Turner Collie & Braden inc.

# GREATER HOUSTON AREA REGIONAL WASTEWATER SLUDGE MANAGEMENT STUDY

June 1995

Prepared for:
Texas Water Development Board
Gulf Coast Waste Disposal Authority
City of Houston
Clear Lake City Water Authority

ENGINEERS • PLANNERS • PROJECT MANAGERS
Texas Austin/Dallas/Fort Worth/Houston Colorado Denver Florida

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STATE OF TEXAS
MARK V. LOWRY
REGISTERED PROFESSIONAL ENGINEER


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Principal

Study results indicated that there are no significant barriers to regionalization from an administrative standpoint. Sufficient authority exists in the current state and federal sludge rules to allow a stand-alone sludge processing facility under separate administrative authority and separate permitting requirements. Administration can be provided through either a public or private entity. Under currently existing authority, Gulf Coast Waste Disposal Authority can administer such a facility, while a privately owned and operated processing facility has been established as this study was being performed.

Technical capabilities to provide the necessary treatment to produce "exceptionally clean" sludges exist and are within the capabilities of current utility personnel to operate. Both composting and lime stabilization represent simple processes with minimal operational controls. Both are capable of producing a consistently safe and usable product which can be redirected from disposal to reuse.

The economic feasibility of regionalized sludge management is such that it is comparable in cost to many current practices. Travel distance and dewatering costs play key roles in determining overall system costs per ton of dry solids treated. Location of regionalized plants in areas of concentrated sludge production has the potential to reduce transportation costs enough to offset increased treatment costs.

Approximately 493 permitted wastewater treatment plants in the Houston area currently serve an estimated 2.2 million people and generate approximately 262 dry tons of sludge per day. It is estimated that by the year 2014 the population in the study area will have increased to 3.2 million with an estimated range of sludge production between 262 and 400 dry tons per day. This wide variation represents both conservative and liberal production estimates. This report presents the results of the evaluation of the administrative, technical, and economic feasibility of regionalization of wastewater sludge treatment facilities in the Houston area. This investigation included coordination with each of the political entities and many of the utility districts in the planning area, the Texas Water Development Board, and the Texas Natural Resource Conservation Commission. Information for this study was obtained through questionnaires, local and state agency records, operating companies, interviews, literature case studies, and manufacturer's information.

## RECOMMENDATIONS

1. Central treatment by either composting or lime stabilization is cost competitive versus land application of liquid sludge or landfilling cake sludges and should be pursued.

2. Composting is more expensive than lime stabilization, but does provide a means of disposing of brush waste for those entities who handle this material. This process should be investigated for cities.

3. Public education efforts should be started to inform the public of the benefits of reuse of biosolids.

4. A market study should be performed to determine customer response to biosolid use.

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The purpose of this study was to evaluate the technical, economical, and administrative feasibility of regionalization of wastewater sludge treatment and disposal in the Greater Houston Area. The examination of regional treatment facilities was a direct result of recent federal and state rule changes regarding the handling and disposal of wastewater sludges. These rule changes shifted the regulatory focus to the production of an "exceptionally clean" sludge, and a reduction in the amount of sludge entering landfills. Although the treatment processes required to treat sludge to the required level are expensive, the unit prices generally decrease as sludge quantities increase. Also, the production of an "exceptionally clean" sludge offers reduced liability, a more favorable public image, and a level of treatment above regulatory minimums as a protection against increased regulatory stringency.

As a result, Gulf Coast Waste Disposal Authority (GCA), in cooperation with the City of Houston (COH) and Clear Lake City Water Authority (CLCWA), applied for a Texas Water Development Board (TWDB) matching fund grant to perform a feasibility study. TWDB approved a grant for 50 percent of the total study with the rest of the money provided locally. The three entities mentioned above each made sizable contributions to project funding. In addition, smaller contributions were made by each of the following entities:

- City of Pasadena
- City of Baytown
- City of LaPorte
- City of League City
- City of Seabrook
- City of Webster
- White Oak Bayou Joint Powers Board
- CNP Utility District

GCA awarded a consulting contract to Turner Collie & Braden Inc. (TC&B) of Houston to perform the study under GCA's supervision. This contract was executed on July 1, 1994. A draft report was to be submitted to TWDB by February 28, 1995 and a final report by April 25, 1995. However, in the interest of producing a meaningful study, a 60-

day extension was requested by GCA and granted by TWDB. Submittal dates were adjusted to May 1, 1995 and July 1, 1995, respectively.

The scope of work that was to be performed in this study, as stated in the consulting contract, included the following items:

1. Coordinate with each of the political entities in the planning area, contact them about the study and its objectives. Ask each entity for information pertinent to the study.

2. Compile information from the TNRCC and the special districts on all treatment plants operating in Harris and Galveston counties. Meet with representatives of the managing entities to review the upcoming regulations, the current treatment processes, methods of sludge disposal, and permitting issues. Discuss the interest in coordinating efforts towards a regional processing facility.

3. Obtain monitoring records from TNRCC and the sludge generators describing sludge composition, type of dewatering facilities (if applicable), and records of any solids-related difficulties. From this information, categorize the sludges and develop groupings for various sludge disposal facilities.

4. Conduct a public meeting of the study participants to discuss the findings of the study to this point.

5. Determine site size requirements and identify three alternative sites for these sludge processing facilities. Project sludge production through 2014 based on population data available and using best available per capita sludge generation rates for this area.

6. Develop a conceptual design/layout for typical sludge processing facilities, based on technical information and site descriptions. Provide a discussion of advantages/disadvantages based on experiences in other processing facilities. Provide a written summary of the rationale used in developing the conceptual design/layout cost information.

7. Describe a distribution and marketing plan including critical evaluation of approaches used in other communities, identification of potential product end-uses, preliminary estimates of possible revenues, and an outline of public education programs.

8. Review current regulations and define the limits of responsibility for sludge generators who provide sludge for additional treatment in permitted sludge processing facilities. Discuss handling of materials determined to be hazardous and develop strategies for handling such materials as they are received at the permitted facility.

9. Develop a routing plan for collection of sludge from the treatment plants for conveyance to these processing facilities.

10. Develop estimated costs, both capital and operating for the facilities. These costs will include the costs for operating and maintenance staff and equipment. Develop projections of cost for disposal by the individual entities for comparison of cost-effectiveness of a regional plan.

11. Identify a plan for administering the regional program on a contract basis with each of the sludge-generating entities.

12. Address regulatory considerations, permit requirements, and permitting strategies.

13. Provide a final report summarizing the findings of the study. Provide a copy of the report to each study participant.

14. Develop a Drought Contingency and Water Conservation Plan. Because drought contingency and water conservation plans have been addressed in previous studies of Harris County, this task will consist of a compilation and reference to this previous work.

## 2.1 Regulatory Background

The current regulatory picture is still one of change and uncertainty at both the state and the federal level. This synopsis of current regulations will focus on each regulatory level separately.

The Environmental Protection Agency promulgated the Code of Federal Regulations Title 40, Subchapter O - Sewage Sludge, Part 503 - Standards for the Use or Disposal of Sewage Sludge Regulations in final form on February 19, 1993, with an effective date of March 22, 1993. These codes are commonly referred to as the 503 rules. However, it is noted that the summary of the rules contained a request that comments and data to be used for Round Two Part 503 rule-making be submitted. This request was made in spite of the fact that the preparation of the current 503 rules took place over a period in excess of 10 years.

The purpose of developing the 503 rules was to establish standards for beneficial use of wastewater sludges that are so stringent they provide the general public with confidence in the process. The ten-year development period included considerable comments from environmental groups and other entities on the need for ensuring public safety by conservative standards. Many of the environmental groups have asked that all sludges be treated to the levels required for unrestricted use to ensure safety.

## 2.2 Permitting

Under the current 503 rules, all sludge management facilities are required to be permitted, either by EPA, or by a state with an approved wastewater sludge program. This requirement could be satisfied by a permit amendment for an existing facility, if additional sludge treatment is to be provided under the auspices of the existing permit. For this situation, the rules require submission of a permit amendment request with the next permit renewal.

For a new facility desiring to start operations, and more specifically a facility not covered by the NPDES permitting requirements, the 503 rules require the submission of a permit application at least 180 days prior to the anticipated start-up of the facility.

## 2.3 Sludge Quality Standards

The 503 rules require compliance with quality standards for pathogens, metals, and vector attraction reduction. For the pathogen requirements, there are two levels of treatment which may be provided, with the higher level of treatment producing a "Class A" material which could be utilized with little or no control over the application area. A somewhat lesser pathogen reduction standard, Class B, is allowed for sites meeting certain site restrictions and obtaining a registration for land application of sludges.

The metals limits are also developed to require very stringent levels for unrestricted use, and sludges meeting these levels are not required to include calculations for cumulative metals loading rates. Ceiling concentrations are established that fix upper limits for acceptance into the land application process. Sludges with metals above the ceiling concentrations are not acceptable for land application. Sludges with metal contents below ceiling concentration but above the lower limit may still be land applied but loading rates must be calculated based on maximum cumulative metals loading allowed.

The final quality requirement concerns the ability of a sludge to form nuisance conditions through attraction of vectors of disease, such as flies and rats. The rules specify certain treatments which must be provided to reduce the attractiveness of sludge to vectors. These rules are particularly important in the predominantly warm, moist Houston area climate. However, in most cases the treatments required to produced materials that are Class A with respect to pathogens are sufficient to meet requirements for vector attraction reduction.

The metals limits of the 503 rules have been successfully challenged in court. The limits were established based on the occurrence of metals such as Molybdenum, Chromium, and Selenium in the sewage sludge study conducted by EPA of sludges nationwide. The courts have ruled that the limits were established based on these occurrences, rather than on health effects, and remanded the rules to EPA for reconsideration. Sources within EPA have indicated the Chromium rule may be abandoned altogether for land application, and the Selenium levels may be eligible for consideration in areas where high levels of Selenium occur naturally in the groundwater and/or surface water. The difficulty with the Molybdenum standard concerns the analysis method. The method specified for use has not yielded consistent results, and further investigation into reproducible methods is continuing. In the meantime, EPA is not reportedly taking enforcement action on Molybdenum violations.

As a further complication, Section 503.6(f) of the current rules specifically excludes sludges containing an amount equal to or in excess of 50 milligrams PCBs per kilogram of solids on a dry weight basis. Sludges with PCB concentrations of less than 50 milligrams per kilogram have been regulated under the 503 rules. A rule proposed in the December 6, 1994 Federal Register (59 Fed Reg 62788) would regulate PCBs under the Toxic Substances Control Act (TSCA). Under this proposed rule, TSCA would classify "PCB remediation waste" as "all environmental media containing PCBs . . . at any PCB concentration". TSCA rules now apply only to wastes containing PCBs equal to or greater than 50 milligrams per kilogram dry weight.

The current state rules are codified in 30 TAC Chapter 312, Subchapters A through G. The state rules, adopted by the Texas Natural Resource Conservation Commission (TNRCC), are similar to the EPA rules, particularly with regard to the sludge quality levels required. The metals limits and the vector attraction reduction requirements are identical to the 503 rules. For the pathogen reduction standards, the limits are the same as those required by the 503 rules with the exception that the 503 rules still allow the use of "Processes to Further Reduce Pathogens" (PFRP), as acceptable technology. Under the TNRCC rules, the portion of the rules allowing the use of PFRP treatments expired March 1, 1994. The rationale used by TNRCC in eliminating the PFRP allowance is that PFRP is a process based standard which requires treatment in a certain manner and assumes that treatment is sufficient to produce an end result material that meets the necessary standards for pathogens. TNRCC prefers testing the end product itself to verify proper pathogen levels for either Class A or Class B materials.

## 2.4 Site Permitting or Registration Under State Rules

The TNRCC 312 rules require that sites processing wastewater plant sludges and sites receiving land applied sludges be either registered or permitted for Class B materials meeting the necessary metals limits and providing vector attraction reduction in the processing. For sludge processing sites co-located on the site of an existing wastewater treatment plant, sludge processing can be accomplished through an amendment to the existing wastewater discharge permit. This amendment would be classified as a major amendment to the permit and would require a public hearing. The process would be managed within the TNRCC by the Watershed Management Division, Permitting Section.

A second option for facility siting is a permitted, stand-alone sludge management facility. An example of such a facility would be a chipped brush and sludge composting operation which is carried out on property not having a valid permit for either the treatment and discharge of wastewater or the disposal of solid waste. This would require the standard permitting activity with the accompanying public hearing requirement. This facility would also come under the purview of the Watershed Management Division, Permitting Section.

A third possibility for siting a facility is in combination with a currently permitted solid waste management facility. This facility would require a registration instead of a permit, although it is within the purview of the Executive Director of the TNRCC to require a permit. The advantage to the registration is that a public hearing is held only if one is requested. This process is handled through the Permits Section of the Municipal Solid Waste Division.

Properties used for land application areas for beneficial use of sludges are also required to be registered prior to receiving sludges for application. If sludges meeting Class A pathogen levels, the more stringent metals levels, and receiving vector attraction reduction treatment are produced, there are no requirements that these sludges be placed on registered or permitted sites. For Class B pathogen reduction sludges that are below the metals ceiling concentrations and have received vector attraction reduction treatment or will receive vector attraction reduction at the site, beneficial land application requires the use of a registered site. The TNRCC rules also require a public meeting of the adjacent landowners, as opposed to a public hearing required of a permitted facility. There are numerous setback distances which must be observed as well.

There has been considerable interest shown both by the TNRCC and by the Texas Legislature in amending the sludge management rules. The Legislature's version was prepared to induce the TNRCC to pull back to the levels of regulation provided by the 503 rules, and to remove the additional requirements imposed by the TNRCC in their current Section 312 rules. The primary focus of the Legislature's version was to remove the requirements for permitting and allow the use of registration for all sludge management activities covered under the 503 rules, to allow the use of PFRP in lieu of specific pathogen determinations, and to remove the requirement for public meetings but require notification of the County Judge. The adjacent landowners would still have the option of requesting a public meeting under the terms of the current bill. The legislation also established maximum times for consideration of registration requests in an attempt to speed up the registration process.

This legislation did not pass. However, TNRCC published proposed changes to the Section 312 rules in the May 5, 1995 Texas Register. These proposed rules do allow the use of PFRP and also require monitoring, but do not set limits for molybdenum, other than the ceiling concentration. In addition, TNRCC published proposed composting rules on June 20, 1995, providing additional clarification of the requirements for permits and registrations for processing facilities. These rules also clarify the requirements for air quality permits and specify operational requirements for air quality standard permit authorization. Both the above noted proposed rules are moving through the adoption process and are not currently in effect. While the regulatory picture contains some uncertainty, the current regulatory climate is one of review and retrenchment rather than a gradual tightening or increasing stringency of the requirements. The prevailing mood of both the state and federal elected officials is one of requiring risk based standard setting and not imposing unfunded mandates. Congress is considering bills to establish a moratorium on new regulations to give the states an opportunity to catch up to the myriad of rules already established. The State Legislature is acting on the bill referenced above to prevent unnecessary deviation from the federal rules in the state rule making process. All of the actions seem to indicate that the current regulatory picture is a realistic one with regard to making decisions on costs of treatment based on current requirements. The only major obstacle that could be foreseen at this time is the possibility of finalization of the TSCA proposed rule regulating all materials with any determinable concentration of PCBs as a regulated waste under TSCA.

## 2.5 Regulatory Enforcement

The total regulatory analysis picture would be incomplete without a view of the overall management picture for wastewater in Texas. Currently, the TNRCC regulates wastewater treatment plants through permitted discharge limitations and through plant inspections performed by TNRCC district office personnel. The current funding levels for regional inspectors have been severely curtailed, and the end result of the cutbacks is for the remaining field personnel to concentrate on the larger dischargers. The rationale for this is that the inspectors will cover a higher percentage of the total wastewater flows with less travel and less time than it would take to cover all of the smaller plants. However, the TNRCC records show that many of the smaller plants have significant problems that need to be addressed. First and foremost among these is the solids management practices in some small plants. As the regulatory emphasis in the 1980's was focussed on the effluent, the small utilities concentrated on removing solids from the effluent and disposing of them in whatever manner was available. Solids inventories were carefully scrutinized to ensure that sludge would not be carried over the weirs in the event of a rainfall event. However, the EPA 503 Rules and TNRCC Section 312 Rules tightened up the requirements for solids disposal and increased the cost of such disposal significantly. As a result, small utilities are much less likely to waste sludge on an as-needed basis because the sooner they fill up the digester, the sooner they will have to pay someone to dispose of the sludge. At the same time, the decrease in inspections has caused the fear of being caught discharging high solids effluent to diminish. As a result, TNRCC records show a decrease in compliance to the point that 50% or fewer of the smaller plants inspected are in substantial compliance at the time of inspection. As a result, solids are once again being maintained in inventory long after their usefulness has diminished and more solids are going over the weir to prevent the utility from having to pay sludge disposal costs.

Current disposal/reuse methods for small producers are limited to a single option of land application. Plants producing liquid sludges without dewatering facilities cannot take their sludges to landfills because materials going to landfills must contain no free liquids. As a result, the smaller producers must demonstrate that Class B pathogens levels are met by testing. They must also show that vector attraction reduction is met, usually through Specific Oxygen Uptake Rate, or SOUR, testing. If compliance is not achieved through digestion in the plant, the only other alternative currently available is chemical stabilization. Concern has been expressed about the ability of many small plants to achieve adequate SOUR levels with 15 days or less digestion time when pilot scale test in the larger plants indicate that digestion times of 30 days and longer are required.

Establishment of one or more regional sludge processing facilities would potentially assist the TNRCC and other regulatory agencies by providing fewer locations to inspect where sludges are being processed for final disposition. Easy access to a cost competitive facility that would also provide some limitation of liability would encourage participation by smaller utilities. Regionalization of sludge processing facilities would increase the reliability and consistency of the final product. The use of chipped brush in the composting process would also help achieve state legislative goals for diversion of materials from the solid waste stream.

### 3.1 Existing Populations and Treatment Facilities

The study area contains an estimated 493 permitted wastewater treatment plants serving an estimated population of 2,200,986 (1990 census). *Table 3.1* summarizes the average daily flows and the total population served by different classifications of wastewater plants in the study area.

***Table 3.1*** **- Treatment Plant Sizes and Populations Served**

| Average Daily Flow (MGD) | Number of Plants | Population Served | Percent of Total Population |
|---|---|---|---|
| 5 and above | 9 | 1,119,272 | 50.8 |
| 1.0 to 5.0 | 32 | 431,174 | 19.7 |
| 0.5 to 1.0 | 50 | 229,044 | 10.4 |
| 0.3 to 0.5 | 52 | 169,436 | 7.6 |
| 0.15 to 0.3 | 63 | 129,864 | 5.9 |
| 0 to 0.15 | 287 | 122,196 | 5.6 |
| **Total** | **493** | **2,200,986** | **100** |

### 3.2 Data Sources

Several sources of data were available for use in determining quantity, quality, and spatial distribution characteristics of sludge currently being produced in the Greater Houston Area. It would have been preferable to use data reported to the TNRCC by the treatment plants. However, according to the current sludge management rules, only those plants with flows equal to or greater than 1 million gallons per day (mgd) are required to collect sludge management data and report it to the TNRCC. As the table above shows, only 41 of the 493 facilities is thus required to provide annual sludge management reports to the TNRCC. While this number is small in comparison to the total number of permitted facilities, it represents approximately 88 percent of the total amount of sludge generated in the study area.

Therefore, the following main sources of sludge management data were considered. The first of these sources was a direct questionnaire distributed to the study participants. There were approximately 40 questionnaires sent and 35 were returned. Of those questionnaires returned, 22 were from facilities with flows greater than or equal to 1 mgd. A sample questionnaire is shown in *Figure 3.1*. This data was used to determine the quantity and quality of the sludge from each given entity and also to develop per capita sludge production rates.

The second source was a database obtained from the City of Houston Health Department, Public Health Engineering Section (COH). The COH has maintained this database of sludge production and disposal information for municipal utility districts within the City's Extra Territorial Jurisdiction (ETJ) since 1988. This data is collected quarterly by calling the responsible party for each district and requesting the sludge information that would normally be kept in the permittee's self-reporting files. A sample data record from this database is shown in *Figure* 3.2. The column headings of QTR_FLOW, MON_FLOW, and REP_FLOW refer to quarterly, monthly, and daily flows in million gallons. AVE_FLOW is permitted average daily flow in million gallons per day. Numbers shown in the sludge column represent total sludge hauled during the quarter being reported.

Population data comprised the third major data source. The population data used came from the (TNRCC) water system database and the 1990 census. The TNRCC water system database included the estimated population served by many of the utility districts in the study area. Where no TNRCC population estimates were available, 1990 census data provided population by census tract. This census tract data was then allocated to district boundaries using a Geographic Information Systems (GIS) database developed previously.

### 3.3 Sludge Production Estimates

Current sludge production within the study area was calculated directly from data reported in the questionnaires. For all other entities, production was estimated using the COH database where information was available and with population data and the calculated per capita sludge generation factor, otherwise. A summary of the sludge estimation methods and number of entities for which they were utilized is shown in

*Figure 3.1* - Sample Biosolids Questionnaire

**Wastewater Biosolids Questionnaire**

Entity Name: ______________________________

Contact Person/
Representative: ______________________________

Contact Address: ______________________________

______________________________

Contact Phone
Number: ______________________________

Questionnaire:

1. What is the estimated population served by your plant? ________
2. What is the average daily flow in MGD? ________
3. What is the design capacity of your plant in MGD? ________
4. What is your sludge production rate in Gal/day? ________
5. What is the solids percentage of your sludge? ________
6. Are your sludges currently being :
   a. Landfilled? Yes No

      Landfill Name ____________

   b. Land applied for beneficial use? Yes No

      Site Registration # ____________
7. Does your sludge meet requirements under the 40CFR 503 rules for:
   a. Class A or Class B pathogen reduction? Yes No Unk
   b. Pollutants? Yes No Unk
   c. Vector attraction reduction? Yes No Unk

*If the answers to 6 a, b, or c are No or Unknown, please provide a copy of the most recent analysis for metals or other pollutants, as well as a brief description of the treatment process, including detention times.*

Please send responses to: Turner Collie & Braden Inc.
P.O. Box 130089
Houston, Texas 77219-0089
Attn: Mark V. Lowry, P.E.

*Figure 3.2 - Sample Record from the City of Houston Database*

| PERMIT_NO_ | PERMITTEE | METH_DISP | SLUDGE | QTR_FLOW | MON_FLOW | REP_FLOW | AVE_FLOW | OPERATOR | TREATMENT | O_PHONE | FACILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 106840 Gal | 31.180 | 10.393 | 0.346 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 65520 Gal | 35.032 | 11.677 | 0.389 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 204120 Gal | 41.803 | 13.934 | 0.464 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 0 None | 43.667 | 14.556 | 0.485 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 191100 Gal | 33.840 | 11.280 | 0.376 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 0 None | 34.216 | 11.405 | 0.380 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 109200 Gal | 37.444 | 12.481 | 0.416 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 109200 Gal | 37.444 | 12.481 | 0.416 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 0 None | 36.630 | 12.210 | 0.407 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 218200 Gal | 37.037 | 12.345 | 0.412 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 109200 Gal | 37.444 | 12.481 | 0.416 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 0 None | 37.444 | 12.481 | 0.416 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 245700 Gal | 30.870 | 10.290 | 0.343 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 147420 Gal | 31.213 | 10.404 | 0.347 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 120120 Gal | 31.566 | 10.519 | 0.351 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 255900 Gal | 31.556 | 10.519 | 0.351 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 0 None | 31.213 | 10.404 | 0.347 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 157140 Gal | 32.213 | 10.404 | 0.347 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | No report | | | | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |
| 11799-001 | Harris Co. MUD #082 | Wet Haul | 0 None | 0.000 | 0.000 | 0.000 | 1.100 | Am-Tex Corp. | Extended Air | 876-3636 | HCMUD 082 |

*Table* 3.2. It should be noted that the number of facilities represented in this table is less than the total number of permitted facilities in the region. This is a result of regionalization already being practiced, where sludges from multiple permitted plants are piped or trucked to a regional treatment plant for further treatment and reuse or disposal from there.

