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WASTEWATER EFFLUENT REUSE AT FORT BRAGG – FEASIBILITY STUDY

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WASTEWATER EFFLUENT REUSE AT FORT BRAGG — FEASIBILITY STUDY

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) makes available the results of a study conducted at Fort Bragg, NC, that evaluated alternatives for the reuse of wastewater treatment effluent.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army facilities engineering activities responsible for the disposal of wastewater treatment effluent.

3. References.

a. "The Army Strategy for the Environment: Sustain the Mission – Secure the Future," Office of the Assistant Secretary of the Army for Installations & Environment (ASA-I&E), 1 October 2004.

b. Army Regulation 200-1, "Environmental Protection and Enhancement," 13 December 2007.

4. Discussion.

a. One of the goals of The Army Strategy for the Environment is to “minimize impacts and total ownership costs of Army systems, material, facilities, and operations by integrating the principles of sustainability.” In response to the Army Strategy, Fort Bragg has established several sustainability goals. One of those goals is to reduce potable water use by 90% before the year 2025.

b. The Waste Minimization and Pollution Prevention (WM&PP) Program, sponsored by ASA-I&E, has funded the demonstration of environmental management technologies at Army installations. The program was funded by the Office of the Assistant Deputy Secretary of the Army for Installations and Environment. The program was managed and executed by the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, Champaign, IL. All research was conducted through a contract with MSE Technology Application, Inc., located in Butte, MT. Funding for this program ended in Fiscal Year 2005, with work continuing through December 2006. The results of the studies completed through this program were intended for the use of the host installations. In most cases, however, the results of the studies would be of benefit to many other Army and Department of Defense (DoD) installations. Funding constraints did not allow formal publication of most of the final reports generated by the WM&PP Program. The Headquarters, U.S. Army Corps of Engineers (HQUSACE) PWTB program, managed by Malcolm McLeod, has provided a mechanism to publish the results of some of those studies.

c. One WM&PP study was conducted to assist Fort Bragg, NC, in achieving its sustainability goal of reducing potable water usage by 90%. That study evaluated the economic feasibility of using wastewater treatment plant effluent to irrigate the parade grounds and golf courses at Fort Bragg. Appendix A contains the majority of the information in the MSE final report for that study, which is entitled: Feasibility Study for the Reuse of Wastewater Treatment Plant Effluent at Fort Bragg. The report presented in Appendix A has been edited for length.

d. A glossary of acronyms and abbreviations is included near the beginning of Appendix A.

e. The objectives of the feasibility study were to examine the physical characteristics of the effluent from the wastewater treatment plant (WWTP) and determine whether that effluent could be used to replace irrigation water at Fort Bragg and Pope Air Force Base (AFB). The approach used to satisfy these objectives included: identification of pertinent regulatory considerations; identification of potential reclaimed water users; evaluation of wastewater supply and reclaimed water demand; establishing alternative reuse scenarios; and performing cost analyses for each alternative.

f. The facilities identified with the greatest potential to use the effluent for irrigation were: Ryder Golf Course, Stryker Golf Course, the parade grounds, and the polo field, all on Fort Bragg, and the Willow Lake Golf Course on Pope AFB. Fort Bragg and Pope AFB are situated such that all potential users can be serviced by one pipeline from the WWTP. The alternative reuse scenarios were simply determined by the length of that pipeline. Those alternatives are as follows:

- Alternative A - Pope Willow Lake Golf Course
- Alternative B - Pope Willow Lake Golf Course plus the Parade Grounds and Polo Field
- Alternative C - Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, plus Ryder Golf Course
- Alternative D - Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, Ryder Golf Course, plus Stryker Golf Course
- Alternative E - Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, Ryder Golf Course, plus Stryker Golf Course with increased effluent carrying capacity for future use.

Willow Lake Golf Course, Parade Grounds, and Polo Field are all currently using Fort Bragg’s potable water, whereas the Ryder and Stryker facilities are using water from dedicated wells.

g. One major concern associated with using treated wastewater effluent to irrigate the five potential users is that the total volume must be adequate to meet the total demand. At the time of the study, the WWTP had an average flow of approximately 5.8 million gallons per day (mgd). The maximum flow was approximately 6.4 mgd, and the minimum flow was 5.2 mgd. The estimated total water volume consumed by Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, and Ryder and Stryker combined was nearly 1.75 mgd. Therefore, on the basis of daily discharge volume, there was enough water to meet the needs of all five users, with additional irrigation water available for future uses. Although total volume is sufficient for irrigation purposes, irrigation timing is an issue. The instantaneous discharge flow rate from the WWTP must satisfy the instantaneous irrigation requirement of all users upstream.

h. Another concern with reusing treated wastewater effluent is water quality. There were some issues with the effluent quality at Fort Bragg meeting North Carolina reuse standards, but it was believed that those issues would be resolved by simple updates to the wastewater treatment plant system and operation. These updates are discussed on page A-11. Table A-2 on page A-11 shows a comparison of the effluent quality with reuse quality criteria.

i. WaterCAD® model software was used to develop and evaluate water distribution systems for each of the scenarios. Table 1 below summarizes the total capital and startup costs, and electricity cost for each alternative, along with the estimated cost savings associated with water and fertilizer. Using these data, the cost savings and the time required to pay back the initial expense are calculated for each alternative.

j. The data in Table 1 indicate that it was feasible and desirable to use WWTP effluent for irrigation purposes at Fort Bragg and Pope AFB. It is assumed that the value of all reclaimed WWTP effluent is at least the value of water used at Willow Lake Golf Course ($1.43/1,000 gal). Alternative D is the most appropriate course of action. Payback for Alternative D is less than 3 years under this assumption. However, alternative E will minimize the cost for future irrigation users. As additional users would be added to the system, the payback period for alternative E would become shorter.

Table 1. Costs and payback for reuse scenarios.
(Assumes value of all reclaimed effluent is $1.43/1000 gal)

				Estimated Annual Cost Savings		
Scenario	**Capital Cost**	**Annual Electricity Cost**	**Water Volume (gpd)**	**Water Savings[1]**	**Fertilizer Savings**	**Payback years**
Alternative A	$704,000	$23,100	402,000	$138,000	$9,500	5.7
Alternative B	$1,451,000	$24,800	517,000	$178,000	$17,300	8.5
Alternative C	$1,580,000	$14,800	1,040,000	$356,000	$29,300	4.3
Alternative D	$1,820,000	$13,800	1,750,000	$600,000	$45,300	2.9
Alternative E	$5,830,000	$13,800	1,750,000	$600,000	$45,300	9.2

[1]Assumes an 8-month watering period

5. Points of Contact (POCs). HQUSACE is the proponent for this document. The POC at HQUSACE is Malcolm E. McLeod, CEMP-II, 202-761-0632, or e-mail: Malcolm.E.Mcleod@hq02.usace.army.mil.

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Appendix A Contents

ACRONYMS AND ABBREVIATIONS

AAFES	Army and Air Force Exchange Stores
AFB	Air Force Base
APAM	Annual Pollutant Analysis Monitoring
BOD	biochemical oxygen demand
CMU	Charlotte Mechlenburg Utilities
CWMTF	Clean Water Management Trust Fund
CWSRF	Clean Water State Revolving Fund
DEP	Department of Environmental Protection
EPA	U.S. Environmental Protection Agency
I&C	instrumentation and control
MSE	MSE Technology Applications, Inc.
NCDENR	North Carolina Department of Environmental and Natural Resources
NH_3	ammonia
NTU	Nephelometric Turbidity Unit
O&M	operating and maintenance
PVC	polyvinyl chloride
PWBC	Public Works Business Center
RTUs	remote terminal units
SCADA	supervisory control and data acquisition
TSS	total suspended solids
TTHM	trialomethane
USACERL	U.S. Army Construction Engineering Research Laboratory
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

UNITS

gpd	gallon(s) per day
gpm	gallon(s) per minute
mgd	million gallons per day
mg/L	milligram(s) per liter(s)
mi^2	square mile(s)
mL	milliliter(s)

Metric Conversion Factors

Multiply	**By**	**To Obtain**
acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters

APPENDIX A: FEASIBILITY STUDY FOR REUSE OF THE WASTEWATER TREATMENT PLANT EFFLUENT AT FORT BRAGG

INTRODUCTION

Background

Current Water Source and Consumption

Water used at Fort Bragg, NC, is obtained from the Little River, which has a drainage area of 348 mi^2. In 2002 Fort Bragg withdrew an average of 8.5 million gallons per day (mgd) of water from the Little River. The primary water treatment plant (WTP) was originally built in 1918, and later upgraded to a 1-mgd capacity. In 2000 the capacity was upgraded again to 16 mgd. The WTP treats and supplies drinking water to the entire cantonment area, Simmons Army Airfield, and all of Pope Air Force Base (AFB), including the Pope Willow Lake Golf Course (Fort Bragg 2001).

Water consumption at Fort Bragg increased from 2,202 million gal in 1992 to 3,067 million gal in 2000, a 39% increase, and this increase has occurred without a rise in population. The increase in consumption is a result of real property development, new barracks design that includes individual bathrooms, and irrigation systems for landscaping. In drought or emergency conditions, the Little River is incapable of supporting daily water demands for the installation, and additional water [up to 3 million gallons per day (mgd)] must be purchased from Fayetteville, or the lakes on Fort Bragg must be used (Fort Bragg 2001).

