Biosolid Management System Alternatives Study

Wastewater Documentation Updates

This report identifies, describes and compares sewage sludge treatment technologies and disposal alternatives for the City and Borough of Juneau (CBJ). It was prepared collaboratively by Tetra Tech and CBJ staff.

I. BACKGROUND

CBJ owns and operates three wastewater treatment plants: Auke Bay (ABWTP), Mendenhall (MWTP); and Juneau Douglas (JDWTP). All of the plants provide secondary treatment using a biologically mediated process known as activated sludge. In order to maintain effectiveness and efficiency of the treatment process it is necessary to remove excess activated sludge from the treatment process. This sludge is known as waste activated sludge (WAS) and is composed of biological organisms, inert solids and residual wastewater. WAS from the ABWTP is aerobically digested and then trucked to the MWTP combined with the MWTP WAS and then dewatered with a belt filter press (BFP) to achieve a sludge cake containing approximately 15% solids and 85% water. WAS from the MWTP is not digested prior to dewatering. WAS generated by the JDWTP is aerobically digested and then dewatered to approximately 15% solids.

From 1990 to 2011, dewatered sludge cake from the MWTP was trucked to the JDWTP, combined with the dewatered sludge cake from the JDWTP, and incinerated in the fluidized bed furnace (FBF) located at the JDWTP. In 2011 the JDWTP FBF was decommissioned due to deterioration of the FBF, estimated repair cost of over $2 million and review of historical high cost of operation. CBJ responded by transporting the dewatered sludge cake for disposal at the local Capital Landfill and the

Arlington Landfill located in eastern Oregon; both landfills are operated by Waste Management Inc. (WM).

Approximately 18.5 wet tons per day of solid waste at 15% total solids are produced. This process annually requires electrical energy costing $20,000, the addition of dewatering polymers for costing $100,000, and approximately 3000 hrs of operating labor.

II. SLUDGE PRODUCTION RATES IN JUNEAU

In 2012 CBJ produced and disposed of approximately 7,280 wet tons of dewatered sludge cake and grit at a disposal cost of approximately $721,200. CBJ's records indicate that approximately 74% of the total dewatered sludge cake produced by CBJ's wastewater treatment plants was disposed of at the local Capital Landfill at a unit cost of approximately $88 per wet ton. The remaining 26% (1915 tons) of the dewatered sludge cake was not accepted by Waste Management (WM) for disposal at the Capital Landfill due to elevated concentrations of residual hydrocarbons contained in the sludge, so it was shipped to and disposed of in WM's Arlington Landfill at an average cost of $131 per wet ton (current cost is estimated to be $140/ton). On an annual basis, the MWTP and ABWTP together produce approximately 79% of the sludge while the JDWTP produces the remaining 21%.

Sludge production rates for year 2012 are presented in Table 1. Sludge production rates are significantly more variable from the JDWTP than from the combined MWTP and ABWTP. The peak week and monthly sludge production rates occurred July through mid-September, and is likely the consequence of peak tourist activity in Juneau, including cruise ships. Figures 1 and 2 provide a graphical illustration of the variability of the waste sludge production rates in 2012.

TABLE 1
Waste Sludge Production Rates for Year 2012

Time Period	MWTP+ABWTP	JDWTP	All CBJ Plants
Annual	14.6 (2.19)	3.9 (0.59)	18.5 (2.78)
Max. 30-day Average	24.0 (3.60)	9.7 (1.46)	27.4 (4.11)
Max. 7-day Average	24.5 (3.68)	14.3 (2.15)	32.8 (4.92)
Max. Day	41.6 (6.24)	25.1 (3.77)	56.6 (8.49)

Values without parentheses are in wet tons per day, based on 15% solids basis and 85% water.
Values within parentheses are tons per day, dry solids basis.

Sludge production rates in 2012 are greater than the annual production rates for years 1986-1988 as reported in the Sludge Treatment and Disposal Facility Plan Amendment dated June 1989. The annual average daily sludge production rate for the MWTP (including the ABWTP) was 1.22 ton per day, the JDWTP production was 0.725 tons per day and the total annual production was 1.95 tons/day, all dry solids basis. Overall this represents an annual increase of approximately 0.5% per year for the last 24 years. Sludge production by the MWTP has increased at a rate of about 2.5% per year while sludge production by the JDWTP decreased at an equivalent rate of 0.85% per year. The ratio of the sludge loads in the average day of the maximum month to the annual average day has not changed and remains to be about 1.5 to 1.

For this initial screening of biosolids management technologies, the sludge production rates shown in Table 1 were used to estimate capital and treatment costs. Appropriate allowances for growth should be defined before proceeding with cost budgeting and design.

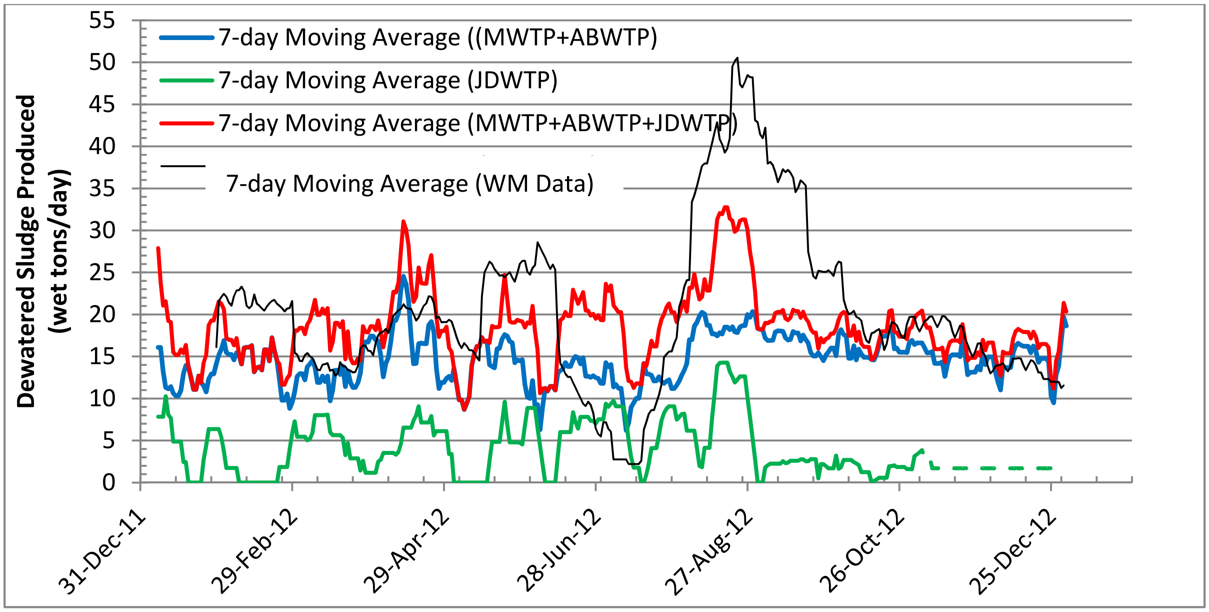

Figure 1. Weekly averages of daily sludge production by the JDWTP, MWTP+ABWTP, and the sum of all dewatered sludge produced by CBJ. WM data includes CBJ dewatered sludge transported to Capital Landfill and Arlington Landfill.

