ATTACHMENT B

New Generation Project Water Study

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City Water Light & Power
Springfield, Illinois

New Generation Project

WATER STUDY

February 2005
Project 34821

Burns & McDonnell
SINCE 1898

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Burns & McDonnell
SINCE 1898

February 11, 2005

Mr. Brian Fitzgerald
City Water Light & Power
3100 Stevenson Drive
Springfield, IL 62703

New Generation Project
Project No. 34821 (STUDY)
Water Study - Final Report

Dear Mr. Fitzgerald:

Attached is the final report for the Water Study in accordance with our Agreement for Professional Engineering Services (City of Springfield purchase order SCSCA04207490) and Amendment No. 2 dated December 6, 2004.

This report discusses the results of the Water Study and has been updated to address CWLP comments provided with the review of the draft issue. This study was performed to address water supply, boron removal and lake water conservation issues to support the addition of the new electric generating unit.

Sincerely,

Dan Fugate

Dan R. Fugate, P.E.
Project Manager

Attachments

cc: Brian Basel
Donald Schilling
Project Files

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City Water Light & Power
Springfield, Illinois

New Generation Project
Project No. 34821

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CERTIFICATION

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License expires 11-30-05

Design Firm Registration Number: 184-001310

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1.0 EXECUTIVE SUMMARY

Burns & McDonnell studied potential makeup water supply sources and wastewater treatment system options for the New Generation Project new coal fired generating unit based on the estimated water requirements and wastewater production rates. CWLP previously retained other consultants to study water conservation options and methods to mitigate boron levels in the wastewater discharged from the plant. Because of the potential impact of the installation of an additional unit at the Stevenson Drive generating facility, the scope of this study was increased to incorporate the results of the previous water studies in the new unit analysis. Options for the site were developed that integrate potential solutions to water concerns for the Dallman Units with the requirements of the new unit.

Based on the cost analysis of various water supply and conservation options, the most economical water source is treated lake water from the city water treatment plant. Future economics may change which may justify the use of gray water as plant makeup, but the estimated cost to use gray water currently does not provide sufficient savings to justify the change from the potable city water supply.

The water study evaluated the previously identified water conservation options and developed additional potential conservation options. The net present value, capital cost, annualized operating cost, and an equivalent lake water cost of each water conservation option are presented later in this report. The analysis indicated treated lake water as the most economical water source. Should the value of lake water change in the future, the information provided will aid CWLP in determining which options to implement to aid in meeting their water consumption reduction goals, when they are finalized.

Pre-treatment of lake water will be required to reduce the potential of scaling and fouling in cooling towers and heat exchangers. Therefore, untreated lake water would not be acceptable. Adding a new clarifier system similar to those used by the city filter plant is not justifiable, because the exiting city filter plant has sufficient capacity to provide the new generation facilities' makeup water demand. Thus city water treatment plant treated water is the recommended water source.

Previous boron mitigation studies indicated that the major source of boron exists in the liquid blowdown from the Dallman 31, 32 and 33 FGD systems. Alternatives for treatment of this water stream were investigated during the water study. The preferred treatment system to address the boron discharge consists of brine concentrators followed by spray dryers to evaporate the blowdown, with only a dry product remaining for disposal.

If treating the FGD system wastewater does not provide the required mitigation of the boron discharge concerns, then other options must be considered. One secondary option evaluated involves converting the existing Dallman Units' fly ash handling systems from

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wet to dry handling to eliminate fly ash from the ash ponds. The fly ash is another significant source of boron that is discharged into Sugar Creek. In lieu of converting the fly ash systems to dry handling, another option would be to convert the ash ponds to a zero discharge operation by using ash pond water for makeup to the new unit. Further studies on the potential for groundwater contamination and ash pond life expectancies would need to be conducted to determine if this option is feasible. Additionally, a study should be conducted on the effect of the existing fly ash content of the ash ponds, as well as the effect of collecting scrubber waste landfill leachate, on the ash pond and ground water quality.

Besides the recommending boron removal and/or water conservation options, Sargent & Lundy also recommended recycling the FGD vacuum pump seal water. This modification would conserve water and reduce the FGD blowdown treatment equipment size (brine concentrators and spray dryers). This modification is currently being made by CWLP.

B&McD recommends a boron mitigation approach which includes a zero discharge FGD wastewater treatment system consisting of two 50% brine concentrators followed by two 50% spray dryers combined with the conversion of the Dallman Units to dry fly ash systems. B&McD also recommends that the primary source of the new unit make-up be provided from the CWLP Filtration Plant. A final water balance is shown in the appendices of this report. This final water balance incorporates the following recommended modifications.

- Existing Dallman Units converted to dry fly ash handling.
- The new unit based on dry fly ash handling
- Ash pond water recovered and returned to Lake Springfield.
- The new unit FGD wastewater and Dallman Units treated and recovered using brine concentrators and spray dryers.

In the event that the Ash Pond water quality is not suitable for direct discharge to Lake Springfield, a wastewater treatment system could be added to allow recovery of the Ash Pond effluent as makeup to the new unit cooling tower for water conservation.

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2.0 INTRODUCTION

City Water Light & Power (CWLP) of Springfield, Illinois, retained Burns & McDonnell (B&McD) to perform a water supply and wastewater treatment study for the existing and new generation facilities at the Dallman Station. The study investigated the availability and feasibility of water supply sources required for the planned new coal-fired unit (200 MW). In addition, the study addressed the wastewater treatment requirements for the new unit and the methods for mitigating the boron in the existing ash pond discharge.

CWLP previously had the following studies performed to address water conservation and wastewater treatment concerns:

- Water Conservation Study, Report SL-008254, Sargent & Lundy, April 23, 2004 report.
- Investigation of Mitigation Strategies for Boron Increase at Outfall 004, Hanson Professional Services, February, 2004.
- Dallman and Lakeside Stations Ash Handling Water Study, CWLP, draft report dated February 16, 2004.

These reports were reviewed in this study, and integrated with the requirements of the new unit to develop a whole-plant (both the new and the existing units) approach to water supply, conservation and wastewater treatment system design.

An important factor to CWLP was the study of options to reduce boron concentrations in plant discharge at Outfall #004 to Sugar Creek from the Ash Water Clarification Pond Effluent. Hanson studied the boron situation for the existing units, especially boron in various plant and ash water streams, and provided several recommendations to CWLP to reduce boron concentrations in their report. It appears that the use of the recently installed SCR equipment for NOx control on the Dallman Units has resulted in a significant increase on the boron concentrations in the ash sluicing water. However, Hanson's study also indicated that the FGD system blowdown liquid streams contain the highest concentrations of boron, which appears to have been instigated by the use of the SCR.

Potentially feasible boron removal options were identified and evaluated and three potentially viable options were selected. The net present value of each option was calculated based on estimated installed equipment cost, and annual operation and maintenance costs. Based on the net present value analysis, and other factors, a preferred boron-removal method was selected as the base-case option. This base-case option was then used in evaluating water conservation options.

There are primarily two water supply sources for the new unit, Lake Springfield water and gray water. The costs of using each of the two water supply sources were estimated.

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Additional methods for conserving lake water were reviewed. Three possible water conservation methods were selected for further study.

These options, combined with two water supply options (Lake Springfield and the gray water), formed the five options studied to provide for the plant water supply and water conservation. A water balance was prepared for each of these five options, and water usage was calculated. Water conservation options were then evaluated using the net present value method, similar to the boron-removal options. Finally, the advantages and disadvantages, as well as the cost-benefit ratios of these options were discussed. Recommendations are provided in Section 7 (Conclusions and Recommendations) of this report.

3.0 WATER SUPPLY

With the addition of a new unit at the Stevenson Drive plant site, the water source to support this operation must be chosen. This section of the Water Study report discusses the investigations that were preformed in this area.

3.1 Lake Springfield

Lake Springfield is the raw water source for the existing Lakeside and Dallman Units. It is also the supply for the city's drinking water treatment plant on site (Filter Plant). The existing units utilize a once-through cooling water system, and thus there is no consumptive loss of the lake water for condenser cooling. The majority of the consumptive use of the lake water for the existing units is ash sluicing water, which accounts for 58.1% of the total consumptive use of the lake water.

The new unit will have cooling towers with a closed loop circulating cooling water system with consumptive losses for condenser cooling. The cooling tower rejects the steam cycle heat primarily by evaporation. To maintain scaling and corrosion within acceptable limits, a portion of the circulating water needs to be removed by blowdown. The circulating water is concentrated up to 10 times to minimize the blowdown discharge. Cooling tower water losses need to be made up. Lake water is one possible source of makeup water. Based on the quality of Springfield Lake water, pre-treatment of the water is recommended before it is used as cooling tower make-up. High total iron and manganese concentrations in the lake water could cause deposit and corrosion problems in the new unit cooling tower and the condenser affecting unit performance. It is preferable to remove these impurities in a pre-treatment process.

Treated lake water could also be used as make-up water, with additional treatment if necessary, to systems such as the FGD systems, demineralizer, plant service water and others. The benefits of using the lake water as make-up to the new unit are that it is readily available, and that sufficient pumping capacities exist to provide the lake water to the new unit. The disadvantage is that, the lake water, which is the fresh water supply source for the city potable water, will become more valuable due to growth in demand, and thus more expensive for use as make-up to the power plant. Water from the city high pressure line would provide pretreated and filtered water for plant use without requiring additional treatment equipment at the plant and without requiring additional plant personnel to operate and maintain the treatment equipment. Unless the value of lake water increases dramatically in the future, it is the most economical source of makeup water.

3.2 Sanitary Wastewater Treatment Effluent (Gray Water)

The use of gray water as make-up water to power plants is becoming a more widely used method to conserve fresh water. Although this type of application has experienced problems at some facilities, there are several successful cases of gray water reuse. The use of gray water has special concerns in the operations and maintenance of power plant

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equipment such cooling towers. Proper pre-treatment is important to minimize the difficulties of reusing gray water.

The city's sanitary wastewater treatment plant (SWTP) is located about 3 miles away from the site. The construction of a pipeline to bring the gray water to the site would be necessary, but this would be costly and thus is a disadvantage compared to using the lake water as make-up water to the new unit. However, the use of gray water provides significant reduction of consumptive use of the lake water.

The SWTP consists of a secondary treatment system using an activated sludge process. Most of the suspended solids and organics in the incoming water are removed, but significant total organic content and solids content still remain that could cause problems in power plant equipment such as the cooling tower. Many reported problems associated with reusing gray water result from high organic, nitrogen, and solids content (and thus high potential for biological activity) of gray water. This could lead to fouling and under-deposit or microbiologically induced corrosion of power plant equipment. The mineral content (dissolved constituents) of gray water is also generally higher than fresh water in the same region. This could cause scaling of sparingly soluble salts (salts with very low solubility in water) such as calcium carbonate and calcium phosphate scales, as well as corrosion due to higher chloride and sulfate concentrations.

Therefore, successful reuse of gray water requires sufficient pre-treatment of the water to reduce or remove the constituents that may cause operating and maintenance problems. Compared to the pre-treatment of the lake water, the pre-treatment of gray water would be more costly and more involved.

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4.0 WASTEWATER TREATMENT

There are several types of wastewater streams generated from various plant systems. Each type of wastewater may require a different treatment. Primarily, they fall in three categories at CWLP. One type of wastewater consists of wastewater streams that can be treated and then returned to Lake Springfield for reuse as fresh water supply. The second type consists mostly of ash sluicing water and currently the FGD system blowdown. This wastewater source is treated and discharged to Sugar Creek. The boron content of the ash sluicing water is significantly less than the FGD blowdown and can continue to be treated in the clarification pond and returned to Lake Springfield. The third type will be a concentrated waste stream which will be primarily the FGD system blowdown. This waste stream contains a highest concentration of boron and cannot be discharged. This waste stream will have to be treated for boron mitigation purposes.

4.1 On-Site Wastewater Treatment Plant

The existing Dallman and Lakeside Units share a common on-site wastewater clarifier treatment plant that receives various wastewater streams from the site, processes them and then discharges the treated wastewater to Lake Springfield. The treatment system includes a settling pond, chemical feed and clarifiers. Oil, floating materials, suspended solids and some heavy metals are removed from the plant wastewater before the water is discharged to Lake Springfield.

The treatment process does not remove any significant amount of dissolved solids, thus concentrated wastewater streams, such as the FGD system blowdown, are not discharged to the on-site wastewater clarifier treatment plant because this would cause contamination of the lake water. The clarifiers in this treatment plant are not capable of handling high suspended solids content, such as ash sluicing water from the fly ash or the bottom ash systems. The treatment plant provides no potential benefit for the conservation of the lake water or the mitigation of boron discharge problems.

Wastewater streams from the new unit, such as plant service water drains, should be able to share the common wastewater clarifier treatment facility. However, modification of the existing plant NPDES permit may be required before the additional wastewater streams could be discharge through the existing wastewater clarifier treatment facility. The discharge from the wastewater clarifier plant is directed to Lake Springfield, which is the raw water supply source to the plant. Thus the wastewater streams treated by the wastewater treatment plant are not considered consumptive losses from lake water.

4.2 Ash Pond Discharge

Currently ash is sluiced to the ash ponds using lake water. Water from the ponds is pumped to the clarification pond. At this stage, chemical treatment of the water is performed, which results in settling and separation of most of the ash fines and particles from the bulk water. The clarified water overflows to Sugar Creek (via Outfall #004). Boron concentration in this discharge has periodically exceeded the discharge limit.

Concentrations of boron higher than the discharge limit of 11 ppm have generally occurred when the plant SCR system is in service (average concentration of 17.9 ppm in Hanson's study report). The highest concentrations of boron are from the plant's FGD blowdown streams (200-400 ppm). However, even when the SCR systems are not in service, boron levels have approached the discharge limit (average 10.1 ppm). Water quality test information indicates that the fly ash sluicing water is also a significant source of boron contamination (40-50 ppm).

It appears, based on initial calculations and analysis, that eliminating the fly ash sluicing water and the FGD blowdown streams from the ash ponds will have the largest impact on the boron discharge problem. Because the FGD blowdown has much higher boron concentrations than any other wastewater streams contributing to the ash pond discharge, removing FGD blowdown from the ash pond alone would reduce boron concentrations below the discharge limit based on the average boron concentrations in these streams reported by Hanson.

CWLP personnel have expressed concerns that fly ash in the ash pond could leach boron, especially during times when the SCR is in service. This potential exists as some ammonia may be collected in the fly ash sluicing water and react with and "dissolve" boron bound to the fly ash. This will make the boron concentration higher in the discharge to Sugar creek. The same mechanism of boron concentration increase is also considered a potential issue on ground water contamination from the ash ponds. Thus, removing fly ash from the ash pond would be beneficial, but the cost of converting the fly ash handling to a dry system is expensive.

4.3 Zero-FGD Discharge Operation

FGD blowdown must be treated, if removed from the ash pond; otherwise it will become a discharge problem elsewhere at the plant. However, treatment options for FGD blowdown to selectively remove boron are limited. The most likely and reliable option would be a treatment process in which boron, as well as other parameters, is indiscriminately removed (separated) from the water. The product water is generally low in dissolved solids, and may be reused as make-up water within the power plant such as makeup to the cooling tower or demineralization system. Thus with respect to the treated wastewater (e.g., FGD blowdown), the treatment process would be a zero-discharge process.

Common zero-discharge processes involve volume reduction of the treated wastewater by mechanical evaporation, or reverse osmosis (RO) as a first stage volume reducing process, followed by mechanical evaporation. Brine concentrators, or evaporators, are typically used as the primary mechanical evaporation equipment. However, most brine concentrators do not recover all water from the influent wastewater stream. Thus the final waste (brine concentrator bleed) must be further treated in a zero-discharge facility. Crystallizers or spray dryers may be used to convert brine concentrator bleed to a solid waste product for disposal. Based on the water chemistry of this application, manufacturers have suggested a spray dryer following a brine concentrator because

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crystallizers may not be able to completely convert the wastewater to a solid waste. However, if an RO system is used, the proper treatment of the RO waste brine is to use a crystallizer due to cost as well as the difference in the water chemistry after an RO system.

These options are discussed later in this report. The equipment and operating and maintenance costs are normally very high for these systems. The disposal of the solids waste generated from the zero-discharge treatment equipment could be costly, too, especially if the waste is considered hazardous. This is not typical but high levels of certain metals may result in a hazardous material classification which would cause the disposal expense to go up significantly. Potential constituents of concern include heavy metals and boron. Thus, zero-discharge options are normally not economical options for water conservation, but necessary means to meet discharge limits - in this case, the boron discharge limit.

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5.0 OPTIONS

The review of options for water conservation and boron mitigation involved the review of previous study identified options. New options were also considered and evaluated if they were considered feasible.

5.1 Previous Study Options

5.1.1 Water Conservation Options

In the S&L study, several potential water conservation options were evaluated. These options were as follows:

(1) Dry fly ash handling systems
(2) Closed-loop recirculating bottom ash systems
(3) Dry bottom ash system for Dallman Unit 33
(4) Sanitary wastewater treatment effluent as additional water source
(5) Recycle of ash pond effluent to Lake Springfield
(6) FGD vacuum pump seal water and routing of FGD sump pit effluent
(7) Ash handling water management
(8) Heat exchangers conversion from city water to lake water

Sanitary wastewater treatment effluent (gray water) as additional water source is discussed in this report. It is compared with using lake water as make-up water to the new unit. Although the original S&L recommendation was only to use the gray water to displace lake water as ash sluicing water, the net result is reduction in the total consumptive lake water usage.

FGD system vacuum pump seal water recovery requires a relatively small capital cost investment; however the potential savings in lake water usage is also small. A more significant reason for the recovery of FGD vacuum pump seal water is that it will reduce the volume of FGD blowdown from the Dallman Units, which will help reduce the boron removal treatment equipment size (i.e. brine concentrators and spray dryers). This option is currently being pursued by CWLP.

The ash handling water management option discussed by S&L involves either putting the ash water pumps in recirculation, or simply turning them off, when there is no demand for ash sluicing. However, running the pumps in recirculation mode for extended time could shorten the useful life of the pumps, and is not preferred. Turning the pumps off when there is no ash sluicing demand would be a better approach, but there are concerns of plugging the ash water lines due to settled ash particles if the lines are not kept flushed.

Heat exchangers conversion to using lake water as the cooling water instead of city water does not reduce consumption of lake water because city water also originates from lake water. Based on the cost of city filter plant water, it is more economical to use treated lake water (clarified and chlorinated), instead of potable water, for heat exchangers and some other users of potable water at the plant. However, many users of potable water are currently connected to the same headers, such as safety showers, eye wash stations, washroom facilities, which require true potable-quality water. The modifications involved in separating the true potable water users and the other potable water users may be expensive.

5.1.2 Boron Mitigation Options

For boron discharge problem mitigation, Hanson recommended the following options:
(1) Selective boron removal by activated carbon, ion exchange resin or chemical precipitation/co-precipitation.
(2) Mechanical evaporation (brine concentrator, crystallizer, spray dryer, etc.).
(3) Reverse osmosis followed by mechanical evaporation.

These options are discussed in detail later in this report. Selective removal of boron, if feasible, could be significantly less costly, but it is not recommended based on the lack of successful commercial operations of these types of systems for FGD blowdown treatment applications. In contrast, mechanical evaporation and/or RO systems are considered more proven technologies for this application. Therefore, pilot testing is recommended for selective boron removal processes, especially the ion exchange resin process, before the option is more seriously considered. Boron-selective ion exchange resin products are widely used in boron removal in ultra-pure water applications (such as in computer chip manufacturing), as well as in wastewater application, but the concentrations of boron and flow rates are much lower than in this application.

Without sufficient information on successful selective boron removal, the basis for this report focuses on more commercially proven technologies such as mechanical evaporation and RO followed by mechanical evaporation. Further analysis of boron removal options concentrates on these options.

5.2 Additional Options

Besides the options S&L and Hanson have provided to CWLP, B&McD also recommends that the following options be considered:

(1) For water conservation, a variation of reusing ash pond effluent as sluicing water is to use it as raw water make-up to the new unit, with proper pre-treatment. The difference between this option and the option discussed by S&L is discussed later in this report.

(2) An option with a combination of water conservation and boron removal is using dry fly ash to mix with brine concentrator bleed. Dry fly ash unloading (to off-site disposal site) may require water for dust control. If brine concentrator bleed could be used for this purpose (and if doing so meets fly ash disposal quality limits), combining the two wastes together for disposal would eliminate or reduce the need for operating a spray dryer provided Unit 33 fly ash was converted from wet to dry handling. In this case, instead of two 50% spray dryers, only one 50% spray dryer would be required.

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One idea considered by B&McD was to reduce FGD blowdown to minimize the equipment size of the boron-removal equipment. The higher the chlorides set-point, the lower the FGD blowdown flow rate is required, provided that the materials of construction are compatible with the higher chloride concentrations. Lower FGD blowdown flow rates will make the brine concentrators/spray dryers smaller. Based on the scrubber design at the Dallman Units, the chloride concentration is maintained below 10,000 ppm for corrosion prevention. Any reduction in the FGD blowdown rate to conserve water would result in an increase in the chloride concentration above the 10,000 ppm limit and is not recommended.

While smaller equipment means lower capital and O&M costs, the higher chloride concentration in the scrubber and gypsum may cause the gypsum to be un-sellable. Currently CWLP is able to sell gypsum which must meet certain quality specifications, including the chloride content. If the gypsum is unmarketable, its disposal will also become a significant operating expense. This option only slightly reduces the boron-treatment equipment size. Its benefit is not significant, but the problem it brings could be a much larger issue. Thus this option was not studied further.

6.0 EVALUATION OF OPTIONS

A more detailed cost and benefit evaluation was performed for the boron treatment options and the water conservation and water supply options. Based on the analysis, the preferred options were selected.

6.1 Wastewater Treatment Options

6.1.1 Plant Wastewater Discharges

According to the S&L water balance, the maximum and average existing plant wastewater discharge to the on-site wastewater clarifier treatment plant is 5.26 MGD and 4.22 MGD, respectively. The maximum and average Lakeside wastewater flow rates are 2.0 MGD and 1.0 MGD. It is assumed that the difference between the average and maximum wastewater flow from Lakeside is storm water flow which will still exist after the Lakeside Units are retired. After the Lakeside Units are retired in 2009, wastewater flow to the on-site wastewater clarifier treatment should decrease by approximately 1 MGD. The maximum capacity of the wastewater clarifier plant is about 7 MGD according to CWLP's staff. Based on the current average flow of 3.22 MGD and a peak flow of 4.26 MGD excluding the Lakeside flow, the treatment plant should be capable of treat an additional 1.74 MGD after Lakeside is retired. This assumes the above derived 1.0 MGD of storm water from the Lakeside plant will still flow to the wastewater clarifier plant for treatment. before it is discharged to the lake.

According to the average water balance of the new unit, total wastewater discharge to the on-site wastewater clarifier treatment plant from the new unit should be less than 1 MGD (the normal maximum should be approximately 0.75 mgd). Thus, after the Lakeside Units retired, the on-site wastewater clarifier treatment plant should still have sufficient capacity to handle all Dallman Units' wastewater, Lakeside plant area storm runoff currently directed to the existing wastewater clarifier plant, and the new unit wastewater. Therefore, no plant modifications will be required to the existing wastewater treatment plant.

6.1.2 Ash Pond Discharges and Boron Removal Approach

Based on the results and recommendations from the Hanson study, as well as information from CWLP's staff, B&McD believes that removing the FGD blowdown stream(s) from the plant discharge to Sugar Creek may provide sufficient reduction of boron in the final wastewater discharge to meet the current 10 ppm limit. Once removed from the Sugar Creek discharge, the FGD blowdown stream must be treated to removal boron from the liquid stream, and/or to convert it to a dry solid waste for off-site disposal.

