Legal and Institutional Barriers to Municipal Wastewater Reuse in Virginia Beach, Virginia

by

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Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF URBAN AND REGIONAL PLANNING

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July, 1982
Blacksburg, Virginia

ABSTRACT

LEGAL AND INSTITUTIONAL BARRIERS
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The availability of water is one of the key elements of urban and rural development. The Western United States has dealt with the problem of inadequate water supply for many years; in recent years the concern over ways to meet the water needs of growing populations and industries has been nationwide.

This thesis is built upon the concept that municipal wastewater reuse is an increasingly important option in the development of new water supplies and that there are four identifiable factors which affect the evolution of reuse applications. In opening chapters the nature of wastewater reuse and its applications are reviewed; technological, economic, social acceptance, and legal-institutional issues are discussed as the major factors affecting the use of reclaimed wastewater.

The preliminary hypothesis of this thesis is that legal and institutional factors are critical obstacles to the reuse of wastewater in satisfying municipal water demand in the State of Virginia. The objective of this thesis is to explore this preliminary statement and generate some information on the nature of legal and institutional factors in Virginia. The City of Virginia Beach is used as a case study because of the City's active interest in water supply and reuse issues, and because of the availability of information.

The State level decision making context within which Virginia localities operate in the areas of water supply and sewage treatment is covered and the institutional and legal issues involved in Virginia Beach's recent reuse proposal are discussed. It is concluded that the hypothesis appears to be supported by the evidence available in Virginia Beach; however, the institutional and legal factors are strongly influenced by State agency perceptions of public health and technological uncertainties in the reuse field. Recommendations for further study are presented in the final pages.

ACKNOWLEDGEMENTS

I would like to thank the members of my committee, John Randolph, Sara Rosenberry, and David Conn, for their direction in the development of this thesis. I would also like to thank Debbie Lindsay for her technical assistance. Finally, special thanks are due to Chris Villanis for her unfailing support and willing help with hole punching, paper stapling, and all the other activities which are often a part of writing a thesis.

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Chapter I

INTRODUCTION

Development and Justification of Study.

This thesis investigation into the legal and institutional barriers to municipal wastewater reuse in Virginia Beach, Virginia, has developed out of three concerns. First, there is the nation-wide concern over how to satisfy water supply needs for growing populations and increasing standards of living. In 1978, the U.S. Water Resources Council concluded that, overall, the nation's water supplies are generally sufficient to meet requirements; however, there exist major water supply problems in most of the nation's 21 water regions and severe local problems in many of the 106 subregions [Culp et al., 1980].

There is no one cause for these water supply dilemmas. Shortages have occured from inadequate distribution systems, ground water overdrafting, pollution of both surface and aquifer supplies, competition between various uses, and increased population growth. As a result, many urban areas, in particular, are coming up with fewer and fewer answers to the water supply question.

The second fact is that the potential for use of reclaimed wastewater in meeting water supply needs is increasing. The distribution of high quality water for domestic uses does not always match the distribution of needy populations. Many of our wastewater effluents are already of a high quality and most are wasted as a water supply source. Therefore, the potential of wastewater reclamation to meet urban water needs is being researched world-wide.

Even without potable reuse (though more so with it) development of wastewater renovation can play a significant role in meeting future water needs. In some regions and cities, reuse will prove to be the optimal solution to satisfying demand. With it will ccme other benefits such as the elimination or reduction of wastewater discharges and the reduction of areawide energy requirements.

Finally, the third fact is that there is a lack of information on the legal-instituitonal factors of reuse development. General research indicates that legal and institutional constraints may be a leading obstacle to development but the available literature is limited. The probable reason for this is that the United States experience with municipal reuse is itself limited and interest in legal and institutional factors as a research subject has been correspondingly low. Of the information available, researchers have focused their attention on the Western United States where the appropriation and use of water has tended to be a more complicated and more immediate social issue.

The Eastern United States, not immune to water supply crises, has little basis for appropriate policy development and further study in the wastewater reuse area. This study attempts to outline the legal and institutional obstacles to reuse as found in one mid-Atlantic case study. The intent is to develop a basis upon which future systematic research could be built.

Research Scheme.

The preliminary hypothesis in this investigation is that State legal and institutional factors are a critical obstacle to the reuse of wastewater in satisfying municipal water demand in the State of Virginia. This hypothesis, based on literature review and intuition, was designed to be "developed" rather than "tested" through this study. In other words, if this hypothesis proved to be a reasonable statement based on a limited case study, then the hypothesis could be tested using a representative sample of localities. The role of this investigation in overall research in displayed in figure 1.

The case study approach is prefered to an aggregate data approach in this case for the reasons that (1) detailed information is available only for very few jurisdictions, and (2) the data tends not to be in a form which could be readily collected and analyzed.

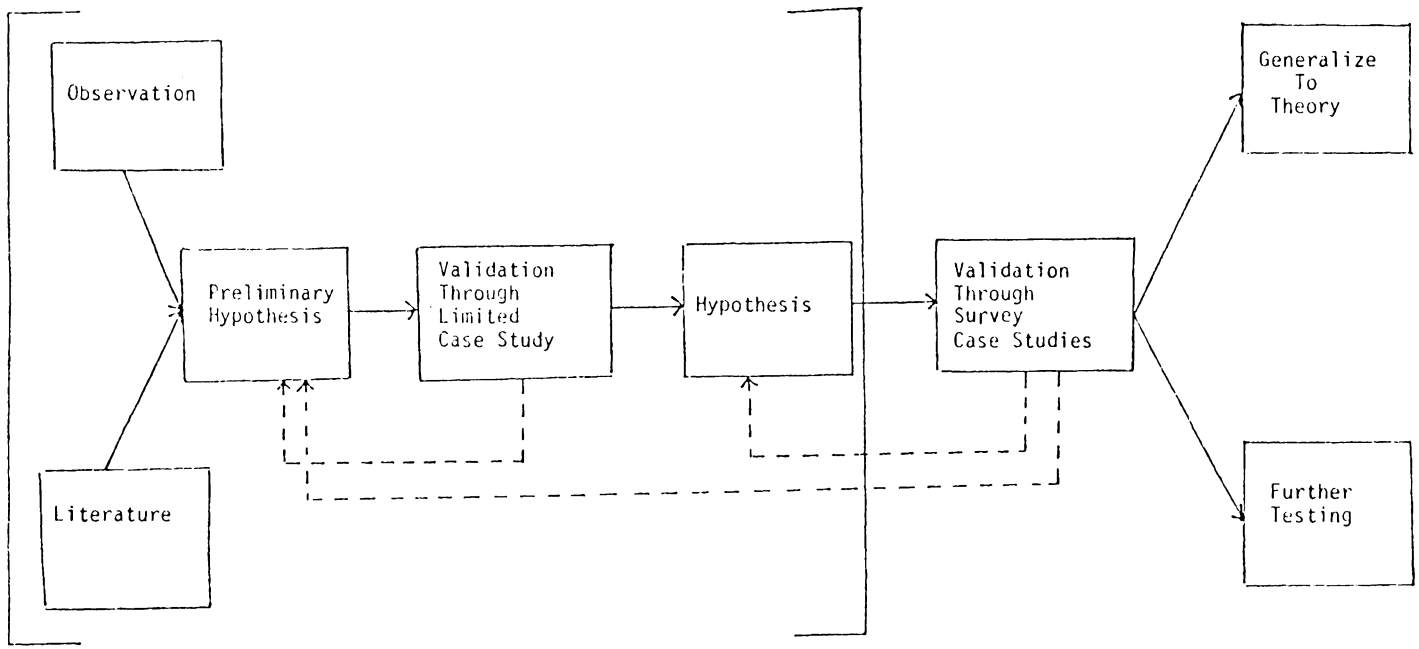

Figure 1. Role of this thesis in research.
Hypothesis development involves the first half of this research scheme.

If further testing of this hypothesis were to be conducted, the case study approach would still be prefered since the hypothesis deals with the process by which wastewater reuse is developed; the elements of such a process are not easily quantified.

The City of Virginia Beach, Virginia has been chosen as a "case study" city for two reasons. (1) The City is in critical need of a dependable water supply for its growing population; safe yield of existing supply is projected to be reached during the 1980's. (2) The City has been active in assessing its water supply options.

This Virginia Beach case study is meant to elicit the critical effects of legal and institutional factors related to State requirements on potential wastewater reuse programs. Though this investigation is limited to one locality, it is assumed that all other jurisdictions in Virginia fall under the same state statutes and regulations. Therefore examining the legal and institutional factors involved in pursuing wastewater reuse in Virginia Beach can give an indication of what effect these factors would have statewide. However, not all conclusions extracted from the Virginia Beach situation can be unconditionally applied to other jurisdictions because of the effect of possibly varying local ordinances and policies.

Recommendations for the study of potential municipal wastewater reuse applications in Virginia and for more general research into the obstacles to reuse development are given. The study concludes with a revised hypothesis which states that incomplete knowledge and the lack of confidence in public health aspects of potable reuse are the critical obstacles to wastewater reuse development as a water supply in the State of Virginia.

Methodclogy.

The investigation involves a general review of wastewater reuse literature, an analysis of the legal and institutional factors affecting wastewater reuse in Virginia, and a case study of Virginia Beach. Sources of data in this thesis involve literature and interviews.

A review of literature in the field of wastewater reuse provides background information on the nature of and extent of reuse in the United States. Documentation of specific reuse programs and studies prepared for reuse program proposals provides information on the type of legal and institutional factors experienced in other parts of the Country.

Documents of the State of Virginia provide information on the current legal and institutional framework for wastewater reuse within which Virginia localities must work. An example of this type of material would be the Code of Virginia.

Case study documents specific to Virginia Beach include the Virginia Beach Water Position Paper and the Malcolm Pirnie, Inc. Water Reuse Assessment. Such materials lay a foundation for the case study and fill gaps of information left from interviews.

Interviews with state and local officials serve as a method of gaining information on the wastewater reuse situation in Virginia and the City of Virginia Beach. Discussion with State officials provides information on current regulation and on the State's perspective of reuse from a policy point of view. Interviews with local officials afford a direct source of information on the water supply situation in Virginia Beach, on the analysis process recently completed to review supply options, and on the legal and institutional factors the city has encountered in investigating the wastewater reuse option.

Interview structure varied based on the agency contacted. In the majority of cases, an individual was contacted more than once because new questions were raised as more information was gained.

Major parties in consideration of this problem were identified as follows:

a) City of Virginia Beach
b) Virginia Health Department
c) Hampton Roads Sanitation District

Secondary parties were identified as follows:

a) State Water Control Board
b) Southeastern Public Service Authority

Contacts made during research include the following:

a) Eric Bartsch; Virginia Health Department
b) Allen Hammer; Virginia Health Department
c) Aubrey Watts; Virginia Beach Department of Public Utilities
d) Tom Leahy; Virginia Beach Department of Public Utilities
e) T. Piland; Virginia Beach Department of Public Utilities
f) Ed Born; Virginia Water Reseach Center
g) Donny Wheeler; Hampton Roads Sanitation District
h) Dale Jones; State Water Contrcl Board

Format.

This thesis is organized into six chapters which move from a general discussion of wastewater reuse to the specific Virginia Beach case study. Chapter II reviews the forms of wastewater reuse currently practiced in this country and is meant to orient the reader to the subject. Chapter III describes the range of factors identified as affecting wastewater reuse. Technological ability and the public health issue, the economics of reuse and methods of financing, public acceptance, and legal and institutional issues are discussed.

The State of Virginia's role in regulating water supply and wastewater treatment, which dictates the decision making context for localities on the subject of wastewater reuse, is covered in chapter IV. In chapter V, the City of Virginia Beach's water supply situation and the legal and institutional factors affecting the potential use of direct potable reuse in the City are examined. Chapter VI is made up of conclusions on the affect of legal and institutional factors on the development of reuse in Virginia Beach and the State of Virginia, and of recommendations for further State action and study.

Chapter II

WASTEWATER REUSE: A SURVEY OF APPLICATIONS

This chapter lays the foundation for understanding what wastewater reuse is, how it can be applied, and what technological and public health problems exist. The major reuse markets are surveyed through descriptions of current applications, technologies, and limitations. It is concluded that some of the more significant benefits from reuse may come from the least developed reuse market - that of commercial and residential non-potable and potable applications.

What is Wastewater Reuse?

Wastewater reuse is quite a simple concept. It is the process of collecting wastewater and treating it for additional use. A 1978 study by the United States Water Resources Council identified over 500 reuse sites in the United States using a total of 680 mgd (million gallons per day) of reclaimed water [Culp et al., 1980]. An important distinction to be made is between planned and unplanned reuse. Planned reuse is the treatment of wastewater with the intent that the reclaimed water be used for other purposes. This type of reuse is the focus of discussion in this paper. Unplanned reuse is the very common result of treated wastewater being discharged to a watercourse which becomes the drinking water supply a few miles downstream.[1]

Current interest in water reuse has developed through concern over water supplies for human activities and consumption. Table 1 displays the rationale and benefits associated with reuse as viewed from the community level. Beyond the benefits associated with water supply, von Dohren [1980] points out that wastewater reuse can eliminate or reduce pollutant discharges and can reduce area wide energy demand. On one hand, reuse can be seen as a process of substitution; that is, replacing potable (drinkable) water used for nonpotable purposes with reclaimed water and thereby increasing the population which can be served from an existing source. On the other hand, reuse might be seen as additive; that is, supplementing potable supplies with appropiately treated reclaimed water.

The least controversial of these two modes of reuse is reclaimed water as substitute for non-potable sources. The many practical uses for this water include agriculture, industrial processing and cooling, landscape irrigation, recreation, and residential fixtures - toilets, for example (see table 2).

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[1] Swayne [1979] states that one-third of the United States population already drinks water containing treated wastewater; Reynolds [1977] estimates that the amount of treated wastewater in drinking supplies varies from 3 percent to 20 percent.

Table 1.

RATIONALE AND BENEFITS OF MUNICIPAL WASTEWATER REUSE.

In Communities Where...

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* Freshwater supplies are limited,
* Freshwater supplies of good quality are limited by surface or groundwater pollution,
* New freshwater supplies must be developed at increasing distance from and/or expense to the community,
* A single large water user or class of users can tolerate a lower grade of water provided at reasonable costs, and/or
* Receiving water requirements are such that costly wastewater treatment facilities must be built...

Wastewater Reuse May Offer Some Very Real Community Benefits...

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* An increase in total available water supply,
* Conservation of highest-quality supplies for potable use and other uses that demand that quality,
* Expansion of beneficial industrial/commercial, agricultural or recreational opportunitiesin your area, and/or
* Obtaining of capital and operating economies in your water management program.

Adopted from Donovan and Bates, 1980.

Table 2.

POTENTIAL MARKETS FOR RECLAIMED WATER.

<u>Groundwater Recharge</u>
Water-table management
Development of salt-water intrusion barrier
<u>Recreational/Environmental</u>
Lakes and ponds
Marsh enhancement
Streamflow enhancement
Fisheries
Snowmaking
<u>Agricultural</u>
Crop irrigation
Commercial nurseries
Commercial aquaculture
<u>Nonpotable Urban</u>
Landscape irrigation
Fire protection
Air conditioning
Toilet flushing
<u>Industrial</u>
Cooling
Boiler-feed
Process water
Construction uses

Adopted from Donovan and Bates, 1980.

Wastewater Treatment Basics.

Advanced treatment technologies and processes now exist which can be applied to wastewater to bring it in compliance with stringent pollution control requirements and to provide high quality water for many reuses. The principle processes involved are chemical treatment, nitrogen removal, ion exchange, filtration, activated carbon adsorption, reverse osmonsis, and disinfection. An example system is displayed in figure 2. The exact treatment train will vary based on the intended use of the wastewater being treated. The major processes and the contaminants they remove are outlined in table 3. Detailed descriptions of these processes can be found in Hammer [1975], Culp et al. [1980], and Gillies [1981].

These advanced processes follow primary and secondary treatments. After primary screening and settling, secondary biological treatment (either a trickling filter or activated sludge) is employed. A well treated secondary effluent can be widely used in industries for cooling, and for irrigation of most crops and landscaping. Secondary treatment processes remove significant amounts of suspended solids, organics, and microorganisms, but not phosphorous, nitrogen, or salts.

Natural solids and those formed by chemical treatment must be removed. Sedimentation by gravity is the simplest

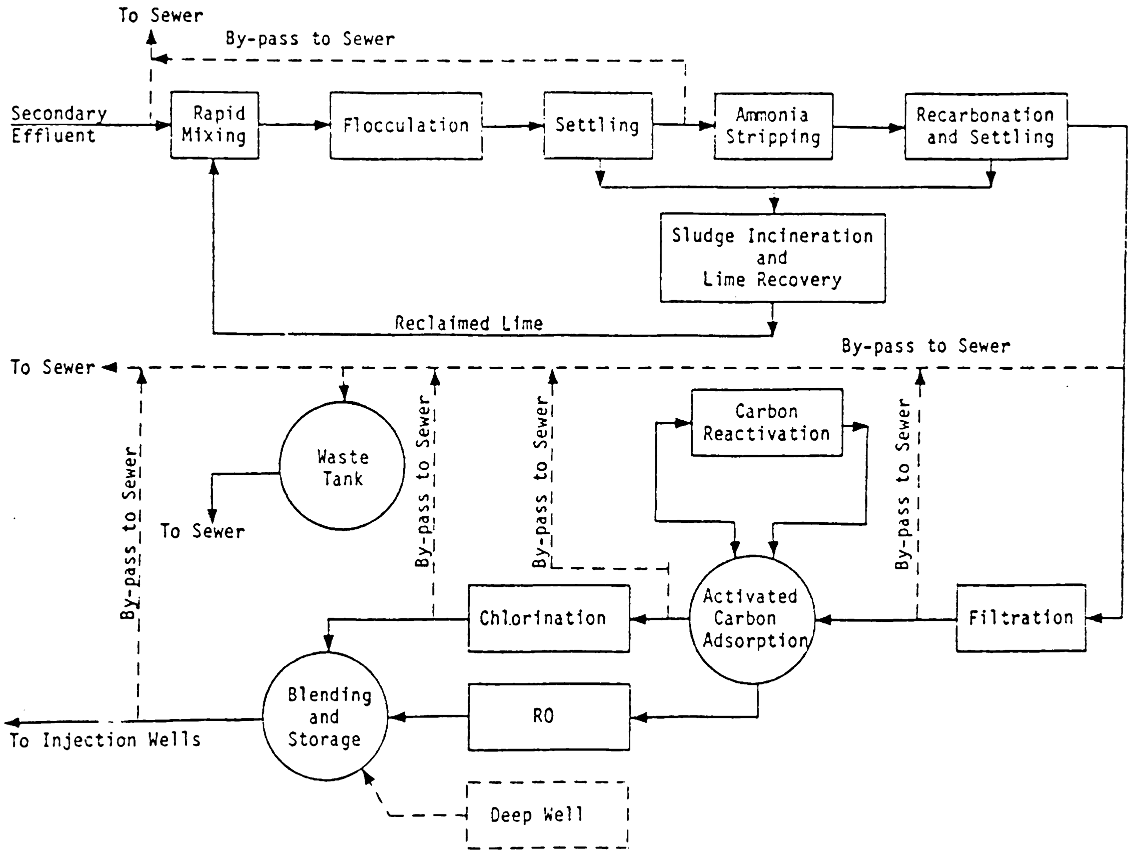

Figure 2. Water Factory 21 Reclamation Process Flow.*

Water Factory 21 is an Orange County (California) Water District project, the treatment train of which is displayed here as an example. The water produced from the "factory" is currently used to halt saltwater intrusion into local groundwater basins; it is expected that in the future, reclaimed water from the factory will become a major source of water in Orange County.

