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CITY OF ELIZABETH CITY, N. C.

SUMMARY REPORT

AND

RECOMMENDATIONS

ON

WATER SUPPLY

AND

WATER TREATMENT FACILITIES

January 1974

Commission No. 4028-0000

QUALITY WATER

J. N. PEASE ASSOCIATES
CHARLOTTE NORTH CAROLINA
ARCHITECTS ENGINEERS PLANNERS

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CITY OF ELIZABETH CITY, N. C.

SUMMARY REPORT

AND

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ON

WATER SUPPLY

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WATER TREATMENT FACILITIES

January 1974

THE PROBLEM

Elizabeth City has an inadequate water supply and a greatly overloaded and deteriorated treatment facility. The present treatment plant was designed for an output of 2.00 million gallons per day. During the first nine months of 1973 the plant output averaged 10% over design. The maximum days were about 75% over design.

At the present time the source of the water supply is approaching the level of being unacceptable as a potable water due to the high chloride level and hardness. Public Health Service standards indicate that a potable water should have a chloride content less than 250 miligrams per litre (250 parts per million).

Hardness is a quality that affects the cost of using the water in the home and in industry. In the home, the cost of soap and detergent is increased with the use of hard water. In industry, it affects the formation of scale in boilers and piping. It represents problems in manufacturing where water is used in processes. In the municipal distribution systems, there are problems of encrustation of piping, even to the point where service pipe is partially or completely blocked.

The shallow well field is a source of high operational and maintenance costs. To expand this water source would only multiply the problems for the future.

The existing treatment facility is inadequate in capacity and has deteriorated physically insofar as equipment is concerned.

THE SOLUTIONS

There are three solutions under consideration for increasing the capacity of the supply and treatment facilities to 5 million gallons per day.

PLAN "A" - Increase the raw water supply by obtaining Additional wells taking water from the intermediate aquafir (75-foot level) generally located around the perimeter of the present shallow well field. Build a 1 million gallon per day desalting plant at the present treatment facility. Renovate the existing treatment facility.

PLAN "B" - Increase the raw water supply by obtaining additional wells taking relatively high chloride water (500 - 600 mg/l) from the aquafir around the 100' level. These wells would also be located around the perimeter of the present shallow well field and would provide a treated capacity of 3 million gallons per day. This supply would have to be desalted. The present shallow well supply would be continued.

Build a 3 million gallon per day desalting plant at the present treatment facility. Renovate the existing treatment facility.

PLAN "C" - Build the Pasquotank Reservoir to utilize water from the Dismal Swamp as the new water supply. Build a raw water pump station at the Reservoir and pipe line to the present treatment facility. This facility would have a dependable supply of 10 million gallons per day with the possibility of increasing this to 12 million gallons per day as described in the 1953 report by J. N. Pease & Company.

Build a fifth filter unit with all the ancillary units required. Renovate the existing treatment facility.

Abandon the present well supply system.

THE CONSTRUCTION COST

The estimates of construction costs of the above PLANS are as follows:

PLAN "A" $4,426,000

PLAN "B" $5,137,500

PLAN "C" $7,976.000

OPERATING COST

The estimates of the annual cost of production of water under these plans for 1976, the first year the expanded system can be expected to be in operation, are:

PLAN "A" .... $592,000 or $665/MG

PLAN "B" .... $557,000 or $625/MG

PLAN "C" .... $434,000 or $487/MG

CAPITAL COST

The cost of funding 85% of the construction cost with local bond funds @5%, 21-year term, averages:

PLAN "A" .... $282,000 per year

PLAN "B" .... $327,000 per year

PLAN "C" .... $507,000 per year

It is anticipated that a maximum of 25% of the construction cost can be financed by grants from the North Carolina Clean Water Bond Fund. There is no certainty that the grants will be that high, however, so we have used 15% as anticipated State funds.

RECOMMENDATION

We recommend that Elizabeth City adopt and implement immediately PLAN "C."

DETAILED REPORT.

More detailed information is supplied in the REPORT OF A STUDY OF ADDITIONS AND IMPROVEMENTS TO THE WATER SUPPLY AND THE TREATMENT FACILITIES OF ELIZABETH CITY, N. C. which follows.

REPORT OF A STUDY
OF
ADDITIONS AND IMPROVEMENTS
TO THE
WATER SUPPLY
AND
THE WATER TREATMENT FACILITIES OF

ELIZABETH CITY, N. C.

January, 1974

1.00 SCOPE

.01 This report has been prepared in accordance with the instructions of the Mayor, City Council and City Manager of the City of Elizabeth City, N. C.

The scope of this report is to investigate existing facilities, study the future requirements and recommend additions and improvements to the water supply and treatment facilities together with an estimate of cost for consideration of City officials.

.02 There are three plans under consideration for augmenting the raw and finished water supply.

.03 PLAN "A".

This plan involves the continuation of the existing shallow well field plus the development of new wells around the perimeter of the Dismal Swamp north and west of the City, together with the use of the present deep wells near the filter plant. See APPENDIX "B" which indicates the location of the new wells and the pipe lines needed to deliver their output to the filter plant. The capacities are as follows:

1. Present shallow-well field .... 1.75 MGD
2. Nine new shallow intermediate horizon wells @ 200 gpm 2.57
3. Existing deep wells 1.25

TOTAL... 5.57 MGD

This plan includes additions and modifications to the present treatment facilities by upgrading the capacity of the present filter units and facilities to treat water from the present shallow well field and the new wells to the extent of 4 MGD. The water from the existing deep wells at the filter plant with chlorides in the range of 500-600 ppm will be treated in a separate desalting unit having a delivery capacity of 1MGD. The treatment plant will have a total design capacity of 5 MGD.

The use of this plan is predicated upon the existence of a satisfactory well supply having a chloride content of not over 200 ppm.

.04 PLAN "B"

This plan involves the continuation of the present shallow well field plus the development of nine new deep wells around the perimeter of the Dismal Swamp north and west of the City, together with the two deep wells at the filter plant. See APPENDIX "C" which indicates the location of these wells and the pipe lines which are needed to deliver their output to the filter plant. The capacities are as follows:

1.	Present shallow well field	1.75 MGD
2.	Six new intermediate horizon wells @ 500 gpm	3.00
3.	Existing deep wells.........................	1.25
	TOTAL ...	6.00 MGD

This plan includes additions and modifications to the present treatment facilities by upgrading the capacity of the filter units and facilities to treat water from the present shallow well field to the extent of 2 MGD. The output of the six new wells and the existing deep wells will be treated in a separate desalting plant having a delivery capacity of 3 MGD. The treatment plant will have a total design capacity of 5 MGD.

.05 PLAN "C"

This plan involves the development of an entirely new raw water supply by constructing the proposed Pasquotank Reservoir, which is described as PROJECT III - DEVELOPMENT OF A SURFACE SUPPLY FROM THE DISMAL SWAMP in the 1953 REPORT on WATER SUPPLY of ELIZABETH CITY, NORTH CAROLINA by J. N. Pease & Company. This description starts on page 15 of this REPORT and will not be repeated here. The reliable capacity of this supply is: ?

