



Environmental Protection Department
Permits and Regulatory Affairs Division

LLNL-TR-424562

Lawrence Livermore National Laboratory (LLNL)
Experimental Test Site (Site 300)

*Salinity Evaluation and Minimization Plan for Cooling
Towers and Mechanical Equipment Discharges*

March 1, 2010

William D. Daily III

**In Compliance with
Waste Discharge Requirements
Order No. R5-2008-0148**

**As Issued by the
California Regional Water Quality Control Board
Central Valley Region**

**This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.**

Table of Contents

Introduction.....	1
Background	2
Facility and Equipment Descriptions.....	4
Cooling Towers and Mechanical Equipment Discharging to Percolation Pits	4
Building 801	4
Building 806	5
Building 809	5
Building 817	6
Building 826	6
Building 827A	7
Building 827C	8
Building 827D	8
Building 827E.....	8
Building 851	8
Cooling Towers and Mechanical Equipment Discharging to Septic Systems.....	9
Building 801	9
Building 805	9
Building 813	9
Building 819	9
Building 825	9
Building 826	10
Building 851A and Building 851B.....	10
Facilities No Longer Using Subsurface Discharge	10
Options for Reducing Salt Discharge to Percolation Pits and Septic Systems.....	11
Improve Operation and Maintenance	12
Option 1. Increase Accuracy of Chemical Dosing.	12
Option 2. Modify Maintenance Schedule to Increase Frequency and Completeness.	13
Option 3. Investigate and Eliminate Leaks.....	13
Option 4. Minimize Drift and Blow Out.	13
Add Automated Processes to Increase Efficiency.....	13
Option 5. Automated Meters and Blow Down Valves.....	14
Option 6. Automate Chemical Injection.....	14
Option 7. Automate Cooling Demand Controls to Reduce Air-Flow at Low Heat Loads.	14
Re-Evaluate Chemical Treatment Strategy	14
Option 8. Insure That the Chemicals Used are Specifically Designed for Site-Specific Chemistry and Operating Conditions.	14
Option 9. High Cycles of Concentration Chemical Dosing.	15
Increase Quality of Make Up Water	15
Option 10. Pre-Treatment of Make Up Water.....	15
Option 11. Change the Source of Make Up Water (Industrial “Waste” Water, Condensate, Etc.).	16
Blow Down Water Management	17
Option 12. Treat the Equipment Wastewater Prior to Discharge.....	17
Option 13. Treat and Re-Circulate Sump Water – “Low Discharge” Operation.	17
Option 14. Treat and Re-Circulate Sump Water – “Zero Discharge” Operation.	18
Option 15. Alternative Discharge Locations.	18

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Option 16. Decrease Concentration Cycles.....	19
Change the Type of Cooling Tower	20
Option 17. Closed Loop Dry (Air-Cooled) Tower.....	20
Option 18. Closed Loop Hybrid (Air and Water) Tower.....	20
Option 19. Plastic Cooling Towers.....	20
Supported Equipment Management.....	21
Option 20. Operations and Management of Supported Equipment.....	21
Treatment Methods	22
Chemical.....	22
A. Liquid or solid chemical additives	22
B. Gas chemical additives.....	23
C. Ion-exchange (softening)	23
D. Ionization	24
Electro-Chemical Methods	24
E. Electromagnetic.....	24
F. Electrolysis precipitation.....	24
Physical Methods	25
G. Filtration.....	25
H. Hydrodynamic cavitation.....	25
I. Ultrasonic cavitation.....	26
J. Reverse osmosis.....	26
K. Evaporation concentrator	26
Option Estimation and Comparison	27
Observations and Recommendations.....	29
Current Progress and Conclusions	31
Figures.....	33
Figure 1. Locations of Site 300 facilities with septic systems and percolation pits.....	33
Figure 2. Cooling tower dimensions. Taken from Baltimore Air Cooling® Brochures.....	34
Figure 3. Building 801 Cooling Tower and Discharge Point Locations.....	35
Figure 4. Building 801 Cooling Tower. Taken from Baltimore Aircoil Company® Brochures.....	35
Figure 5. Building 801 Cooling Tower.....	35
Figure 6. Building 801 Percolation Pit (as indicated by the arrow).....	36
Figure 7. Building 801 Septic System Leach Field Location.....	36
Figure 8. Building 809 Cooling Tower and Discharge Point Locations.....	37
Figure 9. Building 809 Cooling Tower.....	37
Figure 10. Building 809 Cooling Tower Discharge Point/Percolation Pit Access.....	38
Figure 11. Building 809 Cooling Tower Discharge Point/Percolation Pit Access.....	38
Figure 12. Building 817 Cooling Tower and Discharge Point Locations.....	39
Figure 13. Building 817 Cooling Tower.....	39
Figure 14. Building 817 Percolation Pit Access.....	39
Figure 15. Building 825 Cooling Tower and Discharge Point Locations.....	40
Figure 16. Building 825 Cooling Tower.....	40
Figure 17. Building 826 Cooling Tower and Discharge Point Locations.....	41
Figure 18. Building 826 Cooling Tower.....	41
Figure 19. Building 826 Percolation Pit Access.....	41
Figure 20. Building 826 Septic Tank/Leach Field.....	42
Figure 21. Building 826 Septic Tank/Leach Field.....	42
Figure 22. Building 827A Cooling Tower and Discharge Point Locations.....	43
Figure 23. Building 827A Cooling Towers (at left, adjacent to building).....	43

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Figure 24. Building 827A Discharge Location.....	44
Figure 25. Looking east at the Building 827A Septic Leach Field (left/north) and Percolation Pit (right/south).....	44
Figure 26. Building 827C Percolation Pit.....	45
Figure 27. Building 827D Percolation Pit Access.	45
Figure 28. Building 827E Percolation Pit Access (as shown by the arrow).....	46
Figure 29. Cooling Tower Recirculation + Ion-exchange Model.....	47
Figure 30. Dry cooling tower.....	47
Figure 31. Hybrid cooling tower. Taken from Baltimore Aircoil Company® Brochures.....	48
Tables	49
Table 1. Site 300 Shallow Surface Discharge Locations.....	50
Table 2. Baltimore Aircoil Company® Type Wet Cooling Tower Dimensions and Performance.	51
Table 3. Cooling Tower Operating Parameters.	52
Table 4. Mechanical Equipment Discharge Information.	53
Table 5. Options for Cooling Tower and Mechanical Equipment Discharge to Percolation Pits and Septic Systems.....	54
Table 6. Qualitative Estimates of Comparison Categories.....	55
Table 7. Cooling Tower Maintenance Schedule.....	56
Table 8. Treatment Technologies.....	57
Table 9. Overall Applicability of Options by Facility.....	58
References	59

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Introduction

This document was created to comply with the Central Valley Regional Water Quality Control Board (CVRWQCB) Waste Discharge Requirement (Order No. 98-148). This order established new requirements to assess the effect of and effort required to reduce salts in process water discharged to the subsurface. This includes the review of technical, operational, and management options available to reduce total dissolved solids (TDS) concentrations in cooling tower and mechanical equipment water discharges at Lawrence Livermore National Laboratory's (LLNL's) Experimental Test Site (Site 300) facility.

It was observed that for the six cooling towers currently in operation, the total volume of groundwater used as make up water is about 27 gallons per minute and the discharge to the subsurface via percolation pits is 13 gallons per minute. The extracted groundwater has a TDS concentration of 700 mg/L. The cooling tower discharge concentrations range from 700 to 1,400 mg/L. There is also a small volume of mechanical equipment effluent being discharged to percolation pits, with a TDS range from 400 to 3,300 mg/L. The cooling towers and mechanical equipment are maintained and operated in a satisfactory manner. No major leaks were identified. Currently, there are no re-use options being employed.

Several approaches known to reduce the blow down flow rate and/or TDS concentration being discharged to the percolation pits and septic systems were reviewed for technical feasibility and cost efficiency. These options range from efforts as simple as eliminating leaks to implementing advanced and innovative treatment methods. The various options considered, and their anticipated effect on water consumption, discharge volumes, and reduced concentrations are listed and compared in this report.

Based on the assessment, it was recommended that there is enough variability in equipment usage, chemistry, flow rate, and discharge configurations that each discharge location at Site 300 should be considered separately when deciding on an approach for reducing the salt discharge to the subsurface. The smaller units may justify moderate changes to equipment, and may benefit from increased cleaning frequencies, more accurate and suitable chemical treatment, and sources of make up water and discharge re-use. The larger cooling towers would be more suitable for automated systems where they don't already exist, re-circulation and treatment of blow down water, and enhanced chemical dosing strategies. It may be more technically feasible and cost efficient for the smaller cooling towers to be replaced by closed loop dry coolers or hybrid towers.

There are several potential steps that could be taken at each location to reduce the TDS concentration and/or water use. These include: sump water filtration, minimization of drift, accurate chemical dosing, and use of scale and corrosion coupons for chemical calibration.

The implementation of some of these options could be achieved by a step-wise approach taken at two representative facilities. Once viable prototype systems have been proven in the field, systematic implementation should proceed for the remaining systems, with cost, desired reduction, and general feasibility taken into consideration for such systems.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Background

Lawrence Livermore National Security, LLC, operates Site 300. Site 300 is located in the Altamont Hills approximately 10.5 kilometers (6.5 miles) southwest of downtown Tracy, CA. Buildings, equipment, and the research activities outside of the General Services Area Site 300 are supported by cooling towers, septic systems, and mechanical equipment which, by design, produce wastewater, which is engineered to discharge to ground (**Figure 1**). From 1996 to 2008, this wastewater was discharged in accordance with Waste Discharge Requirements, Order Number 96-248 and/or waivers from waste discharge requirements.

In 2008, the CVRWQCB rescinded the Order No. 96-248 upon issuing new Waste Discharge Requirements (WDR), Order Number R5-2008-0148 (Order R5-2008-0148), for discharges from sewage evaporation and percolation ponds, septic systems, cooling towers, mechanical equipment wastewater, and low-threat discharges. Order R5-2008-0148 removed the Class II Surface Impoundments, which were clean closed in 2005.

The CVRWQCB's Basin Plan establishes the control of salinity as a priority. Order R5-02008-0148 incorporates requirements of the CVRWQCB's memorandum issued on April 26, 2007, setting forth guidance for the consistent management of salinity and the need to immediately begin addressing salinity in existing discharges.

The primary contaminants of concern in wastewater discharges from cooling towers and mechanical equipment are salts, or dissolved solids. Order R5-2008-0148 included requirements to address potential impacts from wastewater discharges including evaluations to assess the effect of and effort required to reduce salts in wastewater discharges to the subsurface. In addition, Provision E.3 in the Order required LLNL to prepare and submit by March 1, 2010, a final salinity evaluation and minimization plan to address the sources of salinity in cooling tower and mechanical equipment effluent discharged to the percolation pits. This evaluation is the first part of a two-part analysis regarding salt loading at Site 300. The second part, required in Provision E.5, is a salinity groundwater modeling study (Evaluation of Potential Impact to Groundwater from Percolation Pits and Septic Systems) and is due to the CVRWQCB by November 1, 2010.

The purpose of this proposal, as identified in Order R5-2008-0148 (Provision E.3), is to:

1. Identify the sources or potential sources of TDS in cooling tower and mechanical equipment effluent and estimate the contributions of salinity from these sources.
2. Estimate potential reductions that may be attained through controllable sources.
3. Describe the tasks, costs, and time required to investigate and implement source reduction.
4. Determine water use requirements and other environmental impacts of each option.
5. Report any progress made to reduce salt discharge to the subsurface.

In 2009 and 2010, an assessment was made of the existing cooling towers, mechanical equipment, and discharge locations. Various technical, operational, and administrative options were reviewed for their ability to reduce salts in the discharged water from these sources. This

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

report is the engineering assessment that includes the accumulated data, technical evaluation, cost estimates, and recommendations.

Facility and Equipment Descriptions

Cooling Towers and Mechanical Equipment Discharging to Percolation Pits

This section documents the equipment specifications, operational parameters, and site conditions for each Site 300 facility that currently discharges water to percolation pits. A list of all cooling towers and mechanical equipment discharging to the subsurface is given in **Table 1**. Tower dimensions and basic capacities are given in **Table 2**. Schematic drawings of the various tower models are shown in **Figure 2**. Cooling tower detailed performance information can be found in **Table 3**. The locations and basic information about mechanical equipment that discharge wastewater to percolation pits is given in **Table 4**.

All of the cooling towers at Site 300 are manufactured by Baltimore Aircoil Company[®] (BAC) and are “open” or “wet” systems. A wet cooling tower allows the process cooling water to evaporate, taking advantage of heat transfer of evaporation. As water evaporates from the cooling tower, the salt concentrations in the remaining water increase. If the salt concentration gets too high, the salts crystallize and form scale deposits in the system.

Scaling or deposition of salts as crystal or sedimentary solids reduces the efficiency of the cooling towers. This requires the tower process flow rate to increase to maintain the heat exchange rate and also requires periodic cleaning of the system. Like many standard cooling towers, the formation of scale within the cooling tower and the process piping to supported equipment is limited by the use of anti-scaling chemicals.

To maintain an optimum salt concentration in the water collected in the cooling tower sump, a calculated rate of water is drained from the tower sump and “clean” water is added. The drained water is referred to as “blow down” and the clean water is referred to as “make up”. It is the salts within the blow down water being discharged to the subsurface through engineered percolation pits and septic systems that are the subject of this report.

Each cooling tower is unique in the combination of its design and application. The following descriptions are Site 300 building locations that have a cooling tower either adjacent or nearby. A brief description of the type of cooling tower and discharge location is included.

Building 801

The location of the cooling towers supporting Building 801 is shown in **Figure 3**. This cooling tower has two cells that are adjacent to one another and run in parallel. They are both in operation and operate as a single unit (**Figure 4** and **Figure 5**). They are moderately large-sized, prefabricated, induced-draft, cross-flow cooling towers with vertical-air discharge made by BAC. The model numbers are both 15282 2X (serial U1837501 MAD, belt: 4-B128). The mechanical equipment supported by the cooling tower includes two chillers and one heat exchanger.

