AGRONOMIST REPORT

FINAL

UNC Bingham WWTF

Land Application System Receiver Site

Orange County
North Carolina

Prepared for:

McKim & Creed, PA
Venture IV Building, Suite 500
1730 Varsity Drive
Raleigh, NC 27606

And

North Carolina Division of Water Quality
Aquifer Protection Section
North Carolina Division of Water Quality
1617 Mail Service Center
Raleigh, NC 27699-1617

Prepared by:

Soil, Water, & Environment Group
sjfrederick@swegrp.com

Scott J. Frederick, EI, NCLSS

April 2011

Table of Contents

List of Figures

List of Tables

Executive Summary

The objective of this report is to provide the UNC Bingham Wastewater Treatment Facility (UNCBWWTF) with recommendations for the installation, maintenance, and management of a forested and forage grass land application system on their wastewater receiver site in accordance with accepted professional guidance. This forested land application system utilizes existing tree species that are capable of producing large amounts of biomass and providing favorable soil conditions to enhance adsorption of phosphorus and denitrification of nitrogen.

The UNCBWWTF proposes to land apply wastewater to a forest and forage grass land application system on approximately 5.71 acres out of 57 acres of total land area consisting of two Soil Areas (SA) (SA1 and SA2). Specific Soil Areas were determined by the Soil Scientist Evaluation, SWE Group, 2011. According to the Soil Scientist Evaluation Report, and Water Balance Report (Edwin Andrews & Assoc., PC), approximately 3,500 gpd is available for irrigation and can be applied to all Soil Areas at one rate of .1572 in/wk. based on 80%tile wet-year rainfall data. Final hydraulic loadings were determined by the Water Balance Report (Edwin Andrews & Assoc., PC, 2011) in coordination with the Soil Scientist Report (SWE Group, 2011) and this report.

Soil, Water & Environment Group (SWE Group) personnel completed a comprehensive Agronomist Report of the wastewater irrigation areas at the existing and proposed UNCBWWTF land application system receiver site. Recommendations are provided in this report concerning hydraulic loadings, nutrient loadings, as well as site and irrigation system management of this system. Cropping scenarios, species/system selection, fertilizer recommendations, vegetation establishment and management, and vegetation harvesting regimes are provided.

The wastewater proposed for application will provide supplemental nutrients and a consistent source of water to growing crops, in this case a combination of trees, forage grasses, and understory vegetation. Due to the soils, site conditions, and anticipated hydraulic and liquid loadings, the receiver site is hydraulically limited on all Soil Areas. The maximum average concentrations of nutrients (mg/L) in the wastewater at the proposed UNCBWWTF receiver site will be ~25.0 mg/L total nitrogen (TN) and estimated ~10.0 mg/L total phosphorus (TP) as reported by the system designers (McKim & Creed, 2010). This would supply at most 46.6 lbs TN/ac/yr and 18.7 lbs TP/ac/yr based on the most limiting characteristics for the soil series present. Plant available nitrogen equates to 21.6 lbs PAN/ac/yr for all soil areas. Assuming 75% availability, plant available phosphorus (PAP) would be at most approximately 14.0 lbs PAP/ac/yr for all soil areas.

These total plant available nitrogen concentrations are conservative estimates for the irrigation water and do not take into consideration denitrification occurring in the storage ponds or soil microbial interactions on the receiver site. Therefore actual plant available nitrogen (PAN) will be lower than the PAN concentrations presented.

Soil analyses at the proposed irrigation site indicate there are potential nutrient deficiencies. The wastewater will provide supplemental nutrients and a consistent source of water to growing crops. Recommendations for any nutrient amendments are provided in Table 2. Annual soil testing and monthly analysis of the wastewater should be

accomplished to determine if there are continued nutrient deficiencies at the site. This will help insure proper management of the site and optimize growing conditions.

The combination of mixed hardwood/pine forest and forage grass system at the UNCBWWTF Land Application receiver site will provide sufficient treatment and cycling of the waste irrigation water. Trees transpire large quantities of water from deep in the soil profile and also support large leaf areas for transpiration. Even in the winter, photosynthesis and transpiration continue to remove water and nutrients from the site, albeit at a reduced rate. This land application system exemplifies the effectiveness of a combination forage grass and forest system at renovating wastewater and reducing nutrient loadings to nearby river basins.

1.0 Introduction

Under Section .0500 2T Rules – Waste Not Discharged to Surface Waters set forth by the North Carolina Division of Water Quality Aquifer Protection Section, municipalities, and publicly owned treatment works (POTWs) can divert their highly treated effluent to land application irrigation receiver sites. The concept of land applying wastewater will provide additional treatment, and is consistent with the total maximum daily load (TMDL) program promoted by federal and state regulatory agencies. Many county governments, municipalities, and industries are facing similar situations with finding alternatives for wastewater and wastewater treatment and disposal in nutrient sensitive regions. The proposed receiver sites is a viable point source discharge alternative for wastewater irrigation from the UNC Bingham Wastewater Treatment Facility (UNCBWWTF) and will provide an excellent source of irrigation water for growing forage grasses and/or tree crops.

1.1 Objectives

Soil, Water & Environment Group, PLLC (SWE Group) personnel completed a comprehensive Agronomist Report and site investigation of the proposed receiver site irrigation areas. Recommendations are provided in this report concerning hydraulic loadings, nutrient loadings, as well as site and irrigation system management. Cropping scenarios, species/system selection, fertilizer recommendations, vegetation establishment and management, and vegetation harvesting regimes are provided.

1.2 Methodology

Field investigations were conducted to describe the proposed wastewater receiver site according to the soils, geologic features, hydrology, and wetlands. Nutrient concentrations for irrigation water were analyzed and recommendations are provided for the establishment and maintenance of a wastewater irrigation system on the site. Recommendations are given according to site characteristics including soils, hydrology, vegetation, and any site limiting factors. Also recommendations concerning cover crops and their ability to accept the proposed rates of liquids, solids, minerals, and other wastewater constituents, and appropriate application months as well as maintenance are included in this report.

1.3 Site Description

The UNCBWWTF is located in Orange County near the town of White Cross in the Bingham Township off Orange Chapel Clover Garden Road (SR 1956) (Figure 1). The property consists of several agricultural hay fields currently out of production, adjacent and abutting regenerating and mature pine fringe forest, hardwood forest, and adjacent mature mixed pine and hardwood forest. Existing facility structures occur on the site as

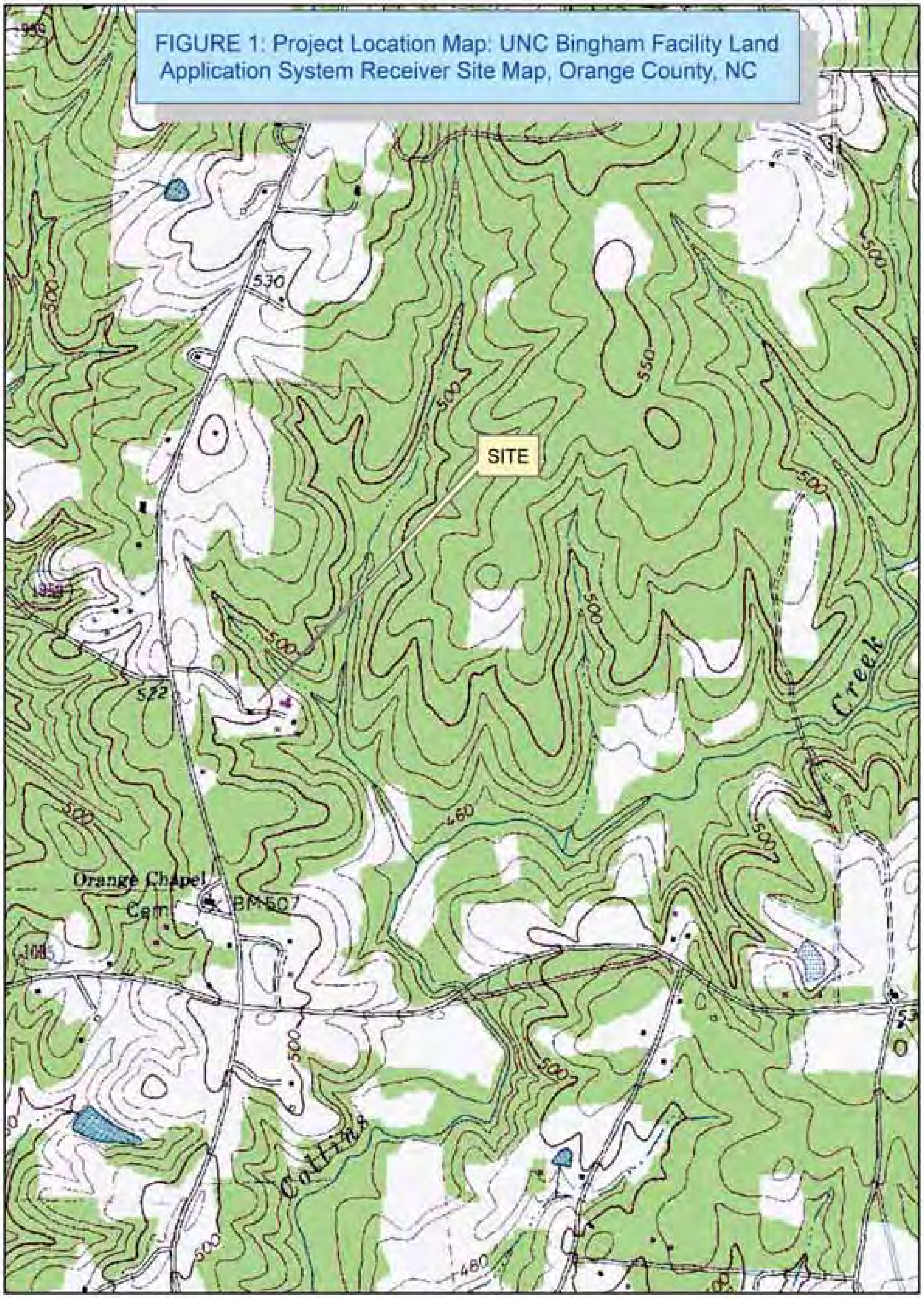


FIGURE 1: Project Location Map: UNC Bingham Facility Land Application System Receiver Site Map, Orange County, NC

Source: NCDOT USGS 1:24,000 (GIS, 2010)

well as an entrance road, existing wastewater irrigation system and infrastructure, and newly constructed expansion irrigation system, storage lagoon, and irrigation infrastructure. Several intermittent stream, wetland, and floodprone complexes occur on the north and east sides of the receiver site. Several drainages course through the property draining upland areas into Collins Creek, a tributary to the Haw River. The site is located in the Piedmont Physiographic Province in the vicinity of the Haw River that is characterized by rolling topography bisected by narrow perennial and intermittent streams.