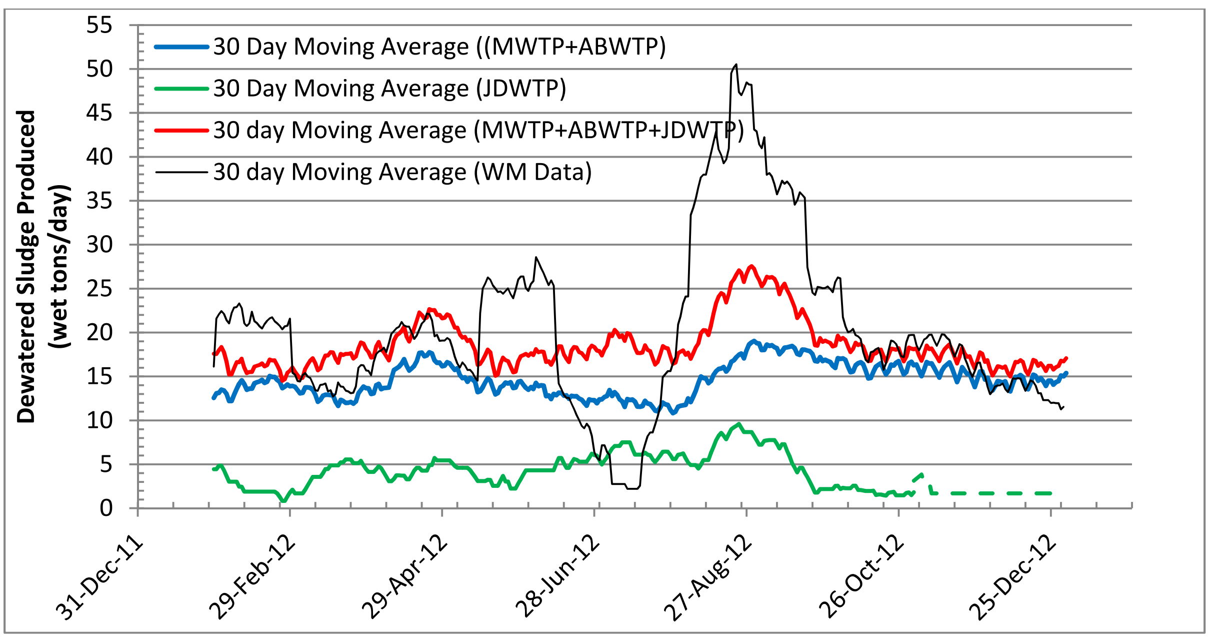

Figure 2. Monthly averages of daily sludge production by the JDWTP, MWTP+ABWTP, and the sum of all dewatered sludge produced by CBJ. WM Data includes CBJ dewatered sludge transported to Capital Landfill and Arlington Landfill.

III. IMPORTANT REGULATORY FACTS CONCERNING USE OR DISPOSAL OF BIOSOLIDS

As required by the Clean Water Act Amendments of 1987, the US EPA developed the Standards for the Use or Disposal of Sewage Sludge (40 CFR 503) to protect public health and the environment from any reasonable adverse effect of certain pollutants that might be present in sewage sludge biosolids. The regulations became effective March 22, 1993. The 503 regulations establish requirements for the final use or disposal of sewage sludge biosolids when the biosolids are:

- applied to land to condition the soil or fertilize crops or applied to the vegetation grown in soil,
- placed on a surface disposal site for final disposal, and
- fired in an incinerator

For each of the regulated uses or disposal practices identified above, the 503 regulations provide general requirements, toxic metals and pathogenic bacteria limits, management practices, operational standards and frequency of monitoring, record keeping and reporting.

The 503 regulations do not apply to sewage sludge that is placed in a municipal solid waste landfill, but such sludge must meet the provisions of 40 CFR 258 Design Criteria for Municipal Solids Waste Landfills. Sewage sludge that is to be landfilled must be dewatered or otherwise concentrated so that it meets the "paint filter test". Passing this test means that no liquid is released when the sewage sludge is placed in a paint filter (60-mesh) within a 5 minute test period.

For sewage sludge that is not placed in a municipal solid waste landfill or monofill, the EPA 503 regulations utilize two classificatons of biosolids defined by their pathogenic characteristics - Class A and Class B. Generally, Class A biosolids meet more stringent standards and are allowed to be discharged more widely in land application uses. Discharge of Class B biosolids generally requires buffers, limits on public access and crop harvest restrictions.

Class A biosolids must be treated by one of the six alternatives shown in Table 2 to reduce the density of pathogenic organisms at the time of final use or disposal. The specific requirements for pathogens in Class A biosolids are less than 1000 fecal coliform MPN per gram of total solids (dry with basis) and less than 3 *Salmonella* sp. MPN per 4 grams total solids (dry weight basis). When compared to Class B biosolids, more disposal options may exist for Class A biosolids due to the high treatment standards required for classification.

Class B biosolids must be treated by one of the methods shown in Table 3. Class B biosolids require less stringent standards for treatment and, once treated, contain small but compliant amounts of bacteria. Because of potential contamination concern, disposal options for Class B biosolids may be limited when compared to Class A biosolids.

EPA 503 regulations also classify biosolids using toxic metal standards. The two classifications used are Exceptional Quality (EQ) biosolids and Pollutant Concentration (PC) biosolids. The limits for each metal are the same for EQ biosolids and PC biosolids. The difference is that EQ biosolids must also meet Class A pathogen standards and PC biosolids need only meet Class B pathogen standards. If biosolids meet the EQ/PC limits, the land application site is not subject to cumulative pollutant tracking of annual loading. The EQ/PC limits are shown in Table 4.

Biosolids that are disposed of or reused on land and not placed in a municipal landfill must also meet the vector attraction reduction (VAR) requirement set for in the EPA 503 regulations. VAR is required because unstablized biosolids pose a disease risk when they come in to contact with humans or other susceptible hosts, both plant and animal. Flies, mosquitoes, fleas, rodents and birds can transmit pathogens to humans and other hosts through physical contact or biologically by playing a specific role in the life cycle of the pathogen. Reducing the attractiveness of the biosolids to vectors reduces the potential for transmitting diseases from pathogens in biosolids. The 503 regulations recognize 12 options that can be used to demonstrate that treated biosolids meet the VAR requirements as indicated in Table 5. Option 12 applies only to treatment of domestic septage. Options 9-11 are not considered viable alternatives for Juneau due to seasonal climatic conditions that would require periodic accumulation and storage of biosolids (i.e. frozen ground conditions in the winter).