According to the S&L water balance, the average Dallman FGD system blowdown wastewater is approximately 0.15 MGD (about 104 gpm). The B&McD water balance for the new unit indicates that the new FGD system blowdown could be approximately 70 gpm, which is a total of 174 gpm FGD blowdown for all units. B&McD's calculations also confirmed with the Hanson study that the removal of FGD wastewater from plant Outfall #004 would likely reduce boron concentration in Outfall #004 to below the current discharge limit. More importantly, if the FGD blowdown streams (including the new unit) are allowed to be discharged to the ash ponds in future, Outfall #004 would almost certainly exceed the boron discharge limit after the new unit is in service.

Based on Hanson's study report and water quality (boron concentrations) of various water streams directed to the ash ponds, the average boron concentration of the current combined FGD wastewater is about 201 ppm at a flow rate of 0.15 MGD. The total flow of the discharge to Sugar Creek is about 3.78 MGD with an average boron concentration of 17.9 ppm during times when the SCR is in operation. Removing the FGD wastewater blowdown from the ash ponds is estimated to reduce the concentration of boron in the discharge to Sugar Creek down to about 10 ppm of boron, which is lower than the discharge permit limit of 11 ppm, although the margin is not large.

However, based on some latest water analyses of the FGD wastewater samples, boron concentrations over 400 ppm have been reported. Thus, not removing the FGD wastewater from the ash ponds will create a potential for exceeding the boron discharge limit. After the new unit is in service, the wastewater from the new Unit FGD will add significantly more boron to the ash ponds. Therefore, it appears that the minimum requirement to mitigate the boron problem at CWLP is the treatment FGD blowdown.

If only removing FGD blowdown steams from the ash ponds is not sufficient to comply with the boron limit in the discharge to Sugar Creek, then converting the fly ash system to dry handling would provide the additional reduction in boron concentration in the ash pond water. Calculations using average boron concentration measurements and water balance flow rates from Hanson's and S&L's study reports were performed. The results indicated that, in addition to removing the FGD blowdown streams from the ash ponds, converting Dallman Unit 33 fly ash to dry handling alone would further reduce boron concentration in the ash pond discharge to Sugar Creek from the above 10 ppm to about 5 ppm. If all Dallman Units' fly ash systems were converted to dry handling, the boron concentration would become less than 1 ppm (0.94 ppm). Therefore, if necessary, converting some of all of Dallman fly ash systems to dry handling would provide the additional reduction in boron concentration in the discharge to Sugar Creek.

All options discussed below are based on removing the FGD blowdown streams from the ash ponds only. These were reviewed in more detail, and manufacturers that specialized in providing these types of systems were contacted for equipment and operating cost information. The information was then used to calculate the life-cycle costs of each option.

6.1.3 Boron Removal Options

Unfortunately, FGD wastewater contains extremely high concentration of dissolved solids and suspended solids. This could make it hard to use many less-expensive options

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to remove boron. For example, materials of construction need to be corrosion resistant; certain processes such as reverse osmosis (RO) will not have high recovery due to the limitation on osmotic pressure, and the high suspended solids content requires pre-treatment.

The Hanson study evaluated several options including selective boron removal, as well as general dissolved solids remove such as RO and mechanical evaporation. However, B&McD's investigation into the selective boron removal methods indicated that, due to the high boron concentrations in the wastewater stream, the application of selective media, such as ion exchange resin or activated carbon, would not be realistic (frequent regeneration or media change-out will be required). On the other hand, chemical precipitation or co-precipitation of boron is not expected to be effective, but in this case, it is because of the relatively low concentrations of boron in the wastewater compared to its solubility.

General TDS removal methods, such as RO and mechanical evaporation, are the only proven technologies applicable for boron removal for the application at CWLP. When TDS in general is being removed, the treated water normally becomes a high-quality water stream that can be reused back in the power plant. This is the concept of zero-discharge. The concentrated wastewater from the primary treatment (e.g. brine concentrator) is then converted to a dry solid waste product (e.g. by crystallization or spray drying) that could be disposed in an off-site landfill. Alternatively, because of the volume of this concentrated wastewater stream is much smaller after it is treated by the brine concentrator, it could be mixed with other solid wastes from the plant, such as fly ash, as a means of dust control and to be disposed together if environmentally acceptable.

6.1.3.1 Option 1-1 - Brine Concentrator Followed by Spray Dryer (Single Train)

Brine concentrators are mechanical evaporators that separate and recover water from the wastewater solution. The recovered water is high-quality, and may be reused in many power plant applications. The concentrated solution left behind is of much smaller volume, but still in a liquid (slurry) form. The most commonly used brine concentrators are called falling film seeded slurry brine concentrators, and most of these use a vapor compressor to provide self-sufficient supply of steam to heat up the wastewater slurry. The heated wastewater evaporates and generates steam that is compressed and used for heating up the wastewater slurry again. The slurry is recirculated in a vertically mounted tube bundle (falling film heat exchanger), with the steam on the shell side. Due to the high concentrations of TDS and chlorides, the wetted materials are normally made from high-grade stainless steels and the tubes from titanium. These types of brine concentrators are normally very expensive. In addition, the vapor compressor and the slurry recirculation pumps consume a significant amount of electricity.

A stream of the concentrated slurry is continuously bled from the system in order to maintain certain levels of TDS and total solids content so that the system scaling is minimized and the unit operates efficiently. Based on the preliminary water chemistry information for FGD blowdown wastewater from CWLP, and after discussions with a manufacturer for these types of equipment, it is believed that a volume reduction as high

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as 30:1 of the wastewater is achievable. However, to be conservative, in the water balances for this study, a 15:1 reduction was assumed. The water balances are attached in the appendices of this report.

The concentrated bleed would be taken to a spray dryer where it is completely dried to a solid form for disposal. The spray dryer is designed based on 20:1 wastewater volume reduction at maximum design flow rate. The above 15:1 reduction is for average operating conditions which have flow rates much lower than the maximum design capacity of the equipment. Thus 15:1 reduction under the average operating conditions will still generate a smaller volume of wastewater to be treated by the spray dryer than its design capacity.

A typical spray dryer atomizes the wastewater slurry in a drying chamber where hot air containing combusted natural gas is injected. When the two meet, all the moisture in the slurry is vaporized, leaving behind the solids to form fluffy conglomerates. The solids either settle on the bottom of the drying chamber, or are carried by the hot air to downstream solids-removal equipment, such as bag houses or cyclones. The remaining solids collected from these systems are then compacted by an "agglomerizer" to increase the bulk density of the solids. This is important if the disposal cost of the solids is calculated based on the volume instead of total mass.

Typical brine concentrator and spray dryer system process flow diagrams are included in Appendices (PFD1, Sheet 1 of 2 and Sheet 2 of 2) with the base case water balance. This system is capable of completely removing boron (and most of the other TDS) from the FGD blowdown streams, and recovering the water for reuse at the power plant. No liquid waste is discharged from the system.

6.1.3.2 Option 1-2 (Base Case) - Brine Concentrators (Dual Train) Followed by Spray Dryers (Dual Train)

Due to the contact with the slurry of highly concentrated wastewater, the brine concentrator and auxiliary equipment may require periodical maintenance, such as mechanical and/or chemical cleaning. In addition, it is possible that the incoming wastewater flow rate could vary significantly (such as the case in which the new unit stays on base load, but the Dallman Units cycle). Incoming wastewater quality also might change. Therefore, it may be desirable to have dual trains of the brine concentrator/spray dryer units, each designed for 50% of the maximum capacity required.

The option varies from the previous one by using two 50% brine concentrators followed by two 50% spray dryer instead of one 100% brine concentrator/spray dryer train. The cost of this option will be higher due to the more pieces of equipment, but the redundancy is considered essential for a system which will serve all four units. Additionally, at the currently projected load factors, only one brine concentrator of the dual units would be in service. It is more efficient to operate the system at full capacity compared to operating a single, 100% brine concentrator turned down to 50% capacity.

6.1.3.3 Option 2 – HERO followed by Crystallizer and Spray Dryer

An alternative to the first stage treatment with mechanical evaporation is to use a RO process to recover high-quality water and concentrate the wastewater (to reduce its volume). However, due to the high concentrations of dissolved constituents in the FGD blowdown streams, very high recovery of an RO system is impossible due to the osmotic pressure and the pressure limitations of commercially available RO membranes.

Based on preliminary information, a conservative estimate of the recovery from an RO system is only about 75% (the RO reject is about 25% of the feed to the RO). Because most of the dissolved solids end up in the RO reject, this 25% concentrated wastewater flow would also contain about 4 times the concentrations of dissolved solids than in the incoming wastewater. For example, if the average incoming flow rate is about 200 gpm, then the wastewater stream is about 50 gpm. Similar to the brine concentrator/spray dryer arrangement, a post-RO treatment is required to treat the HERO reject. In this case, a crystallizer would be utilized to further recover the water in the waste stream, and to transform the dissolved solids in the HERO reject into a solid form for disposal.

Because the FGD blowdown contains very high concentrations of sparingly soluble salts such as calcium (Ca), magnesium (Mg), sulfate, and silica, as well as high suspended solids (gypsum particles), it must be pre-treated to reduce or replace these constituents, before the water could be treated by an RO. An effective treatment to remove hardness (Ca and Mg) from water is a lime/soda softener, where lime and soda ash are added. The use of soda ash will add alkalinity that is necessary for the hardness to precipitate. The sodium ions (Na) will in effect replace the calcium and magnesium that is in the noncarbonate form.

After the lime/soda softener, water would contain relatively low hardness, but silica concentration is not affected by lime/soda softener as much as hardness. When concentrated in the RO system at neutral or acid pH, silica concentration may exceed its solubility and cause a scaling problem on the RO membranes. In this application, another constituent that has similar problems is boron. At neutral or acid pH, boron generally has lower solubility. Boron crystallizes to form boric acid, which is a waxy substance that could foul up the RO membranes. A high-pH RO system effectively solves this problem by operating the RO system at elevated pH (11 or higher). At this pH level, silica and boron stay in their soluble form and will not cause scaling problems. Thus following the lime/soda softener, a HERO system (a patented high-pH RO system design) is used. HERO is still an RO system, so its recovery is limited by the osmotic pressure. HERO product water is good-quality water that could be reused in the power plant.

Due to the limitation of the recovery of the HERO, the size of the crystallizer is much bigger (50 gpm) than the spray dryer after the brine concentrator, which means it is much more expensive. However, the cost of the HERO is generally cheaper than brine concentrator systems, and consumes much less electricity.

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Compared to the brine concentrator/spray dryer design, the HERO design has some disadvantages. From a simplicity point of view, the brine concentrator option is more favorable because it involves fewer components to operate. In contrast, the HERO system consists of the lime/soda softener (chemical feed, solids removal and disposal), pre-treatment of the HERO system, and the HERO itself. Typically, the pre-treatment includes a polishing ion exchange resin softener, such as a weak acid cation (WAC) resin system, a deaerator to remove CO_2 produced in the WAC unit, and a pH adjustment prior to the HERO. Also, the chemical consumption, as well as the solids removal (for disposal), for the lime/soda softener is significant. Finally, the energy consumption of the crystallizer is much higher compared to the spray dryer following the brine concentrator, which is a trade-off with the cost savings on energy consumption by using HERO in lieu of a brine concentrator unit. A typical process flow diagram (PFD2) is attached to this report following the water balance.

6.1.3.4 Option 3 – Spray Dryer versus Fly Ash Mixing

This option is a variation of Option 1-2 in which the spray dryers may be reduced in capacity. The brine concentrator bleed, instead of being treated by the spray dryer, is used as a dust control agent in fly ash unloading operations. In other words, the brine concentrator bleed is mixed with fly ash to make it wet. The wetted fly ash is disposed of off site, taking away the wastewater with it. Based on available information, B&McD is not able to determine if fly ash mixed with brine concentrator bleed is acceptable to the potential recipients of the fly ash. If this is not a problem for the recipients, this option could save significant money on the equipment capital, as well as O&M costs, of the spray dryer system required in Option 1.

The new unit is being designed to have dry fly ash system. However, based on the preliminary furnace design information, projected average load factors, and typical fly ash wetting water requirement (15-20% moisture content in wetted fly ash), the fly ash from the new unit alone (requiring only 3 - 4 gpm wetting water) would not be able to use all of the normal brine concentrator bleed for wetting (a total of less than 6 gpm under average operating conditions and plant load factors). Thus for this option to be used, Dallman Unit 33 must be converted to dry fly ash system. This study assumed that Dallman Unit 33 would be converted to dry fly ash handling for this purpose.

Unit 33 will produce about 4.1 tons/hour fly ash based on the projected plant load factor for 2010-2025. This will require about 3 gpm of duct control water. Thus by converting Unit 33 to dry fly ash system, there would be sufficient fly ash (in addition to the fly ash from the new unit) for the brine concentrator bleed to mix with. This will eliminate the need for dual trains of spray dyers. A single train of spray dryer is still recommended as a backup in case Unit 33 is offline (not providing the required additional fly ash).

The capital cost of converting Dallman Unit 33 to dry fly ash was estimated to be $4.1M by S&L. B&McD estimated that the cost of the conversion is only about $2.2M if a common fly ash silo is shared between the new unit and Unit 33. This cost is still significantly higher than the capital cost for a spray dryer. However, the O&M cost of the converted dry fly ash system is expected to be much less than that of the spray dryer. Thus the overall economics of this option may be more favorable.

A potential disadvantage is that if the fly ash is not acceptable for sale, and must be taken to a landfill, and if the disposal cost is higher than regular landfill because of the mixing with brine concentrator bleed, this could add significant expenses to the total O&M cost of this option. Another concern with this option is that many potential customers for the fly ash from CWLP prefer pneumatically transferred fly ash, which does not need any wetting agent. In this case this option becomes invalid, unless the customers consider accepting wetted fly ash.

6.1.3.5 Other Options

Some other options, especially those mentioned in the Hanson study, were also reviewed, but were not recommended for this application. These options include:

(1) **Boron-selective ion exchange resin**, such as Purolite S-108 and Rohm & Haas IRA 743. According to ion exchange resin manufacturers, this type of resin has a capacity of about 2 ounces/ft^3 of resin used under certain water chemistry conditions, but the treatment flow is recommended at about 15 BV/h (bed-volumes/hour). The removal of boron by this type of resin is affected by the characteristics of the wastewater from which boron is being removed. Based on information provided by Purolite, high chlorides concentration and low pH generally seems to reduce the effectiveness of the removal of boron by up to 30 times. The FGD wastewater shows both characteristics (high chlorides and low pH), thus boron removal efficiency is not expected to be high. This means multiple stages of ion exchange resin treatment (or simply more resin) may be required, or more frequent regeneration would be required.

The operating cost of the system depends on the concentration of boron in the wastewater. As an example, for total treatment flow rate of 174 gpm with 200 ppm of boron, approximately 550 cubic feet of S-108 will last about 4 hours before the resin must be regenerated if the capacity of resin is at 2 ounces/ft^3. If the boron concentration goes up to 400 ppm, then 1,100 cu.ft. of resin would be required for the same regeneration frequency. Acid and caustic are normally used in regeneration. Based on Purolite's literature for S-108, the total regeneration wastewater for 550 cu.ft. resin every 4 hours is equivalent to a generation of 40 gpm of wastewater containing sulfuric acid and caustic (neutralization between the two will occur if the two wastewater streams are mixed). But if the boron concentration is 400 ppm, then the regeneration wastewater generation doubles at 80 gpm, almost half of the incoming water flow rate.

If this option was selected, a crystallizer must be provided to treat the regeneration wastewater. Compared to the brine concentrator/spray dryer option, this option may be attractive because of the cheaper cost to install ion exchange equipment in lieu of a brine concentrator, but some of the savings may be discounted due to potentially higher cost of the crystallizer compared to the spray dryer. The O&M cost of the ion exchange resin systems is much cheaper than that of the brine concentrator. But the crystallizer O&M cost may be much higher than that of the spray dryer following the brine concentrator.

The biggest concern of selecting this option is that it has not been installed on a FGD blowdown treatment application. Most of ion exchange boron removal applications are for lower concentrations of boron, and for water purification applications. This type of resin may not perform well with the water chemistry of FGD blowdown. For example, it may even require some pre-treatment of the FGD blowdown for the resin to achieve its typical performance for boron removal. Pilot testing would be recommended before this option could be more seriously considered.

There is a good chance that if all fly ash systems are converted to dry systems, selective ion exchange resin could remove a sufficient amount of boron from the FGD blowdown to allow it to be discharged with other wastewater in the ash pond. In this case high boron removal efficiency by the resin is not necessary. However, with only boron concentrations being reduced selectively, the other parameters remain at high concentration levels. The absence of the fly ash water as a dilution water will cause the combined wastewater concentrations for the other parameters, such as sulfate, chloride, metals, etc, to be higher than their current levels. This may cause concerns with groundwater contamination at the ash ponds, as well as concerns with meeting discharge limits to Sugar Creek for parameters other than boron.

(2) **Activated carbon for boron removal.** This option was discussed briefly by Hanson Engineers, but there was not sufficient information to determine the applicability of activated carbon for boron removal. Research into activated carbon manufacturer's capabilities by B&McD has not provided any information regarding boron removal by activated carbon. Thus, this option does not appear to be valid.

(3) **Chemical precipitation or co-precipitation.** Because of the high solubility of boron (2.7% at 32 °F, and 40% at 212 °F), precipitation of boron is unlikely to occur at the concentrations in this application (boron concentration 200 – 400 ppm). Co-precipitation is also unlikely. Hanson Engineers reported a commercially available agent for boron co-precipitation, but indicated that it is more applicable at higher boron concentrations. B&McD's investigation on this agent indicated that the company that produced this material is no longer making it because the product failed to perform. Thus this option is not recommended for further investigation.

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6.2 Water Supply and Conservation Options

Two water supply sources were evaluated for use as make-up water to both the existing units and the new unit, Lake Springfield and the sanitary wastewater treatment plant effluent (gray water). Lake Springfield is the raw water source to the existing units and the city drinking water treatment plant (Filter Plant) located on the plant site, and it is a possible source of raw water to the new unit. A potentially second water source is the gray water. As discussed below, the cost to use the gray water supply source as make-up water to the power generation units is more expensive than using the lake water. However, the use of gray water provides significant reduction on the consumption of the lake water.

6.2.1 Lake Springfield Water versus Gray Water Supply

The city filter plant receives its water from a separate dedicated intake on Lake Springfield. The water is the treated, clarifier and filtered before being stored in large underground storage basins. The treated water is pump from the basins through a several main headers to distributions lines throughout the city. The city water treatment and pumping system has sufficient excess capacity to meet the demand of the new unit without impacting its ability to meet city water needs.

The existing Dallman unit's receive there water from a separate dedicated intake on Lake Springfield. The water is pump by the plant high cooling water pumps which convey water through the existing condensers and back to the lake in a once-through cooling system. Based on the preliminary water balance of for the new unit, total makeup water usage for the new unit is insignificant compared to the once-through cooling water flow rate to the existing units. Thus, no new water intake facilities would be required to supply the lake water to the new unit from the existing Dallman Station cooling water system. Also, no on-site raw water storage would be required, because of available pump and piping system redundancy and close proximity of the lake. Booster pumps and interconnecting piping would have to be installed to extract water from the once-through cooling water pipeline, because the once-through system operates at a low pressure.

In contrast, to use the gray water supply, a pumping station at the SWTP, an approximately 3-mile pipeline, and on-site storage or secondary water source and forwarding pumps, would be required. In addition, sanitary wastewater effluent could cause severe operational problems in cooling towers (the primary water users of the new unit) and the FGD systems, which take cooling tower blowdown as make-up water. High solids content and high bio-activity could cause fouling and fouling-induced corrosion problems in plant equipment such as cooling tower, condensers and FGD systems.

To use the gray water source, and to minimize operating and maintenance expenses and potential operation problems, a pre-treatment facility is recommended to remove contaminants in the gray water that could cause equipment problems. Even with pre-treatment, especially if the pre-treatment is less effective, some O&M costs, such as chemical treatment in the cooling tower, would still be higher than if lake water is used.

The construction of the pipeline must cross multiple highways and some commercial and residential properties that are not owned by CWLP. Obtaining easements across other properties could be time-consuming and costly. These costs are not included in the cost estimate for this option.

In summary, it is more costly to use gray water than lake water, as make-up water to the new unit. The cost-benefit characteristics of the two water supply options are summarized in the following table:

Table 3-1, Lake Springfield Water versus Gray Water as Make-up to New Unit:

Comparison Items	Lake Springfield	SWTP Gray Water
Capital Cost Pumps, pipeline, and tanks	$150,000	$3.7M[1]
Pumping Cost	$0.00139/1,000-gal[3]	240 hp, continuous[1] ($0.02/1,000-gal if electricity costs $20/MW-hr)
Pre-treatment Equipment Cost, installed	$4.5M[1]	$6M[1]
Pre-treatment Operating Cost	~50 hp[1], chemicals (acid, caustic, biocide and coagulant) are required.	~75 hp[1], chemicals (acid, caustic, biocide and coagulant) are required.
Maximum Cycles of Concentration in Cooling Tower	>10	<8
Cooling Tower Design And Construction	High-efficiency fill may be used for lake water due to lower potential of fouling.	Low-Foul fill may be required for gray water. Cost is about $400,000 higher than the high-efficiency fill.
Additional Cooling Tower Chemical Cost	N/A[2]	More-frequent biocide treatment and higher concentrations, or more expensive types, of scale and corrosion inhibitor treatment are expected. Possibly more chemical waste (in blowdown) due to lower cycles of concentration.
Other Considerations:	- All installation and equipment modifications are on-site.	- Off-site construction of pipeline, and working with outside organizations, could be costly.

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Notes:

1. B&McD internal estimates (see attached water conservation options cost analysis tables).
2. This item lists the additional chemical cost items associated with using gray water as make-up.
3. Per information provided by CWLP letter 2/11/2004.

In reviewing the potential use of gray water for plant makeup, CWLP advised that the use of gray water will not be pursued at this time as part of this project. They may consider future use of gray water if it becomes less expensive than other make-up supply sources.

6.2.2 Water Conservation Options

CWLP stated that water conservation of Lake Springfield water is a high priority as CWLP's options for obtaining additional raw water supplies are limited and potentially very costly. . S&L provided some recommendations in their study for conserving lake water, mostly by modifying the plant systems, but also by reviewing and improving operational procedures and water management practices.

Another option that B&McD investigated was to use the ash water clarification pond effluent back to the new unit as make-up water. This is a variation from the S&L option of recycling the ash water clarification pond effluent as ash sluicing water, but the important difference is that this option does not create a closed loop because the recycled water is used in another system (the new unit cooling towers primarily) and is not returned to the ash ponds.

This option would require pre-treatment of the ash pond water to remove ash fines, suspended solids, and certain metals that the clarification pond could not completely remove, but it provides significant net reduction on the lake water usage. In addition, compared to the reuse of the SWTP effluent, this option provides similar reduction on the lake water usage with far less costs. A water balance for each of the first five options below was prepared and attached in the appendices of this report. The water balances are for the new unit and all three Dallman Units based on the average unit load factors for 2010-2025.

Many of these water conservation options result in significant reduction of ash sluicing water, which is currently fed by the lake water. Thus, reduced lake water usage could also mean lower flows in Sugar Creek which is currently where the ash sluicing water is discharged from the clarification pond. In some small streams reduced flow in certain drought times of a year could be of concern to plants or animals living in or around the streams. In this study, we have assumed that the effect on the hydrology and the ecology of Sugar Creek is not significant as a result of the water conservation options discussed below. However, this would need to be further investigated.