The soils present on the proposed receiver sites, according to the Orange County Soil Survey (USDA, GIS 2010), are mapped as Georgeville silt loam, Herndon silt loam, as well as lowland loam soils consisting of Chewacla series soils. The vegetation on the proposed forested land application areas consist of upland pine and hardwoods including: yellow poplar (*Liriodendron tulipifera*), hickory (*Carya* sp.), northern red oak (*Quercus rubra*), white oak (*Quercus alba*), red maple (*Acer rubrum*), black cherry (*Prunus serotina*), black gum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), sugar maple (*Acer saccharum)*, Loblolly pine (*Pinus taeda*), Shortleaf pine (*Pinus echinata*), Virginia pine (*Pinus virginiana*), sassafras (*Sassafras albidum*), other small understory woody species. Vegetation in the fields and open areas consist of a variety of herbaceous grasses, forbs, and broadleaf species. Fields will either be kept open and planted with perennial forage grasses such as coastal Bermuda or fescue, or will be planted with an appropriate tree species selected for the soil, proposed liquid loadings, and landscape position.

2.0 Irrigation Water Remediation/Application

Waste irrigation water applied to the receiver site will be utilized in several ways. Water will be lost through transpiration by vegetation, evaporation from the vegetation and soils surface, and percolation through the soil profile. This water will also enter nearby surface waters in wetlands and streams via lateral flow. Any excess nutrients in the wastewater will be treated through microbial processes, plant uptake, adsorption to soil solids, and biologically mediated chemical transformations (i.e. denitrification).

The primary objective of establishing a wastewater receiver site using tree species and forage grasses is to effectively renovate the water through the plant-soil system to prevent nutrients, BOD and other unwanted constituents from entering groundwater and nearby surface waters. Forest and forage systems under wastewater irrigation create a soil/plant system that effectively renovates wastewater through nutrient use and concentration, adsorption, and fixation. This has been demonstrated at facilities throughout the southeastern U.S.

Nutrients promote plant growth and microbiological activity in the soil. Municipal wastewater is a fertilizer to these organisms and they respond by increasing metabolism and growth. Because there is a decreased need to use machinery on the site for competition control and mowing in the plantation forest system, soil structure is maintained or improved while at the same time soil microbiological activity is increased due to litter accumulation. This results in a gradual improvement in soil conditions for wastewater absorption, infiltration, and renovation.

The estimated average annual nitrogen uptake of forested ecosystems for southern forests is 250 lb/ac/yr for 40-60 year old mixed hardwood species, 200 lb/ac/yr for 20-year old loblolly pine with no understory, and 250 lb/ac/yr for 20-year old loblolly pine with understory (Crites et al, 2000). According to other publications (Rubin, 1994, EPA, 1981), the maximum total nitrogen that can be applied to forested sites is 200-400 lb/ac/yr. Other research indicates that forest plantations with canopy closure can assimilate nitrogen levels in excess of the 200 lb/ac/yr (Rubin and Frederick, 1994). In a particular study near Helen Ga., a southern mixed hardwood forest on a 30% slope was given a loading rate of 3.0 in/wk. The nitrogen loading rate was 608 lb/acre and the percolate nitrate concentration was 3.7 mg/L (Nutter et al, 1978).

Trees transpire large quantities of water from much deeper soil depths compared to grass cover. Trees also support much larger leaf areas for transpiration. Even in the winter, photosynthesis and transpiration continue to remove water and nutrients from the site, albeit at a reduced rate. Irrigation water should not be applied to the site whenever icing of trees can cause physical damage. Such conditions may predispose the trees to disease and insect damage.

2.1 Irrigation Water Characterization

Wastewater can be described as containing varying levels of essential plant nutrients, organic compounds, trace minerals, and potentially phytotoxic compounds. Each of these typical wastewater constituents are assimilated or transformed on a receiver site through physical, chemical, and biological processes. The proposed maximum concentrations of nutrients (mg/L) in the proposed irrigation water using an AdvanTex system at the UNCBWWTF are anticipated to be ~25.0 mg/L TN, and ~10.0 mg/L TP (McKim & Creed, 2011).

2.2 Micronutrients and Trace Metals in Soils / Wastewater

Once the irrigation system is established, annual soil testing must be instituted. The soil test results will provide recommendations that will enable proper maintenance. Once soil testing begins, tests must be accomplished annually to determine trace metals, particularly zinc and copper, as well as exchangeable sodium percentage (ESP) and concentrations of macro and micro nutrients in the soil.

2.2.1 Salt Loadings

Imbalances with nutrients such as sodium, calcium, and magnesium may occur in a spray irrigation system and cause degradation in soil structure, lower soil permeability, lower soil water infiltration, and lower uptake of nutrients in plants. One way to evaluate the potential soil problems that may occur on a site receiving irrigation water is to calculate the sodium adsorption ratio (SAR) for the irrigation water.

The SAR of any irrigation water must be determined and monitored. The SAR is calculated as the ratio of sodium (Na) to one half the square root of calcium (Ca) and magnesium (Mg) with all concentrations expressed as equivalents. The SAR calculation is:

$SAR = Na/(Ca/2 + Mg/2)^{½}$ (units in meq/L)

Generally an SAR in excess of 10 is considered to be a hazard on most soils for irrigation purposes and system operators must take special precautions to monitor salt levels of sodium in both irrigation water and soil. In a sandy soil, however, the SAR of irrigation waters is less of a concern because of the limited exchange capacity of the receiver soils. Traditionally an SAR in excess of 7.5 is considered to be a mild hazard to irrigation and system operators should consider establishing a similar monitoring program. If the level of sodium in the soil exchange complex increases to a level over 10, then corrective measures such as gypsum addition or injection of magnesium hydroxide into the irrigation water should be implemented.

Continuing operations with high levels of sodium can result in problems with soil infiltration and nutrient imbalances. Nutrient imbalances can be controlled through gypsum application. The sodium in the wastewater and soil should be closely monitored to prevent future problems with the land application receiver site.

The second concern regarding the SAR is potential adverse impact to plant materials. Irrigation waters with high SAR values may change the osmotic potential in the soil solution and this often results in adverse impact to plant materials. For these reasons, the SAR must be monitored closely. For example, irrigation with liquid containing an SAR of 20 is permissible, provided system monitoring indicates no long-term adverse consequence to the soil and the plant material (Rubin, 2003). Recent water quality testing data indicates the UNCBWWTF irrigation water has an SAR of less than 10 (SAR = 3.5) (Envirochem, 2010).

2.2.2 Soil Sodium

Another measure of sodium, completed for the soil, to determine potential problems with irrigation systems, is called the exchangeable sodium percentage (ESP). ESP is calculated as follows:

ESP = Na/CEC * 100

Where: Na is an index value for sodium

This calculation should result in data no greater than 10-15%. Soils with ESP values > 10-15% can be remediated through under draining and adding soluble sources of Ca such as gypsum ($CaSO_4$), being careful of Mg deficiencies in plants. Ca/Mg ratios should be kept in balance. The Ca/Mg ratio should not exceed 10/1 to 15/1 based on routine soil testing.

If ESP values exceed 15% then amendments such as gypsum or another calcium substitute should be added to correct the situation. A prescription of 1 ton/2units ESP is recommended to address this problem.

Excessive sodium in the soil system can lead to management problems in the future and affect the overall capacity of the site. The ESP at the UNCBWWTF receiver site is ~2.0 %, so no corrective measures are necessary.

2.2.3 Trace Metals

The USEPA regulates the levels to which selected metals can accumulate on any waste receiver site. Most metal levels in domestic wastewater are sufficiently low that accumulation in the soil is not an issue. Zinc (Zn) and copper (Cu) concentrations, however, are frequently monitored in municipal wastewater at levels of 0.5 to 1.0 mg/1 (Nutter, 1986; Rubin, 1996). The irrigation water received at the UNCBWWTF is anticipated not to exceed domestic wastewater concentrations and recent effluent samples revealed a copper concentration of .021 mg/L and zinc concentration of .82 mg/L.

The levels of zinc and copper anticipated in this wastewater should not limit the potential for irrigation onto forested sites. The maximum cumulative levels permitted for the life of the land application site are 1,338 lb./ac Cu and 2,498 lb./ac Zn (USEPA, 1981). The site life (existing fields and new fields) based on these regulated metals and current concentrations found in the effluent, is in excess of 19,000 years for copper and 949 years for zinc for the maximum liquid application rate proposed (Edwin Andrews & Assoc., 2011, USEPA, 2002).