In addition, since 1970, the population of the Raleigh-Durham-Chapel Hill area has doubled, and the expansion of water-using industries has grown along with this population increase. The State of North Carolina is currently pursuing a proposed interbasin water transfer project that will divert water from the Upper Cape Fear Basin for use by the Raleigh-Durham-Chapel Hill community. This project would remove water from the Cape Fear River Basin to augment the Neuse River Basin in support of the enormous urban growth in Raleigh and Cary. The little River is part of the Cape Fear River Basin and may be adversely affected by this proposal along with the rest of the region. The implication of increased demands on the Upper Cape Fear watershed and the Little River is difficult to determine at this time. Data that could assist Fort Bragg in determining status of their current and future water source include flow data upstream and downstream of the intake on the Little River (currently, no U.S. Geological Survey gauge stations exist on the Little River or streams draining from Fort Bragg); water quality monitoring data on stream segments that impact Fort Bragg; storm water quality outfall monitoring data; watershed delineation, land use assessment, and imperviousness determinations for Fort Bragg; and stream morphology information (Fort Bragg 2001).

Groundwater

Upon depletion or contamination of the Little River, the next available source of water is the groundwater from the Upper Middendorf aquifer, followed by the Black Creek Aquifer. If these groundwater supplies are contaminated, the next remaining water source is the Upper Cape Fear aquifer, which is already impaired in South Carolina. Therefore, if the Little River becomes contaminated or depleted, Fort Bragg as well as other communities may have future difficulty producing or purchasing sufficient quantities of potable water (Fort Bragg 2001).

The Upper Middendorf aquifer is currently considered by Fort Bragg to be polluted beyond drinking water limits. Pollution occurred as a result of numerous hazardous material spills (fuel, petroleum products, etc.) throughout the history of the installation and contamination from pre-1950s landfills (Fort Bragg 2001).

Loss of capacity from the Little River would necessitate the development of groundwater sources for use as drinking sources and/or the implementation of conservation technologies and practices to reduce use of surface water. It would also result in additional costs to purchase water from the community, as well as require rationing in times of shortage. If the water systems at Fort Bragg are privatized, the installation may also experience an increase in the price of water as rates are commercialized (Fort Bragg 2001).

Potable water supplied by the Fort Bragg WTP is used to irrigate the Pope AFB Willow Lake Golf Course. After several attempts were made to develop an adequate well system to sustain Willow Lake's irrigation needs, it was determined that adequate well yields could not be obtained. Additionally, installation of a well system may cause migration of and irrigation with contaminated groundwater (NCDENR 2000). Using reclaimed water from the Fort Bragg Wastewater Treatment Plant (WWTP) for irrigating Willow Lake Golf Course would reduce the withdrawal of water from the Little River and reduce the amount of wastewater discharged to the Little River.

Fort Bragg's Stryker and Ryder Golf Courses both use groundwater for irrigation, and both of these courses withdraw water from the Middendorf aquifer (the same aquifer used by Spring Lake) and have adequate well yields. Because of the contamination in the Upper Middendorf aquifer, Fort Bragg is evaluating the possibility of contamination in the Middendorf aquifer and the risks and benefits from drawing water from this aquifer. Stryker Golf Course has a sandy soil, and infiltration of irrigation water allows dry areas to appear on the course. To alleviate this problem, an additional storage pond was constructed to increase storage during non-peak, irrigation periods. The well field for the Stryker Golf Course, which consists of six water supply wells, was also tested to determine the sustainable yield of the aquifer. Aquifer test results at the well field predicted that the aquifer provided a reasonable sustainable yield of 450 gallons per minute (gpm) and possibly more (Geraghty & Miller 2000).

Water Conservation Goal

At the time of this study, potable water was used to irrigate landscape areas at Fort Bragg and adjacent Pope Air Force Base (AFB), NC. The Fort Bragg WTP supplies potable water to Pope AFB. To meet Fort Bragg's sustainability goal of 90% reduction in potable water usage, use of potable water for landscaping irrigation at Fort Bragg and Pope AFB had to be curtailed. It was also recognized that the Upper Cape Fear Basin, the water source that feeds the Little River, would rapidly become depleted due to overuse. Due to drought conditions in 2002 the flow rate decreased significantly in Little River; consequently, Fort Bragg began drawing water from reservoirs.[1]

Wastewater Treatment Plant System

In 2002 Fort Bragg operated a Federally Owned Treatment Works to treat the municipal domestic and industrial wastewater from the main cantonment area, Simmons Army Airfield, and Pope AFB. The plant discharges on average approximately 5.8 mgd of treated effluent to the Little River. The Public Works Business Center (PWBC) Maintenance Division operates and maintains the WWTP, and

[1] Verbal correspondence with Pope AFB.

the PWBC Environmental Division manages compliance with all applicable water regulations associated with the sewage treatment plant and storm water management.

Fort Bragg’s WWTP was originally built in the 1940s. The plant was rebuilt in 1991 and now operates at a maximum capacity of 8 mgd. The WWTP serves a population of approximately 68,000. The collection system is composed of over 2 million linear feet of pipeline and 10 major lift stations. The Little River, a Class C water in the Cape Fear River Basin, receives 1,921 million gal/year of treated effluent from the Fort Bragg system.

System Processes

The Army is permitted to operate a maximum capacity 8-mgd wastewater treatment facility located at the Fort Bragg WWTP, NCSR 1451, Cumberland County, discharging to Outfall 001 and consisting of the following wastewater treatment components:

- mechanical bar screen;
- grit removal/separator;
- oil skimmer;
- dual-oxidation ditches, each with a center clarifier;
- chlorine contact chamber;
- effluent flow measurement;
- postaeration;
- aerated sludge holding tank with sludge thickening;
- four secondary clarifiers;
- sludge drying beds;
- ultraviolet disinfection system; and
- standby power system.

As stated above, the discharge from the Fort Bragg WWTP flows into the Little River.

Approach and Scope

MSE Technology Application, Inc. (MSE) Butte, MT, reviewed the regulatory requirements of reclaimed water treatment effluent, compiled existing facility information, gathered information for the potential sites for irrigation (golf courses and landscape areas), analyzed reclaimed water demand and wastewater supply, modeled alternatives for distribution of the reclaimed water, and prepared a cost analysis. This study is not a design effort, nor an implementation plan – those efforts would be a future phase in the process of implementing effluent reuse, if funded.

REUSE ISSUES

Public Health Regulations

The North Carolina Department of Environmental Protection (DEP) has developed very stringent regulations for the quality of reclaimed water, including the operation and design of reclaimed water “public access” systems that provide such water (e.g., for golf courses and residential irrigation). In developing these requirements, DEP's highest consideration is the protection of public health. Reclaimed water is monitored and tested daily to ensure DEP standards are met or exceeded. Reclaimed water is generally of higher quality than the surface water individuals might come in contact with in nearby rivers, streams, lakes, or ponds. Reclaimed water must be separated from potable water during distribution and reuse, and its application will be restricted to designated and approved areas.

Restricting irrigation to times of the day or year when people are not present is another way to avoid direct contact. Irrigating only at night or when a facility is closed can be incorporated into the management plan. Establishing buffer areas between the irrigated sites and general public access and thoroughfares is another approach to avoid contact with the treated effluent. Fencing or signs may also be needed to help define the buffer area.

A sign reading "Nonpotable Reclaimed Water – Not for Drinking" shall be posted at all points where consumption of the water may be attractive to the public; however, this requirement does not apply to sprinkler heads. Signs reading "This Facility is Irrigated with Reclaimed Water – Not for Drinking" shall be posted at conspicuous locations in areas irrigated with reuse water. Where signage is not feasible (such as a valve box in a street), the above wording shall be engraved on brass tags riveted to the outside and inside of the component. A signage plan shall be submitted to the City and approval obtained from the City before connecting to the City's reuse water system. These signage provisions apply to both new construction and cases where an existing irrigation water line is connected to the City's reuse water system. To the extent practical, reuse components shall be painted purple (e.g., valve box lids, valves, valve operators, control boxes, etc.).

Agronomic Issues

The reuse of WWTP effluent requires consideration of several agronomic issues. Although reclaimed water may be a good resource in some areas, treated effluent typically has a lower quality than the domestic water that a golf course may be using. This is because wastewater treatment does not remove all the compounds that are dissolved in the water during its first use. As a result, there is typically about a 10% increase in total dissolved salts (Stowell 1999).

Consequently, it is sometimes difficult to maintain turf grasses and golf courses in premiere condition. Unfortunately, there are no simple formulas to determine the outcome of accepting reclaimed water on the landscaped areas. In some cases where the golf course is using high quality well waters, the switch to reclaimed water may be an issue; however, it is possible that the reclaimed water will provide a higher quality water source. Each situation should be evaluated on a case-by-case basis.

For areas such as golf courses, parks, polo and parade grounds, and other areas where the public will have contact with the residual constituents in the reclaimed wastewaters that are applied to the area, it is important to sample the turf, grass, and other vegetation and soil for an accumulation of pathogenic organisms. This monitoring is essential to evaluate the reliability of the effluent monitoring and to ensure the public of safe conditions.

