DESIGN OF A WATER SOFTENING PLANT FOR MERIDIAN TOWNSHIP

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Carl N. Danielson

1950

This is to certify that the

thesis entitled

DESIGN OF A WATER SOFTENING PLANT

FOR MERIDIAN TOWNSHIP

presented by

CARL NICHOLAS DANIELSON

has been accepted towards fulfillment
of the requirements for

M.S. degree in SANITARY ENGINEERING

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Major professor

Date SEPTEMBER 28, 1950

O-169

DESIGN OF A WATER SOFTENING PLANT

FOR

MERIDIAN TOWNSHIP

By

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A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN SANITARY ENGINEERING

Department of Civil and Sanitary Engineering

1950

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Historical

It may well be said that there is no more vital substance to living processes and life itself than water. The only other material to which such a statement may be credited is air; and air, as such, is not necessary to the existence of many lower orders of life bodies. Air is universally abundant on earth, and its acquisition by higher animals involves merely the involuntary act os breathing. Water, on the other hand, while most abundant, is not universally so, and great efforts have been required in its collection and utilization. Consequently, the history of man's search for, and methods of acquiring water is the history of man himself. Some of man's ancient works are yet standing as mute testimony to the driving power of his thirst for water, and to his delight in a copious supply. To the fortunates of this country, thirst is merely the incentive which causes them to move to the water faucet and draw out a clear sparkling glass. Thirst in ancient times, however, was a very real and serious thing, and is yet so on some parts of the globe. It is said that desert travelers in Africa have at times been obliged to kill their camels for the water in the stomach of the animal.

References to great thirst are made in the Bible in the Psalms of the Hebrew poets, whose spiritual language is colored by having experienced thirst.

For example, "My soul thirsteth for thee, my flesh longeth for thee in a dry and thirsty land, where no water is". (Psalm 63:1) And again, in a joyous vein, "He clave the rocks in the wilderness, and gave them drink as out of the great depths. He brought streams also out of the rock, and caused waters to run down like rivers". (Psalms 78:15-16) Finally, in the forty-second Psalm we read, "As the hart panteth after the water brooks, so panteth my soul after thee, O God. My soul thirsteth for God, for the living God". Such works could have been written only by men who had experienced serious thirst.

Man's first method of obtaining water to drink was undoubtedly to fall on his knees and drink from the river or pool, or else by scooping it up in the palm of his hand. Gideon made the selection of his elite warriors for the attack upon the Midianites from the method by which they drank. Gideon selected three hundred men out of ten thousand as follows: "Every one that lappeth of the water with his tongue, as a dog lappeth, him thou shalt set by himself; likewise every one that boweth down upon his knees to drink. And the number of them that lapped, putting their hand to their mouth, were three hundred men; but all the rest of the people bowed down upon their knees to drink water". (Judges 7:5-6)

After the natural sources of rivers and pools, man turned to wells for his source of water. Probably the earliest written record of a well is in Genesis 21:30 where Abraham said to Abimelech in a dispute over a well, "These seven ewe lambs shalt thou take of my hand, that they may be a witness unto me, that I have digged this well". Two famous wells of the East are worthy of mention here. One is the Zemzem well at Mecca which is regarded by the Mohammedans as being holy because it is believed to have sustained Ishmael, son of Hagar, and progenitor of the Arabs. This is the well which Hagar is supposed to have found when she was cast out of the house of Abraham by Sarah. The other famous well is the one at which Jesus talked with the woman of Samaria. This well is 105 feet deep, nine feet in diameter, and is hewn out of solid rock. It is one of the earliest known wells, being owned by Jacob some 3500 years ago.

No description of ancient wells is complete without mention of Joseph's well[5] at Cairo, Egypt. This remarkable well is supposed to have been constructed eight hundred or more years ago. The well has a total depth of 297 feet, the upper portion being 165 feet deep and 24 by 18 feet in cross-section, and the lower portion 132 feet deep and 15 by 9 feet in cross-section. The two shafts are not in the same vertical line. The well is cut in solid rock and the upper portion is surrounded by a winding staircase. Water was drawn from the lower shaft by a chain of pots powered by horses or oxen, and dumped into a reservoir at the base of the upper shaft. The water was then elevated to the surface by another chain of pots operated in the upper shaft. The well is of course no longer in use. Chains of pots identical to those described above are yet in use in some parts of Egypt, particularly for conveying water for irrigation purposes.

The Chinese are credited, among other things, with having dug the deepest wells. It is said that the Chinese had a well 1500 feet deep by the beginning of the Christian era.

When considering ancient waterworks, one will often think first of the great aqueducts constructed by the Romans, along with the celebrated Roman baths. The baths of Diocletian have been estimated as being capable of holding 18,000 people at one time. The Roman baths at Bath, England are in a very good state of preservation. Natural hot water still flows through the pool. These bathing establishments must have been magnificient in their luxury. Seneca,[3] the Roman philosopher says of the baths of his day:

> We think ourselves poor and miserable if we do not trample under foot mosaics and precious marbles; the marbles of Numidia are united with

> the stones of Thasus; the light is reflected from crystal, the water flows into the baths by taps of silver, and this is only for the people: what if I were to describe the baths of our freedmen, the crowds of statues, the multitudes of columns supporting nothing, only placed there for decoration, and on account of their dearness? With what noise does the water precipitate itself upon the places destined to receive it. Our luxury has arrived at such a point that we no longer walk on anything but precious stones.

And Seneca uttered these words over a hundred years before the baths reached the height of their glory.

The first of the Roman aqueducts (Aqua Appia) was begun in 312 B.C. by Appius Cladius. This first aqueduct brought water to the poorer sections of Rome where there were no springs. Following this first aqueduct, ten others were built in the following 508 years. Of these eleven, four are still in use through rebuilding. A number of the old aqueducts were carried on arches, and their ruins still stand today. The most impressive of these is the ruins which carried the aqueducts Claudia and Anio Novus.

Sextus Frontinius was water commissioner of Rome around 97 A. D., and it is from his writings that much of the information about the Roman waterworks is obtained. The writings of Frontinius were translated by Clemens Herschel.[4] Frontinius had some of the troubles of the modern waterworks man, notably the existence of unauthorised connections to the water mains. An estimate made by Herschel placed the amount of water supplied to Rome by the aqueducts at 38 gallons per capita per day. The water supplied by the various aqueducts was of course not all of the same quality. Most of it was hard. The Roman's test of a good water, besides its taste and odor, was to observe the health of those people who had been drinking it for a considerable period of time; a commendable procedure.

Some sanitary precautions were known. Vitruvius knew of the dangers of poisoning from the lead pipes which were in use. Sedimentation was recognized as a practical procedure, and was carried out. In addition to settling basins in the hills, enlarged portions in the aqueducts, called piscinas, served as grit chambers. Roman laws concerning pollution of the water were stringent.

The Romans were not the first in water purification by any means. Reference is made in the Bible to Elisha's purification of water with a coagulant (salt) in II Kings 2;19-22. The Chinese put alum in tubs of water to clarify it. Mention is also made in early Sanskrit writings (about 2000 B.C.) on boiling foul water and filtering it through charcoal.

From the day of the Romans till the beginning of the nineteenth century, very little progress was made in the treatment or distribution of water. In fact, regression took place as evidenced by the plagues and epidemics which took place in Europe in the middle ages. Polluted water was undoubtedly the cause of many of these epidemics. The delight in cleanliness and sanitary practices evidenced by the Romans was replaced by a complete disregard for the laws of nature by the Europeans. In the great cholera outbreak in London of 1848-1849 which killed 14,600 people, the Edinburgh Presbytery appealed to Lord Palmerston to proclaim a national fast day in the hopes of preventing further epidemics. Lord Palmerston refused the request and pointed out that further epidemics would surely occur despite prayers and fastings unless sanitary practices were to prevail.

The first principal waterworks constructed in London were the work of the Duchman, Peter Morice, in the year 1582. Morice constructed a pumping engine under the first arch of London Bridge, and later installed a second engine under the second arch. These engines operated on the flow of the tide using three water wheels with sixteen pumps to each wheel. The design was a sound one for the plant, with due replacement and repair, continued in service until 1822 when it was sold to the New River Water Company. The New River Water Company was founded in 1609 and incorporated in 1619. It brought water to London from the springs of Chadwell and Amwell in an open channel. This channel was thirty-eight miles in length, and was about eighteen feet wide and five feet deep. The work was the product of Hugh Myddleton, a Welshman, who was later knighted for his efforts.

The third supply to the city of London worthy of note was that of the Chelsea Water Company, founded in 1724. Like the London Bridge Water Works Company, the source of supply was the river Thames. By 1827, the high turbidity of this water became a source of complaint because of the difficulty experienced in matters of cleanliness. The sanitary aspect of turbid water was not even given consideration. In fact, it was believed the turbid water had no injurious effect whatsoever upon the health. The first filter built to combat the turbidity of the water consisted of a six foot layer of sand and gravel, and was believed to serve only the purpose of straining the sediment out of the water. It required another forty or fifty years for the bacterial action of a filter bed to be understood. Nevertheless, the good results obtained by filtration led to the legislation in 1855 which compelled filtration of all river water used in London.

Among the first waterworks in America was that constructed by Hans Christopher Christiansen at Bethlehem, Pennsylvania in 1754.[2] The first machinery was a pump of Lignum-vitae which was replaced eight years later by three iron pumps. A water works for Philadelphia was agitated by Benjamin Franklin in 17[illegible]9, but was not constructed until 17[illegible], after the major epidemics of yellow fever and dysentery of 179[illegible]. Steam pumps were first used, but proved ineffective. Water wheel powered pumps were installed in 18[illegible]. Cast iron mains placed at Philadelphia were of the earliest to be employed in the United States.

At the beginning of the nineteenth century there were but 17 waterworks in the whole United States. By 1825 this number had doubled, and reached 100 by 1850. At 1875 an exact count placed the number of waterworks at 24[illegible]. A rapid growth then commenced. By 1945 there were about 90[illegible] waterworks in the United States and possessions. Of these, [illegible]4 were filter plants and could provide 5000 mgd of water; while by 1940, 5770 treatment plants were producing over 7000 mgd. The population served by softening plants in 1934 was 2 million and in 1941 this figure had reached 11 1/2 million.

Historically, water softening began with the Thomas Clark patent of 1841. Clark patented the lime process for the removal of carbonate hardness from water. Shortly after Clark's work, Porter developed the use of soda ash in removing the noncarbonate hardness. Early Clark-Porter difficulty was the encrustation of water mains with normal carbonates, a problem subsequently solved by the use of recarbonation with carbon dioxide. The commercial use of zeolite for softening water was developed in 1906 by Robert Gans, a German chemist. These exchange minerals were first introduced in this country in 1914. A summary of water softening installations in the United States for 1940 is given below.[6]

Zeolite, household	500,000
Zeolite, industrial	35,000
Zeolite, municipal	170
Chemical precipitation, industrial	3,000
Chemical precipitation, municipal	564

By 1947, the number of residential zeolite softeners owned and operated by the customer had reached well over 400000 units. In addition to this, the approximate number of soft water units rented to the customer by soft water service companies was 270,000.[21] It is expected that today these figures would be even higher, since the soft water service companies have experienced a phenomenal growth since the late war. To be noted is the universal desire of the citizen for a soft water supply once he has become acquainted with the advantages which accrue. Unfortunately, the employment of the rental soft water units is the most expensive manner in which to soften water, with the exception of using soap. Municipal softening of the entire supply is decidedly the cheaper procedure.