The nominal cooling capacity for this cooling tower is 564 tons or 1,692 gpm at nominal atmospheric and water temperature conditions. Assuming a wet bulb temperature of 78°F, a make up water TDS concentrations of 700 ppm, typical drift values, and a blow down TDS concentration of 2,000 ppm, the blow down volume would be 17 gpm. At its typical capacity

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be about 1,400 gpm, and the blow down would be 11 gpm (**Table 3**).

The formation of scaling in the cooling tower is limited by the use of anti-scaling chemicals. These chemicals are automatically metered into the cooling tower from a 55-gallon drum using a Liquid Metering Incorporated (LMI) metering pump.

The blow down discharge is done continually and regulated automatically using float valves. The concentration of salts in the tower sump is determined by the operator using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to a drain located to the southeast of the cooling tower and, from there, it gravity drains to the percolation pit.

The top of the percolation pit, which is reported to be 12' X 12' X 7', is completely submerged several feet below the ground surface (**Figure 6**) and lies to the west of the facility. The septic system at Building 801 is shown in **Figure 7**.

Building 806

There are several pieces of equipment that generate wastewater that is discharged to a percolation pit. A list of the equipment is included in **Table 4**.

Building 809

The location of the Building 809 cooling tower is shown in **Figure 8**. The cooling tower is currently in operation (**Figure 9**). It is a smaller-style, forced-draft, cross-flow cooling tower made by BAC. The model number of the unit is FXT-FXT-16 (serial no. U041056501 MAD).

The nominal cooling capacity for this cooling tower is 16 tons or 48 gpm at standard atmospheric and water temperature conditions. Assuming these conditions, a wet bulb temperature of 78°F, a make up water TDS concentration of 700 ppm, and typical drift values, the blow down volume would be 0.2 gpm. At its maximum capacity and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be about 65 gpm, and the blow down would be 0.5 gpm. Assuming the Site 300 field conditions just mentioned, and factoring in the observed range of blow down flow rates (0.2-0.5 gpm), it is assumed that the cooling tower currently supplies about 40 gpm of cooling water.

The anti-scaling chemicals are gravity drained into the cooling tower sump from a one-gallon jug through a small tube. The size of the tube dictates the rate at which the chemicals are infused into the cooling tower. Blow down discharge is done continually and regulated by the operator using a ball valve. The rate of blow down flow is determined by the operator by trial and error using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to a percolation pit.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

The top of the percolation pit, which is reported to be 6' X 6' X 6', is completely submerged several feet below the ground surface. Access to the percolation pit is via a 12" round "Christy Box" style utility cover and corrugated steel lined hole (**Figure 10** and **Figure 11**). The piped water is discharged into this hole and, therefore, onto the top of the percolation pit.

Building 817

The location of the cooling tower supporting Building 817 is shown in **Figure 12**. The cooling tower is in operation (**Figure 13**). It is a smaller-style, forced-draft, centrifugal fan, counter-flow cooling tower with vertical air discharge made by BAC. The model number is VXT-25CR. This model is no longer manufactured or supported.

The nominal cooling capacity for this cooling tower is 20 tons or 60 gpm at standard atmospheric and water temperature conditions. At its maximum capacity and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be nearly 78 gpm, and the blow down would be 0.6 gpm. Assuming the Site 300 field conditions just mentioned, and factoring in the observed range of blow down flow rates (0.2-0.5 gpm), it is assumed that the cooling tower currently supplies about 40 gpm of cooling water.

The formation of scaling of the cooling tower is limited by the use of anti-scaling chemicals. These chemicals are gravity drained into the cooling tower sump from a one-gallon jug through a small tube. The size of the tube dictates the rate at which the chemicals are infused into the cooling tower. The blow down discharge is done continually and regulated by the operator using a ball valve. The rate of blow down flow is determined by the operator using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to a percolation pit.

The top of the percolation pit, which is reported to be 7' X 7' X 5', is completely submerged several feet below the ground surface. Access to the percolation pit is via a 12" round "Christy Box"-style utility cover and corrugated steel-lined hole (**Figure 14**). The piped water is discharged into this hole and, therefore, onto the top of the percolation pit.

Building 826

The location of the cooling tower supporting Building 826 is shown in **Figure 17** and is near the northeast corner of the building. The cooling tower is in operation (**Figure 18**). It is a medium-sized, forced-draft, centrifugal fan, counterflow cooling tower with vertical air discharge made by BAC. The model number is VTO-19-G.

The nominal cooling capacity for this cooling tower is 19 tons or 57 gpm at standard atmospheric and water temperature conditions. At its maximum capacity and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be nearly 81 gpm, and the blow down would be 0.6 gpm. Assuming the Site 300 field conditions just mentioned, and factoring in the observed range of blow down flow rates (0.4 gpm), it is assumed that the cooling tower currently supplies about 52 gpm of cooling water.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

The formation of scaling of the cooling tower is limited by the use of anti-scaling chemicals. These chemicals are gravity drained into the cooling tower sump from a one-gallon jug through a small tube. The size of this tube dictates the rate at which the chemicals are infused into the cooling tower.

The blow down discharge is done continually and regulated by the operator using a ball valve. The rate of blow down flow is determined by the operator using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to a percolation pit located about 10 feet from the tower (**Figure 19**).

The top of the percolation pit, which is reported to be 6' X 6' X 5', is completely submerged several feet below the ground surface. Access to the percolation pit is via a 12" round "Christy Box"-style utility cover. The piped water is discharged into the top of the percolation pit.

To distinguish the location of the septic system, the marked location for the septic leach field or tank located to the east of Building 826 is shown in **Figure 20** and **Figure 21**.

Building 827A

There are two cooling towers in operation south of Building 827A (**Figure 22**) adjacent to one another (**Figure 23**). They are made by BAC. The model numbers are both VXT-75CR (belt: 2-B68). BAC no longer makes this unit, but they can replicate it if needed.

The nominal cooling capacity for each of the two cooling towers is 151 tons or 906 gpm total at standard atmospheric and water temperature conditions. At its maximum capacity and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be nearly 1,178 gpm, and the blow down would be 9.2 gpm. Assuming the Site 300 field conditions just mentioned, and factoring in the observed range of blow down flow rates (1.1 gpm), it is assumed that the cooling towers currently supply about 140 gpm of cooling water combined.

The formation of scaling in the cooling tower is limited by the use of anti-scaling chemicals. These chemicals are gravity drained into the cooling tower sump from a one-gallon jug through a small tube. The size of this tube dictates the rate at which the chemicals are infused into the cooling tower.

The blow down discharge is done continually and regulated by the operator using a ball valve. The rate of blow down flow is determined by the operator using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to a drain located at the base of the adjacent stair well at the southeast corner of the building. This drain goes to a percolation pit that lies to the east of the building.

Table 4 lists the equipment throughout the Building 827 Complex that has potential to discharge water.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

There are indications of two separate infiltration systems located adjacent to one another east of Building 827A. The cooling tower initially discharges to a drain, which is adjacent to the southeast corner of the building at the bottom of a stairwell (**Figure 24**). This drain is connected to the south percolation pit (**Figure 25**). The mechanical equipment discharges to the percolation pit to the north (**Figure 24**). The top of the percolation pit, which is reported to be 18' X 18' X 5', is completely submerged several feet below the ground surface. Access to the percolation pit requires some off-road access and has yet to be detailed.

Building 827C

The percolation pit at Building 827C is shown as **Figure 26**. **Table 4** lists the mechanical equipment at Building 827C that has potential to discharge water to the percolation pit.

Building 827D

The percolation pit at Building 827D is shown as **Figure 27**. **Table 4** lists the mechanical equipment at Building 827D that has potential to discharge water to the percolation pit.

Building 827E

The percolation pit at Building 827E is shown as **Figure 28**. **Table 4** lists the mechanical equipment at Building 827E that has potential to discharge water to the percolation pit.

Building 851

The location of the cooling tower supporting Building 851 is located in the northwest portion of Site 300. The cooling tower is relatively new and replaces two older units. It is a medium-sized cooling tower made by BAC. The cooling tower model number is VT0-078-JM.

The nominal cooling capacity for this cooling tower is 78 tons or 234 gpm at standard atmospheric and water temperature conditions. At its maximum capacity and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be nearly 275 gpm, and the blow down would be 2.1 gpm. The facility specific design operating parameters include cooling 248 gpm of water from 95°F to 85°F (wet bulb temperature of 75°F). Assuming a 2,000 ppm TDS discharge concentration, the blow down volume is approximately 1.2 gpm.

The formation of scaling of the cooling tower is limited by the use of anti-scaling chemicals. These chemicals are gravity drained into the cooling tower sump from a one-gallon jug through a small tube. The size of this tube dictates the rate at which the chemicals are infused into the cooling tower.

The blow down discharge is done continually and regulated by the operator using a ball valve. The rate of blow down flow is determined by the operator by trial and error using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to the percolation pit. The percolation pit is reported to be 14' X 14' X 5'.

*Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges***Cooling Towers and Mechanical Equipment Discharging to Septic Systems**

The equipment currently discharging to septic systems, or leach fields, includes a wide variety of boilers, vacuum pumps, pressure relief valves on hot water/steam equipment, humidifiers, filter drains, and water softeners, as well as condensates from air compressors, air conditioners, and refrigeration units. **Table 1** lists the septic system discharge locations. Additional information about mechanical equipment discharges to septic systems is given in **Table 4**. Only the Building 825 cooling tower discharges to a septic system.

Building 801

The mechanical equipment at Building 801 discharging to the septic system is listed in **Table 4**. The septic system at Building 801 is shown in **Figure 7**.

Building 805

The mechanical equipment at Building 805 discharging to the septic system is listed in **Table 4**.

Building 813

The mechanical equipment at Building 813 discharging to the septic system is listed in **Table 4**.

Building 819

The mechanical equipment at Building 819 discharging to the septic system is listed in **Table 4**.

Building 825

The location of the cooling tower supporting Building 825 is shown in **Figure 15**. The cooling tower is in operation (**Figure 16**). It is a smaller-style, forced-draft, centrifugal fan, counter-flow cooling tower with vertical air discharge made by BAC. The model number is VTO-14F. **Table 4** lists the equipment that has potential to discharge water at Building 825.

The nominal cooling capacity for this cooling tower is 14 tons or 42 gpm at standard atmospheric and water temperature conditions. At its maximum capacity and conservative Site 300 atmospheric conditions (wet bulb temperature of 62°F), with a hot water temperature of 90°F and a cool water return temperature of 75°F, the anticipated cooling capacity would be nearly 65 gpm, and the blow down would be 0.5 gpm. Assuming the Site 300 field conditions just mentioned, and factoring in the observed range of blow down flow rates (0.4 gpm), it is assumed that the cooling tower currently supplies about 52 gpm of cooling water.

The formation of scaling of the cooling tower is limited by the use of anti-scaling chemicals. These chemicals are gravity drained into the cooling tower sump from a one-gallon jug through a small tube. The size of this tube dictates the rate at which the chemicals are infused into the cooling tower.

The blow down discharge is done continually and regulated by the operator using a ball valve. The rate of blow down flow is determined by the operator using a TDS meter. Make up water is continuously supplied to the system as needed to offset the rate of evaporation, blow down, and consumption. The blow down discharge water is gravity drained through a pipeline to a septic system. The mechanical equipment at Building 825 discharging to the septic system is listed in **Table 4**.

*Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges***Building 826**

The mechanical equipment at Building 826 discharging to the septic system is listed in **Table 4**.

Building 851A and Building 851B

The mechanical equipment at Building 851A and Building 851B discharge to the septic systems as listed in **Table 4**.

Facilities No Longer Using Subsurface Discharge

Many of the cooling towers at Site 300 have been removed due to discontinued use, facility closings, or replaced with alternative cooling systems. The facilities that have been closed no longer discharge mechanical equipment or cooling tower wastewater to the sub surface. A list of those facilities that have been closed is included in **Table 1**.

Options for Reducing Salt Discharge to Percolation Pits and Septic Systems

This section includes a general analysis of best practicable technologies and methodologies for reducing cooling tower and mechanical equipment process water/salt discharged to the percolation pits and septic systems at Site 300. The following are presented as part of the due diligence engineering evaluation as a comprehensive condensed list of options.

Cooling towers typically operate most efficiently at a constant TDS level. A high concentration will cause scaling. A very low concentration will cause corrosion. Knowing this, there are only three methodologies that can be adopted which will have the effect of decreasing the TDS concentration in the discharge:

1. Keep the concentration in the cooling tower as low as possible without significantly increasing corrosion, and
2. Treat the blow down prior to discharge to the percolation pits.

The first option, to decrease the maintained concentration within the cooling towers, may decrease the effluent concentration, but may not decrease the overall mass of salts discharged to the subsurface as the discharged water volume may increase. A third methodology:

3. Increasing the efficiency of cooling tower operation is beneficial because it minimizes the total water usage. The discharge concentration may be the same, but the total mass of TDS discharged is less.

Technical and operational options that adopt one or more of these methodologies are listed in **Table 5**. In order to evaluate these options, a qualitative approach, based on the parameters listed in **Table 6** was used. The parameters include:

1. Capital cost,
2. Operational and maintenance cost and labor,
3. Savings,
4. Development and acceptance,
5. Effectiveness, and
6. Ability to reduce TDS discharged to the subsurface.

The effect of each option alone on each of the evaluation parameters is delineated as None, Low, Moderate, and High. The qualitative judgment is based on site demonstrations, industry reports, literature searches, manufacturer claims, vendor quotes, field case studies, and engineering experience and judgment with special consideration for Site 300 operating environments.

