Thesis

Wm J. Roberts

Design for a Water Supply,

for the

Town of Walpole Mass.

Thesis. M. I. T. 1891.

William J. Roberts.

WATER SUPPLY.

"Civil Engineering is the art of directing the great sources of power in Nature, to the use and convenience of Man."

Water is one of the great sources of power in Nature, and to direct it to the use and convenience of Man is one of the duties of the Civil Engineer. It goes without saying that water is a necessity. It is as indispensable in the human economy, as the very air we breathe, and without it the fertile land becomes a desert waste. The question of an abundant supply of pure water for cities and towns is one of already great and increasing interest to the engineer. It awakens in his mind the vast possibilities that will surely follow its introduction to a community, hitherto but partially supplied.

To the aesthetic mind come visions of public fountains and pleasing landscapes, to the sanitarian, cleaner streets, cleaner people. The cold practical man weighs the cost and counts the advantages. The fact that a public water supply will save dollars to him, in insurance, manufacturing, or irrigation, is a stronger argument for its introduction than the knowledge that a hundred school-children obtain their drinking water from a polluted well.

The ruins of the great Roman aqueducts, built on such a magnificent scale, attest the early appreciation for this element of refinement and prosperity. The veneration bestowed by the Egyptians on the Nile, the fierce struggles of Assyrians and Persians, for the possession of isolated wells, the great hydraulic works, found by Cortez in Mexico, 400 years ago, all these show the early recognition of the great importance of an abundant water supply, in promoting civilization.

The question of the manner of obtaining water is settled for each locality by its environment.

Probably few parts of the world are so favored in regard to rain fall and topography as New England. With a rain-fall of from 25 to 60 inches a year, with a large number of natural storage reservoirs, in the shape of ponds and lakes, having neither sandy wastes where the percolation and evaporation equal the rain-fall, nor precipitous mountains from which the rain would all escape, in torrents,- the sources of supply are abundant; and it is the numerous possible sources that seem available, that renders so problematical the choice of the best. Nevertheless, in some parts of Massachusetts, the growing population and the increasing difficulty of disposing of sewage, is rapidly diminishing the available surface supplies. Thus given many possible sources of supply, there are three elements to be considered for each source,-viz:- quantity, quality, and cost.

First,-No system is justifiable for which the supply is not both abundant and permanent.

Second,-No system is acceptable for which the supply is not both pure,and free from the probability of future contamination.

Third,-No system is satisfactory that does not repay the investment. Cost might be placed before quantity and quality, for where the estimated cost of a system,exceeds the limits of the town purse, there is no further need to examine quantity and quality.

The object of this thesis has been to examine the possible sources of supply, for the town of Walpole, and to make a plan, and estimate the cost of introducing a supply into the center village. A plan of the town was traced from a map on file, in the office of the State Board of Health. Lines of levels were run and benches established, in all the streets of the center village; and from these were contoured the parts shown, on the accompanying plan. Levels were taken at all street intersections, and at all changes of grade, and from these the contours crossing the streets, were interpolated in the drawing-room; while between streets,they were sketched in in the field.

A familiarity with the topography of the town, was thus acquired, as could be done in no other way. The part of the town under consideration, has seven miles of streets, 260 dwellings, a half dozen thriving Manufactories, and is a growing place of 1500 inhabitants. A map of the town, showing three streams confluent at the center village, suggested that their sources would afford the supply sought. A reconnaissance of the town, and an examination of the three streams- Neponset River, Mill Brook, and Diamond Brook, yielded these facts:- Neponset Reservoir, the source of Neponset River, lies in Foxboro, drains four sq. miles, and has an area of 400 acres. Mill Brook, on the course of which lies Morey's Pond, drains 11 sq. miles, and the pond covers twenty-three acres.

Diamond Brook contributes to Clarke's Pond the drainage of two sq. miles, and the pond itself covers eight acres.

