THE IMPORTANCE OF WATER SUPPLY FOR PRODUCTIVE FACILITIES

1781

6 March 1951

CONTENTS

Page

INTRODUCTION—Mr. John W. Swaren, Member of the Faculty, ICAF ... 1

SPEAKER—Mr. Gustav J. Requardt, of Whitman, Requardt and Associates, Consulting Engineers, Baltimore, Md..... 1

GENERAL DISCUSSION 11

Publication No. L51-118

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

RESTRICTED

Mr. Gustav J. Requardt, Whitman, Requardt, and Associates, was born in Baltimore, Maryland, in 1886. He was graduated as a Civil Engineer from Cornell University in 1909. For five and one-half years he was in the employ of the city of Baltimore, rising from rodman to division engineer. In 1916 he entered the private practice of engineering and has continued in this capacity to date. In 1917-1918 he was engineer for the contractor on the construction of the Aberdeen Proving Ground in Maryland. In World War II he was in charge of designs, plans, and supervision of construction of chemical warfare arsenals in Maryland, Alabama, and Denver, Colorado, of ordnance depots in Alabama, and various structures at the Navy air station at Patuxent, Maryland, at Quantico, and also Bennett Field. He is consultant to the city of Baltimore on new water supply. He was consultant to the city of Philadelphia on a proposed 500 million gallons daily new supply of water from upland sources and on improvements to the existing water-supply system. He was a member on the Board of Advisory Engineers for New Jersey in connection with the diversion of waters from the Delaware River. He is a member of the American Society of Civil Engineers, the American Public Works Association, the American Water Works Association, the American Military Engineers, and the National Society of Professional Engineers.

RESTRICTED

THE IMPORTANCE OF WATER SUPPLY FOR PRODUCTIVE FACILITIES

6 March 1951

MR. SWAREN: Gentlemen, in our course on public utilities we now turn to another area. This morning the talk will be on water. I am sure all of you will appreciate it because of your own physiological necessities.

In seeking for a man to deliver this talk, I wanted one that had the confidence of his fellow engineers. I wanted one who had dealt with the military services and knew something of their way of thinking. I could find quite a number of men who answered those two specifications. But our speaker this morning fills my requirements in another way, perhaps better than any other man I could suggest. In replying to our request to talk to us about the matter of water relations, he answered by saying that he considered the request to speak before this audience an order to duty. In short, he does this as a patriotic matter in addition to the skill which he has in this particular field.

It is a great pleasure to introduce my good friend Mr. Gustav Requardt.

MR. REQUARDT: Last year Mr. Swaren asked me to come over to address a seminar. He has complimented me again by asking me now to address the whole college.

The subject that he has assigned to me is "The Importance of Water Supply in Industrial Mobilization." I will attack the subject by starting out to tell you what water is, the prevalence of water, the procurement of water, and then go on to discuss the importance of water in all our walks of life, especially in industrial mobilization.

Water

We can live without houses or clothes for months and years, we can live without food for days and weeks, but we can't do without water. The need for water is measured in terms of days and hours, and even of minutes.

Water is something we seldom think about. It is all around us. We see it a lot of times. We see it as rain. Sometimes we see it rain every day but we don't realize that it only rains in the summertime about 4 to 5 percent of the time. Water is cheap; it is cheaper than dirt. Water in the city can be bought for five cents a ton. Dirt costs at least a dollar a ton. Topsoil costs perhaps $10 a ton. Under our civilization, water can be put in the third floor of your home, so that in

1764

the middle of the night you can get up and drink a glass of water or half a pint of cool, pure, clear water, under pressure. You don't have to go downstairs for it. It is sold at wholesale at five cents a ton. So you can see how cheap it is.

It is only when a crisis occurs that we realize our dependence upon water. We build water-supply systems, but we don't build them in our economy three times as large as we think we will need. So when it doesn't rain to put water into our reservoirs, a crisis occurs and we go through rationing. We don't water our lawns. Or, as in New York recently, we go without shaving for one day a week because it saves water.