TABLE 2
Pathogen Reduction Requirements for Class A Biosolids

Alternative	Restrictions
1. Thermally Treated Biosolids	Use one of four time-temperature regimes
2. Biosolids Treated in a High pH and High Temperature Process	Specific pH, temperature, and air-drying requirements
3. For Biosolids Treated in Other Processes	Demonstrate that the process can reduce enteric viruses and viable helminth (parasitic intestinal worm) ova. Maintain operating conditions use in the demonstration
4. Biosolids Treated in Unknown Process	Demonstrate by testing that process is unnecessary to reliably achieve the density pathogenic organisms as measured by fecal coliform or *Salmonella species* bacteria to specific density requirements at the time of biosolids use or disposal or when prepare for sale or given away
5. Use of Process to Further Reduce Pathogens (PFRP)	a. **Composting** – in-vessel or aerated static pile method with biosolids maintained at 55^{o}C or higher for 3 days; or windrow method with biosolids maintained at 55^{o}C or higher for 15 days or longer and turned a minimum of five times while temperature of compost is 55^{o}C or higher. b. **Heat drying** – biosolids are dried by direct or indirect contact with hot gases to reduce moisture content of biosolids to 10% or less. Either temperature of biosolids particles exceeds 80^{o}C or the wet bulb temperature of the gas in contact with the biosolids as the biosolids leave the dryer exceeds 80^{o}C. c. **Heat Treatment** – liquid biosolids are heated to a temperature of 180^{o}C or higher for 30 minutes. d. **Thermophilic aerobic digestion** – liquid biosolids are agitated with air or oxygen to maintain aerobic conditions and mean cell residence time (MCRT) of solids is at least 10 days at 55^{o} to 60^{o}C e. **Beta Ray Irradiation** – biosolids are irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at about 20^{o}C. f. **Gamma Ray Irradiation** – biosolids are irradiated with gamma rays from certain isotopes such as cobalt 60 and cesium 137 at about 20^{o}C. g. **Pasteurization** – liquid biosolids are heated and maintained at 70^{o}C or higher for 30 minutes.
6. Use of a Process Equivalent to PFRP	Biosolids are treated in a process equivalent to one of the PFRPs as determined by the permitting authority.

TABLE 3
Pathogen Reduction Requirements for Class B Biosolids

Alternative	Restrictions
1. Monitoring of Indicator Organisms	Geometric mean of seven samples of biosolids tested for fecal shall be less than 2 million MPNs (most probable number) per gram total solids
2. Biosolids Treated in a Process to Significantly reduce Pathogens (PSRP)	a. **Aerobic Digestion** – Biosolids are mixed with air or oxygen to maintain aerobic conditions for a MCRT and temperature between 40 days at 20°C and 60 days at 15°C. b. **Air Drying** – Biosolids are dried on sand beds or paved or unpaved basins for a minimum of three months with two of the three months with ambient average daily temperature above 0°C. c. **Anaerobic Digestion** – Biosolids are mixed in the absence of air or oxygen to maintain aerobic conditions for a MCRT and temperature between 15 days at 35°C to 55 °C and 60 days at 20°C. d. **Composting -** Biosolids are composted using in-vessel, static aerated pile, or windrow methods where the temperature of the biosolids is raised to and maintained at 40°C or higher for 5 days. For 4- hours in the 5-day period the temperature of the compost must exceed 55°C. e. **Lime Stabilization -** Sufficient lime is blended with the biosolids to raise the pH of the biosolids to 12 after 2 hours of contact.
3. Biosolids Treated in a Process equivalent to one of the PSRPs as determined by the permitting authority.	Biosolids must be treated in a process equivalent to one of the PSRPs as determined by the permitting authority

TABLE 4

COMPARISON OF ALLOWABLE TOXIC METALS LIMITS FOR BIOSOLIDS APPLIED TO LAND AND TOXIC METALS CONCENTRATIONS REPORTED FOR MWTP AND JDWTP BIOSOLIDS

Metal	Ceiling [mg/kg]	EQ / PC [mg/kg]	JDWTP [mg/kg]	Meets EQ / PC	MWTP [mg/kg]	Meets EQ / PC
Arsenic	75	41	<6.3 -- <89 (9)	?	< 10 -- <710 (12)	?
Beryllium	85	39	<0.097 -- <1.3 (9)	Y	<0.15 -- < 11 (12)	Y
Cadmium	3000	1200	<0.39 -- <4.7 (9)	Y	<0.62 -- <44 (12)	Y
Chromium	4300	1500	2 -- 36 (9)	Y	<1.5 -- <110 (12)	Y
Lead	840	300	3.5 -- 36 (9)	Y	<4.6 -- <330 (12)	?
Mercury	57	17	1.1 -- 4.6 (7)	Y	0.30 -- 0.75 (12)	Y
Molybdenum	75	----	NT (0)	?	NT (0)	?
Nickel	420	420	<1.0 -- < 22 (9)	Y	<14 -- <220 (12)	Y
Selenium	100	36	NT (0)	?	NT (0)	?
Zinc	7500	2800	<1.4 -- 3.65 (5)	Y	NT (0)	Y

Ceiling means ceiling concentration limit for biosolids applied to land as define in 40 CFR 503.13

EQ: Exceptional Quality. EQ biosolids also meet Class A biosolid pathogen standards. When the above limits are not exceeded, the biosolids are not required to meet cumulative pollutant or annual loading limits.

PC: Pollutant Concentration.. PC biosolids also meet Class B biosolid pathogen standards. When the above limits are not exceeded, the biosolids are not required to meet cumulative pollutant or annual loading limits.

?: Additional testing is needed either due to lack of data or existing test results were not reported to a degree of accuracy to make a determination.

NT: Not tested.

Values not in parentheses are pollutant concentration, mg/Kg.

Values in parentheses refer to number of samples.

TABLE 5

OPTIONS FOR ACHIEVING THE VECTOR ATTRACTION REDUCTION REQUIREMENTS

Option	Vector Attraction Reduction Requirements
1	Reduce mass of volatile solids by at least 38%.
2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench scale unit
3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench scale unit
4	Meet specific oxygen uptake requirement (SOUR) of equal to or less than 1.5 mg O2 per gram of biosolids (dry weight basis) at 20 ^{o}C for aerobically treated biosolids.
5	Use aerobic process at greater than 40 ^{o}C and average temperature of 45 ^{o}C for 14 days or longer (e.g. biosolids compositing)
6	Add strong alkali to raise pH at least 12, measured at 25'C, and without the addition of more alkaline material, maintain a pH of at least 12 for 2 hours; and maintain a pH of at least 11.5 without addition of more alkaline material for an additional 22 hours.
7	Reduce moisture content of biosolids to at least 75% solids; biosolids must not contain unstabilized biosolids from primary treatment and must be have a solids concentration of at least 75% before the biosolids are mixed with other materials.
8	Reduce moisture content of biosolids which may include unstabilized solids to 90% solids.
9	Inject biosolids beneath the solids surface within a specified time depending on level of pathogen treatment.
10	Incorporate biosolids applied to or placed on the land surface within a specified time periods after application to or placement on the land surface
11	Cover biosolids placed on a surface disposal site with soil or other material at the end of each operating day.
12	Alkaline treatment of domestic septage to pH 12 or above for 30 minutes without adding more alkaline material.