1.	From the Dismal Swamp and the Canal overflow	10 MGD
2.	From recovery of lockage water (future)	2 MGD
	TOTAL ULTIMATE.............	12 MGD

This plan includes additions and modifications to the present treatment facilities by upgrading the capacity of the present filter units and related facilities to treat water from the Pasquotank Reservoir. An additional filter unit will be added to bring the total treatment capacity to 5 MGD. There will be changes in the treatment process to accommodate the Reservoir water as described later.

2.00 EXISTING FACILITIES

.01 The present plant went into operation in 1926 after the City had acquired the property of the private utility serving the City. It has a rated capacity of 2 million gallons per day. The plant has not been materially changed since its construction. Some equipment items have been added or replaced.

.02 The structures are in sound condition with minor exceptions. This speaks well for past maintenance. The piping and equipment have served some 44 years. This is certainly a good record. Equipment parts, such as for gate valves, are no longer available from manufacturers and must be custom made. Although there does not appear to be any crisis at the moment, there will come a time when obsolete equipment will have to be replaced.

.03 The coagulation facilities consist of a channel with over-and-under baffles. This provides no flexibility from an operating standpoint.

.04 The sedimentation basins are the conventional design. There is some evidence of short-circuiting. The cause is not apparent and the results are not too serious although we would prefer to see the problem corrected. This may require a test of a unit with a dye tracer which will require wasting the water. The dye should be a visual indication of the action of currents which may be corrected.

.05 The filters are of the design favored at the time of their construction. The underdrains are cast iron pipe with perforations intended to accomplish uniform distribution of water being filtered and wash water during the washing period. Around and above the underdrain piping is a layer of gravel graduated from large to small. Above the small sized layer of gravel there is a bed of sand which does the actual job of retaining the particulate matter and allowing the water to pass through to the gravel bed. Due to the use of excess lime, the only chemical treatment found to be effective for coagulation so far, the lime accumulates in the sand bed and, in a short period of time, effectively "blinds" or clogs the bed. This results in uneven distribution of water percolating down through the sand and upward during the washing process.

.06 The filter rate controller and meters are outmoded as are the gate valves. The piping is adequate for the present rating, but cannot be used for the higher rating now contemplated.

.07 The chemical feeders are adequate for the present. Mr. Harris has accumulated spare parts for the lime feeders which are likely to be needed for replacements. The alum system using liquid alum is fairly new and appears to be in good condition. The temporary timber and metal building housing the alum system is showing signs of deterioration and should be replaced during the proposed program with a permanent structure.

.08 The raw water storage reservoir is in good condition except for the joints which need attention.

.09 The clear well is also in good condition as seen from the outside.

.10 The motor driven raw water pumps are said to perform satisfactorily. Unit No. 1 has a capacity of 750 gallons per minute with 20 H.P. motor. The capacity of Unit No. 2 is unknown with a motor of 60 H.P. The engine driven unit has a rated capacity of 2100 gpm and should be replaced since the engine is not reliable.

.11 The high service pumps are of various ages and are apparently in good condition. The capacities are as follows:

No. 1 -------	1400 gallons per minute,	100 HP
No. 2 -------	700 gallons per minute,	50 HP
No. 3 -------	2000 gallons per minute,	100 HP

.12 The existing auxilliary power unit is a diesel engine-driven generator apparently built in 1942 and used as a ship's auxilliary power plant. It's capacity is 200 KW. The unit has capacity to carry one high service pumping unit plus the small power and lighting in the existing plant. The engine is not as reliable as it should be.

.13 We understand that the heating plant was recently renovated by installing a new boiler. Other than normal replacements it should continue to serve for some time. Any other replocements should not be expensive. There is need for air conditioning the existing laboratory to provide more uniform and better working conditions. This can be accomplished with a window unit.

.14 Our observation of the electrical system indicates many instances of defective wiring such as broken insulation exposed to possible contact. There are instances of violations of the National Electrical Code such as branches taken off a circuit with smaller size wire and no over-current protection. The wiring system has been added to over the years to the extent that it is now in an unorganized condition as well as being hazardous. At its present age the insulation on the wire is definitely poor and if disturbed it breaks or adheres to the conduit so that maintenance requires new circuits.

.15 The transporting and handling of chemicals, principally lime, is a messy and an expensive system insofar as labor is concerned. Storage room is becoming inadequate. The problems will become aggravated as the output of the plant increases in the future.

.16 The City staff has advised us that the tile roof over the control and filter building leaks in "spots." This is probably due to broken tile. We suggest that at the time the filter building extension is being roofed, the existing roof be inspected and repairs made. We question the need for replacing the entire roof unless it is found that the nail fasteners are badly corroded.

.17 The existing wash water tank is described by City staff as being in bad condition in the interior. There is no way to take the tank out of service for sufficient time to clean and coat the tank. Approximately two weeks, as a minimum, would be required. We concur with the staff's recommendation that this tank be removed and replaced with pumping units, one for normal service and one for standby. Each of these units would be rated at 6,600 gallons per minute. The wash water rate would be controlled by a control valve and measuring device in the pipe line from the pumps to the existing wash water line serving the filters. The flow rate will be transmitted to the filter gallery for operator observation.

3.00 DESALINIZATION RESEARCH PROGRAMS

.01 GENERAL. PLANS "A" and "B" include the use of desalinization units to supplement shallow well water. An extensive test program was set up to determine the effectiveness of two types of processes and equipment. These were the Electrodialysis (ED) and Reverse Osmosis (RO), processes. Both processes are in use in various parts of the country and, in fact, in the world. Presently, they are located in arid regions using brackish or sea water.

.02 TEST PROGRAMS. Small field test units were obtained from the manufacturers and set up in the filter plant area. The Electrodialysis unit was operated continuously for three months. The Reverse Osmosis unit was operated about three weeks. Raw water was obtained from Well No. 5 at the filter plant. Brief runs were made with water from Knobbs Creek with the ED equipment althought the raw water could not be said to represent any particular condition except on that day.

The results have been tabulated on attached APPENDIX "A".

The conclusion obtained from these tests is that the well water obtained from approximately one hundred feet below the surface can be treated very effectively and result in a satisfactory potable water.

The equipment for either of these processes has been in full-scale use for considerable time. Improvements are expected to be made with more experience and cost of the membrane materials will likely be reduced rather than escalated due to the increasing usage.

4.00 COLORED WATER RESEARCH PROGRAM

.01 GENERAL. PLAN "C" involves the use of highly colored water from the Dismal Swamp which will be stored in the proposed Pasquotank Reservoir. Such water has always been difficult and expensive to treat.

