EFFICACY OF EVAPORATION PONDS FOR DISPOSAL OF SALINE DRAINAGE WATERS

FINAL REPORT

September 1990

Prepared under contract for the Federal-State
San Joaquin Valley Drainage Program through the
Department of Water Resources

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PREPARED UNDER CONTRACT FOR THE FEDERAL-STATE
SAN JOAQUIN VALLEY DRAINAGE PROGRAM THROUGH THE
DEPARTMENT OF WATER RESOURCES

This report represents the results of a study conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in developing alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, U. S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public Health, (2) surface and ground water resources, (3) agricultural productivity, and (4) fish and wildlife resources.

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Under contract for the U. S. Bureau of Reclamation
through Department of Water Resources Contract No. B-56769

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Table of Contents

Page

SECTION 1

SECTION 2 Water Quality & Chemistry of Pond Waters

SECTION 3 Diurnal Monitoring of Ponds

SECTION 4 Application of Evaporation Rate Models

SECTION 5 Mineralogy of Precipitates

SECTION 6 Trace Element Accumulation in Pond Waters

SECTION 7 Trace Elements Associated with Evaporites

SECTION 8 Magnitude of Salt Load

SECTION 9 Recommended Design and Best Management Practices

Best Design to Sustain Evaporation Rate and Precipitation

SECTION 11 Appendices

List of Figures

List of Tables

List of Tables in Appendix

EXECUTIVE SUMMARY

OVERVIEW

This report contains information and data on site-specific field and laboratory studies on the physical and chemical efficacy of evaporation ponds. Data were collected from the Pryse, Peck and Barbizon evaporation pond facilities. The main goal of disposing saline tile drainage effluents into ponds is the evaporation of the impounded waters. A number of climatic, physical and chemical factors affect evaporation rates. The nature of salts (evaporites) deposited in ponds are strongly influenced by the chemical composition of the tile drainage effluent. The extent of evaporite precipitation is influenced by the degree of evapoconcentration of the impounded waters. Of particular concern is the accumulation of toxic trace elements in the pond facilities. The design and operational management of the ponds may influence evaporation rates.

The following presents highlights on the physicochemical efficacy of agricultural evaporation ponds. Some of the data were collected over a three-year period (1986-89), while others were collected only in 1989.

▲ Pond Waters - Salinity and Major Solutes

- The average electrical conductivity (EC) of tile drainage discharged into Pryse pond was 29.7 dS/m (mmhos/cm), Peck pond, 10.4 dS/m, and Barbizon pond, 8.4 dS/m.

- The ECs in Cells 1 and 2 in Pryse pond ranged from a minimum of 25.6 to a maximum of 175 dS/m. On a meq per liter basis, waters in Pryse pond are classified as $NaCl$-Na_2SO_4 type.

- The ECs in Cell 1 through Cell 6 in Peck pond ranged from a minimum of 8.3 to a maximum of 109 dS/m. Waters in Peck pond are Na_2SO_4 type.

- The ECs in Cells A, B and C, separated by wind-break berms, in Barbizon pond ranged from a minimum of 8.8 to a maximum of 48.3 dS/m. Waters in Barbizon pond are the Na_2SO_4-$NaCl$ type.

▲ Pond Waters - Trace Elements

- The concentration of trace elements reported herein is the total dissolved concentration in µg per liter (ppb) for arsenic (As), molybdenum (Mo) and selenium (Se) and mg per liter (ppm) for boron (B).

- The average influent concentration of B was 9.3 ppm in Pryse pond, 7.1 ppm in Peck pond and 3.5 ppm in Barbizon pond. The average As and Mo data reported herein are consistently greater than those reported by the Central Valley Regional Water Quality Control Board.

- Using chloride (Cl) as a nonreactive parameter to estimate the degree of evapoconcentration in ponds (ECF), the measured concentration of B in all ponds increased in direct proportion to Cl.

- The average influent concentration of Se was 10 ppb in Pryse pond, 570 ppb in Peck pond, and less than 10 ppb in Barbizon. Using the Cl-based ECF, the measured concentration of Se in pond cells was less than that predicted by ECF. This implies that some of the Se was lost from the pond water by removal mechanisms such as volatilization, adsorption or reduction to elemental Se.

- The average influent concentration of As was 1,080 ppb in Pryse pond , 620 ppb in Peck pond, and 1,320 ppb in Barbizon pond (Note previous comment). Based on ECF calculations, the measured concentration of As in pond cells was significantly less than Cl and had largest extent of immobilization among the trace elements. The removal mechanisms are similar to those identified for Se, and As tends not to accumulate in the water column.

- The average influent concentration of Mo was 2,790 ppb in Pryse pond, 640 ppb in Peck pond, and 890 ppb in Barbizon pond (Note previous comment). Based on ECF calculaltions, the degree of accumulation of Mo was intermediate between As and Se in most ponds.

- The above observations indicate that the reactivity of trace elements in pond facilities are in the order of As > Se ≥ Mo with B accumulating in direct proportion to Cl, an assumed nonreactive constituent.

▲ Diurnal Monitoring - Evaporation Rates

- The Peck, Pryse and Barbizon ponds were extensively monitored over 24-hour periods in March and August 1989 to evaluate evaporation rates with above-the-pond weather data as well as within-the-pond physicochemical changes.

- Diurnal monitoring of weather data was obtained with a portable Campbell Scientific weather station every half hour during a 24-hour period. Parameters measured were wind speed, wind direction, gross solar radiation, relative humidity and air temperature.

- Solar radiation generally peaked before noon in the spring (March) and just before noon in the summer (August) monitorings. Relative humidity tended to be low during the day and increased significantly at night. The air temperature peaked at about noon and reached a minimum around midnight. The direction of wind was more or less scattered from all directions at Pryse and Barbizon ponds and predominantly from the northeast at Peck pond. Wind speeds averaged between 0.4 to 0.6 meters per second.

- At the Peck pond facility, two floating Class A evaporation pans were installed containing water within EC of 14 dS/m, and hourly evaporation rates were monitored over a 47-hour period from August 18-20, 1989. Evaporation during the nighttime contributed significantly to total evaporation. The average cumulative evaporation was 14.6 mm.

- In addition at Peck pond, daily evaporation rates were measured with three floating evaporation pans containing waters of ECs ranging from 14 to 90 dS/m in the months of August, September and November, 1989. The EC of water in the pans were increased to correspond to increasing EC in the pond cells over this period. Evaporation rates generally decreased as salinity increased. For example, on September 2, 1989 the daily evaporation rate was 7.7, 6.6, and 6.3 mm per day, respectively, for pans containing waters of EC 14, 20 and 47 dS/m. Moreover, daily evaporation rate with EC 14 dS/m water was 8.0, 6.2, 4.7, and 2.3 mm per day, respectively, for the months of August through November, 1989.

- Cumulative evaporation measurements from Peck pond were correlated to calculated reference evapotranspiration (ET_o) from a nearby CIMIS weather station in Murrieta Farms. An ET_o correction factor (Y) was determined to correlate cumulative pond water evaporation rates (E) at different salinities up to EC of 61 dS/m, i.e.,

$$Y = 1.3234 - 0.0066\ EC\ (dS/m)$$

$$E = (ET_o)(Y)$$

- The relations between evaporation rate and dependent variables such as wind speed, vapor pressure differences between air and water surfaces, salinity and specific gravity are presented.

- Dalton's model was used to calculate evaporation rates from pure water and saline waters (EC = 14 dS/m) and these were compared to measured data. Although the calculated results deviated in some cases substantially at hourly intervals, improved trends were obtained by smoothing over longer elapsed time intervals.

▲ Diurnal Monitoring - Pond Waters

- At the same time the above-the-pond weather data was being monitored at Peck, Pryse and Barbizon ponds, pond waters were monitored at 2-hour intervals for water temperature, density, EC, pH, DO (Dissolved Oxygen) and Eh (redox potential).

- Cyclical variations in several water quality parameters were observed. For instance variations in DO are directly related to the activity of phytoplankton and water temperature. Fluctuations in water temperature are dampened and lagged slightly behind air temperature.

- In contrast, diurnal changes in EC, density, pH and Eh were not readily distinguishable.

▲ Pond Mineralogy and Trace Elements

- Minerals (evaporites) precipitated along the shorelines, in drying pond bottoms, and within the brine water column were sampled from 1987-1988.

- The types of evaporites formed in the water column were strongly influenced by the initial chemistry of the drainage influent water and degree of evapoconcentration. The formation of such evaporites could be predicted by C-Salt, a brine chemistry model previously reported in the Interim Report.

- In contrast, evaporites formed along shorelines are subjected to extreme ranges of wetting and drying and tended to reflect larger mineral assemblages as saline waters are subjected to near air dryness.

- In the Peck, Pryse and Barbizon ponds, 1 borate, 3 chloride, 10 carbonate, and 19 different sulfate minerals were identified. These evaporites ranged from hydrated and nonhydrated species, e.g., gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$), double salts, e.g., bloedite ($Na_2SO_4 \cdot MgSO_4 \cdot 5H_2O$) and burkeite ($Na_2CO_3 \cdot 2Na_2SO_4$), and triple salts, e.g., polyhalite ($K_2SO_4 \cdot 2CaSO_4 \cdot MgSO_4 \cdot 2H_2O$) and tychite ($2Na_2CO_3 \cdot 2MgSO_4 \cdot Na_2SO_4$).

- The following evaporites were found in all three ponds: thenardite (Na_2SO_4), polyhalite, tychite, halite (NaCl), nahcolite ($NaHCO_3$), and nesquehonite ($MgCO_3 \cdot 3H_2O$).

- Since the influent waters to ponds are characterized as Na_2SO_4, NaCl-Na_2SO_4 or Na_2SO_4-NaCl type waters, the predominant evaporites formed are thenardite and halite. In addition, the presence of calcium and carbonates in these waters also produce evaporites such as gypsum and calcite ($CaCO_3$) in copious amounts.

- Seven evaporite samples were obtained from Peck pond and subjected to mineral identification and chemical analyses of redissolved salts. These samples were dominated by thenardite (Na_2SO_4) with morphologies ranging from fine-grained minerals found along shorelines to large crystals and slabs found in drying to dried pond bottoms. A representative water sample was also collected and chemically analyzed.

- The evaporite samples were dissolved in distilled deionized water (1 gram evaporite in 100 ml water) and analyzed for several trace elements (Se, As, B, Mo), major solutes (SO_4, Cl, Na, Ca, Mg, K), and DOC (Dissolved Organic Carbon).

- Based on the above chemical analyses the association of trace elements in the evaporites were ascertained. The molar ratio of SO_4 to a given trace element in the evaporite was compared to the ratio of SO_4 to a given trace element in the pond water. The results show that B, Se, and As were depleted in the evaporite (solid phase) as compared to the pond water (solution phase) while Mo was enriched in the evaporite.

- Additional studies are needed in other pond facilities to ascertain this relationship as well as the mechanisms of trace element adsorption to evaporites and occlusion (trapped) and co-precipitation of trace elements in evaporites.

▲ Magnitude of Salt Load

- An overall assessment was made on the 27 evaporation ponds with a total surface area of 7,070 acres that annually receive 31,900 ac-ft of subsurface drainage from about 56,500 acres of tile-drained fields containing 810,000 tons of salts (TDS).

- The above data were transformed into unit values. For example,
    - ➩ Each acre of tile-drained field required 0.125 ac of pond.
    - ➩ About 0.6 ac-ft/ac-yr of tile-drained effluents were collected and disposed into ponds.
    - ➩ About 4.5 ft/yr of tile effluents were disposed into ponds.
    - ➩ The concentration of TDS in tile effluents obtained from the field was about 14.3 tons/ac-yr.
    - ➩ The concentration of TDS in tile effluents disposed into ponds was about 25.4 tons/ac-ft.
    - ➩ The mass of TDS disposed in ponds was about 115 tons/ac-yr.

- The 31,900 ac-ft/yr of tile effluents discharged into ponds is nearly twice that discharged from drains in the Grasslands Subarea to the San Joaquin River.

- The 810,000 tons/yr of TDS disposed in ponds is about one-fourth of the estimated 3.1 million tons/yr of salt accumulation in the San Joaquin Valley's west side. CH2M HILL's estimate is 743,800 tons/yr.

- Assuming the density of evaporites as 2.66 g/cm^3 (thenardite) the annual volume of salts accumulating in the ponds is about 164,500 cubic yds or an average deposition thickness of 0.17 in/yr.

- Assuming the density of evaporites as 1.28 g/cm^3 (not well-developed crystalline forms), about 342,000 cubic yds of salt are accumulating in the ponds annually or an average deposition thickness of 0.36 in/yr.

- The above range of estimates on annual salt deposition in ponds indicate huge amounts available for possible salt harvesting or for disposal. However, the presence of toxic elements in the salt deposits may constrain how these salts are ultimately disposed.

▲ Best Design and Management Practices

- The factors and conditions sustaining evaporation and salt deposition rates were evaluated. Many of these factors are not readily manageable (changeable) while a few may be manageable such as regulating salinity levels or increasing absorbed net solar radiation using a dye, 2-Naphthol Green.

- Evaporation rate of water is strongly affected by salinity of the pond water. Typically, salinity in ponds are lowest in the winter and spring, and highest in the summer and fall.

- In addition to pond water salinity, formation of salt crusts on the surface of water bodies severely restricts evaporation rates.

- Use of cells in pond facilities with gates to serially transfer water of varying salinities may sustain evaporation rates.

- Pond water depth appears not to be a major factor influencing evaporation rates.

- To minimize seepage of pond water into underlying ground water basins and adjacent lands, perimeter interceptor drains are recommended. If seepage needs to be further controlled, collector drains could be installed beneath the ponds.

- Other methods of reducing seepage losses are the deposition of algal mats or burial of straw layers in pond bottoms.

- The ORMAT process is being advanced to enhance evaporation rates. Due to proprietary constraints, the initial capital costs and effectiveness are not readily available or known.

- The best management options and design features to sustain evaporation and salt precipitation rates may be overridden by considerations to make ponds safer to wildlife by making the ponds less attractive and reducing contaminant hazards.

INTRODUCTION

Statement of the Problem

Agricultural drainage and associated salinity and toxic element problems affect areas of the San Joaquin Valley, some moderately and others severely. The widely publicized selenium toxicity problems at Kesterson Reservoir heightened public awareness of this problem.

Backlund and Hoppes (1984) indicate that 1.5 million acres (0.6 million hectares), equal to 27%, of the 5.6 million acres (2.3 million hectares) of irrigated lands in the San Joaquin Valley are affected by shallow ground water to within five feet of the land surface and that 2.3 million acres (0.9 million hectares), or 41%, are affected by water quality problems, including salinity, pesticide residues, nitrates and toxic elements.

Figure 1.1 (San Joaquin Valley Drainage Program (SJVDP), 1989) delineates areas in the west side of the San Joaquin Valley having water table depths from 0 to 5 feet and from five to 20 feet. Subsurface drainage in these areas began in the 1950's. The Northern (least water quality impact) and Grassland Subareas have opportunities to discharge their irrigation return flows into the middle reaches of the San Joaquin River. As water quality objectives for the river grow more stringent, drainage from the two northernmost subareas will need to be increasingly reduced.

In contrast, the Westlands Subarea has no surface drainage outlet. Drainage waters are accumulating in the vadose region. The Tulare and Kern Subareas are located in a hydrologically closed basin with limited opportunities to discharge drainage into the lake beds. The SJVDP (1989) has enumerated numerous management options for drainage and drainage-related problems, e.g., selenium and salts. A combination of viable in-valley drainage management options is being sought to determine the best management practices (BMP). One of the most effective BMPs is source control with improved water management practices. But, even with source control BMPs, a residual of drainage waters containing elevated concentration levels of TDS and toxic elements will still need to be treated, or disposed, or both. This drainage problem is most critical in the Westlands, Tulare and Kern Subareas.

In the 1970's, the Tulare Lake Drainage District constructed two evaporation pond facilities and Carmel Ranch one pond with a total surface area of over 3,000 acres (1200 hectares) to dispose of over 15,000 ac-ft/yr (18.5 million m^3) of drainage collected from over 27,000 acres (66,700 hectares) of tile-drained fields (Department of Water Resources (DWR), 1988). Between 1981 and 1985, 24 more evaporation ponds were constructed. Most are located in the Tulare and Kern Subareas with several as far north as in the Grassland Subarea.

Earlier, concern focused on potential seepage of hypersaline waters from ponds into usable ground waters and adjacent lands. Since the Kesterson Reservoir crisis, the emphasis has shifted toward potential bioaccumulation of selenium and other constituents in the aquatic food chain and toxicity to birds attracted to the ponds. Several ponds have either exceeded the soluble threshold limit concentration of 1,000 μg/L selenium or begun to exhibit toxicity problems similar to those at the Kesterson Reservoir.

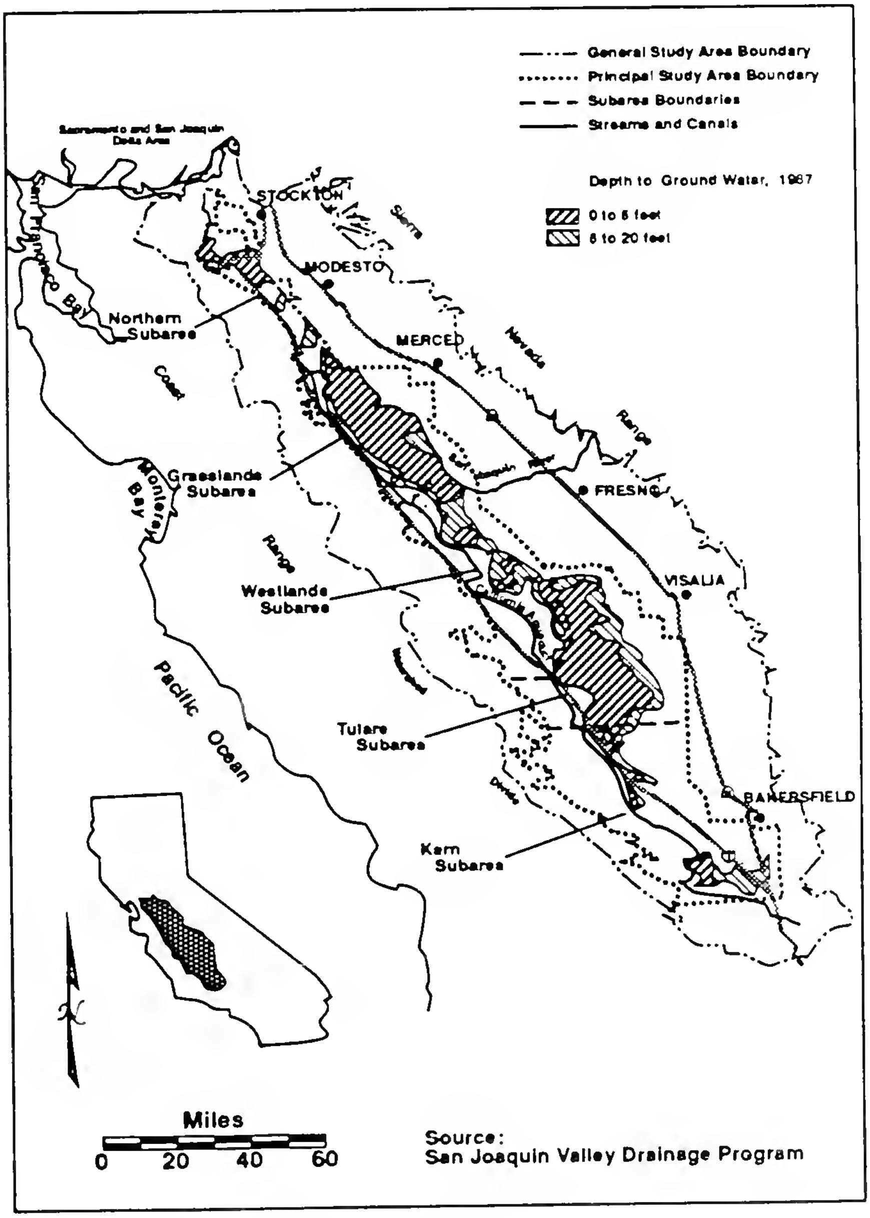
Aside from the highly visible concerns of bioaccumulation and hydrogeology, the following management-oriented questions need to be addressed to fully evaluate the efficacy of evaporation ponds:

- How long can ponds effectively operate? What variables and conditions would limit their operation?
- At what levels of salinity do evaporites begin to precipitate? What kind of salts, how much and from where? How does the initial inflow chemistry influence evaporite formation?
- What parameters affect evaporation rates of pond water? How do salinity, wind speed, wave action, temperature, turbidity, and thin surface salt crusts influence evaporation rates?

- What changes are expected to occur in the mineralogy and chemistry of pond wasters subjected to cyclic evaporative salinization (drying) and dilution-dissolution (wetting) of evaporites?
- Which trace elements might co-precipitate with evaporites? Will salt deposits containing toxic trace elements need to be ultimately disposed in Class I hazardous dump sites?
- What pond design and management practices will best sustain evaporation rates and precipitate salts?

Scope of Report

This report addresses physical and chemical characteristics and factors in evaporation ponds, with emphasis on seasonal pond water chemistry, water evaporation and salt accumulation, but does not address biological aspects. The previous interim report (Tanji and Grismer, 1989) contained a literature review and synthesis on these topics.



Source:
San Joaquin Valley Drainage Program

Figure 1.1 Areas of Shallow Groundwater

SECTION 2
WATER QUALITY & CHEMISTRY OF POND WATERS

Introduction

This section describes the sampling methods and analysis procedures for the major solutes, and the trace elements including molybdenum, arsenic, boron and selenium. Trends in solute and trace element concentrations in the ponds are also described.

Sampling and Measurement Procedures

Pond Water Sampling

Two sites at each pond were sampled using one liter Nalgene polypropylene bottles. Water samples were taken 2-3 meters in from the shoreline of each pond at representative corners. One water sample was immediately analyzed on-site for pH, temperature, DO, Eh, alkalinity*, EC, and density (Table 2.1). The second 1-liter sample was brought to the University of California West Side Field Station near Five Points and filtered. The samples were first vacuum filtered through No. 2 Whatman filter paper to eliminate the large particles. Solutions were then pumped through a 6" diameter, 0.45μm membrane filter using a peristaltic pump (Geotech Environmental Equipment Inc). The final filtering was through a Gelman 0.45 μm membrane filter (Millipore filter holder) using a suction flask. About 400 to 500 mL of the resulting filtrate was acidified with nitric acid to ~ pH 2.0 for trace element analysis. The remaining unacidified filtered sample was kept cold under ice and reserved for anion and carbon analysis.

Table 2.1 Pond Water Sample On-Site Measurement Instrumentation

Parameter	Equipment
○ Electrical Conductivity (EC)	YSI Model 32 Conductance Meter with YSI 3417 dip-type plastic cell and YSI 701 Temperature Probe.
○ pH, temperature (Centigrade)	Markson Model 90 pH/temperature meter with Markson Duramark or Tefmark II pH electrode, YSI 701 temperature probe.
○ Redox potential (Eh)	Markson Model 90 pH/Temperature Meter, Markson redox combination platinum electrode, YSI 701 temperature probe.
○ Dissolved oxygen (DO)	YSI Model 51B, YSI Oxygen/Temperature probe.
○ Alkalinity	Acid titration to pH 4.5 with Markson pH meter and pH electrode, YSI 701 temperature probe.
○ Density	Fisher Specific Gravity Hydrometer, range 1.000-1.225 and cylinder.

Chemical Analysis

The Applied Research Laboratories (ARL) Model 3510 Inductively Coupled Plasma Spectrophotometer (ICPS) instrument was used for sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), arsenic (As), molybdenum (Mo) and boron (B) determination. For ICPS analysis, the standards (Inorganic Ventures, Toms River, New Jersey), in various concentrations, were acidified, and 5 ppm scandium (Sc) and 10 ppm bismuth (Bi) added as internal standards. Internal standards are also added to all acidified samples to be analyzed by ICPS. A standard comparable to the sample concentration was analyzed after every six samples to check for recovery. Intermittently, a dilute sample and a previously analyzed sample were inserted as samples to check reproducibility.

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*Alkalinity is presented in this report in terms of mg/l $CaCO_3$

- Sulfate (SO_4) and chloride (Cl) were analyzed using a Shimadzu HPLC (LC-6A pump, C-R3A Chromatopac processor, SCL-6A Controller); 1ppm Limit of Quantitation (LOQ).
- Nitrate (NO_3) was determined using a Shimadzu HPLC (LC-6A pump, SPD-6AV UV/Vis Detector, SCL-6A Controller); 20 ppb LOQ.
- Carbon was analyzed using a Dohrmann DC-80 Carbon Analyzer; Total Dissolved Carbon (TDC), 1 ppm LOQ.
- Selenium was quantified using a Technicon BD-40 Heating Block and Control Unit digester, with Technicon auto-analyzer sampling pump fitted with a glass sampling probe, proportioning pump, regulated water bath, and recorder, and a Turner Flourimeter Model III with a continuous flow cuvette; Se, 1 ppb LOQ.

Description of Field-Measured and Chemical Analysis Data

Introduction

A summary of results from chemical analyses of the evaporation pond water and inflow samples are shown in Tables 2.3 to 2.12. The tables include data for inflow waters as well as the average values from each pair of sampling sites taken from each cell. In addition, the minimum, maximum and average values for each cell are presented. Particular emphasis in this discussion will be placed on the important trends and possible implications.

Field-Measured Data

The results of on-site analyses at Peck, Pryse and Barbizon evaporation ponds are shown in Tables 2.3 to 2.6. Only salinity, as reflected by the EC, fluctuated significantly with season.

EC values of pond waters overall ranged from 8.78 dS/m at Barbizon pond to 174 dS/m at Pryse pond. Inflow waters were generally lower in salinity ranging from 7.73 dS/m at Barbizon pond to 33.5 dS/m at Pryse pond. The conductivity was typically lowest during the Winter sampling time, while maximum values have typically been found during the Summer or Fall seasons. Lower ECs may be due to the dilution through addition of new drainage water. The pH of inflow waters were between 7 and 8, while the pH of the pond waters were up to 2 pH units above that of the inflow. The Eh measurements indicate that with only a few exceptions, the waters were weakly oxidizing. Changes in Eh do not appear to be closely linked to changes in dissolved oxygen concentration indicating perhaps that the dominant redox couple does not involve oxygen as the electron donor/receptor which facilitates the electron transfer necessary for redox reactions. There were some differences between the alkalinity of inflow and pond waters which suggests, in some cases, that there was a re-equilibration between atmospheric CO_2 and soluble carbonate minerals when the water was released from the confines of the tile drain system into the free surface water body.

Chemical Analysis Data

- *Major Solutes*

The major solutes include Na^+, Ca^{2+}, Mg^{2+}, K^+, HCO_3^-, Cl^-, SO_4^{2-} and NO_3^-. The ternary diagrams in Figure 2.1 show the dominance of the SO_4^{2-} anion and Na^+ cation in inflow and pond waters. Significant proportions of Cl^- are also found at Barbizon and Pryse ponds. Only relatively low concentrations of CO_3^{2-} were found.

Fluctuations in the concentration of the major solutes may be matched with those of EC and among themselves which indicates that these changes over time are functions of the degree of evapoconcentration as well as changes in the composition of inflow waters.

In terms of average values, the dissolved organic carbon (DOC) concentrations increase in the order Peck<Barbizon<Pryse. It may be possible that high values are linked to a biological factor including macrophyte, algal, and microbial activities.

- *Trace Elements*

The trace elements considered in this study include As, B, Mo and Se. The concentrations reported are total dissolved values for a particular element. It is important to remember that these elements do not exist in appreciable quantities as singular atoms. Instead, they typically

are in the oxyanion forms (that is, bound to oxygen atoms). For instance, dissolved Se may exist as H_3SeO_3 or H_3SeO_4, and any of the conjugate forms. Organic methylated forms of Se may also be present in significant quantities and are included along with the oxyanions in the reported total concentration value. The speciation of each element is essential in conclusively determining the fate and toxicological impact.

Boron concentrations are generally in the order of mg/L while the other three trace elements are present in the order of µg/L. An extremely high level of B (226.9 mg/L) was observed in cell 2 of Pryse pond in August 1988 compared to the 3 year average of 70.60 mg/L. The conservancy (i.e., non-reactivity) of B is well illustrated by the similarity in the rise of Cl^- and B concentrations, each almost showing a ten fold increase.

Selenium concentrations are below quantitation levels at Barbizon pond while it is barely detectable at Pryse pond and occasionally exceeds 1 mg/L at Peck pond especially in cell 5.

Arsenic concentrations greater than 1 mg/L have been detected in Pryse and Barbizon pond waters while the highest concentration at Peck pond is 0.95 mg/L which was found in one inflow sample. The highest pond water As concentration at Peck pond is 0.84 mg/L and this was during the time the pond cell was being drained to dryness. Concentrations exceeding 2 mg/L were found for Mo in many samples from all ponds. Additionally, Pryse inflow and pond waters showed extremely high levels of Mo ranging from a minimum of 1.40 mg/L in inflow to 24.51 mg/L in cell 2. While other solute concentrations in the pond water decreased with the lowering of the degree of salinity as indicated by a 58.3 dS/m drop in EC, Mo increased from the previous season because of a greater than three-fold increase in the inflow water Mo concentration.

It should be noted that the analytical data reported for As and Mo, as determined by the ICP, are consistently higher than those reported by the CVRWQCB and DWR for the period 1986-88 (Personal communication, D. Westcot and S. Ford). The extent of the data discrepancies varied depending on the element and pond. Despite the differences, the database is subsequently used in section 6 of this report because the error appears systematic rather than random.

The presence of trace elements in the drainage waters and consequently pond waters may be associated with the distribution of trace elements in the San Joaquin Valley. Bradford et al., (1989a) have reported on the distribution of 20 trace elements on the basis of three geologic regions: the Alluvial Fan (AF) region, the Basin Rim (BR) region and the Lakebed (LB) region (Table 2.2). Peck pond is situated in the AF region while Barbizon pond is in the BR region and Pryse pond in the LB region. Of the four trace elements of interest here, the AF region is high in B, Mo and Se. The BR region is high in B only, and the LB region is high in As, B and Mo. These observations are mostly consistent with the regional dominance of certain trace elements in different ponds: B is high in all ponds; Se is high at Pryse pond; As and Mo are relatively dominant in Pryse pond.

Table 2.2 Distribution of Trace Elements in the San Joaquin Valley
(L = low, M = moderate, H = high)

REGION	As	B	Mo	Se
Alluvial Fan	L	H	M	H
Basin Rim	L	M	L	L
Lakebed	H	H	H	L

Conclusions

The high salinities achieved at Pryse pond through evapoconcentration of drainage waters presents extremely high concentrations of B and Mo in the environment. Arsenic seems to maintain a level concentration in the pond waters independent of the degree of salinization. Selenium was not detectable at Barbizon pond, and did not rise significantly in highly concentrated waters at Peck or Pryse ponds. The degree to which these trace elements accumulate in the pond waters may be calculated and the results are presented in the section on evapoconcentration factors elsewhere in this report. Furthermore, the accumulation of certain trace elements depends on the location of the ponds in the San Joaquin Valley relative to the geologic setting.

Whether these levels of trace elements pose substantial risks to wildlife and waterfowl needs to be answered by those researchers studying the toxicological effects and concentrations in the biological components.