The areas of the ponds and reservoir were given by the owners, and the drainage areas were taken by planimeter, from the new State map. Before proceeding to eliminate from consideration, any one of these three possible sources of supply, from surface water, the quantity required must be decided upon.

QUANTITY.

How much water will a given population consume? The usual mode of estimating, is by the gallon per capita. A table compiled in 1877, gives the average consumption, of twenty-one American cities, sixty-five gallons, of twenty-one Foreign cities, twenty-five gallons.

The following table, compiled by Croes, in 1884, gives the average daily consumption of 178 American cities.

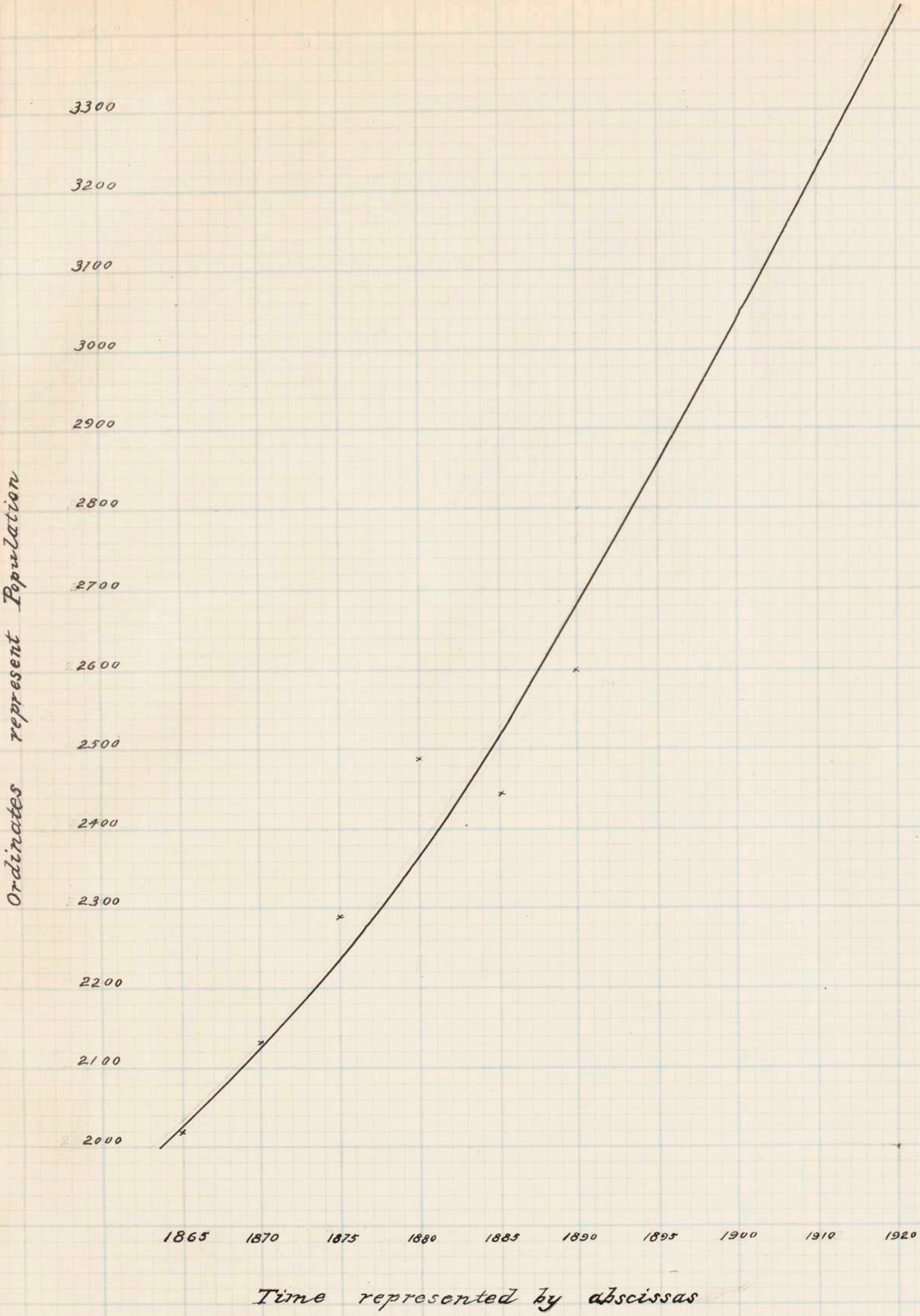
49	Cities,	Population,	10000-15000,	consume	76	gallons.
33	"	"	15000-20000,	"	69	"
17	"	"	20000-25000,	"	71	"
41	"	"	25000-50000,	"	86	"
11	"	"	50000-75000,	"	80	"
4	"	"	75000-100000,	"	95	"
15	"	"	100000-250000,	"	102	"
4	"	"	250000-500000,	"	89	"
4	"	"	500000 & over,	"	92	"

