Final Report

Large-Scale Composting System as a Means of Controlling Water Hyacinth, Eichhornia crassipes

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Contract # 582-8-77063

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Executive Summary

Project Title:	Large-scale Composting System as a Means of Controlling Water Hyacinth, *Eichhornia crassipes.*	
Project Start Date:	May 22, 2008	
Project Completion Date:	December 31, 2010	
Funding:	Total Budget	$442,432
	Total Federal Funds	$265,459
	Total Expenditures of Federal Funds	$229,027
	Total Match Accrued	$152,685
	Budget Revisions	<$36,432>
	Total Expenditures	$381,712

Summary of Accomplishments:

- A five acre compost facility, including a storm water collection pond, was constructed to state requirements to allow for composting vegetative materials, oils and grasses, meat, fish and dairy material.
- Determined that water hyacinth seeds and other propagules are destroyed when composted in piles maintaining temperatures of 135 degrees Fahrenheit and above.
- Determined that a compost feedstock blend of food waste from cafeterias (10%), poultry litter (15%), water hyacinth plants (25%) and wood chips (50%) reached the desired temperature of 135 degrees Fahrenheit, and created a mature compost that met or exceeded given industry quality standard.
- Developed a set of best management practices to create mature, quality compost from water hyacinth.
- Determined that composting appears to be an effective way to manage the invasive aquatic species, water hyacinth.

List of Acronyms

AASL	Agricultural Analytical Services Laboratory at Penn State University
AC/FT	Acre-Feet
BMP	Best Management Practices
CM	Centimeter
KG	Kilogram
KG N/ha	Kilograms of Nitrogen per hectare
KG P/ha	Kilograms of Phosphorus per hectare
MG	Milligrams
MG/KG	Milligrams per Kilogram
MG/L	Milligrams per Liter
MM	Millimeter
MMHOS	Millimhos
MMHOS/CM	Millimhos per Centimeter
N/A	Not Applicable
QAPP	Quality Assurance Project Plan
TCEQ	Texas Commission of Environmental Quality
STA	U.S. Compost Council's Seal of Testing Approval
TMECC	Test Methods for Examination of Composting and Compost
TTC	Triphenyl Tetrazolium Chloride

Introduction

The water hyacinth, Eichhornia crassipes, is a native of the Amazon River, but has become a significant aquatic weed problem in the United States. It is found in all major river systems in the U.S. The problems caused by water hyacinth include obstructing waterways, impeding drainage, destroying wildlife resources, and lowering the dissolved oxygen in waterways resulting in reduced oxygen available to animals and plants.

Although herbicides have been used to kill water hyacinth, harvesting either mechanically or by hand is preferred for environmentally sensitive areas. A major problem with harvesting as a method to remove the plant from waterways is to then dispose of the plant such that seeds are rendered non-viable.

The intent of this study is to determine if large scale composting is an effective means of disposing of water hyacinth by rendering the seeds and other propagules non-viable while producing a quality compost product for the horticulture industry.

<u>Description</u>

The project involved the development of a large-scale demonstration compost operation that utilized invasive water hyacinth harvested from Spring Lake, at the origin of the San Marcos River. Poultry litter and other feedstocks were combined with water hyacinth to produce a mature compost that destroyed the water hyacinth seed. The results of the study were presented to interested parties and will serve as an example Best Management Practice (BMP) for other water bodies with water hyacinth problems.

<u>Composting Site</u>

The compost operation is located on the Muller Farm, which is owned by Texas State University and located outside of the Edwards Aquifer recharge zone. The farm is used primarily as an alternate pasture for cattle raised on the University's Freeman ranch. Approximately five acres are being used for the composting operation; the site provides open areas for the compost piles, a storm water collection pond, an improved all-weather road, electricity and supplemental water and fencing of the site.

<u>Compost Feedstocks</u>

Feedstocks chosen for this project included the following percentages: food waste from the cafeterias (10%), poultry litter (15%), water hyacinth plants (25%) and wood chips (50%). This feedstock blend was based on guidelines provided by the Texas Commission on Environmental Quality, use of materials available to the area and the ability to reach temperatures that destroyed the water hyacinth seed.

<u>Composting and Control of Hyacinth Seeds</u>

Because of the lack of information in research literature on the temperature at which water hyacinth seeds are destroyed, tests were conducted in University laboratories to determine the approximate temperature at which water hyacinth seeds die. Samples of compost containing scarified and unscarified water hyacinth seeds were monitored for three days in temperature chambers that were held at 120° degrees F, 135 degrees F and 150 degrees F. This study found that water hyacinth seeds were rendered non-viable at temperatures at or above 135 degrees Fahrenheit. This finding allows for water hyacinth to be safely utilized as a feedstock in the composting process even though it is an invasive species since temperatures above 135 degrees Fahrenheit kills seeds and these temperatures are relatively easy to maintain in a compost pile when appropriate proportions of carbon and nitrogen-containing feedstocks are used .

Rows of feedstock blends were laid out in separate areas and monitored for heat, moisture and maturity. Piles were built to be 5 to 6 feet tall and 10-12 feet wide. This height and width allowed the piles to be insulated and generate enough heat to kill pathogens (including the weed seeds of interest), but did not allow too much heat to be generated in the piles which can result in spontaneous combustion.

Eleven compost piles were created from 22,000 pounds of water hyacinth, 20,000 pounds of food waste, 25,000 pounds of poultry litter, and 38,000 pounds of wood chips. This study created an estimated 66 yards of compost valued at $1980 from materials that were otherwise considered problematic. In the past, water hyacinth in this area of Spring Lake was typically harvested and dried on the river bank where it was a wasted product and also had the potential to add to the seed bank around Spring Lake. Poultry litter is considered to be a groundwater contaminating agent and the expense to dispose of the litter costs a substantial amount of money. Food waste from the Texas State cafeterias was previously put in trash receptacles and cost the university in trash hauling fees. In a pilot study conducted by researchers at one dining hall on campus, waste audit results demonstrated the value of the composting operation to the university in terms of savings in waste hauling expenditures, as well as showed the percent contamination, and percent waste diverted to the university's recycling and composting program. There was a statistically significant difference between pre and posttest waste audits. The pilot site composting program resulted in a net loss of $3,741.35 to the university during the first year (because of initial set-up costs of containers for the diversion of the food waste), but was expected to produce a positive net return of $2,585.11 in subsequent years. Results also indicated opportunities for further diversion such as the incorporation of compostable cups and utensils, as well as through expanding the operation to include more collection locations. With more collection sites and, therefore, more efficiency, the expanded composting program has the potential to save the university $12,925.55 in trash removal and disposal fees if all dining halls are included in collections. The program has the potential to provide $24,000 worth of compost annually for use on campus (600 yards x $40 per yard).

One hundred 1 gallon samples were collected in this study and then screened to 2 millimeters (mm) to observe for seeds and other propagules. No seeds or propagules of water hyacinth were found.

Each of the 11 compost piles were sampled again after all piles had cured. Samples were sent to Pennsylvania State Agricultural Analytical Services Laboratory (University Park, Pennsylvania) for compost quality testing. The quality tests conducted in this study employed the U.S. Compost Council Seal of Testing Approval (STA) program which employs the standards to which producers involved with the Compost Council's STA program adhere.

Workshops/Demonstrations

A series of workshops and demonstrations were conducted for interested parties (see appendix IV.1 for complete listings). These workshops included water hyacinth harvesting, blending of feedstocks, building compost windrows, testing protocols, and BMPs.

A website (http://www.rivers.txstate.edu/research/rivers/san-marcos-river-projects/san-marcos-composting-system.html) was maintained and updated throughout the project that gave an overview of the project objectives and updates on research findings.

Project Tasks, Goals, and Accomplishments

TASK 1: PROJECT ADMINISTRATION

Goal: To effectively coordinate and monitor all technical and financial activities performed under this grant, preparing regular progress reports and maintaining project files and data.

- Appropriate structure and management oversight has been established between the principle investigators, Texas State University, the TCEQ project manager and TCEQ support staff.
- Nine quarterly reports and nine quarterly reimbursement requests have been completed and submitted to TCEQ.
- Two satisfactory annual TCEQ contractor evaluations have been received for this project.
- A fact sheet for this project has been completed and revised.(See Appendix I.1)
- A website (http://www.rivers.txstate.edu/research/rivers/san-marcos-river-projects/san-marcos-composting-system.html) on the project has been created

TASK 2: DEVELOPMENT OF COMPOSTING PROGRAM

Goal: Develop and operate a composting facility at Texas State University that utilizes agricultural and other waste to produce compost that is beneficial for the environment. Finished compost will be utilized on University property after tests confirm that water hyacinth seeds have been destroyed and the compost is safe for use.

- A composting site has been constructed at the University's Muller Farm. The five acre site provides open areas for the compost piles, a storm water collection pond, an improved all-weather road, electricity and supplemental water, and is completely fenced. (See attached photos in Appendix II.1)The site has been certified to comply with Texas General Permit requirements. (See Appendix II.2).
- Authorization has been received from TCEQ to operate a compost facility. (See Appendix II.3)
- Sources from which to obtain the needed feedstocks have been identified and agreements reached regarding provision of feedstocks.
- Compost blend ratios of 25% water hyacinth, 15% poultry litter, 10% food waste and 50% wood chips have been determined to provide required temperatures for effective decomposition.
- Students assisting in the composting operation have been trained regarding safe and effective operation of equipment, as well as proper procedures for composting materials.
- Compost facility has been operated and maintained according to procedures described in Quality Assurance Project Plan (QAPP), assuring for health and safety of staff,

prevention of on-site pests, and safe land application of finished products. (See Appendix II.4)
- Developed and implemented a land application plan for mature compost generated (See appendix II.5)
- Recommendation made to the administration of Texas State University-San Marcos to maintain continued operation of composting facility (See Appendix II. 6).
- Determined the impact on water quality through the removal of water hyacinth (See Appendix II.7).

TASK 3: COMPOST MONITORING, DATA COLLECTION

Goal: To monitor compost quality from various feedstocks; to conduct tests to determine proper temperatures for destruction of water hyacinth seeds; to determine composting feedstock blends best suited for destruction of water hyacinth seeds at proper temperature; and to test the quality of compost and confirm the destruction of water hyacinth seeds from composting process.

- A Quality Assurance Project Plan (QAPP) was submitted and approved. One year revisions to the plan were made and approved.
- The following feedstocks were collected from noted sources in compliance with QAPP:
    - Water hyacinth – Spring Lake/ San Marcos River
    - Poultry litter – Tyson Foods, Sequin Texas
    - Food waste – Texas State University Cafeterias
    - Woodchips – Bartlett Tree Services, San Marcos
- Several attempts were made to identify an effective medium in which to germinate water hyacinth seeds. A procedure used by the Lady Bird Johnson Wildflower Center was found to be highly effective and consistently yielded positive results in germinating water hyacinth seeds (See Appendix III.1).
- Nine temperatures chambers were purchased and initial tests run to determine temperatures at which water hyacinth seeds were destroyed. Tests indicated that temperatures at 135 degrees F and above destroy water hyacinth seeds. (See Appendix III.2)
- Based on industry standards set by the U.S. Compost Council Seal of Testing Approval program, the study found that the quality of compost created from water hyacinth was in the acceptable to ideal ranges, and no viable water hyacinth seeds existed in the resulting compost. (See Appendix III.3)
- Field tests of the mature compost were conducted and indicated that a potting mixture using compost generated in this study was a suitable alternative to peat. (See Appendix III.4).

TASK 4: HYANCINTH COMPOSTING OUTREACH AND EDUCATION

Goal: To provide information to other interested parties on composting techniques for invasive weeds.

- Eighteen presentations and/or demonstrations were given to interested parties during the past 18 months. (See Appendix IV.1)
- Best Management Practices were developed for the proper handling and destruction of water hyacinth seeds using a composting system (See Appendix IV.2).

TASK 5: SUBMIT INTERIM AND FINAL REPORTS

<u>Goal:</u> To provide TCEQ and EPA with comprehensive reports on activities conducted during the course of this project.

- Nine quarterly reports describing progress occurring on this project were developed and submitted to TCEQ
- A Fact Sheet describing the project and its findings was developed and updated annually
- A website (http://www.rivers.txstate.edu/research/rivers/san-marcos-river-projects/san-marcos-composting-system.html) on this project was developed and maintained
- An interim report describing the first year's activities and findings was submitted to TCEQ on December 18, 2009 (See Appendix V.1)
- A final report on the activities and findings of this project was submitted to TCEQ on January 31, 2011.

Summary

Composting appears to be an effective way to manage the invasive species, water hyacinth, since seeds and other propagules were killed and the compost produced met industry quality standards. Though 22,000 pounds of water hyacinth were removed during the study period, this study did not indicate that the removal of water hyacinth impacted the water quality of the area either negatively or positively. Pre-test and post-test water quality samples were collected for electrical conductivity and dissolved oxygen content at the water hyacinth harvesting site for periods before and after removal of the invasive species. However, water quality sample data was collected by volunteers from the Texas Stream Team and limited; therefore, results may be distorted from a lack of data points.

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Appendices

Appendix I. 1 - Project Fact Sheet

Title:	Large Scale Composting System as a Means of Controlling Water Hyacinth, Eichhornia Crassipes
Water Body:	Upper San Marcos River (Segment 1814); Guadalupe River below San Marcos (Segment 1803)
Location:	Sink Creek in flow into Spring Lake to Lake Dam; Elm Creek (Segment 1803a) and Sandies Creek (Segments 1803c)
River Basin:	Guadalupe River (18)
Contractor:	Texas State University – San Marcos
Project Period:	May 22, 2008 to December 31, 2010

Project Summary

Water hyacinth is one of the most invasive aquatic species worldwide. Water hyacinth is an invasive aquatic plant that blocks waterways and lowers the dissolved oxygen resulting in reduced available oxygen for animals and other plants**.** Spring Lake contains water hyacinth, which if not managed, may pose a threat to the unique ecosystem in the lake. It has been successfully composted in the past, but a large scale system had not been investigated to determine if all plant propagules were destroyed in the process. The intent of this study was to determine if composting is an effective means of managing water hyacinth while producing a quality compost product for the horticultural industry. The first **(1)** objective of this study was to germinate seeds of water hyacinth by implementing germination tests that have shown success in related studies. It was found in this study that 62% (62/100) of water hyacinth seeds successfully germinated on filter paper media soaked in distilled water and placed in petri dishes held at a constant temperature of 80 degrees Fahrenheit for 14 days. The second **(2)** objective of this study was to determine the temperatures at which water hyacinth seeds were rendered non-viable. This study found that water hyacinth seeds were rendered non-viable at temperatures at or above 135 degrees Fahrenheit. The third **(3)** objective of this study was to conduct a compost demonstration project which included harvesting water hyacinth from Spring Lake, located in the Upper San Marcos River, and create a compost blend with poultry litter from the Elm Creek and

Sandies Creek Watersheds, along with other feedstocks. This study created 11 compost piles derived from 22,000 pounds of water hyacinth, 20,000 pounds of food waste, 25,000 pounds of poultry litter, and 38,000 pounds of wood chips. The sources of the chicken litter, Elm Creek (Segment 1803A) and Sandies Creek (Segment 1803C), are listed on the 2006 303(d) List of impaired water bodies for depressed dissolved oxygen and elevated levels of bacteria. The fourth **(4)** objective of this study was to determine if the composting process rendered water hyacinth seeds and propagules non-viable. Results of this study indicated that the composting process reached and sustained high enough temperatures to kill and fully decompose seeds and other propagules of water hyacinth. Therefore, water hyacinth can be composted without the potential danger of it spreading. The fifth **(5)** objective of this study was to determine the quality of the compost produced. This study found that the quality of compost created from water hyacinth was in the acceptable to ideal ranges of given industry quality standards, though there was a learning curve by the student workers in the preparation of the piles using the large equipment. The sixth **(6)** objective of this study was to improve water quality by removing poultry litter from bacteria-impaired watersheds and determine how and if the removal of water hyacinth impacts water quality. This study did not indicate that the removal of water hyacinth impacted the water quality of the area either negatively or positively. The project also included utilizing different feed stocks and developing a composting program in an approved area; securing necessary permits, registrations and notifications; developing a QAPP; conducting laboratory work to determine the best mixture of feed stocks to destroy the hyacinth seeds; and providing information through workshops, lectures and on-site demonstrations of hyacinth removal and composting practices. Given that the effectiveness of the compost process in destroying water hyacinth seeds has been demonstrated, the same method may be used to control water hyacinth in other water bodies.