Potential turf problems observed can be brown and yellow patches on some grasses, salt crystals on tips of grass blades, sparse growth of grass populations in greens and tees, elevated levels of salt in soil solutions, and increased susceptibility to pathogens. Some general parameters that need to be monitored are water quality (including total salinity), sodium permeability, total suspended solids (TSS), chlorine, nutrient considerations, and pH levels.

At greater than 1 milligram per liter (mg/L) residual chlorine, foliage damage can occur to sensitive plants. However, it should be noted that the residual chlorine in the WTP effluent that is presently used for irrigation is higher than the levels in the WWTP effluent that would be used for irrigation.

If the TSS are high, then the hydraulic conductivity of the soils may decrease and not allow the water to infiltrate the subsurface (i.e., allowing the water to flow into surface drainage areas away from the plants, preventing uptake into their root systems). Once monitoring has determined there is no detrimental effect to human or plant life, it is assumed that monitoring is no longer required.

Regulatory and Permitting Issues – Reuse Water Systems

In 1996 North Carolina amended its statutes governing the disposal of wastes that are not discharged to streams or other waterways. These nondischarge rules were modified to define and control highly treated wastewater effluent for reuse application. The previous rule governed the disposal of secondary wastewater effluent, biosolids, and some industrial wastes (Fort Bragg 2001). During the wastewater treatment process, a tertiary quality effluent is produced prior to the water being reused. In the redefined statutes, reuse is defined as a tertiary quality effluent with water quality parameters shown in Table A-1.

Table A-1. Reuse water quality requirements.

Parameter	Monthly Average	Daily Average
TSS	5 mg/L	10 mg/L
Fecal coliform	14/100 mL	25/100 mL
BOD_5	10 mg/L	15 mg/L
NH_3	4 mg/L	6 mg/L
Turbidity	10 NTU (continuous monitoring required)	

The specific requirements for the use of reclaimed water are similar to many other states and allow for typical reuse applications (such as irrigation) on golf courses, public areas, fire suppression, and decorative ponds and for industrial use. However, the rules specifically prohibit reuse in hot tubs, spas, and swimming pools. Reclaimed water cannot be used to irrigate edible crops. In addition, the rules prohibit the use of reclaimed water from being used as a raw water supply for potable water systems (ENR 2001).

Cross-connection control is another critical component addressed within the reuse water requirements. All reuse systems must be color coded purple and identified as reuse piping, either by painting, marking tape, or other identification (ENR 2001). Hose bibs or other connections must be in a lockable vault and marked as reuse. The system should also have cross-connection control and/or backflow prevention programs as necessary. State of North Carolina regulations require that each property served by reclaimed water contain an approved backflow prevention device on the potable water service to that property. Therefore, in addition to providing new reclaimed water services to the area, a potable water service can be maintained by retrofitting it with a backflow prevention device. Once the system is in place, it will need to be certified that the irrigation system is completely isolated from the potable water system and that there are no prohibited uses connected to the irrigation system.

In addition to protecting public health, there are regulatory requirements for protecting the State’s waterways. Spray irrigation systems are required to maintain buffers from streams and wells. For most streams, the spray influence must not be within 25 ft of any surface water or wetland. For higher quality streams, the required buffer is 100 ft. Potable wells are provided with a 100-ft buffer, while non-potable wells have a 10-ft buffer. Runoff is not allowed from any reuse application (ENR 2001).

Several permits and approvals are required from federal, state, and local authorities to construct and operate a new reclaim/ reuse water system. Regulatory requirements will be developed through discussions with the regulatory agencies, review of applicable guidelines and regulations, and aerial survey along the proposed pipeline routes. It should be noted that an Environmental Assessment would not be required for the reuse project if the new reuse system were installed within an existing right-of-way or in previously disturbed areas.

Providing project description and project location information to both the North Carolina Natural Heritage Program and the North Carolina Department of Cultural Resources will start the permitting process. The North Carolina Natural Heritage Program will review the information to identify potential impacts to rare plant/animal species and habitats or significant natural resources. The North Carolina Department of Cultural Resources will review the information to identify potential impacts to archeological/historical resources.

Prior to construction, permits and approvals will need to be obtained from several authorities, which include the NCDENR, U.S. Army Corps of Engineers, North Carolina Department of Transportation, North Carolina Department of Insurance, and other authorities (Miles et al. 2002).

Effluent from the Fort Bragg WWTP (the reclaimed water facility) is required to meet the non-point discharge standards for a reclaimed water distribution facility. The effluent must meet and follow the North Carolina regulations for reclaimed water and water reuse as stated in the North Carolina Administrative Code, Section 15A NCAC 02H.0219. In Fort Bragg's discharge permit, it is written that the effluent from Fort Bragg's WWTP could be used for irrigation purposes under a non-discharge permit standard, which would allow WWTP effluent reuse as an option for Fort Bragg.

Current Wastewater Treatment Plant Effluent Water Quality

To determine whether the Fort Bragg WWTP presently discharges water of acceptable quality for reuse, water quality data from the Fort Bragg WWTP were acquired and compared to the reuse water quality standards and the water presently being used to irrigate the different reuse alternatives listed in this document.

Table A-2 summarizes the water reuse standards required of re-claimed wastewater facilities, the National Pollutant Discharge Elimination System permit requirements required by the NCENR, and the potable water from Fort Bragg's WTP. The potable water is currently being applied to and is the only water supply for Pope AFB's Willow Lake Golf Course for irrigation. The Parade Grounds and Polo Field also use potable water for irrigation of the grounds. Table A-2 also shows WTP backwash effluent data, which is currently not meeting regulatory requirements. There may be plans to transport the backwash to the WWTP where it could then be considered for reuse opportunities.

The monthly average water quality of Fort Bragg water treatment effluent is also provided in Table A-2. From the reuse water quality requirements provided in Table A-1, the WTP and WWTP water quality parameters can be compared. Other water quality parameters provided in Appendix C include pesticides, synthetic organic chemicals, volatile organic chemicals, drinking water metals, cyanide in drinking water, threshold odor test, pH, total dissolved solids, and nitrate/nitrite. These parameters are within the regulatory standards required for public consumption and for irrigation water.

In comparing the quality of WTP water used on the golf course to the quality of the effluent for the WWTP that could potentially be used for irrigation of the golf course, it is apparent that the total residual chlorine is higher for the potable water than for the water treated at the WWTP. On the other hand, the total phosphorus and the ammonia (NH_3) levels in the potable water are lower than the effluent from the WWTP. In summary, the lower chlorine level in the WWTP effluent would be less stressful to plant life and the increased phosphorus and NH_3 would provide nutrients to the plant life, which may result in less fertilizer being necessary. Other parameters that were evaluated and compared include alkalinity, chloride, pH, and specific conductance.

In comparing WWTP effluent data to the reuse water quality requirements for the observed period, the data reflect that the wastewater discharge exceeds the imposed reuse effluent parameters during the months beginning in April through October. The imposed monthly average biochemical oxygen demand (BOD) parameter of 10 mg/L was exceeded during this period, as was the imposed NH_3 of 4 mg/L. The imposed BOD limitation was exceeded by 1.9 mg/L, and the NH_3 limitation was exceeded by 1.1 mg/L. The TSS effluent imposed limit was also exceeded by 2.8 mg/L. For all other parameters, there were no exceedances. Most of the exceedances occurred from April 2001 to July 2001. After this period, monthly data did not exceed the imposed limits. Also, during the time these samples were taken, there was a maintenance problem at the WWTP in that one of the big turbines that control the dissolved oxygen in the oxidation ditch was inoperable. The plant has since recovered and has acquired a supplemental aerator in case of future problems with the turbines.

To further determine whether the wastewater treatment effluent levels remain above the imposed limits would require further evaluation of the effluent data. The daily average reuse limits for the discharge were not exceeded during the period evaluated, indicating that the monthly average limits were not exceeded by a large amount.

Table A-2. Wastewater and potable water quality assessment for reuse purposes.

Parameter	**Reuse Water Quality Requirements**		**Ft. Bragg WWTP Effluent Requirements**		**Ft. Bragg WWTP Effluent Data**	**Ft. Bragg WTP Effluent Data – Backwash**	**Ft. Bragg WTP Potable Water**
	Monthly Average	**Daily Average**	**Monthly Average**	**Daily Average**	**[1]Monthly Avg. Discharge No. 001**	**[2]Monthly Avg. Discharge No. 002**	**Monthly Average (July 2001–2002)**
Flow (mgd)	NOL	NOL	8.0	NOL	5.4	0.48	NOL
BOD_5 20 °C (April 2001 – Oct. 2001) (mg/L)	10	15	16	24	11.9 Fail*	NOL	NOL
BOD_5 20 °C (Nov. 2001 – March 2002) (mg/L)	10	15	30	45	4.1	NOL	NOL
TSS (mg/L)	5	10	30	45	7.8 Fail*	10.7 Fail*	NOL
NH_3 as N (April 2001 – Oct. 2001) (mg/L)	4	6	3	NOL	5.1 Fail*	NOL	.24
NH_3 as N (Nov. 2001 – March 2002) (mg/L)	4	6	11	NOL	3.1	NOL	.24
Fecal coliform (geometric mean) (#/100 mL)	14/100	25/100	200/100	400/100	3.0/100	NOL	NOL
Total residual chlorine (mg/L)	NOL	NOL	NOL	NOL	0.43	0.60	1.05
Turbidity (NTU)	10	10	[3]50	NOL	NM	3.5	100% below 0.5 NTU
pH (min – max)	NOL	NOL	6 – 9	6 – 9	6.6 – 8.2	6.0 – 8.9	5.4 – 9.5
Dissolved oxygen (mg/L)	NOL	NOL	NOL	> 5.0	8.2	NOL	NM
Conductivity (µmhos/cm)	NOL	NOL	NOL	NOL	317	NOL	NM
Temperature (°C)	NOL	NOL	NOL	NOL	20.0	NOL	20.5
Total N (NO_2 + NO_3 +TKN) (mg/L)	NOL	NOL	NOL	NOL	7.9	NOL	NM
Total phosphorus (mg/L)	NOL	NOL	NOL	NOL	1.6	NOL	0.37

NOL = No Observable Limit

NM = Not Measured

Note: Fort Bragg is required to monitor for all parameters listed above. Analysis is required for Annual Pollutant Analysis Monitoring (APAM) requirement, Reporting Form A. All pollutants listed on the APAM form must meet the quantitative limit targets for the NCDENR.

