Biosolids master planning: a roadmap to success

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Abstract: Biosolids master planning is critical to the long term sustainability of a wastewater plant. However, when wastewater treatment plants are designed or expanded, biosolids treatment and final use may not receive the same consideration as the liquid stream. Careful planning and design of the biosolids management system can minimize unforeseen modifications and risks resulting from regulatory changes, reduced access to land application or landfill, or unanticipated operating cost increases. An effective biosolids plan must provide direction for the future, while considering opportunities for diverse outlets, potential for technology changes, and long term sustainability. This paper discusses the elements of an effective biosolids master plan and provides information from three biosolids planning case studies as illustrations.

Keywords: Biosolids master planning; residuals management; sustainability

Introduction

Biosolids master planning often does not receive the same level of attention as the liquid stream processes at a wastewater treatment plant. Not only are the disposal and final use of the solids somewhat of an afterthought, but selection of a biosolids management alternative can be a more complicated decision than selection of liquid stream treatment, which is typically designed to meet specific regulatory effluent requirements. While a number of liquid treatment technologies can be used, the design requirements are fairly straightforward. Conversely, biosolids management can offer a wide variety of final use and disposal options, which, in addition to regulatory requirements, also drive biosolids treatment technology selection.

Biosolids treatment and management systems also have a tendency to “evolve”. It is not unusual for publicly owned treatment works (POTWs) to install the minimum treatment required to address immediate needs, with little consideration for future regulatory changes or system flexibility. Further, over-reliance or lack of oversight of contract operations can increase potential risks to a POTW. A biosolids master plan ensures that as many factors as possible are addressed when developing the POTW’s biosolids roadmap. While treatment requirements are somewhat dynamic and technologies continually emerge, the master planning process can be used to identify flexible management options that can minimize the impact of future changes.

Elements of a Master Plan

While the drivers and issues vary with each installation, the methodology and key elements of a master plan are somewhat universal. The most critical step is to develop a comprehensive strategy to effectively collect and process information on plant operations, existing facilities and equipment, regulatory information, and drivers for change, to ensure that the result of the master planning process is a viable tool that reflects the needs of the owner for the immediate and long term planning period. Within the planning process, a number of elements must be addressed to develop a complete and accurate plan. These elements are as follows:

- **Understand your current system**: A thorough evaluation of the POTW’s existing biosolids program (from end-use/disposal through plant influent) is necessary in order to understand...
current bottlenecks or deficiencies, determine baseline conditions, and need to create alignment with overall organizational and operational policies and goals. The National Biosolids Partnership, an alliance of the National Association of Clean Water Agencies (NACWA), Water Environment Federation (WEF), and U.S. Environmental Protection Agency (EPA), has developed checklists and templates to aid POTWs in assessing their current program with respect to sustainable biosolids management. These resources are available on the NBP website and are based on ISO principles, in addition to outreach and interaction with program stakeholders.

- **Determine system drivers.** It is important to understand the issues and concerns driving the master planning process. Many of these are apparent, such as anticipated changes in regulations or ordinances. It is advisable to discuss potential modifications in regulations or ordinances with the appropriate government officials to identify issues that could impact a biosolids master plan. There can also be hidden drivers, based on past staff experiences, staff personalities, or unseen political or outside influences. Input from staff and key decision makers should be encouraged as early as possible during the master planning process to help identify hidden drivers.

- **Identify planning period.** Due to the changeable nature of regulatory and social/political requirements, planning periods for biosolids master plans should typically address short term and long term goals, using 5 to 10 year periods for short term and 15 to 20 year periods for long term goals, respectively. The 20 year period also corresponds with the expected lifespan of many types of processing equipment.

- **Identify viable final uses for biosolids.** It is important to “begin with the end in mind” when developing biosolids management alternatives. More than one POTW has implemented treatment processes only to be faced with non-viable end uses. Possible final uses range from landfill disposal of cake or ash to beneficial use through land application or conversion to an energy product. After identifying suitable end uses, categories of treatment technologies can be selected to support the potential end uses. If a beneficial final use is identified, market studies may be required to confirm demand and access to the market. It is also important to consider flexibility of outlets. One of the most important lessons learned from biosolids management is that the only sure thing is change. Regulatory and market conditions can change during the life of a project; consequently, options that provide flexible outlets are attractive. All options should include backup or contingency plans in the event that the primary end use is no longer available.