Table 2.3 Field-Measured Data for Seasonal Characterization of Peck Evaporation Pond Waters

Description	Season	Date of Measurement	EC (µmhos/cm)	pH	Eh (mV)	Alkalinity (mg/l)	DO (mg/l)	T (°C)
Peck Pond								
Cell 1, Inflow	Summer	8/25/86	11,380	7.23	184	282	y	y
Cell 1, Inflow	Fall	11/16/86	10,600	7.18	226	265	7.7	18
Cell 1, Inflow	Winter	2/8/87	10,920	7.55	198	275	7.4	16
Cell 1, Inflow	Spring	5/17/87	10,830	7.64	208	275	7.3	19
Cell 1, Inflow	Summer	8/5/87	10,340	7.36	162	300	5.6	26
Cell 1, Inflow	Fall	11/14/87	8,530	7.21	240	250	8.4	15
Cell 1, Inflow	Winter	2/20/88	8,350	7.20	30	255	6.8	11
Cell 1, Inflow	Spring	5/21/88	11,850	7.19	226	250	7.6	25
Cell 1, Inflow	Summer	8/9/88	11,530	7.11	202	270	6.4	21
Cell 1, Inflow	Fall	11/12/88	9,730	7.70	119	215	6.0	17
Cell 1, Inflow	Winter	2/17/89	x	x	x	x	x	x
Cell 1, Inflow	Spring	5/20/89	x	x	x	x	x	x
Minimum			**8,350**	**7.11**	**30**	**215**	**5.6**	**11**
Maximum			**11,850**	**7.70**	**240**	**300**	**8.4**	**26**
Mean			**10,406**	**7.34**	**179**	**264**	**7.0**	**19**
Cell 1	Summer	8/25/86	11,085	8.69	167	113	N/A	N/A
Cell 1	Fall	11/16/86	14,100	8.57	168	175	9.0	16
Cell 1	Winter	2/8/87	10,980	8.37	214	188	9.8	17
Cell 1	Spring	5/17/87	11,425	8.38	150	170	8.4	20
Cell 1	Summer	8/5/87	13,355	8.93	135	110	10.7	27
Cell 1	Fall	11/14/87	9,650	8.51	156	123	9.6	13
Cell 1	Winter	2/20/88	8,360	8.40	56	175	10.5	9
Cell 1	Spring	5/21/88	13,190	8.32	186	163	10.3	25
Cell 1	Summer	8/9/88	15,055	9.05	134	110	11.7	23
Cell 1	Fall	11/12/88	14,740	8.83	164	115	10.1	14
Cell 1	Winter	2/17/89	14,135	8.17	157	110	12.6	15
Cell 1	Spring	5/20/89	15,650	8.80	340	105	9.4	21
Minimum			**8,360**	**8.17**	**56**	**105**	**8.4**	**9**
Maximum			**15,650**	**9.05**	**240**	**188**	**12.6**	**27**
Mean			**12,644**	**8.58**	**169**	**138**	**10.2**	**18**
Cell 2	Summer	8/25/86	25,085	9.06	122	125	N/A	N/A
Cell 2	Fall	11/16/86	17,050	8.87	161	123	9.7	17
Cell 2	Winter	2/8/87	13,105	8.38	220	148	10.5	17
Cell 2	Spring	5/17/87	12,700	8.41	123	170	8.3	20
Cell 2	Summer	8/5/87	18,940	9.16	136	115	12.6	27
Cell 2	Fall	11/14/87	24,200	8.88	120	147	10.5	13
Cell 2	Winter	2/20/88	15,240	8.96	95	188	11.6	9
Cell 2	Spring	5/21/88	18,555	8.33	173	160	9.9	26
Cell 2	Summer	8/9/88	31,000	8.72	132	205	7.6	23
Cell 2	Fall	11/12/88	48,650	8.95	81	328	10.7	14
Cell 2	Winter	2/17/89	46,150	8.63	166	335	13.1	16
Cell 2	Spring	5/20/89	N/A	N/A	N/A	N/A	N/A	N/A
Minimum			**12,700**	**8.33**	**81**	**115**	**7.6**	**9**
Maximum			**48,650**	**9.16**	**220**	**335**	**13.1**	**27**
Mean			**24,807**	**8.76**	**139**	**188**	**10.4**	**18**
Cell 3	Summer	8/25/86	14,395	9.04	108	108	N/A	N/A
Cell 3	Fall	11/16/86	27,900	9.13	172	168	8.7	17
Cell 3	Winter	2/8/87	25,870	8.98	206	175	10.9	18
Cell 3	Spring	5/17/87	20,600	8.54	127	188	7.9	20
Cell 3	Summer	8/5/87	29,700	8.85	155	153	8.5	28
Cell 3	Fall	11/14/87	25,300	9.07	128	170	9.7	14
Cell 3	Winter	2/20/88	20,400	8.98	100	195	10.7	9
Cell 3	Spring	5/21/88	31,850	8.64	182	255	8.4	25
Cell 3	Summer	8/9/88	42,850	8.68	135	268	6.6	23
Cell 3	Fall	11/12/88	56,550	8.99	131	395	9.7	14
Cell 3	Winter	2/17/89	54,900	8.57	212	433	12.3	16
Cell 3	Spring	5/20/89	109,000	8.84	348	109	7.6	22
Minimum			**14,395**	**8.54**	**100**	**108**	**6.6**	**9**
Maximum			**109,000**	**9.13**	**348**	**433**	**12.3**	**28**
Mean			**38,276**	**8.86**	**187**	**218**	**9.2**	**19**

x: No sample y: Not analyzed **: Out of operation N/A: Not available

Table 2.4 Field-Measured Data for Seasonal Characterization of Peck Evaporation Pond Waters

Description	Season	Date of Measurement	EC (µmhos/cm)	pH	Eh (mV)	Alkalinity (mg/l)	DO (mg/l)	T (°C)
Peck Pond								
Cell 4	Summer	8/25/86	25,010	8.98	118	120	N/A	N/A
Cell 4	Fall	11/16/86	27,000	8.95	171	171	8.3	17
Cell 4	Winter	2/8/87	19,820	8.58	207	155	10.5	17
Cell 4	Spring	5/17/87	21,950	8.61	130	183	8.8	20
Cell 4	Summer	8/5/87	44,800	8.95	144	223	11.4	28
Cell 4	Fall	11/14/87	N/A	N/A	N/A	N/A	N/A	N/A
Cell 4	Winter	2/20/88	**	**	**	**	**	**
Cell 4	Spring	5/21/88	**	**	**	**	**	**
Cell 4	Summer	8/9/88	**	**	**	**	**	**
Cell 4	Fall	11/12/88	**	**	**	**	**	**
Cell 4	Winter	2/17/89	**	**	**	**	**	**
Cell 4	Spring	5/20/89	**	**	**	**	**	**
Minimum			**19,820**	**8.58**	**118**	**120**	**8.3**	**17**
Maximum			**44,800**	**8.98**	**207**	**223**	**11.4**	**28**
Mean			**27,716**	**8.81**	**154**	**170**	**9.7**	**20**
Cell 5	Summer	8/25/86	30,505	8.86	116	158	N/A	N/A
Cell 5	Fall	11/16/86	37,630	9.22	147	230	8.5	18
Cell 5	Winter	2/8/87	28,250	8.84	194	205	9.3	18
Cell 5	Spring	5/17/87	30,800	8.65	139	248	8.3	20
Cell 5	Summer	8/5/87	48,700	8.93	150	255	10.1	28
Cell 5	Fall	11/14/87	34,400	8.77	141	295	9.9	13
Cell 5	Winter	2/20/88	25,700	9.01	109	273	10.9	9
Cell 5	Spring	5/21/88	44,150	8.90	180	290	9.0	26
Cell 5	Summer	8/9/88	59,950	8.73	127	355	8.4	22
Cell 5	Fall	11/12/88	43,450	8.70	157	348	9.1	14
Cell 5	Winter	2/17/89	50,300	8.52	202	370	12.7	16
Cell 5	Spring	5/20/89	84,650	9.05	276	658	10.1	22
Minimum			**25,700**	**8.52**	**109**	**158**	**8.4**	**9**
Maximum			**84,650**	**9.22**	**276**	**658**	**12.7**	**28**
Mean			**43,207**	**8.85**	**161**	**307**	**9.5**	**19**
Cell 6	Spring	5/17/87	9,345	8.57	132	103	5.2	21
Cell 6	Summer	8/5/87	19,125	9.09	124	95	8.8	28
Cell 6	Fall	11/14/87	15,620	8.87	124	118	9.0	13
Cell 6	Winter	2/20/88	11,430	9.25	102	123	11.9	8
Cell 6	Spring	5/21/88	17,500	8.77	174	120	9.5	27
Cell 6	Summer	8/9/88	21,725	8.98	114	118	9.9	23
Cell 6	Fall	11/12/88	35,350	9.51	117	220	8.2	12
Cell 6	Winter	2/17/89	26,950	8.75	182	178	13.2	16
Cell 6	Spring	5/20/89	36,600	9.59	244	188	9.5	21
Minimum			**9,345**	**8.57**	**102**	**95**	**5.2**	**8**
Maximum			**36,600**	**9.59**	**244**	**220**	**13.2**	**28**
Mean			**21,516**	**9.04**	**146**	**140**	**9.5**	**19**

**: Out of operation y Not analyzed N/A Not available

Table 2.5 Field-Measured Data for Seasonal Characterization of Pryse Evaporation Pond Waters

Description	Season	Date of Measurement	EC (µmhos/cm)	pH	Eh (mV)	Alkalinity (mg/l)	DO (mg/l)	T (°C)
Pryse Pond								
Cell 1, Inflow	Summer	8/26/86	31,560	7.62	162	920	y	y
Cell 1, Inflow	Fall	11/15/86	30,980	7.49	186	810	8 8	18
Cell 1, Inflow	Winter	2/7/87	27,770	8 13	198	840	10.0	15
Cell 1, Inflow	Spring	5/16/87	30,200	7 41	134	805	6 4	23
Cell 1, Inflow	Summer	8/4/87	33,500	7.40	206	815	6.2	25
Cell 1, Inflow	Fall	11/14/87	27,400	7 44	215	810	8.2	20
Cell 1, Inflow	Winter	2/20/88	27,100	7.51	181	875	7 5	19
Cell 1, Inflow	Spring	5/21/88	33,100	7.52	206	835	7.3	27
Cell 1, Inflow	Summer	8/9/88	29,800	7 46	159	865	8 6	28
Cell 1, Inflow	Fall	11/12/88	31,000	7.54	136	840	8 0	22
Cell 1, Inflow	Winter	2/11/89	22,700	6 71	122	770	10.6	12
Cell 1, Inflow	Spring	5/20/89	30,700	7.61	256	885	7.4	26
Minimum			**22,700**	**6.71**	**122**	**770**	**6**	**12**
Maximum			**33,500**	**8.13**	**256**	**920**	**11**	**28**
Mean			**29,651**	**7.49**	**180**	**839**	**8**	**21**
Cell 1	Summer	8/26/86	53,390	8 52	169	638	N/A	N/A
Cell 1	Fall	11/15/86	46,750	8 50	139	693	8 1	15
Cell 1	Winter	2/7/87	25,645	8 67	192	598	12 5	15
Cell 1	Spring	5/16/87	43,300	8 33	145	555	5 5	23
Cell 1	Summer	8/4/87	63,150	8 50	183	590	5 0	27
Cell 1	Fall	11/14/87	46,750	8.36	188	708	13 6	18
Cell 1	Winter	2/20/88	41,150	8 51	152	735	6 7	20
Cell 1	Spring	5/21/88	47,250	8 72	96	625	5 0	29
Cell 1	Summer	8/9/88	58,550	8 56	79	655	10 9	29
Cell 1	Fall	-11/12/88	63,200	8 75	134	805	2 1	22
Cell 1	Winter	2/11/89	43,500	8 33	115	725	13.2	12
Cell 1	Spring	5/20/89	53,050	8.73	240	780	16 1	27
Minimum			**25,645**	**8.33**	**79**	**555**	**2**	**12**
Maximum			**63,200**	**8.75**	**240**	**805**	**16**	**29**
Mean			**46,807**	**8.54**	**152**	**675**	**9**	**22**
Cell 2	Summer	8/26/86	129,050	8 34	114	1,260	N/A	N/A
Cell 2	Fall	11/15/86	70,745	8.24	140	890	5 1	14
Cell 2	Winter	2/7/87	35,850	8 75	178	535	10 7	13
Cell 2	Spring	5/16/87	85,000	8.83	123	423	4.2	22
Cell 2	Summer	8/4/87	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	Fall	11/14/87	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	Winter	2/20/88	65,150	8 92	137	665	6 4	21
Cell 2	Spring	5/21/88	71,400	8 77	154	530	7.8	30
Cell 2	Summer	8/9/86	174,700	7.42	-150	1,560	4 5	32
Cell 2	Fall	11/12/88	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	Winter	2/11/89	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	Spring	5/20/89	133,350	8 27	187	933	3 9	29
Minimum			**35,850**	**7.42**	**-150**	**423**	**4**	**13**
Maximum			**174,700**	**8.92**	**187**	**1,560**	**11**	**32**
Mean			**95,656**	**8.44**	**110**	**849**	**6**	**23**

y Not analyzed N/A. Not available

Table 2.6 Field-Measured Data for Seasonal Characterization of Barbizon Evaporation Pond Waters

Description	Season	Date of Measurement	EC (µmhos/cm)	pH	Eh (mV)	Alkalinity (mg/l)	DO (mg/l)	T (°C)
Barbizon Pond								
Inflow, Cell C	Spring	5/16/87	8,720	7.43	212	530	3.3	23
Inflow, Cell C	Summer	8/4/87	8,110	7.83	186	510	5.5	25
Inflow, Cell C	Fall	11/15/87	x	x	x	x	x	x
Inflow, Cell C	Winter	2/21/88	x	x	x	x	x	x
Inflow, Cell C	Spring	5/22/88	x	x	x	x	x	x
Inflow, Cell C	Summer	8/10/88	x	x	x	x	x	x
Inflow, Cell C	Fall	11/13/88	x	x	x	x	x	x
Inflow, Cell C	Winter	2/11/89	7,730	7.36	125	705	9	7
Inflow, Cell C	Spring	5/21/89	8,860	7.33	276	660	8	20
Minimum			**7,730**	**7.33**	**125**	**510**	**3**	**7**
Maximum			**8,860**	**7.83**	**276**	**705**	**9**	**25**
Mean			**8,355**	**7.49**	**195**	**601**	**6**	**19**
Cell A, West	Summer	8/26/86	23,390	9.10	153	660	y	y
Cell A, West	Fall	11/15/86	29,500	9.05	168	665	6.1	19
Cell A, West	Winter	2/7/87	11,040	7.49	179	665	8.8	20
Cell A, West	Spring	5/16/87	28,100	8.70	177	550	10.8	27
Cell A, West	Summer	8/4/87	29,200	9.43	151	355	12.0	29
Cell A, West	Fall	11/15/87	20,800	8.62	173	500	9.2	9
Cell A, West	Winter	2/21/88	16,810	8.47	-93	520	10.6	8
Cell A, West	Spring	5/22/88	24,100	8.95	161	395	8.3	23
Cell A, West	Summer	8/10/88	39,900	8.88	18	260	4.4	22
Cell A, West	Fall	11/13/88	22,300	7.72	124	525	7.8	14
Cell A, West	Winter	2/11/89	14,360	8.58	75	545	10.0	6
Cell A, West	Spring	5/21/89	31,500	8.81	243	315	10.4	19
Minimum			**11,040**	**7.49**	**-93**	**260**	**4**	**6**
Maximum			**39,900**	**9.43**	**243**	**665**	**12**	**29**
Mean			**24,250**	**8.65**	**127**	**496**	**9**	**18**
Cell B, East	Summer	8/26/86	21,850	9.10	147	675	y	y
Cell B, East	Fall	11/15/86	27,900	9.16	172	665	6.0	19
Cell B, East	Winter	2/7/87	21,530	8.62	182	555	9.0	18
Cell B, East	Spring	5/16/87	27,700	8.92	188	555	12.0	27
Cell B, East	Summer	8/4/87	27,200	9.32	148	455	9.0	29
Cell B, East	Fall	11/15/87	23,600	8.80	172	490	10.4	8
Cell B, East	Winter	2/21/88	16,450	9.07	-15	495	14.0	9
Cell B, East	Spring	5/22/88	26,200	9.26	163	425	8.0	23
Cell B, East	Summer	8/10/88	48,300	9.40	23	290	6.8	21
Cell B, East	Fall	11/13/88	19,710	8.85	118	675	6.0	13
Cell B, East	Winter	2/11/89	12,910	9.07	94	505	10.2	6
Cell B, East	Spring	5/21/89	x	x	x	x	x	x
Minimum			**12,910**	**8.62**	**-15**	**290**	**6**	**6**
Maximum			**48,300**	**9.40**	**182**	**675**	**14**	**29**
Mean			**24,850**	**9.05**	**125**	**525**	**9**	**17**
Cell C, East	Summer	8/26/86	20,900	9.10	147	675	y	y
Cell C, East	Fall	11/15/86	28,000	9.06	153	660	7.0	19
Cell C, East	Winter	2/7/87	18,770	8.59	150	555	8.6	18
Cell C, East	Spring	5/16/87	21,400	8.98	157	545	14.3	29
Cell C, East	Summer	8/4/87	25,200	9.21	149	475	9.1	29
Cell C, East	Fall	11/15/87	24,200	8.78	171	470	9.0	9
Cell C, East	Winter	2/21/88	16,000	9.21	5	505	15.0	9
Cell C, East	Spring	5/22/88	25,500	9.07	164	465	8.8	23
Cell C, East	Summer	8/10/88	21,500	9.42	-132	400	2.5	22
Cell C, East	Fall	11/13/88	11,170	8.98	113	570	6.8	13
Cell C, East	Winter	2/11/89	8,780	9.22	95	515	10.2	6
Cell C, East	Spring	5/21/89	9,320	8.25	260	690	17.8	19
Minimum			**8,780**	**8.25**	**-132**	**400**	**3**	**6**
Maximum			**28,000**	**9.42**	**260**	**690**	**18**	**29**
Mean			**19,228**	**8.99**	**119**	**544**	**10**	**18**

x: No sample y: Not analyzed

Table 2.7 Results of Laboratory Chemical Analysis of Peck Evaporation Pond Waters

Description	Date of Sampling	EC (µmhos/cm)	pH	Eh (mV)	Na	Ca	Mg	K	HCO3	Cl (mg/l)	SO4	NO3	DOC	As*	B	Mo*	Se
Peck Pond																	
Cell 1, Inflow	8/25/86	11,380	7.20	184	2,260	534	115	16	146	860	5,100	95	75	0.86	7.06	0.80	0.48
Cell 1, Inflow	11/18/86	10,580	7.18	226	1,968	464	115	10	348	710	4,486	48	67	<	5.06	0.87	0.52
Cell 1, Inflow	2/8/87	10,918	7.55	198	2,411	446	119	1	368	709	5,492	44	85	0.89	2.62	0.90	0.72
Cell 1, Inflow	5/17/87	10,830	7.64	208	2,280	480	130	5	366	799	4,247	114	78	0.95	5.79	0.74	0.82
Cell 1, Inflow	8/5/87	10,340	7.36	162	1,807	432	99	7	397	470	3,344	56	83	0.70	8.46	0.74	0.38
Cell 1, Inflow	11/14/87	8,530	7.21	240	1,958	500	112	9	329	661	3,939	64	66	0.29	5.82	0.08	0.05
Cell 1, Inflow	2/20/88	8,350	7.20	30	2,500	477	112	7	342	731	4,455	83	69	0.43	5.22	0.37	0.55
Cell 1, Inflow	5/21/88	11,850	7.19	226	2,302	448	110	5	360	818	4,449	98	74	0.19	5.57	0.61	0.74
Cell 1, Inflow	8/9/88	11,530	7.11	202	2,686	494	120	9	366	1,072	5,528	106	59	<	5.51	<	0.79
Cell 1, Inflow	11/12/88	9,730	7.70	119	2,013	420	87	8	287	945	4,938	38	21	<	5.06	<	0.69
Cell 1, Inflow	2/17/89	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Cell 1, Inflow	5/20/89	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Minimum		**8,350**	**7.11**	**30**	**1,807**	**420**	**87**	**1**	**146**	**470**	**3,344**	**38**	**21**	**0.19**	**2.62**	**0.08**	**0.05**
Maximum		**11,850**	**7.70**	**240**	**2,686**	**534**	**130**	**16**	**397**	**1,072**	**5,528**	**114**	**85**	**0.95**	**7.06**	**0.90**	**0.82**
Mean		**10,404**	**7.33**	**179**	**2,196**	**470**	**112**	**8**	**331**	**777**	**4,598**	**74**	**68**	**0.62**	**5.42**	**0.64**	**0.57**
Cell 1	8/25/86	11,085	8.65	187	2,345	500	132	18	171	890	5,175	68	34	0.61	7.27	0.86	0.58
Cell 1	11/18/86	14,090	8.57	187.5	2,839	486	131	13	244	1,034	5,400	42	25	0.19	5.90	1.06	0.70
Cell 1	2/8/87	10,979	8.37	214	2,395	485	123	3	263	761	5,407	40	40	0.56	3.36	0.93	0.72
Cell 1	5/17/87	11,425	8.38	149.5	2,236	404	140	8	241	798	4,580	89	53	0.41	6.53	0.74	0.74
Cell 1	8/5/87	13,355	8.93	135	2,264	423	135	10	168	788	4,906	53	41	0.58	7.32	0.89	0.64
Cell 1	11/14/87	9,650	8.51	156	2,297	483	121	13	180	856	4,763	56	45	0.38	6.14	0.06	0.10
Cell 1	2/20/88	8,360	8.40	56	2,931	523	147	5	229	819	5,064	60	50	0.46	6.75	0.43	0.49
Cell 1	5/21/88	13,190	8.32	185.5	2,719	468	133	4	240	863	5,017	75	54	0.24	5.58	0.75	0.76
Cell 1	8/9/88	15,055	9.05	133.5	3,534	523	181	13	174	1,198	8,251	87	44	N/A	8.08	N/A	0.86
Cell 1	11/12/88	14,740	8.83	164	3,737	462	180	13	171	1,548	7,438	68	29	N/A	8.60	N/A	1.01
Cell 1	2/17/89	14,135	8.17	157	3,751	583	144	13	168	1,219	6,973	59	18	N/A	7.78	N/A	0.78
Cell 1	5/20/89	15,650	8.80	340	3,770	818	196	24	156	1,369	7,809	60	N/A	N/A	9.02	N/A	N/A
Minimum		**8,360**	**8.17**	**56**	**2,236**	**404**	**121**	**3**	**156**	**761**	**4,580**	**40**	**18**	**0.19**	**3.36**	**0.06**	**0.10**
Maximum		**15,650**	**9.05**	**340**	**3,770**	**818**	**196**	**24**	**263**	**1,548**	**7,809**	**89**	**54**	**0.61**	**9.02**	**1.06**	**1.01**
Mean		**12,843**	**8.58**	**169**	**2,886**	**496**	**147**	**11**	**200**	**1,012**	**5,732**	**63**	**39**	**0.43**	**6.86**	**0.72**	**0.67**
Cell 2	8/25/86	25,085	9.10	121.5	5,975	687	374	39	204	2,380	12,400	N/A	49	0.75	20.14	1.89	1.00
Cell 2	11/18/86	17,059	8.87	181	4,021	811	207	28	186	1,565	8,400	37	59	N/A	7.55	1.51	0.75
Cell 2	2/8/87	13,105	8.38	220	3,534	462	138	5	208	1,114	7,269	43	30	0.81	5.00	0.98	0.64
Cell 2	5/17/87	18,800	8.41	122.5	2,668	407	142	11	244	928	5,355	62	69	0.39	6.60	0.86	0.98
Cell 2	8/5/87	18,940	9.18	135.5	3,466	466	187	15	180	1,281	7,304	58	71	0.63	9.98	1.09	0.72
Cell 2	11/14/87	24,200	8.88	120	6,904	491	425	62	220	2,765	13,579	19	88	0.30	20.22	0.15	0.42
Cell 2	2/20/88	15,240	8.96	94.5	5,556	495	279	20	256	1,969	10,848	48	87	0.41	14.08	0.99	0.51
Cell 2	5/21/88	18,555	8.33	173	4,262	498	227	16	238	1,622	8,441	36	63	0.28	9.29	0.97	0.72
Cell 2	8/9/88	31,000	8.72	132	8,404	464	393	38	336	3,047	14,919	18	63	N/A	19.14	N/A	0.48
Cell 2	11/12/88	48,650	8.95	81	16,868	455	789	64	473	8,872	29,350	N/A	104	N/A	38.19	N/A	0.22
Cell 2	2/17/89	46,150	8.63	168	15,319	459	783	60	470	8,381	30,047	N/A	108	N/A	31.34	N/A	0.08
Cell 2	5/20/89	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Minimum		**13,105**	**8.33**	**81**	**2,668**	**407**	**138**	**5**	**180**	**928**	**5,355**	**18**	**30**	**0.28**	**5.00**	**0.15**	**0.08**
Maximum		**48,650**	**9.18**	**220**	**16,868**	**811**	**789**	**64**	**473**	**8,872**	**30,047**	**62**	**108**	**0.81**	**38.19**	**1.89**	**1.00**
Mean		**24,980**	**8.78**	**139**	**6,996**	**489**	**369**	**32**	**274**	**2,718**	**13,447**	**42**	**70**	**0.51**	**16.32**	**1.03**	**0.58**

< Below limit of quantitation (LOQ)   x: No sample   DOC: Dissolved Organic Carbon   N/A: Not available   *Values reported are consistently greater than that reported by CVRWQCB

Table 2.8 Results of Laboratory Chemical Analysis of Peck Evaporation Pond Waters

Description	Date of Sampling	EC (µmhos/cm)	pH	Eh (mV)	Na	Ca	Mg	K	HCO3	Cl (mg/l)	SO4	NO3	DOC	As*	B	Mo*	Se
Peck Pond																	
Cell 3	8/25/86	14,395	9.05	108	2,905	525	173	22	171	1,115	8,375	N/A	41	0.62	9.47	1.13	0.81
Cell 3	11/18/86	27,895	9.13	171.5	8,560	587	397	44	250	2,545	13,300	41	37	N/A	21.78	2.97	1.25
Cell 3	2/8/87	25,869	8.98	208	8,523	568	451	49	250	3,103	18,506	48	37	0.27	15.72	1.55	1.20
Cell 3	5/17/87	20,800	8.54	127	4,845	512	307	21	278	1,955	10,428	82	102	0.24	14.67	1.38	0.91
Cell 3	8/5/87	29,700	8.85	154.5	5,662	589	380	30	232	2,277	12,142	81	83	0.77	18.42	1.76	1.27
Cell 3	11/14/87	25,300	9.07	128	7,453	554	472	61	244	2,978	15,104	73	89	0.41	22.88	0.22	0.30
Cell 3	2/20/88	20,400	8.98	100	7,530	568	415	32	271	2,711	14,542	64	81	0.54	20.94	1.39	1.23
Cell 3	5/21/88	31,850	8.84	182	8,173	625	472	34	372	3,065	18,137	50	95	0.54	17.75	1.87	1.19
Cell 3	8/9/88	42,850	8.88	134.5	12,770	517	606	54	418	4,580	22,739	47	74	N/A	28.48	0.48	1.44
Cell 3	11/12/88	58,550	8.99	131	20,215	462	1,034	77	549	8,368	35,602	N/A	58	N/A	44.91	0.84	2.02
Cell 3	2/17/89	54,900	8.57	212	18,979	438	1,008	88	595	8,041	39,090	N/A	102	N/A	42.39	0.62	1.49
Cell 3	5/20/89	109,000	8.84	348	40,858	530	3,872	304	1,448	22,589	94,460	14	N/A	N/A	166.5	N/A	N/A
Minimum		**14,395**	**8.54**	**100**	**2,905**	**438**	**173**	**21**	**171**	**1,115**	**8,375**	**14**	**37**	**0.24**	**9.47**	**0.22**	**0.30**
Maximum		**109,000**	**9.13**	**348**	**40,858**	**625**	**3,872**	**304**	**1,448**	**22,589**	**94,460**	**82**	**102**	**0.77**	**166.5**	**2.97**	**2.02**
Mean		**38,278**	**8.86**	**167**	**12,023**	**539**	**782**	**68**	**423**	**5,277**	**24,869**	**58**	**73**	**0.48**	**35.32**	**1.27**	**1.17**
Cell 4	8/25/86	25,010	9.00	118	5,555	661	356	41	204	2,200	11,300	N/A	48	0.73	19.23	1.62	0.89
Cell 4	11/18/86	28,993	8.95	170.5	6,397	568	368	48	256	2,530	12,480	54	50	N/A	24.23	2.80	1.40
Cell 4	2/8/87	19,818	8.58	207	4,596	450	238	34	226	1,466	9,228	43	41	0.28	11.02	0.99	0.93
Cell 4	5/17/87	21,950	8.81	129.5	4,882	562	306	26	262	1,983	10,816	96	89	0.26	14.88	1.32	1.11
Cell 4	8/5/87	44,800	8.95	144	9,485	669	631	50	339	4,181	21,415	126	110	0.84	30.48	2.72	2.06
Cell 4	11/14/87	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cell 4	2/20/88	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cell 4	5/21/88	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cell 4	8/9/88	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cell 4	11/12/88	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cell 4	2/17/89	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cell 4	5/20/89	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Minimum		**19,818**	**8.58**	**118**	**4,596**	**450**	**238**	**26**	**204**	**1,466**	**9,228**	**43**	**41**	**0.26**	**11.02**	**0.99**	**0.89**
Maximum		**44,800**	**9.00**	**207**	**9,485**	**669**	**631**	**50**	**339**	**4,181**	**21,416**	**126**	**110**	**0.84**	**30.48**	**2.80**	**2.06**
Mean		**27,714**	**8.82**	**154**	**6,183**	**582**	**379**	**40**	**267**	**2,472**	**13,048**	**80**	**67**	**0.53**	**19.96**	**1.89**	**1.28**

< Below limit of quantitation (LOQ) DOC: Dissolved Organic Carbon N/A Not available --: Out of operation *Values reported are consistently greater than that reported by CVRWQCB

Table 2.9 Results of Laboratory Chemical Analysis of Peck Evaporation Pond Waters

Description	Date of Sampling	EC (µmhos/cm)	pH	Eh (mV)	Na	Ca	Mg	K	HCO3	Cl (mg/l)	SO4	NO3	DOC	As*	B	Mo*	Se
Peck Pond																	
Cell 5	8/25/86	30,505	8.85	118	6,460	595	463	8	250	2,990	13,100	N/A	55	0.70	25.10	1.13	1.03
Cell 5	11/18/86	35,123	9.22	147	7,687	1103	1,161	81	421	3,850	17,200	65	53	N/A	49.07	4.71	1.60
Cell 5	2/8/87	28,246	8.84	194	7,848	555	494	68	290	2,738	15,993	58	57	0.39	20.37	1.92	1.40
Cell 5	5/17/87	30,800	8.65	139	8,156	558	556	51	360	3,437	17,493	72	117	0.17	27.81	2.11	1.60
Cell 5	8/5/87	48,700	8.93	150	9,831	663	704	64	378	4,937	24,384	138	111	0.78	37.01	3.18	1.99
Cell 5	11/14/87	34,400	8.77	141	10,614	546	799	107	409	4,732	23,025	66	113	0.38	35.89	0.35	1.11
Cell 5	2/20/88	25,700	9.01	109	10,260	572	641	43	369	3,924	19,747	91	98	0.41	9.99	1.90	1.59
Cell 5	5/21/88	44,150	8.90	180	12,437	536	701	53	421	4,572	23,414	92	99	0.56	34.08	2.39	1.08
Cell 5	8/9/88	59,850	8.73	127	20,907	578	897	100	534	7,763	37,389	107	90	N/A	46.84	0.69	2.86
Cell 5	11/12/88	43,450	8.70	157	14,519	465	788	69	479	6,334	27,270	N/A	58	N/A	37.59	0.52	1.58
Cell 5	2/17/89	50,300	8.52	202	18,888	451	886	89	515	7,182	34,272	N/A	88	N/A	41.10	0.70	2.21
Cell 5	5/20/89	84,850	9.05	278	32,619	607	1,892	170	897	12,909	61,983	7	N/A	N/A	90.90	N/A	N/A
Minimum		**25,700**	**8.52**	**109**	**6,460**	**451**	**463**	**8**	**250**	**2,738**	**13,100**	**7**	**53**	**0.17**	**9.99**	**0.35**	**1.03**
Maximum		**84,850**	**9.22**	**278**	**32,619**	**1,103**	**1,892**	**170**	**897**	**12,909**	**61,983**	**138**	**117**	**0.78**	**90.90**	**4.71**	**2.86**
Mean		**42,906**	**8.86**	**161**	**13,165**	**602**	**630**	**75**	**444**	**5,447**	**26,272**	**80**	**83**	**0.48**	**37.98**	**1.78**	**1.64**
Cell 8	5/17/87	9,345	8.57	132	1,824	383	105	19	156	798	3,819	36	53	0.27	5.23	0.65	0.38
Cell 8	8/5/87	19,125	9.09	124	3,647	598	196	24	159	1,531	7,850	50	59	0.60	11.45	1.18	0.57
Cell 8	11/14/87	15,820	8.87	124	4,562	524	236	42	183	1,893	8,957	16	42	0.26	12.65	0.16	0.17
Cell 8	2/20/88	11,430	9.25	102	4,100	436	201	21	201	1,527	7,798	25	35	0.46	16.91	0.73	0.44
Cell 8	5/21/88	17,500	8.77	174	3,492	554	169	17	192	1,299	7,366	60	44	0.41	9.23	0.97	0.73
Cell 8	8/9/88	21,725	8.98	114	6,668	473	314	28	198	2,029	10,541	80	32	N/A	13.57	N/A	0.99
Cell 8	11/12/88	35,350	9.51	117	11,839	453	550	47	314	4,551	20,768	N/A	22	N/A	25.92	0.46	1.59
Cell 8	2/17/89	26,950	8.75	182	7,798	474	397	36	262	3,088	15,263	41	23	N/A	16.52	N/A	1.11
Cell 8	5/20/89	38,600	9.59	244	10,674	495	544	58	275	4,085	21,013	3	N/A	N/A	25.56	N/A	N/A
Minimum		**9,345**	**8.57**	**102**	**1,824**	**383**	**105**	**17**	**156**	**798**	**3,819**	**3**	**22**	**0.26**	**5.23**	**0.16**	**0.17**
Maximum		**38,600**	**9.59**	**244**	**11,839**	**598**	**550**	**58**	**314**	**4,551**	**21,013**	**80**	**59**	**0.60**	**25.92**	**1.18**	**1.59**
Mean		**21,518**	**9.04**	**146**	**6,067**	**488**	**304**	**32**	**216**	**2,309**	**11,486**	**39**	**38**	**0.40**	**15.23**	**0.60**	**0.75**

N/A: Not available

*Values reported are consistently greater than that reported by CVRWQCB

Table 2.10 Results of Laboratory Chemical Analysis of Pryse Evaporation Pond Waters

Description	Date of Sampling	EC (µmhos/cm)	pH	Eh (mV)	Na	Ca	Mg	K	HCO3	Cl (mg/l)	SO4	NO3	DOC	As*	B	Mo*	Se
Pryse Pond																	
Cell 1, Inflow	8/26/86	31,560	7.60	162	6,260	311	575	5	1,180	6,480	7,000	<	238	1.03	11.97	2.12	0.02
Cell 1, Inflow	11/15/86	30,971	7.49	188	6,039	292	502	81	1,037	6,035	7,000	4	197	0.57	8.35	8.46	<0.01
Cell 1, Inflow	2/7/87	27,763	8.13	198	6,378	262	413	47	1,068	5,366	7,416	4	181	2.30	5.08	3.02	<0.01
Cell 1, Inflow	5/16/87	30,200	7.41	134	6,144	354	568	26	1,019	6,808	7,797	9	226	1.50	10.78	3.92	0.02
Cell 1, Inflow	8/4/87	33,500	7.40	208	6,604	311	490	22	1,049	6,811	8,041	14	230	1.13	8.49	3.98	0.02
Cell 1, Inflow	11/14/87	27,400	7.44	215	6,524	298	514	38	1,037	6,210	7,712	5	215	0.73	10.04	1.51	0.01
Cell 1, Inflow	2/20/88	27,100	7.51	181	7,024	308	543	15	1,110	6,699	8,597	24	240	0.71	9.98	2.95	0.01
Cell 1, Inflow	5/21/88	33,100	7.52	208	7,683	357	573	21	1,068	7,021	8,516	8	239	0.65	10.05	3.29	0.01
Cell 1, Inflow	8/9/88	29,800	7.46	159	7,248	304	472	21	1,104	6,039	6,961	7	233	<	9.31	1.58	0.01
Cell 1, Inflow	11/12/88	31,000	7.54	136	7,302	301	539	18	1,068	7,307	9,870	y	227	<	9.45	1.40	0.01
Cell 1, Inflow	2/11/89	22,700	6.71	122	6,540	256	423	20	988	6,004	8,091	2	198	<	7.68	1.45	y
Cell 1, Inflow	5/20/89	30,700	7.81	256	7,284	304	494	31	1,135	6,232	8,217	y	y	y	10.18	1.83	y
Minimum		**22,700**	**6.71**	**122**	**6,039**	**256**	**413**	**5**	**988**	**5,366**	**6,961**	**2**	**181**	**0.57**	**5.08**	**1.40**	**0.01**
Maximum		**33,500**	**8.13**	**256**	**7,683**	**357**	**575**	**81**	**1,180**	**7,307**	**9,870**	**24**	**240**	**2.30**	**11.97**	**8.46**	**0.02**
Mean		**29,650**	**7.49**	**180**	**6,751**	**306**	**509**	**27**	**1,072**	**6,418**	**7,935**	**8**	**220**	**1.06**	**9.26**	**2.79**	**0.01**
Cell 1	8/26/86	53,390	8.50	169	10,465	240	1,050	10	830	13,000	15,000	N/A	223	0.78	23.43	3.45	0.03
Cell 1	11/15/86	46,750	8.50	139	8,689	294	980	73	927	9,780	9,600	4	170	0.45	16.37	10.03	0.02
Cell 1	2/7/87	25,643	8.67	192	10,011	264	748	70	794	9,295	12,563	4	153	1.08	9.91	4.67	N/A
Cell 1	5/16/87	43,300	8.33	145	9,555	211	782	39	729	10,457	12,898	4	193	0.66	16.28	5.82	0.01
Cell 1	8/4/87	63,150	8.50	183	10,044	250	970	38	793	11,733	15,732	8	221	1.44	20.77	6.08	0.01
Cell 1	11/14/87	46,750	8.36	188	10,809	277	1,003	77	924	12,604	14,721	3	201	0.53	18.04	2.71	0.01
Cell 1	2/20/88	41,150	8.51	152	11,631	279	926	34	952	10,661	13,670	8	215	0.79	16.91	4.64	0.01
Cell 1	5/21/88	47,250	8.72	96	11,584	192	824	31	802	10,879	12,996	3	162	0.56	15.18	5.79	0.01
Cell 1	8/9/88	58,550	8.56	79	18,185	208	981	50	866	14,875	17,368	3	185	N/A	20.13	3.01	0.01
Cell 1	11/12/88	63,200	8.75	134	18,001	231	1,159	48	1,049	16,028	21,173	N/A	207	0.69	23.21	3.15	0.01
Cell 1	2/11/89	43,500	8.33	115	12,456	193	861	36	949	13,823	17,770	N/A	195	N/A	17.18	2.78	7.20
Cell 1	5/20/89	53,050	8.73	240	13,762	220	957	57	1,019	12,227	16,012	N/A	N/A	N/A	24.37	2.73	N/A
Minimum		**25,643**	**8.33**	**79**	**8,689**	**192**	**748**	**10**	**729**	**9,295**	**9,600**	**3**	**153**	**0.45**	**9.91**	**2.71**	**0.01**
Maximum		**63,200**	**8.75**	**240**	**18,185**	**294**	**1,159**	**77**	**1,049**	**16,028**	**21,173**	**8**	**223**	**1.44**	**24.37**	**10.03**	**7.20**
Mean		**48,807**	**8.54**	**152**	**12,099**	**238**	**938**	**47**	**888**	**12,113**	**14,958**	**4**	**193**	**0.77**	**18.48**	**4.55**	**0.73**
Cell 2	8/26/86	129,050	8.35	114	49,500	850	4,445	50	1,875	71,000	23,400	N/A	591	1.52	104.73	10.03	0.02
Cell 2	11/15/86	70,741	8.24	140	16,799	361	2,226	193	1,187	16,150	26,065	12	190	1.42	38.34	24.51	N/A
Cell 2	2/7/87	35,848	8.75	178	14,544	372	1,379	183	724	14,850	17,155	4	137	0.59	21.53	8.94	N/A
Cell 2	5/18/87	85,000	8.83	123	17,068	308	1,326	63	583	14,995	29,719	4	215	N/A	36.26	7.23	0.01
Cell 2	8/4/87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	11/14/87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	2/20/88	65,150	8.92	137	21,030	428	1,424	79	888	15,033	34,331	4	185	1.42	30.31	8.17	0.01
Cell 2	5/21/88	71,400	8.77	154	19,559	261	1,238	55	720	15,181	24,836	28	191	1.03	26.65	5.74	0.37
Cell 2	8/9/88	174,700	7.42	-150	117,472	79	10,032	558	2,153	143,897	62,947	22	553	4.75	226.9	13.49	0.01
Cell 2	11/12/88	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	2/11/89	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cell 2	5/20/89	133,350	8.27	187	48,384	459	3,358	223	1,220	42,844	57,782	N/A	N/A	N/A	80.12	8.40	N/A
Minimum		**35,848**	**7.42**	**-150**	**14,544**	**79**	**1,238**	**50**	**583**	**14,850**	**17,155**	**4**	**137**	**0.59**	**21.53**	**5.74**	**0.01**
Maximum		**174,700**	**8.92**	**187**	**117,472**	**850**	**10,032**	**558**	**2,153**	**143,897**	**62,947**	**28**	**591**	**4.75**	**226.9**	**24.51**	**0.37**
Mean		**95,655**	**8.44**	**110**	**38,044**	**390**	**3,179**	**175**	**1,144**	**41,744**	**34,529**	**12**	**295**	**1.79**	**70.80**	**10.31**	**0.06**