.02 DISCUSSION. Our understanding of the original use of highly colored water from Knobbs Creek came verbally from Mr. Robert W. Luther, PE, who was water chemist at the time, 1930 or thereabouts. Knobbs Creek source was abandoned in 1933 in favor of the present well field due to salt intrusion from the Pasquotank River. After Mr. Luther's death, we inquired of the City staff concerning operating reports which would provide a basis for using a highly colored water supply. The staff was unable to find such records. Mr. Luther had repeatedly stated that the swamp water was treatable, but that close control was imperative; and that the hydrogen ion level (pH) had to be retained without correction normally expected. Otherwise, some color would return in the treated water.

We requested the City to enter into a program to verify our understanding of the treatment process. The City elected to employ Mr. Moffett rather than attempt to do the research with its own labor and facilities. Mr. Moffett moved in a mobile laboratory and researched the basic problem of color removal using water from the swamp which will become the Pasquotank Reservoir under this Plan "C". Mr. Moffett's report is made a part hereof by reference.

The process is quite similar to the existing process except for change in chemicals and the addition of an additional phase of passing the filtered water through activated carbon beds to remove the remaining color particles which would be visually objectionable.

The research program by Mr. Moffett indicates quite clearly that the swamp water can be successfully treated and produce a very satisfactory water. The end product will be much more satisfactory than that of either the present PLAN "A" or PLAN "B". It will be so good that it should be a selling point to highly sophisticated industries, such as electronics.

If PLAN "C" is adopted and implemented, the City must upgrade its entire operating staff and procedures in order to insure that the process is properly carried out in practice. Further, a properly equipped laboratory is essential since test procedures are considerably more sophisticated than those required with the present treatment process.

We recommend that the staff at the plant be headed by a competent water chemist. He must have adequate education and experience and be placed in charge of plant operations. Preferably, this person should be a chemical engineer. The operating staff should be upgraded in competence and initiative. The existing emergency and complaint telephone answering service for City services must be transferred to some other office to avoid interruption of plant operations and surveillance.

5.00 PROPOSED ADDITIONS AND MODIFICATIONS

.01 GENERAL. The objective of the proposed additions and modifications is to provide a water treatment plant of adequate capacity for the foreseeable future, to extend the life of existing facilities and to do this at the minimum cost consistent therewith.

We do not contemplate any change in the filtration and treatment process under PLANS "A" and "B". Much research has gone into the problem of clarification with the pecularities of the well water now being used. The recent development of filter aids does not seem to apply to this case. Should Elizabeth City go to a surface source, PLAN "C" in lieu of wells as suggested as a possibility by the J. N. Pease & Company report of 1953, the present and proposed facilities should prove entirely satisfactory with adjustment in chemical usage as described later.

The records for the past five years have been examined. The average daily volume of water delivered to the distribution system is approximately two million gallons per day. The flow is remarkably uniform throughout the typical week, with some seasonal variations. The monthly daily averages are as follows:

	1968	1969	1970	1971	1972	1973
Jan.		1.83	2.18	1.91	1.94	2.11
Feb.		1.82	2.15	2.08	1.79	2.12
Mar.		1.80	2.04	2.11	1.79	2.11
April	1.85	1.87	2.04	1.99	1.72	2.15
May	1.97	1.96	2.00	2.06	2.06	2.18
June	1.99	2.07	2.08	2.01	2.16	2.35
July	2.06	2.21	2.10	2.02	2.19	2.20
Aug.	2.09	2.18	2.20	1.89	2.19	2.27
Sept.	2.03	2.23	2.11	1.88	2.15	2.29
Oct.	1.95	2.14	2.01	1.65	2.21	
Nov.	1.87	2.03	1.90	1.84	2.03	
Dec.	1.84	1.99	1.88	1.96	2.02	

The problems which will be encountered in renovation work involve scheduling. It is obvious that no filter unit could be taken out of service without grossly overloading the units left in service. In fact, a period greater than twenty-four hours would do so. It would involve a serious risk to the integrity of the water system and fire protection of the City to do so.

We conclude that the only way to proceed with this program is to provide a new treatment unit and place it in service before interrupting service of any of the other units. Scheduling the construction of the proposed clear well in this program and the recent construction of an elevated tank in the present distribution system, ahead of any work on existing units should provide the necessary factor of safety of continuity of service.

.02 TREATMENT PROCESS UNDER PLAN "C".

Changes in the treatment process are contemplated with the use of the proposed surface supply of Pasquotank Reservoir. These changes come about by the research program undertaken by Mr. J. William Moffett, R & D Process, whose report is made a part hereof.

Briefly, the process provides for the following steps:

1. Introduction of sodium hydroxide (NaOH, soda ash) and mixing of that chemical with the raw water,

2. Introduction of ferric chloride ($FeCl_3$) with an instantaneous in-line mixer,

3. Introduction of activated silica,

4. Coagulation for 30 minutes in a variable speed paddle mixer to permit optimum formation of floc,

5. Distribution of the coagulated water to the sedimentation basins,

6. Settling of the floc in the sedimentation basins with 2.73-hour detention,

7. Distribution to the sand filters,

8. Filtration through the mixed media (coal and sand) filters at a rate of 4 gallons per square foot per minute,

9. Transfer of the filtered water by pumping through pulsed activated carbon beds having a residence time of 30 minutes,

10. Introduction of soda ash for pH adjustment,

11. Chlorination of this effluent with discharge to clear well storage.

See APPENDIX "D" for process diagram

The change in chemical application will eliminate the use of alum and lime (solid form) and use liquid NaOH and $FeCl_3$. Both of these chemicals can be delivered to the plant in liquid form by tank truck or rail tank car. When delivered by tank car, the chemicals will be pumped through underground piping to storage tanks at the filter plant. Tank car delivery is considerably cheaper than tank truck.

Two 8,000 gallon tanks and associated piping, pumps and equipment will be provided for each of the chemicals except activated silica. Storage for activated silica and a feeder will be at ground level since the volume used is not great.

These changes will eliminate the present unsatisfactory handling methods. Application to the water in process will be by pumping. Activated silica will also be handled in solution. No activated carbon will be required for control of tastes and odors since the carbon filters will provide for control of these problems as well as color removal.

Covered storage will be provided for six ton containers of liquid chlorine. Two scales will be provided for containers in use for both pre-chlorination and post-chlorination with loss-of-weight transmitted to the Operator's Office.

There is the possibility of the appearance of manganese in the swamp water with construction of the Pasquotank Reservoir. The shallow depth would seem to ameliorate the problem, but there is no way to be sure that it will not occur. Should it do so, sufficient chlorine would have to be introduced in the pre-chlorination treatment to oxidize the manganese.

.03 NEW FILTER UNIT UNDER PLAN "C".

The new filter unit will be the same size and configuration as the existing units except for the underdrain system and filter media.

By utilizing the presently accepted practice of design of these elements, it is possible to increase the filter rate from two gallons per minute per square foot of filter media area to four gallons per minute per square foot.

We propose to use a "false bottom" of the Wheeler type with 12" of graded gravel and 3" of torpedo gravel above it; then filter media of 24" consisting of either multi-media (Micro-Floc) or dual media (Metropolitan or its equivalent). This filter construction has been most successful in practice.

