Detroit Water and Sewerage Department

Wastewater Master Plan

DWSD Project No. CS-1314

Long-Term Solids Disposal Alternatives for Detroit Wastewater Treatment Plant

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Appendix A - Review of Solids Reuse/Disposal Technologies

Acronyms

APC	Air Pollution Control
BFP	belt filter press
CAAA	Clean Air Act Amendments
CaO	Quick lime, Calcium Oxide
CHR	conventional high rate
CSO	combined sewer overflow
CY	Cubic yards
D&M	Distribution and Marketing
DS	Dry solids
DT	dry tons
DTPD	dry tons per day
DWP	Detroit Wastewater Partners
DWSD	Detroit Water and Sewerage Department
DWWTP	Detroit Wastewater Treatment Plant
EQ	Exceptional Quality
EQS	exceptional quality sludge
FBI	Fluidized Bed Incineration (with energy recovery)
LF	Linear feet
LMF	Lime Mixing Facility
HRT	hydraulic retention time
MG	Million gallons
mgd	million gallons per day
MDEQ	Michigan Department of Environmental Quality
MHF	multiple hearth furnaces
NAAQS	National Ambient Air Quality Standards
NAS	Needs Assessment Study
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NSR	New Source Review
PCB	Polychlorinated Biphenyl
POTW	Publicly Owned Treatment Works
PFRP	Process for Further Reduction of Pathogens
RFP	Request for proposal
RFQ	Request for qualification
SSO	Sanitary Sewer Overflow
O&M	Operations and Maintenance
THC	Total hydrocarbons
TM	Technical Memorandum
TMDL	Total Maximum Daily Loads
USEPA	U.S. Environmental Protection Agency
WAS	Waste Activated Sludge
WT	Wet tons
WWMP	Wastewater Master Plan
WWTP	wastewater treatment plant

Executive Summary

This TM (Technical Memorandum) is part of the Wastewater Master Plan effort. The main purpose of this TM is to develop long-term Solids Disposal Alternatives for the Detroit Wastewater Treatment Plant (DWWTP).

The DWSD owns and operates one of the largest single site WWTPs in the United States. The plant treated an average of 750 million gallons per day (mgd) of wastewater during the interval from 1996 to 2000. The peak permitted primary treatment capacity is 1,520 mgd, with a planned increase to 1,700 mgd by 2004. The peak permitted secondary treatment capacity is 930 mgd. The current DWWTP solids treatment processes include gravity thickening of the primary and secondary sludge, belt-filter-press (BFP) and centrifuges for dewatering, and multiple-hearth-incineration (MFH) or landfill disposal of the dewatered sludge.

The disposal of sewage sludge is regulated primarily by federal EPA Part 503 and Clean Air Act, and State of Michigan Part 24 regulations. The key elements of the federal and Michigan regulations are summarized and future trends are discussed in this TM.

Solids disposal technologies, both proven and emerging ones, are reviewed. A total of nine alternatives (in addition to Minergy) are selected for evaluation. These nine alternatives are developed around our understanding of issues in three key areas: the project framework, the capacities needed, and the space and land availability at the WWTP. These nine selected alternatives are evaluated and ranked per the criteria established for DWSD, and the final two alternatives are selected and recommended for further evaluation.

These are Alternative 4 (upgrade the MFH incinerators) and Alternative 5 (installation of new FBI incinerators) with LMF as backup. A phased decision making process is also recommended as a means to update these alternatives while also considering new technologies in the future.

The final conclusions of the TM are:

1. The most appropriate long-term alternatives for further evaluation are upgrade of the MHF facility (Alternative 4) and installation of a new FBI system incorporating energy recovery (Alternative 5).
2. The DWSD can benefit from new technology development using a phased decision making process to evaluate these technologies at each update of its Solids Master Plan.
3. Anaerobic digestion would warrant further evaluation as a core processing technology if DWSD elects to replace the existing WWTP with a new facility.

The TM also recommends further studies by DWSD:

1. DWSD should conduct a detailed evaluation of Alternative 4 and 5 (the MHF, and FBI with energy recovery). The evaluation should identify the detailed upgrade needs, life-cycle cost analysis, and O&M issues for each, and take into account any future availability of land and space on site.
2. DWSD should conduct a study on the market conditions for Class A and Class B biosolids, in support of its next update of the Solids Master Plan.

3. DWSD should conduct a detailed characterization of present and projected sludge composition in support of its Solids Master Plan.

Long-Term Solids Disposal Alternatives for Detroit WWTP

1. Introduction

This Technical Memorandum (TM) addresses the scope of a subtask of the Wastewater Master Plan: Developing a Long-term Solids Disposal Alternatives for Detroit Wastewater Treatment Plant (DWWTP).

1.1 Purpose of the Technical Memorandum

The main purposes of this TM are to:

- Develop feasible sludge disposal alternatives for the DWWTP based on the current technologies and regulations.
- Discuss each alternative developed and general steps needed to implement the solution.
- Prepare a conceptual dollars-per-ton disposal cost estimate for each alternative.
- Provide study recommendations.

This TM also attempts to cover some specific issues to the degree that the available information and scope of the project permit. These issues include:

- Confirm for planning purposes the land space availability onsite for various alternatives.
- Summarize the available information from Detroit Water and Sewerage Department (DWSD) Needs Assessment Study (NAS) report (Needs Assessment Study for the Detroit Wastewater Treatment Plant, DWSD Contract No. PC-744, 2001), and present our understanding of the solids loading rates to be managed under average and peak loading conditions, the present capacities of the key elements of the solids processing system (thickening, incineration, Lime Mixing Facility [LMF], etc.), and when the additional capacities of mainstay and back-up processing capacity must be available to meet the future capacity deficits.
- Summarize the current status and future trends of federal and state regulations on solids disposal, and identify any potential impacts on DWSD's long-term solids planning effort.
- Identify long-term alternatives for solids management meeting base load and peak load requirements, to include appropriate current, emerging, and future technologies.
- Screen the long list of alternatives and select a short list.
- Screen the short list of alternatives.
- Recommend two alternatives.

1.2 Wastewater Master Plan Overview

The DWSD serves approximately 77 communities, including the City of Detroit. The 904-square-mile service area encompasses about 3.2 million people. The population is concentrated in the City of Detroit and in Wayne, southern Macomb, and southeastern

Oakland Counties. This TM is part of an overall Wastewater Master Plan (WWMP) that encompasses the following:

- Wastewater collection and treatment
- Onsite sewerage disposal
- Sanitary sewer overflow (SSO) control
- Combined sewer overflow (CSO) management
- Collaboration with other wastewater treatment providers

DWSD began its WWMP project in August 2000. This 3-year study will compile the results of previous and ongoing wastewater planning efforts within the DWSD service area, and it will include new analyses of wastewater collection and treatment needs to 2050. The study will be fully coordinated with related planning efforts for the WWMP, the Long-Term CSO Control Plan, and new improvements at the WWTP.

The DWSD owns and operates one of the largest single site WWTPs in the United States. The plant treated an average of 750 million gallons per day (mgd) of wastewater from 1996 to 2000. The peak primary treatment capacity is 1,520 mgd, with a planned increase to 1,700 mgd by 2004. The peak secondary treatment capacity is 930 mgd. The plant was put into service in 1940 when it used primary treatment to remove about 50 to 70 percent of pollutants. In the 1970s, secondary treatment facilities were added to provide a higher degree of treatment. The combination of primary and secondary treatment removes more than 85 percent of incoming pollutants, exceeding federal and state requirements.

Task F.1, developing a long-term solids disposal alternatives for DWWTP, is one of the tasks under the overall WWMP project.

1.3 Technical Memo Organization

This TM is organized as follows:

- Summarize regulatory trends and other legal considerations.
- Summarize key information on the existing facilities from a review of the present DWSD solids processing and residuals management programs, and a review of a previous DWSD solids reuse alternatives study and the last solids master plan.
- Describe the characteristics of the solids production based upon existing information.
- Develop the alternatives for the long term based upon a review of the available solids disposal alternatives/technologies, after consideration of current, emerging, and future technologies.
- Select two recommended alternatives for further technical and economic evaluation.
- Discuss the implementation issues to be addressed.
- Provide supporting appendices with technology review and economic cost information.

2. Legal and Regulatory Considerations

2.1 Legal Considerations

The primary legal consideration overarching the development of long-term solids management alternatives is the contractual relationship between the DWSD and Minergy. This review does not address the legal considerations that exist because of this contract. There are a number of projects being undertaken by DWSD that must be completed on a schedule that is coordinated with commissioning and test period dates in this contract. For study purposes, it is assumed in this TM that any other alternative that is considered can be implemented without hindrance from the legal relationship that DWSD has with Minergy.

2.2 Highlights of Regulatory Trends

The following considerations were developed from the regulatory review, and the TM team experience as background:

- No immediate changes are anticipated in the regulations, but land application changes are expected in the future. It is too early to predict the extent of changes, and we expect that there will be much greater public interest in the biological quality of the applied material in the years ahead.

- In reference to incineration upgrades, several of the U.S. Environmental Protection Agency (USEPA) regions are taking a harder look at the dollar magnitude of upgrades. Several regions have required publicly owned treatment works (POTWs) to prepare New Source Reviews (NSR), when the cost of the upgrade equals or exceed 50 percent of the replacement cost. The NSR then becomes a step in the process leading to issuance of an air permit to construct the upgraded facilities. This may have implications for a future upgrade of the multiple hearth furnaces (MHF) at the WWTP.

- At the state level, we see selected states (California and Florida) where trends exist with respect to land application of Class B biosolids, such that that we anticipate the eventual elimination of land application of Class B biosolids. Stabilization options that only produce Class B biosolids may only be viable as a backup (disposal to landfill) for the primary alternative. An eventual tightening of the regional air quality classification may occur and impact future incinerator emission controls, but there is no specific proposal at the moment.

- Perhaps more importantly is the continuing obligation of DWSD to invest in its existing incinerators should their use be shifted to backup status.

- At the local level, there has been a bellwether trend toward local bans and ordinances on land application of Class B biosolids that may impact the long-term sustainability of land application or land reclamation.

2.3 Summary of Regulations

Existing federal and state regulations on the disposal and reuse of the DWSD WWTP's solids are briefly described in this section. The regulations cover various solids management methods, such as land application (which includes the distribution and marketing [D&M] of compost, alkaline stabilized biosolids, heat-dried pellets, etc.), surface disposal, and incineration. In addition, potential impacts of regulatory trends are provided for gaining a

sense of how certain biosolids management practices may be affected in the future. It is important to note that these potential impacts are based on best professional judgment and available information; final regulations and associated impacts may differ from the views contained in this memorandum.

The following regulations, issues, and potential impacts to the DWSD's future biosolids management program are highlighted:

- Federal Part 503 Regulations, Standards for the Use and Disposal of Sewage Sludge
- Federal Clean Air Act Amendments (CAAA)
- Michigan Department of Environmental Quality (MDEQ) Regulations
- Future regulations pertaining to dioxins, incineration, radioactivity, mercury, and nutrient management
- National practices and trends

2.3.1 Federal Regulation – Standards for the Use and Disposal of Sewage Sludge (Part 503 Regulation)

2.3.1.1 Overview – Subpart A: General Provisions

The 503 Regulations establish numerical, management, and operational standards for the use or disposal of biosolids that are applied to land (including products sold or given away), placed in or on surface disposal sites, or incinerated. These standards apply to the persons who operate the systems or prepare the biosolids, or who practice these three basic use/disposal methods.

Compliance with the Part 503 Regulation was required by February 19, 1994, if no facility construction was needed, and by February 19, 1995, if facility construction was necessary. Monitoring, recordkeeping, and reporting requirements were effective July 20, 1993, except for total hydrocarbons from incinerators, which had to meet the 1- or 2-year schedule, depending on facility construction. The USEPA amended the Part 503 Regulation in 1994 and 1999.

2.3.1.2 Subpart B: Land Application

The land application category includes agricultural land application, forest application, land reclamation, range-land application, and distribution and marketing of any biosolids product that will eventually be applied to land.

The land application requirements specify maximum concentrations and annual and cumulative loadings for metals; the applicability of each is dependent on the biosolids quality and use. Land application management practices are identified. Operational standards for pathogen reduction and vector attraction reduction are also required.

Pollutant limits in Subpart B Tables 1-4 are presented in Table 2-1.

Table 2-1. Summary Tables for Land Application Subpart B

Pollutant	Subpart B TABLE 1 Pollutant Ceiling Concentrations (mg/kg)[a]	Subpart B TABLE 2 Cumulative Pollutant Loading Rates (kg/ha)[b,c]	Subpart B TABLE 3 Pollutant Concentrations (mg/kg)[c]	Subpart B TABLE 4 Annual Pollutant Loading Rates (kg/ha-year)[b,d]
Arsenic	75	41	41	2
Cadmium	85	39	39	1.9
Copper	4,300	1,500	1,500	75
Lead	840	300	300	15
Mercury	57	17	17	0.85
Molybdenum	75	NA	TBD	NA
Nickel	420	420	420	21
Selenium	100	100	36	5
Zinc	7,500	2,800	2,800	140

Table numbers are from Subpart B: Land Application, EPA Part 503 Regulation. All values are on a dry weight basis.
[a] Applies to all biosolids to be land-applied.
[b] Multiply by 0.9 to convert to lb./ac.
[c] Applies to bulk biosolids land-applied.
[d] Applies to biosolids sold or given away in bag or other container for land application.

The Regulation states separate requirements for pathogen and vector attraction reduction. Pathogen requirements have two classifications: Classes A and B, with Class A being the more stringent.

Biosolids that meet the Class A pathogen requirements, one of the vector attraction reduction requirements (criteria 1 through 8 in Subpart D: Pathogen and Vector Attraction Reduction), and the numerical criteria in Table 3 are referred to as "Exceptional Quality" (EQ). As such, these biosolids have minimal regulatory requirements.

Biosolids that are Class B with respect to pathogen requirements are restricted to bulk application to agricultural land, forest, or reclamation sites. There are additional site restrictions specific to Class B biosolids, such as food crop, grazing, and public access restrictions. For Class B biosolids, one of the first ten criteria specified under Subpart D (described later) for vector attraction reduction must be met in order to land apply biosolids.

2.3.1.3 Subpart C: Surface Disposal

Generally, surface disposal refers to sludge-only landfills (monofills) and dedicated land disposal. Subpart C of the Part 503 Regulation applies to any person who prepares biosolids that are placed on a surface disposal site, to the owner/operator of the site, and to the

surface disposal site itself. This subpart does not apply to biosolids stored on an area of land or to the land on which the material is stored.

The Part 503 Regulation does not apply to disposal of biosolids in municipal solid waste landfills. Disposal or use of biosolids at municipal solid waste landfills are regulated under 40 CFR Part 258. Biosolids disposed in a municipal solid waste landfill must be non-hazardous and pass the Paint Filter Test. Other site-specific requirements may be required depending on the state and landfill.

2.3.1.4 Subpart D: Pathogen and Vector Attraction Reduction

As specified in Subpart D of the Part 503 Regulation, either Class A or B pathogen reduction requirements must be met when biosolids are applied to the land or placed on a surface disposal site. In addition, the regulations require reduction of vector attraction, that is, control of those characteristics of biosolids that attract disease-spreading agents (e.g., flies or rats) when applied to the land or placed on a surface disposal site. There are no pathogen or vector attraction reduction requirements for biosolids fired in an incinerator that achieves such reduction during the incineration process.

2.3.1.5 Subpart E: Incineration

Subpart E of the Part 503 Regulations covers incineration. In particular, the following are specified: pollutant limits, operational standards, frequency of monitoring, recordkeeping, and reporting. The regulatory requirements on pollutant emission are summarized below.

2.3.1.5.1 Pollutant Limits for Incineration.

- **Beryllium**. Maximum 10 grams per 24 hours (National Emission Standards for Hazardous Air Pollutants [NESHAP] 40 CFR Part 61 Subpart C)
- **Mercury.** Maximum 3,200 grams per 24 hours (NESHAP 40 CFR Part 61 Subpart E)
- **Lead, Arsenic, Cadmium, Nickel and Chromium.** Determined by a site-specific formula that takes into account National Ambient Air Quality Standards (NAAQS) or Risk Specific Concentrations developed by the USEPA, the dilution effected between the stack discharge and the nearest receptors as determined by a USEPA-approved model, and the air pollution control (APC) system efficiency. The result is the maximum allowable metal concentration in the biosolids feed to the incinerator.

2.3.1.5.2 Operational Standards for Incineration.

- **Total hydrocarbons (THC).** Less than 100 ppmv measured as propane, corrected to 7 percent oxygen and 0 percent moisture, on a monthly average basis.
- **Carbon monoxide can be monitored in lieu of THC.** Less than 100 ppmv, corrected to 7 percent oxygen and 0 percent moisture, on a monthly average basis.

2.3.2 Michigan Regulations on Biosolids Disposal

The MDEQ handles issues related to the disposal and use of biosolids generated from municipal water and WWTPs and other facilities, as well as air permits for biosolids incinerators. Land application of biosolids in Michigan is regulated by Michigan Administrative Rules of Part 24 - Land Application of Biosolids, prepared by MDEQ Surface Water Quality Division, effective on November 2, 1999. These rules establish standards for the land application and beneficial recycling of biosolids originating from domestic sewage treatment systems and sanitary sewage treatment systems. Part 24 adopted the same pollutant

limits as well as pathogens and most vector attraction reduction criteria established in the 40 CFR Part 503. Under Part 24, a residuals management program is required for permit application. Part 24 also contains requirements (such as pollutants monitoring and soil testing etc.), in addition to the 40 CFR Part 503, that must be met for land applying and distributing biosolids in Michigan.

Sewage sludge incinerators are currently regulated under the MDEQ's APC Rules, adopted pursuant to Part 55, Air Pollution Control, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Act 451). Air Quality Division issues two types of air use permits: one is permits to install for any potential source of air pollution, and the other is renewable operating permits.

2.3.3 Summary of Current Regulations and Future Trend

Table 2-2 summarizes the key points regarding the USEPA and MDEQ regulations on the disposal and reuse of the WWTP's solids. Excerpts of the major sub-rules from Part 24 and Air Pollution Control Rules are also presented in Table 2-2.

Table 2-2. Summary of USEPA and MDEQ Regulations on WWTP Solids Disposal or Reuse

Biosolids Issue	General Description
Existing Regulatory Issues *Federal Part 503 Regulations*	The USEPA promulgated the Part 503 Regulation in February 1993 and amended them in August 1999. Subpart A, General Provisions – The Part 503 Regulation applies to biosolids that are land-applied, surface disposed, or incinerated. Several exclusions are noted in the rule. Subpart B, Land Application – Numerical limits and associated management practices are specified. Subpart C, Surface Disposal – Surface disposal refers to biosolids-only landfills and dedicated land disposal practices. Pollutant concentration limits are specified for the biosolids as well as for that site; nitrogen in the groundwater must be monitored. If a daily cover is placed, pathogen requirements do not have to be satisfied. Subpart D, Pathogen and Vector Attraction Reduction – Criteria are specified for two categories: Class A or B. Reduction of vector attraction (e.g., control of flies, rats, etc.) is also required. Management options and reduction standards are provided. Subpart E, Incineration. Pollutant limits, operational standards, and monitoring and reporting requirements are specified.
Existing Regulatory Issues *Clean Air Act Amendments CAAA)*	The CAAA also regulate sludge incinerators. Particulate emissions and opacity limits are required. It also requires monitoring and reporting, and performance testing.

Biosolids Issue	General Description
Future Regulatory Issues *Dioxins*	The Part 503 Regulations do not include limits on concentrations of dioxins, dibenzofurans, or PCBs in sludge. Proposed regulations for dioxins in biosolids that are land applied are pending. No federal regulations for dioxins are planned for biosolids that are surface disposed or incinerated.
Future Regulatory Issues *Incineration*	If the USEPA decides to regulate sludge incinerators under Section 129 in the future, there may be some quality parameters that may affect the incinerator's ability to meet the regulations (e.g., dioxin, dioxin-like pollutants, mercury, etc.).
Future Regulatory Issues *Radioactivity*	Radioactive materials are ubiquitous in the environment and can enter the collection system and WWTP from a variety of sources. While elevated levels of radioactivity in biosolids are typically localized, monitoring of radioactive materials is required to identify the potential for radiological incidents. No criteria for radionuclides currently exist for biosolids management practices.
Future Regulatory Issues *Mercury*	Most USEPA programs are concerned with some aspect of mercury exposure. Stringent water quality criteria have been developed for mercury under the Great Lakes Initiatives. Wastewater treatment works, such as the DWSD's, will be expected to play an important role in mercury reduction through pretreatment, and strategies to develop Total Maximum Daily Loads (TMDLs). Future requirements will likely place pressure on the state to address emissions of mercury. Most of the mercury that comes into a WWTP is concentrated in the sludges, with a large percentage of that contained in the uncontrolled emissions if incineration is employed. Although the fate and transport through thermal processes are not completely known at this time, a lot of work has been done, and virtually all of the mercury vaporizes in the combustion zone and can be carried out with the exhaust gases if not controlled. The state-of-the-art technology includes injection of powdered activated carbon (PAC) into the exhaust stream and then capture of the PAC and with it, the particulate matter on fabric filters.
Future Regulatory Issues *Nutrient Management*	Biosolids are good sources of nutrients; agronomic application rates are currently based on the nitrogen content of the biosolids and the crop nitrogen needs. Application of biosolids based on crop nitrogen requirements usually adds more phosphorus than is needed by the crop. Soluble phosphorus may be carried in the runoff. For biosolids application, buffer zone requirements must be satisfied. The Michigan EPA may implement nutrient management regulations in the future. These limits will depend largely on site characteristics, crop nutrient requirements, water quality, as well as concentrations of bioavailable nutrients in the biosolids.
Future Potential Regulatory Issues *Endocrine Disruptors*	Endocrine Disruptors have the potential to be the main future regulations for WWTP discharges, drinking water, and biosolids. The USEPA is currently screening the potential Endocrine Disruptors. Any regulation is still several years away.

Biosolids Issue	General Description
Existing MI Administrative Rules *Part 24. Land Application of Biosolids*	MDEQ Part 24, effective on November 1999, includes the following major sub-rules: • Land application permit • Imposition of more stringent requirements; proof of payment of costs and fee required; local ordinances • Application of limitations • Management practices • Operational standards; pathogens and vector attraction reduction • Frequency of monitoring • Record keeping • Pathogens • Vector attraction reduction
Existing Regulatory Issues *Air Pollution Control Rules*	MDEQ - Air Pollution Control Rules, includes the following major sub-rules: • Air Use approval • Emission Limitations and Prohibitions - Particulate Matter • Emission Limitations and Prohibitions - Sulfur Bearing Compound • Emission Limitations and Prohibitions - Existing Sources of Volatile Organic Compound Emissions • Emission Limitations and Prohibitions - Misalliance • Intermittent Testing and Sampling • Continuous Emission Monitoring

2.4 Summary of National Practice

Based on similar long-term solids disposal studies that CH2M HILL has performed, the following are some of the more obvious trends:

- As urban areas continue to expand, a greater quantity of biosolids material is generated, requiring increased emphasis on wet season storage and increased amounts of land for land application programs.
- Also as a result of urban expansion, there is less readily available land for application and populations have been established closer to land application areas, creating the potential for negative public perception or other population-based issues for land application programs.

More specific trends respective to various practices nationwide are summarized below:

- **Class A vs. Class B.** Well-executed and –situated Class A and B operations have both generally been proposed and expanded or copied by others as landfilling has been replaced by other programs. The specific constraints of a particular plant will dictate the cost-effectiveness of a particular option. Class A processes generally cost more than Class B processes. However, where the distance to a land application area is great, the generally lower disposal cost of a Class A product , sometimes reduced by revenue from sales, can offset higher capital and processing costs. Land applying Class B is becoming increasingly difficult. Several states have already or are considering banning the land application of Class B.