Pre-Design Considerations

Prior to entering into the actual design of the water softening plant, it was considered advisable to investigate such items as the reasons for constructing such a plant and also the type of plant to be employed. It was felt that extensive research was required in order to determine not only what is present practice in the water treatment field, but also what has been the practice in times past. Investigation of possible future developments was also considered advisable.

Since the basic raw material is water, it was felt that some of the properties of this substance should be considered. Water is present in immense quantities on earth and it is little wonder that the ancients considered it to be one of the so-called four elements; fire, air, water, and earth. Life as we know it cannot be sustained without water, and the existence of life on the other planets of our solar system is considered doubtful due to their lack of this vital substance. Water as a compound has the formula of H_2O, being composed of two atoms of hydrogen and one atom of oxygen. This is probably the most widely known of chemical formulas. Water has a formula weight of 18.016. It is a highly polar compound, and possesses an affinity for a great number of materials. The dipole moment of water is 1.84×10^{-18} electrostatic units. The molecular form is triangular. The high dipole moment of the water molecule accounts for the great affinity which water possesses towards a wide variety of materials. If water does not react chemically with a substance, it may be bound to the material by virtue of its dipole. Ions in solution are usually hydrated and will drag several molecules along with them when moving under the influence of an electric charge. The existence of the heavy isotopes of hydrogen, deuterium and tritium, is for the present of interest only in respect to the manufacture of the H-Bomb. The effect upon man of the presence of these materials in his drinking water is unknown. Deuterium exists in normal hydrogen to the extent of one part in 5000, while tritium is slightly less plentiful.

Water possesses an amazing solubility towards a wide variety of materials. It is considered to be a universal solvent. Natural waters employed for public use hold a number of minerals in solution, principal of which are calcium and magnesium salts. The above two materials are the source of the universal housewifely complaint of "that hard water". Considerable work has been performed on the solubility of metallic carbonates. The application of thermodynamic principles to this problem has been developed by Kelly and Anderson. When a metallic carbonate dissolves in water, fourteen possible reactions may take place, and all fourteen must be in equilibrium at saturation conditions such as those encountered in the lime-soda softening of water.

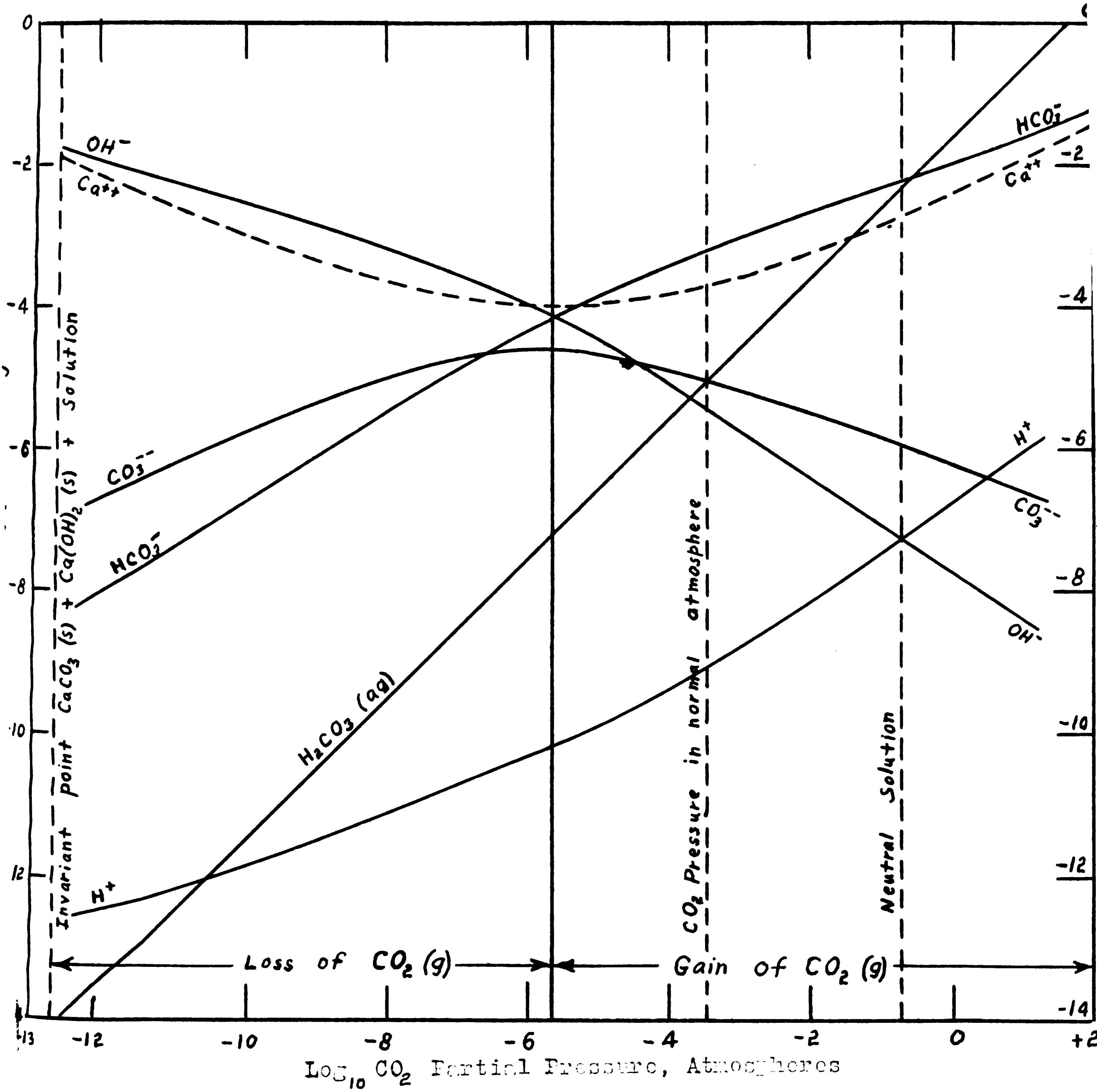
Reactions in the dissolution of a metallic carbonate: 16

$$MeCO_3\,(s) = MeCO_3\,(aq)$$
$$MeCO_3\,(aq) = Me^{++} + CO_3^{--}$$
$$MeCO_3\,(s) + H_2O = Me^{++} + OH^- + HCO_3^-$$
$$MeCO_3\,(s) + H_2CO_3\,(aq) = Me^{++} + 2\,HCO_3^{--}$$
$$MeCO_3\,(s) + 2\,H_2O = Me(OH)_2\,(s) + H_2CO_3\,(aq)$$
$$Me(OH)_2\,(s) = Me(OH)_2\,(aq)$$
$$Me(OH)_2\,(aq) = Me^{++} + 2\,(OH)^-$$
$$H_2O = H^+ + OH^-$$
$$H_2CO_3\,(aq) = H^+ + HCO_3^-$$
$$H_2CO_3\,(aq) = H_2O + CO_2$$
$$HCO_3^- + H_2O = OH^- + H_2CO_3\,(aq)$$
$$HCO_3^- = H^+ + CO_3^{--}$$
$$Me(HCO_3)_2\,(s) = Me(HCO_3)_2\,(aq)$$
$$Me(HCO_3)_2\,(aq) = Me^{++} + 2\,(HCO_3)^-$$
$$MeCO_3\,(s) + H_2CO_3\,(aq) = Me(HCO_3)_2\,(s)$$

Solution of problems on solubility of metallic carbonates involves the use of the thermodynamic functions; heat of formation, free energy, entropy, and the equilibrium constant. In the case of calcium carbonate, the above fourteen equations may be reduced to five plus the equation of electrical neutrality. With the additional data of the CO_2 partial pressure, the concentrations of the various ions in solution may be obtained by simultaneous solution of the five equations of the equilibrium constants. Repetition of such calculations at various CO_2 partial pressures results in the accompanying graph on the solubility of $CaCO_3$ in water. It should be noted that the concentration of the

Composition of $CaCO_3$ solution versus
Equilibrium partial pressure of CO_2

Solubility of $CaCO_3$ in Water



Equations which are basis of graph:

(a) $CaCO_3\,(s) = Ca^{++} + CO_3^{--}$

(b) $H_2O\,(l) = H^+ + OH^-$

(c) $H_2CO_3\,(aq) = H^+ + HCO_3^-$

(d) $H_2CO_3\,(aq) = H_2O + CO_2\,(g)$

(e) $HCO_3^- = H^+ + CO_3^{--}$

(f) $2\,Ca^{++} + H^+ = 2\,CO_3^{--} + HCO_3^- + OH^-$

calcium ion passes through a minimum and is increased by either increasing or decreasing the CO_2 pressure from this point. With increasing CO_2 pressure, CO_2 is absorbed by the solution, but with decreasing CO_2 pressure, CO_2 is evolved and the concentration of the OH^- ion increases until solid $Ca(OH)_2$ is formed. The appearance of the added phase results in an invariant point at which the composition of the solution and the partial pressure of the CO_2 are fixed as long as both solid phases are present.

Experimental work has been performed by Green[25] of the National Aluminate Corporation along similar lines. Green, however, eliminates several variables by working with solutions below saturation, and precluding the possibility of precipitation of OH^-, CO_3^{--}, or the loss of CO_2 or H_2O. Green investigated the variation of pH with temperature at various total alkalinities. His work was concerned with the changes which took place in the finished water, particularly that water to be used in boiler installations.

In the design of a water treatment plant, the first question to be answered is how much water will be required. Population studies are the first basis of this determination followed by the type or class of customer. Population figures for Meridian township are listed below and plotted in the accompanying graph.

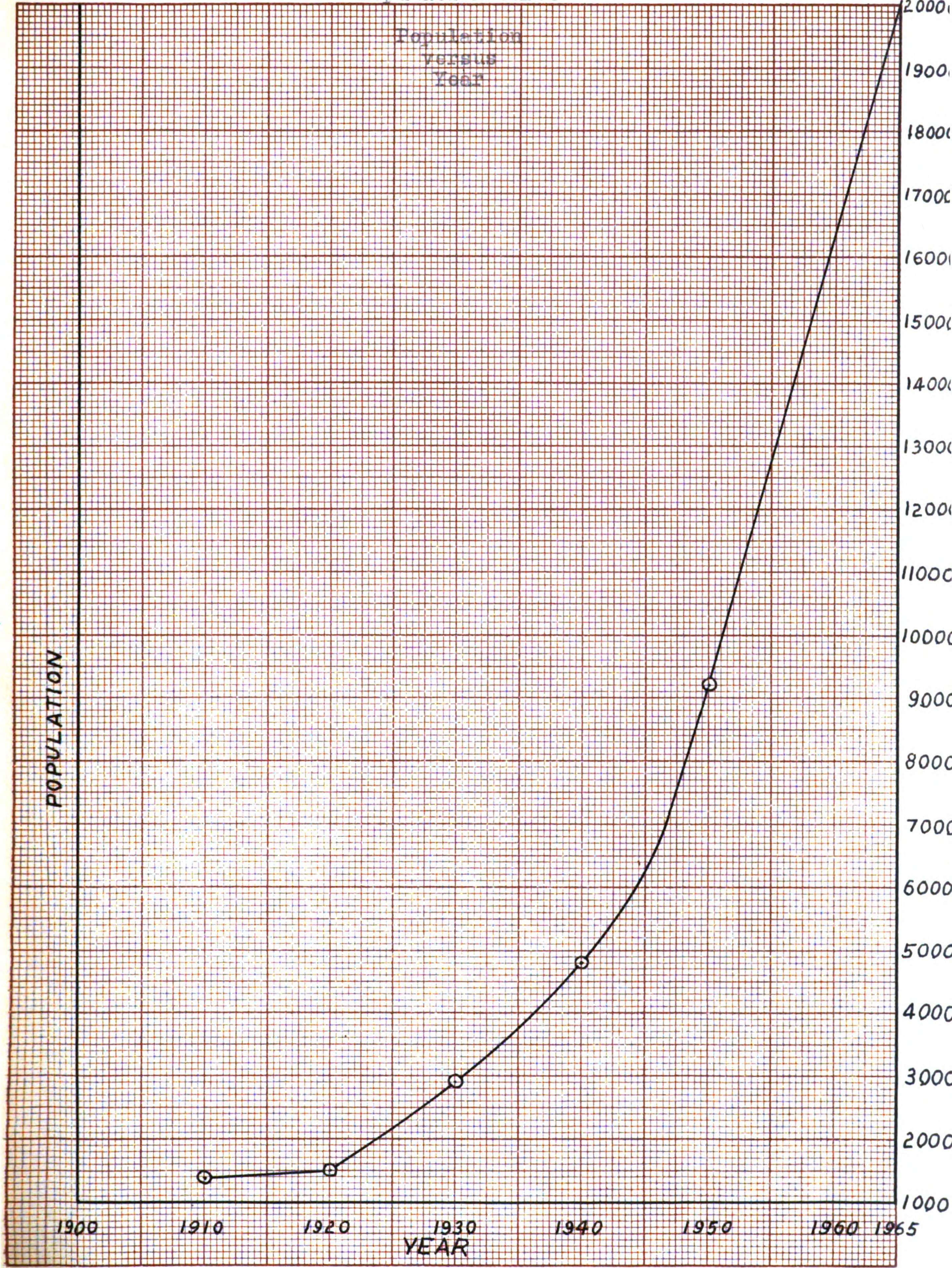
Population figures for Meridian Township

