City of Riverside

WASTEWATER COLLECTION AND TREATMENT FACILITIES INTEGRATED MASTER PLAN

VOLUME 8: SOLIDS TREATMENT AND HANDLING
CHAPTER 2: SUMMARY OF PLANNING STUDIES

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City of Riverside

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SUMMARY OF PLANNING STUDIES

2.1 PURPOSE

The purpose of this chapter is to summarize the findings and recommendations from the 2003 Bio-Solids Handling Improvements report (2003 Report) that was completed for the City of Riverside (City) Regional Water Quality Control Plant (RWQCP) biosolids facilities. A copy of the report is included as Appendix A.

The 2003 Report includes descriptions of the RWQCP facilities at the time of study, while Volume 8, Chapter 1 - Existing Facilities, includes the facilities that the RWQCP currently has. A few changes have been observed since the 2003 Report, such as an installed centrifuge and discontinued usage of the sludge-drying beds.

While the 2003 Report included design criteria and evaluations of several biosolids management/processes as listed in Section 2.3, this master plan only includes the design criteria (Volume 8, Chapter 3 - Design Criteria) and evaluations of the thickening and digestion processes. The design criteria included in this master plan have been updated to meet the new planning period requirement.

2.2 OBJECTIVES OF THE 2003 REPORT

The following are the stated objectives of the 2003 Report:

1. To develop and to recommend necessary process improvements to treat wastewater solids removed for average dry weather wastewater flows of up to 40 mgd.
2. To provide space planning for facilities up to 50 mgd.
3. To provide the planning level costs for the recommended improvements.
4. To recommend project phasing and scheduled implementation of improvements.

2.3 ORGANIZATION OF THE 2003 REPORT

The 2003 Report consists of 11 chapters. Chapter 1 presented the recommended system. Chapters 2 and 3 provided the planning level cost for the recommended facilities and a recommended schedule for implementation of improvements. There were total of seven Technical Memoranda (TMs), which were prepared to evaluate options for handling wastewater solids production from the RWQCP for an ultimate plant capacity of 50 mgd. These TMs were included as part of the 2003 Report as Chapters 4 to 11. The titles of these seven chapters are listed as follows:

- Chapter 4: TM No. 1 - Solids Projections and Thickening Evaluation.

- Chapter 5: TM No. 2 - Digestion Options.
- Chapter 6: TM No. 3 - Heat Energy Options.
- Chapter 7: TM No. 4 - Dewatering and Air Drying Options.
- Chapter 8: TM No. 5 - Heat Drying Options.
- Chapter 9: TM No. 6 - Composting Options.
- Chapter 10: TM No. 7 - Side Stream Treatment Options.
- Chapter 11: TM No. 8 - Evaluation of Options. TM No. 8 evaluated all the options discussed in the seven TMs described above and developed a recommended system including a preliminary estimate of capital costs.

Summaries of Chapters 4 through 11 are provided in the following Sections.

2.4 CHAPTER 4: TM NO. 1 - SOLIDS PROJECTIONS AND THICKENING EVALUATION

This chapter discussed the evaluation of the RWQCP process performance and developed raw solids projections. It also discussed the raw solids thickening practices.

2.4.1 Objectives

The following objectives were addressed in this chapter of the 2003 Report:

1. Reviewed the plant sludge production and solids system operational data.
2. Confirmed the solids production at the time of the study.
3. Estimated the design flow of solids quantities for 40- and 50-mgd average raw wastewater influent flow and determined average, peak month, and peak day quantities.
4. Evaluated the thickening performance and assessed long-term improvement options for solids thickening.

2.4.2 Summary and Recommendations

At the time of the study, the RWQCP's raw solids processing facilities consisted of two Dissolved Air Flotation Thickeners (DAFTs). Chapter 4 provided a description of the equipment, which is also described in Volume 8, Chapter 1 - Existing Facilities, of this Master Plan.

The chapter also presented solids projections for the 40- and 50-mgd flow conditions. These are summarized below in Table 2.1.

Table 2.1 Solids Projections[1]
Wastewater Collection and Treatment Facilities Integrated Master Plan
City of Riverside

	Average Primary Sludge	Average Raw WAS
40 mgd		
TSS 1,000 lbs/day	39	35
VSS 1,000 lbs/day	32	28
Flow, mgd	0.12	0.61
50 mgd		
TSS 1,000 lbs/day	49	44
VSS 1,000 lbs/day	40	35
Flow, mgd	0.15	0.76
Peak Daily Factors		
Solids	2.2	1.4
Flow	2.0	1.4

Notes:
(1) Table taken from Table 3 of TM No. 4 of the 2003 Report.

A comparison of DAFT solids loading for Waste Activated Sludge (WAS) thickening and co-thickening was included in the evaluation. Design criteria for these evaluations were described in the 2003 Report and can be found in Volume 8, Chapter 3 - Design Criteria, of this Master Plan. For the evaluation, it was assumed that the thickening system must be able to handle average daily loading with one unit out of service and a peak daily loading with all units in service.

Based on the evaluation, two additional DAFTs are required for both thickening options, two 39-foot DAFTs for WAS thickening or two 44-foot DAFTs for co-thickening, to handle the solids produced at the ultimate flow of 50 mgd. There are advantages in using co-thickening, such as increased digester detention time and production of a thicker sludge feed to the digester. A list of advantages and disadvantages of co-thickening can be found in Chapter 4.

Details of implementing either thickening system need to be developed in the design phase. The performance of the thickening process ties to the size and performance of the digestion process. As a result, the thickening process was further discussed in Chapter 5.

A list of equipment and process improvements, which were based on site visits made during the time of study, were recommended to improve DAFT plant performance. These are listed below:

1. Add a submerged weir for influent solids distribution and better float control.
2. Add turbidity monitoring on subnatant to better control capture efficiency.

3. Add a high-level switch, high-level alarm, and solenoid valve to prevent the pressurization tank from becoming water logged.
4. Replace the existing manually operated valve with an automatic air-operated throttling valve with flow controller and flow.
5. Resize the polymer storage and feed systems to closely match the required polymer usage.
6. Replace the bottom sludge removal system.

2.5 CHAPTER 5: TM NO. 2 - EVALUATION OF DIGESTION OPTIONS

This chapter evaluated the different digestion options including Mesophilic Digestion, Temperature-Phased Digestion (TPAD), and Class A TPAD.

2.5.1 Objectives

The following objectives were addressed in Chapter 5 of the 2003 Report:

1. Define digestion options using existing tankage at the RWQCP.
2. Define process schematics, key piping/equipment needs and estimated performance benefits of the top two options in terms of volatile solids destruction, gas production, dewatering impacts, recycle impacts, and product odor.
3. Define capital costs for the two options evaluated.

The process objectives for this study were to maximize solids destruction, increase gas production, minimize odor impacts, and consider Class A product requirements as defined by EPA 40 CFR Part 503 regulations.

2.5.2 Summary and Recommendation

The anaerobic digestion process consists of five digesters (Digester Nos. 1 to 5) ranging from 0.603 to 1.8 million gallons in size. Only the two biggest digesters are in service. A description of the existing anaerobic digestion equipment was included in the chapter.

A brief description of each proposed alternative (Mesophilic Anaerobic Digestion, Thermophilic Anaerobic Digestion, Temperature-Phased Digestion, and Acid/Gas-Phased Digestion) was included in the report. Both Thermophilic Anaerobic Digestion and Acid/Gas-Phased Digestion were dropped from further consideration due to their potential to cause odor problems.

A projection was made of the thickened solids loading at 40 and 50 mgd. Table 2.2, (information taken from Table 2 of the chapter) lists the design solids and hydraulic loading.

Table 2.2	Design Solids and Hydraulic Loading[1] Wastewater Collection and Treatment Facilities Integrated Master Plan City of Riverside			
	Primary and WAS Flow, mgd	**Co-Thickened Flow, mgd**	**TSS, lbs/day**	**VSS, lbs/day**
Design Loading - 40 mgd				
Average	0.26	0.22	101,191	81,491
Peak 2 Week	0.37	0.31	141,667	114,087
Design Loading - 50 mgd				
Average	0.33	0.47	126,489	101,864
Peak Day	0.47	0.39	177,084	142,609

Notes:
(1) Table taken from Table 2 of TM No. 5 of the 2003 Report.

Design criteria for Mesophilic and TPAD were described in Chapter 5 of the 2003 Report.

The chapter included a discussion of each evaluated option, Mesophilic and TPAD. The additional required tankage was determined based on the existing facility and the design criteria. This was heavily dependant on the choice of thickening method. For this reason the additional required tank volumes were determined for both thickening choices (refer to Table 2.3).

Table 2.3	Additional Digester Volume Requirements[1] Wastewater Collection and Treatment Facilities Integrated Master Plan City of Riverside	
Digester Option	**Separate Thickening**	**Co-Thickening**
Mesophilic System		
Additional Vol. Required, MG, Peak 2 Week	1.92	0.71
Additional Vol. Required, MG, Avg. Without Digester No. 4	2.72	1.68
Number Required	2	1
Depth, feet	32	32
Diameter Required, feet	85	95
Temperature-Phased System		
Thermophilic Digestion Phase		
Additional Vol. Required	None	None
Mesophilic Digestion Phase		
Additional Vol. Required, MG, Peak 2 Week	2.4	0.5
Additional Vol. Required, MG, Avg. Without Digester No. 4	2.36	1.74
Number Required	2	1

Table 2.3	Additional Digester Volume Requirements[(1)] Wastewater Collection and Treatment Facilities Integrated Master Plan City of Riverside	
Digester Option	**Separate Thickening**	**Co-Thickening**
Depth, feet	32	32
Diameter Required, feet	79	94

Notes:
(1) Information extracted from Table 4 of the 2003 Report.

The same number and sizes of additional digesters would be required for both the TPAD and the mesophilic system for either thickening option. This means that the new facilities would have the flexibility to operate in either TPAD or in mesophilic mode. These new digesters would be constructed in the open area adjacent to the cogeneration facility behind Digester Nos. 1 and 2.

In order to meet Class A pathogen reduction requirements, thermally treated biosolids from the RWQCP must be subjected to one of the two temperature regimes that are applicable to the plant. For solids concentrations less than 7 percent, biosolids must be heated for at least 15 seconds, but less than 30 minutes, or the temperature of sludge must be 50 degrees C or higher with at least 30 minutes of contact time. Another key ingredient to meeting Class A facility requirements is there must be no possibility of short-circuiting. This is typically achieved by operating under batch mode. Additional tankage (i.e., thermophilic batch tanks) would be required if the RWQCP wants to achieve Class A TPAD.

Construction and capital costs for the new thickening and digestion alternatives were estimated and described in the chapter. The estimated capital cost for the co-thickening option was more expensive then the separate thickening option.

As discussed earlier, the required additional digestion facilities are heavily dependent on the thickening option. A present-worth cost analysis was included to evaluate the economic impact on the thickening and digestion system, for both thickening options, taking into account the required mesophilic digester facilities needed to support the respective option. The present worth cost for the WAS only thickening (with Mesophilic Digestion, based on a planning period of 20 years and with a 3 percent discount, rate) was less expensive than the co-thickening option. A life-cycle cost analysis showed that the TPAD and the Mesophilic Digestion options were nearly equal. Based on this information, the study recommended the continued operation of Mesophilic Digestion.

The study recommended implementation of additional DAFT facilities to continue separate thickening of primary sludge and WAS with DAFTs, based on the present worth analysis. It recommended installation of one new 50,000-gallon thickened solids blending tank and two 32-foot deep, 90-foot diameter digesters to match Digester Nos. 1 and 2. Conversion to TPAD could be considered in the future.

2.6 CHAPTER 6: - TM NO. 3 - HEAT ENERGY OPTIONS

This chapter discussed the additional heat required and the changes in gas production due to the changes to the RWQCP solids processing operation. It also evaluated the different heating and energy options for the proposed solids system modifications.

2.6.1 Objectives

The objectives of this chapter, as stated in the 2003 Report, are listed below:

1. Reviewed the design and operational information of the existing facilities.
2. Reviewed the existing digester gas and the landfill gas (LFG) system and gas characteristics.
3. Defined the plant heating needs, including digestion changes.
4. Reviewed applicable air quality limitations.
5. Defined and evaluated options for meeting the future RWQCP heat needs and energy performance requirements.

2.6.2 Summary and Recommendations

2.6.2.1 Existing Conditions

A summary of existing conditions in regards to the heating and energy system at the RWQCP was included in the chapter. The RWQCP's cogeneration system converts the fuel energy in the digester gas, LFG, and natural gas into electricity and heat energy. Each cogeneration engine is cooled by water circulating through the engine cylinder jacket, and this hot engine jacket water is used to heat the RWQCP together with heat recovered from the hot engine exhaust gases.

Table 1 in Chapter 6 of the 2003 Report summarized the digester gas flow rates and projected flow rates from 1991 to 2025. The energy value for the mesophilic digesters ranged from 6.5 million Btu/hour (MMBtuh) in 1991 for a flow of 28.5 mgd to 19.4 MMBtuh in 2025 for a flow of 50 mgd. The projected energy from TPAD for 2025 is 23.3 MMBtuh. A summary of the gaseous fuels the RWQCP receives and burns was included in the study. This included the digester gas, natural gas, and LFG.

2.6.2.2 Heating and Cooling System and Equipment

The three Caterpillar cogeneration engines use about 34 MMBtuh of energy, of which 3.5 MMBtuh of jacket water heat and about 8.3 MMBtuh of engine exhaust heat are recovered and available for use. The RWQCP also has several hot water boilers that have a little over 15 MMBtuh of heating capacity. It also has a steam generator with unknown heating capacity for steam cleaning purposes. The RWQCP heating system is interconnected with the laboratory chilled water system, which uses a nominal 150-ton absorption chiller that is "powered" by heating water from the cogeneration system. This absorption chiller requires heat at the highest possible temperature in order to function. This requirement forces the heat loop to deliver 190- to 200-degree Fahrenheit hot water.

The RWQCP is within the jurisdiction of the South Coast Air Quality Management District (SCAQMD). The cogeneration engines are subjected to emissions limits as shown in Table 2.4.

Table 2.4 Emission Limits for Existing Cogeneration Engines[1]
Wastewater Collection and Treatment Facilities Integrated Master Plan
City of Riverside

Air Contaminant	Emission Limit, lbs/hour each
Reactive Hydrocarbons	2.1
Nitrogen Oxide, as NO_2	2.3
Sulfur Dioxide	0.4
Carbon Monoxide	8.0
PM10 Particulate Matter	1.0

Notes:
(1) Information extracted from Table 6 of the 2003 Report.

The engines are equipped with a continuous emission monitoring system, to ensure compliance with the NO_x emissions limit.

2.6.2.3 Projected Heat Needs

The chapter showed that implementation of the TPAD options, as discussed in the previous chapter, would make maximum usage of the available heat produced by the cogeneration facility. As recommended, the projected additional heat required for the new sludge digestion system was estimated to be about 25 MMBtuh for raw sludge heating, with another 2 MMBtuh required for mesophilic digester shell heat losses and 2 MMBtuh required for thermophilic digester and sludge holding tank shell heat losses. The engines can provide only up to a maximum of 12 MMBtuh of heat, leaving 17 MMBtuh short.

Nine heat production options were evaluated and they are listed below:

1. Recovering engine after cooler heat.
2. Replacing the Laboratory Building absorption chiller.
3. Adding engine exhaust after-burners.
4. Adding more boilers.
5. Adding compressor heat recovery.
6. Recovering digester sludge heat.
7. Using water-source heat pumps.

8. Adding a solar hot water heating system.
9. Adding natural gas-fired fuel cells.

Of the nine options, only Option 4: addition of boilers and Option 6: digester sludge heat recovery were deemed promising and attractive options. The estimated construction cost for each heat production option was very similar, $3.58 million for Option 4 and $3.92 million for Option 6. The estimated annual Operation and Maintenance (O&M) cost for the sludge heat recovery option, however, was only one third the cost of the additional boilers option. Therefore, the study recommended implementation of the sludge heat recovery option.

2.7 CHAPTER 7: TM NO. 4 - DEWATERING AND AIR DRYING OPTIONS

Chapter 7 discussed the evaluation of belt press and centrifuge dewatering options to handle the anaerobically digested solids. It also included a discussion on the sludge-drying beds, which the RWQCP has since phased out due to odor problems.

2.7.1 Objectives

The objectives of this chapter, as stated in the 2003 Report, are listed below:

1. Reviewed performance and operational data of the existing dewatering equipment at the time of the study.
2. Assessed dewatering improvements/options in light of thickening and digestion options.
3. Evaluated improvements to air-dried storage to address wet weather storage needs, air-dried product uses, and Class A sampling issues.
4. Defined capital costs for dewatering and air-dried storage.

2.7.2 Summary and Recommendations

2.7.2.1 <u>Existing Dewatering and Sludge-Drying Facilities</u>

This chapter included a description of the existing dewatering facilities and the Sludge-Drying Facilities at the time of the study. The RWQCP has discontinued the use of the 29 sludge-drying beds due to the continuous odor problems. The RWQCP had two 2.2-meter Andritz SMX belt presses with an average capacity of 120 gpm each and a peak capacity of 220 gpm each, at the time of the study. The biosolids material was considered to be Class B product at the time of the study.

The following digested sludge characteristics were anticipated based on the thickening and digestion performance:

1. Depending on the specific thickening and digestion process, a total solids content of between 1.9 and 3.2 percent.
2. Depending on the specific digestion option used, a volatile solids content of 62 to 67 percent.

The anticipated digester sludge flow rates (based on 5 days/week, 16 hours/day operation) for the ultimate plant size of 50 mgd for the two thickening options were:

1. Separate Thickening - average flow of 477 gpm and a peak 2-week flow of 667 gpm.
2. Co-Thickening - average flow of 402 gpm and a peak 2-week flow of 563 gpm.

2.7.2.2 Dewatering Options

The two dewatering options considered in the study were the Andritz SMX belt presses and high-speed centrifuges. A centrifuge dewaters to a higher solids content than a belt press, but the electrical power load per machine is substantially higher with a centrifuge. Fewer numbers of operating machines and less foul air ventilation horsepower, however, would be required with centrifuges. Performance data for each option was included in Table 2 of the report.

A cost and non-cost assessment for two dewatering options was included:

- Option 1:
  Refurbished and new belt presses.
- Option 2:
  All centrifuge dewatering.

Based on the performance data and the dewatering design criteria, a total of five belt presses (two new, two existing, plus one spare) or three centrifuges (two operating and one spare) would be required.

Layout and configuration of each option was provided in the chapter. Both options would require an addition to the west side of the existing dewatering building.

The study also concluded that if centrifuges were used, the centrifuge dewatered cake has to be sent to heat drying facilities or taken off-site for land application, because odor from air-drying digested centrifuge biosolids is expected to be considerably greater than air drying of belt press cake.

The recommendation called for upgrading the two existing belt presses and installing one centrifuge for 40 mgd. Installation of two additional centrifuges was recommended for 50 mgd. Heat-drying capacity would be provided for centrifuge-dewatered cake.

2.7.2.3 Sludge-Drying Bed Improvements

Sludge-drying bed improvements were discussed in the chapter, but since sludge-drying beds have since been phased out, these are not described in this report.

2.8 CHAPTER 8: TM NO. 5 - HEAT DRYING OPTIONS

This chapter discussed the different heat-drying options to ensure that the RWQCP biosolids meet Class A biosolids quality and allow for phasing out of the sludge-drying beds.

2.8.1 Objectives

The objectives of this chapter, as stated in the 2003 Report, are listed below:

1. Identified heat-drying vendor systems, including systems that were lower-cost and may not produce commercial grade granules or pellets.
2. Summarized product beneficial use markets.
3. Prepared schematics, equipment sizing and layouts, as well as heat/energy requirements for drying. Identified heat source options and costs.
4. Defined air emission and odor control limitations and provided necessary control equipment.
5. Determined condensate characteristics and recycle impacts.
6. Developed a cost estimate for an alternate capacity/size of a thermal-drying system to replace the sludge-drying beds.

2.8.2 Summary and Recommendation

Drying systems are categorized into “direct” or “indirect” dryers, in which direct dryers normally use heated air as a heating source, and indirect dryers use steam or hot oil as a heating source. The dry product from the dryer is generally valued based on its nitrogen content for use as a fertilizer amendment. It is important to minimize the temperature and moisture content of the final product, as well as the oxygen content in the air/gas that is in contact with the heat-dried product to prevent auto-heating. The exhaust air stream organics from the sludge would also need to be controlled to limit the concentrations of air contaminants.

Eight heat-drying systems (a mixture of direct and indirect systems) were described in the chapter. Five of these systems were well suited for plants that are at least the RWQCP size, and their final products were all pellet or granules of uniform size. However, these systems would cost tens of millions of dollars for handling the RWQCP drying needs.

The remaining three systems were more economical, but would produce a less uniform and contain a much larger variety of particle size in the finished products. These three options were:

1. Fenton.
2. InnoDry.
3. Komline-Sanderson processes.

The chapter included detailed descriptions of the systems.

The Fenton dryer runs in batch operation and has a capacity of 13.7 cubic-yards per batch (cu-yd/batch), while the InnoDry and Komline-Sanderson are continuous-feed dryers and both have a capacity of 10 dry tons per day (dtpd). The Fenton dryer requires the most heat energy (1,600 Btu/lb of water), while the Komline-Sanderson dryer requires the least energy (1,130 Btu/lb). Based on these energy requirements, it would take approximately 1.5 to 2.2 million Btu of heat to dry a wet ton of 20-percent solids sludge to a 90-percent dry product.

All three sludge dryers required use of a hot oil or thermal fluid to indirectly heat the sludge. The temperature requirement for the hot oil is about 340 to 420 degrees Fahrenheit. Compared to the hot water heat recovery potential from the RWQCP cogeneration system (modifications can be made to increase the cogeneration system heating water to 200 degrees Fahrenheit), the hot oil temperature is much higher.

For the study in this chapter, it was assumed that a portion of the cogeneration heat would be used to warm the oil heater burners' combustion air, thus, reducing the amount of natural gas fuel needed.

A list of dryer system components was included in the chapter, as well as the sludge dryer auxiliary systems for all three options.

The RWQCP heat-drying alternatives criteria and costs were estimated, based on the projected dewatered sludge production and each of the alternatives drying capacity. The number of heat dryers required depended on the type of operation (7 days versus 5 days a week). Table 2.5 lists the heat-drying criteria and capital cost estimates.

The estimates showed that both capital and life-cycle costs for all three systems were very similar. The study suggested that the initial heat-drying facility would not need to include all the units as shown above. It suggested that the installation be split into two phases where Phase 1 assumed a combination of belt press and centrifuge dewatering and Phase 2 assumed all centrifuge dewatering and complete phase out of the sludge-drying beds.

Table 2.5 Heat Drying Criteria and Capital Cost Estimate (50-mgd Facility)[1]
Wastewater Collection and Treatment Facilities Integrated Master Plan
City of Riverside

Process Design Criteria	Fenton	InnoDry	Komline-Sanderson
No. of units (7-day operation)	5	3	3
No. of units (5-day operation)	6	4	4
Average evaporation capacity, lb/hr (7-day operation)	6,157	6,157	6,157
Average evaporation capacity, lb/hr (5-day operation)	8,620	8,620	8,620
Peak evaporation capacity, lb/hr (7-day operation)	7,697	7,697	7,697
Peak evaporation capacity, lb/hr (5-day operation)	10,775	10,775	10,775
Total Capital Costs	**$19,860,000**	**$20,970,000**	**$15,510,000**
Total 20 Year Life-Cycle Cost in 2002 Dollars (4% interest)	**$20,770,000**	**$17,330,000**	**$15,510,000**

Notes:
(1) Information extracted from Table 3 of TM No. 5.

2.9 CHAPTER 9: TM NO. 6 - COMPOSTING OPTIONS

This chapter evaluated the composting option as a solids treatment alternative to produce Class A biosolids. The study evaluated two enclosed processes: aerated static pile and in-vessel composting.

2.9.1 Objectives

The objectives of this chapter, as stated in the 2003 Report, are listed below:

1. Defined biosolids composting arrangements and costs.
2. Defined green waste quantities and characteristics available for composting.
3. Developed alternative composting arrangements, schematics, and layouts, providing fully-contained and fully-controlled systems for odor control.
4. Developed construction and capital cost estimates for alternative composting systems.

2.9.2 Summary and Recommendations

The primary objectives of composting systems are to destroy pathogenic organisms and to reduce moisture of the sludge to around 40 to 50 percent. Composting also stabilizes the organic wastes in the biosolids and produces a stable, manageable, and marketable end product.

The primary feedstocks to a composting system are the dewatered biosolids and bulking agents such as woodchips or green waste. The bulking agents adjust the carbon to nitrogen ratio (C:N) of the mixture and provide the structure and porosity required to allow adequate air movement throughout the mixture. The bulking agents also increase the surface area for biological reactions to occur.

As mentioned earlier, the two alternatives considered for evaluation were Aerated Static Pile Composting and In-Vessel Composting. Detailed descriptions of each alternative were included in the chapter.

The study estimated that the RWQCP produces an average of 80 wet tons/day of biosolids and about 125 tons/day of green waste, which are available for composting. Based on these estimations, a composting facility with an operating capacity of 40 wet tons/day of biosolids is feasible. Both composting processes are capable of handling this feed rate. The advantages and disadvantages were described in the chapter.

The study recommended the use of the In-Vessel process based on the proven track record and its adaptability to enclosed composting. The estimated space requirement for the composting facility was 4.9 acres, which included a process area, curing area, and biofilter areas. The estimated total capital cost (including odor control for the entire building and composting ventilation) was approximately $34.8 million.

The study concluded that composting was a possible solution for recycling biosolids and green waste for the RWQCP. However, due to the high costs and amount of labor involved in the composting process, it should only be considered to supplement other solids handling alternatives rather than be designed to handle the entire solids production at the RWQCP.

2.10 CHAPTER 10: TM NO. 7 - SIDE STREAM TREATMENT OPTIONS

This chapter documented the evaluation of side stream treatment options, which would reduce the oxygen demands in the activated sludge process by treating the dewatering process liquid separately.

2.10.1 Objectives

The objectives of this chapter, as stated in the 2003 Report, are listed below:

1. Reviewed recycle stream treatment technology.
2. Provided preliminary sizing criteria and costs for the selected alternative.
3. Developed a process schematic and equipment needs for the side stream treatment alternative.

2.10.2 Summary and Recommendations

Six alternatives were evaluated for the side stream treatment. These included:

1. Steam Stripping:
   Involves passing the filtrate through a stripper containing mass transfer media and in contact with steam.
2. Activated Sludge Process:
   A conventional activated sludge plant built specifically to treat the side stream flow. A low SRT can be used due to the warm temperature of the waste stream.
3. Short SRT Process:
   Similar to conventional activated sludge process, but with an additional feature. The waste nitrifying sludge from this process is added to the effluent from the process and returned back to the mainstream process, which accelerates the nitrification process in the mainstream process.
4. SBR Process:
   A variant of the activated sludge process, where both aeration and settling are provided in a single tank.

5. <u>SHARON Process</u>:
   An activated sludge process operating at an elevated temperature. The process operates without a clarifier, thus all solids formed pass on into the effluent, which must be returned to mainstream process for further treatment. The nitrification stops at the formation of nitrite, which requires less oxygen.

6. <u>Trickling Filter</u>:
   This process has been used for nitrification of side streams and in this application would require a high degree of solids removal to prevent coating onto the biofilm surface, which might displace the nitrifiers.

The study compared the advantages and disadvantages of the six technologies and recommended the use of a conventional activated sludge process since it would make the best usage of the available tankage at the RWQCP. It would incorporate flexibility into the design to allow operation in either “Short SRT” or SHARON process modes.

The following lists the major design assumptions/requirements that are necessary to convert the existing tankage to an activated sludge facility for side stream treatment:

1. All available tankage would be necessary to accomplish nitrification.
2. No reactor volume is available for denitrification.
3. Old secondary clarifiers have sufficient structural integrity to level the floors to support diffuser installation.
4. One of the old secondary clarifiers would be converted to its original duty with the addition of a new mechanism.
5. DO control for both air modulation and pH control for pacing the caustic addition would be required.
6. For the short SRT process, waste nitrified sludge piping is needed for both combinations with the main plant’s waste sludge and for addition to the mainstream plant’s influent.
7. For the SHARON process, provisions for bypass of the secondary clarifier would be required.
8. Return sludge pumping would be upgraded to have variable speed capability and be designed for 100 percent of average daily flow.

The estimated capital cost for the side stream recycle treatment facilities was $6.4 million for reusing existing structures and $6.9 million to demolish the existing structures and build new facilities. Table 2.6 lists the preliminary design data for the centrate treatment facility, as presented in the chapter.

Table 2.6 Preliminary Centrate Treatment Facility Design Criteria(1)
Wastewater Collection and Treatment Facilities Integrated Master Plan
City of Riverside

Item	Value
Average Future Centrate Loadings	
Flow, mgd	1.08
Ammonia Nitrogen, mg/L	560
Assumed Daily Load Peaking Factor	1.5
Centrate Clarifier	
Number	1
Diameter, feet	40
Sidewater Depth, feet	10
Average Surface Overflow Rate, gpd/sf	680
Aeration Tank Volume	
Number	3
Volume, mil gallons/each	0.375
Sidewater Depth, feet	10
Aerobic SRT, days	5
MLSS, mg/L	900 to 3,700
DO Control, mg/L	2.0
Average/Peak Air Requirement, scfm	12,600/19,000
Number of Blowers (variable speed)	3
pH Control, units	7.2 to 8.0
Average Causing Requirement, gpd/50% soln.	4,400
Min. Storage Requirement, based on 14 days, gal	62,000
Secondary Clarifier	
Number	1
Diameter, feet	80
Sidewater Depth, feet	10
Average Surface Overflow Rate, gpd/sf	210
Return Sludge Capacity, mgd	1
Number RAS Pumps	1 duty + 1 standby

Notes:
(1) Information extracted from Table 2 of the 2003 Report.

2.11 CHAPTER 11: TM NO. 8 - EVALUATION OF OPTIONS

This chapter summarized and evaluated the recommendations from the previous chapters and developed recommended solids handling process facilities for the RWQCP. It also provided a preliminary estimate of capital costs.

2.11.1 Objectives

The objectives of this chapter, as stated in the 2003 Report, are listed below:

1. Reviewed and compared options presented in the previous chapters.
2. Recommended facilities including immediate improvements needed to address capacity problems, as well as phasing options for facilities up to 40 mgd.
3. Developed costs for the recommended facilities and improvements.

2.11.2 Summary and Recommendations

The chapter recapped the RWQCP existing facilities and the treatment plant's capacity at the time of the study. As stated above, it also summarized the evaluations and recommendations from each of the previous chapters. A brief summary of the recommendations of each chapter is listed below:

1. <u>Thickening Process</u>:
   The study recommended construction and conversion to co-thickening, addition of a new DAFT to be constructed for co-thickening, and retrofit of the other existing DAFTs to be part of the co-thickening system.
2. <u>Digestion Options</u>:
   The chapter evaluated two options:
   Mesophilic Digestion and TPAD. It recommended continued operation of Mesophilic Digestion based on the similar life-cycle cost of both options. TPAD could be considered at a later date.
3. <u>Heat Energy Usage Options</u>:
   Since TPAD was not recommended; there is enough heat energy to continue to operate the digesters in the mesophilic mode. A shortfall of heat from cogeneration was predicted when the plant is operated at 50 mgd. The shortfall could be provided by adding a new boiler or replacing the absorption chiller with an electric chiller. About 2 to 4 MMBtuh of surplus heat would be available to warm the oil before it is brought up to the necessary heat-drying temperatures.
4. <u>Dewatering and Sludge-Drying Bed Options</u>:
   The chapter recommended the use of centrifuges to supplement belt press dewatering to provide for additional dewatering capacity. Ultimately three new high-capacity (200-gpm) centrifuges would be needed to provide sufficient capacity

with adequate redundancy. It also recommended that the sludge-drying beds be phased out and replaced with heat-drying.

5. Heat-Drying Options:
   Three indirect drying systems were evaluated. The costs of all three systems were similar. The study recommended implementing heat-drying facilities and further evaluation during final design.

6. Composting Options:
   Composting requires significant odor control and it is a labor and land intensive process; therefore it was not recommended for the RWQCP.

7. Side Stream Recycle Treatment:
   The study recommended the use of conventional activated sludge, using the four old sedimentation tanks and one gravity thickener as the process tankage. The City decided at a review meeting not to implement this process.

The chapter developed options for the solids handling facilities expansion in two phases, Phase 1 for 40 mgd and Phase 2 for 50 mgd. The list of recommended facilities and improvements can also be found in Chapter 1 - Recommended System of the 2003 Report. The total capital cost for Phase 1 was estimated to be $26.8 million and $32 million for Phase 2. A site plan for the ultimate 50-mgd facilities was also included in the report.

BIO-SOLIDS HANDLING IMPROVEMENTS FINAL REPORT

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BROWN AND CALDWELL

March 18, 2003

Mr. John Claus
Waste Water Operations Manager
Public Works Department
Water Quality Control Plant
City of Riverside
5950 Acorn Street
Riverside, California 92504

12/2276-009

Subject: Final Report on Bio-Solids Handling Improvements at Riverside Regional Water Quality Control Plant

Dear Mr. Claus:

In accordance with out contract, we are pleased to submit 10 copies of the final report on Bio-solids Handling Improvements at the Riverside Regional Water Quality Control Plant. This report has been prepared to serve as a planning document for design and construction of solids handling improvements at the treatment plant.

We have recommended a two-phase approach for the construction of improvements at the plant:

- Phase One will focus on immediate improvements to existing facilities and construction of new facilities to treat up to 40 MGD.

- Phase Two addresses solids treatment needs up to 50 MGD.

Our recommended approach would reduce the odors coming from the existing sludge drying beds by phasing out the drying beds over time and would ensure that Riverside's bio-solids meet all Class A bio-solids requirements. This is very important due to increasing restrictions of disposal of Class B bio-solids. The modifications to the thickening and dewatering operations and the addition of the heat drying process will give the operations team the treatment capacity and reliability to continue to economically meet the permit requirements.

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Should you have any questions or need additional information, please do not hesitate to contact me at (949) 660-1070.

Very truly yours,

BROWN AND CALDWELL

Azee Malik
Project Manager

cc: Bob Finn, Brown and Caldwell

CITY OF RIVERSIDE
REGIONAL WATER QUALITY CONTROL PLANT

BIO-SOLIDS HANDLING IMPROVEMENTS
FINAL REPORT

Submitted by:
Brown and Caldwell

March 2003

REGISTERED PROFESSIONAL ENGINEER
No. C049061
Exp. 9/30/04
CIVIL
STATE OF CALIFORNIA

EXECUTIVE SUMMARY

INTRODUCTION

This report has been prepared to serve as a planning document for design and construction of solids handling improvements for the City of Riverside Regional Water Quality Control Plant (RWQCP). This report addresses solids handling facility needs to treat up to 50 MGD with an earlier phase to treat up to 40 MGD. Proper planning and appropriate implementation of biosolids handling process improvements and additions will ensure the cost effective treatment and disposal of wastewater biosolids.

The recommended plan is intended to enable the RWQCP to continue to reliably process biosolids as wastewater flow increases. The intent is to construct Phase One (40 MGD) and then build the additional facilities over several years as they are needed. To facilitate this phased approach, individual process improvements are expressed in terms of the equivalent plant influent flow capacity they can handle.

Previous Planning

The original target influent flow rates of 40 and 50 MGD were previously established in a Master Plan Update prepared in May 1992. It was agreed with City staff to use these projections as a basis for scheduling design and construction of necessary process improvements. The plant may reach 40 MGD by the year 2010 and 50 MGD by 2030. Due to uncertain growth patterns, individual processes may need to be expanded at different times. Planning for new facilities should begin far enough in advance to allow sufficient time for engineering and construction of needed capacity.

Objectives

The objectives of this report are to:

- Develop and recommend necessary process improvements to treat wastewater solids removed for up to 40 MGD average dry weather wastewater flows and provide space planning for facilities up to 50 MGD.
- Provide planning level costs for these improvements.
- Recommend project phasing and scheduled implementation of improvements.

Existing Conditions

The RWQCP is a tertiary wastewater treatment plant that currently treats approximately 31 MGD. Existing solids handling processes include:

- Primary sludge thickening within primary sedimentation basins
    - Primary sludge from Plant 1 is thickened in the Plant 2 primary sedimentation tanks.
    - Primary sludge concentration is limited to approximately 4.0 % solids.
- Dissolved air flotation thickening (DAFT) of waste activated sludge (WAS)
    - Two – 36 ft diameter DAFTs.
    - Capacity is limited because there is no redundant unit.
    - Thickened solids concentration is approximately 3.5 to 4%.
- Mesophilic anaerobic digestion
    - Two – 90 ft diameter (1.64 million gallon) digesters (digesters 1 & 2) operating.
    - One – 88 ft diameter (1.8 million gallon) digester (digester 4) out of service.
    - One – 75 ft diameter (1.06 million gallon) digester (digester 3) used for digested sludge storage.
    - Low thickened solids concentration produces a higher hydraulic loading on the anaerobic digestion system reducing the available solids retention time. This makes it more difficult to meet EPA Part 503 requirements.
    - Peak 2-week required solids retention time of 15 days cannot be met without bringing digester 4 back on line.
    -
- Belt filter press dewatering
    - Two – 2 meter (100 gpm) belt presses.
    - No redundant unit.
    - Average dewatered cake solids concentration is 12%.
    - Increased hydraulic loading forces units to operate at the upper end of their operating range thus reducing performance.
    - High moisture content cake prolongs air drying time increasing the potential for nuisance odors.
- 29 sludge air drying beds (total area 8 acres)
    - Air drying beds are a source of nuisance odors.

Heat used for anaerobic digestion is supplied from waste heat recovered from the cogeneration facility. The cogeneration facility burns a combination of natural gas, landfill gas and digester gas. Boilers are provided to supplement cogeneration heat when needed.

Process Evaluation and Options

As a part of this study, seven technical memoranda (TMs) have been developed to evaluate solids handling process options. These memoranda are included in this report as Chapters 4 through 10. These seven Chapters included the following:

- Chapter 4 – Solids Projections and Thickening Options
- Chapter 5 – Digestion Options
- Chapter 6 – Heat Energy Options
- Chapter 7 – Dewatering and Air Drying Options
- Chapter 8 – Heat Drying Options
- Chapter 9 – Composting Options
- Chapter 10 – Sidestream Treatment Options

An additional eighth technical memorandum was prepared to evaluated the options presented in the chapters listed above and is included as Chapter 11 - Evaluation of Options.

Thickening Options

Two DAFT options were evaluated:

- WAS thickening.
- Primary sludge and WAS co-thickening.

To improve thickened solids concentration and delay future digester expansion, co-thickening was chosen as the recommended thickening option.

Digestion Options

Three anaerobic digestion options were evaluated:

- Mesophilic digestion.
- Temperature phase digestion (TPAD).
- Class A TPAD.

The two TPAD options were evaluated as a means of increasing volatile solids reduction, increasing gas production and providing a means of achieving higher quality solids. Since life cycle costs for TPAD and current mesophilic digestion options were nearly equal, continued operation of mesophilic digestion is recommended. Conversion to TPAD could be considered in the future.

Heat Energy Options

Heat usage options related to the advanced digestion options were evaluated. Implementation of the TPAD options discussed above would make maximum usage of available heat produced by the cogeneration facility. Although the heat required to operate TPAD would actually exceed available heat production, additional heat could be provided by supplemental boilers and sludge heat recovery between the thermophilic and mesophilic phases.

Dewatering and Air Drying Options

Two dewatering options to handle the anaerobically digested solids were evaluated

- Belt press dewatering.
- Centrifuge dewatering.

As noted above, capacity deficiencies were identified with the existing dewatering system that require immediate attention. Supplemental capacity could be provided by using a rental or purchasing a used belt press or centrifuge. Conversion of the dewatering facility to centrifuges is recommended to increase dewatered cake solids content from 12 to 25%. Increased cake solids content will reduce ultimate disposal costs.

Current air drying practices were also evaluated in light of the monitoring required to certify Class A quality biosolids. Dried product storage was considered to provide a means of keeping the dried product from becoming wet during the rainy season. An important drawback of continuing the practice of air drying is nuisance odors. Therefore, to promote a good neighbor relationship with the surrounding community and improve reliability, heat drying is recommended.

Heat Drying Options

Three different indirect heat drying options were evaluated as a means of producing Class A quality biosolids and allow for phasing out current air drying process. Benefits of heat drying are:

- Overall reduction of nuisance odors.
- Reliable drying during wet weather.
- Reliable production of Class A biosolids making beneficial use options more readily available.

- Free up space currently occupied by air drying beds for other liquid processes or provide a larger buffer zone on the west side of the plant site.

Implementing heat drying would also utilize surplus heat from the cogeneration facility, but would require supplemental heat from another fuel source. Air emissions and odor control would need to be addressed when this option is implemented.

Composting Options

Two enclosed composting processes were evaluated, aerated static pile and in-vessel composting, as alternate methods of producing a Class A product. This option did not prove to be cost effective compared to the other options available for producing Class A material because of its higher capital and operating costs, as well as land requirements.

Sidestream Treatment Options

To address sidestream recycle impacts on the aeration process, treatment options for liquid removed in the dewatering process were evaluated. This sidestream treatment would reduce oxygen demands in the existing activated sludge process by treating this flow separately. The recommended process was the activated sludge process utilizing existing tanks that had been abandoned. During the project status meeting held on October 31, 2002, the City stated that this option was not needed because the sidestream would be handled by process improvements being made to the liquid treatment system.

More detailed discussion of all the options can be found in the Chapters noted above.

Recommended Project

The recommended project is divided into two phases. Phase One and Phase Two facilities are summarized below. Figure ES – 1 shows space planning for ultimate buildout of the solids handling facilities. Figure ES - 2 shows the recommended implementation schecule.

Phase One Facilities

Existing DAFT and Digester 4 Improvements

DAFT improvements

- Pressurization system and control modifications to prevent water logging.
- Polymer system modifications to optimize polymer usage to improve thickened sludge concentration.
- Bottom sludge removal modifications to increase bottom sludge removal.
- Conversion of two existing DAFTs to co-thickening.

Digester 4 improvements

- Digester feed system valve control automation.
- Digester gas collection and conveyance.
- Digester mixing improvements to ensure complete digestion and avoid short circuiting.
- Replace existing boilers with new boiler and possibly replace existing heat exchanger.

New DAFT (Co-thickening)

- One 48 ft diameter DAFT.
- Control building and ancillary equipment.
- Odor control facilities.
- One 20,000 gallon thickened solids blending tank and digester feed pumps.

Dewatering

- Supplemental rental or used belt press.
- One new 200 gpm centrifuge.
- Ancillary equipment and conveyance to heat drying.

Heat Drying

- Dewatered cake surge bin(s).
- 20 dry ton per day heat drying equipment.
- Dried product storage and truck loading.

Phase Two Facilities

New DAFT (Co-thickening)

- One 48 ft diameter DAFT.
- Ancillary equipment.

Dewatering

- Remove existing belt press facilities.
- Two new 200 gpm centrifuges (one duty and one standby).
- Ancillary equipment and conveyance to heat drying.

Heat Drying

- Dewatered cake surge bin(s).
- Another 20 dry ton per day heat drying equipment.

The recommended project is described in more detail in Chapters 1 and 11.

Project Costs

Table ES –1 summarizes Phase One estimated project costs. Detailed cost estimates for the 40 and 50 MGD facilities are included in Appendix C. Vendor quotes for dewatering and heat drying equipment are included in Appendix D.

Table ES – 1 Estimated Project Costs

Phase One (40 MGD)				
Item/Process	**Costs ($1,000)[a]**			
	Construction	**Contingencies 30%**	**Admin/ Engr 25%**	**Total Capital**
DAFT and Digester 4 Improvements (allowance)[b]	600	200	200	1,000
DAFT Process	4,200	1,300	1,400	6,900
Dewatering Process	1,500	500	500	2,000
Heat Drying	10,100	~~3,000~~	~~3,300~~	16,400
Total Cost Phase One	16,400	5,000	5,400	~~26,800~~
Phase Two (50 MGD)				
Total Cost Phase Two	32,000			

a. All costs are shown in 2003 dollars.

b. No detailed costs have been developed for DAFT and Digester 4 Improvements. Detailed costs will be developed in final design.

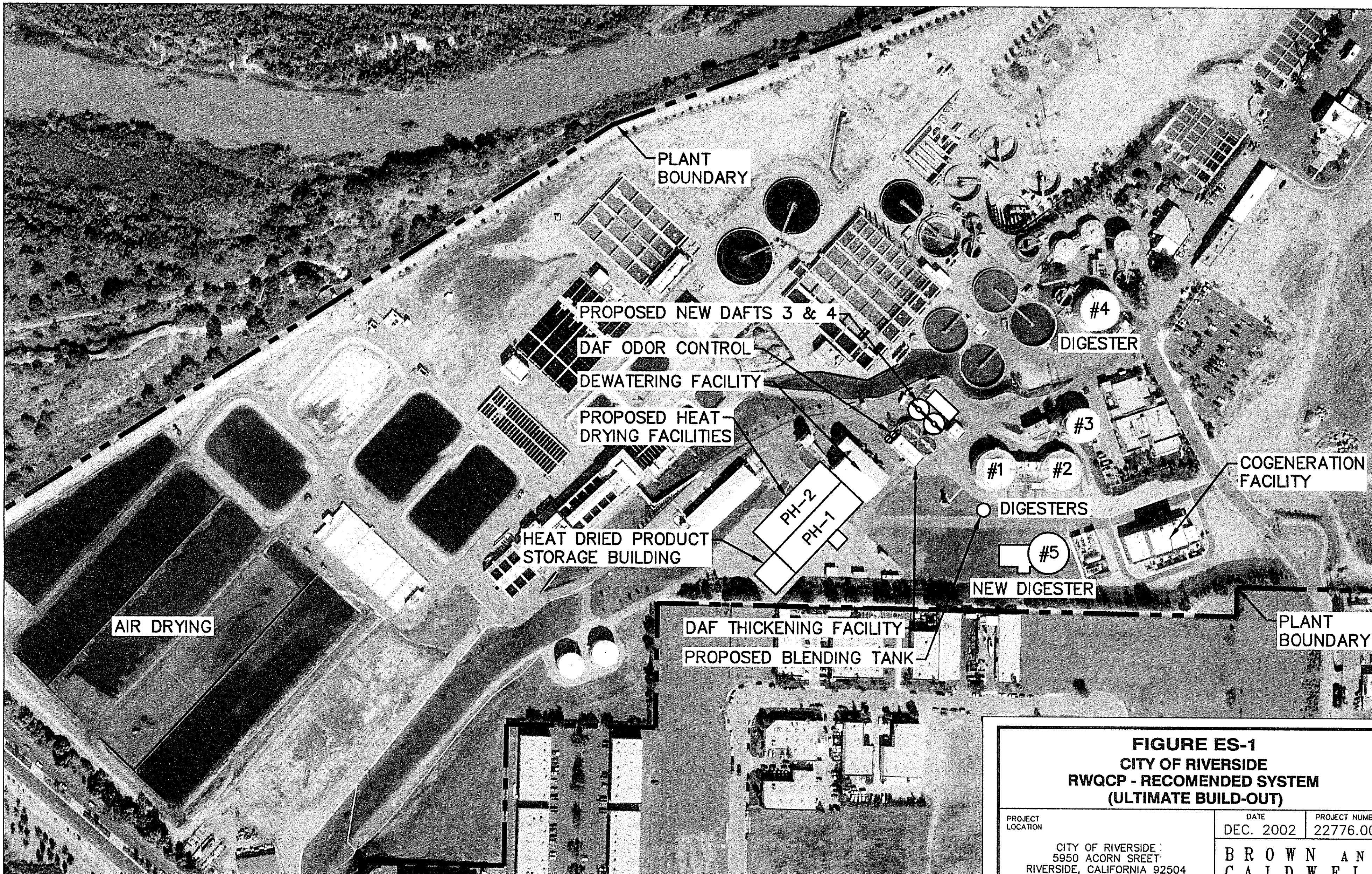

FIGURE ES-1
CITY OF RIVERSIDE
RWQCP - RECOMENDED SYSTEM
(ULTIMATE BUILD-OUT)

PROJECT LOCATION	DATE	PROJECT NUMBER
CITY OF RIVERSIDE 5950 ACORN SREET RIVERSIDE, CALIFORNIA 92504	DEC. 2002	22776.009
	BROWN AND CALDWELL IRVINE, CALIFORNIA	

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RIVERSIDE REGIONAL WATER QUALITY CONTOL PLANT
BIO-S0LIDS HANDLING IMPROVEMENTS IMPLEMENTATION SCHEDULE

Biosolids Handling Process Improvements	Preliminary Capital Costs	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020	2025
Phase One Facilities Design and Construction																
Digestion (Bring digester 4 on line allowance)	1,000															
DAF thickening	7,000															
Dewatering	2,000															
Heat Drying	14,800															
Total capital cost Phase One ($1,000)	24,800															
Phase Two Facilities Design and Construction																
DAF thickening																
Digestion																
Dewatering																
Heat Drying																
Total capital cost Phase Two ($1,000)	32,000															

FIGURE ES - 2 IMPLEMENTATION SCHEDULE

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CHAPTER 1 – RECOMMENDED SYSTEM

INTRODUCTION

Project Background

The City of Riverside Regional Water Quality Control Plant (RWQCP) is a tertiary wastewater treatment plant that currently treats approximately 31MGD. Brown and Caldwell was retained to study current solids handling facilities operation and develop options for future expansion in two phases to process solids removed from 40 and 50 MGD average dry weather influent flows. These capacity requirements were established by the City at the kickoff meeting held on June 4, 2002. At the draft report review meeting held on February 14, 2003, the City revised these target phases to align with current budget planning. Proper planning and appropriate implementation of biosolids handling process improvements and additions will ensure the cost effective treatment and disposal of wastewater biosolids. The recommended plan is intended to enable the RWQCP to continue to reliably handle solids for both phases. The intent is to phase in new facilities over several years rather than bring them on all at the same time. To facilitate this phased approach, individual process improvements are expressed in terms of the equivalent plant influent flow capacity they can handle.

The original target influent flow rates of 40 and 50 MGD were previously established in a Master Plan Update prepared in May 1992. The current plant influent flow was projected to occur by 1995. It was agreed with City staff to use these projections as a basis for scheduling design and construction of necessary process improvements. Assuming only a small percentage of this reduced growth in wastewater flow is attributed to water conservation, the plant may reach 40 MGD by the year 2010 and 50 MGD by 2030. Due to uncertain growth patterns, individual processes may need to be expanded at different times. Planning for new facilities should begin far enough in advance to allow sufficient time for engineering and construction.

Objectives and Report Organization

Objectives

As stated in the scope of work for this project and as discussed at the kickoff and subsequent draft report review meetings, the objectives of this report are to:

- Develop and recommend necessary process improvements to treat wastewater solids removed for 40 MGD and 50 MGD average dry weather wastewater flows.
- Provide planning level costs for these improvements.
- Recommend project phasing and scheduled implementation of improvements.

Report Organization

This report is organized to address the objectives listed above. Chapter 1 presents the recommended system. Chapter 2 provides planning level costs for facilities recommended in Chapter 1. Chapter 3 provides a recommended schedule for implementing planned facilities. As a part of this study, eight technical memoranda (TMs) have been developed to evaluate solids handling options. These eight technical memoranda are briefly summarized as follows:

- **Technical Memorandum 1 – Solids Projections and Thickening Evaluation**
  This TM evaluated existing process performance and developed raw solids projections as a basis for developing the other solids handling options. This technical memorandum also evaluated existing raw solids thickening practices. Since thickening process performance directly impacts process sizing of anaerobic digestion facilities, the two dissolved air flotation thickening (DAFT) options discussed in TM1 were further evaluated in TM2.

- **Technical Memorandum 2 – Digestion Options**
  This TM developed anaerobic digestion options including mesophilic digestion, temperature phase digestion (TPAD) and Class A TPAD. The two TPAD options were developed as a means of increasing volatile solids destruction, increasing gas production, and to provide a means of achieving higher quality solids. The life cycle cost analysis showed that the TPAD and current mesophilic digestion options were nearly equal. Therefore, continued operation of mesophilic digestion is recommended. Conversion to TPAD could be further considered in the future.

- **Technical Memorandum 3 – Heat Energy Options**
  This TM evaluated heat usage options related to the advanced digestion options developed in TM2. This TM showed that implementation of the TPAD options discussed in TM2 would make maximum usage of available heat produced by the cogeneration facility. As noted in TM3, the heat required to operate TPAD would actually exceed available heat production at times and would require some additional heat to be provided by supplemental boilers. Air emissions limits would need to be discussed with the South Coast Air Quality Management District, (SCAQMD) at that time.

- **Technical Memorandum 4 – Dewatering and Air Drying Options**
  This TM evaluated belt press and centrifuge dewatering options to handle the anaerobically digested solids. Current air drying practices were also evaluated in light of the monitoring required to certify Class A quality biosolids. Dried product storage was considered to provide a means of keeping the dried product from becoming wet during the rainy season. Mitigation measures for odor from air drying are also discussed in this TM. Centrifuge dewatering is recommended to provide additional dewatering capacity to supplement belt press dewatering. Use of centrifuges for dewatering would be best linked to heat drying.

- **Technical Memorandum 5 – Heat Drying Options**
  This TM evaluated three different indirect heat drying options as a means of producing Class A quality biosolids and allow for phasing out the current air drying process. Implementing heat drying would also utilize surplus heat from the cogeneration facility, but would also require supplemental heat provided by another source of fuel. Air emissions and odor control would need to be addressed when this option is implemented. Heat drying is recommended to provide a means of producing Class A biosolids and phase out air drying.

- **Technical Memorandum 6 – Composting Options**
  This TM evaluated two enclosed composting processes, aerated static pile and in-vessel composting, as alternate methods of producing Class A biosolids. This option did not prove to be cost effective compared to the other options available for producing Class A material because of its higher capital and operating costs, as well as land requirements. Composting is not recommended.

- **Technical Memorandum 7 – Sidestream Treatment Options**

This TM evaluated treatment options for liquid removed in the dewatering process. This sidestream treatment would reduce oxygen demands in the existing activated sludge process by treating this flow separately. The recommended process was the activated sludge process utilizing existing tanks that had been abandoned. During the project status meeting held on October 31, 2002, the City stated that this option would no longer be needed because the sidestream would be handled by process improvements being made to the liquid treatment system.

- **Technical Memorandum 8 – Evaluation of Options**
  This TM evaluated all the options discussed in the preceding TMs and developed a recommended system including preliminary estimate of capital costs. Further discussion of the recommended system is included in this Chapter.

These technical memoranda have been revised to incorporate comments from the City during the project status meeting held on October 31, 2002. Detailed discussions of all the options are found in the technical memoranda that are included as chapters of this report following Chapter 3.

Existing Facilities

The solids handling facilities that are a part of this plant are shown in Figure 1-1 and consist of the following:

- Dissolved air flotation thickening (DAFT) of waste activated sludge (WAS).
  - Mesophilic anaerobic digestion.
  - Belt press dewatering.
  - Air drying.

Heat used for anaerobic digestion is supplied from waste heat recovered from a cogeneration facility. The cogeneration facility burns a combination of natural gas, landfill gas, and digester gas. Boilers are provided to supplement cogeneration heat when needed. Air quality limits discussed in TM3 indicate that the cogeneration facility is nearing its NO_X emission limits that would need to be addressed if additional combustion equipment was proposed. Table 1-1 summarizes each of these unit processes, operating criteria and current capacity. Table 1-2 summarizes current solids production quantities and flows based on plant influent flow stated previously. Values shown in Table 1-2 were updated to reflect DAFT performance improvements reported at the October 31, 2002 status and February 14' 2003 draft report review meetings.

Table 1-1 – Summary of Solids Handling Processes[a]

Process Facility/Operating Criteria	**Value**
DAF Thickening	
Number of Units[b]	2
Gross Surface Area (sq. ft.), ea	1,018
Effective Surface Area (sq. ft.), ea	943
Total Surface Area (sq. ft.)	1886
Total Surface Area w/one unit out of service (sq. ft.)	943
Solids Loading (lb/sq. ft./day) WAS thickening (current approach) Co-thickening (future) Average Peak day	 14.5 30.0 45.0
Hydraulic Loading (gpm/sq. ft.)	1.0 –2.0
Allowable solids loading, avg w/one unit out, (lb/day) WAS thickening (current approach) Co-thickening (future)	 13,700 28,300
Allowable solids loading, peak day w/all units, (lb/day) WAS thickening (current approach) Co-thickening (future)	 27,300 84,900
Allowable hydraulic loading, avg w/one unit out	943 gpm (1.36MGD)
Allowable hydraulic loading, peak day w/all units	1886 gpm (2.71 MGD)
Air-to-Solids Ratio	.025-.04
Capture rate, %	95
Thickened solids concentration, % WAS thickening (current approach) Co-thickening (future)	 4.0 5.0 – 6.0

(table continues)

Table 1-1 (continued)

Process Facility/Operating Criteria	Value			
Anaerobic Digesters				
Digester No.	1	2	3	4
Diameter, ft	90	90	75	88
Sidewater Depth, ft	32	32	32	38.5
Volume, million gal	1.64	1.64	1.06	1.8
Status	In service	In service	Digested Storage	Out of service
Total Current Digester Volume, million gal (excluding No. 3 and 4)	3.28			
Total Current Digester Volume, million gal (excluding No. 3)	5.08			
Allowable Average flow for min. 18 day solids retention time with one unit out, MGD	0.18			
Allowable Peak 2-week flow for min. 15 day solids retention time with all units in service, MGD	0.33			
Volatile Solids Reduction,%[c]	53			
Digester Gas Production, cu ft/lb VS removed[c]	13			
Dewatering				
Number of Belt filter presses	2			
Belt width, meters	2			
Unit capacity[d]				
Average, gpm	100			
Peak, gpm	150			
Dewatered cake solids conc., %[d]	12			
Air Drying				
Number of drying beds	29			
Total drying area, acres	8			
Dried product solids conc., %	90+			

a. Unless otherwise noted, all information stated in this table was obtained from the plant O&M manual.
b. Number of DAFTs includes only DAFT 1 & 2. Thickened WAS concentration reported by the City.
c. VSR and gas production obtained from plant performance data.
d. Belt Press performance based on plant data.

Table 1-2 – Summary of Current Solids Production at 31 MGD

Parameter	Values				
	TSS		VSS		Flow
	%	Lb/day	% of TSS	Lb/day	MGD
Thickened Primary Sludge					
Average daily	4.15	30,500	82	25,000	0.09
Peak daily	3.42	37,100	82	30,300	0.13
Unthickened WAS					
Average daily	0.53	27,400	79	21,600	0.61
Peak daily	0.54	38,300	80	30,700	0.85
Thickened WAS[a]					
Average daily	4.0	24,700	79	19,500	0.07
Peak 2-week	3.5	34,500	82	28,300	0.12
Combined Thickened Sludge					
Average daily	4.1	55,200	80.5	44,400	0.16
Peak 2-week	3.4	71,600	81.9	58,600	0.25
Digested Biosolids[b]					
Average	2.6	34,700	66	24,000	0.16
Peak 2-week	2.3	48,600	68	33,600	0.25
Dewatered Biosolids[c]					
Average daily feed	2.6	58,400	66	38,500	0.27
Peak 2-week feed	2.3	81,700	68	55,600	0.42
Average cake, tpd (dry)	12	27.7			
Peak cake, tpd (dry)	12	38.8			
Average cake, tpd (wet)	12	227			
Peak cake, tpd (wet)	12	323			

a. Assumes 90% capture by DAFT and stated float concentration.
b. Assumes 53% VSR in digestion, 7days per week operation.
c. Assumes 95% capture by dewatering, 5 days per week, 16 hour per day operation.

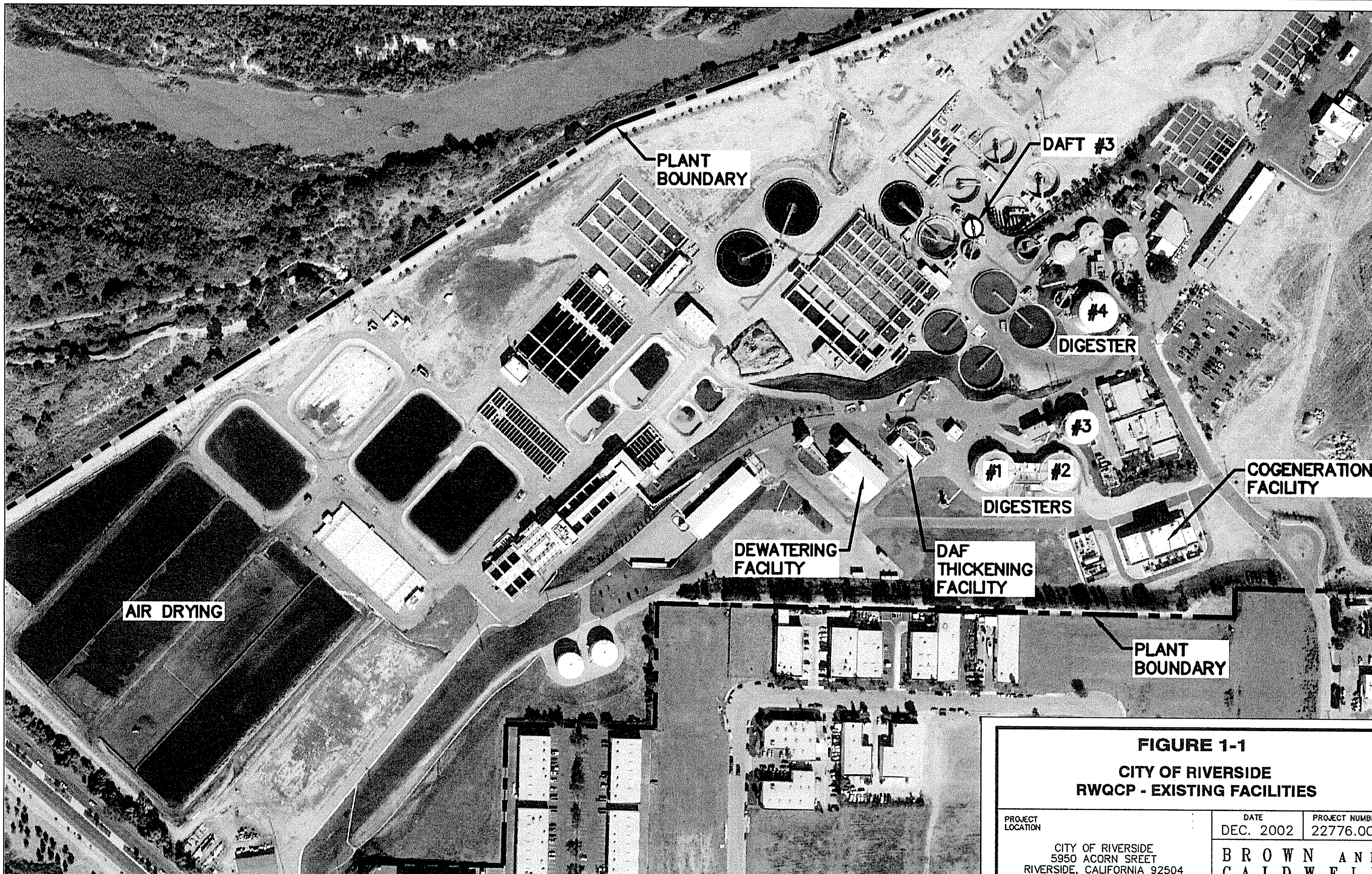

FIGURE 1-1

CITY OF RIVERSIDE
RWQCP - EXISTING FACILITIES

PROJECT LOCATION	DATE	PROJECT NUMBER
CITY OF RIVERSIDE 5950 ACORN SREET RIVERSIDE, CALIFORNIA 92504	DEC. 2002	22776.009

BROWN AND CALDWELL
IRVINE, CALIFORNIA

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Recommended Project

Technical Memorandum 8 evaluated solids handling options presented in Technical Memoranda 1 through 7. The outcome of this evaluation identified recommended facilities for 40 and 50 MGD plant capacities. This section summarizes recommended improvements for solids handling processes Phase One (approximately 40 MGD) and Phase Two facilities. Figure 1-2 shows the site plan for the ultimate 50 MGD facilities.