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6.2.2.1 Option 1 (Base Case) - Use Lake Water for Make-up with Pre-treatment

In this option, lake water is extracted from the existing Dallman Units' cooling water pipelines to feed to a pre-treatment system on site. This option has no reduction on lake water consumption, but it will have the minimum cost among the water conservation options. As discussed earlier in this report, due to some impurities in the lake water, such as iron manganese, suspended solids, it requires pre-treatment before it could be used as a make-up water to power plant equipment such as cooling towers, condensers, reverse osmosis, demineralizers, service water, FGD mist eliminator wash water, and ash handling system make-up water. The treatment cost is included in the evaluation of this option.

For some of the problems caused by these impurities, such as manganese deposit in condenser tubes which has been known to cause corrosion on stainless steel or copper alloys, higher-grade stainless steel is an alternative to pre-treatment of the make-up water. This alternative could save some money on capital cost, as well as operating and maintenance cost, compared to pre-treatment of the make-up water. However, it is a conservative approach to remove the problem from the source rather than dealing with it in the power plant equipment.

Also, even if higher-grade materials could avoid excessive corrosion damage, deposit of iron, manganese, or other impurities on equipment such as cooling tower fill or condenser tubes, would still affect the performance of the fouled equipment. As an example, fouled condenser tubes will lose heat transfer efficiency. In some cases, the fouling could significantly decrease steam turbine output due to insufficient heat rejection by the condenser. The potential revenue loss might easily exceed the savings from upgrading materials instead of pre-treating the make-up water.

This option does not save any lake water, but requires the least amount of equipment and has a low capital and operating and maintenance cost.

6.2.2.2 Option 2 - Use Gray Water for Make-up with Pre-treatment. Use Lake Water as Backup

In this option, gray water from the city's Sanitary Wastewater Treatment Plant (SWTP) is pre-treated and transferred to CWLP's plant site for make-up to the new unit, primarily the cooling towers. S&L recommended using gray water as ash sluicing water. In addition, properly pre-treated gray water could be used as make-up water to the FGD system and the bottom ash system for the new unit. Water used for service water and demineralizer feed water is provided by treated lake water. Thus a lake water make-up water source would still be required.

Due to reliability issues associated with a 3 mile pipeline, either a large storage tank or a backup water source would be required. Because lake water is available and less costly than a large storage tank, it is recommended that lake water be used as an emergency backup for cooling tower make-up in case gray water supply is interrupted.

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As discussed earlier, gray water is more expensive than lake water as a make-up water source primarily because pipes line and pumps must be installed to transfer the water from the SWTP, about 3 miles away, to the Dallman Station. Gray water contains impurities that could cause problems such as fouling and corrosion, and thus pre-treatment is recommended. In this study, the pre-treatment method is assumed to be the same technology as the lake water pre-treatment process, which is clarification in a clarifier to remove suspended solids and some organic matters. Other treatment technologies, such as microfiltration or ultrafiltration, may be used in this application, but the clarifier equipment and O&M costs are expected to be less expensive than microfiltration or ultrafiltration.

Breakpoint chlorination is also included in the design to provide free residual chlorine in the treated water to prevent biological growth in the transfer pipeline from the SWTP to the unit site. The treated gray water may be used for cooling tower make-up, FGD system make-up, ash handling system make-up or ash sluicing water (for the Dallman units). When used as ash sluicing water, it would eventually be discharged to Sugar Creek, where the SWTP already discharges its treated effluent, thus the impact on the discharge permit may not be an issue. However, the water in the ash pond will essentially become treated gray water, and it needs to be determined if this is acceptable from a ground water quality protection point of view. In this study, it was assumed that this is not a concern, but again this may need to be further investigated.

S&L's report points out that the reuse of gray water on site could cause drainage of gray water to Lake Springfield, the source of drinking water to the city. The drainage could be from plant equipment drains or unintentional spills or overflows of equipment containing the reused gray water. This may be resolved by collecting any such drainage separately, and by sending the collected water to the cooling tower or the FGD as make-up water.

Because of the higher content of dissolved solids and other impurities, gray water is not considered as good as the lake water in terms of water quality. Thus, its usage in the power plant may be limited. The use of gray water is not recommended for potable water, service water and RO or demineralizer make-up water due to the potential of bio-fouling. However, for cooling tower make-up, ash sluicing, FGD system make-up or even for the mist eliminators, which generally requires fresh water, pre-treated gray water is considered acceptable.

Due to the higher content of dissolved solids content, the number of cycles of concentration in the cooling towers is lower than if lake water is used. For Option 1 and the other options, 10 cycles of concentration was assumed in the cooling towers when pre-treated lake water is the make-up water, but for this option only 8 cycles is recommended. This results in higher quantities of blowdown. Cooling tower blowdown is sent to the FGD system as part of the total make-up water, but sufficient fresh water must be provided for the FGD mist eliminator because cooling tower blowdown is not acceptable for this application.

Because the total make-up water flow to the FGD is pre-determined based on the system design and unit load factors, more cooling tower blowdown to the FGD means less fresh water make-up. This makes the combined water quality worse than that of Option 1. Thus, to be conservative, the water balance design shows some of the cooling tower blowdown being directed to the brine concentrator so that the combined FGD make-up water is still of similar quality to that in Option 1.

This design increases the quantity of wastewater to be treated by the brine concentrator and the spray dryer, which in turn increases the operating and maintenance cost of the plant. However, increasing the maximum design capacity (currently at 200 gpm) of the brine concentrator is not necessary because of this additional wastewater. This is because the average wastewater flow rate (151 gpm) for this option is below the maximum design capacity due to the relatively low load factors. If the plant should run at higher load factors for a short time, the FGD systems could tolerate more cooling tower blowdown for the short time durations. However, the chance for all units to operate at 100% for an extended time is small.

6.2.2.3 Option 3 - Dry Fly Ash Systems for All Existing Dallman Units

This option is the same as Option 1, except that it also requires that all of the three existing Dallman Units be converted from wet to dry fly ash transfer, storage, and unloading equipment. The collected dry fly ash could be taken off-site for disposal in a landfill, or for sale as a construction material. The units with converted dry fly ash systems would no longer require ash sluicing water, which in turn will reduce the ash water flow to the ash ponds, as well as the discharge to Sugar Creek. Lake water usage is also reduced.

Unit 33 generates the most fly ash due to its PC furnace (as opposed to cyclones for Units 31/32), and its projected load factor is much higher than Units 31/32. In addition, Unit 33 could utilize a shared silo with the new unit, which will be installed regardless of the fly ash transfer method of Unit 33. Converting only Unit 33 to dry fly ash is the most economical alternative. In the net present value cost analysis included later in this report, this alternative is discussed and reviewed in more detail. The comparison between converting all Dallman Units to dry fly ash and converting only Unit 33 is provided. A concern with not converting Units 31/32 to dry systems is that there is still a potential boron leaching problem in the ash ponds if all fly ash is not removed.

A concern with sending any fly ash to the pond is that during times when the SCR is in operation, any ammonia slipped from the SCR could be adsorbed by the fly ash, and then dissolved in ash water. The interaction between ammonia and boron in fly ash will cause it to be released into water and increase the potential of exceeding the discharge limit of boron to Sugar Creek. Therefore, besides being a possible water conservation option, Option 3 is also an option to mitigate the boron discharge problem at CWLP.

Based on calculations of boron concentrations in the wastewater streams at the ash ponds, the effect of removing all fly ash water from the ash ponds could be analyzed as follows:

- The total existing fly ash water to the ash ponds, according to the S&L water balance, is about 1.13 MGD based on the average water balance for the Dallman Units. According to the Hanson study report, the average boron concentrations of Dallman Units' fly ash sluicing water streams are 38 ppm, 58.7 ppm, and 41.1 ppm, respectively.
- Based on the S&L and Hanson report number: an average discharge flow rate to Sugar Creek at 3.78 MDG, with an average boron concentration of 17.9 ppm when the SCR is in operation.
- Assuming an average of the three boron concentration values above, which is about 46 ppm, removing all fly ash sluicing water (1.13 MGD) from the ash pond would reduce the boron concentration in the discharge to Sugar Creek to about 6 ppm, which is well below the discharge limit of 11 ppm.

However, this is based on only the Dallman FGD blowdown wastewater being sent to the ash ponds. After the new unit is in service, the FGD wastewater from the new unit (assuming 0.1 MGD and 200 ppm of boron), combined with that from the Dallman FGD units (0.15 MGD and 201 ppm of boron), would potentially cause violation of the boron discharge limit (discharge flow at 2.65 MGD without fly ash sluicing water, at boron concentration of 13.5 ppm).

Therefore, it appears that the conversion of all Dallman Units to dry fly ash will not solve the boron discharge problem by itself. However, combined with a zero-discharge treatment for the FGD wastewater (e.g., brine concentrator and spray dryer), these options have a high probability of maintaining boron release to Sugar Creek below the discharge limit at all times.

Instead of converting all Dallman Units to dry fly ash, an alternative is to convert only Unit 33 to dry fly ash system. Unit 33 generates much more fly ash than Unit 31/32 combined due to its PC furnace design. Thus converting Unit 33 to dry fly ash eliminates most of the fly ash that is current being sent to the ash ponds. It is also possible to share the ash silo of the new unit with Unit 33 which makes converting Unit 33 to dry fly ash more economical. However, a concern with not converting Units 31/32 to dry systems is that there is still a potential boron leaching problem in the ash ponds if all fly ash is not removed.

6.2.2.4 Option 4 - Common Closed-Loop Bottom Ash System (with mechanical dewatering) for All Existing Dallman Units

This option is also the same as Option 1, but involves converting all of the three existing Dallman Units to sluicing bottom ash into mechanical dewatering equipment (dewatering bins, settlers or thickeners). The supernate from the dewatering equipment is recirculated as ash sluicing water instead of using the lake water. The system has unrecoverable losses such as evaporation and moisture entrained in the dewatered ash. Due to the evaporation, concentrations of dissolved solids, some of which are sparingly soluble, could eventually build up and could cause scaling of equipment. Other constituents such as chlorides and sulfates could also cause corrosion at elevated concentrations. Thus a blowdown would be required from the system, similar to the operations of a cooling tower. Besides blowdown, water is also lost from hopper seal water overflow. The blowdown from this closed-loop bottom ash system could typically be used as make-up water to FGD systems.

The mechanical dewatering equipment would consist of 3x50% dewatering bins and 100% settling and surge tanks. All Dallman Units will share a common system. Bottom ash sluiced from the units is first transferred to the dewatering bins, where most of the ash particles settle and separate from the ash water. The supernate overflows to the settling tank for further ash particles separation. The final clarified water is collected in the surge tank and used for the next ash sluicing cycle.

There is a potential disadvantage to this option. Both S&L and Hanson stated that the removal of bottom ash water from the ash pond discharge could cause the boron concentration to increase drastically. This is because the bottom ash sluicing water with relatively low concentrations of boron acts as dilution water to other wastewater streams such as the fly ash sluicing water and FGD blowdown.

However, if all FGD wastewater is to be treated with a zero-discharge process, and all fly ash systems are converted to dry fly ash systems (no fly ash sluicing water), the remaining streams to the ash ponds will not have significant boron content based on the Hanson study report. In this case, this option would not cause the concerns of not having sufficient water to dilute boron-laden wastewater streams to the ash pond.

Currently Units 31/32 bottom ash is being dredged and sold as a construction material. Unit 33 bottom ash is a different type of bottom ash that is not sellable, thus it is collected separately. Due to the lack of information on the current available pond storage space, the remaining life of the ash pond is not known. According to CWLP a highway construction project in Springfield potentially would be able to use about 50% of the ash in the ponds. If this does not happen, CWLP may also dredge the pond and dispose of the ash in a landfill. Thus it is assumed for this study that the ponds will have sufficient service life in future.

6.2.2.5 Option 5 - Recycle of Ash Water Clarification Pond Effluent as Make-up to the New Unit

A variation to S&L's options is to reuse the clarification pond effluent as raw water to the new unit. The important difference here is that this option does not create the closed-loop that will exist if the reclaimed water is used for ash sluicing except when the new unit is offline. The blowdown from the cooling tower will be sent to the FGD systems as make-up water, which sends its wastewater to the brine concentrator. Normally the clarification pond effluent is discharged to Sugar Creek, and is thus a consumptive loss of lake water for the operations of the Dallman Units. But if it is reused as make-up water to the new unit, then equal quantity of lake water is saved for the operations of the new unit, and thus the consumptive use of lake water for the new unit is reduced.

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Compared to gray water, ash sluicing water (using lake water) is much better in quality. However, pre-treatment would still be recommended due to the potentially high ash fines and suspended solids, as well as some metals content, in the recycled ash water. Most of the recovered water from the clarification pond is from the Dallman unit's ash sluicing water. Thus Options 3 and 4 above, which will reduce ash sluicing water to the ash ponds, will in turn reduce the quantity of ash water that is available for recovery from the clarification pond. If neither of Options 3 & 4 are selected for actual implementation (all Dallman Units will still sluice both their fly ash and bottom ash to the ash ponds), the average clarification pond effluent water available for recovery is less than 2 MGD based on the water balance. The average total raw water requirement is about 3 MGD for the new unit. Thus some lake water must still be consumed.

The pre-treatment of the lake water and the recovered ash water is very similar. Suspended solids and certain metals are the primary concern. Thus, there only needs to be one pre-treatment system that is shared between the lake water and the recovered ash water. In Option 1, a clarifier system was assumed as the pre-treatment equipment. This equipment would be able to pre-treat the recovered ash water as well. Thus the pre-treatment system of this option is assumed to be identical to that in Option 1. The existing pump house would be reused and the pipeline and pumps would be modified to transfer the clarification pond effluent to the new clarifier.

An added benefit of this option is that under the average projected plant load factors, all of the clarification pond effluent is recovered. Thus, normally there is zero-discharge of ash water to Sugar Creek, and boron discharge is eliminated. During times when the Dallman Units are running at increased load factors, and if as a result the ash sluicing water from the Dallman Units exceeds the total make-up water requirement for the new unit, then some means of temporarily storing the excessive ash water is required. Otherwise discharge to Sugar Creek is inevitable. This could also occur when the new unit is in an outage while the Dallman Units are still in service.

If the excessive ash sluicing water could be reused for other applications at the plant, then the discharge to Sugar Creek could be permanently discontinued, and the plant becomes a true zero-discharge plant. A possible way to achieve this is to recirculate the ash sluicing water still as ash sluicing water for the Dallman Units only when there is more ash sluicing water than the need as make-up to the new unit. The length of time of this mode of operation is not expected to be long because the new unit is designed to be a base loaded unit. In this mode of operation, for short periods the ash pond water quality could become worse due to the closed-loop concentration effect as discussed earlier, but most of the time the water quality remains the same as the normal water quality in the ash ponds. In addition, continuing to sluice fly ash to the ash ponds may still cause boron contamination concerns in ground water.

If this design change is possible, it might also save a significant cost of converting the fly ash systems to dry systems. As discussed earlier in this report, fly ash water carries much more boron than the bottom ash water, and only removing the FGD wastewater from the

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ash pond may not resolve the boron discharge problems. If fly ash systems are converted to dry systems, the boron level would be further reduced. This is assuming that there will still be discharge to Sugar Creek from the ash ponds. If all ash pond effluent is recycled, then the cost of converting to dry fly ash systems is not necessary for the purpose of boron mitigation because the discharge of boron to Sugar Creek is permanently eliminated.

In this option, and other water conservation options, it is assumed that the impact on the flow in Sugar Creek will have no adverse effect on the ecology in and around of the creek. However, this should be further investigated should any of the water conservation options be selected.

6.2.2.6 Closed-Loop Ash Water Systems (Recirculating Ash Water Clarification Pond Effluent) for Existing Dallman Units

This option could be applied to both fly ash and bottom ash systems. The existing ash ponds and the clarification pond functionally act as the dewatering "equipment" and supernate "collection tank" that would be included in Option 4 above. However, the cost of this Option is much less expensive than Option 4, at only $1.44M according to S&L (B&McD's estimate is $1.57M). This option basically only involves installing a pump station at the clarification pond effluent and a pipeline to transfer the clarification pond effluent back to the plant, similar to Option 5 above. The recovered ash water is to be reused as ash sluicing water.

The difference between the mechanical dewatering systems in Option 4 and this option (or between Option 5 and this option) is that due to the use of the ash ponds as means of ash-water separation, the water in the ponds that is concentrated due to the closed-loop operation could cause ground water contamination. According to the S&L and Hanson's studies, such concentration effect will cause several ground water quality standards to be exceeded, which may require re-permitting or lining of the existing ponds. However, this could lead to other issues, and is not recommended by B&McD. Thus although this option is expected to be less costly than Option 4, it is not considered a viable option due to the issue with ground water quality.

6.2.2.7 Dry Bottom Ash Systems for Existing Dallman Units

According to S&L, only Dallman Unit 33 is suitable for conversion to dry bottom ash due to existing equipment and space limitations. However, the cost-benefit ratio of this option is expected to be unfavorable (bottom ash is only a small portion of the total ash content in the Unit 33 PC furnace), and the industry experience of this type of systems is limited. Thus this option was not considered a favorable option.

6.2.2.8 Water Management Options

S&L's report also lists various options to reduce lake water consumption by modifying the operational procedures of certain systems and equipment, and by small equipment additions or modifications. Primarily there are three options that are listed below for discussions:

(1) **Recycle of FGD system vacuum pump seal water.** In this option the seal water is collected and pumped back to the FGD systems instead being discharged to the FGD wastewater sump which is then discharged to the brine concentrator (in future). This option does not save significant amount of water (only about 0.06 MGD based on the average plant load factors of the Dallman Units). However, the reduced FGD wastewater discharged to the brine concentrator will make the brine concentrator much smaller, and thus less costly to install and operate. The equipment for this option is currently being installed by CWLP.

(2) **Ash Handling Water Management.** In this option S&L reviewed the CWLP study on water usage in the ash handling sluice system and related recommendations on installing a recirculation loop to minimize flow to the ash ponds. S&L agreed that a significant water saving (1.84 MGD) could be realized by only flowing to the ash ponds when ash removal was required, in lieu of the current practice of continuous flow. S&L did caution, that placing the sluice pumps in a recirculation mode for periods exceeding 1 hour could result in damage to the sluice pumps, and recommended that ash pumps be shut down if the duration between ash removal cycles exceeded 1 hour.

If the existing fly ash handling systems are converted from wet to dry handling, the potential water saving associated with this recommendation would increase. A significant power savings could be realized by shutting down the sluice pump between ash removal cycles. This would be most significant on Unit 33 where ash removal requirements would be minimal if the wet to dry fly ash conversion is pursued. A detailed analysis of the ash sluicing system operation is beyond the scope of this report. However, eliminating continuous sluice water flow to the ash ponds has significant merit. System modifications and operating procedure changes could be implemented to both conserve water and reduce power usage in ash sluicing operations without significant capital expenditure. Factors such as system water hammer, deposition in the sluice lines, cold weather freeze up, and system modifications for ease of operation would need to be addressed.

(3) **Use Lake Water for Heat Exchangers.** Currently many plant process equipment and plant services equipment (including building HVAC) are cooled by potable water from the filter plant. Lake water was used in the past, but was discontinued due to bio-fouling, especially in summer. Potable water from the filter plant does not have the fouling characteristics of the lake water and has been used successfully for many years.

Potable water usage could be reduced by converting the heat exchanger coolers back to lake water. However, some potable water users (users that require potable water) are connected to the same headers as the heat exchangers. The separation of these potable water users from the rest of the system could be costly. Additionally, tube

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pluggage may be a problem if the tube size is less than ½ inch, unless an effective pre-chlorination system was used. Also, the heat exchanger are spread out within the plant making local pre-chlorination and possible de-chlorination (required to meet NPDES limits) costly.

6.2.3 Water Usage

Water usage of the CWLP power generation units for each year from 2010 to 2025 were calculated based on CWLP-provided load factor projections for each unit. Annual average water balance flow rates were used for total water usage calculations for each of the five water conservation options discussed in the section above. The table titled "Table 1 - Lake Water Usage for Each Water Conservation Option (2010-2025)" summarizes the results (see attached table in the appendices). The result of the calculations is also discussed in Section 7. Lake water usage for makeup water obtained from the existing city filter plant would be the same as Option 1, because the water source and treatment methods are the same.

The data is also graphed on three charts for easy comparison. The charts titled "Figure 1 - Water Usage By Option (2010-2015)", "Figure 2 - Water Usage By Option and Unit", and "Figure 3 - Water Usage By Option and Unit (Combined) are attached in the Appendices. From the charts it can be seen that Option 2 (gray water as make-up) would consume the smallest amount of lake water as expected. Among the other options, Option 5 has the lowest lake water consumptive use because of the significant amount of water recycled from the ash pond. Also, the new unit lake water consumption is about the same for all of the average-load water balances (except Option 2). This is because most of the water consumption at the new unit is cooling tower make-up water, which stays the same independent of the options.

Option 1, as discussed before, consumes the largest amount of lake water because no lake water conservation options are included in this option. The difference between Option 1 and other options on the bar charts gives a good indication on how much lake water is conserved.

6.3 Cost Evaluation

For each of the boron removal equipment options, the installed equipment cost was either obtained from manufacturers or estimated internally by B&McD based on past project cost information for similar equipment. Similarly, the operating cost of the equipment was obtained from manufacturers or estimated by B&McD. Based on this information, the net present value of the various options was calculated for 2010 - 2025. The most viable option, based on the net present value analysis and other factors, was then selected.

Using this preferred boron removal option as the basis, the water conservation options net present value analysis was also performed. The installed equipment costs for the various

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water conservation options as discussed above were estimated by B&McD. S&L's report also provided estimated equipment cost, but the numbers were verified by B&McD, and some of the S&L costs were not considered to be representative of the most economical way of achieving the same goals. Thus the B&McD estimates were used in this cost analysis.

The net present value calculations of the boron removal options and the water conservation operations are presented in the tables (Table 2 and Table 3) in the Appendices.

6.3.1 Boron-Removal Options Summary

Among the options studied, Option 1-2 is the preferred option based on net present value and reliability. This option provides two 50% brine concentrators followed by two 50% spray dryers. Compared to Option 1-2, Option 1-1 is less costly (100% brine concentrator/spray dryer), but Option 1-2 has a potentially higher reliability because of the redundant equipment design. Because the availability of all Dallman Units and the new unit (a total of four power generating units) depends on the availability of this FGD wastewater treatment equipment, Option 1-2 is the preferred option.

For all of the boron-removal options, it is assumed that the solids waste generated from the spray dryers must be disposed in a commercial landfill, but it should be considered as a "non-hazardous" waste. Fly ash mixed with brine concentrator bleed is assumed to be disposed in the coal mine because of the low disposal cost. This needs to be further investigated because quality requirements of solids waste accepted by the coal mine are not currently available. If the acceptability of solids waste for disposal in the coal mine varies from option to option, then the annual operating cost, and thus the net present value, of certain options may be different. This is due to the fact that disposal cost at other commercial landfills, where the solids waste may be accepted, may be much more expensive.

If the Dallman Units are converted to dry fly ash systems, there would be sufficient dry fly ash to mix with wastewater generated from the brine concentrator. However, the fly ash may not be acceptable as a construction material for sale. If it is disposed of in a landfill or back to Turris Mine, there could also be concerns of leaching of contaminants into ground water or surface water (ash is impounded at Turris, but the impoundment discharges to a river under an NPDES permit). Thus, Option 4 of the boron removal options, although the lowest cost option based on the net present value calculations, is not to be selected as the preferred option. However, further investigation of fly ash quality and fly ash quality requirements (for sale or for disposal) is needed to finalize the analysis of this option.