1886.

Chicago,			average	daily	consumption	118	gal.
St Louis,			"	"	"	70	"
New York,			"	"	" "	65	"
Boston,			"	"	"	79	"
Washington,			"	"	"	130	"
Seattle,.			"	"	"	53	"
Astoria,			"	"	"	50	"
Akron,			"	"	"	50	"
Taunton,	Pop.	20700,	"	"	"	37	"
Newton,	"	22000,	"	"	"	38	"
N.Bedford	"	34000,	"	"	"	105	"
Fitchburg,	"	16740,	"	"	"	78.	"

Our method of living leads to enormous waste. Eliminate all useless waste and abuse of privilege, and thirty gallons a day is shown by reference ample for all ordinary supply,(except for Manufacturing.)

Walpole's present population is 2600, and its estimated population, for 1910, is 3250. Should the introduction of water supply accelerate the growth of the town, say to 20 per cent,increase in


3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
Ordinates represent Population
1865
1870
1875
1880
1885
1890
1895
1900
1910
1920
Time represented by abscissas

ten years, the population in 1910, twenty years hence, would be 3600. Of the present population, about one half live in the center village, and this is the only portion of the town, considered in the present thesis.

Taking 2000 as the maximum number to be supplied, twenty years hence, and allowing fifty gallons to each person, we arrive at a quantity of 100000 gallons a day, as the average amount to be obtained throughout the year.

The most careful investigations of rain-fall, evaporation, and percolation, have shown that for Eastern Massachusetts, it is safe to assume that thirty inches of rain will fall in the dryest year, and that one-third of that amount is collectable.

Then the drainage area must be large enough, so that one-third of thirty inches, on that area will yield 100000 gallons a day, or 36500000 gallons a year.

$$A \times 43560 \times \frac{10}{12} = \frac{100000 \times 365}{7.5}$$

$$A = 134 \text{ acres}$$

From this it is seen that our drainage areas are ample in each case, and in the comparison of the three sources, quantity need not be considered.

QUALITY..

To determine the question of quality eleven samples of the Walpole waters were collected, and by the kindness of Mrs Ellen H. Richards, a complete chemical analysis of the same is presented herewith. Mr Gary N. Calkins also furnished a report of a biological examination, of one sample from Neponset Reservoir.

These reports are given complete in the appendix.

A study of these analyses shows the surface waters of Neponset Reservoir,- that from Morey's and Clarke's Ponds, and from the pond at South Walpole, quite suitable for drinking.

The chlorine in the three sources considered is about normal, as shown by the map recently published by the State Board of Health.

In hardness they do not differ appreciably. In color Neponset Reservoir and Clarke's Pond are .35 while Morey's Pond is 1.7 In color, Clarke's Pond and Neponset Reservoir agree quite nearly with Cochituate water.

The two sources Morey's Pond and Clarke's Pond, having so many features in common, it seems best to decide before going farther, which of the two is the more available. Situated about equally near the center of the town, and of nearly equal elevation, the cost of pumping from either would be the same.