Phase One Facilities

Existing DAFT and Digester 4 Improvements

DAFT Improvements

- Add a high level switch, high level alarm, and solenoid valve to prevent the pressurization tank from becoming water logged.
- Automate the existing pressurization pumps manually operated valve with air operated throttling valves with flow controller and flow meter.
- Optimize the polymer system to more closely match required polymer dosage.
- Modify the bottom sludge removal system to improve efficiency.
- Convert DAFTs 1 and 2 to co-thickening.

Digester 4 Improvements

- To provide sufficient detention time at peak 2-week flow, Digester 4 needs to be brought back into service. Bringing this digester back into service would require the following:
    - Automate thickened sludge feed valves.
    - Modify controls for thickened sludge feed and digested sludge withdrawal to a PLC based system coordinated with Digesters 1 and 2.
    - Digester gas piping should be evaluated before placing this unit back into service.
    - A new hot water boiler and possibly a new heat exchanger are required.
    - Automate mixing pump system valves and replace the mixing pump.

New DAFT (Co-thickening)

- One – 48 ft diameter DAFT.
- Distribution box.
- Control building sized for ultimate needs.

- Pumps, piping, controls for one new DAFT and two converted DAFTs.
- One 20,000 gallon thickened sludge blending tank.
- Digester feed pumps, piping and controls to feed existing digesters. Provide space for future thickened sludge preheating.

Addition of these facilities will increase thickened solids feed concentration to digestion. This will allow construction of additional digestion capacity to be deferred until plant influent flow nears 43 MGD. Equivalent plant influent flow capacity for the thickening system will be approximately 39 MGD with one unit out of service.

Dewatering

Dewatering facilities assume 5 days per week, 16 hour per day operation.

- Refurbish existing belt filter presses.
- Supplement existing capacity with rental press or purchase used BFP for next several years service.
- One – 200 gpm high solids centrifuge installed in space provided for future belt press 3.
- Dewatering feed pump, polymer feed pump, piping and controls.
- Dewatered cake conveyance to heat drying.

Combined capacity of centrifuge and belt press dewatering will provide plant influent flow capacity for approximately 45 MGD with one belt press out of service. One centrifuge alone would be capable of handling approximately 40 MGD plant influent flow.

Heat Drying

Heat drying facilities assume 5 days per week, 16 hour per day operation. No redundant units are recommended. Critical spare parts will be kept on hand to repair unit that is down. Wet cake from belt presses can be sent to air drying during down time.

- 20 dry ton per day heat drying equipment.
- 125 ft x 90 ft building with provisions for expansion.
- Two – 20 cubic yard dewatered cake surge bins[a].
- Dried product conveyance and loading.
- Odor control facilities.
- Dried product storage for two weeks production.

Note:

a. Surge bin provided for variation in dewatered cake production.

Future Phase Two Facilities

Thickening (constructed before 38 MGD is reached)

- One – 48 ft diameter DAFT.
- Pumps, piping, and controls for one new DAFT.

Anaerobic Digestion (constructed before 43 MGD is reached)

- One – 90 ft diameter, 32 ft sidewater depth digester (to match digesters 1 and 2).
- Pumps, piping, heat exchanger, backup boiler, controls, etc in new control building.

Dewatering (constructed before 40 MGD is reached)

Dewatering facilities assume 5 days per week, 16 hour per day operation.

- Remove existing belt presses.
- Two more – 200 gpm high solids centrifuges (one duty and one standby).
- Dewatering feed pumps, polymer feed pumps, piping, and controls.
- Dewatered cake conveyance to heat drying.

Heat Drying (constructed before 40 MGD if operating hours not extended)

Heat drying facilities assume 5 days per week, 16 hour per day operation. No redundant units are recommended. Critical spare parts will be kept on hand to repair unit that is down. Extended operating hours may be used to increase system capacity when one unit is out of service to continue to produce Class A material.

- A second 20 dry ton per day of heat drying equipment, (see note above for Phase One system if operating hours not revised – See TM8).
- Expansion of Phase One building to house additional equipment provided for Phase Two.
- Two – 20 cubic yard dewatered cake surge bins.
- Dried product conveyance to truck loading.
- Expansion of odor control facilities for Phase Two.

Equipment Criteria

Design data and criteria for the Phase One and Phase Two facilities are shown in Table 1-3 for the recommended solids handling facilities listed above.

Preliminary Layouts

As noted above, the site plan for the recommended project is shown on Figure 1-2. A preliminary layout of the recommended dewatering facilities is shown on Figure 1-3. Manufacturer's equipment drawings for drying equipment are included in Appendix B for reference. More detailed equipment layouts and Piping and Instrumentation Diagrams will be developed during detailed design.

Table 1-3 – Design Data and Performance Criteria

Item/Criteria	Phase One	Phase Two
DAFT Co-thickening		
Avg daily, Solids Loading, lb/day	100,700	117,000
Peak daily, Solids Loading, lb/day	151,000	152,000
Thickened solids concentration, %	5.0 – 6.0	
Capture, %	90	
Surface Loading, lb/sf/day	30-45	
Hydraulic Loading (including recycle), gpm/sf	1.0 – 2.0	
Number of units added	1[a]	1[b]
Diameter, ft	48	48
a. Number of DAFTs added for Phase One is based on no additional equipment provided to meet current capacity deficiencies. b. Total number of DAFTs at 50 MGD = 2 existing + 2 new = 4		

Anaerobic Digestion			
	Phase One - Digester 4 on-line		
	Phase Two		
	Flow MGD	TSS Lb/d	VSS Lb/d
Thickened solids flow, avg [c]	0.30	126,000	102,000
Thickened solids[c] flow, peak 2-week	0.42	177,100	143,000
Avg HRT (one unit out), days	18		

(table continues)

Table 1-3 (continued)

Anaerobic Digestion			
	Phase One - Digester 4 on-line		
	Phase Two		
	Flow MGD	TSS Lb/d	VSS Lb/d
Peak HRT (all units), days	15		
Volatile solids reduction, %	53		
No, of units added	1		
Diameter, ft	90[d]		
Sidewater depth, ft	32[d]		

c. Thickened solids flow assumes co-thickened sludge concentration of 5.0%.
d. Future new digester sized to match existing digesters.

Dewatering						
	Phase One			**Phase Two**		
	Flow MGD	TSS Lb/d	VSS Lb/d	Flow MGD	TSS Lb/d	VSS Lb/d
Digested solids flow, avg [e]	0.26	58,001	38,301	0.30	72,500	48,000
Digested solids[e] flow, peak 2-week	0.38	81,201	53,621	0.42	101500	67,200
Dewatering feed solids[f] flow, avg	0.55	121,802	80,431	0.63	152,300	100,800
Dewatering feed solids[f] flow, peak 2-week	0.46	170,523	112,604	0.88	213,200	141,100
No, of centrifuges added	1			2		
Average centrifuge unit capacity, gpm	200			200		
Peak 2-week centrifuge unit capacity, gpm	250			250		
Avg belt press unit capacity, gpm	100			Removed		
Peak belt press unit capacity, gpm	150			Removed		
Cake solids concentration, %						
Belt press	15 to 18					
Centrifuge	25 to 27					

(table continues)

Table 1-3 (continued)

Dewatering						
	Phase One			**Phase Two**		
	Flow MGD	TSS Lb/d	VSS Lb/d	Flow MGD	TSS Lb/d	VSS Lb/d
Capture, %	95					
Cake conveyance to heat drying surge bin(s)	Positive displacement piston pump or enclosed conveyance system.					

e. Digested solids flow based on 53% VSR, 7 day/week.
f. Dewatering feed solids flow assumes 5 days per week, 16 hrs per day operation.

Heat Drying		
Plant design flow	**Phase One**	**Phase Two**
Avg daily Dewatered cake, dry ton per day[g]	39	48
Peak 2-week Dewatered cake, dry ton per day[g]	54	67
Average evaporation capacity, lb/hr 5 days per week, 16 hours per day operation	6,157	7,697
Peak evaporation capacity, lb/hr 5 days per week, 16 hours per day operation	8,620	10,775
Minimum unit capacity	10 dtpd	
Number of units[h]	Two	Two
Cake conveyance to dryers	Positive displacement pump	
Dried product conveyance to truck loading	Screw conveyor, (water cooled)	
Biofilter – Odor Control Max. H_2S conc, ppm Air residence time, sec. Biomedia depth, ft Air velocity thru media, ft/min Air humidity Foul air blower Drive	 25 90 3-4.5 min 3 saturated centrifugal, fiberglass Variable speed, flow controlled	

g. Dryer feed solids flow assumes 5 day/week, 16 hr/day dewatering operation.
h. Number of units based on 10 dtpd drying units.

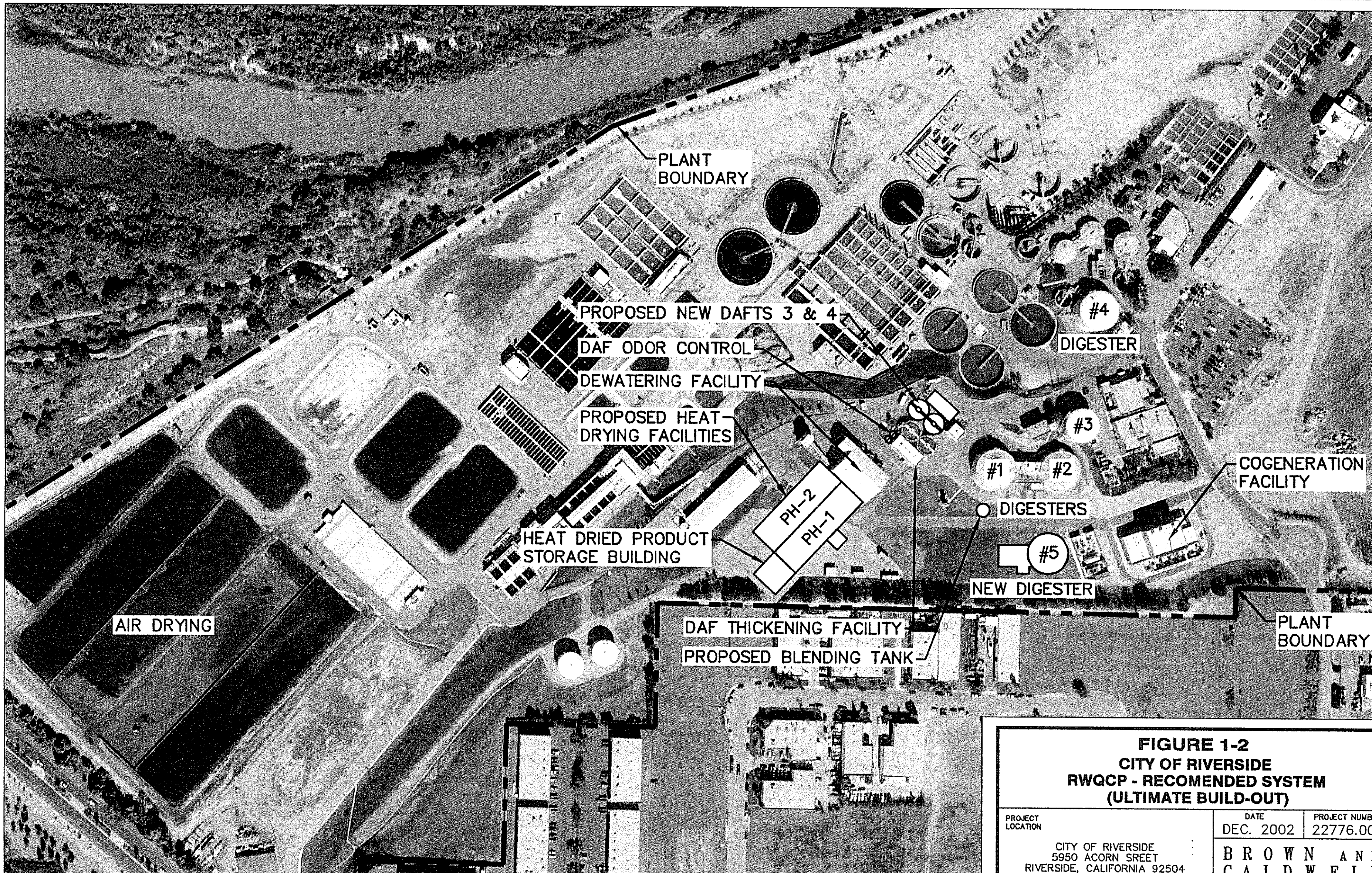

FIGURE 1-2
CITY OF RIVERSIDE
RWQCP - RECOMENDED SYSTEM
(ULTIMATE BUILD-OUT)

PROJECT LOCATION	DATE	PROJECT NUMBER
CITY OF RIVERSIDE 5950 ACORN SREET RIVERSIDE, CALIFORNIA 92504	DEC. 2002	22776.009
	BROWN AND CALDWELL IRVINE, CALIFORNIA	

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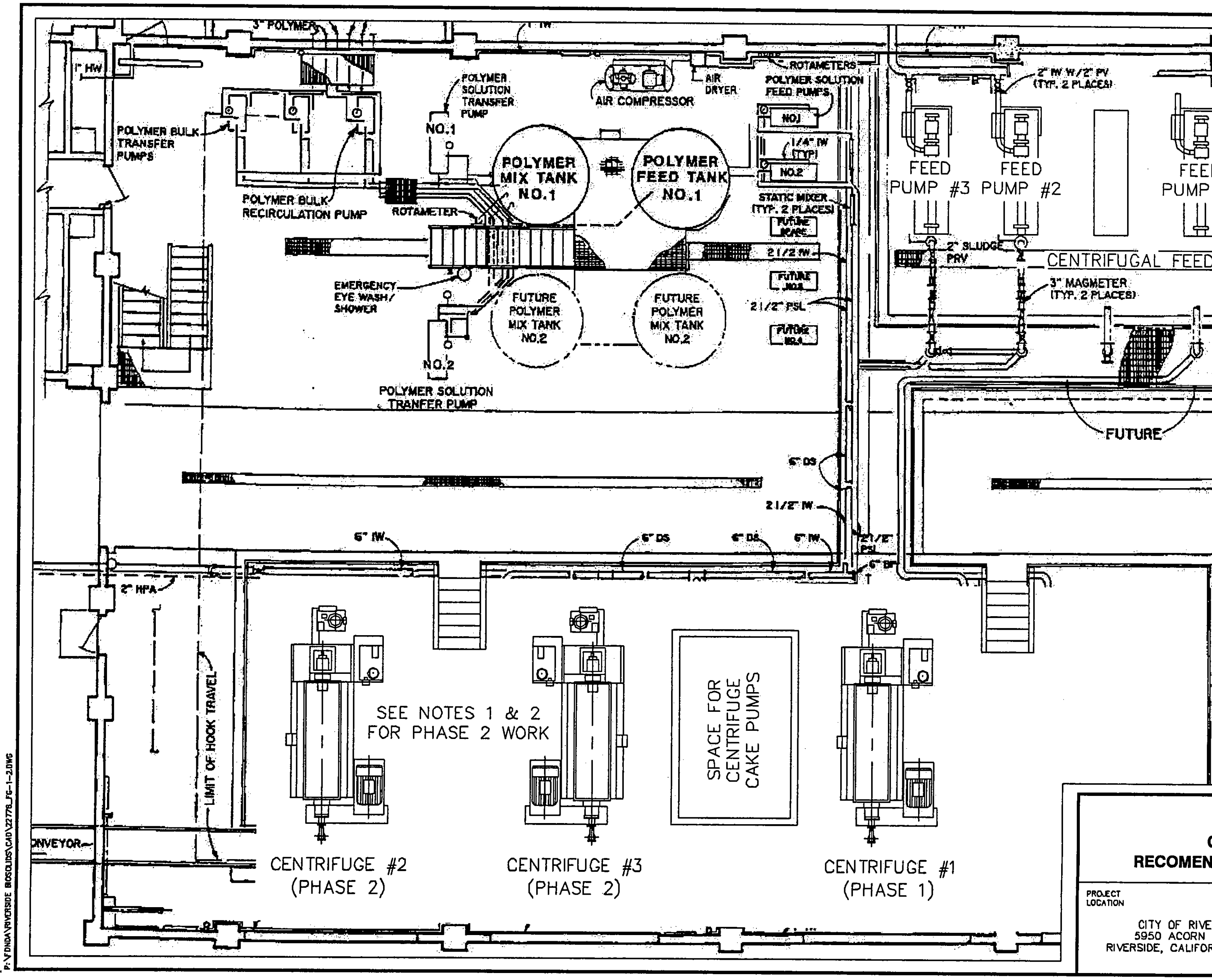

NOTES:

1. PHASE 2 CENTRIFUGES INSTALLED IN SPACE PREVIOUSLY OCCUPIED BY BELT PRESSES 1 & 2.
2. BELT PRESSES 1 & 2 TO BE DEMOLISHED DURING PHASE 2.

FIGURE 1-3

CITY OF RIVERSIDE
RECOMENDED DEWATERING SYSTEM

PROJECT LOCATION	DATE	PROJECT NUMBER
CITY OF RIVERSIDE 5950 ACORN SREET RIVERSIDE, CALIFORNIA 92504	DEC. 2002	22776.009
	BROWN AND CALDWELL IRVINE, CALIFORNIA	

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CHAPTER 2 – PROJECT COSTS

Capital costs have been developed for each process system for both the Phase One and Phase Two systems recommended in Chapter 1. Table 2-1 summarizes estimated capital costs. Detailed cost estimates for the 40 and 50 MGD (Phase One and Phase Two) facilities are included in Appendix C. Vendor quotes for dewatering and heat drying equipment are included in Appendix D.

Table 2-1 – Estimated Project Costs

Phase One (40 MGD)				
Item/Process	**Costs ($1,000)[a]**			
	Construction	**Contingencies 30%**	**Admin/ Engr 25%**	**Total Capital**
DAFT and Digester 4 Improvements (allowance)[b]	600	200	200	1,000
DAFT Process	4,200	1,300	1,400	6,900
Dewatering Process	1,500	500	500	2,000
Heat Drying	10,100	3,000	3,300	16,400
Total Cost of Phase One	16,400	5,000	5,400	26,800
Phase Two (50 MGD)				
Total Cost of Phase Two	32,000			

c. All costs are shown in 2003 dollars.

d. No detailed costs have been developed for DAFT and Digester 4 Improvements. Detailed costs will be developed in final design.

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CHAPTER 3 – PROJECT IMPLEMENTATION

On June 4, 2002, Brown and Caldwell held a kickoff meeting with the City of Riverside Public Works Department Water Quality Control Plant management and operations staff to further define the basis for facility planning for the solids handling facilities. At that meeting, the City directed Brown and Caldwell to evaluate facility needs for 40 and 50 MGD rather than specific planning periods. At the draft report review meeting held on February 14, 2003, the City revised these target phases to align with current budget planning. Technical Memorandum 8 defined Phase One facilities in terms of equivalent plant influent flow capacity. Intermediate phases may follow based on the capacity of each process unit.

As described in Chapter 1, facilities have been defined for both 40 and 50 MGD. In 1992, a Master Plan update was prepared for the RWQCP that projected future flows up to the year 2040 (see Appendix E. for copy of Master Plan update flow projections). Current plant average dry weather flow was projected to occur by the year 1995. Reduced flows may be a result of both economic factors and water conservation. While water conservation efforts tend to reduce wastewater flow, they tend to increase solids concentrations, with the net effect being that wastewater solids removed would remain as projected. Therefore, it was agreed with City staff to use these projections as a basis for scheduling design and construction of necessary process improvements. To facilitate long range planning it may be assumed that growth within the Riverside service area may occur at a similar rate as previous projections. Based on this assumption, flow projections could be made starting at the current reduced flow and parallel the projected growth rate. This would result in an average dry weather flow of 40 MGD to occur by year 2013 and 50 MGD to occur by the year 2040. Therefore, design and construction of facilities needed for Phase One should begin immediately. Design and construction of other phases should begin far enough in advance to ensure engineering and construction can be completed in time to provide needed capacity. This implementation schedule should be reviewed again every three years. Figure 3-1 shows an implementation plan.

RIVERSIDE REGIONAL WATER QUALITY CONTOL PLANT
BIO-S0LIDS HANDLING IMPROVEMENTS IMPLEMENTATION SCHEDULE

Biosolids Handling Process Improvements	Preliminary Capital Costs	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020	2025
Phase One Facilities Design and Construction																
Digestion (Bring digester 4 on line allowance)	1,000															
DAF thickening	7,000															
Dewatering	2,000															
Heat Drying	14,800															
Total capital cost Phase One ($1,000)	24,800															
Phase Two Facilities Design and Construction																
DAF thickening																
Digestion																
Dewatering																
Heat Drying																
Total capital cost Phase Two ($1,000)	32,000															

FIGURE 3 -1 IMPLEMENTATION SCHEDULE

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CHAPTER 4 - TECHNICAL MEMORANDUM NO. 1, ASSESS CURRENT SOLIDS OPERATION, THICKENING SYSTEM AND DETERMINE SOLIDS PROJECTIONS

City Of Riverside Water Quality Control Plant Assess Current Solids Operation, Thickening System and Determine Solids Projections
Technical Memorandum No. 1

Prepared By: Brown and Caldwell

Date: Revised December 20, 2002

Introduction

Assessing current conditions and making projections of future solids quantities is the basis of a sound solids handling master plan. Brown and Caldwell held a kickoff meeting with the City of Riverside Public Works Department Water Quality Control Plant management and staff on June 4, 2002 to further define concepts and criteria that would be a part of this master planning effort. The City established 40 and 50 MGD influent flow conditions rather than a specific design year as the basis for all concepts being developed. Currently, another engineering firm is evaluating the liquid process to address liquid stream capacity and treatment requirements. Solids projections presented in this technical memorandum are based on current levels of treatment. Enhancements and modifications to thickening, digestion, dewatering, drying and recycle stream treatment will have some impact on future solids quantities. Changes to solids quantities from these processes will be addressed in other technical memorandums.

Objectives

As stated in the scope of work for this project and as discussed at the project kickoff meeting, the following objectives are addressed in this technical memorandum.

1. Review plant sludge production and current solids system operational data

2. Confirm existing solids production

3. Estimate design flow solids quantities for 40 and 50 MGD average raw wastewater influent flow and determine average, peak month, and peak day quantities.

4. Evaluate future thickening performance and assess long-term improvement options for solids thickening.

Existing Conditions and Solids Projections

Existing Conditions

The existing raw solids processing facilities at the Riverside Water Quality Control Plant (RWQCP) consist of dissolved air floatation thickeners (DAFT)s. A description of current solids processing equipment is included in Table 1.

Table 1. Existing Raw Solids Processing Facilities[a]

ITEM	VALUE
Dissolved Air Flotation Thickeners (DAFT)s	
Number of Units	2
Tank Diameter (ft.)	37
Sidewater Depth (ft.)	10
Gross Surface Area (sq. ft.)	1,018
Effective Surface Area (sq. ft.)	943
Solids Loading (lb/sq. ft./day)	9.5-14.5
Hydraulic Loading (gpm/sq. ft.)	0.8-1.0
Air-to-Solids Ratio	.025-.04
TWAS Transfer Pumps	Thickeners Nos. 2 & 3
Number of Units	1 per DAF
Type	Progressive Cavity
Capacity (gpm)	150
Recycle Pressurization Pumps (Duplex)	
Number of Units	1 per DAF
Type	Duplex, centrifugal
Flow Rate (gpm)	1,000

[a] Information obtained from Plant O&M manual provided by the City

Solids Projections

The City provided both wastewater and solids data spreadsheets for the years 1997 to October 2001. Brown and Caldwell evaluated recent data for the year 2001 as the basis for solid projections for 40 and 50 MGD influent flow. Table 2 summarizes raw solids data for 2001. Table 3 summarizes raw solids projections for the 40 and 50 MGD flow condition. Solids projections are made based on current levels of treatment.

Table 2. 2001 Raw Solids Summary

Month	Primary Sludge %TS	Primary Sludge flow	Primary Sludge TSS	Primary Sludge VSS	DAFT Influent Flow	WAS TSS	DAFT Influent TSS	DAFT Influent VSS
	%	MGD	LB/D	LB/D	MGD	mg/l	LB/D	LB/D
Monthly flows								
January	4.59	0.06	22,823	19,359	0.61	6,099	33,170	26,852
February	4.46	0.07	26,432	21,654	0.62	6,063	35,025	28,938
March	4.78	0.08	33,194	27,242	0.64	5,518	27,643	20,126
April	4.58	0.07	28,300	23,294	0.65	5,600	30,189	24,596
May	4.17	0.09	29,592	23,994	0.65	5,518	27,359	21,110
June	4.12	0.09	30,435	24,779	0.64	5,974	31,261	25,582
July	4.02	0.09	30,425	24,658	0.62	4,762	24,429	19,789
August	3.80	0.12	36,694	29,764	0.55	4,710	21,655	17,300
September	3.56	0.13	37,090	30,347	0.56	4,388	20,298	16,869
October	3.47	0.10	30,029	24,444	0.56	4,737	21,979	17,861
Average	4.15	0.09	30,529	24,953	0.61	5,337	27,392	21,908
Max mo	4.78	0.13	37,090	30,347	0.65	6,099	35,028	28,938
Peak daily								
January	5.03	0.08	32,955	24,531	0.63	7,800	40,373	32,181
February	4.51	0.26	96,026	78,261	0.63	8,114	42,582	34,065
March	4.60	0.11	43,957	35,695	0.67	6,240	34,676	27,048
April	4.30	0.09	33,023	27,574	0.66	6,420	34,267	27,498
May	4.61	0.10	38,713	31,938	0.65	6,240	33,648	26,582
June	4.06	0.10	33,831	27,309	0.65	6,640	35,326	27,599
July	4.03	0.11	35,294	29,118	0.63	5,760	29,400	22,932
August	3.19	0.14	37,626	30,542	0.61	5,510	27,197	21,486
September	3.99	0.14	45,086	36,970	0.59	4,850	22,716	18,094
October	4.76	0.13	50,282	39,723	0.59	5,550	25,262	19,413
Avg day	4.31	0.12	44,679	36,166	0.63	5,982	31,611	24,377
Peak day	5.03	0.26	96,026	78,261	0.67	8,114	42,582	34,065

Primary removal rates were evaluated based on influent strength and primary sludge quantities and were calculated to be approximately 53%. This is within industry norms and is most likely due to primary sludge from Plant 1 being blended with Plant 2 influent. Waste activated sludge quantities appeared to slightly lower than calculated values based on reported thickened sludge quantities going to the digester. This apparent discrepancy may be due to multiple WAS flow meters compounding errors. Since the thickened sludge quantities were higher than they would be calculated to be from WAS quantities, reported thickened sludge quantities will be used for evaluating digester options.

Table 3. Solids Projections

	Average Primary sludge	Average Raw WAS
40 MGD		
TSS 1000 lb/day	39	35
VSS 1000 lb/day	32	28
Flow, MGD	0.12	0.61
50 MGD		
TS 1000 lb/day	49	44
VS 1000 lb/day	40	35
Flow, MGD	0.15	0.76
Peak Daily Factors		
Solids	2.2	1.4
Flow	2.0	1.4

Peak Factors

Peak factors are the ratio of the maximum observed sludge and flow quantities observed within a defined time period to the average sludge quantities for that period. The data used to project future sludge quantities was also used for developing these peak factors. Peak month and peak day factors are also shown in Table 3. These peak factors have been compared to industry norms and appear to be reasonable. These factors will be used to evaluate the existing thickening system capability of handling future solids loading and make recommendations for future expansion to the thickening system.

Sludge Thickening

Design Criteria.

The existing thickening system thickens primary solids in the primary sedimentation basins and waste activated sludge is thickened in DAFTs described above. This thickening system evaluation assumes that primary solids will continue to be thickened in the primary sedimentation basins when thickened separately. During the kickoff meeting, operations staff indicated that fresher primary sludge appears to digest better and reduces potential process impacts on the secondary treatment system. Brown and Caldwell noted its experience with co-thickening primary and secondary solids in DAFTs at San Louis Obispo and other facilities and the City asked that the co-thickening option be considered as well. Solids loading rates of up to 40 lb/sf/day or higher with thickened solids at 5.5% with polymer addition have been achieved consistently at the King County Washington South Plant at Renton for over a decade. A comparison DAFT system solids loading for both WAS thickening and co-thickening is also included in this evaluation. It is assumed that the thickening system must be able to handle average daily loading with one unit out of service and peak daily loading with all units in service. Design criteria for both WAS thickening and co-thickening are summarized in Table 4.

Table 4. Existing DAFT Design Criteria

Parameter	Value
Number of DAFTs	2
Diameter (ft)	37
Effective surface area (sq. ft)	943
Solids loading - Separate thickening [(a)] (lbs/sf/d) - Co-thickening [(b)] (lbs/sf/d)	 9.5 to 14.5 22 to 30
Solids Capture	95%
Float solids concentration (without polymer addition) - Separate thickening [(c)] - Co-thickening [(d)]	 4.5 – 5.0 5.0 - 5.5

(a) Solids loading for separate thickening taken for Plant O&M manual
(b) Solids loading for co-thickening taken from Brown and Caldwell recent experience.
(c) Solids concentration reported by City staff at October 31, 2002 review meeting
(d) Solids concentration taken from Brown and Caldwell recent experience. Some polymer addition may be required.

Evaluation of Thickening System

The WAS thickening capacity is determined by the solids loading rate and the number of units on line. Based on the criteria shown in Table 4, the existing two DAF thickeners will have inadequate capacity to thicken peak monthly flow with both units on line. Table 5 shows the solids loading and required surface area for the DAFTs at the 50 MGD flow condition.

Table 5. Future DAFT Solids Loading

	WAS thickening	Co-thickening
50 MGD		
Average daily solids loading, lb/day	44,180	93,000[(a)]
Average daily hydraulic loading, gpm	528	790[(a)]
Peak daily solids loading, lb/d	61,851	194,800[(a)]
Peak daily hydraulic loading, gpm	593	1,089[(a)]
Solids Loading criteria lb/sf/d	14.5	40
Hydraulic Loading criteria gpm/sf	0.8 – 1.0	1.0 – 2.5
Required Surface Area (avg. solids), sf	3,047	2,325
Required Surface Area (avg. hydraulic), sf	528	790
Required Surface Area (peak. solids), sf	4,265	4,870
Required Surface Area (peak.hydraulic), sf	740	436
Existing Surface Area, sf (1 unit out of service)	943	943

	WAS thickening	Co-thickening
Existing surface area, sf (all units in service)	1,886	1,886
Additional area required, sf (based on avg)	2,104	1,382
Additional area required, sf (based on peak)	2,379	2,984
Additional units required	2 (39 ft diameter)[b]	2 (44 ft diameter)[c]

(a) Co-thickening solids and hydraulic loading based on primary sludge concentration at 0.5 to 1.0 % with bottom sludge recycle equal to 25% raw solids loading for average and 15% raw solids loading for peak.
(b) WAS thickening unit size based on peak daily solids loading including effluent launder.
(c) Co-thickening unit size based on peak daily solids loading.

Based on the comparison shown in Table 5 two additional DAFT will be needed for both options. Sizes shown will handle solids produced by an ultimate flow of 50 MGD. The existing auxiliary equipment would also need to be duplicated.

As shown in Table 5, co-thickening could also be handled with the same number of units as WAS only thickening with a slightly larger tank to handle peak daily solids loading. The advantages and disadvantages for using DAFTs to co-thicken primary and secondary solids are:

√ Advantages

- All solids can be processed with no concern over the amount of liquid they bring with them. Primary and secondary scum could be thickened prior to digestion thereby reducing hydraulic loading on the digesters.
- Higher float concentration can be achieved which would reduce required digester volume thereby reducing the cost of new digester facilities.
- Primary solids removal rate could be increased simplifying primary sludge withdrawal and reducing possible septic conditions and other impacts on downstream secondary processes.
- Primary sedimentation surface overflow rates could be increased to 2400 gpd/sf at peak flow which could reduce the number of primary sedimentation basins needed to meet future flow conditions.
- Grit could be removed from primary sludge prior to digestion reducing the frequency of digester cleaning.
- Simplified and more homogenous solids feed to digesters. This is more significant with advanced digestion options.

√ Disadvantages

- DAFTs would need to be covered to control odors reducing operator visibility.
- Foul air scrubbing would need to be added to treat odors.

- Dissolution air would need to be increased to meet air to solids ratios
- Sludge grinders or chopper pumps would be needed for primary sludge (this would be recommended regardless of implementation of co-thickening to improve digester operation and produce a more pleasing end product)
- Primary sludge piping would need to be routed to DAFTs, primary sludge pumps would need to be upgraded for higher flows and pump programming would need to be revised.
- Thickened solids pumps and piping would need to be upsized.
- Float collection systems would need to be upgraded.
- Bottom solids degritting cyclones would be needed (primary sludge degritting would be recommended regardless of implementation of co-thickening to reduce grit accumulation in the digesters)

The details of implementing either system would need to be developed in the design phase.

Process Improvements

During the site visit done following the kickoff meeting observations of the existing DAFT equipment were made. Analysis of the data provided indicates that the average float solids concentration is approximately 3.5%. This concentration is on the low end of industry norms for this process. Information obtained from Operations staff indicates that no polymer is currently being used in the thickening system. This could account in part for the lower float solids concentration. Information obtained at the October 31, 2002 review meeting indicated recent modifications have been made to equipment that has improved thickening performance and the average float solids concentration is now in the range of 4.5 to 5.0 %. Other modifications that could be made to process equipment that could improve process performance include:

- Submerged weir for influent solids distribution and better float control.

- Possible addition of turbidity monitoring on subnatant to better control capture efficiency.

A recent site visit by one of Brown and Caldwell's senior operations specialist identified several other modifications that could improve plant performance and simplify operation. Based on these observations the following additional improvements are recommended.

- To prevent the pressurization tank from becoming water logged the addition of a high level switch, high level alarm and solenoid valve is recommended

- Replace the existing manual operated valve with an automatic air operated throttling valve with flow controller and flow.

- In general, the polymer storage and feed systems appear to be oversized. Further evaluation of the polymer system should be done during detailed design to more closely match required polymer usage.

- A more efficient bottom sludge removal system is recommended. Further evaluation of more efficient bottom sludge removal should be done during detailed design

Recommendations

The size and performance of the digestion process is intimately tied to the performance of the thickening process and thickened solids concentration. Therefore, further consideration of recommendations for the thickening process will be discussed in Technical Memorandum 2 – Digestion Options. Life cycle costs will be developed for both thickening options as a part of that Technical memorandum that will allow recommendation of the system that provides the most advantageous solution for the solids handling process.

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CHAPTER 5 - TECHNICAL MEMORANDUM NO. 2, EVALUATION OF DIGESTION OPTIONS

City of Riverside Water Quality Control Plant Evaluation of Digestion Options Technical Memorandum 2

Prepared By: Brown and Caldwell
Date: Revised December 20, 2002

Introduction

Project Background

Efficient digestion of raw wastewater solids protects the environment and public health and reduces solids disposed of from the facility. Solids reduction lowers plant operating costs saving the rate payers money. On June 4, 2002, Brown and Caldwell held a kickoff meeting with the City of Riverside Public Works Department Regional Water Quality Control Plant management and operations staff to further define the scope and design criteria for this digestion options study. Process objectives for this study would maximize solids destruction, increase gas production, minimize odor impacts and consider Class A product requirements as defined by EPA 40CFR Part 503 regulations. Several anaerobic digestion options were discussed during the meeting including mesophilic, thermophilic, temperature phased, and acid/gas phased digestion as well as pasteurization. Data from several plants operating these processes were provided to show the levels of volatile solids destruction and gas production. Each of these options is described in greater detail later in this technical memorandum. Because of their tendency to produce a solids that are more odorous, thermophilic only and acid/gas digestion options have been dropped from further consideration. The ability to produce a Class A product was also discussed and determined to be of secondary importance. On October 31, 2002, a status and review meeting was held with with the City of Riverside Public Works Department Regional Water Quality Control Plant management and operations staff to discuss any comments they may have on the draft technical memorandum. Information received at that meeting is being incorporated into this revised technical memorandum. The most significant comment received at that meeting was on the performance of the existing DAFs. Plant staff reported that thickened sludge concentration has increased from the 3.5% reported in data previously provided to 4.5 to 5%. Plant staff felt that this performance level was achievable on a regular basis since modifications to the existing DAF bottom scrappers and air compressor system had been made.

Objectives.

As stated in the scope of work for this project and as discussed at the project kickoff meeting, the following objectives are addressed in this technical memorandum.

1. Define digestion options using existing tankage at the Riverside Regional Water Quality Control Plant (RWQCP) including options discussed at the kickoff meeting.

2. Develop process schematics, key piping/equipment needs and estimate performance benefits of the top two options in terms of volatile solids destruction, gas productions, dewatering impacts, recycle impacts and product odor.

3. Define capital costs for the two options evaluated

Existing Digestion Facilities

The existing anaerobic digestion process includes five digesters ranging in size from 0.603 to 1.8 million gallons. The smallest of these digesters is no longer in service. The next smallest digesters is currently being used for storage prior to dewatering. This digester is normally unheated and unmixed although it has the equipment necessary to do both. Thickened primary and secondary sludge and primary scum are fed separately directly to the digesters. As discussed in Technical Memorandum 1 (TM1), WAS is thickened in two DAFTs and primary sludge is thickened in the primary sedimentation tanks. Primary sludge from Plant 1 is sent to Plant 2 for further thickening along with the raw wastewater coming to Plant 2. Primary sludge from Plant 2 is fed sequentially to the operating digesters on a time basis every 15 minutes. Operations has indicated that when times between pumping have been extended beyond 15 minutes that holes have developed in the sludge blanket and the sludge can become septic and float. The average primary sludge concentration as shown in TM1 is approximately 4.5%. The average thickened WAS (TWAS) concentration as shown in TM1 is approximately 4.5 to 5.0% (reported by City at October 31, 2002 meeting). The thickened sludge pumps located at the DAFTs transfer TWAS sequentially to the digesters on a timed basis.

Necessary digester heating is provided by individual spiral heat exchangers located in the digester control buildings located at the digesters. Hot water is provided primarily from hot water produced by waste heat at the cogeneration facility. Backup boilers are provided to supply necessary heat when the cogeneration facility cannot provide sufficient hot water to run the plant. Currently most of the plant's hot water needs are provided from the engine generator's jacket water and after cooler water heat exchangers with exhaust heat exchangers supplementing the system occasionally. Use of available heat energy will be addressed in a separate technical memorandum.

A description of the existing anaerobic digestion equipment is shown in Table 1.

TABLE 1 – EXISTING DIGESTER EQUIPMENT

ANAEROBIC DIGESTERS

Digester No.	1	2	3	4
Diameter, ft	90	90	75	88
Sidewater Depth, ft	32	32	32	38.5
Volume, million gal	1.64	1.64	1.06	1.8
Total Digester Volume, million gal (excluding No. 3)			5.08	

MIXING PUMPS

Digester No.	1	2	3	4
No. of Units	2	2	1	1
Type	Vortex Propeller, centrifugal			

Process Alternatives

In addition to considering mesophilic digestion options similar to the approach currently in use at the RWQCP, several other technologies have developed over the last decade that may improve digester performance, obtain Class A biosolids and provide other benefits. Across the country data being gathered from processes now in operation or being pilot tested are showing varying levels of success in increasing volatile solids reduction resulting in increased digester gas production. Several of these technologies were discussed briefly at the kickoff meeting. These processes are described in more detail below.

Mesophilic Anaerobic Digestion

Mesophilic anaerobic digestion is the most common stabilization process used today, and is the process that has been used at the existing RWPCF. Historically, the process was implemented in a 2-stage system where the first tank was used for stabilization and the second for storage and concentration of digested sludge. Modern high-rate digesters are typically single-stage reactors, such as used at Riverside. Organic matter is converted to methane, carbon dioxide, and water; pathogen densities are reduced; and a stabilized sludge is produced. Mesophilic anaerobic digesters is typically operated at temperatures between 35 and 38 degrees C. EPA estimates that over 50 percent of the wastewater treatment plants in the US use this process. Mesophilic digestion at the RWQCP produces a Class B (pathogen) product and easily meets vector attraction reduction requirements for stabilized biosolids.

Two-stage mesophilic digestion could be a process option. This process typically involves a second-stage reactor that has less solids retention time (SRT) than the first stage. The advantage of the process is slightly improved VSR and a product with reduced pathogen content and a product with less odor potential. Some repiping would be required to implement this process variation at the RWPCF.

Thermophilic Anaerobic Digestion

Thermophilic anaerobic digestion is similar to mesophilic anaerobic digestion except that the reactors are operated at temperatures ranging from 50 to 60 degrees C. At present, there are at least a dozen full-scale wastewater plants using thermophilic anaerobic digestion in the US. The major differences between thermophilic and mesophilic digestion are the requirements for sludge heating, temperature control, feed control, and digester gas management. The major advantages of thermophilic digestion are additional VSR and gas production, and the potential to meet Class A requirements. Thermophilic digestion can be undertaken in single-stage systems or in multiple-stage systems. Multiple stage systems have advantages in pathogen control and reducing volatile fatty acid (VFA) concentrations in the product. Some locations report a slightly more odorous product from thermophilic digestion (over mesophilic digestion) and this is largely due to the VFA concentrations. Recent studies by the City of Los Angeles at the Hyperion plant showed that thermophilic digested biosolids were less odorous than mesophilic digested biosolids at the land application site, however they were more odorous at the plant site (Hyperion Advanced Digestion Pilot Program, Hernandez, et al, 2002)

Temperature Phased Digestion

The temperature phased digestion process includes anaerobic digestion systems whereby digestion occurs at two different temperatures – mesophilic and thermophilic. Since each phase has largely different sets of bacteria and since thermophilic reactions proceed at a faster rate, greater total VSR can be achieved. Within each phase, all digestion processes of hydrolysis, acidification, and methane formation occur and should be in balance. Therefore, the pH is not depressed and acid/alkalinity ratios are monitored to show proper health of each phase of the process. The phases can be in either order, but sufficient SRT must be provided in each phase for full methane production.

The more common process order for temperature phased digestion is for the thermophilic system to come before the mesophilic system. This is primarily because of the desire to reduce volatile acids to as low a level as possible in the product, and thereby have a digested product with minimum odor level. The process evolved in Germany in the 1980s and some process developers there have promoted minimum SRT in the thermophilic phase of only 2 to 3 days. However, essentially all German facilities using the process (about 10 are reported to exist) have thermophilic phase SRTs greater than this (Dichtl, 1997).

In the USA, the process has been promoted and developed largely by Iowa State University (ISU), which holds a patent on it. ISU calls the process Temperature Phased Anaerobic Digestion or TPAD. About 8 TPAD systems are now operating in the USA; however, several of these have just recently come on-line and data at others are quite limited. Most of the USA plants are located in the Upper Midwest and Great Plains states (Iowa, Wisconsin, Nebraska). Omaha Nebraska's Papillion Creek WWTP (about 55 mgd) has one of the largest temperature phased digestion systems in the USA.

Significant increases in VSR are being achieved by moving from a single-stage mesophilic system to a temperature phased process. Plants seem to be achieving between 15 and 25 percent additional VSR by making this change. For instance, a plant which had been recording 50 percent VSR with single-stage mesophilic digestion, may achieve about 60 percent VSR by changing to this temperature phased process (a 20 percent increase in VSR).

An advantage of the process is that it operates well at a wide variety of retention times for each phase. In the USA, to implement the process, existing digesters have often been converted from mesophilic to thermophilic service, thereby providing fairly long retention times for thermophilic digestion (greater than 12 to 15 days, typically). For plants wishing to maximize performance, thermophilic retention times in the range of 3 to 8 days may be more appropriate. Mesophilic retention times may be reduced to as low as 10 to 12 days, although at these low-end SRTs, product volatile acid levels may be high enough to cause concern for final product quality.

Acid/Gas Phased Digestion

The anaerobic digestion process proceeds through definable phases. These phases include: hydrolysis - the solubilization of particulate material; acidification - production of volatile acids; and methanogenesis - the production of methane gas. Each phase has groups of micro-organisms which are primarily responsible for these activities. To some extent, these phases can be separated so that the bacteria are grown within desirable or even optimum conditions. The most workable process separation developed to date is to create an acid-phase and a methane or gas-production phase.

The primary characteristics of this phasing approach are the following:

- The first phase (acid-generation) has a short SRT to maximize acid production within an acidic environment – generally pH 6 or less. The result is that little methane gas and little total gas is produced. High concentrations of volatile acids occur in this phase.

- The second phase (gas-generation) has considerably longer SRT because methane-generating bacteria require longer growth times. The pH is above neutral and the vast majority of methane, and total gas, is produced in this phase.

The primary advantage of this approach is that greater volatile solids reduction is possible (over single stage mesophilic digestion) and the approach seems to limit foam production within the process. The process was originally developed at mesophilic temperatures for both phases, but either phase can be at thermophilic temperatures.

This process evolved in the 1970s under the name Acimet, and patents were developed for the process. The treatment plant which has the longest history of using this process is the Woodridge-GreenValley WWTP in DuPage County, Illinois. For about 10 years this plant has operated with acid/gas phased digestion. More recently, a few other facilities in the USA are moving toward using the process or are pilot testing the process. For instance, full-scale testing work at the Inland Empire District in California is underway. A specially built and specially operated acid phase reactor is normally required to achieve the short SRTs and the maximum benefit from the process.

The gas from the first phase reactor at DuPage County contains about 3000 to 10,000 ppm of hydrogen sulfide. This gas is burned directly in a flare. Other options may be required at plants located in areas where SO_x limits are more severe. Also, any leakage of the gas from the acid-phase reactor is likely to be a significant odor problem, due to its extremely high odor level (much more odorous than typical digester gas from mesophilic digestion).

Process Development and Comparison

Solids loading

Raw solids projections were presented in TM1 for both primary sludge and WAS for 40 MGD and 50 MGD design condition. Table 2 shows thickened solids loading projected for use in this digester option evaluation. Flows for primary and WAS thickening assume no changes to current performance (primary sludge concentration 4.5% average and TWAS concentration 4.5% average). Co-thickened flow assumes 5.5% float concentration. Flows and loads were derived from ten months of existing plant data.

TABLE 2 – DESIGN SOLIDS AND HYDRAULIC LOADING

Design loadings - 40 MG	Primary & WAS Flow, MGD	Co-thickened Flow, MGD	TSS, lb/d	VSS, lb/d
Average day	0.26	0.22	101,191	81,491
Peak 2 week	0.37	0.31	141,667	114,087
Design loading – 50 MGD				
Average day	0.33	0.28	126,489	101,864
Peak day	0.47	0.39	177,084	142,609

Digester options design criteria

As noted in the descriptions of the different digester options, different design criteria would apply to each option. Digester options that increased the potential for odors have been dropped from further consideration. Only Mesophilic and Temperature Phased Anaerobic Digestion are being considered at this time. Table 3 summarizes design and operating criteria for candidate digestion processes. These criteria are developed to meet regulatory requirements, collect digester gas reliably, keep odor emissions to a minimum and provide maximum stabilization for the biosolids product. The required tank volume for each option is heavily dependant on the choice that is made for thickening.

TABLE 3 – DIGESTER DESIGN AND OPERATING CRITERIA

Parameter	Mesophilic System	Temperature Phased System
Retention time in thermophilic digestion	N/A	3.5 days minimum at peak load (5 days minimum at average load)
Retention time in mesophilic digestion	18 days minimum average load (18 days minimum at peak month with all tanks in service)	10 days minimum at peak load (12 days minimum at average load with one tank out of service)
Digester temperatures	35 to 38 C	Thermo 53 to 60 C Meso 35 to 38 C
Vol. Solids loading rate (lb VS/ft^3/day	<0.3	System < 0.3
Digester operation	High-rate complete-mix, all tanks	High-rate complete-mix, all tanks
Cover configuration	Fixed cover, all tanks	Fixed cover, all tanks
Liquid level variation	Range of 4 feet maximum	Thermo-no liquid level variation Meso-range of 4 feet maximum
Bottom configuration	Cone - shape	Cone – shape
Mixing	Hydraulic	Hydraulic on thermo and meso
Heating	Hot water/sludge HEX units	Hot water/sludge HEX units plus heat recovery from thermo to meso
Vol. Solids reduction	53%	61%
Methane production (ft^3 gas/lb VS destroyed)	13 to 17	13 to 17

For this reason, required tank volumes for each option are shown for both thickening choices for comparison. Table 4 summarizes these tank requirements for the ultimate plant capacity of 50 MGD.

TABLE 4 – DIGESTER VOLUME REQUIREMENTS

Digester Option	Separate Thickening	Co-Thickening
Mesophilic System		
Required volume, peak 2 week- MG	7.0	5.79
Required volume, avg w/1 unit out – MG	6.0	4.96
Available volume, peak 2 week	5.08	5.08
Available volume, avg w/o digester 4	3.28	3.28
Additional volume required, peak 2 week	1.92	0.71
Additional volume required, avg w/o digester 4	2.72	1.68

Number required	2	1
Depth required	32	32
Diameter required	85	95
Temperature Phased System		
Thermophilic Digestion phase		
Required volume, avg	1.2	0.98
Additional volume required (assumes using existing 1.64 MG digester)	None	None
Mesophilic Digestion phase		
Required volume, peak 2 week – MG	5.6	4.68
Required volume, avg w/1 unit out – MG	4.0	3.31
Available volume, peak 2 week	3.2	3.2
Available volume, avg w/o digester 4	1.64	1.64
Additional volume required, peak 2 week	2.4	0.50
Additional volume required, avg w/o digester 4	2.36	1.74
Number required	2	1
Depth required	32	32
Diameter required	79	94

Mesophilic Digestion System

Table 4 shows that either one additional digesters would be needed if either separate thickening is continued or co-thickening of primary and secondary sludge in DAFTs is implemented. Required digester volumes shown in Table 4 will provide sufficient volume for 18 days of detention time at average flow with the largest digester (Digester No. 4) out of service and 15 days detention time at peak flow with all digesters in service. Digester No. 3 will remain as a storage tank and may function as a part of the two-stage mesophilic digestion process. Digester No. 3 has heating and mixing equipment and may provide additional digester capacity if needed. At half full, Digester 3 would provide an additional 1.3 to 1.9 days detention time for separate or co-thickened sludge flows respectively. This is extremely valuable and adds flexibility to the dewatering process operation to keep dewatering costs down and minimize adverse impacts associated with final use/disposal of the product. Future digesters would be constructed in the open area adjacent to the Cogeneration facility behind Digester No.s 1 and 2. Figure 1 provides a process schematic for mesophilic digestion at RWQCP.

This option could also includes a relatively small (approximately 50,000 gallon – 20 foot diameter) thickened raw sludge-blending tank. This tank accepts all thickened raw solids and blends these materials so that each digester receives the same feedstock blend. Pumps dedicated to each of the primary digesters, pump raw sludge on a continuous basis at a rate to keep the blending tank at set liquid levels. Equalization of raw sludge pumping can also occur, depending on the size of the blending tank. Digesters provide the greatest performance when fed continuously and when the diurnal feed cycle is largely equalized. TWAS pumping problems can also be largely resolved by pumping to this tank rather than through a valving complex.

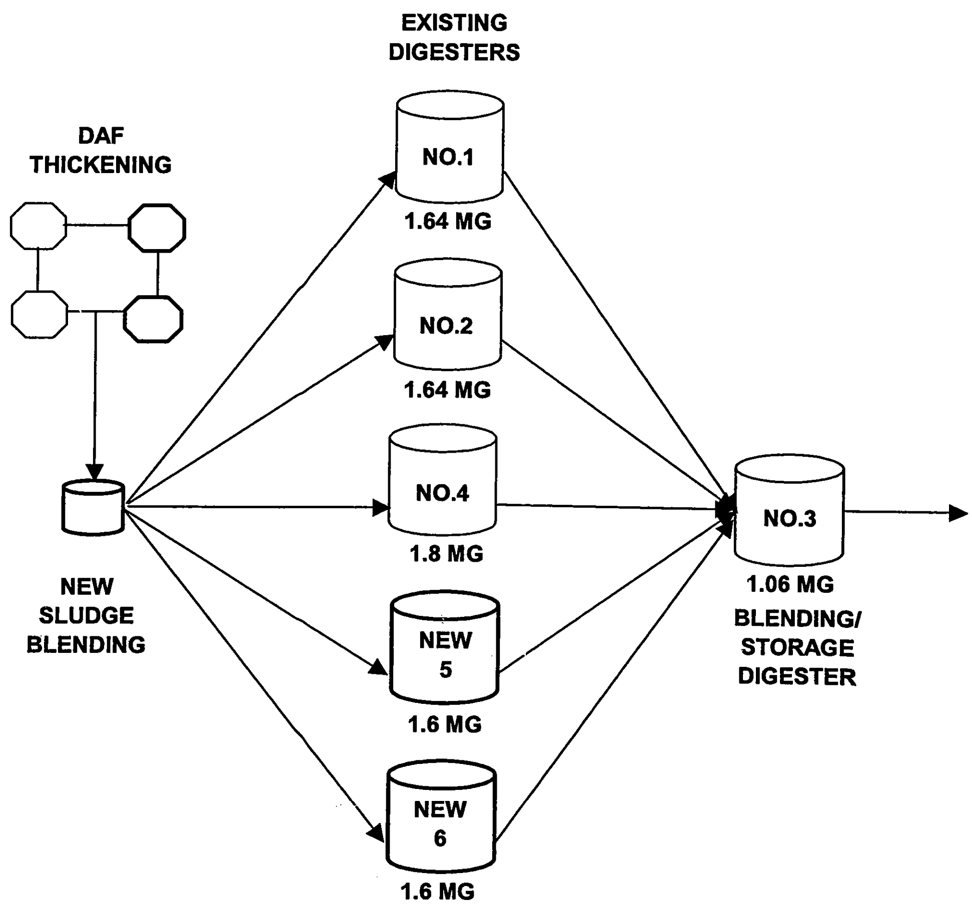


FIGURE 1 – MESOPHILIC DIGESTION

Temperature Phased Digestion (TPAD) System

Table 4 shows that the same number of additional digesters would be required for the TPAD system as the Mesophilic digestion system for the two thickening options. By providing additional digesters that are the same size as the mesophilic digester option greater reliability and flexibility in the digestion system may be achieved. What this means is that the digestion system would have the flexibility to operate either in the TPAD mode when the thermophilic digester is in service or in the mesophilic mode when the thermophilic digester is out of service.

Because the thermophilic digester operates at a higher temperature than the mesophilic digester sludge leaving this digester would need to be cooled prior to entering the mesophilic digesters. Heat recovery could be done in the thickened sludge blending tank by using a sludge to sludge heat exchanger to cool sludge going to the mesophilic digesters. Heat recovery is included in the cost analysis presented later. A more detailed analysis will be necessary during project design. Reliable and consistent temperature control is essential for proper TPAD operation. Future digesters for this option would also be constructed in the open area adjacent to the cogeneration facility behind digester No.s 1 and 2. Figure 2 provides a process schematic for the TPAD system. Figure 3 shows a possible layout for either mesophilic or thermo/meso digestion.

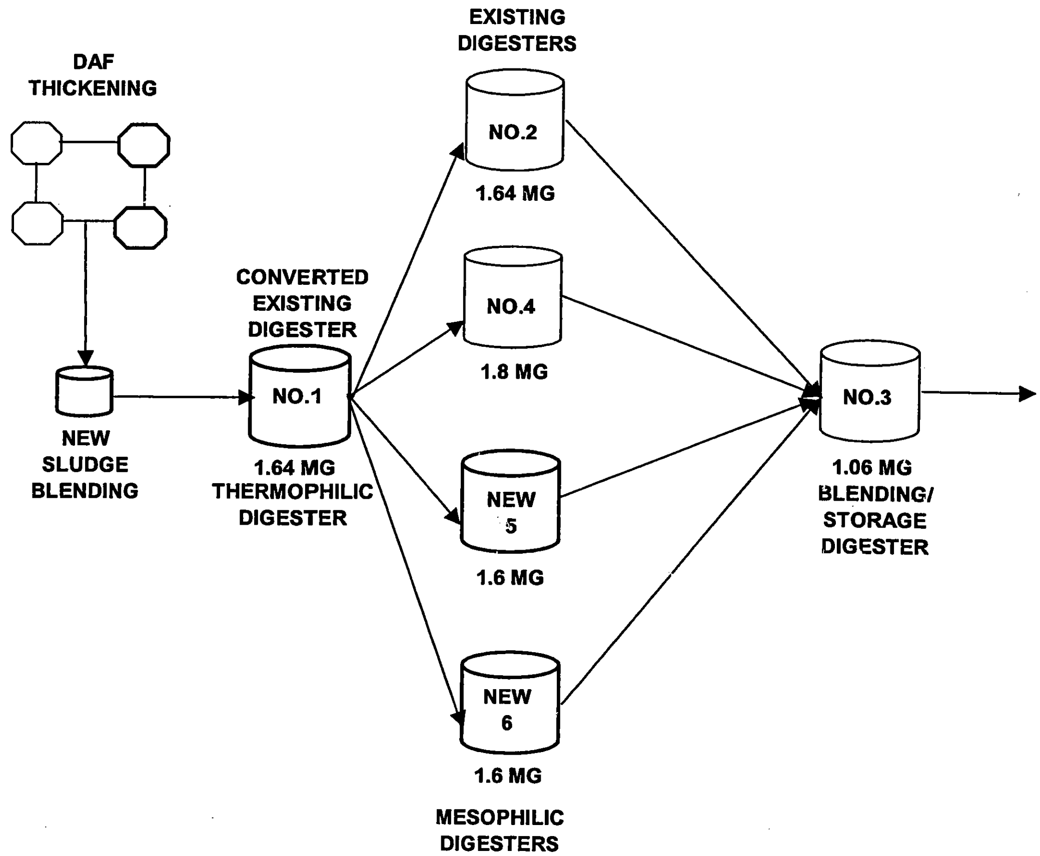


FIGURE 2 – TEMPERATURE PHASED DIGESTION

Initial Temperature Phased Digestion Implementation.

Initial implementation of temperature phased digestion could be accomplished by modifying digester No. 1 or 2 to operate at thermophilic temperatures, and utilize digester No. 4 and the remaining digester as mesophilic digesters. This would be a positive way to confirm the performance of temperature-phased digestion in the near term. Conversion to temperature-phased digestion would involve the following activities:

- Add heat exchange and hot water supply capacity to bring the temperature up to 55 C on a reliable basis for one digester. All raw sludge would be fed to this one reactor and retention time would be about 6 to 7 days under current average conditions.

- Add digester gas condensing capacity for the thermophilic digester gas since the gas will contain considerably more moisture than the existing mesophilic digester gas. Also, confirm that digester gas piping is sufficiently large enough to handle the extra gas production anticipated from the thermophilic reactor in peak loading periods.

- Pump and piping modifications will be required to pump the thermophilically digested sludge to both of the mesophilic digesters. Only one mesophilic digester is actually needed with current loads (providing about 14 to 15 days total retention time under average conditions), but in case one digester is off-line, there should be capability to pump to the other one.

- Modify the operation of the existing heat exchange units on the two mesophilic digesters to be "cooling" exchange units by running cool water through them instead of hot water. This is satisfactory only if the additional heat can be dumped to the plant effluent or another heat sink.

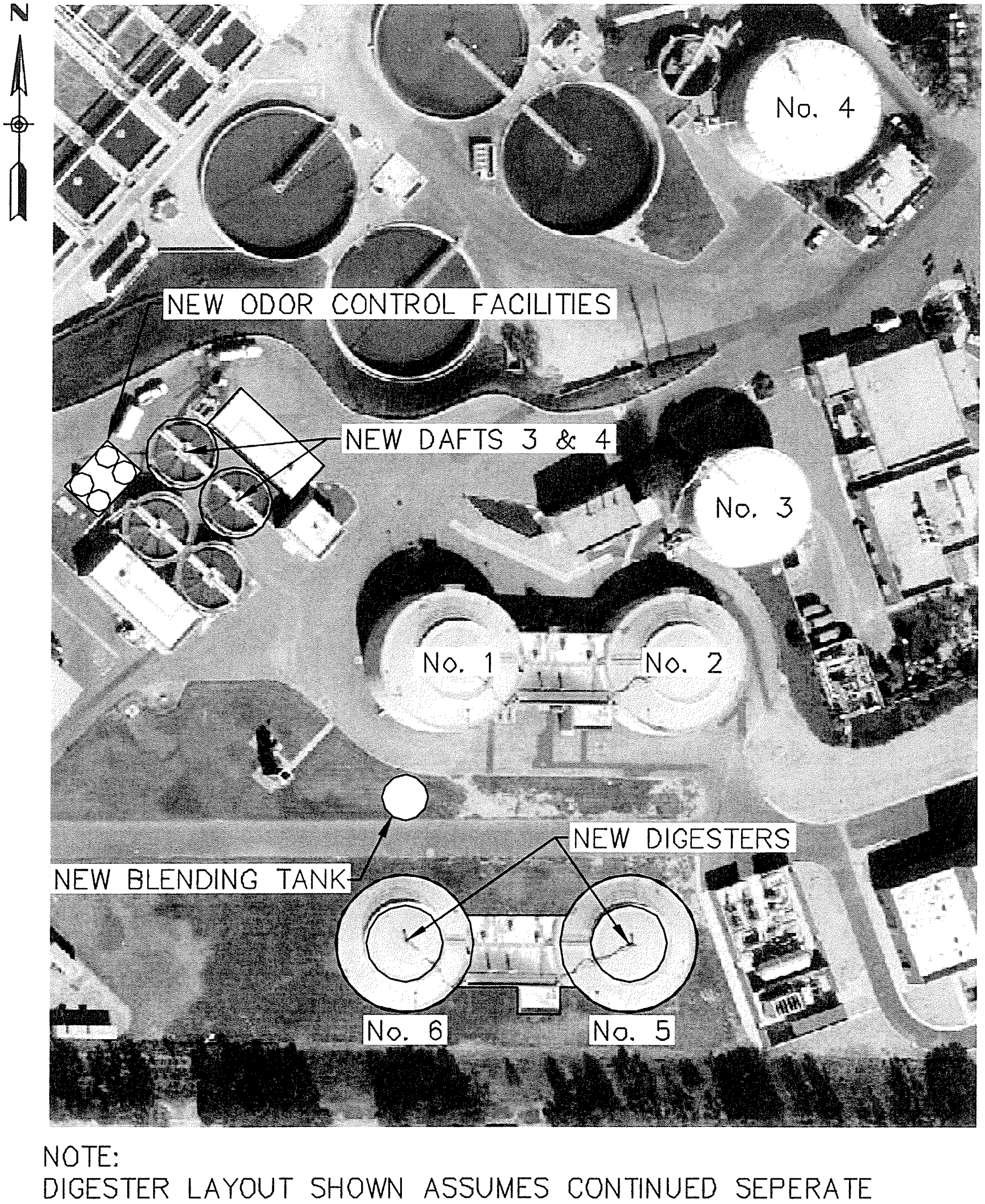
- If the above item is not workable due to the lack of a heat sink, then sludge-to-sludge heat exchange/recovery is needed (recovery of the thermophilic sludge heat to partially heat up the raw incoming sludge). This would require two sludge-to-sludge heat exchanger units (assuming spiral design), for reliability and performance needs.