3.0 Site Specific Soils/Nutrients

3.1 Existing Soil and Site Conditions

A soils investigation was accomplished across the proposed receiver site. A series of 3.5 in. hand auger borings were done across the site to maximum depths ranging from 36 - 84 in. These borings were done to characterize the depth of each of the horizons, the color of the soil material at each of the various depths, the texture, structure, consistence of the soil material within each of the horizons, and depth to bedrock or other limiting horizon. These augerings were also done to verify the boundaries of mapping units indicated in the USDA soil survey for Orange County, NC (USDA GIS, 2010).

The USDA Orange County Soil Survey for the site shows two (2) predominant series present within the irrigable soil areas: Georgeville silt loam and Herndon silt loam. Considerable variability in depth, color, and texture was evident across the site depending on landscape position and historical agricultural land use. These variations resulted in subsequent variations in hydraulic loading potentials between the two soil series but not within soil series sampling. Field investigations revealed similar locations for the soil series relative to the NRCS soil survey.

The hand auger borings confirmed that the soils mapped on the site according to NRCS (USDA) are present in the proposed receiver areas. The majority of the soils on the proposed receiver site consist of Georgeville and Herndon silt loam soils, with the remainder of the lowlands consisting of Chewacla loam soils. Soil Area 1 (SA1) soils on the receiver site consist of Georgeville silt loam soils. Slopes range from 2-6%. These soils are very deep, well drained, moderately permeable soils that formed in material mostly weathered from fine-grained metavolcanic rocks of the Carolina Slate Belt. Seasonal high water is typically >6 ft. SA1 soils comprise approximately 62% (3.56 ac) of the total receiver site acreage (5.71 ac).

Soil Area 2 (SA2) soils on the receiver site consist of Herndon silt loam soils. Slopes range from 2-6%. These soils are very deep, well drained, moderately rapid permeability soils that formed in material mostly weathered from fine-grained metavolcanic rock of the Carolina Slate Belt. Seasonal high water is typically >6 ft, however soil variabilities across the site indicate some seasonal perching conditions closer to the surface, probably indicative of slower permeable inclusions. SA2 soils comprise approximately 37% (2.15 ac) of the total receiver site acreage (5.71).

A description of the soil areas including predominant soil series, and existing vegetation is summarized in Table 3.

Table 1: UNCBWWTF Land Application System Receiver Site Soil Area Descriptions.

Soil Area	Predominant Soil Series	Existing Vegetation
SA-1	Georgeville	Grass, Mixed Pine/Hardwood
SA-2	Herndon	Grass

3.1.2 Soils Analysis

A composite sample of the top 0-12 inches of soil representing the irrigable upland areas was collected and analyzed for nutrient composition by NCDA (Table 4). Soil analyses of the proposed irrigation site indicate that there are nutrient deficiencies, especially nitrogen and phosphorus. This conclusion is based on the potential crop response to particular nutrients if fertilizer is applied to the site. The cation exchange capacity (CEC) and base saturation (BS%) are low as well. The addition of wastewater to the site will improve soil fertility and consequently the growing conditions and productivity of this site. Additional agronomy recommendations are found in the Agronomist Report (SWE Group, 2011)

Table 2: Composite Soil Analysis of Uplands (N=22) at the UNCBWWTF Receiver Site, Orange County, NC (2010)[1].

Depth	pH	Phosphorus ppm (Index) [2]	Potassium ppm (Index)	Calcium ppm (%)	Magnesium ppm (%)	CEC [3]	BS% [4]
Uplands							
0-6 in.	**4.8**	**23.4 (19.5)**	**69.1 (35.4)**	**211.6 (33.1)**	**94.3 (14.7)**	**6.1**	**50.7**
6-12 in.	**5.0**	**4.8 (4.0)**	**55.0 (28.1)**	**166.7 (29.8)**	**100.9 (17.7)**	**5.4**	**49.9**

[1] Laboratory Soil Test Reports (2010).
[2] Index values reported by NCDA (2010) http://www.ncagr.com/agronomi/pdffiles/ustr.pdf
[3] Cation exchange capacity (meq/100g) – defined as the amount of cations adsorbed on soil-particle surfaces per unit mass of the soil under chemically neutral conditions.
[4] Base saturation – defined as the percentage of the CEC occupied by base cations

Table 3: Range of Nutrient and Lime Recommendations as lbs/ac or tons/ac for Lime, for the UNCBWWTF Land Application Receiver Site, Orange County, NC (2010) [1].

	Recommended Application			
	Soil Area 1	**Soil Area 2**	**Soil Area 3**	**Soil Area 4**
Lime	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0
N	80-120	80-120	80-120	80-120
P	40-90	40-90	40-90	40-90
K	0-60	0-60	0-60	0-60
Trace	-	-	-	-

1. Nutrient and Lime Recommendations provided by the NCDA - Agronomic Division (2010)

Maintenance of soil fertility is an important component of any land treatment operation. Without vegetation, the effectiveness of any land application operation is compromised. In general the soils mapped by NRCS and SWE Group at the UNCBWWTF land application receiver site are well suited for land application. The soil depth is sufficient to allow irrigation of water in addition to rainfall for the best soils. The lower horizons are deep and the forest cover and vegetation provides a means for nutrient and water cycling.

The irrigation water applied will provide supplemental nutrients and a consistent source of water to growing crops. Soil testing should be done on an annual basis, and additional nutrient applications should be consistent with the recommendations to maintain crop productivity and maximize wastewater irrigation.

3.2 Nutrient Loadings

The supplemental nutrients in the proposed irrigation water will enhance the soil fertility on the receiver site. Soil testing provides site specific lime and fertilizer recommendations for specific crops and field conditions and to optimize growth.

The management of soil fertility without soil testing is not recommended since soil nutrient and pH relationships are complex. Acid soils, for example, can limit root growth and cause certain nutrients to be unavailable for plants. Unless soil acidity and pH are corrected through liming, applying fertilizer may not correct the problem. Soil testing measures the soil's nutrient-holding capacity and provides a sound basis for land management decisions. Fertilizer recommendations based on soil test information optimize crop yield, save money, and protect the environment from excess fertilizer runoff. Following recommendations for lime application can produce similar benefits.

It is recommended and often a permit condition to test the soils on an annual basis in order to fine-tune irrigation events on the receiver sites. Sampling should be done during the same time of the year and samples need to be analyzed by a lab certified for the testing of soil.

3.2.1 Nitrogen Loadings

The nitrogen content of a wastewater source and the current volume irrigated are utilized to determine the amount of plant available nitrogen applied to a site. The total nitrogen level in a wastewater source is determined by measuring the levels of total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3), and nitrate/nitrite nitrogen ($N0_3$/$N0_2$) in the irrigation water. $N0_3$/$N0_2$ and NH_3 are the inorganic forms of nitrogen and total Kjeldahl Nitrogen (TKN) is the organic form of nitrogen. In most domestic wastewater facilities, including the UNCBWWTF, the biological activity in the storage lagoons will break down the organic matter releasing and or consuming the nitrogen as energy in the process. It is estimated that the nitrogen in the wastewater will primarily be in the inorganic fraction, and of this amount, a large portion will occur in the NH_3 form.

It should be noted that the following approximate PAN calculations do not account for the microbiological transformations in the soil and storage lagoons such as mineralization and immobilization or ammonium volatilization. When accounted, actual plant available nitrogen loadings will be less than calculated approximate PAN loadings.

Proposed design nitrogen concentrations for the UNCBWWTF wastewater were used for estimating PAN loadings. Liquid irrigated onto the receiver sites will contain approximate levels of nitrogen reported as ~25.0 mg/l total nitrogen (TN).

Potential Hydraulic Loadings:

Soil Area 1 (3.56 ac) (.157 in/wk)
2,182 gpd
Soil Area 2 (2.15 ac) (.157 in/wk)
1,318 gpd

Liquid Loadings:

Soil Area 1 (.157 in/wk) – (80^{th} %tile)
25.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 3.56 ac = 46.4 lbs TN/ac/yr

Soil Area 2 (.157 in/wk) – (80th %tile)
25.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 2.15 ac = 46.6 lbs TN/ac/yr

Soil Area 1&2 (.157 in/wk) – (80th %tile)
25.0 mg/L TN * (1,277500 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 5.71 ac = 46.6 lbs TN/ac/yr

PAN
PAN= MR(TKN-NH3)+[(1-VR)*(NH3)]+(NO3+NO2)= 11.6 ppm
Where

PAN= Plant Available Nitrogen
MR= Mineralization Rate (40%)
VR= Volatilization Rate (50%)
*TKN= Total Kjeldhal Nitrogen (~25.0 ppm)
*NH3= Ammonia Nitrogen (<1.0ppm)
*NO3= Nitrate Nitrogen (~1.58ppm)
*NO2= Nitrite Nitrogen (~.014pmm)

*Source: McKim & Creed (2011) - Proposed AdvanTex System

Soil Area 1 (.157 in/wk) – (80th %tile)
11.6 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 3.56 ac = 21.6 lbs TN/ac/yr

Soil Area 2 (.157 in/wk) – (80th %tile)
11.6 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 2.15 ac = 21.6 lbs TN/ac/yr

Soil Area 1&2 (.157 in/wk) – (80th %tile)
11.6 mg/L TN * (1,277,500 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 5.71 ac = 21.6 lbs TN/ac/yr

This annual approximate PAN nitrogen loading rate is calculated by multiplying the amount of ~PAN nitrogen in the wastewater by the gallons of wastewater applied. This number is then converted to pounds of ~PAN nitrogen being applied on the entire site and subsequently divided by the total acreage to yield pounds of ~PAN nitrogen per acre per year. The final numbers show that the annual average hydraulic loadings anticipated by the current design will result in a maximum annual average application of approximately 21.6 lbs PAN/ac/yr during an 80%tile wet rainfall year for all soil areas.