The price set upon the water rights of Morey's Pond is $1500 a year. The price fixed by Mr Clarke for the entire ownership, of Clarke's Pond is $5000. equivalent to $300 a year; a saving of $1200 a year in favor of Clarke's Pond. Add to this the more favorable analysis of Clarke's Pond in color, and it seems best to omit Morey's Pond from further discussion.

A more careful comparison of Neponset Reservoir supply and that from Clarke's Pond, is necessary, on account of their widely different situations. Their close agreement in quality makes a choice depend entirely on the consideration of cost.

The elevation of Neponset Reservoir as given by the State map is 270 feet above mean sea level, and will afford a supply by gravity.

A supply by gravity is maintained with less trouble, care and cost, than a supply furnished by pumping. The law of gravitation works continuously and uniformly, without the labor or thought of Man. When we work against the law of gravitation, as in the case of pumping a water supply, the machinery performs its duty properly,only by constant care and unremitting,intelligent direction, and at continued cost,- two matters that can not be avoided, in the running of pumping machinery.

HEAD.

The head under which a supply can be used has two important bearings, one as affects its usefulness when taken directly from hydrants, as a protection against fire, and the other that which affects its usefulness, for domestic service.

That head which is sufficient for domestic service has only a limited value for fire service. A head of 90 to 100 feet equivalent to 40 to 45 pounds pressure per sq. in. is considered a good pressure, and on this basis this system is designed.

A difference in contours of 40 feet for different parts of the town will make this pressure vary between wide limits; but for the larger part of the town, which is situated below the 160 feet contour, and above the 140 foot contour, the pressure will be quite uniform. The elevation of Neponset Reservoir is 270 feet, the elevation at the intersection of Stone & Main Sts, in front of the Town Hall is 157 feet, giving a static head of 113 feet.

The distance is 20000 feet and there would be corresponding to this a loss due to friction represented by:-

$$\theta = .04 \frac{l}{d} \frac{v^2}{2g}$$

Taking 100000 gallons a day as the average consumption this [illegible] equals 70 gallons per minute. The maximum draught is taken at twice the average, or 140 gallons per minute.

Allowing for two fire streams 20 cubic feet each, or 300 gallons per minute gives a total maximum draught 440 gallons per minute.

$$\text{Then } Q = .978 \text{ c.f.p.s.} \qquad v = \frac{Q}{A} = \frac{.978}{.785} = 1.245$$

$$\theta = .04 \times \frac{20000}{1} \times \frac{1.245^2}{64.4} = 19.2 \text{ ft for 12" pipe.}$$

The velocity varies inversely as the area of cross section, hence inversely as the square of diameter; therefore the friction loss varies inversely as the cube of diameter, and the friction loss for a ten inch pipe would be $19.2 \times (\frac{6}{5})^3 = 33.2$ ft.

A loss of 19 feet leaves 113-19 equals 94 feet available head by using 12 inch pipe. Using therefore 10 inch pipe the head would be 113-33 equals 80 feet, corresponding to a pressure at Town Hall of only 35 pounds per sq. in.

The cost of 12 in. pipe as given by the City Engineer of Boston, is $1.85 per foot laid. For 20000 linear feet the cost is $37000.

The cost of gate-house, gates, screens, and other appurtenances, at entrance to Main is estimated at $2000.

The value of the water rights is a difficult matter to settle, and is a question on which hardly any two would agree; but from the following figures the estimated value is $36000.

Morey's Pond and water power, having a head of 12 feet (approx.) and a quantity equal to the drainage of 10 square miles is valued at $25000. $\frac{25000}{10 \times 12} =$ $200 per sq. mile per foot fall.

Clark's Pond $\frac{5000}{2 \times 10} =$ $250 " " " " "

On this basis the Manufacturing value of Neponset Reservoir can be fairly estimated. There are four developed water powers, between Neponset Reservoir and Walpole, having a total head of 40 feet.(approx.)4 sq.m x 40 ft.fall x $200-$250 is $32000-$40000. say $36000.

Neponset Reservoir Supply. (By Gravity.)

COST.