1. Average monthly results for the period April 2001 to March 2002.
2. Average monthly results for the period September 2001 to June 2002.
3. The discharge shall not cause the turbidity of the receiving water to exceed 50.0 NTU.

* WWTP effluent data that exceeded the reuse water quality requirements.

Suggested Wastewater Treatment Process Improvements

There have been only minimal exceedances of reuse water quality standards for WWTP effluent. The three parameters were BOD_5, TSS, and NH_3 as nitrogen (see Table A-2 for comparison). According to Fort Bragg personnel, it appears the reuse water quality standards could be met with minor adjustments to the wastewater treatment system (e.g., maintaining the turbines and the entire plant, which would address the BOD_5 and NH_3 problems and may affect the TSS parameters to meet the requirements). Also, placing a settling tank or using the existing clarifiers at the WWTP for settling prior to irrigating the Willow Lake Golf Course may accomplish reduction of the TSS if necessary. Three clarifiers at the WWTP are available for further treatment or storage of reuse water and two trickling filters that could be made into storage areas if necessary. Each clarifier has a diameter of 74 ft, a side water depth of 8.5 ft, and a holding capacity of 36,500 cu ft. Retention of the reuse water will also allow for residual chlorine to dissipate into the air (Huck et al. 2000).

If NH_3 still exceeds the reuse water quality requirements, an NH_3 stripping process is available for nitrogen removal that simultaneously removes phosphorus and suspended solids and reduces the BOD. Ammonia stripping is done either before or after secondary treatment, and the process consists of adjusting the pH of the wastewater to a value above 10 (lime is used for this purpose) and then air stripping the NH_3 (at pH >10, nitrogen is present as NH_3) in a stripping tower (Ramalho 1983). Inclusion of the NH_3 stripping process would be warranted only if modification of the current wastewater treatment process does not meet the required reuse water quality standards mandated by the State of North Carolina.

POTENTIAL RECLAIMED WATER USERS

The primary potential users for the reclaimed water from Fort Bragg’s WWTP are Pope AFB Willow Lake Golf Course, Fort Bragg Parade Grounds and Polo Field, and Fort Bragg Ryder and Stryker Golf Courses. Willow Lake Golf Course and the Parade Grounds and Polo Field are currently using Fort Bragg’s potable water, whereas Ryder and Stryker Golf Courses are using well water.

To organize this study for the water balance and cost analysis, a distribution route was required. The locations of the potential uses made it possible to bring treated effluent to all five users using one distribution main. Therefore, the alternative distribution scenarios merely consisted of starting with the closest user for the first scenario, and then adding next closest for each subsequent scenario. The distribution scenarios are identified as Alternatives A thru E, and are listed below.

- Alternative A - Pope Willow Lake Golf Course
- Alternative B – Pope Willow Lake Golf Course plus the Parade Grounds and Polo Field
- Alternative C - Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, plus Ryder Golf Course
- Alternative D - Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, Ryder Golf Course, plus Stryker Golf Course
- Alternative E - Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, Ryder Golf Course, plus Stryker Golf Course with increased effluent carrying capacity for future use

A schematic of the distribution showing all potential users is shown in Figure A-1. Pope Willow Lake Golf Course is first on the route, and also the highest priority to use reclaimed water due to its current use of potable water.

Pope Willow Lake Golf Course

The Pope Willow Lake Golf Course is an 18-hole course with 99 irrigated acres. The total length of the course is 7,300 yd. This course uses 100% potable water from Fort Bragg, and the total water use rate is estimated at 402,000 gallons per day (gpd). There are no current reservoirs on the course, which is fertilized approximately three times per year.

Parade Grounds and Polo Field

Fort Bragg has two areas, the Parade Grounds and the Polo Field, which use 100% potable water for irrigation. The Parade Grounds has a sprinkling system, and the total water usage is estimated at 43,200 gpd. The Polo Field does not have a sprinkling system. Instead the water is applied manually using portable pumps connected to fire hydrants. These areas have a total water use rate estimated at 72,000 gpd.

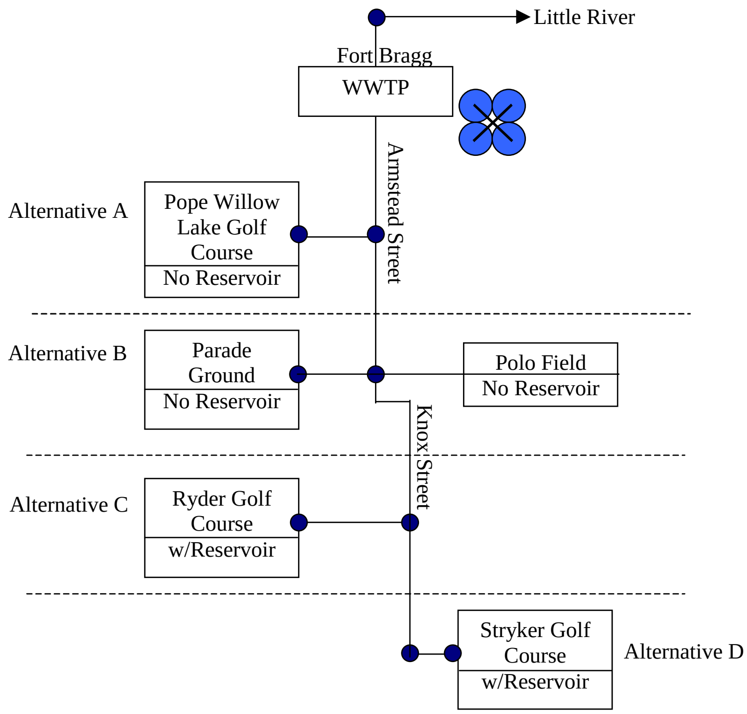

Figure A-1. Distribution schematic for Alternatives A through D.

Ryder and Stryker Golf Courses

Both Ryder and Stryker Golf Courses are 18-hole courses located at Fort Bragg. Both courses obtain water for irrigation from a series of wells that withdraw groundwater from the Middendorf aquifer system. The groundwater is sampled for metals, pesticides, and other contaminants.

Ryder has a pond with a 1,629,163-gal holding capacity, and Stryker has a pond with a 750,000-gal holding capacity. The total water use rate for Ryder is 521,000 gpd, and the total water use rate for Stryker is 710,000 gpd. These golf courses are also fertilized approximately three times per year.

WATER BALANCE

Data Collection

Interviews were conducted with the project contact at Fort Bragg, the Pope Willow Lake Golf Course manager, Pope AFB Environmental Compliance Officer, other Pope AFB personnel, the Ryder and Stryker Golf Course manager, WWTP personnel, and WTP personnel. Because flow monitoring equipment did not accurately reflect actual usage, water volume was estimated using sprinkling times, the number of heads, and the capacity of each head.

Meeting Irrigation Flow Demands

A major concern with using treated wastewater effluent to irrigate the golf courses and other areas at Pope AFB and Fort Bragg is that the volume may not be adequate to meet the demands. Data from April through September for 2000 and 2001 determined that the WWTP had an average effluent flow of approximately 5.8 mgd during that period. For this same period, the maximum flow was approximately 6.4 mgd, and the minimum flow was 5.2 mgd. The estimated total water volume consumed by Willow Lake Golf Course, the Parade Grounds and Polo Field, and Ryder and Stryker Golf Courses is nearly 1.75 mgd (See Table A-3). Even at the minimum daily flow rate, effluent volume was enough to irrigate all of these grounds, as well as enough for other areas in future expansions.

However, irrigation is not done throughout the day, but during short periods in the morning and evenings, which makes instantaneous flow an issue. From diurnal charts documenting WWTP effluent discharge for several days during the month of May 2002, the lowest discharge flow was approximately 1,180 gpm, which occurs from 4:00 a.m. to 6:00 a.m. Even at this low flow, water is sufficient to meet Willow Lake Golf Course's irrigation needs. These charts show that typically flow is adequate to irrigate the Parade Grounds and Polo Field during the evening when those grounds are generally watered. The WWTP data show that from 10:00 p.m. to 3:00 a.m., the discharge rate drops from approximately 3,130 gpm to 2,080 gpm, which is sufficient to meet the watering needs of those grounds.