***Table 3.2* - Summary of Sludge Estimation Methods**

| Estimation Type | %of Total Sludge Prod. | Number of Entities |
|---|---|---|
| Calculation using questionnaire data | 84 | 30 |
| Estimated from COH database | 10 | 113 |
| Estimated using TNRCC population data | 1 | 104 |
| Estimated using density based population | 5 | 201 |
| **TOTAL** | | **448** |

As seen in *Table* 3.2, sludge production estimates were determined from questionnaire data and COH data for a total of only 143 facilities. In terms of overall production; however, the majority of the sludge produced was determined based on this reported data. Sludge production estimates using the COH data were developed by calculating an average quarterly amount using the most recent period of four consecutive quarters for which data was reported. This was done to account for the entities that do not dispose of sludge every quarter. With the wet quantity and the sludge handling method known, a sludge amount in dry pounds per quarter was estimated. This was accomplished by assuming standard values for percent solids coming out of each sludge handling process. *Table* 3.3 summarizes the percent solids assumptions that were utilized. These percentages were obtained in discussions with utility operations companies and plant personnel and were verified with information contained in the EPA handbook entitled *Sludge Treatment and Disposal*.

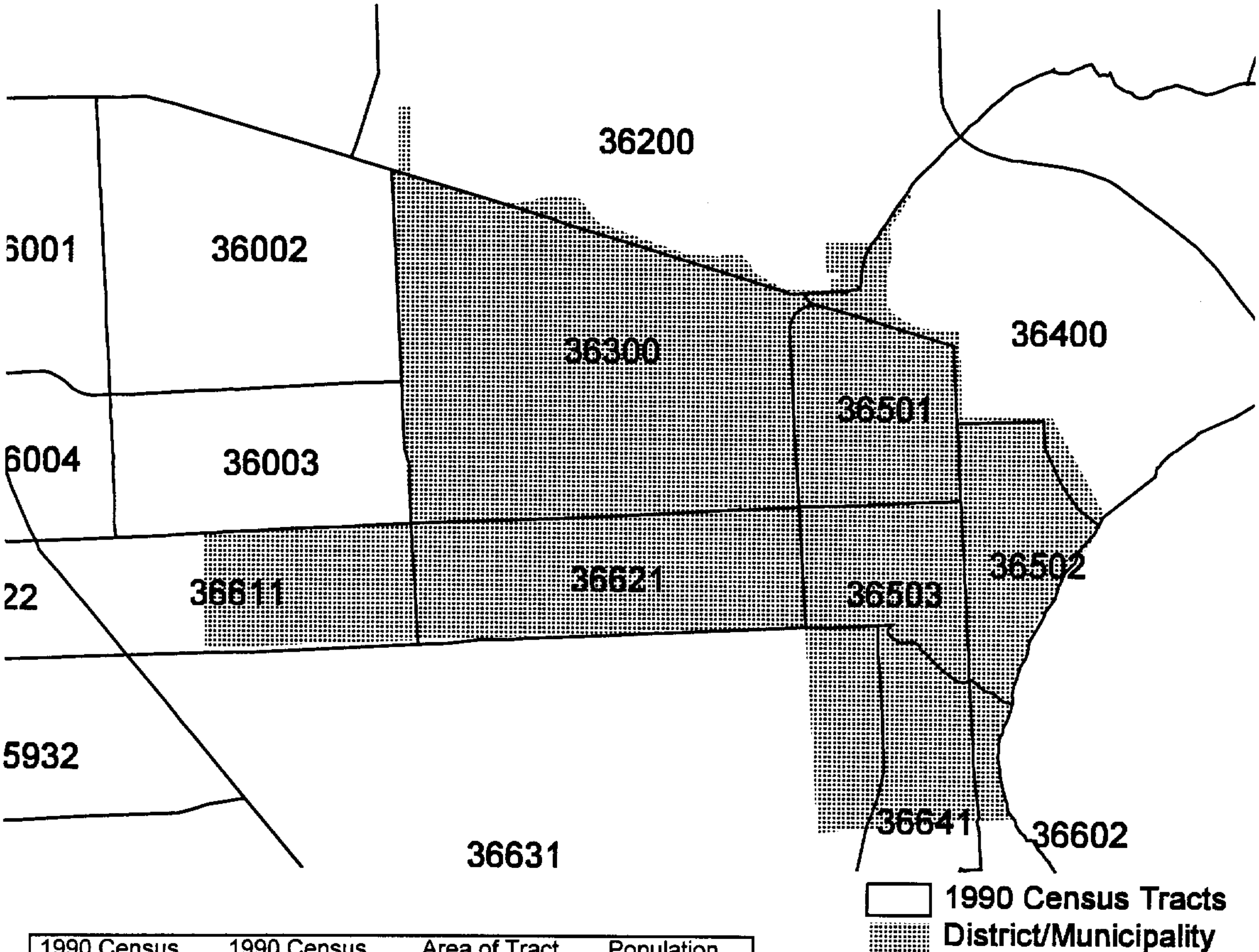
*Table 3.3* - **Percent Solids for Different Sludge Handling Processes**

| Process Name | Percent Solids |
|---|---|
| Sludge Concentrator | 7.0 |
| Centrifuge | 10.0 |
| Vacuum Filter | 20.0 |
| Belt Press | 16.0 |
| Drying Beds | 20.0 |
| Vacuum Drying Beds | 20.0 |
| Wet Haul | 2.5 |

Where data from the COH database was not available, sludge production was estimated using the population of each entity. Population data were derived either from the TNRCC water system database or from density based calculations using 1990 census tract data and the GIS to establish composite population densities within each entity. *Figure 3.3* illustrates an example density based population calculation.

The populations determined were then multiplied by the estimated per capita sludge production rate of 0.08 dry pounds per day to determine total sludge production for each entity. The methodology used to determine the per capita sludge production rate is illustrated in *Figure 3.4*. Analysis of the data reported through the questionnaires and from the City of Houston data base provided a range of numbers for per capita sludge generation. The larger cities and districts reported data that provided per capita generation rates ranging from 0.15 to 0.25 pounds per capita per day. Data from some of the smaller facilities, however, indicated generation rates comparable to the calculated rate determined in this exercise. Since feasibility of a regionalized facility depends greatly on the amount of sludge processed, underestimation of the amount of sludge produced would not adversely impact the cost analysis. If a facility were to be constructed in an area where the available sludge was overestimated, however, the reduction in throughput could result in a potentially significant cost impact. Since the intent of the study was to provide small facilities with upgraded treatment possibilities, the per capita generation rate calculation

# Figure 3.3 - Sample of Density Based Population Estimate from GIS




| 1990 Census Tract No. | 1990 Census Population Density (cap/ac) | Area of Tract Within District (ac) | Population (Density*Area) |
|---|---|---|---|
| 36002 | 3.348 | 16.21 | 54 |
| 36003 | 4.348 | 15.02 | 65 |
| 36200 | 0.002 | 256.33 | 1 |
| 36300 | 1.769 | 3917.66 | 6930 |
| 36400 | 0.161 | 280.41 | 45 |
| 36501 | 1.248 | 1031.06 | 1287 |
| 36502 | 3.649 | 841.58 | 3071 |
| 36503 | 2.312 | 774.49 | 1791 |
| 36602 | 4.705 | 135.26 | 636 |
| 36611 | 3.001 | 863.78 | 2592 |
| 36621 | 4.772 | 1611.01 | 7688 |
| 36641 | 1.371 | 554.84 | 761 |
| | TOTAL | 10297.66 | 24921 |

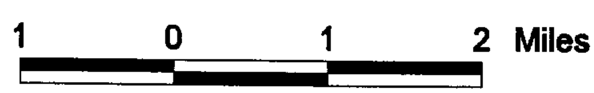
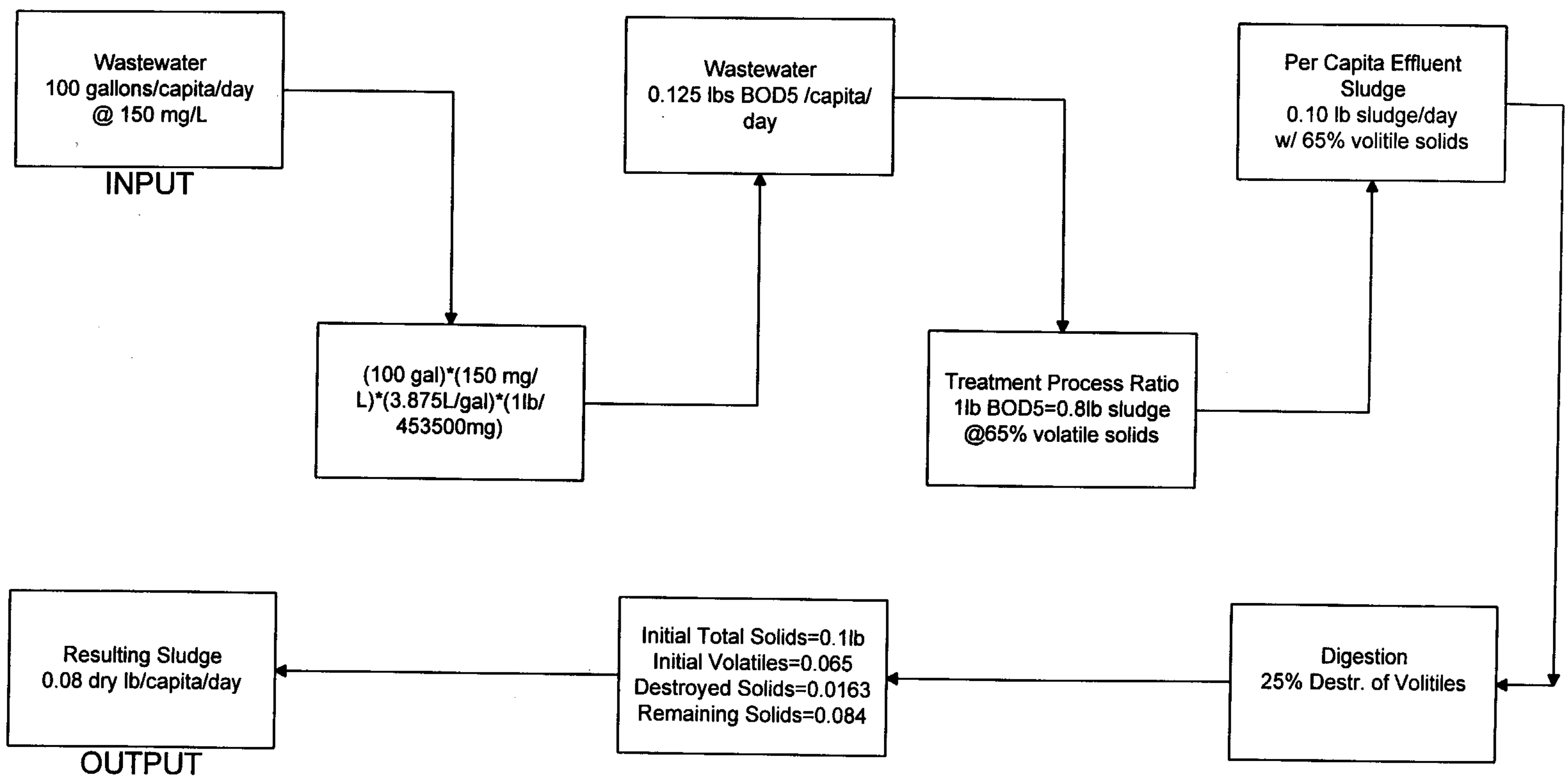


*Figure 3.4* - **Methodology for Determining the Per Capita Sludge Production Rate**



shown previously was used to ensure that at least the amount of sludge calculated would be available for treatment in each regional facility.

Total estimated daily sludge production for the study area was determined by adding the estimated productions from each entity. The resulting sum indicated a total daily sludge production of 262 dry tons. Exhibit 1 shows the approximate contribution of each area in terms of daily sludge production, with color coding for different ranges of daily production in total dry pounds. For the City of Houston, the shaded areas represent the wastewater collection service areas of the regional sludge processing facilities. While sludges are generated at all city plants, only the regional plants produce sludge for final disposal or reuse.

### 3.4 Sludge Quality Characteristics

Successful reuse of wastewater sludges requires a high quality product that is acceptable to the general public. The treatments investigated as candidates for regional processing facilities provide the necessary reduction of pathogenic organisms and the needed treatment to reduce the attractiveness of sludge to rats and flies by reducing or eliminating odors and suitable breeding conditions. The third area of interest regulated under both the state and federal sludge rules is content of metals. The metals content of sludge is of concern because of the possibility for these metals to move from the sludge into plant tissue and be taken up in products that eventually find their way into the food chain. Control of metals content to extremely low levels to prevent uptake into the food chain is a cornerstone of the 503 sludge rules. Sludges which meet the highest standards for pathogen removals, the most stringent metals limits, and provide vector attraction reduction treatment are suitable for uncontrolled use and provide the highest level of assurance to the public.

It was anticipated that sludge quality data would be readily available for review since it is required for land application for beneficial use. However, it was determined that such data was not reported to the TNRCC by any systems of less than 1 mgd flow. In addition, many of the cities are taking their sludges to landfills instead of land application sites. Sludges hauled to the landfills are required to be tested for metals only to the extent that they demonstrate they are not hazardous wastes. They are not required to test for all of the metals listed in the federal and state sludge rules for land application for beneficial use.

While the metals content results were not as extensive as hoped for, there are numerous indications that the majority of the sludges would be candidates for land application programs. The cities in the area do have active industrial waste pretreatment programs in place, which does limit the amount of metals that can be discharged into the municipal wastewater system. As an example, the City of Houston's program has resulted in significant reductions at the Almeda Sims plant to the extent that sludges which previously did not meet the land application criteria are now acceptable. Additional testing will be required for those cities that do not have specific metals test data.

In terms of numbers of systems, as indicated previously, the cities and large flow dischargers comprise a small portion of the total number of systems, but a large portion of the total sludge quantity produced. By contrast, municipal utility districts comprise the majority of the permitted wastewater dischargers. These districts consist primarily of restricted residential housing communities that serve little, if any, industry and, therefore, would not be expected to have significant amounts of metals in their wastewater and, ultimately, in their wastewater sludge. This generalization was proven, to a limited degree, based on data summaries supplied by one of the major utility operations companies. Their data indicated that of 60 facilities they operated, only two facilities had any difficulty with the metals limits in their sludges. Both were commercial districts that were not typical of residential development. The other indication is that most of the sludges produced by the utility districts are currently being land applied to agricultural land. As such, the sludges are required to meet at least the ceiling concentration requirement for metals for such beneficial use.

### 3.5 Future Sludge Production Estimates

As a part of the study, future sludge production through 2014 was estimated for the service areas of the proposed facilities. This was accomplished by using the population growth estimates of both the TWDB and the Center for Public Policy (CPP) at The University of Houston.

The estimates from TWDB were included in the *Draft 1994 Consensus Texas Water Development Board Population Projections*. A copy of this report was supplied to TC&B by TWDB on December 9, 1994. The report contained population growth estimates for all of the cities within the study area as well as for the unincorporated areas in each county.

The CPP received a grant from the U.S. Department of Education, the City of Houston, and other agencies to conduct a study to produce population and employment growth projections in Harris County and the surrounding counties. These were long-term projections based on methodology accepted by a technical review committee. The projections were done at the census tract level. This higher level of detail provided more reliable projections on the smaller scale than did the TWDB material. These projections were especially useful for estimates in unincorporated areas.

*Table 3.4* shows a comparison of the county-wide population projections from TWDB and CPP for Harris and surrounding counties. As can be seen from the comparison, the two projections differ significantly in some counties. However, the counties of primary interest in this study, Harris, Brazoria, and Galveston differ by only 0.5 percent, -0.1 percent, and 9.3 percent, respectively for 2010. This difference was considered to be acceptable for the study purposes. Since the numbers represented by the CPP were broken down into smaller areas that were more readily usable, the CPP population estimates were chosen for this study.

Population growth estimates were prepared for the entities within the service areas of each of the proposed sites. Projections for 2014 were used to estimate the sludge production in the future. Sludge quantities were estimated by multiplying the estimated incremental increase in population for each area by the estimated sludge generation rate per person of 0.08 lb/day. The amount of sludge projected by this method was then added to the current sludge production allocated to that same area. Again, it is recognized that this generation rate is lower than the rates reported by the larger cities. However, it does provide a conservative value for determining regionalization feasibility. If the purpose of the study had been to assess the overall magnitude of the possible sludge disposal problem in future years, a higher generation rate would have been used.

## Table 3.4 - Comparison of CPP and TWDB Population Estimates for Harris and Surrounding Counties

| County Name | 1990 | 1993 | 1994 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BRAZORIA** | | | | | | | | | | | |
| CPP | 191,707 | 198,116 | 200,304 | 202,543 | 222,273 | 241,962 | 263,416 | 279,779 | 297,414 | 316,443 | 336,987 |
| TWDB | 191,707 | | | | 227,929 | | 263,258 | | 303,383 | | 355,395 |
| Comparison | 0.0% | | | | 2.5% | | -0.1% | | 2.0% | | 5.2% |
| **FORT BEND** | | | | | | | | | | | |
| CPP | 225,421 | 250,543 | 259,522 | 268,824 | 334,165 | 411,272 | 505,935 | 590,428 | 683,080 | 790,456 | 913,912 |
| TWDB | 225,421 | | | | 307,920 | | 412,765 | | 545,413 | | 704,684 |
| Comparison | 0.0% | | | | -8.5% | | -22.6% | | -25.2% | | -29.7% |
| **GALVESTON** | | | | | | | | | | | |
| CPP | 217,399 | 221,520 | 222,946 | 224,403 | 236,648 | 248,526 | 260,936 | 270,434 | 280,278 | 290,480 | 301,047 |
| TWDB | 217,399 | | | | 249,048 | | 287,678 | | 335,000 | | 383,957 |
| Comparison | 0.0% | | | | 5.0% | | 9.3% | | 16.3% | | 21.6% |
| **HARRIS** | | | | | | | | | | | |
| CPP | 2,818,199 | 2,900,308 | 2,928,202 | 2,956,366 | 3,207,736 | 3,443,890 | 3,689,627 | 3,855,205 | 4,028,132 | 4,208,811 | 4,397,569 |
| TWDB | 2,818,199 | | | | 3,217,689 | | 3,707,869 | | 4,315,000 | | 4,667,749 |
| Comparison | 0.0% | | | | 0.3% | | 0.5% | | 6.6% | | 5.8% |
| **LIBERTY** | | | | | | | | | | | |
| CPP | 52,726 | 54,071 | 54,526 | 54,985 | 59,771 | 66,872 | 76,056 | 89,335 | 104,155 | 121,438 | 141,588 |
| TWDB | 52,726 | | | | 58,738 | | 66,053 | | 75,000 | | 85,158 |
| Comparison | 0.0% | | | | -1.8% | | -15.1% | | -38.9% | | -66.3% |
| **MONGOMERY** | | | | | | | | | | | |
| CPP | 182,201 | 201,710 | 208,674 | 215,871 | 284,269 | 357,729 | 439,174 | 516,895 | 602,374 | 701,989 | 817,892 |
| TWDB | 182,201 | | | | 252,890 | | 329,131 | | 419,954 | | 522,783 |
| Comparison | 0.0% | | | | -12.4% | | -33.4% | | -43.4% | | -56.4% |
| **WALLER** | | | | | | | | | | | |
| CPP | 23,390 | 24,342 | 24,668 | 25,000 | 27,787 | 34,488 | 42,781 | 52,893 | 64,139 | 77,775 | 94,310 |
| TWDB | 23,390 | | | | 28,260 | | 36,337 | | 44,071 | | 52,016 |
| Comparison | 0.0% | | | | 1.7% | | -17.7% | | -45.5% | | -81.3% |

## 4.1 Data Sources

The principal data source used in the sludge routing analysis was a commercially available GIS street network coverage of the study area. This coverage was used to find the shortest road distance path from a sludge production point to the proposed regional sludge handling/disposal sites. The sludge production point was taken as the nearest street network node from the location of the plant or the centroid of the city or utility district service area, if the plant location was not known.

Alternative sludge handling/disposal sites were theoretically located in areas of concentrated sludge production with the idea of minimizing the haul distances. However, it is recognized that a sludge facility should probably not be located in densely populated areas, so a GIS land use coverage developed for the City of Houston and Harris County was also utilized. Sludge processing facilities were sited in large undeveloped or industrial land use areas as close to the center of the sludge production area as possible. *Exhibits 2, 3,* and *4* show the approximate processing facility location, as well as the land use surrounding it. These locations are in general conformance with the siting criteria for municipal solid waste management facilities contained in the *City of Houston Citizen Advisory Committee on Solid Waste Disposal Solutions Report*. *Exhibits 5, 6,* and *7* show the boundaries of the sludge producing areas contributing to the site, as well as the haul route from each contributing wastewater plant to the regional sludge processing facility. It should be noted that the proposed sludge processing facility locations are general locations only and it is not intended to imply that a detailed siting analysis was performed for this study.

## 4.2 Process Considerations and Assumptions

As noted previously, the current sludge rules contain three separate requirements for sludge quality. These three requirements include maximum levels of metals for unrestricted use and ceiling concentrations for restricted use for metals, maximum levels for pathogens, designated "Class A" or "Class B" for pathogens, and vector attraction reduction treatments. The purpose of this study is to determine if regionalization results in sufficient economy of scale savings to allow the sludge to be collected from smaller facilities, treated to a higher standard, and used in an uncontrolled manner for beneficial reuse.

In order to meet the requirements for uncontrolled use, sludges must meet the "clean sludge" limits, meaning the metals content is so low there is no possibility of metals accumulating in the food chain. As noted previously, removal of metals once they are in the sludge is not cost effective. They must be eliminated from the source if the sludges produced are to be applied to beneficial reuse. In addition, the limited data available indicated that the majority of sludge in the study area appears to be suitable for use from a metals standpoint. As a result, regional sludge processing facilities would not include metals removal.

There are a number of different techniques that can be used to produce a material that meets the "Class A" pathogen levels required for uncontrolled use. These techniques include various types of heat treatment, including heat drying, composting, and chemical stabilization with and without supplemental heat. A literature search was conducted to determine the advantages and disadvantages of each type of treatment, as well as the minimum throughput needed to minimize the cost per unit treated.

Many of the techniques investigated were capital intensive processes that were used in areas where land cost is high and additional construction dollars are used to minimize the amount of land needed. For this application, those processes including in-vessel composting and some types of heat drying were excluded. An analysis of the sludge available indicated that there would be approximately 25 to 30 dry tons per day available to the proposed location to the southeast (*Exhibit* 2 and 5) and approximately 15 dry tons per day for the locations investigated to the northwest (*Exhibits 3, 4, 6,* and *7*). In addition to the above criteria, operational experience in Texas was also used as a screening requirement for inclusion as a valid technology.

As a result of the above analysis, two processes were selected for further evaluation as regional processing facilities. Both processes are currently in use in Texas in sludge processing applications. Both processes are capable of producing sludges that meet the requirements of the "Class A" pathogen levels. Both processes also meet the requirements for vector attraction reduction treatment techniques within the same treatment scheme that produces the "Class A" pathogen levels.

The first of the two processes involves composting of the sludge with a bulking agent. Composting is an aerobic decomposition process which uses naturally occurring bacteria to break down the organic compounds in the sludge, and releases carbon dioxide and water vapor as breakdown products. While this process occurs naturally, it must be carefully managed to maintain aerobic conditions throughout the processing unit. The purpose of the bulking agent is to provide a structure that prevents the sludge from compacting and sealing portions of the materials away from the oxygen necessary to maintain aerobic conditions. Where oxygen is not provided as needed, the process turns anaerobic with the release of unwanted noxious odors. The higher the volatile content of the sludges being processed, the higher the rate at which oxygen is utilized, and the greater the probability of developing anaerobic conditions.

The composting method chosen for investigation consists of two phases. The first phase uses the aerated windrow process to provide the volume of air needed to maintain aerobic conditions. The sludge is mixed with chipped wood waste at a ratio of one part sludge to two parts wood chips by volume. This ratio is approximate only, as the desired sludge/wood chips mixture is approximately 50 percent solids by weight. As a result, the ratio must be adjusted to accommodate the moisture content of both the sludge and the wood chips on an ongoing basis.

Control of nitrogen content is also important in reducing the possibility of forming and releasing ammonia to the atmosphere. Some adjustment in relative materials volumes may be required to provide the proper mix from a nitrogen standpoint as well. Incoming sludge and wood chips are blended at a receiving station and arranged into windrows of approximately 20 feet across at the base, 7 feet high in the center, and 6 feet across at the top, and in the shape of a trapezoid. This windrow is formed over perforated plastic pipe, with the length of the windrow depending upon the volume of materials to be started in the composting process.

A number of bulking agents can be used to provide the necessary void space needed for the process. Certain types of agricultural waste, such as rice hulls and corn shucks and shredded mixed municipal solid waste are potential candidates for bulking agents, but control of the void space is difficult for these products and the potential for growth of odors is greater. Wood chips have been used successfully by the two operating composting facilities in Texas and have been readily available for several reasons. Recent goals for landfill tonnage reductions set by the Texas Legislature have emphasized removal of yard waste and tree trimmings from the solid waste stream. The intent of the reduction goals is to see this material recycled and not landfilled. However, in order to prevent nuisance conditions, brush and tree trimmings must be chipped or shredded to prevent development of rodent harborage conditions. In addition, the moisture content and volatile solids content of brush after chipping make it difficult to compost without adding water. As a result, many cities are looking for alternative ways to dispose of their brush waste. Pallets and other untreated lumber products can also be chipped to provide the necessary bulking agent for composting operations.

