WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: An Assessment of the North Carolina Water Reuse Regulations

Focus Categories: WW, IG

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Principal Investigator:

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Statement of the Critical Regional or State Water Problem(s)

This proposal addresses North Carolina water reuse regulations, one of the priority topics for 2000-2001 Water Resources Research Institute (WRRI) funding. The Institute provided the following statement of need:

Little research has been conducted in North Carolina on the impacts of reclaimed water beyond irrigation use. Existing State regulations are based on information and regulations developed in other states. Research is needed to determine if (a) North Carolina regulations are adequate to protect human health, and (b) whether State regulations are acceptable to the public. (from NOTICE OF WATER RESOURCES RESEARCH GRANTS, Topics of Highest Priority for Fiscal Year 2001)

State laws governing reuse must be carefully framed to insure both public health protection and public acceptance of water reuse as a viable option in water management planning. The North Carolina water reuse regulations were promulgated in 1996 in response to growing municipal interest in water reuse (Section 15A NCAC 2H.0200 of the NC code governing "waste not discharged to surface waters"). The regulations were drafted by an expert committee seeking to obtain a sensible integration of regulations used in other states with those recommended in federal documents such as *Guidelines for Water Reuse* (EPA, 1992). However, the committee recommendations were also subject to the necessary process of compromise, and they were written without benefit of any North Carolina pilot or demonstration project data, since none were available.

There are now two full-scale water reclamation facilities operating in North Carolina. The planning, permitting, and implementation of these and upcoming projects under the existing reuse legislation has given rise to a number of regulatory concerns. The first and most frequently stated is that North Carolina coliform limits are higher than those in states such as California and Florida, where there is a long history of water reuse practice and research. Several members of the committee that drafted the North Carolina reuse regulations have commented that although they believe the state regulations are adequate, in retrospect, they would prefer that the coliform limits be more stringent and consistent with the federal recommendations (personal communications with Drs. Daniel Okun, 1999 and James Crook, 1998). A second concern stems from continued research on pathogen fate and removal. There are indications that fecal coliforms may not be adequate microbiological indicators for the possible presence of viral and parasite pathogens. Studies in water and wastewater have repeatedly shown that enteric viruses and parasites are much more resistant to biological treatment, physical-chemical removal processes and disinfection processes than are total and fecal coliform bacteria and other indicator bacteria (e.g., fecal streptococci and enterococci). These viruses and parasites also are more persistent in the environment than are indicator bacteria. Third, municipalities have raised a concern about whether existing set back distance requirements are sensible and achieve the desired outcome. This issue is probably best captured in a quote from one practitioner:

…current regulations allow the withdrawal of water for irrigation purposes immediately downstream of a wastewater outfall – even when treated effluent from that outfall constitutes more than 90 percent of the streamflow. This water may be applied directly to (say) a golf course with no further treatment or oversight whatsoever. By contrast, if the waste discharger wants to provide that same effluent directly to the golf course for irrigation purposes – but without first discharging it to the stream – it must meet all the treatment and buffering requirements of the reuse regulations.

With the start-up of two full-scale water reuse projects in Raleigh and Charlotte, NC, the WRRI Advisory Committee recognized the opportunity to address these and broader issues about the efficacy of current water reuse legislation as it applies to the existing installations and future reuse facilities. The State bears a responsibility to document the quality of reclaimed water that is being produced at these facilities in compliance with North Carolina regulations. Further, it must continue to evaluate and revise legislation to maintain an optimum balance between health protection and legislative incentives for water reuse.

Statement of Results, Benefits, and/or Information

The results of this study will include:

A review of a minimum of 10 months of water quality monitoring data from the reuse facilities in Raleigh and Charlotte, NC and from the delivery sites where the water from each treatment plant is used for irrigation. The data will be compiled from the plant monitoring programs and from tests performed in the Environmental Engineering Laboratories at UNC-Charlotte and the Microbiology Laboratories at UNC-Chapel Hill.

The health risks associated with water reuse are a function of the adequacy, effectiveness, and reliability of the treatment system, as well as the extent of direct contact. The benefit of compiling and analyzing this data is that it will allow an assessment of:

1. treatment process performance reliability,

2. water quality emitted from the wastewater treatment plant and from the irrigation system, and

3. the potential for bacterial, viral, and parasite contamination in the grassed irrigated land, and in the grassed buffer surrounding the irrigated land.

A written review of the most recent and pertinent literature about the adequacy of various microbiological indicator organisms and the required limits to safeguard public health. The benefit of this document is that it will highlight new findings about fecal coliforms as indicators of viral and protozoal pathogens, and it will provide a state-generated resource and rationale for regulatory decisions regarding water reuse.

A water balance model that can be applied to estimate the increase in runoff flow and contaminant loading associated with incremental decreases in setback distances. The benefit of this analysis is that it will initiate some quantitative analysis of the merit of existing setback requirements. It can serve as a basis for more sophisticated modeling and field verification studies in the future if warranted.

Taken together, these results will yield the first North Carolina facility-based data on the applicability of the state water reuse regulations. They will constitute an assessment of whether the facilities routinely achieve the legislated water quality requirements and/or the requirements necessary to safeguard public health.

Nature, Scope, and Objectives of Research

<u>Objectives of the Proposed Research</u>

The objective of this research is to examine state water reuse regulations with respect to their ability to (1) stipulate water quality standards that will safeguard public health; (2 permit sensible facility design and operation plans that stimulate confidence in municipal water reuse options. Specific questions to be addressed include:

1. How consistently does the quality of reclaimed water at the *point of discharge from the treatment plant* meet state regulations?

2. Does compliance with existing fecal coliform limits insure minimal exposure to virus or parasite pathogens?

3. Is the quality of reclaimed water at the *point of distribution* adequate if the water meets state regulations at the treatment plant?