From Culp et al., 1980

* Figure is from Cline (1979), pg. 160.

Table 3.

TREATMENT PROCESSES USED FOR RECLAMATION.

Process	Principle Contaminants Removed
Primary Sedimentation	TSS, BOD, grease, oil
Activated Sludge	BOD, COD, TSS, grease, oil, some heavy metals
Nitrification	BOD, COD, TSS, ammonia, some heavy metals
Denitrification	Nitrate
Trickling Filter	BOD, COD, TSS
Rotating Bio-Contactor	BOD, COD, TSS, ammonia, some heavy metals
Filtration	TSS, turbidity
Activated Carbon Adsorption	BOD, TSS, coliforms, TOC
Chemical Coagulation/ Flocculation	BOD, COD, TSS, phosporous, some heavy metals
Ammonia Stripping	ammonia
Selective Ion Exchange	ammonia, TSS
Reverse Osmosis	TDS
Chlorination	coliforms
Ozonation	coliforms, color, tubidity
Land Treatment	BOD, COD, TSS, ammonia, phosphorous, oil, grease, coliforms

From Williams et al., 1979.

form of removal and requires sludge removal facilities. Even after settling devices are used, fine materials will remain in the wastewater; additional straining or filtration may be required. Commonly a "rapid sand" filter is used for this. More recently, however, mixed media filters have been employed. Some simply use a graded media while others consist of anthracite coal on top of a sand bed. Microscreening devices may also be used; diatomaceous earth filters are often used for industrial applications [Middleton, 1977].

Nitrogen is removed through nitrification-denitrification processes or if it is in the form of ammonia, by either air stripping or chlorination. Ion exchange, more commonly used to remove calcium and magnesium cations, can also be used in N removal. If the wastewater is to be used for agricultural irrigation, nitrogen need not be removed since it is a nutrient. In recreational applications, however, nitrogen may stimulate overgrowth of algae and other aquatic plants, and/or be toxic to fish. Nitrogen as ammonia needs removal for industrial applications also since the ammonia will corrode copper and brass equipment.

In reclaiming water for potable or near-potable uses, the dissolved organics concentration needs to be as low as possible. After the normal treatment has been applied, organic materials can be reduced by passing the water through a bed of activated carbon or by treating the water with powdered carbon. Reverse osmosis is another process that is sometimes incorporated because of its high efficiency removal of almost all inorganic, organic, and biological constituents [Gillies, 1981].

Disinfection is the last process and is used to combat remaining microbial contaminants. Hypochlorous acid (chlorine's most effective disinfection form) is used to destroy pathogenic microorganisms; coliform and enteric bacteria are most easily killed, while protozoal cysts and enteric viruses tend to be more resistant to chlorine [Hammer, 1975].

Ozone has been found to be a powerful oxidizing agent for disinfection. Though ozone reacts quickly and does not impart taste or odor to potable water [Gillies, 1981], it has not been favored for use in the United States because ozone lacks the residual disinfecting power of clorine and because ozone must be generated on-site. Another method of disinfection involves radiation; a small scale purification system developed in Colorado employs ultraviolet sterilization for this purpose [Mankes, 1979].

The physical and biological treatment processes all produce waste material. "In wastewater reuse systems, it is of vital importance to plan for use or disposal of the residues remaining after treatment. Their handling and disposal costs may be half the total cost of treating wastewater" [Middleton, 1977]. Combined primary and waste-activated sludges most often go to an anaerobic digester where the materials decompose to a more stable substance. The methane and carbon dioxide produced will be vented or the methane can be burned for heat. Digested sludges are dried by mechanical filters or on sand beds; the dried sludge may be incinerated, dumped in a landfill, or spread onto land as a soil supplement [Middleton, 1977].

<u>Agricultural Reuse</u>.

Reusing municipal wastewater for irrigation is the oldest and largest form of reuse. Advanced treatment is not always required depending on the particular application and needed water quality (cotton, for instance, can be irrigated with wastewater having only been through primary treatment). (Appendix tables 1 and 2.)

Noy [1977] outlines the advantages and disadvantages of using treated wastewater for irrigation (tables 4 and 5). He explains that wastewater is often the cheapest water available in arid areas; in some cases, it may be the only water available for irrigation. Though the required health standards are typically less stringent for irrigation than other uses, the necessary treatment is important in calculating costs. The major cost, however, is in transporting the water.

Since there are seasonal variations in the use of water for some agricultural industries (eg. fruit and vegetable canning), there is a need for efficient storage on both an operational and seasonal basis. Ponding is the most obvious answer to this need; however, groundwater recharge and subsequent pumping can be used. It has been found that the latter mode significantly improves water quality since perculation removes some undesirable suspended and soluble constituents [Noy, 1977].

Sprinklers are the most common method of application. Where only primary treatment has been used, sprinkler nozzles may clog; few such problems have been associated with secondary treated effluent. Unpleasant odors may prevail where sprinkling is used and mosquito and horsefly breeding has occurred in sewage puddles; these nuisances diminish with increased levels of treatment [Noy, 1977]. Trickling irrigation is now used more extensively in a number of countries. This method is especially effective in arid areas since it saves on water consumption and increases crop yields. Another benefit is that the contact between the treated effluent and the crop is lessened and this reduces the possible contamination of crops by pathogens.

Table 4.

ADVANTAGES IN THE USE OF TREATED WASTEWATER FOR IRRIGATION.

---

1. low-cost source of water
2. an economical way to dispose of wastewater to prevent pollution and sanitary problems
3. an effective use of plant nutrients contained in wastewater
4. providing additional treatment before being recharged to the groundwater reservoir

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Adopted from Noy, 1977.

Table 5.

POSSIBLE DISADVANTAGES IN THE USE OF TREATED WASTEWATER FOR IRRIGATION.

1. the supply of wastewater is continuous throughout the year, while irrigation is seasonal and dependent on crop demands
2. treated wastewater may plug nozzles in irrigation systems and clog capillary pores of heavy soils.
3. some of the souble constituents in wastewater may be present in concentrations toxic to plants
4. health regulations restrict the application of wastewater to edible crops
5. when wastewater is not properly treated, it may be a nuisance to the environment

Adopted from Noy, 1977.

Water quality is of concern to irrigators. Treated domestic effluent and industrial wastes may contain soluble constituents at concentrations toxic to plants. Some industries may add heavy metals at concentrations which are toxic to the plants or the animals feeding on them. Other wastes may contain organic compounds such as organic acids or phenols that restict root zone biological activity [Noy, 1977]. In California, the bacteria standards are most stringent when reclaimed water is sprayed on food crops. Arizona also requires various levels of bacteria removal based on the type of agricultural use. Secondary treatment and disinfection are often required [Donovan and Bates, 1980].

The effect of TDS (total dissolved solids) or salinity is one of the most important water quality considerations in agriculture. Salinity will cause a change in the osmotic pressure of the soil solution which is related to the availability of water for plant consumption. A "physiological drought" condition can occur [Everest and Paul, 1979]. Water quality recommendations for irrigation can be found in Appendix tables 3 and 4.

Recreational Reuse.

Donovan and Bates [1980] describe the various "recreation and environmental" applications of reclaimed wastewater as ranging from maintenance of landscape ponds (eg. on golf courses) to full scale water-based recreation sites for swimming, fishing, and boating. Other uses include snowmaking and the creation of marshlands.

Wastewater used in recreational lakes must satisfy both health standards and standards that will make the lake acceptable from a recreation standpoint [Middleton, 1977]. A treatment train is recommended in California for each type of recreational water reuse; the recommendtion is linked to the degree of body contact involved in each use. Secondary treatment and disinfection are required for reuse in landscape ponds. More stringent disinfection is required for recreational bodies where fishing and boating are permitted. Finally, secondary treatment followed by coagulation, filtration, and disinfection are required for water bodies allowing wading and swimming. (Appendix tables 1 and 2.) The control of nutrients - phosphorous and nitrogen primarily - is essential where excessive algae growths would interfere with the intended use of the site [Donovan and Bates, 1980].

Most of the recreational reuse facilities in the United States are found in California [Donovan and Bates, 1980]. A hypothetical treatment system is displayed in figure 3. A primary example is the Santee Lakes project in which reclaimed wastewater from an aquifer constitutes the major water supply for the lakes (infrequent heavy rains supplement-ed by natural groundwater and runoff also contribute). The project has developed to the point of being used for a swimming area [Ongerth and Jopling, 1977]. (Appendix figure 1.) Other large and successful reuse projects include Lake Tahoe in northern California and Apollo Park in Los Angeles.

An interesting wetlands project in the San Francisco has met with success. As described by Denigen and Nute [1979], losses of wetland habitat in the area have resulted in significantly reduced populations of wildlife and migratory waterfowl through the Bay region. In 1974, the Mountain View Sanitary District (near Martinez, California) started a full scale pilot wetlands enhancement program on low lying reclaimed tidelands owned by the district. The purpose was to demonstrate the feasibility of using treatment plant effluent to create a wetlands environment.

Industrial Reuse.

According to Donovan and Bates [1980], reuse of reclaimed water for industrial and large scale commercial applications is one of the most underexploited market areas in the United States. Industries can often tolerate water of less than drinking water quality and are often centrally located near populated areas that generate wastewater. Reuse, then, can be an acceptable response to industies' concern over diminishing water supplies, and a good way of preserving higher

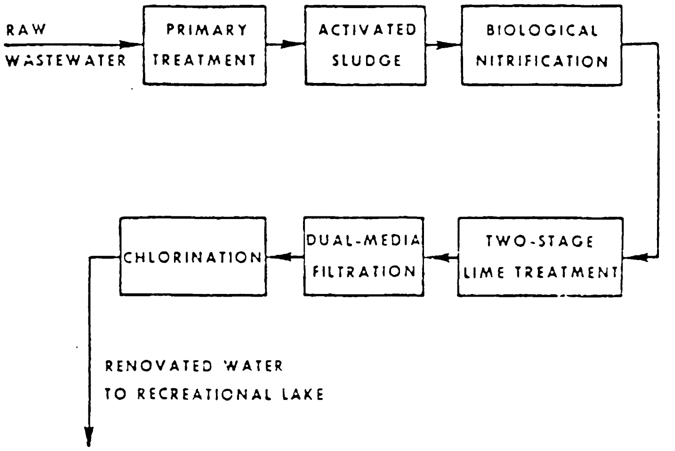


Figure 3. Treatment System for Producing Recreational Lake Water.

From Middleton, 1977
pg. 25

quality water for other urban uses. The technologies incorporated in an industry to facilitate water reuse must be cost effective and not interfere with plant processes [Kosarek, 1979].

Cooling is the predominant application of reclaimed water, accounting for 99 percent of the total reported volume of industrial reuse. Industries use either a once-through or a recirculating process. With once-through cooling water only minimal treatment is required; course screening and periodic shock chlorination for slime control can be applied. With the recirculating process, the same cooling water makes many cycles; cooling towers or spray ponds are used to re-cool the water after each heat-exchange cycle. A portion of the water is continuously "wasted" in order to avoid the build up of contaminants. This quantity is replaced with make-up water which must be of high quality since contaminants concentrate in the cooling cycle and/or nutrients provide food for the growth of organisms [Donovan and Bates, 1980].

A second major use of reclaimed wastewater is as boiler-feed water. Many industries, however, have not found this economical because of the additional treatment requirements. Reclaimed water is often used as "process water" in processes particular to the various industries.

Prominent water reusers are power plants. In power generation, reclaimed wastewater can be applied to boiler make up, NOx and SO2 scrubber make-up, cooling tower operations, turbine cooling injections, and potable sources for employees. In petrochemical processing, water is reused in boiler make-up, process waters, cooling waters, cooling tower make-up, and product wash water. The mining industry has found reclaimed water useful for metal leaching solutions, ore washing, floatations, process water, and boiler make-up [Kosarek, 1979]. Typically, the water being applied in these instances is from secondary municipal wastewater treatment plants or from tertiary ponds filled with surface runoff and treated wastewater (figure 4). Secondary effluent followed by further treatment by coagulation, sedimentation, sand filtration, foam fractionation, and carbon adsorption has also been recycled by the paper and pulp industry in manufacturing processes [Roy and Chian, 1979]. Table 6 displays the additional treatment processes typical of industrial water reuse.

There are four major industrial problems associated with sewage contaminants. Calcium phosphate deposits can cause scaling; lime treatment is generally used to remedy this. The potential for bacterial slime and algae growths require shock chlorination treatments. Ammonia content may inter-

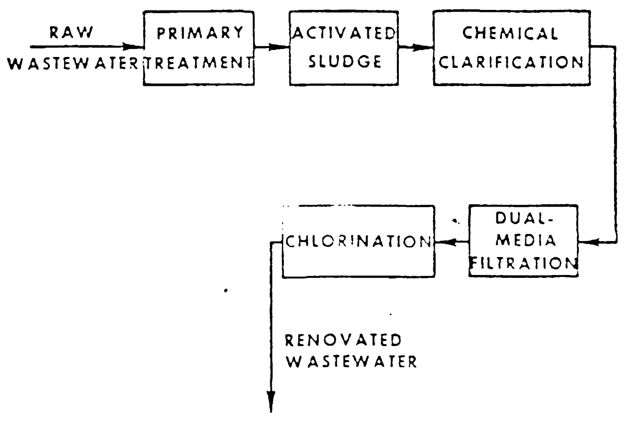


Figure 4. Treatment System for Producing Industrial Water.

From Middleton, 1977
pg. 27

Table 6.

EXAMPLES OF FACILITIES
USING RECLAIMED WATER FOR COOLING *

1. City Power Generating Station; Burbank, CA

   2.0 mgd

   Shock chlorination, pH adjustment, corrosion inhibitor, antifoam agent.

2. City Electric, Martin Drake Plant; Colorado Springs, CO

   21.0 mgd

   Lime clarification, filtration, GAC adsorption, chlorination.

3. Nevada Power Co.; Las Vegas, NV

   27.0 mgd

   Shock chlorination, lime clarification, pH adjustment, corrosion inhibitor.

4. El Paso Products Co.; Cdessa, TX

   4.8 mgd

   Lime clarification, recarbonation, pH adjustment, filtration, ion exchange scftening, antifoam agent.

* Listed treatments are in addition to the municipal wastewater treatments.

Adapted from Donovan and Bates, 1980.

fere with lime softening and corrode copper; it is commonly stripped in the cooling towers. Foaming, caused by detergent constituents in the water, can cause a loss of control in the cooling towers. Anti-foaming agents are used for periodic problems, while carbon adsorption or foam stripping are used for more chronic problems [Goldstein, et al., 1979]. Water quality recommendations for cooling and boiler-feed water can be found in Appendix tables 5 and 6.

The Kaiser Steel Corporation's Fontana, California plant is an example of a large water reuse program using 0.5 mgd treated sewage and 5.2 mgd industrial waste make-up water. The plant was constructed inland far from ample sources of process water and was designated to recycle water through successively less high quality demanding uses (cooling, process, dust arrest, and slag cooling). The process water is recycled and reused up to 40 times before being lost to steam [Ongerth and Jopling, 1977].

Groundwater Recharge.

Reclaimed wastewater has been used to recharge aquifers in several U.S. areas where excessive groundwater withdrawals have caused serious water supply problems. Such recharge can prevent ground subsidence and, in coastal areas, salt-water intrusion into freshwater supplies. Groundwater recharged with effluent has become a source of nonpotable waters and is recognized as benefiting from additional treatment through the percolation process [Donovan and Bates, 1980].

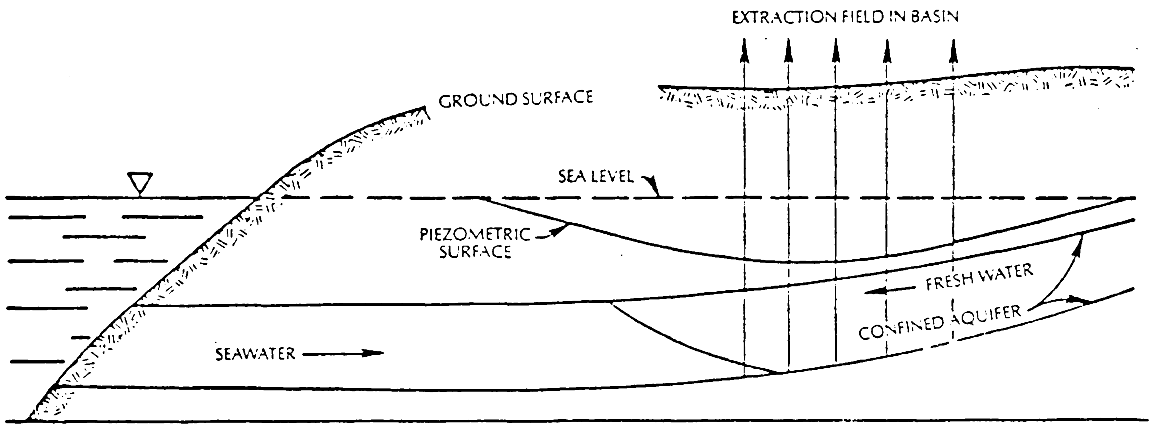
The two common methods of recharge are spreading and injection. Reclaimed water can be applied to spreading basins overlying an aquifer and allowed to percolate through the soil. Injection wells allow water to be directly pumped into the aquifer and are used mostly for controlling salt-water intrusion [Donovan and Bates, 1980]. Recharge through spreading can be accomplished at a lower capital investment than other methods of reuse since the reclaimed water is commonly transported to spreading areas in existing water channels and less treatment is required [Nellor et al., 1979].

Because the boundaries between potable and nonpotable aquifers are rarely well-defined, the possibility of contamination of drinking supplies is seen as a concern. The primary health emphasis has been on trace organic constituents but additional issues have focused on the potential effects of trace metals, minerals, and microorganisms. Wastewater quality standards vary with aquifer use; consisitant standards between states have not yet developed.