Because Ryder and Stryker Golf Courses both have holding ponds available, it is assumed they will be used as reservoirs to hold sufficient volumes of water for sprinkling purposes. These ponds would be outfitted with remote terminal units (RTUs) that would be programmed to signal to the existing supervisory control and data acquisition (SCADA) panel to control the pond levels. It is expected that these ponds would be filled during the day when discharge from the WWTP is at its peak. Water would then be drawn from these holding ponds during the morning or evening to irrigate the Ryder and Stryker Golf Courses.

Table A-3. Summary of irrigation water volume and water costs.

Input water cost per 1,000 gals =	$ 1.43					
	Willow Lake	**Ryder**	**Stryker**	**Parade Grounds [5]**	**Polo Field [5]**	**Total**
Greens:						
Number of heads	72	152	154	72	120	
Capacity, gpm/head	30	20	n/a	30	30	
Watering schedule, min/day	20	5	n/a	20	20	
Total water volume, per day	43,000	15,000	120,000	43,000	72,000	
Fairways & Rough:						
Number of heads [1]	598	460	596	n/a	n/a	
Capacity, gpm/head [2]	30	55	n/a	n/a	n/a	
Watering schedule, min/day	20	20	n/a	n/a	n/a	
Total water volume, per day	359,000	506,000	590,000	n/a	n/a	
Entire Grounds:						
Total water volume, per day	402,000	521,000	710,000	43,000	72,000	1,748,000
Total water volume, per month	12,060,000	15,630,000	21,300,000	1,290,000	2,160,000	52,440,000
Total area, acres	99	80	80	12	20	
Heads per zone	30 to 35	n/a	n/a	n/a	n/a	
Summary:						
Water cost, $/1000 gallons [3]	$1.43	$1.43	$1.43	$1.43	$1.43	
Monthly water cost	$17,000	$22,000	$30,000	$2,000	$3,000	
Annual water cost [4]	$136,000	$176,000	$240,000	$16,000	$24,000	$592,000
WWTP Average Effluent Flow, gpd	-	-	-	-	-	5,843,000
WWTP Maximum Effluent Flow, gpd	-	-	-	-	-	6,396,000
WWTP Minimum Effluent Flow, gpd	-	-	-	-	-	5,218,000
Percent of total WW used	6.9%	8.9%	12.2%	0.7%	1.2%	29.9%

[1] According to Willow Lake personnel, there are 72 heads on 18 greens and a total of 670 heads on the golf course. Therefore, it was assumed the difference is 598 heads on the fairways and rough.
[2] Sprinkler heads at Pope operate at 30 gpm @65psi. The pressure is unknown for Ryder.
[3] This is the cost currently paid by Willow Lake for potable water for irrigation purposes. Although water for the Ft. Bragg golf courses is currently from wells and therefore at no cost to them, for purposes of this cost comparison, this same unit cost was also used for Ryder and Stryker in certain parts of this analysis.
[4] Assumes grounds are watered at the same daily rate for an eight-month total period per year.
[5] Although the Parade Grounds and Polo Field are not golf courses, for the purpose of calculating the water volume, the sprinkler zone configuration was assumed to be the same as for the Willow Lake, Ryder, and Stryker golf courses.

The main purpose of the holding ponds is for short-term storage. If long-term storage is necessary, measures would have to be taken to control algae growth.

Currently, the Willow Lake Golf Course and the Parade Grounds and Polo Field do not have reservoirs. It has been assumed that the treated effluent for watering these grounds would be pumped directly from the WWTP. It is possible that existing unused clarifiers at the WWTP could act as reservoirs to guarantee that water is available for irrigation flow when needed.

Pump discharge rates and hydraulic head necessary to meet watering demands at Pope AFB and Fort Bragg are based on water modeling completed at steady state. Basically, this is a snapshot of watering requirements at any given time and is sufficient for a feasibility study such as this one. However, to provide a more realistic picture of the overall watering demands for these areas, dynamic water modeling would be required. From this study, a better balance of water supply and demand could be made to ensure that all watering needs are met as effectively as possible.

DEVELOPMENT OF REUSE ALTERNATIVES

WaterCAD® Version 5.0 from Haestad Methods, Inc., of Waterbury, CT, was used to model multiple WWTP water reuse and water distribution scenarios for this study. Preliminary conceptual designs were established and ran through multiple iterations of the model. The existing engineering designs used in the model were established from information provided by personnel at Fort Bragg and Pope AFB Directorates of Public Works, and by the associated end-use facilities. Where insufficient engineering/ design information existed for modeling purposes (e.g., site-specific pipeline routes), a best engineering assumption was made and likewise plugged into the model's software. Prior to performing a preliminary engineering design, the routing of all pipelines was field-verified to identify potential construction restrictions, such as rights-of-way, buried utilities, vehicular traffic limitations, environmental restrictions (e.g., wetlands), military constraints (if any), and potential future land uses. Cost projections and analyses for each alternative are included later in this document.

Quantities and types of construction materials and all construction methods, such as pumps, valves, piping, backflow prevention devices, cross-connection controls, labeling and signage, etc., must ultimately comply with all appropriate federal, state (North Carolina Administrative Codes), county, and city standards for the distribution of treated WWTP effluents. Additional military standards, if any, may also apply.

Water Model

The WaterCAD® model software accounts for all major water distribution infrastructure. This includes pumps, piping, valves, junctions, and end-user delivery points, such as tanks, reservoirs, and/or pressurized on-demand irrigation systems. The software automatically changes the final model based upon the information supplied and the laws of fluid dynamics and pressurized pipe flow.

The model was run at a steady state for this conceptual feasibility study; consequently, the model will need to be reiterated for dynamic conditions that more accurately reflect actual field conditions for all subject facilities and demands. Such dynamic parameters would include peak water demands by time of day, days per week, month, and year (i.e., seasonal fluctuations). Variations in water temperature will likewise impact model results. Peak demands and associated water distribution hardware systems will need to be recalculated based upon which alternative is selected so that all hardware is properly designed and all customer facilities are adequately served.

The wide range of flows for water reuse for Alternatives A, B, C, D, and E will have dramatic effects on the resultant infra-structure required. Dynamic and variable parameters such as pump horsepower, pump and pipeline pressures, total water flow, water velocities through each specific pipe, and pipe diameters are all intimately related through the demands of each alternative and need to be re-verified prior to performing the preliminary engineering designs.

Model Distribution Routing

All water distribution routing scenarios are depicted on Figure A-1. The diagram depicts Alternatives A, B, C, and D. The layout for Alternative E is the same layout as Alternative D. The routing of all pipelines needs to be field verified to identify all potential construction restrictions.

Alternative A – Route to Pope Willow Lake Golf Course

Alternative A routes water from the WWTP to the Pope AFB Willow Lake Golf Course only. The Willow Lake Golf Course has no holding reservoir to store water for subsequent use. The water distribution line in this alternative is designed to be connected directly to the Pope AFB irrigation distribution system under pressure and will serve on-demand irrigation needs.

Alternative B – Route to Pope Willow Lake Golf Course plus the Parade Grounds and Polo Field

Alternative B routes treated WWTP water to the Pope Willow Lake Golf Course as described above in Alternative A and also serves the irrigation demands of the Parade Grounds and Polo Field. As in Alternative A, neither the Parade Grounds nor the Polo Field facilities have a holding reservoir to store water for subsequent use. Consequently, the water distribution line in this alternative is designed to be connected directly to the three irrigation distribution systems under pressure and will serve the irrigation needs of all three customers on demand.

Alternative C – Route to Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, plus Ryder Golf Course

Alternative C serves the on-demand irrigation needs of all three facilities as described above in Alternative B and also serves the water supply needs of the Ryder Golf Course. However, Ryder Golf Course has a surface water storage reservoir, which may be supplied during off-peak hours. This off-peak demand capability includes time of day use, as well as weekly and monthly demand fluctuations.

Alternative D – Route To Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, Ryder Golf Course, plus Stryker Golf Course

Alternative D serves the irrigation needs of all four facilities as described above in Alternative C and also serves the water supply needs of the Stryker Golf Course. This alternative is the most complicated of the four models in that five separate facilities are being served simultaneously from a single WWTP source. Stryker Golf Course is similar to Ryder Golf Course in that it also has a surface water storage reservoir that may be supplied during off-peak hours. Therefore, Alternative D is designed to serve the on-demand irrigation needs of three separate facilities and the off-peak demand irrigation needs of two additional facilities. Alternative D, serving five separate facilities, has the most hardware requirements. Approximately 6.2 mi of piping would need to be installed to serve all five facilities.

As previously stated, the model software was run under steady-state conditions to perform this conceptual feasibility study. This model will need to be reiterated for dynamic conditions that more accurately reflect the dynamic needs of all five customer facilities.