A surface wash of the same type presently proposed for use and in process of installation in the existing filters will be used. By adding this new unit and increasing the rate of filtration, the plant will have a rating of 5 million gallons per day as against 2 MGD presently.

.04 OLD FILTER UNITS.

The existing filter units will be reworked to provide the same construction as the proposed new unit.

.05 FILTER PIPING AND CONTROLS.

The new filter unit under PLAN "C" will be equipped with a modern filter rate controller with proper pipe sizes. Valves will be the pneumatically operated butterfly type. The operating table will be located on the Filter Operating Floor with the valve controls, rate of flow and loss of head gauges.

The unit will be provided with a turbidimeter with remote recorder in the Operator's Office.

The existing units will be reworked to provide the same piping, controls and instrumentation as the new unit. This will require cutting into and replacement of certain existing piping. This work can be accomplished only over the weekend.

.06 FLASH MIXER.

The new flash mixer will be constructed at the end of the existing mixing chamber under PLANS "A" and "B." The detention time will be two minutes. The purpose of this unit is to quickly mix the lime with the raw water before it enters the flocculators.

The 24" raw water line will be routed from its present position of entry into the mixing chamber along the mixing chamber along the structure to the new flash mixer. An in-line paddle mixer will be required by PLAN "C" to obtain instantaneous mixing.

.07 FLOCCULATORS UNDER ALL PLANS.

New flocculators of the paddle wheel type will be installed in a new structure at the rear of the Sedimentation Basins. The detention time will be 30 minutes at rated capacity. The structure will be divided into two units with paddles in series in each unit. The piping will be gated so that one unit can be taken out of service without interfering with the other unit. The drives will be variable speed motors. Piping will be used to convey the flocculated water to the existing and new sedimentation basins.

.08 SEDIMENTATION BASINS.

The new basin under PLANS "A" and "C" will be essentially of the same design and capacity as the existing basins. Detention time will be 2.73 hours at rated capacity.

Both old and new basins will be equipped with "tube settlers", a device for developing more effective sedimentation. With them it is believed that the present short circuiting will be corrected.

.09 NEW CLEAR WELLS.

Each new clear well will have a capacity of 1.5 million gallons. The existing clear well has a capacity of 1.0 million gallons so that the combined capacity will constitute 80% of one day's supply at rated capacity.

The construction will be concrete similar to the existing except that it will be rectangular in plan to best fit the site and remain as close as possible to the high service water pumps. Space remains for possible future construction of a duplicate unit. It is said that discharge lines from deep well Nos. 4 and 5 cross the site. If this proves to be the case, one or both of these lines will have to be moved.

.10 RAW WATER PUMPS.

The engine driven pump will be removed and a new motor driven unit will replace it. The new unit will be driven by a two speed motor and have a capacity of 5,250 gallons per minute at high speed. This unit can supply the plant at its rated capacity.

.11 HIGH SERVICE PUMPS.

The existing three motor driven units will remain in service and the engine-generator unit will be removed from the pump room. We propose to add a fourth motor-driven pump having a capacity of 3,000 gallons per minute. This will provide a total pumping capacity of 7,100 gallons per minute or 9.5 million gallons per day. With the largest unit out of service, there would be a capacity of 5.5 million gallons per day. Retention of all of the existing units with the proposed units provides flexibility needed at this time with the 700 gpm unit still available. When the basic output of the plant increases to, perhaps, 1500 gpm the small unit can be replaced with one of a greater capacity.

The present pumps take their suction through foot valves which have a high loss of head and consequently use unnecessary power. We propose to remove the foot valves and install an automatic priming system on all pumping units.

.12 EMERGENCY POWER.

Elizabeth City has experienced repeated power interruptions of extended periods of time. Under these circumstances it would be unwise to depend upon the existing utility service under emergency conditions.

We propose to replace the existing diesel engine driven generator with another unit having a capacity of 300 KW. This capacity is adequate to operate all electrical motors, lighting and small power required to operate the filter plant at its rated capacity of 5 MGD.

The following plant units are included in determining the generator capacity:

Raw Water Transfer Pump No. 3	75	H. P.
Flash Mixers	10	H. P.
Flocculators	3	H. P.
High Service Pump No. 4	150	H. P.
Air Compressor	$7\frac{1}{2}$	H. P.
Filter Sweep Pump	5	H. P.
Laboratory	5	KVA
Plant Lighting	5	KVA
Miscellaneous	5	KVA

.13 HOUSING FOR ALUM STORAGE/FEEDER - PLANS "A" AND "B".

The present housing for the liquid alum storage and equipment shelter is of temporary construction and we recommend that it be replaced with permanent construction together with the adjoining facility for chlorine storage.

The structure we recommend is precast concrete construction with built-up roofing.

Covered storage for six ton-containers for liquid chlorine will be provided adjacent to the alum storage. A scale will be provided for a container in use with loss-of-weight transmitted to the Operator's Office. The necessary piping to the existing chlorinator will be provided.

.14 CHEMICAL STORAGE BUILDING AND TRANSFER SYSTEM - PLANS "A" AND "B".

The present storage room available on the third floor of the main building is inadequate to hold the amount of chemical (lime) needed for a 5 MGD plant. In fact, it is barely adequate at the present time.

We recommend that a storage building be constructed immediately behind the existing wash water tank. This building will have capacity to hold at least two and one-half freight car loads of lime. The structure will be of simple, permanent construction using a concrete slab on grade, precast concrete wall and roof with built-up roofing.

Our recommendation visualizes a palletized operation. Chemicals will be received at the building from trucks. Delivery to Elizabeth City can be by railroad as at present or by truck from the source of supply. With the storage capacity proposed, direct trucking from the source to the plant may prove more economical and flexible.

From the new storage building to the third floor of the main building now used for storage, we propose a belt conveyor for transporting the chemicals. This conveyor would start at floor level in the new storage building and rise over the new alum storage building into the third floor storage room. It would be supported on new footings and structural steel columns and by the alum storage structure.

At the new storage building, the incoming chemicals in bags will be stacked on pallets and moved into the storage area with a fork lift truck. When transfer to the third floor storage room is needed, the fork lift will be used to bring the pallets to the belt conveyor. The bags will be placed on the belt by hand. At the third floor storage room the bags will be removed from the belt and placed on pallets to be moved into reserve storage on that floor or directly to the chemical feeder hopper. A small capacity walkie type fork lift can be used for this operation.

With the proposed system of handling bag chemicals, the labor requirements will be considerably reduced. Further, it will be considerably cleaner at the main building.

As an adjunct to the chemical handling system, we propose to add a bag discharge and dust collector to the existing lime feeder. If this can be accomplished with the existing storage hopper, the release of dust into the storage room will be minimized.

.15 CHEMICAL STORAGE AND FEEDERS - PLAN "C".