- **Advanced Digestion.** There has been significant development of advanced digestion processes in the last 10 years, generally focused on high temperature anaerobic digestion processes. Common advantages include increased pathogen destruction (production of a Class A vs. B product), and increased volatile solids destruction and methane gas production. Disadvantages include increased capital and processing cost, and odor.
- **Land Application.** Land application programs have been, and still are, popular because of inherent low costs where ample land is available within a reasonable transportation distance. There has been a tendency toward large-scale remote programs (that support large metropolitan areas, such as Seattle, Portland, New York City, and Washington D.C.) that are cost-effective because the economies of scale and single delivery point outweigh the long-haul considerations.
- **Composting.** Composting programs flourished beginning in the 1970s, but new programs are being implemented far less frequently today and many older facilities have shut down. This development has come about as the true costs of composting are realized and odor problems have led to costly mitigation measures and public acceptability issues.
- **Heat Drying.** Although it is a long-proven method of sludge processing, heat drying has only become popular in the past 15 years as technology issues have been resolved, the basic process has been more formally defined and endorsed by regulations, and the need has expanded (mostly in the eastern U.S.) for alternatives to landfilling, incineration, and ocean dumping.
- **Landfilling.** The percentage of biosolids being landfilled has drastically decreased over the past 20 years as solid waste and recycling legislation has made biosolids landfilling more costly and/or specifically prohibited. However, there has been some recent research indicating that biosolids help in the decomposition of solid waste in a landfill and thus provide some benefit. It is unlikely, however, that the acceptability of landfilling will improve in the near future.
- **Incineration.** Although retrofitting existing incinerators to comply with new air pollution and Part 503 regulations is reasonably easily accomplished, these regulations, coupled with the bias of regulations and the general public, have made implementation of new sludge incinerators difficult.

2.5 DWSD NPDES Permit Requirements and Other Obligations

This study focus only on the long-term disposal alternatives. The specific issues of the DWSD solids processing needs are discussed in the Solids Master Plan, and in the DWSD submittal to the Federal District Court, Eastern District of Michigan, Southern Division. Nonetheless it is useful to review the permit obligations briefly.

The current WWTP operates under an extension of the old National Pollutant Discharge Elimination System (NPDES) permit (which expired on October 1, 2002) (MI0022802) while the new one is being negotiated with MDEQ. Section D of the permit addressing a "Program For Effective Residual Management" is the sole section dealing with residuals management. No numerical limit was set in the permit for solids quality. The permit requires DWSD to set forth the Program For Effective Residual Management. The required elements of the program include:

- A management plan (treatment, storage, disposal, contingency plans).
- An inventory of residuals production, storage, and disposal for a period of 1 year.
- Any analysis of the residuals.
- A monitoring program.
- If land application is proposed, include site maps, soil analyses, application rates, proposed vegetation and other pertinent information.
- If groundwater degradation potential exists, include a hydrogeologic study.

DWSD is required to submit program certification of proposed modifications to the MDEQ for approval on or before June 1 of each year. DWSD is also upgrading its solids removal and dewatering equipment to comply with the requirements of the Federal Court Order.

3. DWSD Solid Management Programs

3.1 Introduction

This section provides an overview of the existing solids processes at the WWTP, a description of the quality of the blended sludge, a review of the long-term issues for solids management, and a summary of previous solids management studies for the WWTP. This information provides the basis for development in Section 5 of the long-term alternatives evaluated in this TM.

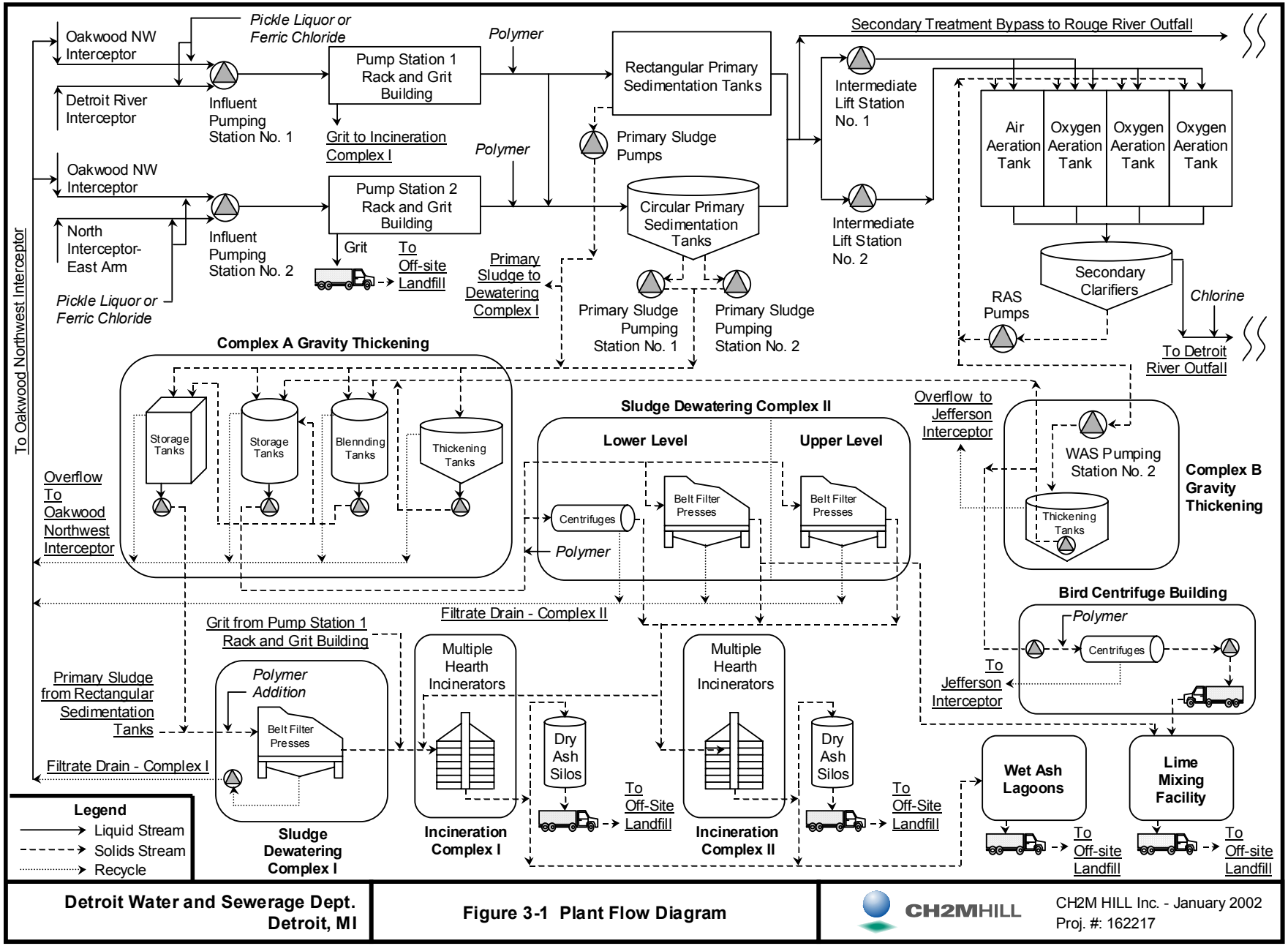
3.2 Solids Treatment Processes at the WWTP

3.2.1 Description of Current Treatment Processes

This section provides a brief summary of the DWWTP solids processing processes. For more details on the process description and ongoing improvement project, please refer to the TM A.4.z (Review of Detroit Wastewater Treatment Plant Technical Memorandum, 2002) under the WWMP and Detroit Wastewater Partners (DWP) NAS report Revision 3 (2002).

Figure 3-1 (from the TM A.4.z: Review of Detroit Wastewater Treatment Plant Technical Memorandum, 2002) shows the current WWTP process diagram, and Table 3-1 is a summary of the present and post-PC-744 processing capacities for each operation, and its unit processes. The present solids handling and disposal program at the WWTP consists of four main unit operations:

- Complex A and B Gravity Thickening
- Complex I and II Dewatering and Cake Conveyance
- Complex I and II Incineration and Landfilling of Ash
- LMF



Detroit Water and Sewerage Dept. Detroit, MI

Figure 3-1 Plant Flow Diagram

CH2MHILL

CH2M HILL Inc. - January 2002
Proj. #: 162217

Complex A's six gravity thickeners receive primary sludge from the rectangular and circular primary clarifiers. Complex B's six gravity thickeners receive waste activated sludge (WAS) from the secondary clarifiers. The thickeners at both complexes serve to thicken the sludge prior to dewatering and provide sludge storage during high solids loading periods or during periods of major emergency shutdowns at the dewatering complexes. Combined, Complex A and B have a firm sludge thickening capacity of at least 500 dry tons per day (DTPD), with 880 dry tons (DT) of storage capacity. At the completion of PC-744 by 2007, the total peak thickening capacity is expected to be at 940 DTPD.

Complex I consists of 10 belt filter presses (BFPs), with a total firm capacity of 240 DTPD. The BFPs discharge sludge cake to a conveyor belt system, which transfers the sludge to the Complex I incinerators.

Complex II's lower level dewatering area currently contains 16 BFPs, and four high-solids centrifuges that were installed during 2001. The 16 BFPs are past their useful life per the NAS; therefore, the total firm capacity of Complex II lower level is less than 226 DTPD (the 16 BFPs have been replaced with new centrifuges under PC-744). The Complex II upper level contains 12 new BFPs, with a total firm capacity of 416 DTPD. The Complex II conveyor system transports dewatered sludge primarily to the Complex II incinerators. However, both Complex II upper level and Complex II lower level have alternate (or backup) disposal routes. The total firm dewatering capacity is now less than 872 DTPD, and it will be increased to 1,163 DTPD post PC-744 by 2007.

DWSD operates and maintains a MHF sludge incineration facility comprised of Complex I and Complex II facilities. The incineration facility is used to process residual sludge solids by drying and combusting the dewatered sludge for volume reduction by thermal conversion into exhaust gas and inert ash. Complex I has six multiple-hearth incinerators, and Complex II has eight. The total incineration firm capacity is about 454 DTPD, and there is no plan yet to increase its capacity, especially if Minergy is commissioned.

The LMF stabilizes dewatered sludge from Complex II lower level dewatering units and/or the Bird centrifuges. The facility consists of lime silos, screw conveyors, and a series of conveyor belts that transfer the dewatered cake to the mixers (also referred to as pug mills). The mixers blend lime with the dewatered cake and transfer the stabilized cake sludge to the lime mixing pad for further stabilization. Front-end loaders are used to transfer the stabilized cake from the lime mixing pad to trucks for landfill disposal. The existing total capacity is about 221 DTPD, and it will be upgraded per Solids Master Plan as part of the backup plan. The LMF is being expanded to handle a peak two-week 940 DTPD for cake of 28% DS or greater. It is intended to be a backup process to Minergy or, to an improved incineration process.

3.2.2 Long-Term Solid Treatment Process Issues

DWSD is active in two key areas to meet its future solids processing needs. The first area is replacing the BFPs with centrifuges. When DWSD completes CS-1290 in 2004, there will be 10 centrifuges in the Complex II lower level dewatering complex, 10 BFPs in the Complex I dewatering complex, and 12 BFPs in the Complex II upper level dewatering complex.

The second area is the replacement of onsite incineration technology with a new, offsite process called Minergy. Minergy technology recycles the inert solids in the wastewater sludge into environmentally inert products (glass aggregates). Per the DWSD Plan for Long-

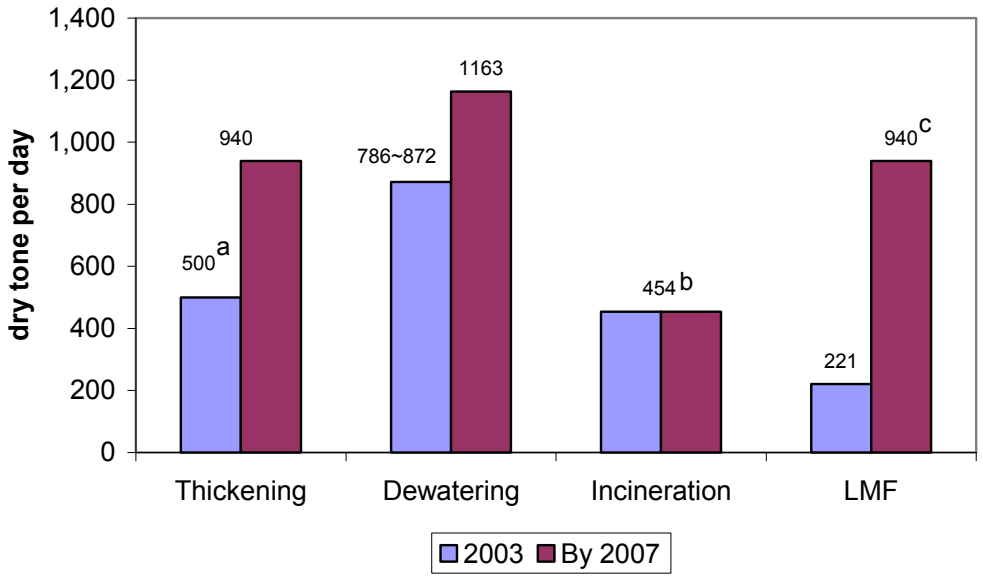
Term Measures to Ensure Compliance with Permit Requirements report in 2000, once Minergy has successfully operated for a time sufficient to establish reliability and credibility, DWSD may change the incinerators to "standby" mode. DWSD intends to maintain a backup plan even if the Minergy process is selected in the future per the same report.

The existing firm capacity of the solids handling system is about 675 DTPD, based on evaluating the data provided in the NAS, Revision 2 (2001). Table 3-2 summarizes the existing firm processing capacity and unit availability assumed for firm capacity as well as the future planned capacity based on NAS. The data clearly indicates that dewatered sludge processing through incineration or lime mixing is the limiting process for solids handling processes. A slightly different firm capacity of 630 DTPD was reported by the WWTP Dynamic Modeling team (Appendix E of the Needs Assessment Report, Revision 2, 2001). This was due to the higher unit capacity that was used for the Complex II incinerators by the Modeling Team (NAS used 72 DTPD and the modeling team used 61 DTPD). Staff from the DWP provided a rough estimate between 700 to 800 DTPD. It is noteworthy that this capacity is about the same as the 650 DTPD used in this TM as the base load solids production rate under future conditions.

The 1996 DWSD Long-Term CSO study reported a firm capacity of 552 DTPD for the solids handling facilities. This number does not include the capacity of the LMFs and a different unit availability was assumed for major processes.

DWSD's Solids Master Plan (in the Needs Assessment Study for Detroit Wastewater Treatment Plant, 2001) determined that a firm solids processing capacity of 940 DTPD will be needed for a period of up to 2 weeks. The post PC-744 firm capacity of the gravity thickening and dewatering will both reach the 940 DTPD capacity. PC-744 will realize a higher firm capacity of 1,163 DTPD for the dewatering processes after replacement of the Complex II upper level BFPs in early 2007.

Figure 3-2 and Table 3-1 (both from the Review of Detroit WWTP TM, 2001) present the solid handling unit capacities prior to and post the PC-744 WWTP improvement project. One update since the previous TM is that the 10 BFPs that were to be replaced with centrifuges will instead be upgraded.



a. The existing capacity information for the Gravity Thickeners was from NAS report. See Table 3-1 for details.
b. The post PC-744 capacity of the incinerators depends on the ultimate solids disposal method selected by DWSD. For example, the incineration system could be idled if Minergy is selected, and the LMF used as a backup.
c. DWP-1074 project will expand the current LMF to handle a 940 DTPD peak loading rate for up to 2 weeks.

Figure 3-2. Existing and Post PC-744 Firm Capacity of the Solids Handling Facilities Based on Needs Assessment Study (PC-744)

Table 3-1. Existing and Post PC-744 Firm Capacity of the Solids Handling Facilities (Summarized from DWP NAS Rev 2)

		Gravity Thickeners[a]		Dewatering Complexes			Incineration[b]		
		Complex A	Complex B	Complex I	Complex II Lower	Complex II Upper	Complex I	Complex II	Lime Mixing Facilities
Existing Capacity	Total No. of Units	6	6	10 BFPs (near end of useful life)	16 BFPs (past useful life) and 4 (new condition) Centrifuges	12 BFPs (new conditions)	6	8	2 pug mills
	Units Available for Firm Capacity	5 of 6 (@ 4% solids)	5 of 6 (@ 2% solids)	6.5 of 10	0~4 of 16 BFPs + 2 of 4 Centrifuges	8 of 12	3 of 6 (PC 744 Appendix E)	4 of 8 (PC 744 Appendix E)	1 of 2
	Firm Capacity	920 dry tons (firm storage capacity)	460 dry tons (firm storage capacity)	240	0~96 + 130 = 130 ~ 226	416	166	288	221 (PC 744 Appendix E)
	Total	**Thickeners process a minimum of 500 DTPD (400 PS + 100 WAS)**		**Dewatering = 786 ~ 872 DTPD**			**Incineration = 454 DTPD**		**LMF = 221 DTPD**
		The solids storage capacity in Complex A is 520 DT	The solids storage capacity in Complex B is 360 DT	There is an additional 90 DTPD firm capacity for back up dewatering from Bird centrifuges assume 1.5/3 units each@60 DTPD, PC 744 Appendix E					
Post PC-744 Capacity	Total No. of Units	Not specified		All 10 BFPs to be upgraded by 2005	6 or 8 Centrifuges to replace 16 BFPs by 2004 (CS-1290) and 4 existing Centrifuges	12 BFPs			
	Units Available for Firm Capacity	Not specified	Not specified	9 of 10 BFPs	6.5 of 10 or 12 Centrifuges (4 existing and proposed 6 or 8 new to replace all BFPs)	8 of 12			
	Firm Capacity	Not specified	Not specified	325	422	416			
	Total	**Thickening = 940 DTPD**		**Dewatering = 1163 DTPD + ?? Backup (not decided yet)**			**454 DTPD per Plan A**		**940 DTPD peak loading**
		Based on the DWSD PC-744 Solids Master Plan (Needs Assessment Study for Detroit Wastewater Treatment Plant, 2001, Page 3-40), DWSD's current sludge thickening (Complex A and B) and blending facilities will be upgraded and used for long-term sludge processing to meet projected sludge processing requirements of 940 DTPD.		i. Bird Centrifuges: based on the DWSD PC-744 Solids Master Plan (Page 3-44), a fourth dewatering facility is needed to be able to provide the necessary supplemental production capacity during extended period of major rehab/replacement at other three facilities (C-1, Complex II lower and upper levels). Several other factors in determining whether or not to proceed with the design and construction of a replacement for the Bird Centrifuge Facility need to be evaluated. ii. Rental Centrifuges: based on the DWSD PC-744 Solids Master Plan (Page 3-47), An analysis of evaluating the performance and use of each unit is needed in order to provide a basis to determine whether to keep the centrifuges (some or all) or terminate all the centrifuges.			It depends on which ultimate disposal plan chosen, Plan A: Minergy, Plan B: Existing Multiple Hearth Incineration and Plan C: New Fluid Bed Incinerations. Plan A is the most preferred and Plan C is the least preferred so far.		Need upgrade or a new lime mixing facilities for long-term backup disposal no matter which disposal plan chosen, Plan A or Plan B.

a. The existing capacity information for the gravity thickeners was from Appendix E of the NAS Rev 2 report (2001, DWP).
b. The number of unit availability used here for the incinerators were from the Appendix E of the Needs Assessment Study. No unit availability information was found in the NAS text. The unit availability of the incinerators used in the 1996 DWSD Long-Term CSO Plan (Wade-Trim) was higher than the number listed here. It was assumed 4 out of 6 for Complex I and 5 out of 8 for Complex II incinerators. Using a similar unit capacity, this gave the firm capacity of 221 DTPD and 359 DTPD for the Complex I and II incinerators respectively for the Long-term CSO Plan.

3.2.3 Projected Future Solids Production

Based on the Solids Master Plan, the long-term average daily sludge quantities are expected to be in the range of 500 to 600 DTPD. For purposes of this study it is assumed that a capacity of 650 DTPD will handle the maximum monthly load under dry weather conditions. After peak wet weather events, when major CSO storage facilities are used, including the proposed Upper Rouge Tunnel, the solids loading to DWWTP is expected to rise to about 940 DTPD for 1 to 2 weeks after each event. These projections apply through 2050. As noted earlier, it is assumed that this peak rate will be encountered over two-week intervals for an average of eight weeks each year.

According to the DWP, the Upper Rouge Tunnel is expected to be used approximately 55 times per year and that the dewatering of the Upper Rouge Tunnel will contribute about 600 million gallons (MG) per year to the WWTP.

3.2.4 Current WWTP Solids Characteristics

The most recent information on hand from the DWSD is that contained in the *Biosolids Reuse Alternative Study Report* prepared by DWSD in 1998. This information is assumed to be representative of the quality of the blended primary and waste activated solids production at the WWTP. However, there is no information to provide insight on the expected impact if any of the operation of the Upper Rouge Tunnel on the future quality of the solids production.

Table 3-2. Current WWTP Solids Characteristics

Metal	Ceiling Concentration, mg/Kg (from EPA Part 503 Subpart B Table 1)	Exceptional Quality, mg/Kg (from EPA Part 503 Subpart B Table 3)	DWSD, mg/Kg
Arsenic, As	75	41	11
Cadmium, Cd	85	39	29
Copper, Cu	4,300	1,500	335
Lead, Pb	840	300	127
Mercury, Hg	57	17	0.5
Nickel, Ni	420	420	159
Selenium, Se	100	100	4
Zinc, Zn	7,500	2,800	1,375
Molybdenum, Mo	75	—	—

Source: DWSD Biosolids Reuse Alternative Study Report, 1998

The available but limited data for every parameter indicate that the DWSD sludge is of a better quality than stipulated in the Ceiling Concentrations of Part 503. To achieve EQ sewage sludge, a sludge also has to meet the following three quality requirements (which would apply if for example lime stabilization were applied):

1. Not exceed the EQ pollutant concentrations in Table 3 of USEPA Part 503 regulation.

2. Meet or exceed the Class A pathogen requirement: pH greater than 12 for 72 hours; temperature greater than 52 deg C for 12 hours; and a greater than 50 percent dry solids (DS) content at the end of 72 hours.

3. Meet or exceed the vector attraction requirement: of a pH greater than 12 for 12 hours, followed by a pH greater than 11.5 for an additional 22 hours.

The DWSD sludge monitored in 1997 did meet the EQ requirements for EQ from the standpoint of the pollutant concentrations. Unfortunately, more recent quality information was not available to the authors of the TM.

3.3 The DWSD Solids Master Plan

The DWSD Solids Master Plan (see reference below) has investigated several alternatives for future ultimate disposal facilities. This was done by considering the existing facilities, commitments, preferences, and potential future regulatory drivers. The alternatives considered at that time included incineration and Minergy, and the issues considered included the logistics of implementing an alternative biosolids reuse technology, and the continued hauling of sludge (stabilized and unstabilized) to landfill.

According to the NAS study report (Needs Assessment Study for Detroit Wastewater Treatment Plant, Revision 2, 2001), DWSD had by then signed a contract with Minergy for long-term solids processing and disposal. The contract sets forth that if Minergy fails to meet some of the stipulated conditions, DWSD can void the contract and pursue other options. Because of this reason, three potential planning scenarios for ultimate disposal of solids were developed: Plans A, B, and C. These plans are summarized in Table 3-3.

Table 3-3. Summary of Disposal Alternatives for Solids Master Plan

Plan	Primary Method of Disposal	Backup Method of Disposal
Plan A	Minergy	New Lime Mixing Facility
Plan B	Existing Multiple Hearth Incineration	New Lime Mixing Facility
Plan C	New Fluid Bed Incineration	New Lime Mixing Facility

DWSD has since completed its negotiations with Minergy. According to the April 2003 report from DWSD on its Comprehensive Plan to the U.S. District Court, the Minergy project continues to move forward, but it has encountered certain unknown impediments, and DWSD continues to monitor the status.

3.3.1.1 Plan A (Minergy)

According to the Solids Master Plan, there are two documents that contain the present DWSD plan for long-term solids disposal. The first document is the *1999-2000 Program for Effective Residuals Management*, which was submitted to the MDEQ on June 1, 2000. This document states that "…DWSD has entered into a 16-year contract with Minergy Detroit, LLC, to dispose of the WWTP's sludge." This document clearly states that it is DWSD's intention that Minergy is the long-term solids disposal option. This intention was reconfirmed with DWSD since the REV-0 Needs Assessment (Needs Assessment Study for Detroit Wastewater Treatment Plant, 2001).

The second document is the *Plan for Long-Term Measures to Ensure Compliance with Permit Requirements,* which was submitted August 1, 2000, as part of the Second Amended Consent Judgement. This plan indicates that "… backup plans are being maintained in case unforeseen issues should arise for the Minergy contract …". This document clearly states that DWSD desires some contingency plans for ultimate disposal of solids.