Water appears in solid, liquid, and gaseous forms. When pure it is colorless and weighs 62.5 pounds per cubic foot, or about one pound a pint. It freezes at 32 degrees and boils at 212. Water forms 71 percent of the earth's surface. The oceans and rivers and lakes of the world cover three-quarters of the whole globe. The rest of it is dry land.

The hydrologic cycle represents the balance of water which exists between (1) oceans, lakes, and underground storage; (2) the solid part of the earth; and (3) the atmosphere. Evaporating from water bodies, water forms clouds in the sky; then as rain it falls to the earth, to return again to the sea with no loss.

Rainfall on land is disposed of in some or all of four ways: (1) It evaporates again into the atmosphere, (2) it is held in surface soil and is used by growing things, (3) it percolates through top layers and thence into the ground-water table, and (4) it runs off into surface streams and rivers. For our purposes the underground supply and the surface runoffs are of the most importance.

Ground water exists under practically all the earth's area. It appears at the surface at sea level, at artesian wells, and at springs and rivers. At other places it is deep below the surface and can only be gotten at by drilling wells.

Ground water travels through rock fissures, or more slowly through sands and gravels on its way to seek lower levels. In the latter case it is likely to be filtered clear of contamination, but in both cases the ground water is likely to carry elements, such as iron and lime, which have been dissolved from the rocks and sands through which the water has passed.

The surface runoff of rains is a prolific source of water supply for man's needs. The amount of this runoff ranges from zero—that is, all the rain soaks into the ground and none runs off—in some parts of

the country, to 19 percent of the total rainfall in the Mississippi Valley Basin, to 35 percent in the Potomac River Basin, to 51 percent in the Susquehanna River Basin, and to 70 percent in the upper Connecticut River Basin.

Prevalence of Water

Rainfall, the source of all our water supplies in America, is highly variable. In some places in the United States no rain will fall in the course of a year, while in others as much as 60 to 100 inches will fall in a year. In general, over the whole country, many times the amount of water we need will fall as rain, while in some particular parts there is so little rain that water must be transported great distances by man-made structures.

Again, there is such a concentrated need for water in some places that great water transportation systems are required. Mention can be made of the 250-mile aqueduct and pumping stations which bring Colorado River water to Southern California and the two 150-mile conduits bringing water by gravity from the Catskills and from the upper Delaware River Basin to supply the 9 million people densely clustered around Manhattan Island.

On the average, some 30 inches of rain per year fall on the Continental United States. This, divided by the number of our people, 150 million, amounts to 44,000 tons of water that fall from the sky, speaking again in averages, for each person in the United States. Of those 30 inches, 21.5 inches return to the air by evaporation; 8.5 inches (about 25 percent) flow down the streams and also percolate into the ground-water table. Of the 30 inches a year of average rainfall in America, we, for all our purposes, industrial and domestic, use only three-fourths of an inch.

The speaker has no fear of a water shortage in this country. There must be management and planning to conserve our waters and there must be vision in the building of structures in the advance of needs. New York City last year went through a period of rationed water, but the situation was caused by a temporarily lessened rainfall; a rapidly advancing rate of water demand; and a delay in building, in advance, the necessary reservoirs and aqueducts. With rainfall and runoff again back to normal, the New York reservoirs are now overflowing and water-use restrictions have been removed. New York is using in the neighborhood of one billion to 1.1 billion gallons a day on the average through its whole distribution system.

The city of Baltimore now is in a dangerous situation, in that its watersheds and storage reservoirs are capable of producing only 148 million gallons daily under drought conditions, whereas the city's needs

are for about 200 million gallons daily. Baltimore is now building a new 100 million-gallon-daily supply and the city will not be water-rationed if the next drought is delayed for a few years more.

Droughts do occur in various parts of America. One can come next year or it may not come in the next 10 years. I don't know enough about cycles of sun spots to say that droughts can or cannot be predicted in advance. I can only go by past experience and say that we can design our water systems so that we will have enough water to take care of our needs during such droughts as we have had in the past.