- **Identify economic factors affecting alternative selection.** It can sometimes be difficult to determine expected costs for labor and utilities. Future rates can vary not only with expected inflation, but based on market conditions. Utility rates often fluctuate with time of use. Since estimating future costs is an inexact science, economic evaluations should include a sensitivity analysis. This will help identify the economic risk associated with different options under varying operating cost conditions.

- **Determine non-economic factors impacting selection.** Non-economic factors typically include both social and environmental issues, such as flexibility, impact on neighbors, odor potential, carbon footprint, system complexity and reliability. While the list of non-economic factors is similar for most installations, the importance of each is site specific. Moreover, the potential risk (e.g., safety, environmental, regulatory, operations, public, likelihood of seeing your POTW’s program in a newspaper headline) associated with these non-economic factors is highly variable and can be significant if not adequately addressed during the master planning process. An evaluation with subjective scoring of non-economic factors does not always provide a representative picture of potential risk and the need for a mitigation plan, and can provide an unbalanced comparison of end-use options and treatment technologies.

- **Investigate status of technologies.** Emerging technologies often appear attractive from a capital or energy recovery perspective. However, newer technologies typically have limited information on long term reliability or true operating costs. It is important to be aware of the
uncertainties associated with an emerging process and, in conjunction with the owner, to evaluate sensitivity to this risk.

- **Determine sustainability of process evaluated.** While sustainability has long included issues such as reliability, it has expanded to include consideration of long term availability of the selected final use options, energy use, carbon footprint, impact of future regulations, political climate, and resource recovery.

Each of these issues has an impact on the suitability of a system and technology; however, the impact or weight of each of these issues varies among plants and utilities. Identifying the true weights is often an iterative process, based on information provided by the stakeholders, including plant and utility staff, rate payers, political and environmental organizations, as well as engineering experience.

**Master Planning Methodology**

The development of a biosolids master plan is a step-wise process based on using a team approach, which combines the knowledge and experience of the owner and the entity performing the planning. The basic steps are as follows:

1. **Information gathering.** This step includes compilation of plant data, information on the existing system and equipment, solids quantities, quality, and trend data, regulatory information, drivers and issues. This step typically requires site visits, data evaluation, formal and informal discussions with staff. Preliminary investigation into possible final use options should be performed during this step.

2. **Educational and decision making workshops.** Workshops are an effective tool to disseminate information on technologies, to obtain input and feedback, and to make decisions. During a typical master planning process, educational workshops are used to update the team members on technology descriptions, status, and suitability. Workshops are also used to screen possible alternatives to a manageable number for evaluation to avoid consuming excessive resources in terms of time and money, as well as diluting the level of detail that can be applied to any of the alternatives. Screening methods are used to reduce the “world of options” to those that are representative of the best combination of final use and technologies. While the number of alternatives evaluated varies, an effective master planning process typically includes three to six major alternatives. Since the planning process is a “big picture” evaluation rather than a design, detailed variations should be avoided as much as possible. If a management alternative is selected, additional investigation into process equipment should be performed to identify the desired system configuration and design. The type of screening processes used can vary from a discussion of issues and technologies with the planning team to a life cycle analysis based on preliminary sizing, costs, and non-economic factors.

3. **Use of advisory groups.** Advisory groups consisting of staff from utilities experiencing similar drivers and issues can be very useful when identifying and screening management alternatives, providing a “fresh set” of eyes, and identifying risks or challenges associated with different types of treatment technologies, delivery methods, and operations. When organizing an advisory group, ideal members belong to utilities of similar size and in a somewhat similar geographic region, maximizing the similarity of drivers and issues. The benefit increases if the advisory group members have recently performed a master planning activity. An additional benefit is the opportunity for utility managers to discuss organizational and management issues related to potential changes in “biosolids culture.” For example, a decision to cease thermal oxidation at a plant and initiate digestion, hauling, and land application represents a major change in operations and may pose process and management challenges and costs that are difficult to ascertain in the planning process.
4. **Develop system requirements and life cycle costs.** Equipment and facility requirements for the selected management alternatives should be developed based on current and future solids quantity and quality information and should address implantation and construction issues, site availability, phasing options, and life cycle costs. Detailed investigation into market opportunities for beneficial use options can be conducted during this step. Permitting requirements, while identified during the information gathering step, should be investigated and confirmed.