The content of these two plans, in addition to information gathered during needs assessment of the solids processing facilities, served as the basis of Plan A. Should DWSD select Minergy as the long-term solids disposal, a sequence of projects are proposed for Plan A in the NAS (for Detroit Wastewater Treatment Plant, 2001Revision 2, 2001) report.

3.3.2 Plan B (Existing Incineration)

The investigation of the existing incinerators by the NAS team indicates that, with investment in a systematic upgrade program, presently estimated as $65 million, these units will be capable of continuing as the long-term ultimate disposal process. This includes meeting air discharge requirements as well as providing similar performance to fluid bed incinerator technology, which is considered to be state-of-the-art.

3.3.3 Plan C (Fluid Bed Incineration with Energy Recovery)

Another alternative plan for ultimate disposal of sludge cake at DWSD's WWTP involves demolition of the existing incinerators for replacement with new fluid bed incinerator technology. The preliminary estimates indicate that this type of upgrade in incinerator technology would cost approximately $200 million. This capital investment exceeds by threefold the present estimate of $65 million to upgrade the existing incinerators. On this basis the installation of new fluid bed incinerators was not recommended at this time in the Solids Master Plan. However, it is unclear if Plans B and C were evaluated on the basis of life-cycle costs.

3.3.4 Summary of Critical Issues/Decisions Recommended by the Needs Assessment Study

As noted in the previous sections, the Minergy alternative (Plan A) for ultimate solids disposal requires that several key components at the WWTP be modified to accommodate this offsite facility. To this end, DWP and DWSD have started modifying the key components listed below:

- The construction of Minergy conveyance and outloading facilities (DWP-1004 and PC-691).
- Performance of short-term upgrades to the incinerators for interim use ($16 million, which is separate from the above noted $65 million in improvements for a long-term operation).
- Upgrade of the LMF for long-term backup capacity.
- Maintaining the availability of an existing request for qualifications (RFQ) for procurement of other beneficial use technologies for long-term backup.

Although Plan B does not appear likely at this time, the planning efforts for Plan B were also described. The key components of Plan B include:

- Implementation of the long-term upgrades to the incinerators ($65 million).
- Replacement of the incinerator conveyors.
- Upgrade of the LMF for long-term backup capacity.

- Continuation of the implementation of the Complex I and II incineration control system rehabilitation.

3.3.5 Contingency Planning

A contingency plan has been developed to address the possibility of any interruption during the 16-year Minergy contract, for any reason (financial, catastrophic failure, contractual, regulatory, etc.) The two key components of the plan are:

- Implementation of an interim solids disposal alternative (up to several years)
- Procurement of a long-term disposal alternative (greater than 10 years)

The interim plan would be implemented very quickly and operate until a long-term alternative can be identified and operated. The interim alternative must meet the following criteria:

- Be implemented quickly (within several weeks)
- Handle all of DWSD's sludge until a long-term alternative is implemented (potentially up to several years)
- Be capable of lying dormant for years yet operational within weeks

The selected interim alternatives are:

- Incineration
- Unstabilized sludge hauling
- Stabilized sludge hauling

3.3.5.1 Incineration

Incineration is a fairly complex and expensive process that also requires a relatively specialized operations and maintenance (O&M) staff. Incinerators require from one to two weeks to warm up if left cold when unused, or they have to be kept warm by burning natural gas. It was estimated by the Solids Master Plan that it will take an additional $65 million to upgrade the existing incinerators for suitable for long-term use. It is noted that upgrading the incinerators for long-term and backup uses are at the same cost level because both have the same long-term reliability requirements.

The Solids Master Plan has concluded that incineration is a viable option as a primary, long-term, continuous solids processing option, but not as an interim backup option.

3.3.5.2 Unstabilized Sludge Hauling/Landfilling

A contingency plan involving the hauling and landfilling of unstabilized sludges would require almost no capital improvement if the same loading facility as for Minergy could be used for outloading transports to landfill. It was not recommended in the contingency plan due to the uncommon practice and uncertain regulatory concerns that may bring this practice to a close.

3.3.5.3 Lime-Stabilized Sludge Hauling/Landfilling

The hauling and landfilling of lime stabilized sludge involve the following processes:

- Transferring of sludge cake to the LMF
- Mixing of the sludge with lime in pug mills (mixers capable of mixing solid and semisolid materials)
- Conveying the mixed sludge to a holding area

- Loading the sludge into trucks for hauling and landfilling

Lime stabilization followed by haul and landfill was selected by the DWSD as the interim backup process for Minergy during the 16-year contract period. The basis for selection included that fact that it can be implemented rapidly, has a lower cost as compared with incineration, and has been used at the WWTP in the past.

DWSD is very familiar with this type of operation, and the lime stabilization processes are all capable of being started up relatively quickly even after periods of inactivity. The contract award for a new LMF in 2003 was $25 million for the LMF and a new central off-loading facility.

3.3.5.4 Procurement of a Long-Term Disposal Alternative.

While the interim disposal option is being implemented as a Minergy backup, DWSD will still need to procure a more viable option for long-term operation if Minergy were to encounter operating problems. Two options were proposed under the Solids Master Plan:

- Initiate an RFQ/RFP process for procurement of an alternative beneficial reuse process
- Evaluate incineration as a long-term option for disposal.

The Solids Master Plan recommends that both options to be conducted concurrently.

3.4 DWSD 1998 Biosolids Reuse Alternative Study

The report looked for alternatives beyond the current two disposal methods: incineration and landfill after lime mixing. At the time of report (February 1998), 88 percent of the WWTP solids were being incinerated, and the rest were being landfilled after lime mixing.

The goal of the study was to incorporate the most appropriate process to supplement the existing two disposal methods (MHF incineration and lime stabilization). Ten biosolids reuse technologies were evaluated. Eight of the alternatives would convert the biosolids into an organic soil amendment product or a fertilizer. One would use the biosolids as a binder material to produce pellets from coal fines. The last one uses biosolids as a source material for the manufacture of glass aggregate products for the construction industry.

The four recommended technologies of were: Minergy, N-Viro, Altex, and Bio-Gro. Briefly:

- The Minergy process combusts the organics in sludge and converts the inerts into glass aggregate. There is a Minergy facility in Fox Valley, Wisconsin, that is rated at 500 DTPD capacity, but there is a high paper mill sludge component in the sludge source at this site.

- The N-Viro Corporation produces a soil amendment product. N-Viro Soil was produced at over 30 locations worldwide at the time of the report.

- The Altex technology is a Biobinder process that uses sludge as a binder material to produce pellets from coal fines. Altex had established a joint venture with Detroit Edison (an electric utility) for the production and marketing of fuel pellet products.

- Bio Gro, a division of Wheelabrator Water Technologies, Inc., was founded in 1978 and developed the Bio-Fix process for lime-stabilization of biosolids. The Bio Gro company has considerable experience in Michigan with land application of stabilized biosolids.

Pilot demonstration initiatives were started at the WWTP to further evaluate the four potential reuse technologies. Prior to December 1997, proposals had been submitted to the Great Lakes Protection Fund by Minergy Corporation and Altex Technology, Inc. A proposal for a pilot study of the land application of lime-stabilized biosolids was submitted to WWTP for review in February 1998.

More details are presented in the technology review of Appendix A, including a proposal for reclamation of mined lands in the Upper Peninsula and for reclamation of disturbed lands on Fighting Island in the Detroit River. An alternative not selected in the original report, Fighting Island reclamation option, is located near to the WWTP and also included in this summary.

A summary of the alternatives studies in the DWSD's 1998 report *Biosolids Reuse Alternatives Study* is shown in the Table 3-4 (all information is cited from the report, the cost estimates are in 1997 dollars). Appendix A contains further descriptions of these technologies. The basis for these estimates could not be reviewed in the preparation of this TM, and updated information is needed before comparison is made.

Table 3-4. Summary of the Five Studied Alternatives in DWSD's 1998 Report Biosolids Reuse Alternatives Study

Process	N-Viro	Bio-Gro	Fighting Island Land Reclamation	Altex Technologies	Minergy
Process Description	N-Viro soil lime, alkaline stabilization	Bio-Fix Process, lime stabilization	Land Reclamation, Fighting Island, Ontario	Fuel pellets, Bio Binder process	Glass aggregate construction material
Process Logistics	Offsite 132,000 sg ft. process foot print	Offsite	Offsite, Fighting Island	Offsite, Detroit Edison	Offsite, National steel
Demonstrated Capacity (single site)	565 wet tons/day	195 wet tons/day	Pilot only	Pilot only	435 wet tons/day
Potential Capacity	650 wet tons/day up to 1,000 DTPD	650 wet tons/day	2,500 wet tons/day	1,000 wet tons/day	1,500 wet tons/day
Source	Raw sludge	Raw sludge	Raw sludge	Raw sludge	Raw sludge
Production Schedule	Continuous	Continuous	Seasonal	Continuous	Continuous
Distribution Schedule	Seasonal	Seasonal	Seasonal	Continuous	Continuous
Estimated Cost	$37 /wet ton	$40 /wet ton	$28 /wet ton	$37 / wet ton	$27.50/wet ton
Liability Probability	Low	Low	Low	Very low	Very low
Process Complexity	Low	Low	Medium	High	High

4. Development of Alternatives

4.1 Background

The alternatives are developed around our understanding of issues in three key areas: the project framework, the capacities needed, and the space and land availability at the WWTP.

4.1.1 Alternative Development Framework

The assumed framework (as illustrated in Figure 4-1) is as follows:

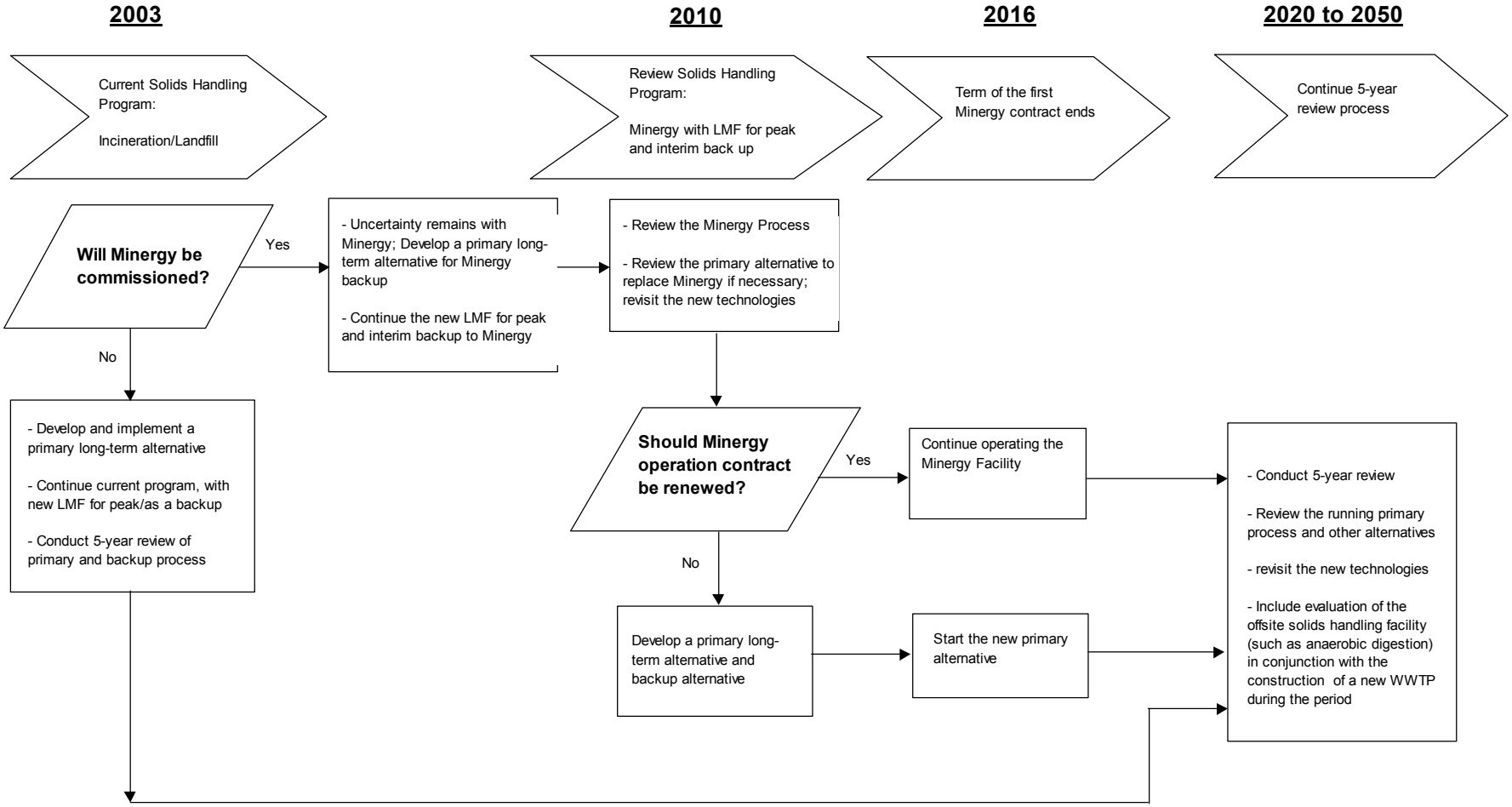
- The present core project for sludge stabilization over the time period to 2016 is Minergy, which is supposed to provide sludge stabilization by conversion of up to 650 DTPD of DWSD sludge into a commercial product.
- There are potential contractual and operational uncertainties with the Minergy process, for which reason this report assumes that either of two cases will prevail.
- The first case is that Minergy will be commissioned and operated for the term of its contract, that is to 2016. We also assume that at a time at least 5 years prior to the completion of this period, the DWSD will undertake a review of the Minergy project as well as of other alternatives, including those emerging and future alternatives that appear feasible at that time, and that DWSD will make its choice and proceed. We call this deferred decision process ***phased decision making*** at several locations in this TM.
- The second case is that Minergy is not commissioned, meaning that an alternative project will have to be implemented and operational from as early as 2004.
- To address this uncertainty the report will define the phases of planning as (1) interim (from 2004) and (2) long term (from 2016), and we will develop the associated list of projects that is needed for either phase.
- The time horizon of the study is 2050, and we assume that a review of the solids processing program will be made such that upgrades of existing technologies or selection and implementation of new technologies can take place at 2016 and 2032, to get to 2050 in a phased decision making process.

4.1.2 Capacities Needed

Our assumptions for the solids handling process capacity are:

- **Capacity needs for the long term.** Any alternative will have to provide for the solids production rates without and with the CSO tunnel system in place. The assumed solids production rates from the startup of the CSO tunnel system are base at 650 DTPD and peak at 940 DTPD. The assumed startup date of the CSO tunnel system will be after 2010, but for study purposes we assume the peak capacity of 940 DTPD should be available by 2004.

Figure 4-1. Illustration of the Phased Decision Making Process of the Alternative Development Framework



- The proposed alternatives are to address: capacity for base load of 650 DTPD; capacity for peak load (assumed to be an additional 290 DTPD, where the additional 290 DTPD is to be managed from the containment associated with an assumed four 2-week periods for an assumed **8 weeks/year** of operation at the peak rate.
- On this basis the total annual production of raw solids amounts to 252,840 DT, of which 233,600 DT (93.6 percent) occurs at the average rate of 650 DTPD and 16,240 DT (6.4 percent) occurs as the peak of 290 DTPD over 8 weeks per year. Also the average rate of 650 DTPD occurs over 44 weeks or about 84.6 percent of the time.

4.1.3 Space and Land Area Availability

Our assumptions for the land availability on the existing WWTP site are:

- Space availability in the existing process areas after completion of the PC-744 projects, and with or without the Minergy project, will be the first determinant of what kinds of additional processing capacity can be supported on site. For study purposes it is assumed that the incineration systems installed in Complexes I and II, and possibly the buildings housing these systems, will eventually be removed if the Minergy process is commissioned, making this space/area available for a new processing facility subsequent to completion of the term of the Minergy contract should DWSD so desire.
- However, should the Minergy facility not be commissioned then the space/area of Complexes I and II will become available only after there is enough back-up lime stabilization and outloading capacity to allow the shutdown of one complex, and then the other, in a phased demolition/construction program.
- Onsite land availability is a second determinant and will depend upon the outcome of the Wastewater Master Plan. It is assumed that there is enough land available (say 3 acres) to accommodate an expansion of the LMF for whatever purposes, but that any process that is land intensive (e.g., requiring more than 3 acres) will not be feasible without offsite expansion.
- The issue of where to find the land for an offsite expansion to accommodate a new solids handling or stabilization process is outside the scope of this study.
- Estimates of land area needed to support an offsite alternative are provided, but no indication can be given of how the land need may be met, whether by private contractor or by DWSD land acquisition.

4.2 Management Practices under Consideration

The management practices under consideration in the development of alternatives were as follows:

- No action
- Land application
- Land reclamation
- D&M of Class A biosolids products
- Combustion, either with or without recovery of energy, with ash disposal to landfill
- Conversion to or use in commercial products, e.g., glass aggregate

- Conversion to or use as a fuel product, such as a pyrolysis unit or blending of cake with coal as an alternate fuel for electrical power generation

The issues that are considered in the selection of preferred management practices for the long term were as follows:

- The data base for sludge characterization that was available is not current and complete enough for all D&M alternatives. However, for purposes of this TM it is assumed that the sludge quality is acceptable.
- It is unlikely that the Federal District Court or the MDEQ will support the landfill disposal of unstabilized sludge as a long-term alternative; therefore no further consideration is given to the landfilling of other than a Class B biosolids.
- It is also unlikely that local jurisdictions will support the land application of Class B biosolids for more than 5 to 10 years, so no consideration is given to this approach.
- It is assumed that land reclamation would be accomplished using Class B biosolids.
- The ultimate cost of the Minergy project is uncertain, and this study team does not have access to the cost experience for Minergy; therefore this report draws no conclusions for the Minergy project, technically, economically or otherwise.
- There is no precedent for the offsite conversion of sludge cake to a fuel as an offsite operation supporting a power station at the scale of up to either 650 or 940 DTPD; therefore, no further work is directed at a technology for the preparation and combustion of a sludge–amended coal at this time.
- DWSD has not investigated the feasibility of D&M of Class A biosolids products that would be manufactured from its solids production. It is assumed for study purposes that there would be a market, but that any revenues from the sales of biosolids products would be offset by the marketing costs.

4.3 Grit, Screenings and Skimmings

The management of grit, screenings and skimmings will have to be addressed in the next update of the Solids Master Plan, when process selections are made. For purposes of this TM, the management of these residuals can be addressed only in general terms at present. Grit is removed from the influent wastewater flow as a preliminary treatment step, and may also be generated as part of a separate raw primary sludge degritting operation. Screenings are also removed from the influent wastewater flow as a preliminary treatment step, and may also be generated in a separate sludge straining operation if the raw primary or blended primary and waste activated sludge is to be processed for beneficial reuse or dewatered by high speed centrifuge. The provision of grit and screen systems for the entire wastewater flow is standard practice in wastewater treatment plants, and these residuals are usually disposed to landfill. On the other hand the provision of enhanced removal of grit and screenings from sludge is dependent in the selected solids stabilization and dewatering methods, as discussed below.

Skimmings are the floatable fat, oil and grease components that are generated and collected at the primary sedimentation tanks, and may also include the biological foam that is generated and collected in the aeration and secondary sedimentation tanks and connecting

channels. The skimmings are typically collected, concentrated and processed in the stabilization operation when feasible, or else disposed to landfill, as discussed below.

Enhanced grit removal from primary sludge is used to minimize the accumulation of grit deposits in anaerobic digesters, and to minimize abrasive wear on high speed dewatering centrifuges. Enhanced screenings removal from the sludge stream using strainer devices is a recent innovation to minimize the accumulation of debris in digesters, to protect centrifuges from clogging with debris, and to improve the appearance of digested or lime stabilized biosolids products.

The typical management approach for grit from a sludge degritting operation is to combine it with the grit removed from the influent wastewater flow for landfill disposal. Similarly, the screenings from a sludge straining operation would be combined with the screenings from the influent wastewater flow and disposed to landfill. However, enhanced grit or screenings removal would not be not required with the incineration alternatives because these materials can be pumped to and combusted in either a MHF or FBI system.

Skimmings are concentrated and can be fed to digesters and FBI systems but are difficult to handle in MHF systems. The difficulty arises from the variable energy content of skimmings, which can cause excessive heat release within the confinement of a hearth. Concentrated skimmings at the DWSD plant are blended with grit and screenings and landfilled.

In summary, enhanced Grit and screening removal is used with anaerobic digestion and/or high solids centrifuge dewatering, but it is not necessarily with incineration.

4.4 Technologies for Long-Term Alternatives

The technologies and alternatives proposed for further evaluation are those that have a proven track record in treatment works at the scale of size and complexity of the DWWTP. It is also recommended that the DWSD establish an iterative process of phased-decision making to support the evaluation of emerging and future technologies each time that the Solids Master Plan is updated. More detailed general technology review is summarized in Appendix A.

The technologies selected for evaluation in this planning cycle are described below.

4.4.1 No Action Alternative

This alternative was rejected as unacceptable because as noted in Section 3 the present reliable capacities of incineration at Complex I and II (454 DTPD) and lime stabilization at the LMF (at 221 DTPD) sum to 675 DTPD, which is less than the 940 DTPD peak capacity needed once the CSO tunnel program is in operation.

4.4.2 Alkaline Stabilization

The present capacity of the LMF is 221 DTPD, and it is being upgraded at the present time with a peak loading capacity of 940 DTPD for up to 2 weeks with >28% DS (DWP-1074). It is not designed to specifically to produce Class A or B solids, however, based on the design dose, it is capable of meeting Class B. This study will consider the use of alkaline stabilization in multiple roles. These are:

- As a base load facility processing 650 DTPD to either Class A or Class B standards

- As a peak period facility processing 290 DTPD to Class B standards, and
- As a back-up system with capacity to process the difference between an assumed future reliable incineration capacity (650 DTPD and the peak production rate of 940 DTPD, or 290 DTPD, to a Class B standard.

4.4.3 Anaerobic Digestion

It is assumed that anaerobic digestion would be provided to accommodate the entire solids production rate of 940 DTPD from the peak period. The principal merits of an anaerobic digestion installation would be:

- The mass and volume reductions that are obtained from the destruction of 50 percent or more of the volatile solids in the raw sludge blend.
- The production of enough digester gas to meet as much as one-third of the electricity requirements and all of the heating requirements of the treatment plant
- The amenability of digested biosolids for such outlets as landfilling or land reclamation with the dewatered cake
- The elimination of the need for backup facilities
- The elimination of the need for the land area and space now assigned for dewatering, incineration, lime stabilization, and outloading facilities at the WWTP.

Offsetting these benefits would be the need to locate such a facility offsite because of the land area requirements, necessitating multiple significant changes in the WWTP. For study purpose it was assumed that an onsite liquid sludge pretreatment and pumping station would be needed to provide:

- Screening of the liquid primary sludge
- Separate degritting of the primary and WASs
- Separate pumping of each sludge to the offsite location

In this scenario the two sludges would be separately thickened, then blended for digestion, dewatering, further processing if applicable, and outloading at the offsite location. As the anaerobic digestion complex would be offsite, a pumping distance of about 1 mile is assumed, but this will depend upon the actual site location. Alternately, and with a specific offsite location designated, engineering study may show that it is more cost-effective to pump a blended thickened sludge to the offsite location.

The Part 503 regulations have stimulated the development and application of new processes for the production of Class A biosolids products by or including processing by anaerobic digestion. Anaerobic digestion using the CHR (conventional high rate) process has been practiced for many years at large municipal WWTPs. In summary:

- The production of a liquid digested Class A biosolids by PRFP requires the combination of both thermophilic and batch processing, and as such is still (in our judgment) yet to be demonstrated as reliable at the scale of the DWSD WWTP. (Reference projects exist in the Midwest, e.g., at WLSSD in Duluth, MN).