This number is higher than actual plant available nitrogen loadings because, as previously stated it does not account for soil microbiological interactions and potential denitrification processes occurring in the storage ponds prior to application. These numbers were used to provide a conservative estimate of total plant available nitrogen to meet the agronomic needs of the receiver crops and to protect adjacent streams and groundwater from nutrient enrichment. The anticipated liquid loadings are within acceptable nutrient loadings for the proposed land application systems as indicated by state water quality agencies and demonstrated in other permitted natural forest/forage land application systems in the southeast. In fact, these PAN loadings are very low and supplemental N will be required to optimize crop production.

3.2.2 Phosphorus Loadings

Domestic wastewater contains low levels of phosphorus as total phosphorus (TP), phosphate (PO_4) or (P_20_5). Each of these forms of phosphorus can be essential as nutrients for plants. Plants generally require phosphorus at a rate of 25% to 50% of the nitrogen application rate. The TP concentration for the UNCBWWTF will have a proposed design concentration of ~10.0 mg/L. Liquid irrigated onto the receiver site will contain a TP level calculated as:

Potential Hydraulic Loadings:

Soil Area 1 (3.56 ac) (.157 in/wk)
2,182 gpd

Soil Area 2 (2.15 ac) (.157 in/wk)
1,318 gpd

Liquid Loadings:

Soil Area 1 (.157 in/wk) – (80^{th} %tile)
10.0 mg/L TP * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 3.56 ac = 18.7 lbs TP/ac/yr

Soil Area 2 (.157 in/wk) – (80^{th} %tile)
10.0 mg/L TP * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 2.15 ac = 18.6 lbs TP/ac/yr

Soil Area 1&2 (.157 in/wk) – (80^{th} %tile)
10.0 mg/L TP * (1,277,500 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 5.71 ac = 18.7 lbs TP/ac/yr

Under acidic soil conditions, phosphorus fixation will be dominated by Al and Fe compounds. A regular soil testing regime, and liming program, should be followed to allow maximum agronomic availability of both native and fertilizer applied phosphorus. The efficiency of phosphate uptake by plants will be higher if lime is applied to the site prior to irrigation. Assuming 75% availability, PAP will be ~14.0 lbs/ac/yr for both soil areas. These phosphorus loadings can be assimilated by the cover crops and soils specified. In fact, P loadings are low and supplemental P may be required to optimize crop production.

The assimilative capacity for phosphorus is below that for nitrogen and the existing levels of phosphorus can be assimilated by the forest crops and soils specified provided an effective sedimentation and erosion control program is in place. The sedimentation and erosion program in place for the facility is necessary to reduce the loss of phosphorus, which exits a site adsorbed to fine soil particles lost with runoff during storm events. Riparian buffers are also important sinks for phosphorus transported in overland flow during periods of unusually high precipitation. The UNCBWWTF receiver site will have vegetated buffers around waters of the state adjacent to irrigation fields to help trap and sequester phosphorus moving toward surface waters.

3.2.3 Organic Loadings

Average monthly BOD (biochemical oxygen demand) and TDS (total dissolved solids) in the effluent is anticipated to be between <10 mg/L and <5 mg/L respectively, based on design effluent concentrations.

Given that a site with moderately drained soils can accommodate up to 10,000 lb/ac/yr organic loadings (Carlile et al., 1974 Crites et al., 2000, EPA, 1981, Rubin, 2002), the organic loadings at the proposed receiver site will be within the site limitations.

3.2.4 RYE Calculations (NCDWQ)

NCDWQ aquifer protection section permit application guidance requires an analysis of nutrient uptake by crops using software and a database developed by N.C. State University, the Natural Resource Conservation Service, the North Carolina Department of Agriculture and Consumer Services, and the North Carolina Division of Soil and Water Conservation. This nutrient management software allows an analysis of the nutrient requirements of proposed crops at the receiver site. Nutrients analyzed include nitrogen and phosphorus.

The analysis for the UNCBWWTF included a variety of soils and two crop regimes; forage grass and natural forest. The forage grass nutrient requirements were calculated for fescue and Coastal Bermuda grass. No data is currently available in the nutrient management software for forest systems. So, nutrient recommendations were based on current literature, site and soil conditions, and historical permitted forest systems in the State. Nutrient management recommendations are given in Table 4 below.

Table 4: Nutrient uptake and removal and yields for proposed cover crops at the UNCBWWTF receiver site.

Soil	**Crop**	**RYE (tons)** [1.]	**Nitrogen Application Rate (lb/ac/yr)** [1.]	**Irrigation Area (ft^2)**	**Phosphorus Removal (lb/ac/yr)** [1.]	**Irrigation Area (ft^2)**
SA1	Fescue	3.2	136	53,186	51	56,732
Georgeville	Coastal Bermuda	3.8	159	45,492	46	62,898
	Forest	-	150 +	48,222	40 +	72,333
SA2	Fescue	3.9	174	22,291	63	36,410
Herndon	Coastal Bermuda	4.8	213	20,512	58	30,132
	Forest	-	150 +	29,128	40 +	43,692

1.] Based off management recommendations from NCSU et al. (http://nutrients.soil.ncsu.edu/yields/)

The anticipated nutrient loadings at the UNCBWWTF are within economic-based agronomic limits supported by NCDWQ at this time. The site is limited by hydraulics and therefore nitrogen and phosphorus can be assimilated by the system within both soil areas. Overall, the UNCBWWTF will function as a viable receiver site for treated wastewater and enhance growth of established and new cover crops based on RYE application rates.

3.2.5 Recommendations

A composite wastewater sampling program should be instituted to address the various inputs to the land application system irrigated through the UNCBWWTF program. The wastewater parameters to be monitored include as a minimum the following: total nitrogen and plant available nitrogen (Kjeldahl-N (organic) and NH_3-N, nitrate, and ammonium (inorganic)), total phosphorus, potassium, sodium, calcium, magnesium, copper, zinc, BOD, and TSS. These are all critical parameters in a forage or forested land application system. The sodium adsorption ratio (SAR) of the liquid irrigated should be less than 10-15, however spraying is not precluded should an SAR value higher than 10 occur. Only, additional site management steps may be necessary, such as adding gypsum directly to the fields or injecting magnesium hydroxide into the irrigation water should plant or plant-soil relationships become compromised. The operator of the WWTF must be informed of the results obtained through the monitoring effort. The operator may be required to modify management operations as a result of the monitoring data, and quick, timely responses to impending soil fertility changes will avert long term problems in this program. Optimization of land treatment operations will require addition of supplements as determined by soil test data.

4.0 Forest System Site and Species Selection

Forest systems have a variety of attributes favorable for treatment and cycling of municipal wastewater including: 1.) Most natural forest stands sites are nutrient deficient and capable of assimilating large amounts of nutrients through biotic conversion and soil adsorption, and 2.) Trees have perennial root systems, which allow year round uptake of nutrients and enhance infiltration.

Detailed knowledge of site history and soil characteristics is necessary for proper design and maintenance recommendations of wastewater application systems. Ideal wastewater application sites will have deep (>1m) soils with loam to sandy loam surface horizons over silt loam to sandy clay loam subsurface horizons. Soils well suited for high nutrient and hydraulic loading rates will be well drained (water table >1m deep) with pH values between 5.5 and 7.0 (Frederick et al., 1994). Soils that are very clayey or very sandy are somewhat limited for wastewater applications, although waste characteristics and application rate are important mitigating factors. The soils present at the UNCBWWTF receiver site are well-suited for forest establishment and wastewater land application.

Hardwood (deciduous) species tolerant of saturated soils are generally preferred for wastewater application. Hardwood species are generally preferred because of high nutrient uptake, rapid early growth rates, ability to resprout after harvest, and tolerance of saturated conditions as compared with most *Pinus* (pine) species. However, well established pine stands are tolerant of increased soil wetness due to irrigation.

4.1 Site Selection

Site selection is critical when establishing a wastewater application system. Existing published data (i.e. soil surveys, hydraulic conductivities, etc.) are useful to determine general site characteristics, but detailed information may be necessary for proper design of the system. Detailed field study provides data regarding microsite variation, existing soil fertility, in-situ soil texture and morphology, and water table depth. This site specific data are essential to establish proper loading rates, species recommendations, and maintenance recommendations.

4.2 Species Selection

In the case of plantation establishment, species selection is dependent on the anticipated hydraulic loading, waste characteristics, soil characteristics, seedling availability, and desired rotation length (i.e. final product desired). Several hardwood tree species have been successfully used throughout the Southeast for biomass plantations and wastewater application (Table 4). These species vary in their tolerance to flooding and soil saturation, and exhibit different growth potential according to soil characteristics. The objective of species selection is to maximize growth and nutrient uptake for a given wastewater application.

Based on the anticipated hydraulic loading rates, wastewater characteristics, soil and site characteristics, several tree species are recommended for the moderate to well drained soil areas (SA1 and SA2) (Appendix – Figure 4). Hardwood species are generally preferred because of high nutrient uptake, rapid early growth rates, ability to resprout after harvest, and tolerance of saturated conditions as compared with most *Pinus* (pine) species. Further, the potential for coppice woodland operations enhances potential for nutrient removal and hydraulic loading to sites.