The present housing for the liquid alum storage and equipment shelter will be replaced with permanent construction. All chemicals used will be in liquid form and new storage tanks and chemical pumps will be involved. The present chlorinators will be moved to an area adjacent to the chlorine tank storage area and equipped with pumps for forced injection. This plan will eliminate the need for the present dry chemical storage room on the third floor and the chemical feeder room on the second floor. All chemical storage and feeding will be concentrated at ground level. These facilities will be much better than the present facilities for handling and feeding chemicals. They will eliminate the chemical storage and conveying system proposed for PLANS "A" and "B".

.16 ELECTRICAL SYSTEM - PLANS "A", "B" AND "C".

The plant is presently served at 2300 volts, and the main service equipment is oil circuit breakers mounted on slate panels. The 2300 volt service will be replaced with a 480 volt service and the oil circuit breakers with a 1200 ampere high interrupting capacity fused switch and motor control center.

The new 150 H.P. high service pump No. 4 will have a 460 volt motor with auto-transformer starter in the motor control center. The existing high service pumps 1, 2 and 3 will be rewound for 460 volts and No. 3 will be changed from wound rotor to a straight squirrel cage induction motor, one at a time.

The motors now being served at 230 volts will be reconnected for 460 volt service.

The miscellaneous electrical loads for lighting and receptacles will be served through a 480 to 120/208 volt dry-type transformer.

The new 480 volt service will be installed along with the new 300 kw 480 volt diesel engine generator set prior to the removal of the existing engine-generator set.

The existing low voltage wiring will be reworked as required for safety and continuity of service.

6.00 DESALINIZATION PLANTS.

.01 DESALINIZATION PLANT - PLAN "A"

Under PLAN "A" the water from the existing shallow well field plus water from new wells as shown on the map designated APPENDIX "A" will be treated and filtered as at present with a total design capacity of 4 MGD.

As previously noted, it is not possible to renovate the existing filters and upgrade their design capacity without first adding treatment capacity since the present filters are working at or above design capacity.

Since the validity of obtaining additional satisfactory raw water from the proposed well field is open to question, it is our opinion that the supplemental capacity should be obtained through the use of a desalting plant having a capacity of 1 MGD. The supply for this plant unit will be the existing deep wells located near the filter plant. These wells produce water with a chloride content of 500 to 600 ppm. This is comparable to brackish water and can be desalted satisfactorily by either the Electrodialysis or Reverse Osmosis processes.

Should PLAN "A" be adopted, the City could obtain operating experience from the desalting plant which would be helpful in the future if the shallow wells and the proposed wells fail.

A desalting plant can be described as a manufactured unit supplemented with accessories and housed in an extension of the present Filter Building to maintain the appearance of the present plant. We recommend that this building extension be sufficient to have additional units up to a total capacity of 3 MGD should the wells fail and the high chloride water have to be used in the future. Development at this time is still continuing by a few manufacturers. Improvements in the systems will undoubtedly be made in the future which may tend to lengthen the life of the membranes, the efficiency, and possibly reduce the cost. To invest in this process at this time is not assuming too much risk in our opinion.

.02 DESALINIZATION PLANT - PLAN "B".

Under PLAN "B", water from the existing shallow well field will be continued in use in the filter plant which will be renovated as described in Section 4 of this report.

A new well field will be developed around the edge of the Dismal Swamp generally as shown on APPENDIX "C". These wells are expected to produce water having a chloride content range of 200 ppm to 600 ppm with a capacity of 400 gpm, taking water from the 100 foot depth. Water from the two deep wells at the filter plant can be used also.

The new well water will be treated in a desalinization plant having a product output of 3 MGD. The filter plant will continue to produce approximately 2 MGD. The blended water capacity will be 5 MGD.

The desalinization plant equipment will be housed in an extension of the present Filter Building.

7.00 WATER QUALITY

The following tabulation provides data on the quality of raw and finished waters based upon the assumptions indicated at design capacity. Variations from these assumptions must be anticipated in practice. Variations at specific production rates less than design must also be anticipated and should be more favorable than at design capacity.

	Raw Water	Filtered Water	Desalted Water***	Finished or Blended Water
PLAN "A"				
Capacity	5.28 MGD**	4.00 MGD	1.00 MGD	5.00 MGD
Chlorides - Shallow Wells				
Chlorides - Inter. Wells	100 mg/l			
Chlorides		110 mg/l	70 mg/l	106 mg/l
Hardness*	260 mg/l	112 mg/l	160 mg/l	122 mg/l
Turbidity	12 JU	0.7 JU	0.1 JU	0.6 JU
PLAN "B"				
Capacity	5.64 MGD **	2.00 MGD	3.00 MGD	5.00 MGD
Chlorides - Inter. Wells	100 mg/l	110 mg/l		
Chlorides - Deep Wells	600 mg/l		160 mg/l	
Chlorides				140 mg/l
Hardness*		112 mg/l	100 mg/l	104 mg/l
Turbidity	1.0 JU	0.7 JU	0.1 JU	Negligible
PLAN "C"				
Capacity	5.10 MGD**	5.00 MGD	---	5.00 MGD
Chlorides	65 mg/l	0	---	0
Hardness*	45 mg/l	0	---	0
Turbidity	1 to 50 JU*****	0	---	0
Color	250 to 700**** mg/l	3****	---	3

* As $CaCO_3$
** Includes wash water from filters and brine reject from desalting process.
*** Product water (plant effluent).
**** 30 after sand filters; 3 after carbon filters
***** Range of valves during periods of low precipitation and high precipitation

10.00 PROS AND CONS

.01 PLAN "A". This plan is predicated upon obtaining well water of relatively low chloride content. The Guyton report indicates some possibility of this from the intermediate level - perhaps above 75 feet. Any acceptance of this plan must recognize the risk in finding suitable water in adequate quantity to continue the present treatment process up to a quantity of 4 million gallons per day. In our opinion the risk cannot simply be accepted on the basis of proceeding with a full well development program. As Mr. Guyton has recommended, further drilling and testing must be done. This would involve a further extended delay which can ill be afforded.

Assuming that an adequate supply of low chloride water was found, we doubt that there would be any guarantee that it would not fail in the future.

The quality of this supply would not be materially better than the present supply which is a blend of shallow well water and intermediate level water.

The cost of this PLAN "A" is less than the other alternatives, but the treatment cost is the highest of the three. See pages 22 and 27.

There may be one favorable factor in that the introduction of one desalting unit under this PLAN would provide the City with good operational experience with the desalting process should it have to expand this process in the future.

.02 PLAN "B". This plan is also predicated upon obtaining well water but with a higher chloride level. Since the additional well water under this plan will be desalted there is much greater flexibility with desalting units. Further, there does not seem to be much risk in developing such a supply having a 600 mg/l or lower chloride concentration. However, we assume that Mr. Guyton would still advocate additional testing for such a program.

The quality of the blended water (2 mgd filtered plus 3 mgd desalted) would be better than the present water or that of PLAN "A".

The cost of developing PLAN "B" is estimated to be higher than PLAN "A" and the cost of operation lower than for PLAN "A".