Year	Population
1910	1392
1920	1513
1930	2378
1940	4767
1950	9115

The amazing growth of the township in the past ten years should be noted. At the present time construction of new dwelling units is at a very high peak with one home being completed each day. It is expected that within a few years the township will be required to incorporate on a municipal basis.

There are four methods of predicting future population trends.[15] The Arithmetical Method consists of adding to the existing population the same number of people for each future period. The extended population curve is then a straight line. The annual increase is taken from the previous yearly growth. This method is applicable to old cities of limited growth. The Uniform Percentage Rate of Growth method assumes a city will grow at a rate corresponding to a uniform percentage of the population of the previous period. The extended population curve then becomes a compound interest curve. This method is not very accurate with young cities which are expanding rapidly. Results are apt to be high. The Decreased Rate of Growth method is applicable to old cities which tend to increase at a lower rate than in earlier periods.

Meridian Township
Population Curve



This method requires comparison with other cities which were of comparable size and character at some previous period. The method is difficult to apply since cities show such a wide variation in their growth characteristics. The last method is the Curvilinear Rate of Growth method. This assumes an extension of the population curve consistent with the curve of the known portions. With this method also, comparison may be made with existing cities which had similar characteristics at some previous period. The Curvilinear Rate of Growth method will be used for Meridian township as indicated on the graph.

It is presumed that actual construction of a water treatment plant for Meridian Township would not be commenced for at least five years due to existing financial obligations of the township. Further, it is assumed that such construction would be designed to care for population increases for an additional ten years. This assumes the predicted population at 1965 to be the basis for design. This population figure is 20,000.

Water usage is divided into two general classifications, Domestic, and Commercial and Industrial. Domestic usage varies with the living conditions of the consumer, but will average from [illegible] to 30 gallons per capita per day. Commercial and Industrial usage is that water supplied to manufacturers and to commercial establishments such as laundries and night clubs. In addition to the above classifications of customers, a certain amount of water is required by the municipality for public use. Such water would be used in municipal buildings and for fire protection and sprinkling and flushing of the streets. A certain amount of water is also classified as unaccounted for water. This water is lost through leakage, unauthorized connections, and meter and pump slippage. Unauthorized connections may be a major item in those cities where separate fire protection mains are provided. Industrial users are prone to draw on their fire protection mains for other purposes. Unaccounted for water will amount to about twenty percent of the water pumped to the distribution system.

Steel states that an annual average total daily consumption for a large group of cities located in twenty-nine states averaged 119 gallons per capita per day, with ranges from 60 to 300 gallons per capita. For Meridian Township an average per capita consumption of 100 gallons per day will be used as the basis for design.

The capacity design basis is then 8,000,000 gallons per day.

The quality of the water to be treated must next be taken into consideration. Natural waters vary widely in their characteristics, and are roughly grouped into two general classifications, Ground Water and Surface Water. Surface waters are those collected in natural reservoirs such as lakes or streams, or are collected in impounding reservoirs by the use of dams. The quality of surface water depends upon the earth formation over which the water flows on its way to the collection point. Surface waters will contain considerable matter in suspension, much of it organic. This is true even of such seemingly clear waters as those in the great lakes. By the same token, surface waters may be expected to contain considerable microscopic and macroscopic life, and will require treatment to remove or destroy such life bodies. Surface waters will also contain materials in solution and may be quite hard, that is, contain considerable amounts of calcium and magnesium salts in solution.

Ground waters are generally of low turbidity and high purity with regard to life bodies. Their source is beds of gravel or sand which in past geological ages were laid down by seas, old lakes and river beds, or by glaciers. Such water bearing strata of sand or gravel are known as aquifers. Ground water may also exist in underground free flowing streams. Such streams are limited to limestone areas.

Ground water is collected in some cases by filtration galleries or by dug or driven wells. The usually high purity of well water is generally considered to be one of the major advantages of this source of supply. However, well water may easily be contaminated by life organisms by percolation of such polluting materials from the ground surface through faults or fissures in the soil. This is particularly possible in limestone areas. Contamination by soluble toxic materials is also possible. Ponding of cyanide wastes by industrial concerns is a highly reprehensible practice since tests have been made which indicate cyanide in solution may travel as high as five miles through the ground strata. Cases of such pollution of public supplies are on record.

A particular disadvantage of deep well waters is their almost universal hardness, especially in the midwestern areas of the United States. The substances in solution with ground water of course depend upon the nature of the water bearing strata from which the water is drawn. Indicative of these materials which may be in solution in a ground water is the following standard analysis form employed by a nationally known laboratory which specializes in water analysis. It should be pointed out that while these minerals are troublesome for a number of reasons, their amounts are small in relation to the whole part. It is known then that the salts in solution in ground water exist almost entirely in the ionic form.

The Black Laboratories, Inc.

Water Analysis:

Identification and Description:

Laboratory Number____, Raw water--City of K
Sample 1-[illegible]-47, [illegible], clear.

Chemical Analysis:

Laboratory Number........................	____	
pH Value.................................	____	

Titrations, ml.

A Reading................................	____	
B Reading................................	____	
M.O. Reading.............................	____	
Soap Hardness............................	____	

Concentrations:	ppm	epm
Hydroxide (OH)...........................	____	____
Carbonate (CO_3).......................	____	____
Bicarbonate (HCO_3)....................	____	____
Sulfate (SO_4).........................	____	____
Chloride (Cl)............................	____	____
Silica (SiO_2).........................	____	____
Nitrate (NO_3).........................	____	____
Fluoride (F).............................	____	____
Iron (Fe)................................	____	____
Aluminum (Al)............................	____	____
Calcium (Ca).............................	____	____
Magnesium (Mg)...........................	____	____
Sodium (Na)..............................	____	____
Soap Hardness............................	____	____
Suspended Solids.........................	____	
Dissolved Solids.........................	____	
Organic, Ether extraction................	____	
Phosphates (PO_4)......................	____	____
Carbon Dioxide (CO_2)..................	____	____
Ammonia (NH_3).........................	____	____
Hydrogen Sulfide (H_2S)................	____	____
Total Solids.............................	____	

Dissolved Solids From Conductance.....____

Both to the waterworks man and to his customers, those most troublesome cations to be found in water are Ca^{++}, Mg^{++}, and Fe^{++}. Anions which cause difficulty are CO_3^{--}, HCO_3^{-}, SO_4^{--}, and S^{--}. Silica is also troublesome to those customers maintaining boiler installations. Boiler men have long recognized the necessity of treatment of water beyond its mere sterilization. Economic losses due to hardness scale were and still are considerable. Even a very thin layer of scale on a boiler flue results in a drastic reduction in rate of heat transfer, causing increased fuel loss through waste heat. Build-up of scale in boiler flues eventually causes a rise in temperature of the flue wall to the point where burning of the metal takes place and the flue fails.

Corrosive properties of natural waters are troublesome to industrial and domestic customers alike. Corrosive water is also a costly proposition to the waterworks management. Corrosion is in itself a very large subject, and will not be entered into to any extent here. The domestic consumer quickly realizes The effects of corrosion when he is called upon to replace his hot water tank, furnace coil, and other plumbing fixtures at frequent intervals.

The domestic consumer's concept of the processes employed and equipment required to provide him with the glass of water from his tap is hazy indeed. This lack of information is due to poor waterworks public relations. The condition exists because in former times it was thought that the public utility which performed with the least fuss was also the best one. Consequently, the domestic consumer thinks of the waterworks as being comprised of a well, an overhead tank, and a pipeline to his home. Generally he prefers nothing else be done to his water, and eyes with suspicion such processes as coagulation and softening. He is apt to grumble darkly that the water is "doped with chemicals". Consequently, when the subject of a municipal water softening system is broached, he rebels at the large costs involved even though he may be persuaded to the viewpoint that the water is not contaminated with doubtful materials.

The first question the citizen asks is "Why should my water be softened in the first place". Considerable work has been done on the economics of municipal softening of public water supplies. The major expense item of hard water is soap wastage. Softening of a water is the process of the removal or reduction of the calcium and magnesium ions in solution. If this is not done at the centrally located waterworks, it will be done unknowingly by the consumer when he cleanses himself, his laundry, or his dishes.

The customer sees the end result of hard water in the ring around his bathtub, the resistant grease on his dishes, and in the tuttle-tale gray on his best white shirt. A comparison will be made here between softening of a water with lime or with soap, assuming the water hardness to be only calcium bicarbonate. ($Ca(HCO_3)_2$) Chemical reactions are below:

Softening with lime:

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3\downarrow + 2\ H_2O$$

It can be seen one unit of lime, $Ca(OH)_2$ removes one unit of bicarbonte hardness, which corresponds to one pound of lime, as CaO, removing 2.01 pounds of hardness.

Softening with soap: Soap will be here assumed to be the sodium salt of stearic acid, although it is actually the sodium salts of a mixture of stearic, oleic, and palmitic acids, among others. The reaction is here represented:

$$Ca(HCO_3)_2 + 2\ C_{17}H_{35}COONa = Ca(C_{17}H_{35}COO)_2\downarrow + Na_2CO_3 + H_2O$$

It can be seen that two units of soap are required to remove one unit of hardness. This corresponds to one pound of soap removing only 0.266 pounds of hardness.

On a comparative basis then, to remove one pound of water hardness 0.74 pounds of lime are required as opposed to 3.78 pounds of soap. On a cost basis the comparison is startling. To remove one pound of hardness requires $1.79 worth of soap and only 1.2 mils worth of lime. (Lime at $7.00 a ton; Soap at 47.5 ¢ a pound.)

