparks from this fire caused two barns and a house across the Muskegon River to be destroyed. Here only one fire hydrant was in reach and this too was so clogged with stones that no stream was secured. A loss of $40,000 resulted and would probably have been more if the wind had been blowing toward the town.

Both of these fires were in the same section of the town where plenty of pressure would have been available except for careless construction and lack of care in cleaning out the pipe when laid. That the system needs overhauling and improvements is evident. While running our pressure tests on the fire hydrants, we discovered defects. There were two hydrants with broken bases so that no water at all could be secured from the nozzle and from two other hydrants, neither of them near the place where trouble was caused by stones during fires, stones so large they clogged the nozzle, were thrown out. The water had to be shut off, the nozzle unscrewed and the stone removed before any reading could be taken in each case.

During the construction of the water works system, little care was used in cleaning out the pipes. They were let down by means of ropes, bell end first, and the gravel and stones scooped up while sliding in to place were not cleaned out.

From our flowing pressures and level notes, it is evident that enough pressure will be available for ordinary fire purposes when hydrants are repaired and the stones cleaned from the pipes. Changes and improvements will be noted in our recommendations for extension of service.

Waste and Leakage.

Little can be said about waste and leakage as there are no meters on the system. The pumps are not run at a constant speed and so there is no accurate method of determining the amount of water pumped. As in other unmetered towns there is much water used unnecessarily. As the line is practically new there should be no leaks and so we will say that the rather high consumption is caused by careless usage.

FINANCES.

First Cost and Method of Payment.

The water works system is managed by the water works committee which is composed of one half of the members of the village council. A water works engineer is elected to oversee the system and to run the pumps at all times.

The bond issue, as has been stated, was for $17,000, this to be paid in installments of $1,000 per year raised by taxation upon the assessable property of the village. Below is given a complete statement as filed by John Nuveen and Company, of Chicago, buyer of the water works bonds of Newaygo.

John Nuveen & Co.

Municipal Bonds.

First National Bank Bldg.

CHICAGO.

We own and offer, subject to prior sale,

TAX EXEMPT IN MICHIGAN.

$17,000

Newaygo, Michigan

Water Works 5's.

Dated Sept. 1, 1912. Maturing as shown below.

Principal and semi-annual interest (March 1st and September 1st) payable at the Banking House of John Nuveen & Co., Chicago. Denomination $1,000.

Financial Statement.

Estimated true value of property --------------		$750,000
Assessed valuation for taxation (1912) --------		$488,310
Total bonded debt, this issue only ---	$17,000	
Less water debt ---------------------	$17,000	
Net bonded debt ----------------		Nothing.

Population, 1,207 (1910)

These bonds are issued by Newaygo for a water works system and are a direct obligation to the entire town.

NEWAYGO is located in Newaygo County, in the western part of the State, 30 miles north of Grand Rapids. It is on the Pere Marquette Railroad and the Muskegon River, which afford ample transportation and shipping facilities. The Muskegon River furnished excellent water power and the Grand Rapids - Muskegon Power Company which delivers power to Grand Rapids, Muskegon, and vicinity, has a power site with a develonement of 18,000 H.P., located a few miles east of Newaygo.

The surrounding country is good farming and fruit raising land, peaches, apples, grain, vegetables and berries being the principal crops grown there.

We furnish the opinion of John H. Hill, Esq., of Chicago, approving legality of the issue.

MATURITIES AND PRICES.

$1,000 due Sept. 1, 1914; 101.51

$1,000 due Sept. 1, 1915; 102.23

$1,000 due Sept. 1, 1916; 102.92

$1,000 due Sept. 1, 1917; 103.57

$1,000 due Sept. 1, 1918; 104.20

$1,000 due Sept. 1, 1919; 104.91

$1,000 due Sept. 1, 1920; 105.39

$1,000 due Sept. 1, 1921; 105.94

$1,000 due Sept. 1, 1922; 106.48

$1,000 due Sept. 1, 1923; 106.99

$1,000 due Sept. 1, 1924; 107.48

$1,000 due Sept. 1, 1925; 107.95

$1,000 due Sept. 1, 1926; 108.40

$1,000 due Sept. 1, 1927; 108.84

$1,000 due Sept. 1, 1928; 109.25

$1,000 due Sept. 1, 1929; 109.65

$1,000 due Sept. 1, 1930; 110.03

Accrued interest to be added. Average maturity 10 years.

Yielding 4.20 %.

* Acceptable as Security for U.S. Postal savings deposits.

The total net cost of the present system over ran the bond issue close to $2,000, being $18,740.57. The items which over ran were;- The laying of the mains which were underestimated by about $1,000, and the water wheel and power house which were underestimated about $500 each. Fernette and Bradfield of Grand Rapids made the original survey and cost estimate, and the installment was made by the Hydraulic Engineering Company of Grand Rapids. Some money will probably yet be realized from the old plant, which of course should be credited to the new.

Water Rates.

The water rates per month for the village of Newaygo are;- a flat rate of $0.45 for domestic purposes, with $0.25 additional for bath and $0.25 additional for lawn hydrant for sprinkling purposes.

RECOMMENDATIONS FOR EXTENSION AND IMPROVEMENTS.

Source.

The present springs and reservoirs will furnish the extra water needed in the proposed extension, with few changes and improvements. In fact we can assume that no changes in the present source will be necessary.

Pumping.

For all ordinary purposes the service pump now in use will fulfill the added requirements due to extension. It has a rated capacity of 144,000 gallons per day. With 30 new taps benefitting 150 more people, each using 130 gallons per day, the total consumption would be about 104,000 gallons. Of course it would be well to have a larger pump for emergencies but it is not at all likely that the town would agree to such installation. A better plan to be used would be to install meters. This has been done in a number of cities and always has the effect of cutting down the water consumption materially. In many cases this reduction has been one half or more. With this condition the present pump would be large enough.