- Alternate approaches entail the maintenance of thermophilic temperatures and an analytical regimen that verifies the reliability of the process, such as is done at the Hyperion WWTP of the City of Los Angeles.
- Thermophilic processing has not eliminated problems of fecal regrowth after dewatering, and the production of odor in the cake if high shear dewatering devices are used; much is yet to be learned.
- The end product of liquid Class A digestion has the same appearance as that of liquid Class B digestion, and poses a number of aesthetic and marketing problems to be understood and avoided.
- The recommendation of this study is to adapt a strategy for a new anaerobic digestion system that provides a proven process (CHR) and that can be adapted to incorporate process advances as they develop. The Class B biosolids from a CHR facility could be landfilled as a core outlet while such uses as land reclamation are developed.

It is also recommended that DWSD embark on a marketing study to ascertain what demand there would be for Class A biosolids products, whether as digested liquid sludge, compost, pellets from a thermal drying process, or cake from an alkaline stabilization process. The outcome of the study would be used to establish the direction to be taken with respect to upgrade of the anaerobic digestion process and the merits of adding such facilities as composting and/or thermal drying as Class A products, using some or all of the anaerobically digested sludge as feedstock. The same marketing study should also evaluate beneficial reuse possibilities for Class B biosolids.

In order to estimate the volume of anaerobic digestion capacity needed, it is assumed that the thickened sludge blend will contain 5percent DS, for which a digester volume of about 75.4 MG would be required to provide a minimum of 15 days of HRT (hydraulic retention time) at the peak loading rate of 940 DTPD. With egg-shaped digesters sized at 4.5 mg (the largest capacity presently in use in the world), a total of 18 digesters would be required to provide a 15-day HRT, and these would occupy a space of about 18 acres including an operations building, laboratory, gas handling and co-generation facilities. The would also be the largest egg-shaped digester installation in the world. The digested sludge would either be outloaded as a Class B biosolids cake or processed further by thermal drying or composting to a Class A product for outloading to D&M. The recycle streams from thickening, dewatering and (as applicable) thermal drying or composting would be returned to the liquid treatment system by pump station and force main.

If the anaerobically digested solids were to be processed further by thermal drying or composting, it may be possible for DWSD to obtain approval from MDEQ to provide the anaerobic digestion capacity at a lesser HRT under peak flow conditions, by providing an advanced anaerobic digestion process such as two-phase digestion in lieu of CHR digestion. For example the Two-Phase Anaerobic Digestion Process can accomplish adequate volatile solids destruction in as little as 12 days total retention time, as is being demonstrated at the City of Baltimore Back River WWTP. Nonetheless, with the additional facilities needed at this location, a site requiring from 25 to 40 acres would be needed, allowing for minimal storage of the final material. However it is essential that the digestion facility have enough redundancy to avoid the need for a back-up lime stabilization facility.

4.4.4 Distribution and Marketing of Class A Biosolids

Class A biosolids can be distributed and marketed in such forms as solids that are lime stabilized to Class A standards, as pellets from a thermal drying facility, and as composted biosolids products. It is assumed that lime stabilization to Class A would be done as an onsite operation by upgrading/expanding the existing LMF. However, as noted above, the anaerobic digestion of the peak production followed by dewatering and either thermal drying or composting would be an offsite operation, and fully contained with its own back-up. Also, while all of the sludge would be digested anaerobically, the thermal drying or composting operations would be sized for the average 650 DTPD solids production rate, and the peak period production would be landfilled unless the volume could be worked into the process using liquid or cake storage capacity.

4.4.5 Landfilling of Stabilized Biosolids

The landfilling of stabilized biosolids will require either lime stabilization to Class B standards (an onsite operation) or anaerobic digestion followed by dewatering (an offsite operation).

4.4.6 Land Reclamation with Stabilized Biosolids

Land reclamation with stabilized biosolids will also require either lime stabilization to Class B standards (an onsite operation) or anaerobic digestion followed by dewatering (an offsite operation). We assume that a limed material would be provided by DWSD only if the lime stabilization alternative were pursued. Otherwise any lime requirement would have to be met by the contractor.

Two destinations for land reclamation have been considered in the past, a mining region on the Upper Peninsula of Michigan, and a reclamation site on Fighting Island across the Detroit River in Canada, about 5 miles downstream from the Rouge River. A mine reclamation operation in the Upper Peninsula would involve the following steps: outloading of cake onto a tractor-trailer for haul to a marine terminal; transfer of the cake to a vessel; transport to a terminal on the Upper Peninsula; unloading of the transport vessel to local highway or rail transport to the site; transfer to a local storage site for accumulation and/or outloading for direct application for land reclamation purposes. Because of the assumed lack of more than a few days of storage capacity at the treatment plant, the shipping operation would have to be year-round to be a mainstay alternative for DWSD.

A land reclamation operation at a site on Fighting Island would require similar operations as above, but have a much shorter transport distance than an Upper Peninsula destination. An impediment to a Fighting Island operation is the unexpected opposition from the Federal government to the shipping of residuals across the international border. To our recollection, there has never been a project approved by the U.S. Department of State that has involved the international shipment of Class B biosolids.

4.4.7 Multiple Hearth Furnace Incineration

It is assumed in this onsite alternative that the existing facilities would remain in service to provide the immediate capacity needed from 2004 if the Minergy project were to be halted. The MHF alternatives would have to provide reliable capacity for 650 DTPD, the base load as above. At present the capacity is estimated to be 454 DTPD. To increase the capacity of the MHF units and for them to remain in service it is assumed that the MHF units would have to be upgraded immediately and again at 16-year intervals (for example in 2016 and

2032) in order to meet anticipated air pollutant emission requirements through the year 2050. It would be appropriate to compare the cost of the upgrade at each interval with alternative technologies, including those that today are viewed as emerging or future, in a phased decision making process. The LMF would continue to be used to provide for the peak load periods as well as for backup purposes.

4.4.8 Fluidized Bed Incineration with Energy Recovery

This alternative would be applicable if found to be more cost-effective than continuing with the existing MHF units at the next or a future upgrade, or if these units were more cost-effective relative to other alternatives at the completion of the Minergy contract in 2016. It is also assumed that upgrades to meet anticipated air pollutant emission requirements might be required by the 16th year of service to extend the useful life of the units to 2050. The FBI alternatives would also provide a reliable capacity for 650 DTPD, that is, for the base load as above, until the contract term is reached in 2016. The LMF would continue to be used to provide for the peak load periods as well as for standby purposes.

4.4.9 Minergy Gasification/Vitrification

This alternative will be implemented by a private contractor operation at Zug Island. The Minergy operation would provide reliable capacity for the base rate of 650 DTPD until 2016. Any future use of the Minergy facility should be reviewed in a phased decision making process at this time. The DWSD would have to decide whether to relinquish its incinerator operating permits if Minergy were to be commissioned, because of the cost of a standby operation as discussed earlier. Again, the LMF would continue to be used to provide for the peak load periods as well as for some portion of the standby needs.

4.5 Emerging and Future Alternatives

A number of alternatives have been placed in this category because there is insufficient information available to support a decision for such a process today. It is suggested that DWSD use the above-mentioned phased decision making process, deferring a decision for any such process until such time as the process has been demonstrated as reliable at a scale and with a sludge feedstock (a blended primary and WAS) that is commensurate with the DWSD application. We propose that the following (and future yet-to-be-identified) technologies be evaluated at the same time as the next upgrade is considered to an incineration or other such system, assumedly at about 16-year intervals to 2050.

4.5.1 Air/Oxygen-Blown Gasification/ Vitrification

This term refers to a family of processes that provide for air or oxygen-blown direct heated gasification, and that are operated at temperatures that result in the production of a vitrified ash product (slag) and a low BTU gas that can be used for energy production purposes. The Minergy Process incorporates these principles. Some years ago Texaco developed a process that never advanced to the demonstration scale. There are several installations in Germany, one of which is under development by BWB, the water and sewer utility of Berlin.

4.5.2 Steam Gasification

Steam gasification is also known as pyrolytic gasification or steam reforming. There are several variations of this process in the early stages of development, including the USS (for Ultra-Superheated Steam) Process under development by F. Michael Lewis, Inc., now being tested at the 1-DTPD scale at a research facility in Ohio.

4.5.3 Supercritical Water Oxidation

Supercritical water oxidation processes are also known as wet oxidation or wet combustion, and cause the oxidation of organics at supercritical pressure and temperature in a liquid state, with the addition of compressed air or oxygen into the pressure vessel. There has been some interest in the process for the destruction of hazardous waste. It has yet to be applied at any scale for the destruction of sewage sludge.

4.5.4 Solids-to-Fuel Conversion

This process family is exemplified by the Enersludge (Trademarked) Process, in which dried sludge is heated to vaporization in the absence of oxygen. The vaporized sludge is mixed with the char residue, which as a result of catalytic reactions produces a fuel grade oil. A portion of the char is then consumed to heat to dryness the incoming sludge. This process is being pilot tested at a municipal WWTP in Australia.

4.6 Alternatives Selected for Evaluation

The alternatives selected for description and evaluation are presented in Table 4-1. A total 10 alternatives are listed, and each is categorized in terms of outlet for the biosolids, base, peak load, and back-up technologies used, and onsite and offsite space requirements. The alternatives include outlets to landfilling, to land reclamation, to D&M, incineration with and without energy recovery, and the Minergy facility. These alternatives are described in the next section.

Table 4-1. Alternatives Selected for Additional Evaluation

Alt	Outlet for Biosolids	Base and Peak Load Technologies (DTPD)	Back-Up Technology (Capacities in DTPD)	Onsite Space Needed (Acres)	Offsite Space Needed (Acres)
1A	Landfilling - Class B Biosolids	Anaerobic digestion (940)	N/A; landfill contract	N/A	25 to 40
1B	Landfilling - Class B Biosolids	Alkaline stabilization (650 base & 290 peak)	N/A; landfill contract	3 (add'l alkaline stabilization)	NA
2A	Land reclamation - Class B biosolids	Anaerobic digestion (940)	Landfill back-up contract	N/A	25 to 40
2B	Land reclamation - Class B biosolids	Alkaline stabilization (650 base & 290 peak)	Landfill back-up contract	3 (add'l alkaline stabilization)	NA
3A	D&M of Class A Biosolids	Alkaline stabilization (650 base & 290 peak)	Alkaline stabilization to Class B & landfill backup (940)	3 (add'l alkaline stabilization)	N/A
3B	D&M of Class A Biosolids	Anaerobic digestion (940) & thermal	Landfill for peak period excess (290)	N/A	25 to 40

Alt	Outlet for Biosolids	Base and Peak Load Technologies (DTPD)	Back-Up Technology (Capacities in DTPD)	Onsite Space Needed (Acres)	Offsite Space Needed (Acres)
		drying (650)	& back-up (940)		
3C	D&M of Class A Biosolids	Anaerobic digestion (940) & composting (650)	Landfill for peak period excess (290) & back-up (940)	N/A	25 to 40
4	MHF Incineration	Multiple Hearth Furnaces (650); alkaline stab'n (290)	Alkaline stabilization to Class B and landfill (290)	3 (add'l alkaline stabilization)	NA
5	FBI with Energy Recovery	Fluidized Bed incinerators (650); alkaline stab'n (290)	Alkaline stabilization to Class B and landfill (290)	3 (add'l alkaline stabilization)	NA
6	Minergy	Gasification/Vitrification (650)	Alkaline stabilization to Class B and landfill (290)	3 (add'l alkaline stabilization)	NA

5. Description of Alternatives

5.1 Introduction

This section contains a description of each alternative listed in Table 4-1 (Section 4) in terms of:

- Description of facilities
- Solids quantities and residuals to be managed.
- Phasing of the elements of the alternative
- Brief operational narrative for base and peak period operations

5.2 Alternative 1A – Landfilling of Class B Biosolids (Anaerobic Digestion)

5.2.1 Description

It is assumed that the facilities for this and the other anaerobic digestion alternatives (2A, 3B and 3C) would be located offsite and within 1 mile of the DWSD WWTP. The facility would be supported with an onsite sludge pretreatment and pump station, providing degritting of the primary sludge and the separate screening and pumping of the two unthickened liquid sludges. At the receiving location the two sludges would be thickened separately, then blended and fed to the anaerobic digestion facility. The anaerobic digestion facility, consisting of egg-shaped digesters, would incorporate the CHR process and be sized to digest the peak loading rate of 940 DTPD.

The facility would consist of the following components, all of which except the first are located offsite):

1. Degritting, screening and pump station for liquid sludge transfer (onsite)

2. Dual liquid sludge pipeline, each 5,000 LF
3. Primary sludge thickeners (assume gravity thickeners)
4. Gravity belt thickeners (WAS)
5. Recycle flows balancing tank
6. Recycle pump station and pipeline (5,000 LF)
7. Thickened sludge blending and preheating station
8. Anaerobic digesters (18 each 4.5 MG egg-shaped digesters)
9. Digested sludge storage tanks
10. Dewatering station (high solids centrifuges)
11. Digested cake short-term storage bins and outloading station
12. Digester gas handling and co-generation station
13. Operations building including laboratory facilities
14. Yard piping, road network, fencing, security and lighting, etc.
15. Weighing station and lanes for tractor-trailers
16. Staff parking
17. Land area - the assumed area required is 25 acres offsite

5.2.2 Quantities

The quantities are assumed as follows:

- The anaerobic digesters would receive 650 DTPD for 44 weeks of the year (84.6 percent of the time) and 940 DTPD 8 weeks of the year, for a total of 252,840 DT/year.
- The raw sludge blend is 75 percent volatile solids and 25 percent fixed solids, and the VSD (volatile solids destruction) efficiency is 50 percent in the egg-shaped digesters.
- The annual digested biosolids production rate is 158,025 DT/year.
- The high solids centrifuges operate at 95 percent solids capture efficiency and produce a cake of 30 percent DS content.
- The cake to be sent to landfill amounts to 150,124 DT/year or 500,124 WT (wet tons)/year.
- The maximal volume generated during a day of production at the peak rate of 940 DTPD is estimated at about 2,070 CY (cubic yards), assuming a bulk density of 0.9 WT per CY).

5.2.3 Phasing

The anaerobic digestion facility would be constructed and commissioned offsite, during which time the existing onsite facilities would remain operational. Upon commissioning of the new facilities, DWSD would be able to shut down the entire onsite solids processing operation. This would include the primary and WAS thickening, dewatering, incineration, lime stabilization and outloading systems.

5.2.4 Operations

The anaerobic digestion facility would be designed and operated to achieve a minimum HRT of 15 days under the peak loading rate of 940 DTPD, equivalent to about 22 days HRT under the average loading rate of 650 DTPD. The digested biosolids are to be landfilled as

Class B material, and it is assumed that landfill contracts would be arranged to accept the peak digested cake production rate by coordination of operations with the landfill.

5.3 Alternative 1B – Landfilling of Class B Biosolids (Alkaline Stabilization)

5.3.1 Description

This facility would be located onsite, and would consist of an expanded version of the LMF and Central Outloading Facility, which at present is being expanded as the interim back-up process for Minergy during the 16-year Minergy contract period. To accommodate the peak loading rate as a mainstay process, it would be necessary to expand this facility to replace the MHF incineration system capacity. It was assumed that the added facilities can be provided onsite occupying no more than 3 acres, and that the 3 acres are available for this purpose. It is also assumed that an open pad storage facility sized to hold 3 days of peak period cake production can be provided in this area.

5.3.2 Quantities

It is assumed that:

- The alkaline stabilization facility will receive 650 DTPD for 44 weeks of the year (84.6 percent of the time) and 940 DTPD 8 weeks of the year, for a total of 252,840 DT/year.
- The annual production of 252,840 DT/year will be processed at a quicklime (CaO) dose of 0.15 ton CaO per DT to yield a Class B biosolids. The required CaO delivery rate is 141 tons CaO/day under peak loading rate conditions.
- The annual production of stabilized material would amount to 290,766 DT/year at a 50 percent DS content.
- This is equivalent to 581,532 WT/year, which would be sent to landfill as Class B alkaline stabilized biosolids.
- The maximal volume generated during a day of production at the peak rate of 940 DTPD would be about 2,400 CY, assuming a bulk density of 0.9 WT per CY).

5.3.3 Phasing

The expanded alkaline stabilization facility would be constructed and commissioned before the existing MHF incineration system were shut down. It is assumed that the operation of the existing LMF and Central Outloading Facility would be continued while the new facility is constructed, and that upon completion the operation of the two facilities would be integrated.

5.3.4 Operations

The alkaline stabilization facility would be operated 'on demand', at loading rates varying from 650 to 940 DTPD. Operations at the latter rate are assumed to take place over a total of 8 weeks each year. It is assumed that an open pad storage site would be provided to hold up to 3 days of peak period production.

5.4 Alternative 2A – Land Reclamation with Class B Biosolids (Anaerobic Digestion)

5.4.1 Description

This alternative would consist of the offsite anaerobic digestion facility described in Alternative 1A. The anaerobically digested solids would be outloaded to tractor-trailers and transported directly to a reclamation site, or alternately to a marine terminal for transfer via waterborne vessel to a receiving terminal and ultimately to a reclamation site. It is assumed that there would be no more than 3 days of storage capacity provided at the anaerobic digestion facility, making the land requirement for this alternative in the order of 25 acres.

For study purposes it is assumed that two reclamation sites would be used equally to establish an economic cost evaluation scenario, namely, waterborne transport over a 500-mile distance to a terminal and storage facility for a mined land reclamation site on the Upper Peninsula, and waterborne transport over a 10-mile distance to a terminal and storage facility at the Fighting Island reclamation site in nearby Canada. However as noted earlier in reference to a Fighting Island reclamation project, it has been unprecedented in our experience for the U.S. Department of State to give approval for export of biosolids.

5.4.2 Quantities

The quantities for this alternative are the same as for Alternative 1A, namely about 500,000 WT/year of cake at 30percent DS would be produced for land reclamation purposes.

5.4.3 Phasing

As in Alternative 1A, the anaerobic digestion facility would be constructed and commissioned offsite, during which time the existing onsite facilities would remain operational. Upon commissioning of the new facilities, DWSD would be able to shut down the entire onsite solids processing operation. This would include the primary and WAS thickening, dewatering, incineration, lime stabilization and outloading systems.

5.4.4 Operations

As in Alternative 1A, the anaerobic digestion facility would be designed and operated to achieve a minimum HRT (15 days was assumed) under the peak loading rate of 940 DTPD, equivalent to about 22 days HRT under the average loading rate of 650 DTPD.

The digested biosolids would be dewatered and the cake (unlimed) would be transported from the site as Class B material. An onsite storage facility (an open pad with runoff control) would be provided to handle volumes of cake equivalent to up to 3 days of cake production, in order to accommodate an occasional interruption in the removal of material from the site.

The cake would be transported by tractor-trailer from the site to a marine terminal for loading onto waterborne transports. Under emergency conditions the cake would be hauled directly to landfill, but this would be used only for a short period of time at the most. It is anticipated that the cost of landfilling would be offset by penalties in the contracts with the waterborne transport companies.

5.5 Alternative 2B – Land Reclamation with Class B Biosolids (Alkaline Stabilization)

5.5.1 Description

As in Alternative 1B, this alternative would be located onsite and would consist of an expanded version of the LMF and Central Outloading Facility, which at present is being expanded as the interim back-up process for Minergy during the 16-year Minergy contract period. To accommodate the peak loading rate as a mainstay process, it would be necessary to expand this facility to replace the MHF incineration system capacity. It is assumed that the added facilities could be provided onsite occupying no more than 3 acres, and that the 3 acres are available for this purpose. It is also assumed that an open pad storage facility sized to hold 3 days of peak period cake production can be provided in this area.

5.5.2 Quantities

The quantities for Alternative 2B are the same as for Alternative 1B, namely about 582,000 WT/year at 50percent DS would be produced and transported to land reclamation.

5.5.3 Phasing

The expanded alkaline stabilization facility would be constructed and commissioned before the existing MHF incineration system is shut down. It is assumed that the operation of the existing LMF and Central Outloading Facility would be continued as the new facility is constructed, and that upon completion the operation of the two facilities would be integrated.

5.5.4 Operations

The alkaline stabilization facility would be operated 'on demand', at loading rates varying from 650 to 940 DTPD. Operations at the latter rate are assumed to take place over a total of 8 weeks each year. The alkaline stabilized material would be transported from the site as Class B material. An onsite storage facility (an open pad with runoff control) would be provided to handle volumes of cake equivalent to up to 3 days production, in order to accommodate an occasional interruption in the removal of material from the site.

The cake would be transported by tractor-trailer from the site to a marine terminal for loading onto waterborne transports. Under exigency conditions the cake would be hauled directly to landfill, but this would be used only for a short period of time at the most. It is anticipated that the cost of landfilling would be offset by penalties in the contracts with the waterborne transport companies.

5.6 Alternative 3A – Distribution and Marketing of Class A Biosolids (Alkaline Stabilization)

5.6.1 Description

This onsite alternative is similar to Alternative 1B except that the dosage rate of quicklime is increased to 0.25 ton/DT and the material is stored and monitored closely to ensure that the required pH and temperature regimens are maintained as described in Section 4. It is also assumed that the increased processing will result in a cake with a DS content of 60percent.

Again, the facility would be located onsite and would consist of an expanded version of the LMF and Central Outloading Facility, which at present is being expanded as the interim

back-up process for Minergy during the 16-year Minergy contract period. To accommodate the peak loading rate as a mainstay process, it would be necessary to expand this facility to replace the MHF incineration system capacity. It is again assumed that the added facilities can be provided onsite occupying no more than 3 acres, and that the 3 acres are available for this purpose. It is also assumed that an open pad storage facility sized to hold 3 days of peak period cake production can be provided in this area.

The back-up to the production of Class A biosolids would be to operate the alkaline stabilization to produce Class B biosolids for landfill disposal. A back-up landfill contract or contracts would be required.

5.6.2 Quantities

It is assumed that:

- The alkaline stabilization facility would receive 650 DTPD for 44 weeks of the year (84.6 percent of the time) and 940 DTPD 8 weeks of the year, for a total of 252,840 DT/year.
- The annual production of 252,840 DT/year would be processed at a quicklime (CaO) dose of 0.25 ton CaO per DT to yield a Class B biosolids. The required CaO delivery rate is 235 tons CaO/day under peak loading rate conditions.
- The annual production of stabilized material would amount to 316,050 DT/year at a 50 percent DS content.
- This is equivalent to 526,750 WT/year to be sent to D&M as Class A biosolids.
- The maximal volume generated during a day of production at the peak rate of 940 DTPD is estimated at about 2,180 CY, assuming a bulk density of 0.9 WT per CY).

5.6.3 Phasing

The expanded alkaline stabilization facility would be constructed and commissioned before the existing MHF incineration system were shut down. It is assumed that the operation of the existing LMF and Central Outloading Facility would be continued as the next facility is constructed, and that upon completion the operations of the two facilities would be integrated.

5.6.4 Operations

The alkaline stabilization facility would be operated 'on demand', at loading rates varying from 650 to 940 DTPD. Operations at the latter rate are assumed to take place over a total of 8 weeks each year. It is assumed that an open pad storage site would be provided to hold up to 3 days of peak period production.

5.7 Alternative 3B – Distribution and Marketing of Class A Biosolids (Anaerobic Digestion and Thermal Drying)

5.7.1 Description

This offsite facility would be integrated with the anaerobic digestion facility of Alternative 1A. The thermal drying operation would be sized to handle the dewatered digested sludge production from the base load of 650 DTPD. The peak period excess dewatered digested

sludge production (from the additional 290 DTPD received during the peak period) would be landfilled.

The facility would include the elements listed for Alternative 1A, as well as the following additional elements:

18. Dryer building
19. Storage silos
20. Silo building

5.7.2 Quantities

The quantities for this alternative would be the same as for Alternative 1A. However the quantities to thermal drying and to landfilling are uniquely as follows:

- The annual production of dewatered digested biosolids from the digestion of 650 DTPD of raw sludge is 147,875 DT/year, or 408 DTPD. This material at a DS content of 30 percent would be transferred to thermal drying.
- The output of Class A biosolids from thermal drying would be 147,875 DT/year or 165,417 WT/year at 90 percent DS.
- The annual quantity of cake to be landfilled from the digestion of 290 DTPD over a total of 8 weeks annually would be 54,133 WT at 30 percent DS.

5.7.3 Phasing

The anaerobic digestion and thermal drying facilities would be constructed and commissioned offsite, during which time the existing onsite facilities would remain operational. Upon commissioning of the new facilities, DWSD would shut down the entire onsite solids processing operation. This would include the primary and WAS thickening, dewatering, incineration, lime stabilization and outloading systems.