The above work assumes stoichiometric balance in equations, whereas actually excess of lime and soap are required. A survey made in 1935 by H.W. Hudson[18] resulted in the statement that one pound of lime would neutralize as much hardness as twenty pounds of soap. Hudson's work resulted in the equation:

$$X = \frac{C - 75D + 75F}{F - D}$$

Where:

X = hardness of water supply in ppm, the softening of which will be paid for in soap economy alone.

75 = demonstrated attainable hardness of water in ppm from municipal water softening plants.

F = soap waste per capita per year per ppm hardness.

C = capital overhead charges, including superintendence per capita per year.

D = cost of chemicals per capita per year per ppm hardness.

Hudson found that softening of a water containing only 145 ppm of hardness would be economically feasible.

Hudson's work was re-evaluated in 1947 by T.E. Larson.[12] Larson's work indicated that municipal softening of water is even more of a paying proposition today.

The next question which the citizen may pose will be "Why soften all the water when actually only a small amount of it is used for cleaning purposes". The answer to this question is also an economic reason.

It is cheaper to soften the entire municipal supply (approximately 100 gallons per capita per day) at a centrally located plant, than it is to soften at the citizens home that amount of water used for cleaning purposes. Hudson placed this amount of water at 1.8 gallons per capita per day when he made his survey. A test made at Fort Dodge, Iowa on domestic hot water consumption indicated that hot water usage has risen sharply since Hudson's day. Consumption per capita per day varied from 4 to 18 gallons and averaged out at 10 gallons, which was 57 percent of the total water used.

Extensive work on the economics of softening has been done by H.M. Olson[7] in regard to customer owned home softeners as compared with municipal softening. Olson cites the particular case of Madison, Wisconsin which is worthy of note. Madison water users have gone all out for home softeners to the extent of forty per cent of the customers. A cost analysis showed that the investment made and maintenance expenses paid by this forty per cent of the population would have been sufficient to build and maintain a municipal water softening plant which would soften all of the water for all of the customers. Since this time, Madison users have installed home softeners to the extent of sixty per cent of the population.

Additional work by Olson indicates that softening of a supply to zero hardness would be advantageous with regard to soap savings. He believes that with water containing a hardness of 85 to 100 ppm, a saving of seventy-five per cent of the soap could be effected if the hardness were reduced to zero. It is indicated that consumption of soap by hardness begins at about the 35 ppm point.

The third point which John Doe may bring up is the fact that his wife is now using the so called synthetic or soapless soaps. These materials, of which sodium lauryl sulfate is an example, do not react with water hardness, and no savings could be accomplished by the use of soft water. While the citizen is correct in the statement that the synthetics obviate the desirability of soft water, it is still a fact that the use of soap by the nation is yet on the rise. It is not likely that soap will ever be replaced for certain operations. Commercial laundries and certain manufacturing operations will probably always require soap. In addition, the use of bar toilet soap for personal cleanliness is constantly on the increase. Bar toilet soaps are one of the more expensive classes of soap.

If the citizen has been convinced of the desirability of soft water and the economic advantages of its use, work may then progress on the design of the water softening plant.

A survey of the general methods employed in the softening of water is here indicated. The two principal methods of water softening are the lime-soda method and the zeolite, or ion exchange method. A third method employs the use of lime for the removal of temporary, or bicarbonate hardness; and uses the ion exchange method for the removal of permanent, or non-carbonate hardness. Acute corrosion at the water softening plant has been the major difficulty with this method. The use of sodium hexametaphosphate to combat this corrosive tendency is considered promising.

The lime-soda method is sub-divided into the cold lime process and the hot lime-soda method. Zeolites, into sodium and hydrogen zeolites. Sodium zeolites exchange the sodium ion for the hardness ions in the water, the resulting sodium salts having no hardness properties. The hydrogen zeolites exchange the hydrogen ion for the hardness ions resulting in an acid water. The acid water from the cation exchanger may be neutralized with caustic or may be completely demineralized by passing it through an anion exchange material. Such materials are basic resins, being condensation products of amines with formaldehyde. The reaction may be represented: 6

$$R'_2N\,R'' + HCl = R'_2N(HCl)R''$$

and the regeneration reaction:

$$R'_2N(HCl)R'' + Na_2CO_3 \text{ (excess)} =$$
$$2\, R'_2N\,R'' + 2\, NaCl + H_2O + CO_2$$

where the R's may be hydrogen or alkyl groups.

Deionalized water is equal in quality with distilled water and is generally applicable only to specialized industrial purposes.

The hot lime-soda process also has only industrial application and is used in connection with boiler feed waters. The temperature employed is near the boiling point which speeds up the reaction, facilitates coagulation and precipitation, and drives off dissolved gases. Reactions involved are the same as with the cold lime process.

The cold lime-soda process is the oldest process of water softening. The calcium ions in the hard water are removed as $CaCO_3$ and the magnesium ions as $Mg(OH)_2$. Typical equations for these reactions are:

For carbonate hardness:

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2\, CaCO_3 + 2\, H_2O$$
$$Mg(HCO_3)_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + 2\, H_2O$$

Then, since $MgCO_3$ is fairly soluble:

$$MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3$$

For non-carbonate soluble calcium and magnesium salts:

$$MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2$$
$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2\, NaCl$$

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3 + Na_2SO_4$$

From the above equations it can be seen that, for carbonate hardness, each unit of calcium bicarbonate requires one mole of lime while for each mole of magnesium bicarbonate there is needed two moles of lime. For non-carbonate hardness the calcium salts require one mole of soda ash per mole of calcium, while per mole of magnesium salt, one mole of lime and one mole of soda ash is required.

One of the early difficulties encountered in the lime soda ash softening process was the supersaturation of the water with normal carbonates of calcium and magnesium. Distribution systems carrying the water become encrusted with deposits of the carbonates. Especial difficulty was encountered in hot water systems. Sand filters were also a source of trouble because the particles of sand became cemented together by the deposited carbonates.

Previous and present practice of combatting the encrustation by carbonates is the récarbonation of the water with carbon dioxide gas. Encrustation is eliminated by the neutralization of the excess lime and the conversion of the normal carbonates to bicarbonates. Present practice is to recarbonate to a pH of about 9.5 to 9.7. This does not entirely convert the remaining carbonates to bicarbonates, and some encrustation in sand filters will take place. However, recarbonation to a lower pH is not practiced because the resulting water would be corrosive towards plumbing, and also would show a high solubility towards finely suspended calcium carbonate and magnesium hydroxide.

Treatment of the water with alum, a mixture of sulfuric and phosphoric acids, or with nitre cake would accomplish the same result as does recarbonation. In general, the method is merely the treatment of the water to convert the supersaturation carbonates to acid, and soluble, salts.

The first equipments for the production of CO_2 at water softening plants were bulky. They consisted of the fire pot, a gas scrubber, and a blower to draw the flue gases through the scrubber and force them into the water to be treated. With this system, serious corrosion difficulties were encountered with the blower and scrubber units. Present equipments are package units, and get around the corrosion problem by placing the blower ahead of the fire pot thus creating a forced draft unit. Gas, oil, or coke may be used as fuel with these units. A newer type of unit utilizes submerged combustion of gaseous fuel. With all of the above systems it is obvious that only about ten per cent of the gases handled are actually utilized. Waterworks provided with such systems must be equipped with adequate ventilation facilities due to the nature of the remainder of the gas which is not absorbed by the water.

An improved method of recarbonation employes liquid or solid CO_2. Equipments required with this method are less expensive and simpler than those for the combustion units. The price of the CO_2 is higher, but for the large waterworks, the system is economically practical.

Another method of stabilizing lime softened water against deposition of carbonates is by the threshold treatment of the water with sodium hexametaphosphate.[22] This method is not dependent upon alkalinity or pH and does not affect pH. The hexametaphosphate does not react with the carbonate but is instead believed to inhibit the formation of the carbonate crystal nucleus. The amounts required are unbelievably small, one to two parts per million being all that is required. The method also offers the additional advantages of the reduction of corrosion and red water difficulties. The material also appears to be entirely safe for human consumption.

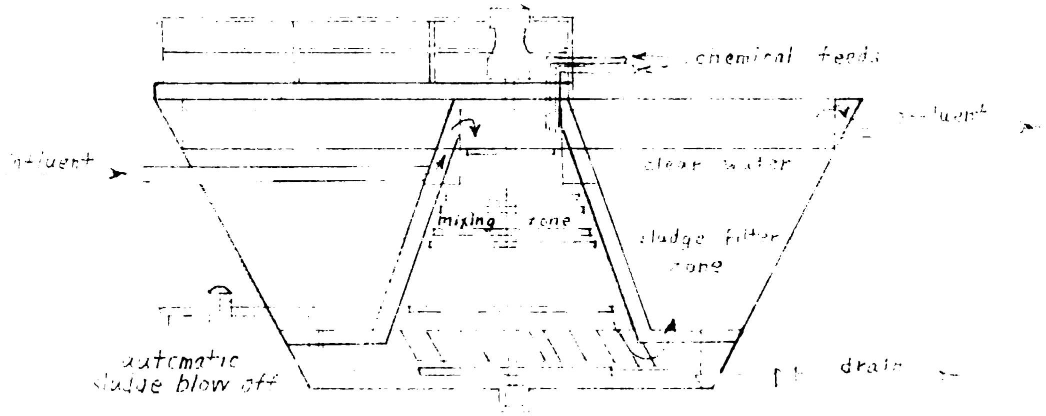
The elements required for softening water by the lime-soda method would then include chemical feeders, mixing and flocculating basins, recarbonation equipment, and rapid sand filters. A plant which has flocculating and settling in separate compartments is referred to as a conventional plant. A plant in which clarification of the flocculated and softened water is promoted by upward filtration through a suspended strata of previously formed sludge is known as the upflow or sludge blanket type. A new name which has been suggested for this type of equipment is "solids contact basin". Both types of plant are much used.

Three types of upflow basins are offered by manufacturers, all patented devices. They are the Accelator, made by the Infilco company; the Hydrotreator, made by the Dorr company; and the Precipitator, made by the Permutit company. All three are similar in operation. It is presumed that if the lime-soda method of softening is to be the final choice for Meridian Township water, one of these three devices will be employed. Their principal advantage over the conventional method is the saving in space and hence in construction costs.

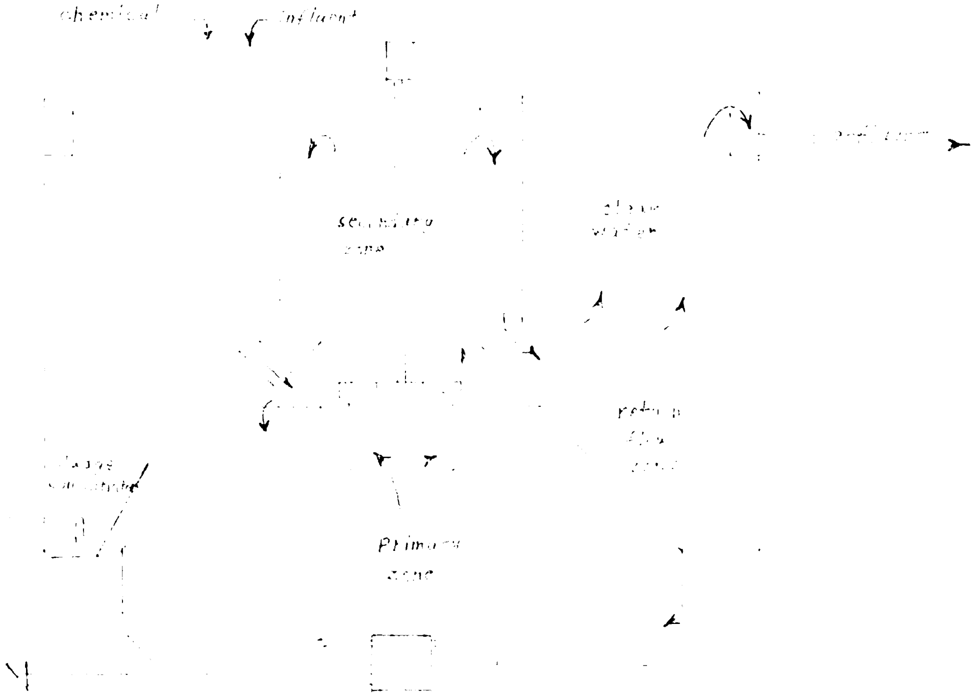
A relatively new idea in softening water with lime and soda ash is the Spiractor which is manufactured by the Permutit Company. This device is conical in shape, and in use is partially filled with a granular calcium carbonate. The raw water, along with the softening chemicals, is introduced tangentially at the base of the cone. The granular $CaCO_3$ acts as a catalyst to the softening reaction, and the hardness content of the water is precipitated on these granules.