The variability of rainfall is illustrated by the last seven-year record of southern California. The normal rainfall of southern California, around Los Angeles, is a little over 15 inches a year. In those seven years ending last December the deficiency of rainfall below normal was enough to equal the rainfall of two and a third years. In other words, some 36 inches did not fall that were expected to fall. That was a terrific deficiency. If Los Angeles and the other cities of southern California had not been foresighted enough to build a remarkable 250-mile conduit from the Parker Dam on the Colorado River into Los Angeles and then down to San Diego, that deficiency would have been devastating. They were able to bring in the Colorado River water to this area by this long conduit and thereby save the day.

Procurement of Water

Water is procured from the underground supply or from dams and reservoirs on streams which store the heavy wet-weather flows for use in times of small dry-weather flows, or it is procured directly from large rivers and lakes, where the amount of water available is considerably larger at all times than the immediate demands. Many cities and industries in California, Texas, Georgia, and Florida obtain water from underground sources by means of pumped wells. Baltimore, New York, Jersey City, San Francisco, Los Angeles, Denver, Albany, Boston, and many other cities obtain water stored in impounding reservoirs where the stream is not sufficient at its least flow to supply the demand. Such places as Chicago, Philadelphia, Washington, Buffalo, Cleveland, Richmond, St. Louis, and New Orleans obtain water from large lakes and rivers near them.

The procurement of water from underground sources is interesting. Water in sandy or gravelly soils reaches up to a level or table dependent upon amount of water, elevation of land, nearness to ocean or streams, size of sand grain, and so forth. In some cases the water-bearing stratum or aquifer is encased above and below by impervious rock or clay layers. When such waters are tapped by wells, they will flow upward, sometimes to above-ground elevation, dependent upon natural source and outlet. Some ground waters tapped on the Eastern Shore of Maryland and in central

New Jersey have their sources west of the Potomac River and west of the Delaware River at such elevations that the pressure in the trapped aquifers will produce true artesian well water.

In general, however, most ground water is obtained from pumped wells. A modern deep well consists of a steel casing sealed on the outside to prevent contamination from surface waters and reaching to the gravelly or sandy aquifer, where a screen is placed. The casing may be up to 18 inches in diameter, and it may go down 600 or 700 feet. An inner tube is then erected, at the lower end of which is hung a series of bowls or stages of a centrifugal pump. With a shaft to the surface and a vertical motor at that point, the well may now be pumped but at a rate not greater than that at which water flows to the screen at steady "drawdown." Gravel packed on the outside of the screen will tend to slow up the velocity of water so as not to loosen the surrounding sand, and thus when the well is pumped, clear water will flow out at the ground surface.

Care must be taken that the well is not pumped beyond the steady "drawdown." If you do, you will find that you sink the water table of the whole area and you have to drill your well deeper. Or, if you are near the ocean, you may draw in salt water.

The calculations to obtain a steady supply of water from a flowing stream are quite complicated. It is necessary to know more than the average flow of a stream in order to test its adequacy for a definite water procurement purpose. Knowing the past history of stream flow and the record of rainfall on a given watershed—watershed means the area from which falling rain will reach that stream—a dam can be designed to form a reservoir sufficient in volume to gather the heavy wet-weather flows and pay out the stored water to supply the daily needs of the community or industry at times of dry weather or small stream flow. Such reservoirs must be large enough to sustain the demand at periods of extreme drought. It must be remembered that evaporation from the reservoir surface must be allowed for, which is sometimes as much as 50 inches per year. Also all water going over the spillway cannot enter the useful supply. In many cases some percentage of water must be "let down" into the stream bed to provide flowing water for property owners below the dam.

Where water is taken from streams and rivers large enough at time of drought to supply the current demand, large impounding reservoirs are not required—only a moderately costly diversion and intake structure need be built.

Many well-water supplies need iron-removal and hardness-reduction treatments; so practically all surface supplies should be filtered before use. Filtration generally consists of the coagulation of the raw water

by means of a chemical--lime, iron, or alum--the removal of most of the turbidity and solids in the water by means of the sedimentation of the chemical floc, and then the polishing of the water to obtain clarity and sparkle and freedom of tastes and odors by filtration through a bed of prepared sand some 24 inches thick. Prechlorination and postchlorination are resorted to in order to sterilize and make safe the water supply. Bacteria will come through the filter even though it is two feet deep. We depend upon chlorination to kill those bacteria which might escape.