5.7.4 Operations

The anaerobic digestion facility would be designed and operated to achieve a minimum HRT of 15 days under the peak loading rate of 940 DTPD. This is equivalent to about 22 days HRT under the average loading rate of 650 DTPD. The thermal drying facility would be designed to process the digested dewatered biosolids production from the base load of 650 DTPD, which after digestion would amount to about 405 DTPD. The digested biosolids from the peak period excess loading of 290 DTPD would be landfilled as Class B material, and it is assumed that a landfill contract or contracts would be arranged to accept the intermittent loads as needed.

5.8 Alternative 3C – Distribution and Marketing of Class A Biosolids (Anaerobic Digestion and Composting)

5.8.1 Description

This offsite facility would be integrated with the anaerobic digestion facility of Alternative 1A. The composting operation would be sized to handle the dewatered digested sludge production from the base load of 650 DTPD, as was the case with thermal drying in Alternative 3B. The peak period excess dewatered digested sludge production (from the additional 290 DTPD received during the peak period) would again be landfilled.

The facility would include the elements listed for Alternative 1A, as well as the following additional elements:

18. Main process building
19. Product storage building
20. Odor control biofilter building

5.8.2 Quantities

The quantities for this alternative would be the same as for Alternative 1A. However the quantities to composting and to landfilling are uniquely as follows:

- The annual production of dewatered digested biosolids, from the digestion of 650 DPTD of raw sludge, is 147,875 DT/year. This is equivalent to a transfer to composting of 492,920 WT/year at 30 percent DS.
- The output of Class A biosolids from composting is estimated at about 1,000,000 CY annually (allowing 2 CY per WT of feed sludge).
- The annual quantity of cake to be landfilled from the digestion of 290 DTPD over a total of 8 weeks annually would be 54,133 WT at 30 percent DS.

5.8.3 Phasing

The anaerobic digestion and composting facilities would be constructed and commissioned offsite, during which time the existing onsite facilities would remain operational. Upon commissioning of the new facilities, DWSD would shut down the entire onsite solids processing operation. This would include the primary and WAS thickening, dewatering, incineration, lime stabilization and outloading systems.

5.8.4 Operations

The anaerobic digestion facility would be designed and operated to achieve a minimum HRT of 15 days under the peak loading rate of 940 DTPD, equivalent to about 22 days HRT under the average loading rate of 650 DTPD. The composting facility would be designed to process the digested dewatered biosolids production from the base load of 650 DTPD, which after digestion would amount to about 405 DTPD. The digested biosolids from the peak period excess loading of 290 DTPD would be landfilled as Class B material, and it is assumed that a landfill contract or contracts would be arranged to accept the intermittent loads as needed.

5.9 Alternative 4 – Multiple Hearth Incineration

5.9.1 Description

This onsite alternative would consist of an upgrade of the existing MHF incineration system for reliable operation at a loading rate of 650 DTPD, with Class B alkaline stabilization of the peak period excess production of 290 DTPD 8 weeks annually. The entire facility is already in place and a new incinerator complex would not be required.

The alkaline stabilization would be provided using the existing LMF and the Central Outloading Facility. Because the MHF incineration operation would have enough reliable capacity to incinerate 650 DTPD, no additional back-up capacity is proposed.

5.9.2 Quantities

The quantities are assumed as follows:

- The incineration system would receive 650 DTPD (236,600 DT/year) of dewatered cake at 30 percent DS on a year around basis.
- The ash production from the incineration system is estimated at 59,150 DT/year as dry ash (this is based on a fixed solids content of 25 percent in the raw sludge blend). It is assumed that the ash will be landfilled, although there may be reuse opportunities developed for the ash in the future.
- Alkaline stabilization would receive 16,240 DT/year of dewatered raw sludge (290 DTPD for 8 weeks each year). This material would be dosed at 0.15 ton CaO/DT for Class B alkaline stabilization.
- The alkaline stabilized sludge to landfill would amount to 18,676 DT/year at 50 percent DS, or 37,350 WT/year.
- The total residuals to landfill would amount to 59,150 tons of ash plus 37,350 WT of alkaline stabilized sludge, or 96,500 tons/year.

5.9.3 Phasing

The current improvement program at the LMF and Central Outloading Facility will have to be completed before the incineration system upgrades can be undertaken. Ideally this work would be undertaken and completed before the initiation of operations with the Upper Rouge Tunnel, which will contribute a significant portion of the peak period excess solids production.

5.9.4 Operations

The MHF incineration system would be operated at an assumed steady state loading rate, an optimal condition for an incineration system in any case. The alkaline stabilization system would be operated during peak solids production period, that is, intermittently. A landfill contract would have to be structured to accommodate the variable rates of transfer as well as transfers from any back-up operations. Back-up operation would be required only if there is an emergency shutdown of incineration units causing a reduction to less than 650 DTPD of incineration capacity.

5.10 Alternative 5 – Fluidized Bed Incineration with Energy Recovery

5.10.1 Description

This onsite alternative would consist of the installation of a new FBI (fluidized bed incineration) system with energy recovery facilities. The installation would likely consist of eight FBI units at 28-ft freeboard diameter, and be designed for reliable operation at a loading rate of 650 DTPD. As with Alternative 4, Class B alkaline stabilization would be provided for the peak period excess production of 290 DTPD over an estimated 8 weeks annually. These units would replace the existing MHF units, and a new incinerator complex would be required.

The construction steps would be as follows :

1. Phased demolition of the existing MHF incinerators

2. Phased demolition of buildings
3. Construction of new buildings
4. Construction of new incinerators, wet electrostatic precipitators, cyclones, waste heat boilers and venturi scrubbers.
5. Construction of other facilities.

The alkaline stabilization would be provided using the existing LMF and the Central Outloading Facility. Because the FBI incineration operation would have enough reliable capacity to incinerate 650 DTPD, no additional back-up capacity is proposed.

5.10.2 Quantities

The quantities are assumed as follows:

- The FBI system would receive 650 DTPD on a year around basis (236,600 DT/year) of dewatered cake at 30 percent DS.
- The ash production from the incineration system would be 59,150 DT/year as dry ash (this is based on a fixed solids content of 25 percent in the raw sludge blend).
- The FBI ash would be captured in a wet system and dewatered to an assumed 50 percent DS. Therefore the amount to landfill would be 118,300 WT/year. As noted in the case of Alternative 4, there may be reuse opportunities developed for the ash in the future.
- Alkaline stabilization would receive 16,240 DT/year of dewatered raw sludge (290 DTPD for 8 weeks each year). This material would be dosed at 0.15 ton CaO/DT for Class B alkaline stabilization.
- The alkaline stabilized sludge to landfill would amount to 18,676 DT/year, at 50 percent DS, or 37,350 WT/year.
- The total residuals to landfill would amount to 118,300 WT of ash plus 37,350 WT of alkaline stabilized sludge, or about 156,000 tons/year.

5.10.3 Phasing

The current improvement program at the LMF and Central Outloading Facility would have to be completed before the incineration system upgrades can be undertaken. Additionally it is to be anticipated that an FBI installation would have to be placed in an entirely new building, to accommodate its greater weigh and different dimensional aspects. Should land become available, it may therefore be desirable to place the FBI system in a new building at another location onsite in order to allow the existing MHF units to be kept in service until the new facility is commissioned. Again it would be ideal if this work could be undertaken and completed before the initiation of operations with the Upper Rouge Tunnel, which will contribute a significant portion of the peak period excess solids production.

5.10.4 Operations

The FBI incineration system would be operated at an assumed steady state loading rate, an optimal condition for an incineration system in any case. The alkaline stabilization system would be operated during peak solids production period, that is, intermittently. A landfill

contract would have to be structured to accommodate this variability in transfers as well as transfers from any back-up operations. Back-up operation would be required only if there is an emergency shutdown of incineration units causing a reduction to less than 650 DTPD of incineration capacity.

6. Selection of Recommended Alternatives

6.1 Selection Basis

The selection criteria for identifying two alternatives for further investigation were as follows:

- Compatibility with existing facilities and operations
- Compatibility with site and space availability
- Compatibility with the long-term WWMP for the treatment plant
- Proven at the scale and with the blended sludge feedstock that is generated at the DWSD WWTP
- Compatibility with DWSD goals for resource recovery and/or energy recovery
- Minimization of residuals to be disposed, including scum, biosolids and/or ash
- Flexibility to accommodate future conditions, including changes in the permit and technology
- Acceptable to the user communities that are served by DWSD
- Acceptable to the community that surrounds the DWSD WWTP
- Relative ranking of cost effectiveness

6.2 Discussion

6.2.1 Compatibility with Existing Facilities and Operations

Alternatives 1B, 2B, 4 and 5 involving incineration and alkaline stabilization are viewed as most compatible with the existing facilities and operations. These alternatives would be located onsite, and incorporate processes that have been in use at the WWTP. However, as plant personnel do not have familiarity with operation of alkaline stabilization for production of a Class A biosolids, Alternative 3A is not included in this selected list of alternatives (see Table 4-1).

6.2.2 Compatibility with Site and Space Availability

The most compatible alternative in terms of site and space availability is Alternative 4 (MHF incineration). However this assumes that the site and space that could be made available from transfer of the present solids processing operation to an offsite location is not needed for additional liquid processing in the long term. The answer to this issue is beyond the scope of this TM. Nonetheless if the space were needed for more liquid processing, then the anaerobic digestion alternatives could be ranked here. Alternately, a new FBI system with energy recovery could also be located offsite, but also require a liquid sludge transport system and offsite thickening and dewatering systems as well.

6.2.3 Compatibility with Long-Term Wastewater Master Plan

The existing treatment works is quite limited in terms of capacities for space-extensive primary and secondary clarifiers, and there are other processes that are bottlenecks as well. The extent to which these problems could be alleviated with the space that would become available from the transfer of solids processing operations to an offsite location is unknown to the authors at this time.

6.2.4 Proven Technology

The DWSD is one of the largest wastewater treatment works in the world. As such it is not a suitable proving ground for new technology. The authors of this TM were given a dilemma - to identify future and emerging technologies that might be appropriate in the future, and to balance these against a plant that may soon lose a long-term facility (Minergy) and be left with the consequences.

To address this dilemma, the authors have chosen technology variations that are demonstrated for plants of this scale, and have deferred to phased decision-making for future consideration of new technologies as these are advanced to proven status. All the technologies described in Section 5 are viewed as proven technologies. Therefore this criterion offers no differentiation of the technologies selected for evaluation.

6.2.5 Compatibility with DWSD Goals for Energy and/or Resource Recovery

It has been assumed that DWSD wishes to demonstrate to its customer base that it is responsive to goals for energy and/or resource recovery. Alternatives 2A, 2B, 3A, 3B, 3C and 5 are responsive to one of these goals or the other. Absent however from this listing are the landfill disposal alternatives and MHF incineration, the present technologies in use.

6.2.6 Minimization of Residuals to be Disposed

The two alternatives that minimize the residuals to be disposed as biosolids, scum, grit and/or ash are Alternatives 4 (MHF incineration) and 5 (FBI with energy recovery). These hold the advantage because ash and grit are the only residuals remaining.

6.2.7 Flexibility to Accommodate Future Conditions

Two alternatives are considered for this criterion. The first is the FBI bed technology (Alternative 5) which has become the state-of-the art in incineration, and the second is anaerobic digestion technology (incorporated in Alternatives 1A, 2A 3B and 3C), because it is a core technology supporting many downstream processing options.

6.2.8 Relative Cost

The cost estimates are summarized in Table 6-1. The cost estimates were developed for all the alternatives in Table 6-1 except Alternative 6 (Minergy) for which no cost basis was available. The cost estimates are designated as CH2M Class 5, that is,

> "prepared based on limited information, where little more than proposed plant type, its location, and the capacity are known. Strategic planning purposes include but are not limited to, market studies, assessment of viability, evaluation of alternate schemes, project screening, location and evaluation of resource needs and budgeting, and long-range capital planning. Examples of estimating methods used would include cost/capacity curves and factors, scale-up factors, and parametric and

modeling techniques. Typically, little time is expended in the development of this estimate. The expected accuracy ranges for this class estimate are –20 to –50 percent on the low side and +30 to +100 percent on the high side."

Table 6-1. Summary of Preliminary Cost Estimate Comparison

Alt.	Description	Capital Cost	Annual Cost (/year)	Unit Cost (/DT)	Note
1A	Anaerobic Digestion (940)	$ 726,000,000	$ 133,900,000	$ 530	Off Site
1B	Alk. Stab'n (B) (940)	$ 54,100,000	$ 63,400,000	$ 251	On Site
2A	Land Reclamation (Anaerobic Digestion) (940)	$ 726,000,000	$ 125,400,000	$ 496	Off Site
2B	Land Reclamation (Alk. Stab'n) (940)	$ 54,100,000	$ 53,500,000	$ 212	Off Site
3A	D&M of Alk. Stab. (A) (940)	$ 84,100,000	$ 47,500,000	$ 188	On Site
3B	D&M of Anaerobic Digestion (940) & Thermo Dried (650)	$1,086,000,000	$ 161,900,000	$ 640	Off Site
3C	D&M of Anaerobic Digestion (940) & Composted (650)	$ 899,000,000	$ 126,800,000	$ 499	Off Site
4	MHF Incin (650) and Alk. Stab. (290)	$ 105,000,000	$ 33,500,000	$ 132	On Site
5	FBI (650) & Alk. Stab. (290)	$ 200,000,000	$ 38,100,000	$ 151	On Site

The results of the cost estimates presented in Table 6-1 show the following trends:

- The offsite alternatives (those involving anaerobic digestion) are simply much greater in cost than the incineration and alkaline stabilization alternatives. This is because the offsite development includes liquid sludge pumping, thickening, blending, anaerobic digestion, dewatering and outloading facilities as a minimum. Clearly there would have to be an overwhelming advantage to DWSD to pursue an offsite development that would involve the replacement of the existing thickening and dewatering facilities, and to justify a shift from incineration to anaerobic digestion.
- Of the onsite alternatives, the differences between /among the incineration and alkaline stabilization alternatives are not significant given the level of accuracy in the estimates. On a cost basis, further investigation should therefore be given to the two incineration alternatives, with emphasis on developing a better understanding of the life of the existing units. Our concern is that the cost of the MHF upgrades could conceivably attain a level where the USEPA regional reviewers decide to request a New Source Review as part of the process, which can complicate the effort significantly.
- To the best of our knowledge the DWSD has not performed the intensive analytical work or prepared marketing studies to justify the development of a D&M program. Before a D&M program were to proceed it would be essential that DWSD have these tasks completed and evidence supportive of a D&M program in hand.

- The costs of the land reclamation program were developed assuming that half the cake solids production would be directed to a reclamation site on the Upper Peninsula and the other half to a site on Fighting Island. Both alternatives are dependent on the expeditious removal of the stored material from the plant, meaning that local storage sites would have to be provided for each location. Moreover in the case of Fighting Island, an international border would have to be crossed, and approvals for such plans have not been forthcoming from the U. S. Department of State in cases elsewhere (Washington, DC and City of Los Angeles).

6.2.9 Presentation of Relative Rankings

Table 6-2 summarizes the selection of the two recommended processes for current DWWTP solids handling program. In summary of our evaluations, and in the absence of clear evidence that DWSD desires to expand the existing treatment plant site at this time, the two incineration alternatives (Alternatives 4 and 5) be advanced for further evaluation at this time. Each would serve as an alternative to the Minergy facility. Each would maximize the economy of the solids management program at the WWTP, and satisfy on a relative scale more of the criteria above. There are still many issues to be addressed with each alternative, and it is these issues that should be addressed if the DWSD were to accept this recommendation.

It should be noted that this selection only reflects the current DWWTP situation and technology status. This review and selection process (with additional feasible alternatives included) should be re-visited every five years or when major factors change.

Table 6-2. Comparison of Solids Disposal Alternatives – Relative Scoring

	1A: Anaerobic Digestion (940)	1B: Alk. Stab'n (B) (940)	2A: Land Reclamation (Anaerobic Digestion) (940)	2B: Land Reclamation (Alk. Stab'n) (940)	3A: D&M of Alk. Stab. (A) (940)	3B: D&M of Anaerobic Digestion (940) & Thermo Dried (650)	3C: D&M of Anaerobic Digestion (940) & Composted (650)	4: MHF Incin (650) and Alk. Stab. (290)	5: FBI (650) & Alk. Stab. (290)
Compatible with existing facilities and operations	L	M	L	M	M	L	L	H	H
Compatible with site and space availability	L	M	L	M	L	L	L	H	H
Compatible with the long-term WWMP	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Proven at the scale for DWWTP	H	H	M	M	H	H	M	H	H
Compatibility with DWSD goals for resource recovery and/or energy recovery	L	L	H	H	H	H	M	L	H
Ability to handle scum, biosolids, and/or ash	L	M	L	M	L	L	M	H	H
Flexibility to accommodate future changes in the permit and technology	H	L	H	L	L	H	H	M	H
Acceptable to the community that surrounds the DWSD WWTP	M	M	M	M	M	M	M	M	M
Permitting	M	M	M	M	M	M	M	H	H
Reliability	H	H	M	M	H	M	M	H	H
Flexibility and Complexity	H	H	L	L	M	H	M	H	H
Marketability	M	M	L	L	H	H	H	H	H
Size and Land (onsite)	H	M	H	M	M	H	H	M	M
Size and Land (off site)	L	H	L	H	H	L	L	H	H
Plant Impacts	L	M	L	M	M	L	L	H	M
Nuisance Issue	L	L	L	L	L	H	L	H	H
Relative Cost	L	M	L	M	M	L	L	H	H
Overall Score	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**H**	**H**

"H" = high rating, "M" = medium, "L" = low, "TBD" = To be determined by future assessment.

7. Implementation Issues

7.1 Basic Considerations

The implementation plan for a long-term solids management program appears to be contingent on the outcome of three key questions:

- Will Minergy be able to fulfill its contractual obligations?
- Will it be possible for DWSD to provide an offsite location for anaerobic digestion and other facilities should this course of action be favorable?
- Should DWSD or the private sector manage post-Minergy solids processing and disposal operations at the WWTP?

Each issue is addressed separately, and the outcome to each could change the implementation plan substantively.

7.2 Outcome of Minergy Contract?

Should the Minergy facility be commissioned, now understood to be scheduled for or after July 2004, it will be taken through a trial operating period at a loading rate of 300 DTPD, and if this phase is successful the loading rate to the facility will be ramped up to full capacity within two years (by 2006). DWSD will have to maintain its MHF units in operational standby status until the facility is declared in compliance with its contract. The standby status will require capital investment for upgrades, and an annual O&M expenditure. The maintenance of standby status is necessary for DWSD to preserve its permit to operate the incinerators, and may be needed for the duration of the Minergy contract if DWSD wishes to preserve incineration as a future option. For a Minergy operation in compliance with its contract, the DWSD will have the time to evaluate its alternatives for the period after 2016, the term for the Minergy contract. The post-2016 alternatives could include:

- Continuation of the contract with Minergy;
- Selection and implementation of a contract for a private sector facility; or,
- The implementation of a DWSD-owned facility.

The technology choices for a post-Minergy facility under the second and third options above could be: an upgrade of the existing MHF furnace complex, which would also require DWSD to invest in and operate the MHF units over the life of the Minergy contract to preserve the option for a future incineration project; or a new technology that could emerge from the phased decision making process.

Should Minergy cease to be viable for some reason, it is anticipated that DWSD will use its contingency plan that is based upon the use of alkaline stabilization with landfill disposal. The key would be to obtain enough operating life at minimal investment to allow DWSD to develop and implement its decision on a long-term program. It is further anticipated that this decision would be to either further upgrade the MHF units for the long term, or to pursue another long-term alternative such as an FBI system with energy recovery, or a private sector processing and disposal contract or series of contracts.

7.3 An Offsite Location for Anaerobic Digestion and Additional Processing?

The area and space limitations of the treatment plant site preclude the consideration of options that include anaerobic digestion, unless additional land is acquired or made available. A process scheme incorporating anaerobic digestion with or without further processing by thermal drying or composting would require an additional 25 to 40 acres of land. It is unknown whether this land can be obtained at the Detroit Marine Terminal or at Zug Island, but both sites are proximate to the main treatment plant site. Presumably the property being used by Minergy at its Zug Island site would become available if Minergy ceased to be a viable option.

The anaerobic digestion option would allow DWSD to surplus its thickening, dewatering, incineration and lime stabilization facilities at the main plant site, freeing up space and land for liquid treatment operations if needed. This option would also reduce the cake solids to be moved to beneficial reuse or disposal by as much as 40 percent, and provide a digester gas stream that would support a co-generation facility or a thermal drying facility. A decision for this option would represent a sea state change for the DWSD from combustion and volume minimization toward beneficial reuse and energy recovery. It is anticipated in the Capital Improvement Plan of the wastewater master plan, that the existing WWTP may need to be replaced completely by a new one between 2030 and 2050. Whenever this happens, the offsite anaerobic digestion process may warrant evaluation as one of the potential solids handing alternatives.

7.4 A DWSD or A Private Sector Solids Processing Facility?

The development of offsite facilities can be executed by either a private sector firm or firms, or by the DWSD. The private sector firm or joint venture of firms would have more flexibility, and could raise capital and move faster than the DWSD, but would not have certain essential administrative powers such as eminent domain.

It is unusual for an agency like the DWSD to turn over the entirety of its solids production to a single contractor for final processing and disposal. The usual approach for an agency in DWSD's position would be to award multiple contracts for the processing and removal of processed solids, in order to create competition among the contractors for the material, and to have excess capacity in case one contractor fails to perform. DWSD has pursued this approach in the past.

With private sector involvement the DWSD will have to surrender the day to day control of its solids processing operations, and operate at arm's length within the conditions of its agreements. This may require changes in the operation of the liquid treatment train to accommodate, for example, unusual but price-advantageous delivery schedules that would be written into a service contract. Nonetheless, even with a private sector arrangement the DWSD cannot avoid its ultimate responsibility for the management of its solids.

7.5 Implementation Plan

The implementation plan is subject to a number of unknown such as presented above and cannot be elaborated in details at this time. However, there could be several possible courses of action, depending upon whether:

- Minergy becomes operational
- Minergy does not proceed, and land application looks viable

- Minergy does not proceed, and land application does not appear viable

In general, the alternative development framework (Figure 4-1) can be used as an initial guidelines for developing such an implementation plan.

DWSD needs to decide soon whether or not to spend money to upgrade the existing incinerators in Complex I, and this decision depends completely on Minergy. If Minergy proceeds, the Complex II incinerators become back-up for Minergy and Complex I incinerators can be shut down and not upgraded. However, if Minergy does not proceed, then work needs to be done in Incinerator Complex I as well as some at Complex II. It is our recommendation in this case that DWSD also re-visit an FBI alternative. The discussions on the detailed work required are beyond scope of this TM.

8. Conclusions and Recommendations

The conclusions of this study are as follows:

1. The most appropriate long-term alternatives for further evaluation are upgrade of the MHF facility (Alternative 4) and installation of a new FBI system incorporating energy recovery (Alternative 5).
2. The DWSD can benefit from new technology development using a phased decision making process to evaluate these technologies at each update of its Solids Master Plan.
3. Anaerobic digestion would warrant further evaluation as a core processing technology if DWSD elects to replace the existing WWTP with a new facility.

The recommendations are as follows:

1. DWSD should conduct a detailed evaluation of Alternative 4 and 5 (the MHF, and FBI with energy recovery). The evaluation should identify the detailed upgrade needs, life-cycle cost analysis, and O&M issues for each, and take into account any future availability of land and space on site.
2. DWSD should conduct a study on the market conditions for Class A and Class B biosolids, in support of its next update of the Solids Master Plan.
3. DWSD should conduct a detailed characterization of present and projected sludge composition in support of its Solids Master Plan.