6.3.2 Water Conservation Options Summary

A common disadvantage of the water conservation options studied is that the cost of Lake Springfield water is too low to justify significant capital and/or O&M costs to implement

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water conservation options. Unless the demand for lake water becomes such that the City will have to expend significant capital on another source of fresh water, it is not economical to implement the discussed water conservation options on existing systems that consume lake water. The cost of each option, both in terms of total net present value and in terms of the estimated cost of lake water, is presented based on the annualized total option cost.

The equipment and construction costs were estimated by B&McD, using manufacturer-provided information. The operating and maintenance cost for each options was also estimated by B&McD based on input from equipment design information and information from plant staff. The cost calculations for the water conservation options are summarized in the table titled "Water Conservation Options" attached in the appendices. Option 1 (base case) of using lake water without any water conservation options is the least expensive option (an annualized lake water cost of $0.79/1,000 gallons), and also the simplest option. Converting the fly ash systems to dry systems is the most expensive option in terms of the cost of the water saved (>$6/1,000 gallons).

A benefit of converting the Dallman Units to dry fly systems is the reduction of ash loading to the ash ponds, which might be approaching their full capacity. However, the added equipment (ash silos, unloading equipment, dust control, truck traffics) will also add significant operating costs to the total plant operating budget. The operating costs include disposal cost for the collected ash which CWLP is not paying for now.

One alternative to converting all Dallman Units to dry fly ash systems is to only convert Unit 33, the largest fly ash producer among the Dallman Units. The total capital cost and the net present value (see attached water conservation options cost comparison) of this alternative is reduced by $3.46M. However, it only slightly improves the economics of converting the fly ash system, and is still unfavorable compared to most of the other options.

Similar to the conversion to dry fly ash, the conversion to closed-loop bottom ash systems also reduced lake water consumption, but the capital cost, as well as the operating costs of these systems (e.g. off-site disposal of ash), is expected to be high. The equipment will also occupy additional space on the existing plant site, which by itself could be an adverse factor in the planning for the new unit.

The base case option (Option 1) is the preferred option due to its lowest net present value among all options. The net present values of each option were also converted to annualized total cost. An equivalent lake water cost (ratio of the annualized total cost to lake water saved) was calculated for each option. Option 1 has the lowest equivalent lake water cost at $0.79/1,000 gallons. The lowest equivalent lake water cost among the other options is Option 2 (gray water) at $1.39/1,000 gallons. Although the water cost for Option 1is less expensive than the potable water cost established by CWLP for the filter plant water ($1.55/1,000 gallons), the treatment methods are similar. Therefore, the actual cost to produce the water using a new clarifier treatment system or the existing water treatment plant should be similar. Because the existing city filter plant has available

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excess capacity to meet the new unit's makeup demand, additional capital expenditure for water treatment capacity is not justifiable. The new water treatment plant would also add operating and maintenance expense. Thus based on the economical factors, it is not practical to select any lake water conservation options.

The costs of the S&L proposed options involving water management issues were also calculated in the table. These options are relatively inexpensive, but some are with important benefit to CWLP, and thus should be incorporated for future plant design and operations. For example, the reduction of final FGD wastewater is essential to CWLP as this will significantly reduce the cost of the boron removal system.

Ash sluice pump operating procedure modifications offer some significant water and power savings. It is recommended that a separate study be conducted after a final decision on fly ash conversion is made to optimize the operation of this system. Some system improvements would be required as well as modifying operating procedures.

Using treated lake water for all or part of the miscellaneous heat exchangers instead of potable will not affect lake water consumption. It would reduce plant potable water demand, but segregation from the users requiring potable water and local chlorination and de-chlorination equipment would be costly. Based on the current excess capacity in the city filter plant, the cost for the required system modifications and concern for tube fouling, it is not recommended that any action to convert from potable water to lake water be taken at this time.

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7.0 CONCLUSIONS AND RECOMMENDATIONS

Boron Mitigation at Ash Pond Discharge

Previous study reports on boron mitigation, ash handling water usage and water conservation by Hanson Engineers, CWLP, and Sargent & Lundy were reviewed and analyzed. The study results indicated that the most significant source for boron was FGD wastewater, but fly ash also contributed a significant amount of boron to the plant discharge. Bottom ash boron contribution was determined to be limited compared to the two above. Therefore, the most effective option to resolve the boron discharge problem at the ash water ponds is to prevent the FGD wastewater from being discharged to the ponds.

The zero-discharge system for treating FGD wastewater, consisting of two 50% brine concentrators followed by two 50% spray dryers, is the preferred boron mitigation option. However, this treatment option by itself would only reduce boron concentration in the discharge to Sugar Creek to less than the discharge limit by a small margin, and the calculations were based on average boron concentrations of a limited number of samples taken in the Hanson study. Fly ash is the second largest contributor to the boron discharge problem. Thus, converting the Dallman Units to dry fly ash systems, in addition to the zero-discharge system for FGD wastewater, would most likely maintain boron concentrations below the discharge limit at all times.

Due to the additional cost involved in converting fly ash to dry systems, it may be desirable for CWLP to implement these options in phases. The first step would be to install the zero-discharge system (brine concentrator/spray dryer) for treating the FGD wastewater. If future data indicates that this option by itself is not sufficient to mitigate the boron discharge problems, then in the second phase, conversion of the fly ash to dry systems may be implemented. Conversion of only Unit 33 to dry fly ash is preferred because Unit 33 produces the most fly ash due to its PC furnace design, provided that fly ash from Units 31/32 will not cause boron concerns in the ash ponds. In addition, Unit 33 could share a common ash silo with the new unit, which makes this modification more economical.

If ash water from the clarification pond could be recycled back to the plant at all times, conversion to dry fly ash is not necessary for the purpose of more certain boron mitigation. This option is actually a more economical solution than converting to dry fly ash systems. However, the disadvantage is that this option might involve closed-loop ash sluicing operations during short durations of time when the new unit is in an outage. This closed-loop effect has the potential to make the ash pond water quality, and possibly the ground water quality, to become worse during these times. Also, continuing to send fly ash to the ash ponds may also be a concern for boron contamination of ground water. Before these issues can be resolved, this option is not considered a viable option.

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Water Conservation

Based on the cost analysis, it is not economical to implement any lake water conservation options at this time. However, other factors, such as the additional boron-removal options discussed above (converting to dry fly ash or recycling of clarification pond effluent), may be implemented, which results in lake water conservation. This study has assumed that the water conservation options, which would result in reduced Sugar Creek flow, will have no impact on the ecology in or around the creek.

The ash ponds are believed to be approaching their useful life. However, currently there is insufficient information to determine if this is the case (CWLP stated that there is a good chance that the ash could be dredged and used for a highway project). Additionally, dredging the pond and disposing of the dredged ash off-site is always an option. Therefore the current recommendation to CWLP is to keep at least the bottom ash systems of the existing units unchanged until an important factor has changed in future.

The table below compares the total cost of the different water conservation options, as well as lake water consumed for each option, for years 2010 - 2025:

Water Conservation Options	Net Present Value (Annualized Lake Water Cost, $/1,000-gal)	Total Lake Water Used, Million Gallons (Acre-Ft.), 2010-2025	Average Consumption of Lake Water, MGD
Option 1, Lake Water Make-up Water	-$8,930,099 ($0.79/1,000-gal)	32,268 MG (99,026 Acre-Ft.)	5.53 MGD
Option 2, Gray Water Make-up Water	-$21,315,459 ($1.39/1,000-gal)	8,579 MG (26,328 Acre-Ft.)	1.47 MGD
Option 3, Dry Fly Ash	-$19,463,737 ($6.50/1,000-gal)	27,697 MG (84,998 Acre-Ft.)	4.74 MGD
Option 4, Closed-Loop Bottom Ash	-$20,179,721 ($3.83/1,000-gal)	24,178 MG (74,199 Acre-Ft.)	4.14 MGD
Option 5, Recycling Clarification Pond Effluent	-$10,705,114 ($1.50/1,000-gal)	21,334 MG (65,473 Acre-Ft.)	3.65 MGD

From the data above it can be seen that Option 1, using lake water for the new unit water requirements, is the most economical option. Again, this conclusion is based on the current low cost of the lake water ($1.39/Million Gallons). Unless this cost of lake water changes in future due to the need to expand or construct another fresh water lake, or wells, it would be hard to justify the cost for any of the water conservation options. Although, based on established filter plant water cost, the economic analysis indicates that Option 1 with a new separate pretreatment system is more economical than using

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filter plant effluent, CWLP has indicated the existing filter plant has excess capacity and can produce water more economically than a new water treatment plant designed to serve just the makeup requirements for the new plant.

Therefore, based on the information available, B&McD recommends that, for the new unit, lake water provided from the CWLP Filtration Plant be used as the primary source of make-up water. A final water balance is provided in the appendices of this report. This final water balance incorporates the following recommended modifications.

- Existing Dallman Units will be converted to dry fly ash handling.
- The new unit will be based on dry fly ash handling
- Ash pond water will be recovered and returned to Lake Springfield.
- The new unit FGD wastewater will be treated and recovered using brine concentrators and spray dryers.

In the event that the Ash Pond water quality is not suitable for direct discharge to Lake Springfield, a new water treatment system could be added to allow recovery of the Ash Pond effluent as makeup to the new unit cooling tower, if the value of water conservation exceeds the cost of a new water treatment plant and associated added operating and maintenance expense.

APPENDICES

Water Balance Diagrams
Typical Brine Concentrator/Spray Dryer Process Flow Diagram
Typical HERO System Process Flow Diagram
Water Usage Projection for 2010-2050
Water Usage Charts
Boron Treatment Options Cost Comparison
Water Conservation Options Cost Comparison

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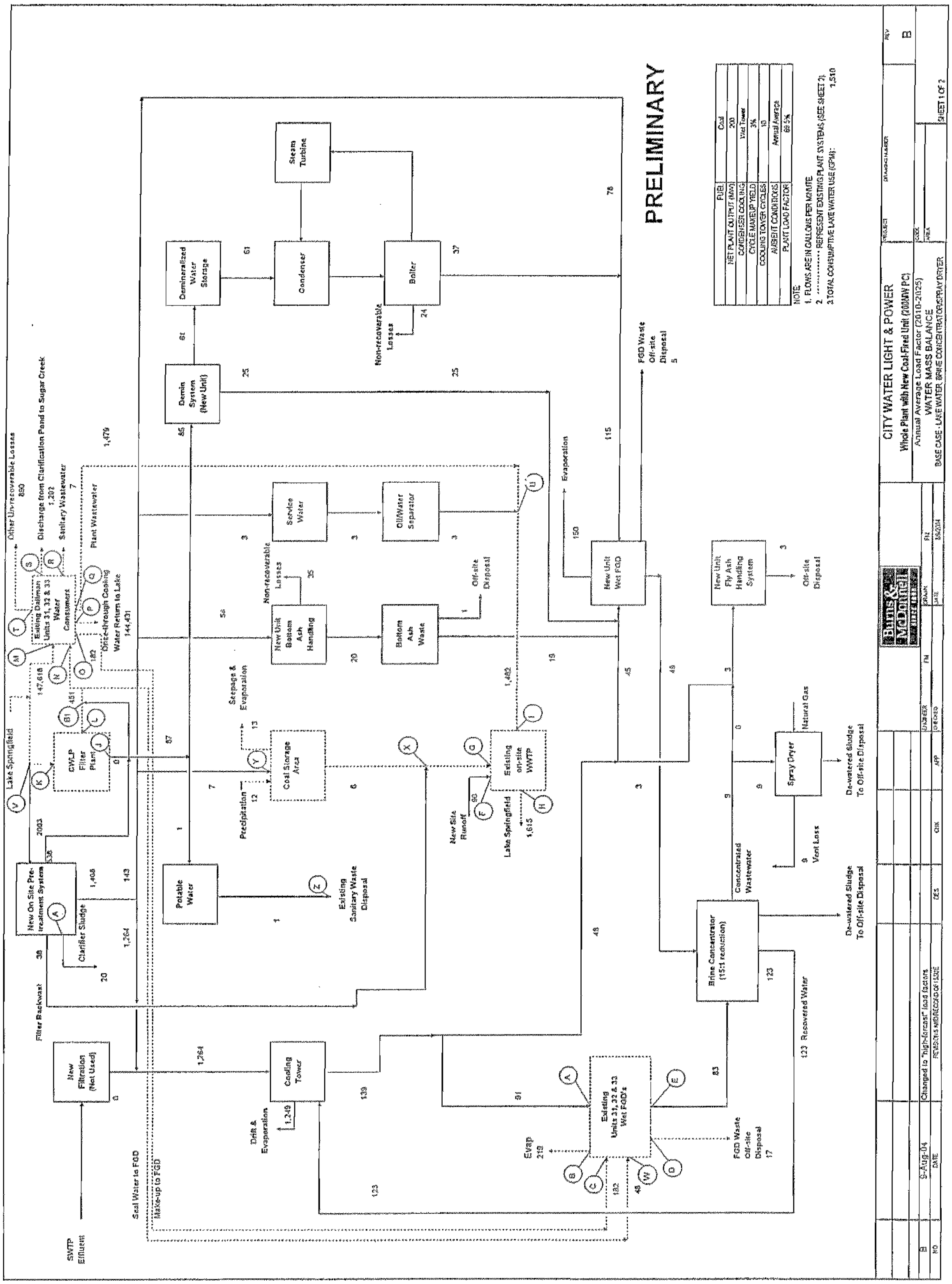

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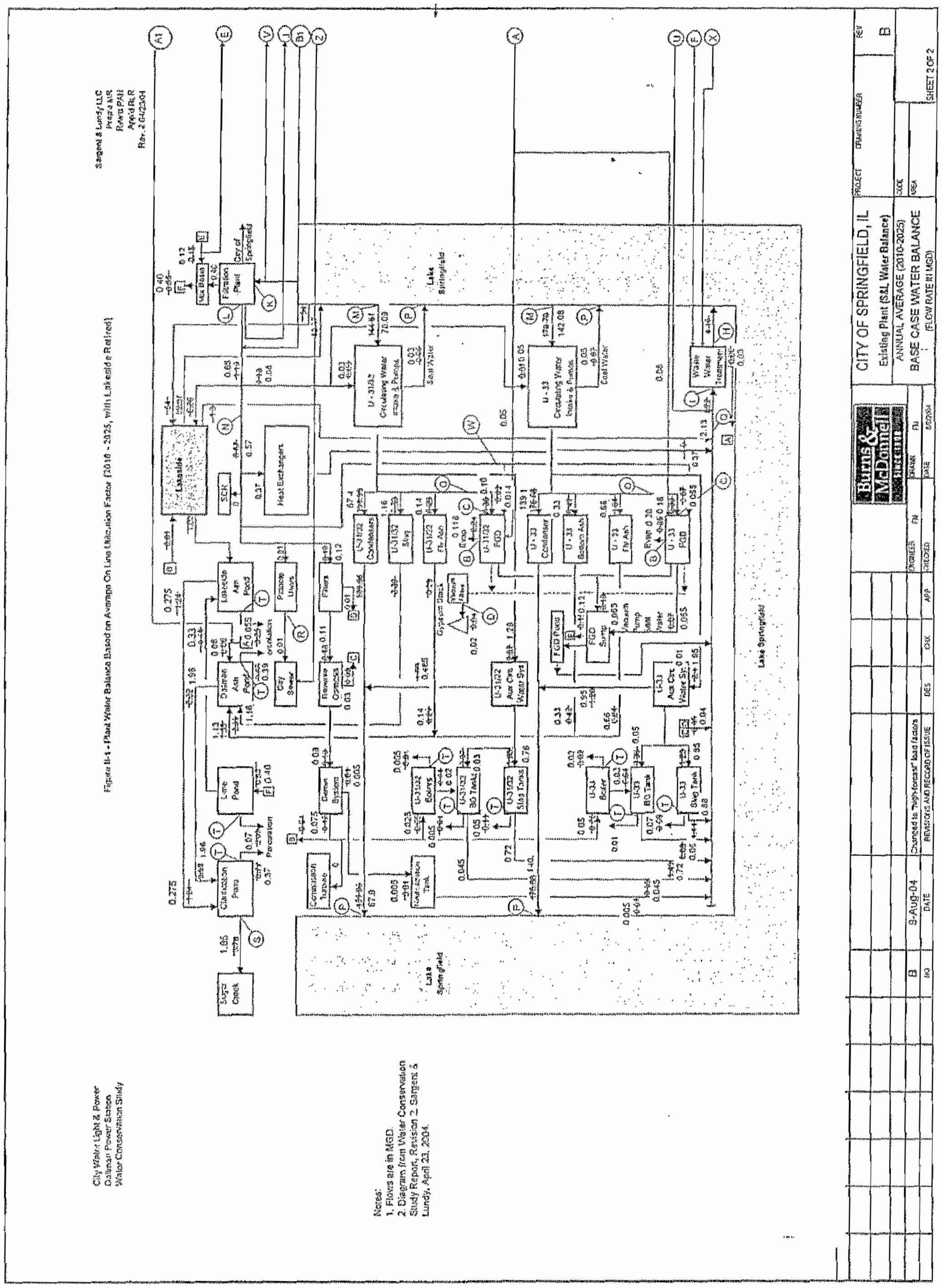
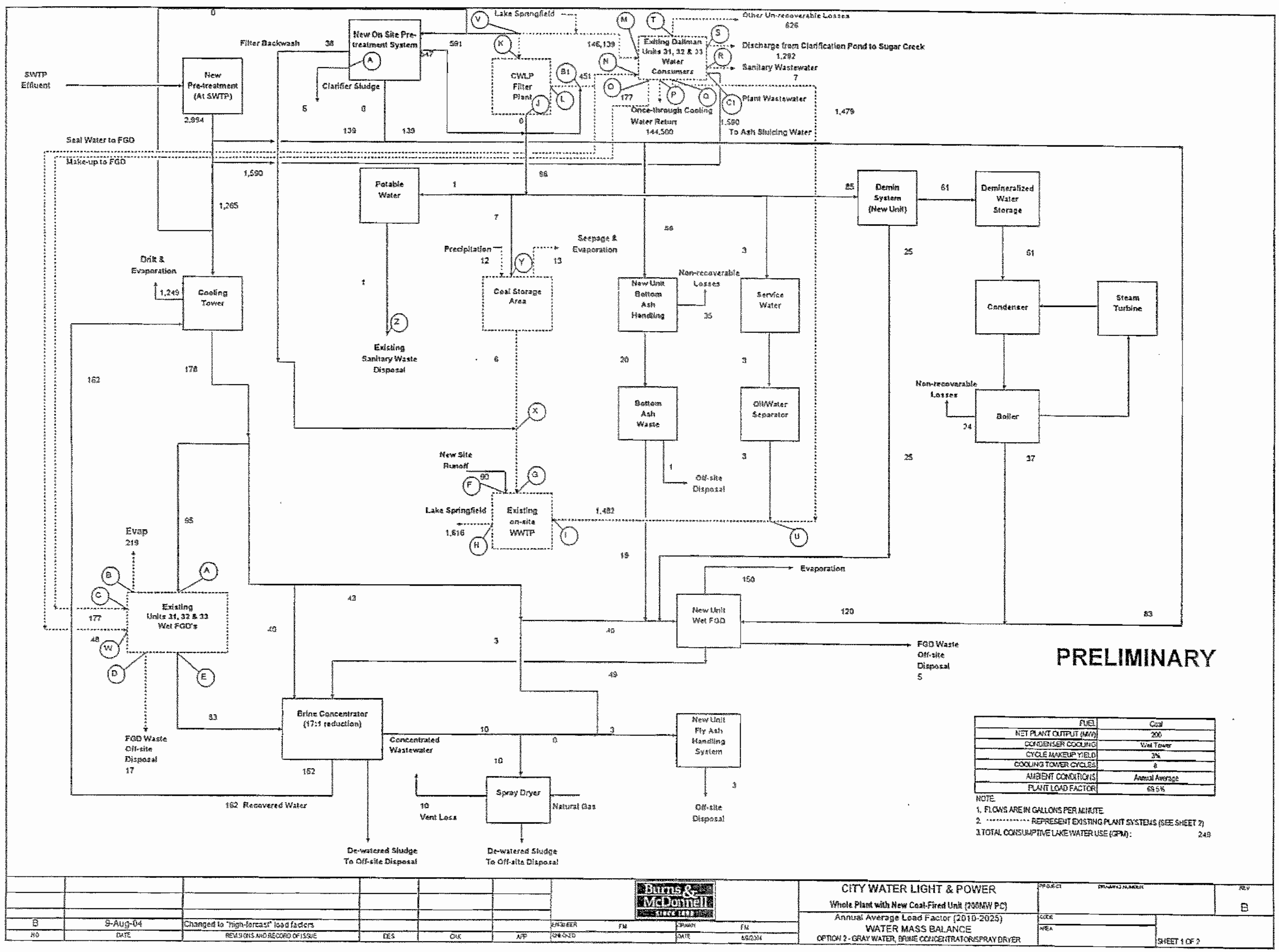
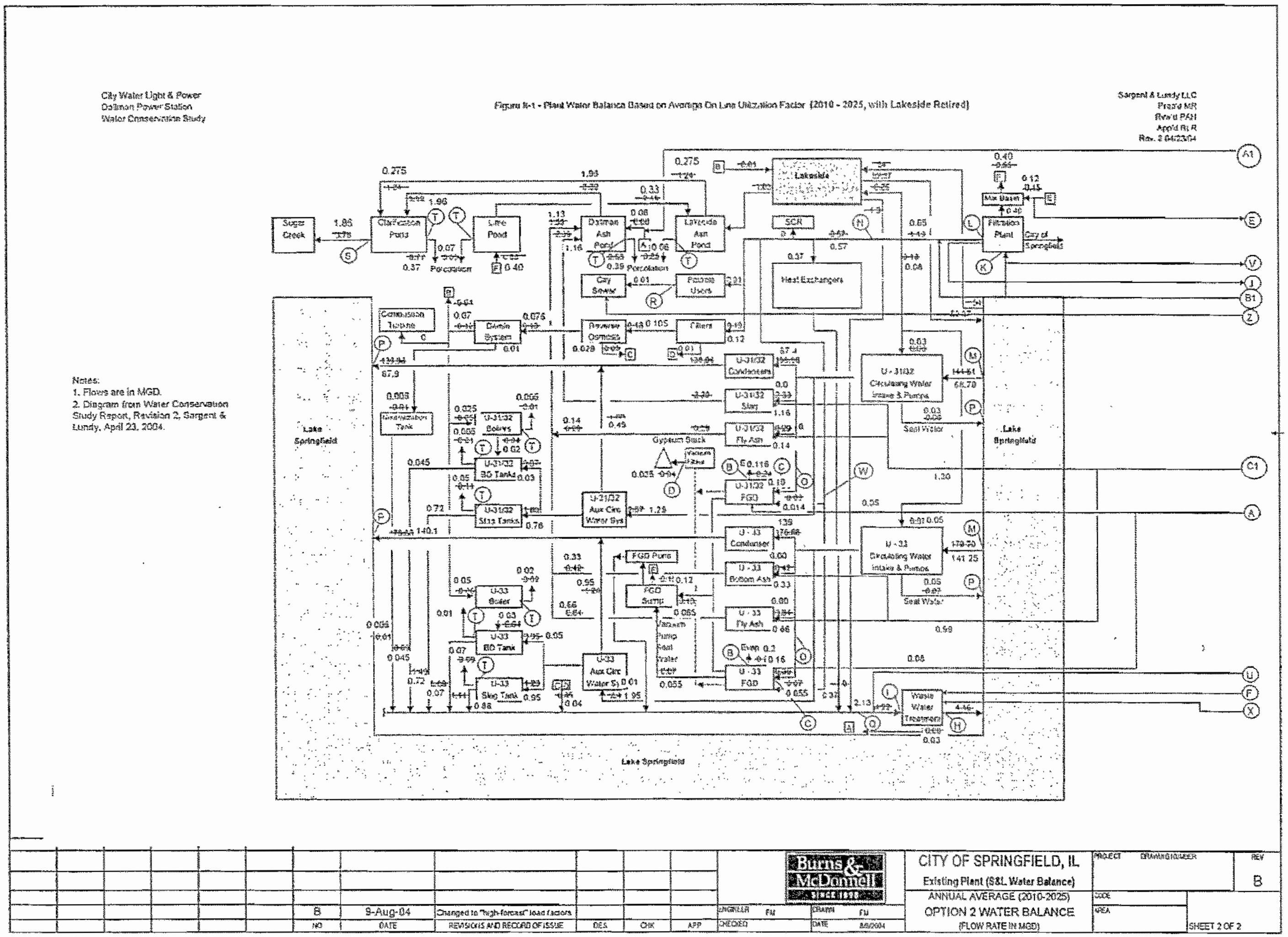
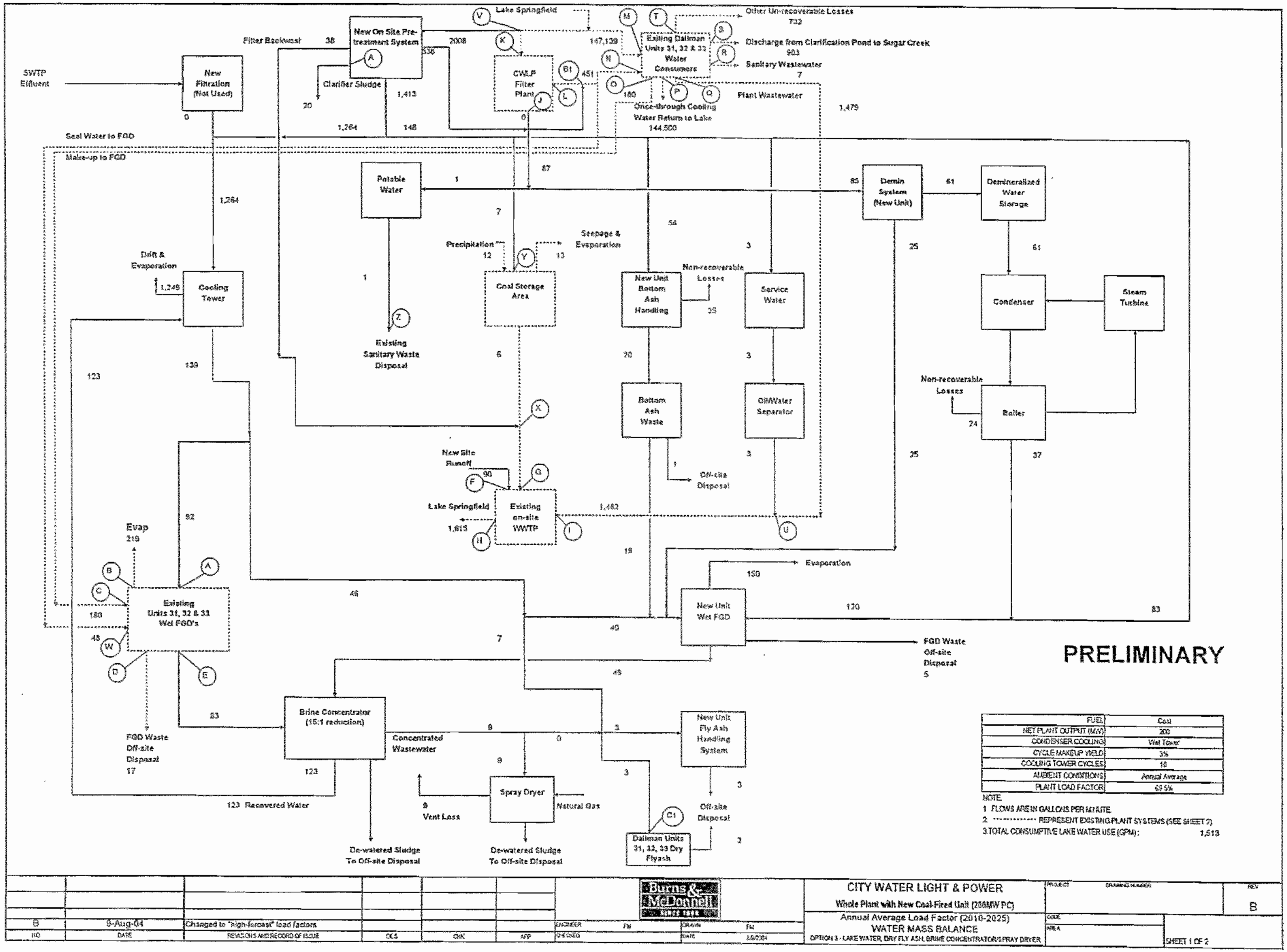
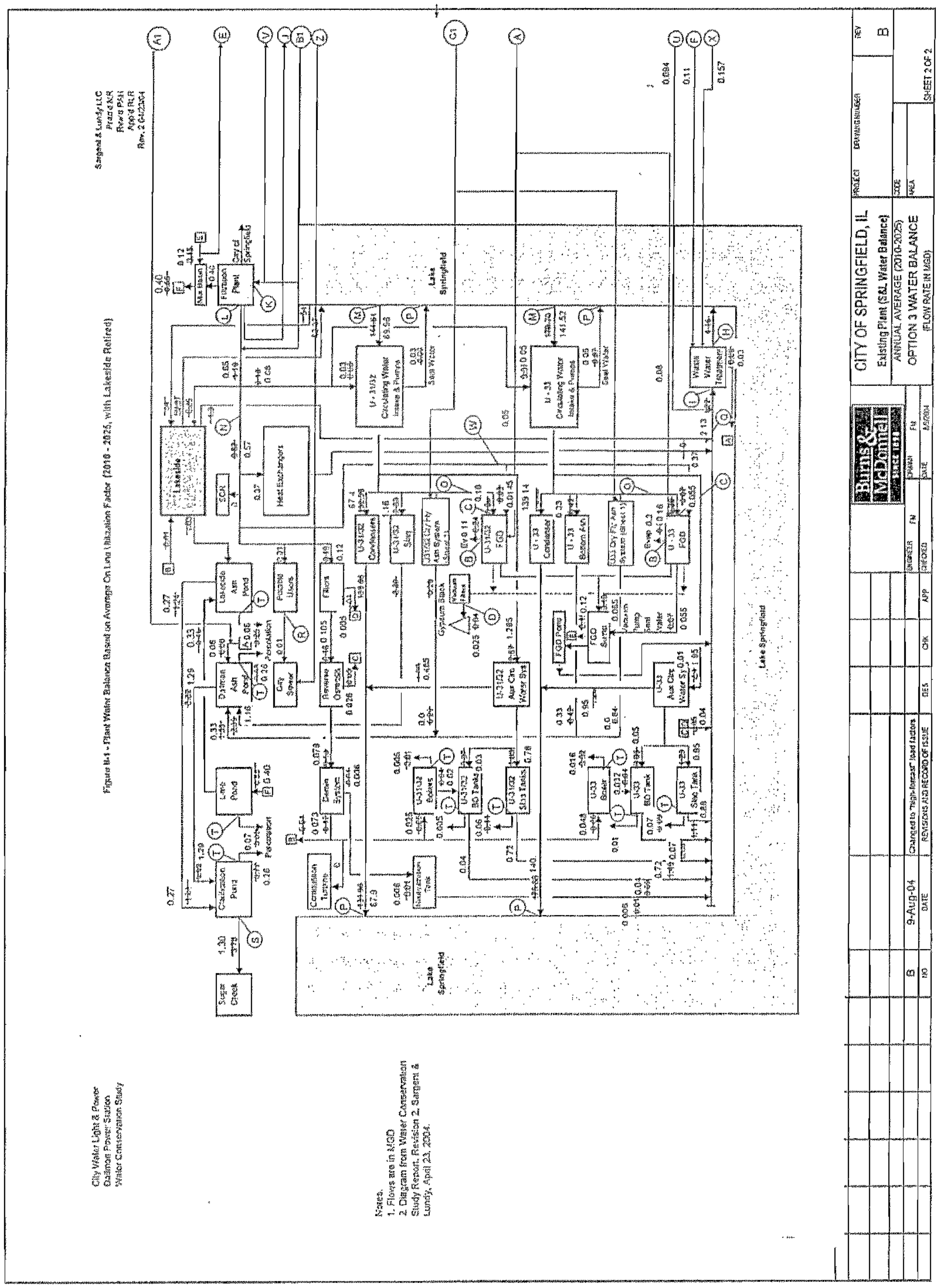