As a result of the above noted sources, the wastewater sludge composting operation at Brazos River Authority's Temple-Belton Regional Sewerage System (TBRSS) has seen an excess of available bulking agent to the point that they are trying to compost some of that material separately. In addition to the tree trimmings and brush, untreated wood wastes such as pallets and wooden packing materials of all descriptions can also be successfully reduced to chips in modern tub grinders. For regional sludge processing facilities whose customers are primarily cities with responsibility for collection of yard waste and tree trimmings from power line and right-of-way maintenance, the development of composting can provide an additional benefit to these customers by providing them with a ready means of brush and wood waste disposal.

Aeration for the aerated windrow process is provided by blowers which are capable of reversing the flow of air into the pile. Air can either be forced into the windrow by maintaining pressure on the perforated pipe and forcing the air into and through, or by connecting the plastic pipe to the intake of the blowers and drawing air through from the outer edges of the pile to the perforated pipe at the bottom. This air reversal is an important component of the odor control process within the pile as the partially treated compost acts as a biofilter to stabilize or remove odors before they can be exhausted to the atmosphere.

In addition to providing the necessary structure to maintain aerobic conditions, the wood chips also provide the necessary bacteria to begin the process. The final step in compost production is screening of the product. The wood chips that have not broken down sufficiently to pass through the screen are removed and recycled to begin the composting process again. Recycled chips amount to approximately 30 percent by volume of the total amount of chips needed. They also contain sufficient bacterial activity to start the process with little lag time.

Once the process is started, temperature within the pile rises to levels of 55 degrees C (130 degrees F) and higher and pathogens are killed by the heat. Processes operating at temperatures in the range from 45 to 75 degrees C are known as thermophilic processes. The heat generated is sufficient to kill weed seeds, including common undesirable tomato and squash seeds. The current EPA 503 rules require a ceiling level for indicator organisms and either no more than a specific number of pathogens per weight of material, or treatment under specific conditions for a specified period of time. The latter process is referred to as "Processes to Further Remove Pathogens", or PFRP. For composting, treatment to levels acceptable as PFRP requires material in an aerated static pile to achieve temperatures of 55 degrees C (130 degrees F) for at least three days, with temperatures monitored throughout the pile. Current TNRCC Section 312 rules require monitoring of pathogen levels and do not permit the use of PFRP as an alternative, although new rules are proposed to restore the PFRP alternatives.

Although the requirements for PFRP require only three days at the 55 degrees C (130 degrees F) temperature, there is some lag time before the proper temperature is reached. In addition, there will be considerable variation in sludge quality and possibly sludge moisture content in the incoming sludges. Weather conditions can also play a role, as well as the need to recycle greater amounts of composted product to use as a blanket to retain heat or to start a sluggish process. As a result of the above uncertainties, and based on operational experience of the TBRSS facility, a total processing time in the aerated windrow process of 28 days was chosen. This is a conservative number and may be reduced as operational experience is gained.

In addition to the aerated windrow treatment, the second step in the proposed process is conventional windrow composting. When used following the aerated windrow treatment, activity in the compost is generally reduced and this results in somewhat lower temperatures in the pile. This corresponds to mesophilic treatment, in the range from 20 to 45 degree C, although initial temperatures will be above this range. In this step, the same size and shape piles are placed on uncovered concrete pads and aeration is provided by a commercially available compost turner. This equipment consists of a travelling bridge which straddles the compost pile. Rotating equipment under the bridge turns and "fluffs" the compost to ensure adequate aeration. After successful completion of the aerated windrow portion of the process, the oxygen demand of the compost is reduced to the point that the necessary oxygen can be provided by this process. Compost is turned on an as needed basis to maintain aerobic conditions and temperatures are again recorded to determine the approximate rate of biological activity within the pile.

Repeated turning and bacterial action use up the organics in the waste and result in lower temperatures in the pile. When activity is reduced sufficiently, the compost is moved from the windrow stage to storage in static piles without aeration. The net effect of the staged treatments and the static pile storage is an approximate 50 percent reduction in volume over the initial volume of the sludge and wood chip mixture. For a facility processing 25 dry tons of 16 percent solids sludge per day, the initial windrow volume will be approximately 370 cubic yards, or the volume of the wood chips alone. The volume of sludge, based on operational experience with both the City of Austin and TBRSS, is taken up in the void spaces within the wood chips and does not result in a volume increase when added to the chips. After the approximate 50 percent volume reduction provided in the treatment train, the expected output of the planned facility would be between 175 and 200 cubic yards of final compost product per day.

*Figure 5.1* depicts a conceptual compost facility design layout with the necessary areal dimensions to provide a throughput of approximately 25 tons of dry solids sludge at 16 percent solids content per day. As noted above, the detention times in each area are sufficiently conservative to allow for variations in compost processing and the two stage process allows operational flexibility to experiment with different process variations for different end uses. Compost produced for home gardens and tender vegetation may require additional processing to produce a very low bacterial activity prior to release. On the other hand, compost produced for vegetation establishment on highway road shoulders and embankments may require less preparation before release.

Another critical factor that should be accounted for is set back distances or buffer zones. The proposed layout shows only the process requirements of the facility and does not establish buffer zones. However, at the present time there are no specific buffer zones established for composting facilities. Buffer zones which are established for other wastewater treatment components generally refer to set back distances from occupied residences and office buildings. For this study, the proposed site locations selected were located in industrial or agricultural areas not currently used for residences or office buildings. It would be necessary to either secure additional property to prevent residences and office buildings from being constructed within 150 feet of the treatment units, or to obtain easements for surrounding property that would accomplish this same end. It is not known at this time if additional buffer zone requirements will be added in future versions of the composting rules, although plant experience will play a large part in determining the pressure brought to bear for additional rules. In addition to the buffer zone recommended above, the site is laid out to provide some screening from the sludge unloading operation and the chipping operation that produces the wood chips. The exhaust of the blowers in the windrow process can also be directed through "biofilters", consisting of finished compost for odor control if needed.

The second process investigated was chemical stabilization with lime. This process involves mixing of the incoming sludges with quicklime in a pug mill or other mixer. The process utilizes the increase in pH of the mixture and the heat generated in the chemical mixing process to inactivate microbiological pathogens in the sludge.

The layout of a typical lime stabilization facility is shown in *Figure 5-2*. One of the advantages of the lime process is the simplicity and ease of operation of the facility. The layout needs to facilitate movement of materials through the site to allow proper access with truck traffic for delivery of sludges and lime. Lime storage is required to maintain a sufficient inventory to maintain treatment conditions in the event of disruption of lime deliveries. Lime silos must be weathertight to prevent moisture from being drawn into the quicklime and releasing heat and resulting pressures of thermal expansion in the silos.

Once on the site, the sludge must be mixed with lime as quickly as possible to prevent the build-up of unwanted odors. The mixing must be thorough to ensure that all sludge particles come in contact with the lime and are subject to the elevation in pH. Under the 503 rules and the TNRCC 312 rules, either the fecal coliform or salmonella bacteria must be monitored and found to be below prescribed levels, and the sludge/lime mixture pH must be above 12 for 72 hours. In addition, the temperature of the sludge/lime mixture must be 52 degrees C or above for 12 hours or longer, and after treatment the mixture must be air dried to a solids content of 50 percent or greater.

The site layout developed includes storage for seven days worth of lime to ensure continuity of treatment. In addition, the process includes area for initial treatment of the sludges equal to 12 days of processing time at 15 dry tons per day input. The final stage is for air drying to reach the proper moisture content. This stage allows for approximately three weeks of production. Air drying can be assisted during inclement weather by using the material moving equipment to break open the piles and reaerate the material.

After the required 50 percent solids content is reached and the necessary testing for pathogens is completed, the material is then ready for delivery to agricultural land application, land reclamation, or other uses. Because of the texture and appearance of the material, there is little consumer demand for the product in residential applications. However, there is a significant demand for the product for agricultural applications, both for the soil amendment properties of the sludges and the benefits of the lime for acid soils. As noted before, materials meeting all of the requirements for metals content, pathogen reduction, and vector attraction reduction can be placed on the land in an uncontrolled or unrestricted fashion. These materials can be used in agriculture without the necessity for setback distances from roads and drainageways, and can be applied to smaller pieces of property that would be uneconomical for use as registered sites for restricted applications. They can also be applied to soils with pH less than 6.5, where materials that are restricted to application to registered lands cannot. These acidic soils benefit even more from the lime.

Both of the processes selected for further study, as noted above, meet the stated goal of providing an end product that is suitable for uncontrolled use. In both cases, however, the process requires a dewatered sludge of 16 to 22 percent solids content. Further investigation of the costs showed that this dewatering process is a significant cost factor in overall cost of participation in a regional facility. This is particularly true for the smallest facilities which do not have sufficient volume to support either a fixed dewatering facility or a mobile dewatering facility. For these systems, some minimal wet haul of sludges will be required to accumulate sufficient materials to use mobile or fixed dewatering facilities.

Contacts with local sludge hauling companies, utility operating companies, and sludge applicators provided limited data on hauling distances and costs. The minimum cost reported was obtained from several sources as approximately $.035 per gallon for haul distances of up to 15 miles. The EPA liquid sludge hauling cost algorithm was applied to a 15 mile haul distance and a cost of approximately $.025 was obtained, excluding profit and application to the land, confirming that the $.035 per gallon cost is a reasonable estimate. As a result, the 15 mile haul distance was chosen as the maximum haul distance allowed for collection of sludges.

Once the sludges are collected, as noted above, they must be dewatered in order to be processed further. A regional collection facility will require a storage tank with sufficient air input to maintain aerobic conditions until the material is dewatered. If small regional collection facilities are used at the site of existing permitted facilities, mobile dewatering units could be used and the filtrate returned to the plant for treatment. As an alternative, fixed dewatering facilities can be operated at lower cost per ton of dry solids, and the possibility of a more permanent regional collection facility could be further investigated. Since this study was concentrated primarily on providing the additional treatment, and since mobile dewatering facilities are common and readily available to the area, the costs associated with mobile dewatering were used for the analysis. For purposes of comparison, however, *Table 4.1* shows the minimum amounts of sludge needed on a daily basis to support the activities of co-composting with wood chips and lime stabilization as enhanced treatment, and both mobile and fixed facility dewatering as necessary intermediate steps in providing a sludge suitable for enhanced treatment. The dewatering process investigated for this report was the belt filter press. Other types of dewatering equipment, such as centrifuges, may have a slightly different point where mobile dewatering becomes less economical in comparison to fixed facility dewatering.

***Table 4.1*** **- Approximate Minimum Economical Sludge Facility Size**

| **Process Name** | **Type of Sludge Input** | **Minimum Size** | **Units** |
|---|---|---|---|
| Enhanced Treatments | | | |
| Aerated Windrow / Windrow Composting | Dewatered cake sludge (approx. 16% solids) | 25 | Dry tons/day |
| Lime Stabilization | Dewatered cake sludge (approx. 16% solids) | 10 | Dry tons/day |
| Intermediate Treatments | | | |
| Mobile Dewatering | Digested sludge (approx. 2.5% solids) | 0.14 *or* 150,000 | Dry tons/day Gallon/day (Ave daily flow) |
| Fixed site Dewatering Facility | Digested sludge (approx. 2.5% solids) | 0.90 *or* 1,000,000 | Dry tons/day Gallon/day (Ave daily flow) |

## 4.3 Alternative Site Locations

Three proposed sludge handling/disposal facilities were identified and service areas were developed based on the maximum 15-mile haul distance. As noted previously, these sites are shown on *Exhibits* 2, 3, and 4 and routes to each of the facilities are shown on *Exhibits 5, 6* and *7*. The routing plan shown for Site 1 (*Exhibit 5)* is the minimum distance from the point of collection to the regional facility without intermediate stops. These plants use mobile dewatering which would only be used to produce full truckloads. *Table 4.2* summarizes the sludge production within the 15-mile radius service area as well as the population served.

*Table 4.2* - **Summary of Proposed Alternative Sludge Sites**

| Site Number | Site Location / Description | Number of Facilities Served | | Sludge Production (dry ton/day) | Population Served |
|---|---|---|---|---|---|
| 1 | Bayport Channel (Southeast Harris County) | 16 | Current | 47 | 399,015 |
| | | | 2014 | 50 | 468,243 |
| 2 | Northwest Harris County | 117 | Current | 11.2 | 237,301 |
| | | | 2014 | 13.3 | 289,650 |
| 3 | North Harris County | 138 | Current | 16.7 | 284,979 |
| | | | 2014 | 19.8 | 362,182 |

Site No. 1, The Bayport Channel site service an area with a high enough sludge production to justify a composting facility at this time. The other locations would be more suitable for a lime stabilization facility and/or to serve as regional dewatering facilities. The high percentage of small capacity plants in the service areas of sites 2 and 3 make mobile dewatering marginally economical or unsuitable for sludge from a single plant. Therefore, sludge from these facilities would have to be wet hauled to a collection facility for dewatering. The collection facility would need a large digester that would be used as a storage facility that will be dewatered either by a mobile unit on a periodic basis or a fixed dewatering system. For cost estimation purposes, it was assumed that a mobile dewatering facility is set up at the site of an existing permitted plant and that the sludges from neighboring plants are collected by the regional authority and trucked to the plant with the mobile facility set up. This assumption minimized setup charges by bringing the sludge to the mobile facility and permitting continuous operation for a week or more. Filtrate from the dewatering operation would be treated in the existing plant under a cost sharing agreement, with the costs allocated in the analysis for digestion time and filtrate treatment.

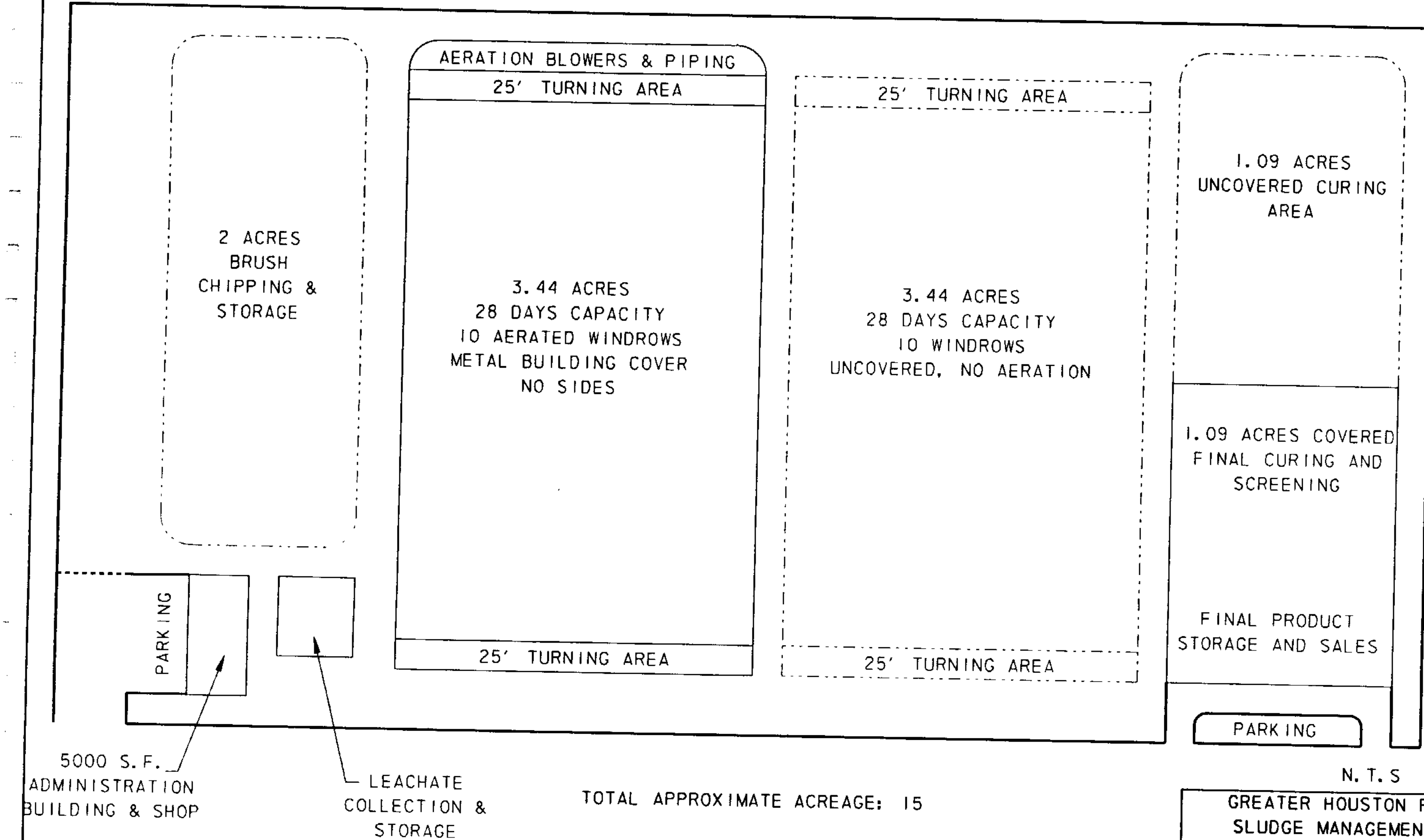
Conceptual site layouts have been prepared using information gathered from existing facilities in operation in Texas as well as information from Environmental Protection Agency publications, journal articles, discussions with operations personnel, and other sources.

## 5.1 Composting Facility

The composting site layout has been developed to incorporate both aerated static pile processing in windrow form, as well as conventional windrow turning area for compost maturation. This proposed layout is shown in *Figure 5.1.* Interviews with operations personnel for the City of Austin and the TBRSS provided information on the relative merits of each of the processes. The City of Austin operates a conventional windrow operation without covered areas for compost curing or screening operations. The sludges received at the Austin facility are anaerobically digested sludges that are transported by pipeline from other treatment plants, dewatered on site, and incorporated into the composting process. The sludge is well digested when it arrives at the composting stage. Austin has experienced significant odor problems with the dewatering facility because of the detention time in the pipelines while the sludge is being transported to the plant. The dewatering building is being upgraded to contain the odors since much of the odor is caused by dissolved gasses which are driven off during dewatering. Composting odors have not appeared to present a problem so far, although the dewatering facility odors were strong enough to have provided some masking of composting odors if in fact they occurred.

The TBRSS composting facility receives aerobically digested sludges, and was originally designed for conventional windrow composting with covered composting and screening areas. This facility has experienced significant odor problems with their process in the initial stages, and the current literature indicates that aerobically digested sludges have a greater tendency to produce odors. As a means of resolving the odor difficulties, TBRSS has converted to a modified aerated static pile process in windrow form for the initial treatment, followed by conventional windrow composting for maturation purposes.

Sludges coming into a proposed regional processing facility in the Houston area would be predominantly aerobically digested sludges. They would vary considerably in




GREATER HOUSTON REGIONAL SLUDGE MANAGEMENT STUDY

LAYOUT FOR A 25 DRY TON/DAY COMPOSTING SITE

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| | | |
|---|---|---|
| FIGURE 5.1 | 11-00317-002 | JUNE 1995 |

volatile solids content because of the variability in length of time in digestion processes. For these reasons, the process represented includes 28 days of aerated windrow treatment to control air movement through the compost. The equipment proposed is capable of reversing the flow through the pile for odor control. In addition, the aerated windrow and compost screening areas are covered to facilitate odor control, control process temperature by excluding rainfall from the composting materials, and facilitate screening of final product for recycling of the wood chips. The site is also laid out to allow movement of materials through the site in a left to right sequential movement. The final product distribution area is separated from the incoming materials traffic and all areas are secured by perimeter fencing.

The site layout shown is a generalized layout only, since no specific tracts have been identified for siting the facility. The configuration will ultimately depend upon the geometry of the site selected. In addition, the layout shown is sufficient to contain all of the necessary processing components. However, some additional buffer zone is needed between the active processing areas and the nearest residential development. This buffer can either be provided by procuring easements for the surrounding property or by purchasing additional property for buffer zone use.

Elements of the process that are most likely to produce complaints include compost odors and nuisance particulates (dust) and noise from the chipping operations. These concerns must be addressed in any siting decisions and will influence both the purchase of property and the layout of the site once the land is purchased. While the layout shown is designed to depict the amount of property needed and to facilitate materials movement through the site, it is ideally suited to property that is remotely located and not surrounded by residential areas. The closer the residential areas are to the proposed facility, the more attention must be paid to the buffer zones and nuisance abatement from process facilities. Advantages of the composting process selected are as follows:

1. The aerated windrow process allows closer control of aerobic conditions. The primary source of odors in the TBRSS facility was determined to be anaerobic conditions in the windrows. These conditions developed almost immediately after passage of the compost turner because bacterial activity was so high. Provision of additional air to the mix ensures aerobic conditions and would be

especially critical with non-homogeneous sludges produced in a variety of different facilities. The air requirements can be adjusted for each windrow formed based on the material needs. This process also offers a potential reduction in treatment time to achieve the necessary pathogen inactivation.

2. At the same time the forced aeration provides control over aerobic conditions, it also provides some additional control over temperatures in the windrow. Careful adjustment of the air movement can increase or decrease temperatures as needed to maintain optimal composting conditions.

3. All requirements for final quality of composted sludges can be met after completion of the aerated windrow process. The conventionally turned windrow composting area can be used solely to meet aesthetic requirements for compost users. The compost produced in the modified aerated windrow process would still have significant activity left and could generate too much heat for tender ornamental plants. However, it would be suitable for uses such as land reclamation, treatment of highway medians and other uses where it would be used as a soil amendment to help hold moisture in the root zones. A reduction in the level of treatment needed for specific uses would result in some savings in operational costs.

4. The process is relatively simple to operate, with the process control consisting of proper adherence to the compost recipe to control moisture in the windrow, and proper measurement of temperature throughout the windrow. Adjustments as necessary are made by increasing or decreasing the airflow.

5. Composting with wood waste provides the opportunity to incorporate additional solids with low metals content, thereby increasing the odds of producing a final product that is in accordance with the metals ceiling concentrations as well as the limits for unrestricted use. Wood waste is currently being diverted from the waste streams going to landfills and entities responsible for trash pickup are searching for alternative uses for yard waste, brush, etc. In addition, companies responsible for right-of-way maintenance for streets and power lines are similarly looking for disposal options, oftentimes for material that is already chipped.

6. The final product is suitable for distribution and marketing and can be land applied without restrictions. In addition, there is a demand for the product to the extent that both the Austin and TBRSS facilities can sell their entire production of compost.

7. It uses a waste product for the bulking agent. Although costs are estimated assuming that all of the wood chips will be produced onsite, other facilities receive significant quantities of chips already processed by companies such as tree trimming services, electric utilities, rights of way maintenance crews and

other similar sources who chip the brush for ease of handling and are only looking for a place to dispose of it.

Disadvantages of the process include the following:

1. The process has a high percentage of the total overall cost tied up in equipment and construction costs. As a result, the fixed costs are high and the cost per ton of product will be similarly high if maximum production is not achieved and sustained. In addition, a higher quantity of sludge is required on a daily basis to deliver a product at a per ton cost that is competitive with other processes.

2. Operation and maintenance of the wood grinding equipment is expensive, energy intensive, noisy, and dusty. It must be located in a remote area to prevent excessive complaints.

3. Prolonged periods of cold weather will require recycling of final product as a blanket to cover active composting piles for temperature maintenance. This condition is not common to the Houston area but it can occur. If it does, it will cause an increase in operational costs.

4. All sludges must be dewatered prior to being composted, in order to maintain proper moisture content in the compost recipe.

### 5.2 Lime Stabilization Facility

The second alternative for producing a sludge product meeting Class A pathogen levels which was investigated in this study was lime stabilization. As noted previously, this process uses the heat liberated from mixing quicklime with cake sludges of 16 percent solids content and higher and the high pH of the resulting lime/sludge mixture to kill or inactivate pathogens present. The current state and federal rules require that the pH of the lime sludge mixture be raised above 12 and remain above 12 for a total of 72 hours. During the time the sludge is above pH 12, the temperature of the sludge must also reach 52 degrees Centigrade, and finally the lime/sludge mixture must be dried to a minimum solids content of 50 percent for the sludge to be considered Class A with respect to pathogen levels. The heat generated in the process results in water vapor being driven off. The remainder of the water is removed by air drying, with the drying facilitated by periodic turning of the piles. Lime stabilization applied to a pH of 12 for 2 hours followed by a holding time of 22 additional hours at pH 11.5 or above meets the requirements for vector attraction reduction.