This estimation model is also used to categorize the treatment technologies. As an example, referring to the options on **Table 5**, adding automated meters and valves (Option 5) for an averaged sized cooling tower is expensive, but very effective at reducing TDS discharge to the subsurface.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Improve Operation and Maintenance

There is always room for improvement in operation and maintenance practices. Increased attention to equipment and process streams can promote increased efficiency, less downtime, longer life spans, and fewer overhauls. Drawbacks include increased labor and documentation. As it relates to the reduction in discharged TDS concentrations, improved efficiency will lower the water consumption, and thus the mass of salts discharged. Some suggested improvements in the operation and maintenance of cooling towers are listed in **Table 5** as Options 1 through 4 and are discussed below.

Option 1. Increase Accuracy of Chemical Dosing.

Chemicals are added to open cooling tower water for the following reasons:

- a. Remove microbial growth.
- b. Reduce scaling.
- c. Reduce corrosion.
- d. Adjust pH.
- e. Act as a wood preservative.

Microbial growth within open cooling towers causes bio-fouling of the packing material and other surfaces and decreases the efficiency of heat transfer. It also causes air-borne dispersion of bacteria that cause the disease known as legionellosis. A variety of biocides are used to control microbial growth including chlorine. Anti-scaling chemicals allow dissolved solids to stay in solution at temperatures and pH values that they would typically “plate out” on equipment surfaces. The accumulation of solids on equipment surfaces decreases the efficiency of heat transfer and can damage pumps and valves. Anti-corrosion chemicals protect the equipment surfaces from being attacked. Corroded equipment leads to leaks, inefficiency, downtime, and higher TDS values in the discharged fluid. The combination of chemicals and the aeration of the water can lead to shifts in the pH, which can be adjusted with the addition of acids and bases.

The addition of too little or too much chemical additives can cause undesirable effects on the equipment surface, like corrosion or oxidation or have a competing or nulling effect on other chemicals. Precise dosing minimizes the wasting of expensive chemicals and the concentrations of downstream chemical constituents and reaction products.

Accurate addition of chemicals is typically accomplished with the use of dosing pumps. These pumps inject very small, accurate amounts of chemicals frequently or continuously. Batch chemical addition can “shock” the system and cause spikes of concentrations that can have a deleterious effect on the equipment and the water quality. Batch addition also wastes a significant amount of chemicals in the blow down process.

The cost of a standard injection system varies with the complexity of the chemical treatment process and the amount of automation. Some systems automatically adjust the dose rate based on real time indications of system flow, pH, conductivity, and temperature. For the purpose of comparison, the analysis of increased chemical dosing accuracy assumes that “small” systems have one dosing pump that is not automated. A “large” system has three pumps that are not automated. The effect of automation is taken into account in Option 5.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

The applicability of precision dosing to cooling tower operation is estimated in **Table 5**. It is important to note that accurate estimations of the effect of more precise dosing on a system that is chemically complex is difficult to obtain. Trial and error in the field with the use of scale coupons is advisable. However, reasonable estimates that account for both increases in effectiveness and chemical savings are given for comparison purposes. This option would be applicable to both large and small cooling towers at Site 300.

Option 2. Modify Maintenance Schedule to Increase Frequency and Completeness.

Increasing the frequency, detail, and effectiveness of cleaning can improve the efficiency of cooling tower operations by increasing the heat transfer efficiency. For a dry or hybrid tower, this is important at the packing/air interface and the water/air/tubing interface. For an open wet tower, this is important for keeping debris and sludge out of the heat exchangers that the tower supports. Increasing the heat transfer in the system creates less demand for process water flow and stress on the system as a whole. Affective equipment maintenance decreases both power consumption and secondary heat generation. A sample list of maintenance activities for cooling towers is included in **Table 7**. Establishing a preventative maintenance schedule promotes regular and effective servicing.

Maintaining precise records of adjustments, tests, and repairs is essential for effective long-term operations. This data should not only be recorded, but tracked and studied by the facilities engineer to determine the effect of increased efforts on the equipment performance and discharge quality. This information is the best indication of reduction in water usage and salt discharge to the percolation pits. However, general estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 3. Investigate and Eliminate Leaks.

A cause of high water use and high effluent concentration that is often overlooked is system leaks. If the system is consistently losing water to leaks, then unchecked and un-treated water may be unknowingly discharged to the subsurface. While this may result in an observed lower discharge concentration, it will almost certainly also result in the same salt mass discharged and higher water use. The general estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 4. Minimize Drift and Blow Out.

Drift is water droplets that are carried out of the cooling tower with the exhaust air. Blow out is water that splashed or wind blown out of the cooling tower. These types of water loss typically account for about 0.2% for drift and 0.1% for blow out of the total process water used in the tower. Methods to reduce drift and blow out include use of drift eliminators, wind baffles, and splash guards and regular maintenance and adjustment of the spray nozzles. The general estimates of cost and applicability are given for comparison purposes in **Table 5**. Values may vary between manufacturers, and with variations in water droplet size, air velocities, and water chemistry (affecting surface tension).

Add Automated Processes to Increase Efficiency

The use of automated processes allows for more consistent, accurate, and precise control of critical systems. It is analogous to correcting the steering of a car every minute or every second. The more often you correct the steering, the less time you waste going the wrong direction.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

There are several processes involved with cooling towers that lend themselves to automation. The three major processes addressed in this paper are the tower sump blow down, chemical injection, and fan speed.

Option 5. Automated Meters and Blow Down Valves.

One of the most recommended additions to any cooling tower is the installation of an automated blow down system. These systems continuously monitor the conductivity of the tower sump and open or close the blow down valve based on pre-determined values related to TDS concentration. This keeps the TDS concentration very stable within the system, thus minimizing the “saw tooth” effect that can cause chemical treatments to be less efficient. The increased efficiency is deduced through regular monitoring and comparison of water use rates and maintenance down time, both of which should decrease. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 6. Automate Chemical Injection.

Adjusting the injection rate of anti-scaling, anti-corrosion chemicals, or biocides based on real time data enables the minimization of overdosing. This reduces the amount of TDS in solution and saves cost. It is typically only cost efficient for larger systems. Metering may include pH, temperature, conductivity, and flow rate. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 7. Automate Cooling Demand Controls to Reduce Air-Flow at Low Heat Loads.

The ability to reduce the fan speed for times of lower cooling requirements is beneficial for two reasons: first, decreasing the fan speed saves costs on power, and second, decreasing the fan speed reduces evaporation and thus the TDS levels in the tower sump. It also reduces the need for other chemicals and treatment processes. It is also possible on some systems to reduce the flow rate through the cooling tower by controlling the transfer pumping rate. However, for most cooling towers, there is a range of flow rates that the system is designed to operate under. A water flow rate that is too low can cause excessive blow out at the exhaust. This is not true of closed loop or hybrid systems. The option to control flow rate is addressed in Option 16 and Option 18. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Re-Evaluate Chemical Treatment Strategy

It has been standard practice to operate similar cooling towers with identical or generic chemicals and doses. Cooling tower water chemistry is a function of the make up water, process-piping materials, cooling requirements, and cooling tower type and may vary significantly from facility to facility. There are many chemical dosing approaches that vary in their assumptions and techniques. Some chemical suppliers combine typically required chemicals into one blend. This may or may not be effective for all situations. Some chemicals may be used from different sources that have competing, nulling, or other adverse effects. It may be advantageous to reconsider the various chemical treatment strategies used at Site 300.

Option 8. Insure That the Chemicals Used are Specifically Designed for Site-Specific Chemistry and Operating Conditions.

As indicated previously, each cooling tower facility is unique and may benefit from individual chemical analysis to customize a treatment strategy that is specific to the needs at that location.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Of course, the actual benefit will not be quantifiable until such an analysis is completed, so potential increases in efficiency can only be estimated. However, facilities, which are dosed incorrectly, suffer the effects of corrosion, scaling, and bio-fouling which can be severely detrimental to efficiency. The use of inferior chemicals and chemical blends may also cause operational inefficiencies and increased costs. It may be useful to promote a competitive selection of chemicals and vendors based on cost to treat 1,000 gallons of cooling water make up instead of lowest price per pound of chemicals. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 9. High Cycles of Concentration Chemical Dosing.

The ability to keep the dissolved solids from forming scale deposits on the equipment and packing is one of the primary purposes of chemical dosing. The more effective the chemical is at keeping dissolved solids dissolved, the higher the concentration of TDS within the tower can rise before scaling begins. This is dependent on the water chemistry, temperature, and the prevalence of silt, grooves, and other small angular surfaces where scale tends to form. There are chemicals on the market that allow for very high concentrations of TDS. The downside of operating at high cycles of concentration is that the system chemical balance becomes very delicate. Small errors in operation or the system environment can cause the system to become very corroded, scaled, and inefficient quickly. Automated continuous monitoring of sump water chemistry and adjustments to dosing and bleed control are typically recommended for this application. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Increase Quality of Make Up Water

Increasing the quality of the make up water can provide two alternatives:

1. It can allow for lower volumes of blow down water, and therefore lower volumes of salts, to be discharged to the percolation pit if the cooling tower sump concentrations stay the same, or
2. It can allow for lower concentrations of blow down water discharged to the percolation pits, using the same amount of make up and blow down water.

Of the two alternatives, only the first one is typically of interest to most cooling tower operators. The second alternative typically forces the TDS level in the tower outside the optimal range. Two options are presented that would enable the increased quality of make up water. Either treating the water using physical methods or changing the source of the water.

Option 10. Pre-Treatment of Make Up Water.

The pre-treatment of make up water is a standard practice in many cooling tower applications. Systems that remove salts, metals, and suspended solids are common. The flow rate of the make up is equal to the sum of the blow down, evaporation, windage, and drift. So, although the concentrations within the make up water are lower, the effort to treat it is typically greater than treating the blow down or the sump water. Advantages to treating the make up water include:

1. Utilization of line pressure to drive treatment flows.
2. High potential cycles of operation.
3. Lower chemical usage.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Disadvantages include:

1. Lower cleanup levels.
2. Higher flow rates.
3. May still require sump or blow down treatment.

It is sometimes necessary to treat the influent if it contains contaminants that are not tolerable within the tower for any length of time or would be easier to deal with up front. This may include bacteria, biodegradable organics (BOD), silts and volatiles. There are a wide variety of treatment technologies varying from simple and inexpensive to complex and expensive. The treatment technologies that were considered applicable and are often used in this industry are listed in **Table 8** and discussed in the “*Treatment Technologies*” section. The effects of individual treatment methods are listed in **Table 8**. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 11. Change the Source of Make Up Water (Industrial “Waste” Water, Condensate, Etc.).

Currently, the source of water for make up in the cooling towers is groundwater from an on-site well. This water is filtered and chlorinated prior to use as is the primary source of water for Site 300. There is the possibility that the make up water could come from other sources including:

1. Surface water.
2. Industrial process waters.
3. Groundwater from environmental remediation projects.

The use of potable surface water is an increasing probability since there is a proposal to bring Hetch-Hetchy water to Site 300 and discontinue the use of groundwater. TDS from Hetch-Hetchy water will be 40 mg/L. There are many unknowns tied to this option including infrastructure and operational modifications and cost.

There are a few sources of industrial process water at Site 300, but only use of those that do not contain high levels of metals, cutting oils, or high-explosive compounds would be cost efficient. Some mechanical equipment wastewater, like condensate, may be used without treatment. However, there typically isn’t enough industrial process water to satisfy the make up water requirement. Certainly, incorporating the mechanical equipment wastewater into the make up water as a supplement would be beneficial for conservation, especially if there were treatment processes in place to ensure that any introduced contaminants would be removed prior to use and/or discharge.

Changing the source to enable re-use of environmental restoration groundwater would promote conservation of a limited resource. However, there are distribution and management issues. The sources are not always located conveniently close to the cooling towers and may not be as consistent in availability and flow rate. They are also owned and operated by a different division with differing objectives. Use of environmental restoration water would also require review of regulatory agencies.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

For the purposes of this investigation, only the use of surface water is considered viable for consideration and comparison. Issues affecting the use of surface water include ease of accessibility and water chemistry. Typical surface water has high concentrations of organic matter, fines, and other contaminants associated with run-off requiring pre-treatment prior to use as make up water. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Blow Down Water Management

Blow down water is discharged and make up water is added to a cooling tower sump to maintain a constant concentration of salt within the tower sump. The higher the frequency of sump concentration adjustment using the blow down, the more consistent is the sump concentration, as discussed in Option 5. Therefore, a continuous blow down is preferred to a periodic blow down for increased efficiency of the cooling tower. All of the cooling towers currently employ a version of continuous blow down.

The management of the blow down as it relates to its rate and concentration is discussed in the following four options. Option 12 incorporates treatment solutions that directly address the reduction in concentration and mass of salt solutions discharged to the percolation pits. Salts are the primary contaminants of concern, with regards to subsurface discharge, as specified in the WDR (Order R5-2008-0148) and are specifically identified as sulfate, sodium, and chloride. TDS analysis and conductivity measurements are the key indicators of these combined ions species. Other typical contaminants that should be addressed in any cooling tower treatment system include wind blown debris, silt, hardness, silica, bacteria and algae, and other bio-fouling matter. Treatment technologies that are specifically designed to address these contaminants are discussed in detail in the “*Treatment Technologies*” section.

Options 13 and 14 also propose treatment solutions, but only to the effect of reducing or eliminating the volume of blow down to the percolation trench. This would result in the overall reduction of salt mass entering the subsurface. Option 15 proposes the use of alternative discharge locations. Option 16 describes the alteration of cooling tower operation that will result in the direct reduction of blow down concentration.

Option 12. Treat the Equipment Wastewater Prior to Discharge.