5. **Perform a non-economic evaluation.** Non-economic factors are usually applied to management options and technologies during the initial screening. However, the non-economic evaluation for each of the retained alternatives should be re-visited to confirm the results after refinement.

6. **Check results and generate recommendation.** While the results of each step should be confirmed as part of the process, it is possible that the final results and the ensuing recommendation may be a poor fit for unforeseen reasons. Therefore, it is always necessary to perform a check to test for results and to elicit feedback. Any discrepancies in assumptions that impact results should be addressed and corrected prior to generating recommendations.

**Case Studies**

The master planning methodology and elements can be illustrated through the use of three case studies, Gwinnett County, Georgia; Oklahoma City, Oklahoma; and Reading, Pennsylvania. The Georgia and Oklahoma systems include multiple treatment plants and therefore the master planning process included regionalization issues and options. The Pennsylvania system consists of a single plant.

**Gwinnett County, Georgia**

The Gwinnett County Department of Water Resources (DWR) has three wastewater treatment facilities with varying liquid and solids treatment processes. The total system design flow is 405 ML/d (107 mgd).

The F. Wayne Hill Water Reclamation Center is a 227 ML/d (60.0 mgd) biological nutrient removal facility. The liquid stream processes generate primary solids and waste activated solids (WAS). Primary solids are thickened in the primary clarifiers to approximately 4 percent total solids (TS); WAS is thickened using centrifuges. The primary solids and thickened WAS (TWAS) are anaerobically digested in five egg shaped digesters. Limited sampling data indicate that the digestion process achieves approximately 25 to 30 percent volatile solids reduction (VSr). Digester gas is compressed and stored in four gas storage tanks and is used for digester heating. Excess gas is flared. Dewatering centrifuges produce cake with an average solids concentration of 22.5 percent. The centrifuges are currently operated approximately 12 hours per day, from 2300 to 1100, to take advantage of favorable power rates. Dewatered cake is hauled to a landfill for disposal by contract operators.

The Yellow River Water Reclamation Facility (WRF) is currently in the design process to expand the plant from 55 ML/d to 83 ML/d (14.5 mgd to 22.0 mgd). The proposed process include primary clarification, activated sludge treatment with biological nutrient removal, rotary drum thickening (RDT) of WAS, anaerobic digestion, and centrifuge dewatering. The plan calls for construction of two egg shaped digesters. The digesters are sized to provide an SRT of 12.2 to 15.0 days at design conditions. Expected VSr will 23 to 29 percent. Digester gas will be used for digester heating; excess digester gas will be flared. The digested solids will be dewatered using high speed centrifuges, with an expected cake solids concentration of 22 percent. Dewatered cake is hauled to a landfill for disposal by contract operators.
The Crooked Creek WRF is currently in design for plant improvements with a planned expansion from 61 ML/d (16 mgd) to 95 ML/d (25 mgd). The planned improvements will include biological nutrient removal and solids treatment processes. The improvements will not include primary clarifiers and will generate only WAS. The WAS will be stored in aerated storage basins prior to thickening using new RDTs. Centrifuges will be used to dewater the TWAS to an expected cake concentration of 25 percent TS. Dewatered cake is hauled to a landfill for disposal by contract operators.

At the time of the biosolids master planning process, two of the three facilities were in preliminary design for expansion, including the solids treatment processes. Dewatered cake generated at the three facilities is landfilled by the DWR; however, with the increasing cost of landfill disposal, the DWR was interested in alternatives that would be sustainable from a cost and environmental perspective. Since two of the three plants were in the redesign process, it was considered a good opportunity to evaluate long term biosolids management options.