SWTP Effluent
New Pre-treatment (At SWTP)
New On Site Pre-treatment System
Filter Backwash
Clarifier Sludge
Lake Springfield
CWLP Filter Plant
Existing Dallman Units 31, 32 & 33 Water Consumers
Other Un-recoverable Losses
Discharge from Clarification Pond to Sugar Creek
Sanitary Wastewater
Plant Wastewater
Once-through Cooling Water Return
To Ash Sluicing Water
Seal Water to FGD
Make-up to FGD
Potable Water
Demin System (New Unit)
Demineralized Water Storage
Drift & Evaporation
Cooling Tower
Precipitation
Seepage & Evaporation
Coal Storage Area
New Unit Bottom Ash Handling
Non-recoverable Losses
Service Water
Condenser
Steam Turbine
Existing Sanitary Waste Disposal
Bottom Ash Waste
Oil/Water Separator
Boiler
New Site Runoff
Existing on-site WWTP
Off-site Disposal
Evap
Existing Units 31, 32 & 33 Wet FGD's
Evaporation
New Unit Wet FGD
FGD Waste Off-site Disposal
PRELIMINARY
FGD Waste Off-site Disposal
Brine Concentrator (17:1 reduction)
Concentrated Wastewater
New Unit Fly Ash Handling System
Spray Dryer
Vent Loss
Natural Gas
162 Recovered Water
De-watered Sludge To Off-site Disposal
FUEL Coal
NET PLANT OUTPUT (MW) 200
CONDENSER COOLING Wet Tower
CYCLE MAKEUP YIELD 3%
COOLING TOWER CYCLES 8
AMBIENT CONDITIONS Annual Average
PLANT LOAD FACTOR 69.5%
NOTE:
1. FLOWS ARE IN GALLONS PER MINUTE.
2. .... REPRESENT EXISTING PLANT SYSTEMS (SEE SHEET 2)
3. TOTAL CONSUMPTIVE LAKE WATER USE (GPM): 249
Burns & McDonnell
CITY WATER LIGHT & POWER
Whole Plant with New Coal-Fired Unit (200MW PC)
Annual Average Load Factor (2010-2025)
WATER MASS BALANCE
OPTION 2 - GRAY WATER, BRINE CONCENTRATOR/SPRAY DRYER
B
9-Aug-04
Changed to "high-forecast" load factors
REVISIONS AND RECORD OF ISSUE
SHEET 1 OF 2


City Water Light & Power
Dallman Power Station
Water Conservation Study
Figure II-1 - Plant Water Balance Based on Average On Line Utilization Factor (2010 - 2025, with Lakeside Retired)
Sargent & Lundy LLC
Notes:
1. Flows are in MGD.
2. Diagram from Water Conservation Study Report, Revision 2, Sargent & Lundy, April 23, 2004.
Sugar Creek
Clarification Ponds
Lime Pond
Dallman Ash Pond
Lakeside Ash Pond
Lakeside
SCR
Heat Exchangers
Filtration Plant
Mix Basin
City of Springfield
City Sewer
Process Users
Reverse Osmosis
Filters
Demin System
Combustion Turbine
Neutralization Tank
U-31/32 Condensers
U-31/32 Slag
U-31/32 Fly Ash
U-31/32 FGD
U-31/32 Boilers
U-31/32 BD Tanks
U-31/32 Slag Tanks
U-31/32 Aux Circ Water Sys
U-31/32 Circulating Water Intake & Pumps
Seal Water
Gypsum Stack
Vacuum Filters
U-33 Condenser
U-33 Bottom Ash
U-33 Fly Ash
U-33 FGD
U-33 Boiler
U-33 BD Tank
U-33 Slag Tank
U-33 Aux Circ Water Sys
U-33 Circulating Water Intake & Pumps
FGD Pump
FGD Sump
Vacuum Pump Seal Water
Waste Water Treatment
Lake Springfield
Burns & McDonnell
CITY OF SPRINGFIELD, IL
Existing Plant (S&L Water Balance)
ANNUAL AVERAGE (2010-2025)
OPTION 2 WATER BALANCE
(FLOW RATE IN MGD)
B 9-Aug-04 Changed to "high-forecast" load factors
NO DATE REVISIONS AND RECORD OF ISSUE DES CHK APP
SHEET 2 OF 2


Lake Springfield
Other Un-recoverable Losses
732
Existing Dallman Units 31, 32 & 33 Water Consumers
Discharge from Clarification Pond to Sugar Creek
903
Sanitary Wastewater
7
Plant Wastewater
Once-through Cooling Water Return to Lake
144,500
147,139
Filter Backwash
New On Site Pre-treatment System
Clarifier Sludge
CWLP Filter Plant
SWTP Effluent
New Filtration (Not Used)
Seal Water to FGD
Make-up to FGD
Potable Water
Demin System (New Unit)
Demineralized Water Storage
Precipitation
Seepage & Evaporation
Coal Storage Area
Drift & Evaporation
Cooling Tower
Existing Sanitary Waste Disposal
New Unit Bottom Ash Handling
Non-recoverable Losses
Service Water
Condenser
Steam Turbine
Bottom Ash Waste
Oil/Water Separator
Non-recoverable Losses
Boiler
Off-site Disposal
New Site Runoff
Lake Springfield
Existing on-site WWTP
Evap
Existing Units 31, 32 & 33 Wet FGD's
Evaporation
New Unit Wet FGD
FGD Waste Off-site Disposal
PRELIMINARY
FGD Waste Off-site Disposal
Brine Concentrator (15:1 reduction)
Concentrated Wastewater
New Unit Fly Ash Handling System
Spray Dryer
Vent Loss
Natural Gas
123 Recovered Water
De-watered Sludge To Off-site Disposal
De-watered Sludge To Off-site Disposal
Dallman Units 31, 32, 33 Dry Flyash
Off-site Disposal
FUEL | Coal
NET PLANT OUTPUT (MW) | 200
CONDENSER COOLING | Wet Tower
CYCLE MAKEUP YIELD | 3%
COOLING TOWER CYCLES | 10
AMBIENT CONDITIONS | Annual Average
PLANT LOAD FACTOR | 69.5%
NOTE
1 FLOWS ARE IN GALLONS PER MINUTE
2 ------------ REPRESENT EXISTING PLANT SYSTEMS (SEE SHEET 2)
3 TOTAL CONSUMPTIVE LAKE WATER USE (GPM): 1,513
Burns & McDonnell
SINCE 1898
CITY WATER LIGHT & POWER
Whole Plant with New Coal-Fired Unit (200MW PC)
Annual Average Load Factor (2010-2025)
WATER MASS BALANCE
OPTION 3 - LAKE WATER, DRY FLY ASH, BRINE CONCENTRATOR/SPRAY DRYER
B
9-Aug-04
Changed to "high-forcast" load factors
NO
DATE
REVISIONS AND RECORD OF ISSUE
DES
CHK
APP
ENGINEER
CHECKED
DRAWN
DATE
PROJECT
DRAWING NUMBER
REV
B
SHEET 1 OF 2


City Water Light & Power
Dallman Power Station
Water Conservation Study
Figure II-1 - Plant Water Balance Based on Average On Line Utilization Factor (2010 - 2025, with Lakeside Retired)
Sargent & Lundy LLC
Notes.
1. Flows are in MGD
2. Diagram from Water Conservation Study Report, Revision 2, Sargent & Lundy, April 23, 2004.
Sugar Creek
Clarification Point
Lime Pond
Dallman Ash Pond
Lakeside Ash Pond
Lakeside
SCR
Heat Exchangers
Filtration Plant
City of Springfield
City Sewer
Potable Users
Combustion Turbine
Demin System
Reverse Osmosis
Filters
Neutralization Tank
U-31/32 Boilers
U-31/32 BD Tanks
U-31/32 Slag Tanks
U-31/32 Aux Circ Water Sys
U-31/32 Condensers
U-31/32 Slag
U-31/32 FGD
U-31/32 Circulating Water Intake & Pumps
Seal Water
Gypsum Stack
Vacuum Filters
FGD Pond
FGD Sump
U-33 Boiler
U-33 BD Tank
U-33 Slag Tank
U-33 Aux Circ Water Sy
U-33 Condenser
U-33 Bottom Ash
U-33 FGD
U-33 Circulating Water Intake & Pumps
Waste Water Treatment
Lake Springfield
Burns & McDonnell
SINCE 1898
CITY OF SPRINGFIELD, IL
Existing Plant (S&L Water Balance)
ANNUAL AVERAGE (2010-2025)
OPTION 3 WATER BALANCE
(FLOW RATE IN MGD)
SHEET 2 OF 2
B
9-Aug-04
Changed to "high-forecast" load factors
REVISIONS AND RECORD OF ISSUE

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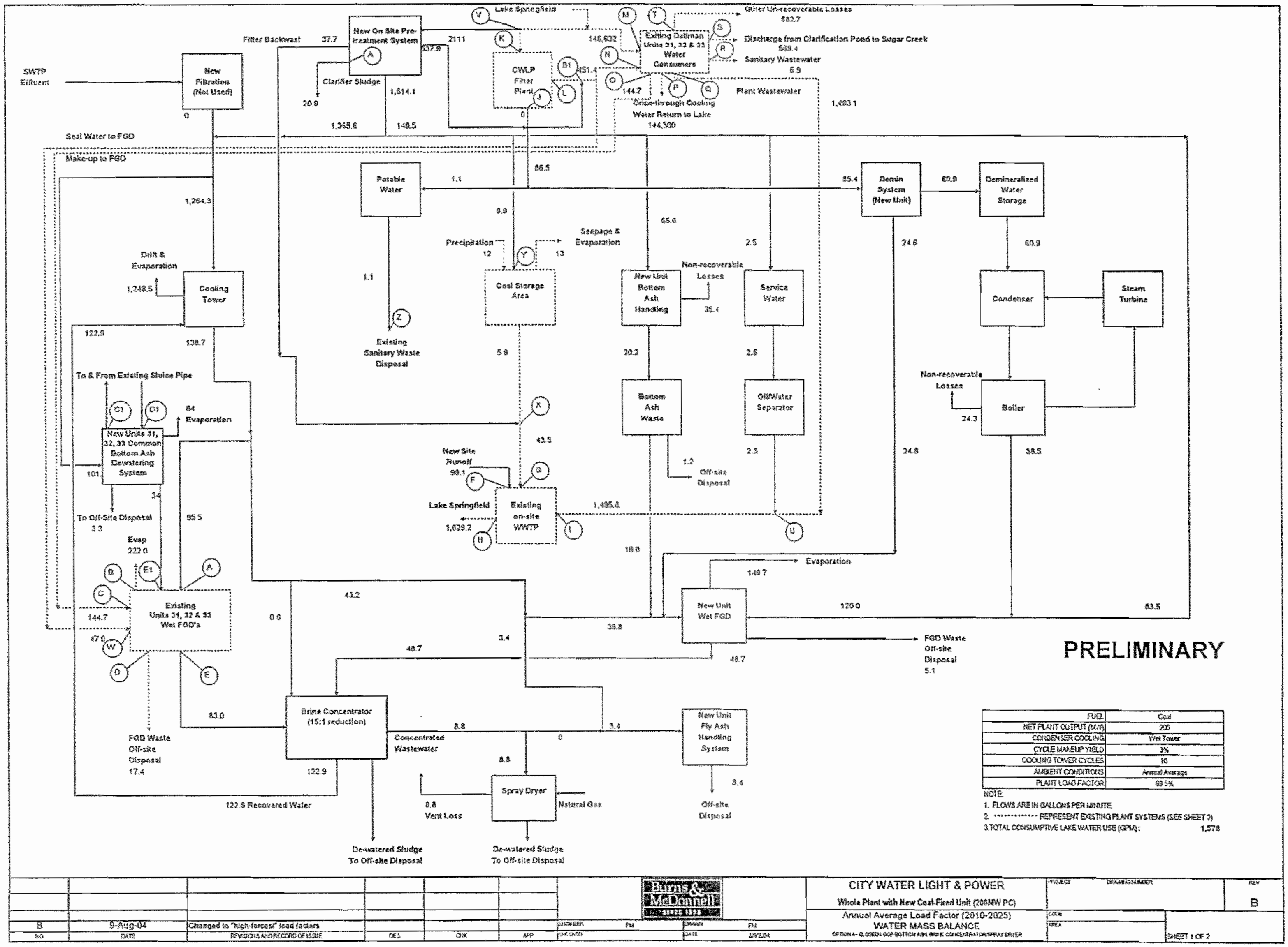

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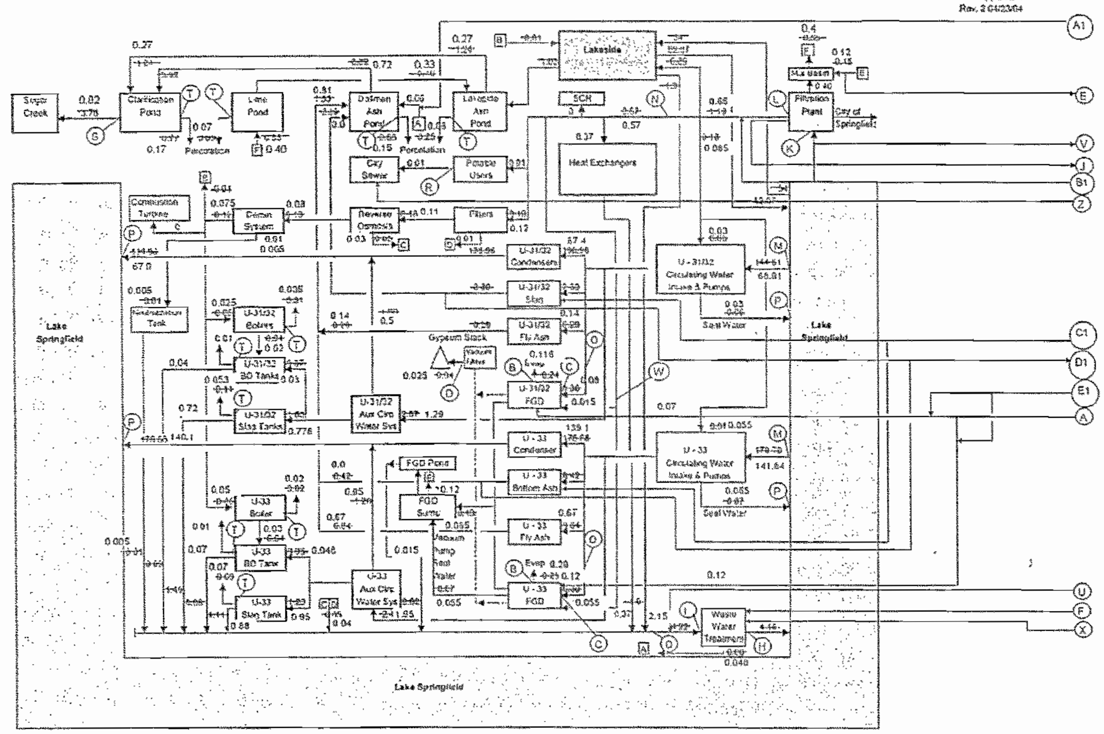
City Water Light & Power
Dallman Power Station
Water Conservation Study

Figure II-1 - Plant Water Balance Based on Average On Line Utilization Factor (2010 - 2025, with Lakeside Retired)

Sargent & Lundy LLC
Prep'd MR
Rvw'd PAH
App'd RLR
Rev. 2 04/23/04



Notes:
1. Flows are in MGD.
2. Diagram from Water Conservation Study Report, Revision 2, Sargent & Lundy, April 23, 2004.