Appendix A
Review of Solids Reuse/Disposal Technologies

Appendix A

Review of Solids Reuse/Disposal Technologies

Alkaline Stabilization

Process Background

Alkaline stabilization includes processes where an alkaline chemical agent is mixed with wastewater solids to produce a stabilized product. Stabilization reduces pathogens, eliminates offensive odors, controls potential for putrefaction of organic matter, and produces a stable product that can be stored and used beneficially. The alkaline agent typically is lime, also known as calcium oxide (CaO). Other alkaline agents such as potassium hydroxide, hydrated lime, Portland cement, and certain waste products, such as hydrated lime tailings, some fly ashes, and kiln dusts, may also be used. A number of advanced alkaline stabilization technologies have been developed that use other chemical additives or special equipment to improve the overall process and product. These processes claim enhanced pathogen control and a more publicly acceptable biosolids product. These traditional and advanced alkaline stabilization technologies include:

- Conventional lime stabilization for a Class A or Class B product
- Lime pasteurization with external heat for a Class A product (This is a proprietary process known as EnVessel Pasteurization [EVP] provided by RDP Technologies, Inc.)
- Alkaline stabilization using cement kiln dust or other reagents for a Class A product (This is a proprietary process from N-Viro called Advanced Alkaline Stabilization using Subsequent Drying [AASSD].)
- Acid trim for a Class A product (A proprietary version of this process is called Bioset.)
- The emerging Unity Process

These processes represent primarily post-alkaline stabilization where an alkaline agent is mixed with dewatered solids cake. Other residuals typically are not post-alkaline stabilized.

Few examples of alkaline stabilization are:

Facility Name	Capacity and Product
Raleigh, North Carolina (Class A or Class B Lime Stabilization)	25 DTPD solids handling facility. Mostly Class B (Class A achievable with higher lime dose); farmland application and roadway landscaping; $290 /DT disposal cost
Warren, Ohio (EnVessel Pasteurization)	10 DTPD solids handling facility, Class A solids, wide land application and fertilizer use, revenue generation
Middlesex County Utilities Authority, New Jersey (N-Viro AASSD)	288 DTPD design capacity. landfill cover and blend with topsoil for distribution
Kingwood, Houston, Texas (Bioset Process)	7 mgd WWTP, Class B, used for landscaping and others

Table A-1 summarizes the advantages and disadvantages of the Alkaline Stabilization process in general.

Table A-1. Summary of Alkaline Stabilization Technology

Criteria	Issues/Comments
Permitting/Regulatory Compliance	Odor control permit required. The process can produce Class A or a Class B material. Pathogens are destroyed and the solids are stabilized. Dilution in product of heavy metals and other contaminants, due to addition of chemicals, can be achieved.
Process Reliability and Redundancy	Process has satisfactory operational history.
Operational Flexibility and Complexity	Very basic and easy for operators to understand. Common equipment used in material handling. Process can easily be switched to produce Class A or a Class B material.
Economic Considerations—capital, O&M, and present worth life-cycle costs	High O&M, medium capital, and present worth life-cycle costs. Depends on alkaline material type and dosage, and storage/drying methods.
Product Marketability	Product can be used as a soil substitute in landfill cover, landfill regrading, land reclamation applications, and in agricultural community. Demand may be seasonal.
Facility Size and Land Requirements	Land intensive technology due to storage/drying, but requires less land than composting.
Plant Impacts—sidestream impacts, operations, etc.	Relatively manpower intensive to operate if subsequent drying required. May be condensate from drying process or stormwater runoff from buildings and leachate from storage, depending on process and technology.
Nuisance Issues—odor (on and offsite), dust, traffic, etc.	Humid and odorous atmosphere in curing area. Strong ammonia release after initial mixing, high ventilation rates required. Product should be enclosed in a building or a reactor vessel. Two or three stage odor control system may be required to remove ammonia and volatile organics. Potentially dusty, but low noise level. High traffic likely due to alkaline material and chemical delivery onsite and product distribution. Potentially high traffic offsite due to increased product volumes.

Composting

Process Background

Composting is the biological decomposition of organic matter under aerobic conditions, resulting in the productions of heat, evaporation of water and destruction of pathogens. Composting facilities are designed and operated to produce a Class A biosolids product. There are numerous composting methods, but all must control the key parameters of feedstock characteristics, moisture content, oxygen supply, and temperature. Many composting facilities include pre- and post-processing to improve operations and the quality of finished compost. Composting methods can be generally classified as windrow, aerated static pile (ASP), or in-vessel systems. Windrow facilities, the least mechanized of the systems, typically require less capital investment, and in-vessel systems, usually proprietary, generally involve higher capital costs. However, there are many variables, such as the type of equipment selected, and whether facility design includes odor control or land purchase, that determine the costs of composting. The basic process flow at any compost facility involves the mixing of dewatered cake with a bulking agent, active composting, curing, and screening or other post-processing.

Active composting typically lasts at least 15 to 21 days. During that time, rapid decomposition raises temperature in the composted pile to thermophilic levels of 50°C to 65°C. Federal regulations require that all biosolids composts comply with a particular time-temperature profile in order to sufficiently reduce pathogens. ASP and in-vessel composting facilities must attain 55°C for 3 consecutive days throughout the composting media, and windrow systems must meet 55°C at the core of the windrow for a minimum of 15 consecutive days, during which time the windrow is turned five times. Federal requirements to reduce vector attraction are 14 days of aerobic composting at a temperature greater than 40°C, with an average temperature of 45°C.

Some examples of composting are:

Facility Name	Capacity and Product
Lake County, Ohio (Aerated Windrow Facility)	14 DTPD solids handling facility Vector attraction is reduced by reducing volatile solids during biosolids digestion. Much of the material is used for landfill cover, but the County has started to distribute material to the public. Six samples a year are taken for heavy metal and pathogen reduction monitoring.
Davenport, Iowa (ASP Composting)	28 DTPD solids handling facility, The material is sold to local residents and landscapers; compost product is sampled monthly for heavy metals and pathogen reduction.
Lewiston-Auburn Water Pollution Authority (In-Vessel Composting)	16,500 CY dewatered cakes handling capacity, product is sold for $5/CY. $380 /DT disposal cost.
Columbus, Ohio (ASP)	28 DTPD facility, product is sold for $ 6/CY (bulk) to $9.50/CY

Table A-2 summarizes the advantages and disadvantages of the primary composting systems and the composting process in general.

Table A-2. Summary of Composting Technologies

Criteria	General Summary
Permitting/Regulatory Compliance	The permitting and regulatory requirements for composting are well-defined on both federal and State of levels and are consistently met at a well-designed, well-maintained, and well-run facility. Because of odor concerns, it is necessary to get air permits as well as biosolids/solids waste permits, but improved odor control design and air modeling tools make this achievable.
Process Reliability and Redundancy	Composting uses multiple trains, and windrow and static pile composting use standard, easily attainable equipment.
Operational Flexibility and Complexity	In general, composting, a biological process, is inherently flexible and can easily be adapted to changing sludge characteristics. The equipment to operate a compost facility is comparatively easy to maintain and operate.
Economic Considerations—capital, O&M, and present worth life-cycle costs	The costs of composting are variable and are a function of location and land requirements, odor control requirements, bulking agent costs, complexity of design, and revenue from sale of product.

Criteria	General Summary
Product Marketability	Facilities of all types market the finished compost. Although some facilities are more successful than others, this is most likely related to the type of marketing program present. There is insufficient information to support conclusions about the relative marketability of composts from particular types of facilities.
Facility Size and Land Requirements	Composting is land-intensive since the biosolids must be processed for 51 days or more onsite before a finished product is produced.
Plant Impacts—sidestream impacts, operations, etc.	There are positive impacts in that grit as well as skimmings can be co-composted with biosolids. There is a small amount of condensate produced in the compost process, and stormwater that falls on the roofs of structures needs to be treated in an approved manner.
Nuisance Issues—odor (onsite and offsite), dust, traffic, etc.	Odors are present during composting but can be treated with a biofilter or chemical scrubber. There is increased traffic to deliver bulking agent to the site and remove compost from the site.

Heat-Drying

Process Background

The purpose of heat drying is to reduce the volume of solids produced at a municipal WWTP and to produce a Class A, stable, and marketable product. Heat drying follows dewatering as the last step of solids treatment. Following heat drying processing, the dried material is usually hauled off by the facility owner or by a private contractor for distribution, and marketed as fertilizer supplement or soil conditioner. Solids commonly are heat dried by themselves. It is possible to include grit and skimmings in the blend, but this is not common because these residuals can adversely affect product quality.

Heat drying reduces the dewatered cake to a dry powder or pellets by adding heat into the system and evaporating the water contained in the dewatered cake. A typical heat drying system includes conveyance of dewatered cake to the dryer, heat drying system, and storage and loading facility for loading the heat dried biosolids into trucks or railroad cars for ultimate use.

Heat drying technology, by definition, meets necessary pathogen and vector attraction requirements and the dried material is usually classified as EQ biosolids under USEPA 40 CFR Part 503. Consequently, there may be some commercial value in the dried biosolids, possibly offering some product revenue.

Several heat drying technologies and heat drying systems are on the market. They vary significantly and typically are proprietary. Selection of technology typically is closely tied to the selection of specific vendor or manufacturer.

Several examples of heat drying facilities are shown in Table A-3.

Table A-3. Large Heat Drying Installations in North America

Location	Evaporative Capacity (lb water Evaporated per hr) / Type of Dryer	Solids Processing Capacity (DTPD)	Owner	Startup
Bayville, NJ[a]	2 × 8,800; direct rotary drum	54	Ocean County Utilities Authority	1997

Baltimore, MD	2 × 13,200; direct rotary drum	82	Bio-Gro/Wheelabrator	1997
Houston, TX	7 × 12,000; direct flash dryer	260	City of Houston	1987
New York, NY	6 × 16,500; direct rotary drum	305	Synagro/Bio-Gro	1993
Baltimore, MD	3 × 13,200; indirect multiple hearth	122	Synagro/Bio-Gro	1994
Quincy, MA[b]	6 × 15,000; direct rotary drum	278	Massachusetts Water Resources Authority	1991
Milwaukee, WI	12 × 9,000; direct rotary drum	333	Milwaukee Metropolitan Sewage District	1994

[a]Disposal cost: $240 /DT
[b]Disposal cost: $300 /DT

Summary of Technology

Table A-4. Summary of Heat Drying Technology

Criteria	Issues/Comments
Permitting/Regulatory Compliance	Treated favorably by the USEPA 40 CFR Part 503 regulations. Capable of producing Class A biosolids per Part 503 Rule with minimal restriction on product use. Produces air emissions and odors that have to be treated. Compliance with the Clean Air Act provisions is feasible and has been successfully practiced. Air permit is likely to be required.
Process Reliability and Redundancy	Reliable and time-proven process. Many successful municipal installations in the U.S. and overseas.
Operational Flexibility and Complexity	Heat drying can be used for both digested and undigested material. Quality and marketability of dried pellets may be affected, however, by processing undigested solids. Heat drying technology is more complex than found in typical wastewater treatment systems. Complexity is comparable to incineration technology. Potential for dust explosions and pellet overheating in storage silos must be controlled.
Economic Considerations—capital, O&M, and present worth life-cycle costs	Relatively high capital, O&M and life-cycle cost intensive due, in part, to initial investment and ongoing fuel requirements. Volume of solids to be managed is significantly reduced by heat drying.
Product Marketability	Dry pellets produced by heat drying may have commercial value. Direct dryers typically produce more uniform pellets compared to indirect dryers. Both national and regional product market opportunities exist.
Facility Size and Land Requirements	Relatively small footprint required. Land requirements for processing are comparable to alkaline stabilization. Storage requires less land area.
Plant Impacts—sidestream impacts, operations, etc.	Direct type, rotary drum heat dryers produce hot condensate stream with organic loading.
Nuisance Issues—odor (onsite and offsite), dust, traffic, etc.	Required offsite traffic is significantly lower than for other management methods, except for incineration, due to reduced product volume.

Incineration

Process Background

Incineration evaporates water and burns all the organic substances present in the wastewater solids. Combustion reactions are exothermic and release large amounts of energy as heat. The initial moisture content of the solids and the organic content determines whether additional fuel is required to support combustion. With sufficient dewatering, combustion usually is self-sustaining, except for the initial warmup and for heat control.

Wastewater solids incineration has been practiced since the early part of the 20th century. Availability of cheap energy, limited capability of wastewater solids dewatering equipment, and minimal or nonexistent air pollution requirements all led to the selection of incineration as a practical and inexpensive method of wastewater solids disposal. However, increasing concern for air quality and experience with solids from more advanced treatment processes, which are more difficult to dewater and require more energy to evaporate the excess water, considerably dampened the enthusiasm for incineration. These problems, coupled with rising energy costs, increasing quantities of wastewater solids, and limited resources, have led to the development of improved dewatering methods and more energy efficient incineration equipment and systems.

Incineration offers significant advantages over other final use options; it reduces the volume of solids to a compact residue consisting of about 5 to 15 percent of the original volume, and it eliminates some potential environmental problems by destroying pathogens and degrading many toxic organic chemicals. Metals are not degraded but are concentrated in the ash and in particulate matter entrained in the exhaust gases generated by the process. Pollution control devices are needed to prevent degradation of air quality. Heat energy can be captured and reused.

Incinerator Design

Over 80 percent of the identified operating municipal wastewater solids incinerators are of the MHF design. The MHF was originally developed for mineral ore roasting nearly a century ago. The air-cooled variation has been used to incinerate wastewater solids since the 1930s. About 15 percent of the identified operating municipal wastewater solids incinerators are FBIs. The FBI was developed for catalyst recovery in oil refining by the Standard Oil Development Company in the early 1900s. The first FBI used for incineration of municipal wastewater solids was installed in 1962.

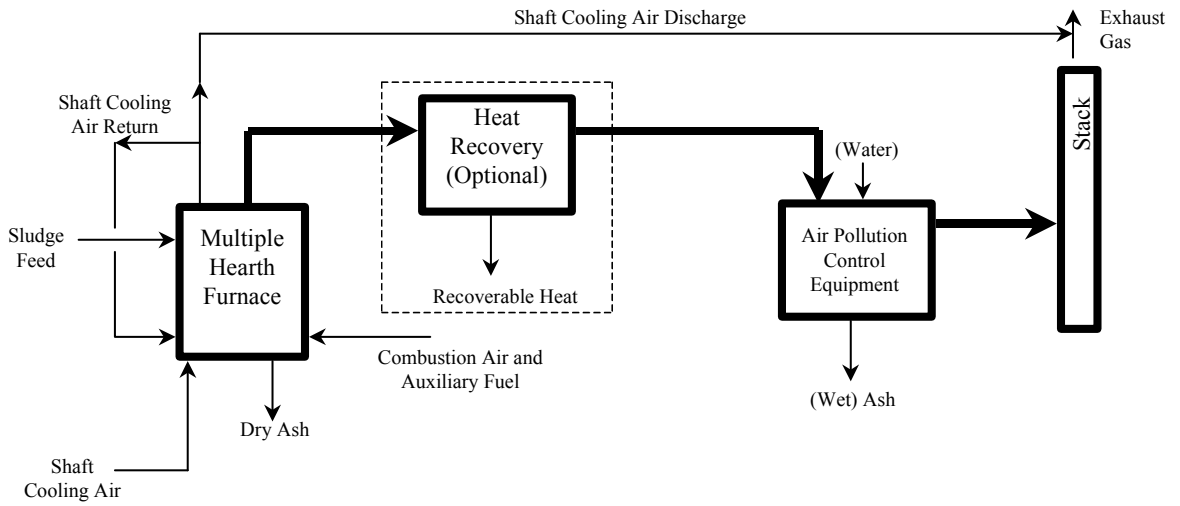
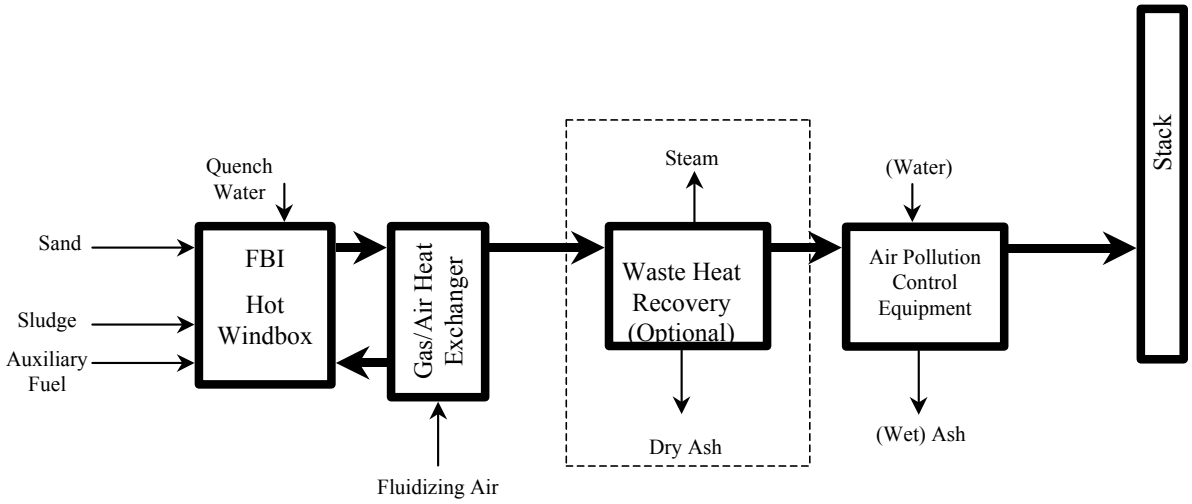


Figure A-1. Typical Schematic Showing MHF and Auxiliary Equipment



FigureA-2. Typical Schematic Showing Hot Windbox FBI and Auxiliary Equipment

Incinerators

Multiple Hearth Furnace. The MHF is a vertical, cylindrical, refractory-lined steel shell containing a series of horizontal refractory hearths, one above the other. A central shaft, hollow to allow the passage of cooling air through it, runs the height of the furnace and rotates within the furnace at roughly one revolution per minute carrying the rabble arms above each hearth with it. There are two or four rabble arms per hearth. Each arm contains rabble teeth or plows that rake the dewatered cake spirally across the hearth as the arm rotates above each hearth. Dewatered cake typically is fed at the periphery of the top hearth and raked toward the center, where they drop to the hearth below. On the second hearth, the solids are raked outward, to holes in the periphery. The alternating drop hole locations on each hearth and the countercurrent flow of rising exhaust gases and descending solids provide contact between the hot combustion gases and the solids feed, to ensure complete combustion.

The MHF can be divided into four zones during incineration (Figure A-3). The first zone, which consists of the upper hearths, is the drying zone, where most of the water is evaporated. The second zone, generally consisting of the central hearths, is the combustion zone, where temperatures reach 1,400°F to 1,700°F. The third zone is the fixed carbon burning zone, which oxidizes the carbon to carbon dioxide, and the fourth is the cooling zone.

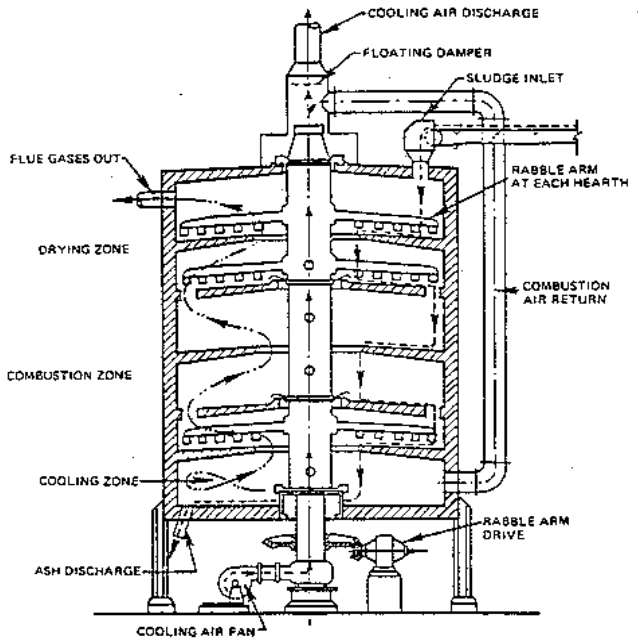


Figure A-3. Typical MHF Cross Section

Excess air of 100 to 125 percent must be provided to ensure adequate burnout of solids cake. Some 20 percent of the ash is airborne, and gas cleaning equipment must be provided for its capture. Occasional odor problems may require installation of afterburning equipment. The ash is collected in a dry form.

Fluidized Bed Incinerator. The FBI is a steel, refractory-lined chamber with a bed supporting plate separating the windbox from the reactor and supporting a bed of sand. Air is heated and injected into the sand bed. At a temperature of 600°F the air will generate sufficient turbulence within the sand bed to produce fluidization; that is, the sand will appear to act as a fluid. The bed is maintained at 1,500°F for incineration. Wastewater solids are injected within the reactor and as soon as they contact the sand/air bed, water flashes from the solids particles and oxidation begins. Ash residual from combustion is airborne and exits from the reactor in the flue gas. It is removed from the gas stream by high-energy scrubbing equipment downstream on the incinerator exit. The ash is collected as a wet ash slurry that must be dewatered. The exit gas temperature is normally in the range of 1,400°F to 1,600°F.

In the typical FBI, the fluidizing air passes through a heat exchanger prior to injection into the combustion chamber. This arrangement is known as a hot windbox. The air preheater at the incinerator exit will heat the fluidizing air to a maximum of 1,000°F while reducing the exiting flue gas temperature by 500°F to 700°F.

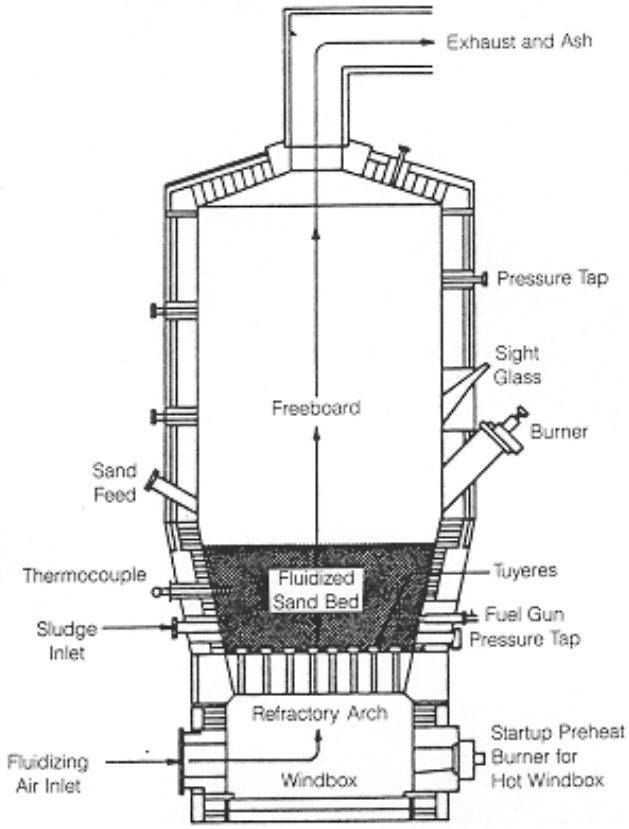


Figure A-4. Typical FBI Cross Section

The FBI is a simple piece of equipment with no moving parts. Furthermore, only one major item of air moving equipment is normally required: the fluidizing air blower (or forced draft fan). The large amount of sand within the incinerator is an effective heat sink. The incinerator can be shut down with minimal heat loss—the sand will retain enough heat to allow startup after a weekend shutdown with the need for only 1 or 2 hours of preheating. Because of the intimate mixing of air and solids in the fluid sand bed, excess air requirements are low (usually around 40 percent). Supplementary fuel is required for startup, reheat, and, depending on the properties of the solids, for incineration.

Representative Case Study of FBI Incinerators: St. Paul, Minnesota

Facility Background

In 1998, the Metropolitan Council of Environmental Services (MCES) completed a comprehensive master plan and facility plan for the Minnesota WWTP (MWWTP) in St. Paul. A major component of the master plan was to examine and recommend improvements to the solids handling and disposal system.

The master plan recommended that fluid bed incineration, together with alkaline stabilization for peak operations, be installed as the preferred alternative and that thermal conditioning of waste activated solids be discontinued. The MWWTP Solids Processing Improvements Project is expected to be completed in 2003–4 and begin operation in 2004–5. A centrifuge demonstration project was completed to determine full-scale impacts of dewatering raw solids. The facility plan further refined the recommendations of the master plan and developed the design of the system to a level of detail sufficient for submittal of an application to amend the air permit.

Brief Description

The existing solids processing operation consists of gravity thickening of primary solids and flotation thickening of waste activated solids. The thickened waste activated solids are thermally conditioned, and either dewatered on vacuum filters or roll presses and incinerated in MHFs, or mixed with thickened primary solids, dewatered on roll presses or by centrifuges and incinerated in MHFs.