Water Right:--	$36000.
Gate House etc. -	2000.
20000 ft. 12 in. pipe---	37000.
	$75000.

Clarke's Pond. (Pumping.)

COST.

Water Right:--	$5000.
Boiler & Pumping Machinery:--	4500.
Engine House:--	2000.
Stand Pipe and Foundations:--	5000.
2 acres at $70. for Stand Pipe:--	140.
4725 ft. 10 in. pipe at $1.60 laid:-	7560.
Contingences.	800.
Total.---	$25000.

By each system the water is delivered at intersection of Stone and Main Streets.

Assuming that the cost of maintenance of the 20000 feet of 12in. pipe will equal the repairs on pumping machinery, and maintenance of 4700 feet of 10 in. pipe, we have a supply delivered by gravity from Neponset Reservoir for $75000. and a supply to be pumped from Clarke's Pond for $25000.

The cost of pumping 100000 gallons a day against a head of 100 feet will be $1000. a year, which capitalized at 5 per cent equals $20000. making the total cost delivered by pumping $45000. as against $75000. delivered by gravity,- a difference of $30000. in favor of a supply by pumping from Clarke's Pond.

STAND PIPE.

A suitable site for a stand pipe is found on the land belonging to Jos. Ellis, near the intersection of Common and Clapp Streets. The land is valued at $70. an acre, is distant 1200 feet from the proposed pumping station. Elevation of hill 224 feet.

On account of the deep railroad cut, across Common Street, it is proposed to carry the 10 in. main down Clapp St.to Stone St. and down Stone St. to Main St.

The following table gives the -

Streets.	Length.	Sizes.
Stand pipe to Stone St.	975	10
Stone	2700	10
Common,	2780	8
Main, west from Front,	3000	8
Spring,	2550	8
West to Spring,	1200	8
West from Spring to end,	1890	6
Lewis Ave.	450	6
Neponset,	450	6
Private way,	225	4
" "	450	4
South,	2450	6
Diamond,	1940	8
East, south of Diamond,	1090	6
Main, from Stone to Kendall,	2550	8
Main, from Kendall to Gillis,	2450	6
East, " Diamond to School,	500	8
" " School to Station,	900	6
School,	1500	8
Cross,	700	6
Morton,	675	6
Kendall,	400	4
Gillis,	800	6
North,	1050	6
Cemetery,	500	4
Station,	900	4
Lane,	640	4
Total-	35715	

Cost of Distribution.

16020 ft.	8 in. pipe	laid at	$1.30	equals	$20826.
12905 "	6 " "	" "	$1.00	"	$12905.
3565 "	4 " "	" "	$. 75	"	$ 2673.75
260 services 50 ft. each, using 1 in. wrought iron pipe cost laid, $.30				"	$ 2900.
260 fixtures			at $6.	"	$ 1560.
55 hydrants			at $40.	"	$ 2200.
24 gates,					
6	4 in. gates		" $19.	"	$ 114.
14	6 " "		" $30.	"	$ 420.
4	8 " "		" $45.	"	$ 180.
55 Branches for hydrants,			" $15.	"	$ 825.
					$44603.75

Total Cost.

Pumping service and 10 in. main,----	$25000.
Distributing service and fixtures,	$44600.
	$69600.

The citizens of Walpole may well congratulate themselves upon the natural advantages, for furnishing so large a proportion of the inhabitants of the town, with an abundant supply of pure water at a comparitively small outlay, compared with a majority of the cities and towns.

GROUND WATER.

Within recent years, water supplies from driven wells have met with popular favor, and an examination for a possible supply by this means, has not been omitted.

Owing , however to the limited time, the investigations of this phase of the question have not been carried to any extent. Furthermore, test wells would be required, before any reliable data could be obtained, as to quantity and quality.

The engineering features for ground water supply, and for the proposed surface water supply, would be quite similar; and the cost of pumping service and distribution would not differ greatly in either case.

That a ground water supply is obtainable, is well known, from the common wells, already supplying the town.