In most cases water is collected at places some distances from where it is to be used. Resort is then had to pipelines, tunnels, aqueducts, and, where elevation is not sufficient, pumping stations, to bring the water to the industrial plants or the distribution systems of cities. To counteract the danger of breakdown in the transmission or pumping systems, large reservoirs or elevated tanks are built close to points of use in the city or industrial plant to maintain the supply while repairs are being made.

The procurement of a source of surface-water supply is a costly matter. New York City from 1905 to 1920 built its great Catskill supply, with a 150-mile aqueduct, at a cost of about $300,000 per million-gallon-daily use. For a 600 million-gallon-daily use, this means that its Catskill supply cost 180 million dollars. It is now spending at twice this rate on its new upper Delaware River supply.

Baltimore is now building its new Patapsco River source, consisting of a 40 billion-gallon reservoir, a 17-mile tunnel, a filtration plant, and with all appurtenant lands, roads, bridges, and riparian damages, at a cost of about $500,000 per million-gallons-daily use.

After water is procured, it need not be used only once. Some industries require water for cooling purposes, adding only a few degrees of heat, and such water is well worth using again for the same or other purposes. The great Bethlehem Steel Company in Maryland, finding its industrial fresh-water-well supply being depleted, has begun the reuse of some 50 million gallons daily of reclaimed sewage of the city of Baltimore. It is reported that at the Kaiser Aluminum plant at Fontana, California, some of the water is reused 49 times. At Youngstown, Ohio, the industries use the Mahoning River for cooling purposes at the rate of 1.7 billion gallons daily with a stream flow of 117 million gallons daily. This means more than a 10-times use and the water temperature is raised to 140 degrees even in December. In California, used water is being returned to the lower gravels to replenish underground supplies. All of such reuse can be classified under the heading of procurement of water.

Within comparatively recent times serious attention has been paid to the procurement of fresh water from the oceans. While evaporation is a very expensive process, other means have been studied; and probably our knowledge of the atomic theory and nuclear fission will help us in

this problem. Estimates for procuring fresh from sea water range from an unlikely 25 cents to $1.25 per 1,000 gallons, or much higher than the cost of procuring water under our present procedures, namely, from 5 to 20 cents per 1,000 gallons.

The procurement of water is becoming more difficult every day. Sources becoming polluted from domestic sewage and industrial waste discharges, erosion of land due to deforestation, filling our streams with muddy water, and the actual careless waste of our water supplies are all factors which make us seek farther afield and more expensively for suitable water supplies.

The conservation of our waters is being actively studied by Federal, State, and municipal governments. Water is a cherished inheritance; we must see to it that those who follow us do not suffer for the lack of it.

The Importance of Water Supply

From time immemorial the location of cities and industries has been influenced by the prevalence and ease of procurement of water. The earliest civilizations appeared in the great river basins of Mesopotamia and Egypt. Settlements were limited to coast lines and river banks, and trading centers grew up at the confluence of navigable streams. Industry goes where water is or is easily procurable. That water is of the utmost importance to business and professional people has been witnessed by the poll of members of the Los Angeles Chamber of Commerce last September, when the subject of water was voted as more important than rapid transit, mobilization for defense, public affairs, legislation, taxes, domestic and world markets, and many other topics influencing business.

Among the most important uses of water are:

1. Moisture in the air makes organic life possible.

2. Drinking water, next to air, is our greatest physical need.

3. Plants, from lowly lichens to giant Sequoia trees, grow only where there is water.

4. The sea is the growing place of immense quantities of fish and other foods used by man.

5. From earliest times water has provided man with a means of transportation.

6. Water dictates the location of cities and farms.

7. Water is a great determinant of political boundaries.

1750

8. Steam power and electricity depend on water.

9. Mechanical and chemical processes and practically all industries need water.

10. In the form of ice, water is used universally for cooling and preserving.

11. Water is one of the greatest natural solvents known to man; and under this heading it is used to keep us, our homes, and clothing clean.