While we do not place much emphasis on this point, there are very few desalting installations of this size now in operation.

.03 PLAN "C". This plan is predicated upon successfully developing the Pasquotank Reservoir and the treatment of the highly colored water which would be impounded.

We have no hesitancy about recommending the reservoir subject to two points of caution. First, the reservoir will be in a sandy soil. Percolation between the swamp and Turner's Cut was checked as thoroughly as possible in the 1957 investigation. This check indicates that it will be minimal at the 3 foot head differential. Still, there is no way to be positive that no peculiarity exists in the reservoir area. We think that the risk is very minimal, but should some such condition appear it will have to be dealt with as may then be indicated.

The projections of flow into the Reservoir are conservative in our opinion, but these projections are based on data relating to a similar stream. See page 18 of our 1953 Report. There have been no flow measurements made on the Pasquotank River. The hedge we have here is that the projection of a reliable yield of 10 MGD is double that of the design capacity of the recommended program. Further, there is the possibility of diverting a portion of the lockage water from the Dismal Swamp Canal into the Reservoir should that become necessary.

As to the treatment process recommended, this has been very thoroughly researched by Mr. Moffett and we are confident that the process will be successful in practice as it was in the laboratory. Again, we must caution that success in practice is more dependent upon the quality of operation (personnel and equipment) than for the other plans.

The quality of the finished product anticipated under PLAN "C" should be far superior to that of either of the other plans. This should be a big selling point in promotion of industrial growth, particularly the desirable industries.

The prediction of cost of operation under this PLAN "C" appears to be conservative though cost of chemicals has more influence on this PLAN than on the other two. A generalization of what the future may hold is risky. An examination of cost data seems to favor PLAN "C" over the other plans not only in the immediate future but also in the distant future when a capacity beyond 5 MGD is needed. No additional costs would be required for the raw water supply, whereas, the other plans would call for additional wells, pipelines, etc. The cost of desalting is basically higher than that of production from surface water.

There will be a distinct advantage to water users if PLAN "C" is adopted in that the water will be soft. This quality of water will be considerably better for boiler feed water with less cost to the industrial or commercial customer for conditioning boiler water and less scaling of steam piping and devices. There is no way to evaluate such savings in dollars. Further, the residential consumer should effect a distinct saving in the cost of soap and detergents.

.04 FUTURE OPERATING COST COMPARISONS.

As a general guide, the operational cost for PLAN "A" at full design capacity (5 MGD) might be $775,000 per year over that shown for 1976 (page 27) while the increase for PLAN "C" might be $433,000, a saving of over $300,000 per year in operational cost in favor of PLAN "C".

.05 POSSIBLE ALTERNATIVES. As with any planning as complex as these projects, there are some variations to the basic plans which can be considered after the basic decision has been reached on which PLAN to adopt for implementation. For instance with PLANS "A" and "B", it would be possible to defer some of the wells and associated pipe line until the time that the capacity of 3 MGD is reached. Another is to defer 2 MGD capacity of the carbon filters of PLAN "C" until the capacity of 3 MGD is reached. These alternatives would not change the operating costs, but would reduce the initial capital outlay somewhat. However, should inflation continue as at the present and past rates, the City might well spend more in the long run for the delay.

Another item which can be considered in the design stage for PLANS "A" and "B" is the use of pneumatic handling of bulk chemicals, particularly lime, from rail or bulk truck delivery to ground storage and then transfer to "dry storage" tanks on the present chemical storage floor. This method of handling dry chemicals has an advantage insofar as safety to personnel is concerned, but is more sophisticated mechanically than a belt conveyor.

Still another item concerns the proposed Pasquotank Reservoir. Our original consideration was to remove trees and brush from the entire inundated area. We have subsequently changed this thinking to that suggested by Mrs. Moore in her report and supported by others. These biologists see an advantage in retaining the tree canopy to provide shade. They assert that the existing species will survive the shallow depth of submergence. They will not propogate so future replacement, if desired, will have to come from planting trees. The shade will be beneficial in reducing evaporation and reducing the chances of algae growth. Mrs. Moore reports that there is very little undergrowth which she recommends be removed.

Preserving the trees removes one possible environmental objection since the existing wildlife would not be materially altered.

Another alternative to the total PLAN "C" is to defer the acquisition of the Pasquotank Reservoir land and the development of the reservoir for a short period of time, say five years. Proceed with the remainder of the PLAN with a firm commitment to complete the PLAN. As an interim measure, the raw water pumping station and pipe line to the filter plant would be built along with the filter plant additions and changes indicated for PLAN "C". Water from the River and contributing swamp area would be treated as proposed. While this interim plan appears feasible, there are serious problems which must be recognized in making a decision to adopt such a plan.

The plan assumes that there is an adequate flow in the Pasquotank River to insure delivery of at least 3 million gallons per day of suitable raw water. A review of the J. N. Pease and Company 1953 report, Table 4, indicates that there would have been a period of three months (Sept. - Nov., 1941) when the withdrawal at 3 MGD would have been greater than the indicated inflow; i.e. any withdrawal from the River would have had to come from the saline source or reverse flow from the Sound. In support of this supposition, the reader is referred to page 88 of the 1953 Report and the table showing the chloride content of Knobbs Creek. It is recognized that Knobbs Creek is considerable distance downstream from the proposed intake. However, normal and wind tides, tropical storms and reverse flow might well create a similar condition to that experienced in 1930-32. Such water would be completely unacceptable.

Another reference is at the top of page 167 of the Report and relates to this problem.

Should this interim plan be considered for implementation, it is our opinion that the existing well field, pipe lines and pumping facilities should be kept in standby condition for use in place of the proposed interim raw water facility.

.06 COMMENTS ON THE BOTONICAL SURVEY.

In the conclusions of Ms. Moore's Survey Report, she points out that lakes fill with inorganic and organic materials until they revert to dry land. She is concerned about this as a problem of the proposed reservoir especially since it is shallow.

Her conclusion that this reservoir may fill up within the span of a person's life is founded on data obtained from technical sources concerned with twenty-four reservoirs or lakes in the southeastern states. These reservoirs or lakes are located in the Piedmont area for the most part. The Piedmont area is subject to erosion of soil which the streams carry into the lakes. This is not the case with water in the Dismal Swamp. The Swamp area proper has a cover or "bog" of decomposed organic origin. Below this cover there is sand. Velocity of run-off water is low. Lake Drummond has a sand bottom. An inspection did not reveal any organic deposits except at the immediate edge.

The main canal and the lateral canal to the Lake control works showed some sloughing of the banks which might be attributed to motor boat wakes. There is very little evidence of dredging in the lateral canal. A native who provided the boat used for the inspection could not furnish definitive information on dredging operations. From the evident age of trees bordering the canal, it must have been many years ago.

Why Didn't they contact the corps

no

As pointed out above, the bottom of Lake Drummond is sand. The maximum depth is claimed to be eleven feet. The depth the boat could draw was about one and one-half feet and this was a considerable distance from shore. There are a few old cypress trees in the water, generally within two or three hundred feet from shore. There was no evidence of water weeds in the water.