IV. DESCRIPTION OF BIOSOLIDS MANAGEMENT ALTERNATIVES

Sludge is a byproduct of the wastewater liquid stream treatment process. The solids removed from the sedimentation tank following wastewater process liquid stream reactor are mostly returned to the liquid stream process tank to maintain the food-to-microorganism ratio within the activated sludge process. Solids must be removed from the activated sludge process to prevent process overload and to achieve process efficiency. The solids are contained in a dilute suspension consisting of 0.5 to 1 percent solids in water; this suspension of microorganism and inert material is called waste activated sludge (WAS). The solids contained in CBJ wastewater sludge consist of 83% organic matter and 17% inert material which is typical for the type of treatment process and wastewater from similar communities.

Only the organic fraction of the sludge can be reduced by digestion or incineration or other oxidative processes. The purpose of a biosolids handling process is to reduce the mass and volume, and if sewage sludge is to be applied to land or beneficially used, to stabilize the organic fraction of the WAS to meet US EPA Sewage Sludge Regulations 40 CFR 503.

A biosolids management system will be comprised of a disposal alternative and a treatment alternative or multiple combinations of each. Be aware that not all disposal options are feasible for all treatment methods. Also, some disposal options may only be realistic for limited amounts of biosolids. For this reason, a combination of alternatives may be necessary to manage all of CBJ's needs.

1. DISPOSAL ALTERNATIVES

A. Landfill – Waste Management Local and Out of Town

Description:

Disposal of biosolids at a permitted sanitary landfill generally only requires that the biosolids do not contain free water as determined by the result of the paint filter test previously discussed. No pathogen or vector attraction reduction process is required for disposal of raw biosolids in a permitted sanitary landfill so long as the moisture requirements are met.

For approximately the last two years CBJ has adopted this approach to disposing of its wastewater treatment plant biosolids. Dewatering of the sludge to at least 12 to 14% solids content is generally required to meet the paint filter test and performance data indicate that CBJ can reliably meet this requirement with its existing sludge dewatering equipment. Because tipping costs at landfills are based on the delivered weight of the waste, it is often cost-effective to reduce the moisture content of the dewatered biosolids to reduce both transportation and tipping costs.

WM has at times refused to accept CBJ biosolids at the Capital Landfill over the last year because of high residual concentrations of hydrocarbons contained in the dewatered biosolids. Residual hydrocarbon concentrations at the levels reported for CBJ's biosolids would not be a concern if WM Capital Landfill contained a liner and comprehensive leachate collection system. Although a specific hydrocarbon source has not been identified, the hydrocarbon concentrations could be caused by leaking underground storage tanks, or illicit dumping.

Cost:

- $88 per wet ton for transportation and tipping costs at Waste Management in Juneau
- $140 per wet ton for transportation and tipping costs at Waste Management Landfill in Arlington, Oregon

Advantages:

- Exempt from permitting and reporting requirements under the biosolids regulations 40 CFR 503 and 40 CFR 258. Design Criteria for Municipal Solids Waste Landfills governs the permitting, methods, and reporting requirements.
- All types of biosolids accepted, Class A, Class B and solid waste

Disadvantages:

- WM has refused biosolids due to high concentration of hydrocarbons
- Regulations may be changing in Washington and Oregon that may prevent biosolids from being accepted
- Perceived odor problem

B. Monofill

Description:

Sewage sludge monofills are sometimes the preferred method for managing wastewater biosolids because beneficial reuse options are not feasible or cost competitive. A biosolids monofill is a landfill that only accepts wastewater treatment plant biosolids.

Sewage sludge monofills are regulated by ADEC 18 AAC 60.470 as well as the Federal 503 regulations. The ADEC regulation stipulates that biosolids must be dewatered to contain at least 10 percent solids by weight. Experience indicates that 15 percent solids or more is needed for a sustainable operation. Sewage sludge monofills do not need to have a liner or leachate collection system if the conditions identified in Table 5 are achieved and are deposited at least 50 feet from the property line. Toxic metals contained in CBJ's biosolids would not likely require a liner or leachate collection system (see analysis, below).

In general, an active biosolids monofill may not be located within 200 feet of an active fault, in an unstable area or in a wetland. Gas monitoring is required in any building within 500 feet of where biosolids are deposited. Sewage sludge that is place in a monofill must meet the vector attraction reduction requirements (VAR) of the 40 CR 503.33(b) (1-11) to reduce potential for animals or insects to transmit diseases or meet the Class A or Class B pathogen reduction requirements (PFRP or PSRP). Therefore CBJs biosolids cannot be placed in a monofill unless additional treatment is implemented.

Based on CBJ's current annual production of sewage sludge of approximately 1,015 tons, dry weight basis, CBJ would be required to complete quarterly sampling and analysis of the sludge being deposited in the monofill to demonstrate:

- arsenic, chromium, and nickel concentrations do not exceed the values in Table 5,
- pathogen density requirements of 40 CFR 503.32 and vector attraction reduction requirements (VAR) in 40CFR (b) (1-8) are achieved.

TABLE 5 Maximum Allowable Pollutant Concentrations in Sewage Sludge Placed in a Monofill Without A Liner and Leachate Collection System			
Distance from Disposal Area to Property Line (feet)	Allowable Pollutant Concentration, mg/Kg		
	Arsenic	Chromium	Nickel
50 to <82	30	200	210
82 to <164	34	220	240
164 to <246	39	260	270
246 to <328	46	300	320
328 to <410	53	360	390
410 to < 492	62	450	420
>492	73	600	420

Cost:

- $25-50 per wet ton for operating cost (not including cost of additional treatment required for placement of biosolids in a monofill)
- Capital cost is 65 acres of land

Advantages:

- Low operational cost
- Class A and Class B biosolids accepted

Disadvantages:

- 65 acres of land required for a service life of 20 years
- Additional treatment required
- Public access to monofill restricted during use and for three years after facility has closed
- Potential objection from nearby property owners

C. Land Application Local

Description:

In other parts of the country, land application of biosolids is often a preferred biosolids management strategy because it has a low capital cost, it is relatively simple and reportedly makes maximum use of the biosolids recycle value. In agricultural areas of the United States, land applied sludge can be an excellent substitute for commercial fertilizers and soil amendments. Additionally, biosolids have been applied and provided benefits to: commercial timber and fiber production lands, federal and state forests, and reclamation or re-vegetation of disturbed or marginal lands such as those which have been disturbed by mining or mineral processing operations and sandy and other unproductive areas.