Water hyacinth continues to invade the Sink Creek inflow/slough of Spring Lake on the upper San Marcos River, affecting water quality in that water body.

Project Description

This project tested whether a large scale demonstration compost operation could be used to destroy an invasive aquatic plant, water hyacinth, and its seeds, and produce a mature compost. Water hyacinth, harvested from Spring Lake in San Marcos, was combined with other feed stocks (poultry litter, wood chips, and food waste) to produce a mature compost that destroyed the water hyacinth and its seeds. The results of the project were presented to interested parties and can serve as an example of best management practices for other water bodies with water hyacinth problems. The project was supported through a research grant from the Texas Commission on Environmental Quality.

Water hyacinth is a native of the Amazon River and became an aquatic weed problem in the United States during the last century. Water hyacinth has caused blocked waterways and lowered dissolved oxygen levels, resulting in reduced available oxygen for aquatic animals and plants. Herbicides have been used to control water hyacinth, but this is not a preferred approach for environmentally sensitive habitats. Harvesting the water hyacinth and then using a composting process to destroy the plant and its seed is an environmentally safe approach. Composting is known to kill weed seeds if temperatures are high enough and maintained for long periods of time. This project tested and documented the effectiveness of composting in destroying water hyacinth and its seeds.

Project Highlights:

Five acres at the Muller Farm property owned by Texas State University was developed for the composting operation. The site complies with WQG 200000 Texas General Permit requirements.

A permit to transport an exotic species (water hyacinth) was obtained from Texas Parks and Wildlife Department; a notice of intent to operate a compost facility was issued by the Texas Commission on Environmental Quality.

Agreement was reached with a number of partners to provide feedstocks for the composting operation. Aquarena Center at Texas State University provided the water hyacinth. Tyson’s Foods Seguin provided the chicken litter. Chartwells, the food contractor for Texas State University, provided food waste from university cafeterias. Bartlett Tree Service provided wood chips.

Lab tests were designed and equipment purchased to determine the ideal conditions for germinating the seeds of water hyacinth. Conditions identified from this experiment were used to determine the viability of seeds exposed to the composting process.

Lab tests were also designed and equipment purchased to determine the temperatures required to destroy the seeds of water hyacinth. The resulting temperatures were maintained in the composting piles.

The composting operation focused on determining the optimal mixture of feedstock to maintain temperatures required to destroy the water hyacinth seed and produce a mature compost. Compost produced by this process were sampled and tested using quality testing standards for compost at the Pennsylvania State University Agricultural Analytical Services Laboratory.

A series of workshops and demonstrations were presented to interested parties regarding this project. These workshops covered water hyacinth harvesting, blending of feedstocks, building and maintaining compost windrows, testing protocols, and best management practices.

Results:

Lab tests validated that germination of water hyacinth seeds were induced on filter paper in petri dishes in incubators maintained at 80 degrees F; 62% of all seeds tested under these conditions germinated within 14 days.

Lab tests validated that constant temperatures of 135 degrees F and above killed all water hyacinth seeds within 3 days.

A large-scale composting system was developed at the Texas State Muller Farm that used water hyacinth harvested from Spring Lake and nearby areas of the San Marcos River as a feedstock. Eleven compost piles were created from 22,000 pounds of water hyacinth, 20,000 pounds of food waste, 25,000 pounds of poultry litter, and 38,000 pounds of wood chips. In the past, water hyacinth in this area of Spring Lake was typically harvested and dried on the river bank where it was a wasted product and also had the potential to add to the seed bank around Spring Lake. Poultry litter is considered to be a groundwater contaminating agent and the expense to dispose of the litter costs a substantial amount of money. Food waste from the Texas State cafeterias was previously put in trash receptacles and cost the university in trash hauling fees. This study created an estimated 66 yards of compost valued at $1980 from materials that were otherwise considered problematic. Researchers conducted a pilot test at one cafeteria. Waste audit results from the pilot test demonstrated the value of the operation to the university in terms of savings in waste hauling expenditures, as well as showed the percent contamination, and percent waste diverted to the university's recycling and composting program. There was a statistically significant difference between pre and posttest waste audits. The pilot site composting program resulted in a net loss of $3,741.35 to the university during the first year (because of the initial costs related to set up of the containers for diversion of food waste), but was expected to produce a positive net return of $2,585.11 in subsequent years. Results also indicated opportunities for further diversion such as the incorporation of compostable cups and utensils, as well as through expanding the operation to include more collection locations. With more collection sites and, therefore, more efficiency, the expanded composting program has the potential to save the university $12,925.55 in trash removal and disposal fees if all dining halls are included in collections. The program has the potential to provide $24,000 worth of compost annually for use on campus (600 yards x $40 per yard).

This study found that the quality of compost created from water hyacinth was in the acceptable to ideal ranges of given industry quality standards. The piles that fell below the acceptable to ideal ranges were attributed to problems due to inexperienced equipment operators at the beginning of the study and were corrected in newer piles. Therefore, with experienced operators and improvements to the compost pad surface, compost of a more consistent and higher quality can be produced by those replicating the study.

The final objective of this study was to determine how and if the removal of water hyacinth impacts water quality. Pre-test and post-test water quality samples were collected for electrical conductivity and dissolved oxygen content at the water hyacinth harvesting site. This study did not indicate that the removal of water hyacinth impacted the water quality of the area either negatively or positively. Water quality sample data was collected by volunteers from the Texas Stream Team and limited; therefore, results may be distorted from a lack of data points. Additionally, the area where water hyacinth was collected was routinely harvested by volunteers before the study had occurred and therefore, no changes were observed.

Project Partners & Funding

The TCEQ and Texas State University – San Marcos are leading research efforts in this project. Other partners contributing to the project include:

San Marcos River Foundation – water hyacinth collection
Tyson's Foods – Seguin – provision of feedstock
Chartwells, Inc. – provision of feedstock
Bartlett Tree Service – provision of feedstock
Texas Disposal System – advice and training assistance

The project has been funded with $442,432 in EPA section 319 and nonfederal matching funds.

Last Updated: November 24, 2010

- Related website(s): http://www.rivers.txstate.edu/research/rivers/san-marcos-river-projects/san-marcos-composting-system.html

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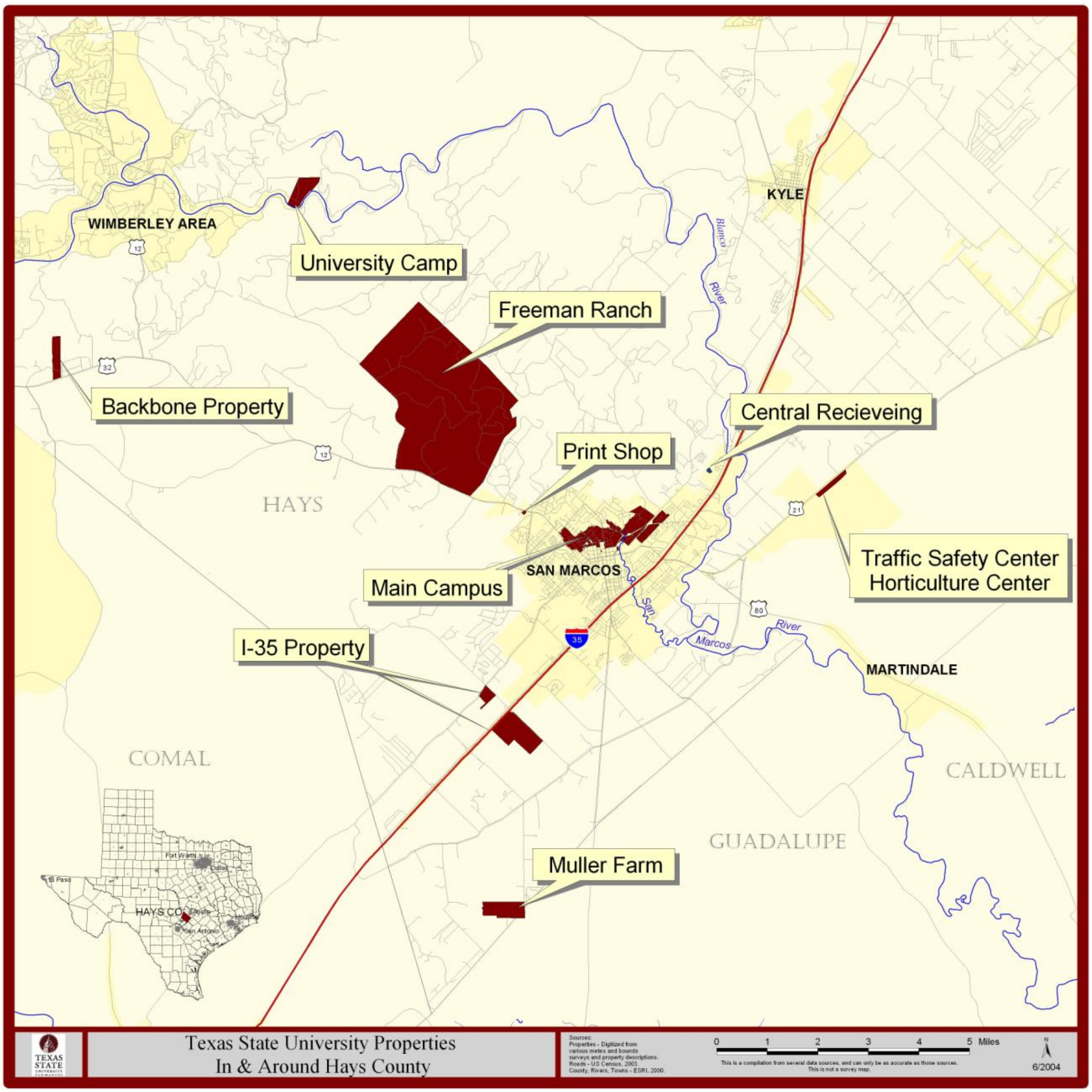
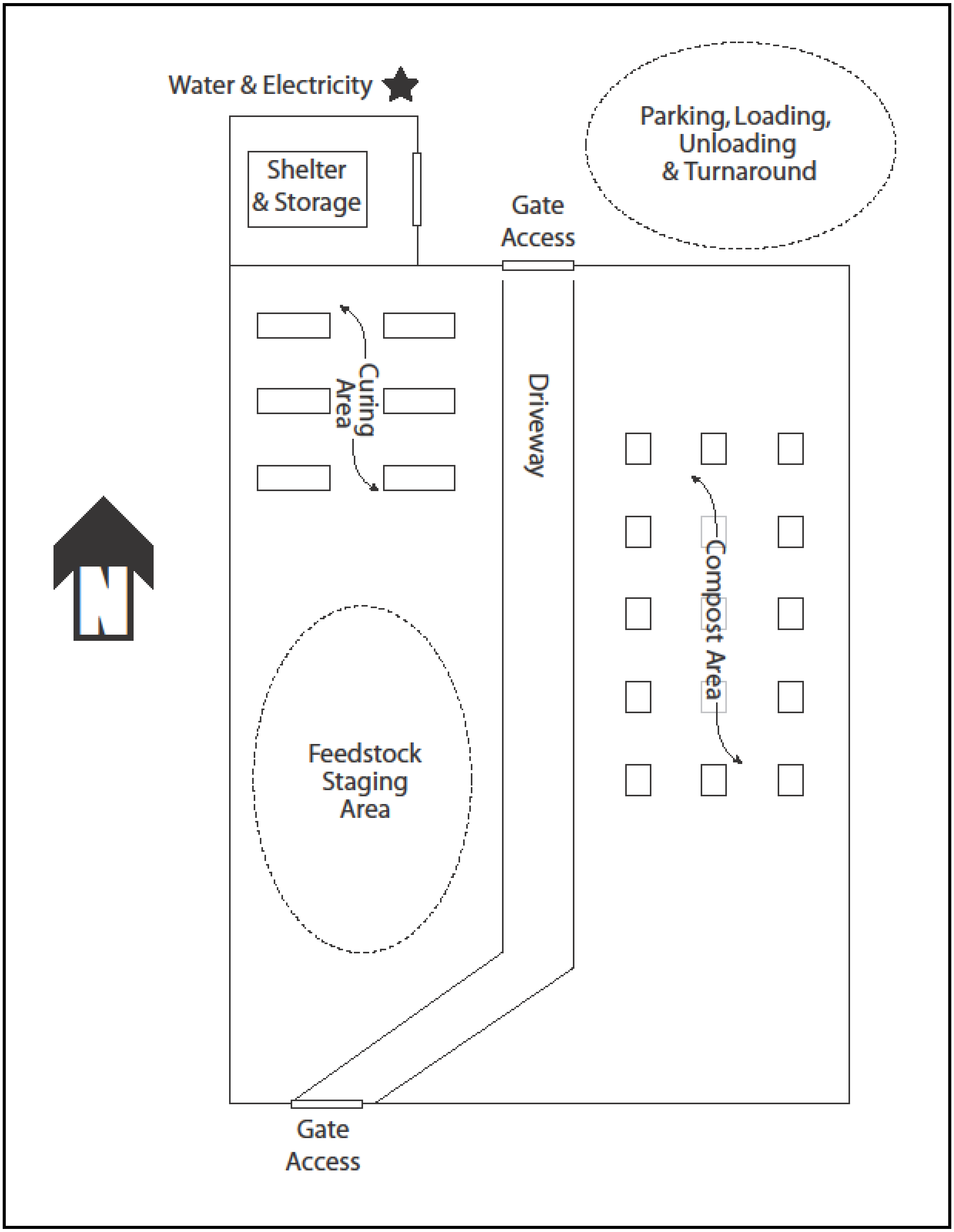
TC10@txstate.edu