- Any exposed materials within the thermophilic digester need to be evaluated to confirm that they can function under the thermophilic temperature range anticipated.

The construction cost to complete the above changes is anticipated to be in the range of $2.5M to $3.0M, including engineering and administration.

Class A Facilities.

Class A facilities are defined by the USEPA regulations 40 CFR Part 503. These regulations set maximum allowable limits of pathogens, vector attraction and heavy metals in biosolids that may be land applied in various applications. These regulations list six alternatives for pathogen reduction, the first of which deals with thermally treated biosolids. To meet Class A pathogen reduction requirements, thermally treated biosolids must be subjected to one of four temperature regimes. Of these four temperature regimes listed in the 503 regulations, only two may apply to the RWQCP. For solids concentrations less than 7%, biosolids must be heated for at least 15 seconds but not less than 30 minutes where D (detention time in days) = $131{,}700{,}000/10^{0.14t\ \text{(temperture in degrees C)}}$ or the temperature of sludge must be 50 degrees C or higher with at least 30 minutes or longer of contact time where $D = 50{,}070{,}000/10^{0.14t}$. Another key ingredient of this alternative is that there must be no possibility for short circuiting.



NOTE:
DIGESTER LAYOUT SHOWN ASSUMES CONTINUED SEPERATE THICKENING. DIGESTER 6 NOT NEEDED FOR CO-THICKENING OPTION.

DATE	PROJECT NUMBER	
09/12/02	22776.002	PROPOSED MESOPHILIC OR THERMOPHILIC DIGESTER PLAN

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA

PROJECT LOCATION: RIVERSIDE WATER QUALITY CONTROL PLANT RIVERSIDE, CALIFORNIA

0 50 100 SCALE IN FEET

FIGURE 3

22776_FG-3

The previously described temperature phased digestion system will not meet Class A requirements because the thermophilic digester is not operated in a batch mode. With continuous or near-continuous feeding and withdrawal, short-circuiting of pathogens through the reactor prevents Class A designation. Therefore, specific additional tankage would be required to meet the Class A standards. Normally, thermophilic batch tanks are expected to meet the Class A requirement and these are described in the first section below. Also described is another option involving a continuous flow pasteurization process, which has been approved by the EPA as Class A.

Class A Process-Batch Tanks.

Class A facilities include a set of batch tanks, which are, in essence, digesters operating in the thermophilic temperature range. For this option, we currently envision operation at temperatures within the range of 57 to 58 C (about 135 to 136 F). This range is suggested because of the following factors:

- By operating thermophilic batch tanks at a temperature of at least 57 C, the time required can be limited to 12 hours. This keeps individual tank sizes down to 305,000 gallons each, to accommodate expected peak daily sludge flowrates for an ultimate plant size of 50 MGD.

- Operating at temperatures higher than about 60 C appears to be detrimental for peak thermophilic digestion performance. The exact temperature at which digestion performance begins to drop is not quantified accurately through current research and development work since few facilities have operated above 55 to 56 C. Research has shown that active anaerobic digestion takes place at 60 C and even 65 C, however, digestion effectiveness is believed to be reduced when reaching temperatures at and above the 60 C range since these high temperatures are likely to stress some thermophilic bacteria.

Multiple tanks are required for batch operation, and one tank is required for a backup or spare tank. An example configuration is provided below using 3 tanks for a given batch period of 12 hours (a fourth tank would be required for backup):

- Tank 1 is being filled

- Tank 2 is in batch storage mode (12 hours minimum at 57.2 C)

- Tank 3 is being drawn down and solids moved to the next process downstream

This operating sequence changes during the next 12 hours, whereby Tank 1 is in batch storage mode, Tank 2 is being drawn down, and Tank 3 is being filled. Valves are automatically reset every 12 hours to provide constant withdrawal of sludge from one of the 3 tanks of this system and so that subsequent heat recovery can take place on a continuous 24 hour/day basis. This arrangement has no adverse operating impact upstream or downstream in the digestion process. Figure 4 provides a process schematic for a TPAD system with Class A batch tanks.

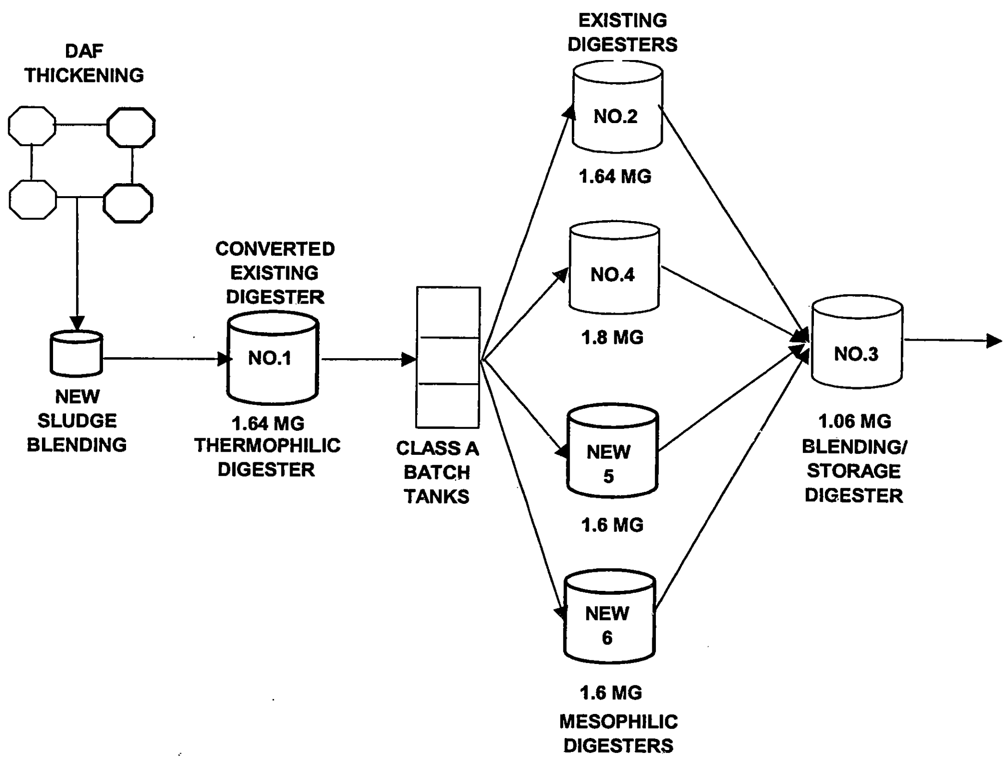


FIGURE 4 – CLASS A TEMPERATURE PHASED DIGESTION

Class A Continous Flow Tanks.

The USEPA has not yet approved continuous flow thermophilic digestion in multiple-stage, complete-mix tanks as a Class A process. However, there is mounting pressure for the EPA to set ground rules for this approach since batch operation, particularly at larger plants, may be cumbersome. The ground rules for such an approach are likely to be affected by the new thermophilic digestion facility at the Annacis Island WWTP in Vancouver, Canada. In using the same pathogen die-off modeling approach for RWQCP that was used at the Annacis Island thermophilic digestion facility, (5 log reduction in pathogen densities), we find that the following system should achieve Class A at the RWQCP without batch operation:

- Thermophilic digestion at 3 to 4 - day retention time (minimum) at 57.2 C

- Subsequent 3 smaller complete mix digesters operated in series at 12-hour retention time and temperature of about 57.2 C (minimum).

Therefore, the same tankage described for the batch operation could serve in the future in a continuous flow (non-batch) system. This provides an improved system and would be flexible in meeting Class A more easily in the future

Alternative Class A Facilities

As described above, batch processes have typically been required to ensure there is no short circuiting. A continuous plug flow pasteurization system has recently been approved by USEPA Region 9 for installation by the Eastern Municipal Water District at the Hemet, CA WWTP. The process that has been approved for this facility is the Ashbrook Eco-Therm ™ Pasteurization process. This process is a continuous plug flow system, which treats liquid biosolids by heating the material above 70 degrees C and maintains that temperature for a period of 30 minutes or longer without short circuiting. The process installed at the 11 MGD Hemet WWTP is located immediately upstream of their anaerobic digesters. To bring the temperature of the pasteurized sludge down to the temperature needed in the digesters, a sludge cooling system has been provided to recover the heat from the pasteurization system. The anaerobic digesters provide the necessary volatile solids destruction to meet the vector attraction requirement to meet Class A biosolids. The cost of the system installed at the Hemet WWTP was approximately $750,000

Cost for Anaerobic Digestions and Thickening Options

Construction and capital costs for new thickening and digestion alternatives are identified in Tables 5 and 6 respectively. New DAFT and digestion costs are taken from recent projects across the Western United States. Construction costs for thermophilic digesters are similar to the cost of mesophilic digesters, although proper design requires materials compatibility at higher operating temperatures. Gas handling for thermophilic digestion needs to accommodate the increased water content of the gas and resulting moisture condensing requirements. Heating systems must provide reliable temperature and temperature control must be able to keep digester temperatures within a narrow range ($\pm$ 0.5 C), especially for Class A operation. Continuous temperature monitoring and automatic control on the recycle-heating loop are required, along with a backup heat exchanger.

TABLE 5 ESTIMATED COSTS FOR THICKENING ^($1,000)

Work Element	Thickening Options	
	Separate Thickening	Co-thickening
New DAFT – (two 39 ft diam)	2,700	NA
New DAFT w/covers– (two 44 ft diam)	NA	3,000
Rehab Existing DAFTs	NA	500
Primary sludge pumps & piping	NA	1,000
Air scrubbers (22,500 scfm)	NA	1,200
DAFT control building (8,000 sf)	1,000	1,000

Bottom sludge degritting	NA	100
Subtotal	3,700	8,800
Contingency 30%	1,100	2,600
Construction Costs	4,800	11,400
Project Costs @ 25% (engr, admin, etc)	1,200	2,800
Total Capital Costs	6,000	14,200

TABLE 6 ESTIMATED COSTS FOR ANAEROBIC DIGESTION ^ (1,000)

Work Element	**Mesophilic Digestion**	**Temperature Phased Digestion**	**Temperature Phased Digestion + Class A system**
Separate Thickening			
Raw sludge blending Tank & pumps	250	250	250
New Digesters	10,000	10,000	10,000
Class A System	NA	NA	3,000
Convert Existing digester to Thermophilic	NA	3,000	3,000
Subtotal	10,250	13,250	16,250
Contingency 30%	3,100	4,000	4,800
Construction Costs	13,350	17,250	21,050
Project Costs 25% (engr, admin, etc.)	3,300	4,300	5,300
Total Capital Cost (Separate Thickening)	16,650	21,550	26,350
Co-thickening			
Raw sludge blending Tank & pumps	250	250	250
New Digesters	5,000	5,000	5,000
Class A System	NA	NA	3,000
Convert Existing digester to Thermophilic	NA	3,000	3,000
Subtotal	7,690	10,690	13,690
Contingency 30%	2,300	3,200	4,100
Construction Costs	9,990	13,890	17,790
Project Costs 25% (engr, admin, etc.)	2,500	3,500	4,500
Total Capital Cost (Co- thickening)	12,496	17,496	22,290

Present Worth Cost Analysis of Thickening and Digestion

As noted in TM1 and as shown in Table 4 the required additional digestion facilities is heavily dependant on the selected thickening option. To evaluate the economic impact on the thickening and digestion system a present worth cost analysis has been prepared for both thickening options taking into account the required mesophilic digester facilities needed to support that options. A list of general economic assumptions made for the two thickening options is provided below.

- Planning period is 20 years
- Net discount rate is 3 percent
- Polymer cost is $1.50 per active pound

Present worth costs for the two thickening options are identified in Table 7. Present worth costs for the three digester alternatives are identified in Table 8.

TABLE 7 PRESENT WORTH COSTS FOR THICKENING OPTIONS ^(1,000)

Cost Element	Separate Thickening	Co-thickening
Annual operating cost		
New & upgraded DAFT		
Power @$0.075/KWH	238	739
Polymer @ $1.50/lb	0	1
Maintenance @ 1% equip cost	25	64
Air Scrubber		
Power	0	7
Chemicals	0	2
Maintenance	0	11.6
New Digesters O&M 5% equipment cost	500	500
Total Annual Cost	763	824
Present Worth Cost		
Total Capital Costs	18,500	26,700
Present Worth Annual Cost, 20 yr @ 3% net discount	15,300	16,600
Total Present Worth Cost	33,800	43,300

TABLE 8 PRESENT WORTH COSTS COMPARISON FOR DIGESTION ALTERNATIVES ^(1,000)

Cost Element	**Mesophilic Digestion**	**Temperature Phased Digestion**	**Temperature Phased Digestion + Class A**
Co-thickening Option			
Annual operating costs			
Annual O&M costs	400	450	500
Gas Energy value	NA	(170)	(170)
Biosolids cost savings over Meso	NA	(180)	(180)
Total Annual cost	400	100	150
Present Worth Cost			
Total Capital Cost	12,500	17,500	22,300
Present Worth Annual Cost, 20 yr @ 3% net discount	6,000	1,500	2,250
Total Present Worth	18,500	19,000	24,550
Separate Thickening			
Annual operating costs			
Annual O&M costs	400	450	500
Gas Energy value	NA	(170)	(170)
Biosolids cost savings over Meso	NA	(180)	(180)
Total Annual cost	400	100	150
Present Worth Cost			
Total Capital Cost	16,650	21,550	26,350
Present Worth Annual Cost, 20 yr @ 3% net discount	6,000	1,500	2,250
Total Present Worth	22,650	23,050	28,700

Thickening and Digestions Recommendations

TM1 offered two thickening options, WAS only thickening and co-thickening of primary and WAS. Implementation of WAS only thickening would require construction of two (2) 39 foot diameter DAFTs. Implementation of co-thickening would require construction of two (2) 44 foot diameter covered DAFTs, new primary sludge pumps and piping to pump thinner primary sludge, bottom sludge degritting and new odor control.

The present worth value for the two thickening options when digestion is also considered is $ 33.8 million for WAS only thickening and $43.3 million for co-thickening. As noted in TM1 other benefits of co-thickening would include possible increased primary sedimentation surface overflow rates and grit removal prior to digestion.

Based on the present worth analysis we recommend that Riverside proceed with the following thickening and digestion system plan

- Plan on implementing addition of DAF facilities to continue separate thickening of primary sludge and WAS with DAFTs
- Plan on implementing a 50,000 gallon thickened solids blending tank and two 32 foot deep, 90 foot diameter digester to match digesters 1 and 2 as a mesophilic digesters.
- Defer a decision on implementing Class A digestion at this time. However, continue to plan for future temperature phased digestion as a part of Class A facilities.

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CHAPTER 6 - TECHNICAL MEMORANDUM NO. 3, HEAT AND ENERGY OPTIONS

City of Riverside Water Quality Control Plant Heat and Energy Options Technical Memorandum No. 3

Prepared by: Brown and Caldwell
Date: October 25, 2002

Introduction

Changes to the City of Riverside solids processing operation will require added heat and may change the digester gas production. This Technical Memorandum evaluates the RWQCP heating and energy options for the proposed solids system modifications.

Objectives

The following objectives are addressed in this technical memorandum:

1. Review the design and the operational information

2. Review the existing digester gas and the landfill gas (LFG) system and gas characteristics

3. Define plant future heating needs, including digestions changes

4. Review applicable air quality limitations

5. Define and evaluate options for meeting the future RWQCP heat needs and energy performance requirements

Existing Conditions and Heating and Cooling Needs

Existing Conditions

The existing RWQCP solids processing facilities are well integrated into and interwoven with the cogeneration system.

The cogeneration system is an energy conversion system. Large engine-generators converted the fuel energy in the digester gas, LFG and natural gas into electricity and heat energy. Some of this heat energy is radiated from the hot engine bodies into the room, or is wasted to the engine lubrication oil, but most of the engine heat energy is collected and used at the RWQCP.

Each cogeneration engine is cooled by water circulating through the engine cylinder jacket, and this hot engine jacket water is used to heat the RWQCP, together with heat recovered from the hot engine exhaust gases.

Digester Gas

The RWQCP digesters are mesophilic, anaerobic digesters, and the digester gas is generally similar to that from other municipal wastewater treatment plant sludge anaerobic digester systems. The current and projected gas flow rates are shown in Table 1.

Table 1. Digester Gas Flow rates and Future Flow Projections

Year	Plant flow, mgd	Design system type	Digester gas production		
			Cubic feet per day	Cubic feet per hour	Energy value, million Btu per hour
1991	28.5	Meso	277,379	11,577	6.5
2002	33	Meso	330,000	13,800	7.7
2005 to 2010	40	Meso	664,000	27,700	15.5
2005 to 2010	40	TPAD	799,000	33,000	18.6
2020 to 2025	50	Meso	830,000	34,600	19.4
2020 to 2025	50	TPAD	999,000	41,600	23.3

Notes:

1. Meso = mesophilic; TPAD = temperature-phased anaerobic digestion
2. The hourly gas production is averaged over a 24-hour day.
3. The energy value, million Btu per hour, is based on 560 Btu per cubic foot, LHV.
4. Data from 1991 was taken from the May 1992 JMM TM-1 Master Plan.
5. Current year 2002 data are approximate.

Landfill Gas and Natural Gas

The RWQCP receives and burns three gaseous fuels: digester gas, natural gas, and landfill gas (LFG). The LFG is produced by the Tequesquite Sanitary Landfill, located about 4 miles northeast of the RWQCB. The Tequesquite Landfill is a mature, closed and inactive sanitary landfill. The production of LFG is diminishing over time and is expected to continue to slowly dwindle until it is completely depleted, possibly in about the year 2022 to 2024.

The typical composition of digester gas, landfill gas and natural gas is shown below in Table 2. Note that he landfill gas is blended with some natural gas prior to use, and the natural gas is blended with air prior to use as RWQCP engine fuel.

Table 2. Typical Composition of Individual Fuel Gases

Gas Constituent	Landfill Gas	Digester Gas	Natural Gas
Methane, (CH_4) percent	38 to 58	50 to 62	85 to 96
Carbon dioxide, (CO_2), percent	30 to 50	32 to 45	0 to 2.5
Ethane (C_2H_6), percent	0 to 1	none	4 to 15
Propane (C_3+) and higher, percent	0 to 0.07	none	0.3 to 3
Nitrogen, (N_2) percent	5 to 15	0.5 to 2	0.5 to 2
Oxygen (O_2), percent	0 to 2	0 to 0.2	0
Water in the gas, as produced	variable	saturated	dry
Hydrogen sulfide, (H_2S), ppm	Up to 2000	300 to 2000	0 to 2
Caloric value, Btu per cubic foot (LHV)	350 to 500	500 to 600	930
Caloric value, Btu per cubic foot (HHV)	400 to 550	550 to 650	1020
Temperature, degree F	60 to 75	90 to 98	60 to 75

Notes:
1. The abbreviation "ppm" is parts per million by volume
2. LHV is the low heating value, or the heating value without the formation of free water.
3. HHV is the high heating value, or the heating value with the formation of free water.

Heating System and Equipment

1. Engines. The three Caterpillar cogeneration engines are the heart of the RWQCP heating system. These clean-burn engines burn fuel, and produce power and heat. Each engine is equipped with an exhaust heat recovery silencer to warm water and thus capture the heat in these 900 degree F engine exhaust gases. The engine body radiation is heat that is not captured. Likewise the engine turbocharger aftercooler heat and the engine lubrication oil heat is too "cool" to use, and is wasted, and not recovered. The full engine energy or heat balance is shown below in Table 3.

Table 3. Cogeneration Engine Heat Balance

	Energy, million Btu per hour	
	Each engine	Total for 3 engines
Fuel input energy, at full load	11.34	34.0
Work (driving the generator)	4.07	12.2
Jacket water heat	1.16	3.5
Engine exhaust heat	4.41	13.2
Engine lube oil heat **plus** Engine turbocharger heat	0.66	2.0
Radiation heat	0.47	1.4
Missing or heat accounted for	0.57	4.7
Total	11.34	34.0

Caterpillar has been very guarded with their engine data and the above heat balance data are based on nominal, or expected engine performance values.

The usable engine heat is recovered or extracted from the engine jacket water, and the engine exhaust gases. The engine jacket water is part of the engine cooling system, so this heat removal is essential or the engine will overheat.

The engine exhaust heat is an optional or voluntary form of engine heat recovery. At times when this engine exhaust heat is not needed, an exhaust bypass valve inside the silencer bypasses the heat recovery from the engine exhaust. The exhaust gases leave the engine at a temperature of about 943 degrees F. Normally, the gases are cooled as they travel through the engine exhaust heat recovery silencer, and they leave this silencer at a temperature of about 368 degrees F. The available engine heat is listed in Table 4.

Table 4. Available Engine Heat

Usable, or recoverable engine heat	Energy, million Btu per hour	
	Each engine	Total for 3 engines
Engine jacket water heat	1.16	3.5
Engine exhaust heat, maximum	2.77	8.3
Total	3.93	11.8

2. Boilers. Several hot water boilers are also located in various buildings throughout the RWQCP. Some of these boilers are fully permitted with the Air District and are in working condition, while others are fully disassembled, and are not useable. These boilers, and a steam generator for steam cleaning, are summarized in Table 5.

   This boiler total below does not include the exhaust heat recovery silencers on the cogeneration engine exhaust piping. Occasionally these engine heat recovery silencers are incorrectly called boilers. They are not fired by any fuel and their heat output is included with the engine heat recovery equipment.

Table 5. Existing RWQCP Boiler Summary

Location or Number	Heating Capacity, MMBtuh	Manufacture and Model	Apparent Condition	Status
Zone 4, boiler 1	4.18	Cleaver Brooks NCB 700-100	Good	Operational, standby duty
Zone 4, boiler 2	4.18	Cleaver Brooks NCB 700-100	Good	Operational, standby duty
Zone 4, boiler 3	4.18	Cleaver Brooks NCB 700-100	Good	Operational, standby duty

Boiler 5	1.275	Ajax WGGFD-1275	Good	Emergency use only
Boiler 6	1.275	Ajax WGGFD-1275	Good	Emergency use only
	unknown	Clayton	Good	Steam generator
Boiler Plant 1, Boiler 1	small	Ajax	disassembled	Completely unusable
Boiler Plant 1, Boiler 2	small	Ajax	disassembled	Completely unusable
Boiler Plant 1, Boiler 3	small	Ajax	disassembled	Completely unusable

Notes:
1. MMBtuh is million Btu per hour
2. The Clayton steam generator is a portable steam-cleaning unit and is technically not a boiler. This item is rarely used.

Each of the three Cleaver-Brooks standby boilers in Zone 4 has a heat output approximately equal to one of the three Caterpillar cogeneration engines.

Cooling System and Equipment

The RWQCP hot water heating system is interconnected with, and to a certain extent, driven by the Laboratory Building chilled water system.

The Laboratory Building has a nominal 150-ton absorption chiller that is "powered" by heating water from the cogeneration system. This absorption chiller has a design full load heat input of approximately 2.6 million Btuh. Because the absorption chiller requires heat at the highest possible temperature in order to function, this chiller forces the heat loop to deliver 190 to 200 degree F hot water.

Air Quality Concerns

The RWQCP is located in the City of Riverside, and is within the jurisdiction of the South Coast Air Quality Management District (SCAQMD).

The SCAQMD has enacted detailed and stringent air quaity standards for stationary combustion sources, including large internal combustion engines and fired boilers. A summary of relevant and potentially applicable air quality standards follows.

The three Caterpillar cogeneration engines are subject to emissions limits and operating requirements. Table 6 shows the emissions limits for each criteria pollutant in pounds per hour.

Table 6. Emissions Limits for Existing Cogeneration Engines

Air Contaminant	Emission Limit, pounds/hour each
Reactive Hydrocarbons	2.1
Nitrogen Oxide, as NO_2	2.3
Sulfur Dioxide	0.4
Carbon Monoxide	8.0
PM_{10} Particulate Matter	1.0

In addition, the engines are outfitted with a continuous emission monitoring system (CEMS) to demonstrate compliance with the NO_x emissions limit. The CEMS measures and records NO_x exhaust gas concentrations, corrected to 15 percent oxygen on a dry basis. Moreover, the total sulfur compounds of the fuel gas used at the facility, calculated as hydrogen sulfide, is limited to 5 pounds per day. The RWQCP currently keeps daily records to prove compliance with this total sulfur emissions limit.

The SCAQMD has also adopted rigorous requirements for boilers in two size categories. "Small" and "large" boilers are classified as boilers with rated fuel input capacities between 2 to 5 million Btu per hour and greater than 5 million Btu per hour (Btuh), respectively. Surprisingly, the regulations for "small" boilers are more stringent than for "large" boilers. The following standards apply to boilers with rated fuel input capacities over 5 million Btuh.

The SCAQMD prohibits the proposed boilers from discharging more than 400 ppm CO and 40 ppm or 0.052 pounds of NO_x per million Btu of input. Furthermore, if the annual heat input is less than or equal to 9 billion Btu per year per boiler, the boilers must also comply with one of the following:

1. Operate the boiler such that the stack-gas oxygen concentrations are always less than or equal to 3 percent on a dry basis for any 15-minute average averaging period; OR

2. Conduct tuning per SCAQMD methods, up to twice per year.

Given the size of the proposed boilers described later in this technical memorandum of 9 billion Btu per year per boiler translates into 818 hours of operation at capacity per boiler. Thus, depending on the duration of the peak heating demands during a given year, the boilers may or may not be subject to the additional operating or tuning requirements outlined above. Moreover, if multiple gaseous fuels are used, a non-resettable, totalizing fuel meter is required per boiler per fuel type.

Projected Heating and Cooling Needs

Sludge Digesters

The RWQCP contains several large tanks constructed as sludge digesters, but only four are currently used for this role. These anaerobic sludge digesters are mesophilic digesters that are maintained at an operating temperature of 98 degrees F to enhance solids reduction and gas production.

Some of the recommended solids digestion project options involve thermophilic sludge digesters. These digesters require heating the sludge to about 57 degrees C, (135 degrees F). This will require far more process heat than is now supplied for the mesophilic sludge digesters digesters, currently operating at about 37 degrees C (98.6 degrees F).

Anaerobic sludge digester heat needs include two components:

- The heat required to warm the cold incoming raw or the feed sludge up to the digester's operating temperature.
- The make-up heat required to offset the heat losses from the warm digester to the cold ground and to the air. This is also called the digester shell heat loss.

Both of these components vary seasonally, in accordance with sludge, air and ground temperatures. Typically, for nearly all municipal wastewater treatment plants, the raw sludge heating component is by far the larger of the two digester heat loads. This raw sludge heat load is computed as follows:

$$Q = m \times Cp \times \text{delta } T$$

where:

Q	=	The required heat or heat load, expressed as Btu per hour
m	=	The sludge mass flow rate, in pounds per hour
Cp	=	The specific heat of the item to be heated, expressed as Btu per pound per degree F. For the clean water, the Cp equals 1.00 Btu per pound per degree F, by definition
delta T	=	The temperature difference between the cold inlet sludge and the heated outlet sludge, in degrees F.

Thus, for heating sludge to a digester:.

m	=	Sludge flow, gpm x specific gravity, pounds per gallon x 60 minutes per hour.
Cp	=	1.0 Btu per pound per degree F, because even thickened

sludge is still 94 to 98 percent water.

delta T = Raw sludge temperature (this is usually the same as the plant influent effluent temperature) minus the digester operating temperature, degrees F.

For the RWQCP at a plant flow of 50 mgd, the calculation parameters are:

- Primary sludge flow = 141,000 gallons per day
- Raw waste activated sludge (WAS) flow = 958,000 gallons per day
- Thermophilic digester temperature = 135 degrees F
- Minimum sludge temperature = 69 degrees F, per February records

Thus,

m =

$$\left(\frac{141{,}000 \text{ gpd (primary)} + 958{,}000 \text{ gpd (WAS)}}{24 \text{ hours/day}}\right) \times 8.34 \text{ pounds per gallon}$$

m = 382,000 pounds per hour

Q =

(382,000 pounds per hour)(1.0 Btu/pound-degree F)(135 - 69) degrees F

Q = 25 million Btu per hour

The digester shell heat loss is a much more complex, and a much smaller number.

<u>Laboratory Building</u>

The Laboratory Building was constructed in 1999, and the heating and cooling system for the lab were connected to the cogeneration heat recovery system.

The building cooling system is an important issue here because the building is cooled by an absorption chiller, and this special type of water chiller uses hot water as its energy source.

Current and Proposed Heat Needs

Plans for future RWQCP sludge digestion needs are outlined in Technical Memorandum 2, dated August 2002. This document, Technical Memorandum 3, provides the increased heat needs for the proposed 50-mgd plant with a modified sludge digestion system, including thermophilic sludge digestion followed by mesophilic digestion. The current and proposed RWQCP heat needs are summarized in Table 7:

Table 7. Current and Future Plant Heat Needs

Item or Parameter	Heat needs, million Btuh		Remarks
	Current 30+ MGD plant	Proposed 50 MGD plant with modified digestion	
Sludge digestion basic type	Mesophilic	Thermophilic + mesophilic	As per BC's Tech Memo 2
Raw sludge heating needs, maximum	8	25.2	At a minimum 69 degrees F sludge temperature
Mesophilic digester shell heat losses, maximum	2	2	Based on adding new, insulated, traditional type sludge digesters
Thermophilic digester and sludge holding tank shell heat losses, total, maximum	N/A	2	Based on converting Digester 1 to a thermophelic digester at 135 degrees F, plus a 50,000 gallon holding tank
Absorption chiller, summer heat needs, maximum	2.6	N/A	Maximum heat need is in the summer. This is not additive to the above
Winter maximum heat need, total	10	29	At minimum February temperatures
Available engine heat recovery, maximum	12	12	From the three current cogeneration engines
Heat shortfall	none	**17**	At the minimum February temperatures

Heat Production Alternatives

The 17 million Btuh heat shortfall for the proposed modified digestion system must be met. Several options for adding heat were considered:

1. Recover and use the engine aftercooler heat
2. Replace the absorption chiller and use the chiller's heat allocation
3. Add engine exhaust duct burners to the cogeneration engine exhaust
4. Add more gas fired hot water boilers
5. cover and use air or gas compressor heat
6. over and use heat from the warm thermophilic digested sludge
7 new water-source heat pumps
8. Add a solar hot water heating system
9. Add natural gas-fired fuel cells

Evaluation

Initial Screening

The initial nine possible heat production alternatives were initially screened based on a subjective review of the positive and the negative features or advantages and disadvantages of that alternative. This is summarized in Table 8.

Table 8. Added Heat Sources, Initial Screening

Alternative summary	Principal Advantages	Important Disadvantages	Screening Status
1. Recover the engine aftercooler heat	• Readily available heat source • Produces no added emissions	Low temperature heat Engine NOx emissions will increase with warmer aftercooler water	Not workable due to added engine NOx emissions concerns, and the low source temperature
2. Replace the Laboratory Building absorption chiller	• Supplies high temperature heat • Reduced chiller maintenance • Produces no added emissions	• The chiller heat savings is reduced in the winter, when we need heat the most • Consumes slightly more electricity than existing	A viable option, but only a partial solution. Possibly a side feature of another option.
3. Add engine exhaust afterburners	• High fuel combustion efficiency	• New and unusual technology and this is not well proven • Generates NOx emissions	Probably not workable due to possible increased engine NOx emissions
4. Add more boilers	• Simple and proven • Boilers can be located where most needed	• Costly • Difficult air permitting requirements • Wastes natural resources	Straightforward but more difficult to permit. A viable option.
5. Compressor heat recovery	• Energy efficient • Produces no added emissions	• Complex • Only a small amount of heat is available • Costly	The quantity of heat is probably too small to meet our needs
6. Digester sludge heat recovery	• Much greater heat capacity than some of the options • Energy efficient • Produces no added emissions	• Complex • Limited success elsewhere • The amount of available heat is great, but it is at a low temperature	Might be possible with water to sludge heat exchangers
7. Water source heat pumps	• Energy efficient • Produces no added emissions	• Very costly • Complex • Heat is at a low temperature	Possible and expensive, but a viable option
8. Solar collectors	• Product no added emissions	• Very costly • Limited to daytime	Possible but an expensive and

	• Energy efficient	operation • Output is reduced in winter when need is greatest	unreliable heat source
9. Fuel cells	• Extremely low emissions • Energy efficient	• Exceptionally costly • Limited heat output	Too expensive to be viable

Alternative Heat Supply Quantified Analysis

1. Engine aftercooler heat. As previously shown in Table 3, each engine produces about 0.66 million Btuh of aftercooler plus lube oil heat. For all three Caterpillar engines, this totals about 2 million Btuh of heat. Caterpillar has been somewhat secretive of their engines for this project and may not be open to any changes to them, particularly changes that potentially could produce more NOx. This option is too risky, with benefits that are too small for further consideration.

2. Laboratory absorption chiller. The 150-ton RWQCP laboratory chiller is a single stage, or single effect, lithium bromide absorption chiller. Replacing the absorption chiller with a conventional high efficiency electric motor driven water chiller would simplify this chilled water system and would free up about 2.6 million Btuh of heat for use elsewhere with very little added electrical energy. While this quantity is not adequate to meet all of our sludge heating needs, it does offer some practical advantages to the RWQCP, and might be used in conjunction with some other heating option.

3. Engine exhaust afterburners. The exhaust gases leaving the cogeneration engines are at a temperature of about 938 degrees F. This exhaust temperature is well below the 1200 degree F minimum NOx formation temperature. Adding exhaust afterburners to each of the three engines could provide about 1.3 million Btuh of heat, or a total of about 4 million Btuh for all three engines. Technically, this could be done, but it would be extremely challenging to do this without creating more NOx. Other heating options are more attractive with fewer risks.

4. Additional boilers. Traditionally, the simplest technique for adding heat is to provide more gas fired hot water boilers. Using natural gas fueled boilers with new low-emissions or burners, two or three 9 million Btuh could be added and permitted for operation at the RWQCP. One of the three boilers is a standby boiler. This is a sound option to evaluate.

5. Compressor heat recovery. Very large air or gas compressors would likely be required to produce the required quantity of heat needed previously noted in Table 7, of about 17 million Btuh.

   The maximum recoverable heat from a compressor is as follows:

   Q = compressor motor HP x 0.75 x 2545 Btuh per HP, Or, for example, from a 100 HP compressor, the heat is as follows:

Q = 100 HP x 0.75 x 2545 Btuh per HP or

Q = 191,000 Btuh

Thus, to produce 17 million Btuh we need 90 times this amount, or all the heat from about 9,000 HP of compressors. This enormous size is clearly impractical, if not totally impossible. Some heat could be recovered from the existing air and gas compressors, but this small amount of heat might not be worth the effort required to utilize it. Other heat recovery options are more economical.

6. Digested sludge heat recovery. The digested sludge leaving the warm thermophilic digester represents one of the largest energy "resources" at the RWQCP. This 135 degree F digested sludge must be cooled down to about 98 degrees F for the mesophilic digesters. Thus, this thermophilic digested sludge heat must be used or wasted in any event. Cooling the 135 degree F thermophilic sludge to 98 degrees represents an energy resource of 14 million Btuh. This is a very substantial quantity and probably the best alternative to simply adding boilers.

7. Water source heat pumps. A water source heat pump is very similar to a conventional air conditioning unit operating in reverse. Heat pumps can be very energy efficient and are typically 3 to 5 times more efficient than electric resistance heating. A heat pump takes low temperature energy or heat from one source, and raises the temperature of that energy so that it becomes usable in another application. Possible low temperature energy sources at the RWQCP include the treated final plant effluent and the digested thermophilic sludge. The final treated plant effluent is a very large, but relatively unconventional heat source. For example, if the temperature of 40 mgd of plant effluent is reduced by just 1 degree F, the available heat totals 14 million Btuh. The Renton WWTP in suburban Seattle uses this technique for heating their digesters. Heat pumps could also be used in conjunction with the sludge heat recovery in Option 6.

8. Solar collectors. Solar energy is a free energy source that is often used in similar but much smaller hot water applications, such as heating swimming pools. Solar energy is a non-polluting, renewable energy resource that can easily provide hot water at 200 degrees F in sufficient quantity to meet the added sludge heating needs. Solar heating systems are handicapped by two fundamental problems: (a) incoming solar radiation is fairly diffuse and thus requires very large, expensive solar collectors, and (b) solar energy is unreliable and non-existent at night. The output of a solar energy system drops off considerably in cold, rainy winter weather when heat is most needed so that a complete standby boiler system would be needed to back up any solar heating system. For these reasons, solar energy is considered too unreliable to be a viable option.

9. Fuel cells. Fuel cells are an exciting new technology that is attracting considerable interest. Fuel cells are very fuel-efficient, quiet, and produce essentially no exhaust emissions. Fuel cells are, however, extremely expensive. Fuel cells are primarily an electric power source, and heat production is secondary. A 1-MW fuel cell system would cost \$10 to \$12 million, but would only produce 2 to 3 million Btuh of heat. Fuel cells are not well suited for this application.

Economic Comparison

1. Cost estimates. Cost estimates were developed for two of the more promising and attractive heat supply options. These two options are the additional boilers option, and the digested sludge heat recovery option. The two options are shown schematically on Figure 3-1.

   The estimate construction costs of these two options are as shown in Table 9.

   As shown in Table 9 the estimated construction cost for the two different heat production options is very similar.

Table 9. Heating System Cost Estimate

Item	Capacity or Sizing Parameters	More Boilers Option	Digested Sludge Heat Recovery	Remarks
Hot water boilers, low NOx burner (30 ppm)	Three at 9 million Btuh	$300,000	$100,000	One standby boiler
Hot water pumps	Various	$50,000	$40,000	
Raw sludge heat exchangers	13 million Btuh	$250,000	$250,000	Concentric tube
Thermophilic sludge heat exchange	12 million Btuh	$250,000	$250,000	Concentric tube
Sludge heat recovery heat exchangers	13 million Btuh	N/A	$300,000	Concentric tube
Sludge cooling heat exchangers, complete	15 million Btuh	$150,000	N/A	Spiral type
Waste heat exchanger	9 million Btuh	N/A	$100,000	Summer use only
Heat recovery water piping, insulated	10-inch-diameter, steel, insulated	N/A	$80,000	
Heat recovery water pumps	1800 gpm	N/A	$100,000	Centrifugal pumps
Hot water piping, insulated	6-inch-diameter, steel, insulated	$50,000	$50,000	
Natural gas piping	2-inch-diameter, steel	$50,000	$40,000	Includes buried pipe
Plant 2W and 3W water piping	2-inch and 4-inch diameter, copper/PVC	$50,000	$50,000	Estimated
Electrical allowance		$500,000	$500,000	Estimated

Instrumentation and controls, allowance		$50,000	$50,000	Estimated
Building allowance	4000 square feet	$500,000	$500,000	Estimated
Subtotal		$2,200,000	$2,410,000	
Contingency	30% allowance	$660,000	$723,000	
Construction Cost		$2,860,000	$3,133,000	
Engineering, admin	25% allowance	$715,000	$783,000	
Total Capital Costs		$3.58 million	$3.92 million	Rounded

Notes:
1. The heat recovery alternative also includes one standby hot water boiler.
2. Boilers are hot water type fueled with natural gas only and with low-NOx burners.
3. Based on a new heating equipment building for the boilers or for the heat recovery heat exchanges. The location of this building is not established.

2. Economic analysis. The annual operating cost of the two different heat production alternatives is shown in Table 10.

   With an annual operating cost of only 1/3 the cost of the other heat production alternatives, the sludge heat recovery option pays back the extra cost in about 1 year and the heat recovery option clearly has the lower and more attractive long-term overall operating cost, and the lowest life cycle cost. This option is recommended.

Table 10. Annual Operating Cost Comparison

Equipment Item	Additional Boilers Option			Sludge Heat Recovery Option		
	Size, HP approx, and number	Annual Hours	Annual Cost	Size, HP, approx and number	Annual Hours	Annual Cost
Hot water pumps	15	4200	$4,700	25	4200	$7900
Boiler burner fans	40 x 3	4200	$12,600	40 x 1	-	---
Heat rec water pump	-	-	---	200	8760	$131,000
Sludge pumps	60	4200	$18,900	75	4200	$23,600
Boiler natural gas	9 mmBtuh	6000	$400,000	-	-	---
Boiler chemicals	-	-	$4,000	-	-	$2,000
Total, per year			**$440,000**			**$165,000**

Notes:
1. The pump motor and burner motor operating costs are based on electricity valued at $0.10 per kWhr.
2. The natural gas cost is based on purchased natural gas at $0.45 per therm and a 78% efficient, low-NOx hot water boiler.
3. The annual operating hours for each alternative is the estimated equivalent full load annual operating hours.
4. The annual boiler chemical cost is an estimate only, based on 1 percent of the annual fuel cost.

5. This estimate assumes that only one pump operates at a time, for pump equipment.

Recommendations

The proposed 50-mgd sludge digestion modifications will require an added maximum of 17 million Btuh of heat in the winter. This is in addition to the capacity of the existing cogeneration system. The recommended heat production option for the needed additional heat is Option 6, the digested sludge heat recovery system. This option has a roughly equivalent construction cost and a much lower annual operating cost than the additional boilers alternative.

Some of the features of the recommended digested sludge heat recovery system are as follows:

- Heat recovery from the digested 135 degree F thermophilic sludge is captured in a water-to-sludge concentric pipe heat exchanger and this warm heat recovery water is used to heat the incoming raw sludge. This heat recovery captures about 13 million Btuh.
- Final raw sludge heating for the thermophilic sludge digester is provided by a second heat exchanger in series that is supplied with heat from the cogeneration system.
- The remaining 4 million Btuh winter and springtime heat load is supplied by the standby boiler.
- In the late summer, when sludge heating needs are at their lowest, excess recovered sludge heat is wasted to the treated final plant effluent.
- Replacing the absorption chiller with an electric motor-driven chiller is also an option of value, and this could provide some of the required heat.
- All heat exchangers are conventional design concentric tube or spiral type sludge heat exchangers similar to those in dozens of similar wastewater treatment plants.
- Two of the three required heat exchangers for the sludge heat recovery option are required for both options evaluated.
- A standby boiler is provided with the heat recovery equipment for exceptionally cold weather or reduced system performance.
- Equipment will be housed in a new single-story building.
- The overall cost of the heat production system, and a building to house it, will be about $4 million.

7

CHAPTER 7 - TECHNICAL MEMORANDUM NO. 4, EVALUATION OF DEWATERING AND AIR DRYING OPTIONS

DRAFT
City of Riverside Water Quality Control Plant Evaluation of Dewatering and Air Drying Technical Memorandum 4

Prepared By: Brown and Caldwell
Date: Revised December 20, 2002

Introduction

Project Background

For digested sludge dewatering, a major decision for the RWQCP is whether to change to newer equipment for higher cake solids concentration. Improvements to cake concentration can have a significant impact on existing air drying facilities by reduction in volume being hauled to the drying beds, reduced drying time and labor costs. With increasing restriction for disposal of Class B biosolids, Riverside must look toward the future to develop ways of meeting Class A biosolids requirements by modifying existing operations and monitoring practices. On June 4, 2002, Brown and Caldwell held a kickoff meeting with the City of Riverside Public Works Department Water Quality Control Plant management and operations staff to further define the scope and design criteria for this dewatering and air drying options study.

Dewatering options discussed at this meeting focused on the use of centrifuges to replace existing belt press dewatering. Replacing or upgrading of existing dewatering equipment could be important in the near term. Optimizing dried product storage area is important for achieving sufficient air drying capacity. During wet months, from December to April, having a place to store dried material would avoid the need to re-dry material. Ways of improving existing air drying system would consider covering a portion of the beds.

Objectives

As stated in the scope of work for this project and as discussed at the project kickoff meeting, the following objectives are addressed in this technical memorandum.

1. Review current performance and operations data of existing dewatering equipment.
2. Assess dewatering improvements/options in light of thickening and digestion options. Dewatering options should consider odor control

requirements, power and polymer usage, and the benefits of increased cake dryness.

3. Improvements to air-dried storage in light of wet weather storage needs, air dried product uses and Class A sampling issues.
4. Define capital costs for dewatering and air-dried storage.

Existing Dewatering and Air Drying Facilities

Dewatering Facilities

The existing dewatering facilities include two (2) 2.2 meter Andritz SMX belt presses with an average capacity of 120 gpm each and a peak capacity of 220 gpm each. Operations staff indicated that this equipment operates 4 days a week from 5 AM to Midnight and 1 day a week for 24 hours. Both machines operate together without a redundant unit. Maintenance of this equipment must be completed during down time periods or on weekends to ensure sufficient capacity. Dewatered cake is discharged onto a belt conveyor that discharges into a loading hopper then into standard 6 cubic yard dump trucks. Once a truck is loaded, it transports its load to the air-drying beds located on-site. At current digested solids concentration of approximately 2% solids and an average feed rate of 150 gpm, the existing machines have a total capacity of 36 dry tons per day. Based on an analysis of recent data, it appears that these machines have reached their capacity limit and additional dewatering capacity is needed immediately. Currently there are no odor control facilities for either the dewatering or truck loading building. Due to sufficient buffer zone surrounding the dewatering and truck loading buildings, odors are diluted adequately to avoid odor complaints. However, increased solids production could mean increased odors. Plans for expanded dewatering facilities should include some method of odor control to be conservative.

Air Drying Facilities

The existing air drying facilities include twenty nine (29) drying beds covering a total area of approximately 8 acres. These drying beds are located on the west side of the site adjacent to Jarupa Street, which is a major thoroughfare adjacent to the site. Very little buffer zone is available between this roadway and the western edge of the drying beds. The loading rate reported in the plant O&M manual is 10 to 12 lbs/sf/yr at a depth of 12 to 18 inches. Operations staff have indicated that dewatered cake can be piled as high as 4 feet as long as it is turned over periodically. As stated above, dewatered cake is normally transported to these drying beds and spread with front-end loaders. To promote drying, the dewatered cake is turned frequently (approximately 40 hours per week). During the hotter dry summer months this schedule may be increased to make drying more rapid. Water drained form the wet cake drains to an underdrain pump station that pumps to the waste backwash water lagoons. Air dried biosolids at about 90% solids concentration can be achieved using this process. During wet weather periods, there has been a problem with storm drainage that has caused some rewetting problems at the northwest corner of the site. Improvements to drainage and dried product storage should be considered as improvements to the air-drying facilities. Once the product is dried it is piled onsite and occasionally trucked by a contractor to off-site land application sites. Off-site contractor trucking operations are typically conducted only 2 to 3 times per year.

To date, this biosolids material has been classified as Class B biosolids product and the City's contractor has land applied the material in accordance with Class B pathogen requirements. However, during 2001 and 2002 the City has sampled this product on a few occasions and had these samples analyzed for the required Class A pathogens in EPA's Part 503 rules. On all occasions, the analysis has shown that the biosolids meet Class A pathogen density requirements, which are listed here:

Fecal coliform density less than 1000 MPN/gram dry solids
(or salmonellae less than 3 MPN/4 grams dry solids)

Enterovirus density less than 1 PFU/4 grams dry solids

Viable helminth ova less than 1 viable ovum/4 grams dry solids

Most agencies which have attempted to achieve Class A biosolids from direct air drying of anaerobically digested dewatered biosolids have not been successful. A Water Environment Research Foundation (WERF) study on low-technology methods of achieving Class A biosolids (lagooning and air drying, primarily) has been underway since the late 1990s and led by Brown and Caldwell (Perry Schafer as Principal Investigator). This research program has shown that the few agencies which have been successful in producing Class A biosolids through air drying of anaerobically digested dewatered biosolids have been successful because of the following methods:

1. Some agencies have air dried the biosolids in windrows and have achieved temperature increases within the windrows, achieving a semi-composting operation without adding carbonaceous bulking agents.
2. Some agencies in desert regions have dried the material to such an extent (90 to 95 percent solids) that the pathogens (and perhaps most other microorganisms) are killed by desiccation – i.e., there is insufficient moisture remaining in the material to support good microbial life.
3. When agencies have air dried their biosolids slowly (while retaining moisture longer), they have had better pathogen kill. This success in slow drying is likely to be related to additional biological activity and better stabilization that can occur with longer drying times.

Also, because of hot summer conditions, temperatures within the biosolids on the drying beds at the Riverside plant may reach elevated levels, particularly when little moisture remains in the material. This could provide additional pathogen destruction. The actual reasons or mechanisms for the high degree of pathogen reduction at Riverside are probably a combination of the above factors, but the extremely dry nature of the final product (about 90 % solids is reported) is expected to be important in meeting Class A pathogen density levels.

Digested sludge flow and characteristics

Digested sludge characteristics are anticipated to be as follows, based on anticipated raw sludge thickening performance and digestion performance:

- Total solids content between 1.9 and 3.2 percent, depending on the specific thickening and digestion process used.
- Volatile solids content in digested sludge of 62 to 67 percent (of total solids) depending on the specific digestion option used

Digested sludge flow rates vary depending on the thickening method used and the operating hours for dewatering. Table 1 shows the digested sludge flow rates for the ultimate plant size of 50 MGD for the two thickening options discussed in TM1.

Table 1 – Digested Sludge Flowrates for Dewatering (All values within table are gpm)

Operating options	Separate Thickening		Co-thickening	
	Avg	Peak 2 week	Avg	Peak 2 week
5 days/week, 16 hrs/day	477	667	402	563

Dewatering Options

Estimated performance of dewatering options is shown on Table 2. The Andritz SMX belt presses are currently achieving approximately 12% cake solids at an average feed rate of 150 gpm. Performance could be improved if the feed rate was reduced to 100 gpm that would provide a longer detention time on the belts. More frequent doctor blade and belt maintenance could also improve cake solids, but this would be at the expense of increased labor for maintenance and increased parts costs. Other modifications could be made to the belt presses, such as adding rollers, but Andritz indicated that these modifications would probably only add 1 to 1.5% dryer cake. Andritz estimates that a 2% improvement in cake concentration could be expected from an increase of 1% in feed solids concentration. The increased feed solids concentration could also reduce polymer usage as well. For purposes of this analysis, a 15 % cake is possible from improved existing belt presses at lower flows and 18% from new belt presses.

High-speed centrifuges creating "G" forces in the range of 2500 to 2800 are estimated to produce dewatered solids content of 25 to 28 percent for mesophilically digested sludge for medium size to large size machines, respectively. For temperature phased digested sludge, these estimated cake solids percentages should increase slightly because of lower volatile solids content of the digested material. Solids capture is slightly better for operating centrifuge systems over belt press operations. Electrical power load per machine is substantially higher with centrifuges, but this is largely offset by the fewer number of operating machines required with centrifuges and less foul air ventilation horsepower required since centrifuge room air does not usually need foul air treatment.

Table 2 - Dewatering Performance Options

Parameter	Current belt press	New Belt press	High-speed Centrifuge[a]	
			Medium size	Large size
Feed rate, gpm Average Peak	 100 200	 150 225	 175 250	 200 300[b]
Cake solids content, estimate for mesophilic digestion	15%	18%	25%	28%
Cake solids content, estimate for temp phased digestion	16%	19%	27%	29%
Solids capture	90 to 95%	90 to 95%	96%	96%
Estimate polymer dose (lb active/dry ton)	12	12	20	20
Typical power load per machine, kW	20	25	90[c]	110[c]
Typical raw purchase cost per machine ($000)	250	300	450	650

[a] Does not include foul air ventilation power.
[b] The City of San Diego currently operates at this higher rate with no reduction in performance.
[c] Assumes no energy recovery from DC backdrive

A cost and non-cost assessment for two dewatering options was conducted. Dewatering Criteria for comparison assessment is shown in table 3. The two options are:

- Refurbished and new belt presses to produce slightly higher cake solids content at a reduced flow rate. Also, ventilation improvements are included and additional presses for future capacity increases. Two additional presses would be located in the existing dewatering building, where space has already been provided. One other belt press would be located in an expansion to the existing building west of the existing conveyor.
- An all-centrifuge dewatering option was defined for evaluation. Dewatering units would be located in the existing dewatering buildings, all on a raised deck. Digested sludge feed, polymer, ferric, centrate and foul air piping would be located below this raised deck.

Substantial data exist from other wastewater facilities with similar sludge characteristics to predict approximate performance for centrifuges at the RWPCF. However, pilot testing with controlled feed and careful data collection should be undertaken prior to designing centrifuge additions at the RWPCF. Most centrifuge manufacturers have mobile units that can be used for pilot testing at little to no charge. Obtaining valid polymer dose and energy requirements would be a major purpose of pilot testing since polymer and electrical costs represent a large portion of expected total O&M costs for centrifuge dewatering.

Table 3 - Dewatering Criteria for Comparison Assessment[a]

Parameters	New and refurbished Belt presses	All centrifuge[d] System
No. of machines	4(2 existing) operating 1 spare	2 operating 1 spare
	5 total	3 total
Machines in existing dewatering bldg.	4 BFPs	3
Estimated typical power load, KW[b]	300	270
Estimated polymer use, dry lb/oper. Day[c]	540	900
Dry tons solids aver/day[c]	36	36
Wet tons cake per average operating day[c]	300	133

a For 50 mgd, midway between separate and co-thickening flowrates. Assumes 5 day/week, 16 hour per day operation, except in major peak or unusual situations. Assumes medium size centrifuge

b Including foul air ventilation/treatment.

c Assuming temperature phased digestion and 5 days dewatering per week.

d. Dewatering centrifuges assume 200 gpm capacity

Belt Press and Centrifuge System Layouts and Configuration

Two of the new belt presses will be located in space already provided in the existing dewatering building. One additional belt press would be located in an addition to the west side of the existing building. Figure 1 shows the conceptual layout of the building addition that would house the fifth belt press. In addition to the belt press equipment, a new odor control system would be located along the south west side of the existing building.

The three new centrifuges would also be located in an addition to the west side of the existing dewatering building. To allow the existing dewatering equipment to continue to operate while the new centrifuges are being installed and to avoid potential costly modification to the existing building, this building addition is recommended. Figure 2 shows a conceptual layout of this building addition that would house the four new centrifuges. Because odors can be contained in the centrifuges, a smaller odor control system would be needed. These odor control facilities could also be located along the west side of the existing building.

Figure 3 shows the site plan for these new facilities for both centrifuges and belt presses.

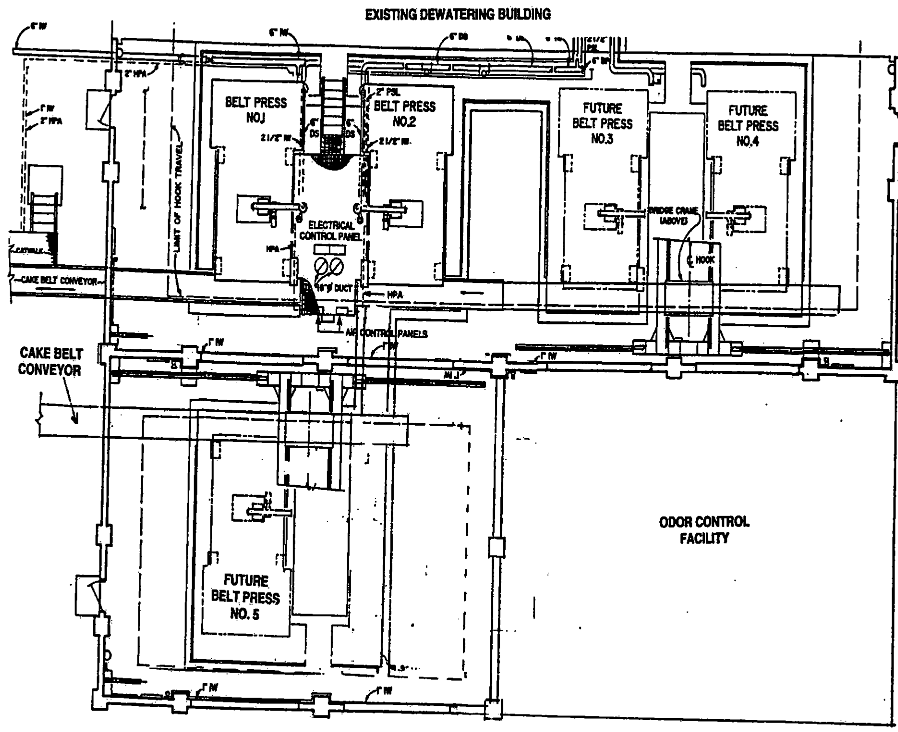


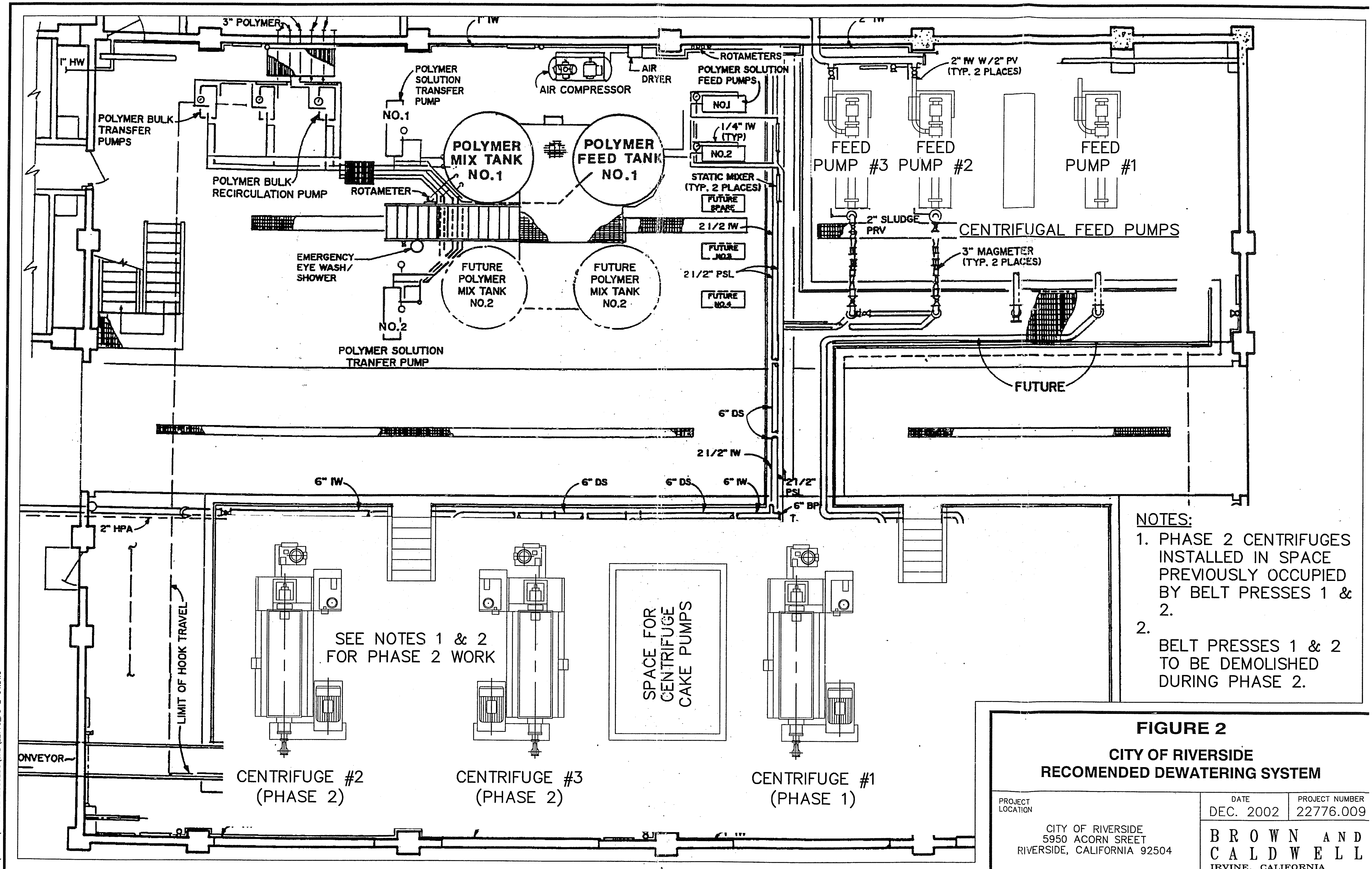
Figure 1 – Belt Press Dewatering Expansion

Dewatering Options Construction and Project Costs

Table 4 identifies construction and capital costs for these two dewatering options.

Table 4 - Estimated Costs for Dewatering Options ($1,000)

Cost element	Belt Press process	All centrifuge system
New dewatering units with installation Belt Presses (3), Centrifuges (3), labor, materials and appurtenances	3,700	4,500
Contingencies at 30%	1,100	1,300
Construction Cost	**4,800**	**5,800**
Project Costs at 25% (Engr., Admin. etc.)	1,200	1,400
Total capital cost	**6,000**	**7,200**



NOTES:

1. PHASE 2 CENTRIFUGES INSTALLED IN SPACE PREVIOUSLY OCCUPIED BY BELT PRESSES 1 & 2.
2. BELT PRESSES 1 & 2 TO BE DEMOLISHED DURING PHASE 2.