<, Below limit of quantitation (LOQ)   y Not analyzed   DOC: Dissolved Organic Carbon   N/A Not available   *Values reported are consistently greater than that reported by CVRWQCB

Table 2.11 Results of Laboratory Chemical Analysis of Barbizon Evaporation Pond Waters

Description	Date of Sampling	EC (µmhos/cm)	pH	Eh (mV)	Na	Ca	Mg	K (mg/l)	HCO3	Cl	SO4	NO3	DOC	As*	B	Mo*	Se
Barbizon Pond																	
Inflow	8/26/86	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	11/15/86	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	2/7/87	11,042	7.49	179	2,594	123	153	4	848	1,488	3,582	2	172	2.06	2.14	1.16	<0.01
Inflow	5/16/87	8,720	7.43	212	1,594	92	107	5	871	1,004	1,901	7	139	0.91	2.73	0.69	<0.001
Inflow	8/4/87	6,110	7.83	168	1,391	73	88	3	659	876	1,700	12	134	1.00	3.27	0.79	0.00
Inflow	11/15/87	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	2/21/88	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	5/22/88	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	8/10/88	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	11/13/88	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inflow	2/11/89	7,730	7.36	125	3,101	64	198	7	897	1,634	3,382	8	180	<	4.04	0.91	0.00
Inflow	5/20/89	8,860	7.33	276	2,213	103	132	10	842	1,228	2,894	y	y		5.12	<	y
Minimum		**7,730**	**7.33**	**125**	**1,391**	**64**	**88**	**3**	**659**	**876**	**1,700**	**2**	**134**	**0.91**	**2.14**	**0.69**	**0.00**
Maximum		**11,042**	**7.83**	**276**	**3,101**	**123**	**198**	**10**	**897**	**1,634**	**3,582**	**12**	**180**	**2.06**	**5.12**	**1.16**	**0.00**
Mean		**8,492**	**7.49**	**192**	**2,179**	**91**	**136**	**6**	**783**	**1,246**	**2,652**	**7**	**156**	**1.32**	**3.46**	**0.88**	**0.00**
Cell A, West	8/26/86	23,390	9.10	153	5,400	112	356	25	854	3,720	7,400	<	210	1.44	10.71	2.02	<
Cell A, West	11/15/86	29,500	9.05	188	6,795	130	458	51	868	4,087	10,300	1	169	1.10	18.10	4.26	<0.01
Cell A, West	2/7/87	21,531	8.62	182	4,662	123	324	22	713	2,639	7,290	4	114	0.45	5.68	1.72	<0.01
Cell A, West	5/16/87	28,100	8.70	177	5,539	246	422	21	714	3,728	8,959	1	198	0.22	10.75	2.37	<0.001
Cell A, West	8/4/87	29,200	9.43	151	8,054	129	414	20	482	3,974	9,551	1	121	0.72	11.94	2.42	<
Cell A, West	11/15/87	20,800	8.62	173	6,592	196	461	36	859	4,166	10,261	1	170	0.20	11.50	0.69	<0.005
Cell A, West	2/21/88	18,810	8.47	-93	8,320	186	428	18	677	3,805	9,572	1	150	0.44	9.79	1.77	0.00
Cell A, West	5/22/88	24,100	8.95	161	5,964	141	424	17	531	3,641	9,182	1	113	<	10.32	2.19	0.00
Cell A, West	8/10/88	39,900	8.88	18	12,730	345	696	28	354	7,084	17,340	1	81	<	14.60	1.04	<
Cell A, West	11/13/88	22,300	7.72	124	6,864	256	478	17	877	4,954	10,468	y	137	<	10.58	0.54	0.00
Cell A, West	2/11/89	14,360	8.58	75	5,148	237	377	13	708	3,337	7,868	y	125	<	8.01	<	0.00
Cell A, West	5/20/89	31,500	8.81	243	2,349	102	140	9	433	1,424	3,011	5	y		5.03	<	y
Minimum		**14,360**	**7.72**	**-93**	**2,349**	**102**	**140**	**9**	**354**	**1,424**	**3,011**	**1**	**81**	**0.20**	**5.03**	**0.54**	**0.00**
Maximum		**39,900**	**9.43**	**243**	**12,730**	**345**	**696**	**51**	**868**	**7,084**	**17,340**	**5**	**210**	**1.44**	**18.10**	**4.26**	**0.00**
Mean		**25,124**	**8.74**	**128**	**6,201**	**184**	**416**	**23**	**638**	**3,860**	**9,267**	**2**	**142**	**0.65**	**10.58**	**1.90**	**0.00**
Cell B, East	8/26/86	21,850	9.10	147	5,000	96	325	28	878	3,500	8,400	<	209	1.37	9.88	2.26	<
Cell B, East	11/15/86	27,895	9.16	172	6,750	118	431	42	866	4,380	9,000	1	125	0.58	18.47	3.93	<0.01
Cell B, East	2/7/87	14,625	8.69	182	5,251	141	315	21	793	2,943	8,171	1	132	0.70	6.01	2.00	<0.01
Cell B, East	5/16/87	27,700	8.92	168	5,558	137	422	17	720	3,863	9,088	1	206	<	10.35	2.18	<0.001
Cell B, East	8/4/87	27,200	9.32	148	5,146	45	336	18	610	3,569	8,001	1	150	0.74	10.26	2.05	<
Cell B, East	11/15/87	23,600	8.80	172	7,470	183	567	45	641	5,021	11,785	1	164	0.32	13.71	0.79	<0.005
Cell B, East	2/21/88	18,450	9.07	-15	5,795	141	396	13	653	3,621	8,596	1	137	0.48	9.41	1.70	0.00
Cell B, East	5/22/88	26,200	9.26	183	8,602	120	466	11	561	4,181	10,335	1	130	<	11.58	2.17	0.00
Cell B, East	8/10/88	48,300	9.40	23	18,570	160	704	35	421	9,723	22,391	1	124	<	20.50	1.29	<
Cell B, East	11/13/88	19,710	8.85	118	8,283	51	376	14	846	4,486	8,557	y	153	<	8.94	0.59	0.00
Cell B, East	2/11/89	12,910	9.07	94	4,748	120	321	13	659	3,101	8,641	1	110	<	7.22	<	<
Cell B, East	5/20/89	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Minimum		**12,910**	**8.69**	**-15**	**4,748**	**45**	**315**	**11**	**421**	**2,943**	**8,400**	**1**	**110**	**0.32**	**6.01**	**0.59**	**0.00**
Maximum		**48,300**	**9.40**	**182**	**18,570**	**183**	**704**	**45**	**878**	**9,723**	**22,391**	**1**	**209**	**1.37**	**20.50**	**3.93**	**0.00**
Mean		**24,222**	**9.06**	**125**	**8,834**	**119**	**424**	**23**	**696**	**4,399**	**9,906**	**1**	**149**	**0.70**	**11.48**	**1.90**	**0.00**

x No Sample y: Not analyzed DOC: Dissolved Organic Carbon <: Below limit of quantitation (LOQ) *Values reported are consistently greater than that reported by CVRWQCB

Table 2.12 Results of Laboratory Chemical Analysis of Barbizon Evaporation Pond Waters

Description	Date of Sampling	EC (µmhos/cm)	pH	Eh (mV)	Na	Ca	Mg	K (mg/l)	HCO3	Cl	SO4	NO3	DOC	As*	B	Mo*	Se
Barbizon Pond																	
Cell C, East	8/26/86	20,900	9 10	147	4,850	90	292	38	897	3,200	8,000	<	202	1.46	9 09	2 21	<
Cell C, East	11/15/86	28,000	9 08	153	6,320	111	406	40	885	4,196	9,000	1	123	0 23	19 55	4 42	<0 01
Cell C, East	2/7/87	18,768	8 59	150	4,498	133	254	19	744	2,460	6,677	1	148	1 93	5 31	1 41	<0 01
Cell C, East	5/16/87	21,400	8 98	157	4,050	112	281	11	702	2,603	5,934	2	180	0 68	7 84	1.72	<0 001
Cell C, East	8/4/87	25,200	9 21	149	4,863	55	331	19	628	3,231	7,099	1	157	0 71	10 18	1.95	<
Cell C, East	11/15/87	24,200	8 78	171	7,725	177	577	47	598	5,304	12,372	1	174	0 18	14 54	0.77	<0 005
Cell C, East	2/21/88	16,000	9 21	5	5,874	150	420	10	665	3,812	8,744	1	138	0 58	10 28	1.32	0 00
Cell C, East	5/22/88	25,500	9 07	184	6489	118	444	13	616	4112	10157	1	156	<	10 68	2 18	0 00
Cell C, East	8/10/88	21,500	9 42	-132	6185	50	260	13	537	3144	8934	1	94	<	8 38	0 55	<
Cell C, East	11/13/88	11,170	8 96	113	3221	50	194	8	726	2259	4671	y	121	<	4 68	<	N/A
Cell C, East	2/11/89	8,780	9 22	95	2660	125	170	4	665	1998	4172	y	107	<	4 68	<	0 00
Cell C, East	5/21/89	9,320	8 25	260	6532	293	668	41	874	5541	13348	y	y	x	16 02	<	y
Minimum		**8,780**	**8.25**	**-132**	**2,660**	**50**	**170**	**4**	**537**	**1,998**	**4,172**	**1**	**94**	**0.18**	**4.68**	**0.55**	**0.00**
Maximum		**28,000**	**9.42**	**260**	**8,532**	**293**	**668**	**47**	**897**	**5,541**	**13,348**	**2**	**202**	**1.93**	**19.55**	**4.42**	**0.00**
Mean		**19,228**	**8.99**	**119**	**5,419**	**122**	**358**	**22**	**711**	**3,472**	**7,928**	**1**	**146**	**0.82**	**10.10**	**1.84**	**0.00**

x No Sample   y Not analyzed   DOC Dissolved Organic Carbon   < Below limit of quantitation (LOQ)   *Values reported are consistently greater than that reported by CVRWQCB

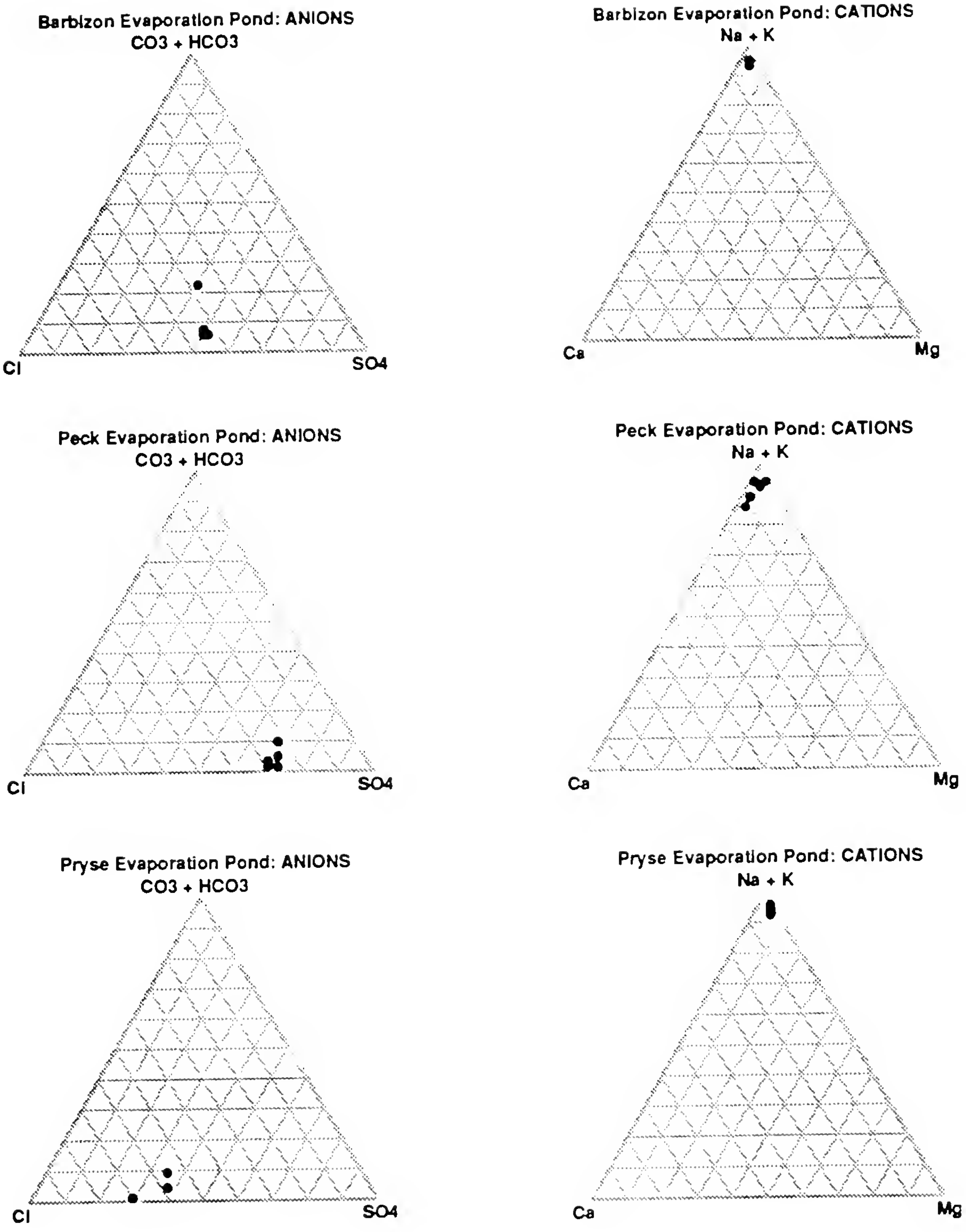


Figure 2.1 Ternary diagrams of the relative concentrations of major cations and anions in evaporation pond waters (meq/l basis)

SECTION 3
DIURNAL MONITORING OF PONDS

Introduction

Diurnal studies were carried out at Peck, Pryse and Barbizon evaporation ponds in March and August 1989. The studies comprised bihourly analysis of water samples from the ponds, and half-hourly data acquisition of weather conditions. Water samples were collected from one site at Barbizon and Pryse ponds, while Peck pond was sampled at two sites in March and three in August. Of the three samples at Peck pond during the August study, one was taken from a pool containing brine shrimp (BS), and another from a brackish pool containing salts (SP). The third sample was taken from an adjacent cell containing less saline water.

Methodology

Water Chemistry Parameters

Pond water was collected at regular intervals at selected locations in 1 L Nalgene polyethylene bottles. Chemical parameters (Table 3.1) were measured and recorded on-site.

Table 3.1 Instruments used for measuring Pond Water Chemical Parameters in Diurnal Study

☐ Temperature and pH	Markson Model 90 pH/Temperature meter, Markson combination electrode
☐ Eh	Markson Model 90 Meter with Markson Pt electrode
☐ DO	YSI Model 54A Oxygen Meter and Probe
☐ Conductivity	YSI Model 32 Conductivity Meter, YSI 3417 Dip-Type Cell, YSI 400 Series Temperature Probe
☐ Density	Fisherbrand specific gravity hydrometer range 1.000-1.225 and cylinder

Evaporation Parameters

Diurnal monitoring for evaporation data at the agricultural drainage evaporation ponds was accomplished using instrumentation developed by Campbell Scientific. The principal device was a CR-21 battery-operated data-logger connected to various weather instruments described later.

Five parameters were monitored every half hour during a 24-hour period. First, wind speed was measured with a Met One 014 wind cup anemometer. Wind direction was monitored using a Met One wind vane. Gross solar radiation was measured using a Lichor pyranometer from Campbell Scientific. Relative humidity was measured using a Physical-Chem instrument also from Campbell Scientific. Additionally, temperature was recorded using a Campbell Scientific temperature probe.

Instrumentation was set up on a pipe and stand cross-bar (Figure 3.1). The wind-speed and the wind-direction instruments were placed 2 m above ground level on one of two cross-bars. All other instruments were attached onto the other cross-bar 1 m above ground level. Due to the extreme heat of the summer monitoring trip, the temperature probe was kept shaded. The CR-21 unit was kept out of direct sunlight and also protected from dew-point moisture by wrapping it in a plastic bag.

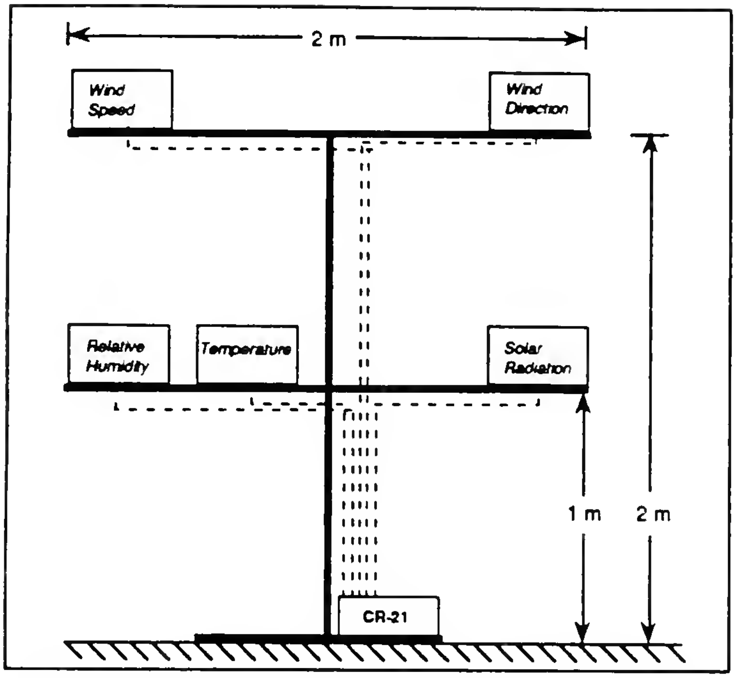


Figure 3.1 Weather monitoring equipment set-up.

Incoming data to the CR-21 data-logger is processed by pre-programmed macro programs which transform the direct readings into the desired units. Data stored in the data logger is transcribed into a computer spreadsheet at the end of each 24 hour monitoring period.

Observations

Pond Waters

Figures 3.2-3.5 and 3.9-3.13 show the pond water diurnal data for March and August, respectively. All data tables for the above figures are in Appendix A. Cyclical variations in several of the water quality parameters were expected and observed in most cases. For example, variations in dissolved oxygen are directly related to the activity of aquatic organisms including algae (Barbizon) and plankton (Peck BS). Fluctuations in water temperature are dampened and slightly lagged those of air temperature. None of these observations were unexpected.

The electrical conductivity (EC) of the waters did not remain constant even though they were corrected for temperature. The EC data also did not exhibit a wave-like nature. Interestingly, the EC did not change dramatically with temperature in Peck SP which contained water in equilibrium with a vast amount of evaporite minerals (mainly mirabilite). The response to temperature change in a saturated solution may increase with larger temperature changes or may be simply a slow process. Diurnal changes in density, pH and Eh were not readily distinguishable and often suffered from 'noise'.

Above Pond

Figures 3.6-3.8 and 3.14-3.16 show the above pond diurnal data for March and August, respectively. All data tables for the above figures are in Appendix A. Solar radiation generally peaked before noon in the March study, but peaked just after noon during the August study. Relative humidity tended to be low during the day and significantly greater at night. The air temperature behaves cyclically, peaking at about 2 to 4 PM and reaching a minimum around 3 to 6 AM. The wind direction data is evenly scattered at all angles except at Peck where the wind predominantly came from the northeast. Wind speeds averaged between 0.4 to 0.6 m.s^{-1}.

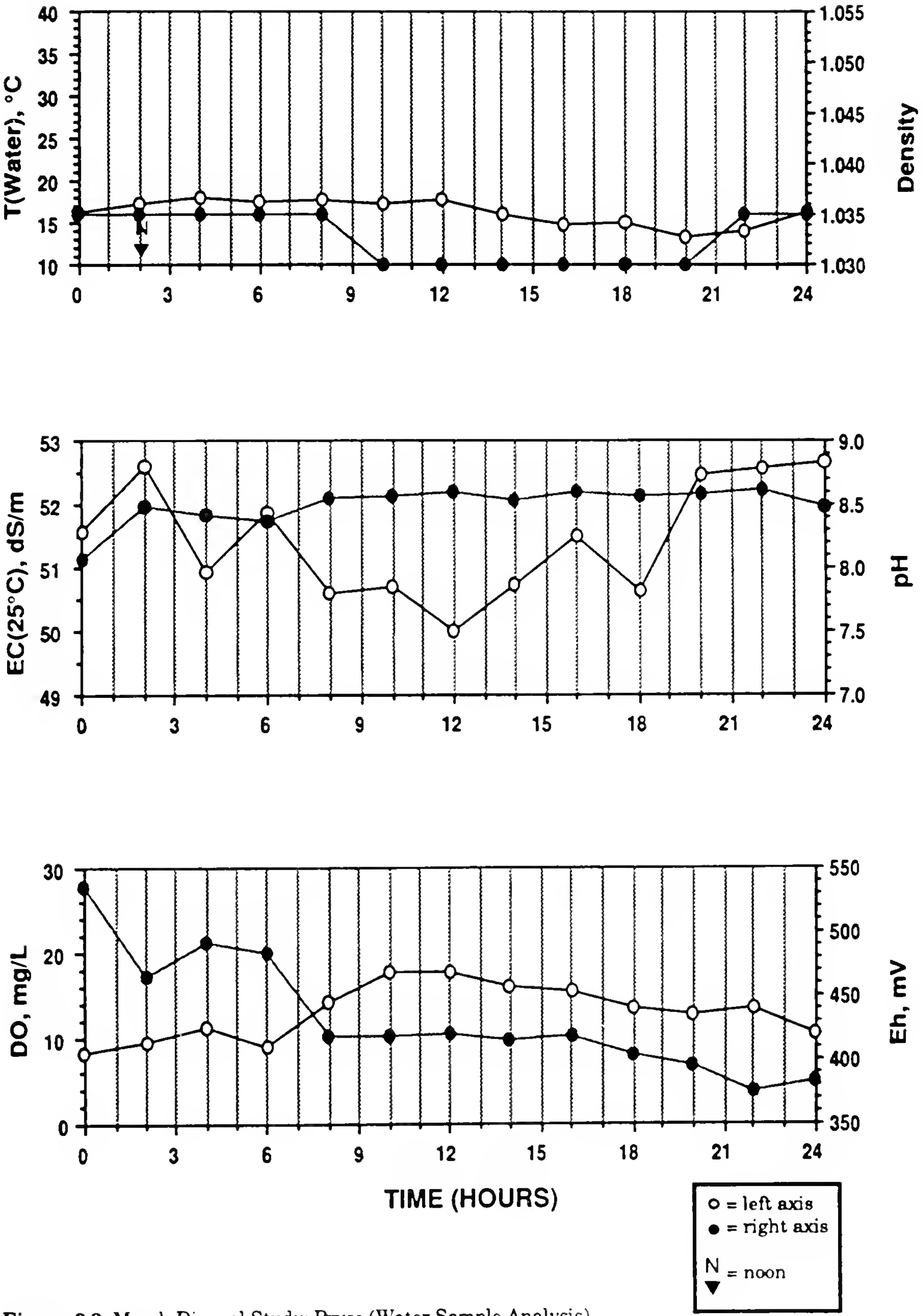


Figure 3.2 March Diurnal Study: Pryse (Water Sample Analysis)

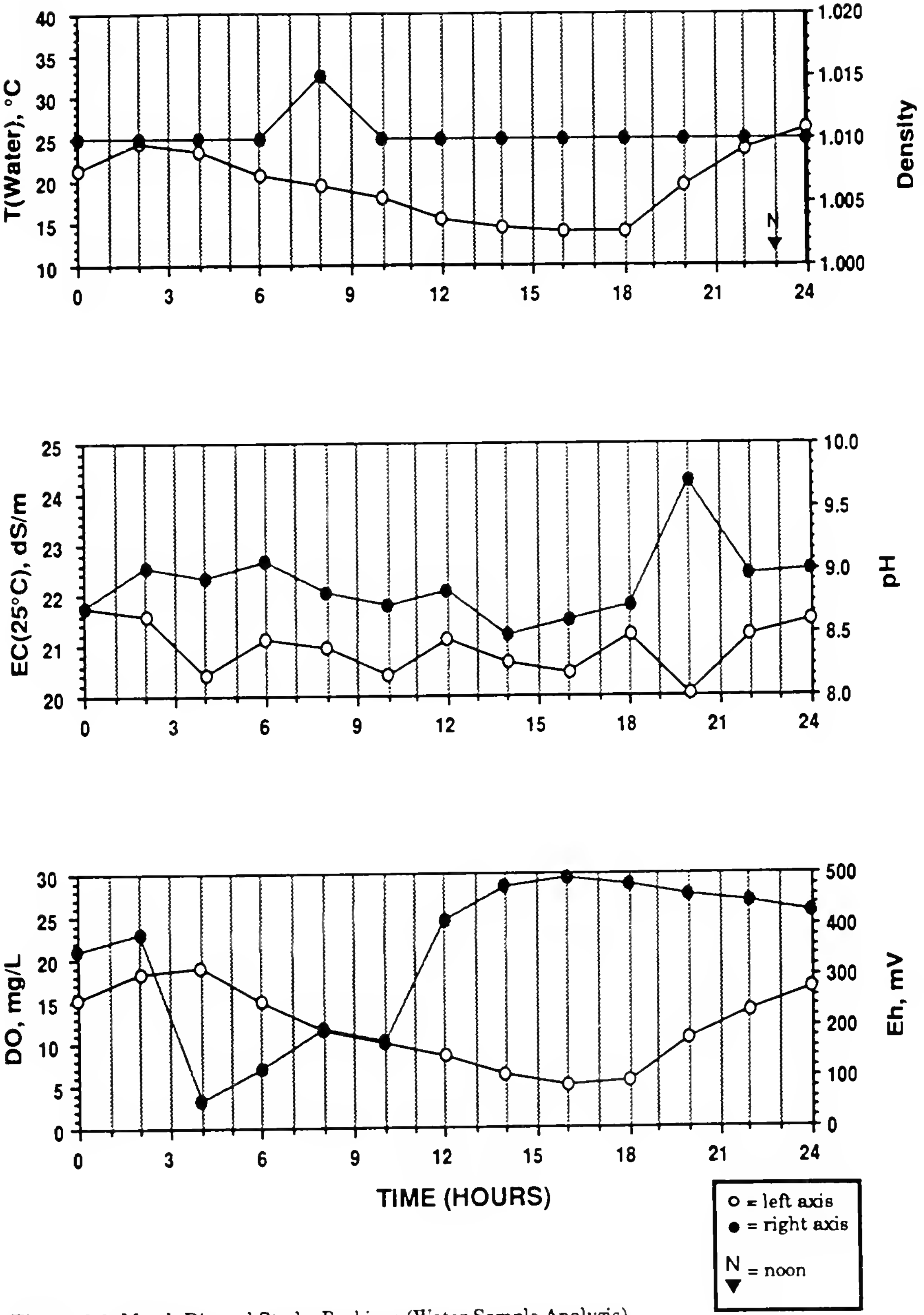


Figure 3.3 March Diurnal Study: Barbizon (Water Sample Analysis)

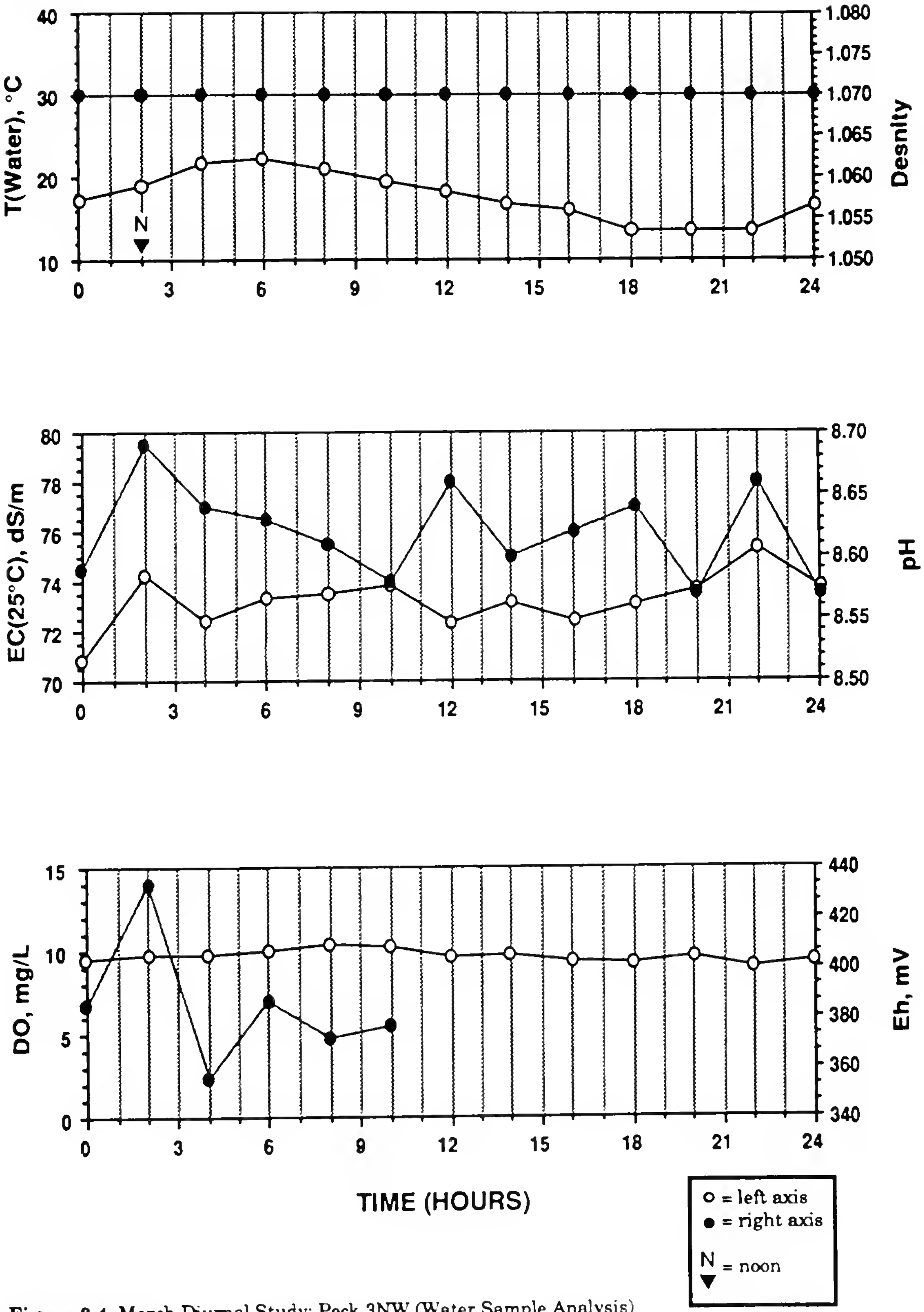


Figure 3.4 March Diurnal Study: Peck 3NW (Water Sample Analysis)

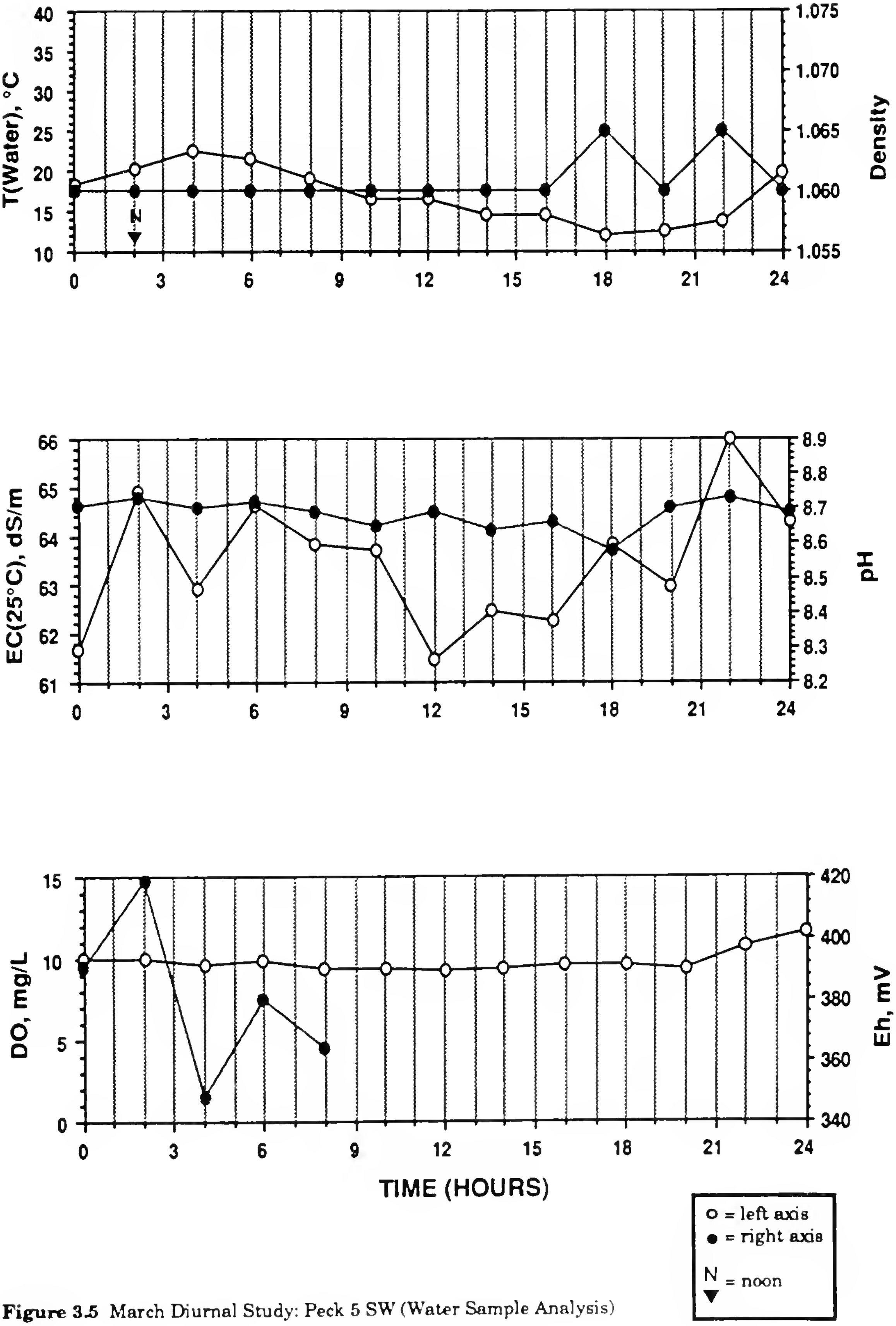


Figure 3.5 March Diurnal Study: Peck 5 SW (Water Sample Analysis)