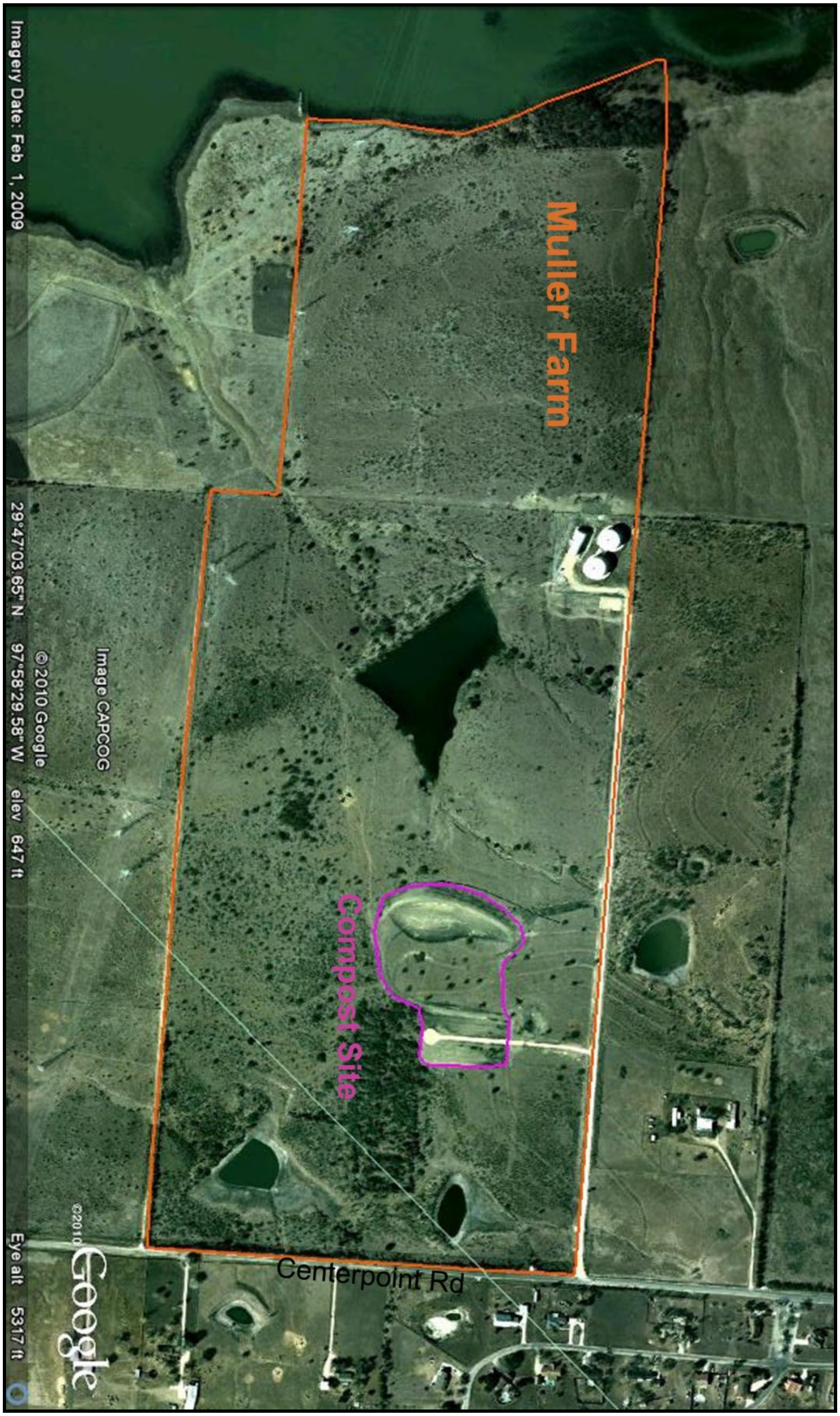
Jack Higginbotham
Project Manager
Nonpoint Source Program
Texas Commission on Environmental Quality
512-239-1000
JHigginb@tceq.state.tx.us

Appendix II. 1 – Composting Site at Muller Farm





Water & Electricity
Shelter
& Storage
Parking, Loading,
Unloading
& Turnaround
Gate
Access
Curing
Area
Driveway
Compost Area
Feedstock
Staging
Area
Gate
Access
N


Muller Farm
Compost Site
Centerpoint Rd
Imagery Date: Feb 1, 2009
29°47'03.65" N 97°58'29.58" W elev 647 ft
Eye alt 5317 ft
© 2010 Google
Image CAPCOG
Google

Appendix II.2 – Texas General Permit Requirements

JOHN D. MERCER & ASSOCIATES, INC.

John D. Mercer, P.E. President *Consulting Engineers*

October 30, 2008

Texas State University
Attn: C. J. Hall
Construction Contract Administrator
601 University Drive
San Marcos, Texas 78666

Dear Mr. Hall:

Attached is a "Water Balance" calculation for the Centerpoint Composting Facility on the Muller Farm. The calculation shows that the retention pond that has been constructed at the facility is sufficient to hold the storm water run-off from the composting area and all other contributing drainage areas without exceeding a fill level that would provide less than the two (2) foot freeboard required by the Texas Commission on Environmental Quality.

For an average precipitation and rainfall year, the water balance shows that there will be a net deficit of 0.919 acre feet as a loss to pond evaporation. The water balance calculation for maximum rainfall and minimum evaporation shows that there will be a net increase in pond storage of 2.691 acre feet. The approximate total storage volume of the pond is 6.1364 acre feet. The calculated run-off from a 25-year/24-hour storm of 7.75-inches is approximately 2.096 acre-feet of pond storage. The pond will have a two (2) foot freeboard at a maximum depth of 11 feet. To comply with the TCEQ regulation for maintaining a tow (2) foot freeboard, the ability to store 2.691 acre-feet must always be available in the pond. This can be provided if the pond level, under normal weather conditions, never exceeds a fill depth of 8.5 feet, or less than four and one half (4 1/2) feet of freeboard. A staff gauge must be install in the pond that will allow monitoring of the pond depth and amount of available freeboard.

A separate calculation of the water requirements for the composting operation indicates a need for approximately 1.47 acre-feet (480,000 gallons) of water per year. During periods of time when there is more than normal rainfall, there will be a net increase in water stored in the pond. During these periods, the stored water could be used in the composting operation in lieu of using and paying for potable water.

Sincerely,

JOHN D. MERCER & ASSOCIATES, INC.

STATE OF TEXAS
JOHN D. MERCER
40374
REGISTERED PROFESSIONAL ENGINEER

John D. Mercer, P.E., President

JDM
E1912/Corresp/water balance letter

Professional Engineers *Registered Professional Land Surveyors*
P O Box 930 *Galveston, Texas, 77553*
7002 Harborside Drive, Suite A *Galveston, Texas 77554* *Office: (409)741-8500 Fax: (409)741-8501*

TEXAS STATE UNIVERSITY
CENTERPOINT COMPOSTING FACILITY
WATER BALANCE
(MAX. RAINFALL - MIN. EVAPORATION)

MONTH	(A) MAX PRECIP. (inches)	(B) AVG RUN-OFF (inches)	(C) AVG INFILTRATED RAINFALL (inches)	(D) MIN EVAP. FROM POND SURFACE (inches)	(E) INCREASE IN STORAGE FROM RAIN ON POND 1.28 ACRES (acre-feet)	(F) EVAP LOSS FROM POND SURFACE AREA OF 1.28 ACRES (acre-feet)	(G) RUNOFF INTO POND FROM 2.60 ACRES AREA (acre-feet)	(H) NET INCREASE/ DECREASE IN POND STORAGE (acre-feet)
JAN	2.45	0.598	1.852	1.71	0.261	-0.182	0.130	0.208
FEB	3.19	0.778	2.412	1.95	0.340	-0.208	0.169	0.301
MAR	2.91	0.710	2.200	2.98	0.310	-0.318	0.154	0.146
APR	4.12	1.005	3.115	3.58	0.439	-0.382	0.218	0.275
MAY	5.79	1.413	4.377	3.84	0.618	-0.410	0.306	0.514
JUN	5.18	1.264	3.916	5.06	0.553	-0.540	0.274	0.287
JUL	2.79	0.681	2.109	6.09	0.298	-0.650	0.147	-0.205
AUG	3.26	0.795	2.465	5.72	0.348	-0.610	0.172	-0.090
SEP	4.87	1.188	3.682	4.31	0.519	-0.460	0.257	0.317
OCT	4.88	1.191	3.689	3.50	0.521	-0.373	0.258	0.405
NOV	3.40	0.830	2.570	2.50	0.363	-0.267	0.180	0.276
DEC	2.82	0.688	2.132	1.82	0.301	-0.194	0.149	0.256
TOTAL	45.66	11.14	34.52	43.06	4.870	-4.593	2.414	2.691

(A) Data from http://midgewater.twdb.state.tx.us/cgi-bin/Evaporation/parseevap.cgi?quad=709&options
(B) Runoff calculated to be 24.4% of Total Rainfall using NRCS EHF2 Program
(C) Calculated as 75.6% of Total Rainfall
(D) Data from http://midgewater.twdb.state.tx.us/cgi-bin/Evaporation/parseevap.cgi?quad=709&options
(E) = (A)/12 x 1.28 ac
(F) = (D)/12 x 1.28 ac
(G) = (B)/12 x 2.60 ac
(H) = (E) + (F) + (G)
(I) = (H)/1.28 ac

STORAGE REQUIRED FOR 25-YEAR/24-HOUR STORM OF 7.75-INCHES:

	(E)	(G)	(H)
Rainfall on pond surface of 1.28 acres	0.827		0.827
Runoff from 2.6 acre drainage area (5.86 inches)		1.270	1.270
POND STORAGE REQUIREMENT FOR 25-YEAR/24-HOUR STORM			2.096

TEXAS STATE UNIVERSITY
CENTERPOINT COMPOSTING FACILITY
WATER BALANCE
(AVERAGE YEAR)

MONTH	(A) AVG PRECIP. (inches)	(B) AVG RUN-OFF (inches)	(C) AVG INFILTRATED RAINFALL (inches)	(D) EVAP. FROM POND SURFACE (inches)	(E) INCREASE IN STORAGE FROM RAIN ON POND 1.28 ACRES (acre-feet)	(F) EVAP LOSS FROM POND SURFACE AREA OF 1.28 ACRES (acre-feet)	(G) RUNOFF INTO POND FROM 2.60 ACRES AREA (acre-feet)	(H) NET INCREASE/ DECREASE IN POND STORAGE (acre-feet)
JAN	1.65	0.403	1.247	2.17	0.176	-0.231	0.087	0.032
FEB	2.15	0.525	1.625	2.47	0.229	-0.263	0.114	0.080
MAR	1.96	0.478	1.482	3.78	0.209	-0.403	0.104	-0.091
APR	2.78	0.678	2.102	4.54	0.297	-0.484	0.147	-0.041
MAY	3.90	0.952	2.948	4.88	0.416	-0.521	0.206	0.102
JUN	3.49	0.852	2.638	6.42	0.372	-0.685	0.185	-0.128
JUL	1.88	0.459	1.421	7.73	0.201	-0.825	0.099	-0.525
AUG	2.20	0.537	1.663	7.26	0.235	-0.774	0.116	-0.423
SEP	3.28	0.800	2.480	5.47	0.350	-0.583	0.173	-0.060
OCT	3.29	0.803	2.487	4.44	0.351	-0.474	0.174	0.051
NOV	2.29	0.559	1.731	3.17	0.244	-0.338	0.121	0.027
DEC	1.90	0.464	1.436	2.31	0.203	-0.246	0.100	0.057
TOTAL	30.77	7.51	23.26	54.64	3.282	-5.828	1.627	-0.919

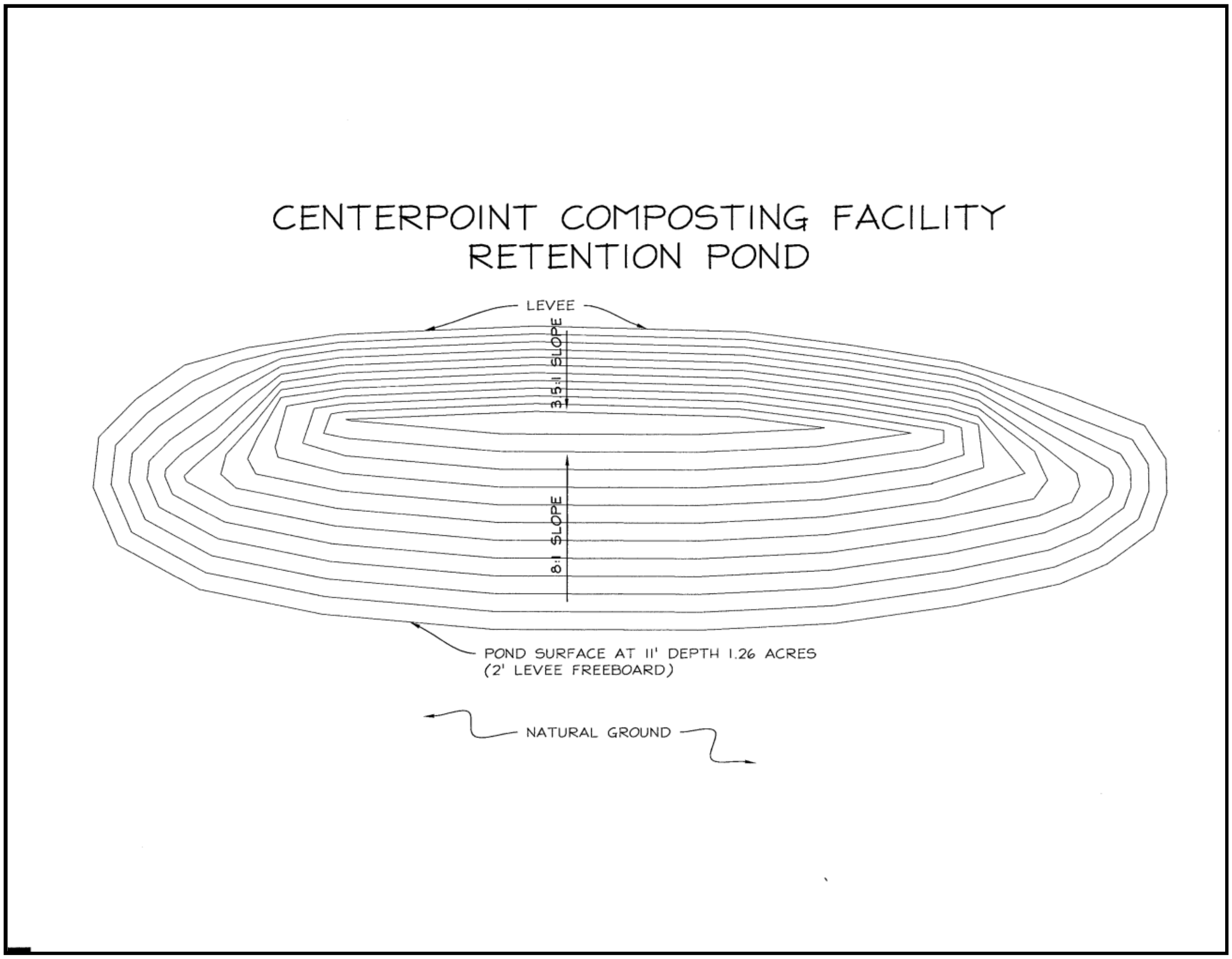
(A) Data from http://midgewater.twdb.state.tx.us/cgi-bin/Evaporation/parseevap.cgi?quad=709&options
(B) Runoff calculated to be 24.4% of Total Rainfallusing NRCS EHF2 Program
(C) Calculated as 75.6% of Total Rainfall
(D) Data from http://midgewater.twdb.state.tx.us/cgi-bin/Evaporation/parseevap.cgi?quad=709&options
(E) = (A)/12 x 1.28 ac
(F) = (D)/12 x 1.28 ac
(G) = (B)/12 x 2.60 ac
(H) = (E) + (F) + (G)
(I) = (H)/1.28 ac

STORAGE REQUIRED FOR 25-YEAR/24-HOUR STORM OF 7.75-INCHES:	(E)	(G)	(H)
Rainfall on pond surface of 1.28 acres	0.827		0.827
Runoff from 2.6 acre drainage area (5.86 inches)		1.270	1.270
POND STORAGE REQUIREMENT FOR 25-YEAR/24-HOUR STORM			2.096

APPROXIMATE POND VOLUME - CENTERPOINT COMPOSTING FACILITY

	Surface Area in Sq. Feet	Surface Area in Acre	Volume in Ac-Ft per Ft of Depth	Stored Volume in Acre-Feet
Bottom	1,476	0.0339		
			0.0662	
1 ft deep	4,293	0.0986		0.0662
			0.1368	
2 ft deep	7,628	0.1751		0.2031
			0.2186	
3 ft deep	11,415	0.2621		0.4216
			0.3091	
4 ft deep	15,517	0.3562		0.7308
			0.4071	
5 ft deep	19,946	0.4579		1.1378
			0.5139	
6 ft deep	24,824	0.5699		1.6517
			0.6295	
7 ft deep	30,022	0.6892		2.2813
			0.7546	
8 ft deep	35,720	0.8200		3.0359
			0.8886	
9 ft deep	41,696	0.9572		3.9245
			1.0303	
10 ft deep	48,067	1.1035		4.9548
			1.1815	
11 ft deep	54,867	1.2596		6.1364
	MAXIMUM STORED VOLUME IN AC-FT		**6.1364**	

NOTE: Pond surface area at 11' depth varies slightly from 1.28 acres used in Water balance spread sheet.