Lime Soda Ash Softeners

Upflow Basins

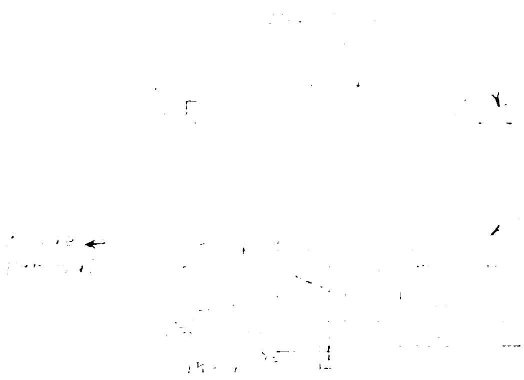


Permutit Precipitator

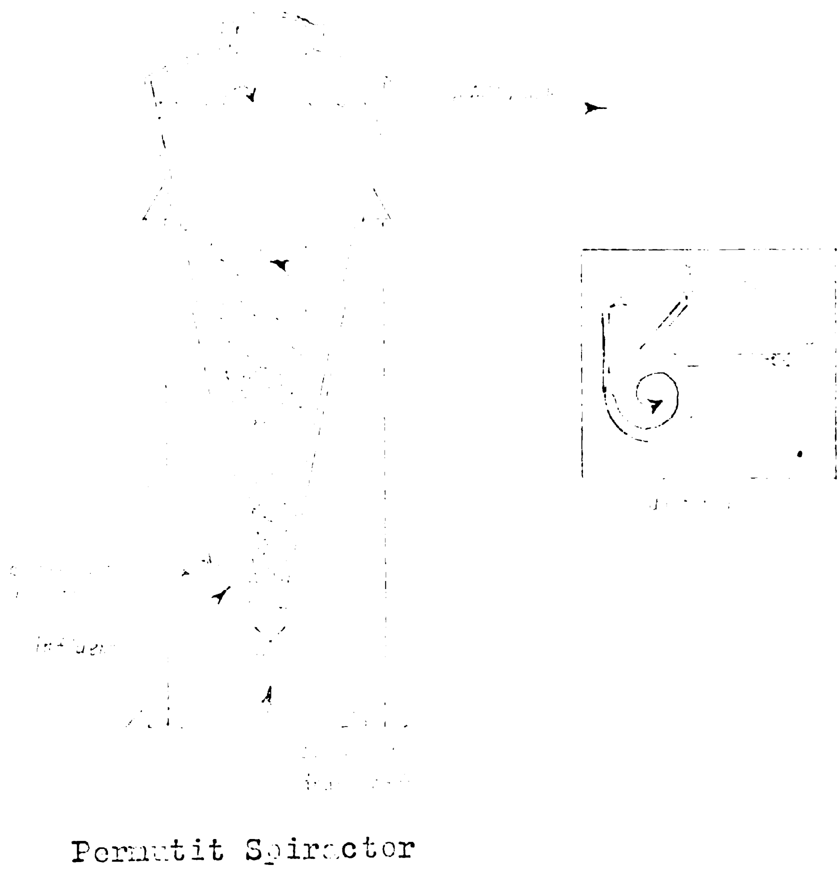


Infilco Accelator

Lime Soda Ash Softeners



Dorr Hydro-treator



Permutit Spiractor

A major advantage is the speed of the reaction. Equipment size is one-thirtieth that of the conventional plant, and one-eighth that of the upflow unit. No sludge is obtained. As the granules of $CaCO_3$ grow in size, they are removed from the bottom of the unit and re-pulverized to the desired size. These units operate under full pressure, here-to-fore a characteristic only of the zeolite units.

Zeolites are a class of hydrated alumino-silicates that contain easily exchangeable ions such as sodium or potassium. During the softening process, the calcium and magnesium ions are removed from the hard water and replaced by the sodium ion. When the zeolite becomes almost completely converted to calcium and magnesium compounds, it is regenerated with an excess of brine, thus restoring the sodium zeolite. Typical equations for the softening reaction are; where Ze represents the zeolite:

$$Na_2Ze + Ca(HCO_3)_2 = CaZe + 2\ NaHCO_3$$

$$Na_2Ze + CaCl_2 = CaZe + 2\ NaCl$$

Zeolites are either natural greensands or artificial products and have a generalized formula: $Na_2O \cdot R_2O_3 \cdot nSiO_2 \cdot xH_2O$ where R_2O_3 is either aluminum or ferric oxide, n represents five or more, and x a varying amount of hydration. The regeneration reaction is as follows:

$$CaZe + 2\ NaCl\ (excess) = Na_2Ze + CaCl_2$$

In the present type of zeolite softener, the zeolite is housed in a large closed cylindrical tank, and rests upon a bed of graded gravel. The water to be softened may flow down through the tank. Sediment which is removed from the water or regenerating brine by the filtering action of the bed must be removed by a strong backwash. Collins recommends that the bed of zeolite be flushed occasionally with chlorinated water to destroy bacterial growths.

The decided advantage of the zeolite exchangers over the lime-soda method is the convenience of the former coupled with the fact that they furnish a water of zero hardness without attention. For municipal softening, zero softened water would not be required. A part of the raw water may be by-passed around the zeolite softeners in order to give the desired degree of hardness to the plant effluent. If the raw water contains iron, the portion by-passed should be treated for its removal. A manganese zeolite may be used for this purpose. Another method of iron removal uses aeration of the water as it is bubbled down over a layer of coke. Should the zeolite method be employed for the treatment of Meriden Township water, it is expected some sort of iron removal equipment would be required.

At this stage, it would seem that the choice of the type of equipments and plant to be employed for softening Meridian Township water lies between the zeolite method and the upflow basin lime-soda method. The zeolite plant offers greater simplicity in operation since it is fully automatic. However, small plants operating with the lime-soda method may also be made almost automatic by the use of chemical proportioning equipment controlled by the raw water meter. The upflow offers a more desirable water, being lower in total solids than that from the zeolite unit. Further, lime softened water is more bacterial free than zeolite softened water. The bactericidal action of lime has been investigated by Hoover,[8] and more recently by Mallmann and Kahler[30] in connection with the upflow type of softener. Hoover found that lime was an efficient bactericidal agent, and further, that finished lime softened water inhibited the growth of new bacterial organisms. Mallmann and Kahler made a comparison between the conventional lime-soda plant and the upflow sludge blanket type. They found that bacterial removal in the upflow basin was superior to that in the conventional plant. Total count reduction was 91.7 per cent and coliform reduction was 97.5 per cent using the Permutit Precipitator, while for the conventional settling tank total count was reduced 95.9 per cent and coliform, 95.8 per cent. Mallmann and Kahler's water supply was the Red Cedar River, an excellent source for pollution studies.

The Spiractor catalytic reactor equipment offers distinct advantages for the small plant, and should be given serious consideration. The Spiractor affords elimination of the sludge disposal problem connected with the lime-soda method, both cold and conventional. Sludge from the lime-soda method is voluminous, being about 99 per cent water, and offers difficulty in its disposal. Usual disposal methods involve ponding, discharge into water courses, utilization at sewage disposal plants, and re-use. Work has been carried out on the disposal of this sludge by its utilization in the elimination of oil refinery wastes, and recycling in a flow softening unit. For the large plant, re-calcining of the sludge and its re-use is practical. A re-calcining plant for Pontiac, Michigan proposes to produce CaO at a total cost of 7.95 dollars per ton. Pontiac's water plant has a maximum design capacity of 17.5 mgd, and an average rate of 10 mgd. Re-calcining offers the neat, efficient method of disposal of lime-soda sludge, and appears to be the best answer to the problem.

Although successful installations of the Spiractor catalytic reactor have been made, the equipment was discarded for the purposes of this design, principally because the equipment is a patented device and natural studies.

The Spiractor catalytic reactor equipment offers distinct advantages for the small plant, and should be given serious consideration. The Spiractor affords elimination of the sludge disposal problem connected with the lime-soda method, both physical and economical. Sludge from the lime-soda method is voluminous, being about 99 per cent water, and offers difficulty in its disposal. Usual disposal methods include lagooning, discharge into water courses, utilization at sewage disposal plants, and re-use. Work has been carried out on the disposal of this sludge by its utilization in the elimination of oil refinery wastes, including an upflow softening unit. For the large plant, re-calcining of the sludge and its re-use is practical. A re-calcining plant for Pontiac, Michigan proposes to produce CaO at a total cost of 7.[illegible] dollars per ton. Pontiac's water plant has a maximum design capacity of 17.5 mgd, and an average rate of 10 mgd. Re-calcining offers the most efficient method of disposal of lime-soda sludge, and appears to be the best answer to the problem.

Although successful installations of the Spiractor catalytic reactor have been made, the equipment was discarded for the purpose of this design, primarily because the equipment is a patented device and could design details rest with the Permutit Company which manufactures the unit. Somewhat the same thing may be said of the zeolite units, which, though widely manufactured, leave to the engineer only the problem of location of equipments and design of the building to house the units. Not that the actual design of cation exchangers is at all an elementary subject; the problem involves application of principles of advanced chemical reaction kinetics. Variables involved are thickness of zeolite bed, rate of water flow, cation exchange capacity of exchanger, and reaction velocity constant, from which may be obtained values of residual hardness of the water at any time in the operation. The problem is also an economic one, since the question arises whether to use a small equipment and regenerate at frequent intervals, thus saving on equipment cost but increasing salt expenses and down time; or to use a large equipment, reducing down time and salt expenses, but increasing equipment costs.

The zeolite unit was discarded, however, for another reason than because of design limitations. Although the Michigan geological formation is badly mixed up due to the glaciers, it is presumed that the water obtained from Meridian Township wells would be very similar to that obtained in the City of East

Lansing. East Lansing's water is to say the least, of an unfavorable character, and it is believed that erection of a zeolite plant for Meridian Township would lead to a finished water of the same quality. The City of Lansing's water, on the other hand, is softened by the lime-soda method, and is of a favorable character. Again it must be assumed that the raw water of the City of Lansing is very similar to that of East Lansing. It is believed that the unfavorable character of East Lansing water is due to bacterial action. The pronounced sulfide taste and odor could be caused by sulface reducing bacteria, the most common of which is Sporovibrio desulfuricans.[46] Sulfate reducing bacteria are by no means the only organisms which will produce sulfide, since a wide variety of micro-organisms including many bacteria as well as various yeasts and filamentous fungi can produce sulfide from a number of sources. It is also likely that bacteria are associated with corrosion of pipe surfaces partly coated with corrosion products and fouling material. Under anerobic conditions bacteria provoke a severe type of corrosion which leads to pitting of steel and graphitization of cast iron.

