PROJECT

DEEP WATER STORAGE FOR

NORFOLK AND ENVIRONS

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Project
Deep Water Storage for
Norfolk and Environs

City of Norfolk

Virginia 23501

November 8, 1966

It is proposed the Old Dominion College, through its Old Dominion College Research Division, make a study of and establish a pilot plant capable of ejecting water into the ground below the Moore's Bridges Pumping Station and/or below the 37th Street Pumping Station, each a part of the Norfolk City Water System.

The purpose of the study and the operation of the pilot plant is to determine the feasibility of storing treated and potable water in enormous quantities, possibly as much as 20 to 40 billion gallons, not subject to transpiration and evaporation or contamination by nuclear or conventional attack, and recovering the water for distribution in the Norfolk Water System immediately.

In the attached prospectus described as "A", is a report by Dr. Arthur C. Munyan of the Old Dominion College; "B", the analysis of the quality of water to be pumped into the subterranean deep aquafers for future use; "C", bibliography of reference books; and "D", a list of items and factual data on which more specific information will be secured during the period of study and the proposed pilot plant operation.

This matter is being brought to your attention since the entire City of Norfolk, the City of Virginia Beach, a portion of

the City of Chesapeake, the U. S. Navy, and other military establishments depend and rely on adequate dependable and potable water supply from the Water Division of the City of Norfolk.

We respectfully request your able assistance and direction in securing Federal funds to initiate the study, research and pilot plant operation to determine the feasibility of pursuing "Project Deep Water Storage" in the Norfolk area.

We believe the several Government agencies, both military and civilian, will and should be vitally interested in this proposed study.

Thomas F. Maxwell
City Manager

Sub-surface Water in Norfolk Area

Purpose of Objectives of Investigation

by Arthur C. Munyan
Old Dominion College

The increasing needs of growing Norfolk and adjacent communities, which it supplies with domestic and industrial water, have imposed urgent demands upon Norfolk. Demands, which are being made at an ever-accelerating pace, cannot be ignored and must be satisfied for the welfare and growth of the City.

Awareness and understanding of the necessity for augmenting presently available quantities of water has long been a primary activity of Council and the Municipal Water Division , and it is ever to their credit that the City has been able to keep abreast of requirements to the present. Construction of new reservoirs, improved treatment facilities, pumping stations, mains and auxiliary services provided the means of maintaining and increasing the daily gallonage level. Deep wells, in Nansemond County, adjacent to City reservoirs, were drilled to augment increasing demands on the reservoirs, but, so far, have not been used because of reservations imposed by local county authorities. Some questions exist concerning future use of these wells, at least for an extended period - perhaps of years.

It is proposed that an investigation be made of the feasibility of development of sub-surface reservoir sands which exist beneath Norfolk, to provide alternative storage for introduced, usable water which could subsequently be recovered unchanged. That is,

perhaps it would be possible to store, underground, treated potable water from a municipal surface plant, when periods of non-peak demand occur, then to withdraw this water by pumping, and without further treatment to place it in the distribution system.

Successful development of such a technique possible could be of manifold value to the City: First, much of the reservoir water now lost from storage by both evaporation and transpiration might be saved (possibly as much as 50% of the total annual capacities of the reservoirs). Second, it may be possible to store underground at least one year's water supply. Third, in the event of war, conventional or nuclear, adequate protection from loss or contamination of the municipal water supply would be much more probable. Lastly, there is a remote geological possibility that the use of new engineering techniques developed on the movements of subsurface fluids could result in a permanent freshening of the presently non-potable waters occupying the deep sand aquifers.

Methods of conducting such an investigation would involve a rather complex series of related activities which, it is suggested, could be programmed as follows:

Phase One

(1) A preliminary geological study and interpretation of presently available data which are surprisingly more numerous than seem casually evident;

(2) A legal investigation into the possibility of having the deep (more than 500 feet) sands declared municipal

reservoirs and thus become unavailable to surface land owners, whose mineral rights, including water, now extend to all depths beneath their property bounds. One alternative would be leasing of the reservoir sand (and mineral)rights to the City for an indefinite period at a nominal single or annual rental fee. Such a move by the City could then prevent unauthorized water withdrawals from the storage aquifers or interference with its dynamics by unauthorized wells.

Phase One (A)

(1) Drill a test well at least to a depth of 1500 to 2000 feet (to be determined by the geology).
Careful testing of the qualities of each of the sand aquifers penetrated at the time of drilling would be done. This would mean not only coring, but also a water-analysis of each sand, as well as E-logs and other data types which might be required.

(2) Laboratory study of the physical characteristics of the sand cores would be necessary to determine permeability, porosity, type of rock, mineral content and its reactibility, quantity and quality of contained mineralized water, and other characteristics.

(3) Evaluation of these data in terms of subsurface water movement at present, and under induced conditions with potable treated water displacing the presently saturating mineralized fluids. Each sand would be treated as a separate entity

and so tested.