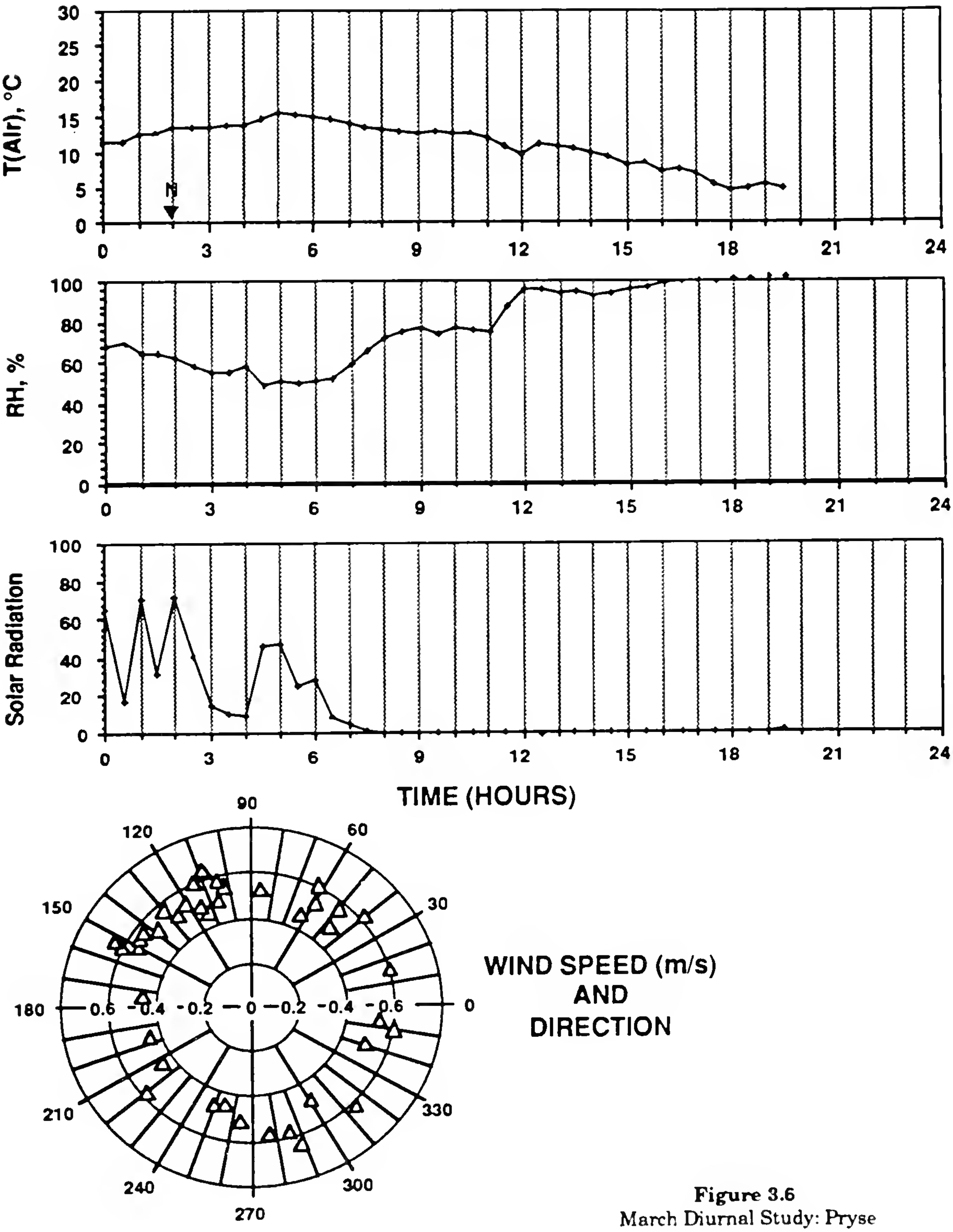
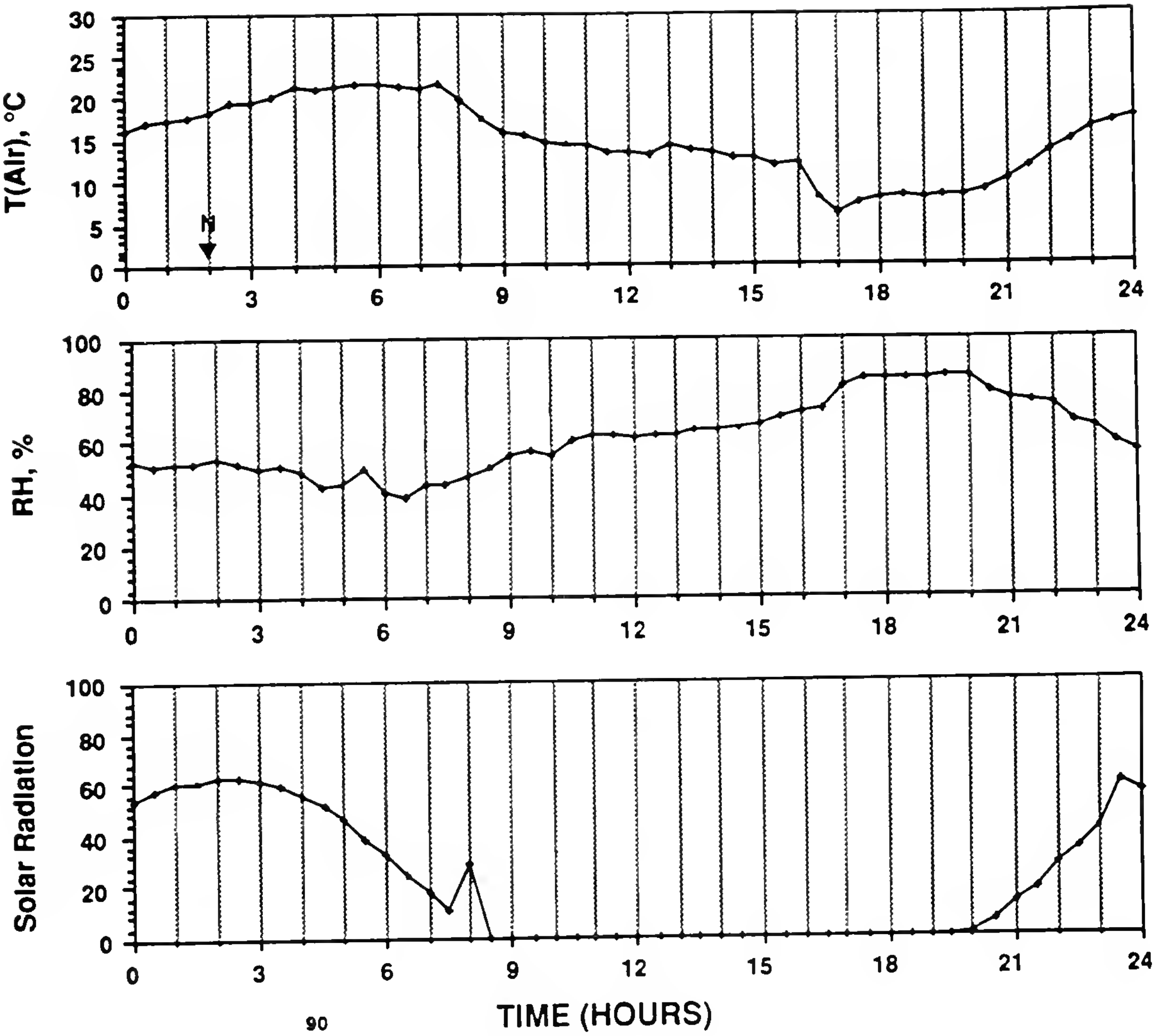


Figure 3.6
March Diurnal Study: Pryse
(Weather Monitoring)



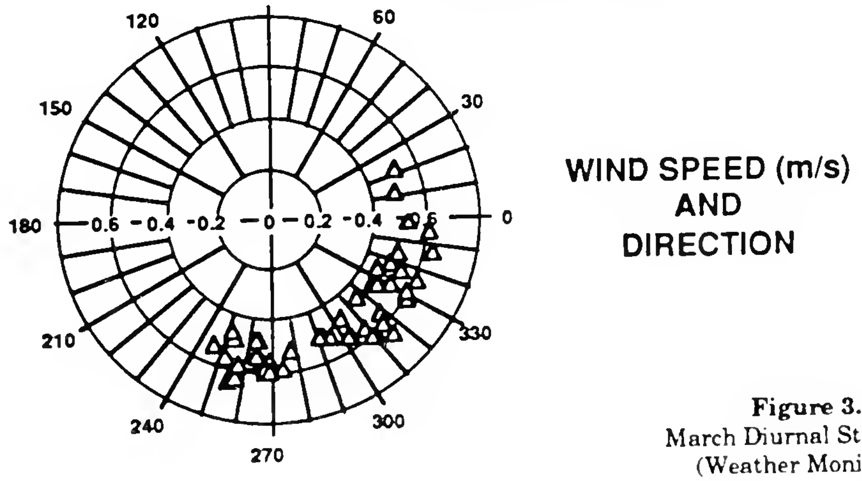
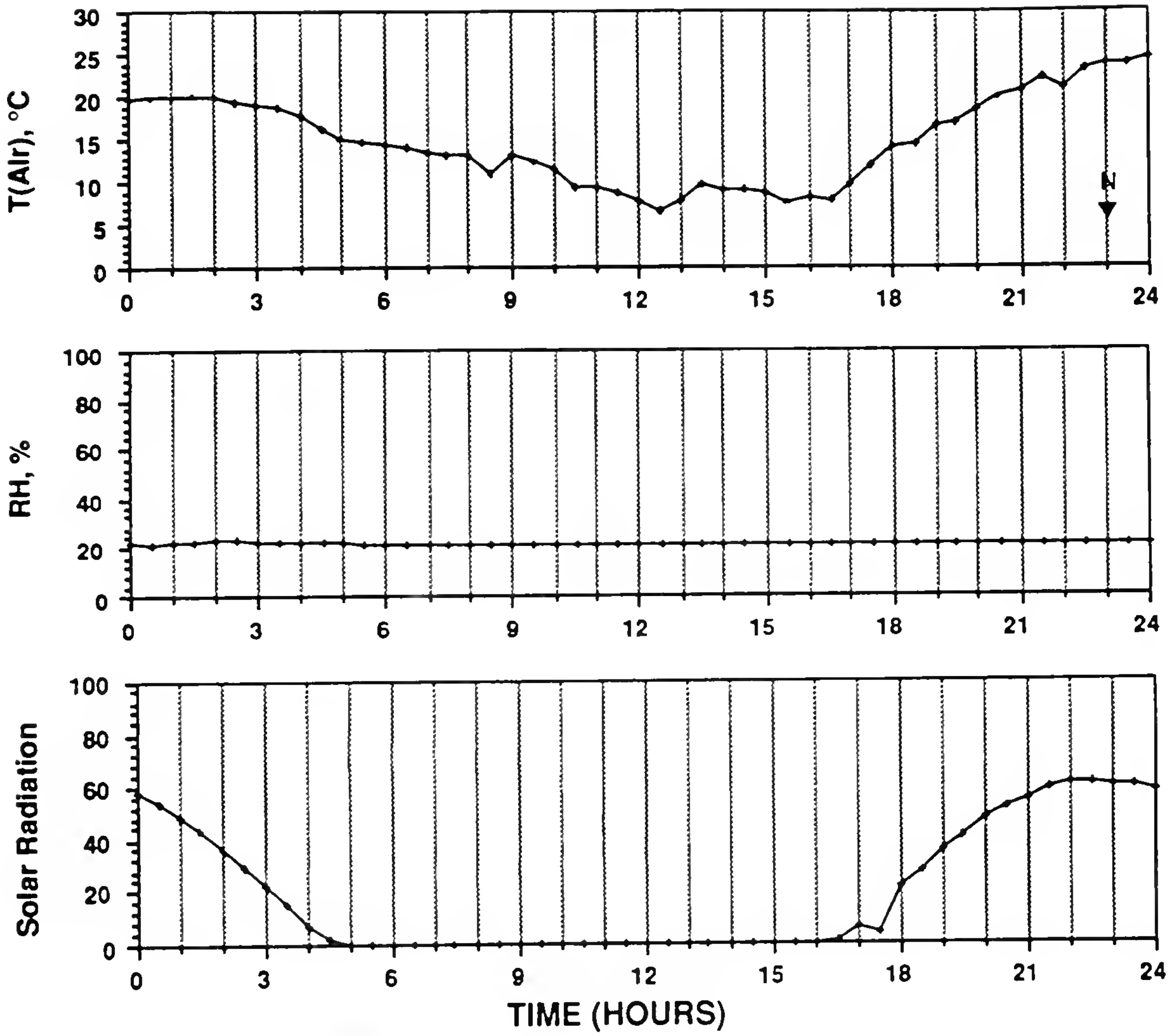


Figure 3.7
March Diurnal Study: Peck
(Weather Monitoring)



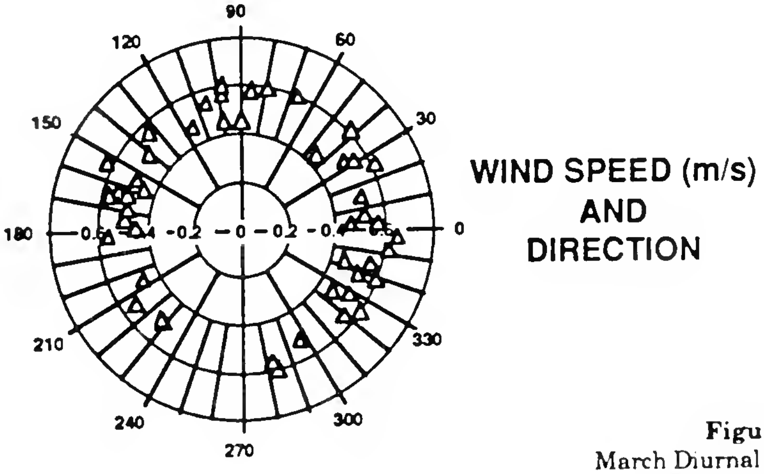


Figure 3.8
March Diurnal Study: Barbizon
(Weather Monitoring)

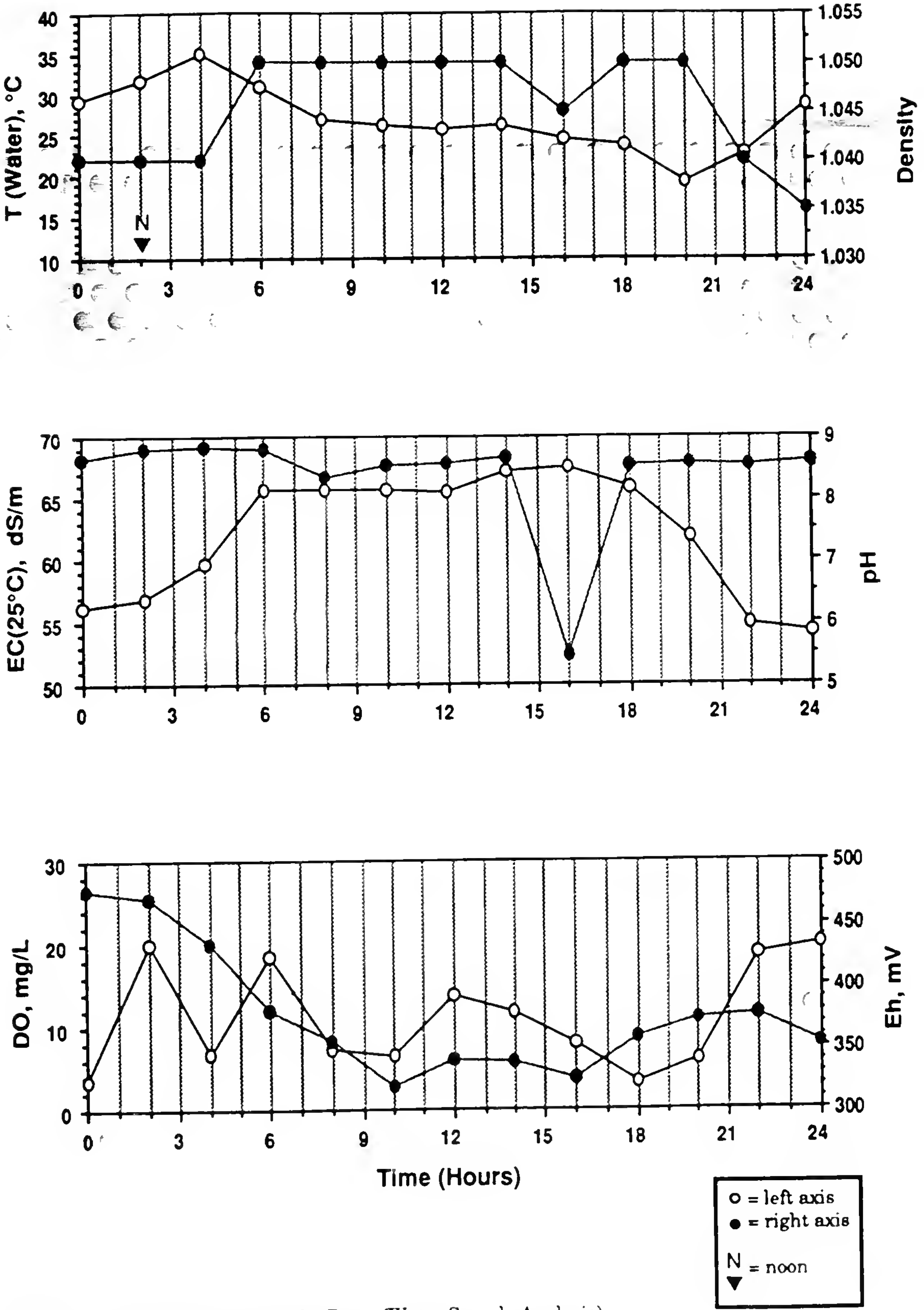


Figure 3.9 August Diurnal Study: Pryse (Water Sample Analysis)

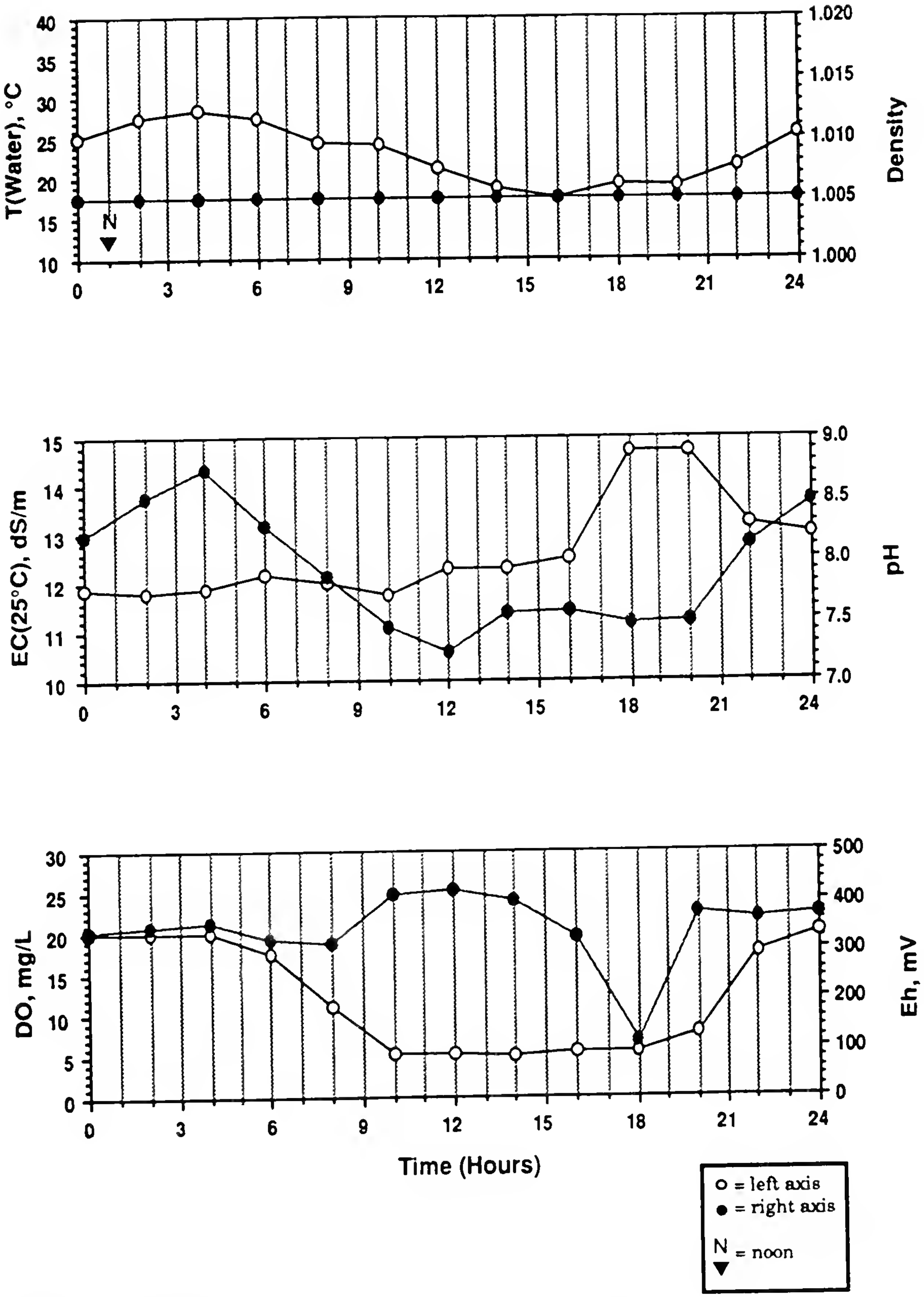


Figure 3.10 August Diurnal Study: Barbizon (Water Sample Analysis)

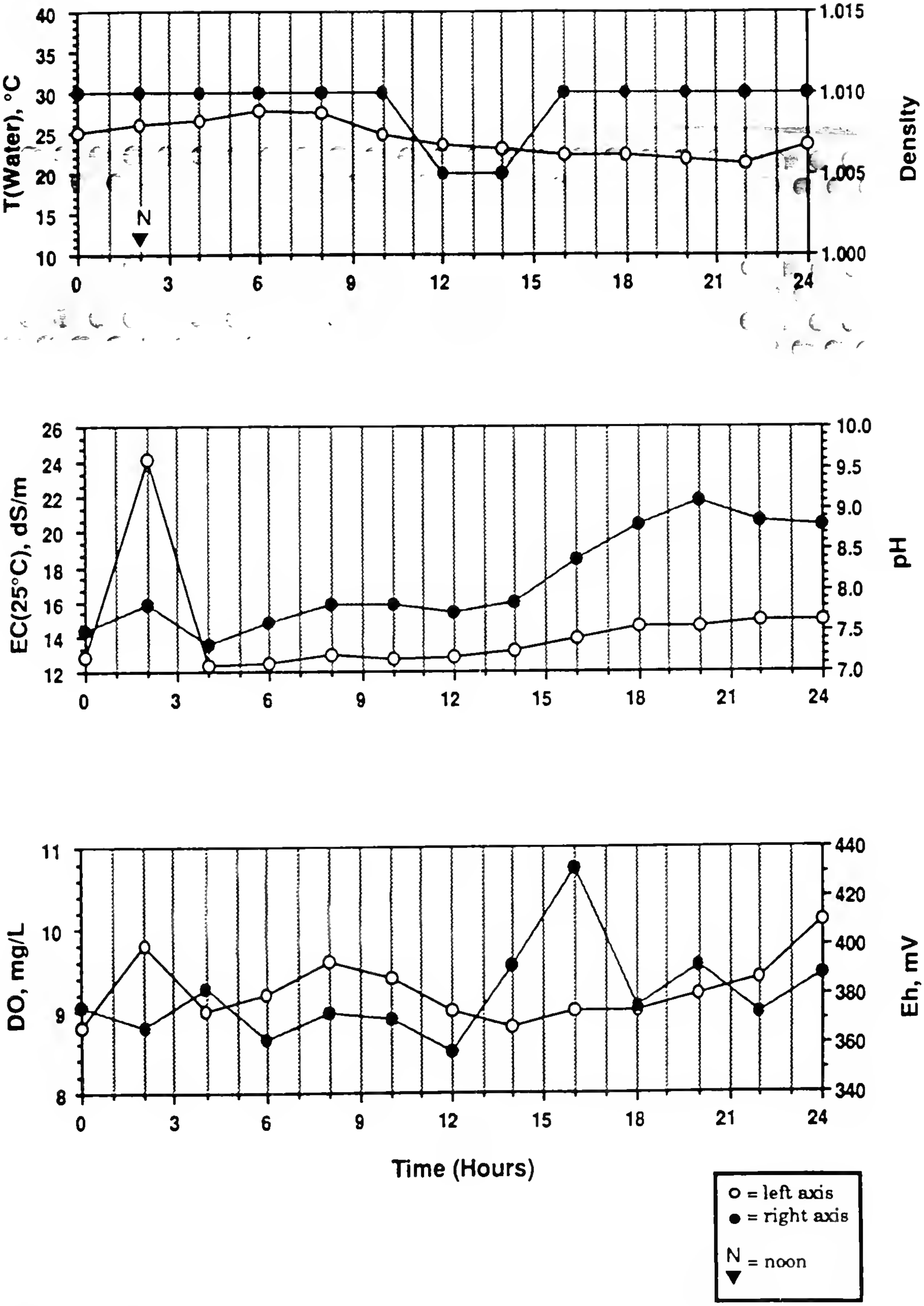


Figure 3.11 August Diurnal Study: Peck 1NW (Water Sample Analysis)

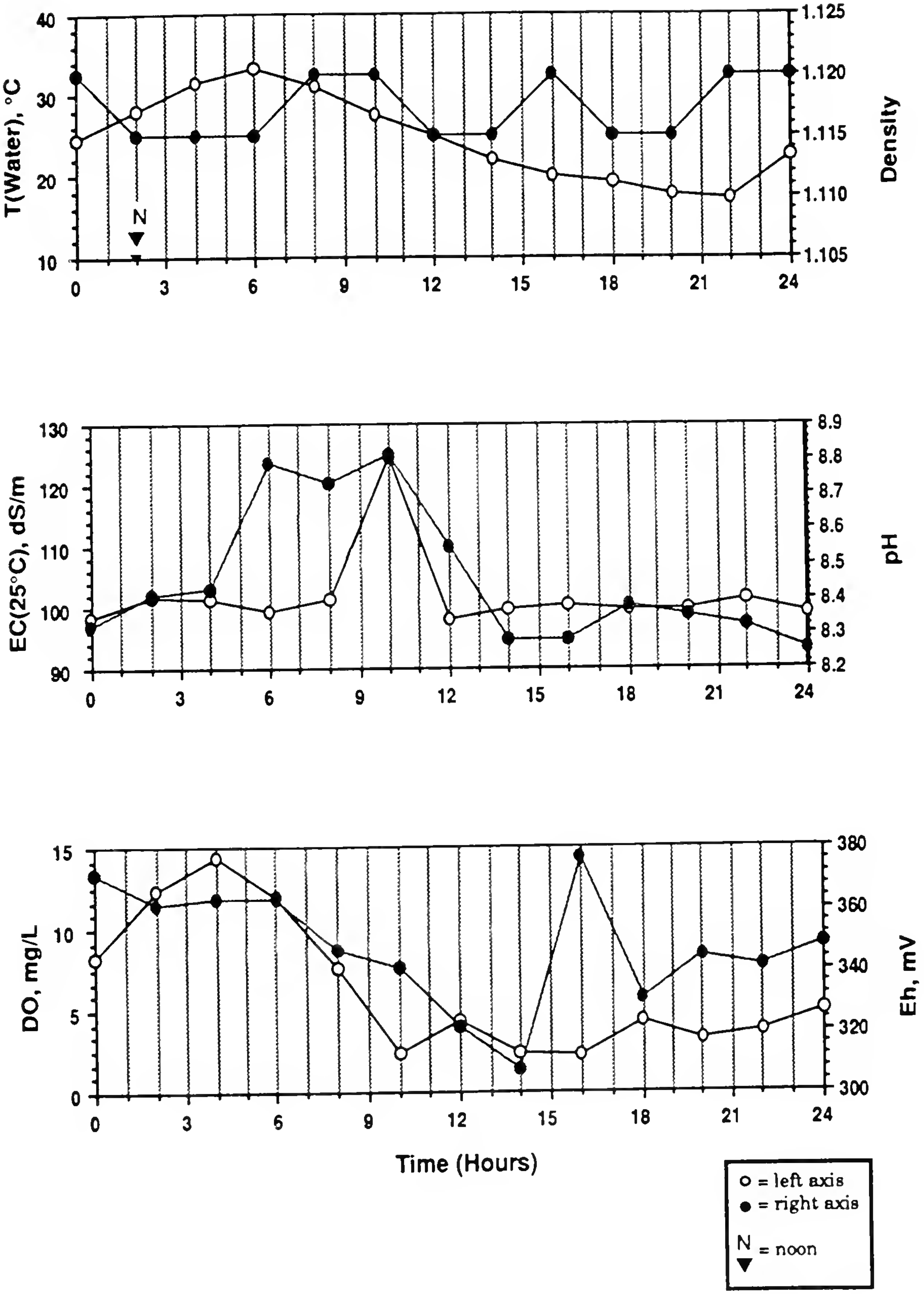


Figure 3.12 August Diurnal Study: Peck BS (Water Sample Analysis)

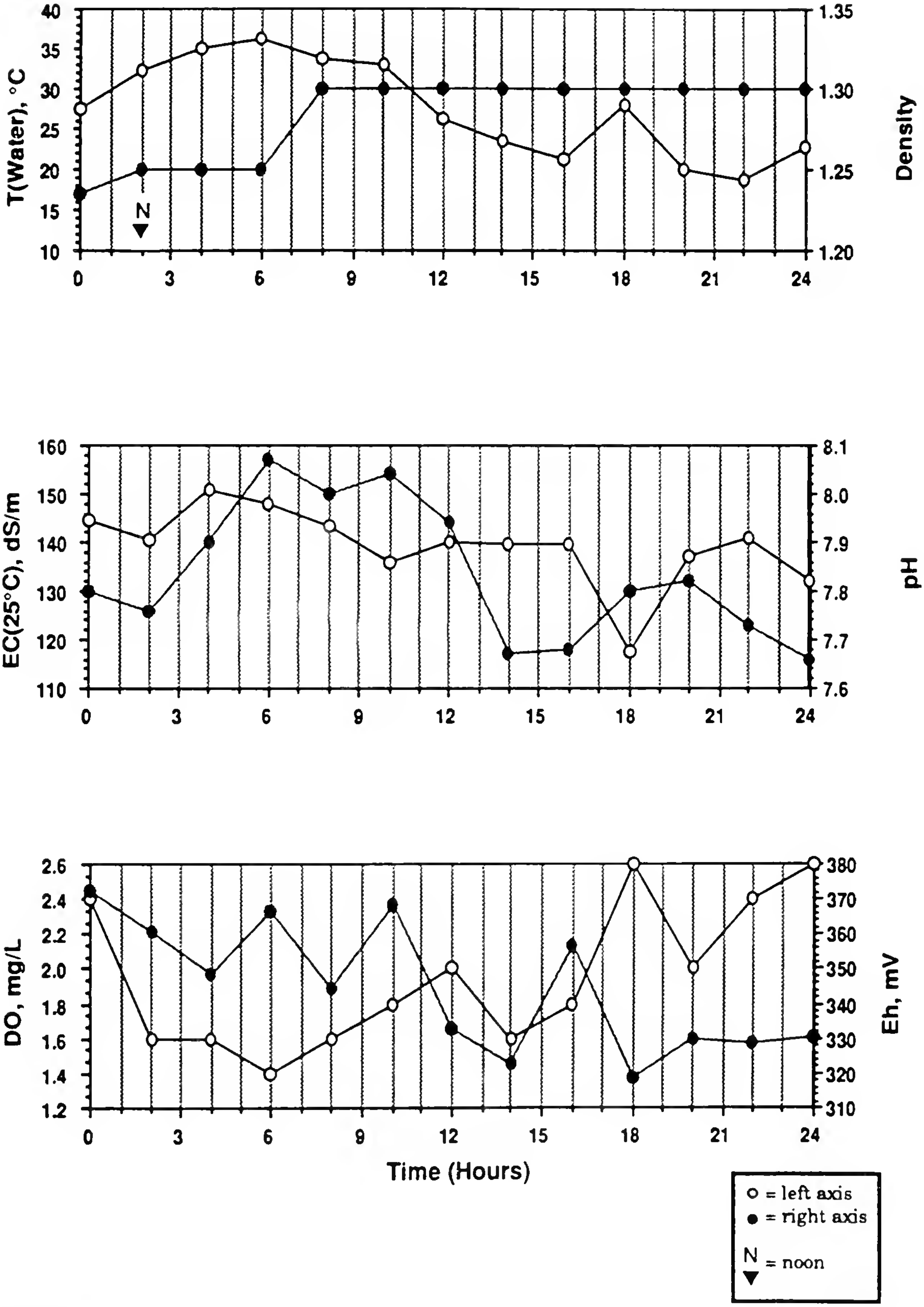


Figure 3.13 August Diurnal Study: Peck SP (Water Sample Analysis)

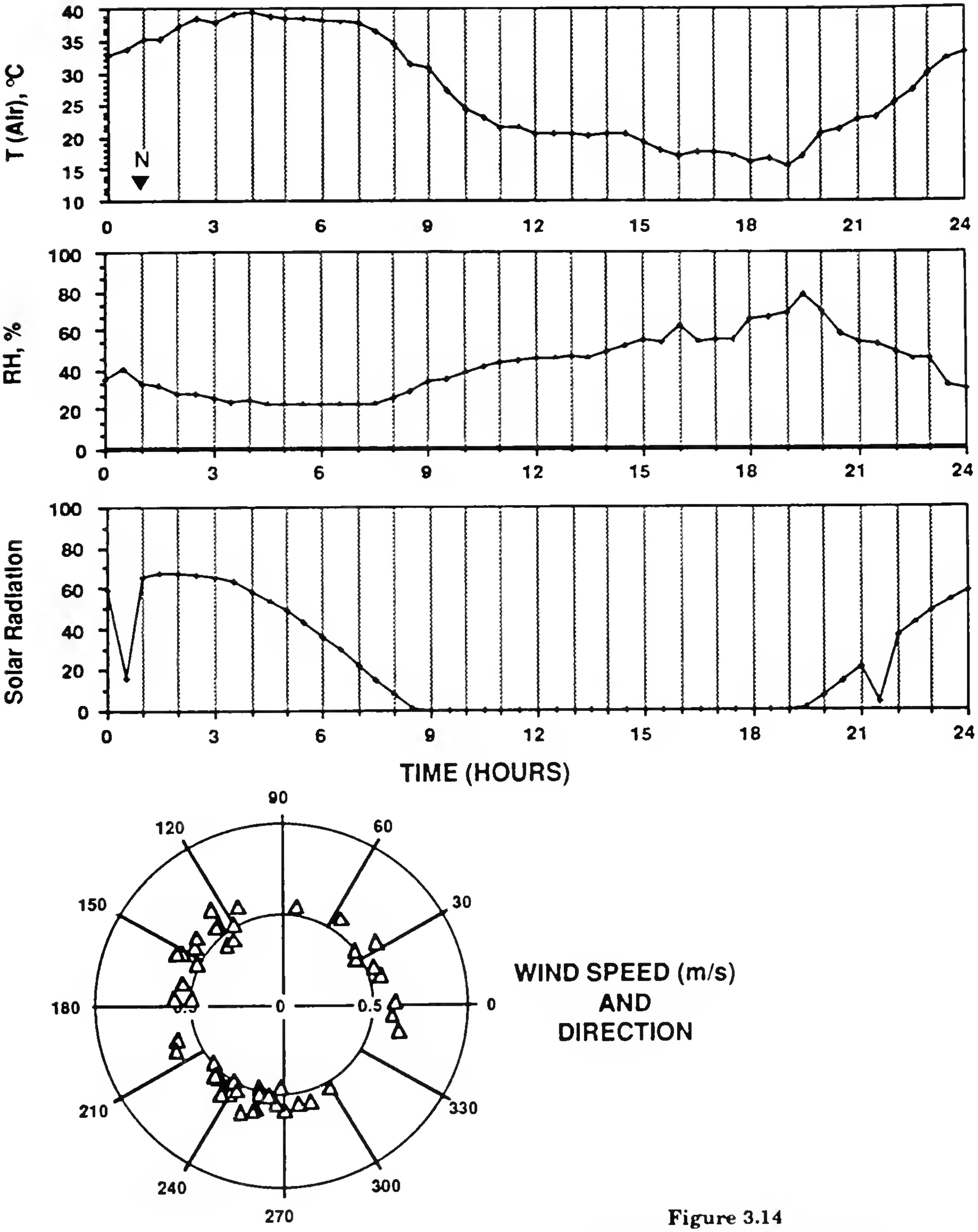


Figure 3.14
August Diurnal Study: Pryse
(Weather Monitoring)