Information on the key elements for the master plan was obtained through discussions with the DWR and its consultants. Based on this information, the system drivers were determined to be a need for a cost effective long term solution. Landfill disposal was acceptable, but provided no flexibility of outlets and increases in tipping fees would have a tremendous impact on the DWR’s operating costs. Green solutions were preferred, but cost and flexibility were paramount. Bulk land application of cake was not considered viable due to increasing urbanization in the area. Emerging technologies were of interest, but the DWR preferred a well-established technology for implementation. Energy recovery was desirable and the DWR was pursuing energy reduction efforts; however, the relatively low electrical rate of approximately USD 0.06/kWh made the payback of energy-related projects unattractive. A 20 year period was used for the long term plan, with consideration of phasing for the short term.

A non-economic evaluation was performed during a technology discussion/screening workshop to narrow alternatives. Management options selected for further consideration included continued landfill disposal (with and without energy recovery through cogeneration [ER]), regional heat drying or regional incineration at the F. Wayne Hill plant, and heat drying at F. Wayne Hill and the Yellow River plants, with cake hauling from Crooked Creek to F. Wayne Hill. Permitting of incineration and distribution and sale of heat dried product were both considered to be viable, based on experiences at other facilities in the region. Landfill disposal of cake was a backup option for both incineration and heat drying alternatives; no backup options were identified for landfill disposal.

The results of the economic evaluation indicated that the least expensive option was incineration, followed by landfill disposal. Heat drying resulted in the most expensive options (Figure 1).

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Figure 1: Gwinnett DWR Alternative Cost Summary
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A sensitivity analysis of the alternatives showed that moderate increases in the landfill disposal rates would significantly increase lifecycle costs of landfill options, making them the most expensive alternatives, while moderate energy cost increases did not change the cost ranking of the alternatives, but made the heat drying alternatives even more expensive. Although heat drying was a high cost alternative, its flexibility of final uses was attractive for a long term solution.

Based on the results of the evaluation, a staged implementation plan was recommended, with continued landfill disposal for the short term, with conversion to incineration or heat drying in the future. Process design for the Crooked Creek and Yellow River plants were modified to support future implementation of either of these processes.

**Oklahoma City, Oklahoma**
The City of Oklahoma City owns four wastewater treatment facilities with a combined capacity of 399 ML/d (106 mgd).

North Canadian Wastewater Treatment Plant is a 300 ML/d (80 mgd) biological nutrient removal facility. The liquid stream processes generate primary solids and WAS. The primary solids are blended with gravity-thickened WAS in a series of holding tanks. The combined sludge, which has solids concentrations ranging from 3 to 8 percent TS, are dewatered to 23 percent TS using BFPs. The dewatered solids are lime stabilized to meet Class B criteria and are transferred to a storage pad prior to bulk land application. A portion of the stabilized biosolids is composted with wood chips using a windrow composting process. The finished product is distributed to local residents. The composting process also includes dewatered cake from the Deer Creek and the South Canadian WWTPs.

The Chisholm Creek WWTP is a 19 ML/d (5 mgd) facility with a multi-stage activated sludge process designed for BOD removal and nitrification. The solids generated from the primary clarifiers and WAS from the final clarifiers are stored in mixed sludge holding tanks and are hauled to Deer Creek WWTP for dewatering.

The Deer Creek WWTP is a 57 ML/d (15 mgd) plant with a combination of rotating biological contactors and an activated sludge process. The WAS from the final clarifiers is transferred to the primary clarifiers for co-settling with primary solids. The co-settled solids are pumped to sludge holding tanks, where they are blended with liquid sludge hauled in from Chisholm Creek WWTP. The combined solids are dewatered using two BFPs, stabilized with lime to Class B standards and conveyed to trucks for hauling to the North Canadian facility.

The South Canadian WWTP is a 23 ML/d (6 mgd) secondary plant consisting of two sequencing batch reactors (SBR) for biological treatment. The plant produces only WAS. The solids treatment facilities at the plant include thickening, aerobic digestion and dewatering. The WAS from the SBRs is thickened in gravity thickeners and pumped to aerobic digesters for stabilization to Class B standards. The stabilized solids are dewatered using a BFP to an average solids content of 14 to 15 percent TS. The dewatered biosolids are hauled to the North Canadian WWTP, where they are combined with solids from the other three plants.