12. Water is the foundation of much of the recreation of mankind.

13. The carrying and diluting qualities of water for the removal of household and industrial wastes have added tremendously to our ease of life. It was not until 1870 or 1880 that London found a means of transporting fecal matter and domestic discharges from homes through a closed drain by the use of the carrying quality of water. In this country, in the cities a home is not considered livable unless it is connected to a sewerage system.

14. Water is the universal quencher of fire.

Industry needs surprisingly large amounts of water. It takes this much water to do these things:

	Gallons
Make a ton of synthetic rubber	600,000
Brew a barrel of beer	470
Produce a ton of aluminum	320,000
Make a ton of smokeless powder	50,000
Can a case of lima beans	250
Generate a kilowatt-hour of electricity	6,000
Condense steam for one kilowatt-hour	80
Test an airplane engine	50,000 plus
Produce a ton of bromine	5,000,000
Refine a barrel of petroleum	770
Make a ton of steel	65,000
Produce a ton of coke from coal	3,600
Make a ton of viscose rayon	200,000
Grow a bushel of corn	5,000

Cities need enormous supplies of water for both domestic and industrial uses. This demand can be rated from well over 200 gallons per person per day in Chicago, to 150 gallons per person per day in New York, to as low as 60 gallons per person per day in smaller communities. Baltimore brings water in from its 300 square miles of surface catchment

areas at 200 million gallons daily; in a year the water would cover the area of the whole city to a depth of four feet—more than the total yearly rainfall, which averages some 43 inches.

Industries use water of different degrees of cleanliness and purity for a variety of needs and purposes. The making of steel calls for fresh water in large quantities for cooling of the product and the rolls, while power plants require clean water for steam making and not-so-clean water (even sea water) for steam condensation. Pulp and paperboard plants require exceedingly clean water in the fine nozzle showers and ordinary fresh water in beating up the pulp. Many manufacturing processes, including food and beverage industries, require water, free of turbidity, dissolved solids, and bacteria. In order to obtain such water, resort is had to coagulation with chemicals, filtration through sand or under high pressure through filter plates, sterilization by means of chemicals, such as chlorine, and, many times, the removal of tastes and odors by electrical ozonization.

During the last war a large Army manufacturing plant, designed by the speaker's firm, was provided with industrial water (not filtered) from two pumping systems having a capacity of 33.5 million gallons daily. Manufacturing floor areas totaled some 808,500 square feet, being about one-third of the total buildings. The designed capacity then was 41.5 gallons per day per square foot of manufacturing space, while the actual use of industrial water up to the end of the war did not exceed 27 gallons per day per square foot. One of the primary reasons influencing the selection of the site for this plant was the proximity to a copious supply of easily procurable water of suitable quality.

One single manufacturing plant in Baltimore, the Bethlehem Steel Company, pumps and uses 550 million gallons daily of brackish river water, purified sewage, and well water for the making of 5 million tons of steel yearly with some 25,000 employees. This is almost three times the amount of water required to supply the demand of one million people in the city of Baltimore and suburbs. Water requirements for the making of electric power in Baltimore approach the municipal or public supply in size. Probably the total industrial water used in Baltimore from private sources is five to six times the municipal supply, which is about 200 million gallons a day.

With the lessened supply of iron ore from the Mesabi Range in the north central United States, ore in greater quantities will be shipped to America from Labrador, from Liberia, and from Venezuela. In this situation water will play a dual role: (1) deep water for the transportation and dockage of ore boats and (2) plentiful fresh water for industrial purposes. The United States Steel Corporation is presently building a tidewater plant on the Delaware River above Philadelphia to take advantage of these new sources of ore and the availability of a copious water supply.

1792

Large bodies of men in military operations can subsist on as little as a quart of water a day per man. In established camps or barracks the available supply should not be less than 70 gallons per man per day. Where military manufacturing is to be done, a big supply of water must be arranged for.

Of all the factors to be taken into consideration for industrial mobilization, factors such as labor supply, source of raw materials, transportation, power, terrain, communication, safety, and so on, no planner should proceed without a lively sense of the prime importance of the sufficiency and procurability of a satisfactory water supply.

I have just read a book called "Water in Industry," recently published by the National Association of Manufacturers and the Conservation Foundation. I would like to read a few of the conclusions.