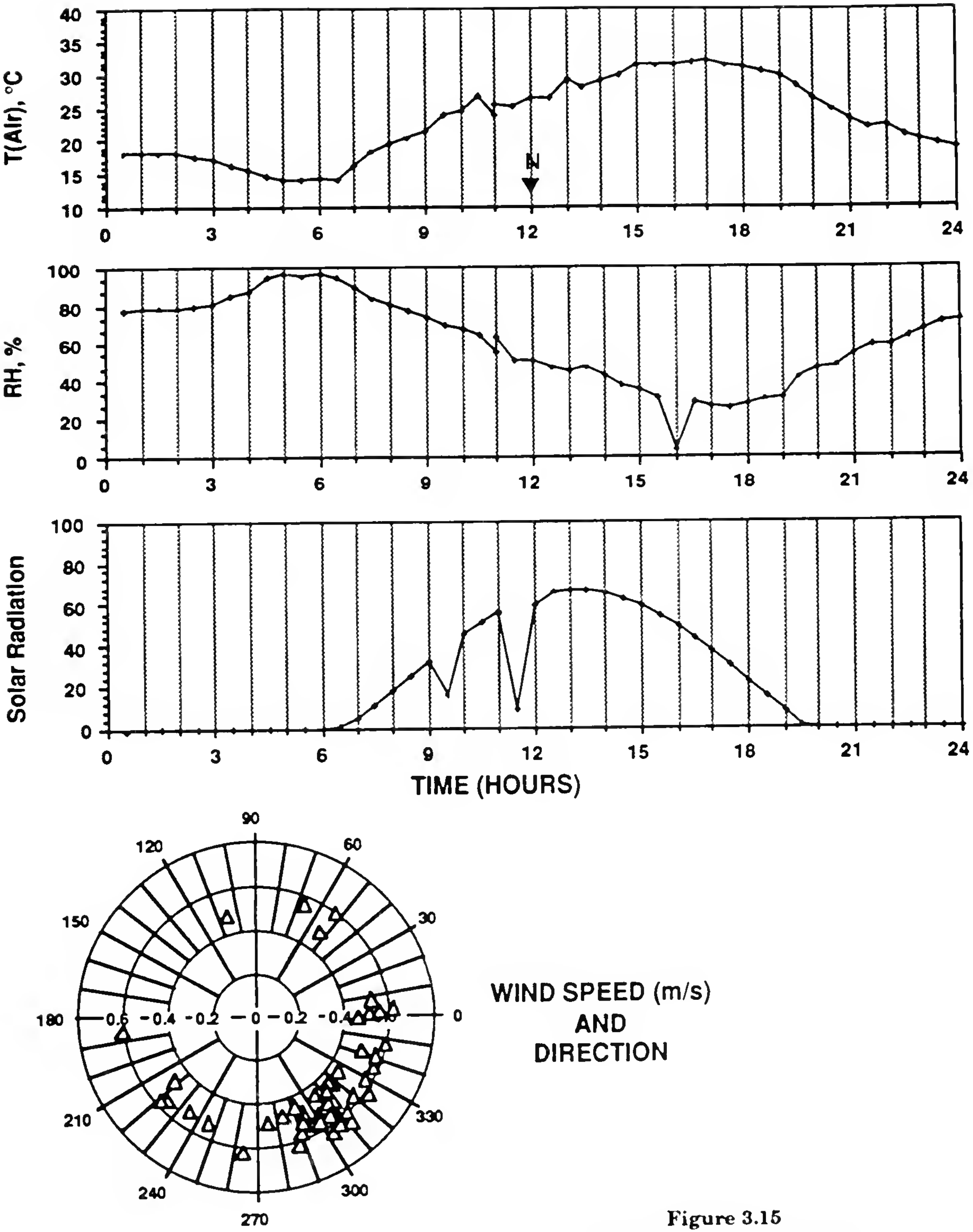


Figure 3.15
August Diurnal Study: Barbizon
(Weather Monitoring)

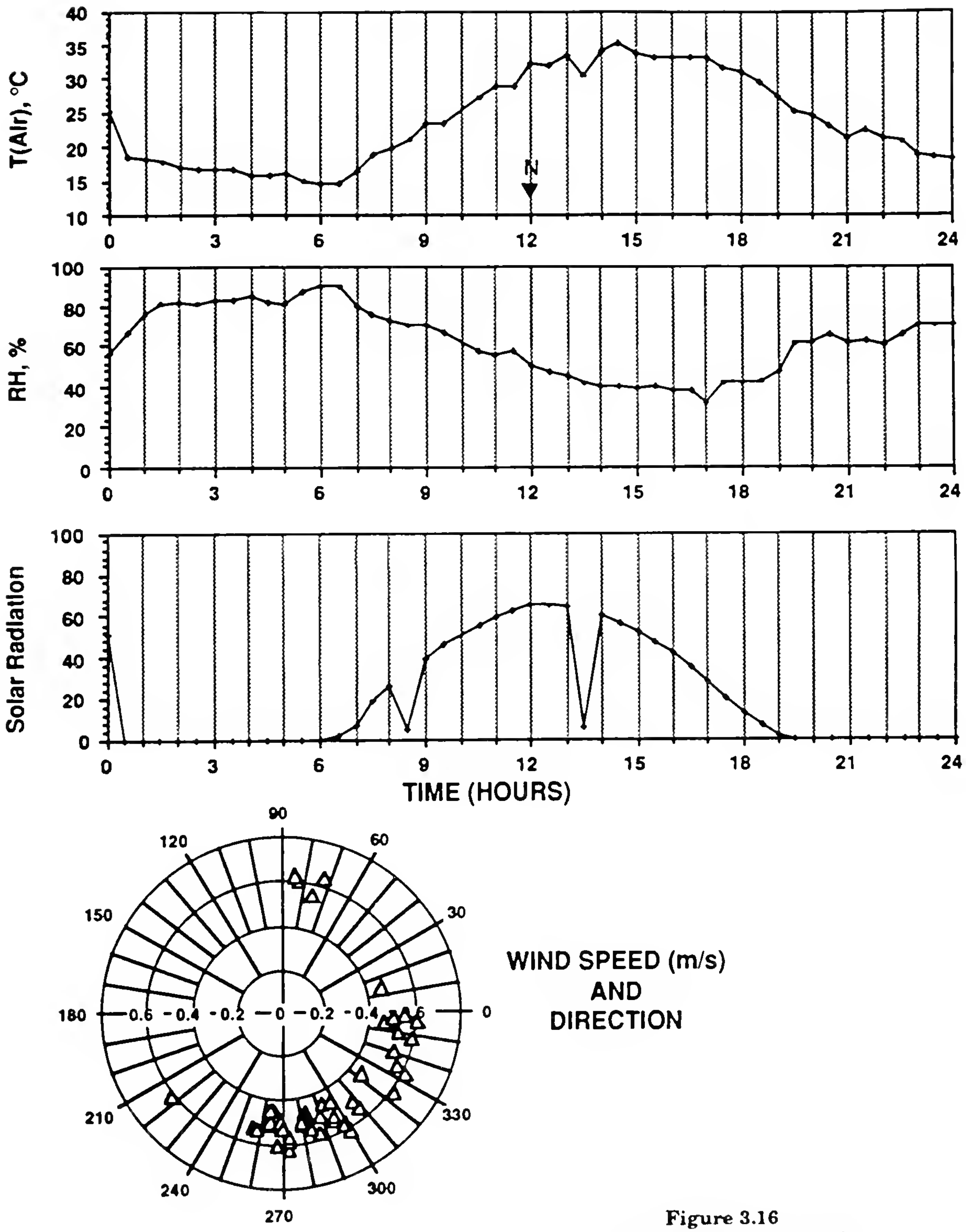


Figure 3.16
August Diurnal Study: Peck
(Weather Monitoring)

CIMIS Weather Data

The CIMIS hourly weather data from stations near to the evaporation ponds under investigation (Peck, Pryse, and Barbizon) for 24-hour periods in March and August, 1989 are included in Appendix B. Fluctuation of conditions recorded in the CIMIS data include: temperature from 7 to 17°C; relative humidity from 40 to 75%; wind speed from 1 to 4.8 mile/hr (usage of miles/hr rather than m/s is necessary for calculations. However, all records of data are in m/s); and vapor pressure from 3.2 mbar to 9 mbar. This suggests that the evaporation rate will also vary similarly.

Floating Evaporation Pan Data

Table 3.2 shows the evaporation measurements from floating evaporation pans located at Peck evaporation pond with different salinity levels. Generally, evaporation rate decreases as salinity increases due to a salinity effect on reducing water surface vapor pressure. Figures 3.17, 3.18, 3.19 and 3.20 show that the evaporation rate from water having an EC=14 dS/m was higher than water with an EC of 30 dS/m. Additionally, water with an EC of 30 dS/m has a higher daily evaporation rate than water of 47 dS/m. Figure 3.21 shows that the cumulative evaporation from the floating pans was of the order EC= 14 dS/m > =30 dS/m > =47 dS/m >ET_0. Table 3.3 contains the 2- day hourly evaporation loss (mm/hr) and cumulative loss (mm) from the floating pans having an EC of 14 dS/m. The data shows that the evaporation rate during night time contributed significantly to the total evaporation. Figures 3.22 to 3.26 show the effect of the individual weather parameters on the potential evapotranspiration (ET_0) and the average evaporation rate from the floating pans containing saline water (EC= 14 dS/m) at Peck pond. Average measured daily evaporation rates of agricultural drainage decreased from 8.0 mm/day in August to 2.3 mm/day in November for the 14 dS/m water (Figure 3.27).

Potential Use of CIMIS ET_0 as a Predictor of Evaporation Rate from Evaporation Ponds

California's network of CIMIS weather stations could provide a useful tool for predicting evaporation rates from evaporation ponds. Cumulative evaporation measurements from Peck pond were well correlated to CIMIS-calculated ET_0 as reported from the nearby station at Murrietta farms. An ET_0 correction factor was calculated for cumulative evaporation rates at different salinity levels from data collected during August through October, 1989. This correction factor was then correlated to the EC of the water up to 61 dS/m (Figure 3.28). The result is a simple linear model with an r-squared value of 87% which yields an ET_0 correction factor from input of the drainage water EC:

$$Y = 1.3234 - 0.0066 \ \mathrm{EC\ (dS/m)}$$

where Y is the ET_0 correction factor.

The actual relation might be not linear, but this relation could be used for making ballpark estimates within the range of salinity used, and it illustrates the potential for developing such a model.

Figures 3.29 a, b and c show the calculated (using the above model) and the measured evaporation rates as well as the cumulative rates (Figures 3.30 a, b and c) from the floating pans containing different salt concentrations (14, 30, and 47 dS/m) at Peck pond. The agreement between the measured and the predicted rate is within acceptable limits.

Table 3.2 Daily evaporation rate from the floating evaporation pans at Peck pond

Date	Pan A (mm/day)	Pan B (mm/day)	Pan C (mm/day)
	EC = 14 dS/m	**EC = 14 dS/m**	**EC = 14 dS/m**
8/11/89	11.20	9.00	9.60
8/12/89	9.70	11.20	9.90
8/15/89	7.30	7.30	7.90
8/17/89	7.40	7.20	7.80
8/19/89	5.50	7.50	7.00
8/24/89	7.10	8.10	8.60
8/25/89	7.20	5.20	7.90
8/26/89	7.80	8.50	8.10
8/27/89	6.70	7.00	7.30
	EC = 14 dS/m	**EC = 30 dS/m**	**EC = 47 dS/m**
9/1/89	6.70	6.40	4.70
9/2/89	7.70	6.60	6.30
9/3/89	6.60	6.90	6.50
9/4/89	6.90	6.40	6.30
9/5/89	7.10	6.60	7.50
9/6/89	10.10	13.30	13.30
9/7/89	4.80	1.70	3.60
9/8/89	6.80	6.60	4.20
9/9/89	6.90	7.10	6.80
9/12/89	4.90	na	4.70
9/13/89	5.20	na	4.10
9/14/89	5.30	na	5.20
9/15/89	5.10	na	5.40
9/23/89	5.50	na	3.20
9/24/89	7.00	na	5.70
9/25/89	4.60	na	4.80
9/26/89	4.30	na	4.90
	EC = 14 dS/m	**EC = 59 dS/m**	**EC = 90 dS/m**
11/2/89	2.10	1.20	2.20
11/3/89	2.20	2.00	1.70
11/4/89	1.60	2.10	2.60
11/5/89	3.20	2.10	2.70
11/6/89	3.54	1.60	2.50
11/7/89	3.40	3.20	3.70
11/8/89	1.00	1.40	1.40
11/9/89	1.80	1.70	1.40
11/10/89	1.80	1.40	1.80
11/11/89	2.20	1.90	1.80
11/12/89	2.40	2.40	1.00
11/13/89	2.10	1.80	2.10

EC values ± 10%
na : Data not available

Table 3.3 Cumulative and hourly evaporation from Peck floating pans (EC = 14 dS/m) for August 18-29, 1989

Date	Time	Elapsed Hours	Pan A (mm/hr)	Pan B (mm/hr)	Average Pans A&B	Pan A cum.(mm)	Pan B cum.(mm)	Average Pans A&B
8/18/89	1600	0	0.00	0.00	0.00	0.00	0.00	0.00
8/18/89	1700	1	0.46	0.16	0.31	0.46	0.16	0.31
8/18/89	1800	2	0.29	0.18	0.24	0.75	0.34	0.55
8/18/89	1900	3	0.53	0.41	0.47	1.28	0.75	1.02
8/18/89	2000	4	0.73	0.39	0.56	2.01	1.14	1.57
8/18/89	2100	5	0.71	0.39	0.55	2.72	1.53	2.13
8/18/89	2200	6	0.75	0.46	0.61	3.47	1.99	2.73
8/18/89	2300	7	0.59	0.36	0.48	4.06	2.35	3.21
8/18/89	2400	8	0.51	0.32	0.42	4.57	2.67	3.62
8/19/89	100	9	0.36	0.37	0.37	4.93	3.04	3.99
8/19/89	200	10	0.11	0.36	0.24	5.04	3.40	4.22
8/19/89	300	11	0.44	0.34	0.39	5.48	3.74	4.61
8/19/89	400	12	0.39	0.37	0.38	5.87	4.11	4.99
8/19/89	500	13	0.68	0.52	0.60	6.55	4.63	5.59
8/19/89	600	14	0.57	0.60	0.59	7.12	5.23	6.18
8/19/89	700	15	0.48	0.77	0.63	7.60	6.00	6.80
8/19/89	800	16	0.27	0.62	0.45	7.87	6.62	7.25
8/19/89	900	17	0.42	0.57	0.50	8.29	7.19	7.74
8/19/89	1000	18	0.11	0.18	0.15	8.40	7.37	7.89
8/19/89	1100	19	0.00	0.12	0.06	8.40	7.49	7.95
8/19/89	1200	20	0.00	0.04	0.02	8.40	7.53	7.97
8/19/89	1300	21	0.00	0.03	0.02	8.40	7.56	7.98
8/19/89	1400	22	0.00	0.02	0.01	8.40	7.58	7.99
8/19/89	1500	23	0.00	0.07	0.04	8.40	7.65	8.03
8/19/89	1600	24	0.00	0.11	0.06	8.40	7.76	8.08
8/19/89	1700	25	0.07	0.18	0.13	8.47	7.94	8.21
8/19/89	1800	26	0.16	0.25	0.21	8.63	8.19	8.41
8/19/89	1900	27	0.48	0.37	0.43	9.11	8.56	8.84
8/19/89	2000	28	0.11	0.23	0.17	9.22	8.79	9.01
8/19/89	2100	29	0.23	0.52	0.38	9.45	9.31	9.38
8/19/89	2200	30	0.39	0.35	0.37	9.84	9.66	9.75
8/19/89	2300	31	0.11	0.36	0.24	9.95	1.02	5.49
8/19/89	2400	32	0.07	0.37	0.22	10.02	10.39	10.21
8/20/89	100	33	0.37	0.45	0.41	10.39	10.84	10.62
8/20/89	200	34	0.91	0.57	0.74	11.30	11.41	11.36
8/20/89	300	35	0.48	0.46	0.47	11.78	11.87	11.83
8/20/89	400	36	0.23	0.23	0.23	12.01	12.10	12.06
8/20/89	500	37	0.04	0.23	0.14	12.05	12.33	12.19
8/20/89	600	38	0.16	0.34	0.25	12.21	12.67	12.44
8/20/89	700	39	0.21	0.30	0.26	12.42	12.97	12.70
8/20/89	800	40	0.64	0.34	0.49	13.06	13.31	13.19
8/20/89	900	41	0.45	0.80	0.63	13.51	14.11	13.81
8/20/89	1000	42	0.14	0.22	0.18	13.65	14.33	13.99
8/20/89	1100	43	0.14	0.12	0.13	13.79	14.45	14.12
8/20/89	1200	44	0.13	0.14	0.14	13.92	14.59	14.26
8/20/89	1300	45	0.21	0.06	0.14	14.13	14.65	14.39
8/20/89	1400	46	0.07	0.07	0.07	14.20	14.72	14.46
8/20/89	1500	47	0.07	0.19	0.13	14.27	14.91	14.59

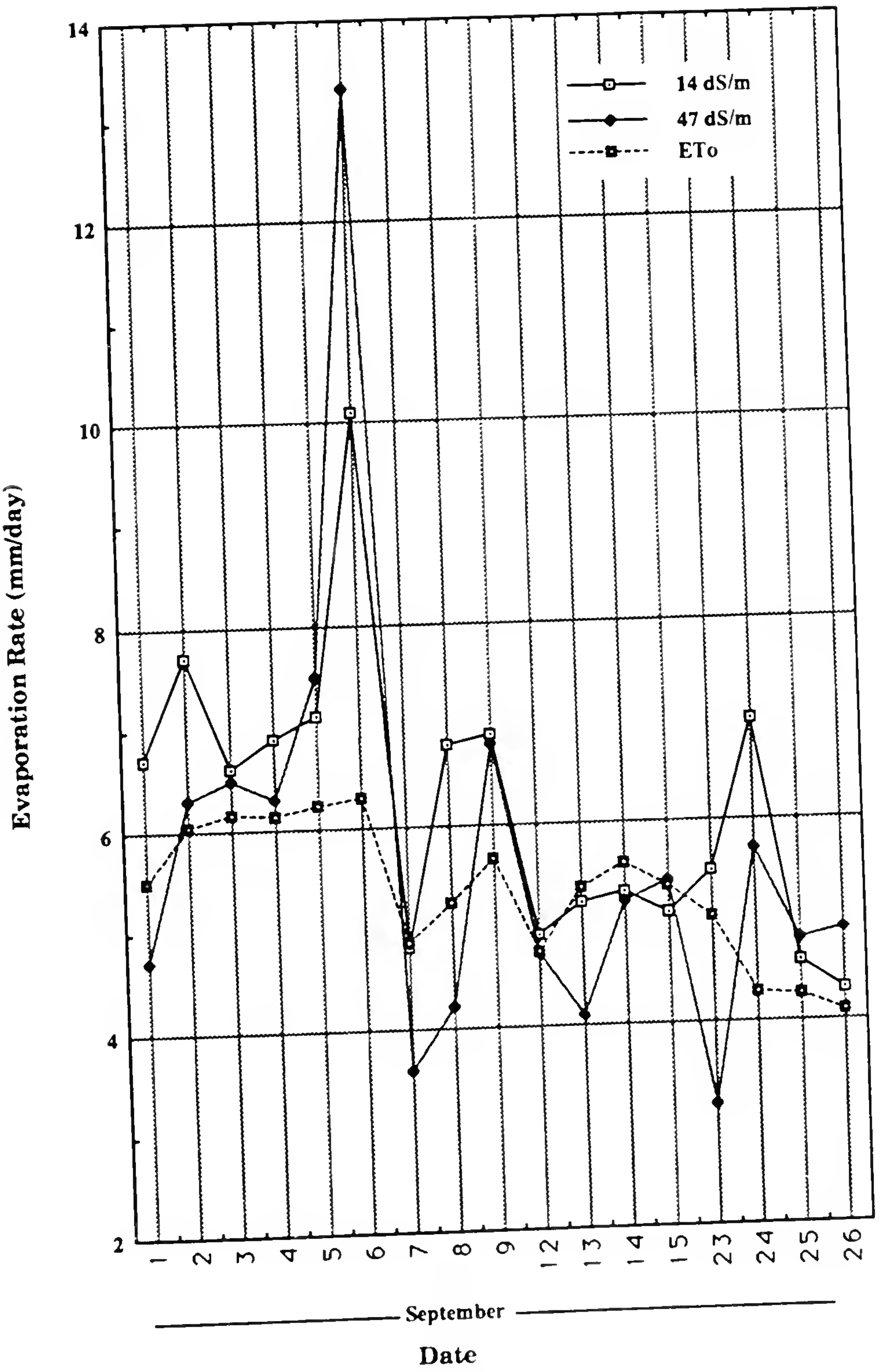


Figure 3.17 Daily evaporation in relation to the salinity level in Peck floating pans and ET_0 during the given dates in September, 1989

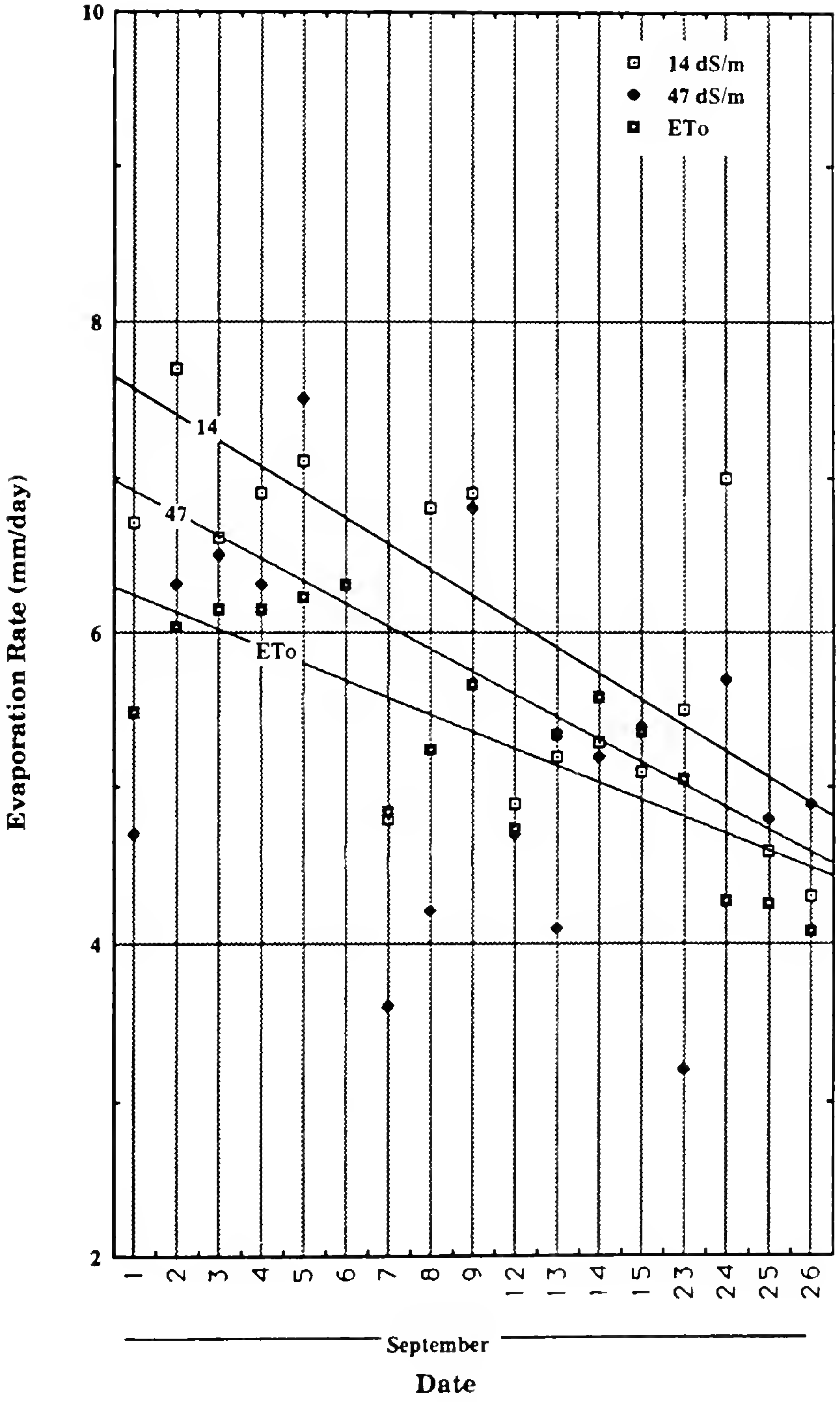


Figure 3.18 Trend of daily evaporation in relation to the salinity level in Peck floating evaporation pans and ET_o during the given dates in September, 1989

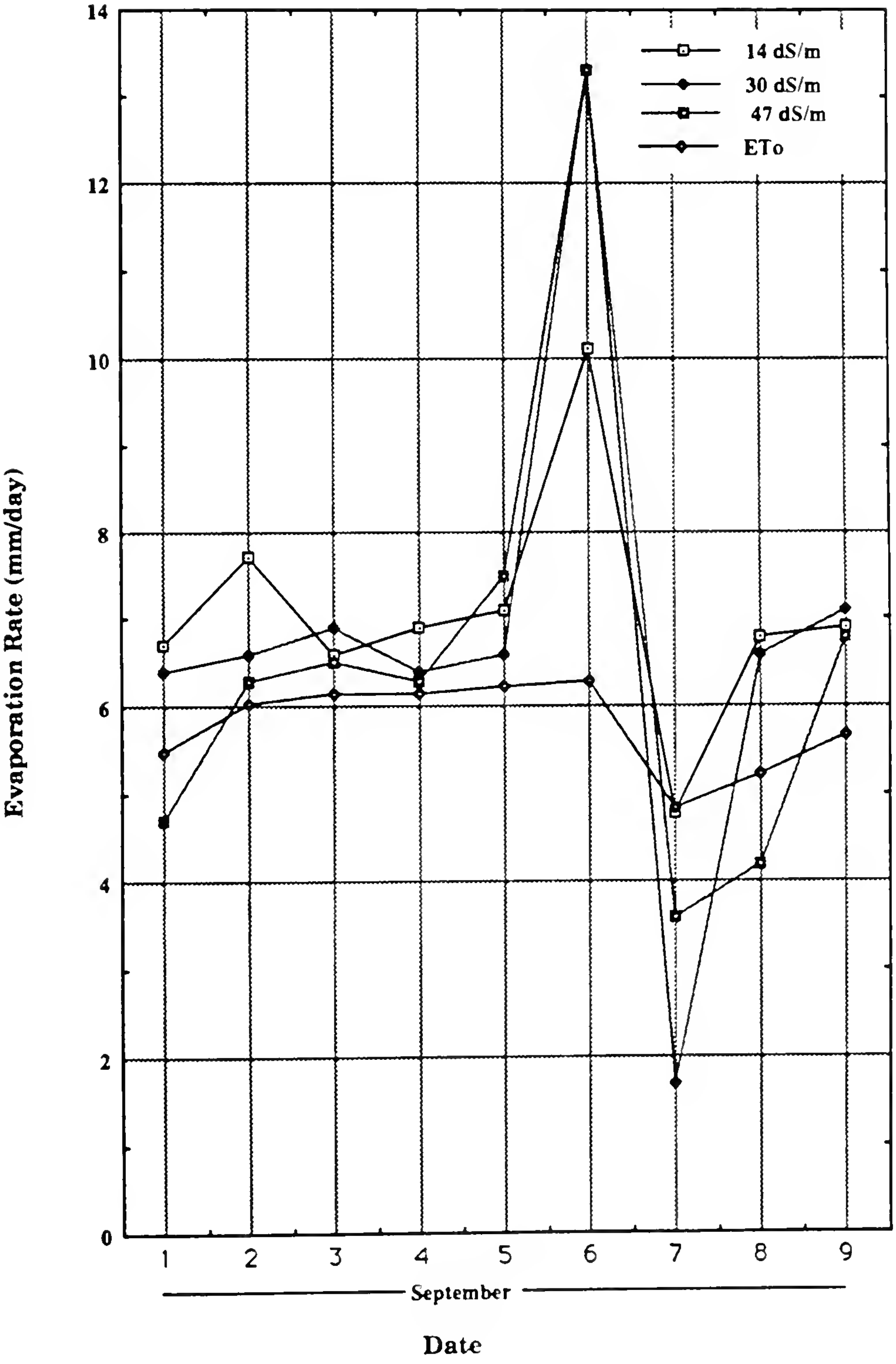


Figure 3.19 Daily evaporation in relation to the salinity level in Peck evaporation floating pans and ET_o for the period Sept. 1 through Sept. 9, 1989

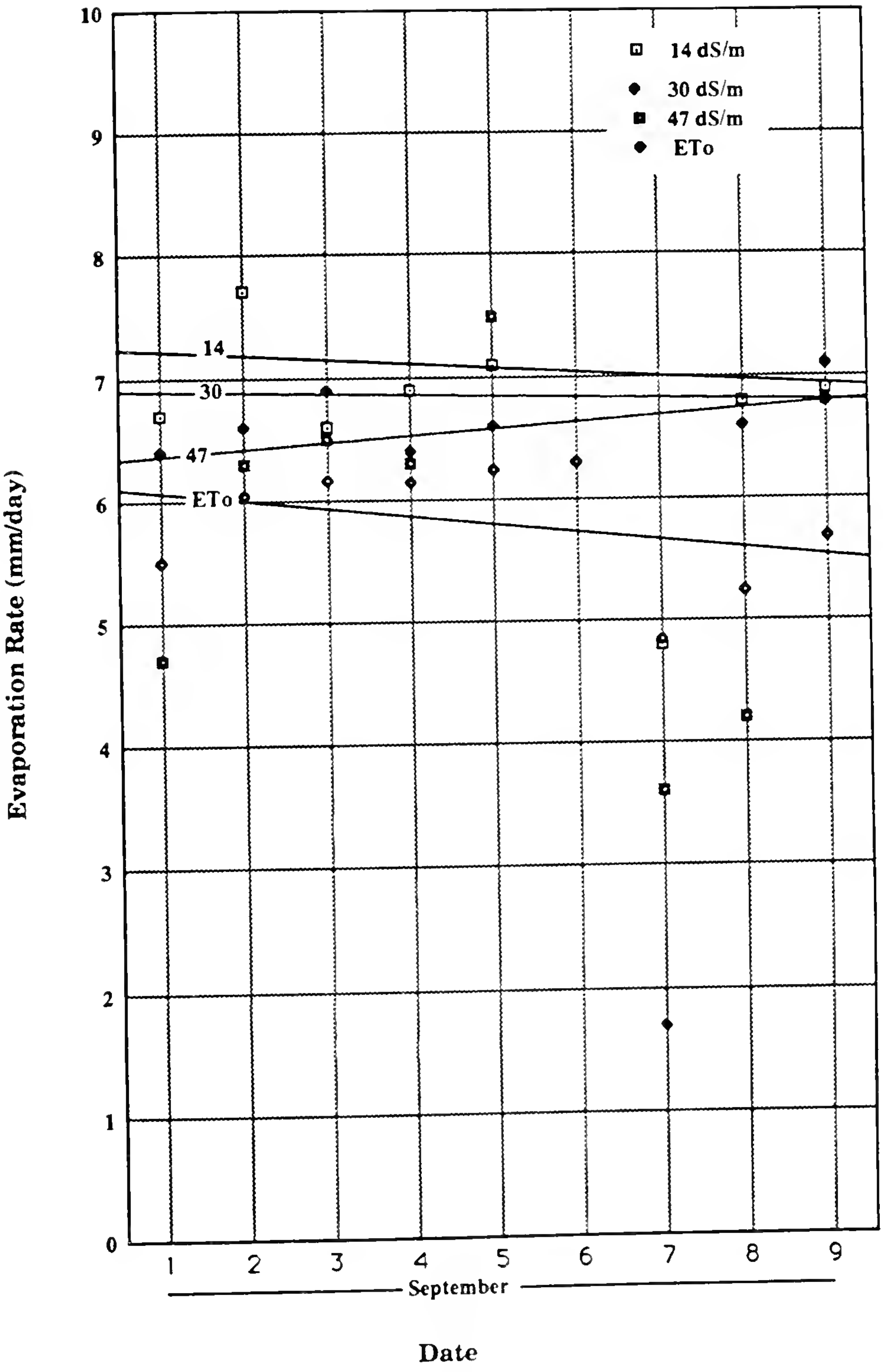


Figure 3.20 Trend of daily evaporation to the salinity level in Peck evaporation floating pans and ET$_o$ for the period Sept. 1 through Sept. 9, 1989

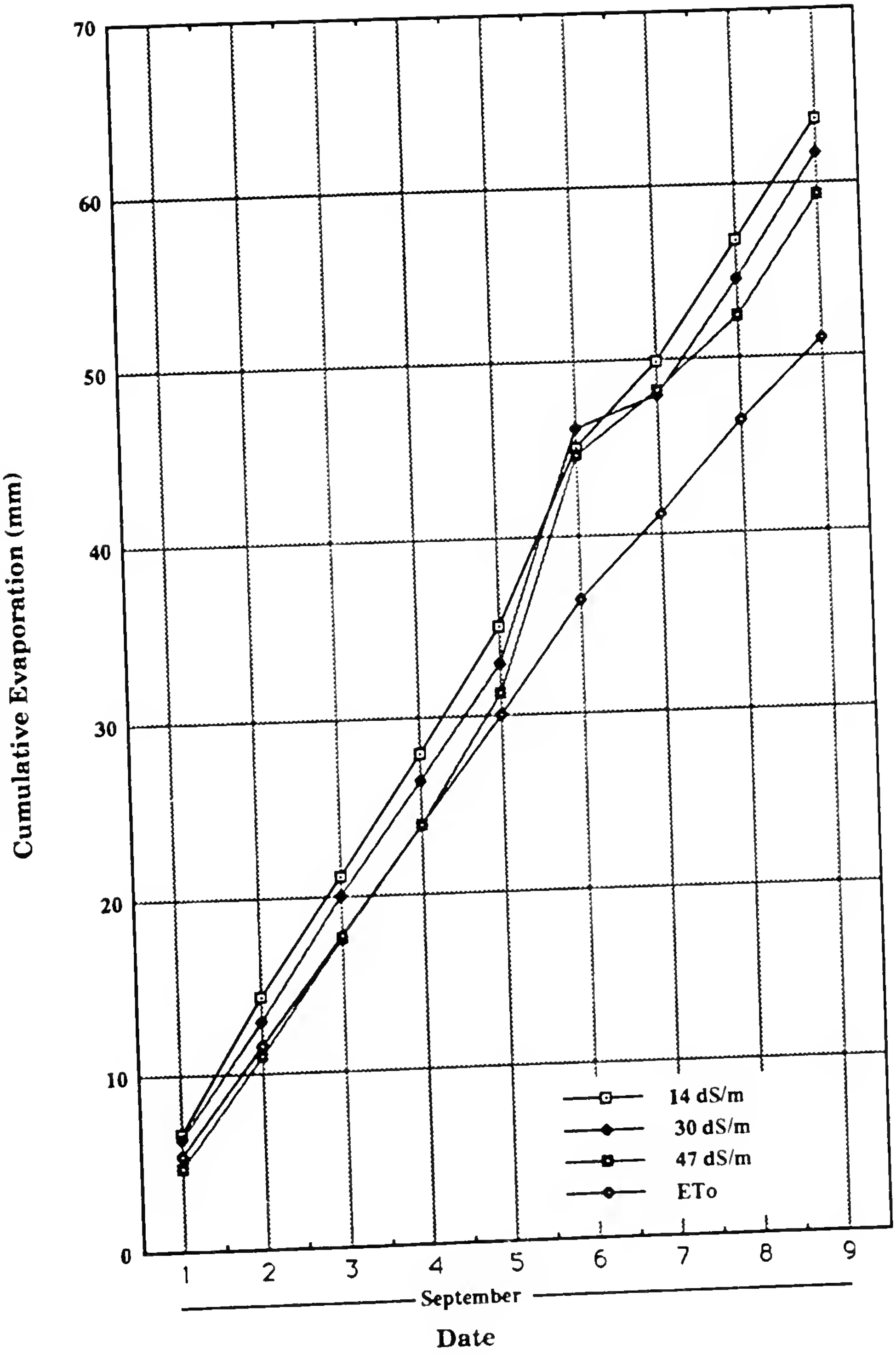


Figure 3.21 Cumulative evaporation in relation to the salinity level in Peck floating evaporation pans and ET_o for the period Sept. 1 through Sept. 9, 1989

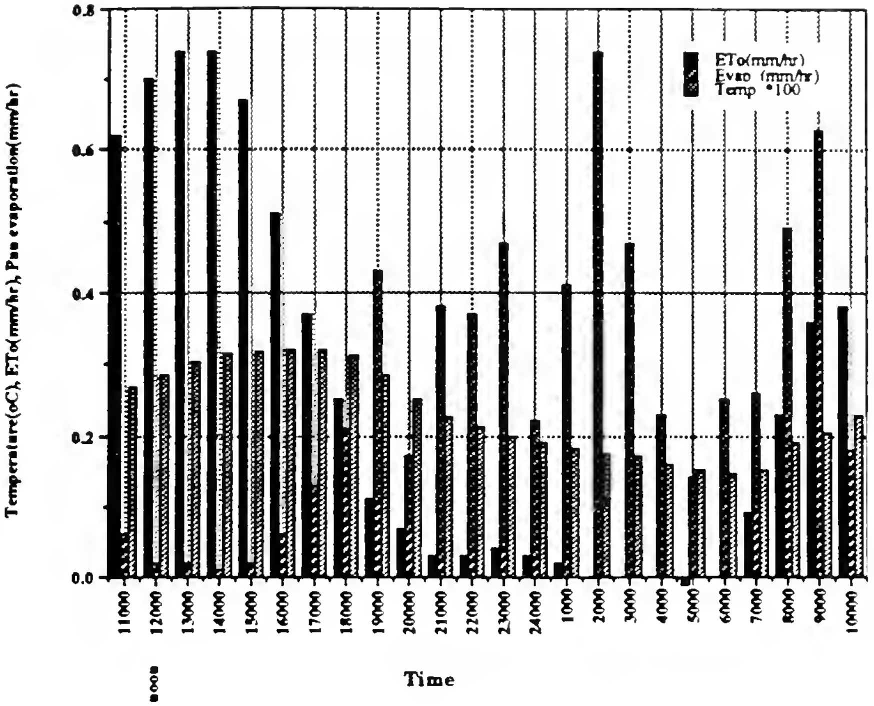


Figure 3.22 Effect of air temperature on hourly ET$_o$ and average evaporation rates from Peck floating evaporation pans (EC = 14 dS/m) for the period August 19-20, 1989