4. Does the application of reclaimed water to grass in areas of unrestricted public access result in microbiological contaminant loadings that would increase health risks due to contact or ingestion?

5. How do the microbiological limits in the current regulations compare to findings reported in the most recent pertinent literature and in the most recently revised regulations from other states?

6. Are the regulations that address design and operation at the treatment facility and distribution site those that optimize public health safeguards without being overly restrictive?

<u>Nature, Scope, and Rationale of the Research Planned to Achieve These Objectives:</u>

In order to accomplish these objectives, the proposed project will include the following tasks:

1) Review of monitoring data from two water reclamation facilities in North Carolina

2) Collection and laboratory testing of reclaimed wastewater samples to measure pollutant concentrations and to assay for indicators of bacterial, viral, and protozoan pathogens

3) Review of recent and pertinent literature on microbiological contaminants associated with reclaimed wastewater

4) Application of a water balance model to predict changes in runoff flow and characteristics resulting from reduced set-back requirements on land receiving reclaimed wastewater spray

The North Carolina water reuse regulations will be assessed as they apply to the operation of two full-scale municipal water reclamation projects in the state. Water quality monitoring and oversight will be conducted at the Mallard Creek Wastewater Reclamation Facility in Charlotte, NC and at the Neuse River WWTP Reclamation Project in Raleigh, NC. Detailed site descriptions are provided in the Methods Section of this document.

The monitoring data and laboratory tests proposed here are intended to provide reconnaissance information about the quality of the water delivered to the distribution system. It is important to recognize that the reuse regulations are stipulated in terms of water quality criteria rather than treatment process criteria. That is, while some states require that certain treatment processes be used, North Carolina requires that the final product meet certain water quality standards regardless of the process used. *The consistency with which the stipulated water quality criteria are met is an important determinant of the overall health risks to persons exposed to the reclaimed water*. A variety of standard water quality parameters will be included in the evaluation of the reliability of treatment processes. Routine testing and reporting of reclaimed wastewater quality is required at the treatment plants for compliance with state water reuse regulations. These data will be supplemented with results from additional testing performed in the research facilities at UNC-Charlotte and UNC-Chapel.

The quality of reclaimed water applied to a site may not be the same as the quality of the water when it was discharged from the treatment facility. For example, reclaimed water at one of the study sites is pumped to a holding pond, where further degradation can occur before it is applied. This is an important distinction, since it is at the at the point of contact, not at the point of distribution, that the public is exposed to reclaimed wastewater. Testing at the distribution site will be heavily weighted toward measures to detect the presence and survival of pathogens (based on indicators for them) where human contact is possible. Additional water quality parameters will be included to track changes in water quality between the treatment plant and the site of application as well as between the site of application and the receiving stream. A detailed description of the testing plan and protocols is provided in the Methods Section.

A literature review summarizing the recent and pertinent literature on microbiological contaminants will be written to accompany the monitoring data. The literature review will draw from the most recent water reuse literature as well as the more general literature of pathogen detection, removal, and fate in the environment. Recommendations will be offered for microbiological water quality criteria, and the review will complement and provide justification for the recommendations.

With regard to setback limits, which are intended to prevent runoff-mediated pollutant load to receiving streams, the expressed concern centers around the fact that the state water reuse buffer restrictions are inconsistent with other permissible scenarios. Reclaimed water cannot be sprayed directly near a receiving stream, but it can be reused indirectly with minimal dilution by discharge from a treatment plant and subsequent pumping back onto land for irrigation. To address this aspect of the regulations, a relatively simple water balance model will be used to estimate the diffuse runoff and contaminant loads predicted under different setback requirements. This analysis, along with input from various stakeholders involved in water reuse facility planning and design, should provide a foundation for reviewing the efficacy of current setback limits as well as other design and operational problems that have been encountered in applying the regulations.. Appropriate stakeholder participants would include design engineers, reclamation plant operators and public utility officials involved with the design of the existing facilities or planned facilities, state regulatory officials, and representatives of the NC Section AWWA-WEF membership with expertise in water reuse.

Methods, Procedures and Facilities

Experimental and Research Activities Plan

<u>Description of the Study Sites</u>. Data will be collected from the Mallard Creek Water Reclamation Facility (MCWRF) and the Tradition Golf Course in Charlotte, NC, and the Neuse River Wastewater Treatment Plant (NRWTP) and the River Ridge Golf Course in Raleigh, NC. The MCWRF treats 6 MGD with a conventional treatment train and nutrient removal. The wastewater is filtered and disinfected by UV irradiation prior to discharge into Mallard Creek. The plant has the capacity to deliver 200,000 gpd reclaimed water for irrigation at the nearby Tradition Golf Course and a municipal park (Mallard Creek Park). The water diverted for reuse is chlorinated with sodium hypochlorite to meet a geometric monthly mean fecal coliform limit of 5 coliform units/100 mL and distributed through a 30,000 ft long header. Irrigation water for the golf course and park is drawn directly from the header. Automatic sensors to detect reduced pressure in the distribution line trigger production of more reclaimed water at the plant.

The NRWWTP treats 60 MGD, and it has the capacity to deliver 2000 gpm (2.9 MGD) of reclaimed water for use at the River Ridge Golf Course, as well as for agricultural irrigation for the City of Raleigh and non-potable water for the treatment plant. Like the Charlotte plant, it has a conventional secondary treatment train with nutrient removal, filtration, and UV disinfection. Water diverted for reuse will is chlorinated with sodium hypochlorite to meet a geometric monthly mean fecal coliform limit of 14 coliform units/100 mL. At the golf course, reclaimed water is stored in an on-site holding pond, and irrigation water is pumped from the pond when needed.