It is believed that break-point chlorination would do much to improve East Lansing water. Break-point chlorination is explained as follows: On the addition of increasing amounts of chlorine to a series of water samples the residual chlorine gradually increases to a point where further additions of chlorine are followed by a decrease in the residual. Finally on still further additions of chlorine the residuals again begin to increase. This second point is designated as the "break-point" and usually is indicated by the instantaneous development of a yellow color following the addition of orthotolidine to the sample.

It would have to be demonstrated that the East Lansing water supply could be made satisfactory before the zeolite method for softening of Meridian Township water could be recommended. If this should be the case, the new East Lansing zeolite plant is of an admirable design, and a similar plant with some modification could be made to suit Meridian Township.

The final choice of type of plant and equipments to be used for the purpose of this design is that the lime-soda ash process employing one of the upflow sludge blanket basins.

Bacteriological Aspects

The relationship between impure water and the dissemination of disease needs no special emphasis, and has been recognized since early times. The most important of the water-borne diseases are those of the intestinal tract and include typhoid fever, paratyphoid, cholera and dysentery. Various parasitic worms may also exist in drinking water. Sickness, including digestive disturbances and diarrhea, may be traced to polluted water, even in the absence of specific disease causing organisms. All the above illnesses are due to organisms from the intestinal discharges of patients or carriers which have obtained egress to drinking water. It is difficult to say how many of man's troubles are due to his pollution of his own drinking water. Public health records abound with cases of water-borne epidemics of diseases of known origin. These epidemics could have been avoided by the simple application of the sanitary rules of nature. The peoples of the world owe more to the Sanitary Engineers than they do to the Doctors, for while the Doctor may only cure you or pronounce you dead, the Sanitary Engineer prevents you from becoming ill countless times each day. The relationship of water to the more exotic diseases, the causes of which are yet hidden, is unknown. The role of water in the etiology of Poliomyelitis has been investigated by

Scobey.[49] He points out that severe epidemics of polio have occurred simultaneously with periods of severe drought, and points to the increased amount of cyanides in natural waters during dry seasons as being a probable cause. Cyanide poisoning can cause gastro-intestinal disturbances and neurological symptoms identical with those of polio.[50] An interesting theory, and possibly a correct one.

The bacteriologist has great difficulty in demonstrating the presence of actual disease producing organisms in a sample of water, and failure to do so cannot be taken as indication that the water is safe to drink. The water sample may have been taken at a time when no pollution had entered, and a sample taken at a different time might tell an entirely different story. Further, certain diseases such as typhoid require a period of time after ingestion before the disease becomes evident. A water sample taken for analysis after the outbreak of the disease is like closing the barn door after the horse has escaped. Consequently, an indicator of pollution has been established in the bacteria, Escherichia coli. This bacteria is present in the digestive tracts of all warm blooded animals, and its presence in a water indicates pollution. Also, E. coli is longer live in natural waters than the pathogens, which die out rapidly outside of their natural environment. A water condemned on the basis of the presence of E. coli may not contain pathogens, but the condemnation is on the safe side.

Water may also contain as well as organisms which are either harmless to man or may cause other troubles not directly connected with disease. The fungus Crenothrix is an example of the latter type. Crenothrix is usually found in iron-containing waters and causes trouble by clogging water mains or imparting an undesirable appearance to the water. The sheath of this organism becomes coated with iron and manganese oxides giving it a brown color.

Control of organisms in water is accomplished by chemical treatment. Copper sulfate is widely used for control of algae in open reservoirs, while chlorine and chlorine compounds are applicable to sterilization of drinking water or sewage effluents. Use of chlorine for sterilization of drinking water had its beginning at Chicago in connection with the Bubbly Creek Stock-yard Company supply. Bubbly Creek was actually an open sewer. Under the direction of C.A. Jennings, this water was coagulated, filtered, and chlorinated with hypochlorites to produce a safe supply. This situation is very common today, since most of our major water courses are heavily polluted. All Surface waters should be chlorinated, because all surface waters are polluted. Most ground waters should also be sterilised as a factor of safety.

Chemicals to be Used

The amount of chemicals to be used at the water softening plant will of course depend upon the characteristics of the water. Since the composition of the water to be expected from Meridian Township wells is unknown, the following analysis will be assumed.

Concentrations	ppm	epm
Hydroxide (OH)	0	0.00
Carbonate (CO_3)	0	0.00
Bicarbonate (HCO_3)	250	4.10
Sulfate (SO_4)	29	0.60
Chloride (Cl)	38	1.07
Silica (SiO_2)	28	
Calcium (Ca)	75	3.75
Magnesium (Mg)	17	1.39
Soap Hardness	257	
Suspended Solids	4-6	

Titrations

A reading, ml.	0.0
M.O. reading, ml.	12.3

pH 7.7

It is observed that the water possesses no phenolthalein alkalinity, hence the alkalinity is due entirely to the bicarbonate. It is also seen that the amount of bicarbonate exceeds the amount of calcium. The calcium is then entirely in the form of the bicarbonate, $Ca(HCO_3)_2$, leaving 0.35 equivalents of the HCO_3^- to be combined with the Mg. The remainder of the magnesium, 1.04 epm, will be in the form of sulfate and chloride. The sulfates amount to 0.60 epm leaving 0.44 epm of the magnesium to be in the form of the chloride. The remainder of the chloride, 0.3[illegible] ppm, is in the form of sodium or potassium chloride, and is of no importance from the softening stand-point.

With the additional data of a 2,000,000 gallon per day design capacity, calculations giving the following information may then be made.

Hardness salts	ppm	#/day
$Ca(HCO_3)_2$	403.5	67[illegible]
$Mg(HCO_3)_2$	[illegible]	4[illegible]0
$MgSO_4$	33.3	605
$MgCl_2$	21.0	[illegible]

The above figures represent the total amount of minerals which should be removed from the water (or altered) per day in order to have a zero softened water. Zero softened water is most desirable to the domestic consumer. However, it is not economically feasible for the municipal plant to soften to zero hardness due to industrial usage. The great bulk of industrial demand is met by a water of around 70 ppm hardness, a value easily met by a properly operated lime-soda softening plant. For Meridian Township, a compromise hardness of 50 ppm is believed desirable. This does not mean that a hardness of 50 ppm is attainable consistently by the lime-soda method, because such results would demand very careful operation. This figure will, however, be used as the basis of calculations. In operation of a lime-soda plant, it is practice to carry excess lime to the extent of 10 to

50 ppm. After recarbonation and filtration, such water may be expected to have an alkalinity of 35 ppm. (as $CaCO_3$). The noncarbonate hardness will then have to be removed to the extent of all but 15 ppm in order to attain a 50 ppm softened water. 15 ppm of noncarbonate hardness (as $CaCO_3$) is then equivalent to 230 pounds per day of $MgCl_2$. The theoretical amounts of materials to be removed from the water per day are:

Hardness salt	pounds	pound mols
$Ca(HCO_3)_2$	6723	41.50
$Mg(HCO_3)_2$	430	2.94
$MgSO_4$	605	5.05
$MgCl_2$	112	1.18

The theoretical amounts of chemicals required to remove the hardness salts from the water are as follows: Per # mol of $Ca(HCO_3)_2$, one # mol of lime (56 #) is required; per # mol of $Mg(HCO_3)_2$, two # mols of lime (112 #) are required; per # mol of $MgSO_4$, one # mol of lime (56 #) and one # mol of soda ash (106 #) are required; and per # mol of $MgCl_2$, one # mol of lime (56 #) and one # mol of soda ash (106 #) are required. The theoretical amounts of chemicals needed are then:

Hardness salt	Chemicals required per day, pounds: lime (CaO)	Chemicals required per day, pounds: soda ash (Na_2CO_3)
$Ca(HCO_3)_2$	2324	
$Mg(HCO_3)_2$	329	
$MgSO_4$	283	535
$MgCl_2$	66	125
Totals	3001	660

As previously indicated, waterworks practice requires the use of excess lime to the extent of ten to fifty ppm as $CaCO_3$. Since it is desired to produce a plant effluent of 50 ppm hardness, the upper limit of excess lime will be used, or 50 ppm. (as $CaCO_3$) This will increase the daily lime requirement by 403 pounds.

In addition, a coagulating chemical will be used to promote floc formation in the upflow softening unit. Alum (Aluminum Sulfate, $Al_2(SO_4)_3 \cdot 18\ H_2O$) will be used to the extent of 147 pounds per million gallons, or 294 pounds per day. (Courtesy of Infilco, Inc.) Alum reacts with soda ash and will increase the soda ash requirements. The chemical reaction is generalized as:

$$Al_2(SO_4)_3 + 3\ Na_2CO_3 + 3\ H_2O = 2\ Al(OH)_3 + 3\ Na_2SO_4 + 3\ CO_2$$

This reaction is an idealized version of what actually takes place in coagulation with alum, since basic sulfates will also be formed. However, the above chemical equation will be used as the basis of calculations, since actual waterworks experience will be required to determine the exact amounts of chemicals needed. On the basis of the above equation then, one # mol of alum (666.4 #) will react with three # mols of soda ash (318 #). This indicates that an additional 140 # of soda ash will be required per day. The chemical requirements of the water softening plant per day will then be:

Lime (CaO)	3467 pounds
Soda Ash (Na_2CO_3)	798 "
Alum ($Al_2(SO_4)_3 \cdot 18\ H_2O$)	294 "

It should be noted that the amount of alum proposed to be used is a minimum, 0.3 grain per gallon. Alum dosages range from 0.3 to 2.0 grains per gallon. This amount of alum is believed to be a safe value because of the high magnesium content of the water coupled with the fact that a high excess of lime is to be used in softening. The magnesium hydroxide precipitated from the water by the excess of lime in the softening reaction acts as a good flocculating agent. This results in a saving in both alum and soda ash, each a more expensive chemical than lime. Use of excess lime to reduce the solubility of $Mg(OH)_2$, thus promoting floc formation, is based on the well known common ion effect. For a slightly soluble salt such as $Mg(OH)_2$ the product of the concentrations of the ions in solution is a constant. Hence, by increasing the number of $(OH)^-$ ions in solution with excess lime, the number of Mg^{++} ions in solution will be decreased.

The previously listed quantities of chemicals required by the softening plant are based on pure reagents, a practical impossibility. Commercial quicklime specifications will usually call for 88 per cent CaO. Specifications for soda ash require that which is known as 58 per cent light soda ash, and shall contain not less than 98 per cent sodium carbonate. Further requirements on soda ash demand it to be in a dry powdered form and contain no lumps, large crystals, or foreign matter. Specifications for alum require the material to be basic and to contain not less than 17 per cent alumina (Al_2O_3) in a water soluble form. This requires an Alum purity of about 99 percent. However, the alum quantity quoted previously is a figure based on practice and is not a theoretical one. The plant requirements of commercial chemicals per day are then:

Lime	3940 pounds
Soda Ash	815 "
Alum	294 "

It is deemed advisable to provide storage space at the water plant for a thirty day supply of chemicals. Specific Gravities of the chemicals are as follows: Lime, 55 $\#/ft^3$; Alum, 60 $\#/ft^3$; and Soda Ash, 42 $\#/ft^3$. Storage requirements are then:

Lime	2149 cubic feet
Soda Ash	585 cubic feet
Alum	147 cubic feet

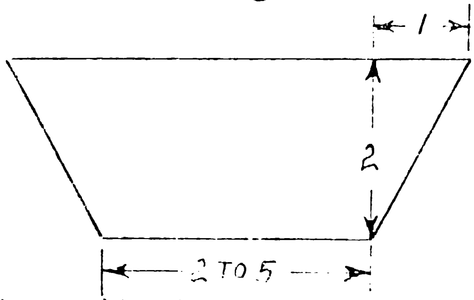
Two lime storage bins of 1100 cubic feet, or 30.25 tons, capacity each will be employed; also two soda ash bins of 306 cubic feet, or 6.43 tons, capacity each; and two alum bins of 86 cubic feet, or 2.58 tons, capacity each.