Many of the bottomland oak species do not exhibit good growth with prolonged soil saturation and subsequent rhizosphere hypoxia (Gardiner et al., 1993). In addition to site considerations, the growth pattern and length of rotation should be considered. Growth patterns of sweetgum (*Liquidambar styraciflua)*, sycamore (*Platanus occidentalis*), and oaks (*Quercus* sp.) vary considerably (Frederick et al., 1994). On a good site, sycamore will grow very fast at first, then taper off after age 6 to 12 years without intermediate thinning. Oak species generally grow slowly at first, followed by a period of rapid growth. Sweetgum exhibits intermediate growth usually equivalent to pine species. However all hardwood species are able to resprout (i.e. coppice) following harvest, producing multiple rotations from one rootstock and maintaining high nutrient and hydraulic assimilation capacity of the system.

We recommend establishing the irrigation system with different species within the existing hardwood forest and maintain the existing vegetation until harvest. Open fields can be managed exclusively for forage species, or combined with forest crops in a tree plantation. When and if harvesting of the existing forest cover occurs, we then recommend replanting the forested areas with a variety of tree species which prefer moderately well-drained soils (SA1 and SA2) and moderate pH levels at 1.8 x 3.0 m (6 x 10 ft) spacings. Sycamore, sweetgum, green ash, and hybrid poplar (*Populus deltoides* X *P. nigra*) have been utilized successfully at several existing wastewater irrigation sites in the southeast (Table 4). These species are ideal for the soil and site characteristics found at the UNCBWWTF receiver site (Appendix – Figure 4).

Buffer plantings can be established, if desired, as a screen between the irrigation fields and roads, and in buffers between the irrigable and non-irrigable areas with seedling spacings similar to the other planting areas. These plantings may include wax myrtle (*Myrica cerifera*) or other fast-growing vegetation suitable for buffers or natural screening. Portions of the proposed buffer zones that are not currently forested should be planted with a variety of native tree species that are adapted to grow on similar sites.

5.0 Vegetation Maintenance and Monitoring

Data obtained through the investigation of the soils and site characteristics at the UNCBWWTF receiver site were utilized to determine the best suitable receiver crop or combination of crops. Recommendations are provided for vegetation maintenance and monitoring on the existing wastewater receiver site.

5.1 Forest System Maintenance

Forest systems used for wastewater application require less maintenance as compared with crop and forage systems. However, periodic inspection and early maintenance are important to ensure the success of forest plantations. Equipment traffic on saturated soils may cause rutting, increase surface ponding, and alter the hydraulic conductivity of the soil and should be avoided. Herbaceous competition should be controlled between planting rows using mowing equipment until canopy closure at year 4 or 5, sooner for recently

Table 5: Characteristics of Common Tree Species Used in Wastewater Land Application Systems.

Species	Flooding tolerance [1,2,3,5]	Preferred soil texture [4,6]	Preferred soil pH range [4,6,7,8,9]
Platanus occidentalis (sycamore)	mod. tolerant	sandy-silt loam (coarse)	5.50-7.50
Liquidambar styraciflua (sweetgum)	tolerant	silt-clay loam (fine)	5.50-7.50
Fraxinus pennsylvanica (green ash)	very tolerant	moderate to coarse	4.15-7.50
Acer negundo (boxelder)	tolerant	v. coarse to v. fine	5.00-7.10
Quercus sp. (oaks)	v. tolerant – mod. tolerant	moderate to fine	4.50-5.50
Nyssa aquatica	very tolerant	moderate to v. fine	4.00-5.50

(water tupelo)			
Populus heterophylla (swamp cottonwood)	very tolerant	heavy clays (fine)	4.60-5.90
Populus deltoides (cottonwood)	v. tolerant – tolerant	f.sandy loam – silt loam	5.50-7.50
Populus deltoides X *P. nigra* (hybrid poplar)	tolerant – mod. tolerant	medium texture	6.00-7.00
Taxodium distichum (bald cypress)	very tolerant	silty clay-loam	4.60-6.90
Pinus elliottii (slash pine)	mod. tolerant	coarse to fine	-----
Pinus taeda (loblolly pine)	intolerant – mod. tolerant	sand-clay	4.50-6.50 (moderately acid)

[1] Baker, 1977; [2] Hook, 1984; [3] Gill, 1970; [4] Willett and Bilan, 1993; [5] Gardiner et al., 1993;
[6] Burns and Honkala, 1990; [7] Harrington, 1991; [8] Baker and Broadfoot, 1979; [9] Broadfoot, 1976

Table 6: Recommended Vegetation Species for Vegetation Areas at the UNCBWWTF Land Application System Receiver Site, Orange County, NC.

Vegetation Area (Soil Area)	**Species**	**Comments**
1	green ash sycamore sweetgum hybrid poplar bald cypress	- plant better drained areas with one or more of these species - species planting depends on seedling availability
2	green ash sweetgum bald cypress	- species planting depends on seedling availability

harvested trees. It should be noted that any equipment trafficking should only take place when the irrigation site is adequately drained. Equipment traffic on saturated soils may cause rutting, increase surface ponding, and alter hydraulic conductivity of the soil. No herbaceous competition control is required at this time with the existing pine and mixed hardwood forest on the receiver site. Herbaceous competition control will be necessary on the open forage grass fields prior to establishment. Following harvest, and replanting, herbaceous competition should be controlled until canopy closure. The following discussion below applies to the system following replanting of hardwood trees.

Irrigation equipment and infrastructure should also be maintained to ensure proper application of wastewater. Herbaceous plants and vines grow rapidly with wastewater applications and may interfere with stationary sprinkler operation. Sprinklers should be routinely inspected and herbaceous/vine growth should be removed. In addition to infrastructure maintenance, periodic inspections of wastewater plantations are necessary to identify and control specific problem areas. Insects, disease, deer browsing, and rodents can damage wastewater plantations and are difficult to anticipate. Early identification of these problems is important to minimize the effects on the system and maximize plantation yield.

5.2 Forest Harvesting Recommendations

Forest Plantation Stands

Thinning and pruning of plantations may be necessary between 5-10 years initially and following harvesting, and pulpwood harvest may occur at 8-20 years depending on wastewater loading, species, and site characteristics. Plantation maintenance recommendations for the UNCBWWTF forested plantation areas include:

- Regular mowing of the forage grass fields and between planting rows within the spray field with low ground pressure equipment (2-4 times/yr.) following adequate drainage/dry down of the spray zone.
- Sprinkler inspection to ensure adequate coverage and adjust for areas where ponding and/or surface runoff may occur such as installing hand valves to fine-tune irrigation events.
- Periodic inspections after severe rainfall events to locate isolated depressions and fill using appropriate loam or sandy loam material to facilitate vertical drainage.

Existing Natural Forest Stands

Both natural stands and plantations irrigated with municipal wastewater exhibit accelerated growth. Since the primary objective of this land application system is nutrient and water uptake, forest stands should be harvested near growth peak to maximize the nutrient removal capacity and evapotranspiration (ET) of the system.

Harvesting can be accomplished using standard mechanized equipment such as feller-bunchers and skidders. Harvesting contractors should be instructed to operate equipment with caution when working around permanent irrigation systems. Site operators should also allow sufficient time for a wastewater site to dry out prior to traffic by heavy logging equipment. Soil rutting, soil compaction and physical damage to irrigation equipment are expensive to repair.

Predominantly Mixed Pine/ Hardwood Stands

It is recommended that no forestry activities such as precommercial thinning cutting be done on these areas for the next 20-25 years. Trees will be competing among themselves and there is no point in doing any stocking reduction until a final canopy height is reached (about 20-30 years). At year 25 it is recommended a thinning be completed to improve quality, species composition and spacing (access). This thinning could be followed by another thinning at about 35 years. This is optional but would help to greatly improve the species composition, quality, and value of the stand. The forest stand could then be clearcut at age 50 or it could be carried on to an older age 60 – 80 years. The latter option will result in higher quality wood and add more value to the stand as well as increasing biodiversity values (wildlife, aesthetics, green space etc).

Overall, the proposed wastewater receiver site is ideal for a forest system. This system will result in the most effective wastewater treatment and assimilation system based on the existing site conditions, hydraulic loading rates, wastewater characteristics, and soil characteristics. A tree system will only require periodic mowing, brushing, and/or herbiciding between planting rows until canopy closure and the inspection of the spray field operation to ensure proper functioning. Following harvest of the trees at peak growth, vegetation will sprout from remnant stumps and the functioning of the system will continue. The long term presence of forest cover and reduced vehicle traffic with forest systems will greatly improve infiltration and other soil characteristics important for renovation of wastewater and recharge of groundwater.

The success of either natural or plantation tree systems depends on the routine operation, maintenance, and optimal performance of the irrigation system. Tree establishment, maintenance, and harvesting should be accomplished by qualified professionals. Routine maintenance should be performed by the certified system operator. Success of the system should result in additional income from the sale of pulpwood and/or sawtimber.

Forested Land Application System Maintenance SUMMARY

Following are recommendations for maintenance of a hardwood spray field plantation at the UNCBWWTF receiver site:

- Maintain a minimum of 10-15 ft. separation between spray heads and tree rows. Spray pressures < 80 psi will not harm or debark planted trees. Trees have been selected for smooth bark to eliminate this problem.

- Band-apply an herbicide such as Oust, Garlan 3, Garlan 4, or Roundup to planting rows if necessary to control herbaceous weeds and vines.

- Follow up inspection and replanting as necessary (within one year following replanting).

- Regularly mow the fields and between planting rows within the spray field with low ground pressure equipment (2-4 times/yr.) following adequate drainage/dry down of the spray zone. Maintain rows and keep track of supplementally planted trees with pin flagging for each row at a minimum. Flagging of individual trees may be necessary during the early stages of growth for one to two years.

- Inspect sprinklers to ensure adequate coverage and adjust for areas where ponding and/or surface runoff may occur. Remove any climbing vines from sprinkler risers.