The treatment of the blow down water prior to discharge is typically done for regulatory compliance issues. This is especially relevant when the discharge is going to surface waters, groundwater, or the sanitary sewer. Treatment is typically not required when the discharge goes to evaporation ponds or even the ocean. The treatment of the blow down water prior to being discharged is the only standard method of reducing the TDS concentrations being discharged to the percolation pits. Most of the previous options are only effective at reducing the TDS mass being discharged to the percolation pits (refer to **Table 8**). General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 13. Treat and Re-Circulate Sump Water – “Low Discharge” Operation.

This option is similar to Option 12 in that it utilizes water treatment technologies to remove contaminants from the cooling tower sump. However, in this case, the treatment process pulls and treats water from the sump as a separate flow stream from the blow down. An example using ion-exchange treatment is shown in **Figure 29**. Due to the removal of contaminants from

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

the sump water, the required volume of discharge blow down and added make up water can be reduced. The flow rate through this re-circulating treatment system is dependent on the operational mode. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 14. Treat and Re-Circulate Sump Water – “Zero Discharge” Operation.

This option is similar to Option 13 in that it pulls and treats water from and replaces water to the sump as a separate flow stream. However, in this case, the treatment process is large enough to eliminate the need to discharge water from the sump. The treatment system removes all of the contaminants that accumulate in the system. This is known as “zero discharge” operation. The flow rate through this re-circulating treatment system is dependent on the operational mode and accumulation of contaminants as measured by real time monitors. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 15. Alternative Discharge Locations.

Having the blow down from all cooling towers re-directed to an alternative discharge location or re-use application would remove all issues related to the contamination of underlying aquifers. It would also serve as a valuable conservation method. A suitable alternative discharge use or location would have the following attributes:

- a. Available at Site 300.
- b. Reasonable cost to build or modify to accept the blow down flow.
- c. Ability to utilize the full volume of blow down water discharged from cooling towers at Site 300.
- d. Tolerant of high TDS and other contaminant levels.
- e. Reasonable costs to treat the water to tolerable levels of contamination.
- f. Within a proximity that would allow for easy transfer.
- g. Available to accept flows at all times.
- h. Regulatory acceptance.

Typical alternative discharge options:

- a. *Sanitary sewer*
The use of the municipal sanitary sewer is not an option because there is no service at Site 300. The existing sewage pond is easily accessible, and it does not have the capacity to accommodate the current blow down volumes. If the blow down volume were reduced, the issue of the sewer pond capacity would have to be addressed. Leach fields are not an option since they essentially result in the same effect as percolation pits.
- b. *Storm sewer*
There is no storm sewer at Site 300.
- c. *Surface water*
The option to discharge to surface waterways is the most viable solution. However, this was the method of discharge prior to the use of the percolation pits. Discharge to surface water ways was discontinued and eliminated as a regulatory possibility with the rescinding of the NPDES permit (Order No. 94-131) on August 4, 2000.

*Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges*d. *Evaporation ponds*

There are no longer any evaporation ponds at Site 300. To construct a pond large enough to accommodate the current combined blow down flow rates could require as much as 30 acres of flat land and an extensive collection system. Other issues to account for would include natural habitat destruction, wetland creation, leachate collection and monitoring, and wildlife management.

Alternative re-use options considered:

a. *Irrigation/ Livestock*

There are no agricultural, irrigation, or livestock resources that are near enough or large enough to assimilate the flows from Site 300 cooling towers.

b. *Black water (toilets)*

There is not a high enough black water use requirement at Site 300 to handle the volume of blow down water currently being discharged. If the blow down volume were reduced, the existing water supply system would have to be significantly modified. Among other things, it would require extensive distribution, holding, overflow, and pumping systems.

c. *Industrial*

Currently, there are no known industrial uses for untreated blow down water at Site 300.

The applicability of utilizing alternate discharge options is given in **Table 5**. It is apparent that all options to re-direct high volume discharge to alternative locations or re-use pose significant obstacles as long as it remains a stand-alone option. If the flow rates were reduced, it may become more applicable to consider alternate discharge location/re-use options.

The applicability of an alternate discharge source for mechanical equipment is more flexible due to the low flow rates. In areas where mechanical equipment and cooling towers are relatively close, the wastewater from mechanical equipment could be re-used as a portion of the make up water. This is especially true if some form of pre-treatment were employed.

Option 16. Decrease Concentration Cycles.

The water use efficiency of cooling towers operation is, to a large extent, based on the cycles of concentration. Cycles of concentration is defined as the number of times the salt concentration within the cooling tower is allowed to increase from its original make up concentration. The higher the concentration of the sump water that still precludes the formation of scale, the less blow down discharge volume is required, thus requiring less make up water. However, the concentration in the water that is discharged will be greater.

The converse is also true. If the cycles of operation are decreased, the concentration of salt in the blow down will decrease and the make up water requirement will increase. In practice, this means that the sump draining system is set to discharge at some pre-determined low level of salt concentration. The limiting factor is that this low concentration must be greater than the make up water concentration. The closer the set point, the more water usage is required.

As the set point for blow down discharge approaches the concentration of the make up water, the volume of make up water increases exponentially and quickly becomes infeasible. The operation

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

of a cooling tower at low salt concentrations is not efficient and can increase corrosion. The increase in water use also increases chemical usage. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Change the Type of Cooling Tower

All of the cooling towers at Site 300 are metal wet cooling towers. They represent the industry standard for this technology. However, there are several different types of cooling systems that are in regular use that would decrease or eliminate the discharge of salt solutions (and concentrations) to the subsurface. Implementation of these options would require complete replacement of the existing cooling towers.

Option 17. Closed Loop Dry (Air-Cooled) Tower.

A closed loop air-cooled system does not allow the process cooling fluid to come into contact with the atmosphere. Instead, the cooling water is run through tubes that are cooled with air (**Figure 30**). There is no water discharged. These systems are not as effective as wet cooling systems as they cannot take advantage of the heat of evaporation which allows the cooling water to be cooled below the ambient air temperature. This can pose a problem on hot days. Due to this decreased efficiency, these systems are typically much larger than their wet cooling tower equivalent. However, for reasonable applications, these systems offer greater flexibility for installation and regulatory acceptance. Two of the facilities at Site 300, previously cooled with wet cooling towers, were converted to air-cooled systems (Building 834A and Building 836A). General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 18. Closed Loop Hybrid (Air and Water) Tower.

A closed loop hybrid tower is a cross between a wet tower and a dry tower. The water is contained within tubing that is run through the tower and does not come into contact with the atmosphere. However, the tubes are cooled by air and/or water (**Figure 31**). These systems typically use the water to both pre-cool the incoming air and directly cool the tubes. Most systems can modulate the process configuration automatically to minimize water use. The water used is re-circulated from the sump and does evaporate. This means that the process fluid can be cooled to lower temperatures than with a dry tower, although not with the efficiency of a wet tower. Since there is evaporation, there is also the need for make up water, the buildup of dissolved solids, and blow down discharge. The volume of blow down is less than for standard wet cooling towers when accounting for the ability to turn the water re-circulation off and on as needed. A reduced blow down volume means less TDS discharged to the subsurface. These systems are more complicated than either the wet or dry towers, but the added flexibility and reduced water usage makes them attractive for demanding designs. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Option 19. Plastic Cooling Towers.

Some manufactures offer plastic or fiberglass cooling towers. The benefit of their use includes:

1. Reduction in chemical use for metal corrosion.
2. No damage from rust in supported equipment.
3. No introduction of dissolved metals into the process stream.
4. Less susceptible to pH extremes.
5. Not as affected by scaling.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

As these towers are not as susceptible to corrosion, scaling, and pH, they are capable of operating at higher cycles of concentration. At high cycles of concentration, the requirement for make up water decreases, thus reducing the mass of salts being discharged to the subsurface.

Supported Equipment Management

Option 20. Operations and Management of Supported Equipment.

One viable option not related to the cooling towers themselves is optimizing the equipment that they support. As an example, a heat exchanger that is old, out dated or under-maintained will put a higher demand on a cooling tower. If the heat exchanger were upgraded or thoroughly cleaned, the reduced demand on the cooling tower would be indicated by a reduce blow down rate.

There is always room for energy conservation. Decreasing the use or level of operation of equipment supported by cooling towers also reduces the demand on the cooling tower. These options are continuously being advocated by Site 300 management. One such example is the immanent conversion of hot water heating at Building 827 from a boiler system to a low discharge electrical resistance system. There are also many facilities that are being consolidated to save energy and cost. General estimates of cost and applicability are given for comparison purposes in **Table 5**.

Treatment Methods

As mentioned previously, the treatment of make up water and/or blow down water will enable the reduction of TDS concentration and/or TDS mass in blow down water. Salts are the primary contaminants of concern, with regards to subsurface discharge, as specified in the WDR (Order R5-2008-0148) and are specifically identified as sulfate, sodium, and chloride. TDS analysis and conductivity measurements are the key indicators of these combined ions species. Other typical contaminants that should be addressed in any cooling tower treatment system include wind blown debris, silt, hardness, silica, bacteria and algae, and other bio-fouling matter. Some water treatment options indirectly reduce TDS in the blow down through increasing cooling tower operational efficiency. Others deal directly with contaminant removal prior to discharge. Indirect approaches includes treating the influent or make up water, a side stream of the sump water, or the process cooling water. A direct approach would be to treat the blow down prior to discharge to the percolation pits. These methods were discussed briefly for Option 10, Option 12, Option 13 and Option 14.

There are many viable treatment technologies that work well with each of the previously discussed approaches. Some are proven standard approaches, while others are innovative and under development. Discussed below are some techniques and technologies that are utilized in the cooling tower industry today. A list of these treatment methods and their relative effect and efficiency is given in **Table 8**. The following are presented as part of the due diligence engineering evaluation as a comprehensive list of viable options.

Chemical

Chemical methods can include liquid, solids, or gas additives. Their purpose is to change the chemistry of the water to increase efficiency and decrease contaminants in the discharge.

A. Liquid or solid chemical additives

The use of chemical additives is a standard practice in the cooling tower industry and the method currently used at Site 300. Chemicals are metered into the influent (make up water), process (cooling water), and effluent (blow down water) to deal with the variety of water chemistry issues previously discussed in Option 1. It is usually advisable to seek the advice and assistance of a chemical supplier that has extensive experience. The two major chemical treatments are for scale reduction and microbial disinfection.

Scale reduction is typically accomplished through chemical means by the use of either acids or anti-precipitants and dispersives. The use of acids is problematic for two reasons. The addition of acid can reduce the pH to a level that is corrosive to metal. Also, the handling of acids is dangerous and costly. The use of anti-precipitants and dispersives allows for easier handling, but may require additional chemical additives to address pH shifts and other side effects. The addition of chemicals to the cooling tower water may also complicate disposal of the blow down to regulated sources.

The second major type of chemical addition for microbial disinfection (biocides and agaeicides), is used to reduce bio-fouling on equipment surfaces and within the process water and to kill

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

bacteria harmful to human health. Other chemical treatments are used as needed for metals removal (chromate) and as a wood preservative.

Many cooling tower chemical suppliers offer blended formulations that require only one metering system to address a variety of treatment issues. These blends are typically proprietary and costly, but there are cost savings in reducing operations and management to deal with multiple chemical additions. However, these blends are prepared for limited range of scenarios and may not be specifically tuned to the needs of the cooling tower water in question. In these cases some chemicals are injected at higher concentrations than needed, thus wasting money and potentially causing deleterious secondary effects.

Discrete chemical injection based on specific required treatment needs enables more effective and controlled management of the system. This is especially true if different chemicals are better injected at different points in the process stream. This may add some complexity and cost.

Potential consultants that specialize in chemical treatment of cooling towers should be asked to bid on supply of chemicals as dollars per 1,000 gallons of water treated instead of dollars per pound of chemicals. This puts the obligation on the supplier to decide which is more effective – blended formulations or discrete chemical injections. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

B. Gas chemical additives

Ozone injection – The ability to maintain cooling tower operations without chemicals has been realized at many installations throughout the world through the use ozone treatment. This entails the installation of ozone generators and injection apparatus. Ozone entrained into water destroys and acts as a disinfectant, inhibits biomass accumulation, and reduces scaling. There is typically no need for chemical adjustment with ozone treatment, thus no residual chemicals in the effluent stream. The systems are expensive, complex, and require detailed analysis of the cooling application and water chemistry to determine applicability. Accurate and continuous monitoring and control of system parameters is essential. These systems are typically only cost efficient on larger cooling towers. This technology is gaining in acceptance and technical advances. There are many configurations and application methods available. Ozone treatment allows for significantly increased cycles of concentrations that reduce water usage and blow down. Used with other treatment options, it may support a zero discharge scenario. There has been some concern about the required maintenance levels associated with their use. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

C. Ion-exchange (softening)

Ion-exchange treatment will remove ions in solution through exchange with those on the resin. Hardness (water softening), silicates, and other dissolved solids are deposited on ion-exchange resins and the resins are either regenerated or disposed of. This process may need to be combined with chlorine removal and pH adjustment. The effect is reduced TDS mass or concentration discharged to the subsurface. Since there is minimal “blow by” using ion-exchange, the result is efficient removal of TDS. This method is well established in many industries, including the cooling tower sector, and is fairly applicable over a wide range of system parameters. Scale up is linear. Other contaminants, like chromate, can also be removed. The major cost associated with this treatment option is the replacement or regeneration of ion-

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

exchange resin. Replacement frequencies may be high and regeneration requires a significant amount of equipment and operations effort. If the resin is replaced by a contracted vendor, then the operational labor can be relatively low. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

D. Ionization

Ionization – Copper-silver ionization has been used for centuries to disinfect water and combat microbial growth. Ionization replaces or supplements chlorination as the bio-fouling treatment. Copper ions attack and damage cell permeability, cause nutrient uptake to fail, and cause all life support systems in the cell to be immobilized. As a result, there is no more cellular growth or cell division, causing bacteria to no longer multiply and eventually die out. With decreased microbial activity, cooling towers operate at higher efficiencies and lower discharge flow rates. This minimizes the mass of salts being discharged. Ionization has a longer effect than most other disinfectants as the metals remain in the water for a long period of time. Metal ionization does not depend on water temperature, but is dependent on pH. Metals will precipitate at high TDS levels and will also react adversely with other chemicals in solution. Some micro-organisms can become resilient to ionization. Residual metals will contribute to the value of TDS in the effluent. This method has been shown to work best in combination with the addition of free chlorine at lower concentrations than would be used independently. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

Electro-Chemical Methods

The purpose and methodology of electro-chemical technologies are the same as standard chemical additives – to change the chemistry of the water to increase efficiency and decrease contaminants in the discharge. The difference is that there is little or no “chemical” addition to the flow stream.