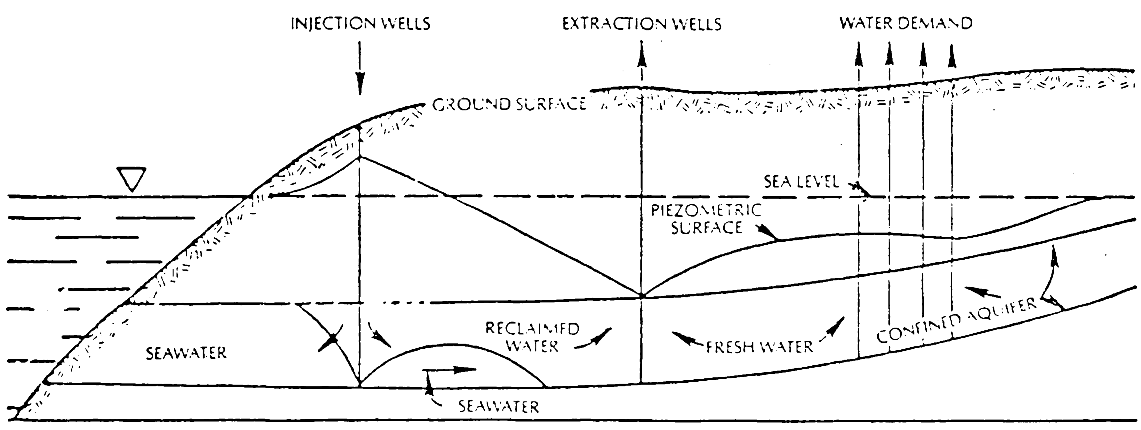
There is, however, no documented evidence of health problems associated with recharge programs. Many technical problems are associated with assessing the relationship between recharge and health effects, as well described in Nellor, et al., [1979]. As a consequence, little is known about the potential effects [Donovan and Bates, 1980]. Though there are major recharge operations existing in California's coastal plains, state health officials there have generally opposed expansion and development of such projects because of these health uncertainties.

Examples of recharge programs include the Oxnard Aquifer in southern California and the Hueco Bolson in El Paso, Texas. The Oxnard system was developed in response to salt-water intrusion caused by overdraft. An injection well serves to form a hydraulic barrier controlling inland movement of sea-water; inland, an extraction well creates a hydraulic separation by removing reclaimed water prior to its interaction with fresh sources (figure 5). The extracted water is used for irrigation [Wedding et al., 1979].

The El Paso system was developed to add to the drinking water supply and serve as a prototype for a larger-scale recycling program estimated to provide one fourth of El Paso's water needs over the next 70 years. The Hueco Bolson could be recharged through percolation basins but an injection well system was chosen due to its low surface area requirements, higher recoveries, and the potential for energy re-



CONFINED GROUNDWATER BASIN SUBJECT TO SEAWATER INTRUSION



HYDROLOGIC CONDITIONS WITH AN INJECTION/EXTRACTION WELL SYSTEM
(WITH THE EXTRACTION WELLS INLAND OF THE INJECTION WELLS)

Recharge of a groundwater aquifer with reclaimed water can control saltwater intrusion in coastal zones. Note suggested use of injection/extraction pairs to help prevent movement of recharged water into potable aquifers. (Source: Wedding, J.J. *et al.* Use of Reclaimed Wastewater to Operate a Seawater Intrusion Control Barrier. Proceedings of the Water Reuse Symposium, Vol. 1, AWWA Research Foundation, Denver, Colorado, 1979. pp. 639-662.)

Figure 5. Groundwater Recharge.
From Donovan and Bates, 1980
pg. 39

covery. The energy recovery factor exists due to the 300 foot head loss incurred by 10 mgd. Assuming an 80 percent recovery, about 320 kw is estimated to be recovered by down hole reversible turbines [Knorr, 1979].

Municipal Reuse.

Though over 325 US communities have programs for using municipal effluent as irrigation water, few are presently reusing water for industrial or domestic purposes, where it could replace potable water [Baumann and Dworkin, 1978]. (table 7.) Long term potable reuse programs have been initiated with success in other countries, however - notably South Africa (Appendix figure 3) and Israel [Williams et al., 1979]. (Hart et al., 1977 and Shelef, 1977 provide more detailed information on these programs.) Several innovative projects have developed in the United States in recent years, namely the Denver Water Department 1 mgd demonstration plant and Virginia's Upper Occoquan Reservoir project.

Baumann and Dworkin [1978] suggest using a reuse system only when water from storage is unavailable to meet demand. Therein, the reclaimed water would function most efficiently as a source of peak supply whereas storage, with a lower operating cost, would provide necessary continuous supply. Where potable reuse is not accepted, a complete dual-distribution system would be required.

Table 7.

GEOGRAPHICAL DISTRIBUTION OF MUNICIPAL REUSE.

State	Number of Municipalities Practicing Reuse				
	Irrigation	Industrial	Recreational	Domestic	Total
Texas	144	5	0	0	149
California	134	1	3	0	138
Arizona	28	2	0	1	31
New Mexico	10	0	0	0	10
Colorado	5	1	1	0	7
Nevada	4	2	0	0	6
Other	12	3	1	0	16
Total	337	14	5	1	357

From Baumann and Dworkin, 1978.

Though interest grows in nonpotable reuse (table 8), there are currently few legal or governmental standards regulating reclaimed water for this purpose. It is commonly suggested that the water to be used on urban landscaping and in the operation of toilets be brought up to drinking water quality standards (figure 6; table 9). For many years, reclaimed water has been used at Grand Canyon for toilet flushing. Treatment of this water has consisted of biological oxidation followed by filtration and chlorination (figure 7).

Utilization of nonpotable reuse in urban areas will be restricted by the need for a complete dual-distribution system. In large cities, the cost would probably be prohibitive; in small towns, though, a dual system might be practical [Middleton, 1977].

Conclusion.

It can be seen that municipal wastewater has many reuse possibilities - for instance, on fields, in parks, in manufacturing processes and power production, in habitat regeneration, in nonpotable home operations, and as drinking water. Applications in industry and agriculture are the oldest and most established modes of reuse; possibilities for more wide spread use and for new forms of use in these areas still exist. Recreational facilities and programs em-

Table 8.

NONPOTABLE URBAN REUSE SYSTEMS.

Location	Starting Date
Grand Canyon Village, AZ	1926
Colorado Springs, CC	1960
Irvine Ranch Water District, CA	1975
St. Petersburg, FLA	1977
Santa Margarita Water District, CA	1979

Adopted from Donovan and Bates, 1980.

Table 9.

DRINKING WATER QUALITY.
(all units in mg/l unless otherwise noted)

Parameters	Drinking Water MCL
Primary Regulations	
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Fluoride	1.4 to 2.4 *
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Radium, p Ci/l	5
Endrin	0.002
Lindane	0.004
Methoxychlor	0.01
Toxaphene	0.005
2,4-D	0.01
2,4,5-TP Silvex	0.01
Turbidity, TU	1 **
Coliform Bacteria (colonies/ 100ml)	1
Secondary Regulations	
Copper	1
Iron	0.03
Manganese	0.05
Sulfate	250
Zinc	5
Color, units	15
Foaming Agents (as MBAS)	0.05
Odor, TON	3
Other	
Trihalomethanes	0.10-

* varies with average annual maximum daily air temperature
** monthly average
+ monthly average, membrane filter technique
- proposed MCL

From Williams et al., 1979.

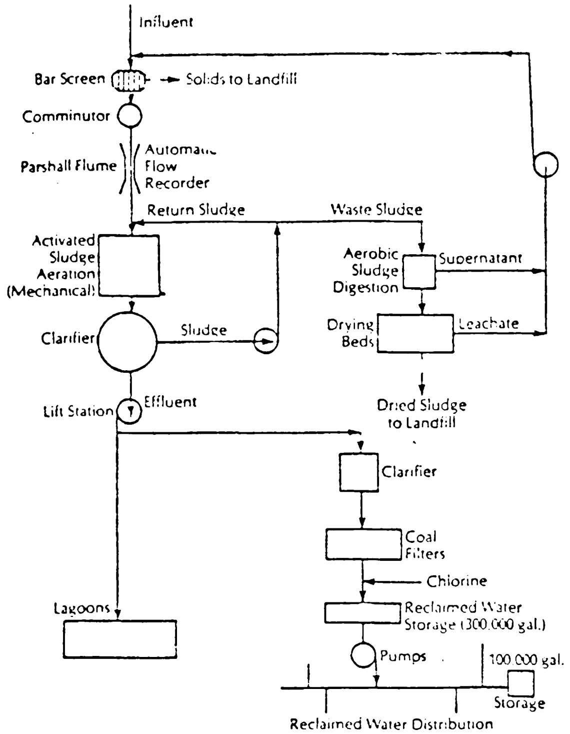


Figure 6. Process schematic for reclaiming water in Grand Canyon Village, Arizona, where water reuse has been practiced for over 50 years. Some 30,000 gpd of reclaimed water is used in a dual distribution system for toilet flushing, landscape irrigation, and occasional construction-site washdown. (Source: Grand Canyon's Reuse System Since 1926. Water Reuse Highlights, AWWA Research Foundation, Denver, Colorado, January 1978. 119 pp.)

From Donovan and Bates, 1980
pg. 3

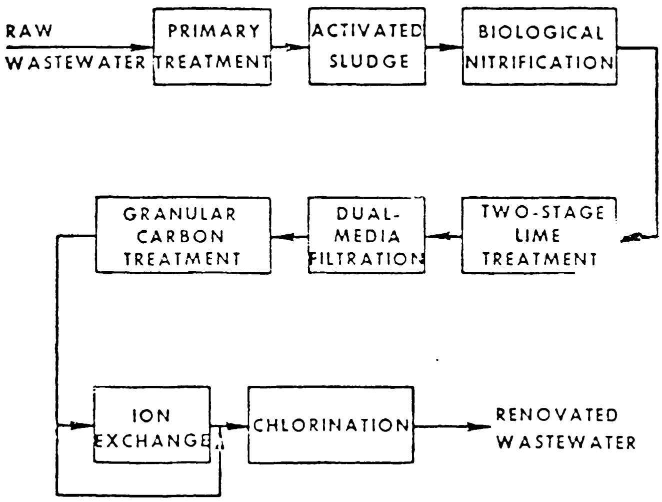


Figure 7. Treatment System for Producing Near-Potable Water.

From Middleton, 1977
pg. 29

ploying reclaimed wastewater have developed along with the reuse technology itself; however, applicatons of much significance outside of California have been few.

The least developed market for municipal wastewater is inside the urban areas themselves in commercial and residential nonpotable and potable reuses. While the ability of any one community to reuse its effluent may technically be limited by the type of waste constituents in the area (eg. an abundance of industrial toxins, etc.), therefore making the concept of such reuse not universally applicable, the potential for municipal water reuse is significant.

Chapter III

FACTORS INFLUENCING THE DEVELOPMENT OF WASTEWATER REUSE

Four major factors shape the development of wastewater reuse in the United States. Technological, economic, social, and legal-institutional influences which affect any reuse proposal are examined in this chapter. Of particular importance for this thesis are the sections on legal and institutional factors, and technological factors. The information in the legal-institutional section is specifically used as a basis for investigating legal and institutional issues in the Virginia Beach case study. The issues raised in the technology section also become significant in the case study.

Though the factors are discussed independently, for clarity, it can be assumed that the feasibility of any wastewater reuse proposal is the product of a combination of these factors; they interact to create either a positive or negative environment for the development of reuse. The interaction between technology, economics, social acceptance, and legal-institutional factors may differ based on the specific situation. The degree to which technological, economic, and social influences are involved in the legal and institutional barriers to reuse development in Virginia Beach will be discussed in specific in later chapters.

Technological Issues.

As described in the last chapter, the degree of water quality required and the level of treatment necessary varies with the intended reuse application. Reasonable questions at this point would be; "How high a quality of water can our current technology produce?" and "Can reclaimed water be used for the highest water use - that of drinking?"

The largest body of knowledge and opinion on reuse technology suggests that the potential quality of reclaimed water is excellent and that direct potable reuse is possible. This is not, however, a unanimous opinion; there exist knowledgable people in the water and wastewater fields who maintain that potable reuse is still a step beyond our current capabilities.

Stanford University professors McCarty and Palmer [1980] sum up one side of this debate:

> Treatment methods are available to render municipal wastewater acceptable for many industrial, commercial, agricultural, and landscaping applications. Numerous reuse projects exist, and their success is testimony to the soundness of this approach. However, reclaimed municipal wastewater has not yet been demonstrated adequately safe for direct use as a domestic water supply. Until this is done, use of reclaimed wastewater for this purpose should not be encouraged.

Some are more confident in our technological abilities. C.C. Johnson, Jr. [1980], Chairman of the National Drinking Water Council, reported in his summary comments at an EPA symposium on potable reuse, "The engineering group was of the opinion that technology does not appear to be a limiting factor in the implementation of potable reuse." Ju-Chang Huang of the University of Missouri [1979] strongly supports our current abilities. Asserting that all the conventional pollutants can be removed effectively from wastewater, Huang concludes that "...our waste treatment technologies would appear to be advanced enough to allow the practice of direct water reuse."

What exists here is more than just a squabble between engineers over technology. Projects around the world have proven that many types of beneficial wastewater reuses can be achieved; over the past 20 years, technological advances have brought us to a point of being able to produce a high quality effluent suitable for water contact recreation and non-potable domestic uses. Beyond the discussion of unit processes and removal efficiencies is the question of risk.

The unknowns with respect to public health risk are what truly divide even advocates of potable reuse. How reliable are our treatment processes? What are the potential health problems associated with potable reuse?

An ironic dilemma faces public health officials and others concerned about the consequences of potable reuse. The dilemma is that many surface and groundwater sources contaminated with domestic and industrial wastes have been used for potable supply for many years. The World Health Organization has concluded that the health risks associated with the drinking of water derived from such sources is only slightly different from those involved in direct reuse of wastewater [Reynolds, 1977].

Some specific potential health problems have been associated with reuse, however. To begin with, public health criteria have not been developed for reclaimed water. Our existing drinking water standards (United States Public Health Service Drinking Water Standards and World Health Organization Drinking Water Standards) are deficient in the sense that they were originally based on the assumption that water would be drawn from best available uncomtaminated sources [Shuval, 1977]; very few synthetic compounds are addressed in the standards and the approach to viruses is generally considered unsatisfactory [Reynolds, 1977].

The effects of indirect reuse have not been fully assessed and the attempts at direct reuse have been few.[2] The

[2] No acute adverse public health effects have been reported in the few potable reuse cases; the lack of reporting of chronic effects, though, may be due to the relatively recent nature of the projects [Reynolds, 1977].

ability to set appropriate criteria, then, boils down to the simple fact that our knowledge of toxicological and epidemiological consequences of potable reuse is incomplete.

At one time, epidemics of waterborne diseases were a major problem in the public health field. With advances in sanitary engineering and the near elimination of such epidemics, considerable concern now focuses on the health effects of biocides, heavy metals, and synthetic/organic contaminants.

Activated sludge, our most effective secondary treatment process has not been shown to remove trace metal concentrations. As for the synthetic/organic compound group, current research indicates that this process cannot remove any significant amount of carcinogenic compounds [Gillies, 1981].

Carbon adsorption, the workhorse of the advanced treatment train, has proven very effective in removing refractory and other organics, and organic or metal-organic biocides. The maximum effective reduction in synthetic organic compounds is 85 percent. Little information is available on this process' removal capabilities with respect to heavy metals [Gillies, 1981].

Most of the research on the technology of reclamation and reuse is still being conducted in the United States, South Africa, and Israel. Prominant field studies in the United

States include California's "Water Factory 21", Virginia's Upper Occuquan project, the "Potomic Project," and Denver's demonstration plant [Culp et al., 1980].

Northern Virginia's Upper Occuquan Sewage Authority Treatment Plant is a good example of a potable reuse project.[3] In Johnson's [1980] view,

> They did it on the basis of the best knowledge they had, the best technology they could devise, and the best reliability they could design. It's working and it's the kind of demonstration from which wisdom is taken. We'll know later on whether or not it was a good or bad experience.

Perhaps more telling an experience will be that of the Denver Water Department's reuse demonstration project. The plant is scheduled for completion in early 1983 with the demonstration to be completed in 1987 [Hennessy, 1981]. Studies to be conducted at the plant include a large analytical program designed to provide data on treatment process units and a comprehensive health effects program [Miller, 1980]. According to Culp [1980], "Once on-line, the plant will yield invaluable data, not only regarding treatment performance information, but also regarding the social and environmental effects of such a project."

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[3] The Upper Occuquan project involves "indirect" potable reuse; local wastewater is highly treated and then released into the large Occuquan reservoir thus becoming part of the area's water supply.

Laboratory research focuses on the monitoring and testing of existing treatment systems plus the development of new techniques. The production of ozone and the reverse osmosis process receive considerable attention also. Other research includes the use of ultra-violet light and ultra-sonics for virus detection and trace metal removal [Culp et al., 1980].

As far as health standards, "one of the principle tasks of all research efforts is to determine quality criteria for various reuse applications" [Culp et al., 1980].

Discussion.

As an influence on the development of wastewater reuse proposals by local governments, existing technology can be considered static and external to the realm of local decision making. A community, for example, interested in reuse for water supply, would have little control over available wastewater reclamation technology. Nor would a local government have much influence over the current state of scientific and regulatory knowledge in the wastewater reuse field. The proposers may, however, have some influence over the regulatory response to these states of knowledge and technology.

Few states have developed regulations specific to wastewater reuse. Existing regulations which affect reuse proposals tend to be those which affect water supply and sewage treatment; these are usually based on the confidence in current treatment technologies and the state of public health risk knowledge. Such regulations and policies in the State of Virginia will be examined in chapters IV and V.

Economic Considerations.

Regardless of the form of wastewater reuse application and the benefits derived, costs will be incurred. The purpose of this section is to describe the types of economic considerations involved in reuse and to describe the forms of financing currently used.

Donovan and Bates [1980] outline the basic components of capital, operation, and maintenance costs associated with reuse proposals.

1. Costs for additional treatment, if required.
2. Costs for conveyance/distribution of the reclaimed water.
3. Costs for storage, if necessary.
4. Costs for monitoring reclaimed water quality.

The perspective generally taken on the costs of reuse is not simply to sum the expenses like those just listed, but to estimate the difference between the cost of reuse and the cost of developing new fresh water supplies. Since the economics of reuse are a key element in determining its feasibility, a reuse project logically will be desirable when its cost is less than that of new supplies and thereby a savings.

Overall, the costs and benefits are situation specific. In particular, unit process costs will vary with the size of the treatment plant. Conveyance and distribution costs are a major influence on the economics of reuse, with the costs of force mains and pumping stations being dominant. The cost of a distribution system, like costs in general, is subject to many variables: the number of users to be supplied, the distance from supply to users, and, if appropriate, the need for a dual distribution system.

Storage costs in wastewater reuse depend on the availability and cost of land, the possible need for at-storage treatment, and the type of storage provided [Donovan and Bates, 1980].

Other costs may be incurred by the users of reclaimed water. An industry, for example, might face the following "penalty costs," as described by Donovan and Bates [1980] and Millikin and Lohman [1979]:

1. On-site hookup to the non-potable system.
2. Facilities for monitoring and adjusting water quality.
3. Additional treatment, if to be provided by the user.
4. Repiping for dual systems on-site.
5. Steps to assure worker safety.
6. Changes in normal practice (eg. quality compensation in cooling system).
7. Possible need for waste disposal.

Elaboration on these costs can be found in Leeds, Hill, and Jewett, Inc. [1971].

Most municipalities in the United States are, fundamentally, in a good position to provide wastewater reuse and gain economic benefits. This is because in 1972 the federal government through the Water Pollution Control Act Amendments required secondary treatment of all municipal sewage, and in some special cases advanced treatment was required. Since these processes are already in place in most instances, the ability to provide reclaimed water for most non-potable uses at a low cost is good. Potable reuse would typically require certain upgrading of facilities.