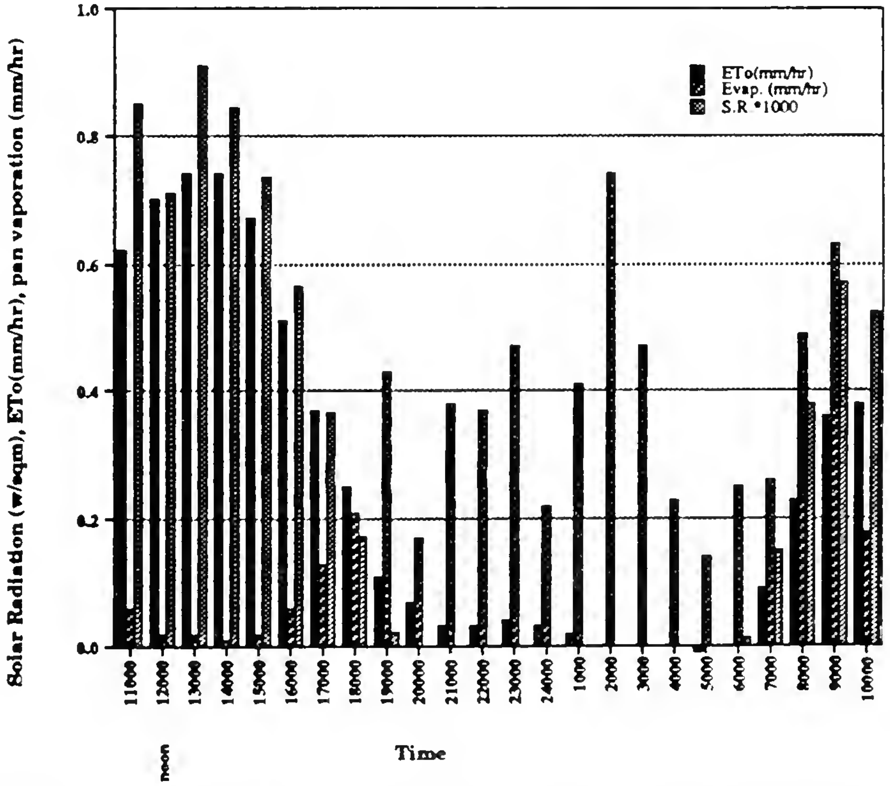


Figure 3.23 Effect of solar radiation on hourly ET$_o$ and average evaporation rates from Peck floating evaporation pans (EC = 14 dS/m) for the period August 19-20, 1989

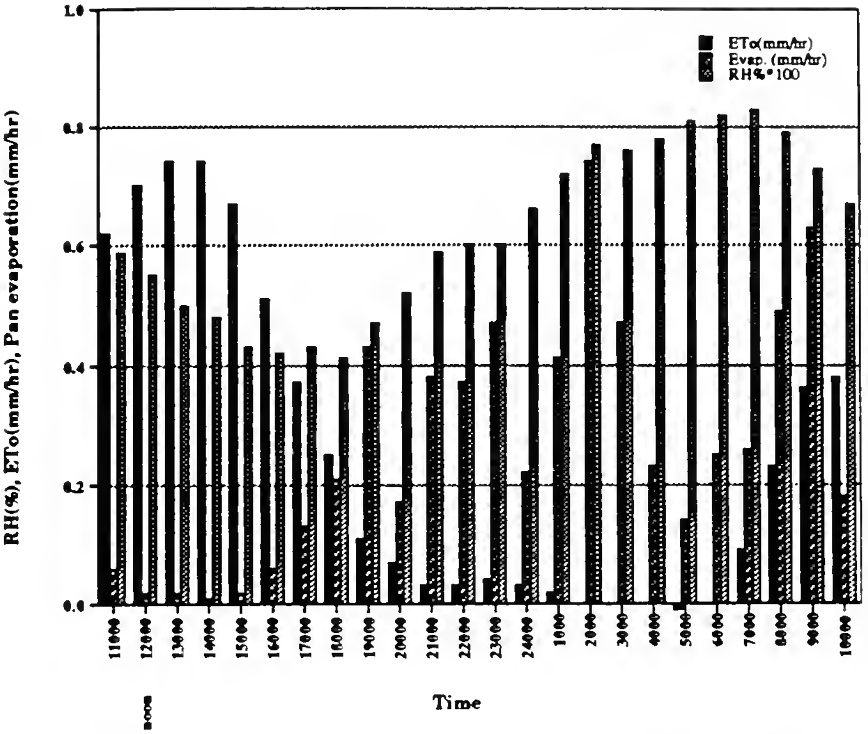


Figure 3.24 Effect of relative humidity on hourly ET_o and average evaporation rates from Peck floating evaporation pans (EC = 14 dS/m) for the period August 19-20, 1989

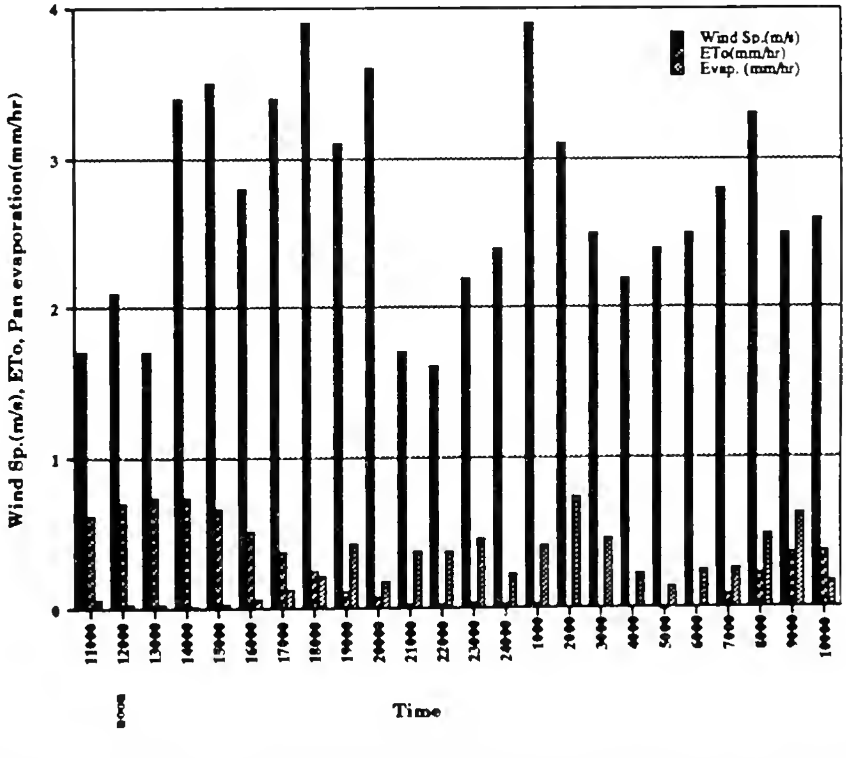


Figure 3.25 Effect of wind speed on hourly ET_o and average evaporation rates from Peck floating evaporation pans (EC = 14 dS/m) for the period August 19-20, 1989

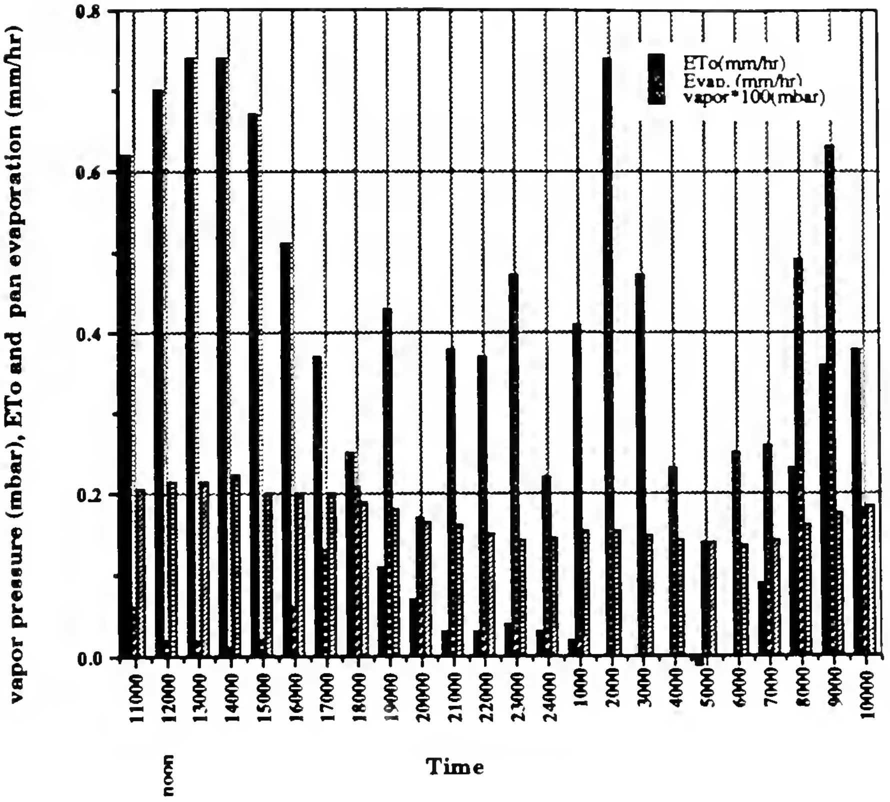


Figure 3.26 Effect of vapor pressure on hourly ET_o and average evaporation rates from Peck floating evaporation pans (EC = 14 dS/m) for the period August 19-20, 1989

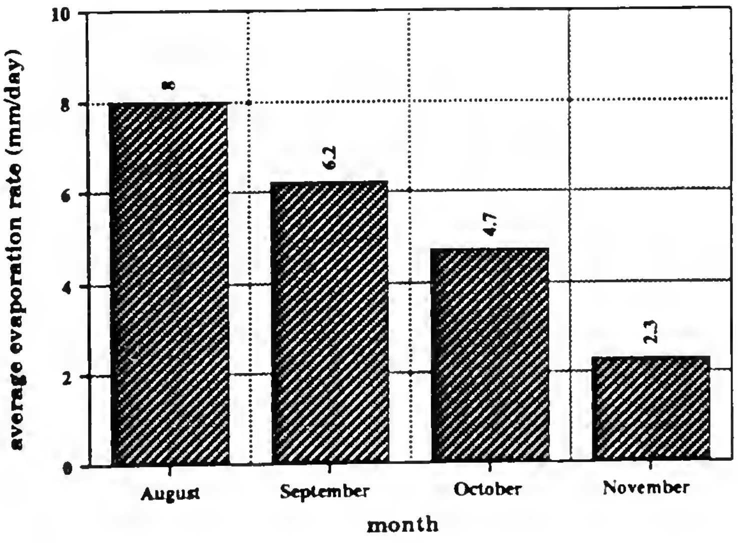


Figure 3.27 Average daily evaporation rate from 14 dS/m Peck floating evaporation pans for four months in 1989

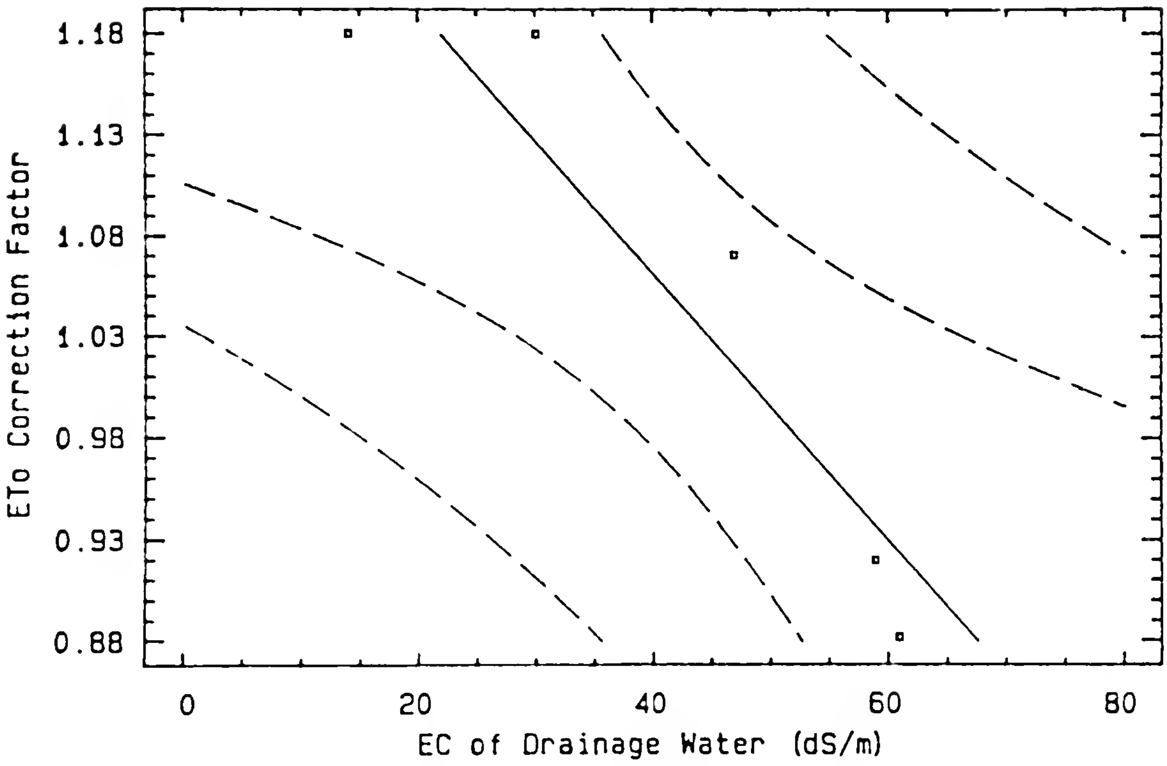


Figure 3.28 Regression of ET_o correction factor on EC of drainage water

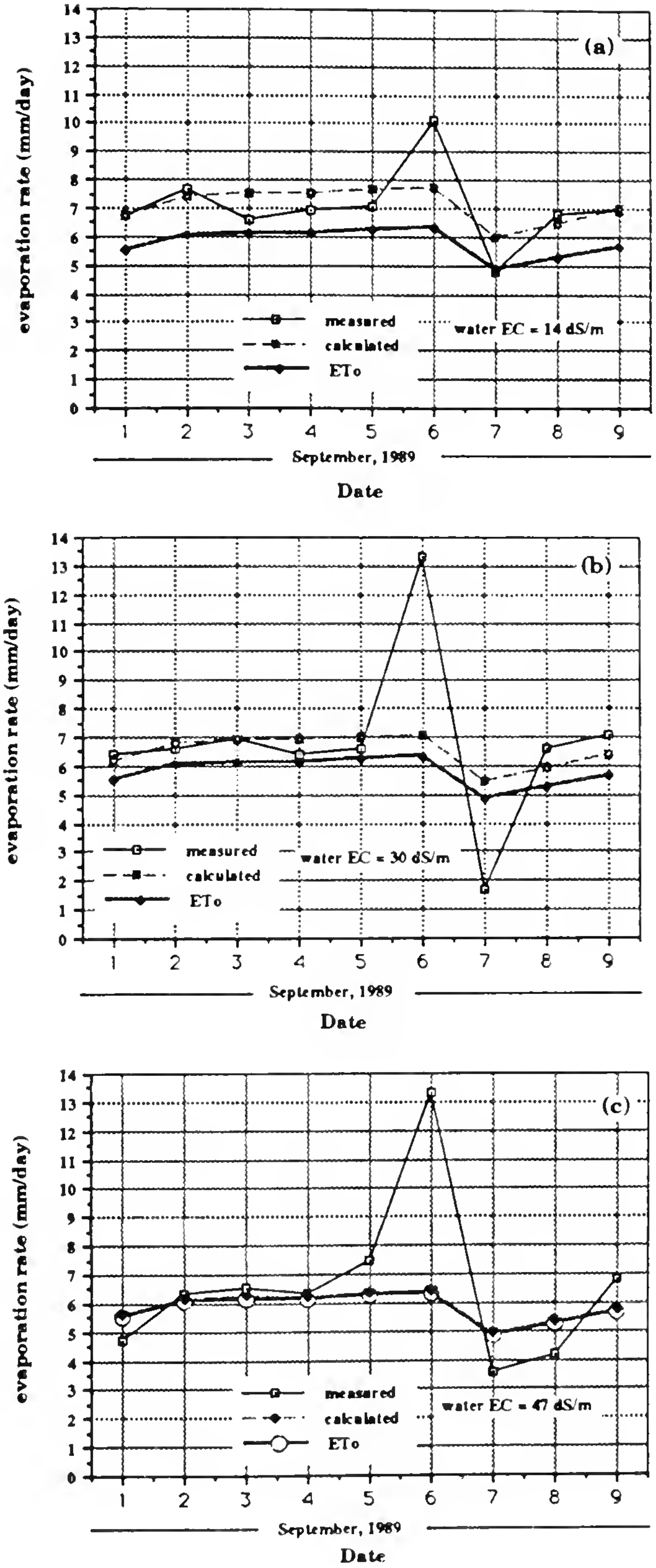


Figure 3.29 CIMIS ET$_0$ measured and calculated daily evaporation from Peck floating evaporation pans with different salinities using the ET$_0$ correction factor

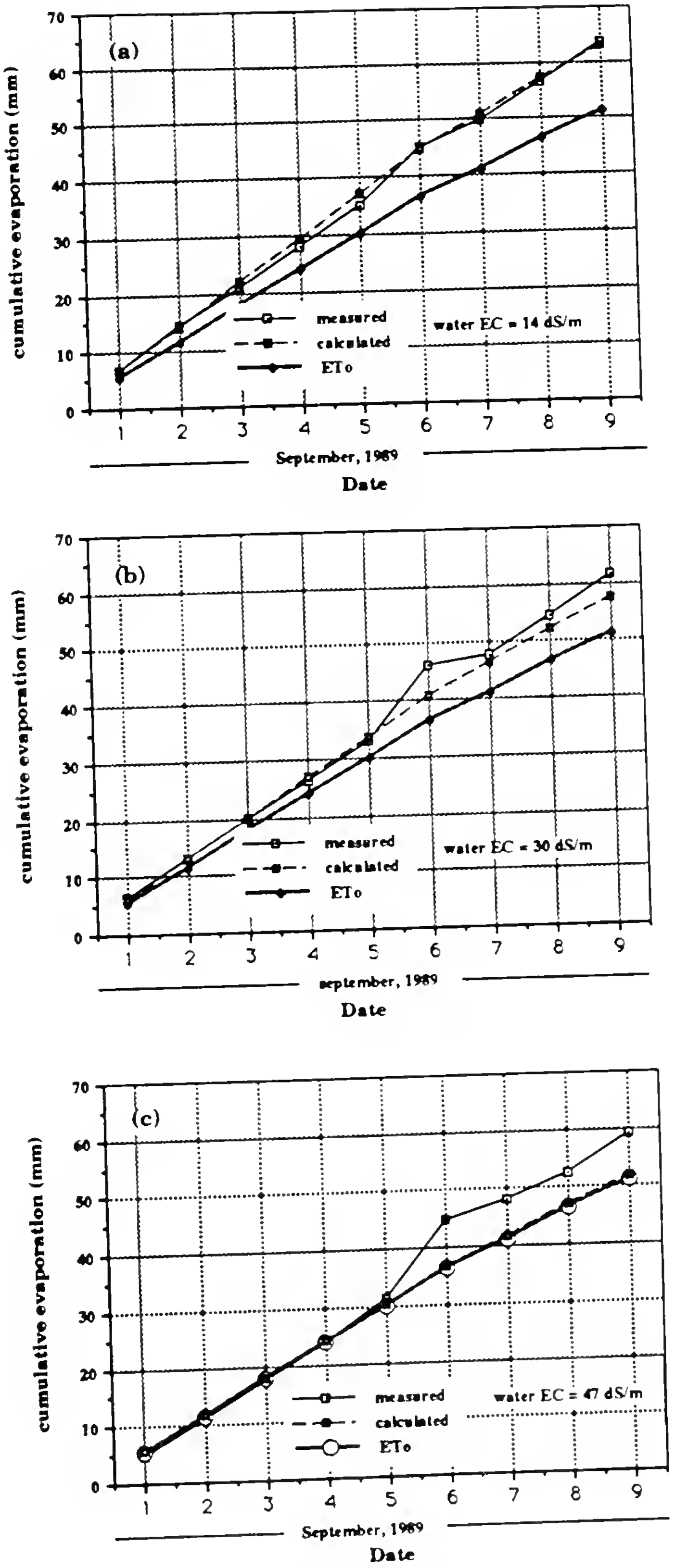


Figure 3.30 Cumulative CIMIS ET$_o$ and measured and calculated daily evaporation from Peck floating evaporation pans with different salinities using the ET$_o$ correction factor

SECTION 4
APPLICATION OF EVAPORATION RATE MODELS

Introduction

Evaporation ponds are one means of disposing saline water from tile drains. Physical, chemical, and biological factors affect evaporation parameters and can either increase or decrease the efficiency of the ponds. These parameters include air and water temperature, solar radiation, humidity, wind speed and direction, wave action, water color, turbidity, salinity chemical composition, organic content and water depth. Wind speed, air and water temperature and water salinity are the most obvious factors that affect the evaporation rate, where the others are less clear, yet just as important in the evaporation process.

The water flux to the atmosphere is a physical process and is proportional to the vapor pressure gradient between the water surface and the air above. A knowledge of the effect of climatic factors on the vapor pressure leads to an estimate of the evaporation rate from the water surface. Many models have been suggested and tested to estimate the evaporation rate from water surfaces.

Estimation of Evaporation Rates

Dalton's model (1834) is used widely, and the equation is of the form:

$$E = f(\mu)\,(es - ea)$$

where:

E = evaporation rate [L/T]
es = vapor pressure in the film of air next to the water surface $[M/T\bullet L^2]$
ea = vapor pressure in the air above water surface $[M/T\bullet L^2]$
$f(\mu)$ = an empirical coefficient that depend on barometric pressure, wind velocity, and other factors $[T\bullet L^2/M]$

This equation has been used to calculate the evaporation rate from pure water surfaces as well as from the floating pan containing saline water (EC = 14 dS/m) at Peck pond. The terms of the equation are estimated as follows:

- ea is used from CIMIS weather data (Table 4.1)
- es is determined by the Janson (1959) equation as

$$es = ew\,(1 - 0.0005373\,S)$$

where:

ew = vapor pressure of pure water obtained from List (1951)
S = the salinity concentration (g/kg)

The values of ew and es are presented in table 4.1. To estimate the wind coefficients, $f(\mu)$, the wind speed and evaporation rate slopes found by Moore and Runkles (1968) are used to construct new relations between the wind speed and wind coefficient $[T\bullet L^2/M]$ (Figure 4.1). Calculated and measured data are presented in Table 4.1.

The comparison between calculated and measured evaporation rates at the same elapsed hour shows some discrepancy (Figure 4.2), while the comparison between the calculated ones at certain elapsed hours with measured data after 10 hours shows slightly improved agreement (Figure 4.3). Smoothing the measured data by excluding some of the above-range values led to good agreement between the calculated and measured data (Figure 4.4). This agreement is due to the heating time (6-10 hours) needed for water molecules to break the water tension and escape from the water surface. More data is needed for verification.

Table 4.1 Calculated evaporation rate from pure water and saline water (EC = 14 dS/m) using CIMIS weather data and measured evaporation rate from saline floating pans at Peck evaporation pond for the 24 hour period on August 19-20, 1989

Time	**Elapsed hrs**	Water Temp (°C)	Air Temp (°C)	Pure water Vap. Pressure (ew) mbar	Saline water Vap. Pressure (es) mbar	Air Vap. Pressure (ea) mbar	Vap. Pressure difference (ew-ea) mbar	Vap. Pressure difference (es-ea) mbar	Wind speed (mile/hr)	Wind coefficient (mm/mbar*hr)
1000	**0**	24.90	25.20	31.67	29.77	19.25	12.42	10.52	6.71	0.03
1200	**2**	26.20	27.60	33.61	31.59	21.05	12.56	10.54	4.25	0.03
1400	**4**	26.40	31.95	47.55	44.70	21.90	25.65	22.80	5.71	0.03
1600	**6**	27.80	34.13	53.20	50.01	20.05	33.15	29.96	7.05	0.04
1800	**8**	27.40	32.58	50.31	47.29	19.55	30.76	27.74	5.67	0.03
2000	**10**	24.80	28.28	37.80	35.53	17.30	20.50	18.23	7.50	0.04
2200	**12**	23.50	22.98	28.09	26.40	15.60	12.49	10.80	3.69	0.02
2400	**14**	23.00	19.90	23.37	21.97	14.40	8.97	7.57	5.15	0.03
200	**16**	22.20	18.20	20.63	19.39	15.25	5.38	4.14	7.83	0.04
400	**18**	22.20	16.73	19.37	18.20	14.55	4.82	3.65	5.26	0.03
600	**20**	21.80	15.63	18.17	17.08	13.80	4.37	3.28	5.48	0.03
800	**22**	21.20	16.03	18.17	17.08	15.25	2.92	1.83	6.84	0.03
1000	**24**	23.40	21.83	26.43	24.84	18.00	8.43	6.84	5.71	0.03

Time	**Elapsed hrs**	Evaporation from Pure water *calculated* (mm/hr)	Evaporation from Saline Water *calculated* (mm/hr)	Floating pan B evaporation *measured* (mm/hr)	Floating pan A evaporation *measured* (mm/hr)	Average evap of pans A &B *measured* (mm/hr)	**Elapsed hrs**	Adjacent pan A evaporation *measured* (mm/hr)	Adjacent pan B evaporation *measured* (mm/hr)	Adjecent avg. pan A&B evap. *measured* (mm/hr)
1000	**0**	0.21	0.18	0.27	0.38	0.32	**10**	0.30	0.30	0.30
1200	**2**	0.16	0.14	0.00	0.01	0.00	**12**	0.31	0.44	0.37
1400	**4**	0.40	0.35	0.00	0.03	0.01	**14**	0.09	0.37	0.23
1600	**6**	0.58	0.53	0.00	0.09	0.05	**16**	0.64	0.51	0.58
1800	**8**	0.47	0.43	0.12	0.22	0.17	**18**	0.36	0.35	0.35
2000	**10**	0.37	0.33	0.30	0.30	0.30	**20**	0.10	0.29	0.19
2200	**12**	0.15	0.13	0.31	0.44	0.37	**22**	0.43	0.32	0.37
2400	**14**	0.13	0.11	0.09	0.37	0.23	**24**	0.30	0.51	0.40
200	**16**	0.10	0.08	0.64	0.51	0.58	**26**	0.14	0.13	0.13
400	**18**	0.07	0.05	0.36	0.35	0.35	**28**	0.14	0.07	0.10
600	**20**	0.07	0.05	0.10	0.29	0.19	**30**	0.04	0.10	0.07
800	**22**	0.05	0.03	0.43	0.32	0.37				
1000	**24**	0.13	0.11	0.30	0.51	0.40				
1200	**26**	na	na	0.14	0.13	0.13				
1400	**28**	na	na	0.14	0.07	0.10				
1600	**30**	na	na	0.04	0.10	0.07				

na : Data not available

Figures 4.5 and 4.6 show the effect of wind speed on evaporation rates. Generally, higher wind speeds (up to 6 mile/hr) result in greater evaporation . This is because the wind is preventing the build-up of a diffusion barrier (Moore and Runkles, 1968). Figures 4.7 and 4.8 show the evaporation rate as a function of concentration as affected by wind speed, air temperature and humidity. At high humidity a smaller vapor pressure difference is present which in turn reduces the evaporation rate. Salinity decreases the vapor pressure of the film next to the water surface. Therefore, evaporation decreases as salinity increases. Evaporation decrease with increasing specific gravity is plotted in Figure 4.9.

Lakshman (1975) studied the influence of wind and water temperature profiles overthe water surface on evaporation rate using the following Dalton's based formula:

$$E = N\,U^{0.8}\,(es - ea) \qquad (1)$$

where:

E is the evaporation in inches/hr
N is the mass transfer coefficient
U is the wind speed in mile/hr
es is saturation vapor pressure in mbar
ea is the vapor pressure of air at 2 m in mbar.

and

$$N = [\{(3.9 \times 10^{-4})\,m^{0.2}\}/\{(m+1)^{1.6}(2m+1)^{0.2}\}]\,(ß/2)^{1.8m}(P/A)^{0.2} \qquad (2)$$

where:

m is the wind profile exponent
ß is the thickness of the turbulent boundary layer in meter
P is the perimeter of the water body in feet
A is the water surface in square feet

For smaller bodies of water (e. g. sloughs and small reservoirs), the transfer coefficient (N) can be simplified to give:

$$N = (2.62 \times 10^{-4})\,(P/A)^{0.2} \qquad (3)$$

A comparison between some of the computed (eq. 2) and experimental values of N in the experiment is in the following table:

Study	Area (sq. ft.)	N computed	N experimental	Error
1 Blucher Dugout	6.3×10^3	1.42×10^{-4}	1.5×10^{-4}	5.30%
2 Lake Hefner	1.0×10^8	9.25×10^{-5}	9.74×10^{-5}	5.03%
3 Wascana Lake (1969-1970)	2.3×10^7	0.879×10^{-4}	0.964×10^{-4}	8.80%

The empirical equations 2 and 3 need to be verified with San Joaquin valley conditions in which the evaporation rate from the evaporation ponds can be estimated accurately.

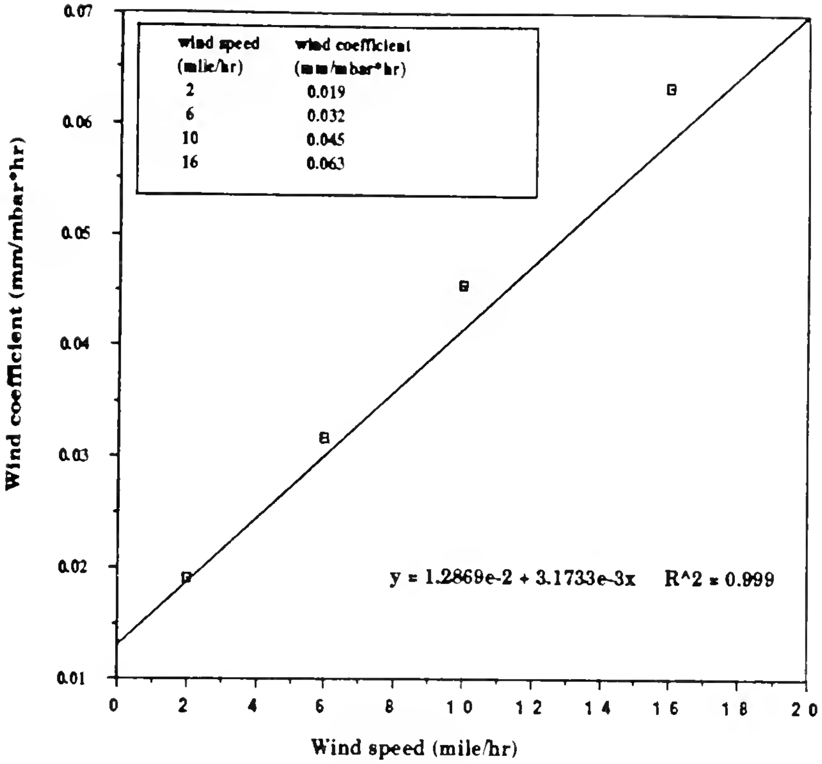


Figure 4.1 Wind coefficient in relation to wind speed

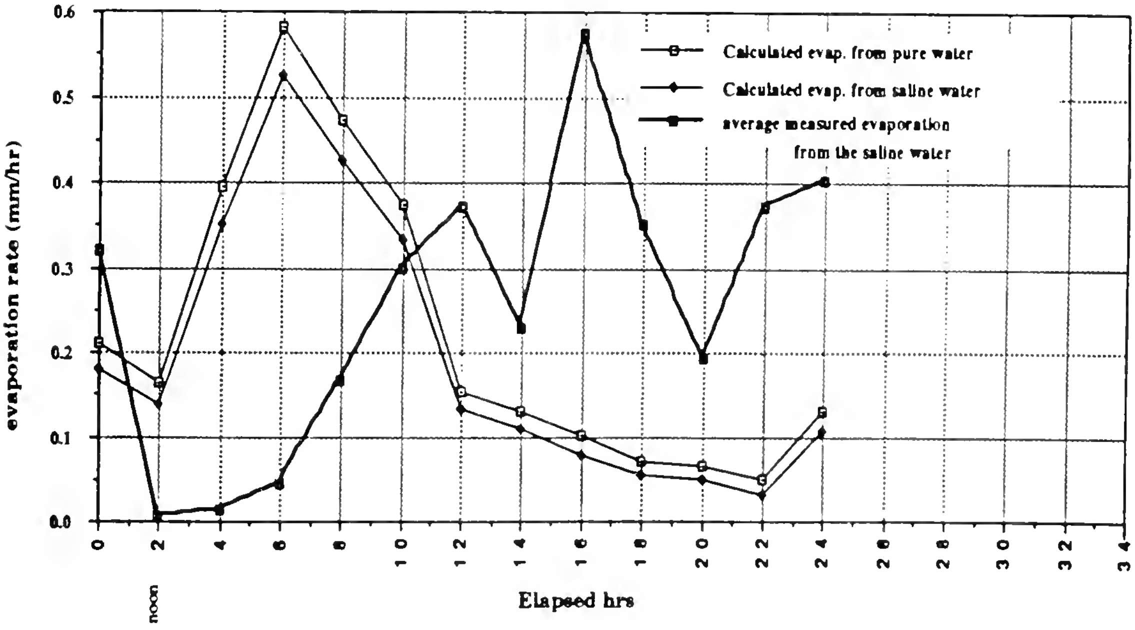


Figure 4.2 Calculated evaporation rate from pure water as well as from saline water (EC =14 dS/m) compared to the measured rate from the saline floating evaporation pan at Peck pond, for the period August 19-20, 1989

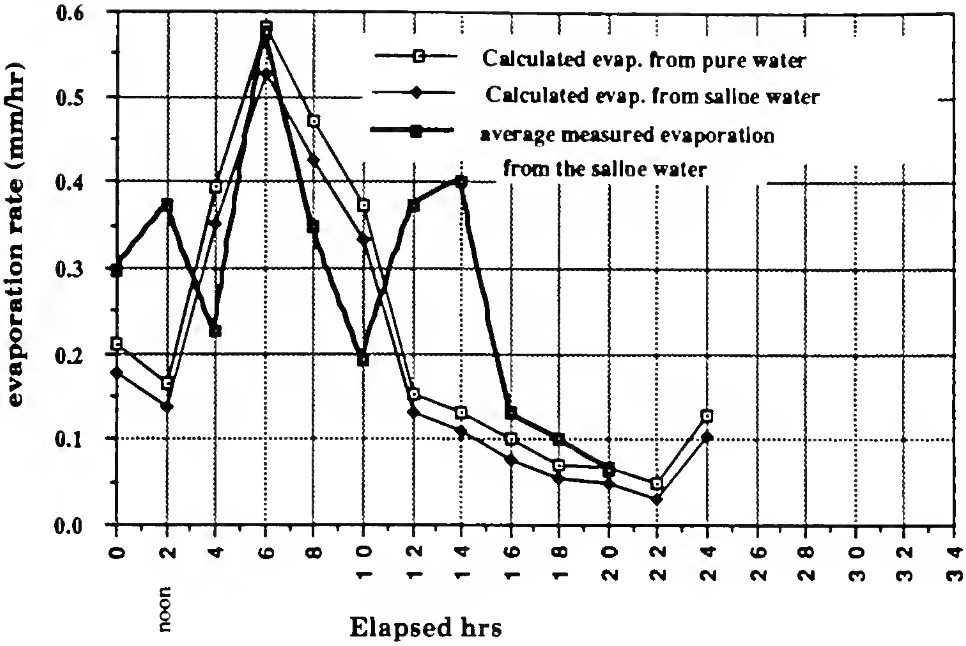


Figure 4.3 Calculated evaporation rate from pure water as well as from saline water (EC =14 dS/m) compared to the measured rate from the saline floating pan at Peck pond for the period August 19-20, 1989 (different data comparison)