Total United States consumption of water is about 125 billion gallons a day. Of this, 25 billion comes from wells; and about 100 billion gallons, from rivers, lakes, and reservoirs. Of this total, American industry uses about 25 billion gallons, or not more than one-fifth, the rest being used by farms, irrigation, and for domestic purposes.

The average rainfall in America is about 30 inches a year, of which 21.5 inches of water returns to the atmosphere through evaporation, and the rest, or 8.5 inches, runs off in streams or into the ground. Only three-fourths of an inch of water is intercepted annually and used directly by man. Thus, there are tremendous possibilities for increasing the use of water.

This book analyzes the replies from 3,057 plants using 8 billion gallons of water a day. These industries use more water as a raw material than any other commodity. The largest users of water were: (1) The electrical industry (for generation and manufacture), (2) the paper and pulp industry, and (3) the petroleum products industry.

As an average, water is used in industry in the following proportions: Three-eighths of the water used in the average plant is for process water, that is, for rinsing, for diluting, and for mixing with the product. One-quarter is used for cooling purposes, and one-quarter for sanitary and service purposes. One-eighth is used for boiler feed.

Most industrial plants use municipal water supplies, but the large users of water get their supplies from company-owned sources. About 60 percent of the plants questioned do not reuse any of the water they take in.

Over one-half of the plants reporting have no facilities for treating their water supply. Over 80 percent apply no treatment

to their waste water. In this 80 percent are many plants which discharge waste water into municipal sewerage systems.

The northeast central region of America, the most important industrial area of the Nation, has shown a greater percentage increase in industrial water use since 1939 than any other region.

A great diversity of opinion exists among industrialists in most localities for the potentialities of the expanded use of water by industry in their areas. Industrialists in the New York area are relatively pessimistic, while those in Chicago are relatively optimistic, about the ability to expand the industrial use of water.

Most industrialists believe that the status of water pollution in their areas is either improving or remaining the same. Very few of them believe it is growing worse.

In summary let me say that water is cheap and is readily procurable in most areas of the Continental United States. Water is necessary for life and for practically all efforts of man. No military mobilization should proceed without deep consideration being given to a satisfactory water supply. There should be no planning of a water supply without thought to its economical use and conservation.

I thank you.

QUESTION: Would you please discuss a little the cloud sea as a source of obtaining water?

MR. REQUARDT: As I said, water falls as rain and then evaporates and forms clouds. It then falls again when there is a certain amount of vapor in the clouds or when the temperature either rises or falls. If a plane flies through a cloud at a certain temperature and emits fine particles of dry ice of extremely low temperature, the vapor in these clouds will condense around these fine particles and they will then become large enough to fall as drops of water or flakes of snow.

Another method of producing rain has been to burn silver iodide and produce smoke. This is done from the ground, not from an airplane. The direction of the wind and the type of cloud have to be watched. This smoke has hundreds of billions of fine particles of silver iodide, and each one of them can be the nucleus for the condensation of vapor until they get large enough to fall. The vapor itself may not be at the right temperature or it may not have anything to build around; thus it needs this little nucleus of silver iodide.

Those are the two methods of producing rain—one, to emit fine particles of dry ice from an airplane going through the cloud; the

other to emit smoke of silver iodide from the ground which reaches the cloud. I don't know much about this. I am telling you what I have read. I have never seen any of these procedures myself.

QUESTION: What about the success of these operations? Have they been successful or not? There has been quite a lot of controversy one way or another about them.

COMMENT: I can tell you about the results of some work that was carried on by General Electric in some joint contracts. You have to have the right temperature and the right conditions. This process is merely a triggering process. You can't just take any cloud and get rain out of it. When conditions are right, you can then start a triggering process and it will rain. Rain has actually been produced in some laboratory experiments. For instance, where there was heavy fog and they wanted to land a plane, to clear the atmosphere, this process has been used successfully to knock a hole in the cloud and clear a way.

MR. REQUARDT: The physicist who contracted to bring rain to the New York watershed during the recent drought would never admit that he was successful. I think he was afraid of a lack of legal authorization and the likelihood of suits being filed against the city of New York for either subtracting rain from other areas or bringing too much rain to a certain area. But during his employment the reservoirs in the watershed filled v Personally I think he did some good, but he never would admit it.