Financing.

Even though a particular reuse project might produce economic benefits, the money for capital investment, operation and maintenance, and debt service costs must still be raised. In general, financing ahould not be considered a major obstacle to reuse development. The major options available to public entities for financing reuse projects are the operating budget, tax levies, grant programs, bond issues, and user charges.*

The operating budget is the first place to look for financing if the project requires only small or moderate expenditures. According to Doncvan and Bates [1980] practi-

* Donovan and Bates [1980] is the principle reference here; see Perrine [1979] also for further discussion of financing techniques.

cally all activities associated with the development of reuse facilities could be financed out of an existing wastewater treatment plant budget. The particular advantage of using an operating budget or some other cash reserve is that the utility's administration can allocate the funds on its own initiative. However, it would seem likely that under this mode of financing, some budgeted items would have to be sacrificed.

The next types of financing to consider are increases in existing levies and charges. For reuse projects which will benefit the whole community, increases in property tax may be appropriate. Donovan and Bates [1980] consider special assessments as appropriate financing mechanisms if projects are of the nature of providing fire fighting water and municipal landscaping, for example.

In situations where capital requirements for the reuse project will be large, the acquisition of grants and the selling of bonds are the major methods of financing. The principle source of federal grant money in this area is the Environmental Protection Agency. Donovan and Bates [1980] summerize the funding opportunities provided by the 1977 Clean Water Act; it should be noted that policies of the current federal administration may curtail the availability of these funds. An important limitation for reuse projects is that conveyance system monitoring devices, and storage tanks tend not to be eligable for funding unless the purpose of the project is water pollution control.

Grants are also available from the Farmers' Home Administration and the United States Department of Agriculture; research and development funds are available from the Office of Water Research and Technology. In some specialized cases, loans are available from the Water and Power Resources Service and the Small Business Administration.

According to Donovan and Bates, "state support is generally available for wastewater treatment facilities, wastewater reclamation facilities, and conveyance facilities, and under certain circumstances, for on-site distribution systems."

The types of bonds typically used for financing public works projects are "general obligation" bonds, "special assessment" bonds, "revenue" bonds, and short term notes. The type of bond chosen will probably depend on the type of reuse project involved. For instance, general obligation bonds, which are typically supported through property taxes, might be most appropriate when it is clear that the whole community will benefit from the project. Revenue bonds, on the other hand, tend to be supported from service charges and might be best used when definable groups within the community pay for and are benefit from the reuse project.

Finally, a user charge can be imposed upon those receiving the reclaimed water. The more recent reuse programs are moving away from the flat rate approach and toward metered charges [Donovan and Bates, 1980]. Determining a user charge for reclaimed water is not much different from the process used to set rates for potable systems. Leeds, Hill, and Jewett, Inc. [1971] outlines guidelines to be used in the pricing of reclaimed water. Charges for reclaimed water are set less than potable water in order to make the reuse project more attractive. Reuse user charges can become complicated, however, if the system involves several reuses which require different qualities of water.

Discussion.

Economic factors are the "bottom line" to reuse proposal feasibility; even when all other factors are favorable, a community must be able to finance the reuse project. As seen in this review of the types of cost involved and the means of financing reuse, economic factors can be considered internal to the local decision making realm.

Particularly important to this thesis are the costs to a locality resulting from Virginia state regulations and policies. These will be examined in chapter V.

Social Acceptance.

Social acceptance is another factor which has received considerable attention. Since 1975, 12 studies have been conducted to guage the public's attitudes toward wastewater reuse (table 10). The purpose of this section is to review the findings of the major surveys and discuss the implications of these findings.

The conclusions of these studies were quite similar, but some variations exist. A review of findings will highlight major conclusions. As a preliminary note, the critical problem with surveying attitudes on water reuse is as Kasperson [1977] states,

> For most Americans the water re-use prospect has not been of sufficient immediacy to allow for this 'mulling over' process. Attitudes to reclaimed water reuse are partially formed and the issues involved only partially understood.

Care must also be taken in drawing conclusions from survey results since what people say they will do and what they actually would do may be different.

One of the earliest studies surveyed 36 communities in four states. According to Kasperson [1977] 60 to 75 percent of the respondents in three states were willing to drink reclaimed water; but in one state, just 46 percent of respondents were so inclined. Two California communities were

Table 10.

PUBLIC ACCEPTANCE OF RENOVATED WASTEWATER: A PARTIAL SUMMARY OF TWELVE SURVEYS.

Study	Type of Survey	Scope; Location	Sample Size	Willingness to Drink (%)
Baumann (1965)	telephone	National: Texas Kansas Mass. Ill.	722	62.0
Bruvold & Ward (1969)	telephone	Cal; 2 suburbs	50	45.0
Clark University Pilot Study (1970)	interview	National; Gloucester Wilmington Kokomo Indianapolis	220	29.0
John Hopkins Univ. (1970)	telephone	Baltimore County, MD	321	
Pagorski (1971)	interview	Park Forest, Ill.	114	81.0
Johnson	interview	National: Phil. Camden Cincinnati Tucson Portland	221	77.4
Clark Univ. Study Proper (1971)	interview	National: Kokomo San Angelo Lubbock Santee Col. Springs	420	48.0

Continued on next page.

Table 10 Continued

Study	Type of Survey	Scope; Location	Sample Size	Willingness to Drink (%)
Bruvold & Ongerth; Bruvold & Ward (1972)	interview	Cal.; 10 paired cities	972	43.6
Carley (1972)	interview	Denver	447	38.7
Gallup Poll (1973)	Mail Ques.	National	2937 (weighted)	38.2
R. Stone & Co. (1974)	telephone	So. Cal. (10 cities)	1000	39.1
Kasperson et al. (1974)	interview	National; 9 cities	80	38.0

Adapted from Kasperson and Kasperson [1977] and Bruvold [1979].

surveyed in 1969 by Bruvold and Ward. Queried on 22 different reuse applications, the respondents' views were clearly related to the degree of bodily contact involved. The major break between a majority favoring and a majority opposing a certain use came at the catagories of uses which required ingestion (eg. cooking).

Kasperson reports that a Clark University study of three cities in 1970 was helpful in suggesting the relatively low knowledge of reuse among the public. In the cities surveyed, approximately 30 percent of those interviewed considered themselves familiar with the idea; acceptance of direct potable reuse was also low, with no more than 32 percent favoring it in any one of the cities.

In one of the largest studies, Johnson [1971] surveyed five cities. Reinforcing Bruvold and Ward's findings, Johnson's results showed a step by step increase in resistance to the use of reclaimed water as the suggested applications moved from non-bodily contact to drinking. Note worthy is the finding that respondents who had used reclaimed wastewater before (such as those in Santee, California) tended to be more favorable toward drinking such water [Kasperson, 1977; Johnson, 1971].

A 1972 survey of Denver residents found approximately 40 percent of respondents favorable toward direct ingestion.

Similar statistics resulted from a nationwide Gallop Poll in 1973.[5] A similar 40 percent acceptance of reclaimed water was found in a 1974 study of 10 California communities; Olson et al., [1979] study of Irvine and Anaheim, California yielded favorable responses of 47 and 45 percent respectively.

In areas where direct potable reuse has been implemented, the public response reaches both ends of the acceptance scale. Chanute, Kansas' 1956-57 emergency use of reclaimed water generated a negative public reaction. Kasperson [1977] suggests that the poor quality of water involved and the fact that people were not informed of the reuse until after it was instituted were influences on the generally poor public response.

The development of direct potable reuse in Windhoek, Namibia has, in contrast, been supported by the public. The use of reclaimed water for recreational lakes in Santee, California was implemented gradually and has gained public acceptance and understanding.

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[5] Considering the fact that the Gallop Poll asked people whether or not they would want to drink "recycled sewage," this writer is surprised that anyone answered favorably. The specific characteristics of the surveys, however, is another issue and will not be discussed here.

The factors influencing a person's acceptance of or opposition to various applications of reclaimed wastewater have been analyzed by most of the surveyors. Though the evidence is weak, Bruvold [1979] reports that correlations between attitudes and sex and age are consistent among studies. Three of the five major studies indicate that younger respondents are more favorably disposed toward potable reuse than were older respondents. Four of these five studies indicated that men are more supportive of potable reuse than are women. Occupation and the quality of current supplies were also factors.

The major factors influencing responses, however, were level of formal education, adequacy of current water supply, and knowledge of/experience with water reuse. According to Kasperson [1977], six of the seven studies which tested the formal education relationship found it to be significant. In Johnson's study [1971], for example, he concludes, "Education was the most significant of the personal factors associated with both acceptance of community consideration of renovated wastewater and with willingness to drink it."

Surveys in communities which had experienced water supply crises generally found a more favorable attitude toward reuse than might be normally expected [Kasperson, 1977]. Again to quote from the Johnson study, "Of the resource characteristics perceived, the adequacy of future supplies appeared to be the most significant in association with acceptance of community consideration of renovated wastewater."

Knowledge of and/or experience with reuse was consistantly important in survey results. Kasperson cites the Clark University study in his examples. Of the respondents who could recall even having heard of water reuse, 52 percent were willing to drink reclaimed wastewater; only 24 percent of unfamiliar persons were willing. This study also found that 65 percent of the respondents from Santee accepted potable reuse.

Promoting Reuse.

The prevailing attitude of the American public, if we can consider the surveys as indicators, is not favorably disposed toward direct potable reuse. It should not be assumed, however, that any one community would not approve a reuse proposal; nor should it be assumed that negative attitudes cannot be changed. The writers reviewed for this section appear optimistic. Baumann and Kasperson [1974] concluded from their literature review, that

> There is little evidence to support the widespread conviction among those charged with proposing solutions to the nation's water supply problems that public opposition constitutes the most important obstacle to the adoption of wastewater reuse systems.

Different authors stress different approaches to promoting acceptance of reuse. Considering the generally favorable existing attitudes toward most reuse applications, Kasperson [1977] opts for an approach which gradually introduces forms of reuse. The more familiar people are with reclaimed wastewater and the greater understanding they develop, the greater the likelihood that they will be receptive to high-order reuse applications.

Huang [1979] has developed a four step approach to overcoming what he calls the public's "psychological unreadiness" for wastewater reuse. First, Huang suggests instituting a new terminology in order to impress upon the public that wastewater is something that is "only temporarily used and can be reused again after it is cleaned up." Second, Huang maintains that the public must be informed that wastewater reuse is not a new concept and that it has been occurring in the U.S. for many years. Huang's third step requires that the sanitary engineering profession take a lead in publicizing current water and wastewater technologies and the abilities to produce high quality water. And fourth, he presents a call for more intensive toxicological research so as to develop appropriate quality standards.

Bruvold [1979] proposes that information campaigns be launched which are designed to reach those parts of society which thus far have been least likely to give reuse much thought - namely the older, less affluent, and less well educated publics. According to Bruvold, the campaigns should stress the need for new water supply sources, the availability of modern technology, the applicable economic benefits, and the fact that public health officials do approve of certain uses of reclaimed water.

To conclude this section a few words are needed on the attitudes of engineers and public health officials. The support of reuse projects by these people would seem critical to community acceptance.

After acknowledging the rational professional conservatism born from health issues, Niemann [1977] suggests that there are behavioral reasons which also contribute to the public health officials' reluctance toward reuse. Public health officials tend to be older, more experienced, and less mobile than engineers - characteristics which "probably enhance a tendancy to maintain the status quo." Niemann's survey also indicates that these officials are traditionally oriented, fear coming in contact with what might be potentially dangerous, and express "revulsion to body wastes."

Consulting engineers have been more willing to accept the concept of direct potable reuse but hesitate to adopt it. These attitudes correlated with factors Niemann considered conducive to innovation; the engineers tended to be younger, less experienced, more mobile, and having greater earning power than public health officials. Niemann's study also suggested regional attitude variations. The strongest resistance to reuse was in the East, generally positive but mixed attitudes were encountered in the Mid-West, and cautious acceptance was found in the West.

Pratte and Litsky [1979] interviewed 12 Massachusetts water resource officials; 50 percent favored wastewater reuse by industries. Reasons for opposition varied. Some respondents believed that the extra treatment steps were unnecessary, some thought that the Metropolitan District Commission could not accomodate reuse, and others thought that is would not be cost effective. Only one respondent was of the opinion that the technological capability does not exist.

In Pratte and Litsky's conclusions they expressed alarm over the relative lack of knowledge of reuse among some respondents. They also concluded that the "opportunity wastewater reuse offers to conserve potable water for higher uses is unrecognized."

Discussion.

Social acceptance of wastewater reuse is a factor internal to a community. Social acceptance, as a factor in reuse development, is not emphasized in the thesis case study because the factor is not directly related to legal and institutional barriers to development. The public support issue, however, is mentioned briefly in the case study in chapter V.

Legal - Institutional Factors.

Of the four factors relevant to the development of wastewater reuse as discussed here, the legal and institutional factors have received the least attention in the literature. The purpose of this section is to survey the recognized legal and institutional issues which may affect reuse proposals.

Legal.

Donovan and Bates [1980] summarize the major legal issues in the following four categories:

1. State Statutes
2. Enabling Legislation
3. Water Rights Law
4. Franchise Rights
5. Case Law

State statutes include water quality laws, environmental statutes, and liability laws. In most states there is a lack of statutes dealing directly with reuse and reclamation.

Enabling legislation may dictate which among municipal organizations will be best suited to operate a reuse project. Such legislation also describes financing constraints and contractual abilities.

Water rights are an important issue in reuse; in some cases water rights facilitate reuse while in other cases they inhibit reuse. Donovan and Bates [1980] describe instances in Western states wherein users found it easier to obtain and use reclaimed water than to obtain appropriated water.

On the other hand, water rights may be an obstacle to reuse where requirements as to the use and return of water are imposed. Cox and Walker [1976] explain that one of several obstacles to reuse under the riparian doctrine occurs when wastewater will be diverted to another location for use, but water use is restricted to riparian land.

Potential problems under the water rights issue typically involve reduced flows in a watercourse, ill defined water rights for surface sources, reduced discharges to a watercourse, changes in the point-of-use or the point-of-discharge, hiararchy of use, and disruption of Indian water rights [Donovan and Bates, 1980].

Franchise law involves special rights or licenses granted "to an individual or corporation to market goods or services in a particular area" [Donovan and Bates, 1980]. Public and private utilities, in this case, may have an "exclusive franchise" where economies of scale do not warrant competition. It is possible that a wastewater reuse project could intrude on another entity's exclusive right to sell water in the service area.

Donovan and Bates [1980] consider case law an issue only in that its review is necessary for assessment of potential conflicts.

In Millikin and Lohman's [1979] examination of legal and institutional barriers to planned reuse in the Colorado River Basin, they first had to assess the "law of the river". The law of the river is a web of international treaties, federal legislation, interstate compacts, state water laws, and contracts which collectively control and appropriate the Colorado River.

Millikin and Lohman found that both incentives and barriers to reuse exist within this system. Complexities and uncertainties surrounding federal and Indian reserved water rights figure prominantly in the Colorado River situation as do the implications of altering the many interstate agreements in the Colorado River Compact. Of a more general nature, it was found that state water law restrictions on changes in water rights were a barrier to reuse. Pursuing changes in the point-of-use or purpose-of-use was often too expensive and time consuming for potential reusers.

State restrictions on charges in stream regime or water quality were considered constraints since recapture and reuse of flow may alter stream regimen, add impurities, or increase consumption thus concentrating existing impurities.

Millikin and Lohman [1979] also discovered that several of the federal and state environmental statutes indirectly interfered with reuse proposals and added "delay, expense, or risk". It was concluded that the statutes inhibit reuse projects in some cases because of natural conflicts (a reuse facility might be poorly planned and cause air pollution, for example) and in some cases because of "a relatively trivial infringement of statuatory authority".

Federal and state water quality control laws and the Colorado River Compact's limitations on consumptive use were both found to be incentives to planned reuse.

Lake and Perrine [1979] and Perrine [1979] describe some of the legal constraints found in Southern California. In some instances, the right of a publicly owned utility to sell reclaimed water has been challenged. The disruption of downstream flow is a potential problem as are antiparalleling statutes (similar to franchise laws).

In a review of three wastewater reuse case studies, Lake and Perrine found legal-contractual factors to be a barrier in just one of the three situations. In this case, the water district had tied up all the reclaimed water through a historic limit clause and through an exclusive rights clause in its supply contract. As a result, surplus reclaimed water goes unused. Interestingly, in one case it was discovered that greater use of reclaimed wastewater would reduce the actual public health risk for the area's population.

Institutional.

Typical institutional barriers to reuse involve conflicting pressures within decision making agencies, conflicts of orientation between water allocation and water quality agencies, lack of agency coordination, and a "zero-risk" attitude among decision makers.

In Millikin and Lohman's [1979] Colorado River Basin study, they discovered that varying pressures of interstate agreements, interstate development plans, and federal policies on environmental control, energy development, and other areas, inhibited innovation among state water management officials. Those officials were forced "into decisions and policies based on precedent and tradition".

It was found that conflicts between water allocation and water quality interests occured on both state and federal levels. Both views can be barriers to reuse. The allocators tend to encourage the return of reused water even when it may exceed quality standards; allocators also tend to disfavor land applications of wastewater. Water quality officials tend to discourage any reuse that may increase the chance of human contact, including irrigation applications. They also inhibit some reuses through an "overly strict interpretation of water quality control regulations".

Lake and Perrine's [1979] analysis found the lack of coordination of authority and agency cooperation to be a significant obstacle to reuse in Southern California. In addition, the lack of a consistant basis for water pricing was seen as a barrier.

The Department of Health Services in California tends toward "failsafe" recomendations for health standards which the Water Resources Control Board is to incorporate into regulations. The investigators raised the concern that this approach of both measuring risk and judging the acceptable level of risk by the health agency was undesirable and produced impractical "zero-risk" policies.

In the three case studies included in this investigation, a variety of administrative-institutional barriers were encountered. In one situation, public health standards setting, interagency conflicts, price determination, and goals conflict were problems. In a second situation, the issue was grants administration; the third case study involved no institutional constraints.

Discussion.

Legal factors in reuse development tend to be imposed upon proposals; these factors, (eg. state regulations) are external to a community's decision making powers. Institutional factors, however, appear to be either internal or external to local control.

Because the studies of legal and institutional barriers to reuse are limited, it is difficult to assess how typical their findings are. The emphasis in the Virginia Beach case study is on legal and institutional barriers.

<u>Wastewater as Innovation</u>.

The technological, economic, social, and legal-institutional factors discussed in this chapter influence the development of wastewater reuse in general and reuse proposals in specific (figure 8). The interaction between these factors may be specific to a proposal. Clearly, overcoming barriers associated with one factor category will have not have much impact on promoting reuse unless barriers in other categories are also overcome.