Biosolids that are land applied are required to be treated by a PSRP. During periods of the year when the soil is wet, frozen or snow covered, biosolids often cannot be applied. Because of the prevailing climate conditions in Juneau, finding a suitable application site within a reasonable distance to the wastewater treatment plants would be difficult. Also, a very large area of land would be required for land application. Finding an area this large, transporting the biosolids and accessing the land would be challenging.

Cost:

- Operating cost would be determined by proximity of the application site and difficulty of application
- Capital cost would be the land

Advantages:

- Low operating cost

Disadvantages:

- Difficult to find available land
- Additional treatment of biosolids required
- On a small scale, finding willing consumers may be difficult
- On a large scale, application on public land may be unacceptable to the community

2. TREATMENT ALTERNATIVES

A. Existing

Description:

This option is based on continuing the present operation at all three treatment plants. At the MWTP, waste activated sludge generated by the SBR process is dewatered to achieve a sludge cake having a solids content of approximately 15% using an existing 1-meter gravity belt thickener in conjunction with a belt filter press. Waste activated sludge generated by the JDWTP is aerated, but only partially digested, and then dewatered on a belt filter press to achieve a solids content of approximately 15%. In both cases polymer is added to the sludge to promote the flocculation of solid and the expulsion of water during the dewatering process. Currently an emulsion polymer is used at the MWTP and a dry polymer is used at the JDWTP.

Although the JDWTP has an operating aerobic digester, it does not necessarily produce Class B Biosolids. Monitoring is inconclusive regarding the ability of the existing digestion process to meet Class B standards. VSS reduction rarely meets the VAR reduction requirement of 38%, no other testing such as oxygen uptake has been performed and the destruction of fecal coliforms has not been demonstrated. In 2005, Carson Dorn recommended upgrading the digester aeration system to increase the oxygen transfer capacity and presumably meet Class B requirements.

Given the uncertainty of the JDWTP biosolids and its relatively low percentage of the total biosolids production, the biosolids produced with this option are considered as unclassified for any disposal other than solid waste.

Cost:

- Treatment per year Less than $50,000

Advantages:

- Current operation- no action alternative
- Simple and does not require additional labor, materials and energy..

Disadvantages:

- Produces a large amount of solid waste with limited disposal options: landfill
- Sometimes contains high amounts of hydrocarbons that are rejected by the local Waste Management landfill

- Solids are not stable and susceptible to generating significant odors during sludge dewatering process and during transport of material to the disposal site.

B. Aerobic Digestion

Description:

This method of digestion is the simplest of the digestion processes and produces Class B biosolids.. The aerobic digester operates on the same principles as the activated sludge process. As food is depleted from the dissolved phase of the wastewater, the microbes enter the endogenous phase where the organisms eat one another, ultimately oxidizing most of the cell tissue to CO2, H2O, NH3, NO2, and NO3. This process would require construction of aerobic digesters at the MWTP and upgrade of the existing digester at the JDWTP.

Up to 80 percent of the cell tissue may be oxidized in this manner; the remaining fraction contains inert and non-biodegradable materials. Factors to be considered during the design process are characteristics and origin of the sludge, hydraulic residence, true solids loading criteria, energy requirement for mixing, environmental conditions and process operation.

This process produces approximately 12.8 wet tons per day of Class B biosolids at 15% total solids. This process requires oxygen and has energy requirements of 3,350,000 kWh per year.

Cost:

- Treatment Cost per year is $500,000 to 700,000 due to high energy consumption and oxygen requirements
- Sludge dewatering costs including labor, materials and polymer would be approximately the same as the existing program.
- One-Time Capital $2-5 million

Advantages:

- ABWWTP and JDWWTP currently employ aerobic digestion
- Volatile Suspended Solids (VSS) are reduced to 38-45 percent, slightly less than the performance of anaerobic digestion but adequate to produce a Class B biosolids
- Produces a stable humus-like end product
- More basic fertilizer values are recovered than by anaerobic digestion or Autothermal Thermophilic Aerobic Digestion (ATAD) process
- Operation is relatively simple
- Cyclic aeration can reduce energy requirements
- Odor is minimal during digestion process and during dewatering and subsequent transport

Disadvantages:

- Higher operating cost associated with supplying oxygen and mixing energy to the digester
- No other useful by-product such as digester gas produced
- Aerobically digested sludge does not dewater as efficiently as anaerobically digested
- Produces a minimal recycle stream

- Decant thickening of digester and filtrate from dewatering can seed and promote sludge bulking in the activated sludge liquids process and may require pretreatment before being returned to the liquid stream processes of the plant.

C. Incineration

Description:

Incineration of biosolids results in near complete conversion of the organic fraction of the sewage solids to carbon dioxide and water but the inorganic fraction remains in a dehydrated form. The resulting product is ash or solid waste. The waste would have to be disposed of at a landfill or a monofill if the metals contained in the ash are not significantly leachable. The popularity of incineration as a treatment process has waned in recent years due to the energy costs and capital costs to meet new stringent air emission standards. In the past, combustion of wastewater solids was both practical and inexpensive. Solids were easily dewatered and the fuel required for combustion was cheap and plentiful and air emission standards were virtually non-existent.

In today's environment, wastewater solids are more complex and include sludges from secondary and advanced waste treatment processes. These sludges are more difficult to dewater and thereby increase fuel requirements for combustion.

Development of more efficient solids dewatering processes and advances in combustion technology have retained the interest in the use of high temperature processes for specific applications where land suitable for biosolids application is scarce or non-existent; destruction of toxic materials or environmentally disruptive substances contained in the biosolids is of concern; or the potential exists for recovery of energy, either with wastewater solids alone or combined with municipal refuse.

The water content of the sludge cake is a controlling factor in determining the amount of auxiliary fuel required to vaporize the water to maintain combustion. The cost of auxiliary fuel is a major operational cost. For example, if the moisture content of CBJs biosolids was reduced to 78% (22% solids), incineration of the biosolids would require only 27% of the auxiliary fuel required at the current moisture content of 85% (15% solids). Improving the dewatering process to this degree would result in an annual saving of approximately $300,000 per year based on a fuel price of $4 per gallon. A positive return on the investment for installation of a more efficient dewatering system would be in the range of 4 to 5 years at the existing biosolids production rate of 2.78 tons per day, dry solids basis.

Fluidized bed furnaces are the most common process used for incineration of sludge in the United States and Europe. In the case of CBJ, the existing incinerator building could be upgraded to house a new incinerator. The ash slurry would be dewatered and sent to a secure landfill.

Approximately 2.7 wet tons per day of solid waste at 35% total solids would be produced in this process. Incineration would require 100,000 gallons of diesel fuel per year plus electricity to handle Juneau’s biosolids.

Cost:

- Treatment per year is $1 to $1.2 million
- One-Time Capital is $10-$15 million

Advantages:

- Undigested sludges from wastewater treatment plants require only dewatering. Digestion is counterproductive because it destroys 30-50% or more of the fuel heating value of the sludge
- Reduces the volume and weight of wet sludge cake by approximately 95 percent, thereby reducing disposal requirements.
- Destroys or reduces toxins that may otherwise create adverse environmental impacts.