Fire Protection.

At present the fire protection is not adequate. First we would suggest that all hydrants be put in good working order. This will mean new hydrants # 9, and # 14. It will mean, if safety is to be assured, that all hydrants be taken up and the stones removed from the bases. These stones in the pipe have caused trouble in both serious fires since the system was installed.

The present fire pump with 500 gallon capacity will pump water as fast as 4 inch mains will economically carry it and so we will not propose a larger one, although it is not really capable of supplying the three streams theoretically needed in a town of this size.

Extension of Mains.

We propose to eliminate the dead end on State Road which caused much trouble and was the main point of discussion in the recent $40,000 fire. This line is in one of the most important parts of the village and as much water is used, we deem it necessary that it be extended so as to form a grid-iron system. Our proposed extension, as shown on the map, will cross Brooks Creek in two places. At one of these no trestle will be needed as there is about 15 feet of earth over a concrete arch. The other point can be spanned by a wooden trestle about 40 feet long. The pipe will have to be encased to prevent freezing in winter.

This line will require about 4,500 feet of 4" pipe, 3 cut off valves, and 5 fire hydrants. From this extension about 30 residences can be supplied with water and added protection given to many on the present system.

This system is practicable since the highest point is 156.9 feet, which means a difference in elevation from the average head of water in the tower of 80 feet, which would

give a static head of 35'. This is more than at several points on the existing system. At the same time it will be on a gridiron system where fire protection is double that of a single pipe with a dead end.

We believe that the easiest and cheapest method to do away with warm water in the tank is to have the feed pipe entering at the top and the supply pipe to the distributing system leading from the bottom of the tank. In this arrangement a more complete circulation of the water will be accomplished.

Cost Estimate of Proposed Extension.

As a basis for the following estimates we used "Gillettes Cost Data". Below is given a table from Gillette showing an itemized cost of a 4" water pipe line, 2,846 feet long and 3.33 feet deep;-

Cost of Labor.

Labor, trenching -------	$0.070	per	foot.
Horses, trenching ------	.001	"	"
Labor, bell holes ------	.015	"	"
Labor, laying pipe -----	.010	"	"
Yarners ----------------	.005	"	"
Pouring lead -----------	.004	"	"
Calkers ----------------	.008	"	"
Labor, backfilling -----	.011	"	"
Horses, backfilling ----	.004	"	"
Distribution of material-	.005	"	"
Foreman ----------------	.017	"	"
Timekeeper -------------	.002	"	"

Miscellaneous ---------- .004 per foot.

Total ---------------- $0.156 per foot.

Cost of Materials.

Pipe, 2,820 feet, 30 tons @ $44.40 ---	$0.461	per	foot.
Specials, 4,482 # @ 3.25 ¢ -----------	.051	"	"
Valves, 9 @ $9.40 --------------------	.030	"	"
Hydrants, 5 @ $28.60 -----------------	.050	"	"
Lead, 2,010 # @ 5.3 ¢ ----------------	.038	"	"
Yarn, 105 # @ 5.4 ¢ ------------------	.002	"	"
Tools, -------------------------------	.015	"	"
Miscellaneous ------------------------	.006	"	"
Total --------------------------------	$0.653	per	foot.

From the above we make the following estimate for our proposed extension:

Pipe, 4,500 feet @ 46 ¢, ----------	$2,070.00
Specials, @ 5 ¢ per foot ---------	225.00
Valves, 3 @ $9.40 ---------------	28.20
Hydrants, 3 @ $28.60 -------------	85.80
Lead, @ 2.4 ¢ per foot -----------	108.00
Yarn, @ 0.2 ¢ per foot -----------	9.00
Miscellaneous, @ 0.6 ¢ per foot ---	27.00
Labor, @ 15.6 ¢ per foot ----------	702.00
Trestle @ $50.00 -----------------	50.00
Total ----------------------------	$3,305.00

CONCLUSIONS.

The gridiron system is best for a public water supply and if pipes are laid properly the most efficient results can be obtained. The best practice is to encircle a city with a large pipe then supply the different parts by feeders, leading from the main pipe. This is not possible in Newaygo because of the topography, part of the town being in a valley and the rest on separate hills. Because of this there are single pipes which result in four dead ends, there being now no chance to close on another pipe.

The ordinary city should have the large mains arranged so that smaller cross pipes can be fed from both ends. In this principle lies the big advantage of a gridiron system, since the cross main is equivalent to two pipes and can furnish double the number of fire streams with the same loss of head, or the same number of fire streams with one fourth the loss as when fed from one end only.

Another advantage of the circulating system is that any part of the system may be cut out for repairs and the rest of the city need not be affected. Dead ends are also objectionable on account of stagnation which exists in the pipes and the deterioration of water which is likely to ensue. The pipes will rust and so-called iron "tubercles" will form on the inside. Also owing to stagnation the water may acquire a distinct chalybeate taste and appear unsightly from flakes of iron rust. Dead ends should be flushed quite frequently to be kept in the best of condition. One dead end would be eliminated in our proposed extension.

From our investigation we can conclude that Newaygo has not a first class water system. Nor could one reasonably expect to find such in a small village. There is plenty of good water procurable and it is hoped that in time more people will be benefited by the system. We feel assured that conditions can be materially bettered at a moderate cost and it seems that the probable saving in fire damages alone would warrant such improvement.

This investigation is not as thorough nor the results so reliable as the best of practice would require for final results. Never-the-less, the statements made and conclusions drawn were written only after careful study of conditions as we found them. It is hoped that the points discussed will be of interest at least and possibly of some value to readers of this thesis.

Index to Blueprints and Drawings.

[redacted]

[redacted]