Alternative E – Route to Pope Willow Lake Golf Course, the Parade Grounds and Polo Field, the Ryder Golf Course, plus Stryker Golf Course with Increased Effluent Carrying Capacity for Future Use

Alternative E is the same layout as Alternative D, with the exception that the piping has been sized up to increase throughput capacity. This alternative will provide treated effluent for irrigation purposes to all five facilities and will also be approximately 6.2 mi long. The major difference is that the pipe has been increased to accommodate a larger volume of water for irrigation to future areas of growth. This alternative would provide the capability of carrying additional effluent to the end of the line to support future irrigation water users. It also provides the capability to use all of the treated effluent for irrigation purposes, with the assumption that the WWTP would discharge up to 11 mgd in the future.

For Alternative D, the pipe was sized to handle 3,650 gpm of treated effluent, or approximately 5.3 mgd. This volume of water was sufficient for irrigating all of the five facilities evaluated in this study. For Alternative E, this volume was roughly doubled in the water model to 7,560 gpm, or approximately 10.9 mgd, which according to flow records at the sewage treatment plant was the peak output during January 2000 through August 2001.[2] This scenario was processed in the water model to hypothetically determine what would be necessary to move the maximum possible amount of treated effluent from the WWTP to the last node on the pipeline located at Stryker Golf Course. In this case, there would not only be a sufficient amount of effluent for watering the existing recreational areas at Pope AFB and Fort Bragg, but also an excess to water large areas requiring irrigation as a result of future growth.

COST ANALYSIS

Methodology

A cost estimate was completed for each of the five alternative reuse scenarios. These cost estimates were prepared with a limited amount of information, have a wide margin of error, and are to be used only for determining the feasibility of using WWTP effluent to irrigate specific areas of Pope AFB and Fort Bragg. This type of estimate lacks detailed engineering, and typically has an accuracy range of –20% to +35%.

Cost estimates were made using a variety of sources, including actual quotes, internal estimates, Petty et al. (1984) and Richardson (2001). The estimated quantity of materials necessary was obtained from summary reports contained in Haestad Methods water modeling. In this model, one of the assumptions was that the treated effluent from the WWTP would be carried to the distribution node for each site. For this reason, this cost estimate does not go beyond this point in determining the costs

[2] Verbal correspondence with Fort Bragg Environmental Department.

associated with installing irrigation systems when necessary or hooking into existing irrigation systems. The budgetary cost estimate completed for this feasibility study also does not include the expenses associated with obtaining permits, dealing with regulatory affairs, and pursuing other legal matters.

These cost estimates assume the work is completed by subcontractors and contain overhead and profit. Costs for pipe, fittings, pumps, and instrumentation were estimated based on outputs from the water modeling completed. Instrumentation includes items such as level controls, level transmitters, and RTUs. The estimated cost for instrumentation was lower than usual because it has been assumed that the existing SCADA system at Fort Bragg would also be used for this project. In addition, the costs associated with engineering, project administration and oversight, bonding, contractor profit, and other fees are also included. Table A-4 summarizes these costs.

Table A-4. Summary of estimated materials and costs to install infrastructure for transporting treated wastewater effluent.

	Total length of pipe, feet				Excavated	Costs					
Scenario	6"	8"	10"	12"	Volume, yd3	Installation	Materials	I&C	Eng. & Admin.	Fees & Profit	Total
Alternative A	-	12,780	-	-	2,840	$156,000	$240,000	$38,000	$170,000	$99,000	$704,000
Alternative B	-	1,960	6,560	12,780	6,882	$302,000	$518,000	$77,000	$350,000	$204,000	$1,451,000
Alternative C	3,000	1,960	6,560	12,780	7,549	$331,000	$528,000	$115,000	$380,000	$222,000	$1,576,000
Alternative D	11,360	1,960	6,600	12,800	9,427	$413,000	$555,000	$154,000	$438,000	$256,000	$1,816,000
Alternative E	-	-	-	130,560	43,520	$1,871,000	$1,577,000	$154,000	$1,405,000	$821,000	$5,827,000
Alternative F	-	-	-	-	0	$0	$0	$0	$0	$0	$0

Scenario Key

Alternative A - Willow Lake GC
Alternative B - Willow Lake + Parade Grounds + Polo Field
Alternative C - Willow + Parade + Polo + Ryder GC
Alternative D - Willow + Parade + Polo + Ryder + Stryker GC
Alternative E - Willow + Parade + Polo + Ryder + Stryker GC with maximum pipe size for future growth

Table A-4 shows the amount and size of purple polyvinyl chloride (PVC) pipe estimated by the water model necessary to install the infrastructure for Alternatives A, B, C, D, and E. This table also contains the estimated volume of material that would be removed in order to install the pipe in an appropriately sized trench. This volume was also used to calculate the amount of soil requiring disposal due to swelling and the amount displaced by the pea gravel bedding. In addition, this volume was also used to calculate the total subcontractor cost for trenching to install the pipe and backfilling to cover the pipe. Other costs in this table are for the materials and labor to install the pipe and the instrumentation and controls (I&C). Additional costs include engineering, contract administration, project oversight, profit, and other expected fees. All of these estimated costs are then added up and used to calculate the payback period relative to the annual cost savings associated with potable water being replaced by treated wastewater.

It should be noted that the cost estimates do not contain contingencies. Estimates are conservative, and contingencies were not thought to be necessary. It is difficult to adjust costs for site-specific conditions, which at the detail level of this study are unknown. Another cost item that has not been considered in this study but could impact the overall cost effectiveness is a potential reduction in fertilizer used. The treated effluent used in watering the grounds at these sites will contain certain nutrients beneficial to the grass. This may result in a reduction in the amount of fertilizer used to keep the grounds healthy and therefore would also result in further cost savings that are not accounted for in this study.

The following assumptions were made regarding this project:

- Irrigation systems are assumed to already exist for each of the areas evaluated.
- The golf courses and other grounds are watered daily over an 8-month period from mid-March to mid-November.
- The existing irrigation systems and lines will be used to water the grounds using the treated wastewater instead of the currently used potable water or well water.
- New water lines will be installed to transport the treated wastewater to each distribution node.
- Purple pipe with proper markings will be used to signify that it contains reclaimed water.
- Buried pipe will be installed a minimum of 24 in.es below grade.
- Other existing infrastructure such as the ponds and water clarifiers will be used.
- The treated WWTP effluent will be available at no cost.
- The treated effluent will meet water quality requirements without additional process improvements. (Since gathering the data provided in this report, WWTP personnel have solved a maintenance problem and state that it can meet the reuse requirements.)
- Solids filtration to protect the vertical turbine pump is not necessary.

- The treated effluent will enhance the growth of the various grasses and other plant life.
- The costs do not include the costs of permitting and Environmental Assessments.
- Installation of pipe will be made in Class A material (i.e., the soil will be soft and easy to dig).
- Shoring and dewatering is not necessary.
- Land along roads is unobstructed (i.e., is not paved or built on, etc).
- There are no obstructions (e.g., utility lines) below surface.
- The pipe lines will be installed in congested areas, which will negatively impact productivity.
- Although Ryder and Stryker Golf Courses currently use water taken from wells, it was assumed that, if this well water was not available in the future, it would cost the same to purchase water as that paid for by the Willow Lake Golf Course.

In this cost analysis, the total cost to install the infrastructure necessary for transporting the wastewater effluent to the appropriate distribution nodes and the estimated annual cost savings were used to calculate the payback period for each alternative. The estimated annual cost savings is attributed to the elimination of using potable water for irrigation purposes, the reduction or elimination of fertilizer usage due to nutrients contained in the effluent for the Ryder and Stryker Golf Courses, and a reduction in electricity costs associated with pumping water from the wells at Ryder and Stryker. Conversely, the electricity used to operate the pumps necessary to transport the treated water to the distribution nodes adds to the cost for using the WWTP effluent to irrigate the Pope AFB and Fort Bragg grounds.

Cost of Individual Alternatives

The Willow Lake Golf Course was the only user that was charged for receiving potable water from the Fort Bragg WTP. The price was $1.43/1,000 gal of water. This price was used as the cost to produce and distribute water from the Fort Bragg Water Treatment

Plant to all users. Both Ryder and Stryker Golf Courses currently obtain their water from a well, at the cost of the electricity to pump it from the aquifer, into a holding pond, and then to the sprinkler heads. However, because of potential problems regarding the continued use of this well, it is assumed that when recycled effluent becomes available, the use of the well will be discontinued.

Alternative A – Willow Lake Golf Course

Historical water usage records were found to be inaccurate. Water usage was estimated based on the total number of sprinkler heads, their flow rate, and the duration of watering. Fertilizer cost could potentially be reduced by 60% of the current cost due to the nutrients contained in the treated effluent when used to water the grounds. Based on the nitrogen content of the effluent, it has been estimated that by using the water from the WWTP, the amount of fertilizer necessary on the golf course would be approximately 40% of the current amount. This results in an estimated cost savings of $9,500/year, based on the cost of fertilizer and the labor necessary to apply it. This estimate assumes other necessary nutrients (such as phosphorus and potassium) would also be contained in sufficient quantities so that additional fertilizing would not be necessary.

To move the water from the WWTP to the distribution node at Willow Lake, the water model estimated it would require approximately 13,000 ft of 8-in. PVC pipe and a single variable-speed vertical turbine pump. In addition, it was assumed that a ball valve, a check valve, one RTU, and various fittings would also be required. The estimated cost for labor and materials necessary to complete this construction is approximately $435,000. With the additional expenses for engineering, contract administration, oversight, bonding, and other fees, the total estimated cost is over $700,000. A summary of these costs is contained in Table A-5 at the end of this section.