QUESTION: I would like to ask two questions. First, is the water of the Hudson River near New York City too brackish to be used as a secondary source of supply in an emergency? This second one may sound foolish, but have you ever had anything to do with water witching and do you have anything to say about it?

MR. REQUARDT: No, the Hudson River is not too brackish. The Hudson is not really a river; it is an estuary, a deep channel. Actually it goes out into the ocean several hundred miles. There is a channel like the Colorado River canyon cut in the continental shelf. The river is deep and the tide extends all the way up to Albany, some 150 miles. The salt water goes up the Hudson farther at times of low rainfall. Sometimes the salinity will be found to have encroached almost as far as Poughkeepsie. From there on up, the river is fresh.

The Hudson River is highly polluted. The city of New York has adhered to a policy of having no filter plants. If the city used Hudson River water in large quantities, it would need filter plants. The Catskill and Delaware waters are fairly clear to begin with and are clarified further through long-time sedimentation in the immense impounding reservoirs.

A year and a half ago in New York during the water shortage the officials looked for all sorts of new sources of water. It was decided to procure Hudson River water at a location about 10 miles below Poughkeepsie, where the big new Delaware River aqueduct crosses the river several hundred feet below the surface. Here a pumping station and a force main were built to connect to a tunnel shaft so river water could be pumped into the shaft. The shaft is under a pressure equal to 600 feet above the river; so the pumping station is required to pump against a 600-foot pressure. At the next period of scarcity the city will pump up to 100 million gallons of heavily chlorinated Hudson River water daily into its system, which has a demand of about one billion gallons daily. This Hudson River water will be mixed in the relation of one to ten. If New York City continues to grow and some years from now has to supply water to 20 million people instead of 9 million, more water from the Hudson River will probably be taken, filtered, and brought to the city as a new source.

As to "water witching," Kenneth Roberts, a writer, has come out forthrightly and said that in Bermuda, where he has his home, he hired a man who found underground water for him with a "dowsing" stick. He has written a book on the idea that one can find water by using this method. In fact, he goes so far as to say that the man doesn't even have to go to Bermuda. He can look at a map of Bermuda in New York City and go over it with his stick and find the spots where water can be found!

Rockville, which is just outside of Washington, gets its water from wells. It was decided to drill new wells to obtain additional water. It was suggested that the wells be located where they would economically fit into the present distribution system. One of the councilmen said, "Here is a man with an electric apparatus in the back of his Ford. He will charge us only 25 dollars and will do some 'dowsing' for these sources." So they hired him. He chased around all afternoon with his secret apparatus. After a while he came down a little valley and said he was ready for us to inspect his spot. He had a row of stones laid out and he said, "Down here is a stream of water 100 feet under the ground. Here is another stream. They come together at this place on this stream, and that is the place to put in your well."

I have no belief in this "dowsing" stuff. I think water may be found in fissures of rock. It comes in wherever the water table is high enough. If you drill in rock, you won't find water unless you strike a fissure and there is water in the fissure, or unless you drill in gravel and there is water in the gravel. This man at Rockville "located" underground water close enough to the distribution system so that a well could be put there and economically hook it into the system. The well was drilled and produced just the same amount of water as was obtained in wells where the dowsing was not used.

QUESTION: I have another question, but this time I am hoping to solve a problem for my wife. Because of minerals being in some waters, she is always complaining of the water being so hard that she isn't able to do her washing. She says that one place is worse than another. Is there any method that you know of whereby water can be made as pure as it is in many places in the Northwest, where the water can be put into the battery of a car? I realize that the reason it is pure there is because those underground waters come from places where there are no minerals. It seems to me that, if some way could be devised that would remove the minerals from the water either at the tap or somewhere else, it would solve the problem. Do you know any way of doing that?