CENTERPOINT COMPOSTING FACILITY
RETENTION POND
LEVEE
3.5:1 SLOPE
8:1 SLOPE
POND SURFACE AT 11' DEPTH 1.26 ACRES
(2' LEVEE FREEBOARD)
NATURAL GROUND

Appendix II.3 – TCEQ Authorization to Operate Composting Facility

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

NOTICE OF INTENT TO OPERATE A COMPOST FACILITY

NOTIFICATION NO. MSW 47040

NOTIFICATION. Texas State University, 601 University Drive, San Marcos, Texas, 78666, has submitted a notification, Texas State University Mueller Farm Composting Project Notification No. MSW-47040, to the Texas Commission on Environmental Quality (TCEQ). The notification regards a municipal compost facility for composting vegetative material, oils and greases, meat, fish, dairy material, and vegetative material. The proposed compost facility will be using a static pile composting methods. The facility will be located 4250 Centerpoint Road, San Marcos, TX, 78666. The proposed site is located on a 161.18 acre tract and is estimated to receive approximately 120 pounds of feedstock per day.

The notification, submitted on March 18, 2008, and the revisions received on June 3, 2008, and August 28, 2008, has been determined to be in general compliance with the applicable provisions of Title 30 Texas Administrative Code (TAC) Chapter 332 Subchapter B - Operations Requiring a Notification, by the staff of the TCEQ.

INFORMATION. Individual members of the public who wish to inquire about the information contained in the notice, or to inquire about other agency permit applications or permitting processes, should call the TCEQ Office of Public Assistance, Toll Free, at 1-800-687-4040. General information regarding the TCEQ can be found on our web site at www.tceq.state.tx.us.

Issued: **OCT 08 2008**

LaDonna Castañuela, Chief Clerk
Texas Commission on Environmental Quality

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

January 27, 2009

Dr. Tina Marie Cade
Associate Professor of Horticulture
Texas State University
601 University Drive
San Marcos, TX 78666

Re: Texas State University Muller Farm Composting Project – Hays County
Municipal Solid Waste (MSW) – MSW No. 47040
Notice of Intent to Operate a Compost Facility
Tracking Nos. 11994193, 12305207, and 12431039; RN105482632 / CN600130934

Dear Dr. Cade:

In response to your Compost Notification, received March 18, 2008, and the revisions received on June 3, 2008, and August 28, 2008, submitted in accordance with Title 30 Texas Administrative Code (TAC), Section (§)332.22(a). We have reviewed the documentation required for the processing of this notification and find it acceptable. The Notice was mailed by the Office of the Chief Clerk and is effective as of October 8, 2008.

The facility shall be operated under 30 TAC, Chapter 332, Subchapter B, relating to Operations Requiring Notification and the information provided in the "Notice of Intent to Operate a Compost Facility," TCEQ Compost Form No. 1. Persons associated with a site must assure that composting operations are conducted in such a way to not cause the discharge of material into or adjacent to waters of the state, the creation or maintenance of a nuisance, or the endangerment of public health and welfare, as stated in 30 TAC §332.4.

If you have questions regarding this letter, please contact Mr. Mario A. Perez, Sr., at mail code (MC 124) of the letterhead address; telephone number (512) 239-6681.

Sincerely,

Richard C. Carmichael

Richard C. Carmichael, Ph.D., P.E.
Manager, Municipal Solid Waste Permits Section
Waste Permits Division

RCC/MAP/ff

P.O. Box 13087 • Austin, Texas 78711-3087 • 512-239-1000 • Internet address: www.tceq.state.tx.us

Appendix II.4 - Protocol for Composting Aquatic Invasive Species

Water hyacinth is one of the most invasive aquatic species worldwide. It has been successfully composted in the past, but a large scale system had not been investigated to determine if all plant propagules are destroyed in the process. The intent of this study was to determine if composting is an effective means of managing water hyacinth while producing a quality compost product for the horticultural industry. An objective of this study was to determine the temperatures at which water hyacinth seeds were rendered non-viable and to determine if these temperatures could be maintained in a composting system. As a waste-management system within agriculture, composting is known to kill weed seeds if temperatures are high enough and maintained for long enough periods of time (Rynk *et al.* 1992). For germination to be inhibited on weed seeds of bindweed (*Convolvulus arvensis*), pigweed (*Amaranthus* spp.), johnsongrass (*Sorghum halepense*) and kochia (*Kochia americana*), temperatures of 120 to 180 degrees Fahrenheit for three to seven days on average must be obtained (Rynk *et al.* 1992). However, in this study, the temperatures needed to kill seeds of water hyacinth were not yet known. Therefore, seed kill experiments were conducted using small ovens to hold compost and water hyacinth seed samples at varying temperatures to discern at what temperatures the embryos were killed. It was found that a temperature at or above 135 degrees Fahrenheit was required to render the water hyacinth seed non-viable. This temperature is easily obtained in a large-scale composting system with proper proportions of carbon and nitrogen. Therefore, researchers concluded that compost piles must be maintained at temperatures of at least 135 degrees Fahrenheit in order to ensure that water hyacinth seed will rendered non-viable.

Eleven compost piles were created with feedstocks at the following percentages: food waste from the university cafeterias (10%), poultry litter (15%), water hyacinth plants (25%) and wood chips (50%). A total of 22,000 pounds of water hyacinth were mixed with 20,000 pounds of food waste, 25,000 pounds of poultry litter and 38,000 pounds of wood chips throughout the study period. Rows of feedstock blends were laid out in separate areas and monitored for heat, moisture and maturity. Piles were built to be 5 to 6 feet tall and 10-12 feet wide. This height and width allowed the piles to be insulated and generate enough heat to kill pathogens (including the weed seeds of interest), but did not allow too much heat to be generated in the piles which can result in spontaneous combustion.

Moisture levels were measured with a 60” meter with a precision level of +/- 10 % (Compost Moisture Meter, Reotemp Instrument Corporation). A moisture level of 50-60% is ideal for compost production. Acidity and alkalinity (pH) was measured with a “Soil pH” sensor (Soil pH direct reading tester, Kelway) with a precision level of +/- 5 %. Acidity and alkalinity levels for compost can vary based on feedstocks. The ideal pH is between 6.8-7.3, but acceptable ranges include a pH from 5.0-8.5. Temperatures of the piles were monitored with a windrow thermometer at 6 randomly chosen areas with a precision level of +/- 1 % (Windrow Compost Thermometer, Reotemp Instrument Corporation). Temperatures above 130 degrees Fahrenheit were desired for weed seed kill. Oxygen levels of piles were controlled through scheduled turning of the piles and measured with a oxygen-temperature monitor (MF420-0-M, MF420-5T-100, J. Dittrich) regularly. The precision level of this instrument was +/- 2 %.

Piles were turned every 5 days (when environmental conditions allowed) to ensure that formerly outer exposed surfaces were buried within the pile each time the pile was turned (Rynk *et al.* 1992). Turning was done with a skid-loader (268B, CAT) by the researcher. Once feedstocks were decomposed, piles were moved to another designated area for curing to occur.

To determine if water hyacinth seeds and propagules were killed in the compost process, one hundred 1 gallon samples were collected and then screened to 2mm to observe for seeds and other propagules. No seeds or propagules of water hyacinth were found. This allows for the species to be composted without the potential danger of it spreading.

Additionally, each of the 11 compost piles was sampled and samples were sent to the Pennsylvania State Agricultural Analytical Services Laboratory (University Park, Pennsylvania) for testing. This study found that the quality of compost created from water hyacinth was in the acceptable to ideal ranges of given industry quality standards, though there was a learning curve by the student workers in the preparation of the piles using the large equipment. The method used in this study for determining the temperatures at which seeds and propagules of invasive species are rendered non-viable could be replicated with other invasive plant species to determine if they have the potential to be utilized as feedstocks in the composting process as well.

Appendix II.5 – Land Application Plan for Mature Compost

Two general plans were developed on how to distribute the compost generated through this project. The initial plan focused on the distribution of the compost generated during this project. It was anticipated that between 70-100 cubic yards of compost would be generated from this research project. While a small portion of the mature compost would be needed for other aspects of the research study, most of the compost generated would be available for use. The Department of Agriculture at Texas State University has a number of gardens and landscape features that require compost application at least twice a year. Any compost left over would be used for plant cultivation in the Department's green house.

A second distribution plan was also identified assuming the University would agree to take over the composting operation. Because of the University's ability to significantly increase the amount of feed stock available, it is assumed that the amount of compost generated at the Muller Farm site would increase to 525-600 cubic yards per year. This amount of mature compost would provide annual applications needed for athletic fields and the golf course maintained by the University.

During the course of this project, several organizations throughout the region inquired about availability of the mature compost. These included the City Parks and Recreation Department who were interested in compost for athletic fields and gardens at its Nature Center. Community garden groups inquired about availability of compost, as did the Hays County Consolidated Independent School District, which is in the process of developing school gardens at its elementary schools. It is felt that on-going operation of the composting facility would have a never ending demand for the compost generated.

Appendix II.6 - Recommendation to the Administration at Texas State University to Maintain and Operate the Composting Facility Created through the TCEQ Project.

From the inception of this project, the administration at Texas State University has been aware and supportive of achieving the projects objectives. The investigators worked closely with staff from the University's Division of Finance and Support Services to identify a site for the composting facility and to develop a very workable facility. Over $45,000 in University resources were provided to develop the composting facility at Muller Farm and to purchase major equipment needed for the project. Moreover, the administration encouraged and supported the projects outreach efforts, specifically through the inclusion of presentations and demonstrations about the project in the campus wide Common Experience on sustainability.

Several meetings were held during the summer of 2010 with the Associate Vice President for Finance and Support Services Planning to explore the possibility of the University maintaining and operating the composting facility developed through the TCEQ project. Although the University maintained a small-scale composting area through the Facilities Department, it was believed a large-scale composting site, as developed at Muller Farm, would provide greater benefits. Issues discussed during these meetings included required operating budgets, potential funding sources, shared space with future research efforts on composting, accessibility to site several miles from campus, and current and future uses of compost on campus. Discussions were also held with City of San Marcos staff to explore a potential partnership between the city and University to operate a large-scale composting facility.

The University administration, currently operating under a 7.5% cut in its FY2011 budget and facing as much as a 15%-20% budget cut during FY2012, decided not to undertake the additional cost of maintenance and operation of the Muller Farm composting facility at this time. Maintenance of the facility, as a research operation, will continue through FY2011, as part of a US Department of Agriculture research grant obtained by the River Systems Institute. Additional proposals are being written to conduct research at the composting facility. Conversations continue between the University and the city about pursuing grant funding to maintain a joint composting operation.

Discussion about the University assuming the on-going operation of the composting facility for future campus needs will again resume once the existing budget crisis has passed.

Attached is an e-mail from the Associate Vice President for Finance and Support Services Planning summarizing the discussion held over the summer regarding the composting facility.

From: Nusbaum, Nancy K
Sent: Monday, August 30, 2010 4:43 PM
To: Cade, Tina Marie; Abbott, Michael L; Guerra, Juan; Smith, Brad M M
Subject: Recap of Today's Meeting

I believe we all left in agreement today that:

1. Until funding becomes available (and especially when there are no budget cuts in place), we will continue to operate as is. No decision was made regarding collaboration with the City at this time.
2. Dr. Abbott and Dr. Cade will continue to solicit grant funding for the research projects at the Centerpoint composting location. That location will continue to be used for research but not for composting by Grounds. If grant funding is not available, the site will stand idle until funding does become available.
3. The compost from the Centerpoint site will be used for the Organic Gardens and elsewhere around Ag. We need to try to identify another way to use the compost once it starts stockpiling.
4. Grounds will continue to run their operation at the Recycling Center and at Aquarena until we can confirm that the location is no longer desirable. Grounds will continue to find ways to use their compost to keep it from stockpiling.
5. Dr. Cade will email us with her findings on becoming a Certified Composting Lab since we ran out of time to discuss it.
6. We all need to continue to look for opportunities for funding of the research composting program and for use of both sources of compost.

If anyone recalls a different outcome please let me know.

Nancy Nusbaum
Associate Vice President for Finance & Support Services Planning
Texas State University-San Marcos
San Marcos, TX 78666
512 245-2244 (voice)
512 245-2033 (fax)

Appendix II.7-Determine How and If the Removal of Water Hyacinth Impacts Water Quality.

Water hyacinth has been used in numerous studies to control water pollution. Researchers as far back as 1948 had proposed using water hyacinth for the removal of nutrients from wastewater effluents (Dymond 1948; Gopal 1987, pg. 279). They based their proposition on the fact that water hyacinth grown in wastewater had higher concentrations of nitrogen and phosphorus than water hyacinth grown under normal conditions (Dymond 1948). The removal of nitrogen and phosphorus was studied further in the 1970's and 1980's where it was found that water hyacinth removed 1980 kg N/ha and 322 kg P/ha annually (Boyd 1970). Boyd's (1970) research went on to find that the amount of nitrogen and phosphorus removed per hectare of water hyacinth was equivalent to the sewage created by 500 people.