- Potentially recovers energy through the combustion of waste products, thereby reducing the overall expenditure of energy.

Disadvantages:

- High capital and operational costs
- High temperature operations create high maintenance requirements and can reduce equipment reliability
- Skilled and experienced operators are required
- Discharges to atmosphere (Carbon dioxide, particulates and other toxic or noxious emissions), surface waters (scrubbing water), and land (furnace residues) may require extensive treatment to assure protection of the environment.

D. Compost

Description:

Composting of wastewater treatment plant biosolids is an extension of the biological treatment process but without free water. The process is a controlled natural process that is mediated biologically under aerobic thermophilic conditions that stabilizes biosolids to meet the PSRP and VAR requirements of the EPA 503 regulations. The primary benefits of biosolids composting is the end product is similar to soil or mulch that can be beneficially used as a natural fertilizer to improve or restore soils for domestic and agricultural plant growth. The product can be a Class A or Class B product depending on the method of composting used and the temperatures achieved during the composting process. Production of a Class A compost requires achieving a temperature of at least $55^{o}C$ consistently for 3 to 15 days depending on the frequency of mixing or turning. Production of Class B compost only requires achieving a temperature of $55^{o}C$ consistently for approximately 4 hours.

Composting to Class B would not be significantly less expensive for capital or operational costs but would be more challenging to find application area. Class B material has significantly more restrictions regarding reuse and would not allow distribution to the public.

Composting is a natural process which generates heat as a result of the biological decomposition of the organic material in the biosolids. In addition to the incoming wastewater biosolids the process requires oxygen, nitrogen, and moisture in the proper proportions with some degree of physical control to help retain the heat given off by the process. This is an important factor for Juneau. Typically the wastewater solids contain too much moisture and not enough porosity for air carrying oxygen to penetrate into the dewatered wastewater treatment plant biosolids to keep it from becoming septic or anaerobic. To overcome this limitation, bulking and absorbent soils such as shredded tire chips, waste paper and cardboard can be blended with the incoming biosolids to achieve a moisture content of 50 – 65 percent and porosity sufficient to allow air/oxygen to penetrate completely into the bulk pile.

There are several composting processes that have been applied successfully to compost unstabilized municipal wastewater biosolids: windrow, aerated static pile and closed-vessel composting. Windrow composting systems are passively aerated, open-air systems. Aerated static pile composting systems are mechanically aerated in a pile, while closed vessel systems periodically mix or turn the biosolids and bulking agent mixture with aeration.

The entire process typically takes 5-8 weeks, but systems are frequently designed for up to 10 weeks solids retention. Some of the compost is recycled to serve as a biological seed and recover heat, and is mixed with the incoming un-composted biosolids and amendment. The portion of the compost that is not recycled is placed in a maturation/curing storage pile and covered for at least 60 days. After the maturation storage period, the compost is mechanically screened to produce a relatively uniform product and to recover bulking material so that it can be recycled. Front end loaders are generally used for mixing and moving the compost around the site.

Control of odors and thermal protection during cold weather conditions are considered the most critical considerations for designing and operating a successful composting system. The controlled mechanical aeration systems used for the aerated static pile and closed vessel composting systems have a good performance record when the extracted off-gas is treated in a composting biofilter, chemical wet scrubber, activated carbon scrubber or thermal oxidizer either individually or in combination.

In 2009, Kodiak operated a pilot composting program with their sewage sludge. They produced Class A biosolids using wood chips as bulking material, forced aeration, aboveground piping and a wood chip filter for off gases. The results of the study found that they needed a ratio of 1:3.2 biosolids to woodchip. They also found that moisture control was very difficult as they needed wet weather in the summer and dry weather in the winter for screening. Odors were a problem during mixing and it took the pile longer than planned to reach the maximum temperature that was needed. Extrapolating from data on Kodiak's pilot program, to compost all of Juneau waste, a 1 acre facility would be needed and the facility cost would be approximately $5-$10 million. Operating costs would be approximately $500-$700,000 per year.

Approximately 9.2 wet tons per day of Class A compost at 32% total solids would be produced.

Cost:

- Treatment per year $500-$700,000
- One-Time Capital $5-10 million and cost of land

Advantages:

- Based on the metals content of Juneau wastewater treatment plant, biosolids would qualify as exceptional quality if composted to meet Class A standards
- Low treatment cost per year

Disadvantages:

- Finding a suitable location acceptable to the public for treatment would be difficult
- Additional treatment of off gas would be necessary to minimize odors
- Water management of the compost pile is difficult
- Large amounts of bulking or absorbent materials required and must be disposed of after use
- Product may not be acceptable by public for land application use

E. Anaerobic Digestion

Description:

Anaerobic sludge digestion is a biologically mediated process accomplished by anaerobic and facultative bacteria that convert 40 to 60 percent of the organic fraction contained in the biosolids feed to carbon dioxide and methane gas. The process is accomplished entirely without oxygen or addition of other substances. Anaerobic digesters must be continuously and thoroughly mixed either through mechanical mixing or digester gas recirculation sparging (mixing). Digesters are generally designed for a detention time of 15 to 25 days. Fifteen days at 35^{o}C is necessary to achieve PSRP requirements for production of Class B biosolids.

There are conventional and high-rate digesters; the conventional design uses a one or two stage process. In any of these systems, provisions are normally made for sludge heating. The one stage digestion systems are the most common.

Digester gas can be recovered, however it increases initial costs because of the necessity of providing explosion-proof equipment. Typically, digester gas has a lower heating value of about 600 BTU/CF, which is about 60 percent of natural gas and contains 25 to 30% carbon dioxide, small amounts of nitrogen, hydrogen sulfide and other gases. Anaerobic digester gas, however, can contain up to 1% hydrogen sulfide which generally needs to be removed to make beneficial use of the gas without detrimental effects on combustion equipment

This process produces approximately 8.9 wet tons per day of Class B biosolids at 18% total solids. The energy input to the system is electricity.

Cost:

- Treatment per year $150,000 to $250,000
- One-Time Capital $5-10 million

Advantages:

- Higher organic loading, i.e. rates of treatment not limited by oxygen transfer as in aerobic digestion
- Minimal need for biological nutrients (N and P) and further treatment
- Less electricity required than aerobic digestion
- Production of a useful by-product (methane) which has a low heat value compared to natural gas

Disadvantages:

- Digesters must be heated to about 30 to 38^{o}C for optimum operation
- Molecular oxygen is toxic to the system and must be excluded
- Higher skilled operation is required
- Anaerobic digesters are easily upset by unusual conditions and are slow to recover
- Mixing in large tanks is more difficult
- Additional safety precautions are needed due to the explosive nature of digester gas
- Recycled filtrate from dewatering of the sludge has a high concentration of ammonia and phosphorus and may need to be treated in a side stream treatment process to avoid shock loading upset of the wastewater treatment plant
- Periodic cleaning of an anaerobic digester is complicated because it is a closed vessel

F. Auto-thermal Thermophilic Aerobic Digestion (ATAD)

Description:

In the ATAD process, volatile solids in waste sludge are degraded in an aerobic, high temperature (55-65ºC) reactor. The reactor is covered and insulated. The high temperature inside is generated by heat released from biological activity in the sludge. The high temperature accelerates destruction of pathogens and organic material.