Most of the solids generated at the plants (approximately 80 percent) are stabilized to Class B criteria using alkaline stabilization and bulk land applied. The remaining solids are composted to meet Class A criteria and are distributed to the public at no charge. All plants currently have contracted operations. While the current system was considered successful and cost-effective, the existing operations contract was expiring in 2012 and the City wanted to take the opportunity to evaluate long-term options. The City currently has plans to expand its composting operation. However, with the increasingly stringent regulations governing land application of Class B biosolids, the City wanted to evaluate alternate management systems, focusing on those that minimize or eliminate production of Class B material. The purpose of the planning effort was to
evaluate long-term biosolids handling and management practices for the four treatment facilities to identify immediate and future needs.

The key issues for the master plan were determined through discussion with City. System drivers were determined to be the desire for a cost effective solution, with an interest in maximizing beneficial reuse through composting. Oklahoma regulations require treatment to meet Class B criteria prior to landfill disposal and landfill disposal is expensive and has limited availability. Consequently, landfill disposal was not considered as a viable long term disposal option. Incineration was not eliminated from consideration, but air quality conditions in Oklahoma City had the potential to make incineration permitting difficult. Bulk land application was considered viable for the short term, but there were concerns with long term sustainability of a Class B program. Any land-based biosolids management practices considered would need to address the increasing concerns associated with phosphorus loadings and nuisance odors at the application sites. Energy recovery was not a significant issue. A 15 year planning period was used for the long term goals; short term goals were evaluated using a 3 to 5 year planning period.

A non-economic evaluation was performed during a technology discussion/screening workshop to narrow alternatives. Management options selected for further consideration included continued operation of the existing system, regional incineration of raw cake, regional composting of all solids, and anaerobic digestion of solids at the individual facilities, with regional drying. All regional treatment would be performed at the North Canadian plant.

The results of the economic evaluation indicated that the least expensive option was continuation of the current process. All other processes were significantly more expensive (Figure 2).

![Alternative Cost Summary](https://iwaponline.com/wpt/article-pdf/5/2/wpt2010038/383523/38.pdf)

**Figure 2:** Oklahoma City Alternative Cost Summary

A sensitivity analysis was performed to determine the effect of changes in natural gas and diesel prices on the overall operating costs for the solids processing alternatives. Increases in diesel prices associated with solids hauling had a significant impact on the operating costs for all options, with the greatest effect on the regional composting option, which was heavily dependent on hauled amendment requirements and diesel-based operating machinery. Increases in natural gas costs most dramatically affected the drying alternative. While digester gas provided approximately 40 percent of the dryer energy requirements, the remaining 60 percent had to be supplied in the form of natural gas. In contrast, the incineration process was autogenous at dewatered cake concentrations greater than 25 to 26 percent and required supplemental natural gas only during startup.

Based on the results of the evaluation, continuation of the existing lime stabilization program was recommended for the short term. Alternate solids processes are to be gradually phased in when regulations and/or social and economic considerations mandate treatment to higher
standards. Phasing the capital improvements also allows the City the opportunity to react to future regulatory changes and trends. The recommended capital improvements phasing timeline for the City is illustrated on Figure 3.

Figure 3: Phasing Plan for Oklahoma City

Reading, Pennsylvania

The Fritz Island WWTP is a 108 ML/d (28.5 mgd) facility that produces Class B biosolids, which are dewatered and landfilled. This management program has worked well; however, due to increasing hauling distances to landfills and rising tipping fees, the City is concerned with long term dependence on landfilling. The biosolids treatment and disposal/final use practices were evaluated in conjunction with a facility upgrade to improve effluent quality.

The existing plant has primary clarification and trickling filter treatment of primary effluent. Primary solids are pumped to a mix tank where they are blended with trickling filter solids. The combined primary solids/biological solids are thickened to approximately 4 to 6 percent TS using gravity belt thickeners (GBTs) prior to digestion. Thickened solids are fed to three anaerobic digesters. The digesters are fed combined thickened secondary solids and primary solids three shifts per day, five days per week. During weekends, the thickening operation is suspended and the digesters are fed primary solids only. The digester VSr ranges from 45 to 53 percent. The existing digesters have had maintenance issues and the digester mixing equipment is out of service, limiting the digester mixing to the recirculation from the digester heat exchangers. Digested solids are dewatered using belt filter presses (BFPs) to approximately 19 percent TS. Dewatered solids are hauled by a contractor to a landfill for disposal.