Another primary reason for using water hyacinth to help manage water pollution is due to the fact that water hyacinth is a heavy metal (iron, manganese, zinc, aluminum, cadmium, lead, mercury, nickel, silver, cobalt, strontium, chromium and copper) accumulator (Gopal 1987). In a study examining the uptake of heavy metals by water hyacinth, it was found that in a pure metal solution containing 3 mg/l of a particular heavy metal, water hyacinth accumulated 1.35mg cadmium, 1.77 mg mercury, and 1.16 mg of nickel (Widyanto and Susilo 1978; Gopal 1987).

Although there are a number of studies that speak of the removal of pollutants from water by water hyacinth, research has also found that water hyacinth contribute to a decrease in water quality (Gopal 1987). Water hyacinth, *Eichornia crassipes,* is one of the most productive plants on earth and is considered the world's worst aquatic plant, in terms of invasiveness (Texas Parks and Wildlife Department, n.d.; Washington State Department of Ecology, n.d.). Water hyacinth forms dense mats that interfere with navigation, recreation, irrigation, and power-generated water resources (Aquatic Ecosystem Restoration Foundation, n.d.; Texas Parks and Wildlife Department, n.d.; Washington State Department of Ecology, n.d.). Water hyacinth blocks waterways used by boats; it impedes drainage canals for irrigation on farm lands, and destroys wildlife habitat by displacing native submerged and floating leaved aquatic plants (Aquatic Ecosystem Restoration Foundation, n.d.; Texas Parks and Wildlife Department, n.d.).

Water hyacinth, *Eichhornia crassipes,* has been found to multiply and spread, clogging hundreds of feet of open river, in just a matter of a few weeks (Allen, 2002). This is a problem caused by water hyacinth because it impedes water flow (Aquatic Ecosystem Restoration Foundation, n.d.). It has been known to inhibit water flow by 40 – 95% (Aquatic Ecosystem Restoration Foundation, n.d.; Gopal, 1987). It was also discovered that water hyacinth in the course of five years, could render a drainage canal 5 feet deep and 20 feet wide, to barely functional at all (Penfound and Earle, 1948). Just as the plant can clog up a waterway, it can also clog up water distribution pipelines and aqueducts (Allen, 2002).

Furthermore, water loss due to evaportranspiration is a problem caused by water hyacinth, *Eichhornia crassipes,* (Aquatic Ecosystem Restoration Foundation, n.d.). Water loss from evapotranspiration of water hyacinth in open conditions, increases three to six times the amount of water lost compared to the normal evaporation rate of water lost from rivers and reservoirs (Penfound and Earle, 1948; Masser, 2007). According to Research Entomologist for the United States Department of Agriculture – Agricultural Research Service [USDA-ARS], Dr. Moran, *Eichhornia crassipes,* "water hyacinth is the most troublesome aquatic weed in both the [Rio Grande Valley] RGV and Texas statewide, as it occupies about 30 major reservoirs plus all of the major rivers in eastern and southern Texas" (2009). In Texas, water loss from reservoirs and rivers is found to be 2.5 billion cubic meters annually, an estimated cost of $83 million dollars (Benton, James, and Rouse, 1978).

Additionally, one hectare of water hyacinth is estimated to have an oxygen depleting load equal to that of the sewage produced by 80 people (Raynes, 1964; Gopal, 1987). With this in mind, water hyacinth mats lower the pH and temperature of the water, altering the critical and stable habitats of native species (Reddy, Sutton, and Bowes, 1983). Also, low oxygen conditions develop beneath the dense water hyacinth mats, preventing all fish but top minnows from utilizing the habitat due to oxygen depletion (Washington State Department of Ecology, n.d.; Penfound and Earle, 1948). These dense mats of water hyacinth create excellent breeding grounds for mosquitoes; therefore, the mosquito populations increase in those areas, which lead to rise of disease spread in developing nations (Aquatic Ecosystem Restoration Foundation, n.d.; Washington State Department of Ecology, n.d.). Mosquitoes are insects that belong to the family *Culicidae,* develop entirely in aquatic environment associated with mats of water hyacinth, *Eichhornia crassipes,* and water lettuce, *Pistia stratiotes,* and many carry diseases and viruses that are not only harmful to plants but humans as well (Aquatic Ecosystem Restoration Foundation, n.d.). Mosquito bites transmit some of the most devastating diseases in the world, such as dengue "breakbone fever", heartworms, encephalitis (ie. West Nile virus), malaria, and yellow fever (Aquatic Ecosystem Restoration Foundation, n.d., p. 31-32). Therefore, public health is a concern in areas around large populations of water hyacinth, *Eichhornia crassipes,* and water lettuce, *Pistia stratiotes (*Aquatic Ecosystem Restoration Foundation, n.d.).

Furthermore, water hyacinth, *Eichhornia crassipes,* takes over areas of native submerged and riparian species, which are an essential part of daily nutrition of not only aquatic species but waterfowl as well (Aquatic Ecosystem Restoration Foundation, n.d.; Penfound and Earle, 1948). Aquatic native species are a critical part of the duct diet, and the displacement of these species by water hyacinth causes waterfowl to abandon the area (Aquatic Ecosystem Restoration Foundation, n.d.).

For this study, water quality data (electrical conductivity, dissolved oxygen) were obtained from the River Systems Institute's Stream Team for areas for months before (August 2008-December 2008) and for months after water hyacinth collection (February 2010-March 2010). The Texas Stream Team is a group of volunteers that are trained to gather information about the natural resources of Texas (RSI 2010). Data were limited to the Rivers Systems Institute's Texas Stream Team data collection points, which are generally taken each month. However, there were months during the study period dates of interest that no data were collected. Therefore, the dates of February 2010 – March 2010 were used due to the fact that data for the dates of interest immediately following water hyacinth collection were missing.

Frequencies and paired t-tests compared variables from water quality samples taken prior to water hyacinth collection versus those collected after water hyacinth collection dates. Data were then analyzed to determine the impact on water quality by water hyacinth.

Pre-test and post-test water quality samples were collected for electrical conductivity and dissolved oxygen content at the water hyacinth harvesting site. Though 22,000 pounds of water hyacinth were removed during the study period, this study did not indicate that the removal of water hyacinth impacted the water quality of the area negatively or positively in terms of dissolved oxygen and electrical conductivity. However, as shown from past research, removal of the plant from rivers has a positive impact on ecosystems that were not directly measured beyond the variable of dissolved oxygen because data was not available. Water quality sample data for electrical conductivity and dissolved oxygen was collected by volunteers from the Texas Stream and limited; therefore, results may be distorted from a lack of data points. It is recommended that further studies be conducted to further examine the quantities of water hyacinth recommended for harvest and the positive versus negative impacts on water quality and further variables that could be used to examine benefits and drawbacks of removal of water hyacinth.

Appendix III.1 - Germinating Seeds of Water Hyacinth

The first objective of this study was to germinate seeds of water hyacinth by implementing germination tests that have shown success in related studies (Gopal 1987). Research has been inconclusive on the optimal conditions for seed germination of water hyacinth (Gopal 1987). Germination testing was employed to determine suitable germination conditions for the seed.

Water hyacinth seed was collected from water hyacinth plants harvested from various areas of Spring Lake and nearby areas of the San Marcos River during the summer and fall season of 2008. Due to the difficulty of collecting a large amount of seeds in the field, flowering water hyacinth from various locations were collected and observed at the Agriculture Department's greenhouses at Texas State University. Seeds collected from these samples were stored in a refrigerator at the Aquarena Center laboratory until germination tests were able to be implemented.

One hundred water hyacinth seeds (two samples of 50) were placed on filter paper media soaked in distilled water in petri dishes and were observed for 14 days for the radical emergence. Research has indicated that water hyacinth seeds will germinate within 14 days (Gopal 1987). The seeds were held in a mini-incubator that was maintained at a constant temperature of 80 degrees Fahrenheit. Previous research has indicated that 80 degrees Fahrenheit is an optimal temperature for water hyacinth seed germination (Gopal 1987). Of the 100 seeds tested, 62 successfully germinated. The germination percentage achieved in the tests was consistent with other germination tests that proved successful (Gopal 1987).

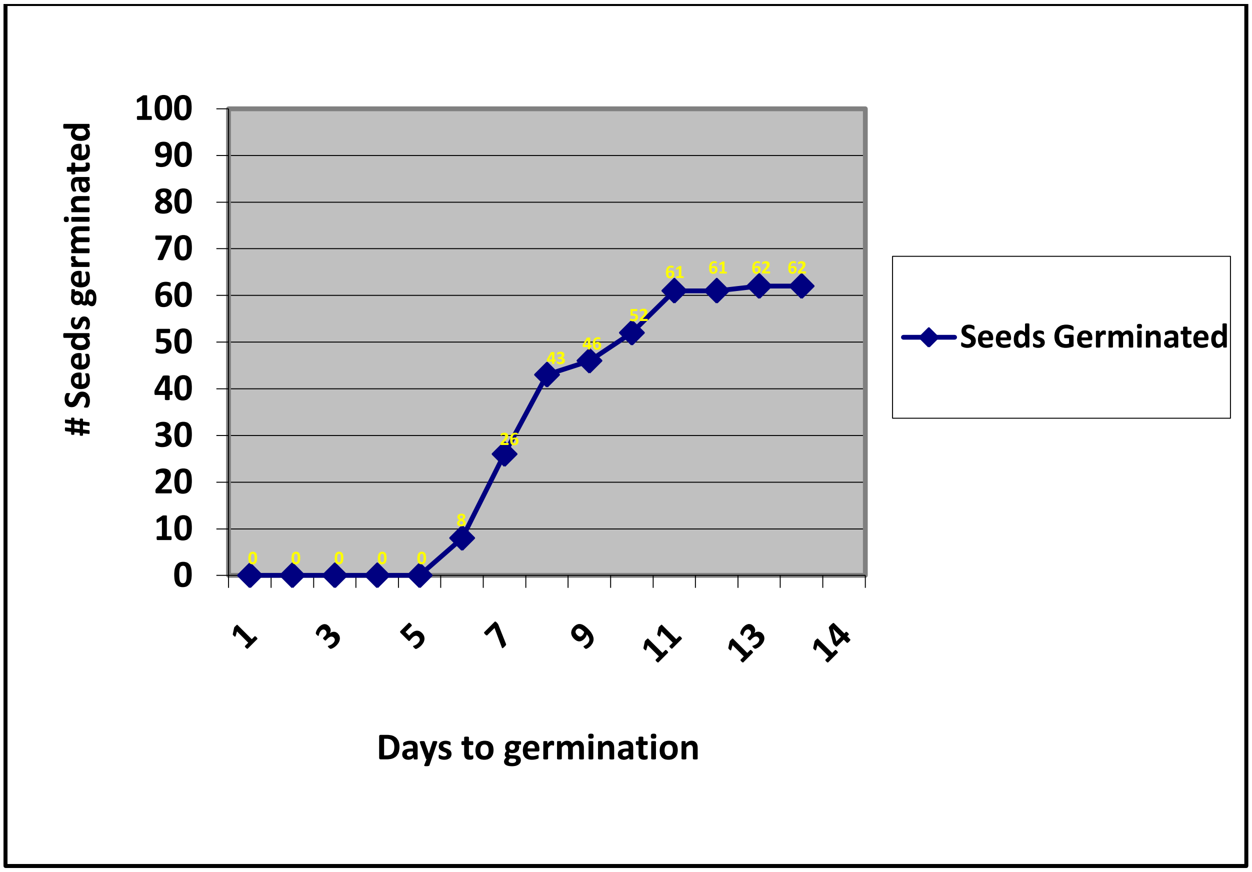


Figure 1: Germination test results illustrating the number of seeds of water hyacinth, *Eichhornia crassipes*, germinated after 14 days using a filter paper media and soaked in distilled water in petri dishes held in an artificial incubator environment in the study of the use of composting as a means to manage the invasive species, water hyacinth.

Appendix III.2 - Determining Temperatures at Which Water Hyacinth Seeds are Rendered Non-viable

The second objective of this study was to determine the temperatures at which water hyacinth seeds were rendered non-viable. As a waste-management system within agriculture, composting is known to kill weed seeds if temperatures are high enough and maintained for long enough periods of time (Rynk *et al.* 1992). For germination to be inhibited on weed seeds of sorghum, bindweed (*Convolvulus arvensis*), pigweed (*Amaranthus* spp.), johnsongrass (*Sorghum halepense*) and kochia (*Kochia americana*), temperatures of 120 to 180 degrees Fahrenheit for three to seven days on average must be obtained (Rynk *et al.* 1992). However, the temperatures needed to kill seeds of water hyacinth were not yet known. Therefore, seed kill experiments were conducted using small ovens to hold compost and water hyacinth seed samples at varying temperatures to discern at what temperatures the embryos were killed.

The tests included the use of 3 ovens (Model 10AF, Quincy Lab) and were conducted at the Aquarena Center laboratory. Water hyacinth seed was collected from various areas of Spring Lake and nearby areas of the San Marcos River during the summer and fall season of 2008. Due to the difficulty of collecting a large amount of seeds in the field, flowering water hyacinth from various locations were collected and observed at the Agriculture Department's greenhouses at Texas State University. Seeds collected from these samples were stored in a refrigerator at the Aquarena Center laboratory. In total, 90 compost samples each weighing 226.7 grams and each holding 10 water hyacinth seeds were tested for 3 days in each oven chamber at temperatures of 120 degrees Fahrenheit, 135 degrees Fahrenheit and 150 degrees Fahrenheit to create an environment and temperatures that could be achieved in an active compost pile. Oven and sample temperatures were checked daily with thermometers (Digital Probe Thermometer, Ward's) traceable to NIST (National Institute of Standards and Technology). Samples were monitored daily and maintained at a 50-70% moisture level, which is the typical moisture level of an active compost pile (Rynk *et al.* 1992).

Previous research has been inconclusive regarding the need to scarify the water hyacinth seed for successful germination; as a result, both scarified and unscarified seeds were used for the oven seed kill tests (Gopal 1987). Of the 90 seed-containing compost samples, 45 of the samples were conducted with scarified water hyacinth seed, and 45 of the samples were conducted with unscarified water hyacinth seed. For both scarified and unscarified seeds, 15 samples were held at 120 degrees Fahrenheit; 15 samples were held at 135 degrees Fahrenheit and 15 samples were held at 150 degrees Fahrenheit. Fifteen samples and 150 scarified and unscarified seeds were treated at each temperature. Three samples at each temperature were treated at one time.

The oven seed kill tests were each replicated. Once the seeds were held for 3 days in ovens, seeds were tested for viability using the procedures determined from the initial testing in which seeds were germinated in petri dishes held at 80 degrees Fahrenheit.

In the first germination tests, no seeds germinated from the sample in the compost held at 135 and 150 degrees Fahrenheit. However, using tetrazolium tests, 2 water hyacinth seeds were found to be viable of the unscarified seeds maintained in the compost sample held at 120 degrees Fahrenheit. The tetrazolium test is a seed viability test that usually takes about 30 minutes to perform. Seed embryos are tested by cutting or piercing the seed coat to expose the embryo. Seeds are then imbibed by soaking them in water, and then biochemical 2, 3, 5 triphenyl tetrazolium chloride (TTC). While TTC is initially colorless, it is converted to formazan red when living tissue is present. Therefore, seed embryos that are respirating or alive will appear stained when soaked in TTC. Dead embryos will not turn red.