The thermal conditioning system will be retired as part of the Solids Processing Improvements Project, and thickened primary and waste activated solids will be mixed and

dewatered by centrifuges, prior to final processing using FBIs or a supplemental alkaline stabilization system. The WWTP treats about 225 mgd of wastewater, resulting in about 185 DTPD of solids that are disposed of by incineration in MHFs. The project will have the capacity to process up to 299 DTPD annual average and 398 DTPD peak week, using a combination of FBI and alkaline stabilization. This technology is designed to ensure reliable solids processing and disposal through 2025.

Regulatory Aspects

A number of environmental permits and approvals are being processed to authorize the construction and operation of the new solids processing facility. The primary regulatory review processes were as follows:

- An air emissions permit major amendment issued by the Minnesota Pollution Control Agency
- A permit, obtained from the USEPA, addressing the requirements of 40 CFR Part 503, Subpart E, which are applicable to FBIs
- Approvals and permits for land application of the alkaline stabilized biosolids, in accordance with USEPA 40 CFR Part 503, Subpart B, and Minnesota Rules Chapter 7041

The Solids Processing Improvements Project is designed to reduce air emissions significantly, compared with emissions from the current equipment, resulting from the decommissioning of several emissions sources and from the application of state-of-the-art processing and pollution control technologies. The project is not subject to review under the federal and state Prevention of Significant Deterioration and nonattainment New Source Review (PSD/NSR) regulations as it is designed so that net emissions will decrease from the improvements. Permits are held by MCES allowing the beneficial use of ash under the current contracts, and no further regulatory requirements must be addressed at this time.

Summary of Technology

Table A-5. Summary of Incineration Technology

Criteria	Issues/Comments
Permitting/Regulatory Compliance	Regulatory requirements are an issue with air emissions, but where incinerators are in use, updating the technology has resulted in less emissions than have already been permitted.
Process Reliability and Redundancy	FBIs have proven more reliable than MHFs due to their simpler technology. A redundancy capacity is usually provided to ensure that full treatment can be maintained at all times and future additional loads for the system are accounted for. However, storage or other methods may be provided in conjunction with incineration systems to ensure full treatment at peak times.
Operational Flexibility and Complexity	FBIs are more flexible in terms of intermittent operation and less complex than MHFs. The associated equipment, including the APC train, can also be operated intermittently without problems. Operator training is essential.
Economic Considerations—capital, O&M, and present worth life-cycle costs	Two types of incinerators—MHF and FBI—were considered. The FBI is replacing the MHF for solids incineration projects around the world. This is due to the superior technology and simpler operation and maintenance factors of the FBI. Capital costs depend on size of operation. O&M costs similar to other biosolids final use options.
Product Marketability	The ash is typically landfilled, but beneficial uses have been found in a few markets. Flexibility of final product (ash) reuse depends on the local market.
Facility Size and Land Requirements	Size depends on solids quantity and redundancy required. Low footprint technology, minimal storage space requirement.
Plant Impacts—sidestream impacts, operations, etc.	Some visual impacts from new structures. Some water quality impacts may occur, resulting from wet scrubbing return water. Minimal safety impacts, with appropriate training.
Nuisance Issues—odor (onsite and offsite), dust, traffic, etc.	Very few odors. Dewatering and conveyance to incinerator are primary sources. Dust from ash must be controlled. Traffic associated with ash removal is less than other alternative technologies as solids are much reduced.

Land Application

This section focuses on the land application of liquid and dewatered Class B biosolids. Constraints associated with land application of Class A biosolids are also briefly evaluated (e.g., alkaline stabilized biosolids).

The application of biosolids to agricultural farmland is a well-established practice in the U.S. Nationally, the beneficial use of biosolids by land application in 1998 was estimated to be 60 percent of the total biosolids generated in the U.S. Land application of typical Class B biosolids was estimated to be 40.6 percent of the 6.9 million dry tons of biosolids produced annually in the U.S.

Land Application Principles

Land application of biosolids consists of applying liquid or dewatered biosolids on or just below the land surface and using the nutrients and organic matter in the biosolids as a fertilizer, soil amendment, or conditioner to grow crops. At a well-managed land application site, biosolids are applied at agronomic rates that do not exceed the assimilative capacity of the soil and vegetative system. Biosolids should be applied at a rate that will ensure constituents of concern (typically nitrogen, phosphorus, and heavy metals) are immobilized, treated, or taken up by plants. This will ensure that the operation will be environmentally sustainable. Proper management can enhance the effectiveness of the natural land application processes.

Since land application of biosolids is a well-established technology, substantial guidance is available on how to design and manage its use.

Site Management Options

Because land application sites typically are agricultural land, biosolids generators or contract operators often can enter into cooperative agreements with local farmers to use their land for application. Other types of land such as forests and mine remediation sites can be used in cooperative programs. Land application programs operated by Madison, Wisconsin; Denver, Colorado; and Columbia, OH are examples of cooperative programs. In these programs, the municipality or contract operator typically hauls and applies the biosolids, and the farmer incorporates the material and manages the site. Alternatively, biosolids generators can purchase and control land application sites exclusively or arrange to have others manage their sites. This approach typically is referred to as a dedicated land application program. For example, entities such as Montgomery, Alabama; the Marine Corps Base Camp Lejeune, North Carolina; and Dekalb County, Georgia, operate dedicated programs ranging from 300 to 3,000 acres.

Representative Case Studies

Orange County, CA Sanitation District

The Orange County Sanitation District (OCSD) in California in operates two WWTPs that produce 200,000 wet tons per year (40,000 dry tons at 20 percent solids) of Class B, anaerobically digested biosolids. Since 1991, OCSD has beneficially reused 100 percent of its biosolids through a cooperative land application program operated in four counties around Los Angeles including Kern, Riverside, and King counties. OCSD uses four private biosolids management companies to haul and apply the dewatered biosolids.

OCSD pays an average unit cost of $135 per dry ton at 20 percent solids to the four private biosolids management companies.

Regulatory Aspects. OCSD has not experienced any problems in meeting USEPA's land application regulations. The intensive monitoring program and third party verification system that OCSD has implemented has allowed this agency to identify and resolve potential problems quickly.

From a public relations perspective, OCSD is experiencing some major hurdles that are significantly affecting its biosolids management program. The major public relations battle being fought by OCSD is Kern County's ban on the land application of Class B biosolids. Kern County provides OCSD its largest land application base, but as of January 1, 2003, the land

application of Class B biosolids is banned in the county. If local municipalities prevail in having the Class B biosolids bans upheld, the OCSD may then pursue land application of Class A biosolids.

Metropolitan Denver Sewage Disposal District No. 1
The MWRD operates the Central WWTP, which has a design capacity of 185 mgd. The WWTP is an activated sludge plant with nutrient removal capabilities. Primary and secondary sludges are stabilized together by anaerobic digestion. The WWTP produces about 84 DTPD of Class B biosolids that meet pollutant concentration limits for EQ biosolids. Centrifuges dewater the biosolids to roughly 16 percent solids. About 95 percent of the dewatered biosolids are applied to agricultural land, the balance being composted and sold under the name METROGRO™.

Product Quality and Use. The dewatered biosolids meet requirements for a Class B biosolids and are applied to various agricultural crops such as dryland wheat, irrigated corn, barley, and oats.

It costs MWRD about $135 per dry ton to operate its land application program. In comparison, its composting costs from $275 to $300 per dry ton.

Summary of Technology

Table A-6. Summary of Land Application

Criteria	Issues/Comments
Permitting/Regulatory Compliance	Demonstrated permittability in U.S. and Michigan. Depending on site suitability, monitoring and recordkeeping requirements may be extensive. Regulations/requirements are well defined at state and federal levels. However, it may be more difficult to permit Class B biosolids application facilities due to public concerns over health effects of biosolids application. Permits are required for anaerobic digestion and processing facilities that are also required to implement this alternative to ensure compliance with pathogen reduction and vector attraction reduction requirements. Permits may be required if offsite storage facilities are required.
Process Reliability and Redundancy	Land application is affected by seasonal cropping demands, inclement weather, good management practices, and public acceptability. Backup options, storage, and additional permitted sites are required to manage biosolids. Numerous successful operational facilities in Ohio and U.S. with long operating histories. Most medium to large operations use multiple sites with multiple crops. Equipment is abundant from a variety of sources, easily maintained, and replaced.
Operational Flexibility and Complexity	Simple to operate and understand. Loading facility at WWTP increases complexity of process. Use of multiple sites and crops increases flexibility. Overall reliability still affected by public acceptance, inclement weather; if contract operation, then potentially less control over process. Backup options and storage generally are necessary elements of a land application program.

Criteria	Issues/Comments
Economic Considerations—capital, O&M, and present worth life-cycle costs	Depends on procurement method (owner operated or contract operation). Medium capital investment and O&M costs. Most land application capital costs are in loading/storage facility and rolling stock and application equipment. Alternative cost must include alkaline stabilization or digestion. O&M costs increase as direct function of required hauling distances to land application sites. O&M costs sensitive to fuel costs. Contract operations costs may vary and increase as new contracts are negotiated.
Product Marketability	Product difficult to store without generating odors. Markets are limited to permitted lands. New land must be permitted for expansions or as other contracts are not renewed. Minimal revenue potential for utility run programs. No revenue potential for cooperative programs.
Facility Size and Land Requirements	Extensive land requirements for application sites. Requires large land-base to manage biosolids year round. Some area required at WWTP for loading/storage facility. Offsite storage may also be necessary. Footprint required depends on product volume and storage time required. Must continually fund improvements and permit land.
Plant Impacts—sidestream impacts, operations, etc.	Thickening and dewatering produce liquid effluent stream that must be returned to the plant headworks. Must provide digestion or alkaline stabilization facilities, as a minimum, for Class B product. Must provide loading/storage facility at plant site.
Nuisance Issues—odor (onsite and offsite), dust, traffic	Increased traffic due to application site location and quantity of biosolids transported. Odors and other nuisance problems may adversely affect land application program. Public opposition may be strong.

The following technology descriptions are mostly excerpts from the 1998 Biosolids Reuse Alternative Study report. Details should be referred to this original report published in 1998.

The N-Viro Technology

N-Viro is a proprietary technology that will produce an "exceptional quality sludge"("EQS") product, as defined in the Section 503. At the time when the report was published in 1998, there were 35 N-Viro Soil™ Facilities being operated worldwide, with sludge processing capacity ranging from 1 to 150 DTPD. The product is typically sold within 100 miles of the N-Viro facility depending upon the local market, per the report.

The utilities used the N-Viro technologies by 1998 include:

Facility Location	Sludge Process Capacity, DT/year
Middlesex County, New Jersey	48,500
Wilmington, Delaware	20,000
Syracuse, New York	12,300
Toledo, Ohio	8,500
Phillipsburg, New Jersey	6,500
Minneapolis/St. Paul, Minnesota	5,100

Key Elements of N-Viro Technology

Traditional stabilization technologies rely on one of three basic processes: Chemical, physical, and biological. For example, digestion is a biological process; heat drying is a physical process; lime sterilization is a chemical and physical process (high pH and high heat); composting is a biological and physical process (biological activity and heat drying). The N-Viro process is similar to composting, in that N-Viro technology includes both biological activity and drying. N-Viro also uses a chemical process (high pH) for disinfection and short-term odor relief.

Process Overview

The N-Viro process involves mixing the wastewater sludge with alkaline reagents and then subjecting the mixture to a controlled period of storage, mechanical turning and accelerated drying. The N-Viro process stabilizes and pasteurizes the wastewater sludge, reduces odors to acceptable levels, immobilizes various toxic components, and generates N-Viro soil™, a product which has a granular appearance similar to soil.

Process Steps

Figure A-6 shows the N-Viro process. It may include the following steps:

- Mixing – Dewatered sludge, between 16 percent and 35 percent solids, is mixed with N-Viro's alkaline admixture compost of cement kiln dust and other alkaline products.
- Chemical Heat Pulse – Chemical reaction between the sludge and alkaline admixture will raise the temperature above 52°C and preferably below 62°C and the pH > 12.
- Drying – three options available: Traditional window drying, accelerated mechanical drying, or accelerated drying by bulking.
- Storage - N-Viro can be stored for extended period of time, in the open or under a roof.
- Distribution/Use – N-Viro can be shipped in bags or by truckload.

Figure A-6. Schematic of N-Viro Process

Bio Gro

Bio Gro is a division of Wheelabrator Water Technology Inc. The Bio Fix chemical stabilization process involves the addition of quicklime to dewatered biosolids. Biosolids are dewatered to 15percent to 30percent solids prior to chemical stabilization. The equipment involved with the chemical stabilization process includes a dewatered biosolids storage hopper, biosolids feeding conveyors, a mixer, product discharge conveyors, and an air/odor pollution control system.

Figure A-7 shows a simplified process diagram.

The lime used in the process is stored in a silo. At the bottom of the silo, a rotary air lock feeds lime to the lime conveyor. The conveyor then transfer the lime to the mixer. Inside the mixer, the dewatered biosolids are thoroughly mixed with the lime. During this process, the lime, calcium oxide, comes into contact with the water bound in the biosolids initiating the reaction between calcium oxide and water. This exothermic reaction produces calcium hydroxide while raising the mixture's temperature and pH. The action of the mixture transfers the lime and biosolids from the input end to the output end where the mixture is transferred via screw and belt conveyors into a truck.

Even though the chemical reaction between the lime and the biosolids is largely completed in the mixer, the chemical reaction continuous while the product is conveyed and loaded in the end-product trucks. By the time the reaction is complete, the product has achieved the Class A pathogen reduction and vector attraction reduction requirements. The product can be used as a soil amendment or landfill cover.

During the mixing process, since the temperature and the pH are high, components like water vapor and ammonia are emitted. The mixer and product conveyors need to be enclosed and ventilated.

The installation list by 1998 include: Bergen County, New Jersey (45 DTPD), Charles County, Maryland (7 DTPD), and Howard County, Maryland (70 WTPD).

Fighting Island Land Reclamation

The Snell Environmental Group (SEG) did this initial evaluation for DWSD. Fighting Island is a part of Sandwich West Township (Essex County – Ontario) (Figure A-8) and has been used for disposal of soda ash products since the mid of 1920's. It was used as a disposal facility for waste from a soda ash chemical plant from 1943 to 1982. The waste includes dissolved salts consisting of calcium and sodium plus limestone type material plus brine and calcium and sodium plus limestone type material plus brine and calcium oxide sulfates, carbonates, magnesium and silicas. The material has an elevated pH in the 10-12 range. An in-situ test pilot program was conducted with USEPA grant for reclamation of the land.

The SEG study concluded that the dewatered WWTP sludge could be stabilized by mixing sludge with the high pH material. The resulting mixture will support selected grass and tree growth. SEG was confident that DWSD sludge could be disposed for 8-9 months a year, over approximately 12 years. The operation would be based on a production rate of 555 DTPD, at an average cost of over $28/wet ton in 1997 dollars. SEG also believed that all the environmental issues could be addressed regarding the Canadian and U.S. regulations

Figure A-7. Schematic of Bio-Gro Process

in terms of reclaiming Fighting Island. Sandwich Township had obtained prior approval for land reclamation at Fighting Island from Environment Canada. However, due to the sludge transport issues in the Township, the project did not meet public acceptance. Also, the U.S. Department of State has been reluctant to approve schemes for export of Class B biosolids.



Figure A-8. Map of Fighting Island and DWSD Wastewater Treatment Plant

References

DWSD. 1998. *Biosolids Reuse Alternatives Study Report*.

BASF Corporation's Rehabilitation of Fighting Island

http://athena.uwindsor.ca/units/glier/conference/HabitatConf.nsf/391878caff867c0185256a1100801cd8/f8faa4d2680e7e71852569dd001989f6?OpenDocument

Altex Technology

This alternative would be implemented by a joint venture between Altex and a regional electric utility, and would serve industrial customers located in the vicinity of the WWTP. The joint venture (BioCorp) would commercialize the BioBinder process, which converts coal fines and biosolids waste into a low-cost fuel product. In the BioBinder process, biosolids from the WWTP would be combined with coal fines to create a durable and valuable fuel pellet for stoker and pulverized coal-fired boiler use. The fuel pellets are cylindrical in structure and are 0.5 to 1 inch in length and 0.5 inch in diameter. The low cost of BioBinder is derived from the low cost of coal fines and cost avoidance for disposal of sludge solids. The envisioned commercial process is shown in Figure A-9.

Per Altex's claim, BioBinder fuel pellets could be used, with some modification, in both stoker and stem coal markets. The stoker fuel use is a one billion dollars market and the steam coal is a $26 billion market. These claims are yet to be substantiated.

Minergy

Minergy is presently the primary solids disposal method for the DWWTP. The Minergy Corporation, a subsidiary of Wisconsin Electric, developed a vitrification process that combusts wastewater solids in a slagging gasifier to produce glass aggregate and steam for electrical power. Vitrification is the conversion of material, usually inorganic, into glass through the application of temperature. The material is heated above its fusion temperature (> 2,500°F), collected molten, and then rapidly quenched to form glass.

Minergy Corp. is a developer of projects and technologies for recycling high volume industrial waste, including fly ash, paper sludge, municipal sludge, and foundry sand. Minergy's Glass Aggregate technology is an alternative to landfilling. Glass aggregates are commonly used for road base, asphalt and chip seal aggregates, roofing shingle granules, and sand blasting grit. The Minergy facility is being constructed at Zug Island, within the National Steel property, and industries located nearby are potential customers for the steam and electricity to be produced.

Glass Aggregate Market

Per the DWSD report, the market for the glass aggregate product is large and diverse. More than 2.5 million tons per year of the material was produced in 1997, in an industry otherwise known as slag marketing. By far the largest market has been for application in building roads. To provide a 1-foot base for 10 miles of four-lane road, over 50,000 tons of aggregate could be required. In comparison, Minergy forecasts that the DWWTP facility would generate approximately 75,000 tons per year of glass aggregate if all the solids production were processed.

Figure A-9. Schematic of Altex Process

Process Description

The process consists of combusting dried sludge solids in a cyclonic slagging furnace to form a molten product from the inorganic fraction which, when quenched, produces a glass aggregate material (Figure A-10). The dewatered cake is dried in a rotary drier fired by natural gas to form a dry material (> 90 percent DS). The process is followed by the first stage of vitrification in a cyclonic slagging furnace. The organic matter in the solids is oxidized and the inorganic matter (ash) forms a molten slag. The slag is collected from the bottom of the furnace and discharged into a quench chamber, where the molten slag forms a glass-like material. The material passes through grinding and screening for sizing into the final product.

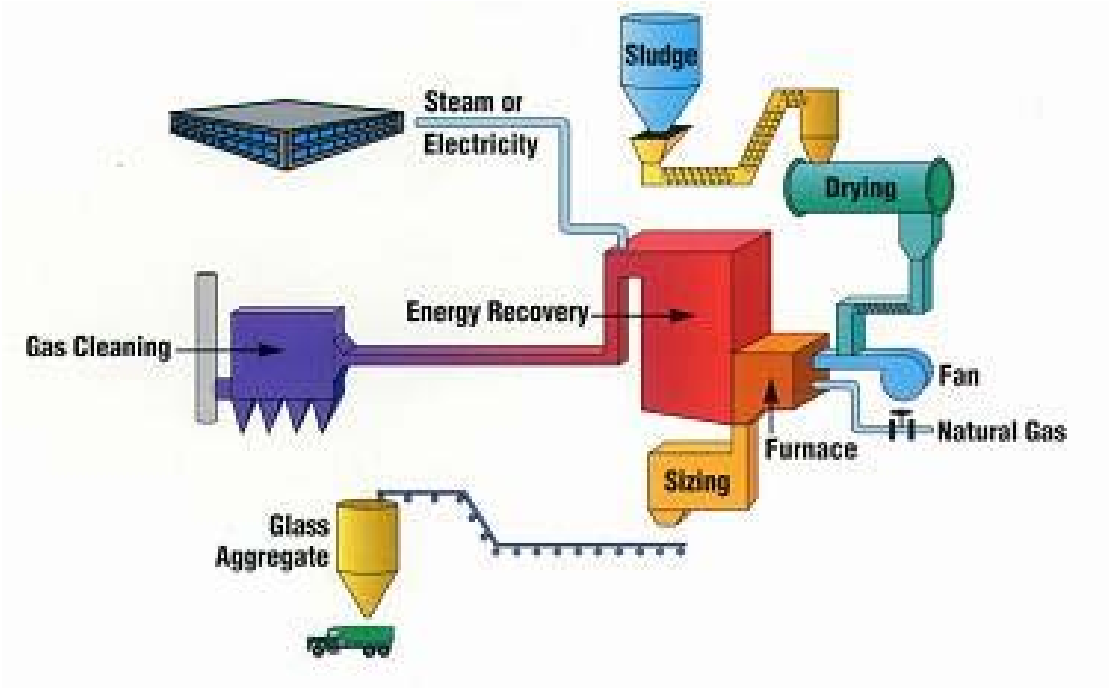


Figure A-10. Minergy Process Flow Diagram

The furnace uses large amounts of natural gas for combustion. The off-gases from the furnace enter a heat recovery steam generator that produces high pressure steam. The cooled gases pass through an APC system (baghouse) and are discharged to the atmosphere. The high pressure steam is used to drive a steam turbine/generator set to produce electrical energy.

For example, a 220 DTPD facility would produce 21.4 MW of electricity but would require 185,000 cubic feet per hour of natural gas to operate the system. The resulting product would be about 20,000 tons per year of glass aggregate. Minergy reports that the markets for the glass aggregate product includes road base aggregate, chip seal asphalt/aggregate, sand blasting grit, roofing tiles and shingle granules, ceramic floor tiles, industrial abrasives, and filtration media.

Key facilities of the Minergy process are: Fox Valley Glass Aggregate Plant, Neenah, Wisconsin (500 DTPD), and Oak Creek Lightweight Aggregate Plant, Milwaukee, Wisconsin (60,000 wet tons/year)

Michigan Upper Peninsula Mining Reclamation Using DWSD WWTP Solids

The MDEQ staff and personnel from mining companies were contacted regarding the potential use of DWSD biosolids for land reclamation of the mining sites in the Upper Peninsula (UP). MDEQ regulations require that land reclamation with biosolids is done under a State permit for land application of biosolids. Under Part 24, the biosolids used for land reclamation have to meet either the pollutant limits for cumulative loading rate or the concentration of each pollutant, as well as Class B pathogen and vector attraction reduction requirements. A summary of the MDEQ regulation on land application was provided in Section 2 of this TM.

Two mining companies in the UP were contacted, Copper Range Company and Ohio based Tilden Mining Company, L.C.

Copper Range Company - White Pine Mine, MI

Copper Range Company left a closed (closed in 1995) copper mine site in White Pine, MI as indicated in the Figure A-11. The surface area owned by Copper Range Company covers approximately 64,000 acres. The underground mine underlies about 25 square miles and extends from the surface to a maximum depth of 2,700 feet (1992, see References below). Based on a news report from Great-Lakes net, the company left un-vegetated tailing basins at the White Pine mine, causing serious dust emissions (1998, see References below). It was estimated by MDEQ personnel that the reclamation area for White Pine mine is at least about 2,000 acres. Mr. Jim Johnson (MDEQ) estimated that the area can take half of the DWSD biosolids production for 10 years based on an application rate of 10 wet tons per acre.

Tilden Mining Company, L.C. - Tilden Mine and Empire Mine

This firm has two active iron mining sites. The first is Tilden Mine, located in Ishpeming, MI (Figure A-11) and the second is the Empire Mine at the Marquette Iron Range. The production capacity of the two mines is about 13.8 million tons of iron per year. No response was received from the company after the team's month long attempt to contact. However, according to the City of Marquette's (MI) estimation, the area in need of reclamation is about 600 -1,000 acres.

According to the information posted in the company's website, both Tilden and Empire Mines are part of ongoing research to improve methods for revegetation tailing basins. Currently, the City of Marquette is applying anaerobically digested biosolids for land reclamation there. The City's wastewater facility produces nearly 2 MG of digested biosolids annually containing over 550 dry tons of solids.

The Marquette wet biosolids (about 6% DS) are transported by tanker to the mining site at a one way distance of 35 miles. The application rate of the wet biosolids varies from 1 wet ton/acre for established vegetation area to 10 wet tons/acre to areas being readied for seeding. The wet biosolids are applied on a daily basis from May to June, and from September to mid November each year before the snow. There are facilities for storing the

wet biosolids produced during the rest of the year at the Marquette WWTP. After following a carefully planned program, significant differences on grass growth were observed for the area that received biosolids versus not. Overall, the City was pleased with this cost effective method for its biosolids reuse.