- Prune trees no more than 60% bole (tree trunk/stem) and 40% crown (remaining branches/leaves) to allow for equipment access and for wood quality as needed annually.

- Maintain site drainage such as road side and adjacent ditches.

6.0 Receiver Site Forage Species Selection

Forage/grass systems are viable options for the UNCBWWTF land application irrigation project. The receiver sites may contain a combination of forage/grass species in the open fields. The forage/grass system will utilize a combination of a variety of shade tolerant and sun favoring forage grass species. These areas will be managed for nutrient and water assimilation.

Selection of this system and location was determined by the soils, existing site conditions, proposed crops, topography, and location of surface waters. Figure 3 (Appendix A) details the proposed receiver site areas and recommended land use. Detailed recommendations for the initial establishment, maintenance, management, and harvesting of vegetation on this system are provided in Section 7.

6.1 Forage Grass System

Forage grass systems can be established on a variety of soils and exhibit characteristics to effectively treat reuse water and assimilate nutrients in growing vegetation. These characteristics include:

1. Forage grasses tolerate a wide range of soil moisture levels.
2. Forage grasses utilize significant levels of nutrients.
3. Forage grasses develop perennial root systems and consume nutrients throughout the growing season.
4. Forage grasses may be perennial and remain productive for several years without replanting.

6.1.1 <u>Site Selection</u>

Site selection is critical when establishing a forage grass reuse water application system. Existing published data (i.e. soil surveys, hydraulic conductivities, etc.) are useful to determine general site characteristics, but detailed site specific information may be necessary for proper design of the system. Detailed field study provides data regarding microsite variation, existing soil fertility, in-situ soil texture and morphology, and water table depth. Site specific data is essential to establish proper loading rates, species recommendations, and maintenance recommendations. This report utilizes site specific data as well as existing soil and land use data.

6.1.2 Species Selection

Forage grass species may be utilized for some of the irrigation water land application system for the proposed project. A variety of forage grass species are compatible with the proposed system including coastal Bermuda grass (*Cynodon* sp.)(only in very open, sunny areas), fescue (*Fetescue* sp.), eastern gamma grass (*Tripsicum* sp.), bent grass (*Agrostis* sp.) and dallisgrass (*Paspalum dilatatum*). All forage grass species will be established and managed to meet the nutrient and hydraulic demands of the growing crop.

Table 7: Recommended Vegetation Crop for Forage/Grass Areas at the Proposed UNCBWWTF Receiver Site, Orange County, NC.

Vegetation Area (Soil Area)	Crop	Comments
SA1 & SA2	Forest and/or Coastal Bermuda grass and other perennial grasses (i.e. tall fescue, or hybrid fescue)	- managed for nutrient and water assimilation.

7.0 Forage Vegetation Establishment, Management, and Harvesting

Data obtained from the investigation of the soils and site characteristics at the UNCBWWTF receiver site were utilized to determine the best suitable receiver crop or combination of crops for the proposed irrigation water. Recommendations are provided for vegetation establishment, management, and harvesting on the proposed water receiver site.

7.1 Fertility

Based on soil fertility samples, fertilizer recommendations for the forage grass receiver crops are provided in Table 3. Fertilizers should be applied to the site at the recommended rates prior to vegetation establishment and management. This is essential to the success of the vegetation and the overall success of the land application system. According to recent soil sampling (NCDA, 2010), supplemental nutrients will be required prior to establishment of a forage grass system, and following system establishment should be continually determined through annual soil testing:

A. .5-1.0 tons lime/ac – Soil pH is moderate to low. pH influences the availability of essential plant nutrients. The lime recommended is required to facilitate the uptake of essential plant nutrients. This should be supplied in the form of dolomitic lime to insure Ca/Mg ratios stay in balance.

B. 80-120 lbs nitrogen/ac – This is generally supplied in the form of urea, ammoniacal nitrogen, or nitrate nitrogen in inorganic fertilizers.

C. 40 to 90 lbs phosphorus/ac – This is generally supplied as a phosphate compound. The phosphorus recommended is essential for root development.

D. 0 to 60 lbs potassium/ac – Generally this is supplied as a salt of potassium such as potassium chloride. Potassium is essential for development of root, stem, and leaf tissue.

E. 5 lbs copper/ac – Bermuda grass requires trace minerals to prosper. If copper levels in the soil are very low supplemental copper must be supplied. Generally this is supplied through the addition of copper sulfate.

F. 0 lbs zinc/ac – Bermuda grass requires this trace mineral to grow and prosper. If zinc levels in the soil are very low supplemental zinc must be supplied. This is usually added in the form of chelated zinc or zinc sulfate.

7.2 Forage Grass System Establishment, Management, and Harvesting

7.2.1 Forage Grass System Establishment

Coastal Bermuda grass can be established on most sun exposed areas using live sprigs at a sprigging rate of 40 bushels per acre. Sprigs should be placed 2 to 3 inches apart with 24 to 30 inch rows during the months of early **March through April**. Sprigging can be completed later in the growing season provided **irrigation is available** to the newly established plants. Establishment of the forage system species should proceed as follows:

1. Disk and subsoil to a depth of 12-18 inches, remove existing vegetation and incorporate chemical controls for existing vegetation for establishment only.
2. Adjust soil fertility with lime and nutrients.
3. Disk and pulverize soil in seedbed.
4. Incorporate seed or sprigs at rates recommended.
5. Irrigate to assure crop germination or sprig development.

Eastern gamma grass, fescue, and dallisgrass should be established on shaded areas and areas with higher slopes using pure live seeds at 15 lbs/ac. Seeds should be placed between 0.75 and 1.0 inches apart during the months of **April through mid June**. Fescue can be established as well. This can be accomplished by disking in a cover crop of fescue in the fall **(Sept.-Nov.)** (broadcast 10-15 lb/ac or drilled at 6 lb/ac). Establishment of a fescue crop is possible in the early spring as well **(Mar.-Apr.)**.

7.2.2 Forage Grass System Management

Forage grass system management recommendations for the UNCBWWTF receiver site include:

- Follow up monitoring of forage plantings within one year after planting.
- Regular cutting of the receiver sites with low ground pressure equipment following adequate drainage/dry down of the spray zone.
- Grass clippings should be mowed on a regular basis left in place to provide organic matter and nutrients for the regenerating crop. Clippings left on the receiver sites provide important carbon and nutrient sources for continued vegetation growth and soil quality improvement.
- Sprinkler inspection to ensure adequate coverage.

Irrigation operations on the forage/grass areas should be limited to times from the very early morning, to late afternoon or early evening. This assures that the crop is irrigated during or near daytime hours and this minimizes the potential for plant diseases to impact the forage crop. Turf and other grass crops are susceptible to fungal infections if irrigated extensively during nighttime hours. The irrigation operations must be scheduled primarily during daytime or near daytime hours. Irrigation in the late evening followed by long periods of dark is not a recommended reuse practice.

7.2.3 Forage Grass Harvesting

The forage system (all species) should produce a yield of 3 to 8 tons/ac/yr, provided nutrient loadings, fertilization, and irrigation is provided. The grass should be mowed on a regular basis and left in place to provide organic matter and nutrients for the regenerating crop. As mentioned before, clippings left on the receiver sites provide important carbon and nutrient sources for continued vegetation growth and soil quality improvement. Mowing on the fields should be done with low ground pressure equipment when the soil is dry or cannot be compacted.

Forage Grass Land Application System Establishment Summary

Following are recommendations for establishment of a forage grass receiver site system at the UNCBWWTF**:**

- Delineate access corridors for sprinkler system and anticipated maintenance areas.
- Lime and fertilize receiver site to improve early growth and survival of groundcover according to recommendations provided in Table 3 and Section 7.1 of this report.
- Rip planting areas and/or disk to improve infiltration and incorporate any surficial organic material, lime, and fertilizer.
- Seed the receiver site with a groundcover consisting of Bermuda grass, tall fescue, gamma grass, dallisgrass and/or annual ryegrass.
- Band-apply a preemergent herbicide to planting areas if necessary to control herbaceous weeds (i.e. 2% glyphosphate sln.).
- Plant forage species within proposed planting areas shortly after site preparation has been completed in early spring or fall. Seeding rates as recommended by Cooperative Extension for fescue are typically 20 to 40 pounds of seed/ac. Rates for Bermuda grass sprigs are typically 40 bushels/ac with incorporation and 60 bu/ac with broadcast distribution. Incorporation is recommended to support sprig survival.
- All planting areas should be irrigated <u>immediately</u> following planting and regularly throughout the first two growing seasons (i.e. March 1 through November 30) to ensure initial survival and growth.

Follow up inspection and replanting as necessary (within one year following planting).

8.0 Conclusions / Summary

Overall, the proposed land application receiver site system is a viable option for wastewater irrigation and remediation at the UNCBWWTF. These systems are also compatible with achieving water quality standards set forth by state agencies for nutrient sensitive regions. This system will result in the most effective wastewater treatment and assimilation system based on the existing site conditions, hydraulic loading rates, wastewater characteristics, and soil characteristics.

Utilizing a combination tree and forage system will require less maintenance than a forage system alone. The long term presence of forest cover and reduced vehicle traffic with forest systems will greatly improve infiltration and other soil characteristics important for renovation of wastewater and recharge of groundwater. When implemented and managed properly, the forested land application system will utilize hardwood tree species capable of producing large amounts of biomass, while providing favorable soil conditions to enhance adsorption and denitrification of phosphorous and nitrogen respectively.

The overall success of the tree system depends on the routine operation, maintenance, and optimal performance of the irrigation system. Tree establishment, management, and harvesting should be accomplished by qualified professionals. Routine maintenance should be performed by the certified system operator.