The system drivers were determined to be the desire to eliminate long term dependence on landfill disposal of cake as well as providing extensive upgrades to the existing solids treatment system in conjunction with a mandated liquid stream expansion/upgrade. Little land is available for Class B bulk land application; consequently, this was not considered to be a viable final use. Based on some previous negative experiences with newer technologies, only well established technologies were of interest to the City. Faced with dramatic increases in electrical rates, energy recovery and on-site power production were desirable. A 20 year planning period was used, with consideration of phased implementation to reduce initial capital costs and to provide flexible response to intermediate and long term changes in technology developments and local issues.

Management options selected for consideration included incineration of raw solids, heat drying of digested solids, and land application of a Class A cake. Landfill disposal was included as a “base case” for comparison. Since Pennsylvania regulations require stabilization prior to landfill disposal, digestion was included for the landfill option. Landfill disposal of cake was a backup option for all alternatives other than landfill; no backup options were identified for landfill disposal.

The results of the economic evaluation indicated that the least expensive option was incineration, followed by landfill disposal (Figure 4). While the City was extremely cost sensitive, the accompanying non-economic analysis indicated that with the given local issues, heat drying had the most favorable score, followed by landfill disposal. Incineration had the least favorable
non-economic score. The low score for incineration was driven by concerns with public perception and permitting and the need to provide contract stabilization to landfill cake during periods when the incinerator was not in service.

![Alternative Cost Summary](image)

**Figure 4:** Reading Alternative Cost Summary

Based on the results of the economic and non-economic analysis, conversion to heat drying was the recommended alternative. However, phased implementation of the solids treatment processes was also recommended to reduce initial capital outlay. This would allow the delay of drying until such time that landfill disposal costs were prohibitive.

A refinement of the recommended result included co-digestion of hauled greasy waste and biogas co-generation. These additions were identified as cost effective methods of reducing reliance on purchased electricity and increasing revenues through grease tipping fees.

**Conclusions**

The biosolids master planning process is a critical step in addressing near- and long-term biosolids needs. Using a well-defined methodology, taking into account key information and ensuring alignment with utility goals and objectives, will increase the likelihood of implementing sustainable, successful biosolids management systems. As shown through the case studies, suitable solutions vary for each utility, based on local drivers, conditions, and owner goals. A summary of the management alternatives selected for evaluation and resulting recommendations for the three case studies is presented in Table 1.

**Table 1:** Summary of considered and selected management alternatives

<table>
<thead>
<tr>
<th>Location</th>
<th>Reading, PA</th>
<th>Gwinnett Co., GA</th>
<th>Oklahoma City, OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of plants</td>
<td>1</td>
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<td>4</td>
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<tr>
<td>Total capacity (ML/d)</td>
<td>108</td>
<td>405</td>
<td>401</td>
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<tr>
<th>Final use options considered&lt;sup&gt;1&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>Landfill</td>
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<tr>
<td>Land application Class B solids</td>
</tr>
<tr>
<td>Land application Class A solids</td>
</tr>
<tr>
<td>Distribution of heat dried product</td>
</tr>
<tr>
<td>Incineration/ash disposal</td>
</tr>
<tr>
<td>Compost production</td>
</tr>
</tbody>
</table>

<sup>1</sup>Recommended alternative in bold text; <sup>2</sup>Recommendation for initial phase; <sup>3</sup>Recommendation for final implementation
As illustrated by the table, recommended long-term solutions can be significantly different than the recommended near-term solution. Consequently, it is important to design flexibility into the solution to allow for changing conditions.

The ranges of unit costs developed for each of the management systems is presented in Table 2. As shown in the table, the solutions recommended for long term implementation were not always the lowest cost option but were considered the best fit, based on local issues and drivers. In addition, some of the processes had highly varying unit costs, driven by the capacity and condition of existing equipment, new equipment requirements, and opex costs for final use options. This cost range illustrates the importance of understanding the site specific issues and requirements when generating cost estimates for biosolids management systems.

Table 2: Unit cost summary (USD/dry tonne)

<table>
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<tr>
<th>Location</th>
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<th>Oklahoma City, OK</th>
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<tbody>
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<td>Landfill disposal</td>
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<td>Land application</td>
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<td>Composting</td>
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