These factors through their internal or external nature and the fact that they combine positive and negative influ-

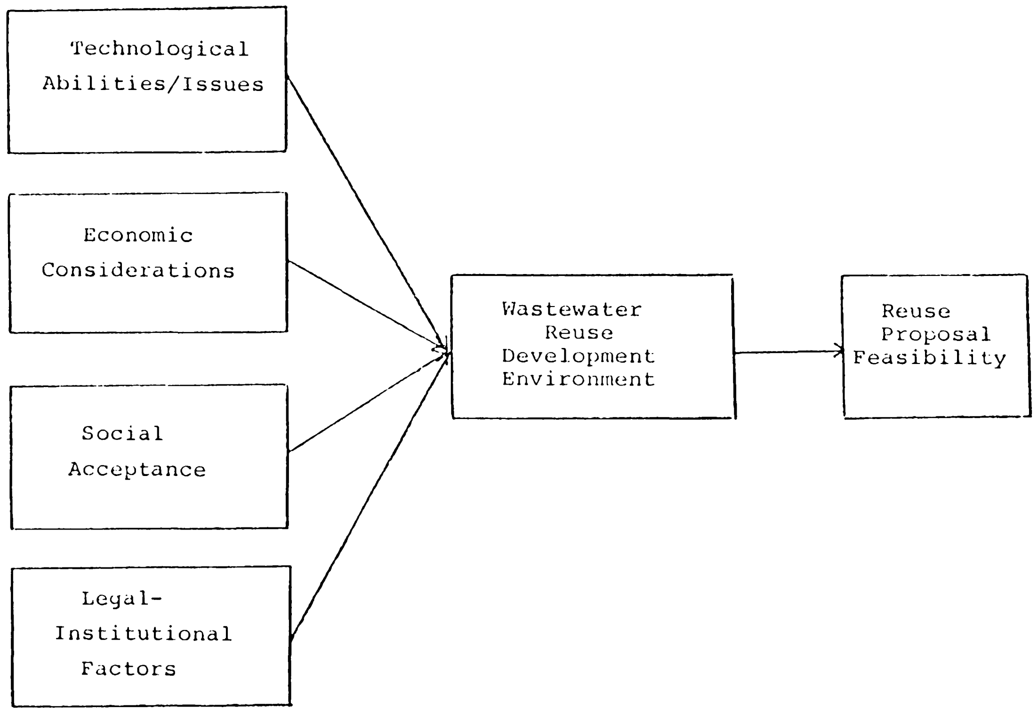

Figure 8. Factors influencing the development of wastewater reuse and reuse proposal feasibility.

Interaction between factors is situation specific.

ences to create a context for the development of reuse, are similar to the types of factors found in other fields. Though the information is limited, some hint as to the reasons why wastewater reuse, particularly potable reuse, has not been actively pursued in this country may come from research into policy innovation and organizational theory.

Gans and Horton [1975] provide some of these hints by their study of human services integration. Basically, Gans and Horton found that the existence of a certain environment increased the chance for innovation among public agencies. Innovation (in this case, services integration) was more likely to occur when the sociopolitical leadership of the locality supported the idea or project, and when the innovation was considered a high priority. In cases where the agency director was aggressive in pursuing coordination and contacts with other important "actors", and was supported by a capable staff, the innovation had a better chance of occuring [Gans and Horton, 1975; pp. 6, 43]. Gans and Horton also concluded that if an innovation was a priority at the national level, then a conducive local environment could be molded [pp. 7, 44].

At the state and local levels which this thesis emphasizes, the "environmental" influences on the development of reuse are important. In the Virginia Beach case study, legal and institutional factors form a major part of this environment for such innovation. It was expected that this environment would be a negative one.

Gans and Horton's [1975] observation about the influence of an innovation's national priority status is clearly applicable to wastewater reuse in the United States. The greatest advancements in reuse have come from countries in which water supply and reuse were high priority objectives (Israel is the classic example). The U.S. federal government has supported wastewater reuse research to a limited extent (about one-fourth of the Denver project has EPA funding, for example). And this support is certain not to increase under the current administration.

If municipal reuse was today what nuclear energy was in the 1950's, we would probably be drinking reclaimed wastewater tomorrow regardless of the apparent insufficient confidence in public health protection. States like Virginia can proceed with reuse proposals at their own initiative but it seems likely that this will be a slow process. A surge in the experimentation with and use of potable reuse in this country will probably not occur unless the federal government takes a leading role.

Conclusion.

It appears, based on the information presented in this chapter, that many but not all of the economic, social, and legal-institutional constraints to reuse would be resolved as a result of answering the public health risk questions. Based on the literature reviewed, however, the legal-institutional category appears to contain the most obstacles to reuse that are not related to health issues. In fact, this literature review implies a relative insiginificance of technological issues in creating legal and institutional barriers. Many of the costs associated with reuse are a result of added treatments and safety factors. Confidence, on the part of public health officials and the public, in the quality of water provided through wastewater renovation would advance social acceptance of reuse considerably. And assurance of continued water quality would affect the area of water rights and health standards also.

Virginia Beach is a good environment for observing the relationships between these factors and the influence of legal-institutional issues particularly because of the City's aggressive search for new water supplies. In considering reuse as a water supply option, Virginia Beach operates in a decision making context over which it has limited control. Economic feasibility and social acceptance may be characteristics of the locality. However, technological capabilities in the field of wastewater reuse are not readily influenced by the City; and the legal and institutional barriers to reuse are dominantly at the State level, making them external to the City's decision making process. It is at the State level that the factors of development combine to form an environment unresponsive to reuse innovation. The following chapter outlines this state legal and institutional context.

Chapter IV

LEGAL AND INSTITUTIONAL ASPECTS OF THE STATE OF VIRGINIA'S REGULATION OF MUNICIPAL WATER SUPPLY AND SEWAGE TREATMENT.

Counties, municipalities, and public service authorities being created and empowered by the State are restricted by, and subject to, the statutes of the State and the policies of its agencies. In the area of wastewater reuse, the City of Virginia Beach is subject to the statutes of the State of Virginia and the policies of the Virginia Health Department and the State Water Control Board. This chapter surveys the State level legal and institutional factors which influence wastewater resuse emphasizing the roles of the Virginia Health Department and the State Water Control Board. With this information as a base, the more specific aspects of the case study can be built in the next chapter.

The Code of Virginia is covered first. It outlines the obligations and abilities of political units in providing adequate water supply and sewage treatment. The ability to set rates and charges for services is discussed in the Code, as are the abilities to make contracts and issue bonds. It does not appear that these issues would be legal hindrances in Virginia Beach, though they may be in other localities.

The primary agencies at the State level in regulating these public services are the Virginia Health Department (VHD) and the State Water Control Board (SWCB). Even though the Code of Virginia does not address reuse in specific, it can be surmised that the VHD has considerable control and discretionary power over reuse through existing broad control over water supply and sewage treatment in the State. The VHD has been open to wastewater reuse proposals but views them in a very conservative perspective based on its public health protection role.

Thus far the VHD has produced one document specific to municipal wastewater reuse, the Interim Protocol. The Interim Protocol serves as a critical document in the Virginia Beach case, as the Protocol forms the VHD's basis for proposal review.

In general, the SWCB supports wastewater reuse for most major applications except domestic use. The SWCB also has experience in water reuse regulation through its adoption of the Occuquan Policy.

Water rights are the final factor to be examined in this review. Virginia operates under the "riparian doctrine" of water rights which embodies some hindrances to wastewater reuse. While a potentially important influence on reuse in the State overall, water rights are not a hindrance to reuse in the Virginia Beach case.

State Regulation of Water Supply and Sewage Treatment. The Code of Virginia addresses the topics of water supply, sewage systems, and public health but does not deal directly with municipal wastewater reuse or recycling. This section will review the Virginia State Statutes as external legal and institutional factors which impact municipal reuse.

Public Service Authorities.

Every county, city, and town is authorized to individually or jointly operate water and sewer projects and to enter into contracts in accordance with these projects. However, many counties and municipalities do not operate their own water and sewage treatment facilities. The Virginia Water and Sewer Authorities Act [15.1-1239] describes the procedures of setting up authorities and details the abilities of these bodies.

Among the powers granted in 15.1-1250, authorities can issue revenue bonds, and "fix, charge, and collect rates, fees and charges for the use of or for the services furnished". They can "combine any water system, sewer system, sewage system disposal system as a single system for the purposes of operation and financing."

Procedures for setting rates and charges are discussed in 15.1-1260. Authorities are enabled to fix and revise rates, fees, and other charges in order to provide sufficient funds for operation. All rates and charges are subject to State Corporation Commission review.

Authorities are also empowered to enter into contracts with other public agencies and with private corpoprations, associations, and individuals. As per 15.1-1268, these authorities are subject to the jurisdiction of the SWCB under the provisions of the State Water Control Law.

From a legal standpoint, the authority to construct reuse facilities and to set water and sewer rates would be a primary concern for a jurisdiction interested in wastewater reuse. Based on the aforementioned sections of the Code of Virginia and the status of the City of Virginia Beach, these issues would not hinder the development of wastewater reuse in the City.

State Agencies.

The Virginia Health Department.

Understanding the broad role and responsibility of the VHD is important to understanding its influence over reuse development in the State.

Sewage Treatment.

Beginning in 1872, the Virginia Health Department's (VHD) jurisdiction has expanded gradually with the adoption of new legislation. Today the VHD and the Virginia Board of Health (VBH) together form the primary State body in matters of public water supply and sewage treatment. Under 32.1-164 of the Code, the Board is given a broad set of responsibilities in the sewage treatment realm.

> The Board shall have supervision and control over the safe and sanitary collection, conveyance, transportation, treatment, and disposal of sewage, all sewage systems and treatment works as they affect the public health and welfare.

In accordance with this assignment, regulations may include, without limitation, the following (selected for relevance to wastewater treatment facilities):

> 1. A requirement that the owner obtain a permit... prior to construction, installation, modification or operation of a sewage system or treatment works...required pursuant to chapter 3.1 of title 62.1 of the Code of Virginia.
>
> 2. Criteria for the granting or denial of such permits.
>
> 3. Standards for the design, construction, installation, modification, and operation of sewage systems and treatment works.
>
> 7. Standards governing the transportation of sewage.

Water Supply.

The role of the VHD and the VBH in public water supply is more involved. First, the State has defined, generally, the characteristics of water qualified for domestic consumption.

> [32.1-167] "Pure water" means water fit for human consumption and domestic use (i) which is sanitary and normally free of minerals, organic substances and toxic agents in excess of reasonable amounts and (ii) which is adequate in quantity and quality for the minimum health requirements of the persons served.

Again, the VBH is granted comprehensive supervision of the water supply process in 32.1-169.

> The Board shall have general supervision and control over all water supplies and waterworks in the Commonwealth insofar as the bacteriological, chemical, radiological, and physical quality of waters furnished for drinking or domestic use may affect the public health and welfare and may require that all water supplies be pure water.

Regulations in accordance with this role may include, without limitation, the following (selected for relevance to reuse):

> 1. Requirements and procedures for the issuance of permits required by this article.
>
> 2. Minimum health and aesthetic standards for pure water.

> 3. Minimum standards for the quality of water which may be taken into a waterworks.
>
> 4. Criteria for the siting, design, and construction of water supplies and waterworks.
>
> 8. Such other provisions as may be necessary to guanantee a supply of pure water.

Continuing in 32.1-172, the Code states

> No owner shall establish, construct, or operate any waterworks or water supply in this Commonwealth without a written permit from the Commissioner. The permit may state the permitted capacity of the waterworks, the permitted source of the water supply, the permitted manner of storage, purification, and treatment for the water supply and such other conditions as the Commissioner may deem necessary to afford a supply of pure water.

Further, the Commissioner may amend or revoke permits, assess civil penalties for violations, and make emergency orders.

Interim Protocol.

Based on this public health regulator role, the VHD was prompted to develop the "Interim Protocol for Consideration of Drinking Water Recycle" in 1981 in response to the Virginia Beach proposal for a potable reuse program (Appendix B). This four page document outlines the "minimum acceptable criteria for establishing a direct recycle drinking water system for the City of Virginia Beach or any other locality in the state" [VHD, 1981; pg. 1].

These criteria do not at this time represent an official position of the VHD; rather they are guidelines for reuse proposals. They represent the Department's attempt to develop a "fail safe system" to the degree technically possible for the protection of the public. It is expected that regulation of wastewater reuse will be on an individual, site specific basis with the Protocol serving as the baseline document. Despite the "unofficial" nature of the document, its criteria are fundamental to the infeasibility of wastewater reuse in Virginia Beach. The elements of the Protocol are surveyed here generally; specific impacts are discussed in following chapters.

Section I of the Protocol describes requirements for public involvement in reuse plans. Among the criteria, a formal assessment of public acceptability is required as is a public education or information program.

Section II, the most detailed part of the Protocol, describes the criteria for experimental approval. According to this section, all potable recycle systems are to be considered experimental; none of the water produced in the first 24 months of operation can be used for potable use. Feasible non-potable reuse "shall have been" utilized before potable recycle is considered. The time frames mandated in the Protocol have been established through in house discussion at the VHD.

The Protocol outlines a three phase approach to system development that must be followed, designates the minimum unit processes which must be included in the flow train, and deliniates the minimum pilot test parameters to be included in a minimum of twelve months testing. A reduced scale experimental plant is envisioned for demonstration. Plan approval is based on these test data; final operation approval is based on a favorable risk assessment. Other continuous monitoring is designated upon approval.

Section III is an outline of administrative criteria. The primary requirement is that of a single administrative authority for control of the entire treatment process.

> The existence of two separate administrative authorities (one over the wastewater treatment facility and another over the drinking water treatment facility) is not acceptable. The entire treatment process must be considered as a single treatment train and shall be monitored, operated, and administered as such [VHD, 1981; pg. 3].

Single agency control is necessary, the Department asserts, to avoid conflicting objectives and procedures which might jeopardize the quality of the water. In most situations in Virginia, single agency control is achievable because one jurisdiction operates both water treatment and sewage treatment.

Under Section IV, Technical Criteria, recycled water may not be used as a sole source of water; for safety reasons, the "critical maximum permissible dilution rate shall be 1:3." The Protocol states that industrial wastes should be minimized and pretreated and if possible eliminated.

Requirements for operational testing and monitoring are outlined in Section V. The Health Risk Assessment is not described in detail in the Protocol but is to be developed by the VHD Division of Epidemiology. Finally in Section VII, the VHD is designated as the body which will make all final health related decisions in recycling projects.

VHD policy is rigid on the reuse issue in that it will not approve a recycle system under any circumstances if a more conventional water source is feasible. Commenting on this stand, VDH Director of Water Supply Engineering Allen Hammer [1982] expressed the opinion that the policy would not be "softened". It is possible that the State might ban reuse altogether in light of the many health unknowns.

Position on Reuse.

The VHD maintains that a conventional water source should be used before any other. In the event that conventional options are examined and prove impossible to implement, reuse optons can be considered.

The VDH's basic purpose is to assure the public of adequate quality and quantity of water regardless of the source. The Department has been open to reuse proposals but views them in a very conservative perspective based on its public health protection role. Unsatisfied with the current knowledge of public health risks and treatment process reliability, the VHD has formulated a cautious, expensive, and time consuming process for implementing reuse proposals as documented in the Interim Protocol.

The State Water Control Board.

Though not as important to municipal wastewater reuse as the VHD, the SWCB is a potentially influential body in this area. The State Water Control Board (SWCB) began as a creation of the State Water Control Law in 1946. Through interest in discharges to state waters and water conservation, the Board is involved in municipal sewage systems and thus, potentially, reuse projects. The Board has, however, neglected conservation and management issues in favor of water quality problems.

The SWCB was originally charged with administering and implementing the Water Control Law; its tasks included the establishment of water quality standards (which were approved by the federal government in 1971). Over the years through amendment of the Act, the Board's responsibilities have been broadened [Walker and Cox, 1976]. The primary method of control of State waters has been the waste discharge certificate. Part (2a) of 62.1-44.15 states that it is also the duty and authority cf the SWCB to "study and investigate methods, procedures, devices, appliances, and technologies which could assist in water conservation or water consumption reduction." Through 62.1-44.36, the SWCB is assigned the responsibility of planning the development, conservation, and utilization of Virginia's water resources.

Though the Board has been legislatively mandated to develop water resources policy, Walker and Cox [1976] explain that the enabling legislation does not convey authority for effecting the resulting policy provisions; "implementation must be accomplished within the scope of existing agency authority" [Cox and Walker, 1976; pg. 26].

The SWCB is mandated under 62.1-44.18 to jointly supervise all sewage systems and sewage treatment works, and instructed to give discharge approvals under 62.1-44.19. Virginia's Groundwater Act of 1973 [62.1-44.83 through 62.1-44.106] further joins the VHD and the SWCB in administration and enforcement in order to "conserve, protect, and beneficially utilize the groundwater of this State, and to ensure the preservation of the public welfare, safety, and health..."

The Code does not set forth any explicit guidelines for resolution of differences between the agencies. Generally, conflicts have been resolved informally [Walker and Cox, 1976].

Occuquan Policy.

Through its overseer role in the sewage treatment area, the SWCB became involved in the Upper Occuquan reuse project. This indirect potable reuse system in operation in Northern Virginia has set the stage for what might be expected in other reuse proposals. It has been anticipated that a similar "Virginia Beach Policy" would be developed if wastewater reuse in that City were deemed acceptable. A review of the Occuquan Policy is helpful to understanding what role the SWCB might play in other municipal reuse projects.

Beginning in 1968, the SWCB conducted two studies and authorized one consultant study examining the Occuquan Reservior water quality problems which resulted from sewage discharges. In 1970, the "Adoption of a Policy For Waste Treatment and Water Quality Management in the Occuquan Watershed" was published. This document represented potential interim and long term solutions to the watershed's pollution problems; the result was a high level wastewater treatment facility and a program of indirect potable reuse.

Though revised over the years between 1970 and 1982, the basic policy document outlines the proposed solutions and gives detailed recommendatons. The long term solution covers treatment plant location, capacity, design requirements, and administrative and technical requirements. The interim solution consists of procedures for expanding existing treatment plants.

The policy also gave birth to the Watershed Monitoring Subcommittee whose job it is to "insure that performance levels are maintained and that the effects of discharges and urban runoff on receiving waters are known" [SWCB, 1974b; pg. C-1].

Position on Reuse.

Though it has not formulated an official position on domestic reuse, the SWCB has established a position favoring municipal reuse for non-potable industrial and agricultural applications. Like the VHD, the SWCB maintains that conventional water sources should be used first.

> SWCB Policy 3.5-3.
> The use of reclaimed water should be considered in water resources planning for urban areas providing auch uses are compatible with the public's health and safety. Acceptable uses which should be considered are:
>
> 1. Cooling waters
> 2. Agriculture
> 3. Irrigation
> 4. Industrial
> 5. Recreational
>
> The direct reuse of sewage effluents as a raw domestic source is not recommended or condoned [SWCB, 1974b; pg. RC-2-5].

<u>Water Rights, Reuse, and Municipalities</u>.

Water rights are rights of use wherein there is an obligation to return diverted water to the environment with minimum impact on subsequent users. In the case of wastewater reuse, "transformation from a conventional system of reuse may be unlawful if injury to downstream water users result" [Cox and Walker, 1976; pg. 156]. The potential for injury and associated legal conflicts will depend on the form of reuse considered. As Cox and Walker [1976] describe it, a case of water recycle which reduces withdrawal will not tend to cause injury to downstream interests; in a case where withdrawals continue at the previous rate but some use is found for the wastewater such that discharges are reduced or eliminated, the chance for injury is high.