With proper site management, hydraulic and nutrient loading management, the site will perform as a means to treat wastewater and protect surface waters entering nearby river basins. Site, soil, vegetation, and water quality all combine to support the existing wastewater land application system. Continuous monitoring of the quality of the irrigation water applied to the receiver site as well as annual soil testing must be accomplished as an ongoing part of this project. The results of the water quality monitoring must be communicated to all personnel involved with this land application system, **including landscape managers**, as well as regulatory agency personnel responsible for assuring compliance with environmental mandates.

9.0 Environmental Effects

If managed properly there should be no adverse environmental effects from the establishment and management of a wastewater land application system at the proposed receiver site. Site, soil, vegetation, and water quality all combine to support the existing system. Continuous monitoring of the quality of the wastewater applied as well as annual soil testing combined with adherence to the recommendations in this report will ensure the system is successful.

The irrigation of this wastewater will increase soil fertility and productivity at the UNCBWWTF receiver site. The existing system will enhance adjacent wetlands and low lying areas with increased base flow. If managed properly, there will be no adverse impacts to groundwater supplies or surface water supplies. The addition of water and nutrients to the site may benefit wildlife through increased biological activity in adjacent wetlands and low lying areas.

10.0 References

Baker, J.B. 1977. Tolerance of Planted Hardwoods to Spring Flooding. S. J. App. For. 1(3):23-25.

Baker, J.B. and W.M. Broadfoot. 1979. Site Evaluation for Commercially Important Southern Hardwoods. U.S.D.A. Forest Service, Southern Forest Experiment Station, General Technical Report SO-26, New Orleans, LA.

Broadfoot, W.M. 1976. Hardwood Suitability for and Properties of Important Midsouth Soils. U.S.D.A. Forest Service, Southern Forest Experiment Station, Research Paper SO-127, New Orleans, LA.

Burns, R.M. and B.H. Honkala. 1990. Silvics of North America. U.S.D.A. Forest Service, Agricultural Handbook 654, Washington, DC.

Carlile, B.L. and J.A. Phillips. 1976. Evaluation of Soil Systems for Land Disposal of Industrial and Municipal Effluents. Water Resources Research Institute, Raleigh, NC. 63 pp.

Crites, R. S. Read, and R. Bastian. 2000. Land Treatment of Municipal and Industrial Wastes. McGraw Hill.

Edwin Andrews & Associates. 2011. Water Balance Report. UNCBWWTF Land Application System. Orange County, NC.

Envirochem, 2010. Environmental Chemists, Inc. Analytical & Consulting Chemists. (Analytical Water Quality Testing).

Evans, R.O. 2001. North Carolina State University – Biological and Agricultural Engineering Associate Professor and Department Extension Leader, Water Table Management and Water Quality, Raleigh, NC (conversation)

Frederick, D.J., M. Young, and R. Lea. 1994. Nutrient Partitioning and Growth Following Different Harvesting Regimes in Sycamore Biomass/Energy Plantations Grown Under Wastewater Irrigation. Final Report, Contract No. 82700V. North Carolina Department of Commerce, Energy Division, Raleigh, NC.

Gardiner, E.S., J.D. Hodges, A.L. Friend, and J.N. Dewit. 1993. Response of Bottomland Oak Species to Rhizosphere Hypoxia. Pages 399-405 in Proceedings of the Seventh Biennial Southern Silvicultural Research Conference, U.S.D.A. Forest Service, Southern Forest Experiment Station, General Technical Report SO-93, New Orleans, LA.

Gill, C.J. 1970. The Flooding Tolerance of Woody Species – A Review. Forestry Abstracts 31(4):671-688.

Harrington, C.A. 1991. PTSITE – A New Method of Site Evaluation for Loblolly Pine: Model Development and User's Guide. U.S.D.A. Forest Service, Southern Forest Experiment Station, General Technical Report SO-81, New Orleans, LA.

Hook, D.D. 1984. Waterlogging Tolerance of Lowland Tree Species of the South. S. J. App. For. 8:136-149.

McKim & Creed, 2010-11. (Personal Communication).

NC Section AWWA/WEA. Development of Reclaimed Water Systems, North Carolina Guidance Manual. 1st Edition: January 1998.

Nutter, W.L.; R.C. Schultz, and G.H. Brister, "Land Treatment of Municipal Wastewater on Steep Forest Ecosystems in Humid Southeastern United States," *Proceedings of the International Symposium on Land Treatment of Wastewater*, vol. 1, Hanover, N.H., 1978, pp. 265-174.

Rubin, A.R., D.J. Frederick. 1994. Wastewater application to hardwood tree plantations – Case Studies. Proceedings: Annual Meeting, South Carolina Professional Engineers, Myrtle Beach, SC 8pp.

Rubin, A. R., 1994. Wastewater irrigation onto managed hardwood forests –design and operation. In: Proc. US Environmental Protection Agency, Region IV National Wastewater Treatment Technology Transfer Workshop. Kansas City, MO. Pp. 108-115. 1994.

Rubin, A.R. 2002. North Carolina State University – Biological and Agricultural Engineering Professor and Extension Specialist, Waste Management, Raleigh, NC. (conversation)

Rubin, A.R. 2003. North Carolina State University – Biological and Agricultural Engineering Professor and Extension Specialist, Waste Management, Raleigh, NC. (conversation)

Section .0500 – Waste Not Discharged to Surface Waters, 15A NCAC 02T .0504 (i) - Agronomic Management Plan. G.S. 143-215.1; 143-215.3(a)(1); Eff. September 1, 2006.

Soil, Water, and Environment Group, PLLC, 201\1. Soil Scientist Evaluation Report. UNCBWWTF Land Application System Receiver Site. Orange County, NC. May 2010.

United States Department of Agriculture, Soil Conservation Service. Soil Survey of Orange County, North Carolina. GIS Web Survey, 2010.

United States Environmental Protection Agency. 1981. Process Design Manual, Land Treatment of Municipal Wastewater. Published by USEPA Center for Environmental Research Information. Cincinnati, Ohio 45268.