NO	DATE	REVISIONS AND RECORD OF ISSUE	DES	CHK	APP
B	9-Aug-04	Changed to "high-forcast" load factors			

Burns & McDonnell SINCE 1898

ENGINEER FM | DRAWN FM | CHECKED | DATE 8/9/2004

CITY OF SPRINGFIELD, IL
Existing Plant (S&L Water Balance)
ANNUAL AVERAGE (2010-2025)
OPTION 4 WATER BALANCE
(FLOW RATE IN MGD)

PROJECT | DRAWING NUMBER | REV B
CODE
AREA
SHEET 2 OF 2

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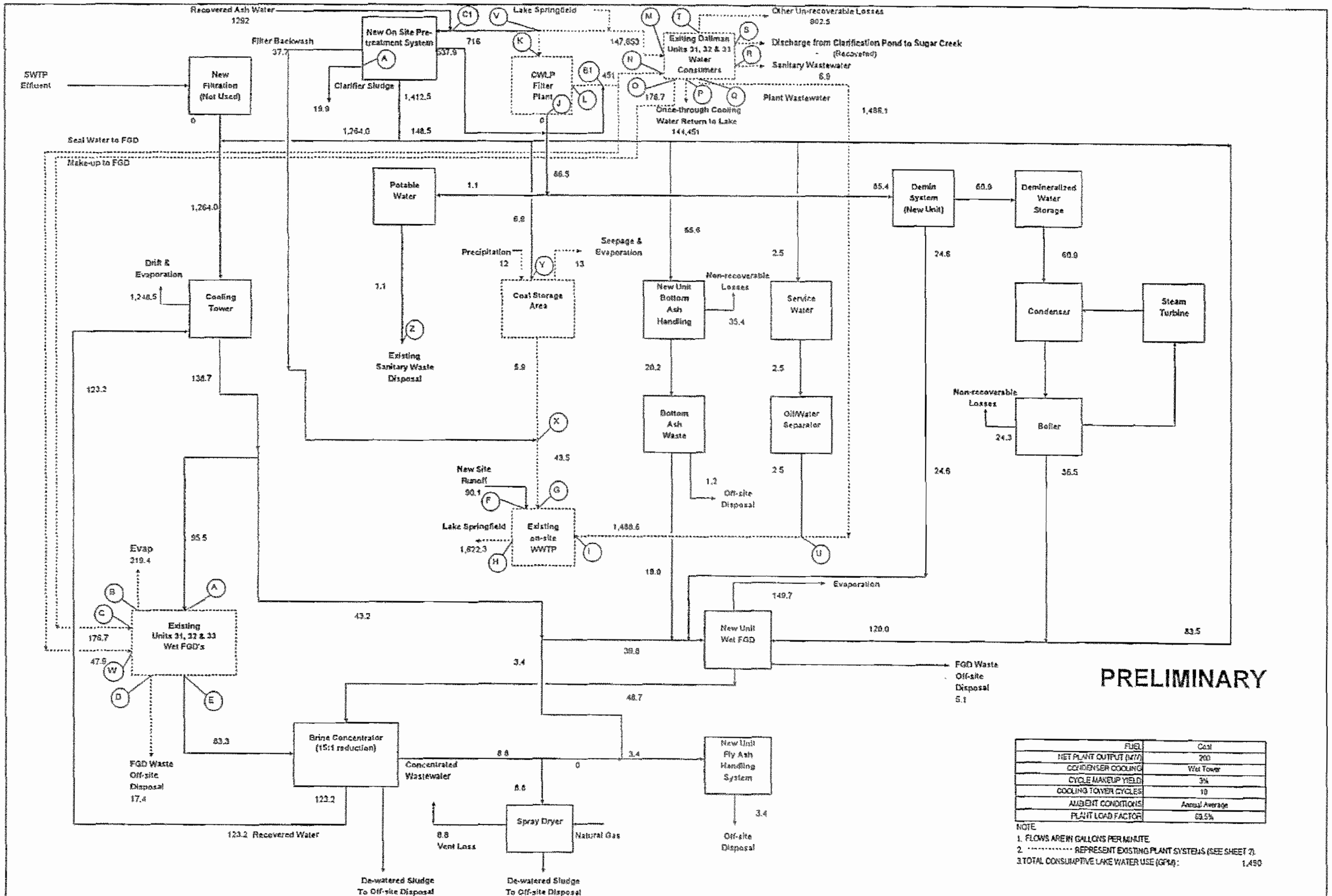


FUEL	Coal
NET PLANT OUTPUT (MW)	200
CONDENSER COOLING	Wet Tower
CYCLE MAKEUP YIELD	3%
COOLING TOWER CYCLES	10
AMBIENT CONDITIONS	Annual Average
PLANT LOAD FACTOR	69.5%

NOTE
1. FLOWS ARE IN GALLONS PER MINUTE.
2. ············ REPRESENT EXISTING PLANT SYSTEMS (SEE SHEET 2).
3. TOTAL CONSUMPTIVE LAKE WATER USE (GPM): 1,450

NO	DATE	REVISIONS AND RECORD OF ISSUE	DES	CHK	APP
B	9-Aug-04	Changed to "high-forcast" load factors			

Burns & McDonnell

ENGINEER FM · DRAWN FM · CHECKED · DATE 8/5/2004

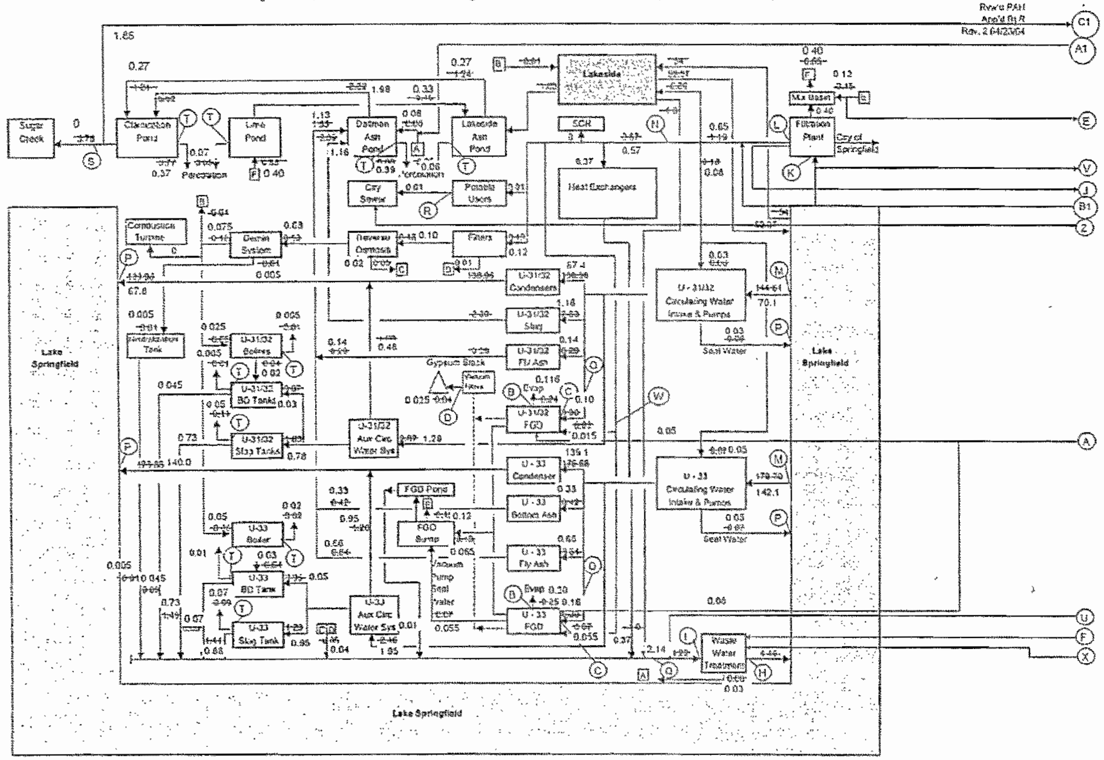
CITY WATER LIGHT & POWER
Whole Plant with New Coal-Fired Unit (200MW PC)
Annual Average Load Factor (2010-2025)
WATER MASS BALANCE
OPTION 5 - REUSE ASH WATER, BRINE CONCENTRATOR/SPRAY DRYER

PROJECT · DRAWING NUMBER · REV B · CODE · AREA · SHEET 1 OF 2

City Water Light & Power
Dallman Power Station
Water Conservation Study

Figure II-1 - Plant Water Balance Based on Average On Line Utilization Factor (2010 - 2025, with Lakeside Retired)

Sargent & Lundy LLC
Prep'd MR
Rev'd PAH
App'd RJR
Rev. 2 04/23/04



Notes:
1. Flows are in MGD.
2. Diagram from Water Conservation Study Report, Revision 2, Sargent & Lundy, April 23, 2004.

B	9-Aug-04	Changed to "high-forcast" load factors				ENGINEER FM	DRAWN FM	Burns & McDonnell SINCE 1898	CITY OF SPRINGFIELD, IL	PROJECT	DRAWING NUMBER	REV
NO	DATE	REVISIONS AND RECORD OF ISSUE	DES	CHK	APP	CHECKED	DATE 8/9/2004		Existing Plant (S&L Water Balance)			B
									ANNUAL AVERAGE (2010-2025)	CODE		
									OPTION 5 WATER BALANCE	AREA		
									(FLOW RATE IN MGD)		SHEET 2 OF 2	

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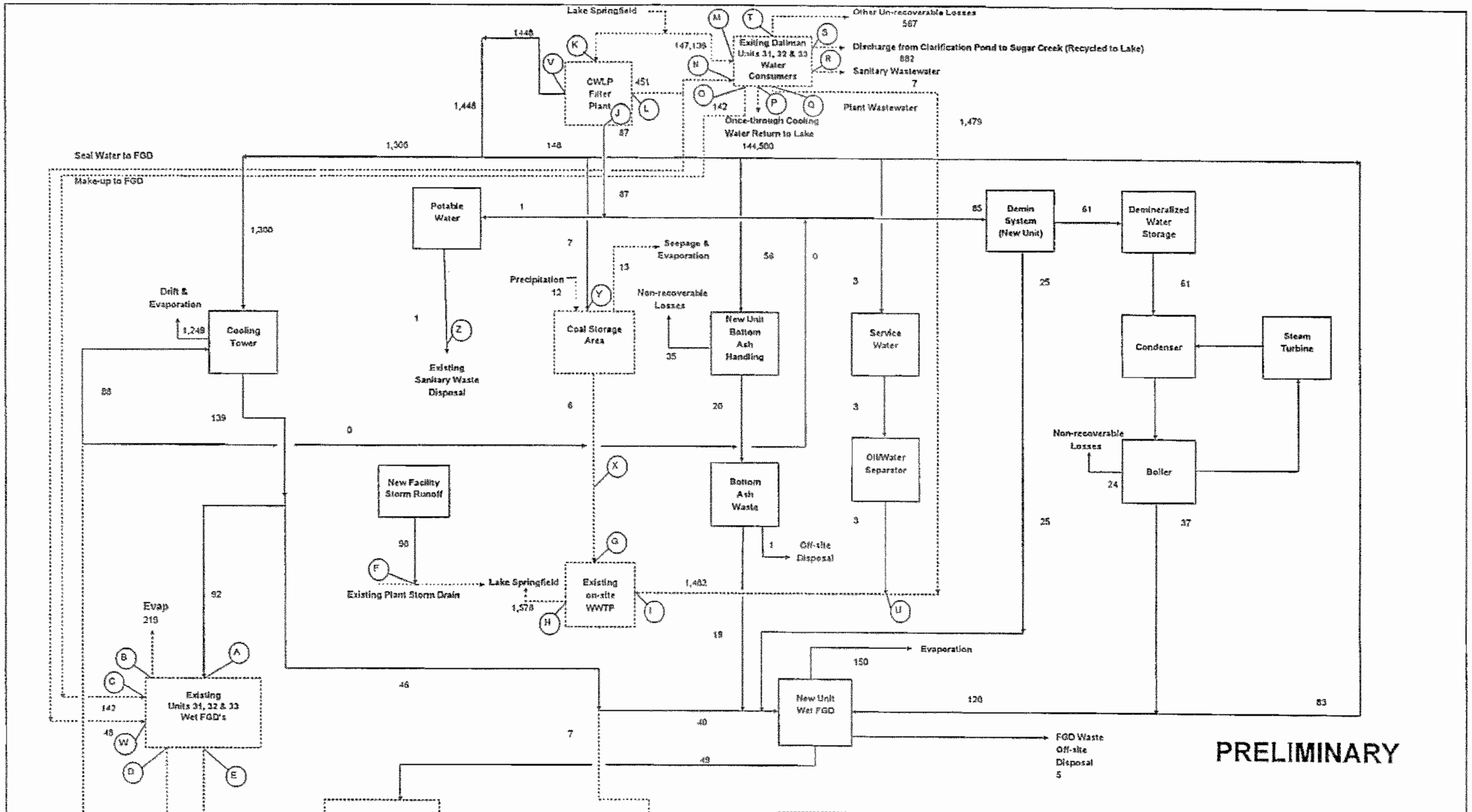


FUEL	Coal
NET PLANT OUTPUT (MW)	200
CONDENSER COOLING	Wet Tower
CYCLE MAKEUP YIELD	3%
COOLING TOWER CYCLES	10
AMBIENT CONDITIONS	Annual Average
PLANT LOAD FACTOR	69.5%

NOTE:
1. FLOWS ARE IN GALLONS PER MINUTE.
2. ------------ SYSTEMS OUTSIDE EPC CONTRACT.
3. TOTAL CONSUMPTIVE LAKE WATER USE (GPM): 2,290
4. TOTAL CONSUMPTIVE LAKE WATER USE (MGD): 3.297
5. TOTAL CONSUMPTIVE USE INCLUDES 0.65 MGD PERCOLATION LOSS FROM PONDS

NO | DATE | REVISIONS AND RECORD OF ISSUE | DES | CHK | APP

Burns & McDonnell

CITY WATER LIGHT & POWER
Whole Plant with New Coal-Fired Unit (200MW PC)
Annual Average Load Factor (2010-2025)
WATER MASS BALANCE
FINAL WATER STUDY REPORT WATER BALANCE - ALL SELECTED OPTIONS

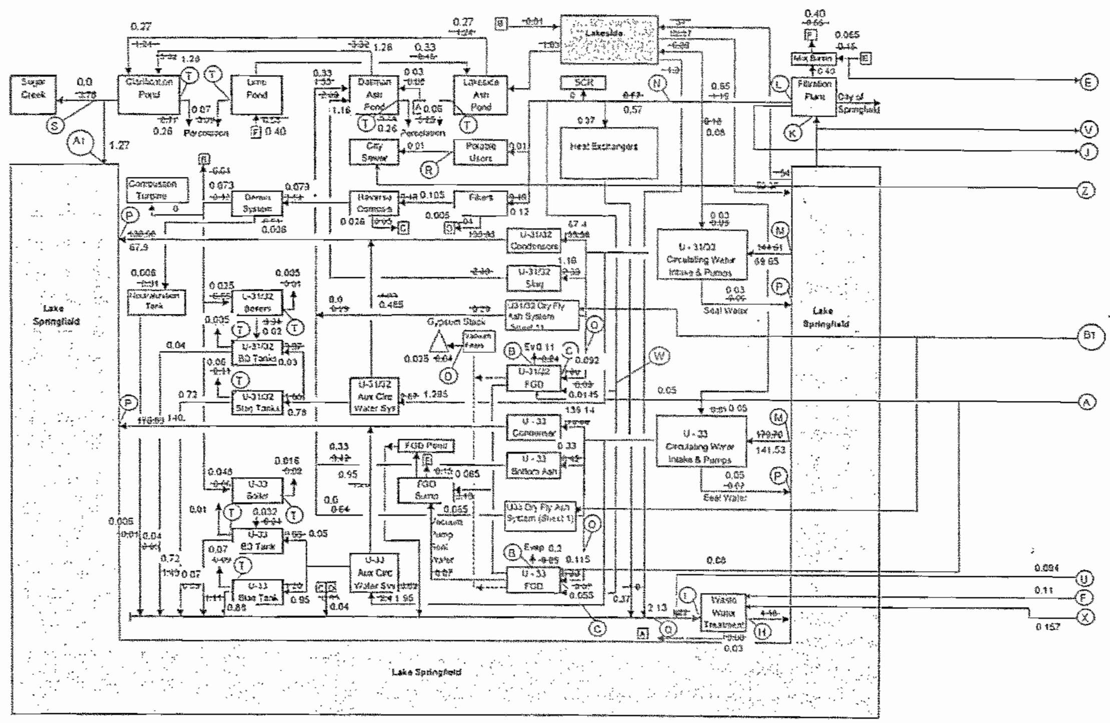
DESIGNED DAS · DRAWN DAS · CHECKED · DATE 12/15/2004

PROJECT · DRAWING NUMBER · REV A · CODE · AREA · SHEET 1 OF 2

City Water Light & Power
Dallman Power Station
Water Conservation Study

Figure II-1 - Plant Water Balance Based on Average On Line Utilization Factor (Average Load Factor of 49.3% for 2010 - 2025, with Lakeside Retired)

Sargent & Lundy LLC
Prep'd MR
Rvw'd PAH
App'd RLR
Rev. 2 04/23/04



Notes.
1. Flows are in MGD.
2. Diagram from Water Conservation Study Report, Revision 2, Sargent & Lundy, April 23, 2004.

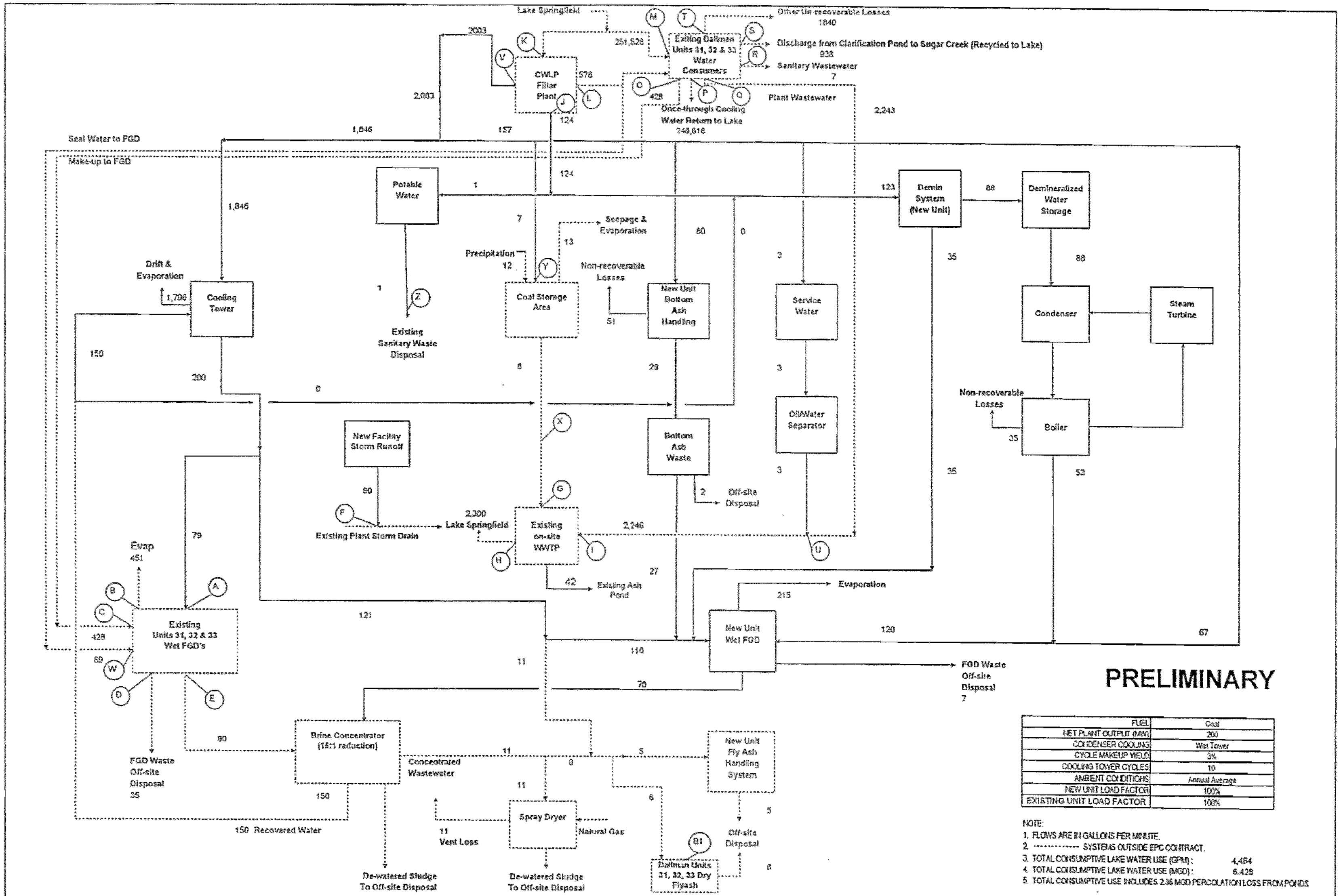
NO	DATE	REVISIONS AND RECORD OF ISSUE	DES	CHK	APP

Burns & McDonnell SINCE 1898

ENGINEER DAS
DRAWN DAS
CHECKED
DATE 12/15/2004

CITY OF SPRINGFIELD, IL
Existing Plant (S&L Water Balance)
ANNUAL AVERAGE (2010-2025)
FINAL WATER STUDY WATER BALANCE
(FLOW RATE IN MGD)

PROJECT
DRAWING NUMBER
REV A
CODE
AREA
SHEET 2 OF 2



FUEL	Coal
NET PLANT OUTPUT (MW)	200
CONDENSER COOLING	Wet Tower
CYCLE MAKEUP YIELD	3%
COOLING TOWER CYCLES	10
AMBIENT CONDITIONS	Annual Average
NEW UNIT LOAD FACTOR	100%
EXISTING UNIT LOAD FACTOR	100%

NOTE:

1. FLOWS ARE IN GALLONS PER MINUTE.
2. ------------ SYSTEMS OUTSIDE EPC CONTRACT.
3. TOTAL CONSUMPTIVE LAKE WATER USE (GPM): 4,464
4. TOTAL CONSUMPTIVE LAKE WATER USE (MGD): 6.428
5. TOTAL CONSUMPTIVE USE INCLUDES 2.36 MGD PERCOLATION LOSS FROM PONDS

NO	DATE	REVISIONS AND RECORD OF ISSUE	DES	CHK	APP

Burns & McDonnell

ENGINEER: DAS | DRAWN: DAS
CHECKED: BCH | DATE: 2/4/2005

CITY WATER LIGHT & POWER
Whole Plant with New Coal-Fired Unit (200MW PC)
Maximum Load Factor
WATER MASS BALANCE
FINAL WATER STUDY REPORT WATER BALANCE - ALL SELECTED OPTIONS