The results of the second set of germination tests saw no germination of any of the seeds maintained in the compost samples held at 120, 135, and 150 degrees Fahrenheit. Tetrazolium tests found none of the seeds in the second set of germination tests to be viable. Therefore, temperatures of 135 degrees Fahrenheit or above were found to render water hyacinth seeds non-viable.

Table 1: Germination[z] and tetrazolium[y] test results conducted with scarified and unscarified *Eichhornia crassipes*, water hyacinth seed in the study of the use of composting as a means to manage the invasive species water hyacinth.

Group	Germination Test	% Germination	Tetrazolium Test	% Stained
Unscarified seed				
120° Fahrenheit	0/300	0%	2/300	0.7%
135° Fahrenheit	0/300	0%	0/300	0%
150° Fahrenheit	0/300	0%	0/300	0%
Total	0/900 Germinated	0%	2/900 Viable	0.1%
Scarified seed				
120° Fahrenheit	0/300	0%	0/300	0%
135° Fahrenheit	0/300	0%	0/300	0%
150° Fahrenheit	0/300	0%	0/300	0%
Total	0/900 Germinated	0%	0/900 Viable	0%

[z]Germination tests were conducted using water hyacinth seeds placed on filter paper media soaked in distilled water in petri dishes and were observed for 14 days for the radical emergence.

[y]The tetrazolium test is a seed viability test that usually takes about 30 minutes to perform. Seed embryos are tested by cutting or piercing the seed coat to expose the embryo. Seeds are then imbibed by soaking them in water, and then biochemical 2, 3, 5 triphenyl tetrazolium chloride (TTC). While TTC is initially colorless, it is converted to formazan red when living tissue is present. Therefore, seed embryos that are respirating or alive will appear stained when soaked in TTC. [x]Dead embryos will not turn red. Seeds were scarified by soaking in a vinegar solution for 30 minutes.

Appendix III.3 - Determine if the Composting Process Renders Water Hyacinth Seeds and Propagules Non-viable and Determine the Quality of the Compost Produced.

The fourth objective of this study was to determine if the composting process renders water hyacinth seeds and propagules non-viable. To carry out this objective, compost was collected, screened and inspected for seeds. If seeds were found to be present they would undergo germination testing to determine if the seeds were still viable. Germination tests would be conducted by placing seeds found onto filter paper media soaked in distilled water in petri dishes and placed in a mini-incubator that maintained at a constant temperature of 80 degrees Fahrenheit. They would then be observed for 14 days.

Compost samples were collected from the cured compost piles and were contained in 1-gallon sized containers. Each 1 gallon compost sample was drawn by collecting at least 5 subsamples at various depths that were then combined to create a composite sample. One hundred 1-gallon samples were taken in total and then hand-screened to ¼ inch. From there the screened material was taken to Lady Bird Johnson Wildflower Center Seed Lab (Austin, Texas) and further screened, using sieves, to 2 mm. The material was then visually examined to see if water hyacinth seeds were present. After visual examination, water hyacinth seeds were not found to be present in the material. Therefore, no germination tests were necessary to conduct. The composting process destroyed all seeds and other propagules of the invasive species, water hyacinth.

The fifth objective of this study was to determine the quality of the compost produced. Each of the 11 compost piles was sampled using procedures defined by the Test Methods for the examination of Composting and Compost (TMECC); these procedures are the industry recommended standards for commercial composting operations. Samples were taken by collecting approximately 1 pint of material from near the surface of each pile, another pint of material midway to the core of the pile, and another pint of material from near the core of the pile. This process was repeated at each of the sampling locations and samples were then placed in a clean 5-gallon plastic bucket and thoroughly mixed. A composite sample of 1 to 2 quarts was then collected from the mixed material and sent to the Penn State Agricultural Analytical Laboratory for testing.

The analysis conducted by Penn State in this study employed the tests that the U.S. Compost Council STA program requires for producers involved with the Compost Council's Seal of Testing Approval (STA) program. These tests are the most comprehensive compost tests that the Penn State Agricultural Analytical Services Laboratory performs. These tests include the following: percent solids, organic matter, pH, soluble salts, total nitrogen, total carbon, carbon:nitrogen ratio, ammonium-nitrogen, phosphorus, potassium, calcium, magnesium, arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, respirometry test, bioassay, and particle size (< 9.5 mm).

The pH of the finished compost was measured by making a slurry of compost and deionized water and then blended to a ratio of 1:5. The sample was then shaken for 20 minutes at room temperature to allow the salts to solubilize in the deionized water. The pH was then measured with an electrometric pH meter. The pH of the finished compost ranged from 7.9 to 8.4, which is slightly alkaline, but still within the typical pH range of compost (5.0-8.5) (Table 1).

The soluble salts were measured by taking the electrical conductivity in a 1:5 (compost:water, weight ratio) slurry and was measured in units of millimhos/cm. The soluble salt content of the finished compost in this study ranged from 0.33 to 2.28 mmhos/cm (Table 1). Compost soluble salt levels typically range from 1 to 10 mmhos/cm. The % solids and % moisture were measured by weighing a sample and then drying it at 70 (+/- 5) degrees Celsius and then re-weighed. The remaining dry solids fraction represented the total solids, and the evaporated fraction represented the % moisture.

The % solids of the finished compost in this study ranged from 51.3% to 73.3%. An ideal % solid for finished compost is 50-60%. The % moisture of the finished compost in this study ranged from 26.7% to 48.7% (Table 1). An ideal moisture level of finished compost is 40-50% moisture.

The % organic matter of the finished compost was measured by using the Loss-On-Ignition Organic Matter Method; which is a direct determination method that indicates organic matter content by quantifying the amount of solid material combusted relative to the original oven dried sample. The % organic matter of the finished compost in this study ranged from 13.4% to 43.9% (dry weight basis) (Table 1). Finished composts typically have an organic matter content of 30-70%.

The nitrogen content of the finished compost was determined by using the Total Kjeldahl Nitrogen Semi-Micro Kjeldahl technique. The total nitrogen content of the finished compost in this study ranged from 0.6% to 1.8% (dry weight basis) (Table 1). Typical total nitrogen levels of finished compost range from 0.5% to 2.5%.

The total carbon content of the finished compost in this study was measured by the Combustion with CO_2 Detection method. This method uses a carbon analyzer (Leco CR-12) to determine total organic carbon in compost. The analyzer operates on the principle of total combustion of a sample in an oxygen-rich atmosphere of a 2500 degree Fahrenheit resistance furnace. The CO_2 produced by the combustion is swept into an oxygen stream through anhydrone tubes to scrub H_2O vapor from the stream. The CO_2 stream is then fed into the infrared detector and the amount of CO_2 produced is measured. The total carbon content of the finished compost in this study ranged from 10.4% to 24.5% (dry weight basis) (Table 1). Typical carbon content of compost has up to 54% total carbon.

The carbon to nitrogen ratio of the finished compost in this study ranged from 13.8 to 18.9 (dry weight basis) (Table 1). A low C:N ratio (< 20) will mineralize or break-down organic N to inorganic (plant-available) N.

Table 1: Finished compost test results from certified quality testing laboratory[z] in the study of the use of composting as a means to manage the invasive species water hyacinth.

Sample 1 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.1	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	0.38 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	73.3%	n/a	50 – 60%
Moisture[v]	26.7%	n/a	40 – 50%
Organic Matter[u]	9.8%	13.4%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.5%	0.7%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.5%	0.7%	n/a
Ammonium N[r]	3.6 mg/kg	5.0 mg/kg	n/a
Carbon[q]	8.3%	11.3%	< 54%
Carbon:Nitrogen Ratio	16.40	16.4	< 20 (Dry weight)
Phosphorus[p]	0.27%	0.37%	n/a
Potassium[o]	0.51%	0.69%	n/a
Sample 2 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.4	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	0.33 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	69.6%	n/a	50 – 60%
Moisture[v]	30.4%	n/a	40 – 50%
Organic Matter[u]	10.3%	14.7%	30 – 70%

			(Dry weight)
Total Nitrogen[t]	0.4%	0.6%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.4%	0.6%	n/a
Ammonium N[r]	3.4 mg/kg	4.9 mg/kg	n/a
Carbon[q]	7.2%	10.4%	< 54%
Carbon:Nitrogen Ratio	17.60	17.60	< 20 (Dry weight)
Phosphorus[p]	0.23%	0.33%	n/a
Potassium[o]	0.44%	0.64%	n/a
Sample 3 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.3	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	0.45 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	65.1%	n/a	50 – 60%
Moisture[v]	34.9%	n/a	40 – 50%
Organic Matter[u]	9.4%	14.4%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.4%	0.6%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.4%	0.6%	n/a
Ammonium N[r]	3.2 mg/kg	4.9 mg/kg	n/a
Carbon[q]	7.1%	10.9%	< 54%
Carbon:Nitrogen Ratio	18.90	18.90	< 20 (Dry weight)

Phosphorus[p]	0.25%	0.38%	n/a
Potassium[o]	0.43%	0.66%	n/a
Sample 4 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.1	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	1.06 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	67.5%	n/a	50 – 60%
Moisture[v]	32.5%	n/a	40 – 50%
Organic Matter[u]	13.7%	20.3%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.7%	1.0%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.7%	1.0%	n/a
Ammonium N[r]	3.3 mg/kg	4.9 mg/kg	n/a
Carbon[q]	9.3%	13.8%	< 54%
Carbon:Nitrogen Ratio	13.80	13.80	< 20 (Dry weight)
Phosphorus[p]	0.43%	0.63%	n/a
Potassium[o]	0.61%	0.90%	n/a
Sample 5 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.1	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	0.97 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	61.6%	n/a	50 – 60%
Moisture[v]	38.4%	n/a	40 – 50%

Organic Matter[u]	15.6%	25.3%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.6%	1.0%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.6%	1.0%	n/a
Ammonium N[r]	3.0 mg/kg	4.9 mg/kg	n/a
Carbon[q]	9.5%	15.4%	< 54%
Carbon:Nitrogen Ratio	15.10	15.10	< 20 (Dry weight)
Phosphorus[p]	0.54%	0.87%	n/a
Potassium[o]	0.56%	0.91%	n/a
Sample 6 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.0	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	1.42 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	68.9%	n/a	50 – 60%
Moisture[v]	31.1%	n/a	40 – 50%
Organic Matter[u]	18.2%	26.4%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.8%	1.2%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.8%	1.2%	n/a
Ammonium N[r]	3.6 mg/kg	5.2 mg/kg	n/a
Carbon[q]	11.7%	16.9%	< 54%
Carbon:Nitrogen Ratio	13.90	13.90	< 20 (Dry weight)

Phosphorus[p]	0.61%	0.88%	n/a
Potassium[o]	0.67%	0.97%	n/a
Sample 7 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	7.9	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	1.91 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	56.4%	n/a	50 – 60%
Moisture[v]	43.6%	n/a	40 – 50%
Organic Matter[u]	21.5%	38.1%	30 – 70% (Dry weight)
Total Nitrogen[t]	1.0%	1.8%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	1.0%	1.8%	n/a
Ammonium N[r]	2.8 mg/kg	5.0 mg/kg	n/a
Carbon[q]	13.8%	24.5%	< 54%
Carbon:Nitrogen Ratio	13.90	13.90	< 20 (Dry weight)
Phosphorus[p]	0.63%	1.11%	n/a
Potassium[o]	0.57%	1.02%	n/a
Sample 8 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.0	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	1.96 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	57.5%	n/a	50 – 60%
Moisture[v]	42.5%	n/a	40 – 50%

Organic Matter[u]	21.5%	37.3%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.8%	1.4%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.8%	1.4%	n/a
Ammonium N[r]	6.4 mg/kg	11.1 mg/kg	n/a
Carbon[q]	12.8%	22.2%	< 54%
Carbon:Nitrogen Ratio	16.0	16.0	< 20 (Dry weight)
Phosphorus[p]	0.57%	0.99%	n/a
Potassium[o]	0.61%	1.06%	n/a
Sample 9 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.2	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	2.28 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	51.3%	n/a	50 – 60%
Moisture[v]	48.7%	n/a	40 – 50%
Organic Matter[u]	19.4%	37.7%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.8%	1.5%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.8%	1.5%	n/a
Ammonium N[r]	2.6 mg/kg	5.0 mg/kg	n/a
Carbon[q]	12.6%	24.5%	< 54%
Carbon:Nitrogen Ratio	15.90	15.90	< 20 (Dry weight)

Phosphorus[p]	0.37%	0.72%	n/a
Potassium[o]	0.47%	0.91%	n/a
Sample 10 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	7.9	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	1.91 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	56.6%	n/a	50 – 60%
Moisture[v]	43.4%	n/a	40 – 50%
Organic Matter[u]	18.3%	32.3%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.7%	1.3%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.7%	1.3%	n/a
Ammonium N[r]	2.8 mg/kg	5.0 mg/kg	n/a
Carbon[q]	10.6%	18.7%	< 54%
Carbon:Nitrogen Ratio	14.40	14.40	< 20 (Dry weight)
Phosphorus[p]	0.27%	0.47%	n/a
Potassium[o]	0.50%	0.89%	n/a
Sample 11 Analyte	Results (As is basis)	Results (Dry weight basis)	Normal Range
pH[y]	8.1	n/a	5.0 – 8.5
Soluble Salts[x] (1:5 w:w)	1.21 mmhos/cm	n/a	1 – 10 mmhos/cm
Solids[w]	58.8%	n/a	50 – 60%
Moisture[v]	41.2%	n/a	40 – 50%

Organic Matter[u]	25.8%	43.9%	30 – 70% (Dry weight)
Total Nitrogen[t]	0.8%	1.4%	0.5 – 2.5% (Dry weight)
Organic Nitrogen[s]	0.8%	1.4%	n/a
Ammonium N[r]	18.9 mg/kg	32.1 mg/kg	n/a
Carbon[q]	14.3%	24.3%	< 54%
Carbon:Nitrogen Ratio	17.00	17.00	< 20 (Dry weight)
Phosphorus[p]	0.25%	0.43%	n/a
Potassium[o]	0.39%	0.66%	n/a

[z]Compost analysis was conducted at Pennsylvania State University Agricultural Analytical Services Laboratory (University Park, Pennsylvania).

[y]The pH of the finished compost was measured by making a slurry of compost and deionized water and then blended to a ratio of 1:5. The sample was then shaken for 20 minutes at room temperature to allow the salts to solubilize in the deionized water. The pH was then measured with an electrometric pH meter (TMECC, 2002). The pH of the finished compost ranged from 7.9 to 8.4, which is slightly alkaline, but still within the typical pH range of compost (5.0-8.5).

[x]The soluble salts were measured by taking the electrical conductivity in a 1:5 (compost:water, weight ratio) slurry and was measured in units of millimhos/cm.