Since the levels and detention times for pathogen kill exceed these requirements, vector attraction reduction is also accomplished. A typical site layout for accomplishing these tasks is shown in *Figure 5.2*.

Operational experience data were gathered from the City of Houston, where lime stabilization has been practiced for over 10 years. Operational problems were experienced initially since the previous EPA and TNRCC rules did not include requirements for vector attraction reduction. Since the vector attraction reduction requirements have gone into effect, the City has had little difficulty with flies and odors at their sludge management sites. The Trinity River Authority was also contacted to determine their operational experiences with lime stabilization. Their experience has also been favorable, since the lime addition resolved a significant problem with odor and fill stabilization in their dedicated land disposal site. Proper mixing of the sludge with the lime is essential to ensuring that all of the sludge is adequately treated, and preventing pockets of material with increased odor and pathogen potential.

Advantages of the lime stabilization process are as follows:

1. The process lends itself well to modular facilities of smaller sizes. The proposed site layout shown is for approximately 15 dry tons per day instead of the 25 dry ton per day facility needed for composting.

2. Processing is completed in a short period of time, minimizing the amount of land needed for the processing facility.

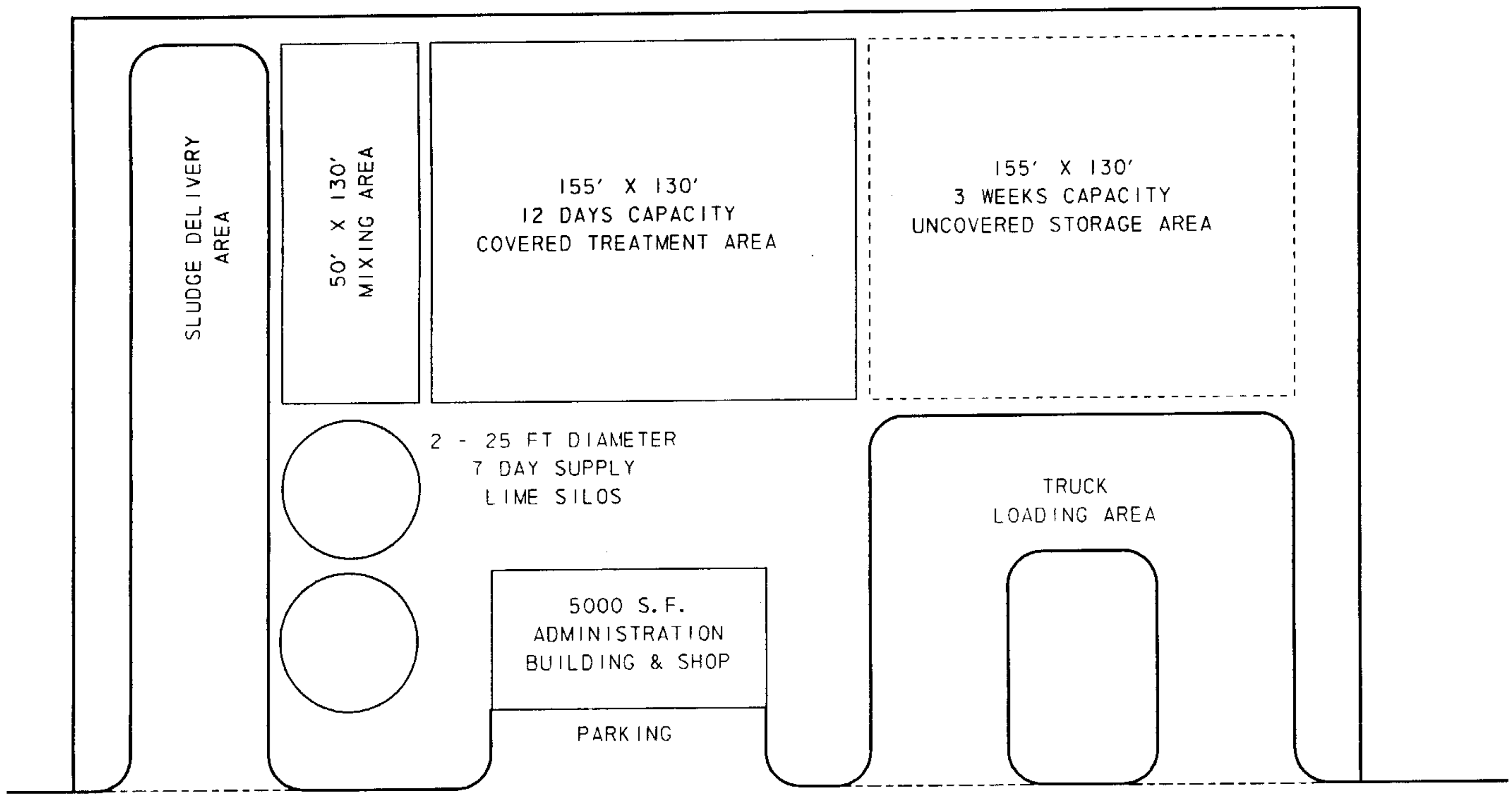
3. Process control is simple and test measurements needed are simple and inexpensive to perform.

4. Lime is oftentimes desirable for agricultural land to neutralize acidic soil pH although current land application rules do not allow use of class B materials on soils with a pH less than 6.5.

5. Fixed costs are relatively small and the cost of the chemical comprises a significant portion of the annual expenses. If treatment is interrupted, there is less fixed cost that must be satisfied. The lime can be held until processing resumes.

Disadvantages of the lime stabilization process for sludge treatment are as follows:

1. Process requires a manufactured chemical in fairly large quantities.




TOTAL APPROXIMATE ACREAGE: 3

N.T.S

| |
|---|
| GREATER HOUSTON REGIONAL SLUDGE MANAGEMENT STUDY |
| LAYOUT FOR A 15 DRY TON/DAY LIME STABILIZATION SITE |
| Turner Collie & Braden Inc. Engineers • Planners • Project Managers |

| | | |
|---|---|---|
| FIGURE 5.2 | 11-00317-002 | JUNE 1995 |

2. As noted elsewhere, transportation costs are a significant portion of the overall cost picture and lime weight adds significantly to the total.

3. Sludges to be treated to Class A pathogen levels must be dewatered. Liquid sludges treated to provide vector attraction reduction will also meet Class B pathogen levels, but cannot generate enough heat to reach Class A pathogen levels.

4. Lime stabilized materials meeting Class A pathogen levels are not perceived as being as useful as composted materials. Generally, this means that lime stabilized materials must be hauled to land application sites for beneficial reuse, with the hauling costs paid by the sludge generator. As further marketing of these materials is pursued, and the receivers perceive them as being more valuable, the receiver may be more willing to pay all or a portion of this cost.

### 5.3 Conceptual Design/Layout Cost Rationale

Costs for the various layouts were developed from existing data provided by operational facilities, from equipment quotes provided by various manufacturers on current equipment prices, and from cost algorithms published by EPA for labor needed to operate various facilities. Steps that were followed in the development of cost information are as follows:

1. The sludge production database was used to locate areas where sludge available within a 15-mile haul distance met the quantity requirements for economical processing. The land-use map was then used to locate a site near the centroid of the production area in areas of either agricultural or industrial land-use.

2. Equipment was based on 40 hours weekly operation with an allowance for downtime for maintenance and repairs.

3. Equipment manufacturers were contacted for current prices on equipment and verified capacities and assumptions on amount of downtime needed.

4. Chemical manufacturers were contacted for current bulk chemical prices for lime and dewatering polymers.

5. Current prices were determined for diesel fuel.

6. A 10-year life for major equipment such as conveyors, loading facilities, compost turners, and similar equipment was assumed.

7. A 5-year life for trucks, tractors and other mobile equipment was assumed.

8. Consumer prices for fuel, chemicals, and other consumables were assumed to increase 3 percent annually.

9. Annualized capital costs based on 6 percent interest for the life of the equipment were determined.

10. Operations and maintenance costs, adjusted to account for 3 percent annual cost increases, were determined.

11. Hours of labor needed for operation and maintenance were determined from EPA algorithms, and an estimated hourly rate for facility operators was developed. Hours developed from the algorithms were compared with number of operators provided for currently operating facilities, and adjusted as necessary.

12. Above costs were assembled into a dollars per dry ton treated per year basis.

## 6.1 Introduction

Biosolids are a significant natural resource which can be reused beneficially without impacting public health. Milwaukee has been successfully managing and marketing its sludge as Milorganite for almost 70 years. However, not all biosolids management programs are successful. In addition to good management practices, feasible costs, and sound technical principles, a biosolids management program must strive to educate the public in order to be successful. The program must also market the product and select a method of distribution. As illustrated in the following sections, the success of any marketing and distribution plan depends on tailoring the program to fit the specific needs of the area it serves.

## 6.2 Public Education

As knowledge about biosolids increases, worry about adverse effects generally decreases. Therefore it is imperative that an aggressive public relations/education program be implemented. Past biosolids management experience shows that the education process must begin before the product is available. Additionally, the information should be simple and easy to understand. Any complaints or accusations should be addressed promptly. It is also advantageous to partner with entities, such as universities, which are considered by the public to be experts in the field. Information was gathered from current literature about programs which have been successful in other areas. Brief reviews of each of the programs are included to provide guidance on the extent of efforts that may be needed for the Greater Houston Area.

The Newton Water Pollution Control Plant, located in Newton, Iowa, manages biosolids through land application on selected sites. Due to the small size of the program, the City of Newton does not have a formal public education program. However, the Water Pollution Control Superintendent is available to give presentations to community groups, and tours of the operation to interested parties.

The Metropolitan Wastewater Management Commission (MWMC), which encompasses Eugene and Springfield, Oregon, had sufficient interest expressed by the general public in recycling issues that they determined an active marketing program for its land application activities was not required. However, they do have a proactive public relations campaign which effectively provides information to the public. An informative newsletter, entitled "The Green Scene", provides useful information to program participants and other interested parties. Additionally, the MWMC participates in an annual public works day and local fairs with exhibits featuring videos, colorful handouts, and equipment demonstrations. The MWMC also gives presentations to schools and other groups, and offers tours of the facilities.

Willow Lake Wastewater Treatment Plant located in Salem, Oregon uses a land application program to provide 100-percent beneficial reuse of biosolids. After anaerobic digestion, Class B liquid biosolids are land applied during dry weather and pumped to temporary on-site storage lagoons during inclement weather. The public relations efforts stress early education, prompt response to complaints, and friendly, professional, and accessible staff members. On one occasion, a landowner filed a complaint with the city alleging that garden plants and shrubs had been damaged by a Biogro application. The staff immediately conducted a comprehensive investigation which included soil and well water analysis. Investigations were also performed by several independent entities recognized as experts in the field. These investigations revealed the destruction of the plants was caused by a misapplication of herbicide by the property owner. In addition to clearing Biogro from suspicion, this incident was also a valuable public relations tool.

The Metropolitan Water Reclamation District (MWRD) of Greater Chicago, Illinois presently applies dry biosolids to land made barren by strip mining operations. The MWRD faced opposition during the early planning stages of their proposed land reclamation program, known as the Fulton County Prairie Plan. Therefore, an intensive public relations effort which included the use of a public relations firm was initiated. The ensuing program utilized informational booklets, slide programs, newspaper advertisements and columns, and project signs and symbols. Additionally, a committee comprised of local officials, interested citizens, governmental agencies, educational institutions, and regional planning agencies was formed to ensure local participation in the program. This committee was instrumental in obtaining public approval of the proposed biosolids management program. The current public relations effort focuses on the MWRD being a good neighbor and a responsible employer in the community.

The Hornsby Bend Biosolids Management Plant located in the City of Austin, Texas uses windrow composting with wood waste bulking agents to produce a Class A product, marketed as Dillo Dirt. Although the city does not maintain an extensive public education program, it does provide brochures and information on Dillo Dirt. The compost manager is also available to give presentations to interested groups and interviews to the media. The environmental consciousness of the citizens of Austin has contributed to the success of the composting activities. In fact, during much of the year, the demand for Dillo Dirt far exceeds the supply.

East Bay Municipal Utility District (EBMUD), located in Oakland, California uses extended static pile composting with wood chips to produce a Class A product, marketed as CompGro. EBMUD relies on word-of-mouth endorsements, professionally prepared brochures, public education programs, and landscape demonstrations to gain public acceptance for the product.

The Metropolitan Waste Control Commission (MWCC) in St. Paul, Minnesota produces three different products from wastewater residuals: a mixture of wastewater sludge incinerator ash and water treatment lime sludge, marketed as NutraLime; a pasteurized (PFRP) sewage sludge product, marketed as N-Viro Soil; and anaerobically digested biosolids. The MWCC has developed several innovative approaches to educating the public about the safety and benefits of recycling biosolids. The MWCC participates in traditional public relations events such as environmental, county, and state fairs and agricultural extension activities. The MWCC also has five demonstration farm sites in various counties surrounding the Twin Cities. "Farmer field days" are advertised through extension newsletters, newspaper columns, and notices sent to interested parties. These presentations allow other farmers, neighbors, and local officials to view the beneficial utilization of biosolids.

In addition to the typical public education tools, the MWCC made arrangements with the Science Museum of Minnesota to provide educational demonstrations on wastewater treatment and biosolids recycling. Most of the audience was excited to find out their waste was being recycled into valuable soil amendments. Following each presentation, planter kits containing biosolids media, a control potting soil, seeds, and instructions were distributed. After the museum presentations, MWCC received several requests to conduct school classroom demonstrations including planting activities.

The MWCC found that demonstration farms and field days are the best way to educate rural populations, while the science museum presentations, planter kits, and classroom programs are the best way to educate urban and suburban populations.

The experience of the MWCC is particularly important in that it recognizes the desirability of identifying specific needs for specific populations. Any program developed to serve a portion of the Greater Houston Area studied here must recognize the diversity of the area. Programs developed to meet the needs of inner city residents will not be applicable to suburban dwellers or rural residents. However, the range of activities developed by the MWCC appears to address most of the identified population in the Greater Houston Area, as well.

One difficulty that should be noted here is that the regional authorities, as proposed, will not cover the entire area. As a result, it will be difficult to specifically target those areas where education is a must. Any program developed must recognize that costs will be greater because of the potentially large population that may become interested and ask for informational materials.

## 6.3 Marketing

Along with contributing to a successful biosolids management program, marketing programs tend to increase the value of the biosolids. Biosolids marketing should utilize the same techniques used by other horticultural products. For example, soil analysis results and application rates should be provided to users. Additionally, marketing efforts should begin before the product is available and adhere to the following guidelines:

- Concentrate on markets which fit the characteristics, such as nutrient content, color, texture, moisture holding capability of the product. Co-composted sludge and brush is not a fertilizer, and it should not be marketed as such, for example.

- Sell benefits of the product rather than features (i.e., what it can do not what it is)
- Maintain competent sales staff with positive attitude

Customers are interested in quality control and reliability, price, availability, and service. The user wants to purchase a product which offers either better performance at the same price or the same performance at a lower cost. Since sales of composted animal manures, potting soil, peat moss, and other soil amendments experience thriving annual sales in the Greater Houston Area, this is the market that should be targeted. The composted product developed should be as close in texture, color, nutrient analysis, and other characteristics as possible to composted materials currently being sold.

It is also important to engage a professional advertising firm to assist with product name and logo development to demonstrate that this is a valuable product worth purchasing, rather than a waste slated for disposal. The advertising firm can also assist in preparation of professional advertisements and brochures.

The marketing should be done in two distinct phases, with Phase I demonstrating to the public that biosolids can indeed be reused beneficially without impacting public health. An important part of Phase I marketing is public education, which is addressed above. The projected growth in the Greater Houston Area provides numerous opportunities for biosolids to be applied in areas such as road right-of-ways, which produce visible beneficial results. Phase I marketing targets include: golf courses, road right-of-way construction/maintenance, subdivision green belt development, wholesale nurseries, and fertilizer compounders/manufacturers.

Phase II marketing targets include: radio and TV gardening shows, garden clubs, environmental groups, organic gardeners, and the general public. Marketing in this phase may also incorporate inserts in water bills, billboard advertising, and newspaper advertisements.

### 6.4 Distribution

Houston, Milwaukee, and Chicago have the longest history of biosolids production of major cities. Milwaukee has a separate staff dedicated solely to advancing sales of

Milorganite, while Houston and Chicago have relied on a single distributor approach for treated biosolids distribution, with an emphasis on bulk sales. Austin, a relative newcomer to the marketing of biosolids, uses licensed distributors to target a more general market for its product. Although demand for these biosolids products occasionally exceeds production capabilities, competition among the producers is growing and transportation costs are increasing. Therefore, it is imperative that an appropriate distribution option be selected from the following:

- distribution to city departments at no cost
- wholesale to state, county, or city governments only
- wholesale to licensed distributors only
- wholesale to a single distribution firm that would handle all other sales
- retail sales to individual users.

The best distribution option should include distributing the product at no cost to city departments in order to produce visible beneficial results, especially during Phase I of the marketing. Also, the product should be wholesaled to licensed distributors only. This would result in lower marketing costs since the distributors would bear the advertising costs. Additionally, competing distributors would perhaps be more aggressive about promoting the product, thus increasing the demand.

The City of Austin's nationally recognized beneficial reuse program utilizes a similar distribution approach. The compost is sold by contract to vendors who pay an annual registration fee of $200. The compost sells for $7 per cubic yard. Registered vendors include topsoil vendors, dirt haulers, nurseries, garden suppliers, landscapers, and a turf farm. Vendors must identify all users receiving more than 1 cubic yard of compost monthly.

### 6.5 Plan Administration

The recommended plan consists of a series of regional sludge receiving facilities that would either receive dewatered cake sludges for treatment to Class A or liquid hauled sludges for dewatering and either hauling to another site or treatment on that site to Class A. The generating authority would be responsible for documentation regarding pollutant levels in the delivered sludge. The operating authority would be responsible for monitoring these pollutant levels and correcting any problems. The operator would also be responsible for insuring that any sludge material produced meets all of the requirements for land application for beneficial use.

These regional sludge management facilities can be administered by either public or private entities. Although the initial capital cost of a large composting facility might discourage a private operator, the lime stabilization and dewatering facilities might be attractive. From the public sector, regional authorities, such as Gulf Coast Waste Disposal Authority or San Jacinto River Authority, could serve as the organizational entity for a sludge processing facility under current authorities, if cities or utility districts in the area showed interest in such a project. The Brazos River Authority currently operates the TBRSS under contract with the contributing cities that produce the wastewater. As noted previously, these cities also provide more than enough brush to accomplish the composting process.

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## 7.1 Cost Development

As part of this study, cost estimates for treating 25 dry tons of sludge per day at a composting facility and 15 dry-ton per day at a lime stabilization facility were prepared. Since a dewatered cake sludge is required input for these processes, dewatering costs were developed. These costs were compared to the reported costs for land applying liquid sludge and for landfilling a dewatered sludge which are currently the only available sludge disposal options. The information used in developing the cost estimates for composting and lime stabilization was obtained from case studies, EPA estimating handbooks, manufacturer's literature, and equipment dealers. The following calculation assumptions were made after analyzing information provided by sludge generators located within the study area:

- Wet hauled sludge is 2.5-percent solids
- Dewatered sludge is 16-percent solids
- Sludge production in treatment is 80-percent of influent organics weight
- Volatile solids content in waste sludge is 60-percent
- Volatile solids destruction in digestion is 25-percent

## 7.2 Costs of Current Practices

To serve as a basis for comparison, costs for current sludge disposal practices were determined. These practices include land application of liquid sludge with a percent solids concentration of between 1.0-percent to 2.5-percent. This range of solids concentration was determined from data provided by local generators/operators. Based on conversations with generators/operators the cost for hauling and application at a land application site varies from 3.5¢ to 7.0¢ per gallon of sludge. The variability of the costs appears to depend upon the proximity of the generation site with respect to the application site as well as other factors such as volume of sludge to be hauled from the plant. *Table 7.1* shows the land application costs for 10,000 gallons of sludge for a range of both costs and percent solids concentrations. Costs per dry ton for the same 10,000 gallons was also calculated and included in this table. An amount of 10,000 gallons was chosen both for convenience of calculations and the fact that it represents a normally sized digester that might be located at a wastewater facility.

*Table 7.1* - **Land Application Costs for 10,000 Gallons of Sludge at Different Percent Solids**

| | Percent Solids | | | |
|---|---|---|---|---|
| | 1.0 | 1.5 | 2.0 | 2.5 |
| Liquid Haul @ 3.5¢/gal | $350 | $350 | $350 | $350 |
| $/dry ton | $840 | $559 | $420 | $335 |
| Liquid Haul @ 4.5¢/gal | $450 | $450 | $450 | $450 |
| $/dry ton | $1080 | $720 | $540 | $432 |
| Liquid Haul @ 5.5¢/gal | $550 | $550 | $550 | $550 |
| $/dry ton | $1320 | $880 | $660 | $528 |
| Liquid Haul @ 7.0¢/gal | $700 | $700 | $700 | $700 |
| $/dry ton | $1680 | $1120 | $840 | $672 |

Landfilling is currently the only other option available to all but the largest entities (i.e. the City of Houston). Existing regulations require that wastewater sludge disposed of in a municipal solid waste landfill must be dewatered to approximately 16-percent solids. Dewatering with a mobile dewatering unit currently costs approximately $172 per dry ton according to local operators. The landfill tipping fee is reported as approximately $54 per dry ton. Hauling to a landfill can typically be accomplished for $41 per dry ton as reported by a number of operators. *Table 7.2* shows the cost to dewater, haul, and landfill 10,000 gallons of sludge that is at 2.5-percent solids from the plant and then dewatered to 16-percent solids. This initial solids concentration was chosen since according to operator experience, this is the minimum optimum solids concentration for effective dewatering.

*Table 7.2* - **Cost for Entity to Landfill 10,000 Gallons of Sludge at 2.5-Percent Solids (1.04 dry tons)**

| | Total Cost |
|---|---|
| Mobile Dewatering | $179 |
| Cake Haul to landfill | $43 |
| Landfill tipping fee | $56 |
| **TOTAL** | $278 |

Dividing the total cost by the 1.04 dry tons yields a total cost for landfilling of $267 per dry ton. This also assumes that the plant has sufficient storage capacity to justify the use of a mobile dewatering unit. If liquid sludge must be hauled to another site for dewatering additional costs will apply. These costs are discussed in 7.3.

## 7.3 Pretreatment Costs for Small Producers

In order to achieve the pathogen reduction that is required to produce a Class A sludge, the sludge must be dewatered to approximately 16 percent solids. As previously mentioned, small capacity plants do not typically provide sufficient sludge storage to make on-site dewatering facilities or even the use of mobile dewatering equipment economical. As a result, sludge from small producers would have to be wet hauled to a collection facility for dewatering before it can be composted, lime-stabilized, or landfilled. It is assumed for the purposes of this study that a collection facility would be a wastewater plant that has excess digester capacity that would be used to store sludge hauled in from smaller plants until it is dewatered by a mobile unit and disposed of. *Table 7.3* summarizes the cost to a small facility to haul sludge to a collection facility, have it dewatered, and have the dewatered sludge hauled to further treatment. The cost shown for digestion was taken from the EPA manual on aerobic digestion and includes the cost to decant and treat the supernatant.

*Table 7.3* - **Cost for Entity to Haul 10,000 Gallons of Sludge at 2.5-Percent Solids to a Collection Facility for Dewatering and Hauling to Further Treatment/Disposal (1.04 dry tons)**

| | Total Cost |
|---|---|
| Wet haul to collection facility @ 3.5¢/gallon | $350 |
| Digestion | $84 |
| Dewatering | $179 |
| Cake haul to further treatment/disposal | $43 |
| **TOTAL** | $656 |

Dividing the total cost by the 1.04 dry tons yields a total cost for pretreatment and transportation of $631 per dry ton. The further treatment/disposal referred to in the table above would be disposal in a municipal solid waste landfill or treatment at a composting or lime stabilization facility. Costs for landfilling, as mentioned previously, are $54 per dry ton. Adding this cost of disposed to the pretreatment costs brings the cost of landfilling for a small generator to $710 per dry ton. Lime stabilization and composting costs are discussed below.

## 7.4 Lime Stabilization Costs

Costs for the 15 dry ton per day lime stabilization facility were developed based on the conceptual site layout discussed in **Section 5.0** and the cost algorithm given in the EPA Handbook entitled *Estimating Sludge Management Costs*. A copy of the algorithm is included in Appendix A of this report. The cost of construction was estimated at $1,899,000, while the equipment cost was estimated at $705,000, for a total capital cost of $2,604,000. Annualizing the capital cost over 20 years at six-percent interest results in an annual cost of $227,000 ($41 per dry ton). The annual operation and maintenance cost for the facility was estimated at $445,000 ($81 per dry ton). The total annual cost including annualized capital costs for this facility is $122 per dry ton. After lime stabilization, the sludge is hauled and land applied at a cost of $27 per dry ton. This results in a total cost of $149 per dry ton for treatment by lime stabilization and subsequent land application.