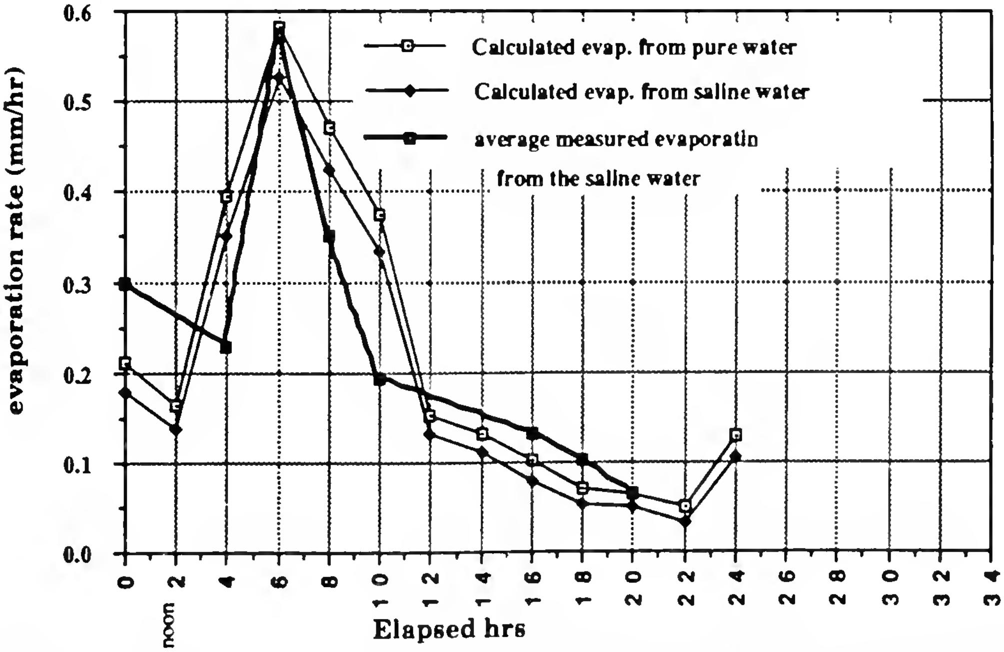


Figure 4.4 Calculated evaporation rate from pure water as well as from saline water (EC =14 dS/m) compared to the measured rate from the saline floating pan at Peck pond for the period August 19-20, 1989 (partially excluded data)

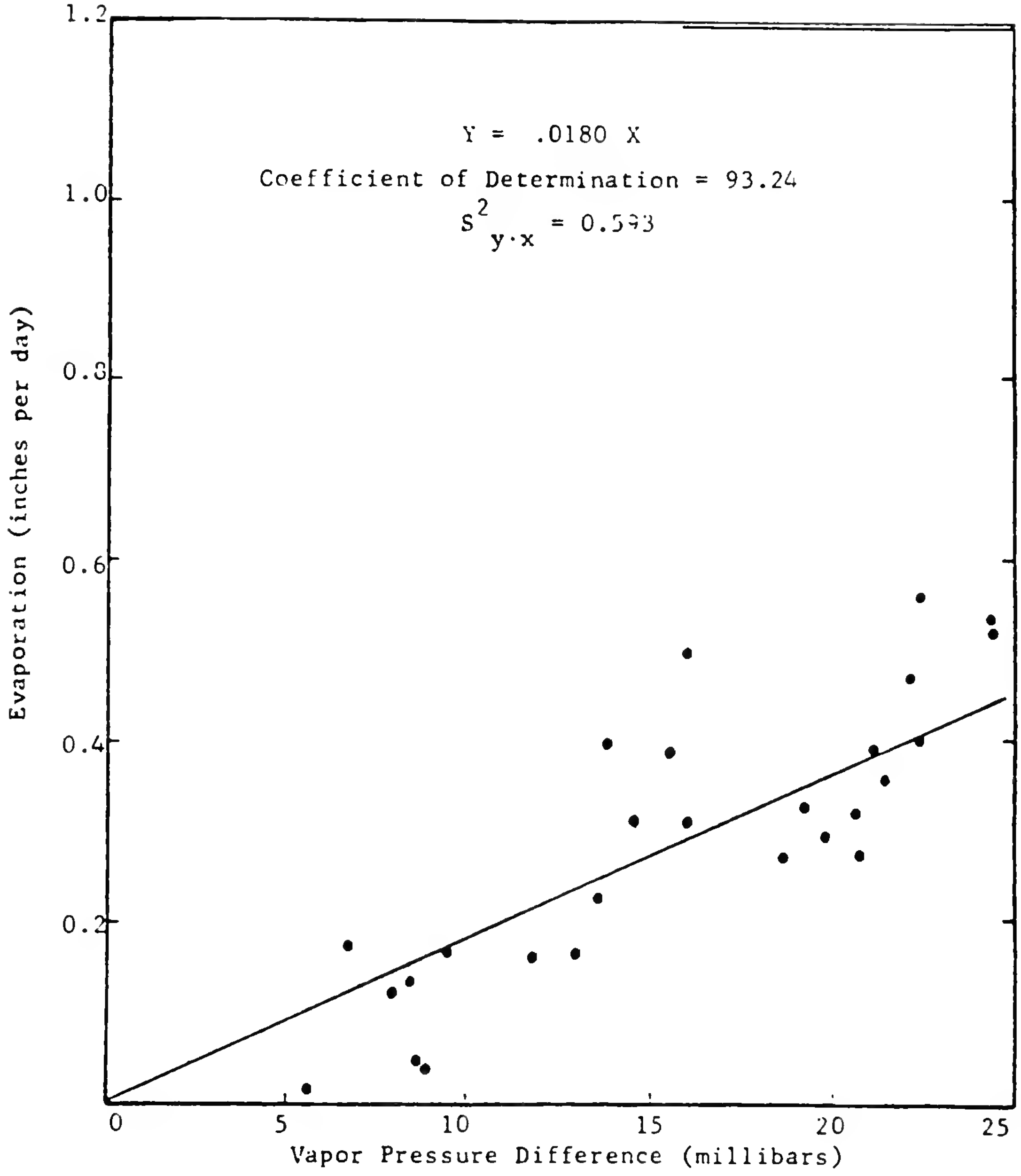


Figure 4.5 Evaporation in relation to vapor pressure differences between air and water surface at a wind speed of 2 miles per hour (Moore and Runkles, 1968)

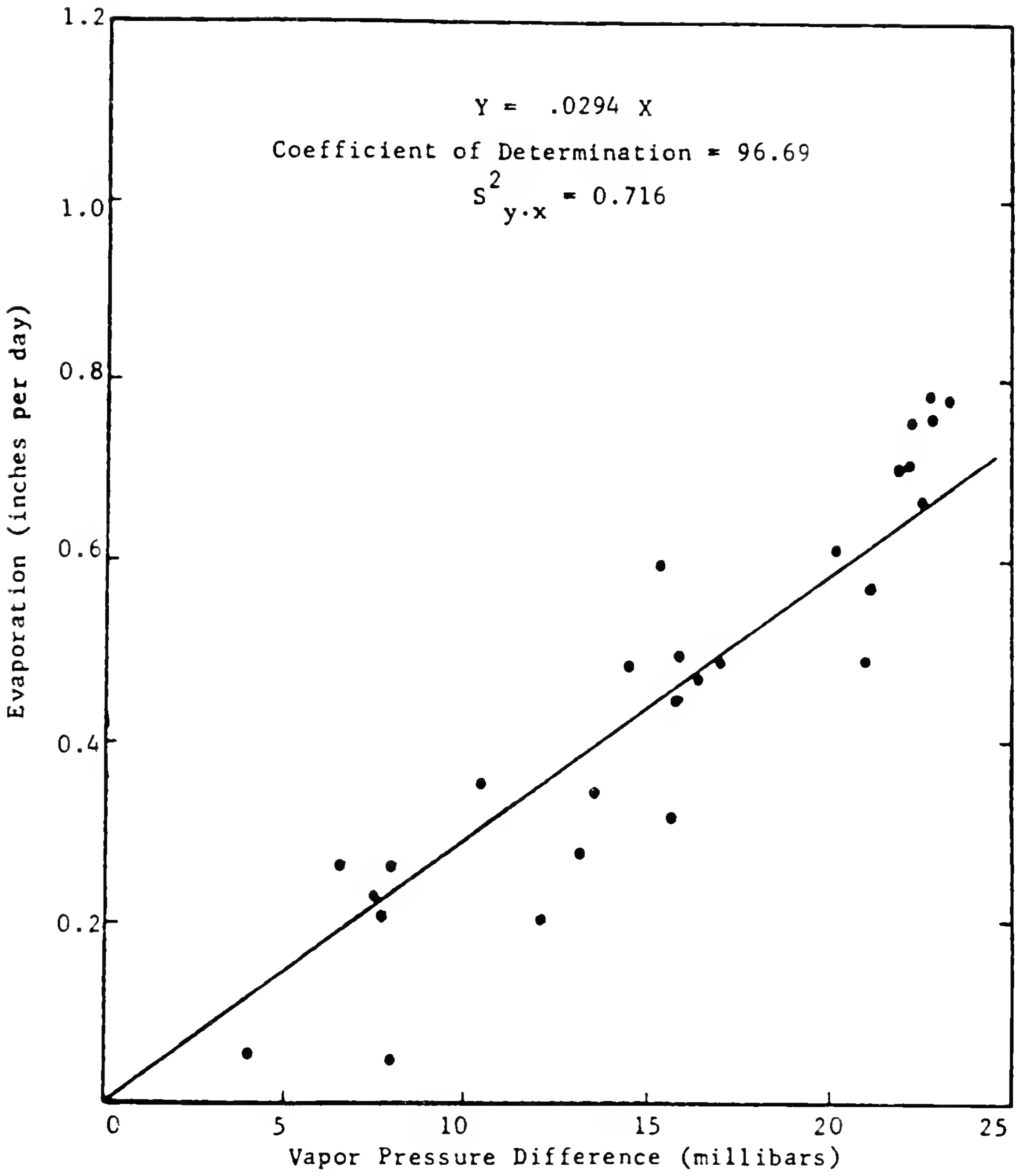


Figure 4.6 Evaporation in relation to vapor pressure difference between air and water surface at a wind speed of 6 miles per hour (Moore and Runkles, 1968)

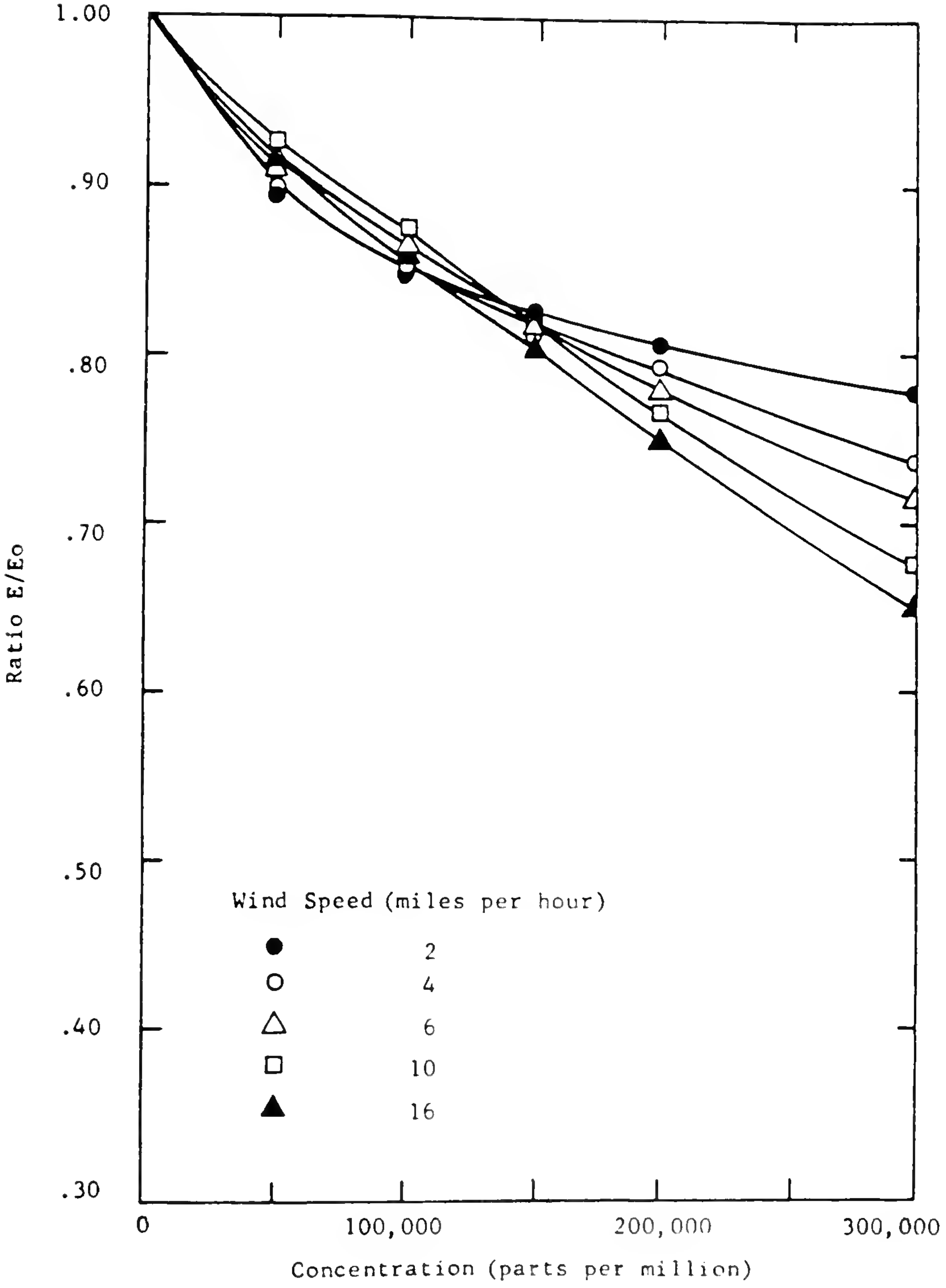


Figure 4.7 Relative evaporation rate [Evaporation from a saline solution to that of evaporation from distilled water (E/E_o)] in relation to wind speed and salt concentration at an air temperature of 76°F and 60% relative humidity (Moore and Runkles, 1968)

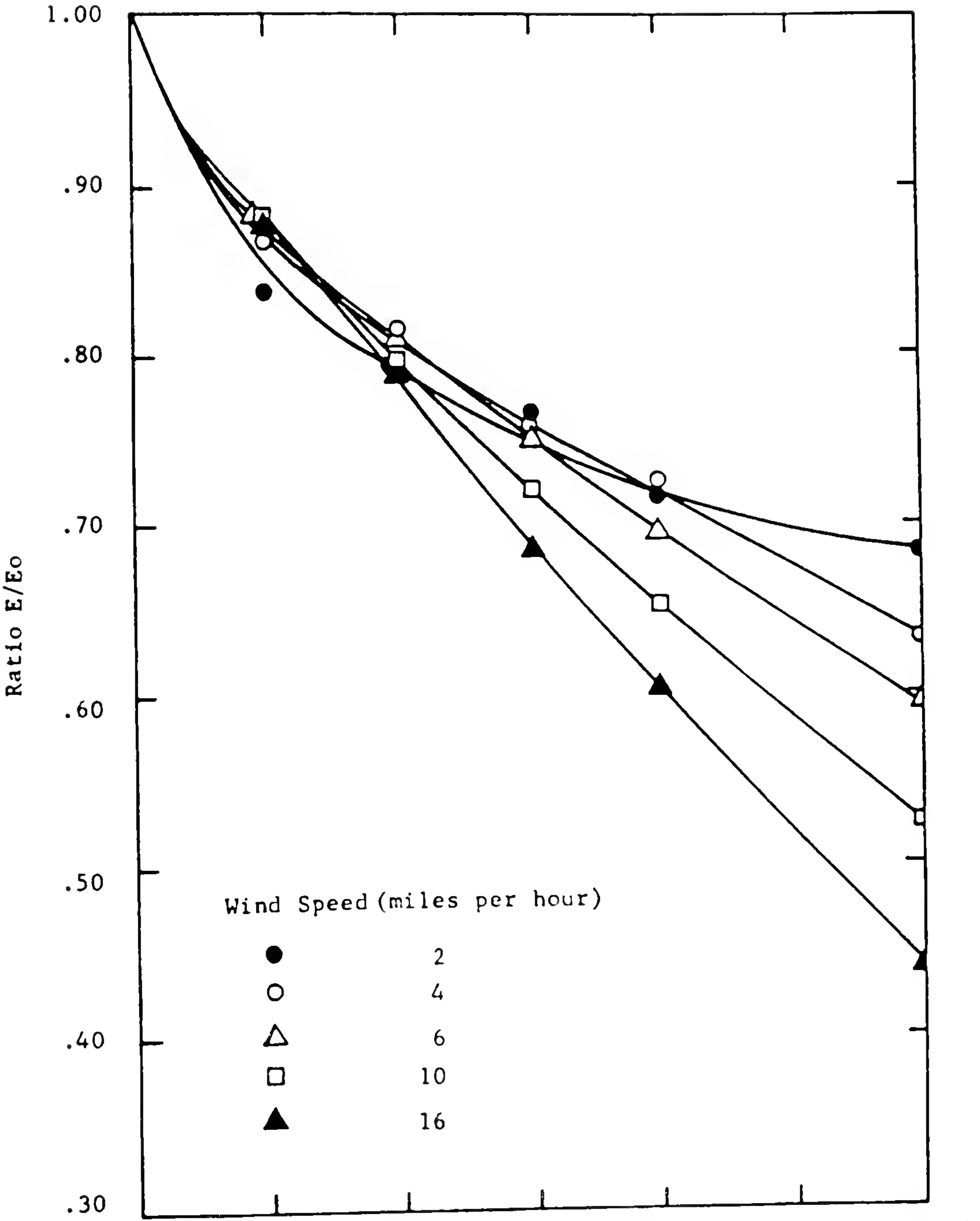


Figure 4.8 Relative evaporation rate [Evaporation from a saline solution to that of evaporation from distilled water (E/Eo)] in relation to wind speed and salt concentration at an air temperature of 76°F and 80% relative humidity (Moore and Runkles, 1968)

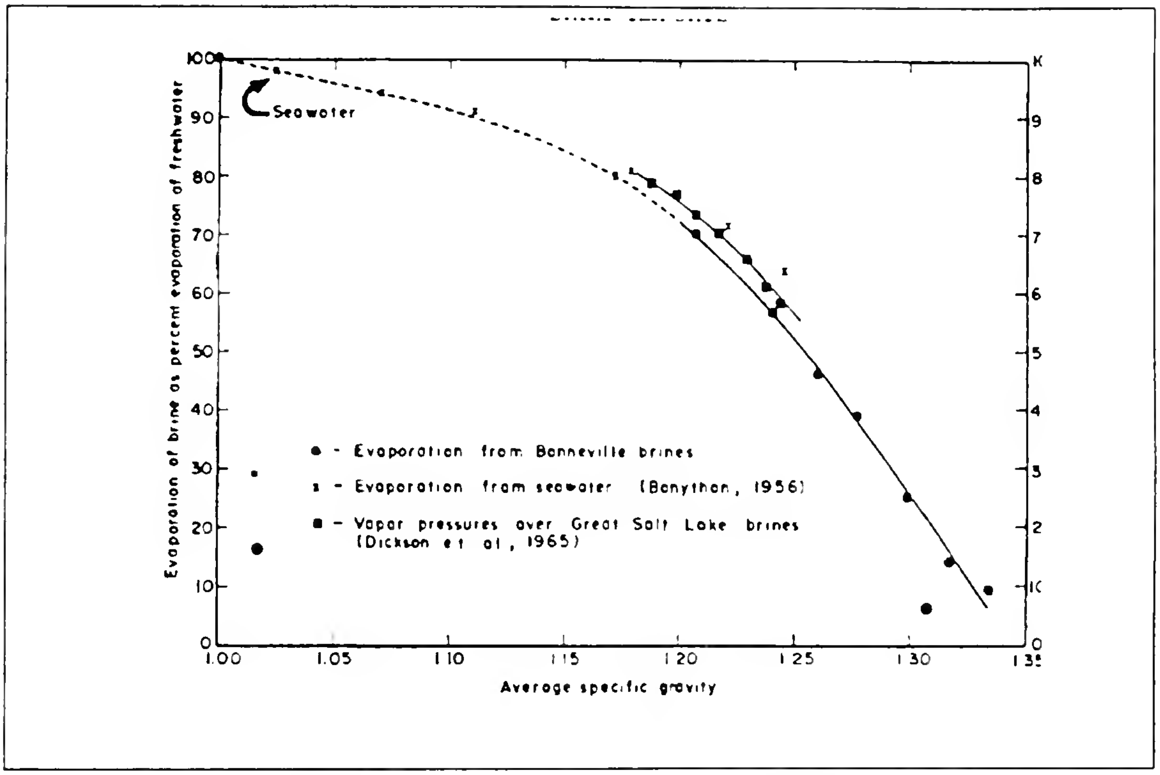


Figure 4.9 Effect of specific gravity on evaporation of brine (L.J. Turk, 1970)

SECTION 5
MINERALOGY OF PRECIPITATES

Introduction to Pond Evaporite Mineralogy

This section presents data on evaporite minerals identified by x-ray powder diffraction(XRPD) analysis. Data on two types of samples are reported: (1) precipitated salts collected from shorelines in ponds and (2) salts formed within the pond water column. Evaporite mineral samples were obtained during monitoring trips (1) in the winter of 1987 at Barbizon pond, (2) winter, spring and fall of 1987 and spring 1988 at Peck pond, and (3) winter and fall of 1987 and spring of 1988 at Pryse pond. The types of minerals precipitated in the water column are strongly regulated by the initial chemistry of the inflow drainage water and degree of evapoconcentration. Most of the mineral samples obtained came from shorelines on which salts precipitated as the pond waterline receded and hence are not predicted by the brine chemistry model unless the pond water is taken to dryness.

Analytical Procedure

Mineral identification was performed with a Diano XRD 8000 X-ray diffractometer equipped with a strip chart recorder. Cu K-α radiation was used to determine the diffraction maxima of the sample. Samples were scanned between 2 and 60° 2θ. Minerals were identified using a computer program that converts the 2θ values to diffraction spacings and compares the d-spacings of the sample to known mineral d-spacings. Known mineral diffraction spacings were compiled from the Mineral Powder Diffraction File, Joint Committee on Powder Diffraction Standards (JCPDS). All minerals reported had both the 100% intensity peak identified and at least three d-spacing matches with known minerals. Gypsum I and II, and Loewite I and II denote identification through differing d-spacings.

The samples have been subjected to a fairly rigorous and thorough analysis. The minerals identified probably account for 99% of the salt samples. The dominant minerals reflect the composition of the water as expected for shoreline salts and the wide variety of other components suggest that evaporite formation is a non-competitive process at the shoreline.

Pond Mineralogy

Table 5.1 presents the evaporite minerals identified in field samples collected from the shorelines and, when available, from within the water column of the three ponds. At all three ponds, halite ($NaCl$) was the only chloride evaporite identified, nahcolite ($NaHCO_3$) and nesquehonite ($MgCO_3{\cdot}3H_2O$) were the only carbonate evaporites identified, and arcanite (K_2SO_4) and thenardite (Na_2SO_4) were the only sulfate evaporites identified. Other minerals detected were present in only one or two ponds and not in the third pond.

In Peck pond, the most diversity in evaporites occurred during the winter, after evaporation had been the greatest and before water was seasonally added to the pond. The least diversity in evaporites occurred during the spring, after new water (either rainfall or agricultural drainwater) diluted the pond waters.

Four minerals are ubiquitous in Peck pond: burkeite ($Na_2CO_3{\bullet}2Na_2SO_4$), halite ($NaCl$), mirabilite ($Na_2SO_4{\bullet}10H_2O$) and thenardite ($Na_2SO_4$). Bloedite ($Na_2SO_4{\bullet}MgSO_4{\bullet}5H_2O$), gypsum ($CaSO_4{\bullet}2H_2O$), nahcolite ($NaHCO_3$) and polyhalite ($K_2SO_4{\bullet}2CaSO_4{\bullet}MgSO_4{\bullet}2H_2O$) were identified in two of the three samplings.

Pryse pond did not follow the same pattern of diversity as at Peck. The most diversity in Pryse occurred during winter. The least diversity occurred during the fall. One reason for this might be that Cell 2 does not receive new water right away, hence this cell remains dry longer than would be expected. When the cell does receive water for dilution, the water comes late in the season.

Three minerals are ubiquitous in Pryse pond: burkeite, halite, and thenardite. Bloedite, gypsum, loeweite ($2Na_2SO_4{\bullet}2MgSO_4{\bullet}5H_2O$), mirabilite, nahcolite, polyhalite and sodium carbonate sulfate ($Na_2CO_3{\bullet}Na_2SO_4$) were identified in two of the three samplings.

Table 5.1 Evaporite Minerals Identified at Barbizon, Peck and Pryse Evaporation Ponds Between August 1986 and May 1988.

Evaporite Type/Name	Chemical Formula	Barbizon	Peck	Pryse
Borates				
Borax	$Na_2B_4O_7 \bullet 10H_2O$		✓	✓
Chlorides				
Bischofite	$MgCl_2 \bullet 2H_2O$	✓		✓
Halite	$NaCl$	✓	✓	✓
Sylvite	KCl	✓		
Carbonates				
Aragonite	$\lambda\text{-}CaCO_3$	✓		✓
Burkeite	$Na_2CO_3 \bullet 2Na_2SO_4$		✓	✓
Calcite	$\beta\text{-}CaCO_3$		✓	
Magnesite	$MgCO_3$		✓	✓
Nahcolite	$NaHCO_3$	✓	✓	✓
Nesquehonite	$MgCO_3 \bullet 3H_2O$	✓	✓	✓
Soda (Natron)	$Na_2CO_3 \bullet 10H_2O$			
Sodium Carbonate Sulfate	$Na_2CO_3 \bullet Na_2SO_4$			✓
Trona	$Na_2CO_3 \bullet NaHCO_3 \bullet 2H_2O$		✓	✓
Tychite	$2Na_2CO_3 \bullet 2MgSO_4 \bullet Na_2SO_4$	✓	✓	✓
Sulfates				
Arcanite	K_2SO_4	✓	✓	✓
Bassanite	$2CaSO_4 \bullet H_2O$			✓
Bloedite	$Na_2SO_4 \bullet MgSO_4 \bullet 5H_2O$		✓	✓
Burkeite	$Na_2CO_3 \bullet 2Na_2SO_4$		✓	✓
Georgeyite	$K_2SO_4 \bullet 5CaSO_4 \bullet H_2O$		✓	✓
Glauberite	$Na_2SO_4 \bullet CaSO_4$			✓
Gypsum I	$CaSO_4 \bullet 2H_2O$		✓	
Gypsum II	$CaSO_4 \bullet 2H_2O$	✓	✓	
Kieserite	$MgSO_4 \bullet H_2O$	✓		
Langbeinite	$K_2SO_4 \bullet 2MgSO_4$			✓
Loewite I	$6Na_2SO_4 \bullet 7MgSO_4 \bullet 15H_2O$	✓		✓
Loewite II	$2Na_2SO_4 \bullet 2MgSO_4 \bullet 5H_2O$	✓		✓
Mirabilite	$Na_2SO_4 \bullet 10H_2O$		✓	✓
Polyhalite	$K_2SO_4 \bullet 2CaSO_4 \bullet MgSO_4 \bullet 2H_2O$	✓	✓	✓
Sodium Carbonate Sulfate	$Na_2CO_3 \bullet Na_2SO_4$			✓
Syngenite	$K_2SO_4 \bullet CaSO_4 \bullet H_2O$		✓	
Thenardite	Na_2SO_4	✓	✓	✓
Tychite	$2Na_2CO_3 \bullet 2MgSO_4 \bullet Na_2SO_4$		✓	✓
Vanthoffite	$3Na_2SO_4 \bullet MgSO_4$	✓		✓

Most of the minerals ubiquitous at Peck and Pryse evaporation ponds are also found at Barbizon. Bloedite, gypsum, halite, loeweite, mirabilite, polyhalite and thenardite are the major evaporite minerals in these ponds. This reflects the fact that the aqueous chemistry of the ponds are similar.

Differences between the ponds are observed in the evaporites which only form in one of the ponds. While no quantitative analysis was done, the minerals discussed below probably did not occur in large quantity. Sylvite (KCl) and arcanite (K_2SO4) were unique at Barbizon. This reflects the fact that Barbizon evaporation pond has a greater percentage of potassium (of total cations) than the other ponds.

- Peck had three unique minerals: calcite ($CaCO_3$), georgeyite ($K_2SO_4 \bullet 5CaSO_4 \bullet H_2O$) and syngenite ($K_2SO_4 \bullet CaSO_4 \bullet H_2O$). Calcite is a surprise. The other two minerals suggest that proportion of Mg is low in this pond relative to other ponds, hence fewer evaporites incorporate Mg. As evapoconcentration occurs, K and Ca precipitate as georgeyite and syngenite.
- Pryse had several unique minerals: soda [natron] ($Na_2CO_3 \bullet 10H_2O$), anhydrite ($CaSO_4$), bassanite ($2CaSO_4 \bullet H_2O$), glauberite ($Na_2SO_4 \bullet CaSO_4$) and langbeinite ($K_2SO_4 \bullet 2MgSO_4$). Soda is probably a result of biologically increased partial pressure of carbon dioxide. At the time soda was identified, five other carbonate or bicarbonate minerals were also identified. Anhydrite and bassanite seem to be occurring instead of gypsum. The hypersaline conditions of Pryse may increase the solubility of gypsum. As seawater is concentrated, glauberite precipitates, so this mineral is not unexpected. Glauberite would probably occur in other ponds if they were as saline as Pryse.
- Of all the minerals identified, only two minerals (halite and thenardite) were found in all ponds.

Salts which precipitate in the pore waters at the sediment-water interface and the overlying water column have also been collected. The morphologies between water column and shoreline salts are easily distinguishable most likely because of the different forms that result from one sample being constantly submerged while the other possibly dries out. Such morphological differences, while indicating mineralogical differences, do not necessarily translate into compositional differences. For instance, while thenardite (Na_2SO_4) and mirabilite ($Na_2SO_4 \bullet 10H_2O$) are two different minerals, they comprise the same number of moles of Na and SO_4 per mole of the mineral and differ only in the hydration status. The dehydration of mirabilite yields thenardite, and this occurs simply by leaving mirabilite in free air.

In general, water column samples form much larger crystals and eventually coalesce into salt slabs. This is in contrast to the shoreline salts which are powdery and fine. Shoreline salts generally form as a result of wetting and drying along the shore as a result of wave action and are usually of the dehydrated form. Salts forming this way may then be wind-blown further up the bank and hence avoid redissolution.

A Note Concerning Mineralogic Nomenclature

Typically, the number of moles of an element in a mole of mineral is expressed as a lump sum. For example, the common mineral thenardite has the chemical formula Na_2SO_4 and is composed of two moles of Na and one mole of SO_4. Likewise, minerals with more than two components such as glauberite are usually found in reference materials such as the JCPDS Mineral Powder Difraction File as $Na_2Ca(SO_4)_2$. However, for the purpose of stressing the point that these are mixed salts rather than entirely unique minerals, they are being expressed as combined simple salts so that, for example, glauberite is given the chemical formula $Na_2SO_4 \bullet CaSO_4$. Water (H_2O) is not considered to be a simple salt and is always expressed in combination with a mineral (e.g., mirabilite, $Na_2SO_4 \bullet 10H_2O$).

SECTION 6
TRACE ELEMENT ACCUMULATION IN POND WATERS

Introduction

During the evaporation of agricultural drainage waters from evaporation ponds, the solutes are separated from their solvent, water. Some solutes are subject to solute transport which physically carries them away from the evaporation pond usually to the groundwater table, but the distribution of the majority of solutes is due to chemical partitioning. The chemical partitioning of a solute is related to its suite of reaction mechanisms and relative reactivity. The elevated concentrations created by evapoconcentration is conducive to driving many reactions. For some reactions, however, a favorable concentration gradient may not be enough.

This set of calculations investigates the general reactivities of certain solutes (arsenic, selenium, boron and molybdenum) which have been highlighted as priority toxicants. Their reactivities are referenced against chloride ions which are assumed to be non-reactive conservative constituents of the evaporation pond waters. Though the study does not pinpoint specific reactions, it is important to determine which solutes causing toxic concern arebeing retained in the water column and hence, pose an exposure risk to wildlife and waterfowl.

Evapoconcentration

This is the term given to the process by which the ratio of solute to water solvent is increased by the removal of the solvent and retention of the solute. The change in the ratio is termed the <u>Evapoconcentration Factor</u> (ECF) and may be calculated for changes over time or progressive cells.

ECF Formulae

The ECF formulae have been derived to provide an estimate of the levels of an element in reference to chloride which is assumed to be a non-reactive component of the solution.

Figure 6.1 shows the equations that are used to calculate predicted values. The Time-Dependent ECF (TDECF) applies to changes in the degree of salinity which occur over time. The Multi-Cell ECF (MCECF) applies to differences in the degree of salinity which occur in multi-cell evaporation ponds. The notation m_{pred} generally represents molar concentration (M) but if the volume of water is assumed constant, then it may be expressed in number of moles.

Calculations with the TDECF and MCECF which are reported here are applied to data obtained between fall 1986 and summer 1988. By virtue of the assumptions in building the formula, the TDECF calculation only provides values which are independent of conditions in-between the two time points of interest. In contrast, the MCECF calculation utilizes averaged data over the time period of interest. Although Pryse comprises two cells, the second cell was saturated with respect to solid phases too often to allow the assumption of non-reactive chloride ions. Hence, the MCECF formula was applied only to Peck pond.

(1) <u>Time-Dependent ECF</u>

$$\mathrm{ECF}(t) = \frac{m_{Cl}(t)}{m_{Cl}(t_0)}$$

$$m_{pred,x}(t) = \mathrm{ECF}(t) \times m_x(t_0)$$

(2) <u>Multi-Cell ECF</u>

$$\mathrm{ECF}(n) = \frac{m_{Cl,n}}{m_{Cl,n=0}}$$

$$m_{pred,x,n} = \mathrm{ECF}(n) \times m_{x,n=0}$$

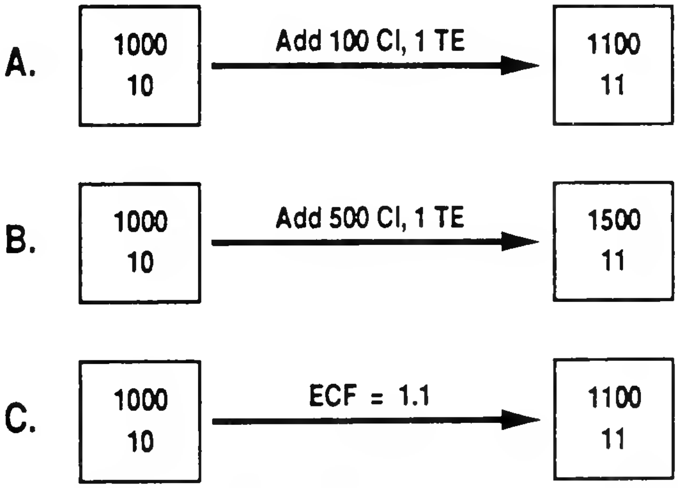
Figure 6.1. Formulae for calculating predicted concentrations during evapoconcentration.
(n = cell number, x = element of interest, t = time)

Verification Example for Time-Dependent ECF Formula

The conditions shown in figure 6.2 have been met satisfactorily at all three evaporation ponds studied. The example above shows that if the inflow Cl:Trace Element Ratio is not the same as the pond water ratio (case B), the increase cannot be expressed in an ECF which would preclude the use of ECFs as a prediction tool. In contrast, the increase due to inflow addition (case A) can be described by an ECF (case C) meaning that deviations in observed values from the ECF-predicted values can be interpreted as reactivity of the trace element.

Conditions for Time Dependent ECF

- Ratio of Cl to TE in inflow water must approximate that in the receiving waters
- Ratio of Cl to TE in inflow water must be approximately constant over the time period of interest



In case B, the TE appears to have decreased in proportion to the Cl while, in fact, both of the constituents have been conserved.

In case A where the inflow water Cl to TE ratio is the same as that in the receiving water, the change in Cl and TE can be reflected by an ECF factor as shown in case C.

Figure 6.2. Conditions necessary for Time-Dependent ECF calculations.