Expensive tests by boring, made by Mr H.D. Dupee, of the Chemical Dye Works, resulted in an abundant supply, 1500000 gallons a day, being obtained; but the quality is such as to make it desirable that additional test wells, be driven above the drainage from the town. The analysis of the water from these wells, 20 in number, shows chlorine much higher than the normal, and hardness too great for a desirable supply.

(See Herald Sept. 10, 1888, for account of wells.)

That the quality of the water now in use from many of the wells, is objectionable, may be seen by the analysis of sample no.7 taken from the Hotel pump. Its quality, or rather its impurity can better be appreciated by a comparison of the analysis of this water, with a common sample of sewage tested at the Lawrence Experiment Station.

	Residue on Evap.			Ammonia		Cl.	Nitrogen	
	Total	Loss on ignition	Fixed	Free	Alb.		Nitrates	Nitrites
Sewage. unfiltered.	48.94	19.11	29.83	1.8202	.5302	5.25	.0000	0000
Sewage filtered.	35.63	12.10	23.53	1.7710	2675	5.25	0000	0000
Difference- Suspended matter.	13.31	7.01	6.30	.0492	2627	0.00	0000	0000
Hotel Water.	35.70			.1026	.0082	4.78	1.8000	.0020

Let the citizens of Walpole awaken to their privileges and responsibilities, and insurer, manufacturer, landscape gardner, and sanitarian will alike welcome the introduction of this" great source of power in Nature, converted to the use and convenience of Man".

W.J. Roberts

Appendix.

References:- Value of steam power and plant to replace water power, (Trans. Am. Soc. Civil Engineers, Vol. Xll. Page 425.)

Driven Wells: -- (Herald, Sept. 10, 1888.)

Mr Langford Contracting Engineer, Room 40, Mason Building, (B). gives the following estimates,- cast iron pipe 12 in. diam. cost $29. per ton, excavating, laying, packing lead, cartage, back-filling to covered depth of 4 & 1-2 ft. at $.40 per linear ft.
For rock excavation, add $4. per cubic yard.
Loss on pipe in cutting 1-2 in. per ft.
Hydrants including two hose and one steamer nozzle, with frost case $40. without frost case $5. less.
12 in. gate, set, including gate box, $50. 50 ft. pipe to each service. 1 inch cement lined pipe, laid, $.28- $.30 per ft.

Fixtures:---	Corporation cock.	
	Lead connection.	at $6. each.
	Side walk stop.	
	Stop box.	
	Inside house fixture.	

8 Hydrants per mile.

References:--- Cunningham Iron Works, Estimate on Stand pipe;

Blake Manufacturing Co.	"	Pumping Machinery.
Chapman Valve Mfg. Co.	"	Gates & Hydrants.

References:-- Boston City Engineer, Laying Water pipe.

"Friction loss in clean pipes".--No. 10. City Doc. City Engineer's Report for 1888, Providence, R. I.

Report of State Board of Health, Mass. 1890. on Quality.

If the engine used has a "duty" of 60000000 ft. lbs. per 100 lbs. coal burned, it will require in lbs. of coal per year for pumping 100000 gallons a day: $\frac{100,000 \times 365 \times 8.33}{600,000} = 50000$ (approx)

25 tons @ \$5.00 = \$125.00

Cost of pumping.

Labor at \$60. per month,	\$720.
25 tons coal at \$5.	125.
Use of telephone; oil and sundries,	155.
	\$1000.

Commonwealth of Massachusetts.—State Board of Health.

MICROSCOPICAL EXAMINATION OF WATER.