FIGURE 2

CITY OF RIVERSIDE
RECOMENDED DEWATERING SYSTEM

PROJECT LOCATION	DATE	PROJECT NUMBER
CITY OF RIVERSIDE 5950 ACORN SREET RIVERSIDE, CALIFORNIA 92504	DEC. 2002	22776.009

BROWN AND CALDWELL
IRVINE, CALIFORNIA

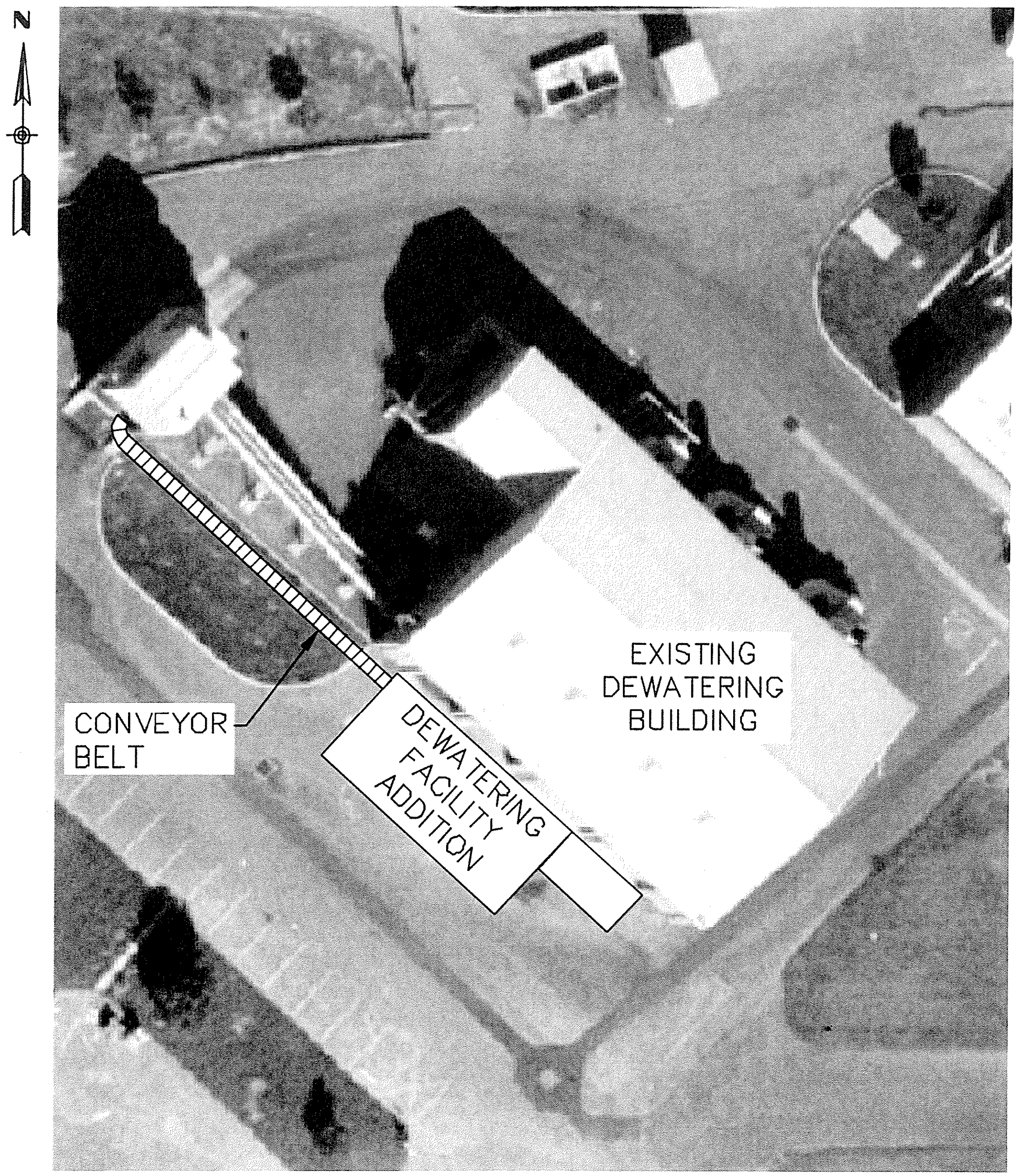
Odor from Dewatered Biosolids and Potential Air Drying

Concern for the odorous nature of digested, then centrifuged biosolids, is being expressed in various forms and locations in North America. Data are beginning to be collected, particularly for high-solids centrifuging (high G-force machines) which is indicating that high shear dewatering (and perhaps high-shear cake conveyance systems) are breaking apart biological floc particles and exposing protein to anaerobic degradation which is producing considerable odorous compounds including a variety of reduced sulfur compounds (Murthy et al, 2002). This is helping to explain the more odorous nature of centrifuged biosolids over belt pressed material. Also, there are scattered data on fecal coliform regrowth following such high-shear centrifuging. Fecal coliform regrowth may be caused by similar biological activity that is stimulated by exposing fresh organic food supply from high-shear processes. These problems are not occurring at belt filter press dewatering locations, evidently because of the low-shear type of processing involved with belt press operations.

When air drying digested centrifuged biosolids, the odor is expected to be considerably greater than air drying of belt press cake. The situation at the Riverside plant is already of concern in terms of long-term odor acceptability of air drying. Therefore, centrifuging followed by air drying is judged to be an incompatible process train for the Riverside plant. Digested centrifuged biosolids could be used directly in composting or heat drying facilities or might possibly be taken off-site immediately as a dewatered product for land application. However, these biosolids management practices have potential problems and/or relatively higher costs associated with them, so that they may not be particularly attractive in handling 100 percent of the Riverside plant dewatered biosolids production. We believe that air drying even a portion (say 25 percent) of the plant production of centrifuged biosolids would be an odor problem at the plant. At the project status and review meeting held on October 31, 2002, plant staff indicated a desire to phase out air drying over the next few years and that heat drying would be necessary to replace this air drying capacity. Therefore, centrifuges could be used for dewatering as long as centrifuge dewatered cake was sent to heat drying.

Recommendations

Based on both higher capital cost and non-economic comparison of the dewatering options, BC recommends upgrading the two existing belt presses and installing one centrifuge for 40 MGD. Two additional centrifuges would be installed for 50 MGD to replace the remaining two belt presses. Heat drying capacity would be provided for centrifuge dewatered cake.



DATE	PROJECT NUMBER	
09/12/02	22776.004	DEWATERING FACILITY EXPANSION

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA

PROJECT LOCATION: RIVERSIDE WATER QUALITY CONTROL PLANT, RIVERSIDE, CALIFORNIA

0 20 40
SCALE IN FEET

FIGURE 3

22776_FG-03-04

Air Drying Improvements

Covered Storage/Air Drying Area

There are various cover and containment technologies available to prevent precipitation from adversely affecting air drying or product storage areas at biosolids drying sites. However, cover/containment systems promoted by manufacturers are geared to relatively smaller POTWs with substantially less area than exists at the Riverside plant. These systems are expected to cost several to many million dollars to implement for the Riverside plant. The benefit of these systms is that contained air drying in winter is possible, but at a much reduced drying rate due to lower temperatures and variable weather patterns. This approach does not seem cost-effective for Riverside.

A more limited approach would be to provide a shed-type cover for a portion of the drying area (see Figure 4 for dried product storage site layout). Plant staff could use this covered area to store dewatered cake, partially air-dried biosolids, or even highly dried product during the wet weather months. Limited air drying operations might also be conducted under such a cover. If 0.75 acres (about 32,500 square feet) was covered with a structural steel shed-type system (no walls), with clear height of 30 feet under the cover, it would cost about $2.1 million. Such an area could contain the following materials:

- If 20 percent solids cake was stored to an average depth of two feet, this covered area could handle production for an estimated 3 to 4 weeks, assuming solids from a 40 mgd plant.
- If 35 percent solids material (partially air dried) was stored to an average depth of three feet, this area could store 3600 cubic yards. This would represent biosolids production for about 2 months (at 40 mgd plant flow).
- If 90 percent solids final product was stored to an average depth of three feet, this storage would represent about 6 months of plant production (at 40 mgd).

Conducting pile turning operations under this type of shed system would limit the amount of material that could be stored and may be difficult to implement without larger area being covered.

A simpler method of covering is to create a pile of dewatered and partially dried material (at about 25 percent solids) and cover it with plastic sheeting during the winter period when most precipitation and least evaporation are anticipated. This type of plastic cover system would reduce moisture addition from precipitation and minimize odor emissions from the pile. However, investigation would be needed to insure that pile temperatures did not rise significantly beneath such a cover.

N

DATE	PROJECT NUMBER	
09/12/02	22776.004	DRIED PRODUCT STORAGE LAYOUT

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA

PROJECT LOCATION			
PROJECT LOCATION	RIVERSIDE WATER QUALITY CONTROL PLANT RIVERSIDE, CALIFORNIA	0 30 60 SCALE IN FEET	FIGURE 4

22776_FG-01

Dried Product Monitoring for Class A Biosolids

Overview of Class A Alternatives and Monitoring Requirements

The 503 Part B regulations list six alternatives for obtaining Class A biosolids status. To achieve Class A status, biosolids must meet certain pathogen density requirements. These six alternatives are as follows:

Alternative 1: Thermally treated biosolids meeting specified time and temperature requirements.

Alternative 2: Biosolids treated in a High pH-High Temperature process meeting specified pH, temperature and air-drying requirements.

Alternative 3: Biosolids treated in other processes that can be demonstrated to reduce enteric viruses and viable helminth ova.

Alternative 4: Biosolids treated in many processes and then sampled to meet pathogen density requirements.

Alternative 5: Use of PFRP – biosolids treated in one of the listed processes to further reduce pathogens.

Alternative 6: Use of process equivalent to PFRP as determined by the permitting agency.

Of these six alternatives for achieving Class A, alternative 4 has been used to certify that Class A biosolids are produced. As stated in the regulations, this alternative requires monitoring of enteric viruses and viable helminth ova along with fecal coliform or galmonallac. The specific density limits are mentioned previously in this Technical Memo.

The other 5 Class A alternatives do not apply to the situation of air drying biosolids. For instance, air drying does not meet temperature or pH requirements of Alternatives 1 or 2. There is no PFRP or PFRP-equivalent process that has been approved for air drying (Alternatives 5 and 6). And, Alternative 3 is a difficult alternative to implement and is not recommended due to its regulatory complexity.

Alternative 4, involving final product pathogen analysis, can only be used where large batches of material are available – i.e., piles of dried product in this case. The City of San Jose has used this Alternative 4 for six years to sample its large annual pile of air-dried biosolids as Class A material. Goleta Sanitary District and a few other agencies in California have also used Alternative 4 to certify piles of product (typically air dried material) as Class A biosolids. To make it economical and workable, typically the pile would need to contain at least several months worth of biosolids production. "Representative samples" are required to be collected from the pile (both horizontally and vertically representative) and the number of samples needed is likely to be similar to the number of months or production within the pile. For instance, San Jose usually collects 12 to 15 representative samples from its annual pile. These samples are then sent to a qualified laboratory for pathogen and indicator testing. Results take 5 to 6 weeks because of the lengthy helminth ova test protocol. If the analytical tests show that the pile contains less than required densities, then the sampled pile is declared to contain Class A biosolids.

However, records must be kept about each pile and the material within the pile, and the pile must be clearly identifiable and kept separate from other material during the sampling, certificatoin, and product disposition phases.

Improving the Reliability of Alternative 4

Since other agencies have sometimes not been able to produce Class A biosolids from the type of processing that Riverside is doing (air drying of digested biosolids to about 90 percent solids), there is some risk from using this approach. A question could be: Is the Riverside product far better than Class A requirements, or is the material on the verge of not passing the tests? And, there is always risk that analytical work will show inappropriately high densities of one of the pathogens or indicators. Based on available research and testing work, we believe Riverside is likely to be on the verge of not achieving Class A pathogen density requirements on some samples. If this is the case, then we should examine how the current solids processing system could be improved or adjusted to increase the likelihood that all samples will achieve Class A requirements. To conduct this assessment, some additional information about the solids system and pathogen testing work will be collected. Alternative methods to improve the reliability of achieving Class A product are listed here:

1. Increasing the temperature of at least one stage of the anaerobic digestion process to the thermophilic range (52 to 57 degrees C). Helminth ova are much more readily inactivated and virus kill is improved at these temperatures.
2. Drying biosolids to higher than 90 percent solids – although this may be difficult to achieve with the area available.
3. Conducting longer storage time for dewatered cake before it is actually air dried – i.e., storing cake in piles for a few months. This, also, is likely to be difficult to achieve due to site limitations.
4. Improving the stability of the biosolids that are sent to the drying area. Improved stability, as measured through volatile solids content or similar measurements, usually coincides with reduced pathogen density.

These options should be briefly evaluated to determine the most likely improvement that can be achieved in final product pathogen densities. This analysis needs to be balanced with the risk that is being encountered by the City – potential failure of a sample to achieve Class A status. If the air dried material can be used or disposed as Class B material (should samples fail the tests), then it may not be worth spending significant effort on improving the reliability of making all of the dried product a Class A product.

Odor Control from Air Drying Operations

In the long-term, odor control at the Riverside plant air drying area is of major concern. The objective must be to reduce odor emissions over time, even as sludge production rises. Odor emissions from air drying are primarily caused by the fact that significant organic material is still subject to degradation after mesophilic anaerobic digestion. Degradable organic material can be minimized by implementing advanced digestion processes, including temperature phased digestion (previously discussed in TM2) and acid/gas phased digestion. Aerobic digestion following anaerobic digestion has also proved to be a major benefit in reducing odor from subsequent air drying operations. This process (aerobic digestion following anaerobic digestion) is used at the 12 mgd Easterly WWTP at Vacaville, California. Aerobic decomposition in particular, if it includes nitrifying much of the ammonia, can be extremely beneficial in reducing air drying odor emissions. Further work on this approach is underway for other projects, and additional information will be presented when it becomes available.

Another method used at large area sites, is to install a solid fence or wall, especially on the downwind sides of the site (nearest toward sensitive receptors) to cause vertical atmospheric mixing of residual odors being emitted. The method has proved to be of major assistance at Sacramento, California in making the large facultative sludge lagoon complex an acceptable process for nearby residents. The twelve-foot high solid wall causes vertical mixing of 2 to 4 times the height of the wall, and the walls are very effective when inversion conditions exist which normally trap odors on the ground surface, and transport them downwind with limited vertical mixing.

Odor control is also enhanced for air drying operations by using the least-intrusive dewatering and cake conveyance processes and minimum polymer dose. Polymer provides additional organic material for decomposition reactions and odor production during drying. Reduced polymer is associated with belt press operations (versus centrifuge), and also frequently with highly stable sludge produced by advanced digestion processes.

CHAPTER 8 - TECHNICAL MEMORANDUM NO. 5, EVALUATION OF HEAT DRYING

City of Riverside Water Quality Control Plant Evaluation of Heat Drying Technical Memorandum 5

Prepared By: Brown and Caldwell
Date: Revised December 20, 2002

Introduction

Project Background

With increasing restriction of disposal of Class B biosolids, it is increasingly important that Riverside look into ways of meeting Class A biosolids requirements by considering different process options. On June 4, 2002, Brown and Caldwell held a kickoff meeting with the City of Riverside Public Works Department Water Quality Control Plant management and operations staff to further define the scope and design criteria for this heat drying options study. At the project status meeting held on October 31, 2002, RWQCP staff indicated that heat drying appeared to have substantial benefits

Objectives

As stated in the scope of work for this project and as discussed at the project kickoff meeting, the following objectives are addressed in this technical memorandum.

- Identify heat drying vendor systems, including systems that are lower-cost and may not produce commercial grade granules or pellets
- Summarize product beneficial use markets and likely changes in the future. Performing a market analysis is outside the scope of this project.
- Prepare schematics, equipment sizing and layouts as well as heat/energy requirements for drying. Identify heat source options and costs
- Define air emission and odor control limitations and provide necessary control equipment
- Determine condensate characteristics and recycle impacts
- Develop cost estimate for alternate capacity/size of thermal drying system to replace air drying. Drying capacity would be for the full plant sludge production and may operate up to 24 hr/day depending on the amount of operator attention the dewatering and drying process needs. As a minimum, 16 hr/day 5 day a week operation should be assumed.

Heat Drying Processes

Heat drying systems involve the application of heat to evaporate water from sludge. This becomes a major advantage in reducing the weight of final product and in creating a biosolids product that is free of pathogens (Class A). In addition, if the process creates hard, dry, and similar-sized particles (usually between 1 and 5 mm in size) that are safe and easy to handle (non-dusty material), the product can be marketable as a fertilizer material. If the sludge is not stabilized through a digestion process prior to heat drying, the final product can be odorous, especially if it becomes re-wetted. Such re-wetting can occur during storage, but most often occurs at the final use site, if land applied.

Vendor-Provided Systems

Heat or thermal drying systems are all essentially provided by vendors or manufacturers, and, therefore, each one is different due to its patented characteristics and the specific features and even the approach to drying taken by the vendor/manufacturer. Drying systems are often categorized according to whether they use a "direct' or "indirect" drying approach as defined here:

- Direct dryers. These are systems whereby hot drying gas (normally heated air) is in direct contact with the sludge material. A large amount of particulates are picked up in these gas streams and major particulate/gas handling and treatment systems are required. Many of these systems recycle the exhaust stream to improve thermal efficiency and provide some thermal destruction of odorous compounds. However, there is more experience in direct drying (than indirect drying) systems for sludge, and more experience in creating fertilizer products.
- Indirect dryers. In these systems, the heating source (steam or hot oil, typically) does not come into direct contact with the sludge. Instead, the heat is transferred to the sludge through paddles, mixers, or related devices. Therefore, the gas handling system is simpler for this approach, but there is somewhat different challenges in creating usable product and uniform particles with several of the processes available.

Some of the more common heat drying systems are described briefly below. These systems are all designed to provide a well-graded product with relatively uniform particle sizes. This approach maximizes the value of the product.

- **ESP Dryer.** The ESP process is a direct rotary drum process with once-through airflow. The dryer is a triple-pass, rotary dryer. A portion of the dried biosolids product exiting the dryer is recycled and blended with incoming dewatered biosolids to create the feedstock to the dryer. The gas/solids mixture entering the dryer is separated in cyclones and filters, and the dry product is classified by screens into oversize, market size, and fines. The oversize is crushed, mixed with fines, and recycled to mix with the incoming dewatered biosolids. The exhaust gases exiting the separation system are cooled and condensed in a wet scrubber, and the non-condensable fraction is heated in an afterburner to destroy odors.

- **Swiss-Combi.** The Swiss-Combi process is a direct-drying, rotary drum process with air circulation. The dryer is a single-pass, rotary dryer. A portion of the dried biosolids product exiting the dryer is recycled and blended with incoming dewatered biosolids to create the feedstock to the dryer. The gas/solids mixture exiting the dryer is separated in a cyclone and fabric filter, and the dry product is classified by screens into oversize, market size, and fines. The oversize is crushed, mixed with fines, and recycled to mix with the incoming dewatered biosolids. The exhaust gases exiting the separation system are divided into two streams. The first stream is recycled to the dryer. The second stream is condensed, and the non-condensable fraction is heated in an afterburner to destroy odors. The afterburner also provides heat recovery from its flue gas. Some plants report drying raw sludge with this dryer.

- **Andritz.** The Andritz process is a direct drying, rotary drum process with air recirculation. The evaporation process in the Andritz direct dryer takes place within a triple-pass, rotating drum. The high-speed air within the drum pulls the material through the drum until it is dry enough and, therefore, light enough to be lifted and pneumatically conveyed out of the drum. The Andritz dryer drum consists of three concentric arranged cylinders, so that the material to be dried flows through the innermost cylinder, back through the middle cylinder, and finally out through the outer cylinder. Flights on the inner walls of the cylinders lift the material and cascade it into the hot air stream. Andritz does not promote their system for raw primary sludge drying.

- **Seghers.** The Seghers process is an indirect, tray dryer process. The vessel is vertically oriented, and hot oil is passed through the trays while the solids fall from one tray to the tray beneath, similar to a multiple hearth furnace. Dewatered biosolids mixed with recycled dry biosolids are fed through a top inlet in the vertical, multi-stage dryer. The dryer has a central shaft with attached rotating arms that are supported by axial-radial bearings at the bottom of the dryer casing. The rotating arms move biosolids from one heated tray to another in rotating, zigzag motion until it exits at the bottom as a dried, pelletized product. The rotating arms are equipped with adjustable scrapers that move and tumble the solids in thin layers over heated, stationary trays. Round pellets are formed through a pearling process. The solids feed preparation technique, in combination with the rolling across the heat trays, causes the pellets to grow from inside out, the way pearls are formed.

- **VA Tech.** The VA Tech process is an indirect, fluidized bed process. Fluidization gases are distributed uniformly across the area of the dryer to keep the dry granules in an evenly floating motion. Inert gases are used for fluidization to provide a safe environment that requires minimal supervision. The heat exchanger is immersed in the fluidized layer to transfer all the energy necessary for evaporating the water from the wet sludge. Generally, steam or hot oil is used as the heat transfer media. The dryer hood collects the exhaust gases containing the evaporated water and some dust. These gases are recirculated for energy recovery and air treatment. The process produces a uniform granulated product that is 90 to 95% dry solids in a single stage. This process has recently been added to the Schwing line and is constructed in a vertical arrangement, which can reduce the process footprint, but can become quite tall.

Most of the systems listed above are well suited for plants that are at least the size of the RWQCP. The final products are all pellets or granules of uniform size. However, the cost of one of these systems to handle the entire drying needs would be in the tens of millions of dollars range. Other dryer systems described below are more well suited to smaller plants and are reportedly less costly. The Fenton system had units sized to cover a range of production solids from 18 to 75 wet tons per day or 3.5 to 15 dry tons per day per dryer. The InnoDry system has units sized that are capable of handling a similar throughput up to 26 dry tons per day per dryer. The Komline Sanderson dryer come in unit sizes that could handle a portion of or up to the full daily production of the RWQCP. The product from these dryers is less uniform and has much larger variety of particle sizes. Consequently, the product has less "value" in the market place.,

- **Fenton.** The Fenton process is an indirect hollow plate dryer. Drying is done in a batch process to ensure compliance with EPA 503 regulations to produce a Class A product. The evaporator unit utilizes a patented sludge feeder with heated hollow discs using hot oil as an evaporating media. Programmed temperature control brings the dewatered cake to evaporation temperatures quickly then controls the temperature at optimum levels to produce a desired dryness. Exhaust air is scrubbed to remove particulates and minimize emissions. Standard size units can be provided for average daily production of 18 to 75 wet tons per day. Fenton also offers a product purchase option for terms of one to three years to provide product disposition.

- **INNOPLANA.** The INNOPLANA drying (InnoDry) process utilizes a two-step drying system that incorporates both indirect and direct drying. The first stage employs a thin film evaporator utilizing hot oil as an evaporating media. Dried solids leave the first stage at approximately 45 to 50% dry solids through an extrusion/chopping mechanism. This chopper shapes the product into spaghetti shaped strands of a selected size and length. The chopped material passes onto a belt dryer which passes the product through a hot air stream utilizing waste heat recovered from the first stage to produce a final dried product up to 90%+ dry solids. Process safety is enhanced because the drying process and dried product are largely dust free and temperatures in the plant are below ignition limits. This largely dust free operation provides vapor condensate and exhaust air with low emissions. Through use of an integral heat recovery system this second stage requires little additional energy to produce the desired dryness. This has been reported to represent approximately 30 to 40% energy savings over other drying systems. This process has been in operation for approximately four years in Europe. The plant in Merenschwand Germany has been in operation since 1996 and is available for pilot trials.

- **Komline-Sanderson.** The Komline Sanderson process is an indirect hollow paddle dryer using hot oil or steam as the heat transfer media. The dual counter-rotating shafts with intermeshing wedge-shaped paddles promote thorough mixing and convey the product through the drying process. No internal adjustments are needed on any of their moving parts. It's high torque mixing system enables it to take the dewatered cake through the plastic range without the need to recycle some of the dry product. The variable speed system conveyor system allows the unit to handle a wide range of solids loads and concentrations. These units are also equipped with an explosion relief system for added safety.

Process Operations Considerations

Dried Product Characteristics

The dried product is generally valued on its nitrogen content for use as a fertilizer amendment providing that it meets the required physical characteristics such as particle size, hardness, and density. To achieve the optimum or desired product, dryer systems may need ancillary equipment items such as screens, grinders, and even a pelletizer/compactor. Dryer systems also employ recycle of dried product to the feedstock at a variable rate to be determined for the specific feedstock and desired product characteristics. In some instances, additives may be mixed with the sludge material to achieve certain desired characteristics. These additives may include oils to assist in binding of product, nutrients to change fertilizer components, and chemical suppressants to minimize heating and potential combustion of product.

Anaerobically digested sludge, when heat dried, usually provides a good, usable product. Removal of hair and plastic debris is important for good product quality, and, therefore, sludge screening is a good approach when a high-quality marketable product is desired. When raw sludge is heat dried, the product can be more odorous than dried digested sludge because little stabilization of the organic material has occurred. The low moisture content in the product is the primary defense against biological activity. If any significant moisture accumulates in the product, then active biological activity is initiated and odor can become significant. For instance, when dried raw sludge is spread on a field, rainfall prior to soil incorporation of the material would likely create an odorous situation.

Product Auto-Heating and Safety

Hot or warm organic material that contains even small amounts of moisture and has an available oxygen supply can generate sufficient biological activity to produce increasing amounts of heat to the point that smoldering or even active combustion can occur. This is called auto-heating. Many such events have occurred with heat dried sludges in North America and overseas.

The control measures for this problem include the following:

- Reduce the temperature of the final product
- Minimize moisture content in the product
- Minimize oxygen content in the air/gas that is in contact with the heat-dried product. This is usually accomplished by containing the final product within a nitrogen gas atmosphere (nitrogen blanketing).

There have also been explosions caused by the organic dust associated with dried sludge. Dust control is, therefore, a major issue in any heat drying facility.

Heat Dryer Air Emissions Controls

All exhaust air stream organics from sludge heat dryers would need to be controlled to limit the concentrations of air contaminants. Some control is achieved within the initial heating process. For instance, temperature and excess oxygen control enables balancing nitrogen oxides (NOx) against carbon monoxide (CO). Whereas, the former increases at increasing temperatures, and the latter decreases at decreasing temperature. This is similar to what happens with automobile emissions. Typically a venturi scrubber installed just downstream of the sludge dryer will remove such mater-solid pollutants such as particulate matter and sulfur oxides to below reulatory limits. Engineered biological oxidizers, chemical oxidizers, or recycling of this air stream back to an existing process for reuse would then be designed to remove the remaining air pollutants to acceptable levels. Dryer systems have normally been able to meet necessary air emission regulations in the United States. The SCAQMD has an additional stipulation in that natural gas fired control devisces such as heat dryers must have a backup fuel system approved by the Executive officer of the air district.

The biggest risk in the context of air emissions would be the potential implementation of stricter regulations for control of dioxins, furans, and other trace toxic contaminants. Such regulation is currently proposed in the SCAQMD and is the subject of much debate. However, such regulatory changes are not expected to effect wastewater treatment plants in the near future.

The air emission that attracts the highest public awareness is invariably odor. Although the process air can be well oxidized and controlled through the use of the aforementioned systems, the ventilation air from buildings, storage tanks and truck loading is a much larger air flow and requires treatment before discharge. Essentially, all of the proposed systems require similar size buildings with consequently similar exhaust airflows to be treated. Bulk media biofiltration and/or activated carbon systems are often installed to insure adequate odor control at all times.

Development of Drying Option

The Fenton dryer, the Innodry and the Komline Sanderson dryers would work well to replace the existing air drying operations. A summary of these three systems are shown in Table 1. Figure 1 shows a schematic of how the dewatering and drying process would work together. Although both the Innodry and Komline-Sanderson dryers are continuous feed dryers a small surge bin is also required to allow more flexibility in dewatering operation. Figure 2 shows a possible site layout for the heat drying facility. The footprint of this facility includes ancillary facilities such as odor control and dewatered cake surge bins, etc. Dewatered cake production quantities are shown in Table 2 for 32, 40 and 50 MGD plant flows. Future production quantities assume similar liquid process performance to current operation.

Table 1 – Heat Dryer Process summary

	FENTON RK 72E	**INNODRYER G4**	**KOMLINE-SANDERSON Model 11W-1200**
Method of operation	Batch	Continuous	Continuous
Dryer type	Indirect – hot oil	Indirect - hot oil, Direct – hot air	Indirect – hot oil or steam
Product type/quality	Ungraded/dusty	Granulated/low dust	Granulated/low dust
Capacity per unit[a]	13.7 cu yd/batch[b]	10 dtpd	10 dtpd
Heat Energy required	1600 Btu/lb water	1250 Btu/lb water	1,130
Dehydrated Solids	90%+	90%+	90%+
Minimum feed solids	16%	18%	18%
Cooling water	150 gpm	212 gpm	200 gpm

a. Assumes 24 hr/day operation
b. Batch size based on wet cake volume

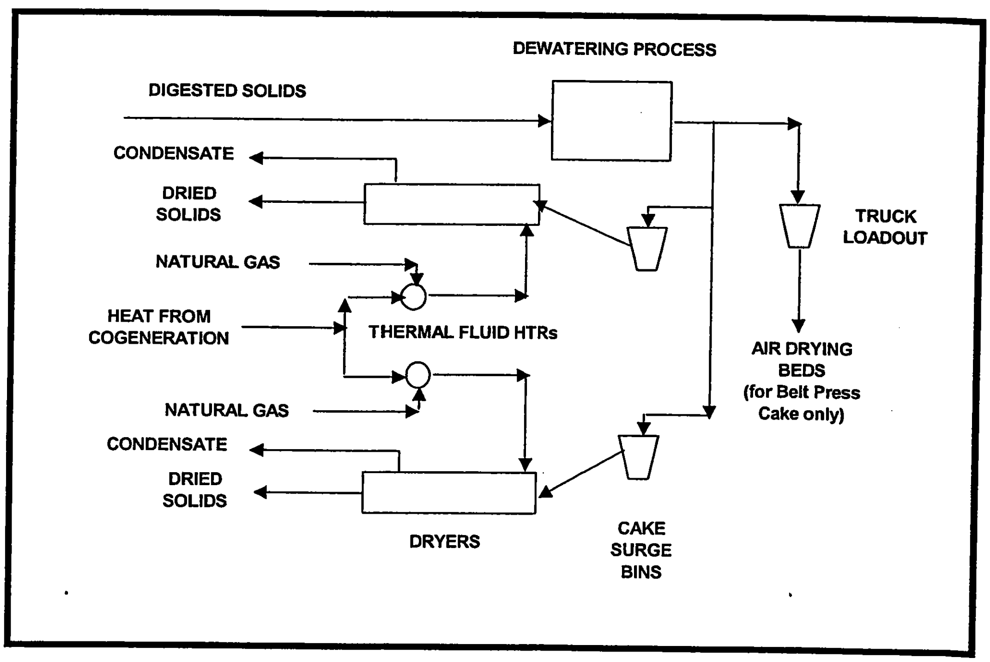


Figure 1 – Heat Drying Schematic

Table 2 – Dewatered Cake Production Quantities[a]

Parameter	Current 32 mgd	40 mgd	50 mgd
Digested solids			
Average, dtpd	19	29	36
Peak 2 week, dtpd	26	41	51
Dewatered cake, 27% solids[b]			
Average 7 day, wtpd	66	102	128
Average 5 day, wtpd	92	143	179
Peak 2 week 7day, wtpd	92	143	179
Peak 2 week 5 day, wtpd	129	200	250
Dewatered cake, 18% solids[b]			
Average 7 day, wtpd	99	153	191
Average 5 day, wtpd	138	214	268
Peak 2 week 7day, wtpd	138	214	268
Peak 2 week 5 day, wtpd	193	300	375

Notes:

a. Assumes 53% VSR in digesters
b. Assumes 95% capture in dewatering
27% from centrifuges (estimated)
18% from new belt presses (estimated)

Abbreviations:
Dtpd = dry tons per day
Wtpd = wet tons per day

Evaluation of Dryer Options

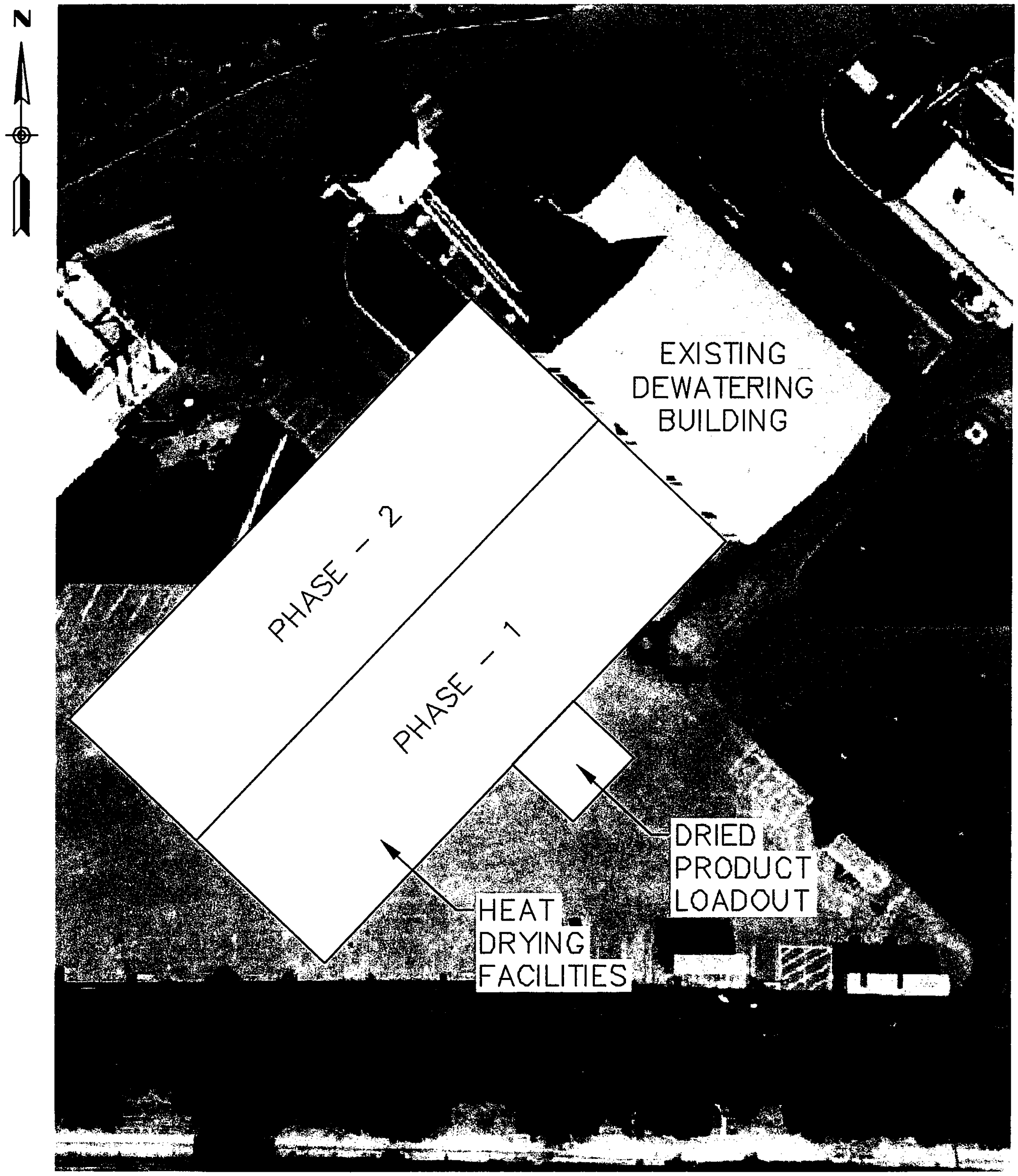
Energy usage and air emissions

Energy Use

Most sludge dryers use heat to evaporate the majority of the water in the sludge, and thus are very large energy consumers. This energy includes the fuel used to heat the sludge and evaporate the moisture, along with the electricity used to operate conveyors, pumps and fans. Typically the heat source is by far the largest energy, and this is usually provided by a natural gas fired burner. This burner flame is used to heat the hot oil thermal fluid.

Energy Consumption

The feed sludge entering a typical dryer is often 16 to 30 percent solids. Conversely the initial feed sludge is therefore 70 to 84 percent water. A sludge dryer that produces a 90 percent dry cake from an initial sludge at 20 percent solids thus removes about 1400 pounds of water per ton of feed sludge. Ideally it takes 970 British thermal units (Btu) to evaporate one pound of clean water. Thus, under laboratory or ideal conditions it takes about 970 Btu per pound, times 1400 pounds, or about 1.36 million Btu to dry one ton of wet sludge at 20 percent solids to a 90 percent dry product.



DATE	PROJECT NUMBER	
11/07/02	22776.005	HEAT DRYING FACILITY SITE PLAN

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA

PROJECT LOCATION			
PROJECT LOCATION	RIVERSIDE WATER QUALITY CONTROL PLANT RIVERSIDE, CALIFORNIA	0 20 40 SCALE IN FEET	FIGURE 2

Sludge dryers do not operate under ideal or laboratory conditions, due to the nature of the product and the difficulty in uniformly applying heat without overheating a portion of the sludge, and thus realistically it takes about 1200 to 1700 Btu of heat energy per pound of water for sludge dryer to evaporate one pound of water. This value includes the combustion furnace or burner efficiency.

The different sludge dryer vendors quoted between 1100 and 1600 Btu per pound of water for their equipment on this application, depending on the specifics and efficiencies of their equipment. Based on this, it would take approximately 1.5 to 2.2 million Btu of heat to dry a wet ton of 20 percent solids sludge to a 90 percent dry product.

Cogeneration System Heat. Technical Memo No. 3 describes the cogeneration system and the possibility of available excess heat. If thermophelic digesters are not used, as per current plans, then the RWQCP would have approximately 2 to 4 million Btuh of excess heat from the cogeneration exhaust heat.

The three sludge dryers reviewed in this Technical Memo all use a hot oil or thermal fluid to indirectly heat the sludge. This hot oil is at a temperature of 340 to 420 degrees F, and is thus much hotter than the hot water heat recovery form the RWQCP cogeneration system. The cogeneration system heating water could be increased to about 200 degrees F with some simple modifications, but this is still too cool to use for heating the hot oil.

The existing engine heat recovery silencers could be replaced with heat recovery silencers that produce 150-psig 365 degree F steam, but this would be about as hot as the heat recovery system could be made. This would still be too cool to warm the hot oil. It could be used to warm the oil heater gas burner combustion air to reduce the amount of natural gas fuel being used.

The cost of this cogeneration system heat recovery system silencer replacement is not included here. For this study we assume that a portion of the cogeneration heat could be used to warm the oil heater burners' combustion air using the existing engine heat recovery system.

Dryer System Components

The principal sludge dryer process components are as follows:

1. **Hot oil thermal fluid heater unit, oil pump and piping.** This includes an oil bath, natural gas piping and gas train, gas burner(s) and oil temperature controls.

2. **Feed hopper/surge bin and sludge conveyance system.** The feed hopper/surge bin receives the wet sludge and serves as a pick-up reservoir for the inclined sludge conveyance system.

3. **Sludge dehydrator or dryer chamber**. This includes the hollow disk rotor (Fenton dryer), thin hollow plate (Innodry dryer) or hollow paddle (Komline-Sanderson dryer) in which the hot thermal fluid circulates, and the fluid circulation shell. The Innodry dryer also includes a belt conveyor drying section that utilizes recirculated hot air.

4. **Process controls and programming.** This includes the PLC controls and programming to control the dryer.

Sludge Dryer Auxiliary Systems

Three sludge drying systems were evaluated including the Fenton dryer, the Innodry dryer and the Komline-Sanderson dryer. These sludge dryer systems are generally similar but, individual components and arrangements differ. Thus their auxiliary systems are quite different for the three sludge dryer systems.

Fenton sludge dryer. The auxiliary systems are as follows:

1. **Exhaust vapor stream Venturi scrubber and condenser:** This condenser and scrubber are located on a stainless steel duct exiting the dryer chamber. Using a process water stream and sprays, the Venturi scrubber cools the water vapors and washes out airborne containments from the gas stream. This Venturi scrubber is fitted with a centrifugal exhaust fan and discharge stack. Each sludge dryer contains two chambers, and each chamber needs 210 gpm of 40-psig water, for a total of 420 gpm, per dryer.

2. **Bioway biologic treatment on the Venturi scrubber vapor exhaust stream:** The biological system is a compost type reactor in which the exhaust passes through a wetted biological media compost bed. One system will serve all of the sludge dryers, and the biological system needs a variable amount of water, up to 60 gpm. For redundancy, two biological systems should be provided.

3. **Water consumption:** The overall water consumption would be 3 times 420 gpm or 1260 gpm for the scrubbers, plus up to 60 gpm for the biological tower, for a total of up to 1320 gpm. This is a very significant plant water use rate. This final plant effluent must be strained to remove larger solids then strained thru a 300-micron filter to meet the dryer supplier requirements. An 8- or 10-inch diameter 3W plant water line, with strainers and filters will be required.

4. **Spent Venturi water and condensate drainage system:** The 1260 gpm of plant water from the Venturi scrubber, plus the condensed water that was evaporated by the sludge dryer is discharged back to the RWQCP head works, or to the primary sedimentation tanks. The total water evaporated is over 419,000 pounds per day, or about 53 gallons per minute. A 14- to 18-inch floor drain will be required for this drainage flow. This will be a significant drainage flow of almost 2 mgd when all the dryers are operating.

5. **Cogeneration system heat piping, pumps and heat exchangers:** If excess cogeneration system heat is used to reduce the oil heater natural gas consumption, heat transfer piping, pumps and heat exchangers will be required. This would likely be a 6-inch insulated steel line conveying

600 gpm of heating water, for a maximum 3 million Btuh system from the cogeneration heat recovery.

6. **Natural gas fuel system.** For a peak operation of 38 million Btu per hour, a 3-inch or 4-inch natural gas supply line will be required.

Innodryer sludge dryer. The Innodryer sludge dryers auxiliary systems are as follows:

1. **Sludge exhaust vapor condenser system:** This system will likely use plant water for condensing.

2. **Thermal fluid pumps and piping:** The dryer oil system includes the oil heater, a centrifugal oil pump, piping, an expansion tank, and temperature and safety controls. The thermal oil operates at a temperature of 340 to 430 degrees F. Innodryer suggests that the oil heaters be located in a separate room.

3. **Film evaporator and belt dryer air use system:** To minimize the exhaust air stream, the hot exhaust for the film evaporator is recycled and used to heat and further dry the final product pellets. This hot air is very moist and the piping contains drip traps and drains. This is a large air system with a total airflow rate of about 50,000 to 75,000 cfm.

4. **Film evaporator / belt dryer exhaust air system.** This includes the exhaust air ducting and fan. The reported exhaust air has a design flow rate of 1500 cfm.

5. **Exhaust air treatment ozone air purification system:** Details of this exhaust air treatment system are not available

6. **Condenser water system.** Each sludge dryer train contains two condensers. One condenser cools the air stream from the thin film dryer, and one condenser cools the belt dryer air stream.

7. **Spent condenser water and exhaust piping drainage system.**

8. **Dryer oil heater natural gas fuel system.** For a peak operation of 33 million Btu per hour, a 3-inch or 4-inch natural gas supply line will be required.

Komline-Sanderson. The K-S sludge dryers auxiliary systems are as follows:

1. **Dried sludge screw conveyor cooling water:** The 20-foot long inclined screw conveyor includes a water jacket for cooling the dried product to approximately 150 degrees F. Plant water might be used for conveyor cooling, and conveyor cooling water flows were not available.

2. **Thermal fluid pumps and piping:** The dryer oil system includes the oil heater, a 60 HP centrifugal oil pump, piping, an expansion tank, and safety devices and controls. The heated fluid is Paratherm HE thermal

oil. The thermal oil operates at a temperature of 355 to 380 degrees F with a design flow rate of 769 gpm per unit.

3. **Paddle dryer off-gas duct**. This ducting is stainless steel for the hot moist gases.

4. **Off-gas condenser/cooler**: This is a Venturi type counter flow gas scrubber. The condenser/cooler vessel bottom is a sump for the sprayed water pumps. Plant water may be required for make-up water.

5. **Stainless steel off-gas ducting**: Based on a quoted vapor off-gas flow of 4040 pound per hour, this could be a very significant duct form each sludge dryer. This warm off-gas stream is very moist and the piping contains drains and drip traps.

6. **Dryer oil heater natural gas fuel system**: A 3-inch or 4-inch natural gas supply line will be required for a peak operation of about 33 million Btu per hour.

Komline-Sanderson's proposed method of air treatment is described below. This system would not likely be acceptable for odor reasons and SCAQMD approval is doubtful. More conventional methods of air treatment would need to be substituted for the equipment listed below.

7. **Off-gas compressor.** Each sludge dryer includes a 30-horsepower liquid-ring type gas compressor. The compressor discharges the gases to the aeration basins. Air discharged to the aeration basins would reduce the amount of air supplied by the aeration blowers.

8. **Off-gas diffuser system**: A diffuser system would be mount in the existing aeration tanks.

Air Quality and Exhaust Emissions

The exhaust emissions include the natural gas combustion products from the oil or thermal fluid heater gas burners as well as the process vapors volatized from the drying sludge as the water is evaporated. Each of these two separate exhaust steams is treated separately in all of the sludge dryers.

Generally the sludge dryer discharge vapors are treated twice. First they are scrubbed and condensed in Venturi scrubbers. The three suppliers employ different types on secondary exhaust treatment, following the scrubbers.

For the Fenton sludge dryers the multiple dryer exhausts are combined and are treated through a single biological system tower. We understand that this type of biological treatment is accepted and possibly favored by the SCAQMD

The Innodryer offers an ozone treatment system for the exhaust off gas stream.

The Komline-Sanderson unit pipes the off-gases from the sludge dryers to the treatment plant aeration system. This would not be acceptable for odor reasons and SCAQMD approval is doubtful. An alternate system would be needed.

Safety Concerns

There are several safety concerns regarding equipment such as the proposed sludge dryers.

1. **Oil heater system.** The thermal fluid must be heated to approximate 340 to 420 degrees F. Oil is used as the thermal or heating fluid, rather than water, because oil can be heated to the required temperatures and will remain liquid at a much lower pressure than water.

2. **Hot oil circulation.** The thermal fluid circulates from the fluid heater to the sludge cake thin film evaporator and to the belt dryer air preheater system. The quantity of thermal oil that is actually circulated is not small.

3. **Conveyor safety.** The sludge conveyors and augers have many potential pinch points and similar safety hazards.

4. **Combustion systems.** The oil heaters have natural gas burners with their associated safety controls, accessories and devices.

5. **Electrical equipment safety.**

6. **Product dust**

Cost for Heat Drying Options

The RWQCP heat drying alternatives criteria and costs are shown in Table 3 along with a listing of cost categories. The primary capital cost categories are defined here:

- Demolition and site preparation – This includes demolition of paving and concrete on the west side of the existing dewatering facility and preparations of the site for a drying facility.

- Dryer Equipment Package – Several vendors have been contacted to discuss dryer equipment prices for a facility of this size. Fenton, INNOPLANA, and Komline-Sanderson were contacted to obtain equipment package pricing. For equal comparison, the systems are developed with one dryer as a backup unit. This allows a high degree of reliability in operation of the system. The Komline-Sanderson system is available in larger unit sizes than the Fenton and Innodry dryers allowing fewer units. However, this would reduce the overall redundancy.

- Building Cost – This is for a new building to house the drying facilities and equipment. The cost includes mechanical, electrical, instrumentation and control, plumbing, lighting, and civil work associated with the building. The building would be on the west side of the existing dewatering building, and would be constructed to fit in architecturally with the plant.

- Dried Product storage – A dried product storage building as described in TM4 – Dewatering and Air Drying Options is assumed for this heat drying option. The cost for this building were developed as a part of TM4. The lower part of the sides of this building would be closed to prevent wind from blowing the dried product. The upper third of the walls would remain open for ventilation

- Ancillaries – this includes major power supply, piping, and major utilities services for this facility. This also includes sludge cake transfer conveyors to the heat drying building.

From these costs, a total construction cost estimate is shown, with 30 percent for construction contingencies. Another 25 percent is added to provide a capital cost estimate for Administration and Engineering. An evaluation of energy usage was calculated for each dryer system. Twenty year present worth energy costs are also shown in Table 3. A complete copy of the present worth energy analysis is included in Appendix A.

Project Phasing

As discussed at the project status meeting held on October 31, 2002, the City should plan to reduce the amount of biosolids being air dried at the RWQCB as soon as possible, and some capacity for heat drying could be logically used to reduce site air drying needs. Therefore, the initial heat drying facility would not need to be as large as the facilities shown on table 3. The number of units required for 7 day versus 5 day a week operation would also affect the number of units installed as well as the size of the building. Table 4 shows possible phasing scenarios. Phase 1 assumes a combination of belt press and centrifuge dewatering. For the 5 day per week scenario (current dewatering operation) one belt press would handle 100 gpm flow and one centrifuge would handle the remaining 200 gpm under peak flow conditions. For the 7 day per week scenario, one centrifuge could handle nearly the entire flow. This would allow maximum use of heat drying and phase out the drying beds much more quickly. Phase 2 assumes all centrifuge dewatering and complete phase out of the air drying beds. Depending on how quickly solids production increases, phase 2 may not occur for 10 or more years.

Conclusions

Three different indirect heat dryers have been evaluated as described above. Both the capital costs and life cycle energy cost for all three vendor technologies are very close. Because the evaluation for the 50 MGD facility was based on 10 dtpd size units, they could be easily phased in over several years to match plant solids production. To reduce initial capital costs, phasing these facilities in over a period of years would be recommended. Other benefits of the phased approach would be realized by taking advantage of advances in technology. Heat drying would provide a reliable means of producing a Class A product that could be disposed of more readily. Full conversion to heat drying would eliminate the use of the air drying beds thus freeing up space for alternate uses.

Table 3 – Heat Drying Criteria and Capital Cost Estimate (50 mgd Facility)

	Fenton	**Innodry**	**Komline-Sanderson**
Process Design Criteria[a]			
Number of drying units required 7 day operation	5	3	3
Number of drying units required 5 day operation	6	4	4
Average evaporation capacity, lb/hr 7 day operation	6,157	6,157	6,157
Average evaporation capacity, lb/hr 5 day operation	8,620	8,620	8,620
Peak evaporation capacity, lb/hr 7day operation	7,697	7,697	7,697
Peak evaporation capacity, lb/hr 5 day operation	10,775	10,775	10,775
Capital Costs[b]			
Demolition/Site Preparation	200,000	200,000	200,000
Dryer Equipment Package	5,500,000	6,200,000	4,780,000
Building - 15,000 sf (including mechanical, plumbing, lighting, civil)	2,000,000	2,000,000	2,000,000
Dried Product Storage	1,500,000	1,500,000	1,500,000
Ancillaries	3,000,000	3,000,000	3,000,000
Base Construction	12,200,000	12,900,000	11,480,000
Plus 30% Construction Scope Contingencies	3,660,000	3,870,000	3,440,000
Construction Cost Estimate	15,860,000	16,770,000	14,920,000
Plus 25% Engr/Admin/Mgt, etc	4,000,000	4,200,000	3,730,000
Total Capital Cost	$19,860,000	$20,970,000	$18,650,000
Total 20 year LCC in 2002 dollars, rounded[c]	$20,770,000	$17,330,000	$15,510,000

a. Dryer criteria based on 27% dewatered cake concentration
b. Capital costs based on costs for similar sized projects in the Western United States and 5 day operation
c. Life Cycle Cost (LCC) assumes 4% interest rate (for energy usage only)

Table 4 – Phasing Options

Phasing Criteria[a]	Fenton	Innodry	Komline-Sanderson
Phase 1 - 40 mgd production, combined belt press and centrifuge dewatering –			
Number of drying units required 24 hr/day, 7 day operation[b]	4	2	2
Number of drying units required 16 hr/day, 5 day operation[c]	4	2	2
Phase 2 - 50 mgd production, 3 centrifuges (2 operating and 1 standby)			
Number of drying units required 24 hr/day, 7 day operation	4	3	3
Number of drying units required 16 hr/day, 5 day operation	5	4	4

a. Assume 53% VSR in digestion
b. One centrifuge would be capable of handling entire average solids production
c. Assumes one belt press and one centrifuge operating

ATTACHMENT - A
PRESENT WORTH ENERGY CALCULATIONS

Riverside WQCP Heat Drying: Energy and 20-Year LCC Cost

12/20/2002 15:27

Item	Fenton RK 72E	Innodryer G4	K-S Model 11W-1200	General Remarks
Dryer manufacturer	Fenton	Schwing	Komline Sanderson	
Sludge dryer capacity, each unit	3 wet tons/hour	10 dry tons/day	10 dry tons/day	Per vendor quote and data
	13.7 cu yrd/batch	1380 pounds per hour		Per vendor quote
Number of sludge dryers needed at 50 MGD (5 dy/wk)	**6**	**4**	**4**	
Dryer inlet sludge feed dryness, minimum	16% solids min	18% solids	18% solids	Per vendor quote
Dryer inlet sludge feed dryness used here	20% solids	20% solids	18% solids	
Dryed or the outlet sludge concentration	90% solids	90% solids	90% solids	Per vendor quote
Dryer exhaust vent flowrate, cfm per dryer	5200	1500		Per unit, exhaust treatment via biotower
Cooling water flowrate, gpm per dryer	420	211		Per unit, per vendor quote
Initial sludge dryer cost each, dollars	$920,000	$1,550,000	$1,195,000	Per unit, per vendor quote
Initial sludge dryer cost total for 50 MGD, dollars	$5,520,000	$6,200,000	$4,780,000	Approximate
Sludge dryer operating hours, per year	4160	4160	4160	for 5 days/week at 16 hrs/day
Dryer heat required, Btu per pound of water	1450	1250	1123	Per vendor quote
Feed sludge water content, pounds per wet ton	1640	1640	1640	For sludge at 18% solids
Wet sludge mass flowrate, tons per day	255	255	255	Basic design parameter
Water evaporation rate, pounds of water per day	418,200	418,200	418,200	Calculated from sludge data
Dryer heat needs, total, million Btu per day (16 hours)	606.4	522.8	469.6	Calculated from water evaporated per above
Dryer heat needs, total, million Btuh	37.9	32.7	29.4	Calculated from vendor data @ 16 hrs/day
Heat energy source used by sludge dryer	natural gas combustion	natural gas combustion	natural gas combustion	Primary heat energy source
Heat from RWQCP cogeneration system, million Btuh	3	3	3	Annual average, approximate
Added heat needed by dryer's burners, million Btuh	34.90	29.67	26.35	Calculated
Sludge dryer fuel use, annual, million Btuh	145,181	123,435	109,626	Calculated
Natural gas cost, per million Btuh	$5.00	$5.00	$5.00	For natural gas at $0.50 per therm
Natural gas total use, annual, million Btuh	145,181	123,435	109,626	Calculated from sludge and vendor data
Natural gas total cost, per year	$725,907	$617,175	$548,130	Calculated
Sludge dryer's operating electrical load, kW	109	80	105	Per vendor. Confirm InnoDryer value
Cooling water pump HP, approximate	10.5	5.3	***10***	Calculated from condenser water flow
Exhaust fan motor HP, approximate	15	5	included above	Estimated only. K-S unit disc to aeration basin
Sludge dryer's total operating electrical load, kW	128.0	87.7	112.5	Calculated
Annual electrical use, kWh per year, each dryer	532,684	364,745	467,821	Calculated
Total electricity use for all sludge dryers per year, kWh	3,196,105	1,458,979	1,871,284	Calculated
Electricity value, per kWhr	$0.10	$0.10	$0.10	Reasonable for a 20 year period
Value of dryer's consumed electricity, per year	$319,611	$145,898	$187,128	Calculated
Energy cost per year each dryer system, total	$1,045,518	$763,073	$735,259	Calculated
20-year LCC multiplier	14.590	14.590	14.590	For 20 years at a 4% annual rate
The 20-year energy cost, LCC in 2002 dollars, rounded	**$15,250,000**	**$11,130,000**	**$10,730,000**	At a 4% LCC annual rate
Total 20-year LCC, 2002 dollars, rounded	$20,770,000	$17,330,000	$15,510,000	Lower number is the better value

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CHAPTER 9 - TECHNICAL MEMORANDUM NO. 6, COMPOSTING OPTIONS

City of Riverside Water Quality Control Plant Composting Options Technical Memorandum 6

Prepared By: Brown and Caldwell
Date: November 15, 2002

Introduction

Background

For centuries, farmers around the world have used composting as a process to convert organic wastes into beneficial soil amendments. The practice of adding biosolids to composting mixtures has been ongoing for more than 30 years. This process is now described in the EPA 40CFR, 503 Part B rule as one of the methods of achieving Class A status for biosolids, provided certain process parameters are achieved. Composting processes that generate temperatures of at least 55^0C are also recognized as acceptable methods for reduction of pathogens and vector attraction. Composting converts biosolids to an end product that is generally more acceptable to the public and may be a means of diversifying biosolids treatment and recycling options.

During a progress review meeting held on 31 October 2002, the City of Riverside (City) informed Brown and Caldwell that approximately 45,000 tons/year of green waste would be available for composting. Any process under consideration would have to provide enclosed facilities with adequate odor control. The City acknowledged that all composting options would present challenges.

Objectives

As stated in the scope of work for this project and as discussed at the project kickoff meeting held in June 2002, the following objectives are addressed in this technical memorandum:

- To define biosolids composting arrangements and their costs.
- To define green waste quantities and characteristics available for composting. Also, to identify biosolids characteristics for composting and process issues.
- To develop alternative composting arrangements, schematics and layouts, providing fully contained and controlled systems for odor control. The site for composting is assumed to be the RWQCP site.
- Provide construction and capital cost estimates for alternative composting systems. The compost product market is assumed to be viable; therefore no specific marketing studies are included.

This memorandum outlines the two most popular composting processes in use in North America, namely: Aerated Static Pile and In-Vessel composting.

Composting Process Overview

Composting may be described as a process by which organic waste materials are physically and chemically transformed by microbial action into a stable and beneficial end product. The primary objectives of most composting systems are as follows:

- Destruction of pathogenic organisms by promoting aerobic activity, which results in temperatures of at least 55^0C during the composting process.
- Stabilization of organic wastes by aerobic decomposition of organic compounds normally present in biosolids.
- Reduction of moisture to around 40-50% in the compost.
- Production of a stable, manageable and marketable end product.

Primary feedstocks to composting systems include dewatered biosolids and other materials, typically bulking agents or amendments. Amendments are added to the biosolids to the extent required to accomplish the following:

- Adjust the carbon to nitrogen ratio (C:N) of the initial mixture.
- To provide structure and porosity for air movement through the mixture.
- To increase surface area available for biological reactions to occur.

The ideal bulking agent (i.e. wood chips) provides solid particles that are around 1-2 inches in diameter. However, green waste can also be used, especially in agitated bed systems. For composting to occur, C:N ratios of initial mixtures need to be maintained between 25:1 and 35:1. Table 1 lists the intrinsic C:N ratios and other properties of certain types green wastes and biosolids.

Table 1. Characteristics of Compost Materials

Material	C:N Ratio	Water Content	Structure
Green Plant Waste	11:1 to 20:1	High	Low
Grass	12:1 to 25:1	High	Low
Garden Waste	20:1 to 60:1	Medium	Good
Wood Chips	100:1 to 150:1	Low	Good
Biosolids	6:1 to 10:1	High	Low

Process Alternatives

Aerated Static Pile Composting

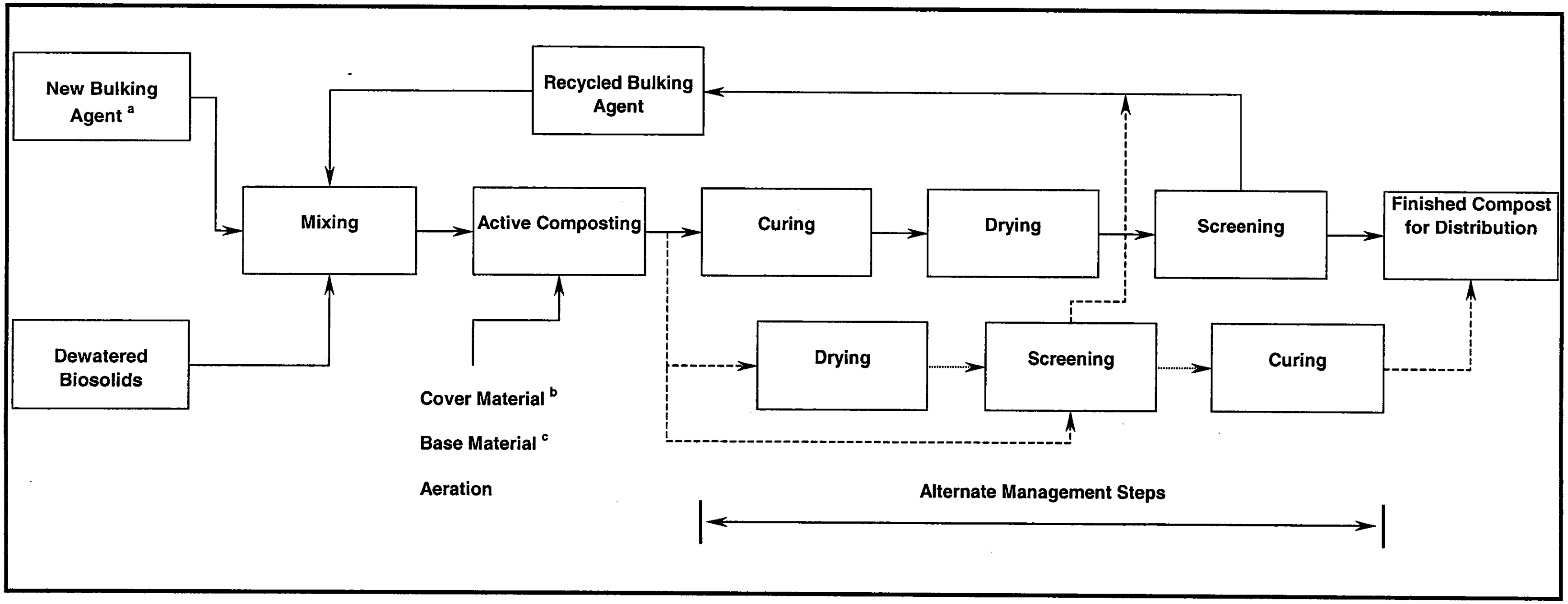
Aerated static pile composting is one of the most common methods of composting practiced in North America due to its relatively low capital cost, economic viability and ability to handle variations in process feedstocks. The primary disadvantage of this method is the relatively large area requirement. The process is started by mixing biosolids with bulking agents and amendments to achieve a composting mixture that has a good structure and a proper C:N ratio. The mixture is then placed over aeration trenches or plenums either in individual piles or extended piles up to 12-ft high. To keep the composting facility under negative pressure, a portion of the fresh air supplied to the building is drawn down through the piles. Blowers connected to the aeration plenums withdraw this air and send it to the foul air treatment system. The piles are normally not subjected to turning or mixing while the composting process is ongoing. However, some turning can be used to supplement aeration and promote biological growth. The EPA 503 rule recommends aerobic processing of biosolids at temperatures of 40^0C or greater for 14 days or more prior to land application of biosolids. Maintaining a temperature of at least 55^0C or more for 3 days during this 14-day period is required for Class A status pathogen reduction. Per industry standards, it is common practice to allow composting to occur for 21 days or more. After approximately 21 days have elapsed, the piles are torn down and the compost is screened for recovery of bulking agent if needed. The compost needs to be cured and partially dried before it is sent to storage or marketed. Figure 6-1 provides a schematic overview of the Aerated Static Pile Composting process.

In-Vessel Composting

Compared with aerated static pile composting, this method requires less floor space and provides better odor control. However, it is more labor intensive, has a higher capital cost and higher operating and maintenance costs. In-vessel systems have also had mechanical problems. This method is similar to the aerated static pile method, with the exception that most of the composting reactions occur in closed vessels or "Bioreactors". Biosolids are mixed with bulking agents in blenders or pug mills and routed to vertical or horizontal plug flow reactors by means of an automated conveyance system. The composting mixture may be agitated and mixed as in agitated bed systems, or allowed to progress unmixed through the reactor. The compost generated after approximately 21 days may be cured and partially dried either in the same reactor vessel or in separate vessels.

Recommended Process

As stated earlier, the City produces 45,000 tons/year or approximately 125 tons/day of green waste, which is available for composting. Biosolids available for composting amount to an average of approximately 20 dry tons/day or 80 wet tons/day. An operating capacity of 40 wet tons/day biosolids is feasible based on the amount of green waste available, and accounting for seasonal variations. This



a. Typically wood chips, wood waste, shredded yard wastes, shredded solid waste, or leaves
b. Typically screened or unscreened compost
c. New or recycled bulking agent

Figure 6-1. Flow Diagram of the Aerated Static Pile Composting Process (Adapted from Biosolids Composting, Water Environment Federation, pg. 121)

represents about 40% of RWQCP biosolids production assuming 35-40 mgd plant flow. Additional bulking agents such as sawdust or wood chips may be needed to produce an optimum feed mixture. Both composting processes discussed in the preceding sections are capable of handling such feed rates, and have their own advantages and disadvantages. Table 2 compares the two processes and applicability to the situation at hand.