City Manager Benton investigated Merchants Mill Pond in Gates County. This is a small lake formed by a dam which is similar to that anticipated at the proposed Pasquotank Reservoir. The water depth may be about four feet maximum. The water is, or was, used to power water wheels for mill power. The operators told Mr. Benton that they did have some trouble from water weeds which was controlled by lowering the water level about a foot. Dropping the water level kills the weeds. The same control could be used at the proposed Pasquotank dam if needed.

At Morgan's Corner at the River bridge there is evidence of some water weeds in the open. However, back in the wooded area none were observed. This was in January, 1974 and may not be an average condition. Spot checks for sediment in the River water revealed no inorganics and insignificant organics.

Our opinion is that there should be no concern about the proposed reservoir filling up to a point where it would be of no value as a water supply.

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Process R & D Inc.
3400 Caldwell Drive
Raleigh, NC 27607

March 1, 1974

Mr. George Rawlins
J. N. Pease & Associates
2925 East Independence Blvd.
Charlotte, NC 28205

Dear George:

Pursuant to our recent conversations concerning the overt presents of algae in Dismal Swamp water, I can make the following comments. First, As you know I obtained my samples from the Pasquotank River just north of Morgan's corner. At no time did I observe an algae bloom in the River. This covers erratic sample times from approximately April through August of 1973.

Secondly, at no time did the presents of algae interfere with coagulation during the course of my testing.

I regret the omission of the above. If you so wish, you may pin this letter to my prior report.

Very truly yours,

J. Wm. Moffett

J. Wm. Moffett
President

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APPENDIX "L"

REPORT ON THE BOTANICAL SURVEY OF THE PROPOSED

PASQOUTANK RIVER RESERVOIR

(conducted during the period, December 27, 1973 - January 3, 1974, by Ms. Julie H. Moore assisted by J. Kenneth Moore)

Submitted January 7, 1974

Report on the Botanical Survey of the Proposed Pasquotank River Reservoir

Statement of Purpose and Methods

In consideration of the Pasqoutank River impoundment proposed to supplement the water supply of Elizabeth City, N.C., an on site vegetational survey of the designated area was conducted during the last week of December, 1973. Field observations focused on existing habitats and vegetational composition, the effects of man's past and continuing activity on the area, the presence of aquatic vegetation in the swamp, river, and nearby ditches and ponds. The primary purpose of the observations is to aid in evaluation of the consequences of impounding the area to a depth of 3.0 feet. The survey was conducted by automobile on all accessible roads around and into the area, by foot along drainage canals, power line right of ways, on paths and old logging roads, and by canoe on the Pasquotank River from highway U.S. 17 to the proposed site of the earth dike and dam. Aerial photographs, topographic maps, and state county road charts were utilized during the survey. Extensive review of significant literature was conducted preliminary to and following the field observation portion of the survey (see Bibliography).

Vegetation

The area to be permanently flooded after impoundment by the proposed dam is a typical Cypress-Gum Swamp forest (*Taxodium distichum* - *T. ascendens* - *Nyssa sylvatica* var. *biflora* - *N. aquatica* association). The swamp forest is almost uniform in composition excluding other vegetation except for some shrubs on raised ground along the river edge and in openings of the forest where humus accumulation allows a foothold above the usually inundated surface. Though the swamp is heavily forested with Cypress and Gum, there appears to be no significant amount of merchantable timber left after past timbering operations. On higher ground, chiefly those few areas where the topography is above 3 feet (see accompanying map) loblolly pine

(Pinus taeda) is fairly well established and apparently replacing an earlier, similar stand of pines. This is evident from very sizable pine stumps observed along the remains of the corduroy logging road which traverses the central portion of the proposed area to the river (see map), and this pine area will likely remain a thin penninusula into the shallow impoundment. Several large beech trees (Fagus grandiflora) stand on a very slight knoll along this old road; blackberry (Rubus sp.) and 5-6 year old wax myrtle (Myrica cerifera) shrubs are filling the road itself.

The cypress-gum swamp which is situated between the 3 and 5 foot contours, thus out of the permanent flooding of the impoundment, is distinguished from the lower cypress-gum forest in that this slightly more elevated forest association includes significant numbers of Sweetgum (Liquidambar styraciflua) and Red Maple (Acer rubrum). This more diverse swamp forest association is characterized by an evergreen appearance during the winter resulting from the presence of American holly (Ilex opaca), Sweet Bay (Magnolia virginiana), Red Bay (Persea barbonia), and ericaceous shrubs including Lyonia lucida and Leucothoe axillaris. Scattered throughout are dense entanglements of vines including Poison Ivy (Rhus radicans), Catbriers (Smilax walteri and S. laurifolia), and Cross Vine (Anisostichus capreolata). Pines are scattered on open raised ground throughout.

The most obvious aquatic vegetation in the river is cow lily (Nuphar lutea ssp. macrophyllum) in extensive populations growing from the shore line to a depth of 4-5 feet into the river channel. Duckweed (Lemna perpusilla) and similar floating aquatics, Spirodela polyrrhiza and Wolffiella floridana, cover the river's surface where there is sunlight and no surface movement.

Aquatic vegetation in the swamp forest is limited by the dense shade on the forest floor in the spring and summer and by periodic drying of the usually inundated forest floor surface. Some herbaceous species do grow on fallen logs and on cypress "knees." Various grasses and sedges growing on the tree bases are common where the canopy is somewhat open. Duckweed floats in openings throughout the swamp. Drainage ditches, powerline right of ways, and natural streams provide open sunny habitats for a wide variety of aquatic species. In addition to the same species found in the river and swamp forest, emergent plants such as pond weed (Potamogeton spp.), swamp dock (Rumex verticillatus), mermaid weed (Proserpinaca palustris), water starwort (Callitriche heterophylla), alligator weed (Alternanthera philoxeroides), pennywort (Hydrocotyle spp.), cat tail (Typha latifolia), water velvet (Azolla caroliniana), smartweed (Polygonum spp.), and various grasses and sedges were common in the open wet habitats. A spring and summer survey of the aquatic plants common in the proposed resevoir site would be quite extensive; most aquatics are dormant during the winter months.

Fauna

The number of larger animals and fish in the Dismal Swamp is reported relatively small (Roseberry, 1959 and Teale, 1951). The remainder, head and hide, of a medium sized doe, apparently victim of hunters, was observed along an old road into the swamp. Droppings of rabbit and unidentified droppings of other small game were observed as well as tracks of raccoon. Bird life included hawks and common species including crow, robin, catbird, tufted titmouse, red-wing blackbird, and red-bellied woodpecker. Large and small nests were present with moderate frequency throughout the swamp forest. Unquestionably, the swamp environment provides habitation for a wide range of animal life. Considering the season, the animal life observed was not representative of the true diversity of the species indigenous to the area.