SAMPLE FROM *Neponset Reservoir.* BIOLOGIST'S NUMBER,

DATE OF COLLECTION, AMOUNT EXAMINED, *1/5 250 cc.* CHEMIST'S NUMBER, *Sample # 2.*

DATE OF EXAMINATION, *4/28/91* DEPTH OF SAMPLE, TEMPERATURE,

Number of Square,	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total.	No. in 100 c.c.
DIATOMACEÆ,																						
Asterionella,																						300
Melosira,																						
Navicula,																						200
Stephanodiscus,																						
Synedra,																						33,200
Tabellaria,																						200
Arachnodiscus																						
CYANOPHYCEÆ																						
Anabæna,																						
Aphanocapsa,																						
Clathrocystis,																						700
Cœlosphærium,																						
Chroöcoccus,																						
Oscillaria																						200
ALGÆ,																						
Chlorococcus,																						800
Cosmarium,																						100
Pediastrum,																						100
Raphidium,																						1,300
Scenedesmus,																						
Staurastrum,																						100
Conferva																						4,800
Palmella																						8,400
Hyalotheca																						100
Pandorina (Disintegrated)																						500
Xanthidium																						100
Closterium																						100
Pandorina																						100
FUNGI,																						
Crenothrix,																						
Leptothrix,																						
Saccharomyces,																						
Zooglœa,																						24,400
Animals ↑ **RHIZOPODA,**																						
Arcella,																						
Difflugia,																						100
Actinophrys																						200
INFUSORIA,																						
~~Ceratium,~~ *Stentor*																						100
~~Dinobryon,~~ *Tintinnidium*																						100
Peridinium,																						200
Trachelomonas,																						200
Euglena																						1200
Encysted Protozoan																						800
VERMES,																						~~100~~
Anurea,																						100
Polyarthra,																						100
Rotatorian Ova																						100
Worm																						100
Rotifer																						200
Synchaeta																						100
CRUSTACEA,																						
Cyclops,																						2
Daphnia,																						
Bosmina																						2
Diaptomus																						2
TOTALS,																						81,900

(Notes. In "amount examined" 1/5 250 cc means that 250 cc. of the original sample were filtered. The sand and organisms were washed into a test tube with 5 cc of distilled water and of this 1 cc was examined; making the organisms examined equal to the number in 50 cc of original sample.

"Pandorina (Disintegrated)" shows decay in the Algae. "Zoogloea" is the name of one stage in the life history of bacteria - it is a jelly-like mass. The numbers represent so many units; a unit is .0020 sq. mm.)

Gary N. Calkins

NOTES.

Amorphous Matter, *~~Zooglœa~~, Many colonies of Synura (an infusorian) in bottle when sample first came in. Apparently went to pieces on filtration.*

WATER ANALYSIS.

Walpole Waters. (Parts in 100,000.) W. J. Roberts. Course I

NO.	DATE OF Collection.	DATE OF Examination.	APPEARANCE. Turbidity.	APPEARANCE. Sediment.	APPEARANCE. Color.	ODOR. Cold.	ODOR. Hot.	RESIDUE ON EVAPORATION. Total.	RESIDUE ON EVAPORATION. Loss on Ignition.	RESIDUE ON EVAPORATION. Fixed.	RESIDUE ON EVAPORATION. Change on Ignition.	AMMONIA. Free.	AMMONIA. Albuminoid.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Hardness.			REMARKS.
	1891																			
1	april 20	22	Slight	considerable	0.4	v. faint or none	faintly vegetable	2.60	1.15	1.45		0000	.0220 .0154	.18	0070	0000	0.2			Synura Colonies Uroglena Volvox } present
2	"	"	slight	considerable	0.35	v. faint or none	Distinctly vegetable	1.85	1.05	0.80		0000	.0174 .0104	.22	0050	0000	0.35			
3	"	"	Slight	slight	0.35	—	—	—	—	—		—	—	.22	0050	0000	0.35			
4	23	25	none	none	0	—	—	—	—	—		—	—	1.8	.0800	0000	5.5			
5	23	26	none	none	0	none	none	13.00	—	—		.0014	.0014	1.6	.0800	0000	5.3			
6	23	25	Slight milky	slight Rusty	.1	Distinctly mouldy	distinctly mouldy	35.70	—	—		.1026	.0082	4.98	1.8000	.0020	12.5			
7	23	25	slight	slight	1.7	—	—	—	—	—		—	—	.22	—	0000	—			
8	"	"	none	none	0	—	—	—	—	—	—	—	—	.64	—	0001	3.1			
9	"	"	Slight	slight	.65	—	—	—	—	—		—	—	.23	—	0000	0.4			
10	bottle broken					—	—	—	—	—	—	—	—	—	—	—	—			
11	23	30	Decided floating threads	Heavy	.35	faintly vegetable	v. faint or none	3.00	1.80	1.20		0000	.0192 .0072	.25	0030	0000	0.5			Spirogyra