### 7.5 Composting Costs

Capital costs, including cost of construction and equipment costs, and operation and maintenance costs were developed for a 25 dry ton per day regional composting facility. These costs were based on the conceptual site layout discussed in Section 5.0 and the cost algorithm given in the EPA Handbook entitled *Estimating Sludge Management Costs*. The labor calculated in the cost algorithm was adjusted based on operational experiences at a similar facility in Texas. A copy of the algorithm is included in Appendix A of this report. The cost of construction was estimated at $4,215,000, while the equipment cost was estimated at $1,197,000, for a total capital cost of $5,412,000. Spreading the capital cost over 20 years at six-percent interest results in an annual cost of $472,000 ($52 per dry ton). The annual operation and maintenance cost for the facility was estimated at $869,000 ($95 per dry ton). After composting, the sludge is either marketed and distributed or given away, therefore there are no hauling or disposal costs associated with a composted sludge product. This results in a total cost of $147 per dry ton for treatment by composting.

### 7.6 Cost Comparison

*Table 7.4* shows the comparison of the various sludge management methods investigated, specifically for smaller producers which require wet hauling of the sludge. For comparison purposes, the various per dry ton charges based on percent solids concentration in the sludges being hauled are used in this table.

*Table 7.4* - **Cost Comparison for Districts That Wet Haul Sludge at 2.5 Percent**

| Costs (per dry ton) | Compost | Lime Stabilize & Land Apply | Landfill | Land Application (@3.5¢/gal) | Land Application (@7.0¢/gal) |
|---|---|---|---|---|---|
| Pretreatment | $631 | $631 | $631 | --- | --- |
| Lime Stabilization | --- | $122 | --- | --- | --- |
| Composting | $147 | --- | --- | --- | --- |
| Haul to Land Application | --- | $27 | --- | $335 | $672 |
| Haul to Landfill | --- | --- | $41 | --- | --- |
| Tipping Fees | --- | --- | $33 | --- | --- |
| Revenue From Sales | -$37 | --- | --- | --- | --- |
| **TOTAL** | **$741** | **$780** | **$705** | **$335** | **$672** |

*Table 7.5* shows the comparison of sludge management options for cities who have high enough sludge production rates to justify the use of mobile dewatering and who are also generally responsible for disposal of brush and yard waste. Since composting is accomplished with chipped brush, there is a cost impact for a city whose participation in a regional processing facility relieves them of paying for brush disposal either in a landfill or in a chipping and composting or mulching operation they operate themselves. For this comparison it is assumed that the ratio of brush to sludge needed for composting is 2:1 on a volumetric basis. Also, there is 1 dry ton of solids in 6.25 wet tons of sludge at 16% solids. This equates to approximately 7.4 cubic yards if the wet unit weight of sludge is 62.4 pounds per cubic foot. Therefore, it would require 14.8 cubic yards of brush to compost 1 dry ton of sludge. If the brush were disposed in a landfill at a tipping fee of approximately $8.60 per cubic yard, it would result in a cost of $127 per dry ton. In actual operation, 20 to 30 percent of the wood chips would be recycled from the screening operation. The variability of the moisture and nitrogen content makes the compost recipe sufficiently

flexible that this 20 to 30% recycle may be offset by increased bulking agent needs. In addition, the volume used for the disposal calculation is based on chipped brush. Loose bulk brush would occupy a much greater volume and have a much higher disposal cost. The costs based on chopped brush represent a conservative cost estimate.

*Table 7.5* - **Cost Comparison for Cities That Are Large Enough to Mobile Dewater and Have Brush Disposal Responsibilities**

| Costs (per dry ton) | Compost | Lime Stabilize & Land Apply | Landfill |
|---|---|---|---|
| Mobile Dewatering | $172 | $172 | $172 |
| Cake haul to regional plant/landfill | $41 | $41 | $41 |
| Composting | $147 | --- | --- |
| Lime Stabilization | --- | $122 | --- |
| Haul to Land Apply | --- | $27 | --- |
| Sludge Tipping Fees | --- | --- | $33 |
| Brush Tipping Fee | --- | $127 | $127 |
| Revenue From Sales | -$37 | --- | --- |
| TOTAL | $323 | $489 | $373 |

For cities that operate their own dewatering facilities, the $172 per dry ton given in the above table would be different depending on their individual costs. The rest of the costs would apply assuming that they could provide a 16 percent solids sludge. For larger districts that have sufficient sludge storage capacity to justify using the mobile dewatering unit, all of the costs except those involving brush disposal would apply.

## 7.7 Cost Conclusions

*Small Systems*

*Table 7.4* shows that the estimated costs for treating sludges from the smallest systems range from \$.076 per gallon for landfill disposal, to \$.089 per gallon for lime stabilization, to \$.083 per gallon for composting, based on sludge at 2.5 percent solids. The picture becomes more favorable for the higher levels of treatment; however, at lower percent solids levels. Cost per gallon for a 1 percent sludge ranges from \$.030 for landfill disposal, to \$.036 for lime stabilization, and to \$.034 for composting. However, this does not account for the increased dewatering costs of this lower percent solid sludge. These levels compare favorably to the \$.035 to \$.07 per gallon ranges given for direct land application. The longer the haul distance from the sludge source to the land application area and the lower the percent solids of the sludge, the more competitive the other methods become.

*Cities*

Costs for the cities and larger utility districts in the area are presented in *Table 7.5*. These costs assume that the facilities are either large enough to allow the use of mobile dewatering facilities or they use on-site dewatering. As the table shows the overall costs are lower for composting when brush disposal costs are included in the analysis. In addition, lime stabilization is potentially competitive with landfilling or composting if additional markets for the resulting product can be developed and the product either sold or given away. The lime stabilization facility costs are also based on a smaller facility which could potentially reduce hauling costs more than this analysis show. Costs for both options are in the range where other factors or advantages may cause individual producers to investigate these options as a means of diversifying their sludge management activities, or for limitation of their liabilities, or for reasons relating to the need to recycle. In addition, recognition of the decreasing availability of landfills and the need to conserve landfill space for wastes less likely to be recycled may also play a part in the ultimate determination.

## 8.1 Introduction

Liabilities inherent in management of wastewater sludges arise in issues of permit compliance, quality of materials provided for beneficial reuse, quality of materials submitted for landfill disposal, transportation of materials to reuse/disposal sites, and possible environmental degradation and public health concerns from reuse or disposal activities. These issues apply equally to large and small operations.

The 503 rules were more than 10 years in the making. One of the reasons it took so long to develop these rules was the need to have levels strict enough to give the public confidence in sludge products. A lot of input was asked for and provided by environmental organizations on levels they would feel comfortable with. The outcome of the rule making process was a rule which, if closely followed, would give assurance to the utility that they were making a product that they could trust and that the public could trust. These elements are key to any discussion of liability, since the belief that a product is safe and meets all applicable standards is a key defense in any case involving the so-called "toxic tort" liability.

## 8.2 Permit Compliance

The 503 rules and the TNRCC Section 312 rules require that sludges prepared for beneficial reuse meet standards for pathogens and metals, and meet treatment technique requirements for vector attraction reduction. The standards and treatment technique requirements must be met whether they are a part of the wastewater discharge permit, a part of a sludge processing facility permit, or a part of a land application site registration. In any event, the sludge generator is required to determine that the sludges produced meet the applicable standards and treatment technique requirements, under penalty of fines and imprisonment. Under these rules, the sludge generator has a duty to produce a product meeting the standards for pathogens and metals and which will not produce nuisance conditions. Material sent to land application programs which does not meet the standards runs the risk of incurring injunctive relief and monetary penalties for violation of the EPA and TNRCC requirements. Since these penalties are assessed per day of violation and each day a sludge resides in an inappropriate location, i.e., sludge land applied for beneficial use which does not meet the metals ceiling concentrations, constitutes a separate offense, the penalties can be substantial. In addition to action taken by EPA or TNRCC, penalties can be assessed in response to citizen suits.

Individual sludge generators will probably continue to control metals content in their sludge since it nearly always costs less to prevent the metals from getting in the sludge in the first place than it does to remove them by treatment. As a result, the generating entity must be able to certify that the material produced meets either the unrestricted use levels for metals, in which case there are no application area restrictions based on metals content, or that the metals are above the unrestricted use levels but below the metals ceiling limits. If metals levels do fall between the unrestricted use and ceiling limits, then proper directions must be supplied to limit the amount of material applied by the end user. These directions must be supplied with the final product, at the point at which the product is sold or given away for beneficial reuse.

Liability issues that arise with respect to metals levels include the following:

1. Allegations of metals contamination of crops grown on land used for beneficial reuse of sludges.

2. Adverse effects on human, plant, or animal life as a result of metals content in forage, food products, or soils.

3. Contamination of creeks or streams on or adjacent to the application area.

4. Allegations of human health effects from contact, from exposure to dust particles containing elevated metals levels, or other pathways.

5. Although not generally well recognized, disposal of sludges in landfills that later become Superfund sites from toxic leachate problems may involve the generator in Superfund liability actions.

Strict adherence to the requirements of the 503 rules and the Section 312 rules and maintenance of the proper documentation provides some protection from the liabilities associated with metals levels. However, the situation varies somewhat depending upon the size of the utility involved. While larger cities may be somewhat more prone to experience elevated levels of metals based on industrial activity, they are also of a size where a one-time disposal of effluent with high metals levels is likely to be sufficiently diluted by the time it is deposited in the sludge. The smaller systems are much more likely to be effected by illicit dumping of metals contaminated materials into one of their manholes, and at the same time, they are only required to sample the sludge once per year. If illegal dumping occurred which raised the levels sufficiently to contaminate property and was traced back to a small producer, the consequences could be disastrous. The sludge generator could be held liable for the costs of remediation of the property to remove the elevated metals levels. Even under this circumstance, however, the clean up activity in all but the most severe cases could be harvesting and disposing of a crop material chosen for its uptake of metals from the soil. Crop cycles could be continued until the metals levels returned to acceptable levels. Although this is a feasible alternative, it would have to be acceptable to the landowner and the landowner's attorneys to be implemented.

### 8.3 Pathogen Levels

Metals contamination can generally be readily determined through reliable testing although the testing is expensive and every load cannot be tested. At the same time, the opportunities for metals contamination are limited, so there are not as many likely sources when investigation is required. This situation is markedly different for pathogens. There are numerous cases of illness in every community at any time for which no obvious causative agent can be located but which are labelled as viral or bacterial in nature. The cost of tracking each infection to its source is prohibitive. Since no inexpensive reliable means of testing for specific pathogenic bacteria and viruses is readily available for widespread use, it is hard for people who have been made sick to prove that their illness came from sludge application to land around or near them. At the same time, it is also difficult for the sludge generator or user to prove that it was not the sludge activities which made people ill when the people who are ill claim that it was. In some communities the opponents to land application of sludges have been able to bring enough political pressure to bear to stop land application activities. For utilities whose only current outlet for sludges is through land application, this can represent a severe financial burden, and one which is impossible to prepare for.

In much the same fashion as discussed above, the vector attraction reduction portion of the rules can be a significant factor in public acceptance of land application activities. When improperly treated materials find their way to land application programs, the credibility of the entire land application program suffers. The development of the land application of sludges in Texas included several notable problems with sludges that were treated to meet the parameters for land application of sludges in effect at that time. These parameters did not account for the needed vector attraction reduction measures in place today, and resulted in significant odor and vector problems in Houston's humid climate. Animosities built up over these problems have continued for over 10 years. Once again, the primary liability is the opposition to the program that may result in termination through political means, leaving small utilities with no accessible options for sludge disposal.

Based on the analysis noted above, the participation of smaller utilities in a regional sludge management program offers some liability protection. While the individual utilities may not have sufficient volumes to dilute a highly contaminated waste, the regional management entity is much more likely to be able to do so. The blended product may exceed the unrestricted use requirements while still not exceeding the ceiling concentrations after mixing the materials with those of other producers. As a result, the product could still be used for beneficial use, but with lower application rates. If an off specification material is traced back to a particular municipality, the liability could be limited to slightly increased costs for reduction in the application rate as opposed to the need to dispose of the material as a hazardous waste in the worst case scenario. In addition, once mixing is accomplished, it is much less likely that the waste from a one time dumping situation will be traced back to a particular entity. It is more likely that the increased costs will be shared by the various contributors, again making the contribution from each generator less of a burden on any one party. At the same time, however, increased sampling of sludges provided by individual generators contributing to batches of material which were later found to contain elevated metals levels, will detect sludges that are consistently above the applicable metals limits and allow for direct action against the generator.

Similar benefits are seen for pathogen reductions and vector attraction reduction treatments as well. The systems providing sludges to regional composting facilities or regional lime stabilization treatment would not be required to certify that either of these two requirements are met. These requirements would be covered under the regional entity's permit or registration. In addition, there could be some cost savings to the participants if digestion facilities could be operated at a lesser detention time based on the achievement of pathogen reductions and vector attraction reduction in the regional management facility. Any reduction in digestion time would need to be balanced against the regional entity's requirement to operate without producing an odor nuisance, as some minimum digestion will be required.

Since overall liability remains in effect, the reductions in the liability of the smaller generators which participate in a regional plan must be offset by increased liability assumed by the regional facility. As noted above, the regional facility must provide sufficient treatment under its permit or registration to assure the production of a material which meets the requirements for metals, pathogen levels, and vector attraction reduction. However, the main liability threat remains the possibility of receiving loads with elevated metals levels which result in the product exceeding land application ceiling levels for pollutants. Under this situation, the regional authority must conduct necessary testing to ensure the product is not hazardous waste. If it does not meet the definition of hazardous waste, the regional facility can either pay for landfill disposal or blend the product with incoming sludges to produce a final product which is below the applicable ceiling levels. In either event, the disposition of these materials will be somewhat more expensive than normal handling and the regional facility contracts must be structured in a manner to allow the facility to recover the additional costs. While the preferred method of cost recovery would be through assessment to the entity that delivered the load with elevated metals levels, it is unlikely that the source of the load can be precisely determined. In addition, all of the utilities run the risk of a "midnight dumper" pulling up to a manhole, or a one-time spill or intentional discharge of metals containing wastes. Spreading the cost over a larger number of participants reduces the impact on any one entity.

While the risks noted above can be contained to a certain extent, it is in the best interests of the regional facility as well as all of the contributing entities to control their waste streams as closely as possible. In addition, requirements for periodic analyses should be strictly enforced, with grab samples collected by the regional facility at irregular intervals and tested to determine sludge quality prior to further treatment. The following listed items are suggested as steps the regional facility can take to make it easier to trace problems back to the source as well as to prevent problems from occurring initially.

1. Records should be kept of all contributors to storage vessels which allow mixing of incoming wastes. A sample should be collected from each load of waste deposited, but the samples should be held under proper storage conditions instead of being submitted for analysis immediately. This is particularly important for sludges hauled in liquid form and mixed prior to dewatering. When the storage vessel is full and completely mixed, a sample should be collected and analyzed for metals content. If the sample from the mixed waste exceeds any of the metals limits, the individual samples should be analyzed to determine concentrations in each load. Care must be taken not to exceed sample holding times for performing analyses. As experience with contributors is gained, the regional facility may reduce the sampling from an every mixed batch basis to a random sampling, if they so desire.

2. Operational protocols for either composting or lime stabilization facilities should be written to require identification of material entering the treatment process. Both processes are essentially batch process, so materials can be identified by location in the processing facility and dates of deposition, treatment, etc. This will be required in both cases for documentation that the materials have received the necessary treatments. Identities should be maintained through the treatment process until the point at which final product quality samples are taken. Once these samples are taken to assure the product meets Class A pathogen levels, applicable metals levels, and the process of vector attraction reduction is documented, the final product can be mixed with other batches for delivery.

3. Written agreements should be secured from each contributor to a regional facility that outline the requirements for participation. This agreement should clearly state the incoming metals levels that are acceptable to the regional facility, as well as the measures that will be taken to locate sources of metals above those limits, if they occur. The costs for the various remedial actions should also be spelled out in advance, as follows:

   a. Costs for additional sampling to locate sources of incoming metals.

   b. Costs for increasing the recycle of product to mix with incoming raw materials for reduction of overall metals levels.

c. Costs for additional labelling needed to reduce product application rate based on limiting material, as well as calculations for determining the limiting factors.

d. Costs for disposing of incoming materials as hazardous wastes if analysis shows the need for such disposal. These costs could encompass the disposal of an entire mixed batch of sludges if the analysis shows the contamination came from one particular source. Otherwise, the costs would be spread among the contributors to that batch.

e. Procedures that will be applied to determine the need for and assess the charges listed above.

f. Compliance with pathogen levels and vector attraction reduction requirements should be specified as the sole responsibility of the regional facility. This wording plus the permitting or registration requirements for the regional facility relieves the individual sludge producer of liability for these areas, and allows them to amend their wastewater permits accordingly.

4. The receiving station at the regional facility should be manned by an experienced wastewater treatment facility operator with knowledge of the physical characteristics of wastewater treatment plant sludges. The receiver should visually inspect each load of material to be deposited at the facility to prevent the acceptance of any obviously non-characteristic materials. The receiver should also be provided with equipment such as a sludge judge for sampling beneath the surface of the load, as well as litmus papers or a meter for quick determination of pH. The receiver should be able to either refuse loads that are suspect, or divert them to individual holding facilities where they will not be commingled with other sludges until analyses are completed. Cost of analyses in these circumstances should be borne by the generator initially, although samples taken from subsequent loads should be the responsibility of the regional facility if samples taken do not indicate any excess metals.

5. Random samples should also be taken of incoming wood waste/chips on an infrequent basis. trees grown in metal contaminated soils could contribute additional metals to the compost mix and that effect must be accounted for if present.

As noted above, the regional facility will be assuming some risk of liability in accepting loads of materials from diverse sources, and that risk must be managed to the greatest degree possible. Production of materials meeting Class A pathogen levels, and applicable metals levels through documentation of testing results, and appropriate vector attraction reduction techniques through process records will provide significant protection from liability for the regional entity, and for the individual generators as well.

In addition to documenting product quality through plant records, the regional utility may be called upon to investigate claims of damage to property alleged to have occurred through use of the product. Activities that may be required include collection of samples of material used, collection of plant samples and soil samples from the effected area, and hiring of experts to review the analyses and determine the causative agent, if possible. At present, the literature search has revealed that such actions are relatively rare for those entities producing biosolids for unrestricted use. Once again, the maintenance of proper documentation of the handling and processing of materials is crucial to defense of any actions which do arise. All of the recommended actions listed above can be cited as helping to provide assurance that the final product is suitable for the intended use.

### 9.1 Regional Water Conservation

The Greater Houston Area has seen a great deal of activity concerning water conservation issues. A major portion of the area is under the jurisdiction of the Harris-Galveston Coastal Subsidence District. The District has a current plan which requires that water using entities convert to surface water to reduce demands on the area aquifers and reduce land subsidence associated with overpumping of ground water. As a result of the controversy over surface water conversion, and as a result of the Subsidence District's efforts to educate consumers on the costs of wasting water and the benefits of wise water usage, there has been an increasing focus on water conservation issues in the area. In addition, all studies funded by the Texas Water Development Board for supply augmentation, supply planning, demand forecasting, and other water related issues have been required to develop a water conservation plan and estimate the demand reduction of such a plan. A regional water conservation plan is currently being developed as part of the Trans-Texas Water plan for the City of Houston. This plan is being funded by TWDB and will be considered as the regional plan when finally adopted by TWDB.

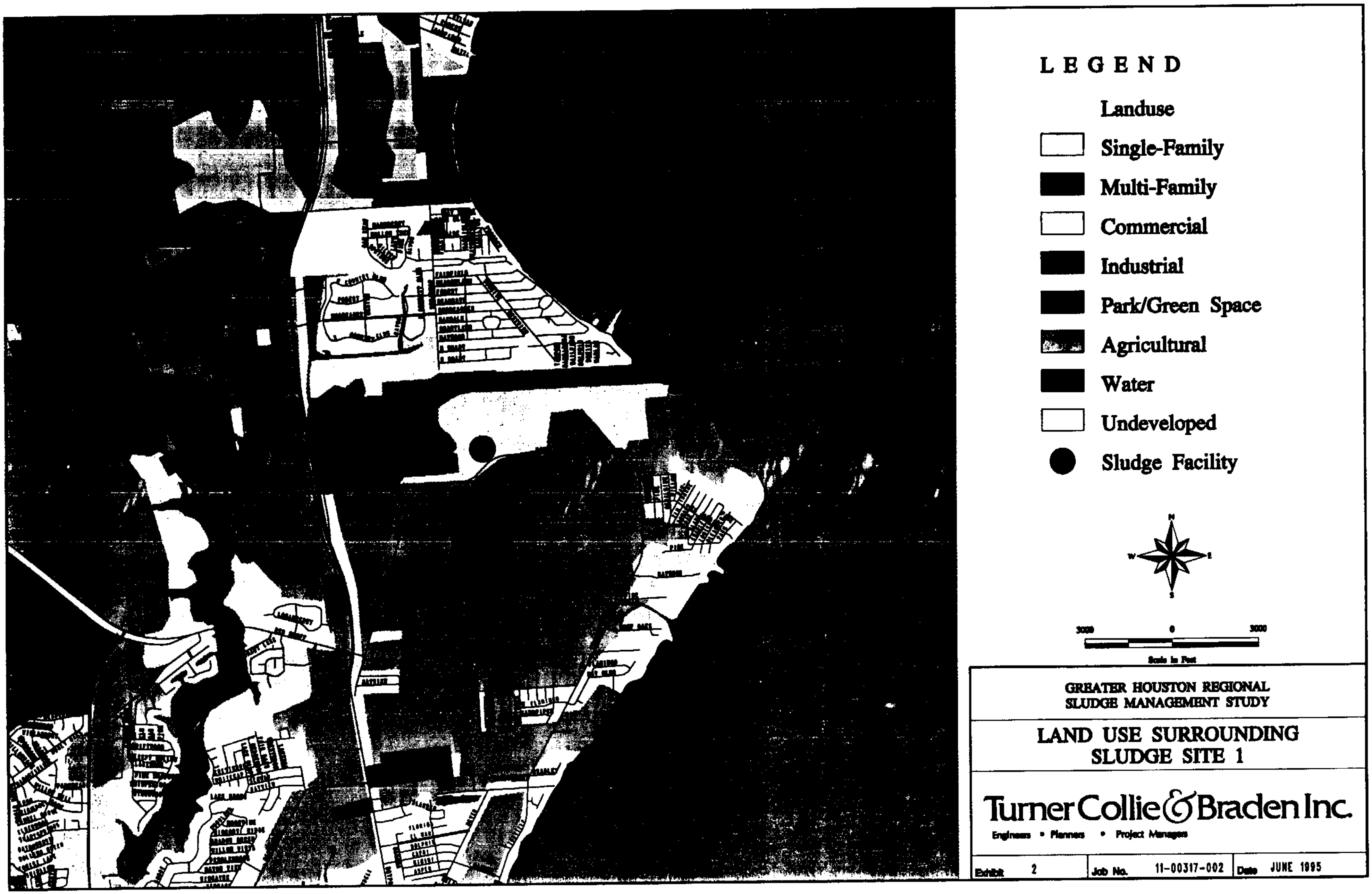
### 9.2 Effects of Water Conservation on Sludge Production

In addition to the plans noted above, there are two factors which will effect the entire Greater Houston Area over the next several years with regard to water conservation. The first of these is the 1991 water efficient plumbing fixtures bill restricting the sale and use of inefficient plumbing fixtures. All new plumbing fixtures must meet reduced flow requirements, including sink and lavatory faucets, showerheads, urinals and toilets, flush valve toilets, and drinking fountains, if they are to be manufactured, imported, or otherwise supplied for sale in Texas. The Texas Water Development Board (TWDB) estimates that these devices have the potential for reducing indoor water consumption between 20 and 40 percent. For the 3.2 million persons in the Greater Houston Area, this savings could amount to 60 to 120 million gallons per year.

The second factor which has the potential to effect considerable savings in water usage is the planned education campaign by the Subsidence District to team with individual water districts to distribute plumbing fixture retrofit kits to students in elementary school throughout the area. Pilot testing of the program in Harris County Municipal Utility District No. 55 (MUD 55), co sponsored by the Texas Water Development Board, The Subsidence District and MUD 55 resulted in average monthly water savings of approximately 18 percent, for single family residences, with additional savings in energy usage for heating the water. Multi-family water users saw a water savings of approximately 27 percent. As a result of these favorable savings numbers, this program is being offered area wide, with the intent of reaching as many of the school classrooms as possible. Without this retrofit program, the possible savings described above would not occur until all plumbing fixtures in the area were replaced because of wear, malfunction, etc. This retrofit program will greatly accelerate the speed at which noticeable savings will occur.