Table 2. Comparison of Aerated Static Pile and In-Vessel Systems

Aerated Static Pile	In-Vessel	Comments for RWQCP
Capable of handling large quantities of feed, more than 100 dry ton/day	Few installations have been designed with a capacity of more than 100 dry ton/day	The anticipated feed rates based on the information at hand suggests both types of systems are suitable
Capable of handling a wide variety of bulking agents and incoming biosolids qualities	Bulking agents required to be amenable to flow and conveyance through mechanical systems, except for agitated bed systems	Due to their nature, green wastes may not be suitable for conveyance via mechanical means. This may result in possible operational issues
Is not as labor intensive as in-vessel systems	Requires significant labor for operation and maintenance	Aerated static pile systems are more suitable
May require lesser amount of bulking agent if final product is screened and bulking agent recovered	Bulking agent commonly used is sawdust, which usually becomes part of product	Regardless of the type of process chosen, green waste may need to be supplemented with other bulking agents
This method is not equipment intensive	In-vessel systems require installation of significant amounts of mechanical equipment and are susceptible to operational difficulties	Aerated static pile systems offer a lower capital cost and simpler operation.
Susceptible to odor and vector problems.	Offers better control over odors since feed mixtures are enclosed in a vessel and foul air is withdrawn for treatment	An enclosed facility for aerated static pile composting can limit odor problems. Foul air treatment for in-vessel systems will incur a slightly lower cost due to reduced air volumes
This method of composting is land intensive	Requires less floor space than aerated static pile systems	With full implementation of heat drying of biosolids, the space freed up from air drying can be used for a composting facility

For the situation at hand, the agitated bed system is recommended because of its proven track record and its adaptability to enclosed composting. Such units are designed, produced and installed by vendors such as U.S. Filter and Longwood Manufacturing Corporation.

The use of green waste as an amendment in compost production offers the best economics since sawdust or wood chips would otherwise need to be purchased. However, the use of green waste as an amendment is not without problems, some of which are listed below:

- High moisture content of green waste and lack of solids content may affect porosity, therefore hindering free movement of oxygen throughout the mixture.
- Seasonal variability of C:N ratio of green waste increases the difficulty of predicting the quantity of green waste required for mixing with biosolids.
- Storage of a supply of green waste may lead to odor problems and possibly introduces additional costs related to odor control.
- Green waste may need to be supplemented by other bulking agents in order to make the system viable.

Preliminary Design

Based on information gathered from conversations with technical staff at Longwood Manufacturing Corporation, a preliminary estimate of the floor space requirements for various components of the composting facility have been prepared. The facility sizing and capital costs associated with design and installation are presented in Tables 3 and 4 respectively. A conceptual site plan is shown in Figure 6-2. The site plan shown in Figure 6-2 assumes a portion of the air drying operations have been replaced by heat drying and additional biofilter area has not been provided to handle the entire building ventilation.

Table 3. Preliminary Facility Sizing

Facility Unit	Floor Space sq. ft
Facility Sizing	
Recommended process area	44,550
Recommended curing area	60,000
Recommended biofilter area [1]	20,000
Additional biofilter area [2]	90,000
Total area required	214,550 sq. ft. (4.9 acres)

1. Biofilter area for treatment of process air only, listed separately to aid visualization of costs associated with composting process only.
2. Additional biofilter area for treatment of air ventilated from composting facility.

DATE	PROJECT NUMBER	COMPOSTING FACILITY SITE PLAN
11/15/02	22776.006	

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA

PROJECT LOCATION: RIVERSIDE WATER QUALITY CONTROL PLANT, RIVERSIDE, CALIFORNIA

0 75 150
SCALE IN FEET

FIGURE 6-2

22776_F6-02

Table 4. Preliminary Facility Cost Estimate

Facility Unit	Cost $ Millions
Cost Estimate, Process Equipment	
Primary equipment (i.e. aeration blowers, compost turning system, bays, rails for turning system etc for composting 325 cubic yards/day of feed mixture),	2.19
Equipment for ventilation system for facilities only (Cost of composting aeration blowers and piping is included in cost of composting equipment). 400,000 scfm for 104,550 sq. ft.	1.00
Equipment for odor control and treatment of foul air from composting process only @ $50/sq. ft	1.00
Optional odor control facilities for treatment of foul air from ventilation system @ $50/sq. ft	4.50
Construction Cost Estimates	
Standard butler type buildings with 20-ft side walls and peak roof height of 22-ft. @ $120/sq. ft for process area plus foundation	5.53
Standard butler type buildings with 20-ft side walls and peak roof height of 22-ft. @ $120/sq. ft for curing area	7.20
Subtotal Construction Cost	21.42
Contingencies @ 30% of subtotal	6.43
Total Construction Cost	**27.85**
Administration and engineering @ 25%	6.96
Total Capital Cost (including odor control for entire building and compost ventilation)	**34.81**
Total Capital Cost (including odor control for compost ventilation only)	**27.50**

Estimated capital costs are based on vendor quotes, estimating guidelines and similar facilities in the western United States. The total capital cost calculated above is preliminary in nature and will be affected by several factors. The following assumptions were made for determining the costs:

- Green waste has a specific volume of 2.18 cu. yd./ton.
- Ventilation at the rate of 16 air changes will be provided, with 4 air changes for the composting process. The cost of the ventilation system includes heating only and not air conditioning.

- The process foul air treatment biofilter receives a volume equal to 4 air changes, with the remaining 12 air changes exhausted via stacks. While this arrangement has been provided for visualizing a conceptual system and costs associated with the composting process alone, it will most likely be unacceptable. Therefore, an additional line has been provided listing the cost for treating the remaining volume of foul air.
- The curing facility does not require odor control, only ventilation.

Cost estimates for a larger system were requested from another vendor as well. U.S. Filter estimated an overall cost of $ 17 million for a composting system operating 5 days a week with a biosolids feed rate of 200 wet tons/day @ 25% solids, and a green waste rate of 125 tons/day. The memo provided by U.S. Filter indicates that the cost of the composting equipment is $ 2.1 million. U.S. Filter recommends a process area of approximately 77,000 sq. ft, a curing area of 55,000 sq. ft, a 3-month product storage area of 140,000 sq. ft and a biofilter footprint of about 60,000 sq. ft. Additional space is also recommended by U.S. Filter for maintenance and operating rooms.

Conclusions

Based on the information available in the literature and from conversations with vendor technical staff, the following conclusions may be drawn:

- Composting is a possible solution for recycling both biosolids and green waste generated in the City of Riverside.
- The use of green waste as an amendment in the composting process will probably generate operational problems. Green waste may need to be supplemented by other bulking agents and amendments to achieve the optimum C:N ratio in the feed mixture.
- Agitated bed in-vessel systems are the best option for implementation due to their proven track record and their adaptability to enclosed composting.
- Due to the costs and labor involved in the composting process, this should only be considered to supplement other solids handling alternatives rather than be designed to handle the entire solids production at the RWQCP site. Due to space availability, composting is only considered feasible as the drying beds are phased out. Maximum buffer zone between any composting facility and neighbors would be required.

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CHAPTER 10 - TECHNICAL MEMORANDUM NO. 7, EVALUATION OF RECYCLE STREAM TREATMENT OPTIONS

City of Riverside Water Quality Control Plant Evaluation of Recycle Stream Treatment Options Technical Memorandum 7

Prepared By: Brown and Caldwell
Date:

Introduction

Project Background

The Riverside RWQCP is a tertiary wastewater treatment facility that is currently treating approximately 31 MGD. Raw solids are thickened, anaerobically digested and dewatered by two belt presses. Filtrate from the dewatering operation is combined with waste backwash water from the tertiary filters in an equalization basin prior to being returned to the primary sedimentation tanks. The secondary treatment system has been designed for partial denitrification to meet discharge limits of ammonia nitrogen of x mg/l. The plant reported that current nitrogen limits could become more stringent in the near future. Even though belt press filtrate is diluted by the waste backwash water, the ammonia load added to the existing aeration system can shock load the system which overloads the aeration blowers.

On June 4, 2002, Brown and Caldwell held a kickoff meeting with the City of Riverside Public Works Department Water Quality Control Plant management and operations staff to further define the scope and design criteria for this recycle stream treatment options study. Process objectives for this study would minimize sidestream recycle impacts on the other treatment processes to ensure compliance with discharge permit requirements, particularly for nitrogen loads. No specific treatment technologies were discussed during the meeting. Use of existing abandoned tanks that were a part of Plant 1 including circular clarifiers and a gravity thickener were indicated to be available for this process.

Objectives

As stated in the scope of work for this project and as discussed at the project kickoff meeting, the following objectives are addressed in this technical memorandum.

1. Review recycle stream treatment technology summarize the alternatives evaluated for sidestream treatment, and to provide preliminary sizing criteria for the selected alternative.

2. Develop process schematic, equipment needs maximizing use of the existing facilities at the RWQCP
3. Define the cost of the recycle treatment system.

Existing Available Tanks

Our scope requires identification of the most cost-effective means for reducing the ammonia loading to the main treatment process. Since capital cost is often the most significant component of a sidestream process, the ability to reuse some existing (currently unused) tanks on the RWQCP site would likely render any alternative considered the least costly alternative. However, if detailed investigation of these structures made during the design phase reveal significant deficiencies use of these structures may be rendered impractical and economically less desireable.

On the site are four (4) circular clarifiers 80 ft diameter by 10 ft sidewater depth and one (1) gravity thickener 45 ft diameter by 10 ft sidewater depth. All appear to be structurally sound, but the old mechanisms are rusted. The thickener is approximately 20 ft higher than the circular clarifiers. In considering the use of this tankage, all process evaluations were based on the future 50 mgd build out flow for the plant.

Process Alternatives

Steam Stripping. Steam stripping has been tested at demonstration scale in North America and Europe for ammonia removal from centrates and filtrates from dewatering of digested sludge. Stream stripping involves passing the filtrate through a stripper containing mass transfer media and in contact with steam. A steam plant supplies steam to the operation. In tests at New York City's 26th Ward WWTP, 85 percent removal was obtained. Economic comparisons showed it was less cost-effective than either separate biological treatment or treatment in the main WWTP. Also, considering that this technology would be unlikely to use any of the available facilities on the site, it would not be cost effective for use at the Riverside WWTP.

Activated Sludge Process. Here, a "small" conventional activated sludge plant is built which treats the sidestream flow. It is possible to get about 85 to 90 percent nitrification. The warm wastewater temperature means that a low SRT can be used (5 days was successful in demonstration trials in New York City). The waste is deficient in alkalinity, so caustic addition is required, along with pH control in the aeration tank to ensure the pH is maintained in an optimum range for nitrification (pH greater than 7.2 and less than 8.0). Because of the high ammonia levels in filtrate, very high oxygen demands are expressed in the aeration tank. It is also possible to incorporate denitrification, provided that additional reactor volume is provided for the denitrification zone. Since filtrate is relatively low in BOD, an external source of carbon is needed. Often methanol is used, or volatile acids created from the fermentation of raw sludge.

This is likely one of the lowest cost options available to Riverside, since there appears to be sufficient existing tanks that could be remodeled to accomplish both settling and nitrification.

Short SRT Process. The "Short SRT" Process is actually a conventional activated sludge process for sidestream treatment, but with an additional feature. As shown in Figure, the waste nitrifying sludge from the sidestream process is added to the effluent from the process and returned to the mainstream process. This waste sludge is high in nitrifier population and causes the nitrification in the mainstream process to be accelerated significantly, at least according to the developer's claims.

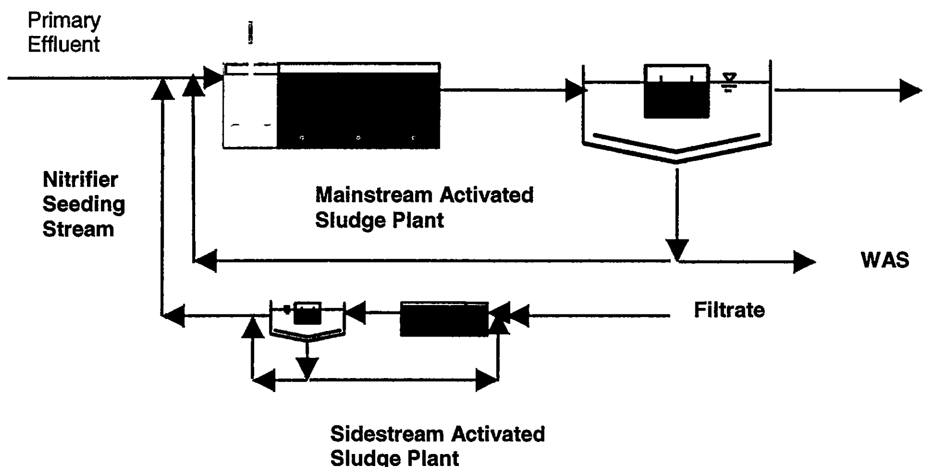


Figure 1. Short SRT Process with Seeding of Nitrifiers to the Mainstream Activated Sludge Plant

Heretofore, this process has not been demonstrated at other than bench scale. We present it here, because it is just a simple modification of the conventional process. Our modeling study for New York City showed that nitrification would be more complete at any given SRT as shown in Figure 2. Essentially, nitrification rates are higher and nitrification can be accomplished in a much smaller volume than would otherwise be the case.

It is a patented process, however, so the user would need to license the technology from Lotopro in order to place it into practice. It may be possible to conduct a trial with Lotopro's permission without cost, but this also would be subject to negotiation. We believe that the process warrants serious consideration by the City of Riverside.

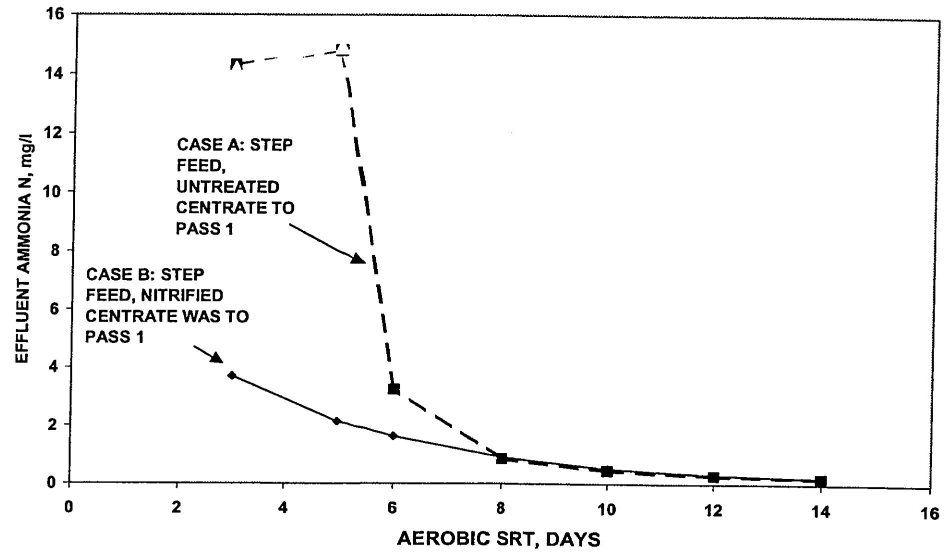


Figure 2. Comparison of Predicted Nitrification Performance for Means of Treating Centrate in New York City. Case A, All Centrate to First Pass. Case B, Short SRT Process with Treated Centrate and Waste Nitrified Sludge to First Pass

SBR Process. The SBR process is a variant of the activated sludge process. The main difference is that both aeration and settling are provided in a single tank (although multiple SBRs are normally provided). Owing to the need for the settling cycle, aeration volumes are similar to the total volumes required for aeration and settling in the conventional activated sludge process. Moreover, an equalization tank is usually provided to store effluent prior to equalize the slug discharges from the process.

The circular configuration of the available tanks make them poorly suited as SBR reactors. And given the available tankage, they would be no less expensive than the conventional process. These factors and their additional control complexity rules them out in favor of a conventional process, in our judgement.

SHARON™ Process. This process was recently introduced into Europe and has been implemented in two large plants there. Basically, it is an activated sludge process without a clarifier. At the elevated temperatures of digested sludge filtrate, simple aeration and caustic addition for pH control is sufficient to nearly nitrify the wastewater. No secondary clarifier is provided, so all of the solids formed pass on into the effluent. Because of this, the effluent must be returned to the mainstream process for further treatment. One stated advantage of the process is that less oxygen is needed, as nitrification stops at the formation of nitrite. This also means that less carbon is needed for denitrification when it is practiced in the mainstream process. The investigators found that there was no seeding benefit to the mainstream process, as all the nitrifiers were in a dispersed growth form and were quickly consumed by the protozoan predators in the activated sludge tank.

The typical design requires 48 hr of aeration. Between the four circular secondary clarifiers, there would be only 33 hours available, which is considered marginal. For this reason, we would consider the process marginal and therefore could not recommend it. The inventors believe the process may work at residence times as low as 24 hours, but have not demonstrated it. However, if a conventional activated sludge sidestream process were built, it would be possible to provide the SHARON™ process as an operating mode to test it out. Again, since this is a patented process, there would have to be negotiations with the patent holders for such a trial.

Trickling Filter. Trickling filters have been used for nitrification of sidestreams, most recently at the Inland Empire Utility Authority, where an existing rock trickling filter was employed. Nitrification on a trickling filter in this application requires a very high degree of solids removal from the sidestream, otherwise solids will coat the biofilm surface and displace the nitrifiers.

Owing to site-to-site variability in wastewater characteristics, employment of trickling filter technology would require a pilot study to determine design parameters for the application. This factor, along with the absence of trickling filters on the site, makes this alternative less attractive compared to other alternatives.

Process Recommendation

Table 1 below is a comparison of the various technologies available. From this table and the above discussion, the process that makes the best usage of the available tankage and is the best proven is the conventional activated sludge process. BC recommends that it be the basis of further evaluations of sidestream treatment and full-scale design if the City of Riverside chooses to provide sidestream treatment. BC would also recommend that the facility be provided the flexibility in design to operate in either the "Short SRT" or SHARON™ process modes. This would give the City the flexibility to optimize its mainstream BNR process (in the case of the Short SRT process) or to minimize the cost of aeration in the sidestream process (in the case of the SHARON™ process).

The sidestream treatment technology area has been evolving rapidly and providing a flexible facility now could pay dividends to the City over the long term.

Table 1. Comparison of Sidestream Treatment Technologies

Technology	Use of existing structures	Relative cost-effectiveness	Comment
Steam stripping	None except for equalization	Poor relative to activated sludge.	High energy requirements.
Activated sludge	Yes	Baseline for comparison to others; lowest cost.	Requires new blower building and caustic feed facility.
Short SRT process	Yes	Similar to activated sludge.	Same as activated sludge, but has mainstream nitrification seeding benefit. Benefit proven only a bench scale.
SBR	Doubtful	Poor relative to activated sludge.	Requires new blower building and caustic feed facility.
SHARON™ process	Yes	Requires construction of more tankage, so more expensive if implemented with full required residence time.	Requires new blower building and caustic feed facility. Has mainstream denitrification benefit, as less carbon is needed for nitrite produced.
Trickling filter	No	Poor relative to activated sludge as existing structures would have to be significantly modified for trickling filter application.	Requires a pilot study for application. Full-scale application requires new caustic feed facility.

Preliminary Development of the Activated Sludge Alternative

Calculations show that all of the available tankage will be necessary to accomplish nitrification in this potential sidestream treatment facility. There is no reactor volume available to accomplish denitrification as well, as the volume in the tanks is just sufficient to prevent excessive diffuser density and to provide the aerobic residence time needed for nitrification alone. Figure 3A shows the flow schematic and Figure 3B shows the possible layout of these facilites. The old gravity thickener is converted to a sedimentation tank to settle out any excess solids carried in the centrate flow. Transmission of excess solids to the sidestream treatment system would raise the mixed liquor level to the point that the aeration capacity would be exceeded. Alternatively, excessive solids loads could require the SRT to be dropped as nitrification could not be sustained.

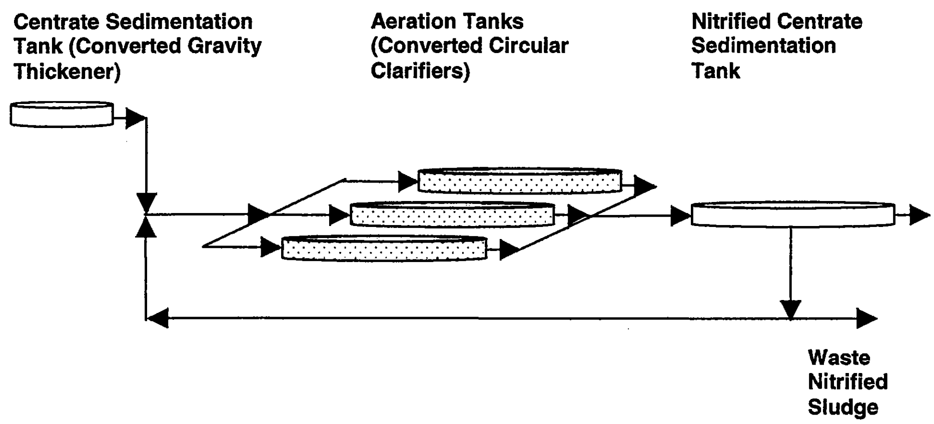
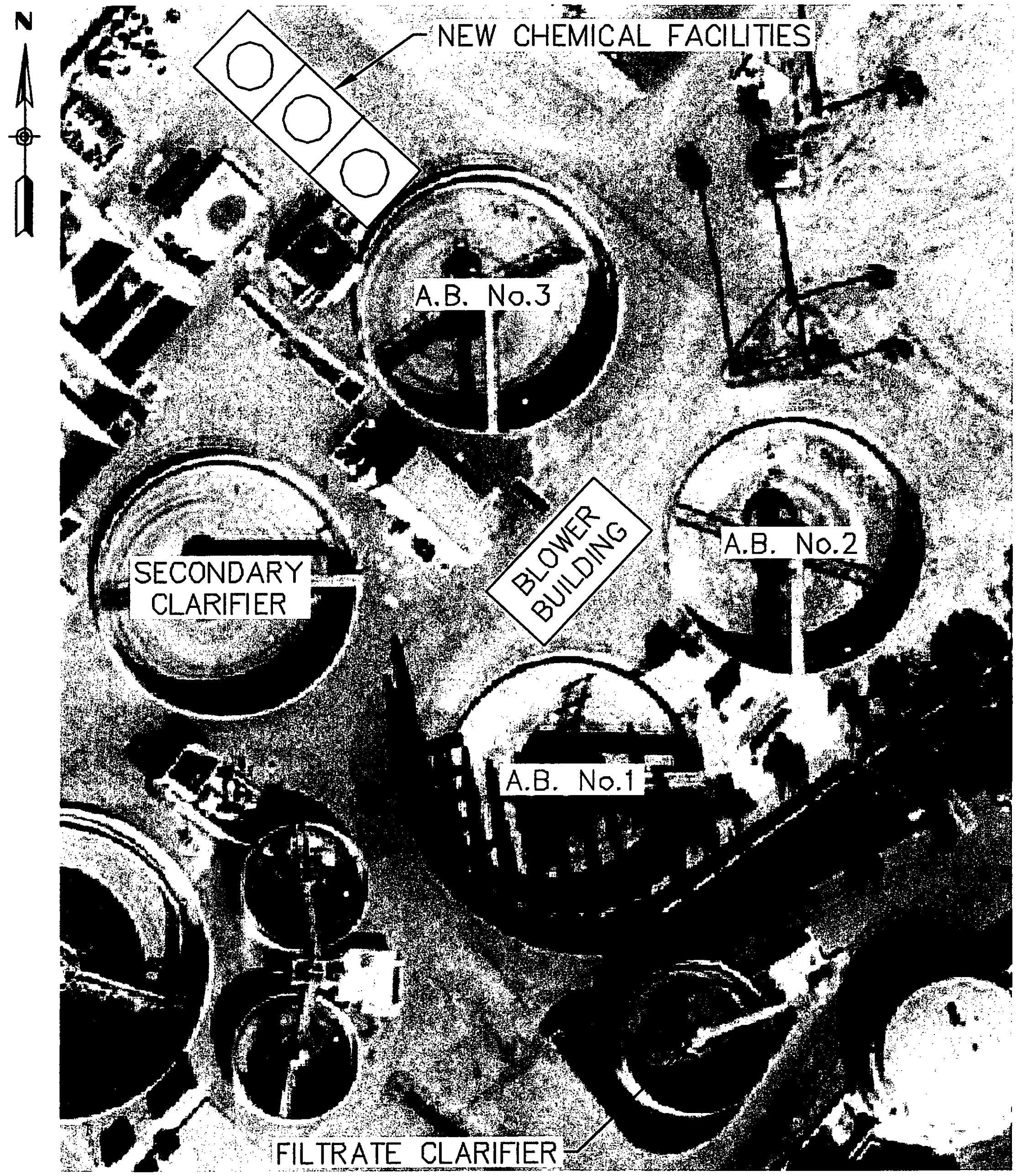


Figure 3A. Activated Sludge Process Flowsheet for Sidestream Nitrification Showing Use of Existing Facilities (New Aeration Blower Building and Caustic Storage and Feed Facilities Not Shown)

The assumption is made that the old secondary clarifiers have sufficient structural integrity to have their floors leveled to support the diffuser installation (this should be checked). BC has been able to do this at Colorado Springs (CO) and at Cobb County (GA), but were not able to do this recently in Hayward.

The modifications called for under this alternative are very similar to ones BC has done before. Figure 4 shows a secondary clarifier converted to aeration duty installed at the Colorado Springs Las Vegas St. Plant. The bottom had to be filled in to create a flat bottom, which was necessary to support the diffuser grid. The shallow sidewater depth (10 ft) required that the aeration efficiency be derated. However, the economics were still highly favorable since this was an existing tank. The water elevation was raised so that the flow would pass through this tank and then on to the existing secondary clarifiers which remained in service (all tanks originally had the same water depth as they were operated in parallel).



DATE	PROJECT NUMBER
09/12/02	22776.007

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA

SIDESTREAM RECYCLE
TREATMENT PLAN

PROJECT LOCATION: RIVERSIDE WATER QUALITY CONTROL PLANT
RIVERSIDE, CALIFORNIA

0 25 50
SCALE IN FEET

FIGURE 3B

22776_FG-01

One of the existing secondary clarifiers would be converted to it original duty with the addition of a new mechanism. The clarifier would also have to be modified to provide an essentially flat bottom and provided with suction sludge removal for rapid sludge removal in order to prevent floating sludge in the final clarifier due to denitrification.

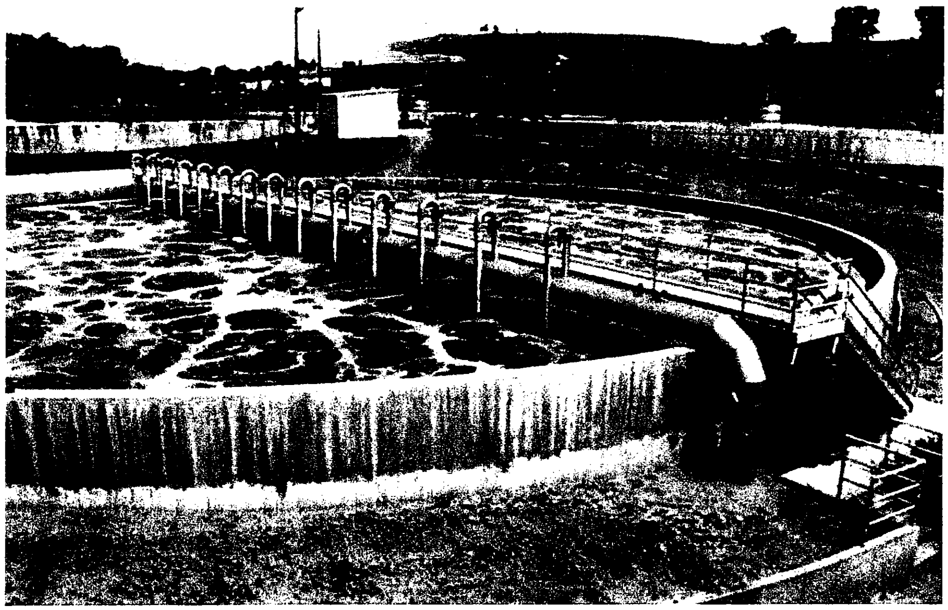


Figure 4. Secondary Clarifier Converted to Aeration Tank at the Las Vegas Street Plant in Colorado Springs

Table 2 provides a preliminary process design for the sidestream treatment facility. Note that both DO control for air modulation and pH control for pacing the caustic addition will be required. Also, to allow testing of the Short SRT process, waste nitrified sludge piping would be provided for both combinations with the main plants waste sludge but also for addition to the mainstream plant's influent. Similarly, to allow testing of the SHARON™ process, provisions for bypass of the secondary clarifier would be provided. This mode would also be used when the secondary clarifier needed to be taken out of service for maintenance.

Return sludge pumping should have variable speed capacity and be design for 100 percent of average flow for their maximum capacity. One pump and one standby are recommended.

Table 2. Preliminary Design Data for Centrate Treatment Facility

Item	Dimension
Average Future Centrate Loadings	
Flow, mgd	1.08
Ammonia nitrogen, mg/L	560
Assumed daily load peaking factor	1.5
Centrate clarifier	
Number	1
Diameter	40
Sidewater depth, ft	10
Average surface overflow rate, gpd/sf	680
Aeration tank volume	
Number	3
Volume, ea., mil gal	0.375
Sidewater depth, ft	10
Aerobic SRT, days	5
MLSS, mg/L	900 to 3,700
DO control, mg/L	2.0
Average air requirement, scfm	12,600
Peak air requirement[a], scfm	19,000
Number of blowers (variable speed)	3
pH control, units	7.2 to 8.0
Average caustic requirement gpd of 50 percent solution	4,400
Minimum storage requirement, based on 14 days, gal	62,000
Secondary clarifier	
Number	1
Diameter	80
Sidewater depth, ft	10
Average surface overflow rate, gpd/sf	210
Return sludge capacity, mgd	1
Number of service RAS pumps	1
Number of standby RAS pumps	1

[a]Peak air requirement approximated as 150 percent of average until peaking factor can be refined through more extensive sampling.

Only limited data were available to support this design, consisting of average monthly ammonia levels and belt filtrate flows for ten months of data. Missing are daily data on a variety of analyses that would be of interest in detailed design. Table 3 presents our recommendations for additional data collection, assuming the City of Riverside desires to proceed with a detailed design for the sidestream treatment facility.

Table 3. Recommended Sampling Schedule to Support Detailed Design

Location	Sample type	Sample analysis	Frequency[a]
Belt press influent	Composite	TS VS Flow	Once per week
Belt press filtrate and washwater	Composite	TS VS Flow Ammonia-N TKN Alkalinity TSS VSS COD sCOD[b] sBOD[b]	Once per week

[a]All samples to be taken on the same day for a six month period
[b]Soluble samples to be filtered through a Whatman GF/C or 934AH filter (not a Millepore filter)

Cost of Sidestream Recycle Treatment

As described above the cost of these facilities assumes that existing structures have sufficient structural integrity to support conversion to aeration basins and a flat bottom circular clarifier. Required chemical facilities for alkalinity addition could also vary significantly due to the lack of sufficient data note in Table 3. Chemical facility cost is based on assumed chemical usage as defined previously. Total capital cost for sidestream recycle treatment facilities including 30% contingencies and 25% for Engineering and Administration are estimated to be $6.4 M reusing the existing structures and $6.9 M to demolish the existing structures and build new facilities. Construction and equipment costs for these facilities are based on similar sized projects constructed in the Western United States. Capital costs for new facilities are also included for reference if existing structures are not suitable for conversion.

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City of Riverside Water Quality Control Plant Evaluation of Options Technical Memorandum 8

Prepared By: Brown and Caldwell
Date: Revised March 2003

Introduction

Project Background

Seven Technical Memoranda (TMs) have been prepared to evaluate options for handling wastewater solids production from the RWQCP for an ultimate plant capacity of 50 MGD. These seven TMs included the following:

- Technical Memorandum 1 – Solids Projections and Thickening Evaluation
- Technical Memorandum 2 – Digestion Options
- Technical Memorandum 3 – Heat Energy Options
- Technical Memorandum 4 – Dewatering and Air Drying Options
- Technical Memorandum 5 – Heat Drying Options
- Technical Memorandum 6 – Composting Options
- Technical Memorandum 7 – Sidestream Treatment Options

Project status and review meetings were held with the City of Riverside Public Works Department Water Quality Control Plant management and staff in late 2002 and early 2003 to review TMs and the draft report that had been submitted. Comments and feedback received from these meetings were summarized in minutes of these meetings. Copies of these meeting minutes are included in Appendix A. Key points from these meetings which effect the evaluation of options included in this Technical Memorandum 8 are as follows:

- To reduce thickened sludge flow rate to the digesters, co-thickening should be considered to increase the thickened solids concentration. Benefits of co-thickening include:
    - Increased gas production from fresher primary sludge feed.
    - Increased capacity of the primary sedimentation tanks as a result of higher allowable overflow rates.
    - More homogenous feed to the digesters.

  The primary benefit would be increased capacity in the digesters.

- To reduce thickening system costs, the existing DAFT 3 located adjacent to the old digesters might be considered as a part of the system. Information received after the meeting indicates that this DAFT has never been operated with sludge and the equipment is likely not workable. Complete replacement of equipment associated with this DAFT is assumed to be required to make this a viable approach.

- Due to odors coming from the air drying beds, the City should plan to phase out the air drying bed operation over time. It is recognized that air drying has provided for a low-cost solids dewatering and drying at the RWQCP and that replacement of this process will be more costly.

- Due to expected increased air drying odors when centrifuge dewatered cake is applied to the beds, centrifuge dewatering is best linked to heat drying equipment.

- Although heat drying is a reliable way to produce Class A biosolids, heat drying should be considered a supplement to air drying (initially) that could be phased in over a period of time to eventually replace air drying.

- Sidestream treatment will be addressed by improvements being made to the aeration basins being developed under a separate engineering contract.

- Project phasing should be done based on process needs rather than the 40 and 50 MGD phases previously defined.

This Technical Memorandum will evaluate the options presented in the other seven technical memoranda based on the feedback received at the most recent review meeting. Previous technical memoranda were not revised to reflect the key issues noted above.

Objectives

As stated in the scope of work for this project and as discussed with City staff at the kickoff meeting held on June 4, 2002 (see Appendix A for copies of meeting minutes), this technical memorandum evaluates options presented in previous technical memoranda and recommend facilities and improvements. Preliminary project costs, project phasing, and an implementation plan have also been developed. The following objectives are addressed:

1. Review and compare options presented in each Technical Memorandum.

2. Recommend facilities including immediate improvements needed to address capacity problems, as well as phasing options for facilities up to 40 MGD.

3. Develop costs for the recommended facilities and improvements.

Evaluation of Existing Solids Processes

Existing Facilities and Solids Production

The RWQCP is a tertiary treatment facility currently treating approximately 31 MGD (average dry weather flow) of influent wastewater flow. The solids handling processes that are a part of this plant include: primary sludge thickening within the primary sedimentation tanks, dissolved air flotation thickening (DAFT) for waste activated sludge (WAS), mesophilic anaerobic digestion, belt press dewatering and air drying. Heat used for anaerobic digestion is supplied from waste heat recovered from the cogeneration facility. The cogeneration facility burns a combination of natural gas, landfill gas, and digester gas. Boilers are provided to supplement cogeneration heat when needed. Air quality limits discussed in TM3 indicate that the cogeneration facility is nearing its NO_X emission limits that would need to be addressed if additional combustion equipment was proposed. Table 1 summarizes each of these unit processes and operating criteria. Table 2 summarizes current solids production quantities and flows based on influent flow stated above. Values shown in this table have been updated to reflect DAFT performance discussed at the draft report review meeting.

Table 1 – Summary of Solids Handling Processes[a]

Process Facility/Operating Criteria	Value
DAF Thickening	
Number of Units[b]	2
Gross Surface Area (sq. ft.), ea	1,018
Effective Surface Area (sq. ft.), ea	943
Total Surface Area (sq. ft.)	1886
Total Surface Area w/one unit out of service (sq. ft.)	943
Solids Loading (lb/sq. ft./day) WAS thickening (current approach) Co-thickening (future) Average Peak daily	 14.5 30.0 45.0
Hydraulic Loading (gpm/sq. ft.)	1.0 –2.0
Allowable Solids Loading, avg w/one unit out, (lb/day) WAS thickening (current approach) Co-thickening (future)	 13,700 28,300
Allowable solids loading, peak day w/all units, (lb/day) WAS thickening (current approach) Co-thickening (future)	 27,300 84,900
Allowable hydraulic loading, avg w/one unit out	943 gpm 1.36MGD

(table continues)

Table 1 (continued)

Process Facility/Operating Criteria	**Value**			
Allowable Hydraulic Loading, peak day w/all units	1886 gpm 2.71 MGD			
Air-to-Solids Ratio	.025-.04			
Capture rate, %	95			
Thickened solids concenteration, % WAS thickening (current approach) Co-thickening (future)	 4.0 5.0 – 6.0			
Anaerobic Digesters				
Digester No.	1	2	3	4
Diameter, ft	90	90	75	88
Sidewater Depth, ft	32	32	32	38.5
Volume, million gal	1.64	1.64	1.06	1.8
Status	In service	In service	Digested Storage	Out of service
Total Current Digester Volume, million gal (excluding No. 3 and 4)	3.28			
Total Current Digester Volume, million gal (excluding No. 3)	5.08			
Allowable Average flow for min. 18 day solids retention time with one unit out, MGD	0.18			
Allowable Peak 2-week flow for min. 15 day solids retention time with all units in service, MGD	0.33			
Volatile Solids Reduction,%[c]	53			
Digester Gas Production, cu ft/lb Volatile Solids removed[c]	13			
Dewatering				
Number of belt filter presses	2			
Belt width, meters	2			
Unit capacity[d]				
Average, gpm	100			
Peak, gpm	150			
Dewatered cake solids concentration, %[d]	12			
Air Drying				
Number of drying beds	29			
Total drying area, acres	8			
Dried product solids concentration, %	90+			

a. Unless otherwise noted, all information stated in this table was obtained from the plant O&M manual.
b. Number of DAFTs includes only DAFTs 1 & 2. Thickened WAS concentration reported by the City.
c. VSR and gas production obtained from plant performance data.
d. Belt press performance based on plant data.

Table 2 – Summary of Current Solids Production at 31 MGD

Parameter	Values				
	TSS		VSS		Flow
	%	Lb/day	% of TSS	Lb/day	MGD
Thickened Primary Sludge					
Average daily	4.1	30,500	82	25,000	0.09
Peak daily	3.4	37,100	82	30,300	0.13
Unthickened WAS					
Average daily	0.53	27,400	79	21,600	0.61
Peak daily	0.54	38,300	80	30,700	0.85
Thickened WAS[a]					
Average daily	4.0	24,700	79	19,500	0.07
Peak 2-week	3.5	34,500	82	28,300	0.12
Combined Thickened Sludge					
Average daily	4.1	55,200	80.5	44,400	0.16
Peak 2-week	3.4	71,600	81.9	58,600	0.25
Digested Biosolids[b]					
Average	2.6	34,700	66	24,000	0.16
Peak 2-week	2.3	48,600	68	33,600	0.25
Dewatered Biosolids[c]					
Average daily feed	2.6	58,400	66	38,500	0.27
Peak 2-week feed	2.3	81,700	68	55,600	0.42
Average cake, ton per day (dry)	12	27.7			
Peak cake, ton per day (dry)	12	38.8			
Average cake, ton per day (wet)	12	231			
Peak cake, ton per day (wet)	12	323			

a. Assumes 90% capture by DAFT and stated float concentration.
b. Assumes 53% VSR in digestion, 7 days per week operation.
c. Assumes 95% capture by dewatering, 5 days per week, 16 hours per day operation.

Evaluation of Existing Capacity

This section evaluates the capacity of existing solids process facilities to identify immediate improvements needed to fill capacity shortfalls. Table 3 summarizes this evaluation of existing capacity and firm capacity needs. At the draft report review meeting, the City reported that DAFT 3 could be used to supplement current capacity. In the early 1990's an existing gravity thickener was converted to a DAFT to create DAFT 3. After the conversion, this DAFT was tested with water and never put into service. The condition of this equipment is poor and total equipment replacement is assumed necessary. Operation of this DAFT would add to the complexity of the system because it is located approximately 500 feet away from the main digestion process and other DAFTs. Use as a redundant DAFT unit would be difficult and would require some modifications to plant piping and operating strategies.

Table 3 – Existing Capacity Needs

Process	Capacity			Comment
	Req'd	Available	Add'tl	
DAF Thickening				
Area (solids criteria) avg w/1 unit out, sq. ft.				Available surface area assumes only DAFTs 1 and 2
WAS thickening	1889	943	946	
Co-thickening[a]	2412	943	1470	
Area (solids criteria) peak daily, sq. ft.				
WAS thickening	2641	1886	755	
Co-thickening	2100	1886	208	
Area (hydraulic criteria) avg w/1 unit out, sq. ft.				
WAS thickening	423	943	None	
Co-thickening[a]	931	943	None	
Area (hydraulic criteria) peak daily, sq. ft.				
WAS thickening	590	1886	None	
Co-thickening	1208	1886	None	
Anaerobic Digestion[b]				
Detention time, avg w/Digester 1 and 2 in service, days				Detention times assume Digester 4 brought back into service.
WAS thickening (4%)	18	20.5	None	
Co-thickening (5%)	18	24.8	None	
Detention time w/Digester 1, 2 and 4 in service, peak 2-week, days				
WAS thickening (4%)	15	20.3	None	
Co-thickening (5%)	15	29.4	None	
Dewatering[c]				
Capacity, avg w/1 unit out, gpm	187	100	87	Additional capacity needed w/one belt press out of service.
Capacity, peak 2-week, all units in service, gpm	292	300	None	

a. Co-thickening DAFT loading includes 25% allowance for bottom sludge recycle. Hydraulic loading assumes primary sludge flow at 0.5 to 1.0% including 100 gpm bottom sludge recycle per DAFT.
b. Peak detention time shown includes volume of Digester 4 which is currently out of service.
c. Dewatering assumes continued 5 days per week, 16 hours per day operation.

Table 4 defines existing capacity in terms of equivalent plant influent flow. Equivalent plant influent flow is derived by dividing allowable loading for each process by current loading and multiplying by current plant influent flow of 31 MGD. By defining existing facilities according to their equivalent influent flow, planning for future expansion of individual processes may be accomplished more easily.

Table 4 – Existing Capacity (equivalent plant influent flow, MGD)

Process	Average w/one unit out	Peak w/all units
Thickening		
WAS thickening	15	22.1
Co-thickening	30.3	34.9
Digestion		
Current 4.1 % feed	35.3	41.9
(co-thickening 5%)[a]	43.0	59.8
(co-thickening 6%)[b]	51.6	71.8
Dewatering		
5 days per week,16 hours per day operation	16.6	31.8
7 days per week, 24 hours per day operation	27.9	53.4

a. Conservative concentration without polymer.
b. This concentration has been achieved at other plants in Southern California and Washington State on a consistent basis.

Review of Table 4 shows that expansion of existing thickening system without including DAFT 3 and dewatering system is needed immediately since the equivalent plant influent flow capacity is at or below existing influent flow. Some relief for dewatering capacity could be achieved by operating this process on a 7 days per week schedule. However, there still would be no redundancy available to allow a unit to be taken out of service for maintenance. Expansion of existing digestion facilities after Digester 4 is brought back on line may be delayed for several years depending on the concentration of the thickened sludge feed. The higher WAS thickened sludge concentrations have been shown to illustrate the effect of anticipated performance improvements. Expected plant influent flows could be handled by the existing digesters by converting the existing DAFT process to co-thicken primary sludge and WAS.

Comparison of Options

Parametric Analysis

When evaluating needed facilities it is important to understand the inter-relationship of individual processes. If a unit process is inadequately sized, it can result in performance that is lower than design. This in turn would affect the performance of downstream processes. To illustrate the effects changes in upstream process performance parameters could have on downstream processes, a parametric or sensitivity analysis was conducted. For example, the digester volume required to achieve an 18-day detention time during average flow was calculated for three different thickened WAS solids concentrations: 4.0%, 4.5% and 5.0% (primary sludge concentration was held constant at 4.1%). A digestion process designed for a thickened WAS sludge concentration of 5.0% would require less volume than a thickened WAS sludge concentration of 4.0% to achieve the required detention times.

The calculations were performed for two different flows, 40 MGD and 50 MGD (avg. dry weather). Parameters such as the TSS and VSS content of the wastewater were assumed to remain unchanged and were simply scaled up from available data. Figures 1 and 2 below illustrate the variation of digester volume required based on different concentrations of the WAS thickened solids concentration (assuming primary sludge concentration held constant at 4.1%). The volatile solids reduction (VSR) in the digester was assumed to be constant at 53%.

The illustrations below show that the required digester volume displays a linear relationship with the concentration of solids in the thickened WAS. A higher solids concentration will result in reduced requirements of digester volume for a given influent flow rate. This statement is true for both average and peak flows as evident in these illustrations.

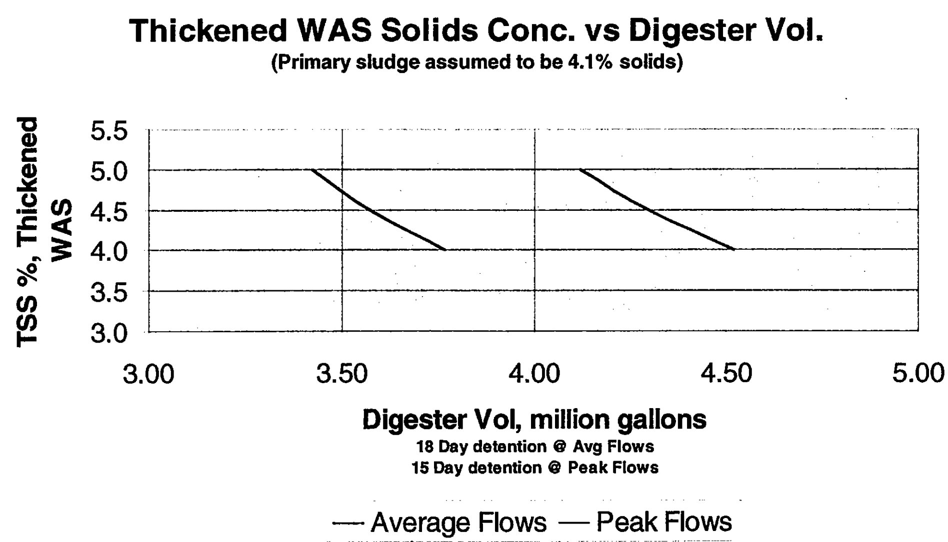


Figure 1. Variation of Thickened WAS Solids concentration with Digester Volume for a plant flow of 40 MGD (VSR of 53% in digester assumed)

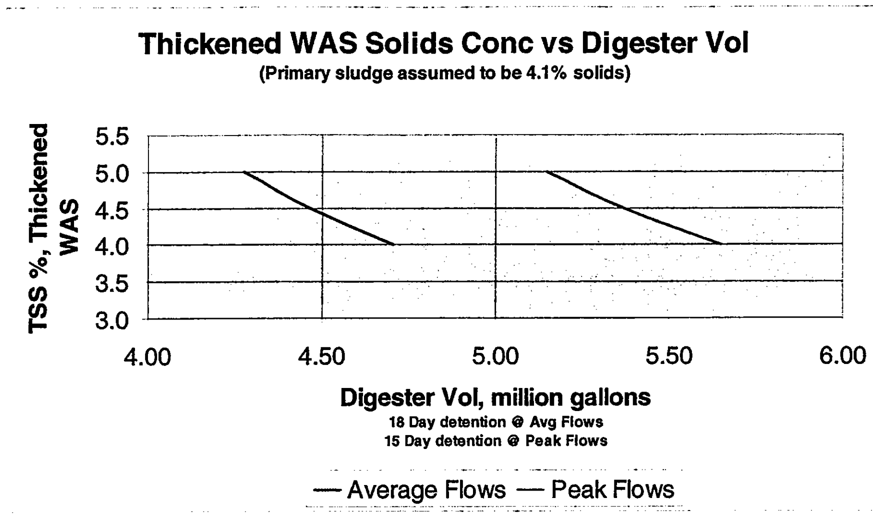


Figure 2. Variation of Thickened WAS Solids concentration with Digester Volume for a plant flow of 50 MGD (VSR of 53% in digester assumed)

Calculations were performed in a similar manner to determine the effect of VSR on cake production. The digester VSR was varied from 53% to 61% and the cake production was estimated. These VSR percentages were selected to correspond to expected performance of mesophilic and TPAD digestion options discussed in TM2. The WAS thickened solids concentration was assumed to remain constant at 5%.

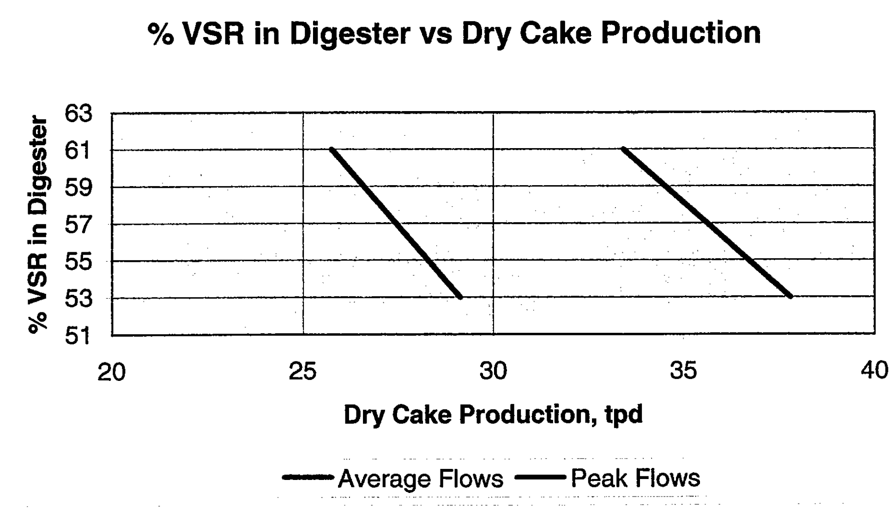


Figure 3. Variation of Dry Cake Production with % VSR in Digester for a plant flow of 40 MGD (Thickened WAS Solids concentration of 5% and Primary Sludge concentration of 4.1% assumed)

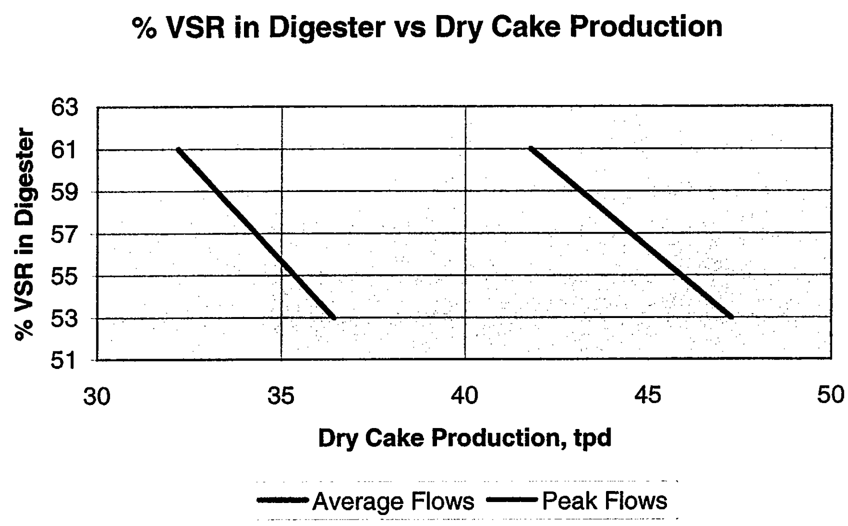


Figure 4. Variation of Dry Cake Production with % VSR in Digester for a plant flow of 50 MGD (Thickened WAS Solids concentration of 5% and Primary Sludge concentration of 4.1% assumed)

These calculations were performed for plant flows of 40 MGD and 50 MGD. Figures 3 and 4 above illustrate these comparisons. Dewatering performance for both at average and peak plant flows will be enhanced by increasing the VSR in the digester. This is also observed in the illustrations above.

Evaluation of Options Summary

As stated in the introduction, seven technical memoranda were prepared. The following section summarizes evaluations and recommendations made in each technical memorandum.

Technical Memorandum 1 – Solids Projections and Thickening Evaluation

Solids projections for 40 and 50 MGD were developed based on most recent data provided by RWQCP staff from the year 2001. This data indicated that the performance of the DAFTs was less than expected. Based on this information, a comparison of current separate thickening of primary and secondary sludge versus co-thickening was provided.

At the draft report review meeting held on February 14, 2003, the plant staff acknowledged that DAFT performance had not improved significantly since repairs and changes had been made to the DAFT equipment and that thickened solids concentration has increased only about 0.5%. As shown in Table 4 the available capacity is insufficient to provide for flows in the near future without having all units on line. As a possible way of reducing capital cost for expansion of the thickening system, the City suggested bringing DAFT 3 back into service. This DAFT, converted from a gravity thickener in the early 1990s, was tested with water and never used to handle sludge. Because it has never been proven to handle sludge and it has been out of service for a prolonged period of time, complete equipment replacement is assumed necessary to make this a viable option. This DAFT is located approximately 500 feet from the other DAFTs and digesters currently in service. Operation of this DAFT as a part of the thickening system would likely require special attention and modification of control strategies. Therefore, bringing DAFT 3 back into service is not considered feasible.

Table 5 shows the additional capacity that would be provided by adding one DAFT for both separate thickening and co-thickening. As shown in Table 5, adding one DAFT under the co-thickening option, the DAFTs would be able to handle more solids because of the higher allowable solids loading rate. As noted in TM2, in addition to the benefit of producing a thicker sludge to feed to the digester, the following benefits could be realized.

- Increased digester detention time.
- More homogenous solids feed to the digesters that could improve digester performance.
- Increased primary sedimentation surface overflow rate.

Since additional DAFT capacity would need to be constructed and conversion to co-thickening would provide the benefits described above, we recommend that a new DAFT be constructed for co-thickening and the other DAFTs be retrofitted to be a part of the co-thickening system. Elements needed in the retrofitted DAFTs would include modifications to the compressor and pressurization system to provide the necessary air-to-solids ratio, modifications to the bottom sludge removal system, and float removal system, covers, and odor control. The new DAFT system would also include a new distribution box, as well as a 20,000 gallon thickened sludge blending tank and digester feed pumps. Provisions could also be made for future thickened bottom sludge degritting and blended sludge preheating.

Table 5 – Capacity Improvements

Criteria	**WAS Thickening**	**Co-thickening**
Number of units currently in service	2	2
Number of units added	1	1
Number of units total	3	3
Diameter[a] (ft) (new unit)	48	48
Net surface area (all units) (sq. ft.)	3356	3356
Net surface area w/1 unit out (sq. ft.)	2413	2413
Allowable solids loading (all units) (lb/day)		
Average	48,700	100,700
Peak	48,700	151,000

(table continues)

Table 5 (continued)

Criteria	WAS Thickening	Co-thickening
Allowable Solids Loading (one unit out) (lb/day)		
Average	35,000	72,400
Peak	35,000	108,600
Equivalent plant influent flow capacity (all units) (MGD)		
Average	55.1	53.9
Peak day	39.4	44.1
Equivalent avgerage plant influent flow capacity (one unit out) (MGD)		
Average	39.6	38.7

a. Diameter includes additional 5 ft for effluent launder and baffle.

Technical Memorandum 2 – Digestion Options

Technical Memorandum 2 evaluated two digestion options including mesophilic digestion and temperature phased thermophilic/mesophilic digestion (TPAD). As noted in the presentation given at the October 31, 2002 review meeting, neither mesophilic nor TPAD would be able to achieve EPA Class A process requirements. However, it was also noted that TPAD produces Class B++ quality biosolids due to the higher VSR and reduced pathogens resulting from the high temperature phase. Only the addition of intermediate batch tanks between the thermophilic phase and the mesophilic phase would be able to ensure a Class A process. The primary benefits of TPAD noted in TM2 were increased volatile solids reduction (VSR) (approximately 61%), which in turn would yield increased digester gas production and reduced solids to dewatering. In addition, having the high temperature phase could also help to achieve Class A biosolids from air drying. TM2 also recommended that a thickened sludge blending tank be installed to simplify digester feed, provide a more homogeneous solids feed, and provide a place to preheat solids before feeding the digesters.

Technical Memorandum 3 evaluated available heat energy from existing cogeneration heat recovery (jacket water and exhaust heat recovery) and determined that for the 50 MGD facility, there would be a 5.4 MMBtu/hr shortfall in heat needed to operate TPAD. This shortfall could be filled either by sludge heat recovery between the temperature phases or by supplemental boilers. Since the present worth costs of the two digestion options were nearly equal, the City indicated their preference would be to continue the current mode of mesophilic anaerobic digestion. The added complexity of these heat recovery systems and operation of digesters at two different temperatures also make the TPAD a more challenging option. As shown in Table 4, current capacity, including Digester 4, would be capable of providing sufficient detention time for an equivalent plant influent flow of 35.4 MGD for WAS thickening, (assuming 4.0% thickened WAS concentration and 4.1% primary sludge concentration). Equivalent plant influent flow of 43 MGD for co-thickening, (assuming 5%

thickened sludge concentration) could be provided by the same number of units. Therefore, construction of a new digester may be delayed until some future date when plant influent flows are approaching these values. TPAD could be considered at a later date also.

Technical Memorandum 3 – Heat Energy Usage Options

Technical Memorandum 3 evaluated heat energy usage for future temperature phased anaerobic digestion as discussed above. Since TPAD is not recommended, there will be more than enough heat available to continue to operate the digesters in the mesophilic mode. At the ultimate 50 MGD plant capacity, there would be a shortfall of heat from the cogeneration heat recovery system of approximately 1.2 MMBtu/hr. This shortfall could be provided either by adding a new boiler or replacing the absorption chiller with an electric chiller. Technical Memorandum 5 – Heat Drying options indicated there would be approximately 2 to 4 MMBtu/hr surplus heat available from exhaust heat recovery if thermophilic digestion was not implemented. Because this heat energy would not be at the temperature needed to heat the hot oil used for drying, it could only be used to warm the oil before being brought up to necessary heat drying temperatures. Other uses of this surplus heat were not evaluated. Further evaluation of heat energy usage options could be done during detailed design.

Technical Memorandum 4 – Dewatering and Air Drying Options

Evaluation of Dewatering Options. Technical Memorandum 4 evaluated two different dewatering options: belt filter presses and centrifuges. This TM also evaluated current dewatering practices and identified current capacity deficiencies that need immediate attention. These deficiencies have been discussed above and summarized in Table 3. Since dewatered cake has been air dried, there has been no pressure to improve cake dryness. A potential problem associated with centrifuge dewatering is the potential for the dewatered cake to produce substantially more odors when placed on air drying beds. At the project status and review meeting held on October 31, 2002, the City indicated continued use of air drying is becoming less likely for two reasons: 1) odor problems associated with open air drying and 2) limited disposal options for Class B biosolids. Therefore, phasing out the air drying facility over time is recommended. A smaller air drying operation continuing to use belt presses achieving 90% solids may be satisfactory to produce Class A biosolids.

Dewatering options developed for the 50 MGD facility indicated that the two existing belt presses would be removed and replaced with 2 new belt presses for a total of 4 belt presses. Alternatively, if the facility were converted to all centrifuges, a total of 3 new high capacity (200 gpm) centrifuges (two duty and one standby) would be needed to provide sufficient capacity with adequate redundancy. Both options assumed no building expansion would be needed. Odor control should be included for either option.

Centrifuges could be placed on pedestals above the space already provided for the belt presses. To provide sufficient head space for removal of centrifuges on elevated platforms, raising the roof and existing bridge crane would be required. Minimal odor control would be needed for centrifuges because foul air is largely contained within the centrifuges. As noted above, the current capacity deficiency could be filled either by using rental belt presses to supplement existing capacity until the permanent dewatering facility expansion is constructed, or by installing one or more centrifuges in the space provided for the two future belt presses. Use of centrifuges to provide needed capacity would only be considered feasible if the product was not air dried.

Table 6 shows recommended dewatering capacity improvements. As noted in this table, the current system, (assuming a 5 days per week/16 hours per day operation) would be capable of only handling solids from an equivalent plant influent flow of 17.2 MGD with one unit out of service or 34.1 MGD with both units in service operating at 150 gpm. As discussed earlier, operating at this peak hydraulic loading rate may be one of the reasons for the lower than expected cake concentration. With the addition of one 200 gpm centrifuge, the dewatering facility would be capable of handling solids from an equivalent influent flow of up to 45.9 MGD with one belt press out of service and 63.1 MGD with all units on line. One centrifuge alone would be capable of handling solids from an equivalent influent flow of approximately 40 MGD at 250 gpm. The capacity of both the existing system and the system with one centrifuge added could be increased by extending the hours of operation from a 5 days per week/16 hr per day schedule to a 7 days per week/24 hours per day schedule or somewhere in between. Centrifuges can run unattended or occasionally attended, so that additional staffing for extended operating hours may not be highly significant. Also, centrifuges operate better and use less energy when they are run continuously rather than starting and stopping. Operating under a 7 days per week schedule would also decrease the size of the heat drying system as well.

Air Drying Options. Technical Memorandum 4 also evaluated the ability of existing air drying beds to achieve Class A biosolids quality. As defined by EPA's Part 503 rule, Alternative 4 – Biosolids treated in many processes and then sampled to meet pathogen density requirements is the only alternative that would apply for certifying Class A Biosolids from air drying. To make it economically workable, the pile of dried biosolids would need to contain at least several months of production. Sampling, monitoring, and record keeping requirements to certify the air dried material as Class A could be done at a reasonable cost. As stated above, Class A biosolids may be achieved from a smaller air drying facility drying belt press cake to 90 to 95% solids concentration provided adequate monitoring is done. The reliability of producing a Class A material could be improved by having at least one high temperature stage of anaerobic digestion in the thermophilic range (52 to 57 degrees C), drying solids to higher than 90% or improving the stability of biosolids sent to air drying. Several methods to reduce odors from air drying were discussed in TM4 including using advanced digestion to reduce organic material, aerobic digestion after anaerobic digestion, and placing a solid wall on the down wind side of the site. Advanced digestion is not needed at this time. Aerobic digestion following anaerobic digestion is a relatively new process that has been tried in Vacaville, California that would require further testing before it could be utilized. Therefore, its value is less certain. Constructing a solid wall fence using plywood would be a relatively inexpensive way to test this method, and a semi-permanent wall could be installed to reduce odor from leaving the site while the City phases out the air drying beds.