No 1 Neponset Reservoir 500 ft from mill - from culvert under O. C. R. R.

No 2 Neponset Reservoir - just at Entrance to outlet at Gate House

No 3 1 1/2 mile below outlet.

No 4 Tap in Station at Walpole

No 5 Faucet - Chemical works

No 6. Pump in Hotel Kitchen. Driven well 38 ft deep.

No 7 Mill Brook just above Confluence with the Neponset

No 8 School House Pump.

No 9 Clarks Pond

No 10 —

No 11 Clarks Pond -

Abstract

A Design for a System of Water Supply for the Town of Walpole.

The question of Water Supply for cities and towns is one of growing interest to engineers.
The object of this thesis was to investigate the possible sources of supply, especially from surface waters for the town of Walpole, Mass., - to make a topographical map of the part of the town under consideration and to estimate the cost of introducing a supply therein. Familiarity with the features of the place was acquired while running the necessary lines of levels and sketching in the contours. Shallow wells, many of which are badly contaminated, furnish at the present time,

the drinking water for the 1500 inhabitants. There are three things to consider in comparing the merits of the different sources, viz: quantity, quality and cost.

1st No system is acceptable that is not both abundant and permanent.

2nd. No system is justifiable that is not both pure and free from the probability of future contamination

3d No system will be satisfactory that does not repay the investment.

Cost might be placed before quantity and quality; for when the cost will exceed the limits of the town purse there is no need to further examine quantity and quality

By comparing the amount used by other towns of equal size with Walpole it was decided that fifty gallons a day to each inhabitant was a liberal allowance.
As the design of the system is intended to cover the growth of the town for twenty years, when the probable number to be supplied will be 2000 an average of 100000 gallons a day is the quantity sought.
A map of the town showing three streams confluent at the centre village suggested that their sources would afford that supply
From the new state map the drainage areas of these three sources was determined by planimeter and found ample in each case to afford the supply sought.

Neponset Reservoir claimed first attention as the only source available for supply by gravitation. A supply from Clarke's or Morey's Pond would have to be pumped against a head of 100 ft. to give an equal pressure. The law of gravitation works constantly and uniformly without the thought or labor of man, ~~and~~ while pumping machinery must have unremitting care and attention.

It is then a question of first cost for the gravity supply compared with first cost, plus expense of pumping for the pumping system. The value of the water power now derived from the three sources is a large and uncertain factor in the estimation of cost. Omitting details,

the total cost of the gravity system from Neponset Reservoir is estimated at $75 000.
For a supply pumped from Morey's Pond $65 000
For a supply pumped from Black's Pond $45 000
The distribution service would be the same in each case and will cost $24 000 completed for use.
Mrs. Richards kindly analyzed eleven samples of the Walpole waters, and found the waters of the three sources to compare favorably with the drinking waters of the other towns in the state.
The samples from some of the wells in daily use showed serious pollution and in one case the sample from the hotel pump

had all the properties of
Lawrence Sewage.

Ground water from deep wells driven in an area free from sewage contamination is becoming a popular method of obtaining a pure supply. A lack of test wells excludes this phase of the question from discussion in this paper.

Few towns in New England are favored with such abundant supplies of pure water and so accessible as Walpole.

Let the citizens of Walpole awaken to their privileges and responsibilities, then insurer, manufacturer, landscape gardener and sanitarian will alike welcome the introduction of this "great source of power in nature

converted to the use and conven-
ience of Man".