Figure A-11. Map of White Pine Copper Mine and Iron Mining Site from Tilden Mining Company

Summary of Land Reclamation in UP

Two critical elements must be considered:

- **Loading, shipping & unloading cost.** the distance from Detroit to the mining sites in UP is about 470 ~ 580 miles, using an estimated unit railway loading, shipping and unloading cost of $0.10/ton/mile, the cost for shipping Detroit average daily biosolids produced of 650 DTPD is $116,000/day. However, there is a possibility that the empty ship returning to the mining site by the mining company can realize a lesser total transport cost.
- **Seasonal impact.** Due to the seasonal factor, both waterborne transport and land application are limited to about seven months each year. Thus over-season storage of an estimated 100,00 dry tons (or say 400,000 CY) would be required somewhere. Alternately, a second alternative would be required for the remaining five months.

References

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Mine Site Visit, Copper Range Company, White Pine Mine. USEPA. 1992

http://www.epa.gov/epaoswer/other/mining/techdocs/copper/copper4.pdf

Tilden Mine and Empire Mining from the Tilden Mining Company

http://www.cleveland-cliffs.com/MiningOperations&Technology.html

Coal Mines in PA

http://www.amrclearinghouse.org/Sub/GOBpiles/index.htm

"Unity" Technology (Unified Environmental Services) and Similar BER Process

The "Unity" process takes raw sludge and feeds it into a long tube as cooling water for the violent reaction of ammonium sulfate and sulfuric acid. The temperature rises to 270 degrees C for 2 seconds and the process meet all EPA Class A criteria. The end product is a fertilizer. It goes from the tube into a granulator then into a single-pass rotary dryer. Screens separate the fines, and oversize material. The product is then cooled to 80 degree F and stored. It is simple process and works in full scale, but may be expensive.

Unified Environmental Services (UES) advised our technical staff that it is preparing a cost for both Detroit and for OSCD (Orange County, CA). The proposals are being based upon the availability of old fertilizer plants essential to the process. At this point, UES claims that they need to have a minimum of 500 wet tons per day at about 25 percent solids. UES has a contract with New York for $92/wet ton and is losing money, but the haul distance is to their facility at Helena AR, near Memphis TN. Without hauling, the cost could be somewhere between $40 to $70/wet ton. The costs depend upon electricity and natural gas. The connected load for 500 wet tons per day is over 3,500 hp and the natural gas use is also high. UES also needs ammonium nitrate, sulfuric acid, and possibly phosphoric acid and ferric chloride in the process. Because of the chemicals, they are only looking at brownfield fertilizer sites that already have acceptance and delivery facilities. An input of 500 wet tons per day of sludge at 25 percent solids will yield 500 wet tons per day of fertilizer at 98 percent solids because of the chemical additions.

The BER process is very similar, but there are some changes in what order the chemicals are added, and less chemicals are used, so that 500 WTPD yields 270 WTPD of 10-10-0 granular fertilizer. A full-scale BER process is at Taos, New Mexico. The plant staff (Dennis Fernandez) says it is very simple to run. The main issue is ammonia odors that are emitted through the dryer exhaust, and BER is debating whether or not to spend the money for an RTO. The plant is a 2 mgd plant, and their processing costs are $98/ton. BER expects to get $125/ton of product, with the buyer covering the hauling costs. Their biggest hurdle with the product is to get enough to promote it properly.

Emerging Technologies

Table A-7 lists the additional emerging technologies that are not ready yet for detailed study on their application potential to DWSD solid disposal.

Table A-7. Summary of Additional Solid Disposal Emerging Technologies

Technology	Description
Gasification/Vitrification	Combustion of solids at high temperature to 'melt" inerts in solids and produce glass-like material. Like Minergy process
Gasification/Prolysis	Heating of dried solids in air-controlled environment to produce fuel gas and char.
Super Critical Water Oxidation	Known as wet oxidation or wet combustion, is the oxidation of organics at super critical pressure and temperature in a liquid state, with the addition of compressed air or oxygen into the pressure vessel.
Solids-to-fuel Conversion	Heating liquid sludge under pressure to chemically convert to pumpable fuel slurry
Chemical Fortification	Addition of chemicals to the biosolids, to produce a high end fertilizer with specific properties that can be sold to the retail agricultural or consumer market.

For a broader but less detailed summary, Table A-8 compares the long list of available biosolids processing technologies.

Table A-8. Comparison of Biosolids Processing Technologies

Process	Description	Advantages	Disadvantages
Stabilization Processes – Liquid:			
Conventional Anaerobic Digestion	Digestion in completely mixed tanks under anaerobic conditions at 29 – 38°C, for a period of greater than15 days. Two stage systems have unheated, unmixed second stage for thickening and further stabilization.	• Valuable end-product, methane, that is combustible and can be used to produce heat for the digestion process and other uses • Relatively low operating costs • Biosolids suitable for application on land as a soil conditioner • Mass of solids reduced • Commonly used and well understood process	• Methane-producing bacteria are slow growing and sensitive to process upset • Digesters have high capital cost • Relatively complex operation • Potential risk from methane gas leak
Thermophilic anaerobic digestion	Similar to conventional, except operating temperatures at 50 – 60°C	• May reduce digestion time • Enhances VS reduction and biogas generation • May produce Class A biosolids	• Poor sidestream quality • Higher digester cost • Requires additional heat input • Process more susceptible to upset • Less biogas for energy recovery • Series operation to prevent short-circuiting
Temperature-Phased Anaerobic Digestion	Combination of thermophilic and conventional anaerobic digestion	• Good pathogen reduction • May produce Class A biosolids	• Limited full-scale experience

Process	Description	Advantages	Disadvantages
Conventional Aerobic digestion	Digestion in completely mixed tanks under aerobic conditions at ambient temperatures, for a period of 20 – 45 days. Typically, two stage systems with thickening in the second stage.	• Low capital costs • Large land area • Easy operation	• High O&M costs • Poor dewaterability of digested solids • No methane biogas • Poor performance at cold temperatures (<15°C) • Odors and foaming
ATAD	Similar to conventional aerobic digestion, except temperatures are in range of 50 – 60°C, for a period of 6 – 12 days. Biosolids thickened before digestion. Tanks are covered. Typically, 2 or more tanks in series.	• Reduces pathogens to produce high-grade Class A biosolids • Decreases space requirements	• Odors and foaming • Questionable dewaterability of digested solids • No energy recovery • High O&M costs • Multiple units • Reliability/upsets • Mechanical thickening required
Vertad Process	Similar to ATAD process in a deep-shaft configuration	• Class A biosolids	• No full-scale experience
Dual digestion	Similar to conventional aerobic digestion, except thermophilic, aerobic stage used before anaerobic digestion. Pure oxygen used for aeration. SRT approx. 1 – 2 days.	• Class A biosolids • Potential SRT reduction • Compatible with oxygen activated sludge	• Odor and foaming control required • Oxygen required for thermophilic aerobic digester • Few full-scale facilities • Mechanical thickening required
Aerobic Thermophilic Pre-Treatment (ATP)	Thermophilic aerobic digestion using air for aeration. SRT approx. 1 – 2 days. Typically used for pretreatment prior to conventional anaerobic digestion.	• Class A biosolids • Potential SRT reduction	• Odor and foaming control required • Few full-scale facilities • Mechanical thickening required
Two-Phase Anaerobic Digestion (TPAD)	Similar to conventional anaerobic digestion, except digesters operated in series, with acidification and methanogenisis in separate digesters	• Potential reduction in digester volume and capital costs • Potential for Class A biosolids	• Limited full-scale experience • Higher potential for process upsets
Pre-pasteurization	Biosolids heated to greater than 70 °C in vessels with retention times greater than 30 minutes.	• Class A biosolids • Add to existing facilities • Small footprint	• Full-scale applications • High O&M costs • Potential odor and scaling problems
Aerobic/Anoxic Digestion	Variation of conventional aerobic digestion	• Reduced oxygen requirements with denitrification • Temperature control with mechanical thickening	• Limited to aerobic digestion facilities
Biocombustion (Pirt) Process	Four stage mesophilic-thermophilic digestion	• High VS reduction reported	• No full-scale experience
Brinecell Process	Brinecell generates chlorine to disinfect biosolids		• No pilot or full-scale experience
High Pressure Anaerobic Digestion	Variation of conventional anaerobic digestion. Operates at 2 – 5 atm.	• Gas compressors not required	• Not proven at full-scale

Process	Description	Advantages	Disadvantages
Irradiation – electron beam	Irradiation source used to disinfect biosolids.	• Good pathogen reduction	• Biosolids not stabilized • Limited full-scale experience • Public concern with radiation • Pathogen regrowth if not stabilized
Lime Stabilization – Liquid	Lime or other alkaline materials blended with sludge for about 1 hour; pH raised to > 12.	• Small area required • Low capital costs • Applicable to small STPs	• High chemical requirements • Biosolids temporarily stabilized • Increase in solids
Liquid A (RDP)	Variation of liquid lime stabilization	• Class A biosolids	• Energy for heating biosolids to 65 °C
Active Sludge Pasteurization	Anhydrous ammonia and phosphoric acid added to thickened sludge	• High temperature (65 – 70 °C) and high pH (pH > 11.5) kills pathogens • High nutrient content	• Biosolids not stabilized • Potential for odor redevelopment • No full-scale experience
Micronair	Combination of aerobic digestion and DAF	• Reduce aerobic digester volume • Increase VS reduction	• Limited full-scale experience
Ozone (Oxyozone, Synox)	Thickened sludge acidified and mixed with ozone for 30 min. Several process variations with dewatering, lime stabilization and drying		• No full-scale experience
Bacterial Metal Leaching	Bacterial acidification of sludge to pH of 2	• Solubilization and removal of metals with dewatering • Good pathogen reduction	• No full-scale experience
Stabilization Processes – Post-Dewatering:			
Irradiation – gamma ray	Similar to electron-beam irradiation	Good pathogen reduction	Limited full-scale experience
Composting-open	Windrow or aerated static pile (ASP) composting. Biosolids mixed with wood chips or other amendments and formed into piles. Piles aerated mechanically or by drawing air through the piles.	• Low capital costs • Class A biosolids possible	• Weather dependent • High O&M costs • Labor intensive • Potential for odors • Potential for pathogen emissions through aerosols • Large land requirements
Composting – Enclosed / In-vessel	Similar to open composting, except compost process occurs in a vessel, channel or building	• Good pathogen reduction because temperatures are maintained at greater than 55°C for longer than 3 consecutive days • Good volatile solids destruction • Easily handled product • Odor free final biosolids product • Lower risk of groundwater and surface water contamination from compost product application • Co-composting with municipal solid wastes can be considered	• High capital and/or operating costs • Biosolids dewatering required • Relatively high land requirements (depending on the compost process used) • Potential for odors during processing; • Existing regulations in Ontario severely restrict potential uses of compost product due to low metal limits

Process	Description	Advantages	Disadvantages
Co-Composing	Similar to biosolids composting, except biosolids is a component in the composting process, with municipal solid waste	• Lower per ton capital and operating costs • Moisture, nitrogen supply for solid waste composting	• Potential for odors • Metal in biosolids may reduce compost value
Vermi-composting	Dewatered sludge mixed with earthworms. Earthworms consume solids producing stabilized castings	• Low capital cost • Lower potential for odors	• Ammonia toxic to worms • Separation of worms and metal contamination of worms • Limited full-scale experience
Thermal Drying - Direct Rotary Dryer	Moisture evaporated from biosolids by mixing hot gas with the biosolids in a rotating drum	• High heat transfer rates due to direct contact of the drying medium with the biosolids, thereby decreasing the residence time of the biosolids within the dryer • Flexibility of temperature control achievable by varying the flow and/or temperature of the hot gas over the biosolids	• Potential for combustion and explosions of the biosolids material in the dryer • Thermal inefficiency due to high sensible heat loss in the stack gases • The large volume of off-gas requiring treatment for dust entertainment and odors
Thermal Drying – Indirect Connective Drying (StorDT, Sludge Master IRC, Dragon Dryer)	Moisture evaporated from biosolids by contact with a hot surface. Hot gas or fluid passed through hollow screw augers and/or hollow shells to provide the heated surface. A small quantity of sweep gas is drawn through the dryer to remove the moisture.	• Minimal volumes of off-gas are produced when compared to direct drying; a relatively low flow rate of purge gas (if any) is required to discharge the vapor resulting from the evaporated liquid • Dust entertainment in the exhaust air is minimized when compared to direct dryers because the heating medium does not contact the biosolids • The atmosphere inside the dryer is inherently inert, minimizing the potential explosive and fire hazards • A higher thermal efficiency can be achieved • A variety of thermal media can be used including • Gas, oil, and steam	• Higher costs for providing a thermal source such as steam, hot water or hot oil (if such a source is not readily available) • Heat transfer surfaces could become fouled if not cleaned regularly
Vertical hearth dryers (thin film)	Solids conveyed vertically down several hearths	• Retrofit for multiple hearth furnace incinerators	• Limited full-scale experience
Thermotech	Variation of combined ATP, centrifuge dewatering and thermal drying. Several process variations	• Used without digestion • Slight increase in product stability over raw sludge thermal drying • Class A biosolids	• High capital costs • Potential for odors • Minimum size requires addition of other feedstock such as food waste or garbage • Limited full-scale operating experience
Flash Dryer	Spray atomization used to inject biosolids into drying zone	• Class A biosolids	• Potential for explosions • Few full-scale operating facilities

Process	Description	Advantages	Disadvantages
Solar Dryer (Thermo-System by Parkson)	Dries liquid or dewatered biosolids to over 70% using solar rays in a greenhouse-like drying chamber	• Energy and operator costs lower than other drying technologies • Consistent product • Odors are contained and can be treated	• Large land area required • Limited full-scale experience
Carver-Greenfield Process	Multiple-effect dehydration using carrier oil	• Class A biosolids may be possible	• Powder product potentially explosive • High capital and operating costs • Limited full-scale facilities
Centridry Process (HumbolDT)	Combined dewatering and drying in a centrifuge	• Class A biosolids may be possible • No solids recycling	• Limited full-scale experience
DryVac / Rollfit	Combines RPFP with thermal drying.	• Class A biosolids may be possible	• Limited full-scale experience
Infrared drying	Variation of indirect drying using infrared heating elements	• Similar to indirect drying	• Limited full-scale experience
Microwave drying	Heat provided by microwaves		• No full-scale experience
Fluidized bed drying	Evaporation in a fluidized bed of sand.	• Rapid drying of sludge	• Limited to pretreatment for incineration • Limited full-scale operating experience
Tray / Belt Dryers	Biosolids conveyed on belts or trays through sev. drying zones		• No full-scale experience
Ball Bearing Dryer (DHV)	Heated ball bearings mixed with sludge in screw conveyors	• Low capital cost reported	• No full-scale facilities
EcoTechnology	Combination of dewatering, direct and indirect thermal drying		• No full-scale experience
Alkaline Stabilization	Biosolids mixed with alkaline materials, such as quick lime or hydrated lime, to increase the pH to inhibit biological activity. A temperature rise with quicklime addition may also kill pathogens and pasteurize the biosolids.	• Simplicity of operation; • Organic nitrogen content of sludge or biosolids is not significantly reduced; • High pH reduces pathogens and the odor potential • High temperatures generated when quicklime is used in post-dewatering stabilization also destroy additional pathogens	• High operating cost due to chemical consumption; • Difficult to handle chemicals; • Volatile solids are not oxidized; risk of odors redeveloping; • Ammonia generation during processing requires odor control; • Biosolids products with a high pH may have restricted uses; • The dry mass of the biosolids is increased considerably.
AASSAD (N-Viro)	Variation of conventional alkaline stabilization. CKD and LKD used as alternative source of CaO. Windrows used for air drying.	• Class A biosolids • Stable pH / high CCE • Good handling characteristics • Revenue from sale as liming agent	• High chemical req'ts • High operating costs • Increase in solids mass • Two chemicals added
Biodry (N-Viro)	Same as AASSAD, except one-pass dryer and scrubber used rather than windrow	• Similar to AASSAD • Improved containment of ammonia and other odor emissions • Only one chemical added	• Similar to AASSAD • High capital and O&M costs

Process	Description	Advantages	Disadvantages
Envessel Pasteurization (RDP)	Variation of conventional alkaline stabilization. Heated screws and through in mixer used to supplement heat from chemical reaction	• Class A biosolids • Low operating costs • Lower chemical req'ts • Flexible operation	• Potential pH instability • Product handling concerns • Odor concerns
Chemifix	Sludge blended with alkaline materials, Portland cement and sodium silicates	• Product with high compressive strength	• High operating cost • Limited full-scale applications
Pori ST Process	Dewatered biosolids further processed by acidification, steam injection, lime addition and second-stage dewatering	• High cake solids content (65 – 70% TS)	• High processing costs • No full-scale facilities
Biofix (Synagro/ Biogro)	Variation of conventional alkaline stabilization. Quicklime blended with biosolids	• Class A or B biosolids • Flexible operation	• High chemical requirements • High operating cost
Bioset	Variation of conventional alkaline stabilization. Sulfamic acid and quicklime blended with biosolids	• Class A biosolids • Lower chemical requirements • Lower area requirements	• High capital costs • Two chemicals added • Potential pH instability • No full-scale fixed facilities

Process	Description	Advantages	Disadvantages
High Temperature Combustion /Oxidation Processes:			
Thermal Oxidation (incineration)	High temperatures and pressures used to break and oxidize cellular material, releasing bound water	• Maximum solids reduction • Energy recovery • Pathogens eliminated • Stable, odorless ash • Easily dewaterable ash	• High O& M costs • High capital costs • High maintenance requirements, ash may be hazardous due to metal leachability • Air pollution control • Public perception
Fluidized Bed Furnaces – thermal oxidation	Sludge combusted in a fluidized bed	• No additional fuel for dewatered cake greater than about 35 % TS	• Same as thermal oxidation
Multiple-hearth furnace – thermal oxidation	Sludge conveyed down over several hearths	• Similar to FBF	• Same as thermal oxidation • Afterburner required for control of emissions
RHOX Process	Variation of MHF with lower top-hearth temperature and external afterburner following air pollution control train	• Lower fuel usage • Lower metal and organics emissions • Economical retrofit technology	• Same as thermal oxidation • Limited full-scale experience
Melting Furnace (Kubota; Cormin)	Slagging furnace that forms ash into glassy material	• Metals will not leach from sintered ash product	• High capital and operating costs • Limited full-scale facilities in Japan only
Glass Aggregate (Minergy)	Heat drying followed by vitrification in a cyclonic slagging furnace with heat recovery	• Metals will not leach from glass aggregate • Production of electrical energy	• High capital and operating costs • Furnaces limited 300 t/d DS or larger • Consumes large quantities of natural gas • Limited full-scale facilities
Catalytic Extraction	Similar to melting furnace. Molten metals and chemical reactants added to oxidize solids	• Complete pathogen destruction and stabilization of solids	• No full-scale experience
Molten-salt Incineration	Combustion in bed of molten salts		• No full-scale experience
Wet Air Oxidation (Kenox)	Similar to Zimpro thermal conditioning; except longer retention time and complete oxidation of organics	• Nearly complete pathogen and organics destruction	• High capital and operating costs • High potential for odors • High maintenance costs • Limited full-scale experience
Deep-Shaft Oxidation (Vertox)	Variation of wet air oxidation in a deep shaft configuration	• Same as Wet air oxidation	• No full-scale facilities in operation
Super Critical Water Oxidation	Oxidation at high temperatures (375 – 650°C) and pressures (220 – 250 bar)	• Rapid oxidation of organics	• Corrosion concerns • No full-scale experience

Process	Description	Advantages	Disadvantages
Oil from sludge (pyrolysis)	Dewatered biosolids pyrolized to produce a viscous oil product. Char (ash) generated as a by-product.	• Reduces solids mass • Produce small quantities of reusable oil product • Small land requirement	• Scaling concerns • Unproven at full-scale • Potential for odors • High capital cost • Drying required • Oil characteristics poor
Gasification (pyrolysis).	Variation of Oil-from-Sludge process. (Syngass – Thermanetic, Renugas)	• Methanol or low BTU gas produced • High capital and operating costs	• No full-scale experience
Electric-arc gasification	Variation of gasification. Heat from electric air, rather than oxidation		• No full-scale experience
Microwave gasification	Combination of pyrolysis and combustion	• Sludge volume reduced • Energy recovered	• No full-scale experience
Co-gasification	Variation of gasification using coal and sludge	• Metals encapsulated at high operating temperatures up to 2,500°C	• High capital and operating costs • No full-scale experience
Oil Extraction (Best, McDonald) Process	Solvent mixed with liquid biosolids, with dewatering, drying, and distillation	• Separates oil from contaminated sludges	• No full-scale experience on biosolids

Table A-9 compares the different biosolids products and end-use options.

Table A-9. Comparison of Biosolids Products and End-uses

Process/	Description	Advantages	Disadvantages
Biosolids End Uses / Disposal:			
Agricultural Land	Injection/incorporation of biosolids into soil on farm sites used for crop growth or pasture land	• Nutrients in biosolids recycled for crop growth • Indirect benefit to Region by reduced fertilizer costs for farmers • Biosolids dewatering not required	• Seasonal application; large storage facilities required • Dependant on willingness of farmers to accept biosolids and farming practices (ie: crop selection) • Weather dependant
Forested Land	Application of biosolids on forested sites to provide fertilizer for tree growth. Typically surface applied on mature stands from logging roads	• Nutrients recycled for tree growth • Biosolids dewatering not required • Improves nature habitat	• Consistent application rate difficult due to rough terrain, limited trails for application vehicles • Application to clear-cuts may affect tree survival due to weed & brush growth
Land Reclamation	Application on disturbed lands at high application rates to provide sufficient organic matter for vegetative growth	• Organic matter and nutrients supports vegetative growth • Reduces environmental impacts (i.e. AMD) • High application rates	• Pretreatments to reduce risks of nutrient, pathogen runoff may be required • Long travel distances to application sites

Process/	Description	Advantages	Disadvantages
Landfill Disposal (monofil, co-disposal, dedicated land disposal)	Biosolids disposed in a landfill	• Year-round operation (not weather dependant) • Reliable disposal method	• Landfill space consumed • High tipping fees
Public Contact (e.g. golf courses)	Application to turf grass, gardens to provide nutrients for vegetative growth. High level of pathogen reduction required since the public may come into contact with the biosolids.	• Potential revenue from sale of biosolids	• High degree of processing required • Potential liability due to public perceptions
Biosolids Products			
Digested Biosolids (liquid)	Liquid product with solids content of 3 – 5 % TS	• Nutrient content conserved • Dewatering not required	• Limited end uses (i.e. agricultural, forested land) • Large storage facilities required
Dewatered Biosolids	Digested biosolids dewatered to a solid material	• Volume reduced	• High odor potential
Compost	Aerobically stabilized organics	• Low odor potential	• High capital and operating costs
Ag-Lime Substitute	Alkaline stabilized biosolids with a high calcium carbonate equivalency (CCE)	• Increases pH of soil • Soil conditioner	• Potential for odor redevelopment
Fertilizer	Dried biosolids used as a component in fertilizer production	• Revenue from sale as fertilizer, usually based on nitrogen content	• Potential for odor redevelopment • High costs to produce
OCI Waste Conversion System	Anhydrous ammonia and sulfuric acid added to drying process to fortify pellets	• High nutrient content	• High cost of processing
Ash	Ash from incineration process	• Application to agricultural land in some cases	• Generally limited to landfill disposal
Brick Production (BioBrick)	Sludge mixed with clay in brick kilns	• Pathogens destroyed	• Lower strength than regular bricks
Aggregate (Minergy)	Dewatered biosolids, ash and clay dried to produce large diameter aggregate	• Light-weight aggregate produced for limited use in masonry and structural concrete applications	• High cost of production
Metal recovery	Metals recovered from ash by acidification, extraction, precipitation	• Potential revenue from metals recovered	• High cost of processing • No full-scale experience
Fuel	Oil, gas (ethanol, methanol)	• Energy value of fuel produced	• High cost of production
Cement-Kiln Fuel	Dewatered or dried sludge burned in cement kiln	• Reduces fuel requirements • Reduces nitrogen oxide emissions from kiln	• Increased ash generation in kiln • Increased contaminants in cement • Limited full-scale operations