MR. REQUARDT: You have used two different words. You have spoken about purity and you have spoken about hardness. Hard water can be described as water that has salts in it--bicarbonates or sodium carbonate or some other type of hardness chemical, temporary or permanent. That hardness is easily discovered by getting in the bathtub and using plenty of soap. When you get out, you will see a heavy mark or ring on the tub. That is not dirt from yourself; it is a curd of minerals. The soap has softened the water and has produced a sediment and it shows on the bathtub as a ring. That curd is evidence of hard water.

A zero soft water is a water in which you need use the least amount of soap. You can take in your hand just a little bit of soap and your hands get very slippery. The soap is quick to dissolve the dirt on your hands. In hard water you have to use much more soap to do the job, because most of the soap goes to counteract the hardness in the water.

There are chemical softening apparatus, suitable for use in a small house, by which you can treat a water of 150 degrees of hardness, which is a very hard water, and reduce it to zero hardness. You don't have to treat all the water, but just that which you use for washing and cooking and things of that sort. The rest, that which you use in the toilet or to sprinkle the lawn, does not need to be softened. These softeners are not very expensive. You can put one in very easily. They require a little bit for maintenance, but not much. They are removable and transportable.

QUESTION: Would you tell us something about the water table in California? You mentioned that surface water is being pumped back into the water table. Just how is that done? Is it over a large area or in just one or two places?

MR. REQUARDT: Southern California was a desert. There is sand in many places at the surface of the ground. The sand becomes coarser and coarser grained as you go down. Then there is gravel. The gravel extends down and toward the sea.

The average rainfall in California is about 15.5 inches a year. Most of it goes into the ground. It lies in this water table or in this gravel. If you are 40 miles from the sea, it might be in the sand 20 or 40 feet above sea level, but it is flowing toward the sea.

In southern California they put down literally thousands of wells. At every little house the owner puts down a well and he gets up water. The ground water has been depleted and the water table lowered because of all these wells taking water up and using it and discharging it into streams. These streams are lined with an impervious bottom of clay or mud which doesn't permit this water to get back into the water table. It flows off to the sea. So the ground-water table does down and down; the people have to extend the depth of their wells.

Now, districts are going to be formed which will take spent water from sewerage systems and give it an extra treatment beyond the ordinary treatment—in other words, it will be used for sewerage and then run through a reclamation plant and given an extra cleansing—and then this water will be spread over the ground to sink in over acres and acres, maybe 15 acres in one locality. It will sink into the ground and replace some of the ground water lost through wells. The sand tends to filter the water as it soaks into the ground.

GENERAL HOLMAN: I know you have had some very interesting experiences in the selection of sites of water supplies for industrial plants. Could you give us some of the high lights of that?

MR. REQUARDT: Yes, I have, General. I remember that in the spring of 1941 General Somervell called us in and said he wanted us to make a secret safari through the Middle West. He said there had been picked four likely sites for a Chemical Warfare plant that the Army contemplated building. We were to examine the sites under various criteria: labor supply, hospital facilities, accessibility to materials, transportation, electric power, housing, water supply, and so forth.

I think one of these sites was a little above St. Louis. It had a dike around it and was subject to being flooded once in a while. There were a number of swamps in another area. There was another one near a town where there were already a large number of war plants. This plant in question was going to use some 12,000 laborers.

We knew that the water-supply problem was a big element. The site selected is in Alabama, adjacent to a large river whose water is rather clear, soft, and not highly contaminated. This plant was built within a year and a half and the water system comprised a super river intake, pumps, sedimentation tanks and force mains, with filters for domestic supply.

So much on the military side. We have studied a number of manufacturing sites; the water supply in every case was one of the elements that we had to look after.

I see Mr. C. G. Paulsen, Chief Hydraulic Engineer of the U. S. Geological Survey, in the room. I may say that the USGS has made many accurate sets of maps showing the terrain over most of the Nation. These are drawn one mile to the inch and have 20-foot contours. The Survey has gauged many streams all over the country and has daily flow records which go back 30 to 40 years. From those magnificent records of the United States Geological Survey one can find where areas with lack or plenty of rainfall or of runoff are situated.

COLONEL VAN WAY: Mr. Requardt, on behalf of the college, I thank you for making a very interesting talk on a subject that we are all too frequently inclined to take for granted. Thanks a lot.

(27 Apr 1951—650)S.