Virginia, being an essentially water rich state, has adopted the riparian doctrine of water rights. The basic concept of this doctrine is that an owner of land bordering a natural stream has the right to make a "reasonable use" of the water on the "riparian property" [SWCB, 1974b; pg. RC-2-10]. The aspects of this doctrine which can have an impact on wastewater reuse are the concept of reasonable use and the restriction of water use to riparian land [Cox and Walker, 1976].

The reasonableness concept as a criterion is defined by the circumstances of a particular situation; the basic determinant is the impact of the proposed use on other land owners with similar rights. "Any use that substantially depletes stream flow to the detriment of others is therefore likely to be unreasonable, with use for domestic purposes constituting the principle exception" [Cox and Walker, 1976; pg. 158]. This concept presents few constraints on change of water use since the doctrine is enforced through the judicial system and "almost all applications of water to the productive enterprises are recognized as reasonable under appropriate conditions" [Cox and Walker, 1976; pg. 159].

The riparian land requirement may be an obstacle to reuse proposals when a diversion of wastewater for use at another location is involved. Since riparian land is that which is in contact with the stream, this requirement is especially critical where land has been subdivided into many tracts and water rights therefore have been abolished.

The extent of enforcement of this requirement varies among riparian doctrine states. The general qualification "allows use on non-riparian land in situations where riparian owners on the stream in question are not injured" [Cox and Walker, 1976; pg. 159]. According to Cox and Walker, non-riparian uses are judged unreasonable per se whenever supplies are not adequate to meet all riparian needs, without regard to relative utilities of the riparian and non-riparian uses. As a result, "the conditions under which wastewater can be transported for use on non-riparian land are very restrictive" [Cox and Walker, 1976; pg. 159].

It is rare for municipal supply to have a preferred status among water uses. Under the riparian doctrine, municipal use has been distinguished from the individual's riparian right of reasonable domestic use and the associated legal reductions in flow [Walker and Cox, 1970].

In the case of a non-navigable stream, a municipality is liable for any damage resulting to downstream riparian owners. A non-riparian municipality could use water from a non-navigable stream as long as damages were not incurred downstream. It appears that municipal use of a navigable stream is not restricted as long as no damages are caused.

The riparian doctrine distinguishes between immediate water use and water storage. According to Walker and Cox [1970] this concept has not been completely defined. Storage rights tend to be more restrictive than use rights when the former exist at all. Storage for future use in a dry season has not been seen as a valid right by the courts. Cases have only involved storage for power production, however.

Interbasin transfer of water is an associated issue of water rights. The Attorney General of Virginia does not consider interbasin transfer legal when a water supplying utility withdraws water from one basin and sells it to residents of another basin. Utilities do, however, transport water to non-riparian lands; the water must be obtained through the right of eminent domain. These transfers have been tolerated.

Agricultural interests and environmental organizations have been particularly vocal in opposition to interbasin transfer. Many other groups have risen to oppose transfers when it appears that the economic development of their water rich areas would be harmed. The Virginia legislature has not seen fit to authorize such interbasin transfers of water; Ed Born [1982] of the Virginia Water Research Center speculates that some type of compensation scheme would be necesary for the legislature to legalize the transfers.

Conclusion.

The Code of Virginia gives the VHD and the VBH considerable control and discretionary powers. Perhaps most important of the Health Board's influences on wastewater reuse is its ability to set the design standards for all phases of sewage treatment facilities, and to develop criteria for siting, designing, and constructing water supply facilities.

On the water supply side, the Board has been given a vague definition of "pure water" which allows considerable interpretation of "reasonable amounts" of contaminants, "adequate" quantity and quality, and "minimum" health requirements. In addition, the Board may set minimum quality standards for the water which may be taken into waterworks. For its specific quality criteria, the State has adopted the Federal Drinking Water Quality Standards. As yet, neither federal nor state standards for recycled municipal wastewater have been established.

The central element of the Board's control is the permit. The Commissioner is able to outline conditions for all aspects of the water supply process in the permit; he/she may also include "such other conditions as the Commissioner may deem necessary to afford a supply of 'pure water'" [32.1-172]. Clearly, this gives a Commissioner great latitude; stipulations will be affected by current attitudes on reuse.

In the Virginia Beach case, the need for VHD approval of the reuse proposal and the VHD's ability to control facility design and planning are critical. The VHD's influence is most clearly manifested in the Interim Protocol and this influence is essentially a negative one from the perspective of implementation.

No body at the State level in Virginia, it appears, has taken a lead in investigating reuse. Ultimately, this makes life more difficult for localities interested in reuse as a water supply option. If wastewater reuse were to be actively studied and encouraged in Virginia, the SWCB has the potential to take a leading role.

However, the SWCB has focused on water quality issues rather than conservation and management. Historically, the SWCB's major involvement has been with water quality: controlling discharges and upgrading sewage treatment plants. There are two main reasons for this emphasis. First, the federal Clean Water Act and various mandated programs of the Environmental Protection Agency made money available for sewage treatment plants and water quality programs. Second, Water quality issues have impacted greater numbers of Virginia residents in relation to supply concerns; few communities have been in a situation of running out of water [Watts, 1982].

As a result of this orientation, much less work has been done on state water management. It is possible that the time for a change in focus has arrived since federal funds for water quality programs are being reduced. Other obstacles remain. Statutorily, the SWCB has the responsibility of planning and managing the State waters; in reality, however, problems of appropriation and public policy have interfered. According to Ed Born of the Virginia Water Research Center [1982], some members of the SWCB would argue that they have not been given sufficient funds to carry out the Board's statuatory responsibilities. The Legislature's HB-1607 reemphasized the Board's duty to prepare a comprehensive plan. In response, the Board requested a one million dollar budget for 1982-84. The legislature refused this request, saying that the SWCB must go ahead with the resources available; the Board then replied that a comprehensive plan would now take over 20 years to complete.

Public policy and the appropriation of surface waters under the riparian doctrine are seen by some as obstacles to proper state water planning. Virginia's Groundwater Act of 1973 created groundwater management districts but left them little to manage as the Act grandfathered in so many forms of water use. Under 62.1-44.87 of the Code of Virginia, permits are not required for agricultural and lifestock watering purposes, human consumption and domestic use, or any single industrial or commercial purpose using less than 50,000 gallons of water per day. The doubtful legality of interbasin transfer under the riparian doctrine plus the separation of control over groundwater and surface water sources has proven to make water planning at the state level difficult if not impossible.

Based on the observed inability of the State to coordinate water management and conservation, to allocate sufficient funds for those purposes, and to approve interbasin water transfer proposals, one could conclude that the concerns of water short areas are not a priority. The VHD and the SWCB, as specific State bodies, have not been committed to investigating and promoting reuse in the State. As a result of this low priority status and lack of interest in reuse, the opportunities for wastewater reuse in Virginia are limited. Watts [1982], himself, said that municipal reuse could become a reality in Virginia Beach before anywhere else in the State; and not even Virginia Beach has been able to accomplish that yet.

In summary, the VHD and the SWCB have ultimate control over wastewater reuse proposals from Virginia localities; in the case of municipal reuse, the VHD is the prominent body. The Health Department has broad responsibility and is in a position to regulate all phases of wastewater treatment and water supply treatment. The VHD has thus far been open to reuse proposals for review. The SWCB, through policy, does not allow reuse for domestic purposes but has been involved in regulating the indirect reuse system in Occuquan Reservoir.

A combination of factors - unclear responsibility, insufficient funding, and prohibitive water rights interpretations - have made comprehensive State water planning and management difficult.

With this context in mind, the specifics of the Virginia Beach attempt at municipal wastewater reuse can be examined in the next chapter.

Chapter V

LEGAL AND INSTITUTIONAL BARRIERS TO WASTEWATER REUSE DEVELOPMENT: VIRGINIA BEACH CASE STUDY.

The objective of this chapter is to examine the legal and institutional factors affecting the development of wastewater reuse as a potable water supply in the City of Virginia Beach. Background information on the City and the nature of its water supply situation is covered first. The City's 1981 study of water supply development options and its assessment of wastewater reuse are then discussed. The major section of the chapter reviews the legal and institutional obstacles underlying Virginia Beach's current inability to consider potable reuse as a feasible option.

It is concluded that, unlike cases in the Western United States, legal issues such as interbasin transfer and contractual relationships do not hinder reuse development in Virginia Beach. Nor are institutional factors such as administrative authority and coordination seen as obstacles. However, the criteria set by the VHD in the Interim Protocol act as legal and institutional barriers to reuse. In the final analysis, the economic and practical realities of implementing a reuse project as per the criteria are beyond what is possible for Virginia Beach at this time.

Setting and Background for the Case Study.

The City of Virginia Beach.

The 300 square mile City of Virginia Beach was established in 1963 from the rural Princess Anne County and the resort community of Virginia Beach. The City is the easternmost jurisdiction in Virginia's Tidewater area. Virginia Beach is boardered on the west by the cities of Norfolk and Chesapeake, and on the south by the state of North Carolina. The north and east edges of Virginia Beach are Atlantic Ocean shoreline.

In 1981, the population of Virginia Beach reached 256,500; the City is the Nation's fourth fastest growing jurisdiction [Department of Economic Development, 1978]. Tourism is an important element in the Virginia Beach economy; over two million people visit the City annually [Department of Economic Development, 1978]. Agriculture is the primary activity in rural sections of the City but the largest sources of employment are retail trade and services.

Several military installations are found within the City's borders and employ 20 percent of the labor force [Department of Economic Development, 1978]. These installations are Camp Pendelton, Fort Story, Little Creek Naval Base, Oceana Naval Air Station, and the United States Naval Amphibious Base [Divison of State Planning and Community Affairs, 1973].

Water Supply and Demand.

The City of Virginia Beach has no reliable source of freshwater within its boundaries. The existing aquifers are shallow and the groundwater is partially contaminated as they are subject to saltwater intrusion and pollution. To a limited extent, though, groundwater is used. Individual wells draw 9 to 12 million gallons per day (mgd) from local aquifers; this water is used primarily for watering lawns, washing cars, and filling swimming pools. After 25 to 30 years of use, these sources are typically subject to saltwater intrusion [Leahy, 1982].

Freshwater surface sources capable of supplying domestic needs do not exist in Virginia Beach. Inland bays and small lakes are, however, used for fire fighting when domestic supply is not adequate.

Virginia Beach's primary source of water have been the surpluses of the City of Norfolk; this has been the case since the 1920's. The current water supply contract, drawn up in 1973, expires in June of 1993. The safe yield of the Norfolk system is 70 mgd and is expected to be reached during the 1980's. It is not expected that Norfolk could continue to supply Virginia Beach's growing water needs.

The average water surplus available to Virginia Beach has been 25 mgd. Average demand has grown to 19 mgd; peak demand has risen to 30 mgd. In its Water Position Paper [1981], the City has estimated that average annual demand may grow to over 40 mgd with a peak demand of almost 60 mgd by the year 2000.

The Tidewater area suffered drought from Fall of 1980 through the Spring of 1981. The Summer peak water demand in Virginia Beach was 30 mgd. By the Fall of 1981, the available water supply out of Norfolk was only 15 mgd [Virginia Beach, 1981]. Mandatory restrictions on water use were imposed in 1980 and lifted in July, 1981; table 11 summarizes these prohibitions and allocations.

By early 1981, the City had made contracts with the City of Suffolk and the Counties of Isle of Wight and Southhampton for the construction and operation of five emergency water wells. The combined capacity of these wells is 20 mgd. The Malcolm Pirnie Inc. [1981] Assessment indicates that this system could provide emergency relief for the next ten years at best.

Water Position Paper.

The City's major step to develop a reliable water supply in the near future has centered on an assessment of 24 options, one of which was wastewater reuse. These options can

Table 11.

SUMMARY OF WATER USE RESTRICTIONS AND ALLOCATIONS IMPOSED BY THE CITY OF VIRGINIA BEACH DURING 1980-1981 DROUGHT.*

<u>Restrictions</u>.

1. landscape and lawn watering prohibited unless a 3 gallon bucket is used

2. filling and refilling swimming pools prohibited

3. car washing prohibited unless a 3 gallon bucket is used

4. driveway and walk washing prohibited

5. hydrant meters for use of fire hydrant water by commercial establishments recalled

6. drinking water in restaurants must be requested by customers

<u>Allocations</u>.

1. Single Family Residential.
   3 person household: 184 gallons/day (represents 75% of normal 300 gallon/day use)
   each additional person: 50 gallons/day

2. Commercial Establishments.
   75% of previous years usage for season

3. Motels.
   standard room: 150 gallons/day
   efficiency unit: 180 gallons/day

4. Medical Facilities.
   no allocation restrictions

Continued on next page.

Table 11 Continued.

<u>Rates</u>.

1. Single Family Residential.
   0 - 75% use: $1.06/1000 gallons
   75 - 100% use: $4.10/1000 gallons
   100%+ use: $14.70/1000 gallons

2. Commercial Establishments.
   0 - 75% use: $1.10/1000 gallons
   75 - 100% use: $4.10/1000 gallons
   100%+ use: 70/1000 gallons

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* Source: Piland, 1982.

be grouped into four categories: shallow groudwater systems, desalinization of deep well brackish water, wastewater reuse, and surface water supplies outside of the City [Malcolm Pirnie, Inc., 1981].

The three primary assessment criteria were (1) ability to provide up to 60 mgd, (2) at a reasonable cost, and (3) without major complications. "Complicating factors" consisted of interstate waterways, interbasin transfers, water quality problems, major regulatory constraints, and declining yields.

Of the options reviewed, the "Appomattox Alternative" was deemed to be the best possible solution to the City's water dilemma. This water supply proposal required legislative approval and the unanimous consent of the ARWA members[6] [Water News, March, 1982]. Despite Governor John Dalton's endorsement of the proposal [Water News, December, 1981], Virginia Beach's bid to join the Appomatox River Water Authority (HB-510) was denied in 1981 because of the interbasin transfer issue. (Through the Attorney General's interpretation of riparian doctrine, interbasin transfer is illegal.)

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[6] The Appomatox River Water Authority currently includes the cities of Petersburg and Colonial Heights, and the counties of Chesterfield, Dinwiddie, and Prince George.

According to the *Position Paper*, investigation into wastewater reuse showed that upon completion of the Hampton Roads Sanitation District's (HRSD) new Atlantic Plant, effluent would be available for recycle into potable supply for Virginia Beach. The reclaimed wastewater would have to be blended with conventional supplies at a ratio of 3:1. "Projected capital costs for a 10 mgd potable reuse plant would be about $3.84 per thousand gallons" [Virginia Beach, 1981; pg.III-22].

Indirect wastewater reuse, as applied in northern Virginia, was not possible in Virginia Beach because of the City's lack of natural water bodies [Virginia Beach, 1981].

Non-potable reuse was rejected based on the lack of markets and the high cost. Virginia Beach does not have any large water-using industries in its borders; the existing lack of water has prohibited the City from attracting such industries [Watts, 1982]. The agricultural sector would not support a useful non-potable system either. Currently farms do not pay for water since rain accomodates the growing season in Virginia Beach; City officials do not believe that this sector would find reuse to be an economical water supply [Leahy, 1982]. Therefore a potential reuse market is unavailable.

The other limitation to a non-potable system is the distribution cost. For a city spread over 300 square miles, the cost of a new distribution system is prohibitive [Watts, 1982].

In the final analysis, the City's position on direct potable reuse was that "Existing regulatory constraints preclude wastewater reuse from serious consideration pending the development of official standards and guidelines" [Virginia Beach, 1981].

The Position Paper does not explain this position nor define "regulatory constraints". To determine the basis for this conclusion one must turn to the Water Reuse Assessment by Malcolm Pirnie, Inc. released one month before the Position Paper. Quoting from the letter of transmittal:

> We believe that the present state-of-the art in water treatment is sufficient to permit the design and operation of facilities to remove specific known contaminants from the Atlantic Plant effluent and to meet any foreseeable standards developed for reuse.
>
> The major obstacle to the expeditious implementation of a potable reuse project is the state of knowledge within the regulatory and scientific communities. The establishment of maximum contaminant levels for all constituents in a water supply which present an unacceptable risk to public health has yet to be developed. As a result, the Virginia Health Department has indicated that they will require a very specific and cautious approach to a potable reuse project. The Health Department's position is in line with regulatory thinking nationwide and, to an extent, represents a more lenient approach than is found in other states.

Still, this statement does not give any indication of the specific factors which, as a result of this knowledge gap, affected Virginia Beach's decision not to pursue reuse. These factors will be examined in the next section.

<u>Legal and Institutional Factors in Reuse Development</u>.

This section will review the legal and institutional factors involved in developing wastewater reuse in the City of Virginia Beach. Discussion is grouped by agency or jurisdiction since it is not always possible to draw a clear line between legal and institutional factors.

Hampton Roads Sanitation District.

The HRSD Atlantic Plant is scheduled to begin operation in 1983; the plant is situated on the southern shore of Virginia Beach and will treat sewage from Virginia Beach and Chesapeake. It was determined that with some additional treatment, a portion of the plant's effluent (destined for ocean outfall) could be a raw water supply for the City of Virginia Beach. Approximately 10 to 15 mgd could initially be diverted for this purpose.

Legal and Institutional Advantages.

The HRSD has been willing to cooperate in assisting the City study reuse and has expressed a willingness in participating in the construction and operation of the advanced processes needed for potable reclamation [Watts, 1982; Malcolm Pirnie, 1981].

The VHD requirement for single agency administration of the wastewater and the water treatment facilities would mean that the HRSD would have to take over water supply. The HRSD is chartered by the State to maintain a sewer system. Therefore, for the HRSD to assume responsibility for processing wastewater to drinking water quality, a charter revison would be necessary [Watts, 1982, Malcolm Pirnie, Inc., 1981]. Watts [1982] believes that if the reuse proposal proved feasible in other aspects, the necessary charter change would be forthcoming from the State. Legal, technical, and political issues would not be a problem.

Though the Malcolm Pirnie, Inc. Assessment implies that the HRSD would not be interested in taking over water supply authority, discussion with Donny Wheeler of the HRSD [1982] indicates the contrary. Wheeler did not believe that single agency administration was necessary in this case but it would be feasible. He added that the HRDS has only been approached about its willingness to supply effluent to Virginia Beach. Discussions have been of a preliminary nature; no policy discussions with the HRSD Commission have taken place.

The City of Virginia Beach.

Legal Issues.

Legally, Virginia Beach has the ability to construct and operate reuse facilities. Possible litigation over franchise law does not appear to be a danger here. The City serves 67,000 homes, approximately 75 percent of all residences and businesses; two small public utilities supply water to 500 homes [Watts, 1982; Virginia Beach, 1981].

Existing contractual arrangements are not an obstacle to wastewater reuse development. After 1993, Virginia Beach will not be under any obligations that could complicate development.

Should wastewater reuse for potable purposes be instituted, the Virginia Beach City Council would be the body responsible for setting rates and charges. Since transporting and transfer issues would not be involved in the Virginia Beach situation, it does not appear that complications in pricing would arise.

If the wastewater reuse arrangement with the HRSD could be worked out, interbasin transfer would not appear to be a complicating factor. Based on the City's experience with legal obstacles, reuse could represent a relief and a source of independence in water supply for the City.