At this point a summation of effort and an appraisal of status of the attainment of objectives in the investigation would be made. It is quite possible that sufficient knowledge would have been obtained at this level to make a recommendation to continue or to abandon the project.

Phase Two

If a decision to continue is made:

(1) Additional wells must be drilled surrounding the No. 1, at distances and locations which are to be determined from information gained by Phase One; and as each subsequent well is drilled.

These wells also should be carefully drilled and tested during drilling, and the information checked in the laboratory as was done for No. 1 well.

(2) The No. 1 well would be pump-tested, after a suitable and adequate completion job of casing, cementation and screen-placement had been performed in it. Thus each sand could be tested individually for capacity, head, drawdown, etc. This could be conducted on certain optimum aquifers while No. 2 was being drilled and similarly equipped.

(3) Probably a total of 5 wells would be drilled in Phase Two. These would be located, very likely, in a pentagonal pattern around No. 1 at distances to be determined by the laboratory and pump data as work progresses.

(4) Establishment of at least an aggregate thickness of 100

feet of sand aquifers under one square mile would be necessary to assure adequate storage and recovery (if effective porosity is 36%) of one billion cubic feet of water. Therefore,

(5) Test injections of treated water into the aquifers selected would then be attempted in a smaller pilot area (perhaps 40 acres). This would probably be tried both by using No. 1 well as the injection point and the 5 auxiliary wells as recovery wells; and also in the reverse manner in order to determine the practicality of the program based on the accumulated information. Recovered water would be tested both as to quantity and quality over an extended time period - probably months.

PHASE THREE

If Phase Two is successful, the pattern of injection and recovery wells could be extended as far as practical from a geologic and engineering standpoint.

Continual checks on quality of such stored water would be necessary, and it is likely that some dynamic balance of pressures would be required. This is, of course, speculation, and something to be determined as the proposed project progresses, but rest assured that subsurface aquifers are not in static, but are in dynamic equilibrium.

MINERAL ANALYSIS*
NORFOLK CITY DELIVERED WATER
1965

Total Residue	114.0
Volatile Residue	42.0
Fixed Residue	72.0
SiO_2	2.0
R_2O_3	0.22
Al_2O_3	0.19
Fe_2O_3	0.03
Ca	23.3
Mg	3.2
Na and K (in terms of Na)	7.2
Mn	0.00
Cl	21.5
F	0.9
NO_3	0.062
NO_2	0.000
SO_4	25.18
PO_4	0.00
CO_3 (as $CaCO_3$)	2.0
HCO_3 (as $CaCO_3$)	31.0
OH	0.0
CO_2 (Free)	0.26
Cl_2 (Free)	0.5
Alkalinity (Total as $CaCO_3$)	33.0
Alkalinity (Phth. as $CaCO_3$)	1.0
pH	8.1
Fe (Total)	0.02
Hardness (Total as $CaCO_3$)	71.8
Al	0.10
Cr^{+6}	0.00
As	0.003
Pb	0.01
Zn	0.000
Se	0.00
Cu	0.05

*All results in parts per million except pH

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During the third quarter of 1966, the City of Norfolk Water Division pumped 5,062,729,000 gallons of water to the distribution system it serves.

This is an average daily pumpage of 54,996,000 gallons which is about normal. Water from the Norfolk Water Division serves all the City of Norfolk, all the City of Virginia Beach, and a great portion of the City of Chesapeake, together with the entire potable water supply required by the Navy and other military establishments in the area.

The raw water produced by the Norfolk Water Division is mainly stored in the three major lakes - Lake Prince, Lake Burnt Mills, and the Western Branch Reservoir located in Nansemond and Isle of Wight County, Virginia.

The total raw water storage capacity available to the Norfolk Water System is approximately 16 billion gallons.

Because of the terrain and topography of the entire area, these main storage reservoirs are relatively shallow. The exposed surface area of the main lakes are extensive, a great deal of this water never reaches the filtration plans in the City but is lost through evaporation and transpiration. Under certain atmospheric conditions, the loss of lake water due to evaporation and

transpiration runs as high as 50 million gallons per day.

On occasions, the lakes are full and run-off is substantial when above-average rainfall occurs. This surplus water goes to waste.

By and large, it is believed that evaporation and transpiration equals the amount of water treated, pumped, and consumed.

The average percipitation is sufficient to supply with ease the demand for water now and in the foreseeable future. The solution to the problem of maintaining sufficient reserves in storage for the anticipated future demands is very real.

The City, together with its engineers and consultants, have made numerous studies of the situation. Acquiring more land for the construction of additional raw-water storage is one way to fulfill this need, but more open reservoirs would still not eliminate or deminish the terrific loss of water through evaporation. Building huge surface closed reservoirs to prevent evaporation and transpiration would be fantastically expensive and impractical.

Another approach to the problem of conserving the surplus water during times of above-average percipitation and eliminate all evaporation and transpiration loss of water in storage, filtered and ready for immediate use is to employ a natural deep sub-surface reservoir that

has existed for eons, but never utilized so far.