To achieve Class A standards for biosolids, a properly operating ATAD system would require about 12 days detention time at 55 to 60ºC. An ATAD process can achieve a greater organic destruction and degree of pathogen reduction with a much smaller reactor as compared to that provided by a conventional aerobic digester. The ATAD system would require approximately one-sixth the volume of a conventional aerobic digester with a thickened sludge feed.

Prior to entering the ATAD reactor, the waste sludge should be thickened to 6 percent. This can be achieved with several mechanical thickeners. For this analysis, a gravity belt thickener was assumed.

Air is supplied with aspirating jet aerators, which provides the oxygen supply to keep the process aerobic and the mixing energy to disperse the oxygen supply homogeneously within the biosolids slurry. Exhaust gas from the ATAD is directed to a cyclic aeration nitrification-denitrification reactor that reduces the concentration of ammonia and soluble Chemical Oxygen Demand (COD) in the liquid phase of the digested sludge. Ultimately this process reduces the impact of the centrate/filtrate recycle stream that is generated when the final biosolids product is dewatered. The recycle stream is discharged to the plant liquids stream process, which is then treated.

Exhaust gas from the nitrification-denitrification process is treated in a wet scrubber to absorb ammonia odors from off gas stream and is then passed through a composting biofilter. The absorbed ammonia water stream from the wet scrubber is returned to the liquids treatment process of the plant.

This process would produce 6.8 wet tons per day of Class A biosolids at 20% total solids and requires 820,000 kWh per year to run.

Cost:

- Treatment per year: $600,000 to $800,000
- One-Time Capital: $5-10 million

Advantages:

- Class A product
- The coupled ATAD followed by the nitrification and denitrification process can collectively remove 60% of the mass of the dry solids content of the sludge entering the ATAD process and improves dewatering characteristics so that 26% solids can be reliably achieved. This process would reduce the annual biosolids production from 6765 wet tons/year at 15% solids to 1560 wet tons/year at 26%, an effective mass reduction of approximately 77%.
- Potential for waste heat recovery

Disadvantages:

- Operators must pay close attention to operating conditions and equipment maintenance.
- Typical operational problems with ATAD systems are poor oxygen transfer efficiency, poor mixing, excessive foam generation, odors and drop in process temperature
- High recycle stream
- High energy costs
- Product may not be acceptable by public for land application use

G. Super Critical Water Oxidation (SCWO)

Description:

SCWO is a high-efficiency thermal oxidation process capable of treating a wide variety of hazardous and non-hazardous wastes including wastewater treatment plant sludge. The process is sometimes referred to as the hydrothermal oxidation process. The SCWO process consists of elevating the temperature and pressure of the waste stream (in this case, the biosolids generated by all three treatment plants) above the critical point of water, which is 3242 psi and 374°C. Under these conditions water becomes a fluid with unique properties that can be used to completely oxidize organic substances contained in the wastewater stream to carbon dioxide and water if there is adequate oxygen available.

Typically an oxidizing agent such as hydrogen peroxide, oxygen, ozone or potassium permanganate must be added to the wastewater or sewage sludge to allow oxidation to occur since the amount of dissolved oxygen in the sludge is not adequate to support complete oxidation of the organic material contained in the biosolids. The supercritical water oxidation process harnesses most of the energy from oxidation to sustain the process in a looped counter-current tubular reactor.

To date, the SCWO process has been used by less than 10 petrochemical industries, the US Department of Defense for treatment of hazardous and extremely hazardous wastes, and one sewage sludge treatment system. The system used specifically for treating sewage sludge was reported to have been constructed in 2001. This system operated for four years before being decommissioned due to severe and unresolvable corrosion, salt precipitation and mineral scale deposition within the reactor, heat exchanger, piping and pumping systems. Another SCWO municipal sewage sludge system was constructed in the last few years in Orlando, Florida but the author has been unable to obtain any information about its function.

In addition to sewage sludge, the system would accept Household Hazardous Wastes (HHW) and Fats, Oils and Greases (FOGS). The system would produce 1 to 3 wet tons per day of solid waste at 35% total solids.

Cost:

- Treatment per year $500-$700,000
- One-Time Capital $10-$20 million

Advantages:

- Small amount of solid waste produced
- Potential waste heat recovery to fuel system, only energy for start-up required
- Accepts HHW and FOGS

Disadvantages:

- No known municipal sewage treatment systems currently functioning in the United States
- Problems with scale and mineral deposits when treating wastes contained in water with substantial dissolved mineral content, small diameter titanium tubes may help to overcome these problems as well as chemical attack and scour of silts and sands

H. Lime Stabilization

Description:

Class B sludge can be produced with lime stabilization without digestion or other processes. This is accomplished by blending lime with the dewatered sludge at the rate of 500 pounds of lime per dry ton of biosolids at 15 to 20%. Retention time in the mixer is generally one minute followed by 30 minutes retention in a curing vessel. The process removes 50 to 75% of the nitrogen in the biosolids by converting Total Kjeldahl Nitrogen (TKN) to ammonia gas. Capital costs for producing lime stabilized sludge are comparatively low as compared to other Class B alternatives.

Approximately19.2 wet tons per day of Class B biosolids at 18% total solids would be produced. Per year, 250 tons of lime and 40,000 kWh would be required to operate the system.

Cost:

- Treatment per year $200,000 to $300,000
- One-Time Capital $1-3 million

Advantages:

- Low Treatment Cost

Disadvantages:

- Highest amount of biosolids produced of all systems in this study
- Potential Odor
- Large amounts of lime can pose safety hazards for staff
- Land application may be difficult if product is not accepted by public

I. Lime + Heat Stabilization

Description:

Class A sludge can be produced with lime and heat. The sludge is heated by indirect application of steam generated by a diesel fired boiler. The process would require approximately 200 tons of lime. Several commercial systems have been developed to couple the lime stabilization process with the sludge dewatering process. FKC and RDP are two manufacturers that have a track record of performance with producing Class A lime stabilized biosolids in conjunction with dewatering.

Approximately 15.7 wet tons per day of Class A biosolids at 22% total solids would be produced. Annual fuel consumption would be 45,000 gallons of diesel fuel and 100,000 kWh of electricity.

Cost:

- Treatment per year $500,000 to $700,000
- One-Time Capital $4-8 million

Advantages:

- Less biosolids produced than with just lime stabilization
- Class A product

Disadvantages:

- Higher treatment cost than with just lime stabilization
- Potential Odor higher than with just lime stabilization
- Large amounts of lime can pose safety hazards for staff
- Land application may be difficult if product is not accepted by public

J. Heat Drying Without Digestion

Description:

Heat drying is accomplished from direct or indirect dryers used to evaporate water from the dewatered biosolids. Heat drying is one of several methods that are used to reduce the volume and improve the quality of biosolids. Heat drying is an ideal process for producing Class A Biosolids in which the product can be used beneficially.