Table 6 – Recommended Dewatering Capacity Improvements

Criteria	Phase One		Phase Two
	Belt Press (Existing Conditions)	Belt Presses & Centrifuge	Centrifuge
Number of units			
Belt Presses	2	2	
Centrifuge		1	2
Unit Capacity			
Belt Press, avg (gpm)	100	100	Removed
Belt Press, peak (gpm)	150	150	Removed
Centrifuge, avg (gpm)	NA	200	200
Centrifuge, peak (gpm)	NA	250	250
Capacity (w/one unit out)			
Belt Press, avg (gpm)	100	100	Removed
Belt Press, peak (gpm)	150	150	Removed
Centrifuge, avg (gpm)	NA	200	200
Centrifuge, peak (gpm)	NA	250	250
Total avg	100	300	200
Total peak	150	400	250
Capacity (all units)			
Belt Press, avg (gpm)	200	200	Removed
Belt Press, peak (gpm)	300	300	Removed
Centrifuge, avg (gpm)	NA	200	400
Centrifuge, peak (gpm)	NA	250	500
Total avg	200	400	400
Total peak	300	550	500
Equivalent Avg Influent Flow, 5 days per week – 16 hours per day operation			
With one unit (belt press) out	16.1	48.2	Removed
Average	17.2	45.9	Removed
Peak 2-week @ peak capacity with all units	34.1	63.1	57.4
Peak 2-week @ peak capacity centrifuge only			
Average	NA	32.1	64.2
Peak capacity		40.1	80.2

Technical Memorandum 5 – Heat Drying Options

Technical Memorandum 5 evaluated heat drying options to replace air drying. Three indirect drying systems were evaluated including the Fenton system, the INNOPLANA (InnoDry) system, and the Komline-Sanderson system. These systems were selected for evaluation based on their relatively low equipment cost, operating simplicity, and product quality. Each machine produces an ungraded product that could either be blended with other fertilizers or land applied by itself. At the draft report review meeting held on February 14, 2003, the City suggested a way of reducing the cost of heat drying facilities may be by initially drying only centrifuge cake to approximately 80% dryness then placing this mostly dry product in the drying beds for continued drying. Vendors of the three systems evaluated have been contacted for a cost comparison of drying the product only 80% or 95%. A comparison of energy costs and equipment costs for drying the product beyond 80% does not appear significant. Therefore, to provide a Class A product we recommend the system be designed to achieve the 95% solids. None of the Vendors indicated there would be a significant change in odors from 80 to 95% solids.

Based on drying facilities needed for the ultimate 50 MGD plant capacity, the capital costs and present worth energy costs for these three systems were very close. Therefore, further evaluation of these three vendors would be considered during final design. Because the evaluation considered using smaller units (approximately 10 dry ton per day each), phasing in a heat drying system over several years could be easily done. To reduce initial capital costs a phased construction approach is recommended. Table 7 shows recommended heat drying facilities improvements

Table 7 – Mimimum Heat Drying Facility improvements

Phasing Criteria[a]	Fenton	InnoDry	Komline-Sanderson
Dewatered cake production, combined belt presses and centrifuge dewatering			
Current solids production, dry ton per hour			
Average 7 days per week/24 hours per day	0.79		
Average 5 days per week/16 hours per day	1.66		
Number of units[b]	2	2	1
Model Number	RK72E-Duplex	G4	17W-4000
Unit capacity dry tons/hr	0.75	0.78	1.85
System capacity dry tons/hr	1.50	1.56	1.85
Dryer heat required, Btu/lb water	1450	1250	1123
Electrical load, kW	256	175	298
Approximate building size[c]	100 x 60	125 x 90	100 x 60
Equivalent plant influent flow capacity			
Average 7 days per week/24 hours per day	61.2	61.2	72.5
Average 5 days per week/16 hours per day	28.0[d]	29.1	34.5

a. Assume 53% VSR in digestion.
b. Assumes no redundant units.
c. Building size includes drying equipment, ancillary equipment, and loading.
d. Effective operating hours may be extended because the last 2 hours of the batch can run unattended.

As shown in Table 7 above, each of the vendors would be capable of handling current and future production depending on the operations schedule used. As discussed in TM5, heat dryers work best when they are allowed to operate continuously because of the time required to reheat the units. Providing the units described above would allow the City to have the flexibility to dry all, or a portion, of their daily production and phase out the drying beds.

Technical Memorandum 6 – Composting Options

Technical Memorandum 6 reviewed available composting technologies that could be implemented at the RWQCP site including aerated static pile and in-vessel compositing. These two technologies were selected because they are the most commonly used in North America. Because of the amount of odors produced during the composting operation, both of these systems would require significant odor control. Composting is also a land intensive process. These two factors, plus the capital costs involved (estimated $35 million) to implement a system that could treat 20 dry tons per day, make this option economically and environmentally infeasible. No further consideration of this option is recommended.

Technical Memorandum 7 – Sidestream Recycle Treatment

Technical Memorandum 7 evaluated several technologies for treatment of sidestream recycle flows to reduce process impacts on the existing aeration basins. The process selected in TM7 was conventional activated sludge utilizing four existing sedimentation tanks and one gravity thickener for process tankage. Using this system to treat these sidestream flows would cost on the order of $7 million and would require substantial use of caustic for alkalinity control. At the project status and review meeting on October 31, 2002, the City indicated that improvements and additions to the existing aeration system were being designed to handle these recycle flows and separate recycle stream treatment would be unnecessary.

Recommended Facilities and Improvements

Recommended Facilities, Improvements and Costs

This section summarizes recommended solids handling process facilities for Phase One and Phase Two. Table 8 summarizes recommended facilities and costs for Phase One and Phase Two.

Phase One Facilities

Existing DAFT and Digester 4 Improvements

Existing DAFT Improvements

- Add high level switch, high level alarm, and solenoid valve to prevent the pressurization tank from becoming water logged.
- Automate existing manually operated valve with an air operated throttling valve with flow controller and flow meter.
- Optimize the polymer system to more closely match required polymer dosage.
- Modify bottom sludge removal system to improve efficiency.
- Convert DAFTs 1 and 2 to co-thickening.

Digester 4 Improvements

- To provide sufficient detention time at peak 2-week flow Digester 4 needs to be brought back into service. Bringing this digester back into service would require the following:
    - Automate thickened sludge feed valves.
    - Modify controls for thickened sludge feed and digested sludge withdrawal to a PLC based system coordinated with Digesters 1 and 2.
    - Digester gas piping should be evaluated before placing this unit back into service.
    - A new hot water boiler and possibly a new heat exchanger are required.
    - Automate mixing pump system valves and replace the mixing pumps.

New DAFT (Co-thickening)

- One – 48 ft diameter DAFT.
- Distribution box.
- Control building sized for ultimate needs.
- Pumps, piping, controls for one new DAFT and two converted DAFTs
- One 20,000 gallon thickened sludge blending tank.
- Digester feed pumps, piping, and controls to feed existing digesters and provide space for future thickened sludge preheating.

Addition of these facilities will increase thickened solids concentration to digestion allowing construction of additional digestion capacity to be deferred until the plant influent flow is near 43 MGD. Equivalent plant influent flow capacity for the thickening system will be approximately 39 MGD with one unit out of service.

Dewatering

Dewatering facilities assume 5 days per week, 16 hours per day operation.

- Refurbish existing belt filter presses.
- Supplement existing capacity with rental press or purchase used belt filter press for next several years service.

- One – 200 gpm high solids centrifuge installed in space provided for future belt press 3.
- Dewatering feed pump, polymer feed pump, piping, and controls.
- Dewatered cake conveyance to heat drying.

Combined capacity of centrifuge and belt press dewatering will provide plant influent flow capacity of approximately 45 MGD with one belt press out of service. One centrifuge alone would be capable of handling approximately 40 MGD plant influent average dry weather flow.

Heat Drying

Heat drying facilities assume 5 days per week, 16 hours per day operation. No redundant units are recommended. Critical spare parts will be kept on hand to repair unit that is down. Wet cake from belt presses may be sent to air drying during down time.

- 20 dry ton per day heat drying equipment.
- Two – 20 cubic yard dewatered cake surge bins[a].
- 125 ft x 90 ft building with provisions for expansion.
- Dried product conveyance and truck loading.
- Odor control facilities.
- Dried product storage for two weeks production.

Note:

a. Surge bin provided for variation in dewatered cake production.

Future Phase Two Facilities

Thickening (constructed before 38 MGD is reached)

- One – 48 ft diameter DAFT.
- Pumps, piping, and controls for one new DAFT,

Anaerobic Digestion (constructed before 43 MGD is reached)

- One – 90 ft diameter, 32 ft sidewater depth digester (to match Digesters 1 and 2).
- Pumps, piping, heat exchanger, backup boiler, controls, etc in new control building.

Dewatering (constructed before 40 MGD is reached)

Dewatering facilities assume 5 days per week, 16 hours per day operation.

- Remove existing belt presses.
- Two – 200 gpm high solids centrifuges (one duty and one standby).
- Dewatering feed pumps, polymer feed pumps, piping and controls.
- Dewatered cake conveyance to heat drying.

Heat Drying (constructed before 40 MGD if operating hours not extended)

Heat drying facilities assume 5 days per week, 16 hours per day operation. No redundant units are recommended. Critical spare parts will be kept on hand to repair unit that is down. Extended operating hours may be used to increase system capacity when one unit is out of service to continue to produce Class A material.

- A second 20 dry ton per day of heat drying equipment (see note above for Phase One system if operating hours not revised).
- Expansion of Phase One building to house additional equipment provided for Phase Two.
- Two – 20 cubic yard dewatered cake surge bin(s).
- Dried product conveyance and loading.
- Expansion of odor control facilities for Phase Two.

Table 8 – Recommended Facilities and Costs

Phase One (40 MGD)				
Item/Process	Costs ($1,000)[a]			
	Construction	Contingencies 30%	Admin/ Engr 25%	Total Capital
DAFT and Digester 4 Improvements (allowance)[b]	600	200	200	1,000
DAFT Process	4,200	1,300	1,400	6,900
Dewatering Process	1,500	500	500	2,000
Heat Drying	10,100	3,000	3,300	16,400
Total Cost Phase One	16,400	5,000	5,400	26,800
Phase Two (50 MGD)				
Total Cost Phase Two	32,000			

a. All costs are shown in 2003 dollars.

b. No detailed costs have been developed for DAFT and Digester 4 Improvements. Detailed costs will be developed in final design.

A

APPENDIX A – MEETING MINUTES

Subject: Riverside Biosolids handling improvements - Kickoff meeting June 4, 2002, 10 AM at the Riverside WWTP.

Attendees:

Name	Position	Organization	Phone #
John Claus	Operations Mgr	Riverside	909-351-6183
Jim Slider		Riverside	909-351-6181
Greg Stevens		Riverside	909-351-6097
Gerald Bossard	Operations Supervisor	Riverside	909-351-6139
Ben Urquiza		Riverside	909-826-5913
Rod Cruze		Riverside	909-351-6011
David Kush	Project Coordinator	Riverside	909-351-6188
Ken Fonda	Project Engineer	BC, San Diego	858-571-6749
Perry Schafer	Project Advisor	BC, Sacramento	916-853-5329
Azee Malik	Project Mgr	BC, Irvine	949-260-6117
Bob Finn	Senior PM	BC, Irvine	949-660-1070

Introduction:
Everyone present introduced themselves and described what their role in the project would be. Following introductions, Azee reviewed purpose of the meeting is to go over the SOW and brainstorm ideas. The project schedule would be discussed at the end of the meeting.

Before getting into the main discussion, the City asked if BC is helping other agencies with environmental insurance. Perry said this issue is an emerging issue for Agencies. Some are handling with insurance, but Riverside would be on the cutting edge of this issue. BC could help the City out if requested.

Review of Tasks:
Task 1 - Solids projections and thickening

- Process data can be obtained from Gerald. Base information is available electronically. The City will transmit this latter.
- Primary and secondary mix to the digesters is approx 50/50. Production is fairly stable with little peak variations. There was some discussion on increasing the percentage of primary solids by chemical addition. Other plants are seeing the benefits. This would impact the secondary system and reduce the loading. Increased primary production would also improve digestion. This should be coordinated with the study JCE is doing.
- Chemical addition to enhance settling could be considered. Ferric is being added now strictly for H2S control. Since ferric costs are going up an economic evaluation of the benefits should be done. Chemiron is the vendor for Ferric. Current delivery schedule is about 8 days for their 4k gal tank.

- To be consistent with other studies that have been done the study should set everything for 40 mgd, with an ultimate ultimate size of 50 mgd. The 40 mgd plant flow could be in 10-15 years.
- Work being done by JCE would be impacted more by our work. JCE isn't handling recycle flows.
- Thickening will be limited to assessing data on the existing system. DAF appear to be working okay. Co-thickening plant 1 sludge in the DAF could be an option since DAFs are generally not hydraulically limited. Adding primary solids could also improve thickening performance.
- Gas production is a side issue of thickening. Operations reported better gas quality when the primary sludge is fresher. Since the primaries in plant 1 are shallow, no thickening is done there. Spreading the load between plant 1 and 2.

Task 2 - Digestion options

- Reviewed process objectives as follows:
    1. Gas production is primary driver.
    2. Class A is not as much of a benefit since class A can be achieved by air drying.
    3. Odor reduction going to the drying beds is desirable.
- Perry reviewed various digester options.
    1. Thermophilic is generally more odorous and would probably not be desirable.
    2. Acid/gas can also be very odorous.
    3. Three phase digestion is being done in Inland empire. VS destruction has not increased significantly. Recycle impacts could also be significant and should not be considered as seriously unless there are some very positive impacts on gas and solids destruction.
    4. Performance data for VSS destruction appears to favor temperature phased digestion with thermophilic following.
- The City asked about impacts of metals concentrated when increased solids reduction happens. Impact on metals has not been significant on effluent. Metals get more concentrated in the solids. This should be checked to see how this could impact the liquid effluent. The City said they are not close to meeting the metals limit on their permit yet.
- Temperature phased digestion would be the one we look at most seriously. Thermo/Meso digestion would not meet class A because it would need to be continuous flow. Batch flow would be needed to meet class A.

Task 3 - Heat and energy options

- Jim Shettler will be the lead on this task. Jim will make a site visit latter to review the system.
- Heating and cooling load data would be needed from the City. TM digestion would increase heat loads. Heat drying would also increase the loads.
- Current cogen operation is about 75% for all three engines with allowance for down times.

- Data for cogen heat production and gas quantity and quality can be obtained from Gerry and Marshall.

Task 4 - Dewatering, drying and storage options

- Dewatering options would be looking at centrifuges to replace belt presses. Replacement or upgrading of existing dewatering would be the next phase immediately following this study. The study would include regulatory considerations.
- The study would look at ways of improving existing system, possibly by covering a portion of the beds. Covering would primarily be for wet months. Solar panels were mentioned as a possibility if beds are covered. Economics of solar panels may not pay off with the low electrical rates.
- Optimizing storage area is important for achieving class A. Belt press cake is typically 12-14% primarily for drainage at the beds. Combustion potential gets higher when it is over 50% dry. This gets to be a problem when beds are stacked higher than 4 ft.

Task 5 - Heat drying and product use

Two different technologies were reviewed - direct and indirect drying.

- Fenton dryer is indirect dryer using oil as a heating media. Fenton dryers are batch fed and relatively small capacity. BC has one Fenton drying facility in Oregon being built now and one other currently under design elsewhere.
- Most vendors produce a product that has a consistent size by screening which makes it more valuable.
- Disposal contract RFP is now being bid. Prices are being obtained for both class A and B.
- Fenton dryer would meet class A. Product would not be size graded.

Drying options were discussed

- Air drying could be supplemented by heat drying for wet months.
- One option could be to feed the sludge beds then feed out of the beds to the dryer when the beds are reaching capacity problems.
- Using exhaust heat from cogen could be a way to preheat the oil.

Air permit is now a title 5 facility because of cogen.

Task 6 - Composting/co-composting

- Would need to interface with Ben to get information on green waste quantities.
- Scope focuses on on-site options.
- All options would need to be enclosed.
- Traffic would need to be considered.
- Having a second party operating it would be a consideration.
- Sludge feed stock would need to be dewatered.
- Composting would only be a partial option based on quantity of green waste. Depending on moisture content of the sludge the mixture would be 50/50 or higher to bulk the wet material.
- Market study would be limited to a review of what others have done.

Task 7 - Recycle stream treatment

- Various technologies are available. Most plants just recycle back to the head of the plant. The plant said that adding high ammonia load to the existing aeration tanks places too much of a load on the air system. Operations would like to keep it separate to reduce impacts on the rest of the plant.
- Impacts of digestion, dewatering and drying options would be factored in. This would essentially be a separate activated sludge plant.
- Reuse of some existing facilites (old clarifier, etc). If existing tanks are used they may not meet requirements structurally.
- Current nitrogen discharge requirements are 13 and could go as low as 2 with 8 being more likely. Comparison of rehab existing tanks versus new should be considered.
- Fail-over should be to go back to plant 1 with flows distributed. Blending with the primaries would equalize the load and provide some benefit to odor control.

Task 8 and 9 - compare options, recommend and report.

Report would be structured as a collection of TMs with an introduction which summarizing the inter relationship of the TMs.

Schedule

- Final report would be okay if done by November - December.
- BC will prepare a draft schedule for TMs for review next week.
- Future meetings will be done on an as needed basis.

City of Riverside
RWQCP Solids Handling Improvements
Progress Review Meeting
October 31, 2002

MEETING MINUTES

Attendees:
Stephen Schultz, Wastewater Systems Manager
John Claus, Wastewater Operations Manager
Gerald Bossard, Wastewater Operations Supervisor
David Kush, Wastewater Projects Coordinator
Ben Urquiza, Wastewater Engineering
Bob Finn, Brown and Caldwell
Azee Malik, Brown and Caldwell
Perry Schafer, Brown and Caldwell
Ken Fonda, Brown and Caldwell

Meeting summary

Introductions:

Since Stephen Schultz was new to the project team, the Brown and Caldwell members of the team introduced themselves and explained their roles in the project.

Agenda and project status:

Azee briefly reviewed the agenda for the meeting and the project status. To date, five of the eight technical memos have been submitted. The purpose of the meeting was to review the high points of these TMs and get City feed back. The following changes to the original schedule were presented and accepted by the City:

TM 5 Heat Drying Options – November 8, 2002
TM 6 Composting Options – November 15, 2002
TM 8 Evaluate Options – November 22, 2002
Draft Report – December 20, 2002
City Review comments on Draft Report – January 6, 2003
Final Report – January 24, 2003

Azee explained that the TMs were written to take a broad brush approach on the issues with the focus being on developing direction for improvements needed for an ultimate plant capacity of 50MGD. Although the plant may not reach this capacity for some time, cost estimates were developed for this capacity for purposes of comparison.

The City indicated that TM 8 should focus on the near term projects needed in the next 8 to 10 years with the Final Report focusing on direction needed for the next 10 to 20 years.

TM 1 – Solids Projections and Thickening Options

Ken reviewed the solids projections and noted observations made on the solids process operations:

- Thickened sludge concentration appeared to be below expected performance
- This performance would have downstream performance impacts on digestion and dewatering.

The City noted that some maintenance had been deferred on the DAFs and Belt Presses that could also account for low performance. Recent modifications to the DAFs – bottom sludge rakes, dissolution air compressor, etc have helped improve performance and thickened sludge concentration is now between 4.5 and 5%

Thickening options comparison based on observations from plant performance were developed for separate thickening and co-thickening of WAS and Primary Sludge was developed. The major advantage noted for cothickening was that consistent 5-6% sludge concentration could be achieved. The capital cost for cothickening was significantly higher, but the present worth value based on separate thickened solids at 4% versus cothickened solids at 5.5 to 6% were $10 million less for cothickening. This difference will likely be reduced when the better WAS thickening performance is factored in.

The final report should look at possible modifications to the existing DAFs that were built in 1989 to improve their performance as well as any additional DAFs that may be needed. Present worth cost comparison should factor in the higher performance of the WAS thickening system.

TM 2 – Digester Options

Perry gave an overview of the TM beginning by stating that achieving a Class A product was not a major factor in this evaluation. Class A options were provided mainly for information purposes. Stephen was concerned that a digested dewatered product was a problem for users whether it was Class B or Class A. A sheet comparing performance of various digester options was included in the handouts. Perry pointed out that the new sludge blending tank ahead of digestion was suggested to ensure more homogenous feed to all the digesters. This would also serve as a place to recover heat for the thermophilic digestion phase of temperature phased digestion (TPAD). The benefits of TPAD were briefly discussed:

- Increased gas production
- Increased volatile solids destruction yielding less solids to dispose of
- Increased chance of achieving Class A with air drying

Ongoing debate by regulators on where samples are collected for Class A certification may also be an issue if the sample point is at the application site.

TM 3 – Heat and Energy Options

Ken reviewed information presented in the TM noting that air permitting limitations could effect any heat production option that required new combustion. The Heat Energy usage evaluation focused on heat needed for the TPAD digestion option. The calculated heat energy shortfall was 5.4 MMBtu. The two heat production options presented were sludge heat recover and new boilers. Sludge heat recover was seen as being less costly to operate and more energy efficient. During summer months some waste heat would need to be rejected either by using effluent cooling or wasting it to the atmosphere through radiators.

The City asked if dumping hot water into the effluent would have an impact on their disharge permit limits. This had not been evaluated as a part of the TM, but would be addressed in the final report.

TM 4 – Dewatering and Air Drying Options
Perry discussed dewatering performance and noted that the cake solids concentration appeared to be low. This could be a result of low polymer usage and high feed rate. The City noted that the belt press performance improves significantly shortly after they are maintained. The City also acknowledged that the belt presses were being operated at the higher end of their hydraulic loading range. Currently there is no redundancy available in the system. The City acknowledged that this could be a major problem that could cause liquid sludge being sent to the drying beds. Increased capacity and redundancy are an important consideration that would be included in the final report. The City indicated that reduced operating hours limited to two shifts would be desireable and that cake storage for weekends and holidays may be required. Perry pointed out that higher odor risks associated with centrifuge dewatering would make centrifuges undesirable if the cake was still being air dried. The City stated that air drying may be phased out very quickly due to neighbor complaints and that this was a significant "risk" to the current biosolids system. Therefore, the dewatering options should consider their impact on heat drying. The City indicated a preference for centrifuge dewatering because is could be operated with less attention and achieve greater solids content. Centrifuges could be placed in the space provided for the future belt presses. Centrifuge design should consider noise levels produced.

Perry reviewed air drying options and Class A reliability improvements. Covered storage was seen as being too expensive and temporary tarps are a problem during windy conditions. Odor control improvements suggested included building a solid fence to force achieve increased vertical atmosphere mixing on the downwind side of the drying beds. This would improve odor dispersion and reduce odor levels.

TM 7 – Recycle Stream Treatment Options
Azee reviewed available recycle stream treatment technologies and noted that the recommended technology was the activated sludge process. The cost of modifying existing tanks for sidestream treatment was estimated to be $6.4 million and would require new chemical storage and blowers. The City said that aeration improvements that were being designed by others has made provisions for sidestream flows which would be less costly.

Upcoming technical memos
Upcoming technical memos include Heat Drying Options and Composting Options. Key considerations for heat drying would include:

- Drying capacity to replace air drying beds entirely.
- Critical failure equipment parts and redundancy requirements
- Heat dried product does not need to have uniform pellet or granule size
- Maximum use of available surplus heat

Composting was briefly discussed also. The City noted that existing green was handling site has been moved due to odor problems. Green waste quantities are estimated to be approximately 42,000 to 45,000 tons per year. Any composting operation would need to be totally enclosed. Off site composting with other agencies would be more likely. However, all composting options sounded challenging.

Other issues
Other issues discussed included:

- Final report should be in three ring binders with nice cover and spine lable
- Final report should briefly summarize regional biosolids management.
- Biosolids privatization was not considered a serious option because the City would loose control of its system with attendant cost impacts..

City of Riverside
RWQCP Solids Handling Improvements
Progress Review Meeting
October 31, 2002

MEETING MINUTES

Attendees:
Stephen Schultz, Wastewater Systems Manager
John Claus, Wastewater Operations Manager
Gerald Bossard, Wastewater Operations Supervisor
Rodney Cruze, Compliance and Monitoring Manager
Ben Urquiza, Wastewater Engineering
Bob Finn, Brown and Caldwell
Azee Malik, Brown and Caldwell
Perry Schafer, Brown and Caldwell
Ken Fonda, Brown and Caldwell

Meeting summary:
Introduction: Introductions were skipped because everyone knew each other.

Review project status: Azee reviewed the status of the project noting that since the last meeting TM 5 – Heat Drying Options, TM 6 – Composting Options, TM 8 – Evaluation of Options and the Draft Report have been submitted. Following this meeting BC intends on preparing the Final Report by revising TM 8 to incorporate comments received during the meeting and Chapters 1 – 3 of the Draft Report. An executive summary, approximately 3 pages in length will be included in the Final report.

Draft Report Review Presentation:
Introduction
Azee highlighted solids issues affecting the City of Riverside including:
- Limitation in Riverside county for Class B biosolids use.
- Long term odor issues from air drying beds
- Dewatering and digestion capacity to meet current needs
- Cogeneration system needs for additional digester gas to replace landfill gas as quantity decreases.
- Rising cost for disposal in Southern California
- Current program using air drying has significant risks.

The City commented that:
- The Class B ban in Riverside is limiting disposal options and that Class A disposal in Riverside County would be categorized by product odor. They felt that if they heat dried to less than 90% they might be able to use it as daily landfill cover mixed with dirt.
- Odor from drying beds needs to be reduced or eliminated. The solid fence idea may buy them some time, but they felt the fence would have to be taller than their existing fence.

- Although centrifuge cake may be more odorous, they suggested possibly drying the cake to 75% then placing it in the beds for further drying. The thought was that this would reduce odors from centrifuge cake and possibly reduce the capacity of the heat drying system.

Project Objectives:
Azee briefly review the original objects for the project and noted where these objectives had been addressed in the report.

Review of TM 8:
Since everyone was familiar with the TMs submitted up to TM 5, Ken briefly reviewed the TMs previously submitting as well as the new TMs noting the following:

<u>Existing and future conditions</u>

- Current Capacity deficiencies exist in the thickening, digestion and dewatering process.
    - Current DAF system has no redundancy
    - Digester 4 needs to be brought back into service do handle peak needs
    - An additional belt press is needed to provide redundancy for dewatering system and reduce loading on existing belt presses.
- DAF and Belt press dewatering performance were lower than expected. Operations noted that the City is saving money by using drying beds after dewatering, the wetter cake is not a significant problem, but should be noted for future improvements. Placing wetter cake on the drying beds prolongs the time for drying and increases the opportunity for odors.
- Because of the lower thickened sludge concentration, the digester system has marginal capacity to meet 503 regulations at peak flow conditions. The City said they were operating at higher than 35 degrees C and that the combined time and temperature met the 503 requirements. Perry questioned this and said he would need to verify this with EPA.
- Planning for future phases was based on 40 and 50 MGD capacities as noted in the kickoff meeting. Future solids flows were noted for these capacities.

<u>Future Thickening Options</u>

- At the previous meeting the City indicated that the DAF system was capable of achieving better performance and that cothickening to achieve higher digester feed concentration was not important. Using a higher thickened WAS concentration made separate thickening have a lower life cycle cost.
- The City commented that if a higher concentration could be achieved by cothickening to delay digester construction that cothickening could be more viable. The City asked that cothickening be reconsidered for this reason.

Digestion Options

- Digestion options were briefly reviewed. The decision made at the last meeting was to continue mesophilic digestion because the life cycle costs for TPAD were not significantly different.

Heat and Energy Options

- Heat energy needs were reviewed and noted that at 50 MGD there would be a shortfall of approximately 1.2 MMBtu/hr using only heat from cogeneration. Additional heat could be provided by either using new boilers or replacing the absorption chiller with an electric chiller.

Review of Dewatering and Drying Practices

- Current belt press dewatering process is operating below expected performance most likely due to hydraulic overloading and low polymer usage. As noted earlier, because dewatering is followed by air drying there isn't a great deal of importance in dewatering to a higher concentration.
- The system has no redundancy and the building has no odor control system.
- The City indicated they were in the process of getting a rental centrifuge to supplement existing dewatering capacity. Perry commented that centrifuge cake may be more odorous due to the higher G forces effecting the cell walls possibly causing continued digestion in the drying beds.
- BC recommended adding centrifuges for future phase as long as there was heat drying for centrifuge cake. Odor control from centrifuges would be less than belt presses because the odors are contained in the centrifuge.
- Adding centrifuges in the existing building may require raising the roof and the bridge crane. This explained why the initial phase dewatering appeared high.
- As a possible way or reducing odors from air drying a solid wall fence could be built on the down wind side. The City questioned how effective this would be because the drying beds were down lower. Perry suggested building a temporary wall with plywood to see how well that would work.

Heat Drying Options

- Drying technologies available are direct and indirect drying. Direct dryers are more difficult to permit because of the larger exhaust quantities.
- Indirect drying vendors evaluated included
    - Fenton – batch drying system that had been to the site for a demo in December. Largest size unit is 10 dtpd. Multiple units would be needed. Fenton is American made.
    - INNOPLANA – continuous drying system that combines an initial indirect dryer to remove 50% of the water then a direct dryer that uses recovered heat to bring the cake to over 90% dryness. Larger units are available to reduce space required. The INNOPLANA dryer is manufactured in Switzerland
    - Komeline-Sanderson – continuous drying system with highest heat transfer efficiency. Larger units are also available. This dryer is manufactured in Germany.

- Heat drying considerations include: product quality, air emissions and product auto heating.
- The City commented that product loading and storage would need to be considered in design with storage being kept to a minimum. A product that is dusty may be a problem for land application. This could be mitigated by coating the product with oil.
- The City liked the concept and favored a phased approach possibly not capable of drying all the cake. They would also like to see if drying to less than 90% would save them anything.

Composting Options

Composting options were briefly reviewed but considered unfeasible because of costs, odors and bulking material limitations. No further consideration of composting would be recommended.

Sidestream Recycle Treatment Options

The recommended treatment option that was presented at the last meeting was briefly reviewed. At that meeting the City had stated that the liquid treatment system would be designed to handle the recycle stream.

Recommended Project, Cost and Schedule

Perry briefly reviewed the recommended projects including immediate improvements and facilities needed for 40 MGD. Immediate improvements recommended were:

DAF thickening

- Pressurization pump throttling valve automation
- Pressurization tank level switches and high level alarm
- Bottom sludge removal
- Polymer system sizing to match required usage

Digestion

- Bring digester 4 back on line including:
    - Automated sludge feed valves
    - Coordination of feed and withdrawal with digesters 1 and 2
    - Verify gas piping capacity
    - Verify adequacy of mixing system

Dewatering

- Refurbish existing belt filter presses
- Supplement existing capacity with rental unit or purchase used unit. The City indicated they were looking into a rental centrifuge

Recommendations for 40 MGD included:

- One new DAF the same size as the others.
- One new digester in addition to bringing digester 4 back into service would be needed.
- One 200 gpm centrifuge with conveyance to heat drying
- 40 dtpd heat drying facility based on 5 day/16 hr/day operation with one redundant unit.

Estimated cost for the recommended 40 MGD facilities is $35 million

Discussion followed on ways to bring project costs down. Some suggestions were:

- Delay construction of new DAF by taking DAF 3 out of mothballs. The condition of DAF 3 would need to be reviewed during design.
- Delay construction of digesters could be done by:
  - Bringing digester 4 back in service. The City acknowledged that a thorough evaluation of work needed would be required
  - Increasing thickened solids feed concentration to digesters would reduce flow and increase detention time. The City acknowledged that current WAS thickening was not producing the 5% float they stated last time and that cothickening could be beneficial if it could delay construction of a digester. Cothickening may also have benefits on increased gas quantity and capacity improvements for primary sedimentation.
- Reduce the size of heat drying by:
  - Drying centrifuge cake to 80% and put on drying beds for the other 10% dryness.
  - Only dry centrifuge cake and put belt press cake on the drying beds

Other issues:

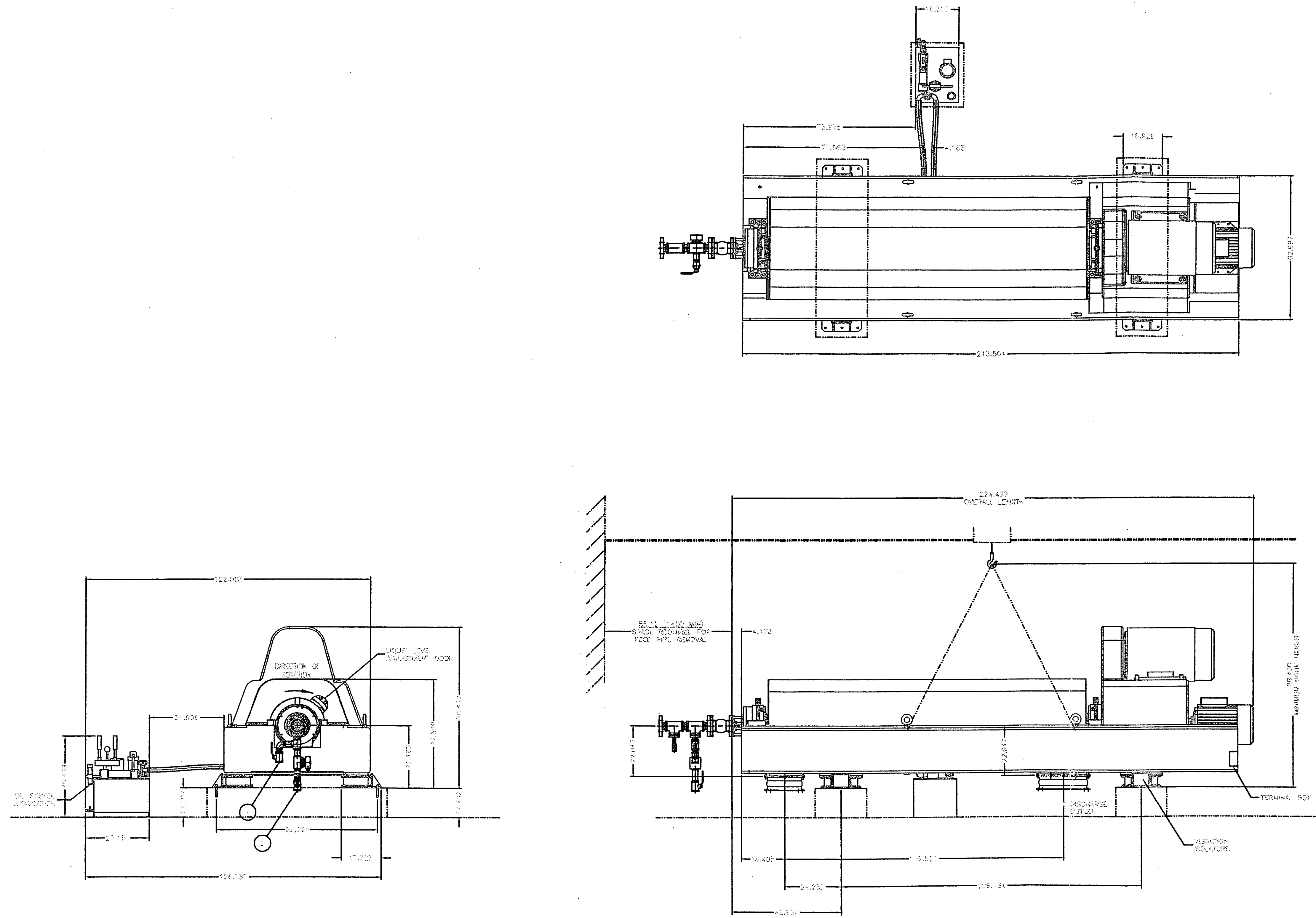
1. CIP budget for WW improvements including both liquid and solids is about 50 million. They are targeting 15 to 20 million for solids handling. If cothickening can delay or reduce primary sedimentation improvements, some of the liquid treatment budget could be moved for solids handling.
2. The City will be pilot testing "Sonix" to see if it improves dewatering and increases digester gas. Perry said there is a competing system called the "Dirk" system that may also be beneficial. Making provisions for this pilot test or future use of Sonix is outside the scope of this project.
3. Recommended project should focus on a system that is within the CIP budget and adds flexibility to drying and disposal. Capacity limitations for thickening, digestion and dewatering need to be handled. The recommended system needs to reduce or eliminate odors.
4. Developing phasing plans for less than 40 and 50 MGD would be a change in the scope as it was discussed at the kickoff meeting.

Actions planned:

1. Re-evaluate thickening and digestion based on mesophilic digestion following cothickening using rehabbed digester 4 and DAF 3.
2. Get info from dryer vendors on ability to dry less than 90% and what are the product odors associated.
3. Get info from belt press vendors to find out if there are BPs that can be automated more.
4. Revise and resubmit the final report by the end of the month.

B

APPENDIX B – MANUFACTURER'S EQUIPMENT LAYOUTS



NOTES:

1. ALL PIPING TO AND FROM MACHINE TO BE COMPLETED WITH FLEXIBLE CONNECTIONS.
2. SEE FOUNDATION DRAWING DMF1355 FOR DESIGN LOADS AND CONNECTION DETAILS

REV	ECR	REVISION	BY	APVD	DATE

ESTIMATED WEIGHT IN LBS:

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES

FABRICATION TOLERANCES .XX±.040 ANG±1° HOLE±.030

MACHINING TOLERANCES .XXX±.005 ANG±.5° HOLE±.030

MILL FINISH ALL OVER

DRAWN BY: DATE

CHECKED BY: DATE

APPROVED BY: DATE

THIRD ANGLE PROJECTION

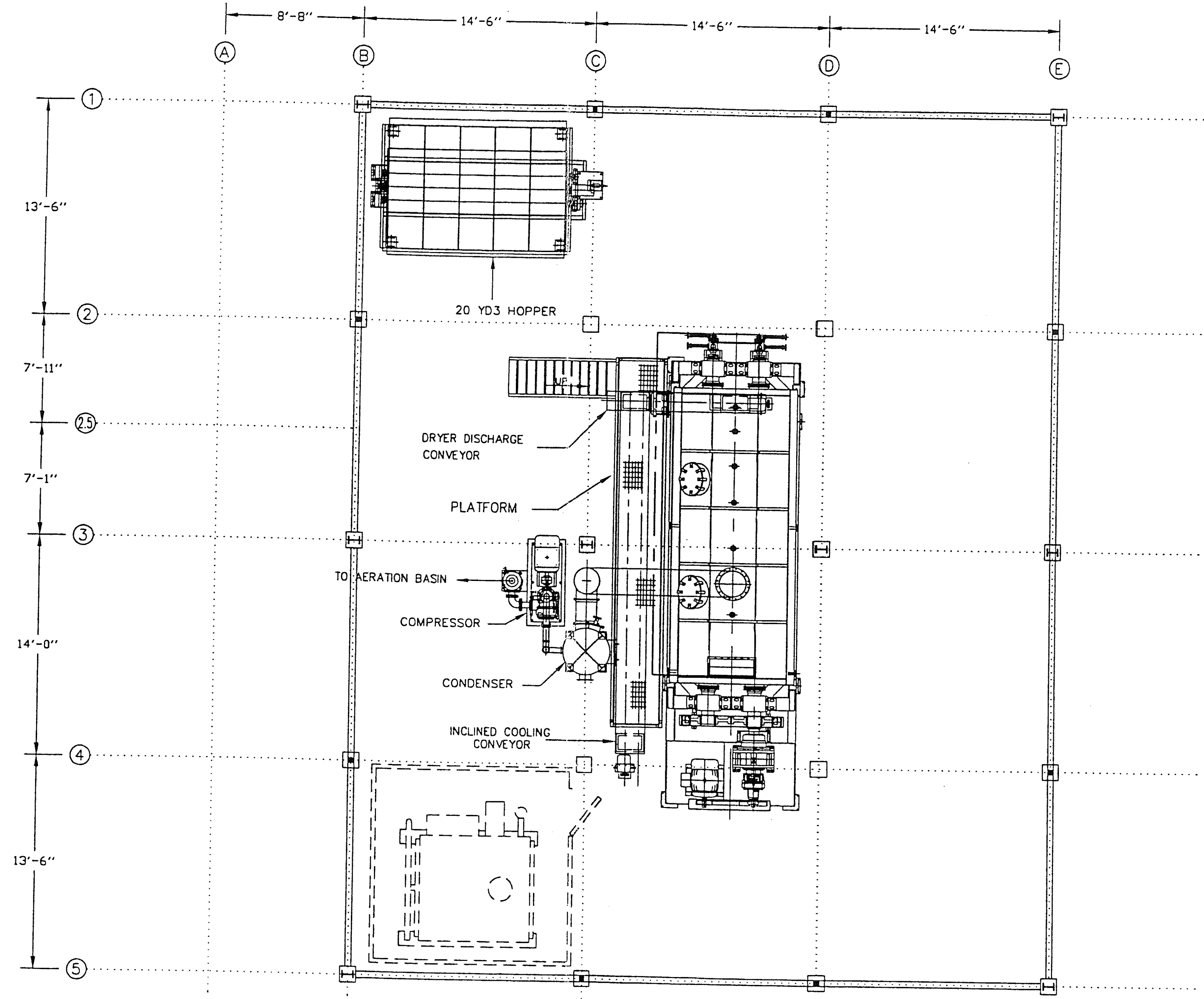
ANDRITZ

ANDRITZ-RUTHNER, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
PHONE: (817) 465-5611

TITLE

SIZE | DRAWING NUMBER | REV

SCALE | FILE | SHEET OF



REV	DRWN	CHKD	DATE	APPR

TITLE

GENERAL ARRANGEMENT
SLUDGE DRYING SYSTEM
PLAN VIEW

TPG 2369
BROWN & CALDWELL
RIVERSIDE, CA

DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY
CPS	CPS	-	-

DATE 10-OCT-02

SCALE ¼"=1'

KOMLINE-SANDERSON
ENGINEERING CORPORATION
PEAPACK, NJ 07977 USA

REFERENCE:

DRAWING NO. TPG2369-101D

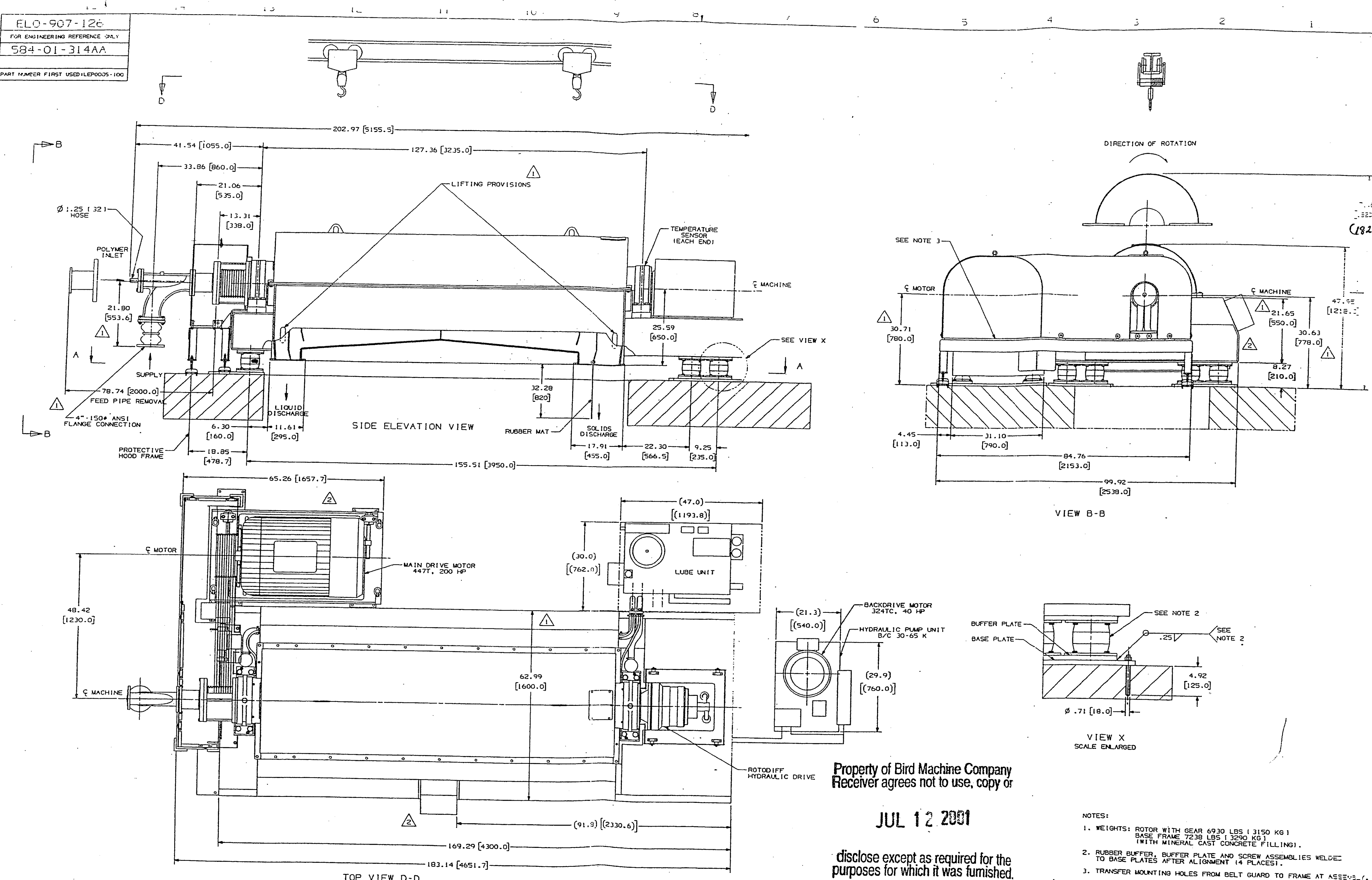
REV

SHT 1 OF 1

PRINT MAY BE REDUCED SIZE, DO NOT SCALE. =ONE INCH(1")

01-JUL-02

ELO-907-126
FOR ENGINEERING REFERENCE ONLY
584-01-314AA
PART NUMBER FIRST USED: LEP0005-100



Property of Bird Machine Company
Receiver agrees not to use, copy or disclose except as required for the purposes for which it was furnished.

JUL 12 2001

NOTES:

1. WEIGHTS: ROTOR WITH GEAR 6930 LBS [3150 KG]
   BASE FRAME 7238 LBS [3290 KG]
   (WITH MINERAL CAST CONCRETE FILLING).
2. RUBBER BUFFER, BUFFER PLATE AND SCREW ASSEMBLIES WELDED TO BASE PLATES AFTER ALIGNMENT (4 PLACES).
3. TRANSFER MOUNTING HOLES FROM BELT GUARD TO FRAME AT ASSEMBLY.
4. DIMENSIONS ARE IN INCHES [METRIC].

Betriebsdrehzahl der Zentrifuge : 2000-2850 1/min
Die unteren Eigenfrequenzen liegen im Bereich 2-9 Hz.
Alle Rohr- und Schurrenanschlisse sind flexibel zu gestalten. (20mm in jeder Richtung mind.)
Ein Untergestell ist so abzustimmen, da dessen tiefste Eigenfrequenz 30% ber der Betriebsdrehzahl der Zentrifuge liegt. (Mit gefllter Zentrifuge)
Dies gilt nicht fr Decken- bzw. Gebudekonstruktion.

Ecklast Nr.	statische Belastung incl. Filgewicht [N]	Dynamische Belastung [N] in vertikaler Richtung: Betriebsdrehzahl	in vertikaler Richtung: Durchfahren der Resonanz	in horizontaler Richtung: Betriebsdrehzahl	in horizontaler Richtung: Durchfahren der Resonanz
1	21535	±1080	±6460	±430	±2155
2	18885	± 945	±5665	±380	±1890
3	18885	± 945	±5665	±380	±1890
4	21535	±1080	±6460	±430	±2155

Maschinengewicht ohne Filgewicht ohne Schurrengewicht	73575N
Filgewicht	7260N
Gewicht des Pumpenaggregates	4415N
Gewicht des Umlaufaggregates	1268N
Gewicht der Antriebseinheit	22640N

operation speed of the centrifuge : 2000-2850 1/min
The natural frequency of the sub-structure shall be 2-9 Hz.
All pipe and chute connections should be in flexible design. (20 mm in each direction)
A sub-structure shall be designed in such a manner that its lowest natural frequency is located 30% above the operating speed of the centrifuge (with filled centrifuge).
This requirement does not apply to floor and/or building structure.

corner load no.	static load incl. bowl charge [LB]	dynamical load [LB] in vertical direction: operating speed	in vertical direction: when passing resonance	in horizontal direction: operating speed	in horizontal direction: when passing resonance
1	4841.1	± 242.8	± 1452.2	± 96.7	± 484.4
2	4245.3	± 212.4	± 1273.5	± 85.4	± 424.9
3	4245.3	± 212.4	± 1273.5	± 85.4	± 424.9
4	4841.1	± 242.8	± 1452.2	± 96.7	± 484.4

machine weight without bowl charge without chutes	[LB] 16539.7
bowl charge	1632.0
weight of pump unit	992.5
weight of oil supply unit	285.0
weight of drive unit	3089.5

STANDARD FABRICATION TOLERANCES	
DIMENSION	TOLERANCE
0" < 12" [0 < 300]	±.04 [1]
12" < 24" [30 < 600]	±.06 [1.5]
24" < 36" [600 < 900]	±.09 [2.2]
OVER 36" [900]	±.12 [3]

BAKER HUGHES
Baker Process
CUSTOMER:
CUSTOMER P.O.#
BAKER PROCESS S.O.#
MACHINE SERIAL NO.
MACHINE TAG NO.
☐ UNCERTIFIED TYPICAL: FOR GENERAL ARRANGEMENT ONLY. DO NOT USE FOR INSTALLATION, FOUNDATION DESIGN ETC.
☐ FOR APPROVAL: UNLESS DRAWING IS RETURNED TO BAKER PROCESS, S. WALPOLE, MA. WITHIN 30 DAYS OF DATE TRANSMITTED FROM BAKER PROCESS, WITH SPECIFIC INSTRUCTIONS NOT TO PROCEED, DRAWING WILL BE

NOTICE

THE OUTLINE AND FOUNDATION DRAWING SUPPLIED BY BAKER PROCESS IS INTENDED TO PROVIDE A FOOTPRINT, ALONG WITH LOADING DATA. IT IS NOT MEANT TO INDICATE FOUNDATION DESIGN. THE FOUNDATION MUST BE DESIGNED AND CONSTRUCTED BY AN INDIVIDUAL

1961	6/19/01	MACHINE DESIGNATION "HUMBOLDT CP3074 CF-2 WAS HUMBOLDT CP3074 CF-4" REVISE MOTOR GEOMETRY	YCC	3
1891	4/4/01	ADD SHEET 3 AND JUNCTION BOX, DELETE VIBRATION SWITCH	CAH	2

CAD DRAWING: UGII
SHEET 1 OF 3
DRAWN BY: CAH
DATE: 8-4-00
TITLE: OUTLINE AND FOUNDATION
MACHINE: HUMBOLDT CP3074 CF-2
DRAWING NUMBER: ELO-907-126

TOLERANCES FOR MACHINED SURFACES

1.	1.125	±.04	(.040)
1.0	1.125	±.02	(.020)
1.00	1.125	±.01	(.010)
1.000		±.005	

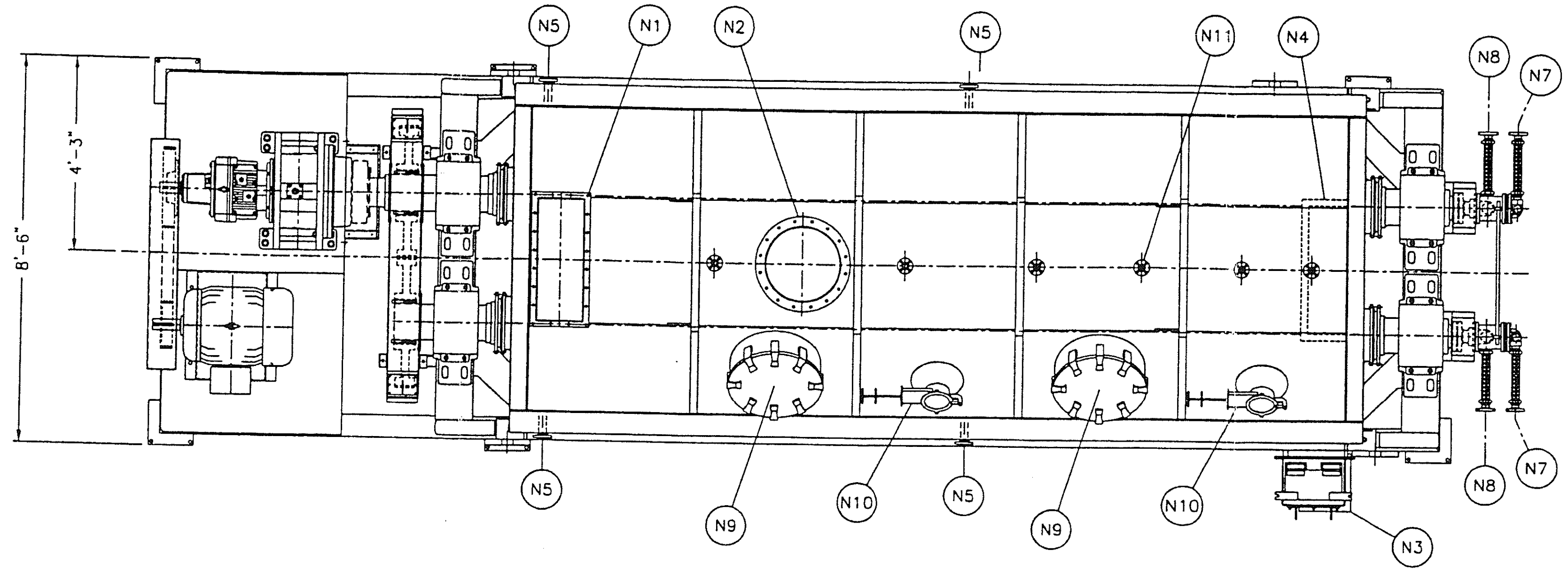
FOLLOW MANUFACTURING PRACTICES

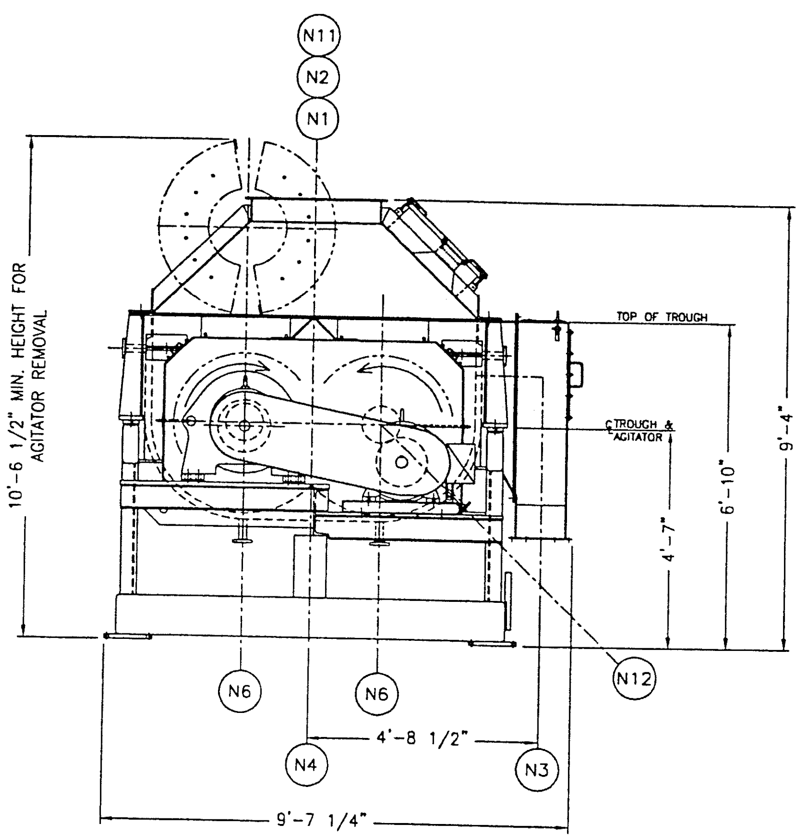
CHECKED BY:
PROD ENG: SDH DATE: 08/10/00
DESIGN ENG: YCC DATE: 08/10/00
MFG ENG: N/A DATE:

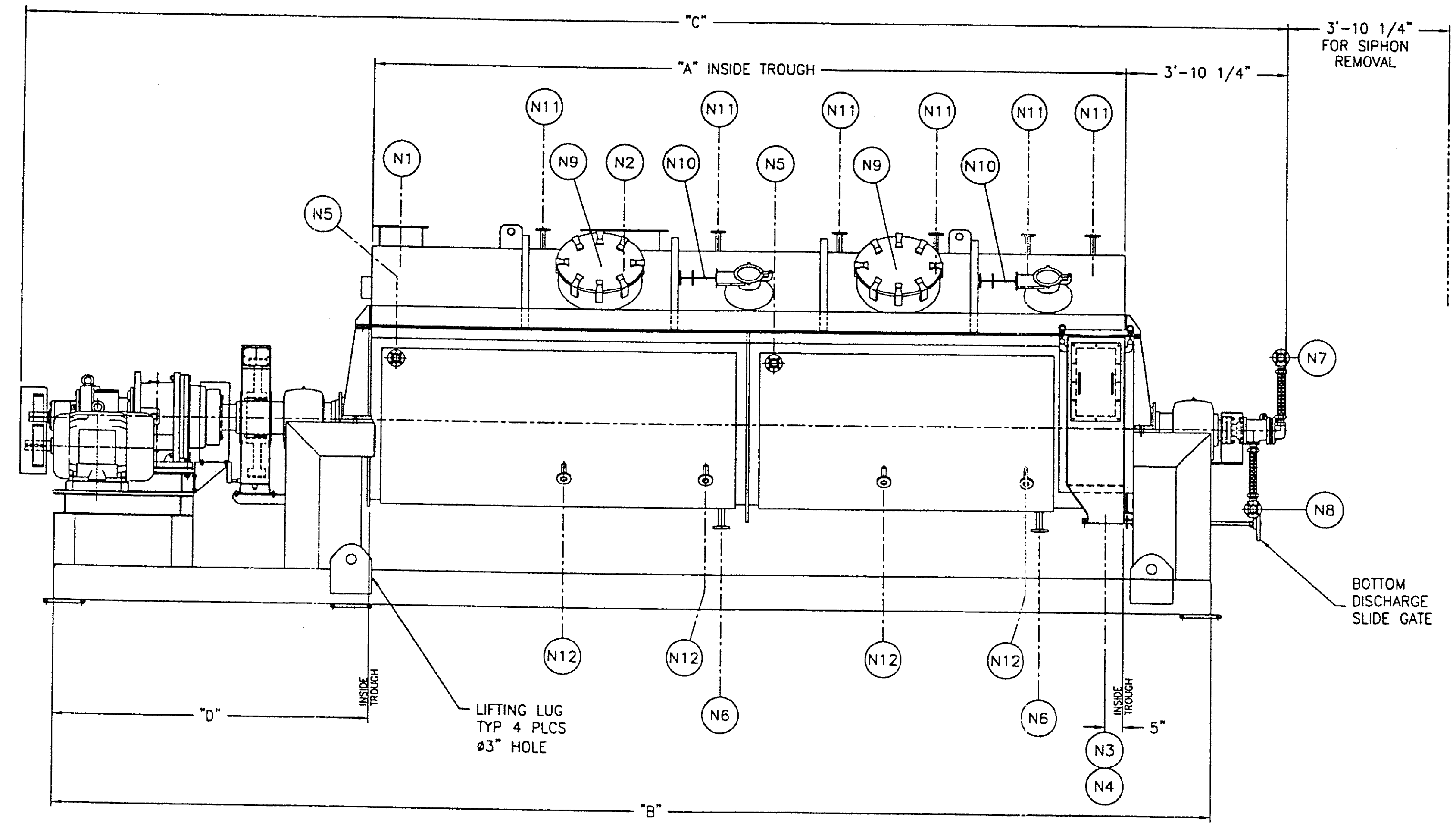
NOZZLE	QTY	SIZE/RATING/MAT'L	SERVICE
N1	1	TO BE DETERMINED	FEED INLET
N2	1	TO BE DETERMINED	VAPOR OUTLET
N3	1	10" x 12"	SIDE DISCHARGE
N4	1	10" x 34"	BOTTOM DISCHARGE
N5	4	1 1/2" 150# RF ANSI FLG	TROUGH JACKET STEAM INLET/LIQUID OUTLET
N6	4	2" 150# RF ANSI FLG	TROUGH JACKET CONDENSATE OUTLET/LIQUID INLET
[illegible]	2	TO BE DETERMINED (BRAIDED HOSE/W FLANGED ENDS)	AGITATOR STEAM INLET/LIQUID OUTLET
N8	2	TO BE DETERMINED (BRAIDED HOSE/W FLANGED ENDS)	AGITATOR CONDENSATE OUTLET/LIQUID INLET
N9	2	24" DIA.	ACCESS OPENING
N10	2	6" DIA.	VIEW PORT W/ISOLATION GATE
N11	6	1"-150# RF ANSI FLG	WATER DELUGE/INSTRUMENTS
N12	4	1"-150# RF ANSI FLG	THERMOCOUPLES

NOTES

1. WEIGHTS SHOWN ARE ESTIMATED WEIGHTS IN POUNDS.
2. REFER TO KOMLINE-SANDERSON ENGINEERING CORPORATION PRELIMINARY SPECIFICATIONS FOR ADDITIONAL INFORMATION SUCH AS DRIVE DESCRIPTION, PRESSURE AND TEMPERATURE RATINGS, MATERIALS OF CONSTRUCTION, ETC.
3. CONNECTIONS ARE NOT DESIGNED TO ACCEPT EXTERNAL LOADS. CONNECTED PIPING AND DUCTS MUST BE INDEPENDENTLY SUPPORTED AND ARRANGED TO ALLOW FOR THERMAL EXPANSION. (HORIZONTAL MOVEMENT 1". VERTICAL MOVEMENT 1/4")
4. LIFTING LUGS ARE DESIGNED FOR VERTICAL LIFT ONLY. SPREADER BARS ARE NOT PROVIDED BY KOMLINE-SANDERSON.