Lake Construction

The most critical environmental change in the creation of a lake by impoundment of a river is that a moving water system becomes a self-contained, static system. All lakes, natural or man-made, are destined to fill with organic and inorganic deposits and eventually disappear. Essentially, the substratum builds up by accumulation of inorganic and organic sediments, the water table is lowered, plants move in, and ultimately a lake is replaced by a forest. The rate of sedimentation in lakes is not uniform. The rate of disappearance of man-made lakes depends on many variables including depth of water, geographical location, soil type, seasonal inflow of sediment-bearing waters, existing vegetation of peripheral areas, and aquatic vegetation of the body of water itself (Reid, 1961).

The singularly most critical factor determining the life span of the proposed Pasquotank Reservoir is the shallow depth, not over 3 feet except in the currently existing river channel. With this significant factor in mind, two alternatives exist for the creation of a lake at the proposed site.

Alternatives

The first alternative is to completely clear the basin of vegetation. Needless to say, this would completely destroy the non-migratory elements of the fauna. Complete clearing would also open the area to maximum sunlight, a major requirement for most aquatic vegetation. Immediately after inundation aquatic plants would begin to invade the shallow water. The existing aquatic vegetation of the river and of the streams and ditches draining into the lake will provide an immediate source of seeds and vegetative material to colonize the newly created water basin. Normally the establishment of plant life in lakes progresses in distinct stages. The depth of the water limits the habitats available for rooted species physically and by determining the depth of light penetration. Floating, non-rooted vegetation is not limited by depth, but rather by availability of nutrients in the water and physical factors such as abrasive currents and sunlight.

Since the proposed impoundment will be very shallow, it is extremely likely that rather than having a zone of vegetation confined to the shore line, the entire lake will be covered by or filled with aquatic plants. Rooted aquatics hasten the filling of lakes by depositing great volumes of organic material, and their root systems trap and bind sediment draining into the lake. The area surrounding the proposed reservoir is actively farmed and many of the drainage ditches which allow cultivation flow directly into the Pasquotank River. Consequently seasonally heavy sediment loads will aid development of a higher substratum in the impoundment. Another problem to be considered is the possibility of excessive vegetative growth due to fertilizer run-off from the adjacent farms. Heavy, dense mats of vegetation could result which can shield underlying water from sunlight, thus inhibiting organic production. In summer, water under such mats has been found to be very low in oxygen; if this condition is severe, death of various aquatic organisms including fish could result(Reid, 1961).

Without employing continual lake management techniques, an open, shallow lake will have a relatively short life span. It is not possible to calculate the life of such a lake in years without extensive regional data, though it seems reasonable to assume, following the normal pattern of natural succession, a significant reduction in size, and thus a reduction in the water-storage capacity of the lake would clearly be observed during a life time (Welch, 1952).

The second alternative to be considered is the possibility of flooding the area without clearing the site first, that is, flood the existing Cypress-Gum swamp. Though the few pines that are scattered through the swamp would be killed by the permanent high water, the Cypress-Gum association would be able to survive. According to observations by DeMaree (1932) cypress can tolerate permanent flooding to a depth of 6 feet. It was assumed for many years that the "knees" of cypress were essential for uptake of oxygen from the atmosphere since the oxygen content of the swamp muck was low due to saturation. Recent investigations show that there is little evidence for this assumption but suggest no other function than physical support. Cypress growing in very deep water do not produce "knees." In instances where the "knees" have been permanently flooded, these structures do not continue to grow, and the trees have shown no adverse effects (Whitford, 1956). Submergence of mature gum for long periods has been observed to have little effect on their growth (Hook et al., 1971), but no reference to permanent flooding of gum forests could be found.

Though it appears that mature cypress and gum can withstand permanent flooding, neither can reproduce itself unless their seeds can germinate on an exposed soil surface. Seed of both trees remain viable for long periods while in water, but do not germinate until they contact unflooded soil. Extensive research on 1 and 2 year old seedlings of both cypress and gum has shown that complete submergence is lethal and that partial submergence may be either lethal or have stunting effects (DeMaree, 1932 and Hook et al., 1971). To maintain a permanent Cypress-Gum forest in the impounded lake, it would be necessary to plant young trees that are sufficiently tall to be above the high water level. This would not be necessary, however, until the currently existing trees begin to die.

Shading of the lake surface by the dense tree canopy would retard growth of aquatic plants and delay filling of the lake. If the canopy were opened by death (the Cypress-Gum species would continue to mature through their normal life span many years prior to their eventual death) or removal of trees, allowing sunlight to strike the water surface, aquatic species would quickly invade the area. Swamp tree species would not reproduce in these flooded openings, and though other tree seeds may germinate in the water, they could not survive under permanent flooded conditions (Hosner, 1958). Consequently, a series of aquatic plant stages would be initiated, accelerating the eventual disappearance of the lake.

There are several advantages to creating a shallow lake without clearing the area. The presence of a Cypress-Gum forest shading the lake surface prolongs the life of the lake by retarding the succession pattern that would lead to a rapid reduction in size of the lake. If cypress and gum trees were planted to perpetuate the forest, this process would be delayed even more. The existing fauna of the region would not be destroyed or as upset as in the case of a completely cleared basin. The terrestrial swamp fauna would have to migrate minimal distances to the outer edges or to islands within the impoundment to adjust to a permanently flooded situation, and much of the bird and other tree top fauna would not be dangerously upset. The expense of maintaining such a lake would probably be less than the cost of clearing the lake basin followed by the additional expense of necessary maintenance to keep aquatic vegetation to a minimum.

Conclusions

The most significant factor in creating the proposed Pasquotank River Reservoir is that the lake will be extremely shallow. In their study for installation of water-supply systems, Wagner and Lanoix recommend "...that the depth of water in a small reservoir at the deeper end should be not less than 1.8 m (6 ft)." (Wagner and Lanoix, 1959). Though all lakes eventually fill with inorganic and organic sediment and a forest exists where a lake once was, this process can take many thousands of years. But in the case of very shallow lakes, this process is greatly accelerated for the entire lake bottom is immediately available for colonization by aquatic species if the substratum is not sterile and if sufficient sunlight is available.

Whether the lake site is cleared before inundation or not, a shallow lake of the proposed dimensions has a much shorter life span than a deeper lake in which many decades of sedimentation are necessary to raise the substrate prior to invasion by rooted plants. No information relevant to actual rates of filling and extinction of lakes could be found, though according to Welch (1952) "... in some instances, particularly in small, shallow lakes, a human life span is more than ample for witnessing the passage of lake ... into relatively dry land." It is difficult to consider the proposed Pasquotank River Reservoir as a lake capable of providing a long term water supply for a growing city.

If the proposed project is completed, maintenance programs will be required to prolong the life of the lake. Surveillance of the lake margins will be necessary to halt the frequent dumping of trash which is currently taking place in numerous sites in the proposed basin area. In addition, potential problems of fertilizer, human and livestock waste, and other sediment run-off from surrounding farm lands must be considered in terms of enforced control and continued surveillance.

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