Using the estimated volume of water used at Willow Lake at a cost to the golf course of $1.43/1,000 gal of potable water, the estimated annual cost is about $138,000. Based on this annual cost becoming a cost savings once the potable water is replaced with treated effluent and the total estimated cost to install the infrastructure to transport treated effluent to Willow Lake Golf Course is included, the effluent reuse system would be paid back in about 5.7 years. This payback calculation also includes the cost savings associated with fertilizer and the expense for electricity for the turbine pump. This scenario assumes the water is pumped directly from the WWTP or from existing clarifiers at the treatment plant to the Willow Lake Golf Course (see Table A-5).

Alternative B – Alternative A plus the Parade Grounds and Polo Field

The Parade Grounds and Polo Field are estimated to require approximately 115,000 gal of water per day for irrigation (see Table A-3). At the current unit rate for potable water ($1.43/1,000 gal), this would amount to a cost of approximately $40,000/year. Assuming this same volume of water is used, it would cost $46,000/year based on current Fayetteville, NC, rates and $48,000/year if the Fort Bragg utilities were privatized. Also, using current methods, it was estimated to cost approximately $7,800 each year to fertilize these grounds. However, if WWTP effluent were used for irrigation purposes, fertilizing would probably not be required due to the nutrient content of the treated water. This is based on the nitrogen content of the effluent and assumes other necessary nutrients (such as phosphorus and potassium) would also be contained in sufficient quantities so that additional fertilizing would not be necessary.

This elimination of using potable water and fertilizing contributes directly to the cost savings associated with using treated effluent to irrigate the Parade Grounds and Polo Field. However, there is an expense for electricity used to move the WWTP effluent to the appropriate distribution nodes.

Alternative B includes installing a system to transport effluent from the WWTP to Willow Lake Golf Course in addition to the Parade Grounds and Polo Field. The estimated volume of water required to irrigate these two areas is 115,200 gpd. The Parade Grounds have a fixed irrigation system, and the Polo Field uses a portable system. The amount of water drawn from the WWTP effluent to irrigate these two areas is approximately 1.9% of the total wastewater assumed available (see Table A-3). With the addition of the Willow Lake demand, the total amount of effluent for Alternative B represents approximately 8.8% of the total volume available.

Transporting treated wastewater to Willow Lake, the Parade Grounds, and the Polo Field would require over 21,000 ft of 8-, 10-, and 12-in. PVC pipe. Based on the water model computations, the discharge rate and required design head would increase significantly as compared to Alternative A. Therefore, a larger force would be required to transport the water, and it was assumed a 780-horsepower vertical turbine pump with a variable-frequency drive would be necessary. It was also assumed that more fittings would be required due to the greater distance, and two RTUs would be necessary to provide control at Willow Lake and the Parade Grounds and Polo Field.

The estimated cost of materials and labor to provide treated effluent for Alternative B is nearly $900,000. The total cost including engineering, administration, and other fees is estimated at $1.45M. This large increase in cost relative to Alternative A is due to the increased distance required in transporting the water and the larger pump capacity needed to move it.

Assuming this cost provide potable water for irrigation purposes could be eliminated by using treated wastewater effluent at the value of $1.43/1,000 gal, the payback period would be 8.5 years (see Table A-5).

Alternative C – Alternative B plus Ryder Golf Course

The Ryder Golf Course uses an estimated 521,000 gal of water per day for sprinkling purposes (see Table A-3). This water is obtained from a well on the course at no cost except for the electricity to pump it from the aquifer and into a holding pond and then to the sprinkler heads. The cost of electricity to obtain this groundwater is estimated at approximately $35,000/year. However, due to potential contamination in this water and future depletion of this aquifer, it is assumed that Ryder will be forced to use alternative water sources (such as potable water). For this scenario, this alternative would result in a total annual cost of approximately $176,000, using the current rate of $1.43/1,000 gal of potable water. If Fayetteville municipal water or the utilities at Fort Bragg were privatized, this would result in a water cost for irrigation of approximately $208,000 and $219,000, respectively. Therefore, if Ryder Golf Course was required to use potable water to irrigate, significant cost savings would be realized by using treated effluent.

In addition to the potential cost savings in using effluent instead of potable water, the amount of fertilizer necessary is estimated to be reduced by approximately 75%. Assuming the current cost to fertilize the Ryder Golf Course is approximately $16,000/year, the new cost would be $4,000, which is an annual net cost savings over current fertilizing practices of $12,000.

This estimate assumes other necessary nutrients (such as phosphorus and potassium) would also be contained in sufficient quantities so that additional fertilizing would not be necessary.

Although the cost savings for using treated effluent over potable water would be quite significant, some of these savings are offset by the cost of electricity necessary to drive a pump to deliver the water to various nodes. If Ryder Golf Course were to discontinue using well water, the cost of electricity to deliver the water to the distribution nodes in Alternative C would be partially offset by the savings in electricity used in the current method of pumping water from a well. Therefore, there is still a net expense for electricity.

Alternative C includes installing a system to transport effluent from the WWTP to Willow Lake, the Parade Grounds and Polo Field, and Ryder Golf Course. The estimated volume of water required to irrigate Ryder is 521,000 gpd. This volume was obtained using sprinkling times, the number of heads, and the capacity of each head at Ryder. It was also assumed that the irrigation system currently being used at Ryder will continue to be used. For this cost comparison among the alternatives, it was assumed that water would no longer be available from the wells and would have to be purchased at the same rate currently paid by Willow Lake Golf Course. The amount of water drawn from the WWTP effluent to irrigate the Ryder Golf Course is approximately 9% of the total wastewater assumed available (see Table A-3). With the addition of the demand from Willow Lake and the Parade Grounds and Polo Field, the total amount of effluent for Alternative C represents about 17.7% of the total volume available.

Transporting treated wastewater to Willow Lake, the Parade Grounds and Polo Field, and Ryder would require over 24,000 ft of 6-, 8-, 10-, and 12-in. PVC pipe. Based on the water model computations, the discharge rate and required design head would change little relative to Alternative B because the distribution mode for Alternative C is at approximately the same elevation as the mode for Alternative B. Therefore, it was assumed that the same size vertical turbine pump used in Alternative B could be used for this scenario. It was also assumed that more fittings would be required due to the greater distance, and three RTUs would be necessary to provide control at Willow Lake, the Parade Grounds and Polo Field, and Ryder.

The estimated cost of materials and labor to provide treated effluent for Alternative C is nearly $975,000. The total cost including engineering, administration, and other fees is estimated at approximately $1.58M. The total cost increase relative to Alternative B is only $125,000 (or approximately 9% higher) because Ryder Golf Course is close to the Parade Grounds and Polo Field and would not require a great amount of additional piping to connect into the Ryder distribution node. Table A-4 summarizes these costs.

Using the same cost that Willow Lake Golf Course pays for potable water, the annual cost to water the Ryder Golf Course would be nearly $176,000/year, assuming an 8-month watering period. With the annual cost of water to Willow Lake and the Parade Grounds and Polo Field added in, the total water cost to irrigate all of the areas included in Alternative C is estimated at $357,000/year. Assuming this cost to purchase potable water for irrigation purposes could be eliminated by using treated wastewater effluent, this would result in a payback period of 4.3 years. This figure is based on the estimated cost of $1.58M to install the infrastructure necessary to replace the current watering system, the expense for electricity, and the cost savings associated with water and fertilizer. This scenario for Ryder assumes the water is pumped from the WWTP to an existing holding pond where it is held until needed (see Table A-5).

Alternative D – Alternative C plus Stryker Golf Course

The Stryker Golf Course uses an estimated 710,000 gal of water per day for sprinkling purposes (see Table A-3). Similar to the Ryder Golf Course, this water is obtained from a well at no cost outside of the electricity to pump it from the aquifer and into a holding pond and then to the sprinkler heads. The cost of electricity to obtain this groundwater is also estimated at approximately $35,000/year. However, due to the potential contamination in this water and potential depletion of this aquifer, Stryker may be forced to use alternative water sources (such as purchasing potable water). For this scenario, this would result in a total annual cost of approximately $240,000, using the current rate of $1.43/1,000 gal of potable water. If Fayetteville municipal water or the utilities at Fort Bragg were privatized, this would result in a water cost for irrigation of approximately $283,000 and $298,000, respectively. Therefore, if Stryker Golf Course were required to use potable water to irrigate, significant cost savings would be realized by using treated effluent.

In addition to the potential cost savings in using effluent instead of potable water, fertilizing would be eliminated at

Stryker. Based on the current cost to fertilize the Stryker Golf Course, this would result in an annual cost savings of approximately $16,000. This is based on the nitrogen content of the effluent and assumes that no additional fertilizing is necessary to make up for any nutrient deficiencies.

Although the cost savings for using treated effluent over potable water on the Stryker Golf Course would be quite significant, some of these savings are offset by the cost of electricity used to distribute the effluent to all of the golf courses and other recreational grounds in Alternative D. If Ryder were to discontinue using well water, the cost of electricity to deliver the water to the distribution nodes in Alternative D would be partially offset by the savings in electricity used in the current method of pumping from a well. Therefore, there is still a net expense for electricity.