E. Electromagnetic

Electromagnetic processes of various types have been utilized to alter the way dissolved solids precipitate. Typically, precipitation occurs on pre-existing solids like bio-mass, suspended colloidal material, and equipment surfaces. The use of electromagnetic treatment changes the chemical environment to favor precipitation as freely suspended crystals in solution. This creates a loose powder that remains in solution and may be filtered out. This is accomplished using electro-magnets and programmable power sources. Electromagnetic methods also indirectly reduce microbial growth and inhibit corrosion. The crystal growth also encapsulates bacteria in solution so that they cannot multiply. Corrosion control is also possible as a secondary effect of pulsed power as an alkaline environment is created. Although electromagnetic options are available commercially in a wide variety of configurations, sizes, and techniques, there is some uncertainty about the general development, acceptance, and applicability of these units. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

F. Electrolysis precipitation

The reduction of TDS and other contaminants in a cooling tower process flow or discharge may be achieved through forced precipitation on electrodes during an electrolysis reaction. The electrically driven disassociation of water can create an environment where precipitation occurs below saturation concentrations right at the electrodes. This controlled precipitation can then be

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

removed through filtration. This enables the reduction or elimination of dissolved solids in the blow down discharge to the sub surface. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

Physical Methods

G. Filtration

Suspended solids in the cooling water provide a surface for bio-mass and scale growth. The removal of suspended solids and debris can reduce sludge accumulation, improve clarity, increased cooling efficiency, and decrease chemical demands. However, depending on the type, filtration may also remove needed chemicals from the water. Filtration alone will not remove dissolved solids, but could be used as a removal technique after a precipitation or flocculation process. There are many types of filtration techniques including:

- i. Membranes and pleated fabrics are used to filter down to sub micron levels. The filter cartridges require frequent replacement and would typically require multiple sequence filtration from large to small to be economical. It is also typical to have two systems in parallel to enable uninterrupted operation during filter change out.
- ii. Granular media filters are vessels packed with fine grained sand that can remove micron sized and larger particles. These filters require back flushing to clean the sand when its capacity has been reached. They can be designed for automatic back flushing. However, this creates a fluid waste stream that must be disposed of or treated with a secondary system. Periodically, the sand must be replaced, which can be a difficult task.
- iii. Screen filters are designed to remove debris prior to more comprehensive filtering. They reduce the replacement frequency of down stream filters.
- iv. Disk filters remove particles in the tens to hundreds of microns. They are available in numerous configurations, styles, materials, and sizes. Many are capable of automated back flushing. The advantage of these systems is their low frequency flushing requirements and the ability to re-use the disks.
- v. Centrifugation utilizes the mass of suspended particles to force them out of solution by applying a centrifugal force to the fluid. This is typically accomplished by spinning the fluid inside a vessel and extracting the fluid from the low velocity center. This leaves the separated particles on the sides or bottom of the vessel. Particles from tens of microns may be removed. Some systems are automatically flushed. To achieve the high velocities, a booster pump may be required.

The general estimates of cost and applicability for filtration are given for comparison purposes in **Table 8**.

H. Hydrodynamic cavitation

Cavitation is the formation and implosion of small gas bubbles in solution. The implosion of these bubbles creates high pressures and temperatures. This effect of this phenomenon is typically observed as the pitting of steel impeller blades. These conditions can be created when the water is agitated, causing pressure fluctuations (hydrodynamic methods). The extreme pressures and temperatures destroy microbial cell structures. It has also been shown to create a precipitate that forms a less tenacious surface scale. This enables operation of cooling towers at higher concentration cycles and lower discharge volumes. There is a large investment in capital

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

equipment. The effect is reduced TDS mass or concentration discharged to the subsurface. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

I. Ultrasonic cavitation

Cavitation via means of ultrasonic vibrations is another method of forming and imploding small gas bubbles in solution. The effects are similar to hydrodynamic cavitation and the general estimates of cost and applicability are given for comparison purposes in **Table 8**. Ultrasonic generators create sound waves or vibrations in materials that, when tuned to the correct frequency, can generate cavitation. The capital expenditure is the same or greater than hydrodynamic methods.

J. Reverse osmosis

By applying a pressure across a semi-permeable membrane, the ions in solution can be concentrated, creating a clean solution. This is a well developed technology for desalination and TDS removal. The cost can be prohibitive since it requires a high pressure system and replacement of fouled membranes. The effect is reduced TDS concentration or mass discharged to the subsurface. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

K. Evaporation concentrator

The ability to evaporate water in order to deal with contaminants in solution is typically reserved for natural processes like evaporation ponds as discussed in Option 15. However, mechanical methods that utilize the manipulation of heat and pressure allow for more compact applications. These methods are typically energy and equipment intensive, but produce a very clean product. Methods include brine concentrators, distillation systems, and unseeded falling film evaporators. These technologies are well developed in the cooling tower and industrial wastewater industry. The effect is reduced TDS mass or concentration discharged to the subsurface. The general estimates of cost and applicability are given for comparison purposes in **Table 8**.

Option Estimation and Comparison

As presented in this report, there are 20 options, 11 treatment technologies and 13 facilities eligible for TDS reduction in discharged water at Site 300. As can be presumed, there is a wide range of costs, configurations, methodologies, equipment, automation, and monitoring choices for each of the options and treatment technologies. The complexity of estimation increases when considering that a combination of options and treatment technologies will be required for an optimal design. Accurate estimation of the most beneficial approach to reduce TDS concentrations in discharged water to the subsurface will eventually require:

1. Detailed engineering design.
2. Facility use planning with programmatic, operations, and management personnel.
3. Equipment and technology vendor analysis and quotes.
4. Field demonstrations.

It is the purpose of this analysis to present preliminary costs and estimates of applicability for each option and treatment technology to facilitate comparison and planning. The categorization of each treatment technology and option is based on engineering judgment, site demonstrations, industry reports, literature searches, manufacturer claims, vendor quotes, field case studies, and special consideration for Site 300 operating environments. It is probable that these designations may vary as available information, technology development, operating environments, and regulatory requirements change.

Technical and operational options are listed in **Table 5**. In order to evaluate these options, a qualitative approach, based on the parameters listed in **Table 6**, was used. The parameters include:

1. Capital cost.
2. Operational and maintenance cost and labor.
3. Savings.
4. Development and acceptance.
5. Effectiveness.
6. Ability to reduce TDS discharged to the subsurface.

Each of these parameters has a range that is delineated and categorized in **Table 6** as None, Low, Moderate and High. For those Options that call for water treatment (Options 10, 12, 13, and 14), the rating of each parameter is an average of the parameters of all treatment options listed in **Table 8**.

The treatment technologies are listed in **Table 8**. These technologies are rated according to the same criteria used for the Options, which are listed in **Table 6**. A differentiation is made in **Table 8** for each Option requiring water treatment.

The overall applicability of each option, specific to each facility, is given in **Table 9**. These designations are based on the data in **Table 5** and **Table 8**, and also consider specific Site 300

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

operating environments. The designations and categories that account for the overall applicability of each option are listed in **Table 6** as:

1. Not useful (None).
2. Limited use (Low).
3. Likely useful (Moderate).
4. Very useful (High).

These designations do not express the willingness of Site 300 management to implement in the field. They are intended to give the general applicability of each option for the various facilities.

Observations and Recommendations

Several observations were made from the review of information contained within this report and from engineering experience that may be useful for future option selection and field implementation.

1. Each facility is unique. Flow rates, heating loads, ambient environments, equipment operation and maintenance, make up water chemistry, and facility ownership and importance may all affect selection of a solution to reduce salt discharge to the sub surface. It is recommended that each facility be considered independently with regards to applicable remedies.
2. There seems to be a rough division of cooling tower sizes. The larger towers are located at Building 801 and Building 827. The smaller towers are located at Building 809, Building 817, Building 825, and Building 826. And while it is prudent to analyze each facility separately, an initial field-testing of options should be employed at one “large” and one “small” cooling tower. This will facilitate the widest range of experience with the least cost. In general, the smaller units justify moderate changes to equipment, and may benefit from increased cleaning frequencies, more accurate and suitable chemical treatment, and changes in sources of make up water and discharge re-use. The larger cooling towers would be more suitable for automated systems, treatment and re-circulation of blow down water, and enhanced chemical dosing strategies.
3. It may be more technically feasible and cost efficient for the smaller cooling towers to be replaced by closed loop dry coolers or hybrid towers.
4. It is recommended that each facility be re-assessed for its chemical additive use. Incorrect application of chemical additives can lead to loss of tower efficiency, discharge of excess chemicals to the subsurface, and increased costs. Cooling tower efficiency is directly related to the mass of salt discharged to the subsurface. Chemical additives discharged to the subsurface, although not chemicals of concern, can be detrimental to water quality and percolation efficiency.
5. Consultants that specialize in chemical treatment of cooling towers should be asked to bid on supply of chemicals as dollars per 1,000 gallons of water treated instead of dollars per pound of chemicals. This will put the obligation on the vendor to provide the most effective and efficient chemical additive scenario. Initial field implementations should include robust monitoring to demonstrate compliance and effectiveness. This should include scaling and corrosion coupons.
6. Increased cycle operation is a typical optimization method that will decrease the mass of dissolved solids discharged to the sub surface. Depending on the discharge requirements, this should be the primary method attempted. However, this will decrease the acceptable margin of error in chemical dosing, blow down management, and system operational variations. This can lead to an increased risk of tower damage, discharge violations, and system downtime. The higher the cycles of concentration, the more important is accurate and precise chemical dosing. A step-wise implementation with robust monitoring is recommended.
7. If a “zero discharge” option is required, it should be considered that this mode of operation is difficult to achieve. Even when practiced successfully, there remains the need to periodically flush the system.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

8. Decreasing the cycles of concentration, as described in Option 16, as a method of decreasing the discharge concentration, is not recommended. It results in a higher use of water and doesn't decrease the amount of salt mass added to the subsurface. It also puts the cooling tower at an increased risk for corrosion.
9. The re-use of mechanical equipment wastewater discharge for cooling tower make up water at Building 801, Building 825, and Building 827A should be evaluated as part of the cooling tower assessments.
10. The allowable TDS discharge into percolation pits is the primary and most sensitive variable affecting the selection of a remedy. The appropriate TDS loading in these discharges should be determined and options considered based on groundwater modeling results. Before options are finalized, LLNL will consult with the regulators.

Current Progress and Conclusions

As described in this report, LLNL has already reduced the total number of water cooling towers at Site 300 from twenty-eight to six between 1997 to the present; some were replaced with air-cooled systems. Most recently in 2008 and 2009, the cooling towers at Building 812 and Building 850 have become inactive as these facilities have been transitioned to cold and dark facilities. This transition to non-active facilities also reduces the mechanical equipment discharges that would also have flowed to the septic system. In particular, the septic system at Building 850 is in the process of closure. These are major actions that have reduced both the concentration and mass of TDS discharge throughout Site 300. LLNL will also continue a program to evaluate non-discharging options when replacing equipment.

In addition, other options have been implemented for mechanical equipment; for example, plans are under way to replace some boiler water use with resistive type heaters that discharge lower water volumes and therefore less TDS mass. Another critical change on the horizon is the site-wide switch in potable water source to the use of very low TDS Hetch-Hetchy water, planned for May 2010. This new source water may significantly lower the potential mass of TDS in discharges from cooling towers. Following the change in source water to Hetch-Hetchy, LLNL will need to reassess salt concentrations in mechanical equipment and cooling tower blow down discharges. The general operations and maintenance of the cooling towers is also expected to change with the order of magnitude decrease in source water TDS.

As mentioned in the Background section of this report, this Salinity Minimization and Evaluation Plan is required by the CVRWQCB as one component as required in Permit WDR R5-2008-0148. The second component is the preparation of a salinity groundwater modeling study (Evaluation of Potential Impact to Groundwater from Percolation Pits and Septic Systems) that is due to the CVRWQCB on November 1, 2010, and incorporates ground water data at Site 300 in the vicinity of cooling towers, percolation pits, and septic systems, and evaluates the potential impact of TDS to the groundwater.

In order to implement this plan, LLNL will determine which options appear to be generally feasible at Site 300, and evaluate those most likely to be effective at specific Site 300 facilities. The options and treatment technologies that are reviewed in this document and listed in **Table 5** and **Table 8** have been categorized to allow for general estimations and comparisons. As discussed previously, the ranges of impact to cost, labor, effectiveness, and development as defined in **Table 6** as “none,” “low,” “moderate,” and “high” are assigned to each option and technology in **Table 5** and **Table 8**. **Table 6** also rates overall usefulness. **Table 9** lists the overall usefulness of each option at each facility.

This plan is not intended to be a comprehensive engineering design document, but rather a general guide to future considerations regarding reducing TDS in discharged effluent from cooling tower and mechanical equipment. The purpose of this document is to provide a due diligence review of options, not a feasibility study for implementation at specific facilities at Site 300.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Before any significant changes are implemented at the Site 300 cooling towers and mechanical equipment, LLNL will review and evaluate the modeling results from the salinity groundwater modeling study in regard to TDS loading in Site 300 ground water. Once this information is complete, LLNL will review options regarding future operations at Site 300. In addition, other key factors must be considered, such as:

- The specific facility characteristics,
- The volume and TDS concentrations in the discharge, and
- The available funding for facilities and activities occurring in that facility.