Most new heat drying biosolids facilities use the direct rotary drying process. Heat dryers use large amounts of energy to evaporate the water from the biosolids.   Typical heat drying systems require 1,400 to 1,700 BTU per pound of water evaporated. Wastewater treatment plants that have anaerobic digesters have used the digester gas to fuel the heat drying units. Dryers are often located at plants in areas where landfilling, incineration and land application of Class B biosolids is prohibitively expensive or not feasible. Exhaust gas from dryers is very odorous and typically requires multiple stage treatment systems to prevent complaints from plant workers and residents in the vicinity of the drying plant. Dust generated by storage and transfer of dried sludge requires special attention during design because dusts can adversely affect human health and cause odors when the dried sludge comes in contact with moisture.

This process produces 3.1 wet tons per day of Class A biosolids at 90% total solids. It requires 100,000 gallons of diesel fuel per year and electricity to operate.

Cost:

- Treatment per year $600,000 to $800,000
- One-Time Capital $5-10 million

Advantages:

- Class A product
- Low amount of biosolids produced
- Potential waste heat recovery

Disadvantages:

- Large amount of fuel required to operate system
- Dust is a health hazard
- Severe odor

IV. LIST OF ABBREVIATIONS

ABWTP	Auke Bay Water Treatment Plant
ATAD	Autothermal Thermophilic Aerobic Digestion
BOD	Biological Oxygen Demand
BFP	Belt Filter Press
CBJ	City and Borough of Juneau
COD	Chemical Oxygen Demand
FBF	Fluidized Bed Furnace
JDWTP	Juneau Douglas Water Treatment Plant
MCRT	Mean Cell Residence Time
MPN	Most Probable Number
MWTP	Mendenhall Water Treatment Plant
PFRP	Process to Further Reduce Pathogens
PSRP	Process to Significantly Reduce Pathogens
SCWO	Supercritical Water Oxidation
TKN	Total Kjeldhal Nitrogen
VAR	Vector Attraction Reduction
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WM	Waste Management

VI. Biosolid Management System Alternatives Matrix

Each System is comprised of Disposal Alternatives and Treatment Alternatives

1. Disposal Alternatives

		Biosolid Product Accepted	Problems	Public Perception Issues	Infrastructure Needs	Operational Cost
A	**Landfill at Local Waste Management**	Class A and B, high hydrocarbon content rejected	May not accept indefinitely due to space limitations	Percieved odor problem	None	$88/wet ton + transportation
B	**Landfill at Out of Town Waste Management**	All Waste	Changing regulations in WA and OR may prevent biosolids from being accepted		Shipping Containers	$140/wet ton + transportation
C	**Monofill**	All Waste	65 acres required for 20 year life	Potential objection from nearby property owners	Land	$25-$50/wet ton + transportation
D	**Local Land Application**	Class A and Class B (more restrictive)	Huge amount of land required	Finding willing consumers difficult, acceptance of application on public land may be difficult	Land	transportation costs

2. Treatment Alternatives

		Biosolids Produced								COST	
		Quality	Approximate Quantity (average wet tons/day)	Disposal Options	Inputs to System - Energy and Other (annual)	Other Outputs	Waste Energy Recovery Possible	Implementation Time Period	Potential Problems	Annual Treatment*	One-Time Capital
A	**Existing**	solid waste	18.5 @ 15% TS	Landfill, Monofill	Electricity			Current Operation	High Energy Consumption for Transportation	Low	NA
B	**Aerobic Digestion**	Class B	12.8 @15% TS	Landfill, Monofill, Land Application	Electricity 3,350,000 kWh	Minimal recycle stream		1-3 years	High Energy Consumption	Medium	$2-5 million
C	**Incineration**	Ash, solid waste	2.7 @ 35% TS	Landfill, Monofill	Diesel - 100,000 Gal/yr Electricity	CO2	Potential waste heat recovery	3-5 years	High Operations Cost	High	$10-15 million
D	**Compost**	Class A	9.2 @ 32% TS	Landfill, Monofill, Land Application	Oxygen, Nitrogen, Water, Bulking Material (shredded tires, paper, cardboard)	Odor, potential leachate		1-3 years	Disposal of surplus material, potential odor, public acceptance and use of product	Medium	$5-10 million
E	**Anaerobic Digestion**	Class B	8.9 @ 18% TS	Landfill, Monofill, Land Application	Electrical Power	CO2, methane, ammonia and hydrogen sulfide if gas is not utilized, odor, higher recylce stream	Digester Gas for cogen and digester heating	1-3 years	Safety Issues for Public and Staff with Explosive Gas	Low	$5-10 million
F	**Autothermal Thermophilic Aerobic Digestion (ATAD)**	Class A	6.8 @ 20% TS	Landfill, Monofill, Land Application	Electricity - 820,000 kWhr polymer (prethickening)	Potential odor	Potential waste heat recovery	3-5 years	Odor a big problem with first generation processes; second generation improvements have much lower odor potential	Medium	$5-10 million
G	**Super Critical Water Oxidation (SCWO)**	solid waste	1 to 3 @ 35% TS	Landfill, Monofill, Land Application	Oxidizing Agent, Accepts HHW and FOGS also	No data	Energy recovered from system fuels treatment process	5-7 years	Process not known to have been successfully implemented in the US for municipal wastewater treatment	Medium	$10-20 million
H	**Lime Stabilization**	Class B	19.2 @ 18% TS	Landfill, Monofill, Land Application	Lime 250 tons Electricity 40,000 kWh/yr	Ammonia, potential odor		1-3 years	Staff safety with large amts of lime	Low	$1-3 million
I	**Lime + Heat Stabilization**	Class A	15.7 @22% TS	Landfill, Monofill, Land Application	Diesel - 45,000 Gal Electricity 100,000 kWh Lime 200 tons	Higher odor potential		3-5 years	Staff safety with large amts of lime	Medium	$4-8 million
J	**Heat Drying without Digestion**	Class A	3.1 @ 90% TS	Landfill, Monofill, Land Application	Diesel 100,000 gal Electricity	Dust, Severe Odor	Potential waste heat recovery	3-5 years	Product may be highly odorous	Medium	$5-10 million

***Does not include disposal costs. Low= <$500k/year, Medium=$500k - $1 million/year, High= $1 million+/year**

Notes:
1. Design Life Expectancy is 40 years for concrete and piping systems, 20 years for pumps and other equipment, and 7 years for shipping containers.
2. Higher potential for odor release during treatment process resulting in Class A biosolid than Class B.
3. Abbreviations: TS= Total Solids
4. Cost data are planning level estimates only prepared by Tetra Tech using CapDet modeling software, manufacturer information, and industry experience.