Interbasin transfer is not limited or prohibited by Virginia statuatory law. Limitations or prohibitions are a result of common law riparian rights. For Virginia Beach the fact that municipal purposes are not ranked as high as other reasonable uses has been an obstacle.

Virginia Beach has found interbasin transfer issues to be a pervasive obstacle to water supply development. Interbasin transfer was listed as a complicating factor in 11 of the 24 options reviewed by the City [Virginia Beach, 1981].

The Virginia Beach Public Utilities Director, Aubrey Watts, contends that the real problem for the City as far as interbasin transfer is concerned is the City's lack of standing in court; the State has been unwilling to support the City on water withdrawal issues.

In sum, it can be said that none of the purely legal issues (eg. statuatory authority) are barriers to reuse in Virginia Beach.

Institutional Factors.

The City and the VHD have been able to work together on this proposal without any communication or coordination problems. The City finds the Department's reserved approach to potable reuse to be appropriate; local officials view the Department's strong and broad responsibility in the water and sewer regulatory realms is necessary [Watts, 1982].

The complicating factor is the lack of standards for reclaimed water. The United States Public Health Service has not developed quality standards and most officials agree that existing drinking water standards are inappropriate to recycled water. With respect to this lack of standards, Watts does not believe that the VHD is following a zero-risk criterion [Watts, 1982].

The Southeastern Public Service Authority (SEPSA) is a regional water resources development agency[7] which has the authority to issue bonds, contract for services, develop and implement services [Watts, 1982]. Therefore, the legal framework for a solution to area water problems exists. The agency has not been able to progress with water supply plans, however, because of recurrent political, institutional, legal, and technical obstacles [Watts, 1982; Malcolm Pirnie, Inc., 1981]. While SEPSA could, in theory, play an influential role in developing regional and local reuse opportunities, the agency has not been involved in Virginia Beach's reuse proposal.

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[7] SEPSA represents Southampton County, Isle of Wight County, Chesapeake, Franklin, Nansemond, Norfolk, Portsmouth, Suffolk, and Virginia Beach.

From an engineering standpoint, professionals have told the City that wastewater can be reclaimed. If it came to fighting the VHD about it, however, the City would be on its own. In essence, the engineers would not take a strong stand in support of potable reuse.

From a social acceptance standpoint, Watts thinks that reuse would work in Virginia Beach before any other locality in Virginia. Though no formal surveys have been conducted, it appears that the residents of Virginia Beach and the City's public officials have not shown any substantial concern over the prospects of wastewater reuse. According to Watts, the residents realize that there is a serious water resource problem and they are willing to try new solutions. The Virginia Beach population tends to be young, highly educated, and of higher incomes. This, Watts believes, makes the City amenable to trying wastewater reuse. There is a considerable military population also which, as a group, is familiar with different types of water sources.

Locally, there is some misunderstanding of the water problem. It is the common perception of people, including residents, that Virginia Beach's tourist trade is the problematic factor in water consumption. In fact, however, the tourist industry has relatively little impact on total water use; at the peak of the tourist season, vacationers use 2 mgd. Watts maintains that if the water supply problem centered on the tourist industry, it could easily be solved by constructing a reuse or a desalting plant in the beach area.

Based on this assessment, there are no factors which might be considered strictly institutional which critically inhibit the development of wastewater reuse in Virginia Beach. The Viginia Health Department's Interim Protocal, however, acts as a legal and instituional barrier in the development of reuse; its effects are examined in the next section.

Virginia Health Department.

It might be expected that a "Virginia Beach Policy", similar in form to the "Occuquan Policy" and based on the "Interim Protocol", would be formulated between the appropriate agencies if Virigina Beach found it feasible to proceed with reuse.

Effect of the Protocol Requirements.

The so called "unknowns" in public health effects have prompted a cautious, conservative approach to reuse on the part of the VHD. Some of the requirements developed under this approach make potable reuse impractical in Virginia Beach.

Several of the VHD's criteria cannot realistically be accomplished in Virginia Beach. The requirement that non-potable reuse be demonstrated before potable reuse can be used is inappropriate in this case because of the high distribution costs and lack of markets associated with non-potable reuse. The "Interim Protocol" states that "natural purification processes should be applied where possible". This approach, creating a greater separation between wastewater processing and advanced treatment, would increase the likelihood of of VHD approval of the proposal. Virginia Beach, however, lacks the natural surface waters to accomplish this.

The Protocol requires a 75 percent dilution rate; that is, only 25 percent of the water supply can be reclaimed wastewater. For Virginia Beach, this makes reuse impractical since the City does not have enough "pure water" to achieve the required mix.

If direct potable reuse is employed, only domestic wastewater can be processed. The VHD would prohibit any further commercial or industrial connections to the wastewater collection system.

Though the City has agreed that the long testing and trial procedures outlined in the Protocol are reasonable, these same requirements make wastewater reuse economically infeasible for Virginia Beach. The estimated time frame for project implementation is 12 years [Malcolm Pirnie, Inc., 1981]. In the final phases, a 12 month pilot testing period would be followed by a 24 month prototype period. For these 24 months, Virginia Beach would have to produce water but would not be able to sell and distribute it. This translates into two years of operation without revenue [Watts, 1982].

Table 12 displays the estimated costs of this proposal. Malcolm Pirnie, Inc. [1981] estimated that indirect potable reuse and groundwater injection systems would cost in excess of the direct potable option. Non-potable reuse was estimated to cost about the same as a potable system.

Conclusion.

Basically, for the City of Virginia Beach, direct potable reuse is too little, too late, for too much. Having worked with the VHD, the City now views wastewater reuse development as a potential solution in the 1990's. Watts does not envision progress in implementaton being made until the Denver studies are completed in the early 1990's.

According to Watts, the City is willing to spend more money on an option like reuse which would make the City independent in the water supply area and avoid the legal and

Table 12.

PRELIMINARY COST ESTIMATES FOR A 10 MGD DIRECT POTABLE RESUE PLANT IN VIRGINIA BEACH.*

1. Capital Costs.	
Pilot Testing Program	$ 600,000
Prototype Testing Program	14,600,000
Risk Assessment and Public Relations Program	2,800,000
Production Plant	50,800,000
Land & Rights-of-Way	500,000
Legal, fiscal, administrative and technical services	7,600,000
Contingencies	5,100,000
Total Capital Costs	$82,000,000
2. Annual Costs.	
Amortized Capital Cost (9% for 25 years)	$2.30/1000 gallons
Operation & Maintenance	1.54/1000 gallons
Total Annual Cost	$3.84/1000 gallons

* Source: Malcolm Pirnie, Inc., 1981.

political problems of other options. But reuse at this point can only deliver 10 mgd to Virginia Beach - only one-sixth of the water required under projections for the 1990's.

For Virginia Beach, reuse is not a good long term investment. Potable reuse could now be developed at a greater cost than other options but the supplementary supply would also carry a high cost. A smaller investment in a surface source outside of the City could provide all the water needed. However, these options would place the City in a continued dependent position and generally are accompanied by legal and political troubles.

In an overall view of reuse development in Virginia Beach, legal issues are a help rather than a hindrance. Whether or not the City has the authority to plan, construct, and operate a reuse facility is not a question. The necessary HRSD charter change is a rectifiable issue. The reuse option is helped by the fact that most every other water supply option that Virginia Beach has is plagued by legal complications.

From an institutional perspective, intra-agency communication and coordination does not appear to be an obstacle. Local opinion appears to be favorable on the reuse prospect. This option is helped by the fact that it, over other supply options, could give Virginia Beach a good degree of independence in the water area.

The half legal, half institutional obstacle over which reuse stumbles is the set of approval requirements developed (though not finalized) by the VHD. The City of Virginia Beach cannot meet these criteria and still have a water supply source of sufficient quantity and reasonable cost. These criteria are based on the State's perceptions of the current state of knowledge and confidence in the potable reuse field. Therefore, while legal and institutional factors are indeed barriers to reuse in Virginia Beach, the critical points are the underlying technical and public health issues. Therefore, if the definition of legal and institutional factors is broadened in this context to include the response of State agency requirements to technical uncertainties, then legal and institutional factors are critical obstacles to reuse development in Virginia.

When considering the necessary environment for the development of wastewater reuse, the findings of this study indicate that the failure to innovate in this area is not the fault of the locality but of the State. It appears as though the local environment is receptive to wastewater reuse innovation. Water supply, in general, is a high priority with the City officials and the residents of Virginia

Beach. Further, the Department of Public Utilities is headed by an intelligent, committed man who is supported by a capable staff.

At the State level, however, legal and institutional barriers to reuse have been constructed such that the ability to pursue municipal reuse at the local level is hindered. Without committment and incentive from the State level, there is little chance that cities like Virginia Beach will find wastewater reuse to be a feasible water supply option.

Chapter VI

CONCLUSION

Primary Conclusion.

Based on this case study the following conclusion can be drawn: legal and institutional factors were the critical obstacles to reuse development in the City of Virginia Beach. However, these factors were not obstacles in and of themselves; rather, they reflected larger issues born out of a lack of confidence, at the State level, in the reliability of reuse technology and in the knowledge of public health effects. The Interim Protocol, as the key document in this case, is the legal and institutional link between the technical issues and the implementation of reuse proposals in the State of Virginia.

Secondary Conclusions.

Two secondary conclusions can also be drawn. First, although the Interim Protocol still stands as a significant barrier for all Virignia localities, the infeasibility of direct potable reuse in Virginia Beach does not necessarily imply that proposals from other Virginia localities would likewise be infeasible. And second, the completion of current studies in the areas of health effects and technical reliability will increase the likelihood of implementation of potable reuse projects in Virginia if the study results are favorable.

Discussion.

The specific obstacles to development of wastewater reuse as a water supply in Virginia Beach were the VHD criteria for approval as described in the "Interim Protocol". The criteria were based on the VHD's interpretation of current knowledge of and confidence in the ability to provide a minimum risk water supply through reuse. The effect of the criteria, whether one considers them reasonable or not, is to make wastewater reuse economically unreasonable.

The nature of the legal and institutional barriers in this investigation differs from that of previous research noted in chapter III. In this case, the definition of legal and institutional factors must be broadened. They are not clearly distinct from other factors affecting water reuse; in fact, the legal and institutional barriers are a manifestation of other issues. In some cases, issues such as contractual relationships or a history of interagency conflict might be obstacles to wastewater reuse yet be wholly independent of other reuse related issues. However, in the Virginia Beach case, the primary legal and institutional obstacle to reuse development, the Interim Protocol, is in fact rooted in the critical issues of public health risk and technological reliability.

The general factor categories discussed in chapter 3 are arranged based on their relationships to one another in the Virginia Beach case study in figure 9. The lack of confidence in public health effects information and the ability to maintain a minimum risk water supply forms the basis for VHD and SWCB policies and procedures. These policies, are in turn, the basis for specific criteria (as those in the "Interim Protocol") for review and approval of reuse proposals. The criteria, in combination with local economic factors, affect the economic feasibility of the proposal. In this case, the "Interim Protocol" is the dominant factor in making potable reuse a very expensive option; the long development time periods and the extensive testing requirements are the essential factors in this expense.

The criteria also interact with local legal, institutional, and political factors to determine the technical and practical ability of the City to implement a reuse project. While the local situation appears to be favorable for reuse, the criteria, again, dominate as negative influences on implementation.

In the final analysis, the economic feasibility of the proposal and the technical/practical ability of the City to implement combine to make potable reuse unpractical in Virginia Beach.

This particular pattern of factors may not necessarily be matched in other Virginia localities. While the current state of knowledge, the legal political and institutional provisions of the State, and the VHD criteria were all looked upon in this study as static factors in a limited time frame, the political, legal and institutional provisions of a locality, the economic situation, and the technical abilities to implement a reuse proposal change over time and space.

According to Alan Hammer [1982] of the VHD, there is little chance that the agency will soften its requirements for reuse proposal approval. Hammer is of the opinion that requirements might become more stringent upon the development of reclaimed water standards. However, the intuitive conclusion would be that with more experience in potable reuse, the resolution of health uncertainties, and the development of standards[8] to guide development, implementation would be made easier.

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[8] While criteria are typically specific and rigid, standards tend to allow a degree of flexibility in the mode of attainment.

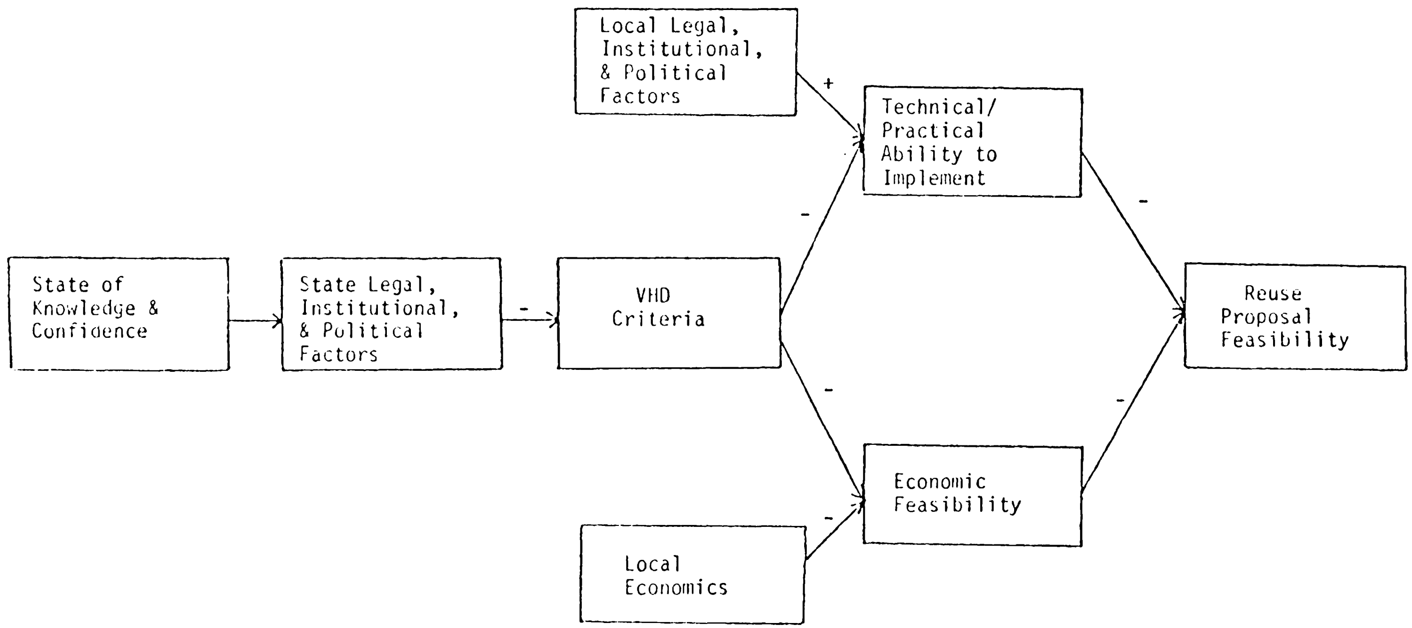


Figure 9. Relationships between factors influencing the development of wastewater reuse for potable supply in the City of Virginia Beach. (+) denotes positive influence relative to proposal feasibility; (-) denotes negative influence on proposal feasibility.

Recommendations.

State Preparation.

The State of Virginia, through the VHD and the SWCB, should prepare itself and its localities for the time when direct potable reuse has the "go ahead" of the scientific community. This could be accomplished in three steps.

First, the State should study and designate those jurisdictions wherein potable reuse would be socially, economically, and environmentally beneficial. Such study could prompt a regional or statewide approach to water supply problems which would allow individual communities, which need potable reuse for supply, to avoid the 75 percent dilemma. If a locality is of such a need for domestic water that its most rational or its only option is reuse, the community could rarely be expected to provide 75 percent or some other large percentage of "pure water". A regional or statewide approach might be used to develop a water supply system for several communities through which they would be able to share the burden of supplying sufficient "pure water" to which reclaimed water could be mixed. The approach could also be applied in cases of communities needing water bodies for natural purification processes or any other local limitations.

Second, the State should develop policy and technical arrangements which would guide and facilitate reuse development when and where appropriate. The point of this step is to set in place a comprehensible process for necessary charter changes and authority designations. Likewise, a rational, coordinated process for the application of required permits would aid localities interested in reuse. Interim Protocol type criteria should be further developed with flexibility in order to accomodate changes in the state of technology and confidence in reuse.

Third, the State, in cooperation with interested localities, should design public information and education programs. These programs could be used to help communities make informed decisions about their water supply and to help prepare publics for the use of wastewater reuse.

Further Study.

If further research into the institutional and legal obstacles to reuse development were to be conducted in Virginia, it might best be focused on appropriate agency policy and State legislation. What tools would be needed in policy and law to make wastewater reuse a possibility for jurisdictions that really need it? How could these tools be created? Based on observations made in this investigation, a workable hypothesis would concentrate more on agencies than on legal issues; it would propose an appropriate state/local structure for the implementation of wastewater reuse. Ideally, such investigation would be a basis for the fist step of State preparation for reuse as previously described.

An hypothesis which does result from this investigation can be stated as follows: Incomplete knowledge and the lack of confidence in public health aspects of potable reuse, as reflected in state legal and institutional requirements, are the critical obstacles to wastewater reuse development as a public water supply in the State of Virginia. Study based on this could include more specific analysis of State policies, procedures, and attitudes. Is the State of Virginia's reaction to the state-of-the-art in wastewater reuse based on incomplete knowledge? Legislative biases? Assessment of public opinion? Basic resistance to change?

A broader context for further research can also be proposed. A comparative study of the process of reuse development in the United States and other countries might address the fact that the United States has advanced reuse in some applications but has lagged behind in other applications. Why has this occured? What can be learned about policy and legal tools from the attempts of other countries? How might the United States better approach reuse development in the future?

APPENDIX A:

Supplementary Tables and Figures

A - Table 1.

Summary of Statewide Standards for the Safe Direct Use of Reclaimed Wastewater for Irrigation and Recreational Impoundments

Use of reclaimed wastewater	Primary[a]	Secondary and disinfected	Secondary coagulated, filtered[b] and disinfected	Coliform MPN/100 ml median (daily sampling)
	Description of minimum required Wastewater Characteristics			
Irrigation				
Fodder crops	X			No requirement
Fiber crops	X			No requirement
Seed crops	X			No requirement
Produce eaten raw, surface irrigated		X		2.2
Produce eaten raw, spray irrigated			X	2.2
Processed produce, surface irrigated	X			No requirement
Processed produce, spray irrigated		X		23
Landscapes, parks, etc.		X		23
Creation of impoundments				
Lakes (aesthetic enjoyment only)		X		23
Restricted recreational lakes		X		2.2
Nonrestricted recreational lakes			X	2.2

[a]Effluent not containing more than 1.0 ml/liter/hr settleable solids.
[b]Effluent not containing more than 10 Turbidity Units.

From Ongert and Jopling, 1977

A - Table 2.