PROJECT | DRAWING NUMBER | REV A
CODE
AREA
SHEET 1 OF 2

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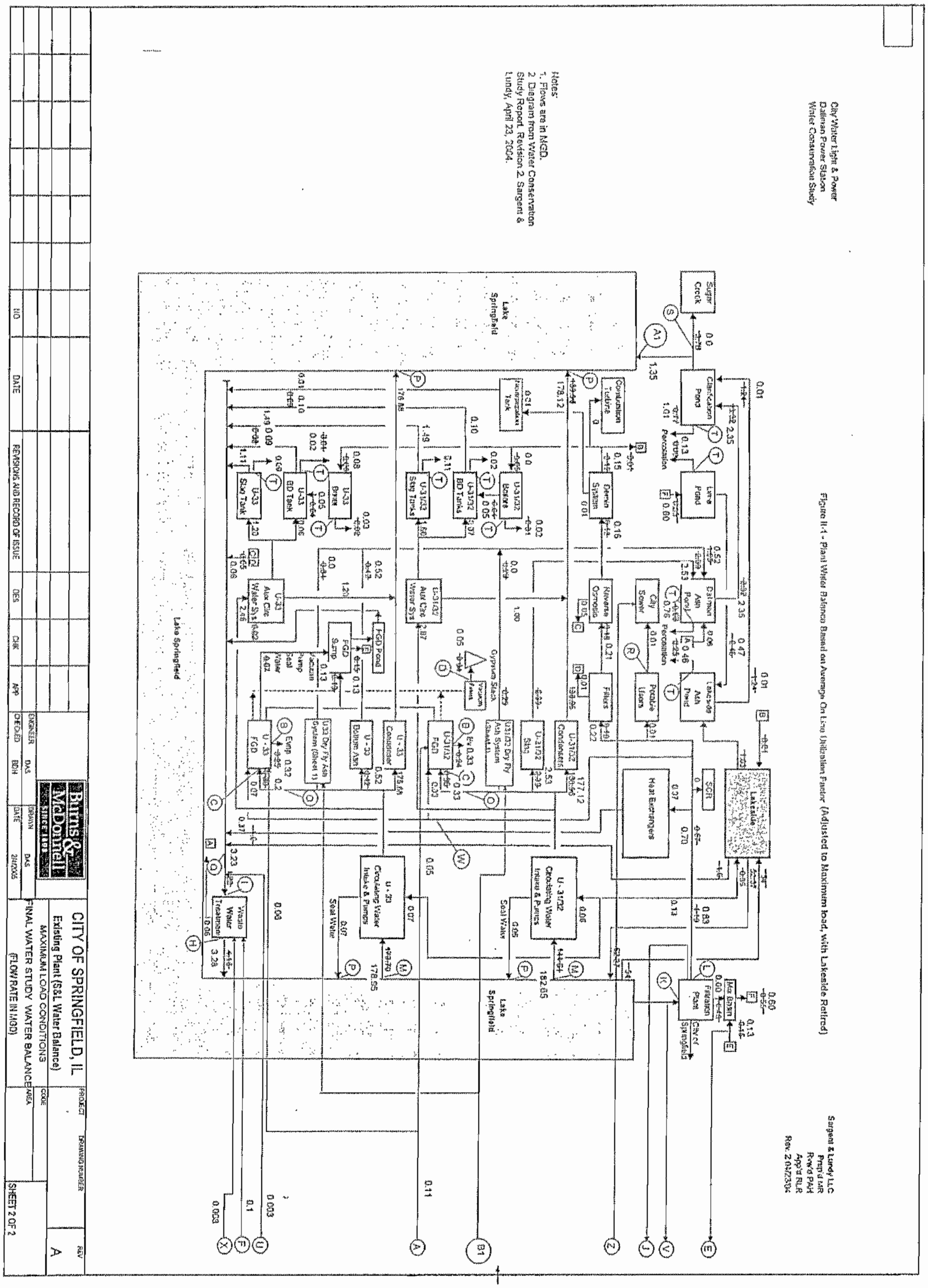
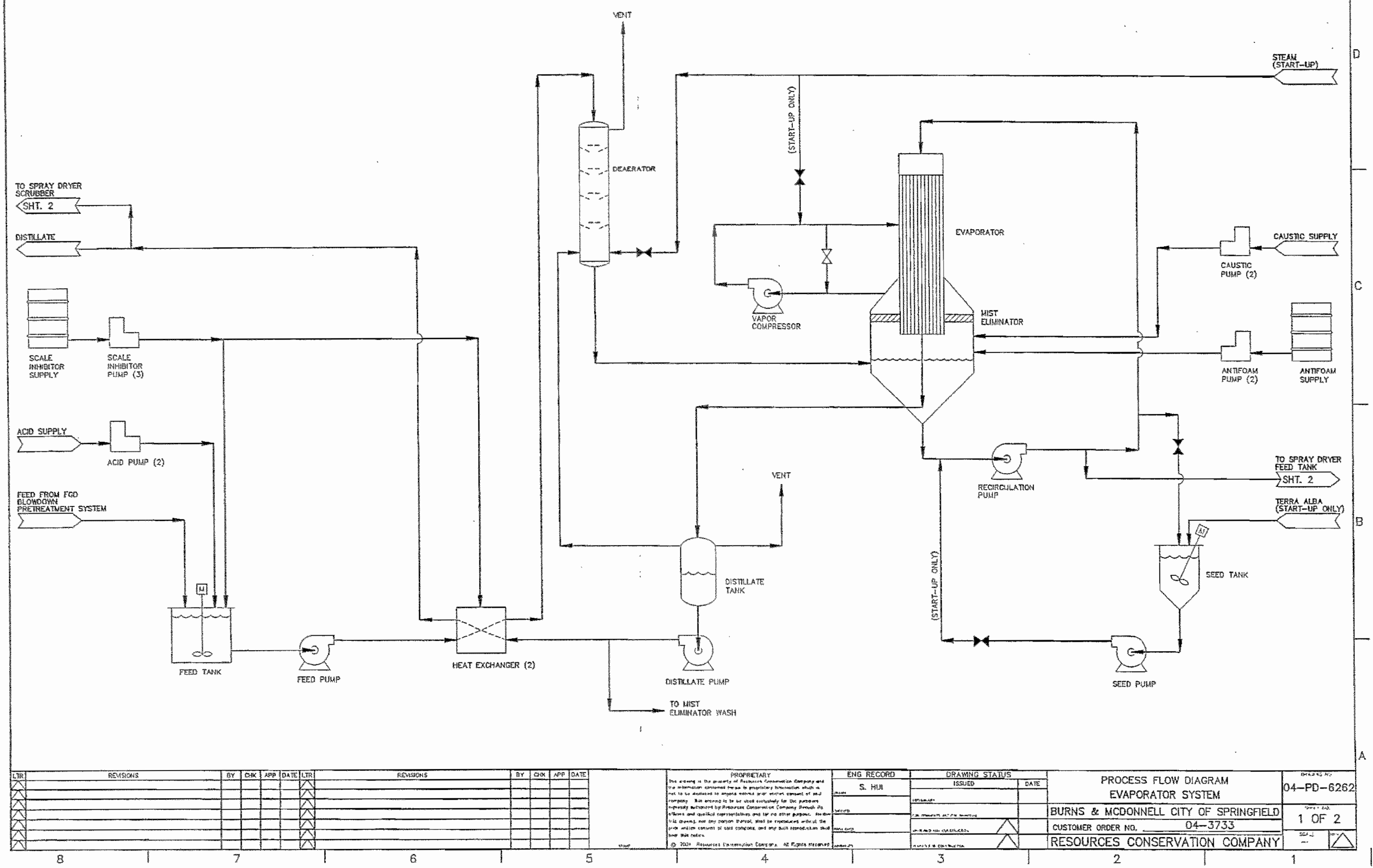
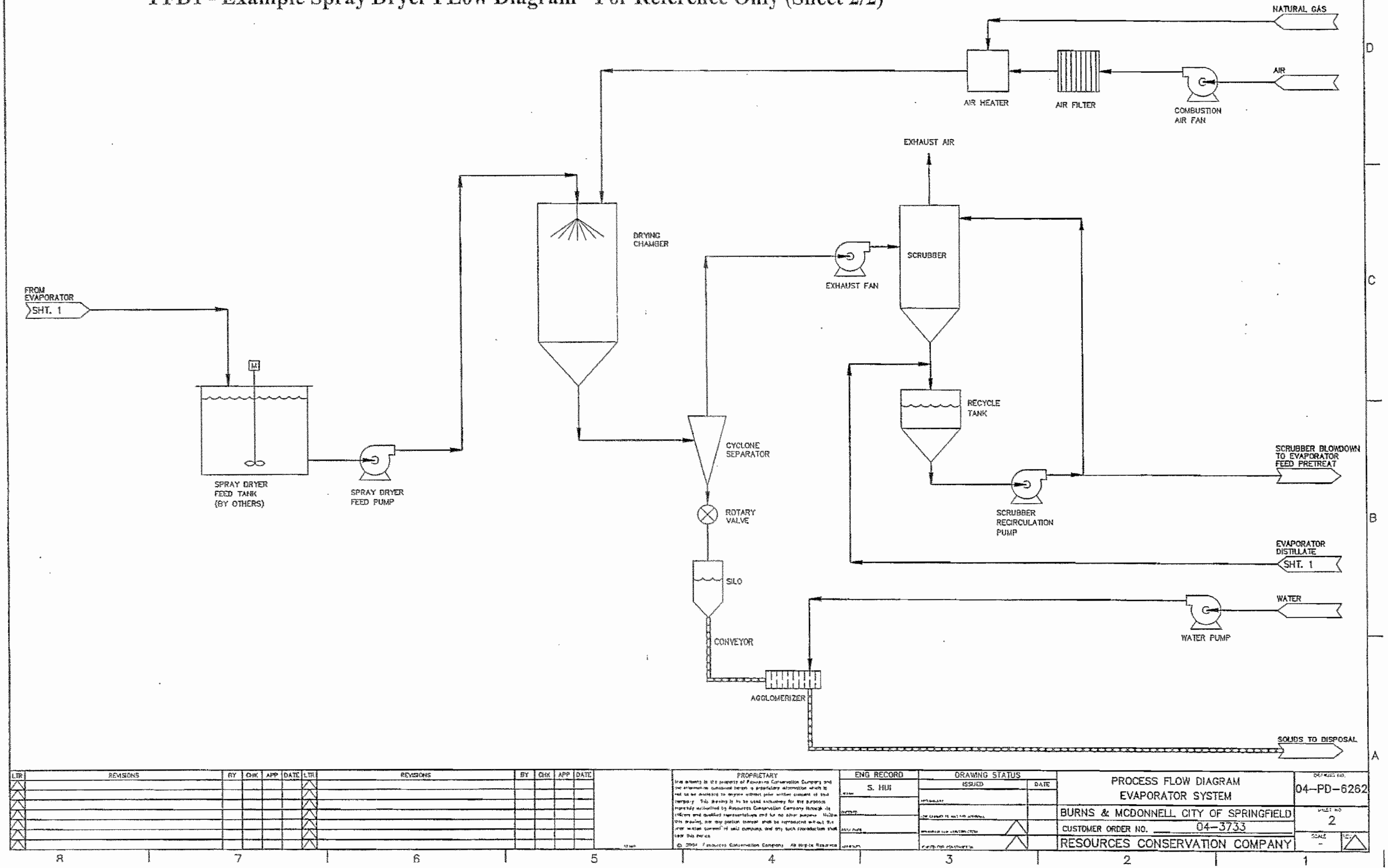
* * * * * PC #1 * * * * *

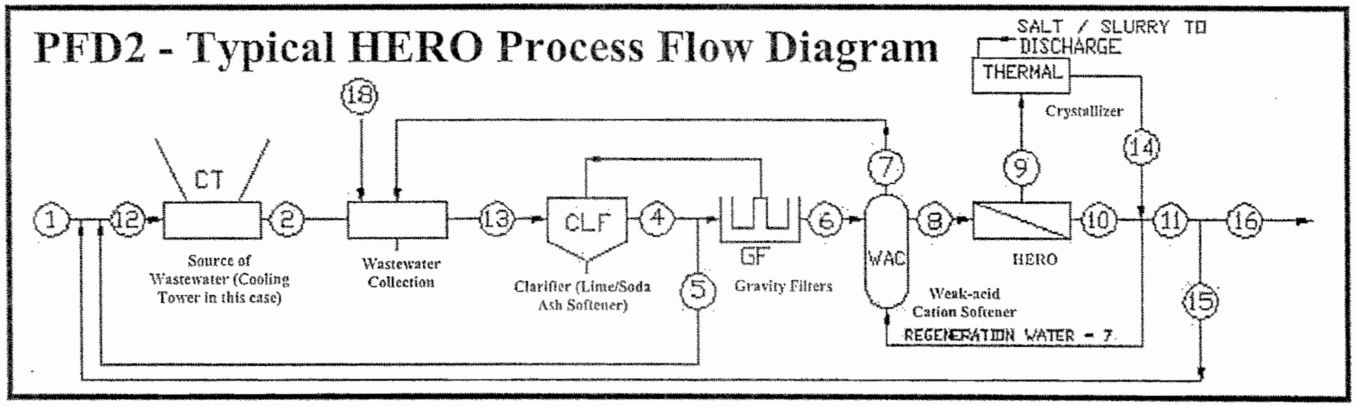


PFD1 - Example Brine Concentrator Flow Diagram - For Reference Only (Sheet 1/2)



PFD1 - Example Spray Dryer FLow Diagram - For Reference Only (Sheet 2/2)




PFD2 - Typical HERO Process Flow Diagram
SALT / SLURRY TO DISCHARGE
THERMAL
Crystallizer
CT
CLF
GF
WAC
HERO
Source of Wastewater (Cooling Tower in this case)
Wastewater Collection
Clarifier (Lime/Soda Ash Softener)
Gravity Filters
Weak-acid Cation Softener
REGENERATION WATER - 7
1
2
4
5
6
7
8
9
10
11
12
13
14
15
16
18

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CWLP - Water Supply And Conservation Study

Table 1 - Lake Water Usage for Each Water Conservation Option

B&McD Project No. 34821

Maximum Conditions at 100% Load

	Calc. Lake Water Usage Consumptive, MGD	Unit Load Factor For Calculation (MW-Weighted)	2010 MG/yr	2011 MG/yr	2012 MG/yr	2013 MG/yr	2014 MG/yr	2015 MG/yr	2016 MG/yr	2017 MG/yr	2018 MG/yr	2019 MG/yr	2020 MG/yr	2021 MG/yr	2022 MG/yr	2023 MG/yr	2024 MG/yr	2025 MG/yr	Total MG
200 MW PC	3.31	100.0%	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210	19,352
DALLMAN 31/32/33	6.06	100.0%	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	2,213	35,401
Annual Total	9.38	N/A	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	3,422	54,753

BASE CASE - LAKE WATER, BRINE CONCENTRATOR/SPRAY DRYER

	Calc. Lake Water Usage Consumptive, MGD	Unit Load Factor For Calculation (MW-Weighted)	2010 MG/yr	2011 MG/yr	2012 MG/yr	2013 MG/yr	2014 MG/yr	2015 MG/yr	2016 MG/yr	2017 MG/yr	2018 MG/yr	2019 MG/yr	2020 MG/yr	2021 MG/yr	2022 MG/yr	2023 MG/yr	2024 MG/yr	2025 MG/yr	Total MG
200 MW PC	2.37	69.5%	865	865	865	865	865	866	866	865	866	866	867	867	867	867	867	868	13,859
DALLMAN 31/32/33	3.15	49.3%	1,088	1,096	1,105	1,113	1,121	1,130	1,138	1,146	1,155	1,163	1,171	1,180	1,188	1,197	1,205	1,213	18,409
Annual Total	5.53	N/A	1,953	1,961	1,970	1,978	1,987	1,995	2,004	2,012	2,021	2,030	2,038	2,047	2,055	2,064	2,072	2,081	32,268

OPTION 2 - GRAY WATER, BRINE CONCENTRATOR/SPRAY DRYER

	Calc. Lake Water Usage Consumptive, MGD	Unit Load Factor For Calculation (MW-Weighted)	2010 MG/yr	2011 MG/yr	2012 MG/yr	2013 MG/yr	2014 MG/yr	2015 MG/yr	2016 MG/yr	2017 MG/yr	2018 MG/yr	2019 MG/yr	2020 MG/yr	2021 MG/yr	2022 MG/yr	2023 MG/yr	2024 MG/yr	2025 MG/yr	Total MG
200 MW PC	0.56	69.5%	203	203	203	203	203	203	203	203	203	203	203	203	204	204	204	204	3,253
DALLMAN 31/32/33	0.91	49.3%	315	317	320	322	324	327	329	332	334	336	339	341	344	346	349	351	5,326
Annual Total	1.47	N/A	518	520	523	525	528	530	532	535	537	540	542	545	547	550	552	555	8,579

OPTION 3 - LAKE WATER, DRY FLY ASH, BRINE CONCENTRATOR/SPRAY DRYER

	Calc. Lake Water Usage Consumptive, MGD	Unit Load Factor For Calculation (MW-Weighted)	2010 MG/yr	2011 MG/yr	2012 MG/yr	2013 MG/yr	2014 MG/yr	2015 MG/yr	2016 MG/yr	2017 MG/yr	2018 MG/yr	2019 MG/yr	2020 MG/yr	2021 MG/yr	2022 MG/yr	2023 MG/yr	2024 MG/yr	2025 MG/yr	Total MG
200 MW PC	2.38	69.5%	866	867	867	867	867	867	868	868	868	868	868	869	869	869	869	869	13,887
DALLMAN 31/32/33	2.36	49.3%	816	822	829	835	841	847	854	860	866	873	879	885	891	898	904	910	13,810
Annual Total	4.74	N/A	1,683	1,689	1,696	1,702	1,708	1,715	1,721	1,728	1,734	1,741	1,747	1,754	1,760	1,767	1,773	1,779	27,697

OPTION 4 - CLOSED-LOOP BOTTOM ASH, BRINE CONCENTRATOR/SPRAY DRYER

	Calc. Lake Water Usage Consumptive, MGD	Unit Load Factor For Calculation (MW-Weighted)	2010 MG/yr	2011 MG/yr	2012 MG/yr	2013 MG/yr	2014 MG/yr	2015 MG/yr	2016 MG/yr	2017 MG/yr	2018 MG/yr	2019 MG/yr	2020 MG/yr	2021 MG/yr	2022 MG/yr	2023 MG/yr	2024 MG/yr	2025 MG/yr	Total MG
200 MW PC	2.47	69.5%	900	901	901	901	901	901	902	902	902	902	902	903	903	903	903	903	14,430
DALLMAN 31/32/33	1.67	49.3%	576	580	585	589	594	598	603	607	611	616	620	625	629	634	638	642	9,747
Annual Total	4.14	N/A	1,476	1,481	1,486	1,490	1,495	1,500	1,504	1,509	1,513	1,518	1,523	1,527	1,532	1,537	1,541	1,546	24,178

OPTION 5 - REUSE ASH WATER, BRINE CONCENTRATOR/SPRAY DRYER

	Calc. Lake Water Usage Consumptive, MGD	Unit Load Factor For Calculation (MW-Weighted)	2010 MG/yr	2011 MG/yr	2012 MG/yr	2013 MG/yr	2014 MG/yr	2015 MG/yr	2016 MG/yr	2017 MG/yr	2018 MG/yr	2019 MG/yr	2020 MG/yr	2021 MG/yr	2022 MG/yr	2023 MG/yr	2024 MG/yr	2025 MG/yr	Total MG
200 MW PC	2.34	69.5%	854	854	854	855	855	855	855	855	855	856	856	856	856	856	857	857	13,686
DALLMAN 31/32/33	1.31	49.3%	452	455	459	462	466	469	473	476	480	483	487	490	494	497	501	504	7,648
Annual Total	3.65	N/A	1,306	1,310	1,313	1,317	1,321	1,324	1,328	1,332	1,335	1,339	1,343	1,346	1,350	1,354	1,357	1,361	21,334

Figure 1 - Total Water Usage by Option (2010-2015)