MODEL	"A"	"B"	"C"	"D"	EMPTY WEIGHT	AGITATOR WEIGHT (EA)	PROCESS VOLUME
11W-1000	18'-0"	27'-7 1/2"	30'-3"	7'-7"	64,000 LBS	14,000 LBS	278 CU FT
11W-1200	21'-4"	31'-5"	34'-0"	8'-0"	70,000 LBS	16,000 LBS	330 CU FT

PRELIMINARY

REV.	DR.	CHK.	DATE	APPR

K-S NARA PADDLE DRYER/COOLER
MODEL 11W-1000............1200
SIDE WEIR

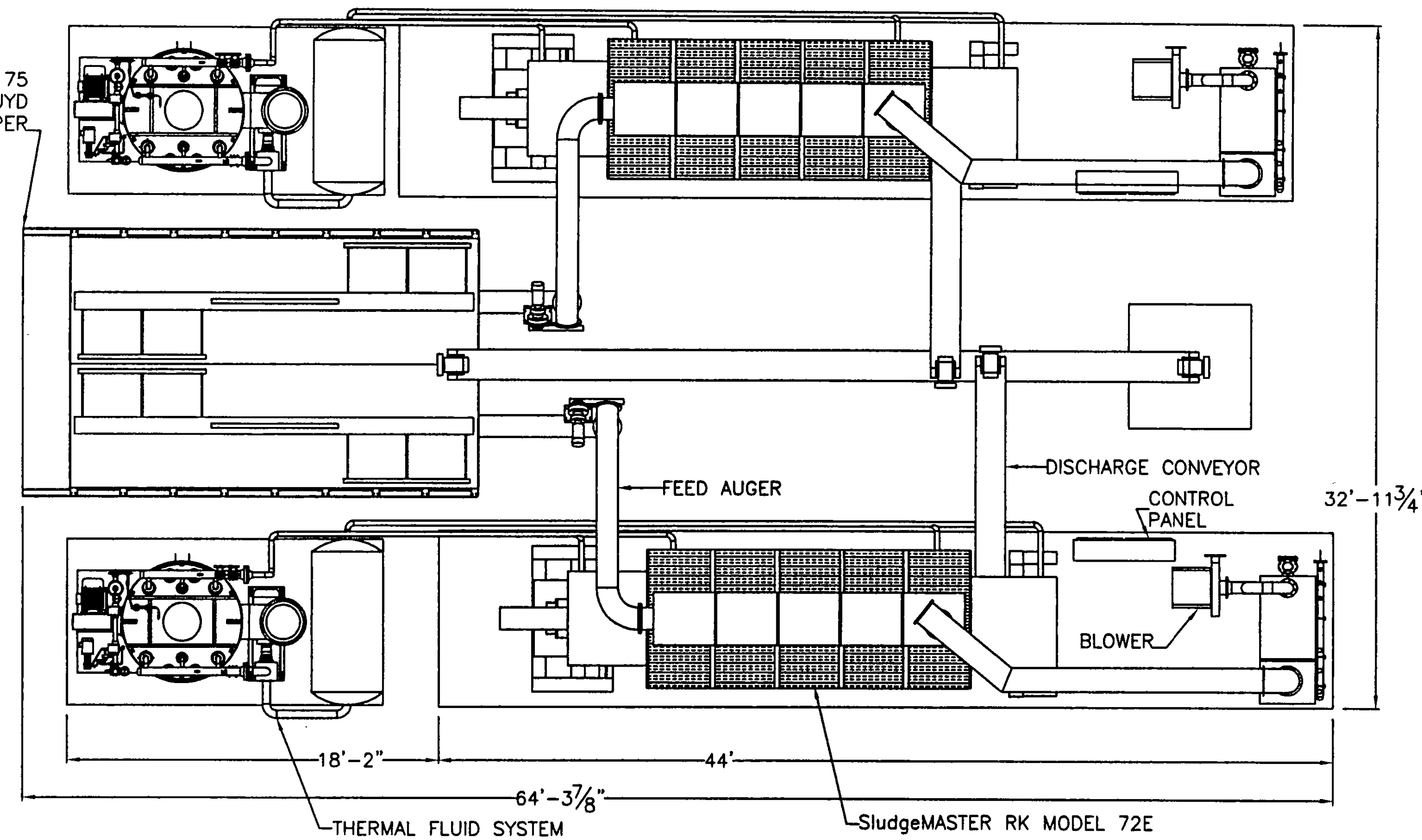
DESIGNED	DRAWN	CHECKED	APPROVED
	DMP		

DATE 8/21/01
SCALE 1/2"=1'-0

KOMLINE-SANDERSON
ENGINEERING CORPORATION
PEAPACK, N.J.

REFERENCE
DWG. NO. CDP11-00001D
SHT. 1 OF 1

NOTE: THIS IS A GENERAL LAYOUT.
ALL DIMENSIONS AND INFORMATION ARE
SUBJECT TO CHANGE WITHOUT NOTICE.



RK 72E DUPLEX

FENTON ENVIRONMENTAL TECHNOLOGIES 4306 SOUTH HIGHWAY 377 BROWNWOOD, TX.	SIZE A	DRAWING NO.	REV
DESCRIPTION: DUAL RK 72E LAYOUT W/ 75 CU YD HOPPER	AUTOCAD RELEASE 12		
DRAWN BY: DATE:	SCALE N.T.S	SHEET 1 OF 1	

C

APPENDIX C – DETAILED COST ESTIMATES

40 mgd PROCESS PLANT UPGRADE OPTIONS

RIVERSIDE WATER QUALITY CONTROL PLANT

RIVERSIDE, CALIFORNIA

Project name	22776-011-40 mgd option
Estimator	B. Matthews
Labor rate table	San Diego - Labor
Equipment rate table	San Diego - Equipm't
Project	22776-011
Estimating Office:	Jax Fla
Estimate Issue No.	01
Revision No.:	07
Final Issue Date:	March 14,2003
BC Project Manager	K. Fonda
QA/QC Reviewer:	B. Matthews
Date Reviewed:	March 12,2003
Estimate Date:	March 14,2003
Design Percentage	Conceptual
Notes	PROCESS AREA LOCATIONS

1100 - CONTRACTOR GENERAL CONDITIONS
1101 - CIVIL/SITE WORK
1102 - DAFT PROCESS UNIT
1103 - CONVERT EXIST> DAF TO COTHICKENING DAF's
1104 - DEWATERING PROCESS UNIT
1105 - HEAT DRYING PROCESS UNIT

Brown and Caldwell
Estimating and Scheduling Department
12959 South Chelsea Harbor Drive
Jacksonville, Florida 32224
Phone No. 904-992-8804
Fax No. 904-379-0250

Description		Quantity	Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
1100										
01100000	SUMMARY			2,822						2,822
01300000	ADMNSTRTV REQUIREMEN			234,730		6,312			20,150	261,192
01500000	TEMPORY FACILITS&CONTI			1,051		12,782		35,904	3,500	53,237
1100				***238,603***		***19,094***		***35,904***	***23,650***	***317,251***
	8,620.00 Labor hours									
	6,839.88 Equipment hours									
1101										
02500000	UTILITY SERVICES			20,760		105,000		5,500		131,260
1101				***20,760***		***105,000***		***5,500***		***131,260***
	220.00 Labor hours									
	220.000 Equipment hours									
1102										
11300000	WATER/WASTEWATER EQL			487,127		724,000		20,525		1,231,652
16010000	ELECTRICAL/INSTRUMENT/						110,000			110,000
17000000	INSTRUMENTATION						115,000			115,000
1102				***487,127***		***724,000***	***225,000***	***20,525***		***1,456,652***
	1,231.00 Labor hours									
	1,231.000 Equipment hours									
1103										
02200000	SITE PREPARATION			14,920				800		15,720
11300000	WATER/WASTEWATER EQL			117,683		1,103,728		30,609	375	1,252,395
15100000	BUILDING SERVICES PIPIN(			5,662		25,500		1,500		32,662
16010000	ELECTRICAL/INSTRUMENT/						325,500			325,500
17000000	INSTRUMENTATION						110,000			110,000
1103				***138,264***		***1,129,228***	***435,500***	***32,909***	***375***	***1,736,276***
	545.75 Labor hours									
	516.000 Equipment hours									
1104										
11300000	WATER/WASTEWATER EQL			131,342		691,500		19,750		842,592
16010000	ELECTRICAL/INSTRUMENT/						115,000			115,000
17000000	INSTRUMENTATION						95,000			95,000
1104				***131,342***		***691,500***	***210,000***	***19,750***		***1,052,592***
	382.50 Labor hours									
	370.00 Equipment hours									
1105										
02200000	SITE PREPARATION			157,486		3,500		45,600		206,586
11300000	WATER/WASTEWATER EQL			770,095		5,550,000		47,425		6,367,520
16010000	ELECTRICAL/INSTRUMENT/						750,000			750,000

Brown and Caldwell
Estimating and Scheduling Department
12959 South Chelsea Harbor Drive
Jacksonville, Florida 32224
Phone No. 904-992-8804
Fax No. 904-379-0250

BROWN AND CALDWELL

Summary Estimate Report

Description	Quantity	Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
17000000 INSTRUMENTATION						250,000			250,000
1105			***927,582***		***5,553,500***	***1,000,000***	***93,025***		***7,574,107***
1,447.00 Labor hours									
1,447.00 Equipment hours									

Estimate Totals

Labor	1,943,678	1,943,678		12,446.250	ch	
Material	8,222,322	8,222,322				
Subcontract	1,870,500	1,870,500				
Equipment	207,613	207,613		10,623.880	ch	
Other	24,025	24,025				
	12,268,138	12,268,138	12,268,138			
Labor Mark-up	349,862			18.000 %		C
Material Mark-up	1,233,348			15.000 %		C
Subcontractor Mark-up	93,525			5.000 %		C
Equipment Mark-up	31,142			15.000 %		C
	1,707,877		13,976,015			
Sales tax (material)	678,342			8.250 %		C
Sales tax (equipment)	17,128			8.250 %		C
	695,470		14,671,485			
Performance Bond	146,715			1.000 %		T
Payment Bond	148,182			1.000 %		T
	294,897		14,966,382			
Material Shipping & Handling	123,335			1.500 %		C
	123,335		15,089,717			
Worker's Travel/Subsistence	1,944			0.100 %		C
	1,944		15,091,661			
Earthquake Insurance	15,092			0.100 %		T
	15,092		15,106,753			
Bldg Risk, Liability Auto Ins.	302,135			2.000 %		T
	302,135		15,408,888			
Start-up, training, O & M	308,178			2.000 %		T
	308,178		15,717,066			
Construction Contingency	4,715,119			30.000 %		T
	Total		***20,432,185***			

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Summary Estimate Report

Estimate Totals

Labor	2,901,375	2,901,375		27,636.634	ch	
Material	8,896,967	8,896,967				
Subcontract	3,072,750	3,072,750				
Equipment	424,091	424,091		20,578.094	ch	
Other	255,545	255,545				
	15,550,728	15,550,728	15,550,728			
Labor Mark-up	522,248			18.000 %		C
Material Mark-up	1,334,545			15.000 %		C
Subcontractor Mark-up	153,638			5.000 %		C
Equipment Mark-up	63,614			15.000 %		C
	2,074,045		17,624,773			
Sales tax (material)	734,000			8.250 %		C
Sales tax (equipment)	34,987			8.250 %		C
	768,987		18,393,760			
Performance Bond	183,938			1.000 %		T
Payment Bond	185,777			1.000 %		T
	369,715		18,763,475			
Material Shipping & Handling	133,455			1.500 %		C
	133,455		18,896,930			
Worker's Travel/Subsistence	2,901			0.100 %		C
	2,901		18,899,831			
Earthquake Insurance	18,900			0.100 %		T
	18,900		18,918,731			
Bldg Risk, Liability Auto Ins.	378,375			2.000 %		T
	378,375		19,297,106			
Start-up, training, O & M	385,942			2.000 %		T
	385,942		19,683,048			
Construction Contingency	5,904,914			30.000 %		T
	Total		***25,587,962***			

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40 mgd PROCESS PLANT UPGRADE OPTIONS

RIVERSIDE WATER QUALITY CONTROL PLANT

RIVERSIDE, CALIFORNIA

Project name	22776-011-40 mgd option
Estimator	B. Matthews
Labor rate table	San Diego - Labor
Equipment rate table	San Diego - Equipm't
Project	22776-011
Estimating Office:	Jax Fla
Estimate Issue No.	01
Revision No.:	07
Final Issue Date:	March 14,2003
BC Project Manager	K. Fonda
QA/QC Reviewer:	B. Matthews
Date Reviewed:	March 12,2003
Estimate Date:	March 14,2003
Design Percentage	Conceptual
Notes	PROCESS AREA LOCATIONS

1100 - CONTRACTOR GENERAL CONDITIONS
1101 - CIVIL/SITE WORK
1102 - DAFT PROCESS UNIT
1103 - CONVERT EXIST> DAF TO COTHICKENING DAF's
1104 - DEWATERING PROCESS UNIT
1105 - HEAT DRYING PROCESS UNIT

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1100												
01100000	**SUMMARY**											
01107700	*Surveying*											
1100	Surveying, crew for building layout, 2 person crew	4.00	day	705.61 /day	2,822	-	-	-		-	-	2,822
	Surveying				*2,822*							*2,822*
	32.00 Labor hours											
	SUMMARY				**2,822**		**0**	**0**		**0**	**0**	**2,822**
	32.00 Labor hours											
01300000	**ADMNSTRTV REQUIREMENTS**											
01310700	*Field personnel*											
0010	Field personnel clerk	52.00	week	480.00 /week	24,960	-	-	-		-	-	24,960
0140	Field personnel, field engineer	24.00	week	1,005.00 /week	24,120	-	-	-		-	-	24,120
0160	Field personnel, general purpose laborer	40.00	week	925.00 /week	37,000	-	-	-		-	-	37,000
0220	Field personnel, project manager	26.00	week	1,605.00 /week	41,730	-	-	-		-	-	41,730
0280	Field personnel, superintendent	52.00	week	1,510.00 /week	78,520	-	-	-		-	-	78,520
9001	Field personnel, health & safety manager	20.00	week	1,420.00 /week	28,400	-	-	-		-		28,400
	Field personnel				*234,730*							*234,730*
	8,560.00 Labor hours											
01320200	*Scheduling*											
0400	Scheduling, cost control, computer-update, micro, incl plots, maximum	12.00	ea	-	-	-	-	-		-	18,600	18,600
0800	As-built drawings, O & M Manuals	1.00	ea	-	-	-	-	-		-	1,550	1,550
	Scheduling										*20,150*	*20,150*
01321500	*Photographs*											
0010	Photographs 8" x 10", 4 shots, 2 prints ea, std mounting	24.00	set	-	-	263.00 /set	6,312	-		-	-	6,312
	Photographs						*6,312*					*6,312*
	ADMNSTRTV REQUIREMENTS				**234,730**		**6,312**	**0**		**0**	**20,150**	**261,192**
	8,560.00 Labor hours											
01500000	**TEMPORY FACILITS&CONTROLS**											
01510050	*Tm pw eq (pr-rtd per job)*											

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
01510050	*Tm pw eq (pr-rtd per job)*											
0040	Temporary pwr equip (pro-rated per job), svce, ovhd feed, 3 use, 200 A	1.00	ea	375.82 /ea	376	710.00 /ea	710	-		-	-	1,086
	Tm pw eq (pr-rtd per job) 8.00 Labor hours				*376*		*710*					*1,086*
01520500	*Office*											
0550	Office trailer, furnished, no hookups, 50' x 12', rent per month	12.00	ea	-	-	345.00 /ea	4,140	-		-	-	4,140
0700	Office trailer, for air conditioning, rent per month, add	12.00	ea	-	-	35.50 /ea	426	-		-	-	426
0800	Office, trailer, furnished, for delivery, add per mile	100.00	mile	-	-	1.50 /mile	150	-		-	-	150
1350	Office, storage boxes, 28' x 10', rent per month	12.00	ea	-	-	103.00 /ea	1,236	-		-	-	1,236
	Office						*5,952*					*5,952*
01520550	*Field office expense*											
0100	Field office expense, office equipment rental	12.00	mo	-	-	136.00 /mo	1,632	-		-	-	1,632
0120	Field office expense, office supplies	12.00	mo	-	-	82.00 /mo	984	-		-	-	984
0140	Field office expense, telephone bill, avg bill/month incl long dist	12.00	mo	-	-	200.00 /mo	2,400	-		-	-	2,400
0160	Field office expense, field office lights & HVAC	12.00	mo	-	-	92.00 /mo	1,104	-		-	-	1,104
9001	Field subcontract, utility underground locating service	0.50	week	1,350.00 /week	675	-	-	-		-	-	675
9901	Field office expense, small tool allowance	1.00	ea	-	-	-	-	-		-	3,500	3,500
	Field office expense 20.00 Labor hours				*675*		*6,120*				*3,500*	*10,295*
01590400	*General equipment rental*											
0160	Rent aerial lift to 25'high 2000 lb cap scissor type	60.00	day	-	-	-	-	-		5,580	-	5,580
6410	Rent toilet portable chemical	12.00	mnth	-	-	-	-	-		900	-	900
6410	Rent toilet portable chemical	12.00	mnth	-	-	-	-	-		900	-	900
7200	Rent truck pickup 3/4 ton 4 wheel drive	12.00	mnth	-	-	-	-	-		15,000	-	15,000
	General equipment rental 6,719.88 Equipment hours									*22,380*		*22,380*
01590600	*Lifting and hoisting equi*											
2600	Rent crane truck mounted, hydraulic, 55 ton capacity	15.00	day	-	-	-	-	-		13,524	-	13,524

Item	Description	Takeoff Qty	Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
	Lifting and hoisting equi								*13,524*		*13,524*
	120.00 Equipment hours										
	TEMPORY FACILITS&CONTROLS			**1,051**		**12,782**	**0**		**35,904**	**3,500**	**53,237**
	28.00 Labor hours										
	6,839.88 Equipment hours										
	1100			***238,603***		***19,094***	***0***		***35,904***	***23,650***	***317,251***
	8,620.00 Labor hours										
	6,839.88 Equipment hours										

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Detailed Estimate Report

Item	Description	Takeoff Qty	Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1101											
02500000	UTILITY SERVICES										
02510820	*Ppng,watr dstr,ductl iron*										
----	Yard Piping Allowance	1.00 ea	5,661.84 /ea	5,662	40,000.00 /ea	40,000	-		1,500	-	47,162
----	Site grading, drainage and landscaping allowance	1.00 ea	15,098.24 /ea	15,098	65,000.00 /ea	65,000	-		4,000	-	84,098
	Ppng,watr dstr,ductl iron			*20,760*		*105,000*			*5,500*		*131,260*
	220.00 Labor hours										
	220.000 Equipment hours										
	UTILITY SERVICES			**20,760**		**105,000**	**0**		**5,500**	**0**	**131,260**
	220.00 Labor hours										
	220.000 Equipment hours										
	1101			***20,760***		***105,000***	***0***		***5,500***	***0***	***131,260***
	220.00 Labor hours										
	220.000 Equipment hours										

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1102												
11300000	**WATER/WASTEWATER EQUIPM'T**											
11300500	*Industrial W/W equipment*											
----	DAFT process control bldg, complete	2,100.00	sf	20.722 /sf	43,516	85.00 /sf	178,500	-		7,875	-	229,891
----	DAFT - process pumps, complete	3.00	ea	7,459.87 /ea	22,380	18,500.00 /ea	55,500	-		1,350	-	79,230
----	DAFT - manual and control valve allowance	1.00	ea	3,019.65 /ea	3,020	25,000.00 /ea	25,000	-		800	-	28,820
----	DAFT - Piping and fitting allowance	1.00	ea	3,774.56 /ea	3,775	15,000.00 /ea	15,000	-		3,000	-	21,775
----	Daft- 48 ft diameter, complete	1.00	ea	414,437.00 /ea	414,437	450,000.00 /ea	450,000	-		7,500	-	871,937
	Industrial W/W equipment				*487,127*		*724,000*			*20,525*		*1,231,652*
	1,231.00 Labor hours											
	1,231.000 Equipment hours											
	WATER/WASTEWATER EQUIPM'T				**487,127**		**724,000**	**0**		**20,525**	**0**	**1,231,652**
	1,231.00 Labor hours											
	1,231.000 Equipment hours											
16010000	**ELECTRICAL/INSTRUMENTATIO**											
16010100	*E & I Subcontractor*											
9001	Electrical and Instrumentation subcontractor	1.00	ls	-	-	-	-	110,000		-	-	110,000
	E & I Subcontractor							*110,000*				*110,000*
	ELECTRICAL/INSTRUMENTATIO				**0**		**0**	**110,000**		**0**	**0**	**110,000**
17000000	**INSTRUMENTATION**											
17000100	*INSTRUMENTATION CONTRACT*											
1001	Instrumentation subcontractor	1.00	ls	-	-	-	-	115,000		-	-	115,000
	INSTRUMENTATION CONTRACT							*115,000*				*115,000*
	INSTRUMENTATION				**0**		**0**	**115,000**		**0**	**0**	**115,000**
	1102				*487,127*		*724,000*	*225,000*		*20,525*	*0*	*1,456,652*
	1,231.00 Labor hours											
	1,231.000 Equipment hours											

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1103												
02200000	**SITE PREPARATION**											
02220880	*Equipment dismantling*											
9929	Equip. dml, air compressor unit, complete	1.00	ea	1,657.75 /ea	1,658	-	-	-			-	1,658
9981	Equip. dml, daf pressurization system, complete	1.00	ea	13,261.98 /ea	13,262	-	-	-		800	-	14,062
	Equipment dismantling				*14,920*					*800*		*15,720*
	36.00 Labor hours											
	36.00 Equipment hours											
	SITE PREPARATION				**14,920**		**0**	**0**		**800**	**0**	**15,720**
	36.00 Labor hours											
	36.00 Equipment hours											
11300000	**WATER/WASTEWATER EQUIPM'T**											
11300500	*Industrial W/W equipment*											
9904	Pumps,mixed sludge recirculation pump	2.00	ea	460.25 /ea	921	8,372.00 /ea	16,744	-		-	150	17,815
9905	Pumps,digester feed pump	3.00	ea	523.013 /ea	1,569	21,328.00 /ea	63,984	-		-	225	65,778
----	Thickened sludge blending tk,20,000 gal.,st,comp. w/nozzles,manway	1.00	ea	3,347.28 /ea	3,347	27,500.00 /ea	27,500	-		6,000	-	36,847
	Industrial W/W equipment				*5,837*		*108,228*			*6,000*	*375*	*120,440*
	69.75 Labor hours											
	40.00 Equipment hours											
11390900	*Wastwtr treatment system*											
9940	DAF cover,steel,not incl insulation,coatings, flashing,38 ft dia	2.00	ea	26,912.40 /ea	53,825	100,000.00 /ea	200,000	-		17,809	-	271,634
----	DAF pressurization system	1.00	ea	41,443.70 /ea	41,444	650,000.00 /ea	650,000	-		5,000	-	696,444
----	DAF air system, complete	1.00	ea	16,577.48 /ea	16,577	145,500.00 /ea	145,500	-		1,800	-	163,877
	Wastwtr treatment system				*111,846*		*995,500*			*24,609*		*1,131,955*
	380.00 Labor hours											
	380.000 Equipment hours											
	WATER/WASTEWATER EQUIPM'T				**117,683**		**1,103,728**	**0**		**30,609**	**375**	**1,252,395**
	449.75 Labor hours											
	420.000 Equipment hours											
15100000	**BUILDING SERVICES PIPING**											
15106100	*Misc. Mechanical*											

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
15106100	*Misc. Mechanical*											
----	Misc. piping and valve allowance, daf pressurization system,complete	1.00	ea	5,661.84 /ea	5,662	25,500.00 /ea	25,500	-		1,500	-	32,662
	Misc. Mechanical				*5,662*		*25,500*			*1,500*		*32,662*
	60.00 Labor hours											
	60.00 Equipment hours											
	BUILDING SERVICES PIPING				**5,662**		**25,500**	**0**		**1,500**	**0**	**32,662**
	60.00 Labor hours											
	60.00 Equipment hours											
16010000	**ELECTRICAL/INSTRUMENTATIO**											
16010100	*E & I Subcontractor*											
9001	Electrical and Instrumentation subcontractor	1.00	ls	-	-	-	-	325,500		-	-	325,500
	E & I Subcontractor							*325,500*				*325,500*
	ELECTRICAL/INSTRUMENTATIO				**0**		**0**	**325,500**		**0**	**0**	**325,500**
17000000	**INSTRUMENTATION**											
17000100	*INSTRUMENTATION CONTRACT*											
1001	Instrumentation subcontractor	1.00	ls	-	-	-	-	110,000		-	-	110,000
	INSTRUMENTATION CONTRACT							*110,000*				*110,000*
	INSTRUMENTATION				**0**		**0**	**110,000**		**0**	**0**	**110,000**
	1103				***138,264***		***1,129,228***	***435,500***		***32,909***	***375***	***1,736,276***
	545.75 Labor hours											
	516.000 Equipment hours											

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1104												
11300000	**WATER/WASTEWATER EQUIPM'T**											
11300500	*Industrial W/W equipment*											
9023	Possitive displacement piston pump, complete	2.00	ea	523.02 /ea	1,046	15,000.00 /ea	30,000	-		500	-	31,546
----	Centrifuge, complete incl. supports	1.00	ea	49,732.44 /ea	49,732	500,000.00 /ea	500,000	-		3,000	-	552,732
----	Polymer Feed pump, complete	1.00	ea	7,459.87 /ea	7,460	8,500.00 /ea	8,500	-		450	-	16,410
----	Manual and control valve allowance	1.00	ea	3,019.65 /ea	3,020	18,500.00 /ea	18,500	-		800	-	22,320
----	Piping and fitting allowance	1.00	ea	3,774.56 /ea	3,775	9,500.00 /ea	9,500	-		3,000	-	16,275
----	Dewatering Bldg. Raise roof, complete	1.00	ea	66,309.92 /ea	66,310	125,000.00 /ea	125,000	-		12,000	-	203,310
	Industrial W/W equipment 382.50 Labor hours 370.00 Equipment hours				*131,342*		*691,500*			*19,750*		*842,592*
	WATER/WASTEWATER EQUIPM'T 382.50 Labor hours 370.00 Equipment hours				**131,342**		**691,500**	**0**		**19,750**	**0**	**842,592**
16010000	**ELECTRICAL/INSTRUMENTATIO**											
16010100	*E & I Subcontractor*											
9001	Electrical and Instrumentation subcontractor	1.00	ls	-	-	-	-	115,000		-	-	115,000
	E & I Subcontractor							*115,000*				*115,000*
	ELECTRICAL/INSTRUMENTATIO				**0**		**0**	**115,000**		**0**	**0**	**115,000**
17000000	**INSTRUMENTATION**											
17000100	*INSTRUMENTATION CONTRACT*											
1001	Instrumentation subcontractor	1.00	ls	-	-	-	-	95,000		-	-	95,000
	INSTRUMENTATION CONTRACT							*95,000*				*95,000*
	INSTRUMENTATION				**0**		**0**	**95,000**		**0**	**0**	**95,000**
	1104 382.50 Labor hours 370.00 Equipment hours				*131,342*		*691,500*	*210,000*		*19,750*	*0*	*1,052,592*

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1105												
02200000	**SITE PREPARATION**											
02220875	*Site demolition*											
----	Site demolition, complete	1.00	ea	157,486.06 /ea	157,486	3,500.00 /ea	3,500	-		45,600	-	206,586
	Site demolition				*157,486*		*3,500*			*45,600*		*206,586*
	380.00 Labor hours											
	380.000 Equipment hours											
	SITE PREPARATION				**157,486**		**3,500**	**0**		**45,600**	**0**	**206,586**
	380.00 Labor hours											
	380.000 Equipment hours											
11300000	**WATER/WASTEWATER EQUIPM'T**											
11300500	*Industrial W/W equipment*											
----	Heat Drying equipment package, complete	2.00	ea	187,500.00 /ea	375,000	1,500,000.00 /ea	3,000,000	-		7,500	-	3,382,500
----	Heat drying equipment bldg, complete	7,500.00	sf	20.722 /sf	155,414	110.00 /sf	825,000	-		28,125	-	1,008,539
----	Dried product storage facility	1.00	ea	82,887.40 /ea	82,887	750,000.00 /ea	750,000	-		5,000	-	837,887
----	Manual and control valve allowance	1.00	ea	3,019.65 /ea	3,020	15,000.00 /ea	15,000	-		800	-	18,820
----	Piping and fitting allowance	1.00	ea	3,774.56 /ea	3,775	10,000.00 /ea	10,000	-		3,000	-	16,775
----	Odor Control equipment package, complete	1.00	ea	150,000.00 /ea	150,000	950,000.00 /ea	950,000	-		3,000	-	1,103,000
	Industrial W/W equipment				*770,095*		*5,550,000*			*47,425*		*6,367,520*
	1,067.00 Labor hours											
	1,067.00 Equipment hours											
	WATER/WASTEWATER EQUIPM'T				**770,095**		**5,550,000**	**0**		**47,425**	**0**	**6,367,520**
	1,067.00 Labor hours											
	1,067.00 Equipment hours											
16010000	**ELECTRICAL/INSTRUMENTATIO**											
16010100	*E & I Subcontractor*											
9001	Electrical and Instrumentation subcontractor	1.00	ls	-	-	-	-	750,000		-	-	750,000
	E & I Subcontractor							*750,000*				*750,000*
	ELECTRICAL/INSTRUMENTATIO				**0**		**0**	**750,000**		**0**	**0**	**750,000**
17000000	**INSTRUMENTATION**											
17000100	*INSTRUMENTATION CONTRACT*											

				Labor		Material		Subcontract		Equipment	Other	Total
Item	Description	Takeoff Qty		Unit Cost	Amount	Unit Cost	Amount	Amount	Name	Amount	Amount	Amount
17000100	*INSTRUMENTATION CONTRACT*											
1001	Instrumentation subcontractor	1.00	ls	-	-	-	-	250,000		-	-	250,000
	INSTRUMENTATION CONTRACT							*250,000*				*250,000*
	INSTRUMENTATION				**0**		**0**	**250,000**		**0**	**0**	**250,000**
	1105				***927,582***		***5,553,500***	***1,000,000***		***93,025***	***0***	***7,574,107***
	1,447.00 Labor hours											
	1,447.00 Equipment hours											

Detailed Estimate Report

Estimate Totals

Labor	1,943,678	1,943,678		12,446.250	ch	
Material	8,222,322	8,222,322				
Subcontract	1,870,500	1,870,500				
Equipment	207,613	207,613		10,623.880	ch	
Other	24,025	24,025				
	12,268,138	12,268,138	12,268,138			
Labor Mark-up	349,862			18.000 %		C
Material Mark-up	1,233,348			15.000 %		C
Subcontractor Mark-up	93,525			5.000 %		C
Equipment Mark-up	31,142			15.000 %		C
	1,707,877		13,976,015			
Sales tax (material)	678,342			8.250 %		C
Sales tax (equipment)	17,128			8.250 %		C
	695,470		14,671,485			
Performance Bond	146,715			1.000 %		T
Payment Bond	148,182			1.000 %		T
	294,897		14,966,382			
Material Shipping & Handling	123,335			1.500 %		C
	123,335		15,089,717			
Worker's Travel/Subsistence	1,944			0.100 %		C
	1,944		15,091,661			
Earthquake Insurance	15,092			0.100 %		T
	15,092		15,106,753			
Bldg Risk, Liability Auto Ins.	302,135			2.000 %		T
	302,135		15,408,888			
Start-up, training, O & M	308,178			2.000 %		T
	308,178		15,717,066			
Construction Contingency	4,715,119			30.000 %		T
	Total		***20,432,185***			

50 mgd PROCESS PLANT UPGRADE OPTIONS

RIVERSIDE WATER QUALITY CONTROL PLANT

RIVERSIDE, CALIFORNIA

Project name	22776-011-50 mgd option
Estimator	B. Matthews
Labor rate table	San Diego - Labor
Equipment rate table	San Diego - Equipm't
Project	22776-011
Estimating Office:	Jax Fla
Estimate Issue No.	01
Revision No.:	07
Final Issue Date:	March 14,2003
BC Project Manager	K. Fonda
QA/QC Reviewer:	B. Matthews
Date Reviewed:	March 12,2003
Estimate Date:	March 14,2003
Design Percentage	Conceptual
Notes	PROCESS AREA LOCATIONS

1100 - CONTRACTOR GENERAL CONDITIONS
1101 - CIVIL/SITE WORK
1102 - DAFT PROCESS UNIT
1103 - ANEROBIC DIGESTION PROCESS UNIT
1104 - DEWATERING PROCESS UNIT
1105 - HEAT DRYING PROCESS UNIT

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			Labor		Material		Subcontract	Equipment	Other	Total
Description		Quantity	Unit Cost	Amount	Unit Cost	Amount	Amount	Amount	Amount	Amount
1100										
01100000	SUMMARY			4,939						4,939
01300000	ADMNSTRTV REQUIREMEN			470,400		9,468			29,450	509,318
01500000	TEMPORY FACILITS&CONTI			1,051		24,854		80,498	3,500	109,903
1100				***476,390***		***34,322***		***80,498***	***32,950***	***624,160***
15,924.00	Labor hours									
13,631.76	Equipment hours									
1101										
02500000	UTILITY SERVICES			22,647		127,500		6,000		156,147
1101				***22,647***		***127,500***		***6,000***		***156,147***
240.00	Labor hours									
240.00	Equipment hours									
1102										
11300000	WATER/WASTEWATER EQL			487,127		724,000		20,525		1,231,652
16010000	ELECTRICAL/INSTRUMENT/						110,000			110,000
17000000	INSTRUMENTATION						115,000			115,000
1102				***487,127***		***724,000***	***225,000***	***20,525***		***1,456,652***
1,231.00	Labor hours									
1,231.000	Equipment hours									
1103										
01500000	TEMPORY FACILITS&CONTI			2,207		6,033				8,241
02300000	EARTHWORK			116,534		13,445		154,488		284,467
02450000	FNDTN&LOAD BEARNG ELE			58,758		81,081		31,846	84,000	255,684
03100000	CONCRETE FORMS&ACCES			143,891		48,935				192,826
03200000	CONCRETE REINFORCEME			99,429		94,548		7,675		201,652
03300000	CAST-IN-PLACE CONCRETE			205,684		247,816		20,892		474,392
04200000	MASONRY UNITS			185		138				323
05500000	METAL FABRICATIONS			1,068		2,280		66		3,414
07100000	DAMPPRFNG&WATERPROC			2,501		9,984	120,748	776		134,009
07200000	THERMAL PROTECTION			899		8,180				9,079
07600000	FLASHING & SHEET METAL			1,201		745				1,945
08100000	METAL DOORS & FRAMES			388		826		17		1,231
08300000	SPECIALTY DOORS			366		4,230				4,596
08900000	GLAZED CURTAIN WALL			2,186		7,425				9,611
09900000	PAINTS & COATINGS			3,186		2,990				6,176
11300000	WATER/WASTEWATER EQL			28,977		456,716		7,332	4,075	497,100
13800000	BUILDING AUTOMATN&CON			418		658				1,076
15050000	BASIC MATERIALS & METH(			5,668		1,700				7,368
15100000	BUILDING SERVICES PIPIN(			228,246		269,973		10,375	134,520	643,114
15200000	PROCESS PIPING			370		510				880
15600000	REFRIGERATION EQUIPMEI			4,557		30,000				34,557
15700000	HTNG/V/ CONDTNG EQUIPN			4,600		5,500				10,100

Description		Quantity	Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
15800000	AIR DISTRIBUTION			518		882				1,400
16010000	ELECTRICAL/INSTRUMENT/						761,966			761,966
17000000	INSTRUMENTATION			2,684		11,550	375,036			389,270
1103				***914,520***		***1,306,145***	***1,257,750***	***233,467***	***222,595***	***3,934,478***
8,405.134	Labor hours									
3,651.334	Equipment hours									
1104										
02200000	SITE PREPARATION			82,887		17,000		15,000		114,887
11300000	WATER/WASTEWATER EQL			137,517		1,102,500		15,475		1,255,492
16010000	ELECTRICAL/INSTRUMENT/						275,000			275,000
17000000	INSTRUMENTATION						165,000			165,000
1104				***220,404***		***1,119,500***	***440,000***	***30,475***		***1,810,379***
661.50	Labor hours									
649.000	Equipment hours									
1105										
11300000	WATER/WASTEWATER EQL			780,287		5,585,500		53,125		6,418,912
16010000	ELECTRICAL/INSTRUMENT/						825,000			825,000
17000000	INSTRUMENTATION						325,000			325,000
1105				***780,287***		***5,585,500***	***1,150,000***	***53,125***		***7,568,912***
1,175.00	Labor hours									
1,175.00	Equipment hours									

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50 mgd PROCESS PLANT UPGRADE OPTIONS

RIVERSIDE WATER QUALITY CONTROL PLANT

RIVERSIDE, CALIFORNIA

Project name	22776-011-50 mgd option
Estimator	B. Matthews
Labor rate table	San Diego - Labor
Equipment rate table	San Diego - Equipm't
Project	22776-011
Estimating Office:	Jax Fla
Estimate Issue No.	01
Revision No.:	07
Final Issue Date:	March 14,2003
BC Project Manager	K. Fonda
QA/QC Reviewer:	B. Matthews
Date Reviewed:	March 12,2003
Estimate Date:	March 14,2003
Design Percentage	Conceptual
Notes	PROCESS AREA LOCATIONS

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1100												
01100000	**SUMMARY**											
01107700	*Surveying*											
1100	Surveying, crew for building layout, 2 person crew	7.00	day	705.61 /day	4,939	-	-	-		-	-	4,939
	Surveying				*4,939*							*4,939*
	56.00 Labor hours											
	SUMMARY				**4,939**		**0**	**0**		**0**	**0**	**4,939**
	56.00 Labor hours											
01300000	**ADMNSTRTV REQUIREMENTS**											
01310700	*Field personnel*											
0010	Field personnel clerk	76.00	week	480.00 /week	36,480	-	-	-		-	-	36,480
0140	Field personnel, field engineer	52.00	week	1,005.00 /week	52,260	-	-	-		-	-	52,260
0160	Field personnel, general purpose laborer	40.00	week	925.00 /week	37,000	-	-	-		-	-	37,000
0220	Field personnel, project manager	76.00	week	1,605.00 /week	121,980	-	-	-		-	-	121,980
0280	Field personnel, superintendent	76.00	week	1,510.00 /week	114,760	-	-	-		-	-	114,760
9001	Field personnel, health & safety manager	76.00	week	1,420.00 /week	107,920	-	-	-		-		107,920
	Field personnel				*470,400*							*470,400*
	15,840.00 Labor hours											
01320200	*Scheduling*											
0400	Scheduling, cost control, computer-update, micro, incl plots, maximum	18.00	ea	-	-	-	-	-		-	27,900	27,900
0800	As-built drawings, O & M Manuals	1.00	ea	-	-	-	-	-		-	1,550	1,550
	Scheduling										*29,450*	*29,450*
01321500	*Photographs*											
0010	Photographs 8" x 10", 4 shots, 2 prints ea, std mounting	36.00	set	-	-	263.00 /set	9,468	-		-	-	9,468
	Photographs						*9,468*					*9,468*
	ADMNSTRTV REQUIREMENTS				**470,400**		**9,468**	**0**		**0**	**29,450**	**509,318**
	15,840.00 Labor hours											
01500000	**TEMPORY FACILITS&CONTROLS**											
01510050	*Tm pw eq (pr-rtd per job)*											

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
01510050	*Tm pw eq (pr-rtd per job)*											
0040	Temporary pwr equip (pro-rated per job), svce, ovhd feed, 3 use, 200 A	1.00	ea	375.82 /ea	376	710.00 /ea	710	-		-	-	1,086
	Tm pw eq (pr-rtd per job)				*376*		*710*					*1,086*
	8.00 Labor hours											
01520500	*Office*											
0550	Office trailer, furnished, no hookups, 50' x 12', rent per month	12.00	ea	-	-	345.00 /ea	4,140	-		-	-	4,140
0550	Office trailer, furnished, no hookups, 50' x 12', rent per month	12.00	ea	-	-	345.00 /ea	4,140	-		-	-	4,140
0700	Office trailer, for air conditioning, rent per month, add	12.00	ea	-	-	35.50 /ea	426	-		-	-	426
0700	Office trailer, for air conditioning, rent per month, add	12.00	ea	-	-	35.50 /ea	426	-		-	-	426
0800	Office, trailer, furnished, for delivery, add per mile	100.00	mile	-	-	1.50 /mile	150	-		-	-	150
0800	Office, trailer, furnished, for delivery, add per mile	100.00	mile	-	-	1.50 /mile	150	-		-	-	150
1350	Office, storage boxes, 28' x 10', rent per month	12.00	ea	-	-	103.00 /ea	1,236	-		-	-	1,236
1350	Office, storage boxes, 28' x 10', rent per month	12.00	ea	-	-	103.00 /ea	1,236	-		-	-	1,236
	Office						*11,904*					*11,904*
01520550	*Field office expense*											
0100	Field office expense, office equipment rental	12.00	mo	-	-	136.00 /mo	1,632	-		-	-	1,632
0100	Field office expense, office equipment rental	12.00	mo	-	-	136.00 /mo	1,632	-		-	-	1,632
0120	Field office expense, office supplies	12.00	mo	-	-	82.00 /mo	984	-		-	-	984
0120	Field office expense, office supplies	12.00	mo	-	-	82.00 /mo	984	-		-	-	984
0140	Field office expense, telephone bill, avg bill/month incl long dist	12.00	mo	-	-	200.00 /mo	2,400	-		-	-	2,400
0140	Field office expense, telephone bill, avg bill/month incl long dist	12.00	mo	-	-	200.00 /mo	2,400	-		-	-	2,400
0160	Field office expense, field office lights & HVAC	12.00	mo	-	-	92.00 /mo	1,104	-		-	-	1,104
0160	Field office expense, field office lights & HVAC	12.00	mo	-	-	92.00 /mo	1,104	-		-	-	1,104
9001	Field subcontract, utility underground locating service	0.50	week	1,350.00 /week	675	-	-	-		-	-	675
9901	Field office expense, small tool allowance	1.00	ea	-	-	-	-	-		-	3,500	3,500

BROWN AND CALDWELL

Detailed Estimate Report

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
	Field office expense				*675*		*12,240*				*3,500*	*16,415*
	20.00 Labor hours											
01590400	*General equipment rental*											
0160	Rent aerial lift to 25'high 2000 lb cap scissor type	120.00	day	-	-	-	-	-		11,160	-	11,160
6410	Rent toilet portable chemical	18.00	mnth	-	-	-	-	-		1,350	-	1,350
6410	Rent toilet portable chemical	18.00	mnth	-	-	-	-	-		1,350	-	1,350
7200	Rent truck pickup 3/4 ton 4 wheel drive	18.00	mnth	-	-	-	-	-		22,500	-	22,500
7200	Rent truck pickup 3/4 ton 4 wheel drive	18.00	mnth	-	-	-	-	-		22,500	-	22,500
	General equipment rental									*58,860*		*58,860*
	13,439.76 Equipment hours											
01590600	*Lifting and hoisting equi*											
2600	Rent crane truck mounted, hydraulic, 55 ton capacity	24.00	day	-	-	-	-	-		21,638	-	21,638
	Lifting and hoisting equi									*21,638*		*21,638*
	192.00 Equipment hours											
	TEMPORY FACILITS&CONTROLS				**1,051**		**24,854**	**0**		**80,498**	**3,500**	**109,903**
	28.00 Labor hours											
	13,631.76 Equipment hours											
	1100				***476,390***		***34,322***	***0***		***80,498***	***32,950***	***624,160***
	15,924.00 Labor hours											
	13,631.76 Equipment hours											

Detailed Estimate Report

Item	Description	Takeoff Qty	Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1101											
02500000	**UTILITY SERVICES**										
02510820	*Ppng,watr dstr,ductl iron*										
----	Yard Piping Allowance	1.00 ea	7,549.12 /ea	7,549	52,500.00 /ea	52,500	-		2,000	-	62,049
----	Site grading, drainage and landscaping allowance	1.00 ea	15,098.24 /ea	15,098	75,000.00 /ea	75,000	-		4,000	-	94,098
	Ppng,watr dstr,ductl iron			*22,647*		*127,500*			*6,000*		*156,147*
	240.00 Labor hours										
	240.00 Equipment hours										
	UTILITY SERVICES			**22,647**		**127,500**	**0**		**6,000**	**0**	**156,147**
	240.00 Labor hours										
	240.00 Equipment hours										
	1101			***22,647***		***127,500***	***0***		***6,000***	***0***	***156,147***
	240.00 Labor hours										
	240.00 Equipment hours										

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1102												
11300000	**WATER/WASTEWATER EQUIPM'T**											
11300500	*Industrial W/W equipment*											
----	DAFT - 48 ft diameter, complete	1.00	ea	414,437.00 /ea	414,437	450,000.00 /ea	450,000	-		7,500	-	871,937
----	DAFT process control bldg, complete	2,100.00	sf	20.722 /sf	43,516	85.00 /sf	178,500	-		7,875	-	229,891
----	DAFT - process pumps, complete	3.00	ea	7,459.87 /ea	22,380	18,500.00 /ea	55,500	-		1,350	-	79,230
----	DAFT - manual and control valve allowance	1.00	ea	3,019.65 /ea	3,020	25,000.00 /ea	25,000	-		800	-	28,820
----	DAFT - Piping and fitting allowance	1.00	ea	3,774.56 /ea	3,775	15,000.00 /ea	15,000	-		3,000	-	21,775
	Industrial W/W equipment				*487,127*		*724,000*			*20,525*		*1,231,652*
	1,231.00 Labor hours											
	1,231.000 Equipment hours											
	WATER/WASTEWATER EQUIPM'T				**487,127**		**724,000**	**0**		**20,525**	**0**	**1,231,652**
	1,231.00 Labor hours											
	1,231.000 Equipment hours											
16010000	**ELECTRICAL/INSTRUMENTATIO**											
16010100	*E & I Subcontractor*											
9001	Electrical and Instrumentation subcontractor	1.00	ls	-	-	-	-	110,000		-	-	110,000
	E & I Subcontractor							*110,000*				*110,000*
	ELECTRICAL/INSTRUMENTATIO				**0**		**0**	**110,000**		**0**	**0**	**110,000**
17000000	**INSTRUMENTATION**											
17000100	*INSTRUMENTATION CONTRACT*											
1001	Instrumentation subcontractor	1.00	ls	-	-	-	-	115,000		-	-	115,000
	INSTRUMENTATION CONTRACT							*115,000*				*115,000*
	INSTRUMENTATION				**0**		**0**	**115,000**		**0**	**0**	**115,000**
	1102				***487,127***		***724,000***	***225,000***		***20,525***	***0***	***1,456,652***
	1,231.00 Labor hours											
	1,231.000 Equipment hours											

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Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
1103												
01500000	**TEMPORY FACILITS&CONTROLS**											
01540750	*Scaffolding*											
6600	Scaffold,h.d. shoring for suspended slab forms,fl area	63.51	csf	34.76 /csf	2,207	95.00 /csf	6,033	-		-	-	8,241
	Scaffolding				*2,207*		*6,033*					*8,241*
	28.23 Labor hours											
	TEMPORY FACILITS&CONTROLS				**2,207**		**6,033**	**0**		**0**	**0**	**8,241**
	28.23 Labor hours											
02300000	**EARTHWORK**											
02315120	*Backfill, structural*											
2220	Backfill, structural, 75 H.P., 150' haul, common earth	9,646.00	cy	1.17 /cy	11,278	-	-	-		7,013	-	18,291
	Backfill, structural				*11,278*					*7,013*		*18,291*
	157.52 Labor hours											
	157.52 Equipment hours											
02315130	*Bedding*											
0100	Bedding, crushed stone 3/4" to 1/2"	250.00	cy	5.44 /cy	1,359	19.552 /cy	4,888	-		323	-	6,570
	Bedding				*1,359*		*4,888*			*323*		*6,570*
	13.333 Labor hours											
	13.333 Equipment hours											
02315200	*Borrw,ldng and/or sprdng*											
2100	Borrow, crushed stone at pit, 3/4"-1-1/2"	605.00	cy	-	-	14.144 /cy	8,557	-		-	-	8,557
2500	Borrow, haul bank run sand 2 mi., spread w/200 HP dozer, bank measure	605.00	cy	2.05 /cy	1,240	-	-	-		2,296	-	3,535
3820	Borrow, delivery charge, min 12 CY, 1-1/2 hr round trip, add	605.00	cy	5.473 /cy	3,311	-	-	-		6,518	-	9,830
	Borrw,ldng and/or sprdng				*4,551*		*8,557*			*8,814*		*21,922*
	88.73 Labor hours											
	88.73 Equipment hours											
02315300	*Compaction*											
7040	Compaction, walk behind, vibrating plate 18" wide, 6" lifts, 4 passes	10,251.00	cy	2.24 /cy	22,939	-	-	-		6,353	-	29,292

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
	Compaction				*22,939*					*6,353*		*29,292*
	585.742 Labor hours											
	585.742 Equipment hours											
02315400	*Excvtng,bulk bank measure*											
0250	Excavating, bulk bank measure, backhoe, hyd, 1-1/2 CY cap. = 100 CY/hr	15,416.00	cy	0.98 /cy	15,034	-	-	-		15,306	-	30,340
	Excvtng,bulk bank measure				*15,034*					*15,306*		*30,340*
	154.16 Labor hours											
	154.16 Equipment hours											
02315440	*Excavating, structural*											
0001	Excavating, structural, mach excav, com earth, hyd backhoe, 1-1/2 CY b	1,006.00	cy	4.33 /cy	4,356	-	-	-		4,435	-	8,790
	Excavating, structural				*4,356*					*4,435*		*8,790*
	55.894 Labor hours											
	55.893 Equipment hours											
02320200	*Hauling*											
0310	Hauling, LCY, no loading, 12 CY dump truck, 1/4 mile RT 3.7 lds/hr	15,416.00	cy	1.14 /cy	17,579	-	-	-		34,607	-	52,186
0550	Hauling, LCY, no loading, 12 c.y dump truck, 10 MI RT, 0.60 lds/hr	5,770.00	cy	5.662 /cy	32,668	-	-	-		64,312	-	96,981
0560	Hauling, LCY, no loading, 12 c.y dump truck, 20 MI RT, 0.4 lds/hr	1,006.00	cy	6.73 /cy	6,769	-	-	-		13,326	-	20,094
	Hauling				*57,016*					*112,245*		*169,261*
	1,430.473 Labor hours											
	1,430.473 Equipment hours											
	EARTHWORK				**116,534**		**13,445**	**0**		**154,488**	**0**	**284,467**
	2,485.851 Labor hours											
	2,485.850 Equipment hours											
02450000	**FNDTN&LOAD BEARNG ELEMNTS**											
02455220	*Piles, concrete*											
3400	Piles, conc, precast, prestressed, 40' long, 14" thick, square	7,425.00	vlf	5.35 /vlf	39,703	10.92 /vlf	81,081	-		26,953	-	147,737
4750	Piles, mobilization for 10,000 l.f pile job, add	7,425.00	vlf	0.971 /vlf	7,208	-	-	-		4,893	-	12,101
	Piles, concrete				*46,911*		*81,081*			*31,846*		*159,838*
	116.944 Labor hours											
	116.944 Equipment hours											
02455350	*Piling special costs*											
0500	Piling special costs, cutoffs, concrete piles	165.00	ea	71.80 /ea	11,847	-	-	-		-	-	11,847

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
02455350	*Piling special costs*											
1150	Piling special costs, testing, 120 ton design load, 240 ton test	4.00	ea	-	-	-	-	-		-	84,000	84,000
	Piling special costs				*11,847*						*84,000*	*95,847*
	240.001 Labor hours											
	FNDTN&LOAD BEARNG ELEMNTS				**58,758**		**81,081**	**0**		**31,846**	**84,000**	**255,684**
	356.945 Labor hours											
	116.944 Equipment hours											
03100000	**CONCRETE FORMS&ACCESSORSS**											
03110420	*Fip,elevated slabs*											
1150	Forms in place, elev slab, flat plate plywd, to 15' high, 4 use	322.00	sf	4.18 /sf	1,345	0.89 /sf	286	-		-	-	1,631
2000	Forms in place, elev slab	6,350.96	sf	2.861 /sf	18,167	3.25 /sf	20,641	-		-	-	38,808
	Fip,elevated slabs				*19,513*		*20,926*					*40,439*
	163.38 Labor hours											
03110445	*Forms place, slab grade*											
2000	Forms in place, SOG, curb forms, wood, 6" - 12" high, 1 use	1,170.00	sfca	5.621 /sfca	6,577	1.942 /sfca	2,272	-		-	-	8,849
	Forms place, slab grade				*6,577*		*2,272*					*8,849*
	43.54 Labor hours											
03110455	*Forms in place, walls*											
2750	Forms in place, walls, job built plyform, over 16' high, 2 use	18,112.00	sfca	6.45 /sfca	116,757	1.35 /sfca	24,397	-		-	-	141,154
	Forms in place, walls				*116,757*		*24,397*					*141,154*
	499.71 Labor hours											
03150660	*Stair tread inserts*											
0550	Stair tread inserts, extruded aluminum safety tread, 4" wide	196.00	lf	5.33 /lf	1,045	6.84 /lf	1,340	-		-	-	2,385
	Stair tread inserts				*1,045*		*1,340*					*2,385*
	20.91 Labor hours											
	CONCRETE FORMS&ACCESSORSS				**143,891**		**48,935**	**0**		**0**	**0**	**192,826**
	727.53 Labor hours											
03200000	**CONCRETE REINFORCEMENT**											
03210600	*Reinforcing in place*											
0400	Reinforcing in place, A615 Gr 60, elevated slabs, #4 to #7	1.074	ton	464.53 /ton	499	590.26 /ton	634	-		-	-	1,133
0400	Reinforcing in place, A615 Gr 60, elevated slabs, #4 to #7	32.032	ton	242.383 /ton	7,764	590.27 /ton	18,907	-		-	-	26,671
0600	Reinforcing in place, A615 Gr 60, slab on grade, #3 to #7	36.10	ton	585.704 /ton	21,144	529.73 /ton	19,123	-		-	-	40,267

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
03210600	*Reinforcing in place*											
0700	Reinforcing in place, A615 Gr 60, walls, #3 to #7	11.092	ton	449.041 /ton	4,981	529.73 /ton	5,876	-		-	-	10,856
0700	Reinforcing in place, A615 Gr 60, walls, #3 to #7	38.50	ton	478.443 /ton	18,420	529.73 /ton	20,394	-		-	-	38,814
0750	Reinforcing in place, A615 Gr 60, walls, #8 to #18	55.904	ton	336.78 /ton	18,827	529.73 /ton	29,614	-		-	-	48,441
2000	Reinforcing in place, unloading & sorting, add to above	101.30	ton	30.53 /ton	3,092	-	-	-		854	-	3,946
2000	Reinforcing in place, unloading & sorting, add to above	80.00	ton	24.40 /ton	1,952	-	-	-		539	-	2,491
2000	Reinforcing in place, unloading & sorting, add to above	32.032	ton	11.95 /ton	383	-	-	-		106	-	488
2210	Reinforcing in place, crane cost for handling, add to above	101.30	ton	33.184 /ton	3,361	-	-	-		928	-	4,290
2220	Reinforcing in place, crane cost for handling, add to above	233.50	ton	69.70 /ton	16,275	-	-	-		4,494	-	20,769
2220	Reinforcing in place, crane cost for handling, add to above	80.00	ton	34.133 /ton	2,731	-	-	-		754	-	3,485
	Reinforcing in place				*99,429*		*94,548*			*7,675*		*201,652*
	558.48 Labor hours											
	97.532 Equipment hours											
	CONCRETE REINFORCEMENT				**99,429**		**94,548**	**0**		**7,675**	**0**	**201,652**
	558.48 Labor hours											
	97.532 Equipment hours											
03300000	**CAST-IN-PLACE CONCRETE**											
03310220	*Concrete, ready mix*											
0300	Concrete, ready mix, regular weight, 4000 psi	1,448.00	cy	-	-	84.50 /cy	122,356	-		-	-	122,356
	Concrete, ready mix						*122,356*					*122,356*
03310240	*Concrete in place*											
2350	Conc in place, elev slab	400.71	cy	92.593 /cy	37,103	84.50 /cy	33,860	-		2,944	-	73,907
4300	Concrete in place, grade walls, 18" thick	513.200	cy	119.181 /cy	61,164	84.50 /cy	43,365	-		5,089	-	109,618
4701	Concrete in place, slab on grade, not including finish	480.60	cy	25.684 /cy	12,344	86.19 /cy	41,423	-		4,006	-	57,772
6800	Concrete in place, stairs, not incl safety treads, free stand, 3'-6" w	196.00	LFns	28.58 /LFns	5,602	5.472 /LFns	1,073	-		120	-	6,794
	Concrete in place				*116,212*		*119,721*			*12,160*		*248,092*
	198.86 Labor hours											
	198.86 Equipment hours											
03310700	*Placing concrete*											
1600	Placing conc, incl vib, elev slab, over 10" thick, pumped	12.00	cy	15.04 /cy	180	-	-	-		59	-	239

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
03310700	*Placing concrete*											
4650	Placing conc, incl vib, slab on grade, slab over 6" thick, pumped	567.00	cy	14.63 /cy	8,295	-	-	-		2,692	-	10,987
5100	Placing conc, incl vib, walls, 10" thick, pumped	13.00	cy	24.61 /cy	320	-	-	-		104	-	424
5350	Placing conc, incl vib, walls, 15" & over thick, pumped	803.00	cy	22.56 /cy	18,113	-	-	-		5,878	-	23,991
	Placing concrete				*26,908*					*8,732*		*35,640*
	79.532 Labor hours											
	79.531 Equipment hours											
03350300	*Finishing floors*											
0005	Finishing slabs, break ties, forms & patch voids	1,170.00	sf	0.96 /sf	1,120	0.03 /sf	32	-		-	-	1,151
0005	Finishing slabs, break ties, forms & patch voids	6,350.96	sf	0.47 /sf	2,976	0.03 /sf	171	-		-	-	3,148
0150	Finishing floors, monolithic, screed, float & broom finish	6,730.00	sf	0.61 /sf	4,094	-	-	-		-	-	4,094
0150	Finishing floors, monolithic, screed, float & broom finish	6,350.96	sf	0.24 /sf	1,512	-	-	-		-	-	1,512
0200	Finishing floors, monolithic, screed, float, & hand trowel	322.00	sf	0.64 /sf	206	-	-	-		-	-	206
0250	Finishing floors, monolithic, machine trowel, for finish floor	6,361.00	sf	0.56 /sf	3,543	-	-	-		-	-	3,543
0950	Finishing floors, granolithic topping, 1:1:1-1/2 mix, 2" thick	6,350.96	sf	0.85 /sf	5,367	0.583 /sf	3,703	-		-	-	9,070
	Finishing floors				*18,818*		*3,906*					*22,724*
	552.612 Labor hours											
03350350	*Finishing walls*											
0010	Finishing walls, break ties & patch voids	18,112.00	sf	0.57 /sf	10,268	0.03 /sf	489	-		-	-	10,757
0150	Finishing walls, carborundum rub, wet rub	18,112.00	sf	1.75 /sf	31,692	0.03 /sf	489	-		-	-	32,181
	Finishing walls				*41,960*		*978*					*42,938*
	1,096.14 Labor hours											
03390200	*Curing*											
0300	Curing, sprayed membrane curing compound	270.87	csf	6.60 /csf	1,787	3.16 /csf	855	-		-	-	2,642
	Curing				*1,787*		*855*					*2,642*
	22.81 Labor hours											
	CAST-IN-PLACE CONCRETE				**205,684**		**247,816**	**0**		**20,892**	**0**	**474,392**
	1,949.952 Labor hours											
	278.390 Equipment hours											
04200000	**MASONRY UNITS**											

Brown and Caldwell
Estimating and Scheduling Department
12959 South Chelsea Harbor Drive
Jacksonville, Florida 32224
Phone No. 904-992-8804
Fax No. 904-379-0250

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
04270200	*Glass block*											
0150	Glass block, no scaf, 4" thk, plain, under 1,000 SF, 8" x 8"	16.00	sf	11.543 /sf	185	8.63 /sf	138	-		-	-	323
	Glass block				*185*		*138*					*323*
	0.80 Labor hours											
	MASONRY UNITS				**185**		**138**	**0**		**0**	**0**	**323**
	0.80 Labor hours											
05500000	**METAL FABRICATIONS**											
05520700	*Railing, pipe*											
0210	Railing, pipe, aluminum, 1-1/2" diameter, clear anodized	80.00	lf	13.35 /lf	1,068	28.50 /lf	2,280	-		66	-	3,414
	Railing, pipe				*1,068*		*2,280*			*66*		*3,414*
	4.671 Labor hours											
	4.671 Equipment hours											
	METAL FABRICATIONS				**1,068**		**2,280**	**0**		**66**	**0**	**3,414**
	4.671 Labor hours											
	4.671 Equipment hours											
07100000	**DAMPPRFNG&WATERPROOFING**											
07130500	*Membrane waterproofing*											
----	T-lock pvc liner, complete installation, subcontractor	7,318.08	sf	-	-	-	-	120,748		-	-	120,748
	Membrane waterproofing							*120,748*				*120,748*
07160150	*Cementits waterproofing*											
0020	Cementitious waterproofing, 1/8" application, sprayed on	6,350.96	sf	0.394 /sf	2,501	1.572 /sf	9,984	-		776	-	13,261
	Cementits waterproofing				*2,501*		*9,984*			*776*		*13,261*
	50.81 Labor hours											
	50.81 Equipment hours											
	DAMPPRFNG&WATERPROOFING				**2,501**		**9,984**	**120,748**		**776**	**0**	**134,009**
	50.81 Labor hours											
	50.81 Equipment hours											
07200000	**THERMAL PROTECTION**											
07220700	*Roof deck insulation*											
1964	Roof deck insul., extruded polystyrene, 60 PSI comp. strength, 3" thic	6,350.96	sf	0.142 /sf	899	1.29 /sf	8,180	-		-	-	9,079

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
	Roof deck insulation				*899*		*8,180*					*9,079*
	52.141 Labor hours											
	THERMAL PROTECTION				**899**		**8,180**	**0**		**0**	**0**	**9,079**
	52.141 Labor hours											
07600000	**FLASHING & SHEET METAL**											
07650600	*Flashing*											
0060	Flashing, aluminum, mill finish, .019" thick	967.12	sf	1.241 /sf	1,201	0.77 /sf	745	-		-	-	1,945
	Flashing				*1,201*		*745*					*1,945*
	53.36 Labor hours											
	FLASHING & SHEET METAL				**1,201**		**745**	**0**		**0**	**0**	**1,945**
	53.36 Labor hours											
08100000	**METAL DOORS & FRAMES**											
08110200	*Commercial steel doors*											
0140	Commercial steel doors, flush, full panel, for narrow lite, add	2.00	ea	-	-	62.25 /ea	124	-		-	-	124
1760	Coml st doors, insulated, 1-3/4" thk, full pnl, 18 Ga., 3'-0" x 7'-0"	2.00	ea	53.29 /ea	107	242.06 /ea	484	-		-	-	591
	Commercial steel doors				*107*		*609*					*715*
	1.07 Labor hours											
08110250	*Door frames*											
0100	Door frs,st chans W/ahr&bar stops,6" chan @ 8.2#/LF,3'x7' dr,wt 150#	2.00	ea	140.70 /ea	281	108.68 /ea	217	-		17	-	516
	Door frames				*281*		*217*			*17*		*516*
	1.231 Labor hours											
	1.231 Equipment hours											
	METAL DOORS & FRAMES				**388**		**826**	**0**		**17**	**0**	**1,231**
	2.30 Labor hours											
	1.231 Equipment hours											
08300000	**SPECIALTY DOORS**											
08310350	*Floor, industrial*											
0351	Floor, industrial, steel 300 psf L.L., dbl leaf, 8' x 6' opg, 645#	1.00	opng	365.97 /opng	366	4,230.00 /opng	4,230	-		-	-	4,596
	Floor, industrial				*366*		*4,230*					*4,596*
	3.25 Labor hours											

Detailed Estimate Report

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
	SPECIALTY DOORS 3.25 Labor hours				**366**		**4,230**	**0**		**0**	**0**	**4,596**
08900000	**GLAZED CURTAIN WALL**											
08950100	*Skyroofs*											
0600	Skyroofs, continuous vaulted, semi-circular, to 20' wide, dbl glazed	165.00	hsf	13.25 /hsf	2,186	45.00 /hsf	7,425	-		-	-	9,611
	Skyroofs 11.31 Labor hours				*2,186*		*7,425*					*9,611*
	GLAZED CURTAIN WALL 11.31 Labor hours				**2,186**		**7,425**	**0**		**0**	**0**	**9,611**
09900000	**PAINTS & COATINGS**											
09910650	*Coatings & paints*											
6000	Coatings & paints, coatings, heavy duty, polyamide epoxy, finish	31.00	gal	-	-	34.37 /gal	1,065	-		-	-	1,065
6100	Coatings & paints, coatings, heavy duty, polyamide epoxy, primer	56.00	gal	-	-	34.37 /gal	1,925	-		-	-	1,925
----	Waterproofing & Moistureproofing Application, primer	89.600	csf	19.861 /csf	1,780	-	-	-		-	-	1,780
----	Waterproofing & Moistureproofing Application, 1 coat	89.600	csf	15.701 /csf	1,407	-	-	-		-	-	1,407
	Coatings & paints 71.232 Labor hours				*3,186*		*2,990*					*6,176*
	PAINTS & COATINGS 71.232 Labor hours				**3,186**		**2,990**	**0**		**0**	**0**	**6,176**
11300000	**WATER/WASTEWATER EQUIPM'T**											
11300500	*Industrial W/W equipment*											
9905	Pumps,digester sludge pump	2.00	ea	654.50 /ea	1,309	21,328.00 /ea	42,656	-		-	150	44,115
9906	Mixer, draft tube type, complete, equip # MIX12-103	1.00	ea	3,351.04 /ea	3,351	150,000.00 /ea	150,000	-		-	1,500	154,851
9907	PRV, digester pressure/vacuum assembly	2.00	ea	837.76 /ea	1,676	5,481.00 /ea	10,962	-		-	150	12,788
9908	Pumps,foam suppresion sludge recirculation pump	2.00	ea	759.22 /ea	1,518	8,372.00 /ea	16,744	-		-	150	18,412
9909	Pumps,sludge storage tank recirculation pump	2.00	ea	680.68 /ea	1,361	12,323.00 /ea	24,646	-		-	150	26,157
9911	Pumps,sludge heating recirculation pump	2.00	ea	612.61 /ea	1,225	8,372.00 /ea	16,744	-		-	150	18,119

Item	Description	Takeoff Qty		Labor Unit Cost	Labor Amount	Material Unit Cost	Material Amount	Subcontract Amount	Subcontract Name	Equipment Amount	Other Amount	Total Amount
11300500	*Industrial W/W equipment*											
9912	Waste gas burner sediment trap, complete	1.00	ea	261.80 /ea	262	3,081.00 /ea	3,081	-		-	75	3,418
9912	Waste gas burner sediment trap, complete	1.00	ea	261.80 /ea	262	3,081.00 /ea	3,081	-		-	75	3,418
9914	gas conditioning sediment trap, complete	1.00	ea	261.80 /ea	262	3,081.00 /ea	3,081	-		-	75	3,418
9915	gas conditioning drip trap, complete	1.00	ea	177.13 /ea	177	3,000.00 /ea	3,000	-		-	50	3,227
9916	Digester gas heat exchanger, complete	1.00	ea	3,403.82 /ea	3,404	9,708.00 /ea	9,708	-		-	250	13,362
9917	Digester gas moisture seperato	1.00	ea	177.13 /ea	177	2,000.00 /ea	2,000	-		-	50	2,227
9918	Digester gas booster blower unit, complete	2.00	ea	837.76 /ea	1,676	14,476.00 /ea	28,952	-		-	150	30,778
9919	Gas particulate filter, gas cond, digester	2.00	ea	177.13 /ea	354	1,500.00 /ea	3,000	-		-	100	3,454
----	Activated carbon filter	2.00	ea	3,351.04 /ea	6,702	60,000.00 /ea	120,000	-		-	1,000	127,702
----	Standpipe, digester, 12" diameter	1.00	ea	1,256.640 /ea	1,257			-		7,332	-	8,589
----	Emergency overflow, 6", glass pipe,fittings,complete	1.00	ea	3,778.82 /ea	3,779	15,000.00 /ea	15,000	-		-	-	18,779
	Industrial W/W equipment 247.20 Labor hours				*28,751*		*452,655*			*7,332*	*4,075*	*492,813*
11390900	*Wastwtr treatment system*											
9801	Arrestor, flame, digester	1.00	ea	225.15 /ea	225	4,061.00 /ea	4,061	-		-	-	4,286
	Wastwtr treatment system 2.15 Labor hours				*225*		*4,061*					*4,286*
	WATER/WASTEWATER EQUIPM'T 249.35 Labor hours				**28,977**		**456,716**	**0**		**7,332**	**4,075**	**497,100**
13800000	**BUILDING AUTOMATN&CONTROL**											
13838200	*Control components*											
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	2.00	ea	29.87 /ea	60	47.00 /ea	94	-		-	-	154
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	2.00	ea	29.87 /ea	60	47.00 /ea	94	-		-	-	154
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	2.00	ea	29.87 /ea	60	47.00 /ea	94	-		-	-	154
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	1.00	ea	29.87 /ea	30	47.00 /ea	47	-		-	-	77
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	1.00	ea	29.87 /ea	30	47.00 /ea	47	-		-	-	77
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	5.00	ea	29.87 /ea	149	47.00 /ea	235	-		-	-	384
3022	Pressure gauge, aluminum case, 0 - 300 PSI, 3.5" dia dial	1.00	ea	29.87 /ea	30	47.00 /ea	47	-		-	-	77

Brown and Caldwell
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D

APPENDIX D – VENDOR QUOTES

APPENDIX D.1 – CENTRIFUGE EQUIPMENT

BIRD

November 7, 2002

Brown and Caldwell
9665 Chesapeake Drive, Suite 201
San Diego, CA 92123

Ph: 858-571-6749
Fax: 858-514-8833

Attention: Ken Fonda

Reference: Riverside WWTP

Subject: Centrifuge Budget Sizing and Pricing

Dear Ken,

Per your request and based on our recent discussions, I am pleased to offer the following budget sizing and pricing. The sizing we are calling out is subject to change as more details of the Riverside project are determined.