Experimental Plan.

Consistent water quality at the point of distribution. For analysis of treatment plant performance reliability and reclaimed water quality, all available monitoring data collected by personnel at NRWWTP in Raleigh and at MCWRF in Charlotte for the period commencing in August 1999 and ending in May 2001 will be obtained. The monitored parameters will include 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), fecal coliforms, NH_3-N, NO_3-N, total dissolved solids (TDS), chloride, chlorine residual, and turbidity or particle count measures. Supplemental tests will be performed when additional data is required.

Microbiological contaminant loadings at the point of application. Microbiological assays for indicators of bacterial, viral, and parasitic pathogens will be conducted as reclaimed water leaves the treatment plants and at the delivery sites. Sampling will occur 5 times at each site between August 2001 through May 2001. At the treatment plants, composite samples collected by the plant operator will be used for testing. At the application site, the spray area under three different sprinkler heads at each site will be used for repeated sample selection. Pretests will be conducted to identify the radial distance from the sprinkler heads that corresponds with the highest water flow, and for each sampling event, samples of water and grass will be selected from this perimeter. A summary of the proposed tests is shown in Table 1.

Comparison of water quality at the point of distribution, point of application, and at the receiving stream. Sampling will occur six times at each site during the period of August 2000 through May 2001. Tests for chemical oxygen demand (COD), chlorine residual, pH and conductance are simple measures that will be used to characterize the system and serve as markers for changes in water quality between the treatment plants and the delivery sites, and between the delivery sites and the receiving streams. (The COD and conductance tests reflect concentrations of organic material and salts, respectively.) Stream water samples will be collected upstream and downstream of the test site. Nutrients (N and P) will be monitored if it can be confirmed that these measures will not be confounded by fertilization practices. Tests at the Raleigh site will compare irrigation water pumped from a pond containing Neuse River water and irrigation water pumped from a pond containing reclaimed water.

Controls. At the Charlotte site, irrigation water is taken directly from of the distribution header. Control samples will include grass from the required buffer area around the irrigation site (5 ft) and from a nearby grassed area similar in character to the irrigation site, but which is located well beyond the largest buffer width (100 ft) stipulated in the regulations. The control sites will be wetted periodically with potable water, so that soil moisture content does not become a confounding variable.

At the Raleigh site, reclaimed water will be pumped from NRWWTP to a holding pond on the golf course. Consequently, irrigation water quality will not reflect the reclaimed water product from the plant. It will be subject to degradation and contamination in the holding pond. Therefore, sampling of grass for the control samples will be obtained from another golf course also adjacent to the Neuse River where water from the river is pumped to a holding pond and stored for irrigation use. Any degradation due to on-site storage should be evident at both sites.

Sampling Protocols. The frequency of water sampling will depend on the irrigation schedule, which will be intermittent and at the discretion of the park and golf course maintenance personnel. Therefore, appropriate coordination will be established to optimize a sampling schedule. Samples from each of three irrigation headers will be taken on each sampling event. Spray will be allowed to flow for at least 10 minutes before sampling so that the distribution pipe is flushed and a representative sample can be obtained. Stream water samples will be taken from upstream of the irrigation site and from downstream of the site on each sampling occasion. Grass blades will be cut at the leaf base for vegetative samples. Grass samples from each of the three irrigation headers will be collected for each sampling event. All samples for microbiological testing will be collected aseptically and handled with the appropriate precautions to avoid contamination. Water pH and specific conductance will be tested at the sampling site. Samples requiring transport will be stored on ice and sent by overnight mail to UNC-Charlotte or UNC-Chapel Hill for testing the following day.

Test Protocols. Chlorine residual will be measured using the AccuVer field test (Hach Co.).

Conductance, pH, and coliform/*E. coli* tests will be performed according to Standard Methods (1992). Chemical oxygen demand measures will be performed using a HACH COD reactor and acid digestion. Coliphages and spores of *C. perfringens* will be analyzed by widely used methods (Bisson and Cabelli, 1979; IAWQ Study Group, 1991). All samples will be dechlorinated before testing when appropriate.

Membrane filtration will be used to enumerate fecal coliforms, *E. coli*, and *C. perfringens* spores in water samples and possibly in grass sample eluates, and standard multiple tube fermentation (MPN) tests will be used for grass sample homogenates (Standard Methods, 1992; Methods of Soil Analysis, Part 2, 1994). Grass samples will be macerated or blended in phosphate buffer (for multiple tube tests) and shaken for 30 minutes, or they will be shaken in alternative aqueous medium for elution from grass sample surfaces; the suspensions will be tested for fecal coliforms and the other fecal indicators as described above.

The *E. coli* in multiple fermentation tube and membrane filtration tests will be quantified by MUG fluorescence under long wavelength UV light. The multiple tube tests will use Colilert medium or lauryl tryptose broth followed by EC-MUG. For membrane filter tests, mFC agar media will be used, followed by nutrient agar-MUG. Coliphages will be assayed by the single agar layer plaque assay method (Grabow and Coubrough) on host *E. coli* CN13 for somatic coliphages and host *E. coli* Famp for male-specific coliphages. Spores of *C. perfringens* will be assayed by first heating samples to 70^{o}C for 15 minutes and then either inoculating iron milk medium for MPN tests or filtering sample through membrane filters for incubation on mCp agar medium, followed by exposure of colonies to ammonium hydroxide fumes.

Table 1. Summary of Proposed Tests (Numbers in parentheses indicate number of samples from each sampling site.)