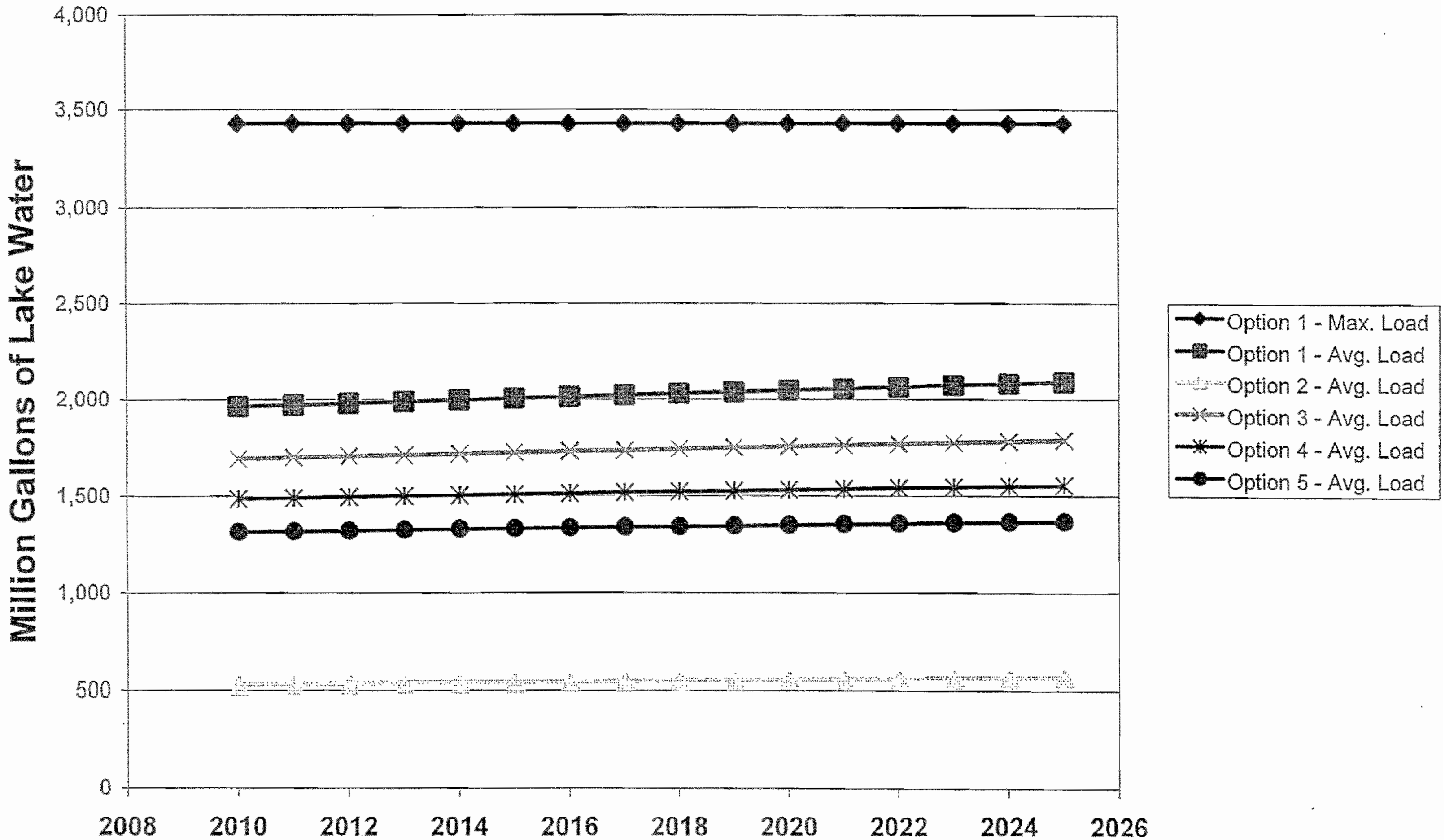


Figure 2 - Water Usage By Option and Unit

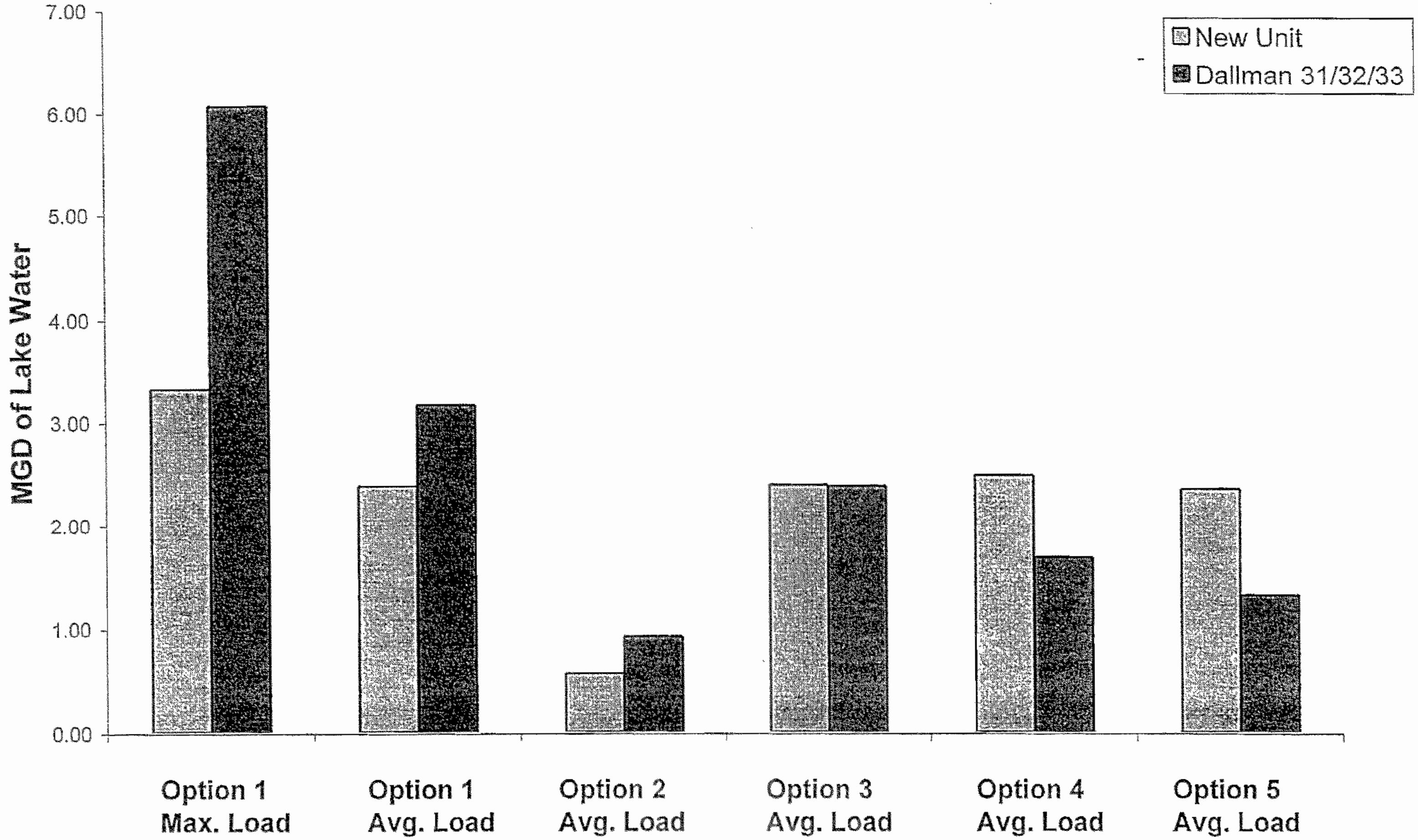
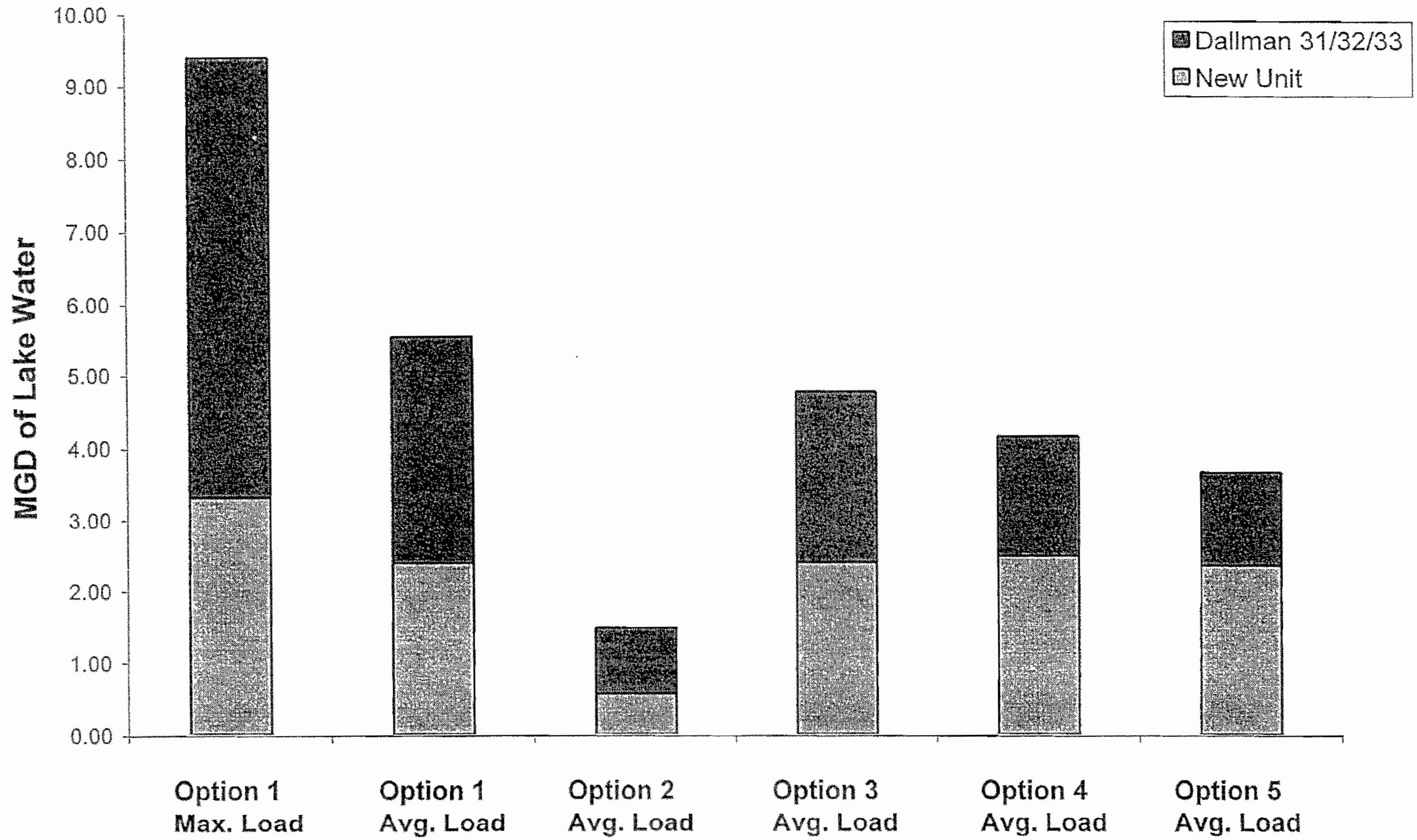


Figure 3 - Water Usage By Option and Unit (Combined)



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* * * * * PC #1 * * * * *

City Water Light & Power
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Table 2 - Boron Removal Options (Based on 2010-2025 average load factors)

Description	Note	Option 1-1 Single Train Brine Concentrator followed by Single Train Spray Dryer	Option 1-2 Dual-Train (50%) Brine Concentrators followed by Dual-Train (50%) Spray Dryers	Option 2 1x100% Lime/Soda Softener, followed by 2x50% HERO followed by 1x100%Crystallizer	Option 3 Same As Option 1-2 except only one Spray Dryer is Used (as backup). Normally BC waste is Mixed with New Unit and Dallman Unit 33 (Modified for this option only) Dry Fly Ash
Equipment Installed Cost	6	$6,155,000	$8,222,000	$6,120,000	$9,356,000
Constructability and Simplicity of O&M		Extensive construction and complicated operations	Extensive construction and complicated operations	More extensive construction and complicated operations than Option 1	Extensive construction and complicated operations, but simpler than Option 1
Electricity Consumption, KW	2,3,7	1,181	1,027	500	1,027
Electricity Cost, $/yr	2	$206,870	$179,887	$87,512	$179,887
Natural Gas Consumption, MMBTU/hr	2,3	3.996	3.996	0	0
Natural Gas Cost, $/yr	2	$210,030	$210,030	$0	$0
Chemicals Consumption					
Chemicals Cost, $yr	6	$50,000	$50,000	$471,750	$50,000
SWTP Make-up Flow, MGD		0	0	0	0
SWTP Make-up Cost, $/yr	2	$0	$0	$0	$0
SWTP Return Flow, MGD		0	0	0	0
SWTP Return Cost, $/yr	2	$0	$0	$0	$0
Filter Plant Flow Reduction, MGD	1	0	0	0	0
Filter Plant Water Cost Savings, $/yr	2	$0	$0	$0	$0
Lake Water Make-up Flow Reduction, MGD	1	0.18	0.18	0.18	0.18
Lake Water Make-up Cost Savings, $/yr	2	$91	$91	$91	$91
Number of Additional Operators		2	2	2	2
Labor Cost, $/yr	2	$160,000	$160,000	$160,000	$160,000
Hazardous Solid Waste Generation Rate, tons/yr		0	0	0	0
Hazardous Solid Waste Disposal Cost, $/yr	2	$0	$0	$0	$0
Non-Haz Solid Waste Generation Rate, tons/yr	4	5,720	5,720	13,441	44,328
Non-Haz Solid Waste Disposal Cost, $/yr	2	$148,714	$148,714	$349,478	$354,625
Waste Disposal Description		Assume waste is sent back to a commercial landfill	Assume waste is sent back to a commercial landfill	Assume waste is sent back to a commercial landfill	Assume waste is sent back to coal mine
Annualized Maintenance Cost, $/yr	6	$50,000	$50,000	$50,000	$70,000
Total Annual Operating Cost		$825,522	$798,539	$1,118,649	$814,421
Total NPV (in terms of total expenses)	5	($14,723,635)	($16,510,561)	($17,731,191)	($17,809,408)
Differential in NPV Compared to Base Case		$1,786,926	Base Case	($1,220,630)	($1,298,847)
Total NPV/MGD of Lake Water Saved		($81,797,973)	($91,725,338)	($98,506,617)	($98,941,157)
Reasons for Rejection of Option					

Notes:
1. Lake Water (and Filter Plant) Make-up Flow Reduction is based on design flow rates and projected, average 2010-2025 load factors.
2. Cost items (per CWLP unless otherwise noted, operation is assumed 365 days a year and the load factor above, and based on the base-case water balance)):
- Electricity, $20/MW-h, Lake Water, $1.39/MG, Potable water from Filter Plant $1.55/1,000-gal, Gray Water $/1,000-gal, Wastewater Discharge to sewer, $0.074/1,000-gal.
- Natural Gas, $6/MMBTU (assumed),
- Labor Cost, $80,000/yr (assumed).
- Waste disposal to coal mine, $8/ton. Non-hazardous waste disposal to landfill, $26/ton, Approved hazardous waste disposal to landfill, $95/ton.
3. Differential consumption between the new systems and the existing systems.
4. Ash generation is based on CWLP "Ash Handling Water Study", 2/16/2004, and assume 15% moisture content in final disposed ash. A ssume 15% moisture in all other solids waste.
5. Cost analysis is based on 15 years service life, 5% discount rate for present worth calculation, and 3% average inflation, Assume $0 plant salvage value.
6. Vendor information, B&McD estimates or assumptions.
7. Dual-train BC(50%) is assumed to use 15% less electricity than single-train BC(100%) on the average due to lower efficiency of turned down operations of the latter.

Equipment Cost Descriptions:
All options: maximum equipment capacity is assumed to be 200 gpm.
Options 1-1, 1-2 and 3: Brine concentrator and spray dryer equipment costs were from Ionics/RCC. RCC stated that for this application the materials are more expensive than most systems, thus use 30% for construction cost.
All options: Dual forwarding pumps and piping at each of the three FGD blowdown sumps (Dallman Unit 31/32, Unit 33, the new unit) to send water to the boron treatment, $40,000 each,
All options exact Option 2: dual-stage self-cleaning screen filters ($40,000) are used to pre-filter solids. Blowdown of solids is assumed to discharge to the seal water recovery system or the vacuum filter feed system.
Option 2: Scope includes one lime/soda softener, dual media filters, dual WAC ion exchange resin softener, one degassifer, one pH adjustment, and dual HERO, with all auxiliary equipment.
Filtration at FGD blowdown sumps is not necessary - only forwarding pumps are required.
Option 3: Assume Unit 33 fly ash is converted to Dry only for the purpose of brine concentrator wastewater mixing. $ of Unit 33 dry fly ash system is based on B&McD estimates.

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Table 3 - Water Conservation Options (2010-2025 Operating Conditions)

		Lake Water Conservation Options					
		Option 1	Option 2	Option 3-1	Option 3-2	Option 4	Option 5
Description	Note	Use Lake Water as Make-up to New Unit, with On-site Pre-treatment	Use Gray Water (pre-treated at the SWTP) as Primary Make-up to New Unit, with Lake Water as Backup	Option 1 with Dry Fly Ash on All Dallman Units	Option 1 with Dry Fly Ash on Dallman Unit 33 only	Option 1 with Closed-Loop Bottom Ash on All Dallman Units, with Mechanical Dewatering	Option 1 with Reuse of Clarification Pond Effluent as Make-up Water to the New Unit Cooling Towers (Note 7)
Equipment Installed Cost	6	$4,500,000	$9,672,625	$10,159,500	$6,700,000	$11,600,500	$6,071,625
Constructability and Simplicity of O&M		Relatively easy to construct and operate	Potentially the most difficult to construct (off-site pipeline) and operate (two separate treatment plants)	More difficult to construct (more space) and operate (more process equipment)	More difficult to construct (more space) and operate (more process equipment)	More difficult to construct (more space) and operate (more process equipment)	Relatively easy to construct and operate
Electricity Consumption, KWh/yr	3	339,865	4,764,715	(201,269)	(131,673)	521,682	617,308
Electricity Cost, $/yr	2	$6,797	$95,294	($4,025)	($2,633)	$10,434	$12,346
Chemicals Consumption		Coagulant, polymer, hypochlorite, acid, caustic	Coagulant, polymer, hypochlorite, acid, caustic	Coagulant, polymer, hypochlorite, acid, caustic	Coagulant, polymer, hypochlorite, acid, caustic	Coagulant, polymer, hypochlorite, acid, caustic	Coagulant, polymer, hypochlorite, acid, caustic
Chemicals Cost, $yr	6	$320,009	$665,721	$320,009	$320,009	$320,009	$320,009
SWTP Make-up Flow, MGD		0	4.31136	0	0	0	0
SWTP Make-up Cost, $/yr	2	$0	$157,365	$0	$0	$0	$0
SWTP Return Flow, MGD		0	0	0	0	0	0
SWTP Return Cost, $/yr	2	$0	$0	$0	$0	$0	$0
Filter Plant Flow Reduction, MGD	1	0	0	0	0	0	0
Filter Plant Water Cost Savings, $/yr	2	$0	$0	$0	$0	$0	$0
Lake Water Make-up Flow Reduction, MGD	1	0	4.06	0.79	0.67	1.39	1.88
Lake Water Make-up Cost Savings, $/yr	2	$0	$2,060	$401	$340	$705	$954
Number of Additional Operators		1	2	2	2	2	1
Labor Cost, $/yr	2	$80,000	$160,000	$160,000	$160,000	$160,000	$80,000
Hazardous Solid Waste Generation Rate, tons/hr		0	0	0	0	0	0
Hazardous Solid Waste Disposal Cost, $/yr	2	$0	$0	$0	$0	$0	$0
Non-Haz Solid Waste Generation Rate, tons/hr	1,4	0	340	47,768	42,636	33,767	0
Non-Haz Solid Waste Disposal Cost, $/yr	2	$0	$8,846	$382,142	$341,085	$270,138	$0
Waste Disposal Description		N/A, sludge is sent to ash pond	Assume waste from the gray water treatment is sent to landfill	Assume waste is sent back to coal mine	Assume waste is sent back to coal mine	Assume waste is sent back to coal mine	N/A, sludge is sent to ash pond
Annualized Maintenance Cost, $/yr		$20,000	$40,000	$38,667	$58,667	$66,667	$35,000
Maintenance Description		General maintenance	General maintenance	General maintenance	General maintenance	General maintenance	General maintenance
Total Annual Operating Cost		$426,806	$1,125,166	$896,391	$876,787	$826,542	$446,401
Total NPV (in terms of total expenses)	5	($8,930,099)	($21,351,459)	($19,463,737)	($15,800,746)	($20,179,721)	($10,705,114)
Annualized Total Option Cost, $/yr		($860,346)	($2,057,048)	($1,875,181)	($1,522,280)	($1,944,160)	($1,031,355)
Equivalent Lake Water Cost, $/1,000-gal		$0.79	$1.39	$6.50	$6.22	$3.83	$1.50
Total NPV/MGD of Lake Water Saved		N/A	($5,258,980)	($24,637,642)	($23,583,203)	($14,517,785)	($5,694,209)
Reasons for Rejection of Option							

Notes:
1. **Lake Water (and Filter Plant) Make-up Flow Reduction is based on design flow rates and projected, average 2010-2025 load factors. S&L reported load factors for Dallman units are 73% (U31/32) and 76.8% (U33).**
2. **Cost items (per CWLP unless otherwise noted, operation is assumed 24 hours a day times 365 days a year, and water and utility usage based on above load factors):**
 - **Electricity, $20/MW-h, Lake Water, $1.39/MG, Potable water from Filter Plant $1.55/1,000-gal, Gray Water $/1,000-gal, Wastewater Discharge to sewer, $0.074/1,000-gal.**
 - **Labor Cost, $80,000/yr (assumed).**
 - **Waste disposal to coal mine, $8/ton. Non-hazardous waste disposal to landfill, $26/ton, Approved hazardous waste disposal to landfill, $95/ton.**
 - **Assume SWTP will charge $0.1/1000-gal of gray water to cover treatment cost not included in other cost items.**
3. **Differential electricity consumption between the new systems and the existing systems (sluice pumps). Negative values represent net savings by the new systems. Option 2 requires additional brine concentrator capacity (see ater balance)**
4. **Ash generation is based on CWLP "Ash Handling Water Study", 2/16/2004, and assume 15% moisture content in final disposed ash. Brine Concentrator/Spray Dryer waste is not included in calculation.**
5. **Cost analysis is based on 15 years (2010-2025) service life, 5% discount rate for present worth calculation, and 3% average inflation. Assume $0 plant salvage value.**
6. **Sargent & Lundy Report, April 23, 2004, B&McD estimates, or assumptions.**
7. **Option 5 assumes that lake water pre-treatment is already included as a part of the new unit cost, and it is shared with the recovered ash water. The quantity of recovered water is after subtracting percolation in ash ponds.**

Equipment Cost Descriptions:
Option 1: Lake Water Pre-treatment - Assume a clarifier (sized for 3000 gpm) followed by 2x700 gpm filters are used, with auxiliary equipment such as chemical feed, clear well and pumps, sludge transfer pumps, and controls.
Option 2: Gray Water Pre-treatment: Assume a clarifer (sized for 3000 gpm) is used, with auxiliary equipment such as chemical feed, clear well and pumps, sludge transfer pumps, and controls. A 1 MGD lake water pretreatment (clarifier + filters) is also included.
Option 3: Same as Option 1 on lake water pre-treatment. All Dallman Units are converted to dry fly ash systems. The cost for Unit 33 dry fly ash conversion assumes the silo would be common with the new unit silo. This saves $2.5M.
Option 4: Same as Option 1 on lake water pre-treatment. All Dallman Units are converted to share a common closed-loop bottom ash handling system with mechanical dewatering systems (3x50% dewatering bins, 100% settling ans surge tanks).
Option 5: New pumps and pipeline will be installed to recycle ash water clarification pons effluent to the lake water pre-treatment system (clarifier) to produce make-up water to the new plant.

Electronic Filing - Received, Clerk's Office, November 21, 2008
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Table 3 - Water Conservation Options (2010-2025 Operating Conditions, Continued)

Description	Note	Water Management Options: Option 6 — Water Management Issues (Recycle FGD seal water)	Option 7 — Water Management Issues (Recirculate Ash Water When not Sluicing Ash)	Option 8 — Using Treated Lake Water for Heat Exchangers (See Note 6)
Equipment Installed Cost	6	$280,000	$50,000	$100,000
Constructability and Simplicity of O&M		Relatively easy to construct and operate	Relatively easy to construct and operate	Relatively easy to construct and operate (assume lake water is filtered)
Electricity Consumption, KWh/yr	3	18,475	0	92,374
Electricity Cost, $/yr	2	$369	$0	$1,847
Chemicals Consumption		None	None	None
Chemicals Cost, $yr	6	$0	$0	$0
SWTP Make-up Flow, MGD		0	0	0
SWTP Make-up Cost, $/yr	2	$0	$0	$0
SWTP Return Flow, MGD		0	0	0
SWTP Return Cost, $/yr	2	$0	$0	$0
Filter Plant Flow Reduction, MGD	1	0	0	0.37
Filter Plant Water Cost Savings, $/yr	2	$0	$0	$209,328
Lake Water Make-up Flow Reduction, MGD	1	0.046	0.997	0
Lake Water Make-up Cost Savings, $/yr	2	$23	$506	$0
Number of Additional Operators		0	0	0
Labor Cost, $/yr	2	$0	$0	$0
Hazardous Solid Waste Generation Rate, tons/hr		0	0	0
Hazardous Solid Waste Disposal Cost, $/yr	2	$0	$0	$0
Non-Haz Solid Waste Generation Rate, tons/hr	1,4	0	0	0
Non-Haz Solid Waste Disposal Cost, $/yr	2	$0	$0	$0
Waste Disposal Description		N/A	N/A	N/A
Annualized Maintenance Cost, $/yr		$0	$0	$0
Maintenance Description		Negligible	Negligible	Negligible
Total Annual Operating Cost		$346	($506)	($207,480)
Total NPV (in terms of total expenses)	5	($283,593)	($44,752)	$2,053,572
Annualized Total Option Cost, $/yr		($27,322)	($4,312)	$197,846
Equivalent Lake Water Cost, $/1,000-gal		$1.63	$0.01	N/A
Total NPV/MGD of Lake Water Saved		($6,174,957)	($44,906)	N/A
Reasons for Rejection of Option				

Notes:
1. Lake Water (and Filter Plant) Make-up Flow Reduction is based on design flow rates and projected, average 2010-2025 load factors. S&L reported load factors for Dallman units are 73% (U31/32) and 76.8% (U33).
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- Labor Cost, $80,000/yr (assumed).
- Waste disposal to coal mine, $8/ton. Non-hazardous waste disposal to landfill, $26/ton, Approved hazardous waste disposal to landfill, $95/ton.
- Assume SWTP will charge $0.1/1000-gal of gray water to cover treatment cost not included in other cost items.
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