Design of the Precipitator Unit

It was concluded to employ the Permutit Spaulding Precipitator unit for softening Meridian Township water. Permutit's unit was chosen due to the company's long experience and good reputation in the water softening field. Cost of the Precipitator is believed to be comparable to units manufactured by the other companies in the field.

The Precipitator unit is designed to meet certain specifications. For plant design purposes, it is first necessary to determine the size of the unit. Basic detention time on the solids contact basin ranges from one to two hours. A recent A.W.W.A. questionnaire to waterworks operators concerning solids contact basins disclosed that of the 34 parties contacted, 18 reported successful operation at design rates, 7 indicated good operation at 75 to 87 per cent of the design rate, 6 at 50 per cent, and 3 at lower rates.[28] From the above then, a 90 minute detention time was concluded to be satisfactory as a basis for design.

Two units are to be employed, indicating a required capacity of 1,000,000 gallon per 16 hour day, or a basic rate of 1,500,000 gallon per 24 hour day per unit. The design is to be based on operation of the plant for sixteen hours per day, providing sufficient storage to take care of the night-time demand, which is normally low. This also permits operation of the plant at 100 per cent of the average demand to take care of peak loads. Capacity of the solids contact basin will then be 93,750 gallons, or 12,533 cubic feet. The Precipitator basin is designed on the basis of a multiple of the figures indicated in the diagram below:



Dimensions of the units to be employed are then:

Depth of tank	= 16 feet
Top diameter	= 39 feet
Bottom diameter	= 23 feet

$$\text{Volume} = 1/3(A_1 + A_2 + \sqrt{A_1 \cdot A_2})h$$

$$\text{Volume} = 1/3(1195 + 415 + \sqrt{4[illegible]})16$$

Volume = 12,344 cubic feet

The Permutit company's specifications on the Precipitator units are as follows: 37

A water treatment plant consisting of two units shall be provided as shown on the drawings. Each unit shall meet the following specifications.

The total detention time in the solids contact basin shall not be less than 90 minutes at the designed rate of flow.

The maximum diameter shall be 40 feet, allowing for freeboard.

The unit shall be constructed to include a centrally located mixing compartment. Raw water and chemicals shall be introduced into the top of this chamber. The water being treated shall pass in a downward direction through the mixing zone so that the complete change of direction of flow will take place before the water enters the solids contact compartment.

The solids contact compartment shall have a restricted entrance port above which the horizontal area shall gradually increase, thus insuring uniform distribution of the treated water and stability of the sludge layer.

The agitator shall consist of paddles, rotating about a shaft and driven through suitable speed reducers by an open motor and suitable equipment to give a speed variation of at least 2 to 1. Manual starting equipment of the cross-the-line type shall be provided. The tip speed of the agitator blades shall not exceed 10 feet per minute at the highest speed of the motor.

Provisions shall be made for intermittent sludge removal operating automatically on an adjustable time cycle. A drain connection and an overflow connection shall also be provided.

Walkway and railings shall be provided. All structural steelwork shall be given a shop coat of priming paint.

The inner structure shall be of steel at least

3/16 inch thick. Necessary structural steel members shall be provided to insure rigidity and properly support the inner sections, baffles and agitator.

The inner structure shall be constructed and shipped in sections designed for field welding.

The outer tank shall be constructed of steel plate at least 1/4 inch thick, shipped in sections designed for field welding.

The agitator shall be mounted vertically and its driving mechanism shall be carried by a bearing located above the water. A corrosion-resisting water lubricated guide bearing shall be provided for the lower end of the agitator shaft.

As part of the treating tank, there shall be furnished a straight raw water conduit of welded steel or cast iron construction from a point one foot outside the tank wall and similar outlet conduit to a point one foot outside the tank wall.

Design of the Recarbonation Unit

Dimensions of the recarbonation basin to be used are below, and location is as indicated on the plans.

Length	88 feet
Width	4 feet
Depth	14 feet

These dimensions provide a capacity of 4224 cubic feet, or 31,596 gallons. Allowance is made for two feet of freeboard. Detention time is then 15 minutes at the maximum rate of flow.

Theoretical calculations may be made as to carbon dioxide requirements based on the following equation.

Recarbonation converts normal carbonates to bicarbonates;

$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$

$CO_2 = (44/100) \times CaCO_3$

CO_2 in pounds per million gal. = $44/100 \times 8.33 \times CaCO_3$ ppm

CO_2 in pounds per million gal. = $3.7 \times CaCO_3$ in ppm

Hoover recommends a factor of 4.6 be used instead of 3.7 to allow for losses. Since for this plant, we are to use a high excess of lime (50 ppm as $CaCO_3$) in treating the water; it will be assumed that all of the alkalinity of the water will be due to carbonates and hydroxides. Hence, the CO_2 requirements per day will then be:

$\# CO_2/day = 4.6 \times 50 \times 3 = 690$

This figure allows for 24 hour operation of the plant and is considered conservative.

Carbon dioxide is to be used in the form of liquid[22] CO_2 rather than as the gaseous mixture obtained from a combustion unit. Gases from the combustion units contain only 13 to 15 per cent carbon dioxide. The remainder of the inerts must, of course, be compressed and handled along with the CO_2. This requires bulky and expensive equipment. Provision must also be made for ventilation of the remainder of the gases not absorbed in the water, for the protection of the health of the plant operators. Liquid CO_2, on the other hand, is absorbed by the water to the extent of 90 per cent, and no ventilation equipment will be required. The large compressor required with the combustion units is eliminated and a small pump for the unloading of tank car or cylinder is substituted in its place. The CO_2 is purchased and stored at 270 pounds per square inch pressure. For application to the water it is to be passed through a reducing and vaporizing valve to 80 pounds per square inch pressure. Metering is to be required and will be accomplished by two gas rotameters of 17 pound per hour capacity each. These rotameters will be mounted on a suitable instrument panel. The distribution system will consist of two 1/2 inch headers on each side of the tank, and fitted with 1/8 inch vertical lines to within six inches of the bottom of the recarbonation basin. Ten vertical lines will be used on each side of the basin and placed at eight foot intervals along the tank length. Distribution of the CO_2 to the water is to be accomplished by twenty, eight foot porous hose diffusers. Provision will be made by the use of valves so that each diffuser may be cut off the line for repair, and also so that either or both of the rotameters may be used. In this manner repairs may be made on the carbonating equipment without interruption of the operation of the carbonation basin.

Carbon dioxide storage requirements for a thirty day supply demand a seven ton capacity based on a 2,000,000 gallon per day plant water rate. Liquid CO_2 weighs about 60 pounds per cubic foot. A cylindrical welded steel tank five feet in diameter and twelve feet in length will be employed. This tank will be coated with a six inch layer of cork insulation, and will be equipped with a safety valve releasing at 350 pounds per square inch, and a lead seal designed to give way at 600 pounds per square inch. Safety features shall vent to the out-doors. A refrigeration unit shall be provided on the storage tank to maintain safe working pressures. All controls on the unit shall be mounted on the instrument panel along with the rotameters. Pressure indicators shall be provided on both the storage tank and on the distribution line.

Filter Wash Trough Design

For the design of the wash water gutters, the method of Stroender will be used. Data needed is as follows: The rate of wash water application is such that a rate of rise of two feet per minute results in the filter box. The wash water should not travel over three feet horizontally before it reaches the adjacent gutter. It is proposed to use three gutters per filter which will allow a two foot horizontal travel of the wash water. The method of calculation is based on the following equation:

$$Q = 1.91\ B\ (Y_1 + L \tan A)^{3/2}$$

and letting $Z = (Y_1 + L \tan A)$

$$Q = 1.91\ B\ Z^{3/2}$$

Where:

Q = Total quantity of water received in trough in cubic feet per second.

B = Width of trough.

Y_1 = Depth at shallow end of trough.

Y_2 = Depth at discharge end of trough = [illegible]/3 Z

L = Length of trough.

A = Slope of bottom of trough.

The total quantity of water to be received by each gutter is obtained as follows:

Rate of rise = 2 feet per minute.

Area of filter bed = [illegible] square feet.

Q = (2)([illegible])/(3)(60) = [illegible].91 c.f.s.

A gutter width of 13 inches will be used. The value of Z obtained from the Stre[illegible] nomograph is then 1.3[illegible].

Y_2 = Water depth at discharge end of gutter.

$Y_2 = (2/3)\ Z = 0.88$ ft.

Y_1 = Water depth at upper end of gutter.

$Y_1 = Z - LS$

S = Slope of bottom of trough = 0.005

$Y_1 = 1.3[illegible] - ([illegible])(0.005) = 0.66$ ft.

The above values for Y_1 and Y_2 are the actual depths of the water in the gutter and do not allow for freeboard. The surface of the flowing water in the gutter should be about three inches below the top of the gutter so that the washing of the filter will be effective. The actual gutter dimensions will then be:

Width	13.0 inches
Depth at upper end	11.0 inches
Depth at discharge end	13.5 inches

Design of the Filter Unit

It was determined to use three filter units for the Meridian Township plant. Three units is about the minimum practical number of filters which may be employed in order that plant capacity will not be too seriously reduced in the event of shut-down of one of the units for repair. Since the plant will be operated on the basis of a 3 million gallon per day rate, each unit must have a capacity of one million gallon per day.

Rapid sand filters are conservatively designed on the basis of passage of 125 million gallons of water per acre of surface per day. Practice is tending towards higher rates of filtration (150 to 190 mgd) using a coarser sand. However, the conservative figure will be used here.

The required area of the filter beds is then calculated as follows:

Number of units = 3

Rate of filtration = 125 mgd = 2 gal. per min per $ft.^2$

Total area required = (3,000,000)/(1440)(2) = 1040 $ft.^2$

A filter unit of width 13 feet and length 23 feet is to be used. The area of each filter is then 336 $ft.^2$ and the total area is then 1008 $ft.^2$ The length-width ratio is 1.77, which is within the limits set by practice. In practice, a ratio of 1.25 to 1.33 may be used.

Arrangement and location of filter beds is indicated on the plans.

Depth of the filter box is ten feet above the effluent collection and wash distribution system. The Leopold false bottom system will be employed here rather than the manifold and lateral system. The Leopold false bottom offers better wash distribution and a simplified design. The Leopold blocks, each of which cover an area of 2 square feet, will be laid longitudinally in the filter box and will discharge into a concrete manifold across the front of the filter. An 18 inch bed of graded gravel will rest on the false bottom, above which will be a 30 inch bed of filter sand. A water depth of 24 inch will be used between the top of the sand bed and the weir edge of the gutters to prevent carry-over of the sand during the wash. A freeboard of 24 inch above the gutter will be used.

The gravel size shall range from 2 1/2 inch at the bottom of the box to 1/8 inch at the top. The filter sand shall range in size from 0.45 to 0.60 mm. and shall have a uniformity coefficient of 1.35 to 1.70. Effective size of sand is that size of the sand grains in a sample above which 90 per cent of the sample, by weight, has larger grains. The uniformity coefficient is the ratio between that size of sand grain above which 40 per cent, by weight, of the sample has larger grains, and the effective size.