Once this information is complete, LLNL will review options for applicability at Site 300.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Figures

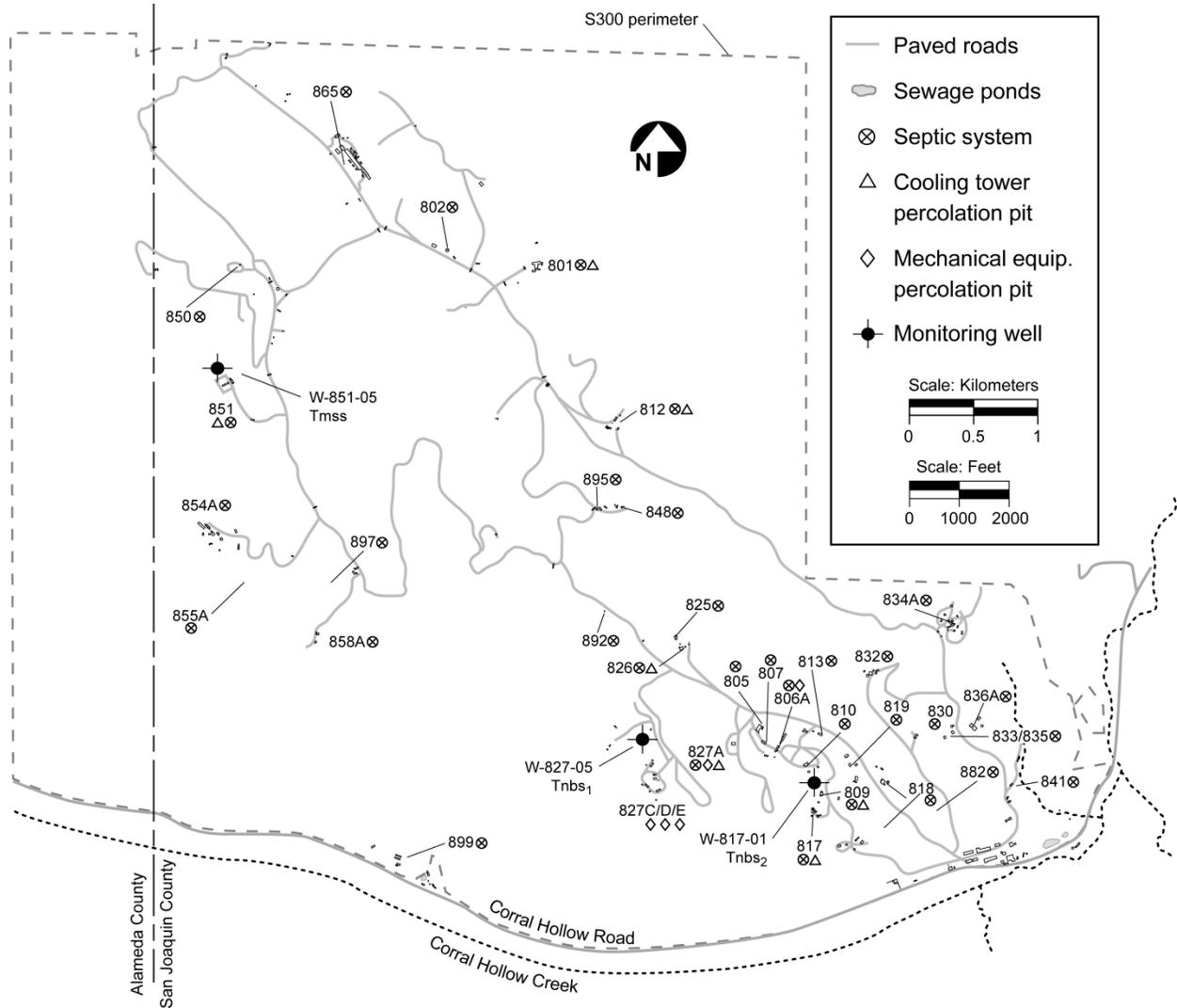


Figure 1. Locations of Site 300 facilities with septic systems and percolation pits.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Figure 3. Building 801 Cooling Tower and Discharge Point Locations.



Figure 4. Building 801 Cooling Tower. Taken from Baltimore Aircoil Company[®] Brochures.



Figure 5. Building 801 Cooling Tower.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 6. Building 801 Percolation Pit (as indicated by the arrow).



Figure 7. Building 801 Septic System Leach Field Location.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

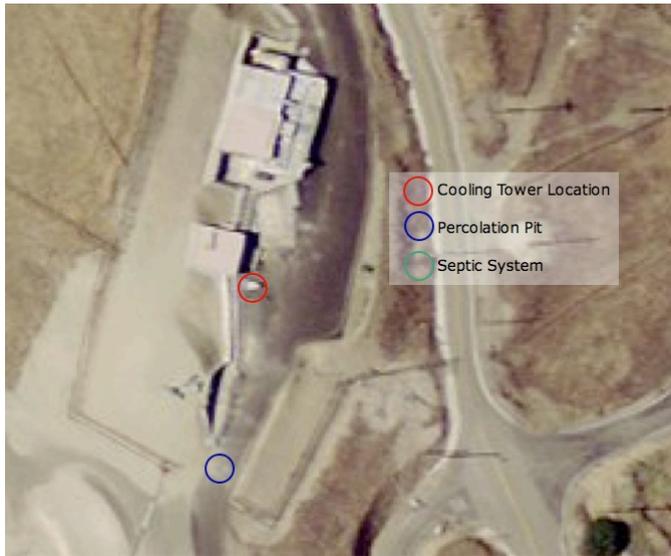


Figure 8. Building 809 Cooling Tower and Discharge Point Locations



Figure 9. Building 809 Cooling Tower.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 10. Building 809 Cooling Tower Discharge Point/Percolation Pit Access.



Figure 11. Building 809 Cooling Tower Discharge Point/Percolation Pit Access.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 12. Building 817 Cooling Tower and Discharge Point Locations.



Figure 13. Building 817 Cooling Tower.



Figure 14. Building 817 Percolation Pit Access.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 15. Building 825 Cooling Tower and Discharge Point Locations.



Figure 16. Building 825 Cooling Tower.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 17. Building 826 Cooling Tower and Discharge Point Locations.



Figure 18. Building 826 Cooling Tower.



Figure 19. Building 826 Percolation Pit Access.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 20. Building 826 Septic Tank/Leach Field.



Figure 21. Building 826 Septic Tank/Leach Field.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 22. Building 827A Cooling Tower and Discharge Point Locations.



Figure 23. Building 827A Cooling Towers (at left, adjacent to building).

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 24. Building 827A Discharge Location.



Figure 25. Looking east at the Building 827A Septic Leach Field (left/north) and Percolation Pit (right/south).

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 26. Building 827C Percolation Pit.



Figure 27. Building 827D Percolation Pit Access.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges



Figure 28. Building 827E Percolation Pit Access (as shown by the arrow).

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

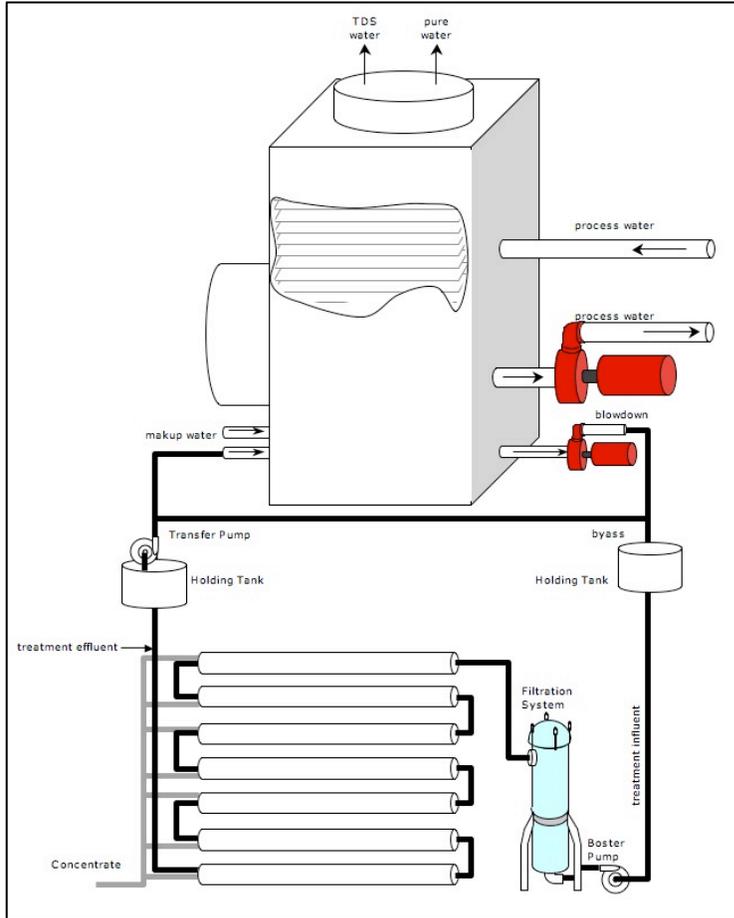


Figure 29. Cooling Tower Recirculation + Ion-exchange Model.

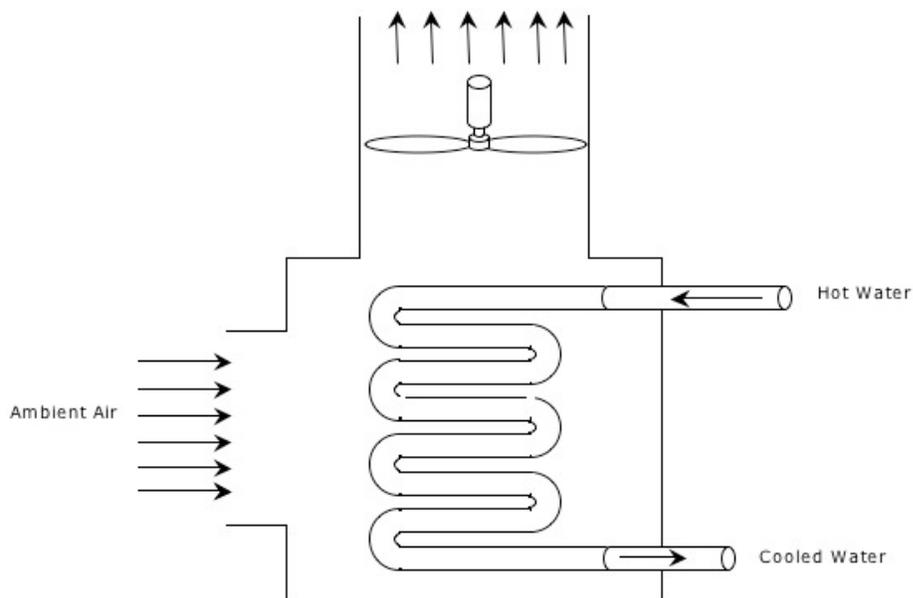


Figure 30. Dry cooling tower.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

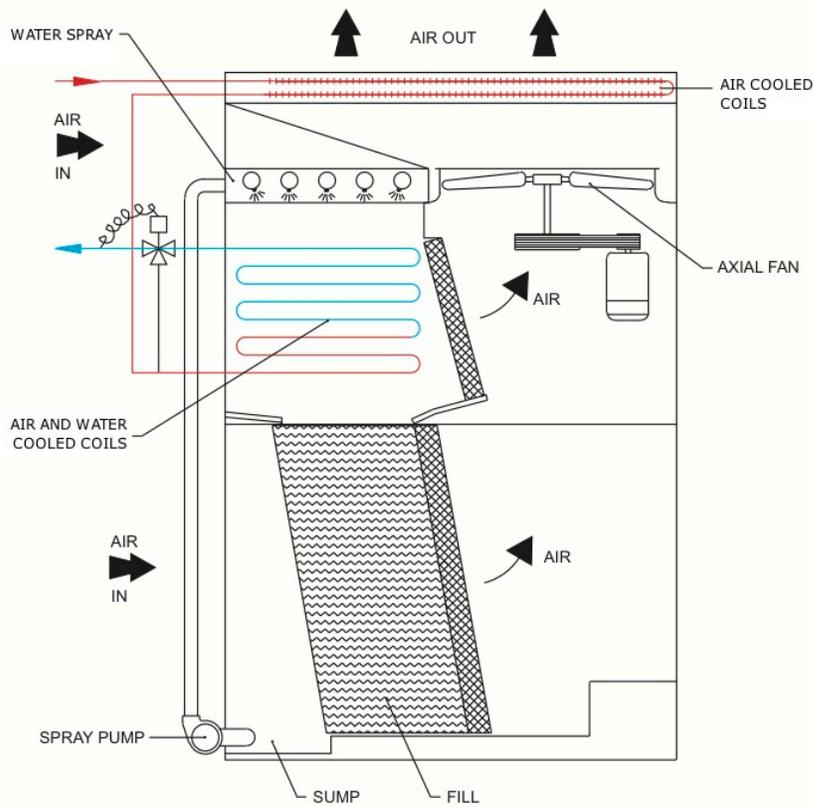


Figure 31. Hybrid cooling tower. Taken from Baltimore Aircoil Company[®] Brochures.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Tables

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 1. Site 300 Shallow Surface Discharge Locations.