Sample Location	**Charlotte**	**Raleigh**
Treatment Plant Monitoring	COD, pH, NH_3-N, NO_3-N, PO_4-P, conductance, Cl_2 residual, FC[a]/*E.coli* (measured by plant operator or by us) phage[b], *C. perfringens*	
Irrigation flow	*Tests performed at test site golf course only. Reclaimed water is pumped directly to irrigation headers with no intermediate detention in a holding pond*	*Tests performed at (a) test site golf course receiving reclaimed water pumped from holding pond and (b) control site, a nearby golf course pumping Neuse River water into a holding pond for irrigation*
	(n=3) COD, pH, N, P, Conductance, Cl_2 residual, FC/*E.coli*, phage, *C. perfringens*	(n=3) COD, pH, N, P, Conductance, Cl_2 residual, FC/*E.coli*, phage, *C. perfringens*
Stream flow (up&down-stream)	(n=3) COD, pH, (N&P?) Conductance, Cl_2 residual, FC	(n=3) COD, pH, (N&P?) Conductance, Cl_2 residual, FC
<u>Grass</u>	*Tests performed on grass under irrigation headers, on grass in buffer zone, and on grass in control region far from buffer zone*	*Tests performed on grass under irrigation headers and on grass in control region*
	(n=3) FC/*E.coli*, phage, *C. perfringens*	(n=3) FC/*E.coli*, phage, *C. perfringens*

(a) FC=fecal coliforms

(b) Phage=somatic coliphage and male-specific coliphages

Quality Assurance/Quality Control

Trained personnel under supervision of the principal investigators will generate all data. Laboratory manuals inclusive of protocols, media recipes, and reliable sources of reagents will be maintained and made available to all research assistants. Most testing will be performed in the UNC-Charlotte Environmental Engineering laboratories or the UNC-Chapel Hill Microbiology laboratories. The UNCC Biotechnology laboratories are also available for access to an autoclave and additional incubators. A coded identification number will be given to each sample upon collection in the field. Specific forms will document each process, how the process was performed, who performed the process, sample code, and location of sample. Experimental data from standardized forms will be transferred into a Microsoft Excel spreadsheet and maintained in the computer hard drive as well as on separate floppy disks.

Water Balance Model. A water balance analysis will be used to estimate “worst case” quantities and quality of runoff from the study sites into the receiving streams under conditions of varying buffer strip widths. Depth to water table and soil type will be used to determine whether subsurface flows can be neglected. Microbiological contaminant loading to the receiving stream will be predicted under conditions where rainfall excess is due to: (1) sprinkler "precipitation" only and (2) rainfall events that represent medium magnitude storms with rainfall depths of 1.2-3.5 cm. According to Novotny (1994), these rainfall criteria are best used to model diffuse pollution inputs.

A spreadsheet will be used for model calculations. The water balance will include components for precipitation, interception, depression storage, infiltration, and evapotranspiration. Rainfall excess will be calculated and transformed into a surface runoff hydrograph for use in the calculations. Interception will be calculated according to Bras (1990) using the formula: $I=a+bP^n$, where I is infiltration, P is precipitation, and a, b and n are empirical coefficients that describe the nature of the vegetative cover. Published estimates are available for depression storage, and they will be modified for cover, soil type and slope for input to the model. Infiltration will be estimated using the Green-Ampt formula modified for small ponding depth (Bras, 1990). This formula relates infiltration to capillary suction, initial moisture deficit, rainfall intensity, and K, the soil hydraulic conductivity. Evapotranspiration will be estimated using the Penman Combination Model (Viessman et al. 1989), which incorporates net radiation measures into the predictions. For the Charlotte site, these measures will be provided from a meterological tower that is located at the Charlotte-Douglas International Airport and operated by UNC-Charlotte Department of Geography and Earth Science faculty. Similar data will be solicited for the Raleigh vicinity, although those contacts have not yet been made.

Review of Related Research

Background. Water reuse is the intentional use of treated wastewater effluent for a beneficial purpose. The first reuse applications were in California for agricultural irrigation, but they now include urban landscape irrigation, groundwater recharge, low streamflow supplementation and effluent diversion to injection wells during periods of high streamflow. In states such as Florida and California, where water reuse has been practiced for several decades, demonstration and full-scale projects have begun for indirect and direct potable reuse, where the reclaimed water either augments or constitutes a drinking water supply source (NC AWWA-WEF, 1998).

The emergence of new modes of water reuse, along with the availability of new information about water quality risks, an accumulation of monitoring data assessments, the availability of new parameter detection methods, and changes in public perception, have all driven consistent regulatory review and revision. However, there are no federal regulations governing reclaimed water use, and standards have developed state by state. A review of state regulations reveals that under this variety of influences, water reuse standards among the states have evolved to be quite different (Asano, 1998; Crook, personal communication, 1998; Crook and Surampalli, 1996, Watts, 1992). For example, for the same use categories, some states mandate certain treatment processes, while others stipulate only the required effluent water quality characteristics. Some states require total coliform monitoring, but others use fecal coliform indicators. Items that may or may not be included in a state plan include provisions for process and equipment redundancy, setback distances, piping and pumping requirements, emergency equipment and protocols, and rules regarding transmission, storage, and distribution.

Both the US Environmental Protection Agency (EPA) and the World Health Organization (WHO) have published water reuse guidelines (US EPA, 1992; World Health Organization, 1989), and their differences are due in part to the fact that they are aimed at different audiences. A recent text edited by Asano (1998) written under the auspices of the United States National Committee of the International Association on Water Quality provides the most recent and integrated overview of a variety of international guidelines and reuse issues.

Overview of Water Reuse in North Carolina. This section chronicles how North Carolina reuse regulations were developed, and it contains a discussion of the major issues of concern regarding existing reuse regulations. It is followed by an annotated bibliography of water reuse research and activity in North Carolina.