[w]The % solids was measured by weighing a sample and then drying it at 70 (+/- 5) degrees Celsius and then re-weighed. The remaining dry solids fraction represented the total solids, and the evaporated fraction represented the % moisture (TMECC, 2002)

[v]The % moisture was measured by weighing a sample and then drying it at 70 (+/- 5) degrees Celsius and then re-weighed. The remaining dry solids fraction represented the total solids, and the evaporated fraction represented the % moisture (TMECC, 2002)

[u]The % organic matter of the finished compost was measured by using the Loss-On-Ignition Organic Matter Method; which is a direct determination method that indicates organic matter content by quantifying the amount of solid material combusted relative to the original oven dried sample (TMECC, 2002).

[t]The nitrogen content of the finished compost was determined by using the methodologies specified in the Test Methods for the Examination of Composting and Compost (TMECC, 2002), specifically the Total Kjeldahl Nitrogen Semi-Micro Kjeldahl technique (TMECC, 2002).

[s]The organic nitrogen content of the finished compost was determined by using the methodologies specified in the Test Methods for the Examination of Composting and Compost (TMECC, 2002), specifically the Total Kjeldahl Nitrogen Semi-Micro Kjeldahl technique (TMECC, 2002).

[r]The ammonium nitrogen content of the finished compost was determined by using the methodologies specified in the Test Methods for the Examination of Composting and Compost (TMECC, 2002), specifically the Total Kjeldahl Nitrogen Semi-Micro Kjeldahl technique (TMECC, 2002).

[q]The total carbon content of the finished compost in this study was measured by the Combustion with CO_2 Detection method. This method uses a carbon analyzer (Leco CR-12) to determine total organic carbon in compost. The analyzer operates on the principle of total combustion of a sample in an oxygen-rich atmosphere of a 2500 degree Fahrenheit resistance furnace (TMECC, 2002). The CO_2 produced by the combustion is swept into an oxygen stream through anhydrone tubes to scrub H_2O vapor from the stream (TMECC, 2002). The CO_2 stream is then fed into the infrared detector and the amount of CO_2 produced is measured.

[p]The phosphorus content of the finished compost in this study was measured by digesting an air-dried, milled sample and determining the phosphorus content using inductively coupled plasma emission spectrospy (ICP).

[o]The potassium content of the finished compost in this study was measured by digesting an air-dried, milled sample and determining the potassium content using inductively coupled plasma emission spectrospy (ICP).

The trace elements and heavy metal content of the finished compost in this study were measured by method 4.06 in the Test Methods for the Examination of Composting and Compost. The trace elements and heavy metal (arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc) content of the finished compost (Table 2) in this study were all below the acceptable levels prescribed by the Environmental Protection Agency.

Table 2: Trace elements and heavy metal test results from certified quality testing laboratory[z] in the study of the use of composting as a means to manage the invasive species water hyacinth.

Analyte Sample 1	Results (As is basis)	Results (Dry weight basis)	EPA[y] Limit
Arsenic (As)	7.4 mg/kg	10.1 mg/kg	41 mg/kg
Cadmium (Cd)	0.5 mg/kg	0.7 mg/kg	39 mg/kg
Copper (Cu)	22.2 mg/kg	30.4 mg/kg	1500 mg/kg
Lead (Pb)	8.2 mg/kg	11.1 mg/kg	300 mg/kg
Mercury (Hg)	0.02 mg/kg	0.02 mg/kg	17 mg/kg
Molybdenum (Mo)	1.5 mg/kg	2.1 mg/kg	75 mg/kg
Nickel (Ni)	10.2 mg/kg	13.9 mg/kg	420 mg/kg
Selenium (Se)	1.1 mg/kg	1.5 mg/kg	100 mg/kg
Zinc (Zn)	54.5 mg/kg	74.4 mg/kg	2800 mg/kg
Analyte Sample 2	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	6.2 mg/kg	8.9 mg/kg	41 mg/kg
Cadmium (Cd)	0.4 mg/kg	0.5 mg/kg	39 mg/kg
Copper (Cu)	18.0 mg/kg	25.9 mg/kg	1500 mg/kg
Lead (Pb)	6.9 mg/kg	9.9 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.02 mg/kg	17 mg/kg

Molybdenum (Mo)	1.1 mg/kg	1.6 mg/kg	75 mg/kg
Nickel (Ni)	8.2 mg/kg	11.8 mg/kg	420 mg/kg
Selenium (Se)	1.1 mg/kg	1.6 mg/kg	100 mg/kg
Zinc (Zn)	47.6 mg/kg	68.3 mg/kg	2800 mg/kg
Analyte Sample 3	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	5.5 mg/kg	8.5 mg/kg	41 mg/kg
Cadmium (Cd)	0.3 mg/kg	0.5 mg/kg	39 mg/kg
Copper (Cu)	16.4 mg/kg	25.1 mg/kg	1500 mg/kg
Lead (Pb)	6.3 mg/kg	9.7 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.02 mg/kg	17 mg/kg
Molybdenum (Mo)	1.0 mg/kg	1.6 mg/kg	75 mg/kg
Nickel (Ni)	7.7 mg/kg	11.8 mg/kg	420 mg/kg
Selenium (Se)	1.0 mg/kg	1.6 mg/kg	100 mg/kg
Zinc (Zn)	44.5 mg/kg	68.4 mg/kg	2800 mg/kg
Analyte Sample 4	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	5.8 mg/kg	8.7 mg/kg	41 mg/kg
Cadmium (Cd)	0.4 mg/kg	0.6 mg/kg	39 mg/kg
Copper (Cu)	27.9 mg/kg	41.4 mg/kg	1500 mg/kg
Lead (Pb)	6.1 mg/kg	9.0 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.01 mg/kg	17 mg/kg
Molybdenum (Mo)	1.1 mg/kg	1.7 mg/kg	75 mg/kg
Nickel (Ni)	7.6 mg/kg	11.3 mg/kg	420 mg/kg
Selenium (Se)	1.1 mg/kg	1.7 mg/kg	100 mg/kg
Zinc (Zn)	65.7 mg/kg	97.4 mg/kg	2800 mg/kg
Analyte	Results	Results	EPA

Sample 5	(As is basis)	(Dry weight basis)	Limit
Arsenic (As)	5.3 mg/kg	8.7 mg/kg	41 mg/kg
Cadmium (Cd)	0.3 mg/kg	0.6 mg/kg	39 mg/kg
Copper (Cu)	33.9 mg/kg	55.0 mg/kg	1500 mg/kg
Lead (Pb)	6.7 mg/kg	10.8 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.01 mg/kg	17 mg/kg
Molybdenum (Mo)	1.0 mg/kg	1.7 mg/kg	75 mg/kg
Nickel (Ni)	6.9 mg/kg	11.2 mg/kg	420 mg/kg
Selenium (Se)	1.0 mg/kg	1.7 mg/kg	100 mg/kg
Zinc (Zn)	69.5 mg/kg	112.9 mg/kg	2800 mg/kg
Analyte Sample 6	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	5.7 mg/kg	8.3 mg/kg	41 mg/kg
Cadmium (Cd)	0.4 mg/kg	0.5 mg/kg	39 mg/kg
Copper (Cu)	35.1 mg/kg	51.0 mg/kg	1500 mg/kg
Lead (Pb)	6.1 mg/kg	8.9 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.02 mg/kg	17 mg/kg
Molybdenum (Mo)	1.1 mg/kg	1.5 mg/kg	75 mg/kg
Nickel (Ni)	7.3 mg/kg	10.6 mg/kg	420 mg/kg
Selenium (Se)	1.1 mg/kg	1.5 mg/kg	100 mg/kg
Zinc (Zn)	119.0 mg/kg	172.6 mg/kg	2800 mg/kg
Analyte Sample 7	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	4.7 mg/kg	8.4 mg/kg	41 mg/kg
Cadmium (Cd)	0.3 mg/kg	0.6 mg/kg	39 mg/kg
Copper (Cu)	41.6 mg/kg	73.8 mg/kg	1500 mg/kg
Lead (Pb)	3.5 mg/kg	6.1 mg/kg	300 mg/kg

Mercury (Hg)	0.01 mg/kg	0.02 mg/kg	17 mg/kg
Molybdenum (Mo)	1.0 mg/kg	1.8 mg/kg	75 mg/kg
Nickel (Ni)	5.5 mg/kg	9.7 mg/kg	420 mg/kg
Selenium (Se)	1.0 mg/kg	1.8 mg/kg	100 mg/kg
Zinc (Zn)	86.4 mg/kg	153.2 mg/kg	2800 mg/kg
Analyte Sample 8	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	4.1 mg/kg	7.1 mg/kg	41 mg/kg
Cadmium (Cd)	0.3 mg/kg	0.5 mg/kg	39 mg/kg
Copper (Cu)	31.3 mg/kg	54.4 mg/kg	1500 mg/kg
Lead (Pb)	4.2 mg/kg	7.2 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.02 mg/kg	17 mg/kg
Molybdenum (Mo)	0.9 mg/kg	1.6 mg/kg	75 mg/kg
Nickel (Ni)	5.5 mg/kg	9.6 mg/kg	420 mg/kg
Selenium (Se)	0.9 mg/kg	1.6 mg/kg	100 mg/kg
Zinc (Zn)	67.0 mg/kg	116.5 mg/kg	2800 mg/kg
Analyte Sample 9	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	3.0 mg/kg	5.9 mg/kg	41 mg/kg
Cadmium (Cd)	0.3 mg/kg	0.6 mg/kg	39 mg/kg
Copper (Cu)	23.5 mg/kg	45.7 mg/kg	1500 mg/kg
Lead (Pb)	4.4 mg/kg	8.5 mg/kg	300 mg/kg
Mercury (Hg)	0.03 mg/kg	0.05 mg/kg	17 mg/kg
Molybdenum (Mo)	0.9 mg/kg	1.7 mg/kg	75 mg/kg
Nickel (Ni)	4.0 mg/kg	7.9 mg/kg	420 mg/kg
Selenium (Se)	0.9 mg/kg	1.7 mg/kg	100 mg/kg
Zinc (Zn)	48.6 mg/kg	94.7 mg/kg	2800 mg/kg

Analyte Sample 10	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	3.7 mg/kg	6.6 mg/kg	41 mg/kg
Cadmium (Cd)	0.3 mg/kg	0.5 mg/kg	39 mg/kg
Copper (Cu)	16.7 mg/kg	29.5 mg/kg	1500 mg/kg
Lead (Pb)	5.5 mg/kg	9.6 mg/kg	300 mg/kg
Mercury (Hg)	0.01 mg/kg	0.02 mg/kg	17 mg/kg
Molybdenum (Mo)	0.9 mg/kg	1.6 mg/kg	75 mg/kg
Nickel (Ni)	5.3 mg/kg	9.3 mg/kg	420 mg/kg
Selenium (Se)	0.9 mg/kg	1.6 mg/kg	100 mg/kg
Zinc (Zn)	43.3 mg/kg	76.4 mg/kg	2800 mg/kg
Analyte Sample 11	Results (As is basis)	Results (Dry weight basis)	EPA Limit
Arsenic (As)	3.2 mg/kg	5.4 mg/kg	41 mg/kg
Cadmium (Cd)	0.5 mg/kg	0.9 mg/kg	39 mg/kg
Copper (Cu)	12.7 mg/kg	21.5 mg/kg	1500 mg/kg
Lead (Pb)	5.2 mg/kg	8.8 mg/kg	300 mg/kg
Mercury (Hg)	0.02 mg/kg	0.03 mg/kg	17 mg/kg
Molybdenum (Mo)	2.8 mg/kg	4.8 mg/kg	75 mg/kg
Nickel (Ni)	5.2 mg/kg	8.8 mg/kg	420 mg/kg
Selenium (Se)	1.5 mg/kg	2.6 mg/kg	100 mg/kg
Zinc (Zn)	31.9 mg/kg	54.3 mg/kg	2800 mg/kg

[z]Compost analysis was conducted at Pennsylvania State University Agricultural Analytical Services Laboratory (University Park, Pennsylvania).

[y]EPA limits retrieved from Stofella et al. 2001.

Most samples of compost fell within acceptable to ideal ranges on all variables tested. It was noted that the few variables tested that were in unacceptable ranges were drawn from compost piles made early on in the study. Therefore, researchers believe that the unacceptable ranges on these variables were most likely due to inexperienced equipment operators at the beginning of the study inadvertently scooping clay and other materials from the compost site pad into the compost while turning the piles with the front-end loader (Rynk *et al.* 1992). With improvements to the compost pad and with more experienced operators, these problems will be resolved in future composting efforts.

Appendix III.4 - Compost Field Tests: Using Compost Created from Water Hyacinth as an Alternative Potting Media in a Greenhouse Setting.

Potting media has an effect on the health, survivability and production of greenhouse plants. Potting media in a greenhouse environment must provide good anchorage, water and nutrient availability and good aeration to the roots. Peat-based potting mixes have been a staple of the industry for the last several decades. However, peat is harvested from wetland areas that are often sensitive habitats for birds and other wildlife. Additionally, the organic matter, peat, develops from centuries of slowly decaying plants under anaerobic conditions, and is, therefore, a non-renewable resource.

The purpose of this experiment was to determine if a compost-based potting media (33% compost: 67% perlite mix or 67% compost: 33% perlite mix) was a suitable alternative to a peat-based potting media (50% peat: 50% perlite) in greenhouse production of 2 tropical plant species: Tropical Hibiscus (*Hibiscus rosa-sinensis*) and Mandevilla (*Mandevilla sp*.). Variables studied included growth, plant health, survivability and flower production.

Plants in the control group were planted in a typical 50% peat: 50% perlite mix. Plants in the compost treatment were planted in 33% compost: 67% perlite mix or 67% compost: 33% perlite mix (Perlite is expanded lava rock that is incorporated into potting mix to allow for better drainage and air exchange). The plants were maintained in a greenhouse for five weeks during the fall semester. The progress of the plants was checked weekly for internode length, number of nodes, number of flowers and overall health of the plants. General observations were also taken on ease of care including how quickly the potting medias dried out in the greenhouse environment.

Results showed that the compost-based potting media was a suitable alternative to peat in greenhouse production of the tropical plant species Tropical Hibiscus (*Hibiscus rosa-sinensis*) and Mandevilla (*Mandevilla sp*.). However, the plants potted in 33% compost: 67% perlite mix tended to dry out rather quickly leading to more maintenance and a greater threat to leaf burn and other plant problems in the 2 species of plants studied. The plants potted in a 67% compost: 33% perlite mix held moisture longer and comparably to the plants potted in the peat:perlite mix and were, therefore, easier to maintain and led to overall healthier plants.

Tropical species of plants have greater moisture requirements when compared to some other species of plants, so it is understandable that the potting mix with a greater proportion of organic matter that allowed for better moisture retention would lead to better growth. With native species of plants or cacti and succulent plant species that are more drought-tolerant and have less nutritional needs, the 33% compost: 67% perlite mix may be a more suitable choice.

Appendix IV.1 - Workshops and Demonstrations Conducted on Composting Water Hyacinth

2008 workshops and presentations

July, 2008 – Hays County Cooperative Extension 4-H presentation, Composting and Vermicomposting at Home, July, 2008, San Marcos, TX (presentation to approximately 20 people).

2009 workshops and presentations

April 21, 2009 – Texas State University, Alkek Library Earth Day Conference, Composting for the Home and at Texas State, Spring, 2009, (presentation to approximately 35 people).