With all of the activity noted above, the question that must be answered is whether reduced water usage will result in increases or decreases in sludge production throughout the area. The production of solids is not dependent upon the amount of water used to carry them. The reduced flows in the sewer lines must still transport the same amount of solids to the treatment plant. However, the reduced effluent flows will have some impact on the mass balance of solids through the treatment plants. The amount of sludge which must be dealt with is dependent upon the amount of five-day biochemical oxygen demand ($BOD_5$) treated in the plant and turned into suspended solids, the efficiency with which the plant turns the soluble $BOD_5$ into suspended solids, and the permitted levels of suspended solids in the effluent. With the same total daily weight of $BOD_5$ coming into the plant and being turned into suspended solids, the only difference in amount of solids that become waste sludge is the pounds per day of sludge discharged in the effluent at the permitted levels. As an example, a treatment plant that discharges 100,000 gallons of effluent per day with a suspended solids level of 15 milligrams per liter is discharging a total of 12.5 pounds per day of suspended solids. If water conservation reduces the total effluent discharge flow by 20 percent, the resulting flow of 80,000 gallons per day at 15 milligrams per liter suspended solids results in a total solids discharge of 10 pounds of suspended solids per day, or a similar 20 percent reduction.

The same process that was used above for an example waste discharger can be projected over the total 3.2 million persons in the study area by assuming that current flows are approximately 100 gallons per person per day. This equates to 320 million gallons per day of wastewater flow. At 15 milligrams per liter effluent solids concentration, the allowable discharge on a daily basis is 20 tons of dry solids. Reducing the effluent flow by 20 percent results in 256,000,000 gallons per day of effluent flow. At 15 milligrams per liter this effluent flow discharges 16 tons of dry solids. With a 40 percent flow reduction, the effluent discharge would amount to 12 tons of dry solids daily. Given the conservative nature of the design estimate for daily sludge production of 268 dry tons per day, the additional 4 to 8 tons of solids which might be captured on a daily basis is not significant for this study.


LEGEND
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Single-Family
Multi-Family
Commercial
Industrial
Park/Green Space
Agricultural
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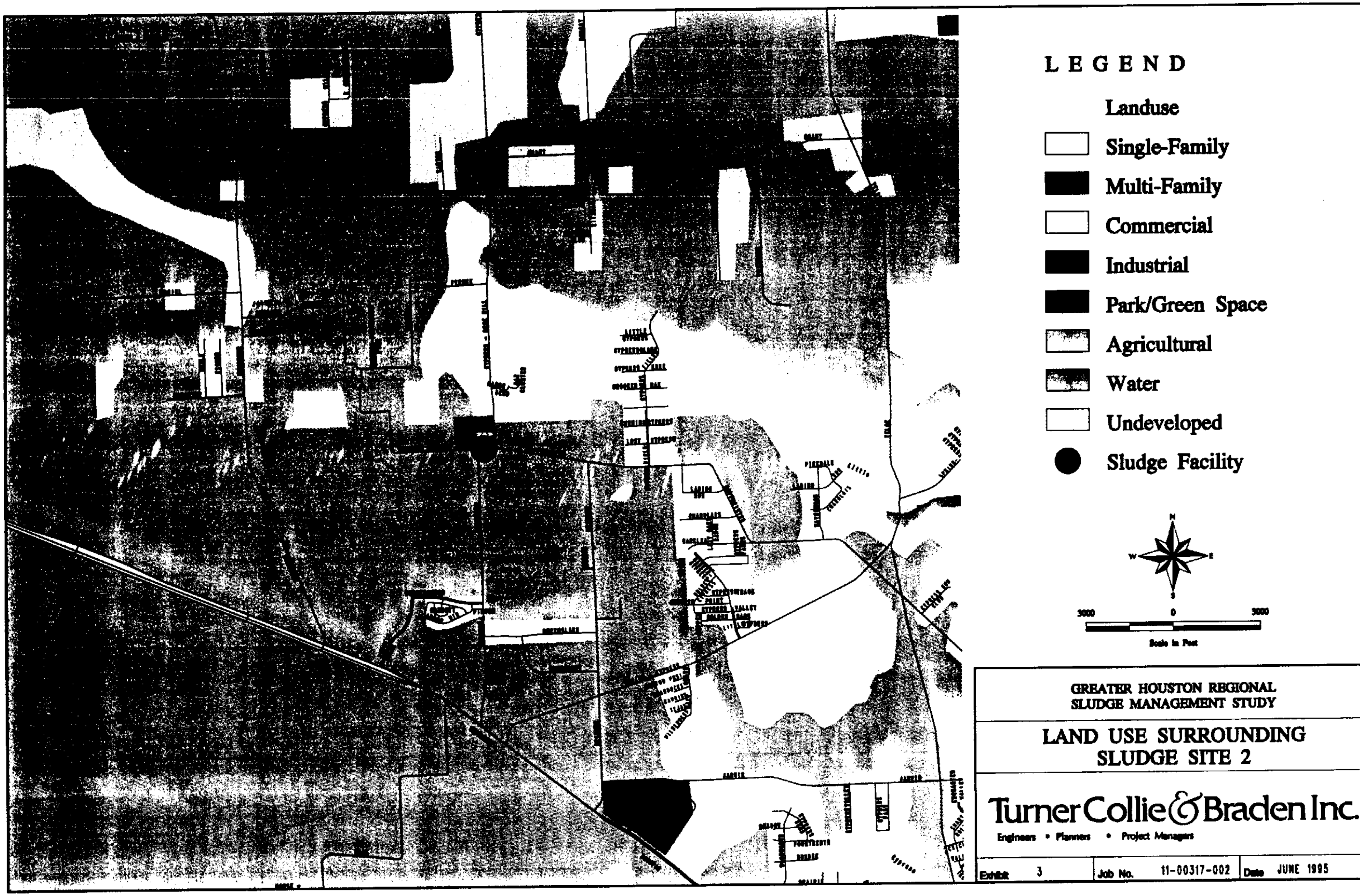
GREATER HOUSTON REGIONAL
SLUDGE MANAGEMENT STUDY
LAND USE SURROUNDING
SLUDGE SITE 1
Turner Collie & Braden Inc.
Engineers • Planners • Project Managers
Exhibit 2
Job No. 11-00317-002
Date JUNE 1995




GREATER HOUSTON REGIONAL
SLUDGE MANAGEMENT STUDY

## LAND USE SURROUNDING SLUDGE SITE 2

Turner Collie & Braden Inc.
Engineers • Planners • Project Managers

| Exhibit 3 | Job No. 11-00317-002 | Date JUNE 1995 |
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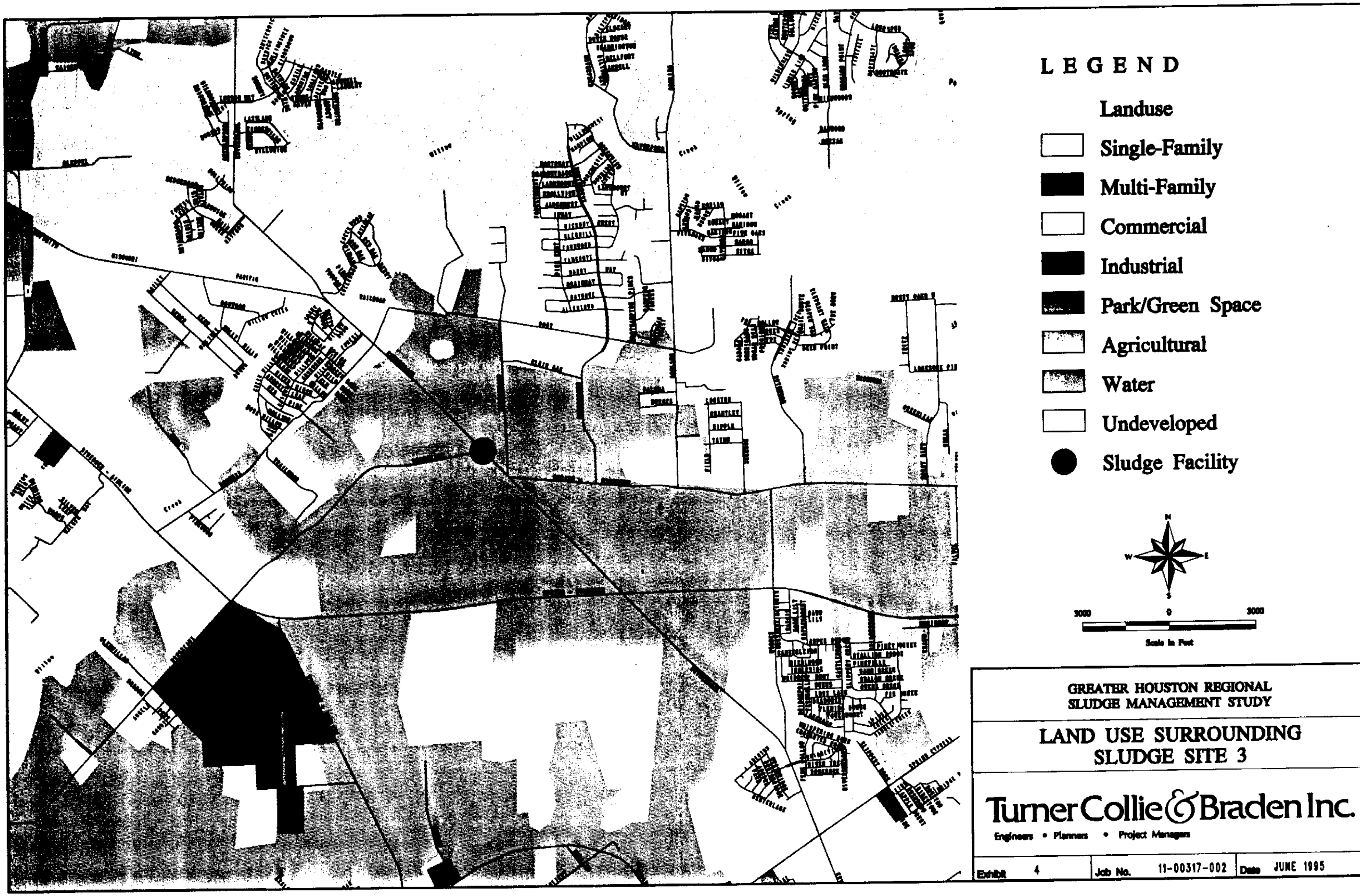



GREATER HOUSTON REGIONAL
SLUDGE MANAGEMENT STUDY

LAND USE SURROUNDING
SLUDGE SITE 3

Turner Collie & Braden Inc.
Engineers • Planners • Project Managers

| Exhibit | 4 | Job No. | 11-00317-002 | Date | JUNE 1995 |
|---|---|---|---|---|---|

# APPENDIX A-6

# LIME STABILIZATION

## A-6.1 Background

Lime stabilization is a process in which lime is added to raw sludge in a quantity sufficient to raise the pH of the sludge to approximately 12.0 for at least 2 hours. The lime-stabilized sludge readily dewaters with mechanical equipment (e.g., filter press, centrifuge, etc.), and is generally suitable for disposal to landfill, dedicated disposal site, or application to agricultural land (except where the existing agricultural soil already has a high pH).

A potential disadvantage of the lime stabilization method is that the mass of dry sludge solids is increased by the lime added and the chemical precipitates that result from the addition. Because of the increased sludge volume, the cost of transport and disposal/application is often greater for lime-stabilized sludge than for sludge stabilized by other methods (e.g., anaerobic digestion).

Two forms of lime are commercially available: (1) quicklime (CaO) and (2) hydrated lime ($Ca(OH)_2$). Quicklime is less expensive but must be converted to hydrated lime on site by slaking. Hydrated lime can be mixed with water and applied directly. Generally, larger treatment plants purchase quicklime, and smaller sewage treatment plants use hydrated lime. For a specific plant, a detailed economic analysis is necessary which takes into account plant size, chemical requirements, chemical costs, and labor and maintenance requirements. In this cost algorithm, the use of hydrated lime is assumed in developing the cost default values. This assumption should produce adequate cost estimates for small and medium size plants (those using up to 5 tons of lime/day), but may result in overestimating O&M costs for larger plants.

### A-6.1.1 Process Design

The design of a lime stabilization system consists of two parts: (1) design of a lime handling system; and (2) design of the sludge mixing system. The design of each is briefly described below.

Design of the lime handling system depends on the form and quantities of lime received at the treatment plant. Lime can be stored in steel or concrete silos or bins. At a minimum, sufficient storage capacity to provide a 7-day supply of lime should be provided; however, a 2- or 3-week supply is desirable. In addition, the total storage volume should be at least 50 percent greater than the capacity of the delivery railcar or truck to ensure adequate lime supply between shipments.

Dry hydrated lime is delivered from storage to a dilution tank fitted directly onto the feeder. The dilution tank is agitated by either compressed air, water jets, or impeller-type mixers. From the dilution tank, the slurry is then transferred to the sludge mixing tank. Smaller treatment plants purchase and store bagged hydrated lime which is mixed with water and metered to the sludge mixing tank as required.

The mixing tank is sized based on detention time. Optimally, the mixing tank should be sized to hold the lime/sludge mixture for 30 minutes. This detention time should allow sufficient contact to raise the pH beyond 12.5. Mixing tanks can be operated in batch or continuous mode. Tank mixing is accomplished either with diffused air or mechanical mixers. Diffused air is more commonly used in lime stabilization.

The lime stabilization process in this cost algorithm includes a lime storage silo sized for 30 days storage; dual batch mixing tanks, each having a capacity to hold 0.5 hours of plant design sludge flow; and a lime feeding system. Normal costs for piping, pumps, electrical, and other accessories are included.

A-6.1.2 Algorithm Development

The following algorithm follows the basic sequence used by an engineer when designing a lime stabilization process. Dosage, contact time, labor, electrical requirements, and capital costs were obtained from information in Reference 4, pages 6-104 through 6-107. Lime costs are based on vendor quotes.

A-6.2 Input Data

A-6.2.1 Daily sludge volume, SV, gal/day.

A-6.2.2 Sludge suspended solids concentration, SS, percent.

A-6.3 Design Parameters

A-6.3.1 Daily sludge volume, SV, gal/day. This input value must be provided by the user. No default value.

A-6.3.2 Sludge suspended solids concentration, SS, percent. This input value must be provided by the user. No default value.

A-6.3.3 Sludge specific gravity, SSG, unitless. This value should be provided by the user. If not available, default value is calculated using the following equation:

$$SSG = \frac{1}{\frac{100 - SS}{100} + \frac{(SS)}{(1.42)\ (100)}}$$

where

SSG = Sludge specific gravity, unitless.
1.42 = Assumed sludge solids specific gravity.

A-6.3.4 Daily operation period, HPD, hr/day. Default value = 8 hr/day

A-6.3.5 Annual operation period, DPY, days/yr. Default value = 3 days/yr.

A-6.3.6 Sludge detention time in mixing tank, DT, hr/batch. Defau value = 0.5 hr.

A-6.3.7 Lime dosage as a fraction of dry sludge solids mass, LD, lb $Ca(OH)_2$/lb of dry sludge solids. Default value = 0.3. The li dosage required is determined by the type of sludge, its chemi cal composition, and the solids concentration. The followi tables are given to provide guidance in selecting an appropria value.

APPROXIMATE LIME DOSE REQUIRED TO RAISE TO 12.5 THE pH OF A MIXTURE OF PRIMARY SLUDGE AND TRICKLING FILTER HUMUS AT DIFFERENT SOLIDS CONCENTRATIONS

| Solids Concentration (SS) (%) | Lime Dose (LD) (lb $Ca(OH)_2$/lb dry solids) |
|---|---|
| 1 | 0.39 |
| 2 | 0.32 |
| 3 | 0.27 |
| 4 | 0.23 |

LIME DOSE REQUIRED TO KEEP pH ABOVE 11.0 FOR AT LEAST 14 DAYS

| Type of Sludge | Lime Dose (LD) (lb $Ca(OH_2)$/lb suspended solids) |
|---|---|
| Primary Sludge | 0.10 - 0.15 |
| Activated Sludge | 0.30 - 0.50 |
| Septage | 0.10 - 0.30 |
| Alum-sludge* | 0.40 - 0.60 |
| Alum sludge* Plus Primary Sludge† | 0.25 - 0.40 |
| Iron-sludge* | 0.35 - 0.60 |

* Precipitation of primary treated effluent.
† Equal proportions by weight of each type of sludge.

A-6.3.8 Hydrated lime content of the lime product used, LC, percent. Default value = 90 percent.

A-6.4 Process Design Calculations

A-6.4.1 Calculate annual lime requirement.

$$ALR = \frac{(8.34)\ (SV)\ (SS)\ (SSG)\ (LD)\ (365)\ (100)}{(100)\ (LC)}$$

where

ALR = Weight of lime product required annually, lb/yr.

A-6.4.2 Calculate volume of lime storage silo (30 days storage assumed).

$$VLS = \frac{(ALR)}{(12)\ (30)}$$

where

VLS = Volume of lime storage required, $ft^3$.
12 = Months/yr.
30 = Bulk density of hydrated lime in storage silo, $lb/ft^3$.

A-6.4.3 Calculate combined capacity of two mixing tanks.

$$MTC = \frac{(SV)\ (DT)\ (2)\ (365)}{(HPD)\ (DPY)}$$

where

MTC = Total mixing tank capacity required, gal.
2 = Design factor.

A-6.4.4 Calculate capacity of lime feed system.

$$LFC = \frac{(ALR)\ (2.0)}{(DPY)\ (HPD)\ (0.167)}$$

where

LFC = Total lime feed system capacity required, lb/hr.

0.167 = 1/6 = Assumed 5-min period of lime feeding divided by 30-min detention period.

A-6.5 Process Design Output Data

A-6.5.1 Annual lime requirement, ALR, lb/yr.

A-6.5.2 Volume of lime storage silo, VLS, $ft^3$.

A-6.5.3 Combined capacity of two mixing tanks, MTC, gal.

A-6.5.4 Capacity of lime feed system, LFC, lb/hr.

A-6.6 Quantities Calculations

A-6.6.1 Calculate annual energy requirement for air mixing.

$$BER = \frac{(MTC)\ (0.03)\ (97)}{(7.48)}$$

where

BER = Annual energy requirement for air mixing, kWhr/yr.
0.03 = Blower capacity factor based on 3 cfm/100 $ft^3$ of tank volume.
97 = kWhr required annually per cfm of blower capacity.

A-6.6.2 Calculate total annual energy requirement.

$$E = BER\ (1.3)$$

where

E = Total annual energy requirement, kWhr/yr.

1.3 = Additional power factor for lime feeding and other minor energy requirements.

A-6.6.3 Calculate annual labor requirement.

$$L = (DPY)\ (HPD)\ (0.5 + \frac{(SV)\ (365)}{50,000,000})$$

where

L = Annual labor requirement, hr/yr.

$0.5 + \frac{(SV)\ (365)}{50,000,000}$ = Labor hour factor.

A-6.7 Quantities Calculations Output Data

A-6.7.1 Annual energy requirement for air mixing, BER, kWhr/yr.

A-6.7.2 Total annual energy requirement, E, kWhr/yr.

A-6.7.3 Annual labor requirement, L, hr/yr.

A-6.8 Unit Price Input Required

A-6.8.1 Current Engineering News Record Construction Cost Index at time analysis is made, ENRCCI.

A-6.8.2 Current Marshall and Swift Equipment Cost Index at time analysis is made MSECI.

A-6.8.3 Cost of lime, LMCST, \$/ton. Default value = \$100/ton (ENRCCI/4,006).

A-6.8.4 Cost of lime storage silo(s), LSCST, $\$/ft^3$. Default value = $\$7.40/ft^3$ (ENRCCI/4,006).

A-6.8.5 Cost of mixing tanks, MTCST, including air mixing system, scrubber, and piping, \$/gal. Default value = \$0.80/gal (MSECI/751).

A-6.8.6 Cost of lime feed system, LFCST, including all accessories, \$/lb/hr. Default value = \$15/lb/hr (MSECI/751).

A-6.8.7 Cost of labor, COSTL, \$/hr. Default value = \$13.00/hr (ENRCCI/4,006).

A-6.8.8 Cost of energy, COSTE, \$/kWhr. Default value = \$0.09/kWhr (ENRCCI/4,006).

A-6.9 Cost Calculations

A-6.9.1 Annual cost of lime.

$$COSTLM = \frac{(ALR)\ (LMCST)}{2{,}000}$$

where

ACSTLM = Annual cost of lime, \$/yr.

A-6.9.2 Cost of lime storage silo.

$$COSTLS = (VLS)\ (LSCST)$$

where

COSTLS = Cost of lime storage silo, \$.

A-6.9.3 Cost of lime feed system with appurtenances.

$$COSTLF = (LFC)\ (LFCST)$$

where

COSTLF = Cost of lime feed systems, $.

A-6.9.4 Cost of mixing tanks with appurtenances.

$$COSTMT = (MTC)\ (MTCST)$$

where

COSTMT = Cost of mixing tanks with appurtenances, $.

A-6.9.5 Annual cost of operation labor.

$$COSTLB = (L)\ (COSTL)$$

where

COSTLB = Annual cost of operation labor, $/yr.

A-6.9.6 Annual cost of electrical energy.

$$COSTEL = (E)\ (COSTE)$$

where

COSTEL = Annual cost of electrical energy, $/yr.

A-6.9.7 Total base capital cost.

$$TBCC = COSTLS + COSTLF + COSTMT$$

where

TBCC = Total base capital cost, $.

A-6.9.8 Annual maintenance material and supply cost.

$$COSTM = (TBCC)\ (0.15)$$

where

COSTM = Annual maintenance material and supply cost, $/yr.

A-6.9.9 Annual cost of operation and maintenance.

COSTOM = COSTLM + COSTLB + COSTEL + COSTM

where

COSTOM = Annual cost of operation and maintenance, \$/yr.

A-6.10 Cost Calculations Output Data

A-6.10.1 Annual cost of lime, COSTLM, \$/yr.

A-6.10.2 Cost of lime storage silo, COSTLS, \$.

A-6.10.3 Cost of lime feed system with appurtenances, COSTLF, \$.

A-6.10.4 Cost of mixing tanks with appurtenances, COSTMT, \$.

A-6.10.5 Annual cost of operation labor, COSTLB, \$/yr.

A-6.10.6 Annual cost of electrical energy, COSTEL, \$/yr.

A-6.10.7 Annual maintenance material and supply cost, COSTM, \$/yr.

A-6.10.8 Total base capital cost, TBCC, \$.

A-6.10.9 Total annual operation and maintenance cost, COSTOM, \$/yr.

## APPENDIX A-9

## BELT FILTER DEWATERING

### A-9.1 Background

Belt filters have become increasingly popular in the United States, often selected as the method for dewatering sludges at new treatment plants. This popularity is due to the high dewatering capabilities and low power requirements of the process.

Belt filters employ single or double moving belts made of woven synthetic fiber to dewater sludges continuously. The belts pass over and between rollers which exert increasing pressure on the sludge as it moves with the belts. Sludges are dewatered initially through the action of capillarity and gravity, and afterwards by increasing pressure and shear force over the length of the filtration zone. The dried cake is removed from the filter belt by a flexible scraper. A second scraper and sprayed water are used to clean the belt.

Sludge conditioning is important in this process in order to achieve optimal dewatering performance. Costs obtained in this algorithm do not include conditioning. Those costs may be obtained using the algorithms in Appendices A-13, A-14, and A-15.

Process design is based on solids and hydraulic loading. However, solids loading appears to be the more critical of the two. Belt filters are purchased from the manufacturer in standard belt widths. In this algorithm, single or multiple units of 0.5-, 1-, and 2-meter widths are considered. To estimate the width of a belt filter, the loading rate (lb sludge/meter/hr) is the key design parameter, as shown in the table below.

| Influent Suspended Solids (%) | 1-2 | 3-4 | 5-6 |
|---|---|---|---|
| Loading Rate (dry solids lb/hr/meter of belt width) | 400-600 | 600-800 | 800-900 |

Capital costs in this algorithm include purchase and installation of one or more belt press units and ancillary equipment, and a building to house belt presses with adequate room for safe operation and maintenance. Annual O&M costs include labor, electrical energy, and parts and materials.

A-9.1.1 Algorithm Development

This algorithm is based on design and cost information obtained from Reference 6, pages 181 through 183, and information supplied by equipment manufacturers. Costs and O&M requirements obtained were fit to equations using a multiple regression program.