Building	Annex	Contaminant Source			Discharge Type	Design Capacity (gpm)	Size (ftxftxft)	Status
801		Cooling Tower			Percolation Pit	0.60	12 x 12 x 7	In use
801	A, D		Mech. Equip.	Sewage	Septic System	48		In use
805			Mech. Equip.	Sewage	Septic System	35		In Use
806	A		Mech. Equip.		Percolation Pit	0.03	4 x 3 x 3	In Use
809		Cooling Tower			Percolation Pit	0.21	6 x 6 x 6	In Use
817	A	Cooling Tower			Percolation Pit	0.21	7 x 7 x 5	In Use
813			Mech. Equip.	Sewage	Septic System	45		In Use
819			Mech. Equip.		Septic System			In Use
825		Cooling Tower	Mech. Equip.	Sewage	Septic System	23		In Use
826		Cooling Tower			Percolation Pit	0.21	6 x 6 x 5	In use
826			Mech. Equip.	Sewage	Septic System	30		In use
827	A	Cooling Tower			Percolation Pit	0.83	18 x 18 x 5	In use
827	A		Mech. Equip.		Percolation Pit	0.10	5 x 4 x 4	In use
827	C		Mech. Equip.		Percolation Pit	0.10	7 x 6 x 6	In use
827	D		Mech. Equip.		Percolation Pit	0.10	6 x 5 x 5	In use
827	E		Mech. Equip.		Percolation Pit	0.10	5 x 4 x 4	In use
851		Cooling Tower			Percolation Pit	0.63	14 x 14 x 5	In use
851	A, B		Mech. Equip.	Sewage	Septic System	40		In use
802		Cooling Tower	Mech. Equip.	Sewage	Septic System	30		Closed
805		Cooling Tower			Septic System			Cooling Tower Removed
807		Cooling Tower						Cooling Tower Removed
810		Cooling Tower			Percolation Pit			Cooling Tower Removed
812		Cooling Tower			Percolation Pit	0.25	12 x 12 x 5	Scheduled for demolition
812	A			Sewage	Septic System	32		Scheduled for demolition
815		Cooling Tower			Percolation Pit			Cooling Tower Removed
828		Cooling Tower			Percolation Pit			Cooling Tower Removed
830		Cooling Tower	Mech. Equip.	Sewage	Septic System	27		Scheduled for demolition
832		Cooling Tower						Cooling Tower Removed
833 /835		Cooling Tower	Mech. Equip.	Sewage	Septic System	32		Cooling Tower Removed
834	A	Cooling Tower		Sewage	Septic System	28		Air Cooling
834	H	Cooling Tower			Septic System			Closed
836	A	Cooling Tower			Surface		n/a	Air Cooling
836	D	Cooling Tower			Percolation Pit			Cooling Tower Removed
850		Cooling Tower	Mech. Equip.	Sewage	Septic System	35		Closed
854	A	Cooling Tower			Percolation Pit			Cooling Tower Removed
865		Cooling Tower						Cooling Tower Removed
870		Cooling Tower			Septic System			Cooling Tower Removed
871		Cooling Tower						Cooling Tower Removed
875		Cooling Tower			Septic System			Cooling Tower Removed
877		Cooling Tower			Septic System			Cooling Tower Removed

*Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges***Table 2.** Baltimore Aircoil Company® Type Wet Cooling Tower Dimensions and Performance.

B.A.C. Model	Nominal Tonnage	Motor HP	Airflow (cfm)	Dimensions		
				L	W	H
FXT-16	16	1/2	5,700	3' 1/8"	6' 10-7/8"	5' 11-7/8"
VTO-19-G	19	3	6,190	3' 11-1/2"	3'	7' 6-1/8'
VTO-14F	14	2	5,460	3' 11-1/2"	3'	7' 6-1/8'
VTO-78	78	10	17,990	8' 11-3/4"	3' 11-1/2'	10' 6-1/8"
15282	282	25	74,600	17'2"	11' 10"	15'7"
VXT-75CR	75	7-1/2	17,000	n/a	n/a	8' 7/8"
VXT-25-CR	25	3	5300	6' 11"	3'	7' 6-1/8'

Nominal tons of cooling represents 3 GPM of water from a 95°F to 85°F at a 78°F entering wet-bulb temperature.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 3. Cooling Tower Operating Parameters

Cooling Tower Location:	801	809	817	825	826	827	851
Tower make:	BAC	BAC	BAC	BAC	BAC	BAC	BAC
Tower model:	15282 (two)	FXT-16	VXT-25CR	VTO-14-F	VTO-19-G	VXT-75-R (two)	VTO-78-JM
Nominal tonnage:	282 (564)	16	20	14	19	151 (302)	78
Nominal cooling flow rate (gpm):	846 (1692)	48	60	42	57	453 (906)	234
Process Parameters/ Requirements-							
Maximum anticipated water temperature leaving facility (F):				90			
Required water temperature supplied to facility (F):				75			
Environmental-							
Maximum anticipated makeup water TDS concentration (ppm):				700			
Maximum anticipated makeup water temperature (°F):				77			
Maximum anticipated ambient air temperature (°F):				87			
Maximum anticipated ambient air humidity (%):				30%			
Associated ambient air wet bulb temperature (°F):				61.96			
Assumed Equipment Performance-							
Assumed Drift and Blowout (%):				0.05%			
Tower sump/ blow-down TDS concentration (ppm):				2000			
Maximum Anticipated Values-							
Maximum cooling flow rate (gpm): ⁶	1087 (2174)	65	78	65	81	589 (1178)	275
Maximum Evaporation rate (gpm): ⁸	17 (34)	1	1.2	1	1.3	9.1 (18.2)	4
Maximum Blow down flow rate (gpm): ⁸	8.5 (17)	0.5	0.6	0.5	0.6	4.6 (9.2)	2.1
Typical Anticipated Values-							
Typical cooling flow rate (gpm): ⁷	700 (1400)	40	40	52	52	70 (140)	248
Typical Evaporation rate (gpm): ⁸	11 (22)	0.6	0.6	0.8	0.8	1.1 (2.2)	3
Typical Blow down flow rate (gpm): ⁸	5.5 (11)	0.3	0.3	0.4	0.4	0.55 (1.1)	1.2

Notes:

1. This is the average TDS for WELL 20.
2. This is the average Temperature for WELL 20.
3. 90% of the time the maximum daily temperature is below 87°F (from 2005 meteorological data)
4. The highest R.H. occurs during the colder months. Therefore the R.H. is assumed to be during the summer months where the ambient temperature equals the assumed maximum (87°F).
5. Calculated from the above values and average atm pressure of 28.6 in. Hg at S-300 in 2008.
6. Taken from equipment specifications for hot water temp = 90F, cold water temp= 80F, and Dew Point temp =66F
7. Taken from observed blow down flow rates as recorded in the Bi-Weekly Report. Building 801 is taken from typical operating parameters of supported equipment.
8. Calculated from heat transfer equations and water balance analysis.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 4. Mechanical Equipment Discharge Information.

Mechanical Equipment Location:	801 A, D	805	806A	813	819	825	826	827A	827C	827D	827E	851 A, B
Major Equipment:	Mechanical equipment wastewater may include discharges from boilers, vacuum pumps, pressure relief valves on hot water/steam equipment, humidifiers, filter drains, and water softeners, as well as condensates from air compressors, air conditioners, and refrigeration units.	Vacuum pumps	Mechanical equipment wastewater may include discharges from boilers, vacuum pumps, pressure relief valves on hot water/steam equipment, humidifiers, filter drains, and water softeners, as well as condensates from air compressors, air conditioners, and refrigeration units. Washing machines discharge to the septic systems at Building 813.					Chiller 1 (SPX Deltech, HE 100-115, 100 sdfm)	External Mounted Air Conditioner	External Mounted Air Conditioner	External Mounted Air Conditioner	Mechanical equipment wastewater may include discharges from boilers, vacuum pumps, pressure relief valves on hot water/steam equipment, humidifiers, filter drains, and water softeners, as well as condensates from air compressors, air conditioners, and refrigeration units.
		Air Conditioner Units						Chiller 2(Train, CGWDO604CJO HAT104FFBAV HG)	Heat Exchanger (Wiegmann, 13062 or 403 S 2-P)	Heat Exchanger (Wiegmann, 13062 or 403 S 2-P)	Heat Exchanger (Wiegmann, 13062 or 403 S 2-P)	
		Chiller						Chiller 3(Train, CGWDO604CJO HAT104FFBAV HG)	Boiler 1 (Lattner, 75 HP)	Boiler 1 (Lattner, 75 HP)	Boiler 1 (Lattner, 75 HP)	
								Air Compressor (IR, SSR UPG-20-125)	Boiler 2 (Lattner, 75 HP)	Boiler 2 (Lattner, 75 HP)	Boiler 2 (Lattner, 75 HP)	
								Various pipeline condensate traps	Chiller (Herrtronic, MDSP 480390)	Chiller (Herrtronic, MDSP 480390)	Chiller (Herrtronic, MDSP 480390)	
Maximum design percolation pit combined waste water flow rate (gpm):	Discharged to septic system	<0.04 gpm	Discharged to septic system					< 0.1 gpm	< 0.1 gpm	< 0.1 gpm	< 0.1 gpm	Discharged to septic system

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 5. Options for Cooling Tower and Mechanical Equipment Discharge to Percolation Pits and Septic Systems.

Option	Cooling Towers							Mechanical Equipment						
	Capitol	O&M \$	Savings	O&M Labor	Development	Effectiveness	TDS Reduction	Capitol	O&M \$	Savings	O&M Labor	Development	Effectiveness	TDS Reduction
<i>Improve Operation and Maintenance</i>														
Qualitative Estimates														
1. Increase accuracy of chemical dosing	Low	Mod	Mod	Mod	High	Mod	Low							
2. Increase cleaning and maintenance schedule	None	Mod	Mod	Mod	Mod	Mod	Mod							
3. Eliminate leaks	Low	None	Mod	None	High	High	Mod							
4. Minimize drift	Mod	None	Low	None	Mod	Low	Low							
<i>Add automated Processes</i>														
5. Automated meters and valves	High	None	Mod	Low	High	Mod	High							
6. Automate chemical injection	High	Low	Mod	Low	High	Mod	Mod							
7. Automate fan controls	High	None	Mod	None	Mod	Mod	Low							
<i>Chemical Treatment Strategy</i>														
8. Site-specific chemical dosing	Mod	Low	Mod	Low	High	High	Mod							
9. High cycles of concentration chemical dosing	Mod	Mod	Mod	Mod	Mod	Mod	High							
<i>Make Up Water Quality</i>														
10. Pre-treatment of make up water (Technologies A through L Table 8)	High	High	Mod	High	Mod	Mod	Mod							
11. Change the source of make up water	High	None	Mod	None	High	Mod	Mod	Mod	Low	Low	Low	High	Mod	Mod
<i>Discharged Water</i>														
12. Treat the blow down prior to discharge (Technologies A through L Table 8)	High	High	Mod	Mod	Mod	High	Mod	Mod	Low	Mod	Low	Mod	Mod	High
13. Treat and re-circulate sump water- low discharge operation	Mod	Low	Mod	Low	Mod	Mod	High							
14. Treat and re-circulate sump water- zero discharge operation	Mod	Low	Mod	Low	Mod	Mod	High							
15. Alternative discharge locations	High	Low	None	Mod	Low	Low	High	Mod	Mod	Low	Low	Mod	Mod	High
16. Decrease cycles in tower	None	Low	Mod	Low	Mod	Mod	Mod							
<i>Modify or change type of Cooling Tower</i>														
17. Closed loop dry (air cooled) tower	High	Low	None	Mod	Mod	Mod	High							
18. Closed loop hybrid (air and water) tower	High	Mod	None	Mod	Mod	Mod	Mod							
19. Plastic towers	High	Low	Mod	Low	High	High	Mod							
20. Supported equipment management	Mod	Mod	None	Mod	High	High	Low	Low	Mod	Low	Low	Mod	Mod	Mod

Notes:
 1. Estimates based on site demonstrations, industry reports, literature searches, manufacturer claims, vendor quotes, field case studies, and engineering experience and judgment with special consideration for Site 300 operating environments. Refer to Table 6.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 6. Qualitative Estimates of Comparison Categories.

	Capitol Costs (\$)	O&M Costs (\$/year)	Savings (\$/year)	O&M Labor (days/ week)	Development/ Acceptance	Effectiveness	TDS Discharge Reduction	Overall Applicability
	Table 5 & 8							Table 9
None	\$0	\$0	\$0	0	Still bench top study	No proven	0%	Not useful
Low	\$0-\$2,000	\$0-\$500	\$0-\$500	1/2	Only few field test	Limited application	0%-10%	Limited use
Moderate	\$2,000-\$10,000	\$500-\$5,000	\$500-\$5,000	1	Many field demonstrations and installations	Good for most systems	10%-50%	Likely useful
High	\$10,000 up	\$5,000 up	\$5,000 up	2 and up	Standard technique with regulatory acceptance	Good for all general application	50%-100%	Very useful

Estimates for cost are based on averaged sized systems.

*Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges***Table 7.** Cooling Tower Maintenance Schedule.**Daily/Weekly**

- * Test water sample for proper concentration of dissolved solids. Adjust bleed water flow as needed.
- * Measure the water treatment chemical residual in the circulating water. Maintain the residual recommended by your water treatment specialist.
- * Check the strainer on the bottom of the collection basin and clean it if necessary.
- * Operate the make-up water float switch manually to ensure proper operation.
Inspect all moving parts such as drive shafts, pulleys, and belts.
- * Check for excessive vibration in motors, fans, and pumps.
- * Manually test the vibration limit switch by jarring it.
- * Look for oil leaks in gear boxes.
- * Check for structural deterioration, loose connectors, water leaks, and openings in the casing.
- * During periods of cold weather, check winterization equipment. Make sure any ice accumulation is within acceptable limits.

Periodic

- * Check the distribution spray nozzles to ensure even distribution over the fill.
- * Check the distribution basin for corrosion, leaks, and sediment.
- * Operate flow control valves through their range of travel and re-set for even water flow through the fill.
- * Remove any sludge from the collection basin and check for corrosion that could develop into leaks.
- * Check the drift eliminators, air intake louvers, and fill for scale build-up. Clean as needed.
- * Look for damaged or out-of-place fill elements.
- * Inspect motor supports, fan blades, and other mechanical parts for excessive wear or cracks.
- * Lubricate bearings and bushings. Check the level of oil in the gear box. Add oil as needed.
- * Adjust belts and pulleys.
- * Make sure there is proper clearance between the fan blades and the shroud.
- * Check for excessive vertical or rotational free play in the gear box output shaft to the fan.