From information secured over many years beginning in 1898 when the City attempted to develope a ground water supply by drilling a deep test well (1,762 feet) up to 1966, when various other wells were constructed in the area of Lake Prince, over 1,000 feet in depth, it has been determined that huge quantities of water are in storage below the surface of the ground, especially at the Moore's Bridges Filteration and Pumping Station.

The quality of the native ground water at this location is not satisfactory for municipal purposes, having a chloride content of 1165 p.p.m.

From the records compiled by N. H. Darton, United States Geological Survey, at the time the test well was drilled at the Moore's Bridges pumping station in 1898 the formations penetrated to a depth of 735 were various colored clays, very dense, and for all practical purposes, impervious.

At 735 feet below surface, water bearing sand or aquafers were penetrated. From this point on down to 1762 feet, more than 400 feet of sand and gravel were penetrated. Each of the sand and gravel stratum penetrated was water bearing but too high in chloride content to be

acceptable.

Subsequent exploration of these deep sand aquifers indicated that this area, identified by the U. S. Geological Survey as Lower Cretaceous, is 36% porous. In other words, each cubic foot of the penetrated aquifer contains 0.36 cubic feet or 2.7 gallons of water.

It is also known that these lenticular aquifers extend from the south bank of the James River southward into the Dismal Swamp area and westward beyond Franklin, Virginia.

Under consideration at this time is a study to determine the feasibility of replacing a portion of this naturally brackish water that occupies an area of approximately one square mile and 300 feet deep between a point 735 feet in depth and the basement rock.

It is believed that in this area of one square mile immediately below the Norfolk Moore's Bridges Filtration Plant there is in storage approximately twenty billion gallons of the naturally brackish water.

The available surplus is to be filtered and treated then injected into the lower aquifers displacing the native brackish water and available for immediate use directly into the distribution system when required.

Such water that is injected into the deep reservoir would have a cover of dense protection clays not subject to evaporation, transpiration, or contamination even by atomic attack. Such amount of filtered water that may be placed in this protected reservoir would be immediately available at any time for distribution.

It is now proposed that the City of Norfolk engage the services of Old Dominion College Research Foundation and conduct a comprehensive study and construct a research pilot plant at a suitable location to determine the feasibility of underground filtered water storage and the recovery of such water at any time.

At such time as funds are available, the Old Dominion College Research Foundation is ready, willing, and able to contract with the City of Norfolk to conduct the proposed study, research and pilot plant operation.

The study, research, and pilot plant operation to be conducted by Old Dominion is to determine but not be limited to the following items:

1. Compatibility of recharge water with formation water at various concentrations.
2. Establish area recharge limits for observation wells.
3. Field permeability tests.
4. Number of wells required and pattern of flow.

5. Static level of water in area, recharge rate, discharge rate and permeability of aquifers.
6. Daily analysis records on recharge water.
7. Pumping tests before recharge to obtain average water analysis.
8. Test pump each aquifer of reasonable thickness.
9. Recharge well design. Diameter, filter gravel size, screen openings and locations.
10. Most practical materials to be employed for both recharge and production wells, casings, and pumps to avoid iron development.
11. Most advantageous location and pattern of recharge and production wells.
12. Most economical and practical rate of recharge and withdrawal.
13. Directional flow and velocity of native water.
14. Estimated cost of operation to inject, store, and recover a given amount of filtered and treated water.

PROJECT-"DEEP WATER STORAGE"

COST ESTIMATES AS PER PHASES
ACCORDING TO DR. MUNYON

PHASE ONE

(1)	Drill test well as outlined (pg 3, ln 11)	$62,000
(2)	Laboratory study (pg 3, ln 18)	3,500
(3)	Evaluation of data (pg 2, ln 13)	2,500
		$68,000

PHASE TWO

(1)	Five observation wells (pg 4, ln 9)	$130,000
(2)	Test pumping #1 well (pg 4, ln 16)	6,000
(3)	Test pumping observation wells (pg 4, ln 22	8,000
(4)	Determine agregate, storage capacity, recovery (pg 4, ln 26)	2,000
(5)	Test injections of treated water (pg 5, ln 4)	5,200
		$151,200

PHASE THREE

Continuous check on stored water over period of at least one year by periodic injection and withdrawal. Assume City of Norfolk would furnish above.

Total direct cost to O. D. C. Foundation for study, operation of Pilot Plant and feasibility report, $219,200. Plus O. D. C. Foundation overhead of 30 per cent $65,760, Total, $284,960

City of Norfolk to furnish without cost to Project:

(1) Land on which to conduct tests and studies
(2) Estimated one billion gallons treated water for injection
(3) Power to conduct pumping tests
(4) Daily analysis of injected and withdrawn water

Estimated cost of water furnished by City	$200,000
Cost of Phase One	68,000
Cost of Phase Two	151,000
Total of Phase One and Two	219,200
O. D. C. Foundation overhead 30%	65,760
	$484,960