North Carolina has only moderate experience with small reuse systems, but there is a growing recognition that water reclamation would offer relief from a number of water quality and supply pressures in the state (Safrit, 1995, Rubin et al. 1976). In recent years, considerable interest in water reuse options in North Carolina has been driven by water quality discharge limitations in coastal areas, reductions in water supply availability in the Triad Region, and strained capacity during high peak demands in densely populated urban areas. However, despite considerable investigatory interest in water reclamation, there has been a reticence to *commit* to such projects without a state record of successful demonstration projects carried out in compliance with state regulations. Several water reuse feasibility reports indicated that although municipal interest was strong, a pool of willing reclaimed water customers and regulatory experience (Kalb and Esqueda, 1997) was not.

In 1992, the Water Resources Research Institute published a review of water reuse regulations from states around the country (Watts, 1992), and it served as documentation that nonpotable reuse is widely practiced and accepted. In 1996, in an effort to stimulate confidence in the state's willingness to support water reclamation, North Carolina updated the state regulations governing "waste not discharged to surface waters." They were principally directed at reclaimed water for "land application to areas intended to be accessible to the public such as residential lawns, golf courses, cemeteries, parks, school grounds, industrial or commercial site grounds, landscape areas, highway medians, roadways and other similar areas." (State of North Carolina DENR). These uses require a higher level of treatment than land application of treated wastewater, which has been practiced for over 20 years in North Carolina for agricultural irrigation (Rubin et al., 1976).

The North Carolina regulations were developed by a technical committee appointed to propose a sensible integration of existing state regulations and federal guidelines. The committee contained some of the most prominent experts and on water reuse in the nation, including Dr. Daniel Okun, Kenan Professor of Environmental Engineering Emeritus at UNC-Chapel Hill and Dr. James Crook, now with Black and Veatch Engineers. Both of these authors are nationally recognized for their expertise in water reuse systems and both made significant contributions to the EPA Guidelines for Water Reuse (1992). However, the North Carolina standards were drafted without benefit of in-state demonstration project monitoring data, and they were translated into legislation through a necessary process of political compromise and attention to public perception issues. In the several years since they were enacted, two major concerns have emerged about the regulations among state regulators, engineers, and public utility administrators.

The first centers around health risks. In unrestricted public access areas, the major risks are exposure to chemicals or microbiological contaminants by direct contact and subsequent ingestion, or by aerosol inhalation. In addition to physical contact, these contaminants may also be transported by storm runoff to surface water, or they may be concentrated by evapotranspiration and transported by percolation to groundwater that is or will be used as a drinking water supply (Bouwer et al. 1998). While it is believed that many trace inorganic compounds are reliably removed during conventional wastewater treatment, there are refractory organic compounds, such as some pesticides and chlorinated hydrocarbons, that if present in the raw water, will remain in the treated effluent. It is estimated that less than 20% of the total organic carbon in reclaimed wastewater has been characterized (WEF-AWWA, 1998).

The health risks of greatest contention are those associated with various degrees of microbiological contamination in reclaimed wastewater. In North Carolina, questions persist about whether the state microbiological criteria are sufficiently rigorous to safeguard human health. State regulations are generally set in terms of conventional total coliforms or fecal coliforms measures, and much of the divergence between state reuse legislation occurs in how these limits are set. Among North Carolina practitioners, an informal survey of opinions about the current coliform and disinfection limits (mean monthly geometric mean fecal coliforms must less than 14 colonies/100 mL, and the daily maximum must be below 25 colonies/100 mL) indicated that many of those interviewed believe the limits are too lenient and should be lowered (see Communication Citations below). For similar reclaimed water end uses, Florida requires no detectable total coliforms in more than 75% of samples, and California limits fecal coliforms to less than 2.2 coliform units/100 mL. There is consensus among many stakeholders that the North Carolina coliform standards should be based on research and data collection rather than patterned after those in other states.

Several reviews of microbiological contaminant issues related to wastewater and reclaimed water use for irrigation are available (Rose, 1986; Asano, 1998; Crook, 1997; WEF and AWWA, 1998). The literature confirms the presence of pathogens in activated sludge (Guentzel, 1978), and in wastewater effluent that has been subjected to secondary treatment and chlorination (Rose et. al., 1996). Removal rates for coliforms, enteric viruses, pathogenic protozoa, and helminths have been calculated, and a recent analysis by Rose et al. (1996) estimated the risk of exposure to 100 mL of reclaimed water from a plant meeting current Florida reuse requirements was between 10^{-6} and 10^{-8}. However, each performance study reflects the product of a particular treatment train, and the treatment trains vary from each other and from those used at the proposed study sites in North Carolina.

Based on treatment removal rate measures, daily microbial application rates of a variety of microbes to soil irrigated with reclaimed water were estimated (Foster and Engelbrecht, 1973). For the system studied, an application rate of 2 inches per week deposited 3.9×10^3 *Salmonella* and 1.6×10^4 viruses per acre, but survival times were not measured. It is well documented that some organisms can survive for prolonged periods in soil, and some of the factors that influence their viability include moisture content, soil moisture holding capacity, temperature, pH, sunlight, organic matter, and antagonism from soil microflora (Greenberg and Kupka, 1957; Bagdasaryan, 1964; Gerba et al, 1975; Duboise et al., 1976). Protozoan parasite cysts have been shown to survive up to six years in soil under ideal conditions (Bryan, 1974 as cited in WEF-AWWA, 1998). Sagik et al., (1980) cite a Romanian study reviewed by Gerba et al. (1975) describing the fate of coliforms in water percolating through soil. Coliforms were tagged with radiolabeled phosphorus, and 92-97% were retained in the first centimeter of soil.