Phase 1

Number of Refurbished BP's	2
Belt Press flow	150 gpm
BP Feed Solids	2.5%
Total BP Solids	3,753 lb/hr (total for both)
Quantity of Centrifuges	2 (1 standby)
Flow per Centrifuge	210 gpm
Feed Solids	2.5%
Total Discharge Solids	2,630 lb/hr (for 1 centrifuge)
Total Solids	6,383 lb/hr

Phase 2

Number of Centrifuges	4 (1 standby)
Flow per Centrifuge	170 gpm
Feed Solids	2.5%
Cent. Discharge Solids	6,383 lb/hr (2,128 lb/hr each)

Based on the above and assuming a 60/40 primary to secondary sludge blend, we would recommend our CP 3074 (26.5" x 105") for Phase 1 and Phase 2. It is conceivable that our CP 3054 (22" x 91") could work, but the anticipated loss in performance (lower solids, higher poly, low centrate quality) deems this option as unacceptable in our opinion.

The CP 3074 at 210 gpm (phase 1) and 170 gpm (phase 2) will yield the highest cake solids, produce the better centrate, and consume lower polymer. Depending on the flow rate, you should expect 25-28% cake solids using 15-20 pounds per dry ton of polymer.

The Budget range for the CP 3074 is between $450K and $525K each, depending on the exact scope of supply and control package.

Our typical scope includes:

- Flame sprayed tungsten carbide or STC Tiles
- Carbon Steel or Duplex Stainless Steel Bowl and Scroll
- Starter panels with wye/delta main drive
- Hydraulic scroll drive
- Flex connectors for feed, liquids and solids
- Control panel with A/B PLC
- Carbon steel panels
- Standard 2 weeks of start up service (8 days on site) per unit
- 1 set of standard tools per order
- Freight to site
- Standard spare parts

I look forward to you review and further discussion relating to the centrifuges for Riverside. I would also be happy to provide additional information (drawings, specifications) if requested.

If you have any questions, feel free to contact me at 303-250-0055.

Best regards,
Bird/Humboldt Centripress

Scott Kelly
Western Regional Sales Manager

CC: Carl Petty – Pacific Process

CP 3054 vs. CP 3074 Comparison Chart

	CP 3054	CP 3074	Comparison Factor
Bowl Diameter inches	21.7	26.4	1.22
Bowl Length inches	91.3	105.5	1.16
RPM	3,140	2,850	0.91
Volume (gal)	87.0	141.0	1.62
G @ Bowl Wall	3,038	3,045	1.0
G-Volume (gal)	264,412	429,275	1.62

As you can see, the CP 3074 offers 1.62 greater G-Volume than the 3054, which in turn translates into:

- Higher cake solids.
- Lower polymer consumption.
- Better centrate quality
- More throughput for future possible plant expansion.
- More throughput for emergency catch-up situations
- Less wear and tear on the centrifuge throughout its life.

We feel that the upside with designing around a larger centrifuge far outweighs the cost savings realized with a smaller centrifuge.

Options

For your reference, the following specifiable options are available from Bird Humboldt for any centrifuge we produce:

Bowl/Scroll: Duplex Stainless Steel or Carbon Steel
Flight Hardening: Sintered Tungsten Carbide Tiles or Flame Sprayed Hardening
Back Drive: Hydraulic or Electric VFD

We can offer any combination of the above as specified by the owner/engineer.

March 14, 2003

To: Mr. Ken Fonda
Brown And Caldwell

Alfa Laval
5400 International Trade Drive
Richmond, VA23231

Tel: +1 804-222- 5300
Fax: +1 804-236-1364
www.alfalaval.com

Subject: **City of Riverside WWTP**

Mr. Fonda:

We are pleased to provide you with our budget price for the above referenced project.

(1) Alfa Laval ALDEC 606 Decanter Centrifuge capable of dewatering sludge to 225 gpm. The units will be complete per the Alfa Laval scope of supply and dimension drawing and include the following:

- Centrifuge frame
- Upper casing constructed of Stainless Steel
- Pillow Block Bearings with forced oil lubrication system
- Centrifuge rotating assembly
- Conveyor drive gearbox
- Conveyor flight hardsurface protection; Sintered Tungsten Carbide (STC) tile assemblies; feed Nozzles shall be STC inserts. All STC to meet the ASTM G-65 Test Procedure A.
- 50 Hp AC/VFD Backdrive motor
- 150 Hp AC/VFD Main drive motor
- Nema 4X operator panel, floor-stand mounted
- Nema 12 free standing starter panel
- Decanter Logic Manager Plus (DLMP) for control of the centrifuge backdrice and dewatering system ancillary equipment.
- Vibration isolators & Vibration switch
- Belt guards
- Solids discharge flexible splash guard
- Feed, polymer, and centrate flexible connectors
- One (1) set required tools for maintenance
- One (1) year warranty against defects
- One (1) set required lubricants
- Eight (8) sets submittal drawings
- Eight (8) sets of Operation and Maintenance Manuals
- Freight to job-site

Subject: **City of Riverside WWTP**

- Alfa Laval shall provide for a total of fifteen (15) days of field service supervision for the purposes of checking the installation of the contractor, start-up and training. Additional days of field service may be purchased at published rates.

Not included in our pricing are the following:

- Field wiring and electrical flexible connections
- Piping & valves
- Anchor bolts
- Conveyors and diverter gates
- Polymer & polymer system
- Solid & Centrate discharge chutes
- Taxes
- Unloading at job-site
- Installation
- Bonds

BUDGET PRICE: **One (1) ALDEC 606 Centrifuge................. $440,000**

Pricing is valid for 60 days. After 60 days pricing may escalate based on the Euro/$ exchange rate in effect at the time of order.

TERMS OF PAYMENT:
25% upon submittals, net 30 days
70% upon delivery, net 30 days
5% upon acceptance, net 180 from delivery

DELIVERY:
Decanter Centrifuge 26 - 30 weeks
Controls-12 weeks

DRAWING SCHEDULE: Drawings for Approval to be submitted within ten (10) weeks of acceptable purchase order.

WARRANTY STATEMENT

1. Warranty is for one (1) year after acceptance or eighteen (18) months after delivery, whichever occurs first. Our warranty is for replacement parts only. Labor for installation is the responsibility of the owner. Alfa Laval will provide supervision at its sole discretion for replacement of major parts (such as bearings) that fail under the warranty period.
2. Alfa Laval considers the equipment accepted and the warranty to begin:
   Upon beneficial use of the equipment, or
   Upon written acceptance of the equipment by the Owner, whichever comes first.

Subject: **City of Riverside WWTP**

We thank you for this opportunity to provide our budget price for this project. Please contact our representative, Mr. Rick Eismin of Coombs Hopkins Co. (760) 931-0555 if you have any questions.

Kind regards,

Michael Berry
Application Engineer

CC: Rick Eismin – Coombs Hopkins

March 14, 2003

To: Mr. Ken Fonda
Brown And Caldwell

Alfa Laval
5400 International Trade Drive
Richmond, VA23231

Tel: +1 804-222- 5300
Fax: +1 804-236-1364
www.alfalaval.com

Subject: **City of Riverside WWTP**

Mr. Fonda:

We are pleased to provide you with our budget price for the above referenced project.

(1) Alfa Laval ALDEC 706 Decanter Centrifuge capable of dewatering sludge between 200 – 350 gpm. The units will be complete per the Alfa Laval scope of supply and dimension drawing and include the following:

- Centrifuge frame
- Upper casing constructed of Stainless Steel
- Pillow Block Bearings with forced oil lubrication system
- Centrifuge rotating assembly
- Conveyor drive gearbox
- Conveyor flight hardsurface protection; Sintered Tungsten Carbide (STC) tile assemblies; feed Nozzles shall be STC inserts. All STC to meet the ASTM G-65 Test Procedure A.
- 50 Hp AC/VFD Backdrive motor
- 200 Hp AC/VFD Main drive motor
- Nema 4X operator panel, floor-stand mounted
- Nema 12 free standing starter panel
- Decanter Logic Manager Plus (DLMP) for control of the centrifuge backdrice and dewatering system ancillary equipment.
- Vibration isolators & Vibration switch
- Belt guards
- Solids discharge flexible splash guard
- Feed, polymer, and centrate flexible connectors
- One (1) set required tools for maintenance
- One (1) year warranty against defects
- One (1) set required lubricants
- Eight (8) sets submittal drawings
- Eight (8) sets of Operation and Maintenance Manuals
- Freight to job-site

Subject: **City of Riverside WWTP**

- Alfa Laval shall provide for a total of fifteen (15) days of field service supervision for the purposes of checking the installation of the contractor, start-up and training. Additional days of field service may be purchased at published rates.

Not included in our pricing are the following:

- Field wiring and electrical flexible connections
- Piping & valves
- Anchor bolts
- Conveyors and diverter gates
- Polymer & polymer system
- Solid & Centrate discharge chutes
- Taxes
- Unloading at job-site
- Installation
- Bonds

BUDGET PRICE:	**One (1) ALDEC 706 Centrifuge................. $550,000** Pricing is valid for 60 days. After 60 days pricing may escalate based on the Euro/$ exchange rate in effect at the time of order.
TERMS OF PAYMENT:	25% upon submittals, net 30 days 70% upon delivery, net 30 days 5% upon acceptance, net 180 from delivery
DELIVERY:	Decanter Centrifuge 26 - 30 weeks Controls-12 weeks
DRAWING SCHEDULE:	Drawings for Approval to be submitted within ten (10) weeks of acceptable purchase order.

WARRANTY STATEMENT

1. Warranty is for one (1) year after acceptance or eighteen (18) months after delivery, whichever occurs first. Our warranty is for replacement parts only. Labor for installation is the responsibility of the owner. Alfa Laval will provide supervision at its sole discretion for replacement of major parts (such as bearings) that fail under the warranty period.
2. Alfa Laval considers the equipment accepted and the warranty to begin:
   Upon beneficial use of the equipment, or
   Upon written acceptance of the equipment by the Owner, whichever comes first.

Subject: **City of Riverside WWTP**

We thank you for this opportunity to provide our budget price for this project. Please contact our representative, Mr. Rick Eismin of Coombs Hopkins Co. (760) 931-0555 if you have any questions.

Kind regards,

Michael Berry
Application Engineer

CC: Rick Eismin – Coombs Hopkins

APPENDIX D.2 – HEAT DRYING EQUIPMENT

FENTON ENVIRONMENTAL TECHNOLOGIES

4306 Hwy. 377 South SludgeMASTER / SludgeMIZER / SludgeMASTER IRC / SludgeMASTER RK Telephone 800-777-1373
Brownwood, TX 76801 "SOLID SOLUTIONS FOR SLUDGE HANDLING PROBLEMS" Fax 915-646-7027

02/27/03

Carl Petty
Pacific Process
14060 Honeysuckle Lane
Whittier, CA 90604

Subject: Riverside, CA
Brown & Caldwell Project # BC064-9

Dear Sir;

In accordance with our phone conversation with Ken Fonda of Brown & Caldwell I would like to submit the following for your consideration.

1. Current solids production is approximately 19 d.t./day @ 7 days/week.
2. Planned cake from a new centrifuge = 25% d.s.
3. Present plant operation = 16 hrs./day @ 5 days per week.
4. Future plant build out = 56.5 d.t./day @ 7days per week.
5. SludgeMASTER RK automatic batch cycle time = approximately 3 hrs.

Therefore:

19 d.t./day X 7 days/week div. by 5 days/week = 26.60 d.t./day.

26.6 d.t./day div. by .25 (%) = 106.4 wet tons/day @ 25% d.s.

106.4 wet tons/day div. by 18 hrs./day* = 5.91 wet tons/hr.

SludgeMASTER RK 72E – D = 3 wet tons per hr. X 2 dehydration chambers = 6 wet tons/hr.

*The dryer will be programmed to shut off automatically after the sixth (6^{th}) batch is completed. This means that the unit will run unattended for only 2 hrs./day at the initial sludge feed rate.

Any multiple additional d-chambers may be planned for and added to the initial installation.The anticipated build out is approximately 56.5 d.t./day or 226 wet tons per day @ 25% d.s.

The 226 wet tons per day production rate would require one duplicate RK 72E-D be installed for slightly over an 18 hr. operating day @ 7 days per week.

Of course you may want a different operating scenario for the final build out.

Budget:

One (1) SludgeMASTER RK 72E-D complete with a 75 cu.yd. hopper.	$1,778,780
Additional burner capacity for utilizing digester gas.	$ 46,000
Four (4) BioMaster biofilters for odor control.	$ 80,000
Setup and reconnection of shipping splits.	$ 40,000
Freight	$ 18,000
Performance Bond	$ 48,700
Estimated Total Price	$2,011,480

As this project matures we will be pleased to work out the specific details on the necessary equipment package.

Meanwhile if you have any questions or we may be of help in any way please call on us.

Best Regards;

Neil M. Campbell
Sales Director
210 497 0508

SCHWING
AMERICA INC.

98 Mill Plain Road
Suite 1A
Danbury, CT 06811

Phone: 203.744.2100
Fax: 203.744.2837
Subsidiary of: Schwing GmbH

February 25th, 2003

Brown & Caldwell
9665 Chesapeake Drive
Suite 201
San Diego, CA 92123

Attention: Mr. Ken Fonda

Subject: InnoDryer options

Dear Mr. Fonda,

Please find below a summary of InnoDryer machines per the various operating scenarios you have specified. Note that the dryers are sized for the capacity noted in the table. If you are considering multiple trains of dryers, you must multiply the number of machines by the increased capacity.

Example: Option 1 is sized for a weekly production of 50 dry tons operating 5 days a week, 16 hours per day. This requires (1) InnoDryer model G3.5. If you wish to process 100 dry tons while operating 5 days a week, 16 hours per day you will need (2) G3.5's.

If you have any questions regarding this information, please do not hesitate to contact me by phone at (651) 653-4231, fax (651) 653-5481, or via Email (cwanstrom@schwing.com).

SUMMARY

	Option 1	Option 2	Option 3	Option 4
Weekly Production	50 Dry Ton	50 Dry Ton	125 Dry Ton	125 Dry Ton
Weekly Operation	5 Days	7 Days	5 Days	7 Days
Daily Operation	16 Hours	24 Hours	16 Hours	24 Hours
Initial Solids Content	25%	25%	25%	25%
End Product Solids Content	80%	80%	80%	80%
Evaporation Rate	3,437 Lbs/hr	1,637 Lbs/hr	8,594 Lbs/hr	4,092 Lbs/hr
Model	G3.5	G2	G4	G4
Quantity	1	1	2	1
Dimension (LxWxH)	60'x36'x28	50'x30'x22'	66'x36'x28'	66'x36'x28'
Budget Price	$1,450,000	$1,100,000	$3,100,000	$1,550,000

	Option 1A	Option 2A	Option 3A	Option 4A
Initial Solids Content	25%	25%	25%	25%
End Product Solids Content	90% Class A	90% Class A	90% Class A	90% Class A
Evaporation Rate	3,611Lbs/hr	1,719 Lbs/hr	9,028 Lbs/hr	4,299 Lbs/hr
Model	G4	G2.5	G4-Qty 2	G4
Quantity	1	1	2	1
Dimension (LxWxH)	66'x36'x28'	52'x33'x26'	66'x36'x28'	66'x36'x28'
Budget Price	$1,550,000	$1,250,000	$3,100,000	$1,550,000

Yours very truly
Schwing America, Inc.

Chuck Wanstrom

Chuck Wanstrom
Regional Manager
Material Handling Group

Cc: Bernie Pawlowski – Saddleback Environmental

Komline-Sanderson
12 Holland Av Peapack, NJ 07977-0257
908-234-1000 Fax: 908-234-9487
www.komline.com

February 25, 2003

Email: Kfonda@brwncald.com

Kenneth D. Fonda
Principal Environmental Engineer
Brown and Caldwell
9665 Chesapeake Drive, Suite 201
San Diego, CA 92123

Re: Komline-Sanderson Proposal TPG-2369 Rev. B

Dear Ken,

Per your request for additional pricing information for drying equipment to handle anaerobically digested belt filter press sludge cake, Komline-Sanderson is pleased to offer the following for your review and consideration.

In the interest of brevity, please refer to our previous quotation TPG-2369 Rev A for general equipment descriptions of the equipment being offered. Pertinent data regarding each of the four (4) cases and the equipment offered are tabulated below.

Process Conditions

	Case A	Case B	Case C	Case D
Dryer Feed Rate (Dry Tons)	20 DT/day	10 DT/day	125 DT/wk	50 DT/wk
No. of Drying Lines	One (1)	Two (2)	One (1)	Two (2)
Dryer Operation	15 Hrs/Day	15 Hrs/Day	24 Hrs/Day	24 Hrs/Day
Wet (lbs/hr) per dryer	14,815	7,407	8,267	3,307
Solids (lbs/hr) per dryer	2,667	1,333	1,488	595
Evaporative Rate (lbs/hr)	12,000	6,000	6,700	2,680
Heat Load (MBTU/Hr) per Dryer	13.5	6.9	7.7	3.1

For all cases, Thermal Oil at 380°F was used as the heat transfer medium. An overall heat transfer rate of 26 Btu/(hr·ft^2·°F) was used with a repletion rate of approximately 85%. The initial solids content was assumed to be 18%. Product exiting the dryer will be above 95% solids and at an approximate temperature of 240°F. Product exiting the product cooler will be below 120°F.

Equipment Offered

	Case A	Case B	Case C	Case D
Dryer Feed Rate (Dry Tons)	20 DT/day	10 DT/day	125 DT/wk	50 DT/wk
No. of Drying Lines	One (1)	Two (2)	One (1)	Two (2)
Wet Cake Feed Silo	60 cyd	60 cyd	60 cyd	60 cyd
Amount of Storage at Design Rate	6.8 hrs	6.8 hrs	12.2 hrs	18.8 hrs
Number of Feed Pumps Supplied	Two (2)	Three (3)	Two (2)	Three (3)
Number of Pumps in Operation	One (1)	Two (2)	One (1)	Two (2)
Dryer Model Number	17W-4000	13W-2000	13W-2200	9W-840
Number of Dryers	One (1)	Two (2)	One (1)	Two (2)
Surface Area / Dryer	4000	2000	2200	840
Volumetric Capacity (cft)	1580	625	680	220
Dryer Empty Weight (tons)	133	53	56	29
Connected HP (per dryer)	400	200	200	75
Discharge Conveyor	One (1) 16"	Two (2) 12"	One (1) 12"	Two (2) 9"
Incline Cooling Conveyor	One (1) 16" double shaft	Two (2) 16" single shaft	One (1) 16" single shaft	Two (2) 12" single shaft
Product Delumper and Pneumatic Conveyor to Silo	One (1)	Two (2)	One (1)	Two (2)
Product Silo	One (1) 3,500 cft	One (1) 3,500 cft	One (1) 3,500 cft	One (1) 3,500 cft
Outlet Spray Duct, Condenser, Exhaust Compressor w/ Bubbler	One (1)	Two (2)	One (1)	Two (2)
Thermal Oil Heater	14 MBTUH	8.6 MBTU	8.6 MBTU	3.7 MBTUH
No. of Thermal Oil Heaters w/ Expansion Tank, I & C	One (1)	Two (2)	One (1)	Two (2)
Hot Oil Flow Rate per Dryer	1450 gpm	950 gpm	950 gpm	500 gpm
No. of Hot Oil Pumps	Two (2)	Two (2)	One (1)	Two (2)
Instrumentation and Control Package. MCC not included	One (1)	Two (2)	One (1)	Two (2)
Total Estimated Connected HP	638	765	398	395
Estimated HP Consumption	400	493	259	247
Tot. Gas Consumption (Therms/hr)	172.4	172.4	96.2	77.0
Utility Costs	$102.93/hr	$108.83/hr	$59.71/hr	$50.29/hr
Utility Cost $/Dry Ton	$13.90	$14.69	$14.44	$15.21

	Case A	**Case B**	**Case C**	**Case D**
Dryer Feed Rate (Dry Tons)	20 DT/day	10 DT/day	125 DT/wk	50 DT/wk
No. of Drying Lines	One (1)	Two (2)	One (1)	Two (2)
Price	$2,547,000	$3,421,000	$1,897,000	$2,440,000

Prices are F.O.B Peapack, NJ. Prices quoted are exclusive of any local, State, or Federal sales or manufacture's taxes of any sort and such taxes and/or charges pertaining thereto are to be borne by the purchaser.

If you have any questions regarding the above information, or if additional information is required, please do not hesitate to contact us at your convenience.

Yours truly,

George M. Fraunfelder

Vice President

K-S	KOMLINE-SANDERSON PADDLE DRYER SIZING CALCULATIONS w/ Thermal Oil	**Komline-Sanderson** 12 Holland Ave Peapack, NJ 07977 TEL: (908) 234-1000 FAX: (908) 234-9487

COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 1**

Input Parameter

	20	Dry Tons per Day	15 Hour/Day Operation
Feed Rate	2667	Dry Lbs/Hr	
% Solids in Feed	18%	Feed Solids	
% Solids in Product	95%	Product Solids	
Solids Specific Heat	0.3	Btu/Lb·°F	
Liquid Specific Heat	1.0	Btu/Lb·°F	
Heat of Vaporization	970.3	Btu/Lb	
Liquid Boiling Point	212	°F	
Initial Temperature	70	°F	
Product Temperature	240	°F	
Oil Temp In	380	°F	
Oil Temp Out	341	°F	
Oil Flow Required	1,450	gpm (calculated on page 2)	

Material Balance

		Feed	Product	Off Gas
Solids	Lbs/Hr	2,667	2,667	-
Water	Lbs/Hr	12,148	140	12,008
Total	Lbs/Hr	14,815	2,807	12,008

Heat Load

Sensible Heat		1,838,637	Btu/Hr	13.6%	Percent of Heat Load
Latent Heat		11,651,166	Btu/Hr	86.2%	Percent of Heat Load
Final Heating Zone		26,330	Btu/Hr	0.2%	Percent of Heat Load
Total Heat Load		13,516,133	Btu/Hr - Process Load		
Dryer Efficiency	98%	13,791,972	Btu/Hr Heat to Dryer		

Logarithmic-Mean Temperature Difference

Sensible Heat Zone	215.3	°F	x	13.6%	=	29.3	°F
Latent Heat Zone	147.5	°F	x	86.2%	=	127.1	°F
Final Heating Zone	134.3	°F	x	0.2%	=	0.3	°F
						156.7	°F

Dryer Sizing

Repletion Rate	85%	
Overall Heat Transfer Rate	26	Btu/hr·ft²·°F
Area Required	3,904	Square Feet

KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

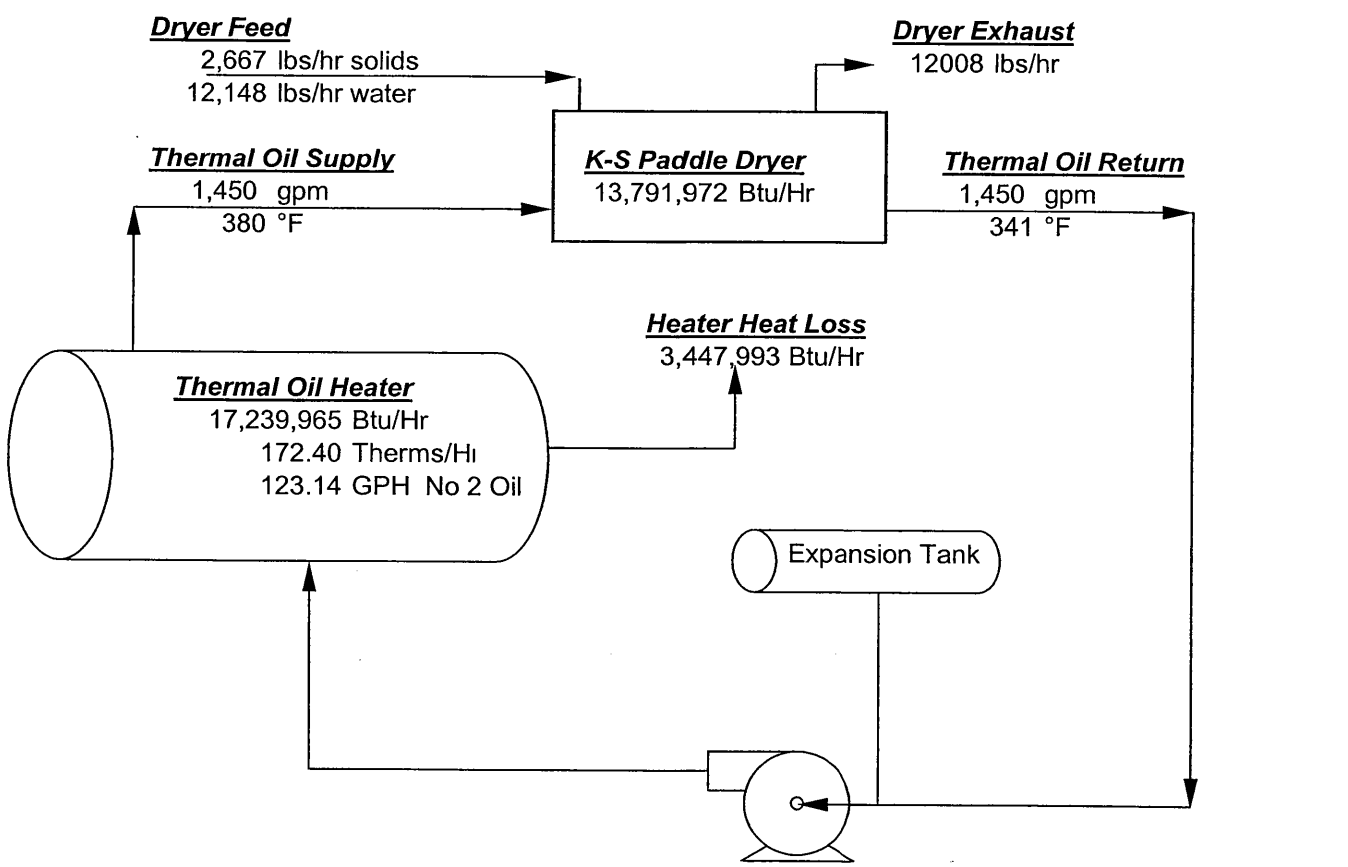
COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 1**

Thermal Oil Parameters

Thermal Oil Type	Paratherm HE or equal	
Oil Density @ Temp	6.2	Lbs/Gal
Oil Spefic Heat @ Temp	0.65	Btu/Lb-°F
Total Hot Oil Mass Flow	539,400	Lbs/Hr
Hot Oil Volume Flow	1,450	gpm

Thermal Oil Heater Requirements

Total Energy Required	13,791,972	BTU/Hr
Boiler Efficiency	80%	
Boiler Energy Needs	17,239,965	BTU/Hr
Therms Required	172.40	Therms/Hr
GPH No.2 Oil	123.14	GPH



K-S	KOMLINE-SANDERSON PADDLE DRYER SIZING CALCULATIONS w/ Thermal Oil	***Komline-Sanderson*** 12 Holland Ave Peapack, NJ 07977 TEL: (908) 234-1000 FAX: (908) 234-9487

COMPANY: Brown & Caldwell — Proj # TPG-2369 — February 25, 2003
LOCATION: Riverside, CA — **CASE 1**

Electric Costs

Electricity Costs	$ 0.085	per Kw		
System HP Required	400	HP		
kW Required	298.3	per hour	$ 25.35	per hour

Oil / Gas Costs for Hot Oil Heater / Boiler

Gas	$ 0.45	per Therm		
Gas Required	172.40	Therms/Hr	$ 77.58	per hour

Utility Costs

Dry Tons per Hour	1.33	Dry tons per Hour
Utilities Cost	$ 102.93	$ / Hr
Cost per Dry Ton	$ 77.20	per Dry Ton
Cost per Wet Ton	$ 13.90	per Wet Ton

KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 2**

Input Parameter

	10	Dry Tons per Day	15	Hour/Day Operation
Feed Rate	1333	Dry Lbs/Hr		
% Solids in Feed	18%	Feed Solids		
% Solids in Product	95%	Product Solids		
Solids Specific Heat	0.3	Btu/Lb·°F		
Liquid Specific Heat	1.0	Btu/Lb·°F		
Heat of Vaporization	970.3	Btu/Lb		
Liquid Boiling Point	212	°F		
Initial Temperature	70	°F		
Product Temperature	240	°F		
Oil Temp In	380	°F		
Oil Temp Out	350	°F		
Oil Flow Required	950	gpm (calculated on page 2)		

Material Balance

		Feed	Product	Off Gas
Solids	Lbs/Hr	1,333	1,333	-
Water	Lbs/Hr	6,074	70	6,004
Total	Lbs/Hr	7,407	1,404	6,004

Heat Load

Sensible Heat	919,319	Btu/Hr	13.6%	Percent of Heat Load
Latent Heat	5,825,583	Btu/Hr	86.2%	Percent of Heat Load
Final Heating Zone	13,165	Btu/Hr	0.2%	Percent of Heat Load
Total Heat Load	6,758,066	Btu/Hr - Process Load		

Dryer Efficiency 98% 6,895,986 Btu/Hr Heat to Dryer

Logarithmic-Mean Temperature Difference

Sensible Heat Zone	219.2	°F	x	13.6%	=	29.8	°F
Latent Heat Zone	152.5	°F	x	86.2%	=	131.5	°F
Final Heating Zone	139.0	°F	x	0.2%	=	0.3	°F
						161.6	°F

Dryer Sizing

Repletion Rate	85%	
Overall Heat Transfer Rate	26	Btu/hr·ft²·°F
Area Required	1,893	Square Feet

KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

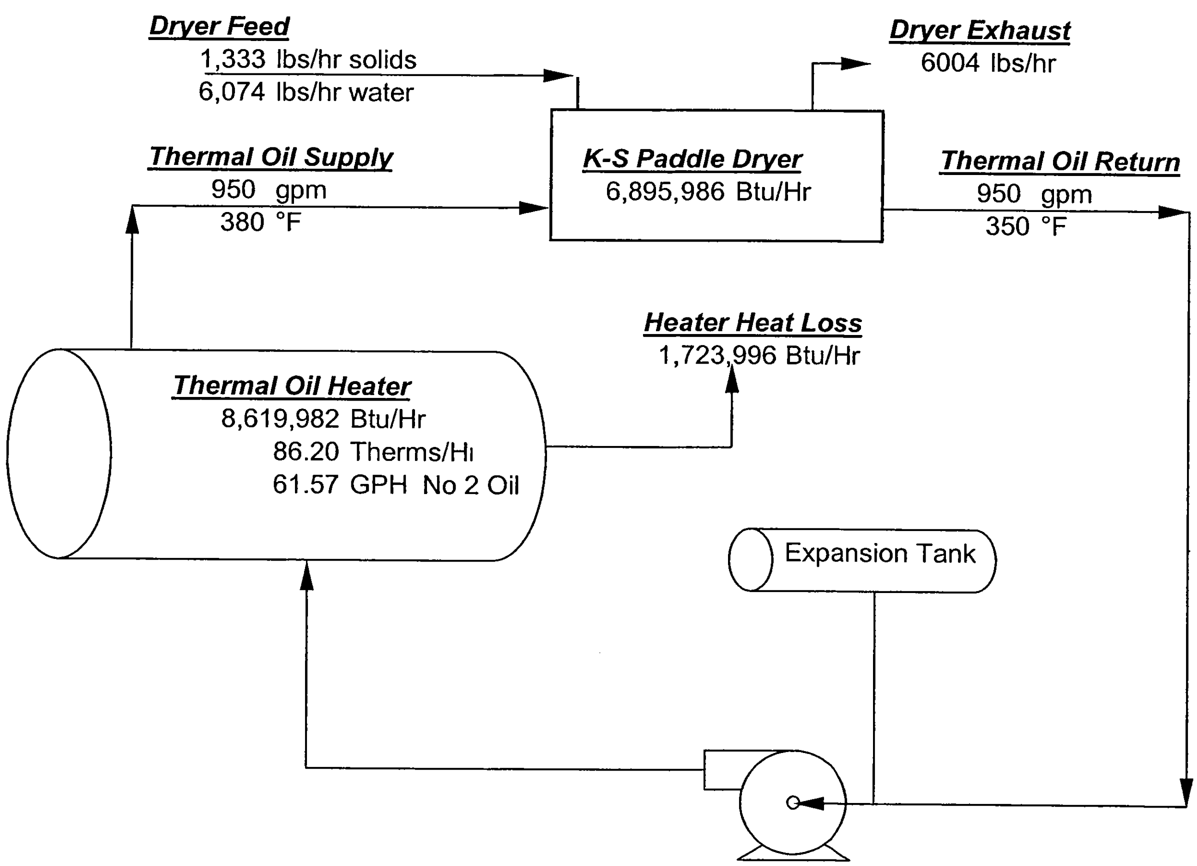
COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 2**

Thermal Oil Parameters

Thermal Oil Type	Paratherm HE or equal	
Oil Density @ Temp	6.2	Lbs/Gal
Oil Spefic Heat @ Temp	0.65	Btu/Lb-°F
Total Hot Oil Mass Flow	353,400	Lbs/Hr
Hot Oil Volume Flow	950	gpm

Thermal Oil Heater Requirements

Total Energy Required	6,895,986	BTU/Hr
Boiler Efficiency	80%	
Boiler Energy Needs	8,619,982	BTU/Hr
Therms Required	86.20	Therms/Hr
GPH No.2 Oil	61.57	GPH



	KOMLINE-SANDERSON PADDLE DRYER SIZING CALCULATIONS w/ Thermal Oil	**Komline-Sanderson** 12 Holland Ave Peapack, NJ 07977 TEL: (908) 234-1000 FAX: (908) 234-9487

COMPANY: Brown & Caldwell Proj # TPG-2369 February 25, 2003
LOCATION: Riverside, CA **CASE 2**

Electric Costs

Electricity Costs	$ 0.085	per Kw		
System HP Required	493	HP		
kW Required	367.6	per hour	$ 31.25	per hour

Oil / Gas Costs for Hot Oil Heater / Boiler

Gas	$ 0.45	per Therm		
Gas Required	86.20	Therms/Hr	$ 38.79	per hour
Gas for Two Systems	172.40		$ 77.58	

Utility Costs

Dry Tons per Hour	1.33	Dry tons per Hour	(Two Systems)
Utilities Cost	$ 108.83	$ / Hr	
Cost per Dry Ton	$ 81.62	per Dry Ton	
Cost per Wet Ton	$ 14.69	per Wet Ton	

KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

COMPANY: Brown & Caldwell — Proj # TPG-2369 — February 25, 2003
LOCATION: Riverside, CA — **CASE 3**

Input Parameter

	125	Dry Tons per Week	24	Hour/Day Operation
Feed Rate	1488	Dry Lbs/Hr		
% Solids in Feed	18%	Feed Solids		
% Solids in Product	95%	Product Solids		
Solids Specific Heat	0.3	Btu/Lb·°F		
Liquid Specific Heat	1.0	Btu/Lb·°F		
Heat of Vaporization	970.3	Btu/Lb		
Liquid Boiling Point	212	°F		
Initial Temperature	70	°F		
Product Temperature	240	°F		
Oil Temp In	380	°F		
Oil Temp Out	346	°F		
Oil Flow Required	950	gpm (calculated on page 2)		

Material Balance

		Feed	Product	Off Gas
Solids	Lbs/Hr	1,488	1,488	-
Water	Lbs/Hr	6,779	78	6,701
Total	Lbs/Hr	8,267	1,566	6,701

Heat Load

Sensible Heat		1,026,025	Btu/Hr	13.6%	Percent of Heat Load
Latent Heat		6,501,767	Btu/Hr	86.2%	Percent of Heat Load
Final Heating Zone		14,693	Btu/Hr	0.2%	Percent of Heat Load
Total Heat Load		7,542,485	Btu/Hr - Process Load		
Dryer Efficiency	98%	7,696,413	Btu/Hr Heat to Dryer		

Logarithmic-Mean Temperature Difference

Sensible Heat Zone	217.8	°F	x	13.6%	=	29.6	°F
Latent Heat Zone	150.6	°F	x	86.2%	=	129.8	°F
Final Heating Zone	137.2	°F	x	0.2%	=	0.3	°F
						159.7	°F

Dryer Sizing

Repletion Rate	85%	
Overall Heat Transfer Rate	26	Btu/hr·ft²·°F
Area Required	2,137	Square Feet

KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

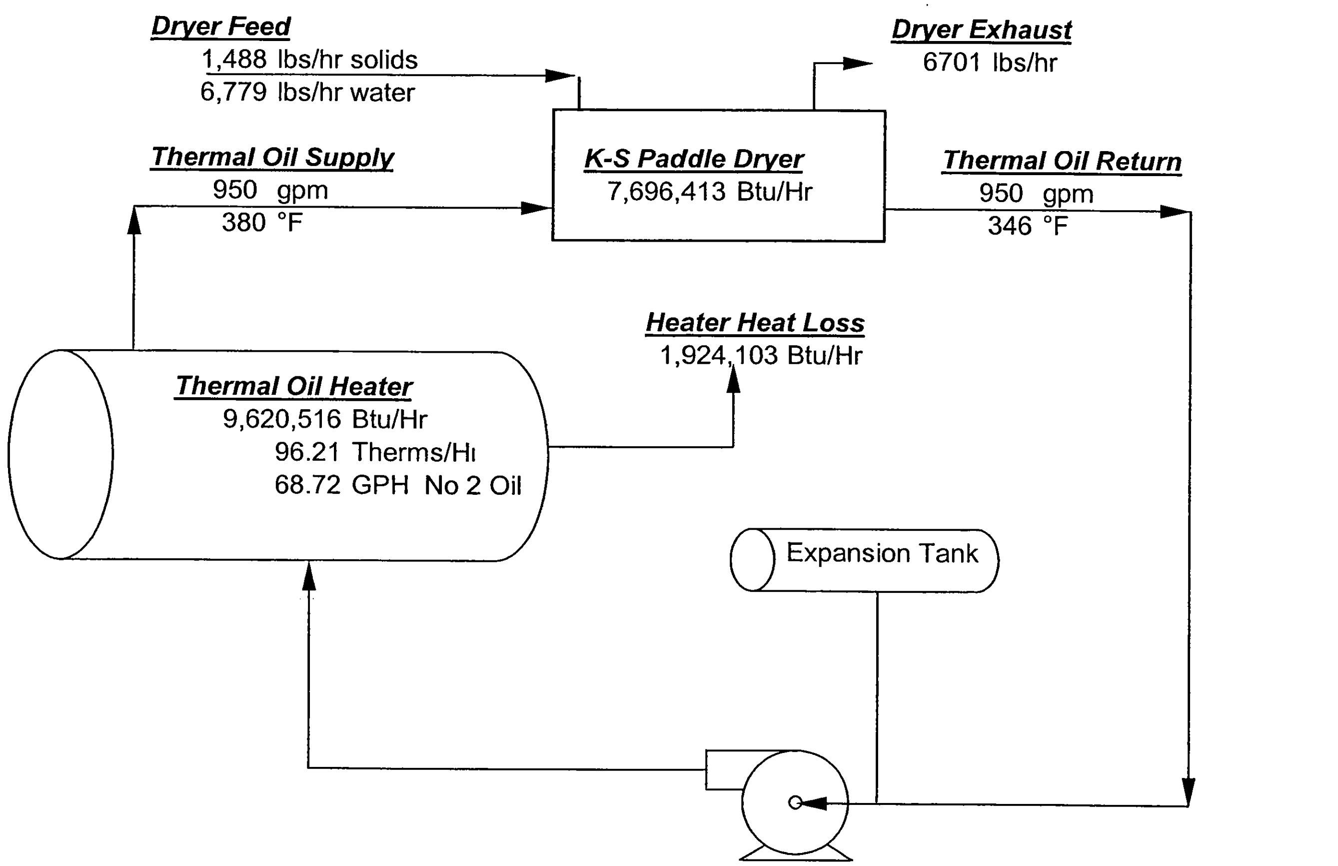
COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 3**

Thermal Oil Parameters

Thermal Oil Type	Paratherm HE or equal	
Oil Density @ Temp	6.2	Lbs/Gal
Oil Spefic Heat @ Temp	0.65	Btu/Lb-°F
Total Hot Oil Mass Flow	353,400	Lbs/Hr
Hot Oil Volume Flow	950	gpm

Thermal Oil Heater Requirements

Total Energy Required	7,696,413	BTU/Hr
Boiler Efficiency	80%	
Boiler Energy Needs	9,620,516	BTU/Hr
Therms Required	96.21	Therms/Hr
GPH No.2 Oil	68.72	GPH



KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 3**

Electric Costs

Electricity Costs	$ 0.085	per Kw		
System HP Required	259	HP		
kW Required	193.1	per hour	$ 16.42	per hour

Oil / Gas Costs for Hot Oil Heater / Boiler

Gas	$ 0.45	per Therm		
Gas Required	96.21	Therms/Hr	$ 43.29	per hour

Utility Costs

Dry Tons per Hour	0.74	Dry tons per Hour
Utilities Cost	$ 59.71	$ / Hr
Cost per Dry Ton	$ 80.25	per Dry Ton
Cost per Wet Ton	$ 14.44	per Wet Ton

K-S	KOMLINE-SANDERSON PADDLE DRYER SIZING CALCULATIONS w/ Thermal Oil	***Komline-Sanderson*** 12 Holland Ave Peapack, NJ 07977 TEL: (908) 234-1000 FAX: (908) 234-9487

COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 4**

Input Parameter

	50	Dry Tons per Week	24	Hour/Day Operation
Feed Rate	595	Dry Lbs/Hr		
% Solids in Feed	18%	Feed Solids		
% Solids in Product	95%	Product Solids		
Solids Specific Heat	0.3	Btu/Lb·°F		
Liquid Specific Heat	1.0	Btu/Lb·°F		
Heat of Vaporization	970.3	Btu/Lb		
Liquid Boiling Point	212	°F		
Initial Temperature	70	°F		
Product Temperature	240	°F		
Oil Temp In	380	°F		
Oil Temp Out	355	°F		
Oil Flow Required	500	gpm (calculated on page 2)		

Material Balance

		Feed	Product	Off Gas
Solids	Lbs/Hr	595	595	-
Water	Lbs/Hr	2,712	31	2,680
Total	Lbs/Hr	3,307	627	2,680

Heat Load

Sensible Heat		410,410	Btu/Hr	13.6%	Percent of Heat Load
Latent Heat		2,600,707	Btu/Hr	86.2%	Percent of Heat Load
Final Heating Zone		5,877	Btu/Hr	0.2%	Percent of Heat Load
Total Heat Load		3,016,994	Btu/Hr - Process Load		
Dryer Efficiency	98%	3,078,565	Btu/Hr Heat to Dryer		

Logarithmic-Mean Temperature Difference

Sensible Heat Zone	221.2	°F	x	13.6%	=	30.1	°F
Latent Heat Zone	154.9	°F	x	86.2%	=	133.5	°F
Final Heating Zone	141.3	°F	x	0.2%	=	0.3	°F
						163.9	°F

Dryer Sizing

Repletion Rate	85%	
Overall Heat Transfer Rate	26	Btu/hr·ft²·°F
Area Required	833	Square Feet

KOMLINE-SANDERSON PADDLE DRYER
SIZING CALCULATIONS
w/ Thermal Oil

Komline-Sanderson
12 Holland Ave
Peapack, NJ 07977
TEL: (908) 234-1000
FAX: (908) 234-9487

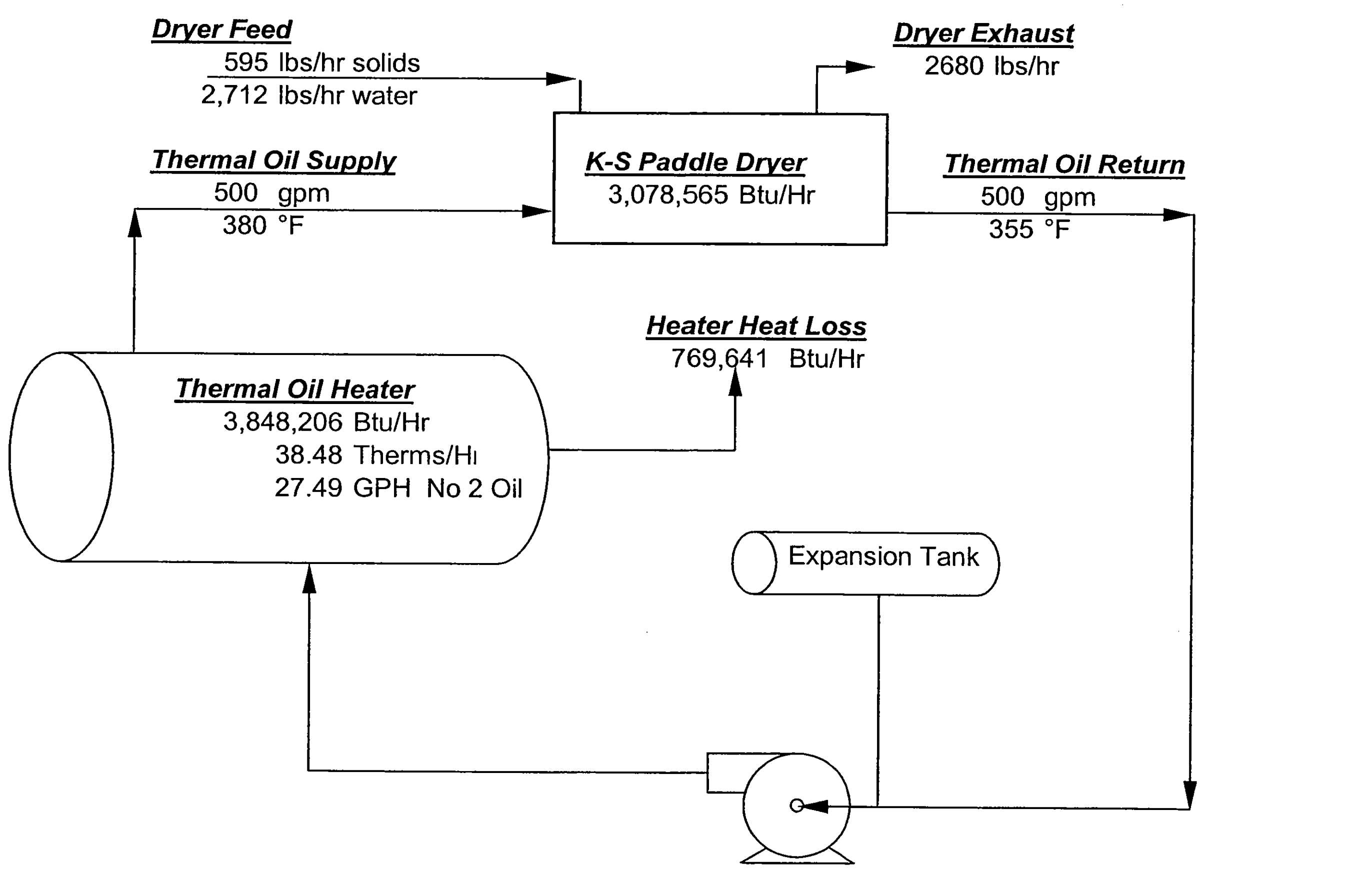
COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 4**

Thermal Oil Parameters

Thermal Oil Type	Paratherm HE or equal	
Oil Density @ Temp	6.2	Lbs/Gal
Oil Spefic Heat @ Temp	0.65	Btu/Lb-°F
Total Hot Oil Mass Flow	186,000	Lbs/Hr
Hot Oil Volume Flow	500	gpm

Thermal Oil Heater Requirements

Total Energy Required	3,078,565	BTU/Hr
Boiler Efficiency	80%	
Boiler Energy Needs	3,848,206	BTU/Hr
Therms Required	38.48	Therms/Hr
GPH No.2 Oil	27.49	GPH



K-S	KOMLINE-SANDERSON PADDLE DRYER SIZING CALCULATIONS w/ Thermal Oil	***Komline-Sanderson*** 12 Holland Ave Peapack, NJ 07977 TEL: (908) 234-1000 FAX: (908) 234-9487

COMPANY: Brown & Caldwell   Proj # TPG-2369   February 25, 2003
LOCATION: Riverside, CA   **CASE 4**

Electric Costs

Electricity Costs	$ 0.085	per Kw		
System HP Required	247	HP		
kW Required	184.2	per hour	$ 15.66	per hour

Oil / Gas Costs for Hot Oil Heater / Boiler

Gas	$ 0.45	per Therm		
Gas Required	38.48	Therms/Hr	$ 17.32	per hour
	76.96	Therms for Two Units	$ 34.63	per hour

Utility Costs

Dry Tons per Hour		0.60	Dry tons per Hour (two Units)
Utilities Cost	$	50.29	$ / Hr
Cost per Dry Ton	$	84.49	per Dry Ton
Cost per Wet Ton	$	15.21	per Wet Ton

Komline-Sanderson
12 Holland Av Peapack, NJ 07977-0257
908-234-1000 Fax: 908-234-9487
www.komline.com

March 17, 2003

Email: Kfonda@brwncald.com

Kenneth D. Fonda
Principal Environmental Engineer
Brown and Caldwell
9665 Chesapeake Drive, Suite 201
San Diego, CA 92123

Re: Komline-Sanderson Proposal TPG-2369 Rev. C

Dear Ken,

Per your request for additional pricing information for drying equipment to handle anaerobically digested belt filter press sludge cake, Komline-Sanderson is pleased to offer the following for your review and consideration.

Again, please refer to our previous quotation TPG-2369 Rev A for general equipment descriptions of the equipment being offered. Pertinent data regarding each of the four (4) cases and the equipment offered are tabulated below.

Process Conditions

	Case Rev C-1	Case Rev C-2	Case Rev C-3	Case Rev C-4
Dryer Feed Rate (Dry Tons)	25 DT/day	10 DT/day	125 DT/wk	50 DT/wk
No. of Drying Lines	One (1)	Two (2)	One (1)	Two (2)
Dryer Operation	15 Hrs/Day	15 Hrs/Day	168 Hrs/wk	168 Hrs/wk
Wet (lbs/hr) per dryer	13,333	5,333	5,952	2,380
Solids (lbs/hr) per dryer	3,333	1,333	1,488	595
Evaporative Rate (lbs/hr)	9,825	3,390	4,390	1,750
Heat Load (MBTU/Hr) per Dryer	11.3	4.5	5.1	2.0

For all cases, Thermal Oil at 380°F was used as the heat transfer medium. An overall heat transfer rate of 24 Btu/(hr·ft^2·°F) was used with a safety factor of approximately 85%. The initial solids content was assumed to be 25%. Product exiting the dryer will be above 95% solids and at an approximate temperature of 240°F. Product exiting the product cooler will be below 120°F.

Equipment Offered

	Case Rev C-1	Case Rev C-2	Case Rev C-3	Case Rev C-4
Dryer Feed Rate (Dry Tons)	25 DT/day	10 DT/day	125 DT/wk	50 DT/wk
No. of Drying Lines	One (1)	Two (2)	One (1)	Two (2)
Wet Cake Feed Silo	60 cyd	60 cyd	60 cyd	60 cyd
Storage at Design Rate	7.2 hrs	9.4 hrs	16.9 hrs	21.1 hrs
Feed Pumps Supplied	Two (2)	Three (3)	Two (2)	Three (3)
Number of Pumps in Operation	One (1)	Two (2)	One (1)	Two (2)
Dryer Model Number	17W-3500	13W-1400	13W-1400	8W-585
Number of Dryers	One (1)	Two (2)	One (1)	Two (2)
Surface Area / Dryer	3500	1400	1400	585
Volumetric Capacity (cft)	1,390	440	440	148
Dryer Empty Weight (tons)	117	44	44	20
Connected HP (per dryer)	350	150	150	60
Discharge Conveyor	One (1) 16”	Two (2) 12”	One (1) 12”	Two (2) 9”
Incline Cooling Conveyor	One (1) 16” double shaft	Two (2) 16” single shaft	One (1) 16” single shaft	Two (2) 12” single shaft
Product Delumper and Pneumatic Conveyor to Silo	One (1)	Two (2)	One (1)	Two (2)
Product Silo	One (1) 3,500 cft	One (1) 3,500 cft	One (1) 3,500 cft	One (1) 3,500 cft
Outlet Spray Duct, Condenser, Exhaust Compressor w/ Bubbler	One (1)	Two (2)	One (1)	Two (2)
Thermal Oil Heater	14 MBTUH	6.6 MBTU	6.6 MBTU	2.5 MBTU
No. of Thermal Oil Heaters w/ Expansion Tank, I & C	One (1)	Two (2)	One (1)	Two (2)
Hot Oil Flow Rate per Dryer	1450 gpm	950 gpm	950 gpm	400 gpm
No. of Hot Oil Pumps	Two (2)	Two (2)	One (1)	Two (2)

	Case Rev C-1	Case Rev C-2	Case Rev C-3	Case Rev C-4
Dryer Feed Rate (Dry Tons)	25 DT/day	10 DT/day	125 DT/wk	50 DT/wk
No. of Drying Lines	One (1)	Two (2)	One (1)	Two (2)
Instrumentation and Control Package. MCC not included	One (1)	Two (2)	One (1)	Two (2)
Total Estimated Connected HP	675	636	341	352
Estimated HP Consumption	351	378	196	217
Tot. Gas Consumption (Therms/hr)	141.9	113.5	63.4	50.7
Utility Costs	$84.81/hr	$73.65/hr	$40.21/hr	$35.76/hr
Utility Cost $/Dry Ton	$12.72	$13.81	$13.51	$15.02
Price	$2,435,000	$2,875,000	$1,630,000	$2,000,000

The utility costs listed above are for dryer operation. For the 15 hour day operation, the feed to the dryer will be turned off at the end of daily operation. The thermal oil heater temperature is reduced and the dryer operation is put into a shut down mode. During the shut down mode, all feed equipment and product handling equipment is turned off. The dryer continues to rotate to prevent the sludge from baking onto the paddles. The condensing equipment and blower remain operational for odor control. The utility costs for these off-hour operations are not included in the above costs.

Prices are F.O.B Peapack, NJ. Prices quoted are exclusive of any local, State, or Federal sales or manufacture's taxes of any sort and such taxes and/or charges pertaining thereto are to be borne by the purchaser.

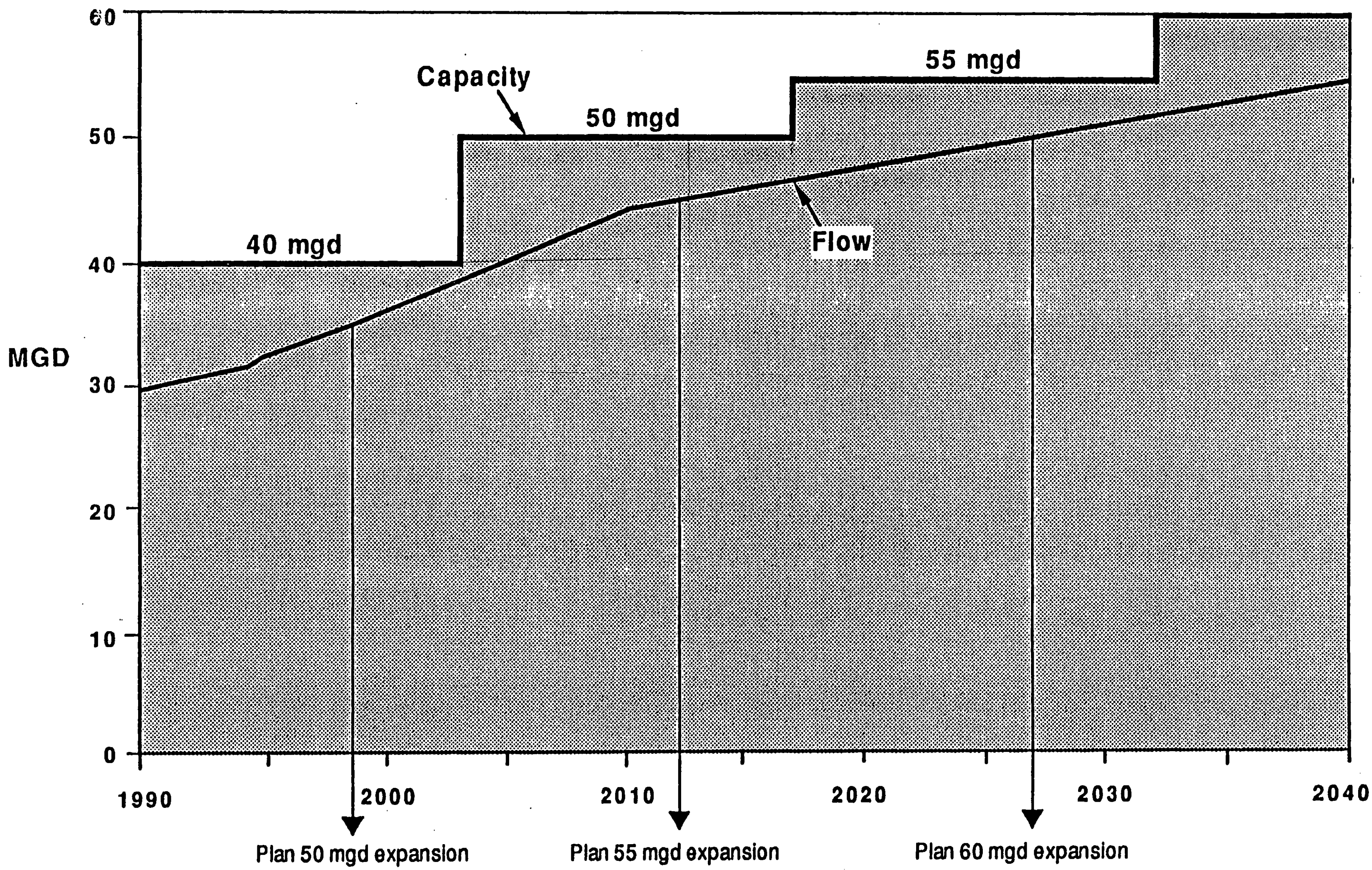
If you have any questions regarding the above information, or if additional information is required, please do not hesitate to contact us at your convenience.

Yours truly,

George M. Fraunfelder
Vice President

E

APPENDIX E – 1992 MASTER PLAN UPDATE FLOW PROJECTIONS



Assumptions: 5% industrial growth until 2010 - then 0.7%, 0.7% domestic growth after 2010, and 3% CSD growth until 2010 - then 0.7%

Riverside Water Quality Control Plant
Projected Flows
(1990 through 2040)
Figure 4-1