Annual

- * Check the casing, basin, and piping for corrosion and decay. Without proper maintenance, cooling towers may suffer from corrosion and wood decay. Welded repairs are especially susceptible to corrosion. The protective zinc coating on galvanized steel towers is burned off during the welding process. Prime and paint any welded repairs with a corrosion-resistant coating.
- * Leaks in the cooling tower casing may allow air to bypass the fill. All cracks, holes, gaps, and door access panels should be properly sealed.
- * Remove dust, scale, and algae from the fill, basin, and distribution spray nozzles to maintain proper water flow.

Taken from DOE, Western Area Power Administration, Energy Services, Technical Brief, "Optimizing Cooling Tower Performance", WSUEEP98013, Rev. 2/98, Table 1.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 8. Treatment Technologies.

Option: Description: Treatment Technology	Option 10 Make up water treatment							Option 12 Treatment prior to discharge							Option 13 Low discharge sump treatment							Option 14 Zero discharge sump treatment						
	Capitol	O&M \$	Savings	O&M Labor	Development	Effectiveness	TDS Reduction	Capitol	O&M \$	Savings	O&M Labor	Development	Effectiveness	TDS Reduction	Capitol	O&M \$	Savings	O&M Labor	Development	Effectiveness	TDS Reduction	Capitol	O&M \$	Savings	O&M Labor	Development	Effectiveness	TDS Reduction
<i>Chemical</i>																												
A. Liquid or Solid Chemical Additives	-	-	-	-	-	-	-	Low	Mod	Mod	Mod	High	Mod	Mod	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. Gas Additives (ozonation)	High	High	Low	High	Mod	Mod	Mod	High	High	Mod	High	Mod	Mod	Mod	High	High	Mod	High	Mod	Mod	Mod	High	High	Mod	High	Mod	Mod	Mod
C. Ion-Exchange (softening)	High	High	Mod	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High
D. Ionization	-	-	-	-	-	-	-	Low	Mod	Low	Mod	Mod	Mod	Low	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Electro-Chemical</i>																												
E. Electromagnetic	High	Mod	Low	Mod	Mod	Mod	Mod	High	Low	Mod	Low	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High
F. Electrolysis precipitation	High	Mod	Low	Mod	Mod	Mod	Mod	High	Low	Mod	Low	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High
<i>Physical</i>																												
H. Filtration	Mod	Mod	High	High	High	High	Low	Low	Mod	Low	Mod	High	High	Low	Low	Low	Mod	Low	High	High	Low	Low	Low	Mod	Low	High	High	Low
I. Hydrodynamic Cavitation	High	High	Mod	Mod	Mod	Mod	Mod	High	High	Mod	Mod	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High
J. Ultrasonic Cavitation	High	High	Mod	Mod	Mod	Mod	Mod	High	High	Mod	Mod	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High	Mod	Low	Mod	Low	Mod	Mod	High
K. Reverse Osmosis	High	High	Mod	High	High	High	High	Mod	High	Mod	High	High	High	High	Mod	Mod	Mod	Mod	High	High	High	Mod	Mod	Mod	Mod	High	High	High
L. Evaporation, concentrator	High	High	Low	High	High	High	High	High	High	Mod	Mod	High	High	High	High	Mod	Mod	Mod	High	High	High	High	Mod	Mod	Mod	High	High	High

Estimates based on site demonstrations, industry reports, literature searches, manufacturer claims, vendor quotes, field case studies, and engineering experience and judgment with special consideration for Site 300 operating environments and qualified in Table 6.

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

Table 9. Overall Applicability of Options by Facility.

Adjacent Building Locations: Discharge Location: Typical discharge Flow rate (gpm): ¹ Discharge TDS concentration (ppm): ²	Cooling Towers							Mechanical Equipment											Reduce TDS Conc.	Reduce TDS Mass			
	801	809	817	825	826	827A	851	801A,D	805	806A	813	819	825	826	827A	827C	827D	827E			851A,B		
	pit	pit	pit	pit	pit	pit	pit	septic	septic	pit	septic	septic	septic	septic	pit	pit	pit	pit	septic				
	11	0.3	0.3	0.4	0.4	1.1	1.2	0.22	0.03	0.03	0.13	<.01	<.01	0.02	0.1	0.1	0.1	0.1	0.03				
	2000							1401	1401	730	1210	1401	1401	1401	920	1220	835	3300	1401				
Options:	Overall Applicability³																						
<i>Improve Operation and Maintenance</i>																							
1. Increase accuracy of chemical dosing	Mod	Mod	Mod	Mod	Mod	Mod	Mod														x		
2. Increase cleaning and maintenance schedule	Mod	Mod	Mod	Mod	Mod	Mod	Mod														x		
3. Eliminate leaks	Low	Mod	Mod	Mod	Mod	Low	Low														x		
4. Minimize drift	Mod	Low	Low	Low	Low	Mod	Mod														x		
<i>Add automated Processes</i>																							
5. Automated meters and valves	None	Mod	Mod	Mod	Mod	High	High														x		
6. Automate chemical injection	None	Mod	Mod	Mod	Mod	High	High														x		
7. Automate fan controls	Mod	Low	Low	Low	Low	Mod	Mod														x		
<i>Chemical Treatment Strategy</i>																							
8. Site-specific chemical dosing	Mod	Low	Low	Low	Low	Mod	Mod														x		
9. High cycles of concentration chemical dosing	Mod	Mod	Mod	Mod	Mod	Mod	Mod														x		
<i>Make Up Water Quality</i>																							
10. Pre-treatment of make up water (Technologies a through j below)	Low	Mod	Mod	Mod	Mod	Low	Low														x		
11. Change the source of make up water	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	x		
<i>Discharged Water</i>																							
12. Treat the equipment waste water prior to discharge (Technologies a through j below)	Mod	High	High	High	High	Mod	Mod	Mod	High	High	Mod	High	High	Mod	Mod	Mod	Mod	Mod	Mod	x	x		
13. Treat and re-circulate sump water- low discharge operation	High	Mod	Mod	Mod	Mod	High	High														x		
14. Treat and re-circulate sump water- zero discharge operation	Mod	Mod	Mod	Mod	Mod	Mod	Mod																
15. Alternative discharge locations	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	x	x		
16. Decrease cycles in tower	None	Low	Low	Low	Low	Low	Low													x			
<i>Modify or change type of Cooling Tower</i>																							
17. Closed loop dry (air cooled) tower	None	Mod	Mod	Mod	Mod	Low	None													x	x		
18. Closed loop hybrid (air and water) tower	Low	Mod	Mod	Mod	Mod	Mod	Mod														x		
19. Plastic towers	Low	Mod	Mod	Mod	Mod	Mod	Mod																
20. Supported equipment management	Low	Mod	Low	Low	Mod	Low	Mod	Low	Mod	Mod	Mod	Mod	Low	x	x								

- Notes:
1. For cooling towers: calculated from heat transfer equations and water balance analysis based on values taken from observed blow down flow rates as recorded in the Bi-Weekly Report with Building 801 taken from typical operating parameters of supported equipment. For mechanical equipment: Taken either from the reported estimated discharge rate in the WDR or as the percolation pit design capacity.
 2. Estimated rates from cooling towers. Reported rates for mechanical equipment discharging to percolation pits. Average values for septic systems from mechanical equipment discharging to percolation pits.
 3. As designated in Table 6. Overall applicability only.

References

- ADVANCED COOLING TOWER WATER TREATMENT,
<http://www.nelsonenvironmentaltechnologies.com/ACTWT.html>
 Non-Chemical Water Treatment Technologies For Cooling Tower, Burke A. West, P.E., CWS-VI, Nelson Environmental Technologies, Inc., 2003 May 3
- "A COMPARISON OF SCALE POTENTIAL INDICES WITH TREATMENT PROGRAM RESULTS IN OZONATED SYSTEMS R.J. Ferguson, French Creek Software, Inc., Kimberton & Hares Hill Roads, Box 684, Kimberton, PA 19442, A.J. Freedman, Arthur Freedman Associates, 390 Penn Estates, East Stroudsburg, PA 18301-9045, (717) 420-1525, Presented at CORROSION '94"
- US DOE, Energy Efficiency and Renewable Energy, Federal Energy Management Program, Best Management Practices: Cooling Tower Management
- Best Management Practice and Guidance Manual for Cooling Towers, Prepared by JEA for the control of pollutants discharged to the sanitary collection system, August 2005
- Cooling Technology Institute web site (<http://www.cti.org/>)
- Water Efficiency Manual, for Commercial, Industrial and Institutional Facilities, A joint publication of the Division of Pollution Prevention and Environmental Assistance and Division of Water Resources of the N.C. Department of Environment and Natural Resources, and Land-of-Sky Regional Council. May 2009- Figures 4-10, 4-11
- DOE, Western Area Power Administration, Energy Services, Technical Brief, Optimizing Cooling Tower Performance, WSUEEP98013, Rev. 2/98, Table 1.
- Ozone Cooling Tower Treatment with and without Mineral Removal, William K. McGrane, Ozone Science and Engineering, Vol 14, pp231-244, 1992
- Clearwater Systems Corporation, Water-Treatment Applications http://www.clearwater-dolphin.com/market_research.htm, "Pulse-Power Water Treatment Systems for Cooling Towers"
- ZERO LIQUID DISCHARGE OPERATION OF COOLING TOWERS AT A MAJOR STEEL MILL, Authors John Kubis, Water & Enviro Tech Company, Inc.; Jeff Reed, California Steel Industries, Inc., Source CORROSION 2008, March 16 - 20, 2008
- Operate cooling towers correctly at high cycles of concentration, Chemical Engineering Progress, Mar 2001 by Hoots, John E, Johnson, Donald A, Lammering, J Dean, Meier, Daniel A
- DEPARTMENT OF THE ARMY U.S. Army Corps of Engineers, PUBLIC WORKS TECHNICAL BULLETIN 420-49-22 12 NOVEMBER 1999, COOLING WATER TREATMENT: LESSONS LEARNED
- Ozone For Cooling Tower Systems - An Update And Lessons Learned At The Kennedy Space Center, DANIEL J. TIERNEY, Space Gateway Support, Kennedy Space Center, FL., IWC-02-32
- Controlling Cooling Water Quality by Hydrodynamic Cavitation, W. A. Gaines, B. R. Kim, A. R. Drews, C. Bailey, T. Loch, Ford Motor Company, Dearborn, MI, Cavitation Device
- Practical Guidelines for Safe Operation of Cooling Tower Water Ozonation Systems, Alan E. Pryor and Mark Fisher, Alten Water Treatment Corporation, 3788 Fabian Way, Palo Alto, CA

Salinity Evaluation and Minimization Plan for Cooling Towers and Mechanical Equipment Discharges

- EFFECTIVE USE OF RECYCLED WATER IN COOLING TOWERS WITH NEW GREEN TECHNOLOGY, Joe Walters, West Basin Municipal Water District, Carson CA Dan Duke, Water Conservation Technology International, Temecula CA
- US DOE, SERDP, Federal Technology Alert, “Ozone Treatment for Cooling Towers”, August 1998
- INEEL, Engineering Design File, “Evaporating Pond Sizing with Water Balance and Make Up Water Calculations”, EDF-ER271, 5/14/02
- Best Management Practice and Guidance Manual for Cooling Towers, Prepared by JEA for the control of pollutants discharged to the sanitary collection system, August 2005
- The Strategic Envirotechnology Partnership, Green Book Technology Summary Report, Utilizing: VRTX Technology, A.W. Chesterton Company, Lisa Grogan, Rich Bizzozero, Jim Cain Massachusetts Office of Technical Assistance, December 2001
- LLNL, Environmental Protection Department letter to Susan Timm of the Regional Water Quality Control Board, Central Valley Region, January 28, 2005, “LLNL Response to the Information Requested by the Central Valley Regional Water Quality Control Board to Revise Water Discharge Requirements Order No. 96-248.
- California Regional Water Quality Control Board, Central Valley Region, Waste Discharge Requirements, Order No. R5-2008-0148, Issued to the U.S. DOE, LLNL, Site 300, Sewage Evaporations and Percolation Ponds, Septic Systems, Cooling Tower discharges, Mechanical Equipment and Wastewater Discharged and Other Low Threat Discharges.
- Disinfectants Copper-silver ionization, Lenntech Water Treatment Solutions, www.lenntech.com/processes/disinfection/chemical/disinfectants-copper-silver-ionization.htm.
- Microbiological Evaluation of Copper Silver Ionization Disinfection Units, Kutz SM, Landeen LK, Yahya MT, and Gerba CP, Proceedings of the Fourth Conference on Progress in Clinical Disinfection. State University of New York, Binghamton, New York, April 11-13, 1988
- Analysis of the electrolytic precipitation rate of calcite, Norio Yanagisawa, Takahiro Matsumura, Journal of Mineralogical and Petrological Sciences, Volume 101, pgs 319-323, 2006
- Evaporation Pond Sizing with Water Balance and Make-up Water Calculations, Idaho National Engineering and Environmental Laboratory, Engineering Design File, Form 412.14, 7/24/2001
- Removal of Chromate from Cooling Tower Blowdown by Reaction with Electrochemically Generated Ferrous Hydroxide, E. I. Onstott', William S. Gregory (Los Alamos Scientific Laboratory), Edward F. Thode (New Mexico State University), Environmental Science & Technology, Volume 7, Number 4, April 1973, pgs 333-337
- Cooling tower vendor literature from Baltimore Aircoil Company® for the HXV, VXT, VTO, FXT, and 1500 series systems, <http://www.baltimoreaircoil.com/english/index.html>



Environmental Protection Department, Lawrence Livermore National Laboratory
P.O. Box 808, L-627, Livermore, California 94551