There is a marked lack of consensus in the literature on appropriate coliform limits for reclaimed water, and whether coliform limits alone are sufficient indictors of risk from pathogenic viruses or protozoa contamination (Rose et al., 1996; Yates, 1994). Pathogenic enteric viruses such as enteroviruses, rotaviruses, Norwalk viruses and hepatitis A are associated with various waterborne diseases, and some states have begun to require enterovirus monitoring (EPA, 1992; Yanko, 1993; Crook and Surampalli, 1996, Asano, 1998). Recent research suggests that coliphages are adequate indicators of human enteric viruses in water and wastewater and have the advantage of being more plentiful as well as easier, cheaper and more rapid to measure than human enteric viruses (Havelaar et al., 1993; Sobsey et al., 1995).

Both *Cryptosporidum* and *Giardia* protozoa have been detected in treated wastewater (Jarroll et al., 1984; Madore et al., 1987), and it is well known that *Cryptosporidium* is resistant to chlorine disinfection. To date, no *Cryptosporidium* or *Giardia* cases have been related to water reuse practices (EPA, 1992), but their possible presence is a concern because not much Cryptosporidium needs to be ingested to cause illness (Okun, personal communication 1999). Spores of *Clostridium perfringens* have been proposed as possible indicators for parasites in water and wastes because their spores are environmentally stable and resistant to treatment, as are the cysts and oocysts of protozoans and the eggs of helminth ova.

The second issue often raised in evaluations of the North Carolina reuse regulations deals with facility design and operation. In addition to water quality limits, the several guidance documents for writing water reuse regulations strongly recommend that design and operational requirements be included for the treatment plant and for the irrigation site, because not all aspects of the treated water quality can be described by the monitoring data. Cost and technical feasibility limit the parameters that can be designated for monitoring. Factors such as source water quality, treatment reliability, and treatment plant and reclaimed water delivery operations are all critical elements in determining effluent water quality. Regulatory stipulations aimed at these factors provide another means to optimize contaminant removal and insure the water is safe for its intended use. Operational standards for the irrigation site are also typically included in water reuse regulations, and they include items such as application rate, groundwater monitoring and setback distances.

For the most part, the North Carolina regulations follow the guidelines for treatment reliability and irrigation operation that were set forth by EPA (EPA, 1992). The standards include requirements for standby power supplies, multiple unit treatment processes, emergency storage or disposal and operator qualifications and availability. They also designate the ways in which irrigation application rates are to be determined and buffer widths are to be set. Typical buffer requirements in North Carolina and other states require setbacks from potable water supply wells, property lines, residential areas, and roadways (EPA, 1992). However, unlike most other states, there is an additional requirement for a 50-100 ft buffer region between the edge of the spray influence and any surface water that receives runoff from the site. The rationale for this buffer region is that it prevents the transport of pathogens to surface waters receiving runoff from the site. Tennessee has such a buffer requirement, but the fecal coliform limits are 200 coliform units/100 mL, which is quite high.

There is a body of literature on aerosol hazards (Teltsch, 1978 and Teltsch et al., 1980), but in areas of public access, certainly the buffer is not required to keep aerosols from surface water if there are no precautions addressing aerosol exposure to patrons in the irrigation area. The typical operating protocol at sites irrigated with reclaimed water is to spray in the evening hours when there are no patrons present, however the regulations do not require this. If the buffers were included as a precaution against aerosol transport of pathogens, it would seem similar precautions would be mandated for spray operations over irrigated turf.

There has been persistent inquiry among North Carolina practitioners about whether or not there is a demonstrable need for requiring setback distances or buffer regions to separate irrigated land from a receiving stream. At the Raleigh wastewater reclamation site, public works representatives have questioned whether the buffer requirements are necessary. The NRWWTP will discharge over half of the plant's treated effluent into the Neuse River, and the coliform limits for such effluent are 200 coliform units/100 mL. The portion diverted for irrigation is subject to much more stringent coliform limits, and yet it must be buffered from entering the same river with storm runoff flow. At the Charlotte facility, a compromise was reached whereby the reclaimed water is disinfected to 5 coliform units/100 mL, and the buffer distance requirement is only 5 ft. The implication is that microbial accumulations in the irrigated soil and grass are safe enough for a public access site, but a subset of microbes dislodged and diluted in stormwater and streamflow would pose a health threat to aquatic organisms in the stream.

The fact that the rationale for some of the state water reuse regulations is not entirely clear to those involved with the current reuse facilities or those planned for other locations in the state is not to say there were shortcomings in the regulations. Rather, it is an indicator of the need to proceed with the dynamic process of examining, refining and documenting the regulations so they accomplish their intended purpose.

An Annotated Bibliography of Water Reuse Activity in North Carolina. The references presented below in chronological order, show how interest and activity in water reuse developed in North Carolina. The annotations begin with documents written over 20 years ago describing the potential benefits of wastewater reclamation, and they indicate several North Carolina scientists contributed to the promotion of its use nationally and internationally. In the 1990's there was a flurry of municipal interest in wastewater reclamation. Much of this activity was marked by a reticence to proceed without demonstration projects or regulations specific enough to foster confidence in the safety and cost effectiveness of water reuse operations. Several of the annotations describe appeals for better state regulations and demonstration projects that can be studied and evaluated. The proposed project would begin that evaluation process.

Rubin, A. R., and B. L. Carlile. 1976. Some important considerations for the land application of wastewater. Water Resources Research Institute of the University of North Carolina and the Division of Environmental Management, North Carolina Department of Economic Resources. Before North Carolina had laws dealing directly with land application, this document provided a rationale and guidance for considering and implementing a land application system. It focuses on the use of applying treated wastewater effluent to land in order to avoid high nutrient loadings and microbiological contamination of sensitive shellfish waters. It was one of the first documents to come out of North Carolina that identifies and promotes the benefits of using reclaimed water for irrigation.

Okun, D. A. 1979. Criteria for reuse of wastewater for nonpotable urban water supply systems in California. Report prepared for the California Department of Health Services.