CDH WASTEWATER RECLAMATION CRITERIA FOR WASTEWATER

Reuse	Required Treatment (a)	Allowable Coliforms (b) (MPN/100 ml)
Food Crops		
Spray irrigation	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2 (d)
Surface irrigation		
General	Bio-oxidation, disinfection	2.2
Orchards and vineyards with no fruit contact with water or ground	Primary sedimentation	ns (e)
Exceptions	Considered on individual basis if crop undergoes pathogen destroying processing	ns
Fodder, Fiber & Seed Crops		
Fodder, fiber and seed crops	Primary sedimentation	ns
Pasture for milking animals	Bio-oxidation, disinfection	23
Landscape Irrigation		
Golf courses, cemeteries, freeway landscaping and landscaping	Bio-oxidation, disinfection	23 (f)
Parks, playgrounds and schoolyards (c)	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2 (d)
Recreational Impoundments		
Nonrestricted	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2 (d)
Restricted to non-bodily contact	Bio-oxidation, disinfection	2.2
Landscape-non-contact	Bio-oxidation, disinfection	23

(a) Primary effluent must not contain more than 0.5 milliliters per liter per hour of settleable solids. Filtration must provide an effluent with a turbidity that does not exceed an average of 2 turbidity units and does not exceed a maximum of 5 turbidity units. Alternative methods of treatment may be accepted if the applicant demonstrates to the satisfaction of CDH that they will assure an equal degree of treatment and reliability.

(b) Median as determined from results of last 7 days for which analyses have been completed.

(c) Proposed requirements will probably be adopted in 1978.

(d) Shall not exceed 23 MPN/100 ml in more than one sample within any 30-day period.

(e) Requirement not specified.

(f) Shall not exceed 240 MPN/100 ml in any sample.

From Everest and Paul, 1979

A - Table 3.

RECOMMENDED LIMITS FOR POLLUTANTS IN RECLAIMED WATER USED FOR IRRIGATION*

TRACE HEAVY METALS

Constituent	Long-Term Use[a] (mg/l)	Short-Term Use[b] (mg/l)	Remarks
Aluminum	5.0	20.0	Can cause non-productivity in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity.
Arsenic	0.10	2.0	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Beryllium	0.10	0.5	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Boron	0.75	2.0	Essential to plant growth, with optimum yields for many obtained at a few-tenths mg/l in nutrient solutions. Toxic to many sensitive plants (e.g., citrus plants) at 1 mg/l.
Cadmium	0.01	0.05	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solution. Conservative limits recommended.
Chromium	0.1	1.0	Not generally recognized as essential growth element. Conservative limits recommended due to lack of knowledge on toxicity to plants.
Cobalt	0.05	5.0	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Copper	0.2	5.0	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solution.
Fluoride	1.0	15.0	Inactivated by neutral and alkaline soils.
Iron	5.0	20.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of essential phosphorus and molybdendum.
Lead	5.0	10.0	Can inhibit plant cell growth at very high concentrations.
Lithium	2.5	2.5	Tolerated by most crops at up to 5 mg/l; mobile in soil. Toxic to citrus at low doses—recommended limit is 0.075 mg/l.
Manganese	0.2	10.0	Toxic to a number of crops at a few-tenths to a few mg/l in acid soils.
Molybdenum	0.01	0.05	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.
Nickel	0.2	2.0	Toxic to a number of plants at 0.5 to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Selenium	0.02	0.02	Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of added selenium.
Tin, Tungsten and Titanium	-	-	Effectively excluded by plants; specific tolerance levels unknown.
Vanadium	0.1	1.0	Toxic to many plants at relatively low concentrations.
Zinc	2.0	10.0	Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils.

[a]For water used continuously on all soils.
[b]For water used for a peroid of up to 20 years on fine-textured neutral or alkaline soils.
*from[15]

From Donovan and Bates, 1980

A - Table 4.

UC COOPERATIVE EXTENSION GUIDELINES FOR INTERPRETATION OF QUALITY OF WATER FOR IRRIGATION (a)

Problem and Related Constituent	No Problem	Increasing Problems	Severe
Salinity (b)			
EC of irrigation water, mho/cm	750	750-3000	3000
Permeability			
EC of irrigation water, mho/cm	500	500	2000
SAR (c)			
Specific ion toxicity (d)			
From root absorption			
Sodium (evaluate by SAR)	3	3 - 9	9
Chloride			
me/l	4	4 - 10	10
mg/l	142	142 - 355	355
Boron, mg/l	0.5	0.5 - 2.0	2.0 - 10
From foliar absorption (e) (sprinklers)			
Sodium			
me/l	3.0	3.0	--
mg/l	69	69	--
Chloride			
me/l	3.0	3.0	--
mg/l	106	106	
Miscellaneous (f)			
NH_4 - N,			
mg/l for sensitive crops	5	.05 - 30	30
NO_3 - N,			
HCO_3 (only with overhead sprinklers			
me/l	1.5	1.5 - 8.5	8.5
mg/l	90	90 - 520	520
pH	Normal range	6.5 - 8.4	--

(a) Interpretations are based on possible effects of constituents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation (UC Cooperative Extension, 1975).

(b) Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity. Refer to tables for crop tolerance and LR. The mmho/cmx640 = approximate total dissolved solids (TDS) in mg/l or ppm; mmho x 1,000 = micromhos.

(c) SAR (sodium adsorption ratio) is calculated from a modified equation developed by U.S. Salinity Laboratory to include added effects of precipitation and dissolution of calcium in soils and related to CO_3 + HCO_3 concentrations.

(d) Most tree crops and woody ornamentals are sensitive to sodium and chloride (use values shown). Most annual crops are not sensitive (use salinity tolerance tables). For boron sensitivity, refer to boron tolerance tables.

(e) Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride absorption under low humidity/high evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.)

(f) Excess N may effect production or quality of certain crops; e.g., sugar beets, citrus, avocados, appricots, etc. (1 mg/l NO_3 - N = 2.72 lbs. N/acre foot of applied water.) HCO_3 with overhead sprinkler irrigation may cause a white carbonate deposit to form on fruit and leaves.

From Everest and Paul, 1979 .

A - Table 5.

RECOMMENDED COOLING-WATER QUALITY CRITERIA
FOR MAKE-UP WATER TO RECIRCULATING SYSTEMS*

Parameter	Recommended Limit[15]	Recommended Limit[10]	Comments[10]
Cl	500	100-500	
TDS	500	500-1,650	
Hardness ($CaCO_3$)	650	50-130	
Alkalinity ($CaCO_3$)	350	20	
pH	**	6.9-9.0	Preferably 6.8-7.2
COD	75	75	Preferably below 10
TSS	100	25-100	Preferably below 10
Turbidity	—	50	Preferably below 10
BOD	—	25	Preferably below 5
Organics (methylene blue active substances)	1	2	2 is good
NH_4	**	4	Preferably below 1
PO_4	—	1	1 is good
SiO_2	50	—	
Al	0.1	0.1	
Fe	0.5	0.5	
Mn	0.5	0.5	
Ca	50	50	
Mg	**	0.5/**	
HCO_3	24	24	
SO_4	200	200	

*from[15,10]. Required limits in mg/l, except for pH units.
**Accepted as received.

From Donovan and Bates, 1980

A - Table 6.

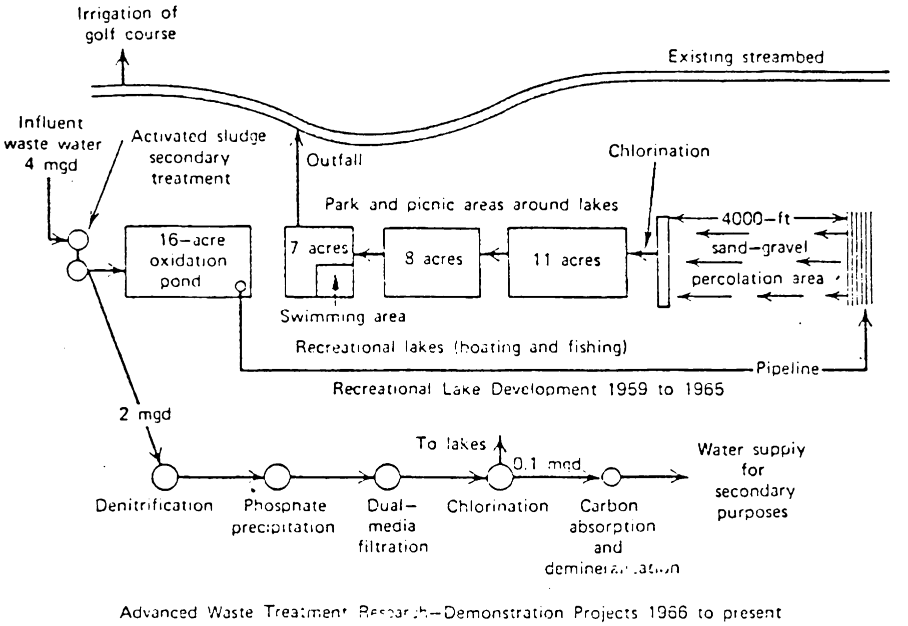
RECOMMENDED INDUSTRIAL BOILER-FEED WATER QUALITY CRITERIA*

Parameter	Low Pressure (psig)	Intermediate Pressure (psig)	High Pressure (psig)
Silica (SiO_2)	30	10	0.7
Aluminum (Al)	5	1	0.01
Iron (Fe)	1	0.3	0.05
Manganese (Mn)	0.3	0.1	0.01
Calcium (Ca)	**	0.4	0.01
Magnesium (Mg)	**	0.25	0.01
Ammonia (NH_4)	0.1	0.1	0.1
Bicarbonate (HCO_3)	170	120	48
Sulfate (SO_4)	**	**	**
Chloride (Cl)	**	**	**
Dissolved Solids (TDS)	700	500	200
Copper (Cu)	0.5	0.05	0.05
Zinc (Zn)	**	0.01	0.01
Hardness ($CaCO_3$)	350	1.0	0.07
Alkalinity ($CaCO_3$)	350	100	40
pH, units	7.0-10.0	8.2-10.0	8.2-9.0
Organics:			
Methylene blue active substances	1	1	0.5
Carbon tetrachloride extract	1	1	0.5
Chemical oxygen demand (COD)	5	5	1.0
Hydrogen sulfide (H_2S)	**	**	**
Dissolved oxygen (O_2)	2.5	0.007	0.007
Temperature F	**	**	**
Suspended Solids	10	5	0.5

*from[15]. Recommended limits in mg/l except for pH (units) and temperature (degrees Fahrenheit).
**Accepted as received (if meeting other limiting values), has never been a problem at concentrations encountered.

From Donovan and Bates, 1980

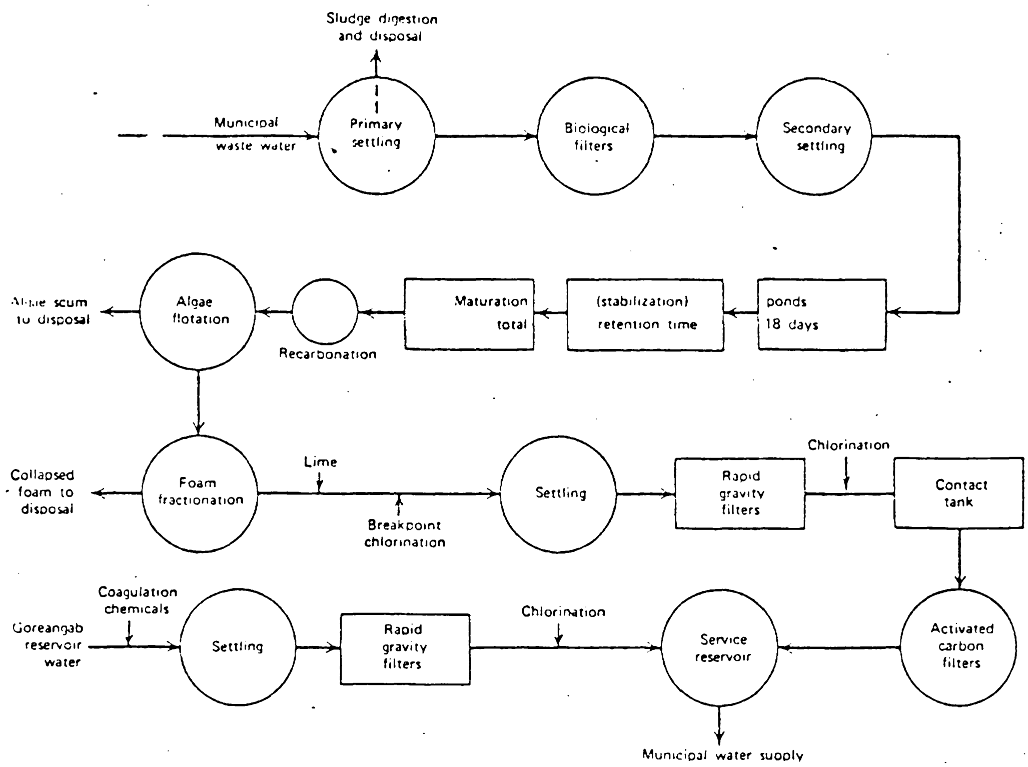
A - Figure 1.



Water reclamation and reuse at Santee, California.

From Hammer, 1975

A - Figure 2.



Schematic of the water reclamation plant and water supply system for Windhoek, Southwest Africa.

From Hammer, 1975

APPENDIX B:

Interim Protocol

JUN 1 5 1981

FILE

ACTION

INFO COPY

COMMONWEALTH of VIRGINIA

JAMES B. KENLEY, M.D.
COMMISSIONER

Department of Health
Richmond, Va. 23219

Interim Protocol for Consideration of Drinking Water Recycle

The purpose of this document is to present an interim protocol for establishing a public water supply system utilizing direct recycle of drinking water from domestic sewage. Current proposals of this nature from the City of Virginia Beach have necessitated the development of this document. This Department specifically reserves the power and responsibility to revise, update, or cancel all or part of this document at anytime based on our expanding knowledge in this area.

This Department does not take lightly the enormous public health implications of a locality distributing directly recycled drinking water to its citizens. Under no circumstances will this Department consider approval of such a system when development of a more conventional water source is feasible. Only by the application of the most sophisticated treatment techniques and the best available monitoring program could a system of this type be successfully put into operation. Above all else this Department must assure that the public health is fully protected and that the public remains confident in the safety of their water supply system.

The following subsections highlight the minimum acceptable criteria for establishing a direct recycle drinking water system for the City of Virginia Beach or any other locality in the State.

Critical Definitions:

Water Reuse - taking a used water or wastewater and treating it to such extent that it can be reused for any benficial use prior to final disposal

Water Recycle - taking a used water or wastewater and treating it to such extent that it can be reused for its original purpose, i.e. going from drinking water to sewage and back to drinking water.

I. Public Involvement

- Any plan for direct recycle of drinking water must include continuing public participation throughout the project planning, implementation and operation phases.

- Public acceptance of direct recycle must be assured by the waterworks owner.

- A formal assessment of public acceptability must be undertaken early in the planning phase.

- Public participation in system administration and planning, through a Citizen's Advisory Committee, should be considered.

- A continuing Public Education or Information Program must be included.

II. Experimental Approval

- Any drinking water recycle system will be considered experimental and is subject to the requirements of Section 3.24 of the Waterworks Regulations,

- All feasible non-potable reuse shall have been utilized before potable recycle is considered.

- A three-phase approach to system development must be followed.

  1. pilot testing
  2. full scale prototype testing
  3. full scale production

- Pilot tests should be designed to select the best process flow train and must include the following unit processes as a minimum:

  1. a high oxidation process,
  2. adsorption,
  3. reverse osmosis or ultrafiltration,
  4. nitrogen removal, if necessary,
  5. ion exchange, if necessary.

- Pilot test monitoring shall include at least twelve months data of continuous operation at the final flow scheme and include the following parameters:

  1. microbiological (bacteria and virus)
  2. toxicological
  3. chemical (inorganic and organic)
  4. mutagenicity (Ames test)

- The Pilot test period shall be used to develop operations control tests (real time monitoring) for the project.

- The full scale Prototype test unit shall include the treatment train developed during the pilot tests and shall continue the extensive monitoring program with increased emphasis on operational control tests.

- Final approval of prototype plans and specifications shall be based on a minimum 12 months of pilot test data.

- All water produced during the first 24 months of stable operation of the prototype shall not be used for drinking (non-potable reuse is recommended).

- Final experimental approval and the experimental operation permit will be issued upon successful completion of the prototype phase and favorable health risk assessment by this Department.

- Extensive monitoring in all parameter groups previously discussed shall continue throughout the experimental operation phase (12-24 months) of actual distribution of recycled water to the public.

- A final operation permit will then be issued after a favorable health risk assessment. Required operational and other continuous monitoring shall be determined at this time.

III. Administrative

- The existence of two separate administrative authorities (one over the wastewater treatment facility and another over the drinking water treatment facitlity) is not acceptable. The entire treatment process must be considered as a single treatment train and shall be monitored, operated and administered as such.

- A formal administrative organization with clear authority for independent action with regard to this project and clearly defined responsibilities shall be established by written agreement between all concerned parties including the Virginia Department of Health.

- The administrative organization should include provisions for technical, public health, and citizen input by one or more advisory committees.

- The administrative organization shall be adopted by ordinance or other formal legal commitment by all included parties no later than 6 months after the initiation of the pilot test phase.

- An absolute necessity to this project is the provision of properly trained operational, laboratory, and administrative staff.

IV. Technical Criteria

- Proven treatment units should be utilized in experimental process trains. Experimental units in experimental process trains are to be avoided.

- Storage requirements will be based on the results of operational control tests developed during the pilot and prototype testing so that any insufficiently treated water may be wasted to non-potable use.

- As an additional safety factor, recycled water may not be used as a sole source of water. The initial maximum permissible dilution rate shall be 1:3 (reuse: other approved potable supply).

- The dilution ratio shall remain relatively constant and shall be accomplished prior to distribution of the finished product.

- Industrial waste should not be recycled. All industrial wastes should be minimized and pretreated. An extensive and comprehensive survey of the sewage collection system is necessary to identify and eliminate, if possible, all sources of industrial waste. No new contributions of industrial waste shall be permitted.

- Provisions for serial monitoring of water quality through each of the various unit processes shall be provided.

- Specific unit process design criteria shall be based upon the results of the pilot and prototype tests as approriate.

V. Monitoring

- All operational tests shall be performed by a single duly authorized certified laboratory (established as a part of the Administrative Organization).

- Special and experimental monitoring may be performed at any laboratory approved by the Department.

- The capability of monitoring all unit processes throughout the treatment train shall be provided.

- Monitoring requirements will include work in each of the following parameter areas:

  1. Bacterial
  2. Viral
  3. Inorganic chemicals
  4. Organic chemicals
  5. Epidemological
  6. Toxicological
  7. Mutagenicity

- Specific parameters to be checked will be developed through and approved by the Virginia Department of Health.

VI. Health Risks Assessment

This section will include the internal mechanism to be used by the Health Department in assess the public health risk potential throughout the term of this project to be developed by the Division of Epidemiology.

VII. Interaction between Department and Waterworks Owner

- All final health related decisions concerning the use of recycled water shall be made by the Virginia Department of Health.

- Specific details of day to day interactions to be developed by negotiation with Waterworks owner.

6/5/81

Allen R. Hammer, P.E., Director
Bureau of Water Supply Engineering

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