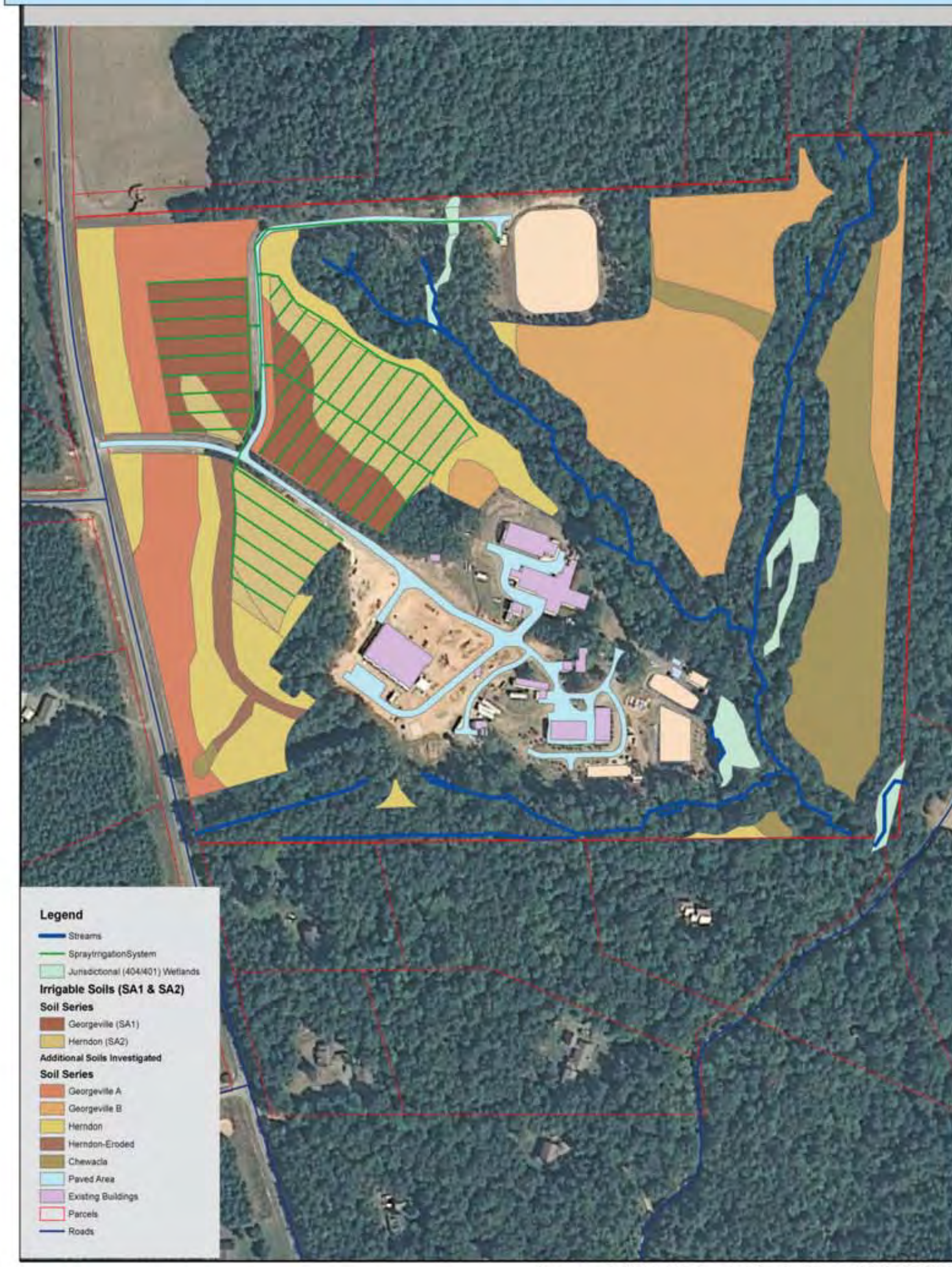
APPENDIX

APPENDIX A
Receiver Site Maps

FIGURE 2: UNC Bingham Facility Land Application System Vegetation Map

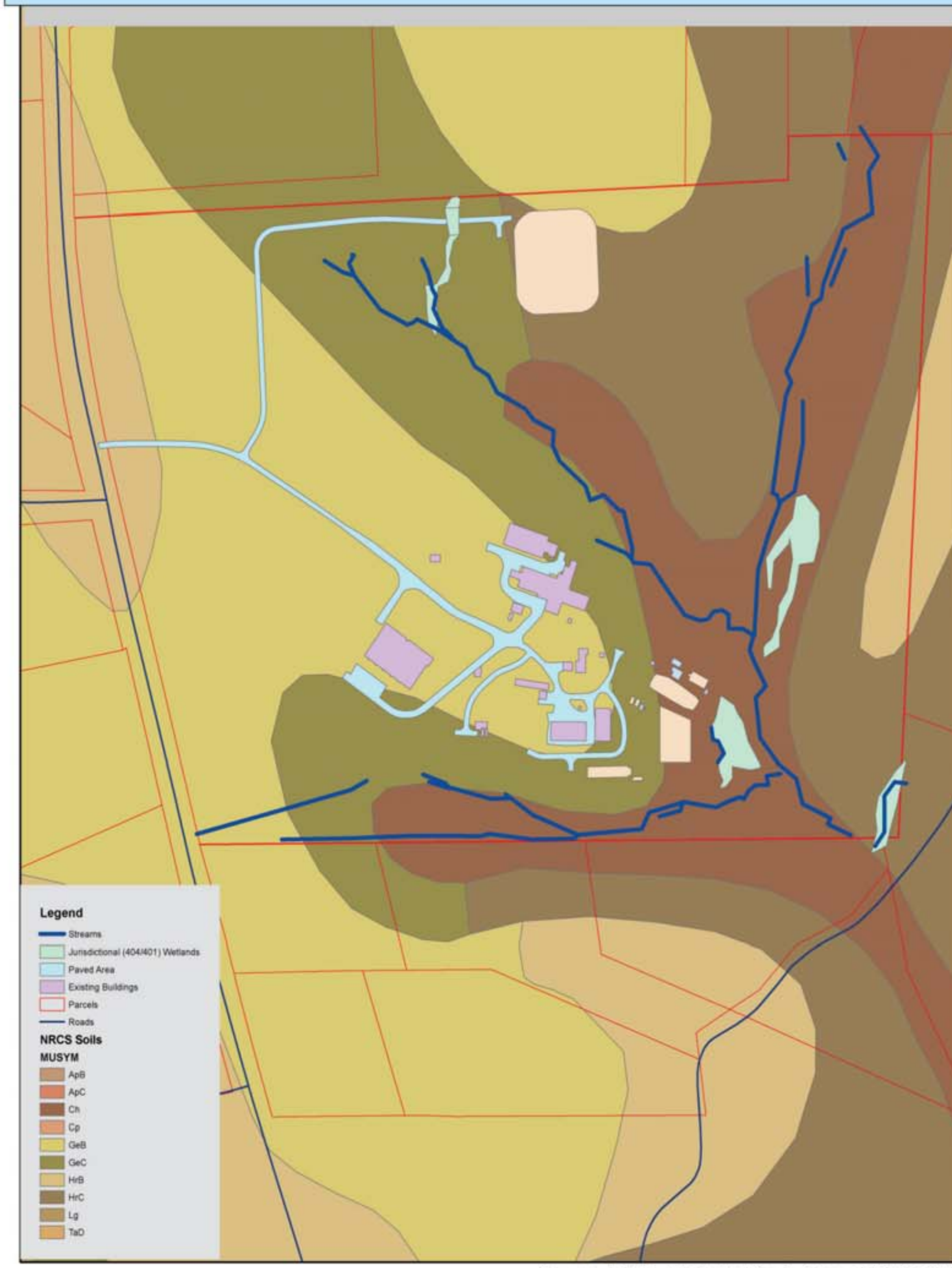
Source: SWE, UNC, McKim & Creed GIS (2011)

FIGURE 3: UNC Bingham Facility Land Application System Irrigable Soils Map

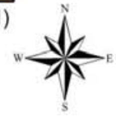


Source: SWE, UNC, McKim & Creed GIS (2011)

FIGURE 4: UNC Bingham Facility Land Application System NRCS (USDA) Soils Map



Source: SWE, UNC, McKim & Creed GIS (2011)



APPENDIX B

PAN, Nitrogen and Phosphorus Balance Calculations

(Page 18, Item 11. Cover crop information, NCDWQ Form: WWIS 12-06)

Reuse Water Characterization

The anticipated effluent will meet reuse water quality standards set forth by NCDWQ. Levels of BOD and total suspended solids (TSS) must be ≤ 10 mg/L and 5 mg/L respectively and meet the federal shellfish standard for coliform of < 14 counts/100mL. Total nitrogen concentrations and total phosphorus concentrations are anticipated to be approximately ~25.0 mg/L and ~10.0 mg/L respectively by means of the current treatment design.

Plant available nitrogen (PAN) can be calculated using the formula below. For purposes of this report, a mineralization rate (40%) and volatilization rate (50%) are utilized. This allows for carryover from previous years and provides a conservative estimate of nitrogen loadings to the forest and/or forage/ornamental vegetation system.

PAN
PAN= MR(TKN-NH3)+[(1-VR)*(NH3)]+(NO3+NO2)= 11.6 ppm
Where
PAN= Plant Available Nitrogen
MR= Mineralization Rate (40%)
VR= Volatilization Rate (50%)
TKN= Total Kjeldhal Nitrogen (~25.0ppm)
NH3= Ammonia Nitrogen (<1.0ppm)
NO3= Nitrate Nitrogen (~1.58ppm)
NO2= Nitrite Nitrogen (~.014pmm)
*Source: McKim & Creed (2011) - Proposed AdvanTex System

Table 4: Nutrient uptake and removal and yields for proposed cover crops at the UNCBWWTF receiver site.

Soil	Crop	RYE (tons) [1.]	Nitrogen Application Rate (lb/ac/yr) [1.]	Irrigation Area (ft^2)	Phosphorus Removal (lb/ac/yr) [1.]	Irrigation Area (ft^2)
SA1	Fescue	3.2	136	53,186	51	56,732
Georgeville	Coastal Bermuda	3.8	159	45,492	46	62,898
	Forest	-	150 +	48,222	40 +	72,333
SA2	Fescue	3.9	174	22,291	63	36,410
Herndon	Coastal Bermuda	4.8	213	20,512	58	30,132
	Forest	-	150 +	29,128	40 +	43,692

1.] Based off management recommendations from NCSU et al. (http://nutrients.soil.ncsu.edu/yields/)

EXAMPLE CALCULATIONS:

Nitrogen Balance to Determine Irrigation Acres if N is Limiting

Soil Area 1
Fescue
TN (.157 in/wk liquid loading: 25.0 mg TN/L annual avg.)
25.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 136 lbs TN/ac/yr = 1.2 ac

Coastal Bermuda grass
TN (.157 in/wk liquid loading: 25.0 mg TN/L annual avg.)

25.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 159 lbs TN/ac/yr = 1.04 ac

Forest

TN (.157 in/wk liquid loading: 25.0 mg TN/L annual avg.)
25.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 150 lbs TN/ac/yr = 1.1 ac

<u>Soil Area 2</u>

Fescue

TN (.157 in/wk liquid loading: 25.0 mg TN/L annual avg.)
25.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 196 lbs TN/ac/yr = .51 ac

Coastal Bermuda grass

TN (.157 in/wk liquid loading: 25.0 mg TN/L annual avg.)
25.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 213 lbs TN/ac/yr = .47 ac

Forest

TN (.157 in/wk liquid loading: 25.0 mg TN/L annual avg.)
25.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 150 lbs TN/ac/yr = .66 ac

Phosphorus Balance to Determine Irrigation Acres if P is Limiting

<u>Soil Area 1</u>

Fescue

TP (.157 in/wk liquid loading: 10.0 mg TP/L annual avg.)
10.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 51 lbs TN/ac/yr = 1.3 ac

Coastal Bermuda grass

TP (.157 in/wk liquid loading: 10.0 mg TP/L annual avg.)
10.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 46 lbs TN/ac/yr = 1.4 ac

Forest

TP (.157 in/wk liquid loading: 10.0 mg TP/L annual avg.)
10.0 mg/L TN * (796,430 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 40 lbs TN/ac/yr = 1.6 ac

<u>Soil Area 2</u>

Fescue

TP (.157 in/wk liquid loading: 10.0 mg TP/L annual avg.)
10.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 48 lbs TN/ac/yr = .83 ac

Coastal Bermuda grass

TP (.157 in/wk liquid loading: 10.0 mg TP/L annual avg.)
10.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 58 lbs TN/ac/yr = .69 ac

Forest

TP (.157 in/wk liquid loading: 10.0 mg TP/L annual avg.)
10.0 mg/L TN * (481,070 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 40 lbs TN/ac/yr = 1.0 ac

Water Balance

Soils	Soil Area	Maximum Irrigation Rate (in/yr) [1.]	Irrigation Area (ft2)
Georgeville/Herndon	SA1/SA2	8.16	248,727

1.] Based on Water Balance (Edwin Andrews & Assoc., PA, 2011)
* Note: This site is hydraulically limited