August 31, 2009-- Sanders, J. and T.M. Waliczek. 2009. Cafeteria composting. Recycling and Sustainability Summit. August, Galveston, TX (presentation to approximately 40 people).

August 31, 2009-- Montoya, J., T.M. Waliczek and M. Abbott. 2009. Using compost to combat water hyacinth. Recycling and Sustainability Summit. August, Galveston, TX (demonstration to approximately 40 people).

October 21, 2009 – Texas State composting program. Recycling and Sustainability Summit. 2009 Compost Camp, Compost Advisory Council, October, Creedmoor, TX (presentation to approximately 70 people).

November 9, 2009 – Austin Organic Gardening Club, *Composting for the Home and at Texas State*, Zilker Botanic Garden, Fall, 2009 (presentation to approximately 50 people).

*Bobcat Blend composting project featured in:
Gillespie, Spike. 2009. You got oatmeal on my hyacinth. Edible Austin magazine, Winter.

2010 workshops and presentations

April 22, 2010 – Earth Day on Texas State University quad (demonstration to approximately hundreds of students, faculty and staff throughout the day).

April 24, 2010 – Earth Day Weekend demonstration (A demonstration was held for 35 students and staff in conjunction with Earth Day).

October 4, 2010 – Montoya, J., J. Sanders and T. M. Waliczek. 2010. Bobcat Blend -- Bobcat Blend – Campus Food Collections and Composting Recycling and Sustainability Summit. October, San Antonio, TX, (presentation to approximately 40 people).

October 4, 2010 – Sanders, J. and T.M. Waliczek. 2010. Bobcat Blend: Funding options for university composting programs. Recycling and Sustainability Summit. October, San Antonio, TX, (presentation to approximately 40 people).

August 2, 2010 – Montoya, J., T. M. Waliczek and M. Abbott. 2010. Large-scale composting as a means of managing Eichhornia crassipes, water hyacinth. HortScience, August , Palm Desert, CA (presentation to approximately 40 people)..

August 2, 2010 -- Sanders, J. and T.M. Waliczek. 2010. Bobcat Blend: An economic analysis of a student-run university campus composting program. HortScience, August, Palm Desert, CA, (presentation to approximately 40 people). .

August 27, 2010 -- Montoya, J., T.M. Waliczek and M. Abbott. Large-scale composting as a means of managing *Eichhornia crassipes*, water hyacinth. Freeman Ranch Research Symposium, August, Texas State University, San Marcos, TX. (presentation to 35 people).

September 29, 2010 – Texas State University, No Impact Week collections and booth on university quad (demonstration to hundreds of students, faculty and staff throughout the day).

October 13, 2010 – Texas State University Environmental Service Committee tour (demonstration to approximately 15 people).

October 13, 2010 – City of San Marcos Parks and Recreation department tour, (demonstration to approximately 5 people).

October 15, 2010 – Texas State University, AG 3308, Organic Gardening class tour, (demonstration to approximately 25 people).

November 18, 2010 – Texas State University, Texas Recycles Day event collections booth on university quad (demonstration to hundreds of students, faculty and staff throughout the day).

*Bobcat Blend composting project featured in:
Sullivan, D. 2010. College Students initiate food waste diversion. Biocycle, September, pg. 65-67.

Appendix IV.2 – Best Management Practices for Composting Water Hyacinth

This study found that water hyacinth seeds were rendered non-viable at temperatures at or above 135 degrees Fahrenheit. This finding allows for water hyacinth to be safely utilized as a feedstock in the composting process even though it is an invasive species since temperatures above 135 degrees Fahrenheit kills seeds, and these temperatures are relatively easy to maintain in a compost pile when appropriate proportions of carbon and nitrogen-containing feedstocks are used. This supported other studies that found that plant pathogens as well as weed seeds were killed if several days of pile temperatures above 130 degrees Fahrenheit were achieved.

Feedstocks were incorporated at the following percentages: food waste from the university cafeterias (10%), poultry litter (15%), water hyacinth plants (25%) and wood chips (50%).

Piles were turned every 5 days (when environmental conditions allowed) to ensure that formerly outer exposed surfaces were buried within the pile each time the pile was turned. Rows of feedstock blends were laid out in separate areas and monitored for heat, moisture and maturity. Piles were built to be 5 to 6 feet tall. The widths of the piles were built to be 10-12 feet. This height and width allowed the piles to be insulated and generate enough heat to kill pathogens (including the weed seeds of interest), but did not allow too much heat to be generated in the piles which can result in spontaneous combustion.

To test for water hyacinth seeds in finished compost, 100 individual 1 gallon samples were taken from finished cured piles of compost and at varying depths from curing piles. When samples were drawn, they were labeled with the time, approximate depths and site from which they were gathered. Each 1 gallon compost sample was drawn by collecting at least 5 subsamples from each cured compost pile. These 5 subsamples were then combined to create a composite sample.

Compost samples were taken to the Ladybird Johnson Wildflower Center seed lab in Austin, Texas. Each sample was screened down to particles less than 2mm in size, which would capture any potential water hyacinth seeds while preventing any larger particles from passing through. Each sample was then visually analyzed per Lady Bird Johnson Wildflower Center's seed identifying procedures to determine if water hyacinth seeds were present in each sample.

Compost was also tested for quality which included tests for weeds and pathogens. Samples were taken by collecting approximately 1 pint of material from near the surface of each pile, another pint of material midway to the core of the pile, and another pint of material from near the core of the pile. Each of the 3 pints were then placed in a clean 5-gallon plastic bucket and thoroughly mixed. A composite sample of 1 to 2 quarts was then collected from the mixed material. This sampling technique was designated as reliable and valid in compost quality testing standards.

Compost samples were sent to Pennsylvania State Agricultural Analytical Services Laboratory (University Park, Pennsylvania) which utilizes testing procedures from the U.S. Compost Council's Test Methods for the Examination of Composting and Compost (TMECC 2002). The analysis conducted in this study employed the tests for the U.S. Compost Council Seal of Testing Approval (STA) program which are required for producers involved with the Compost Council's STA program. These tests are the most comprehensive compost tests that the Pennsylvania State Agricultural Analytical Services Laboratory performs. The tests included the following: percent solids, organic matter, pH, soluble salts, total nitrogen, total carbon, carbon:nitrogen ratio, ammonium-nitrogen, phosphorus, potassium, calcium, magnesium, arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, respirometry test, bioassay, and particle size (< 9.5 mm) within each compost sample. This study found that the quality of compost created from water hyacinth was in the acceptable to ideal ranges of given industry quality standards.

Appendix V.1 Interim Report

Large-Scale Composting System as a Means of Controlling Water Hyacinth, Eichhornia crasspipes

PI: Dr. Michael Abbott; Dr. Tina Cade
Texas State University – San Marcos

Contract # 582-8-77063

Project Description

This project involves the development of a large-scale demonstration compost operation that utilizes invasive water hyacinth harvested from Spring Lake, at the origin of the San Marcos River. Poultry litter and other feedstocks will be combined with water hyacinth to produce a mature compost that destroys the water hyacinth seed. The results of the study will be presented to interested parties and will serve as an example Best Management Practice for other water bodies with water hyacinth problems.

Composting Site

The compost operation is located on the Muller Farm, which is owned by the University and located outside of the Edwards Aquifer recharge zone. The farm is used primarily as an alternate pasture for cattle raised on the University's Freeman ranch. Approximately five acres are being used for the composting operation; the site provides open areas for the compost piles, a storm water collection pond, an improved all-weather road, electricity and supplemental water and fencing of the site.

Compost Feedstocks

Feedstocks chosen for this project, in addition to the water hyacinth include poultry litter, cafeteria food wastes and wood chip wastes. Different proportions of these materials have been combined and composted to determine which feedstock blend will have the greatest effect on the destruction of hyacinth seeds.

Composting and Control of Hyacinth Seeds

Because of the lack of information in research literature on the temperature at which water hyacinth seeds are destroyed, tests are being conducted in University laboratories to determine the approximate temperature at which water hyacinth seeds die. Samples of compost containing scarified and unscarified water hyacinth seeds are being monitored for fifteen days in temperature chambers that are held at 120° degrees F, 135 degrees F and 150 degrees F. Once samples are held for fifteen days, seeds are tested using effective germination procedures to determine if seeds are viable.

Composting of materials takes 15-30 days with piles being turned every five days. Blends of feedstock will be modified to maintain temperatures known to destroy the water hyacinth seeds. Once decomposition of materials is achieved, the compost will be tested to determine whether water hyacinth seeds have been destroyed. Water hyacinth seeds (if not fully decomposed) will be extracted from the finished compost and tested using effective germination protocol to rule out the possibility of viability in the processed seeds.

Additionally, finished compost will be sampled and sent to a certified Seal of Testing Assurance laboratory to test for viable water hyacinth seeds as well as testing the quality of compost produced.

Workshops/Demonstrations

A series of workshops and demonstrations will be conducted for interested parties from across the state. These workshops will cover water hyacinth harvesting, blending of feedstocks, building compost windrows, testing protocols, and best management practices.

If the composting process proves unsuccessful in killing water hyacinth seeds, the workshops will be adapted to focus on proper composting techniques and stock ingredients that should not be included in composting mix. A website (http://www.rivers.txstate.edu/research/rivers/san-marcos-river-projects/san-marcos-composting-system.html) is being maintained and updated throughout the project. A final report on the results of the study will be prepared; submitted to the Texas Commission on Environmental Quality, and made available through the River Systems Institute.

Project Goals and Accomplishments

Goal: To effectively coordinate and monitor all technical and financial activities performed under this grant, preparing regular progress reports and maintaining project files and data.

- Appropriate structure and management oversight has been established between the principle investigators, Texas State University, the TCEQ project manager and TCEQ support staff.
- Five quarterly reports and five quarterly reimbursement requests have been completed and submitted to TCEQ.
- A satisfactory annual TCEQ contractor evaluation has been received for this project.
- A one page fact sheet for this project has been completed and revised.
- A website on the project has been created and is being enhanced (See http://www.rivers.txstate.edu/research/rivers/san-marcos-river-projects/san-marcos-composting-system.html).

Goal: Develop and operate a composting facility at Texas State University that utilizes agricultural and other waste to produce compost that is beneficial for the environment. Finished compost will be utilized on University property after tests confirm that water hyacinth seeds have been destroyed and the compost is safe for use.

- A composting site has been constructed at the University's Muller Farm. The five acre site provides open areas for the compost piles, a storm water collection pond, an improved all-weather road, electricity and supplemental water, and is completely fenced. The site has been certified to comply with Texas General Permit requirements. (See attached photos in Appendix I).
- Authorization has been received from TCEQ to operate a compost facility.
- Sources from which to obtain the needed feedstocks have been identified and agreements reached regarding provision of feedstocks.

- Compost blend ratios of 25% water hyacinth, 15% poultry litter, 10% food waste and 50% wood chips have been determined to provide required temperatures for effective decomposition.
- Students assisting in the composting operation have been trained regarding safe and effective operation of equipment, as well as proper procedures for composting materials.

Goal: To monitor compost quality from various feedstocks; to conduct tests to determine proper temperatures for destruction of water hyacinth seeds; to determine composting feedstock blends best suited for destruction of water hyacinth seeds at proper temperature; and to test the quality of compost and confirm the destruction of water hyacinth seeds from composting process.

- A Quality Assurance Project Plan (QAPP) has been submitted and approved. One year revisions to the plan are currently being reviewed.
- The following feedstocks have been collected from noted sources in compliance with QAPP:
    - Water hyacinth – Spring Lake/ San Marcos River
    - Poultry litter – Tyson Foods, Sequin Texas
    - Food waste – Texas State University Cafeterias
    - Woodchips – Bartlett Tree Services, San Marcos
- Nine temperatures chambers have been purchased and initial tests run to determine temperatures at which water hyacinth seeds are destroyed. Initial tests indicate that temperatures at 135 degrees F and above will destroy water hyacinth seeds. Repetitions of the initial tests are being conducted to verify the initial findings.
- Tests to identify an effective medium in which to germinate water hyacinth seeds have been inconclusive; none of the mediums/techniques used resulted in germination of water hyacinth seeds. We since have consulted with seed bank experts at the Lady Bird Johnson Wildflower Center and decided to use a procedure the Center has found to be highly effective. Preliminary tests have yielded positive results in germination of water hyacinth seeds.

Goal: To provide information to other interested parties on composting techniques for invasive weeds.

- A presentation on our project and a demonstration on composting techniques were conducted at the Earth Day celebration held at Texas State University on April 25, 2009. Over 200 individuals observed the demonstration.
- Information about this project was presented at the 12th Annual Texas Recycling and Sustainability Summit in Galveston on August 31, 2009. Over 35 individuals attended this session.
- A presentation was made at Zilker Botanic Garden to the Austin Organic Gardening Association with approximately 60 individuals attending.

- Students from the Organic Gardening course at Texas State University visited the composting facility for a hands-on demonstration and field trip in October, 2009.

Summary

Construction of the compost site took longer than anticipated, resulting in some delay in initiating this project. The original protocol identified to germinate water hyacinth seeds was more difficult to implement than anticipated and did not consistently result in germination of seed. Consequently further consultation with seed bank experts identified a much simpler, and based on preliminary tests, a much more effective protocol for seed germination. The QAPP has been revised to reflect the new protocol.

The oven seed kill tests are progressing well and preliminary indication is that temperatures of 135 degrees F. and higher will kill water hyacinth seeds. The original ratios for feedstock blends consistently produce temperatures in excess of 135 degrees F.

Compost piles are being constructed and maintained. Expectation is that the compost facility will be operating at capacity by the beginning of the water hyacinth flowering season next spring.

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

December 18, 2009

Michael Abbott
Texas State University
River Systems Institute
601 University Dr.
San Marcos, TX 78766-4616

Re: Interim Report Approval: Contract 582-8-77063 Large-Scale Composting System as a Means of Controlling Water Hyacinth

Dear Dr. Abbott:

On December 18, 2009, the TCEQ received a request via email for approval of the **Interim Report**, Task 5.1 of Contract 582-8-77063. The report was reviewed and approved by TCEQ staff.

Thank you for submitting the above referenced deliverable. If you should need clarification or have any questions, please feel free to contact me at (512) 239-6699 or JHigginb@tceq.state.tx.us.

Sincerely,

Jack Higginbotham
Project Manager, Nonpoint Source Team
Water Quality Planning Division
Office of Water

P.O. Box 13087 Austin, Texas 78711-3087 512-239-1000 Internet address: www.tceq.state.tx.us
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Appendix VI.1 – Project Photos

1. Compost Site Before Construction

2. Compost Site After Construction

3. Picture of Newly Constructed Catchment Pond from Compost Pad

4. Carport at the Compost Site

5. Water Hyacinth Growing near the Aquarena Golf Course

6. Water Hyacinth Collection near Sessoms Creek

7. Water Hyacinth Collection near Sessoms Creek

8. Dump Trailer Unloading Chicken Litter from Tyson Foods.

9. Food Waste Pickup from Commons Cafeteria

10. Food Waste from Commons Cafeteria Pile

11. Compost Pile Construction Using Master Recipe

12. Compost Piles using Master Recipe December, 2009

13. Bobcat Blend Earth Day Compost Outreach