Okun, D. A. 1991. Water reuse: potable or nonpotable? There is a difference! Municipal wastewater reuse: selected readings on water reuse, reprinted from Water Environment and Technology Journal by USEPA Office of Water and Office of Wastewater Enforcement and Compliance, Washington, DC. Dr. Okun, the Kenan Professor of Environmental Engineering, Emeritus at UNC-Chapel Hill, was an early advocate for the many applications of wastewater reclamation nationally and throughout the world. He believes non-potable reuse is gaining wide public acceptance.

Watts, K. N. 1992. Water reuse in selected states. Report prepared for the North Carolina Water Resources Research Institute. This document summarized nonpotable water reuse practices in several states, including North Carolina. It documents the existence of small reuse projects involving small spray irrigation systems to irrigate agriculture. It also mentions that seven golf courses were permitted to spray treated wastewater from subdivisions.

Miles, S. W. and J. T. Ridge. 1993. Water conservation: its place in North Carolina's water resource future. Proceedings: Dollars down the drain – the potential for water conservation and reuse in North Carolina; Triangle J Council of Governments, March 30, 1993.

Mendenhall, T. C. and F. S. Swartz. 1995. Reclamation and reuse at the Charlotte-Mecklenburg Utility Department (CMUD). Proceedings of the NC AWWA-WEF Annual Conference. This presentation reviews a feasibility study conducted by the county to evaluate whether reclaimed water quality, sufficient user demand, and regulatory support were available to justify a commitment to develop a wastewater reclamation facility. The study found that nearly one-third of CMUD water supply capacity was idle most of the year when there was little demand for non-essential outdoor potable water use. The Utility and the NC Department of Environmental Health and Natural Resources (NCDEHNR) agreed to pursue development of the demonstration project, but it was never implemented because the potential users withdrew. The report ends with the statement: "NCDEHNR has concluded that a separate set of regulations and permitting procedures for water reclamation and reuse projects in this state appears to be needed. Further, through the CMUD demonstration project, DEHNR sees an opportunity to gather specific scientific data to use as the bases for developing such regulations and procedures."

DiGiano, F. A. and E. A. Kubiak. 1995. Feasibility of wastewater reuse at the National Spinning Co., Inc. in Washington, NC. Water Resources Research Institiute of the University of North Carolina Project No. 70128. Dr. DiGiano is a Professor at UNC-Chapel Hill. This study was one of the first to examine the use of reclaimed municipal wastewater as process water in textile dying operations. It showed that such a practice is feasible, although certain difficulties with staining remained to be

resolved. In addition to the technical issues, the study contains a discussion about the company's reservations to proceed without state or federal water reuse guidelines. The final report recommends that the state develop regulations to manage and encourage innovative water reuse applications for industry.

Safrit, D. 1995. Minimization via reuse of wastewater effluents and residuals, Proceedings of the NC AWWA-WEF Annual Conference. In this presentation, Mr. Safrit notes that although North Carolina had some regulatory stipulations encouraging wastewater treatment plant effluent reuse rather than discharge to surface waters, there is more that could be done to provide incentives for reuse of municipal or industrial effluents. He discusses the need to address negative public perceptions about the use of reclaimed water.

North Carolina Division of Water Resources. 1996. Strategic management implications of water reclamation and reuse of water resources. NC AWWA/WEA Reclaimed Water Conference. This paper reviews some of the broad implications of water reuse applications on state water resources. It cites some of the local concerns that may drive municipal interest in water reclamation, such as the high costs of capital investments to meet rising potable water demands; pressures to limit wastewater discharges to surface water; and aquifer recharge in areas where groundwater supplies are limited or salt water intrusion occurs. However, it cautions that reuse decisions must include consideration of correlative effects on streamflows and groundwater, and states that increased reuse activity does not preclude the need for water conservation efforts.

Kalb, K. and T. Esqueda. 1997. Water reclamation and reuse as a component of integrated resource planning. Proceedings of the NC AWWA-WEF Annual Conference. This paper reports on a feasibility study conducted by the Orange Water and Sewer Authority (OWASA) serving Chapel Hill and Carboro, NC. to evaluate whether water reclamation should be a component of their water resource management strategy. The study found that there was the potential for reuse of approximately 470 million gallons per year, but concluded that without any applications of the recently enacted state water reuse regulations to use for guidance, there was risk that the capital investments required would not be cost effective. The report contained a recommendation that the Utility proceed with a demonstration project rather than a full-scale reuse program for the following reason: "Though there is wide spread support and enthusiasm for OWASA to implement a water reclamation program, neither OWASA, its customer base, nor the DEHNR have any 'hands on' experience with water reclamation in the state of North Carolina under the newly adopted water reuse regulations."

Okun, D.A. 1997. Distributing reclaimed water through dual systems. Journal of the American Water Works Association 89:52-64.

The North Carolina guidance manual - development of reclaimed water systems. 1998. NC Section AWWA/WEA. A review of the state history of regulating reclaimed water is provided. Regulations pertaining to irrigating golf courses and other public areas were first promulgated in 1987, with revisions in 1988, 1993, and 1996. This document translates and elaborates upon the most recent state water reuse regulations. Its stated intent is to insure that water reuse is included as an option when utilities develop and revise their integrated water resource plans. The manual reviews the planning, design, construction and operation of non-potable water systems delivering reclaimed water. In the section on disinfection it includes the recommendation that a chlorine residual be maintained in long distribution lines – a condition not required by the regulations, but indicative of the fact that practitioners believe it to be a good idea.