Mention should be made here of the other types of filters which may be used at army bases, but which were discarded for the purposes of this design. The slow sand, or English filter has been described previously and was not considered due to its high construction cost. The slow sand filter is very effective in its bacterial removal ability, but filters at the relatively very low rate of 3 million gallons per acre per day. It is, however, probably the most reliable type of filter when operated by inexperienced personnel.

A new idea in water filtration is the diatomaceous earth filter.[33] Diatomaceous earth is a light, cream colored material which has been much used as an effective filter aid in other applications. The diatom is a minute plant of the algae class. The Diatom cell is incrusted with a siliceous epidermal covering, and seen under the microscope, has a skeletal appearance. Advantages claimed for filters using diatomaceous earth are the fact that pre-coagulation is not required even for turbid waters, and the small size of the units. Also, this type of filter will remove cysts of E. histolytica, causative organism of amebic dysentery, which present sand filters cannot be relied upon to do.

The diatomaceous earth filter was discarded due to the newness of the idea, and the probable high cost of the patented equipments.

Clear Water Storage Basin

Location of the Clear Well is beneath the filter units, and construction features are as indicated on the plans. The walls and floor of the basin are of reinforced concrete construction and are 1' - 2" thick. The ceiling of the basin is also of reinforced concrete construction and is 12" thick. The 16" x 16" supporting columns are to be filleted into the floor and ceiling of the basin. Dimensions of the basin are:

Length	49' - 8"
Width	23' - 8"
Depth	12' - 0"

These dimensions provide a capacity of approximately 1,000,000 gallons.

A combination air inlet and air release valve shall be provided for on the clear water storage basin to prevent vacuum or pressure build-up within the basin during pumping or filling. The worst possible condition which might occur would be when the wash water pump plus all three of the high-lift pumps are in operation simultaneously. This would indicate a withdrawal of water from the basin of:

Wash water pump	5200 gal/min
Three 800 gal/min high-lift pumps	2400 gal/min
Total	7600 gal/min

To prevent formation of a vacuum in the clear well, air would have to be admitted into the basin at a rate of approximately 1000 cubic feet per minute. The Simplex type V A C combination air inlet and air release valve is to be used, and specifications are as follows:[43]

There shall be furnished at the point indicated on plans a properly designed air inlet valve, shop tested to be tight against leakage under an operating pressure of 10 pound per square inch.

Valve size shall be 8 inch, permitting an air discharge of 1800 cubic feet per minute at a pressure of 4 inches of water at the base of the valve. The valve fitting shall be flanged.

The air inlet valve shall be of the type having a large opening for the intake of air controlled by a corrosion resistant, non-collapsible, bouyant metal float, the top of which shall form the valve and shall close against a bronze valve seat. The valve body shall be cast iron.

The valve shall be so designed as to remain open for filling the basin until the water has displaced the air in the valve body and risen to the level of the bouyant float. The air passage through the valve shall be of Venturi form and the float otherwise suitably guarded against the impact or high velocity of escaping air which under abnormal conditions may tend to close the valve prematurely.

The valve shall be adjustable, and shall be actuated by a differential pressure of 0.10 psi across the valve.

Flow Meters

Three flow meters are required for the Meridian Township water softening plant. Two will be necessary on the raw influent lines to the precipitators, one for each Precipitator. These meters are required so that proportional and automatic feeding of chemicals may be accomplished. It is recommended that the Permutit company's displacement type dry chemical feeders be employed since these units are adaptable to proportional control, and also since the company's softening units are to be used. The Permutit company's specifications for flow meters to control the chemical feeders would then be acceptable.

One flow meter will be required on the finished water output of the plant. The Simplex Standard Venturi type HO meter is recommended along with the Simplex type HO meter register. Specifications for meter and register are as follows:[43]

The Simplex Standard Venturi type HO meter shall be employed. Size of the unit shall be : Diameter of tube 16" x 6", Length of unit 7' - 8 7/8".

For use with the Venturi tube there shall be furnished one indicating, recording, and totalising meter register, designed for panel mounting and arranged for high head operation.

The instrument shall indicate the instantaneous flow through the line at all times on a uniformly-graduated, direct-reading, flow scale; shall record the flow on a uniformly-graduated, direct-reading, rectangular chart, designed for daily removal; and shall totalize the flow on a direct-reading, five-dial totalizer whose fast-reading dial is at least 4" in diameter to provide for accurate checking at any time.

The indicating, recording and totalizing features shall be separate and distinct.

The instrument shall be of the mercury float operated, purely mechanical type, utilizing a shaped float at least 6" in diameter. No equipment employing the use of any electrical steps other than chart drive clock movement shall be given consideration.

The meter register and its accompanying Venturi tube shall be made by one and the same manufacturer.

There shall be included with the meter register a year's supply of charts, pens, ink, tools, mercury, and a water manometer testing device for checking the accuracy of the instrument at any time.

The equipment offered shall be capable of measuring from a maximum of 3,157.000 g.p.d. to a minimum of 5 % of this maximum with an average error over the entire range not exceeding ± 2 %.

The Venturi metering equipment described shall be installed in complete accordance with manufacturer's recommendations.

Upon the shipment of any instrument there shall be supplied by the manufacturer certified test notes indicating that the instrument has maintained the accuracy required by these specifications.

Pumping Equipments

Since it is presumed that deep well water will be the source of supply for the Meridian Township plant, the primary pumping will be accomplished by deep well turbine type pumps. It should be here noted that a major advantage of the lime-soda ash method of water treatment over the zeolite method, is the fact that surface waters may not be used as a source of supply for the zeolite plant. It would be possible to supply Red Cedar River water with the lime-soda ash plant, and to produce a satisfactory effluent from this source of supply despite its high pollution load.

Four deep wells of 600 gpm capacity each would be required for a dependable supply of water to the plant. Choice of pumping equipment to supply this amount of water would of course be made on the basis of cost and performance. This selection would be made at the time of erection of the plant. The variables to be considered would be the bid cost of the unit, and its guaranteed overall efficiency, hence its operating costs. The pumping head against which each unit would be required to operate would depend upon the characteristics of each well. Draw-down in Meridian Township wells could of course be determined only by experiment after the wells were in. Comparison to East Lansing wells would indicate an expected static head of about 110 feet from draw-down level in the well to the surface of the water in the Precipitator units. A pipe and fittings friction head from well to Precipitator could be calculated from complete piping data, but is estimated not to exceed 10 feet at maximum flow. A pump which would serve to deliver 600 gpm against a 100 foot head would be the Aurora deep well turbine pump, type TMO, size 10", requiring a 40 horsepower motor.

Selection of secondary pumping equipments would again depend upon cost, performance, and pumping head. Pumping head would include the static head from pump floor to the overflow level in the elevated tank, plus friction head from pump to elev ted tank. The static head required would depend upon the fire pressure desired at the highest point in the community which, according to the National Board of Fire Underwriters, should be 50 #/in.² in village mercantile districts where buildings do not exceed two stories.[13] 50 #/in.² equals a head of 115 feet of water. Location of the waterworks and elevated tank at the highest point in the community would be advantageous with respect to the heigth of elevated tank required. In practice, it is considered advantageous to locate the waterworks and the elevated tank at opposite ends of the community in order to level out the water pressure gradient. It will be here assumed, however, that the total pumping head against which the high-lift centrifugal pumps will be required to operate will not exceed 140 feet of water. Pumping equipment which would be satisfactory would be the Aurora type CMB, horizontally split case, double suction, single stage centrifugal pumps.[42] Three pumps of 800 gallons per minute capacity each, operating against a head of 140 feet would be required. Size of the units would be 4 L x 5, and motor requirements for each unit would be 40 horsepower.

In addition, it is proposed to use filter wash water pumping in preference to inclusion of an unsightly wash water tank within the building. Another alternative would be to employ an external wash water tank of pleasing design such as the Horton Watersphere, built by the Chicago Bridge and Iron Company. The required size of such a tank would be around 60,000 gallons, to permit washing of two filters in sequence. Use of a wash water tank as opposed to employing the large wash water pump, is dependent upon combined fixed and operating costs for both systems. Without a detailed cost investigation, the use of the wash water pump is recommended for the purpose of this design. A pump which would be satisfactory for this purpose would be the Aurora type SRH, large capacity horizontal pump, of capacity 6000 gpm operating against a 40 foot head. Size of this unit is 16" x 16", and motor requirement is 100 horsepower.

Plant Location

One location which would be adaptable to the needs of this design of water softening plant is at the end of John R. Street between Mt. Vernon Avenue and the extension of Burcham Drive east. This location would take in lots 15 through 22 and also the extension of John R. Street north of Mt. Vernon Avenue. The area has a Mt. Vernon Avenue frontage of 330 feet, and is 374 feet deep. The location is on a hill top, and the adjoining low land immediately north of this area would also be required for the purpose of Sludge lagoons.

A second general location for this plant would be in the area east of the village of Okemos along the Red Cedar River. This location would permit employment of Red Cedar River water as a source of supply. Also, decanting of sludge lagoon supernatant directly into the river would be possible. No specific site is recommended.

Cost

A rough estimate of the cost of this design of water softening plant would be around $300,000. Time limitations prevented compilation of an engineering estimate. To this figure would have to be added the actual cost of the partial distribution system now under construction in Meridian Township, which figure is $117,000. This distribution system is to serve that area of the township which is just east of the city limits of East Lansing. This area is slightly under one section in extent, of which the heavily built up area is approximately three fifths. The other population center of the township is at the village of Okemos including the Indian Hills and Ottawa Hills subdivisions, and also the Charles Bray Addition and Cedar Bend Heights. This area is also approximately one section in extent. An engineering estimate made previously on the cost of distribution system and waterworks for this area, not including softening, was $297,000. Additional wells and elevated tank storage capacity to supply the whole township would raise this figure by $100,000. The total approximate investment required for a waterworks for Meridian Township to supply 20,000 people would then be around $815,000.

Private construction of home water supplies, estimating four people per family, could easily lead to a combined investment of three times this amount. Elimination of the softening plant would reduce the waterworks investment an amount, but in so doing, would lead to increased expenses to the people of the community which in a short time would match the reduction in waterworks investment.

Costs of such public utilities as waterworks and sewage plants are admittedly high. Notwithstanding, water is still one of the cheapest of all materials, and should rightly be so for a material so abundant. This great abundance of water has in the past led to the concepts of Free Water and the Right to Reasonable Use of Water by industries and municipalities. The concept of Free Water is dead. Flagrant violation of the laws of conservation has made it so. Denuding of forested watershed areas has led to greatly increased rainfall run-off rates, and combined with heavily increased demands upon sub-surface waters, has led to shrinkage of water tables. Water is no longer free, and in many areas is actually scarce. The concept of the Right to Reasonable Use of Water by Industries and municipalities should have died long ago. Reasonable use seems to extend to the dumping of raw sewage into already overloaded bodies of water, and to the discharge of dangerous industrial wastes into rivers and lakes. Examples of wholesale destruction of entire fish populations of rivers and lakes by toxic wastes are all too numerous today. Mankind continues to ignore the laws of God, and refuses to recognize that continued willful squandering of natural resources leads down the wide road to destruction. The passing generation should not point with pride to the fine automobiles and tall buildings they have built, but instead should shrink with shame at the wastage of natural resources to which they have contributed. Water is merely one of these natural resources. Man is an ingenious creature, and given understanding, may yet correct his mistakes through scientific advancement. The price of correction is a high one, but it is the price of survival.

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