A-9.2 Input Data

A-9.2.1 Daily sludge volume, SV, gal/day.

A-9.2.2 Sludge suspended solids concentration, SS, percent.

A-9.2.3 Sludge specific gravity, SSG, unitless.

A-9.2.4 Sludge dry solids loading rate per meter width of the belt press, BFLR, lb/meter/hr.

A-9.2.5 Hours per day process is operated, HPD, hr/day.

A-9.2.6 Days per year process is operated, DPY, days/yr.

A-9.3 Design Parameters

A-9.3.1 Daily sludge volume, SV, gal/day. This input value must be provided by the user. No default value.

A-9.3.2 Sludge suspended solids concentration, SS, percent. This input value must be provided by the user. No default value. Be sure to include SS added by conditioning chemicals.

A-9.3.3 Sludge specific gravity, SSG, unitless. This value should be provided by the user. If not available, default value is calculated as follows:

$$SSG = \frac{1}{\frac{100 - SS}{100} + \frac{(SS)}{(1.42)\ (100)}}$$

A-9.3.4 Sludge dry solids. Loading rate per meter width of the belt press, BFLR, lb/hr. This value is a function of suspended solids in the feed sludge. Default values are 500 for 2 percent SS, 650 for 4 percent SS, and 800 for 6 percent SS.

A-9.3.5 Hours per day process is operated, HPD, hr/day. Default value = 8 hr/day.

A-9.3.6 Days per year process is operated, DPY, days/yr. Default value = 365.

A-9.4 Process Design Calculations

A-9.4.1 Calculate dry solids dewatered per day.

$$DSS = \frac{(SV)\ (SS)\ (SSG)\ (8.34)}{(100)}$$

where

DSS = Dry solids dewatered per day, lb/day.
8.34 = Density of water, lb/gal.

A-9.4.2 Calculate the total width of the belt filter needed to dewater the sludge at the specified loading rate. Costs are based on the use of one or more 0.5-, 1-, and 2-meter-wide unit belt filters. The total width required is sufficient to estimate the costs regardless of the number of units used.

$$TBFW = \left[\frac{(DSS)\ (365)}{(BFLR)\ (HPD)\ (DPY)}\right]$$

where

TBFW = Total belt filter width, meters.

A-9.5 Process Design Output Data

A-9.5.1 Dry suspended solids dewatered per day, DSS, lb/day.

A-9.5.2 Total belt filter width, TBFW, meters.

A-9.6 Quantities Calculations

A-9.6.1 Annual operation and maintenance labor required.

A-9.6.1.1 If TBFW $\leq$ 0.5 meters, labor is calculated by:

$$L = 1,773 \left[\frac{(TBFW)}{0.5}\right]$$

A-9.6.1.2 If TBFW > 0.5 meters, labor is calculated by:

$$L = [-\ 0.34\ (TBFW)^3 + 3,734\ (TBFW)^2 + 441.5\ (TBFW) + 619]$$

where

L = Annual operation and maintenance labor required, hr/yr.

A-9.6.2 Annual electrical energy required.

A-9.6.2.1 If TBFW $\leq$ 0.5 meters, electrical energy is calculated by:

$$E = 22{,}065 \left[\frac{(TBFW)}{0.5}\right]$$

A-9.6.2.2 If TBFW > 0.5 meters, electrical energy is calculated by:

$$E = [- 5.42 (TBFW)^3 + 234.6 (TBFW)^2 + 16{,}020 (TBFW) + 13{,}997]$$

where

E = Annual electrical energy required, kWhr/yr.

A-9.7 Quantities Calculations Output Data

A-9.7.1 Annual operation and maintenance labor required, L, hr/yr.

A-9.7.2 Annual electrical energy required, E, kWhr/yr.

A-9.8 Unit Price Input Required

A-9.8.1 Current Engineering News Record Construction Cost Index, ENRCCI, at time cost analysis is made.

A-9.8.2 Current Marshall and Swift Equipment Cost Index, MSECI, at time cost analysis is made.

A-9.8.3 Cost of operation and maintenance labor, COSTL, \$/hr. Default value = \$13.00/hr (ENRCCI/4,006).

A-9.8.4 Cost of electrical energy, COSTE, \$/kWhr. Default value = \$0.09/kWhr (ENRCCI/4,006).

A-9.9 Cost Calculations

A-9.9.1 Annual cost of operation and maintenance labor.

$$COSTLB = (L) (COSTL)$$

where

COSTLB = Annual cost of labor, \$/yr.

A-9.9.2 Annual cost of electrical energy, \$/yr.

$$COSTEL = (E)\ (COSTE)$$

where

COSTEL = Annual cost of electrical energy.

A-9.9.3 Annual cost of parts and materials.

A-9.9.3.1 If TBFW $\leq$ 0.5 meters, annual cost of parts and materials is calculated by:

$$COSTPM = 1{,}784 \left[\frac{(TBFW)}{0.5}\right] \frac{MSECI}{751}$$

A-9.9.3.2 If TBFW > 0.5 meters, annual cost of parts and materials is calculated by:

$$COSTPM = [-\ 0.708\ (TBFW)^3 + 30.6\ (TBFW)^2 + 2{,}371\ (TBFW) + 1{,}184]\ \frac{MSECI}{751}$$

where

COSTPM = Annual cost of parts and materials, \$/yr.

A-9.9.4 Total base capital cost.

A-9.9.4.1 If TBFW $\leq$ 0.5 meters, total base capital cost is calculated by:

$$TBCC = [243{,}000]\ \frac{MSECI}{751}$$

A-9.9.4.2 If TBFW > 0.5 meters, total base capital cost is calculated by:

$$TBCC = [-\ 158.6\ (TBFW)^3 + 5{,}496\ (TBFW)^2 + 98{,}269\ (TBFW) + 192{,}630]\ \frac{MSECI}{751}$$

where

TBCC = Total base capital cost, \$.

A-9.9.5 Total annual operation and maintenance cost.

$$COSTOM = COSTLB + COSTEL + COSTPM$$

where

COSTOM = Total annual operation and maintenance cost, \$/yr.

### A-9.10 Cost Calculations Output Data

A-9.10.1 Annual cost of operation and maintenance labor, COSTLB, \$/yr.

A-9.10.2 Annual cost of electrical energy, COSTEL , \$/yr.

A-9.10.3 Annual cost of parts and materials, COSTPM, \$/yr.

A-9.10.4 Total base capital cost, TBCC, \$.

A-9.10.5 Total annual operation and maintenance cost, COSTOM, \$/yr.

## APPENDIX A-18

## COMPOSTING - WINDROW METHOD

### A-18.1 Background

In windrow composting, dewatered sludge is mixed with a bulking agent and spread on paved but uncovered areas in windrows with an approximately triangular or trapezoidal cross sectional area of 35 $ft^2$. The most economical and most commonly used bulking agents in the windrow process are previously composted sludge and sawdust. Windrows are approximately 14 ft wide, with access areas between windrows of 10 ft. Windrows are 300 ft long, or less for small plants. Sludge remains in windrows for approximately 30 days, with periodic turning to maintain aerobic conditions and to provide mixing. At the end of the composting period, the sludge is moved to a storage area for additional curing. With properly controlled operation, high temperatures achieved during composting can destroy virtually all pathogens and parasites. However, compost is a suitable medium for regrowth of bacteria, and precautions must be taken to prevent reinfection. Windrow composting may be adversely affected by cold or wet weather.

The algorithm presented below is based on the construction and operation of a windrow composting facility with the following conditions:

- Windrow and access areas are paved with asphalt; the storage area is unpaved.
- Dewatered sludge is mixed with previously composted sludge to obtain an initial solids concentration of approximately 40 percent.
- Windrows are turned mechanically once a day for the first 2 weeks, and three times per week thereafter.
- Compost mix remains in the composting area for 30 days.

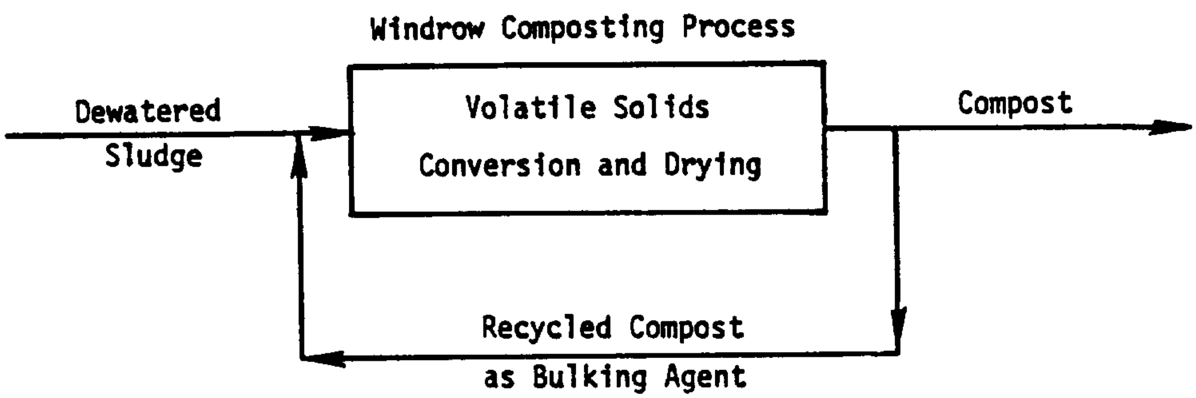
Capital costs include purchase of land, site clearing and grading, paving of composting area, purchase of windrow turning machine and front-end loader, purchase and construction of unloading and mixing structure, and construction of a maintenance and operation building. Operation and maintenance costs include operation and maintenance labor, fuel for composting and ancillary machinery, and O&M materials and supplies.

#### A-18.1.1 Algorithm Development

The following algorithm was developed for windrow composting using previously composted sludge as the bulking agent. Supplemental information was obtained from Reference 4, pages 12-10 through 12-12 and pages 12-16 through

12-22; and through correspondence with the Los Angeles County Sanitation District. The information obtained from references was fit to equations using a multiple regression program.

The process is shown schematically in the flow diagram below. Reference to the diagram should aid the reader in following the material balance calculations that follow. In these calculations, it is assumed that no changes occur to the recycled compost used as bulking agent, since any further conversion taking place in the recycled compost is negligible compared with the conversion of solids in the dewatered sludge.




A-18.2 Input Data

A-18.2.1 Daily dewatered sludge volume entering the composting process, SV, gal/day.

A-18.2.2 Sludge solids concentration in dewatered sludge, SS, percent dry solids.

A-18.2.3 Percent volatile solids in dewatered sludge, VSP, percent of total solids dry weight.

A-18.2.4 Percent volatile solids destroyed during composting, VSC, percent of sludge volatile solids dry weight.

A-18.2.5 Compost solids content percent, CSP, percent dry solids.

A-18.2.6 Dewatered sludge specific weight, SC, $lb/yd^3$.

A-18.2.7 Compost product specific weight, SR, $lb/yd^3$.

A-18.2.8 Mixed dewatered sludge and compost specific weight, SM, $lb/yd^3$.

A-18.2.9 Windrow cross section area, X, $ft^2$.

A-18.2.10 Windrow length, LNTH, ft.

A-18.2.11 Truck unloading and mixing area, AUM, $ft^2$/ton of dry solids/day.

A-18.2.12 Finished compost storage area, ACS, $ft^2$/ton of dry solids/day.

A-18.2.13 Fraction of total composting site area requiring clearing of brush and trees, FWB, expressed as a decimal fraction.

A-18.2.14 Fraction of total composting site requiring light grading, FRLG, expressed as a decimal fraction.

A-18.2.15 Fraction of total composting site requiring medium grading, FRMG, expressed as a decimal fraction.

A-18.2.16 Fraction of total composting site requiring extensive grading, FREG, expressed as a decimal fraction.

## A-18.3 Design Parameters

A-18.3.1 Daily dewatered sludge volume entering the composting process, SV, gal/day. This input value must be provided by the user. No default value.

A-18.3.2 Sludge solids concentration in dewatered sludge, SS, percent of dewatered sludge weight. This input value should be provided by the user. However, if no value is available, default value = 20 percent.

A-18.3.3 Percent volatile solids in dewatered sludge, VSP, percent of total solids dry weight. Default value = 35 percent.

A-18.3.4 Percent volatile solids destroyed during composting, VSC, percent of sludge volatile solids dry weight. Default value = 30 percent.

A-18.3.5 Compost solids percent after composting, CSP. Default value = 65 percent.

A-18.3.6 Dewatered sludge specific weight, SC. Default value = 1,820 $lb/yd^3$.

A-18.3.7 Compost product specific weight, SR. Default value = 865 $lb/yd^3$.

A-18.3.8 Mixed dewatered sludge and compost specific weight, SM. Default value = 1,685 $lb/yd^3$.

A-18.3.9 Windrow cross section, X. Default value = 35 $ft^2$.

A-18.3.10 Windrow length, LNTH. Default value = 300 ft.

A-18.3.11 Truck unloading and mixing area, AUM. Default value = 300 $ft^2$/ton of dry solids/day to be composted.

A-18.3.12 Finished compost storage area, ACS. Default value = 900 $ft^2$/ton of dry solids/day to be composted.

A-18.3.13 Fraction of composting site requiring clearing of brush and trees, FWB. Varies significantly depending on site-specific conditions. Default value = 0.7 for composting sites.

A-18.3.14 Fraction of composting site requiring light grading, FRLG. Varies significantly depending on site-specific conditions. Default value = 0.3.

A-18.3.15 Fraction of composting site requiring medium grading, FRMG. Varies significantly depending on site-specific conditions. Default value = 0.4.

A-18.3.16 Fraction of composting site requiring extensive grading, FREG. Varies significantly depending on site-specific conditions. Default value = 0.3.

## A-18.4 Process Design Calculations

A-18.4.1 Calculate daily wet weight of dewatered sludge to be composted.

$$DS = \frac{(SV)\ (8.34)}{(2,000)} \left[ \frac{1}{\frac{100\ -\ (SS)}{100} + \frac{(SS)}{(1.42)\ (100)}} \right]$$

where

DS = Daily wet weight of dewatered sludge, tons/day.
8.34 = Density of water, lb/gal.
2,000 = Conversion factor, lb/ton.
1.42 = Assumed specific gravity of sludge solids, unitless.

A-18.4.2 Calculate daily dry solids weight of dewatered sludge to be composted.

$$DSS = \frac{(SS)\ (DS)\ (2,000)}{100}$$

where

DSS = Daily dry solids weight of dewatered sludge, lb/day.
2,000 = Conversion factor, lb/ton.

Note: In many cases, the user will know the daily dry solids weight of dewatered sludge, DSS, prior to using the algorithm. If so, DS can be back-calculated as follows:

$$DS = \frac{(DSS)\ (100)}{(SS)\ (2,000)}$$

A-18.4.3 Calculate weight of volatile solids in sludge composted per day.

$$VSS = \frac{(VSP)}{(100)} \times (DSS)$$

where

VSS = Daily volatile dry solids weight, lb/day.

A-18.4.4 Calculate sludge volatile solids destroyed during composting.

$$VSD = \frac{(VSC)\ (VSS)}{100}$$

where

VSD = Sludge volatile solids destroyed during composting, lb/day.

A-18.4.5 Calculate quantity of compost produced.

A-18.4.5.1 Tons of compost produced per day.

$$CPW = \frac{(DSS - VSD)\ (100)}{(CSP)\ (2,000)}$$

where

CPW = Compost produced, tons/day.
2,000 = Conversion factor, lb/ton.

A-18.4.5.2 Cubic yards of compost produced per day.

$$CPV = \frac{(DSS - VSD)\ (100)}{(CSP)\ (SR)}$$

where

$CPV$ = Compost produced, $yd^3$/day.

A-18.4.6 Calculate quantity of compost product mixed with dewatered sludge to obtain a solids content of 40 percent in the mixture. Note: If SS is greater than 40, then R = 0.

A-18.4.6.1 Ratio of recycled compost product to dewatered sludge.

$$R = \frac{0.40 - \frac{(SS)}{(100)}}{\frac{(CSP)}{(100)} - 0.40}$$

where

R = Lb compost product recycled/lb of dewatered sludge.

A-18.4.6.2 Weight of dewatered sludge composted per day.

$$WC = \frac{(DSS)\ (100)}{(SS)}$$

where

WC = Weight of dewatered sludge, lb/day.

A-18.4.6.3 Weight of recycled compost product.

$$WR = R \times WC$$

where

WR = Weight of recycled product compost, lb/day.

A-18.4.6.4 Volume of recycled compost product.

$$VR = \frac{WR}{SR}$$

where

VR = Volume of recycled compost product, $yd^3$/day.

A-18.4.7 Calculate volume of mixed dewatered sludge and recycled compost for composting in windrows.

$$VM = \frac{WC}{SC} + \frac{WR}{SR}$$

where

VM = Volume of mixed dewatered sludge and recycled compost for composting windrows, $yd^3$/day.

A-18.4.8 Calculate number of windrows required, based on a 30-day composting period.

$$NW = \frac{(VM)\ (27)\ (30\ days)}{(X)\ (LNTH)}$$

where

NW = Number of windrows with cross section, X, and length, LNTH.
27 = Conversion factor, $ft^3/yd^3$.

A-18.4.9 Calculate area covered by windrows.

$$AW = \frac{(NW)\ (LNTH)\ (14)}{43,560}$$

where

AW = Area covered by windrows, acres.
14 = Width of windrows, ft.
43,560 = Conversion factor, $ft^2$/acre.

A-18.4.10 Calculate total composting area.

$$AC = \frac{(NW + 1)\ [(10)\ (LNTH)]}{43,560} + AW$$

where

AC = Total composting area, acres.
10 = Distance between windrows, ft.
43,560 = Conversion factor, $ft^2$/acre.

A-18.4.11 Calculate unloading and mixing area.

$$AU = \frac{(DSS)\ (AUM)}{(43,560)\ (2,000)}$$

where

AU = Unloading and mixing area, acres.
43,560 = Conversion factor, $ft^2$/acre.
2,000 = Conversion factor, lb/ton.

A-18.4.12 Calculate finished compost storage area.

$$AS = \frac{(DSS)\ (ACS)}{(43,560)\ (2,000)}$$

where

AS = Finished compost storage area, acres.
43,560 = Conversion factor, $ft^2$/acre.
2,000 = Conversion factor, lb/ton.

A-18.4.13 Calculate total site area required.

$$TLAR = (1.5)\ (AC + AU + AS)$$

where

TLAR = Total site area required, acres.

1.5 = A factor to account for area required for building and buffer around the property.

A-18.4.14 Calculate housing area required.

$$HA = 1.263 \times 10^{-5}\ (DS)^3 - 0.013226\ (DS)^2 + 7.5783\ (DS) + 841$$

where

HA = Housing area, $ft^2$.

This equation is a multiple regression curve fit based on conceptual building areas required for sludge composting operations between 50 and 600 tons/day of dewatered sludge solids.

A-18.5 Process Design Output Data

A-18.5.1 Dewatered sludge (wet weight) to be composted, DS, tons/day.

A-18.5.2 Dry solids weight of sludge to be composted, DSS, lb/day.

A-18.5.3 Weight of compost produced, CPW, tons/day.

A-18.5.4 Volume of compost produced, CPV, $yd^3$/day.

A-18.5.5 Weight of compost recycled to mix with dewatered sludge, WR, lb/day.

A-18.5.6 Volume of compost recycled to mix with dewatered sludge, VR, $yd^3$/day.

A-18.5.7 Volume of mixed dewatered sludge and recycled compost for composting in windrows, VM, $yd^3$/day.

A-18.5.8 Number of windrows required, NW.

A-18.5.9 Area required for composting, AC, acres.

A-18.5.10 Unloading and mixing area, AU, acres.

A-18.5.11 Storage area, AS, acres.

A-18.5.12 Total area required, TLAR, acres.

A-18.5.13 Housing area, HA, $ft^2$.

A-18.6 Quantities Calculations

A-18.6.1 Calculate annual fuel requirement. Fuel for composting machines and other equipment used in the windrow process is a function of the quantity of dewatered sludge processed as follows:

$$FU = 0.00057\ (DS)^3 - 0.53\ (DS)^2 + 413\ (DS) + 15{,}000$$

where

FU = Annual fuel requirement, gal/yr.

This equation is a multiple regression curve fit based on fuel usage for conceptual composting operations between 50 and 600 tons/day of dewatered sludge.

A-18.6.2 Calculate operation and maintenance labor requirement. Operation and maintenance labor is a function of the quantity of dewatered sludge processed as follows:

$$L = [-\ 0.033\ (DS)^2 + 60\ (DS) + 2{,}020]$$

where

L= Operation and maintenance labor requirement, hr/yr.

This equation is a multiple regression curve fit based on labor requirements for conceptual composting operations between 50 and 600 tons/day of dewatered sludge.

A-18.7 Quantities Calculations Output Data

A-18.7.1 Fuel requirement, FU, gal/yr.

A-18.7.2 Operation and maintenance labor requirement, L, hr/yr.

A-18.8 Unit Price Input Required

A-18.8.1 Current Engineering News Record Construction Cost Index, ENRCCI.

A-18.8.2 Current Marshall and Swift Equipment Cost Index, MSECI.

A-18.8.3 Cost of diesel fuel, COSTDF, $/gal. Default value = $1.30/gal (ENRCCI/4,006).

A-18.8.4 Cost of operation and maintenance labor, COSTL, $/hr. Default value = $13.00/hr (ENRCCI/4,006).

A-18.8.5 Cost of land, LANDCST, $/acre. Default value = $3,000/acre (ENRCCI/4,006).

A-18.8.6 Cost of clearing brush and trees, BCRCST, $/acre. Default value = $1,500/acre (ENRCCI/4,006).

A-18.8.7 Cost of light grading earthwork, LGECST, $/acre. Default value = $500/acre (ENRCCI/4,006).

A-18.8.8 Cost of medium grading earthwork, MGECST, $/acre. Default value = $2,500/acre (ENRCCI/4,006).

A-18.8.9 Cost of extensive grading earthwork, EGECST, $/acre. Default value = $5,000/acre (ENRCCI/4,006).

A-18.8.10 Cost of paving, PVCOST, $/acre. Default value = $58,000/acre (ENRCCI/4,006) (reflects cost of bituminous concrete).

A-18.9 Cost Calculations

A-18.9.1 Total cost of land for composting site.

$$COSTLAND = (TLAR)\ (LANDCST)$$

where

COSTLAND = Total cost of land for composting site, $.

A-18.9.2 Cost of clearing brush and trees.

$$COSTCBT = (TLAR)\ (FWB)\ (BCRCST)$$

where

COSTCBT = Cost to clear brush and trees, $.

A-18.9.3 Cost of grading earthwork.

$$COSTEW = (TLAR)\ [(FRLG)\ (LGECST) + (FRMG)\ (MGECST) + (FREG)\ (EGECST)]$$

where

COSTEW = Cost of earthwork grading, $.

A-18.9.4 Cost of paving windrow composting area.

$$COSTPV = (AC)\ (PVCOST)$$

where

COSTPV = Cost of paving windrow composting area, $.

A-18.9.5 Cost of equipment. Equipment cost is a function of the quantity of dewatered sludge processed using the following equation:

$$COSTEQ = [1{,}560\ (DS) + 450{,}000]\ \frac{MSECI}{751}$$

where

COSTEQ = Cost of equipment, $.

This equation is a multiple regression curve fit based on equipment cost for conceptual composting operations between 5 and 600 tons/day of dewatered sludge.

A-18.9.6 Cost of unloading and mixing structure.

$$COSTUM = \left[\frac{(DSS)\ (AUM)\ (20)}{2{,}000}\right]\ \frac{ENRCCI}{4{,}006}$$

where

COSTUM = Cost of unloading and mixing structure, $.
20 = Construction cost of unloading and mixing structure, $/ft$^2$.
2,000 = Conversion factor, lb/ton.

A-18.9.7 Cost of operation and maintenance building.

$$COSTH = (HA)\ (50)\ \frac{ENRCCI}{4{,}006}$$

where

COSTH = Cost of operation and maintenance building, \$.
50 = Construction cost of operation and maintenance building, \$/ft$^2$.

A-18.9.8 Cost of operation and maintenance labor.

$$COSTLB = (L)\ (COSTL)$$

where

COSTLB = Annual cost of operation and maintenance labor, \$/yr.

A-18.9.9 Annual fuel cost.

$$COSTFL = (FU)\ (COSTDF)$$

where

COSTFL = Annual cost of fuel, \$/yr.

A-18.9.10 Annual cost of parts and material.

$$COSTPM = (0.18)\ (COSTEQ)\ \frac{MSECI}{751}$$

where

COSTPM = Annual parts and material cost, \$/yr.

0.18 = Annual replacement parts and materials, percent of equipment cost.