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Communication Citations. The following persons have been contacted for information and assistance during the preparation of this proposal:

Dr. Daniel Okun. Dr. Okun is the Kenan Professor of Environmental Engineering, Emeritus at UNC-Chapel Hill, and he is among the most prominent experts on water reuse in the country. He believes the issues of direct nonpotable water reuse for urban irrigation are relatively well resolved, although he would like to see the coliform limits lowered in North Carolina. He believes the areas of greatest concern for nonpotable water reuse are those relating to trace organics and virus disinfection, and he urges further study of these issues.

Dr. James Crook. Dr. Crook is employed by Black and Veatch Engineers, Boston, MA. He has written prolifically on water reuse issues. He has been an active participant in developing state regulations, including those for North Carolina. Dr. Crook reviewed the history of his involvement with the North Carolina regulations and discussed recent national regulatory trends.

Dr. David Moreau. Dr. Moreau is Professor and Chair of the City and Regional Planning Department at the University of North Carolina at Chapel Hill, and is the former director of the Water Resources Research Institute. Dr. Moreau emphasized the importance of consistency in plant performance and in the quality of reclaimed water at the distribution site. He cited concerns about microbial regrowth and handling problems related to distribution.

Ms. Trill Mendenhall. Ms. Mendenhall is the Residuals Manager of the Charlotte-Mecklenburg Utility Department (CMUD). She was involved in the initial CMUD feasibility investigations of water reuse for Mecklenburg County, NC. She was also a member, with Dr. Crook, of the technical committee that developed and recommended the most recent North Carolina water reuse regulation revisions. The regulations recommended by the committee are not the same as the existing regulations.

Dr. Linda Sewall. Dr. Sewall is Director of the Health Services Division, and as such, she is most concerned about the public health risks associated with microbiological contaminants in reclaimed wastewater. She supported a review of the criteria for bacterial, viral and protozoan organisms in the state water reuse regulations.

Mr. Steve Swartz.. Mr. Swartz, of Swartz Engineering was a contributing author to the recently published (1998) NC AWWA-WEF Guidance Manual for Development of Reclaimed Water Systems. He prepared the feasibility study undertaken by CMUD in 1994 to evaluate a water reuse project at the McAlpine Creek Wastewater Management Facility. He currently chairs the NC Section AWWA-WEF water reuse committee. Mr. Swartz provided a review of how interest in water reuse has developed in North Carolina, and he has been available for questions about the current regulations.

Mr. Tom Vandeventer. Mr. Vandeventer, an engineer with CMUD, oversaw the development of the water reclamation facility at the Mallard Creek Water Reclamation Facility (MCWRF). He provided information and contacts instrumental to the development of the proposal.

Mr. Brent Reuss. Mr. Reuss is an engineer with Black and Veatch Engineers in Charlotte, NC. He designed the water reclamation facilities at MCWRF and provided design and operation data about the system.

Mr. Mike Shafer. Mr. Shafer is an engineer with Black and Veatch Engineers in Raleigh, NC. He is the design engineer for the Neuse River Wastewater Treatment Plant (NRWTP) reuse facility in Raleigh, NC. He provided design and operation data about the system.

Mr. Dale Crisp. Mr. Crisp heads the Raleigh Utility Department, and he has described some of the regulatory issues that have been raised during the planning and design phase of the water reuse facilities at the NRWTP.

Mr. Tommy Escueda. Mr. Escueda is employed by CH2MHill Engineers in Raleigh, NC. He participated in the feasibility study conducted by Orange Water and Sewer Authority in Orange County, NC, and he served with Mr. Swartz on the task force that developed the 1998 NC AWWA-WEF Guidance Manual for water reuse. He offered some comments about the evolution of the current state water reuse regulations and about how they compare to those in other states.

<u>Mr. Bill Kreutzberger</u>. Mr. Kreutzberger is employed by CH2MHill Engineers in Charlotte, NC. As past chair of the NC AWWA-WEF reuse committee, he discussed some of the reuse issues in the State. He was familiar with plans for the reuse facility in Raleigh, NC, and he offered some perspective on how the regulations applied to that system.

<u>Mr. David Love</u>. Mr. Love maintains the greens at the Tradition Golf Course in Mecklenburg County, NC. This golf course currently uses reclaimed water from MCWRF for irrigation. Mr. Love discussed his strong interest in evaluating the quality of the water applied. He is a strong advocate of using reclaimed water for golf course irrigation, but because the system is new to Charlotte and to North Carolina, he would welcome the monitoring proposed in this study.

Schedule of Tasks

			2000						2001			
TASK	J	A	S	O	N	D	J	F	M	A	M	J
Literature Review												
Compiling		*	*	*	*	*						
Writing							*	*	*	*		
Site Monitoring												
Initiation		*										
Data Collection			*	*	*	*	*	*	*	*	*	
Data Analysis												
Water Balance Model		*	*	*	*	*	*					
Report Preparation											*	*

Information Transfer

The subject matters for dissemination will be the items identified in the objectives on page 3, as well as report recommendations based on the answers to the questions posed. This information will be of interest to North Carolina policy makers, regulatory agency personnel, public utility personnel, engineering practitioners and academic researchers. If the results confirm that the current regulations are insuring a consistent and high quality product, the final report should provide the documentation necessary to stimulate municipal investment in new water reuse projects in the state. This would be a worthy and significant accomplishment in view of rapidly increasing population and development and the accompanying need to provide additional water supplies.

It is anticipated that the results of this project will be published as a technical report by WRRI. Since this project is directed largely toward North Carolina needs, it is planned that results would be presented at an Annual Section AWWA-WEF Conference. However, the tests for the persistence of viruses and protozoa in water treated for reuse will be of particular interest to the national water reuse research community. There will be interest in the application of the proposed techniques to reclaimed wastewater. Hence, presentation and/or publication at national conferences of AWWA and/or ASCE and/or in their refereed journals is anticipated.