Alternative D includes installing a system to transport effluent from the WWTP to Willow Lake, the Parade Grounds and Polo Field, Ryder Golf Course, and Stryker Golf Course. Approximately 710,000 gal of water is required to irrigate Stryker each day. This volume was obtained using sprinkling times, the number of heads, and the capacity of each head at Stryker. It was also assumed that the currently installed irrigation system at Stryker will continue to be used.

For this cost comparison among the alternatives, it was assumed that water would no longer be available from the wells at Ryder and Stryker and potable water would have to be purchased at the same rate currently paid by Willow Lake.

Water drawn from the WWTP effluent to irrigate Stryker Golf Course is estimated at approximately 12.2% of the total treated wastewater available (see Table A-3). For Alternative D, the total wastewater effluent demand to irrigate all three golf courses, along with the Parade Grounds and Polo Field, is approximately 29.9% of the total volume available.

Transporting treated wastewater to Willow Lake, the Parade Grounds and Polo Field, Ryder, and Stryker would require nearly 33,000 ft, more than 6 mi, of 6-, 8-, 10-, and 12-in. PVC pipe. According to the water modeling, the discharge rate and design head required to move the water from the Ryder distribution node to the Stryker node would change little compared to Alternative C because elevation decreases from the distribution node at Ryder to the node at Stryker. Therefore, it was assumed that the same size vertical turbine pump used in Alternatives B and C would be sufficient. It was also assumed that more fittings would be required due to the greater distance, and four RTUs would be necessary to provide control at Willow Lake, the Parade Grounds and Polo Field, Ryder, and Stryker.

The estimated cost of materials and labor to install infrastructure to carry treated wastewater effluent to all of the sites in Alternative D is over $1.12M. The total cost including engineering, administration, and other fees is estimated at approximately $1.82M. The total cost increase relative to Alternative C is about $240,000, or approximately 15% higher. The major component of this cost is for installing the additional pipe necessary to connect the Stryker distribution node into the Ryder node and for the additional RTU. The additional cost to tie in Stryker with the rest of the water transport system is not as costly as may be expected because the more expensive, larger diameter pipe and pumps have already been installed upstream in the effluent transport system. A summary of these costs is contained in Table A-4.

The annual cost to water Stryker Golf Course is nearly $240,000/year, assuming an 8-month watering period and the same cost Willow Lake pays for potable water used for irrigation. With the annual cost of water for Willow Lake, the Parade Grounds and Polo Field, and Ryder added in, the total water cost to irrigate all of the areas included in Alternative D is estimated at $592,000/year. Assuming the cost to purchase potable water for irrigation purposes would be eliminated by using treated wastewater effluent, this would result in a payback period of 2.9 years. This result is based on the estimated cost of $1.82M to install the infrastructure necessary to transport the effluent to all the necessary distribution nodes. This calculation also includes the cost savings associated with fertilizer and the expense for electricity. This scenario assumes the water is pumped from the WWTP to an existing holding pond at Stryker where it is held until needed (see Table A-5).

Alternative E – Alternative D with Increased Effluent Carrying Capacity for Future Use

Alternative E is basically designed the same way as for Alternative D, with the exception being the capability to deliver an increased volume of effluent to the last distribution node located at Stryker Golf Course. For this scenario, the water model was set up to determine the parameters necessary to move approximately 10.9 million gal of water from the WWTP to the last leg of the water trunk line each day. This scenario results in a discharge rate of approximately 10.9 mgd of treated effluent, which could hypothetically be distributed anywhere on the Pope AFB and Fort Bragg complexes for irrigation purposes. Water modeling determined that a 1,500-hp vertical turbine pump and more than 6 mi of 24-in.-diameter pipe would be required to accomplish this.

It is also worth mentioning that 24-in.-diameter purple pipe for transporting treated effluent needs to be custom ordered at a cost of more than $60/ft. This compares to a per foot cost of under $6 for 12-in.-diameter purple pipe. For this reason and due to the relative unavailability of the 24-in.-diameter purple pipe, it was assumed that four lines of 12-in.-diameter pipe would be installed in parallel instead of one 24-in.-diameter line. This is a more cost-effective method for handling the same volume of water.

The estimated cost of materials and labor to install this infrastructure capable of handling future demands due to growth at Pope AFB and Fort Bragg is estimated at $3.60M. The total cost including engineering, administration, and other fees is estimated at nearly $5.83M. The total cost for this alternative is $4.01M, or approximately 220% higher than for Alternative D. This significant difference in cost is due to the higher cost for pipe and pipe installation to accommodate the larger volume of water. Another contributing factor to this large cost increase is due to the force required to drive a larger volume of water to the last distribution point on the system. This is estimated to require a 1,500-hp vertical turbine pump with a variable-frequency drive. Table A-4 summarizes these costs.

Assuming this alternative will use 10.9 mgd of WWTP effluent and value the water at $1.43/1,000 gal, the total water cost in Alternative E is estimated at $3.74M/year with a payback period of 1.6 years (see Table A-5). This is based on the estimated cost of $5.83M to install the infrastructure necessary to transport the effluent to all designated distribution nodes. This calculation also includes the cost savings associated with fertilizer and the expense for electricity.

Table A-5. Costs and payback for reuse scenarios.

(Assumes value of all reclaimed effluent is $1.43/1000 gal.)

				Estimated Annual Cost Savings		
Scenario	**Capital Cost**	**Annual Electricity Cost**	**Water Volume (gpd)**	**Water Savings[1]**	**Fertilizer Savings**	**Payback years**
Alternative A	$704,000	$23,100	402,000	$138,000	$9,500	5.7
Alternative B	$1,451,000	$24,800	517,000	$178,000	$17,300	8.5
Alternative C	$1,580,000	$14,800	1,040,000	$356,000	$29,300	4.3
Alternative D	$1,820,000	$13,800	1,750,000	$600,000	$45,300	2.9
Alternative E	$5,830,000	$13,800	1,750,000	$600,000	$45,300	9.2
[1]Assumes an 8-month watering period						

CONCLUSIONS

Table A-5 summarizes the total capital and startup cost for each alternative, along with the estimated expense for electricity and annual cost savings associated with water and fertilizer. Using these values, the time required to pay back the initial expense in cost savings was calculated for each alternative. These costs are rough estimates and are for planning purposes only.

The results from this study indicate that it is probably feasible and desirable to use WWTP effluent for irrigation purposes at Fort Bragg and Pope AFB. Alternative D is the most cost effective course of action. Payback for Alternative D is less than 3 years under this assumption. However, Alternative E does not include the water and fertilizer savings from future users of irrigation water, nor does it include the cost of extending the distribution system to those users. When future users can be identified and the cost to serve those users can be defined, then Alternative E may become the most cost effective.

Discontinuing the use of well water to irrigate the Ryder and Stryker golf courses may cause changes in the ground water hydrology in the area. It is not known how this will affect other groundwater users.

RECOMMENDATIONS

It is also recommended that a more detailed engineering study be performed to:

- verify and confirm actual water consumption needs at the five facilities so that modeling and resultant engineering designs are accurate;
- verify and confirm the final selected pipeline routes, including all elevations, existing utilities, rights-of-way, and future growth plans to be addressed in a comprehensive, detailed pipeline routing plan; and
- continue to investigate the impact of continued use, and discontinued use, of the wells at Stryker golf course.

When future users of reused effluent for irrigation are identified, re-evaluate Alternative E to determine payback.

REFERENCES

ENR Environmental Management Commission, T15:02H.0200, April 1, 2001, North Carolina Administrative Code.

Fort Bragg Integrated Strategic Environmental Plan, Prepared by The Public Works Business Center for Fort Bragg, June 2001.

Geraghty & Miller, *Report of Site Investigations, and Studies,* Enlarge Irrigation Pond, Stryker Golf Course, Project No. PA-30025-0, Ft. Bragg, NC, November 2000.

Huck, Mike; Carrow, R.N.; Duncan, R.R*, Effluent Water: Nightmare or Dream Come True?*, Green Section Record, 2000. http://www.usga.org/green/record/00/mar_apr/effluent.html.

Larry J. Stowell, Ph.D., CPAg, PACE Consulting, Pointers on reclaimed water contract negotiations, Fairbanks Ranch Meeting, June 7, 1999.

Miles, Wayne S.; Patackis, Christopher; Bonne, Robert; Russell, Andrew S.; *Startup and Operation of Cary, North Carolina’s Residential/Commercial Reclaimed Water System,* 2002 American Water Works Association – Water Sources Conference Proceedings, 2002.

North Carolina Clean Water Management Trust Fund, September 6, 2002, site last updated 9/5/02, North Carolina Department of Environment and Natural Resources (NCDENR), http://www.cwmtf.net/.

North Carolina Department of Environment and Natural Resources (NCDENR), Division of Water Resources, Webb, Stephen M., Subject: Potential Feasibility of Irrigation Wells Willow Lake Golf Course, October 2000.

Perry, Robert H., et al, Perry’s Chemical Engineers’ Handbook, 1984, Sixth Edition.

Ramalho, R.S., *Introduction to Wastewater Treatment Processes*, 2d ed., Academic Press, New York, p. 565, 1983.

Richardson Engineering Services, Inc., *The Richardson Rapid System Process Plant Construction Estimating Standards*, 2001.

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