A-18.9.11 Total base capital cost.

$$TBCC = COSTLAND + COSTCBT + COSTEW + COSTPV + COSTEQ + COSTUM + COSTH$$

where

TBCC = Total base capital cost, \$.

A-18.9.12 Annual operation and maintenance cost.

$$COSTOM = COSTLB + COSTFL + COSTPM$$

where

COSTOM = Total operation and maintenance cost, \$/yr.

A-18.10 Cost Calculations Output Data

A-18.10.1 Cost of land for composting site, COSTLAND, \$.

A-18.10.2 Cost to clear brush and trees from site, COSTCBT, \$.

A-18.10.3 Cost of grading earthwork, COSTEW, \$.

A-18.10.4 Cost of paving windrow composting area, COSTPV, \$.

A-18.10.5 Cost of composting equipment, COSTEQ, \$.

A-18.10.6 Cost of unloading and mixing structure, COSTUM, \$.

A-18.10.7 Cost of operation and maintenance building, COSTH, \$.

A-18.10.8 Annual cost of operation and maintenance labor, COSTLB, \$/yr.

A-18.10.9 Annual cost of fuel, COSTFL, \$/yr.

A-18.10.10 Annual cost of parts and material, COSTPM, \$/yr.

A-18.10.11 Total base capital cost, TBCC, \$.

A-18.10.12 Annual operation and maintenance cost, COSTOM, \$/yr.

APPENDIX A-19

COMPOSTING - AERATED STATIC PILE METHOD

## A-19.1 Background

Aerated static pile composting is similar in principle to windrow composting, previously discussed in Appendix A-18. However, in the aerated static pile composting process, the mixture of dewatered sludge and bulking agent remains fixed (as opposed to the periodic turning procedure used in the windrow method), and a forced ventilation system maintains aerobic conditions. A layer of previously composted sludge placed over the surface of the pile provides insulation, allowing for high temperatures throughout the pile. Because the piles do not need to be turned, and the outer layer of previously composted sludge provides insulation, static pile composting is less affected by inclement weather than windrow composting. Both digested and raw dewatered sludges have been composted by this technique.

Bulking agents used in aerated static pile composting include wood chips, rice hulls, or straw. Previously composted sludge is not a suitable bulking agent, since a porous structure must be maintained to allow movement through the pile. This algorithm assumes the use of wood chips as the bulking agent.

Composting, even with the aerated static pile method, is largely a materials handling process, and most systems in the United States use mobile equipment. Labor and bulking agent are the largest operating cost components.

The physical characteristics of the sludge and bulking agent must be defined at various stages of the process. Volatile solids and water are removed during processing, which substantially reduces the sludge weight but does not appreciably reduce the volume.

The aerated static pile process in this algorithm consists of (1) unloading and mixing, (2) aerated pile composting, (3) drying, (4) screening, and (5) storage. An area is also provided for storage of bulking agent.

1. Unloading and mixing. Dewatered sludge is delivered to the unloading and mixing structure. The structure is covered and paved. Sludge is unloaded directly onto a bed of bulking agent (wood chips). The sludge and bulking agent are then mixed with a mobile composting/mixing machine or front-end loader, depending on the size of the operation.

2. Composting. The sludge/bulking agent mixture is moved from the unloading and mixing structure to composting pads by front-end loader. Composting pads are paved but uncovered, with aeration piping and drainage collection permanently installed in trenches. One blower is

provided for each 2,400 $ft^2$ of composting area. Sludge is placed in the extended pile configuration and insulated with screened finished compost. Space is provided for 30 days of composting and curing.

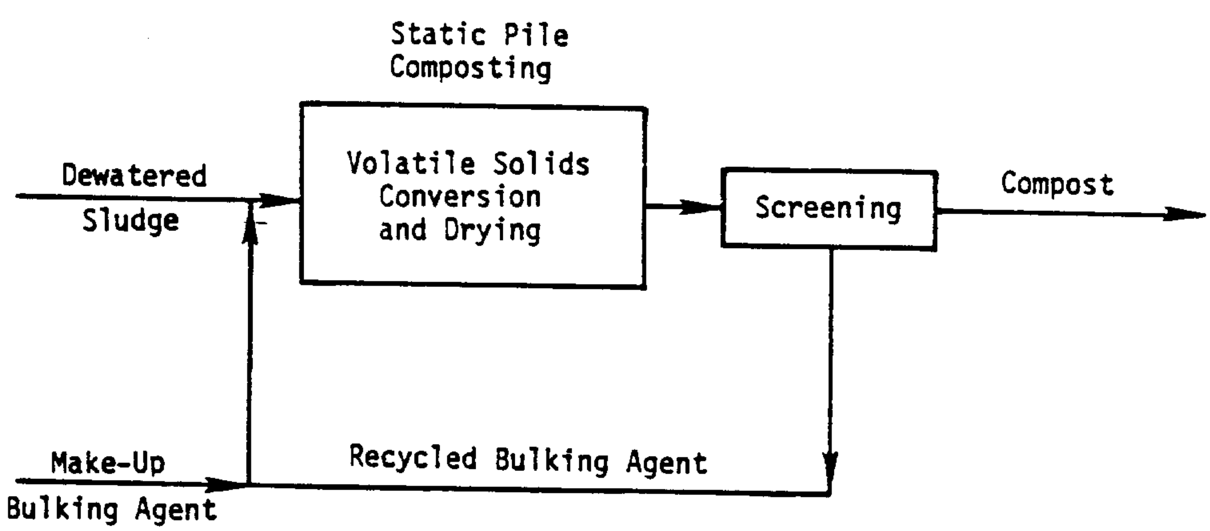
3. Drying. A covered and paved structure provides 5 days of drying time. The structure is open on both ends, similar to the unloading and mixing structure. The sludge/bulking agent mixture is moved from the composting pads to the drying area and turned to achieve at least 50 percent solids by natural drying.

4. Screening. The sludge/bulking agent mixture is moved from the drying structure by a front-end loader to a totally enclosed screening building. Screening removes about 75 percent of the bulking agent. Compost is transferred to an unpaved and uncovered storage area, and screened bulking agent is returned to the unloading and mixing structure.

A-19.1.1 Algorithm Development

Design and cost equations in the following algorithm are based on Reference 4, pages 12-22 through 12-36. Additional data for O&M requirements were taken from Reference 7, page A-181.

The process is shown schematically in the flow diagram below. Reference to the diagram should aid the reader in following the material balance calculations that follow. In these calculations, it is assumed that no changes occur to the bulking agent during composting, since any conversion of the bulking agent should be negligible compared to conversion of volatile solids in the dewatered sludge.



A-19.2 Input Data

A-19.2.1 Daily dewatered sludge volume entering the composting process, SV, gal/day.

A-19.2.2 Sludge solids concentration in dewatered sludge, SS, percent dry solids.

A-19.2.3 Volatile solids in dewatered sludge, VSP, percent of total solids dry weight.

A-19.2.4 Percent volatile solids destroyed during composting, VSC, percent of sludge volatile solids dry weight.

A-19.2.5 Compost solids content percent, CSP, percent dry solids.

A-19.2.6 Compost product specific weight, SR, $lb/yd^3$.

A-19.2.7 Mixed dewatered sludge and bulking agent specific weight, SM, $lb/yd^3$.

A-19.2.8 Bulking agent mixing ratio, BA, $yd^3$/ton dewatered sludge.

A-19.2.9 New bulking agent mixing ratio, NB, fraction of total BA.

A-19.2.10 New bulking agent specific weight, SNB, $lb/yd^3$.

A-19.2.11 Recycled bulking agent mixing ratio, RB, fraction of total BA.

A-19.2.12 Recycled bulking agent specific weight, SRB, $lb/yd^3$.

A-19.2.13 Bulking agent in compost product, BP, lb/day.

A-19.2.14 Truck unloading and mixing area, AUM, $ft^2$/ton of dry solids/day.

A-19.2.15 Composting area, AC, $ft^2$/ton of dry solids/day.

A-19.2.16 Drying area, AD, $ft^2$/ton of dry solids/day.

A-19.2.17 Finished compost storage area, ACS, $ft^2$/ton of dry solids/day.

A-19.2.18 Bulking agent storage area, AB, $ft^2$/ton of dry solids/day.

A-19.2.19 Fraction of total composting site area requiring clearing of brush and trees, FWB, expressed as a decimal fraction.

A-19.2.20 Fraction of total composting site area requiring light grading, FRLG, expressed as a decimal fraction.

A-19.2.21 Fraction of total composting site area requiring medium grading, FRMG, expressed as a decimal fraction.

A-19.2.22 Fraction of total composting site area requiring extensive grading, FREG, expressed as a decimal fraction.

A-19.3 Design Parameters

A-19.3.1 Daily dewatered sludge volume entering the composting process, SV, gal/day. This input value must be provided by the user. No default value.

A-19.3.2 Sludge solids concentration in dewatered sludge, SS. This input value should be provided by the user whenever possible. However, if no value is available, default value = 20 percent.

A-19.3.3 Percent volatile solids in dewatered sludge, VSP, percent of total solids dry weight. Default value = 35 percent.

A-19.3.4 Percent volatile solids destroyed during composting, VSC, percent of sludge volatile solids dry weight. Default value = 45 percent.

A-19.3.5 Compost product percent solids, CSP. Default value = 65 percent.

A-19.3.6 Compost product specific weight, SR. Default value = 1,000 $lb/yd^3$.

A-19.3.7 Mixed dewatered sludge and bulking agent specific weight, SM. Default value = 1,100 $lb/yd^3$.

A-19.3.8 Bulking agent mixed with dewatered sludge, BA. Default value = 2.5 $yd^3$/ton dewatered sludge.

A-19.3.9 New bulking agent mixing ratio, NB. Bulking agent is a function of several factors, including quantity and solids content of sludge processed, characteristics of the bulking agent, and efficiency of screening. Default value = (BA) (0.25) $yd^3$/ton dewatered sludge.

A-19.3.10 New bulking agent specific weight, SNB. Default value = 500 $lb/yd^3$.

A-19.3.11 Recycled bulking agent mixing ratio, RB. Default value = (BA) (0.75) $yd^3$/ton dewatered sludge.

A-19.3.12 Recycled bulking agent specific weight, SRB. Default value = 600 $lb/yd^3$.

A-19.3.13 Bulking agent in compost product, BP. Default value is calculated by:

$$BP = \frac{(NB)\ (SRB)\ (DSS)\ (100)}{(SS)\ (2,000)}$$

where

BP = Bulking agent compost product, lb/day.
2,000 = Conversion factor, lb/ton.

A-19.3.14 Truck unloading and mixing area, AUM. Default value = 300 $ft^2$/ton of dry solids/day to be composted.

A-19.3.15 Composting area, AC. Default value = 7,000 $ft^2$/ton dry solids/day to be composted.

A-19.3.16 Drying area, AD. Default value = 300 $ft^2$/ton dry solids/day to be composted.

A-19.3.17 Finished compost storage area, ACS. Default value = 900 $ft^2$/ton dry solids/day to be composted. Equivalent to approximately 9 days of storage.

A-19.3.18 Bulking agent storage area, AB. Default value = 2,000 $ft^2$/ton dry solids/day to be composted.

A-19.3.19 Fraction of composting site requiring clearing of brush and trees, FWB. Varies significantly depending on site-specific conditions. Default value = 0.7.

A-19.3.20 Fraction of composting site requiring light grading, FRLG. Varies significantly depending on site-specific conditions. Default value = 0.3.

A-19.3.21 Fraction of composting site requiring medium grading, FRMG. Varies significantly depending on site-specific conditions. Default value = 0.4.

A-19.3.22 Fraction of composting site requiring extensive grading, FREG. Varies significantly depending on site-specific conditions. Default value = 0.3.

A-19.4 Process Design Calculations

A-19.4.1 Calculate daily wet weight of dewatered sludge to be composted.

$$DS = \frac{(SV)\ (8.34)}{(2,000)} \left[ \frac{1}{\frac{100 - (SS)}{100} + \frac{(SS)}{(1.42)\ (100)}} \right]$$

where

DS = Daily wet weight of dewatered sludge, tons/day.
8.34 = Density of water, lb/gal.
2,000 = Conversion factor, lb/ton.
1.42 = Assumed specific gravity of sludge solids.

A-19.4.2 Calculate daily dry solids weight of dewatered sludge to be composted.

$$DSS = \frac{(2{,}000)\ (SS)\ (DS)}{(100)}$$

where

DSS = Daily dry solids weight of dewatered sludge, lb/day.
2,000 = Conversion factor, lb/ton.

Note: In many cases, the user will know the daily dry solids weight of dewatered sludge, DSS, prior to using the program. If so, DS can be back-calculated as follows:

$$DS = \frac{(DSS)\ (100)}{(SS)\ (2{,}000)}$$

Similarly, SV can be back-calculated, using the formula in Appendix A-19.4.1.

A-19.4.3 Calculate bulking agent in compost product, BP, default value, if required.

$$BP = \frac{(NB)\ (SRB)\ (DSS)\ (100)}{(SS)\ (2{,}000)}$$

where

BP = Default value for BP, lb/day.
2,000 = Conversion factor, lb/ton.

A-19.4.4 Calculate weight of volatile solids in sludge composted per day.

$$VSS = \frac{(VSP)}{(100)} \times (DSS)$$

where

VSS = Daily volatile solids weight, lb/day.

A-19.4.5 Calculate volatile solids destroyed during composting.

$$VSD = \frac{(VSC)\ (VSS)}{100}$$

where

VSD = Sludge volatile solids weight destroyed during composting, lb/day.

A-19.4.6 Bulking agent required.

A-19.4.6.1 Calculate weight of bulking agent.

$$BAW = \frac{(NB)\ (SNB) + (RB)\ (SRB)}{2{,}000}\ DS$$

where

BAW = Bulking agent weight, tons/day.
2,000 = Conversion factor, lb/ton.

A-19.4.6.2 Calculate volume of bulking agent.

$$BAV = (BA)\ (DS)$$

where

BAV = Bulking agent volume, $yd^3$/day.

A-19.4.7 Calculate volume of mixed dewatered sludge and bulking agent to be composted.

$$MV = \frac{(DS + BAW)\ (2{,}000)}{SM}$$

where

MV = Volume of mixed sludge and bulking agent to be composted, $yd^3$/day.

A-19.4.8 Calculate volume of screened compost required for insulation of aerated piles.

$$SCV = \frac{(DSS)\ (2.15)}{SR}$$

where

SCV = Volume of screened compost, $yd^3$/day.

A-19.4.9 Quantity of compost produced.

A-19.4.9.1 Calculate weight of compost produced.

$$CPW = \frac{DSS - VSD + BP}{(CSP)\ (20)}$$

where

CPW = Compost produced, tons/day.

A-19.4.9.2 Calculate volume of compost produced.

$$CPV = \frac{(DSS - VSD + BP)\ (100)}{(CSP)\ (SR)}$$

where

CPV = Compost produced, $yd^3$/day.

A-19.4.10 Calculate total area required.

$$AT = (1.5)\ (DSS)\ \frac{(AUM + AC + AD + ACS + AB)}{(43,560)\ (2,000)}$$

where

AT = Total area required, acres.

1.5 = Factor to account for additional land area required for buffer, storage, etc.

A-19.4.11 Calculate housing area required.

$$HA = (0.000028735)\ (DS)^3 - (0.029885)\ (DS)^2 + (16.161)\ (DS) + 1,600$$

where

HA = Building area, $ft^2$.

This equation is a multiple regression curve fit based on conceptual building areas required for sludge composting operations between 50 and 600 tons/day of dewatered sludge solids.

A-19.5 Process Design Output Data

A-19.5.1 Dewatered sludge (wet weight) to be composted, DS, tons/day.

A-19.5.2 Dry solids weight of sludge to be composted, DSS, lb/day.

A-19.5.3 Weight of bulking agent required, BAW, tons/day.

A-19.5.4 Volume of bulking agent required, BAV, $yd^3$/day.

A-19.5.5 Volume of mixed sludge and bulking agent to be composted, MV, $yd^3$/day.

A-19.5.6 Weight of compost produced, CPW, tons/day.

A-19.5.7 Volume of compost produced, CPV, $yd^3$/day.

A-19.5.8 Compost recycled to insulate aerated piles, SCV, $yd^3$/day.

A-19.5.9 Total area required, AT, acres.

A-19.5.10 Building area required, HA, $ft^2$.

A-19.6 Quantities Calculations

A-19.6.1 Calculate annual fuel usage. Fuel for mixing machines and other mobile equipment used in the process is a function of the quantity of dewatered sludge processed:

$$FU = [- (0.1016)\ (DS)^2 + (222.64)\ (DS) + (7{,}744)]$$

where

FU = Annual fuel requirement, gal/yr.

This equation is a multiple regression curve fit based on fuel usage for conceptual composting operations between 50 and 600 tons/day of dewatered sludge.

A-19.6.2 Calculate annual electrical energy requirement. Electricity for aeration and screening is a function of the quantity of dewatered sludge processed:

$$EU = (DS)\ (400)$$

where

EU = Annual electrical energy requirement, kWhr/yr.

A-19.6.3 Calculate annual bulking agent required.

$$BAU = (NB)\ (DS)\ (365)$$

where

BAU = Bulking agent usage, $yd^3/yr$.

A-19.6.4 Calculate annual operation and maintenance labor requirement. Operation and maintenance labor is a function of the quantity of dewatered sludge processed.

$$L = [- (0.0331)\ (DS)^2 + (61.03)\ (DS) + (1,959)]$$

where

L = Operation and maintenance labor requirement, hr/yr.

This equation is a multiple regression curve fit based on labor requirements for conceptual composting operations between 50 and 600 tons/day of dewatered sludge.

A-19.7 Quantities Calculations Output Data

A-19.7.1 Annual fuel requirement, FU, gal/yr.

A-19.7.2 Annual electrical energy requirement, EU, kWhr/yr.

A-19.7.3 Annual bulking agent required, BAU, $yd^3/yr$.

A-19.7.4 Annual operation and maintenance labor requirement, L, hr/yr.

A-19.8 Unit Price Input Required

A-19.8.1 Current Engineering News Record Construction Cost Index, ENRCCI.

A-19.8.2 Current Marshall and Swift Equipment Cost Index, MSECI.

A-19.8.3 Cost of diesel fuel, COSTDF, \$/gal. Default value = \$1.30/gal (ENRCCI/4,006).

A-19.8.4 Cost of electrical energy, COSTE, \$/kWhr. Default value = \$0.09/kWhr (ENRCCI/4,006).

A-19.8.5 Cost of bulking agent, COSTB, $\$/yd^3$. Default value = $\$15.00/yd^3$ (ENRCCI/4,006).

A-19.8.6 Cost of labor, COSTL, \$/hr. Default value = \$13.00/hr (ENRCCI/4,006).

A-19.8.7 Cost of land, LANDCST, \$/acre. Default value = \$3,000/acre (ENRCCI/4,006).

A-19.8.8 Cost of clearing brush and trees, BCRCST, \$/acre. Default value = \$1,500/acre (ENRCCI/4,006).

A-19.8.9 Cost of light grading earthwork, LGECST, \$/acre. Default value = \$1,000/acre (ENRCCI/4,006).

A-19.8.10 Cost of medium grading earthwork, MGECST, \$/acre. Default value = \$2,500/acre (ENRCCI/4,006).

A-19.8.11 Cost of extensive grading earthwork, EGECST, \$/acre. Default value = \$5,000/acre (ENRCCI/4,006).

A-19.9 Cost Calculations

A-19.9.1 Cost of land.

$$\text{COSTLAND} = (\text{AT})\ (\text{LANDCST})$$

where

COSTLAND = Total land cost for composting site, \$.

A-19.9.2 Cost of clearing brush and trees.

$$\text{COSTCBT} = (\text{AT})\ (\text{FWB})\ (\text{BCRCST})$$

where

COSTCBT = Total cost to clear brush and trees, \$.

A-19.9.3 Cost of grading earthwork.

$$\text{COSTEW} = (\text{AT})\ [(\text{FRLG})\ (\text{LGECST}) + (\text{FRMG})\ (\text{MGECST}) + (\text{FREG})\ (\text{EGECST})]$$

where

COSTEW = Cost of earthwork grading, \$.

A-19.9.4 Cost of composting pad construction. This cost includes construction of pads and purchase and installation of piping and blowers.

$$\text{COSTCP} = \left[\frac{(\text{DSS})\ (\text{AC})\ (3.15)}{(2{,}000)}\right] \frac{\text{ENRCCI}}{4{,}006}$$

where

COSTCP = Cost of composting pads, \$.
3.15 = Unit cost of composting pads, $\$/ft^2$.

A-19.9.5 Cost of equipment. Mobile equipment and screening equipment costs are a function of the quantity of dewatered sludge processed using the following equation:

$$COSTEQ = [-5.4 (DS)^2 + 5{,}855 (DS) + 435{,}000] \frac{MSECI}{751}$$

where

COSTEQ = Total cost of equipment, \$.

This equation is a multiple regression curve fit based on the 1983 cost of equipment required for composting operations.

A-19.9.6 Cost of unloading and mixing structure.

$$COSTUM = \left[\frac{(DSS)\ (AUM)\ (20)}{(2{,}000)}\right] \frac{ENRCCI}{4{,}006}$$

where

COSTUM = Cost of unloading and mixing structure, \$.
20 = Unit cost of unloading and mixing structure, $\$/ft^2$.

A-19.9.7 Cost of drying structure.

$$COSTD = \left[\frac{(DSS)\ (AD)\ (20)}{(2{,}000)}\right] \frac{ENRCCI}{4{,}006}$$

where

COSTD = Cost of drying structure, \$.
20 = Unit cost of drying structure, $\$/ft^2$.

A-19.9.8 Cost of operation and maintenance building.

$$COSTH = (HA)\ (50)\ \frac{(ENRCCI)}{(4{,}006)}$$

where

COSTH = Cost of operation and maintenance building, \$.
50 = Unit cost of operation and maintenance building, $\$/ft^2$.

A-19.9.9 Annual cost of operation and maintenance labor.

$$COSTLB = (L)\ (COSTL)$$

where

COSTLB = Annual cost of operation and maintenance labor, $/yr.

A-19.9.10 Annual cost of fuel.

$$COSTFL = (FU)\ (COSTDF)$$

where

COSTFL = Annual cost of fuel, $/yr.

A-19.9.11 Annual cost of electrical energy.

$$COSTEL = (EU)\ (COSTE)$$

where

COSTEL = Annual cost of electrical energy, $/yr.

A-19.9.12 Cost of bulking agent.

$$COSTBA = (BAU)\ (COSTB)$$

where

COSTBA = Annual cost of bulking agent, $/yr.

A-19.9.13 Annual cost of parts and material.

$$COSTPM = (0.15)\ (COSTEQ)\ \frac{MSECI}{751}$$

where

COSTPM = Cost of parts and material, $/yr.

0.15 = Annual cost of parts and materials is assumed to be 15 percent of equipment capital cost.

A-19.9.14 Total base capital cost.

$$TBCC = COSTLAND + COSTCBT + COSTEW + COSTCP + COSTEQ + COSTUM + COSTD + COSTH$$

where

TBCC = Total base capital cost, $.

A-19.9.15 Annual operation and maintenance cost.

COSTOM = COSTLB + COSTFL + COSTEL + COSTBA + COSTPM

where

COSTOM = Total operation and maintenance cost, $/yr.

A-19.10 Cost Calculations Output Data

A-19.10.1 Cost of land for composting site, COSTLAND, $.

A-19.10.2 Cost to clear brush and trees from site, COSTCBT, $.

A-19.10.3 Cost of grading earthwork, COSTEW, $.

A-19.10.4 Cost of composting pad construction, COSTCP, $.

A-19.10.5 Cost of equipment, COSTEQ, $.

A-19.10.6 Cost of unloading and mixing structure, COSTUM, $.

A-19.10.7 Cost of drying structure, COSTD, $.

A-19.10.8 Cost of operation and maintenance building, COSTH, $.

A-19.10.9 Annual cost of operation and maintenance labor, COSTLB, $/yr.

A-19.10.10 Annual cost of fuel, COSTFL, $/yr.

A-19.10.11 Annual cost of electrical energy, COSTEL, $/yr.

A-19.10.12 Annual cost of bulking agent, COSTBA, $/yr.

A-19.10.13 Annual cost of parts and material, COSTPM, $/yr.

A-19.10.14 Total base capital cost, TBCC, $.

A-19.10.15 Annual operation and maintenance cost, COSTOM, $/yr.

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The following maps are not attached to this report. Due to their size, they could not be copied. They are located in the official file and may be copied upon request.

Location Of Sludge Production Intensity
Exhibit 1
Job No. 11-00317-002
June 1995

Site 1 Service Area And Minimum Distance Routes
Exibit 5
Job No. 11-00317-002
June 1995

**Please contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.**