Example Calculation Using TD-ECF

An example calculation using the TD-ECF is done here using the following parameters:

	Initial Conditions	Final Conditions
Date	11/15/86	8/9/88
[Cl]	17,500 mg/l	139,133 mg/l
[B]	43.18 mg/l	237.2 mg/l

$$\text{TDECF} = \frac{[\text{Cl}]_{\text{final}}}{[\text{Cl}]_{\text{initial}}} = \frac{139{,}133}{17{,}500} \cong \underline{7.95}$$

$$
\begin{aligned}
[B]_{predicted} &= TDECF * [B]_{initial} \\
&= 7.95 * 43.18 \text{ mg/l} \\
&= 343.30 \text{ mg/l}
\end{aligned}
$$

The above calculation demonstrates the use of the TDECF formulae in the calculation of a predicted boron concentration for *Pryse CELL 2 SE.* The calculated result for this example is shown on the appropriate chart in figure 6.5. The primary variables in this calculation are the initial and final dates because these are what determine the ECF value.

Extended Application of TDECF

The results presented in this report focus on the changes in pond water concentrations between the initial and final sampling dates. However, a more extensive approach is possible by altering the final date used in the TDECF calculation. An example of this extension is shown in the figure below in which 11/15/86 is retained as the initial date, and the TDECF calculation is performed on data from Pryse Cell 2 SE.

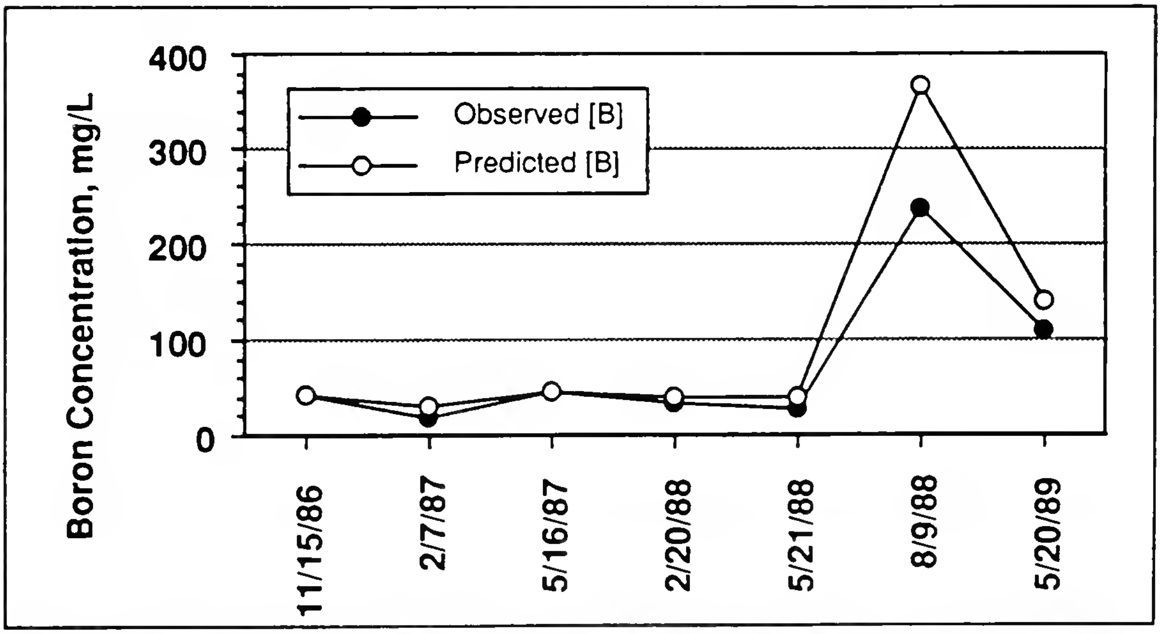


Figure 6.3. Results of TD-ECF Calculation for Pryse Cell 2 SE using multiple final dates.

Figure 6.3 indicates that B is well conserved through the seasons with the exception of the summer 1988 case in which the concentration is many times higher than previous values.

Results

TDECF: The results of the analysis for As, Se, B and Mo are shown in figures 6.4 and 6.5. Arsenic is clearly very reactive (indicated by values less than the limit of quantitation) especially at Barbizon and Peck ponds. Selenium (not detected at Barbizon pond) is slightly less than predicted at Peck pond. The peculiar comparison that is portrayed at Pryse pond probably arises from physical fluxes of Se rather than chemical fluxes. Boron is generally non-reactive and is predicted fairly well by the TDECF. The TDECF calculation also indicates that Mo is reactive for the selected conditions.

For the TDECF formula to be valid, one assumption that needs to be approximately true is that the ratio of chloride to solute be the same at both instances of time (i.e., initial and final). This has been verified with a maximum change in the ratio to be 69%. Since no change is unreasonable to expect, that value of 69% is deemed acceptable given the objectives of the calculation.

MCECF: The calculations for Peck pond (figure 6.6) generally support the observations of the TDECF results. However, molybdenum clearly shows non-reactive behaviour which suggests that it tends to leave and return to the water column according to season. Further calculations using fall dates as initial and final time points should be able to verify this. Finally, the prediction of boron appears to be excellent. There is a high level of confidence in these results because they correspond well with the results that were previously calculated for a single year (Fall 1986 to Summer 1987).

Conclusions

The evapoconcentration factors may be used in predicting solute concentrations assuming that the solute exhibits non-reactive behaviour. Deviations from the predicted trend may be taken as indications of reactivity. The actual significance of the deviations depends on the data set used in the calculations.

Boron has been found to accumulate in the water column whereas selenium appears to undergo a partial removal from the water column. Arsenic tends not to accumulate in the water column while molybdenum undergoes a cycle of removal and restoration according to seasons.

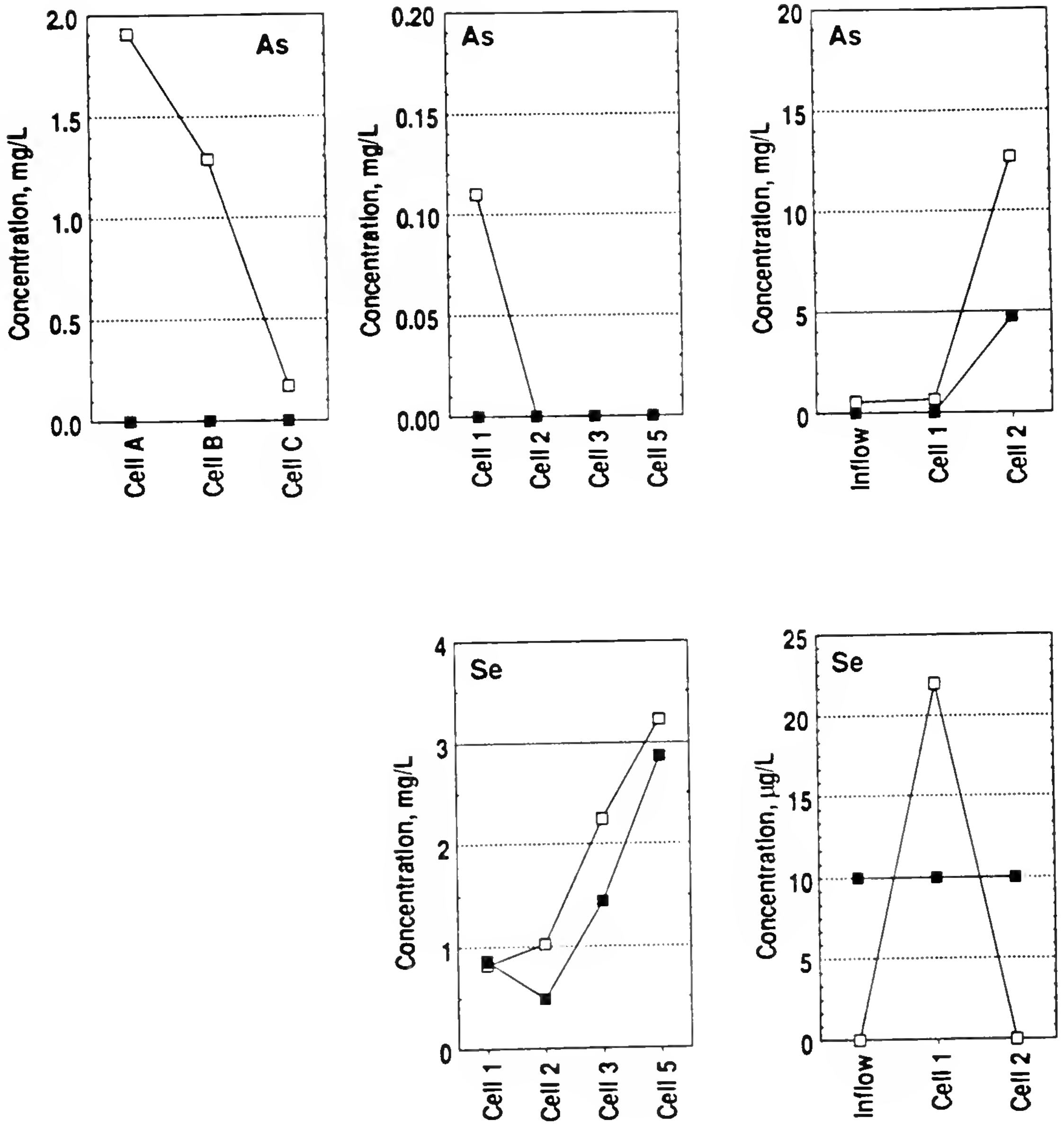


Figure 6.4. Predicted (□) and observed (■) concentrations of arsenic and selenium for (from left to right) Barbizon, Peck and Pryse evaporation ponds. The TDECF method is used.

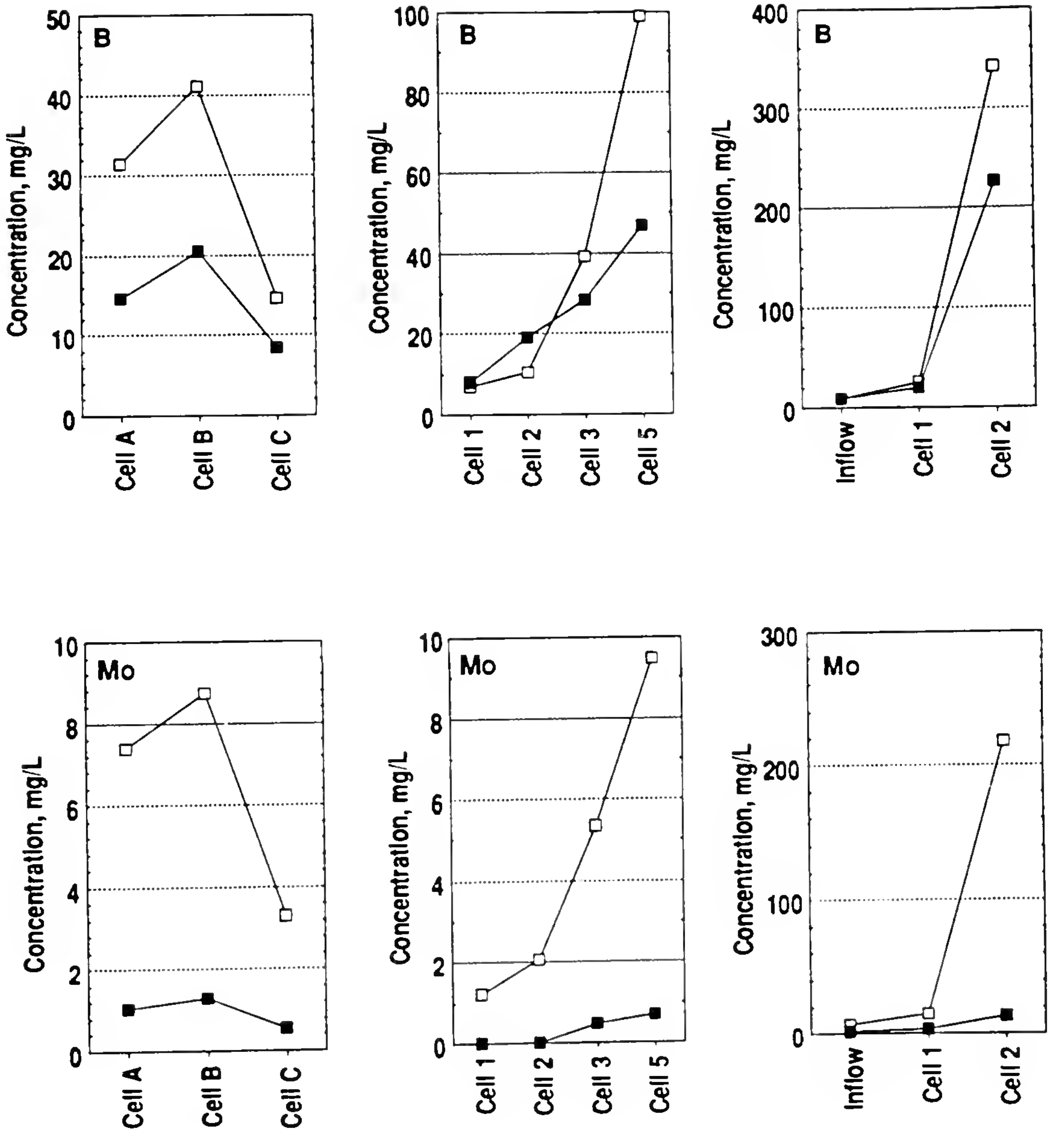


Figure 6.5. Predicted (□) and observed (■) concentrations of boron and molybdenum for (from left to right) Barbizon, Peck and Pryse evaporation ponds. The TDECF method is used.

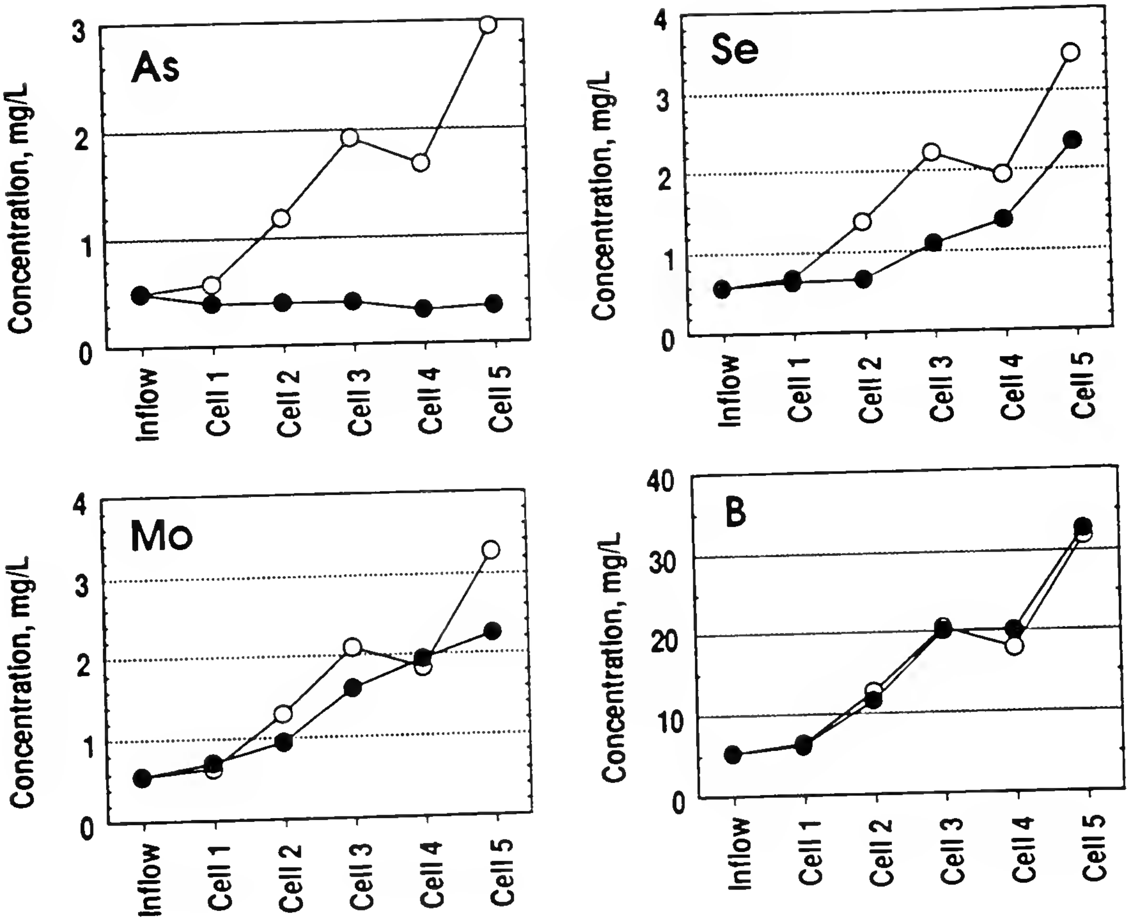


Figure 6.6. Predicted (○) and observed (●) concentrations of arsenic, selenium, boron and molybdenum for Peck evaporation pond. The MCECF method is used.

SECTION 7
TRACE ELEMENTS ASSOCIATED WITH EVAPORITES

Introduction

Trace element concentrations in evaporite minerals forming in agricultural evaporation ponds were examined by dissolving and analyzing evaporite minerals collected from Peck Pond cells 2 and 3. The mineralogy of the salt crusts was found to be dominated by thenardite, a Na_2SO_4 mineral. The evaporites displayed a number of differing morphologies including fine-grained, slabs, and large crystals.

Methodology

The elemental compositions of 7 representative evaporite deposits were determined by dissolving 1 gram of the mineral in 100mL of distilled deionized water. The evaporites were observed to dissolve completely except for a dark colored residue consisting of particulate organic material which was present in some of the samples. The solutions were all filtered through a 0.45 µm membrane filter prior to chemical analysis. The chemical analyses for the dissolved salts are shown in Table 7.1.

Molybdenum was analyzed using a Perkin-Elmer 2100 Graphite Furnace (GFAAS) with deuterium background corrector and a palladium hydroxylamine matrix modifier. Prior to analysis, samples were acidified to pH 2 using nitric acid. To ensure accurate performance of the instrument, replicate samples were run every ten samples and recovery tests every twenty samples (Loya, 1989). Arsenic and selenium were analyzed by Hydride Vapor Generation Atomic Absorption Spectrophotometry (HVGAAS), while boron was analyzed using Inductively Coupled Plasma Spectrophotmetry (ICPS).

Results

Sodium and sulfate were the major chemical constituents comprising the salts which confirm the results of the x-ray diffraction analysis. To examine if the trace elements become enriched or depleted in the solid-phase versus their concentration in the pond waters, the ratio of SO_4 to trace elements in both the solid-phase and solution-phase were plotted (Figure 7.1). The chemical composition of the solution phase was taken as the mean concentrations in Peck Pond Cell 2 SE. The diagonal line shown in Figure 7.1 represents chemical compositions where the ratio of SO_4 to trace element in both the solid phase and solution phase are equal. Above this line is a region where the solid phase is depleted relative to the solution phase. Below this line, the trace element is enriched in the solid phase relative to the solution phase. The diagram shows that As, B and Se are depleted in the solid-phase, while Mo concentrations were nearly equal, to slightly enriched in the solid-phase.

Table 7.1 Trace elements associated with pond evaporites (values in µmoles/L)

		SO_4	Se	As	B	Mo	DOC	Na	Ca	Mg	K	Cl
Peck 2	Fine Salt	76,251	0.61	0.33	200	43	3,239	119,226	4,620	6,560	290	6,310
Peck 2	Slab	88,115	0.04	0.52	92	20	439	161,005	237	897	139	4,972
Peck	Long	89,673	0.04	0.25	57	17	179	156,929	14	740	243	3,787
Peck	Slab	86,237	0.11	0.11	273	37	770	157,439	445	2,601	176	11,144
Peck	Long	87,255	0.16	0.08	121	23	370	160,496	267	880	252	4,659
Peck 3	Slab	92,102	0.43	0.04	24	5	335	166,101	158	610	1	499
Peck 3	Crystals	87,398	0.08	0.07	70	8	663	144,701	3,519	400	1	3,021
Peck 2 SE	Water	135,858	7.22	6.41	1,471	10.2	6,083	297,565	12,444	14,568	818	75,430

These results represent only one pond and one type of evaporite mineral (thenardite) and therefore the results of these preliminary studies should not be extrapolated to other sites. More work is currently underway to determine the mechanisms responsible for the distribution of trace elements between the solution and solid phases. Future studies will be expanded to include different evaporite minerals from a number of different locations.

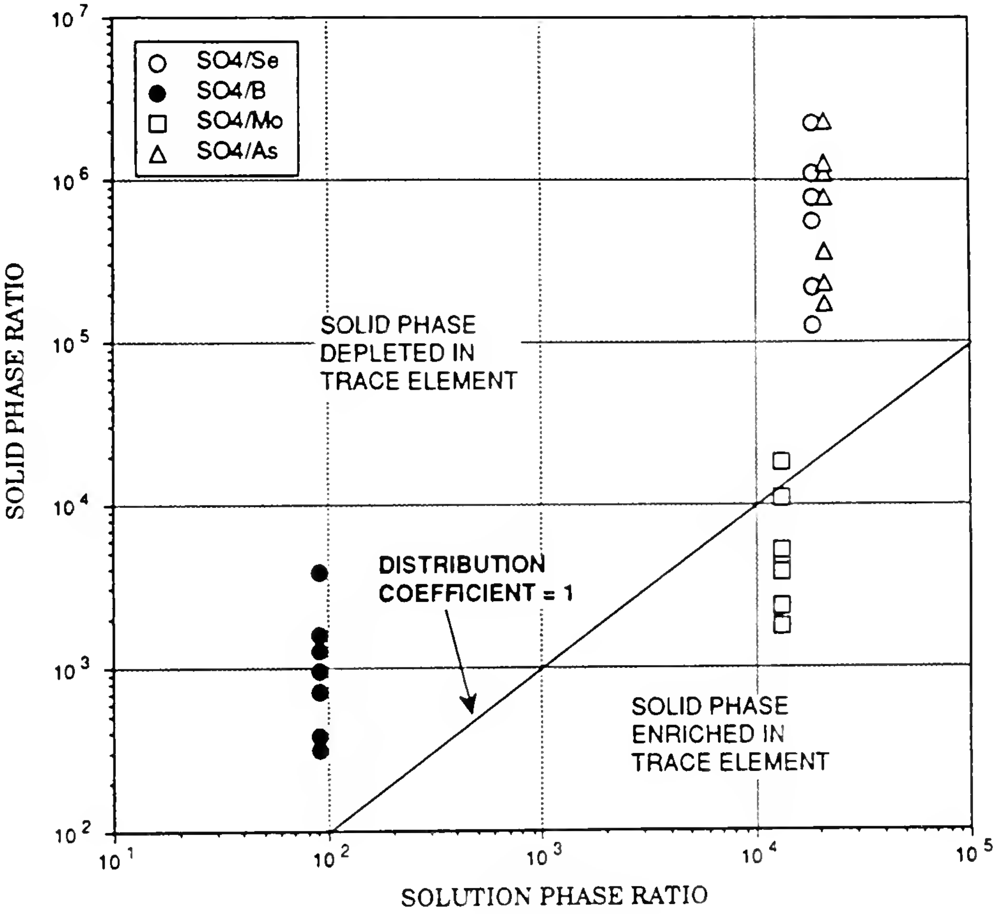


Figure 7.1 Trace Elements Associated with Evaporites from Evaporation Ponds

SECTION 8
MAGNITUDE OF SALT LOAD

Introduction

In the previous interim report (Tanji and Grismer, 1989), a brine chemistry model (C-Salt) was utilized to simulate the sequence and quantities of salts precipitating as pond waters are evapoconcentrated up to a 50-fold decrease in volume. This report takes another approach in assessing the magnitude of salts accumulating in evaporation ponds. The primary data used herein are from the Central Valley Regional Water Quality Control Board (Westcot et al., 1988) and the Department of Water Resources (1988) that were summarized in the interim report.

Unit Values

The 27 evaporation ponds have a total pond surface area of about 7,070 acres annually receive about 31,900 ac-ft of subsurface drainage from about 56,500 acres of tile-drained fields containing about 810,000 tons of salts (TDS). These data are transformed into unit values as follows:

$$\text{unit tile effluent} = \frac{31\,900 \text{ ac-ft/yr}}{7\,070 \text{ ac}} = 4.51 \text{ ft/yr} \tag{8.1}$$

The unit tile effluent is the average annual surface depth of drainwater disposed into the ponds.

$$\text{unit pond surface} = \frac{7\,070 \text{ ac}}{56\,500 \text{ ac}} = 0.125 \tag{8.2}$$

The unit pond surface is the acres of pond surface for each acre of tile-drained field.

$$\text{unit field drainage} = \frac{31\,900 \text{ ac-ft/yr}}{56\,500 \text{ ac}} = 0.56 \text{ ac-ft/ac-yr} \tag{8.3}$$

The unit field drainage is the average annual quantity of subsurface drainage water collected from the fields and disposed into ponds.

$$\text{unit TDS from fields} = \frac{810\,000 \text{ tons/yr}}{56\,500 \text{ ac}} = 14.3 \text{ tons/ac-yr} \tag{8.4}$$

This unit TDS is the average annual quantity of salts collected in the tile effluents from the fields.

$$\text{unit TDS into ponds, concentration basis} = \frac{810\,000 \text{ tons/yr}}{31\,900 \text{ ac-ft/yr}} = 25.4 \text{ tons/ac-ft} \tag{8.5}$$

This unit TDS gives the average annual salt accumulation discharged into the ponds.

$$\text{unit TDS into ponds, weight basis} = \frac{810\,000 \text{ tons/yr}}{7\,070 \text{ ac}} = 115 \text{ tons/ac-yr} \tag{8.6}$$

This unit TDS is the average annual weight of salts discharged into the ponds.

Magnitudes Discharged into Ponds

The 31,900 ac-ft/yr of subsurface drainage discharged into ponds is nearly 1.9 times the 17,000 ac-ft/yr of groundwater discharged from drains in the Grasslands Subarea into the San Joaquin River (CH2M HILL, 1988). The 810,000 tons/yr of TDS disposed into ponds is about 5.8 times the 139,400 tons/yr of TDS in the ground water discharged from drains in the Grassland Subarea into the San Joaquin River. CH2M HILL (1988) gives another estimate of 743,800 tons/yr disposed into ponds.

The 810,000 tons/yr of TDS disposed in ponds is about 26% of the estimated 3,100,000 tons/yr of salt accumulation in the San Joaquin Valley's west side (CH2M HILL, 1988).

In addition, the quantities of trace elements disposed into ponds are about 595 tons/yr of boron, 4,340 lbs/yr of selenium, 7,900 lbs/yr of arsenic, and 44 tons/yr of molybdenum.

Accumulation in Ponds

As noted in the interim report, the average measured seepage rate from the evaporation ponds is about 1.0 ac-ft/ac-yr.

$$\begin{aligned}\text{Net Volume Evaporated} &= 31\,900 \text{ ac-ft/yr} - (1.0 \text{ ac-ft/yr})(7\,070 \text{ ac}) \\ &= 24\,830 \text{ ac-ft/yr}\end{aligned} \tag{8.7}$$

This annual net volume of water evaporated in the ponds is about 77.8% of the total drainage influent if seepage losses are accounted for.

$$\text{Net TDS Accumulation} = \frac{24\,830 \text{ ac-ft/yr}}{31\,900 \text{ ac-ft/yr}}\, 810\,000 \text{ tons/yr} = 630\,500 \text{ tons/yr} \tag{8.8}$$

This is the annual net weight of salts accumulating in the ponds when seepage losses are considered.

In order to estimate the volume of TDS accumulating in the pond, density of the salt precipitates must be assumed. Because the pond waters are predominantly of the Na_2SO_4 -type water, thenardite (Na_2SO_4) is the principal evaporite mineral formed in these ponds. The density of pure crystalline thenardite is 2.66 g/cm^3 (Sonnenfeld, 1984). The density of other predominant evaporites identified in the salt deposits are 2.71 g/cm^3 for calcite ($CaCO_3$), 2.32 g/cm^3 for gypsum ($CaSO_4 \bullet 2H_2O$), and 2.23 g/cm^3 for bloedite ($Na_2SO_4 \bullet MgSO_4 \bullet 5H_2O$).

Assuming a density of 2.66 g/cm^3 for salts precipitated in ponds, the annual volume of salts accumulating is estimated to be about 164,500 cubic yds or an average deposition thickness of 0.17 in/yr.

In contrast, simulation runs by C-Salt as given in the interim report assumed that the density of precipitated minerals to be identical to the calculated density of the brine from which precipitation took place. The density of the brines when precipitation was occurring ranged from less than 1.1 to 1.4 g/cm^3 as pond waters were evapoconcentrated 50-fold. This lower density is more representative of the shoreline salt deposits.

Assuming a density of 1.28 g/cm^3 gives an estimated annual volume of salt accumulation of about 342,000 cubic yds or an average deposition thickness of 0.36 in/yr.

The above range of estimates on annual salt deposition in ponds indicate huge amounts available for possible salt harvesting or for disposal. The potential for commercial salt harvesting is, however, constrained by the level of purity, distance to the market and economics of worldwide markets (Personal communication, E. Lee). Moreover, the presence of toxic elements such as selenium, arsenic, boron, molybdenum and uranium may constrain how these salts are to be ultimately disposed.

SECTION 9
RECOMMENDED DESIGN AND BEST MANAGEMENT PRACTICES

Introduction

Many factors affect the evaporation and precipitation rate in evaporation ponds. As some of these factors are not readily changeable, evaluation of each factor's manageability (or the degree to which the factor can be controlled) to accelerate evaporation and precipitation is addressed. Although evaporation and precipitation are inter-related, they are evaluated separately in finding manageablility factors. These factors will eventually be combined when recommending the design and best management practices for evaporation ponds.

Factors Which Affect the Evaporation Rate

Table 9.1 shows factors which affect the evaporation and those factors which are manageable to increase the evaporation rate. Net radiation, salinity and color of effluents can be controlled by specifying design and management practices.

Table 9.1 Evaporation rate factors and manageability

EVAPORATION RATE FACTORS	MANAGEABLE FACTORS
➪ *Climatic property*	➪ *Climatic property*
Net Radiation	Net Radiation
Humidity	
Air Temperature	
Wind Velocity and Direction	
➪ *Water Property*	➪ *Water Property*
Salinity	Salinity
Color	Color
Temperature	
Chemical Compostition	
Turbidity	

Net Radiation

Net radiation is defined as the difference between the amount of solar radiation which reaches the earth's surface, and the amount of reflected and reradiated radiation. Evaporation rate is calculated using the energy balance and Bowen ratio:

$$E = \frac{R_n - S}{L(1 + B)} \qquad (1)$$

E = evaporation
R_n = net radiation
S = heat stored in water
L = latent heat of water vaporization
B = Bowen ratio

According to equation (1), if the absorbed net radiation in solution, R_n, increases, the evaporation rate will also increase. To increase the absorption of solar radiation in ponds, a dye such as 2-Naphthol Green is often used.

Bonython (1965) compared evaporation rates between undyed and dyed salt ponds. At Dry Creek in South Australia during the 1948-1949 summer season, 58 acres of dyed salt-crystallizing ponds were compared with 87 acres of undyed ponds supplied saturated brine. Results showed that crystallization of salt in dyed ponds was 15-20% more than in undyed ponds. This indicates that the use of dye contributes significantly to increasing evaporation rates and the subsequent precipitation of salts.

Salinity

Salinity is directly related to seasonally variable drainage volume. Tanji and Grismer (1989) showed that in the San Joaquin Valley, the water volume in evaporation ponds is high during winter due to pre-plant irrigation and rainfall, and is low in late summer and fall because evaporation rate exceeds drainage drainage input. Therefore, salinity is high in summer and low in winter.

Evaporation decreases with increasing salinity as this and many other studies have shown (Bonython, 1965; Janson, 1959; Moore and Runkles, 1968; Salhotra et al., 1959). In addition, salt crusts may form on the water surface with increasing evapoconcentration resulting in a reduction of evaporation rate (Adams, 1934). Adequate design and management should thus aim at keeping salinity sufficiently low or removing salt crusts to maintain a reasonable evaporation rate.

To achieve an adequate evaporation rate, the evaporation ponds should be divided into several cells so that waters can be separated according to their salinity range. The water with the lowest salinity should be directed into the first cell and, as evapoconcentration proceeds, it should be conducted to other cells.

Ormat Process

Ormat Engineering, Inc, is advancing the Ormat process to enhance evaporation rates of dilute brines. This process is used to concentrate Dead Sea brine for minerals recovery in Israel and is also being demonstrated in a USBR project to recover energy from solar ponds at El Paso, Texas.

The patented Ormat process involves pumping dilute brine through a large number of nozzles at a height of 30 meters so that the saline water is in contact with dry air. Due to proprietary constraints, details on the Ormat process are not completely known. This process appears to have a high initial capital investment and high operating cost. A potential problem exists of salt drift to adjacent lands.

Color of Solution

The color of solution affects the degree of net radiation absorption. The darker the color of the solution, the higher the absorption of net radiation. As mentioned earlier, the dye 2-Napthol Green is commonly used to alter the color.

Salt Precipitation

Precipitation of evaporites is a function of ion activities , solution temperature, chemical composition and pH. Each factor depends on several interacting variables which interact not only with each other but also with evaporation rate. For example, water temperature is dependent on absorption of net radiation, latent heat transfer and sensible heat transfer. Generally speaking, if water temperature is high, more minerals are dissolved due to an increase in the solubility product and the evaporation rate decreases. As far as the efficiency of evaporation ponds is concerned, the manageable factor affecting evaporation rate and salt precipitation is solute concentration and salinity.

Precipitation of salts usually occurs when the ion activity product of solutes exceeds the solubility product of a particular mineral. When evapoconcentration of pond waters causes

precipitation, the salts may either form a surface-covering crust or suspended particles which settle and accumulate on the pond bottom.

Since salt crusts on the surface of the pond reduce the evaporation rate significantly, surface salt crusts should be minimized or removed to ensure maximum efficiency of the evaporation.

One method of removing salt crusts might be to control the flow of effluent using gates between adjacent cells. If differences in water level are maintained throughout cells, salt crust can be removed through addition of effluent from a more dilute cell.

Another suggestion is to carry out salt removal during the night because cooler temperatures generally decrease the solubility product and hence, more salts will be available for removal by some mechanical means.

Sadan Proposal

Abraham Sadan and Cominco Ltd has a patent (Swinkel et al., 1986) to separate and purify salts in a non-convective solar pond. They contend that a brine consists of combinations of higher hydrated and lower hydrated or anhydrous forms of salts. The patent claims that under saturated conditions it is possible to crystallize salt in a higher hydrated form, dehydrate it to a lower hydrated form in a non-convective solar pond, and recover the salt from the bottom of a pond in solid, pure form essentially free from other salts in the brine.

Sadan (Sadan, 1987) presented to the Westlands Water District a proposal to recover high purity anhydrous Na_2SO_4 using an example of reducing 8,000 ac-ft/yr of tile effluents to 14.25 ac-ft (52,000 tons) of anhydrous Na_2SO_4, 4.25 ac-ft (12,000 tons) of NaCl and 20.0 ac-ft (36,000 tons) of $MgCl_2$ bitterns. The proposal requires a 1,500 acre preconcentration pond from which $CaCO_3$ and $CaSO_4 \cdot 2H_2O$ would precipitate leaving 180 ac-ft of concentrated brine. The brine goes to a 16 acre deca pond in which $Na_2SO_4 \cdot 10H_2O$ (mirabilite) would precipitate out leaving a sulfate brine of 80 ac-ft. A 16 acre winter cooling pond is also required in which $Na_2SO_4 \cdot 10H_2O$ would precipitate and dissolve. The cooled brine of 50 ac-ft is transferred to a 12 acre pond to precipitate NaCl. The remaining 20 ac-ft of bitterns is stored in a 36 acre non-convective pond from which Na_2SO_4 may precipitate.

In the above process, selenium was assumed to remain in the dissolved state and evapoconcentrate in the brines. The example given estimated Se would increase from 0.31 to 15.08 mg/liter in the preconcentration pond, from 15.08 to 33.46 mg/liter in the deca pond, from 33.46 to 53.89 mg/liter in the winter cooling pond, and from 53.89 to 136.20 mg/liter.

Our assessment is that the process outlined above would require extremely close controls on salinity levels to preferentially precipitate out $Na_2SO_4 \cdot 10H_2O$, NaCl and Na_2SO_4. This may be possible in an industrial processing plant but probably not in agricultural evaporation ponds. Moreover, the assumption that Se would evapoconcentrate in a conservative manner and not be reactive is contrary to our observations in evaporation ponds.

Best Design to Sustain Evaporation Rate and Precipitation

Although the current design of evaporation ponds is based on United States Department of Agriculture-Soil Conservation Service (1982) design criteria, the best design considered here is based on having the highest efficiency and the least detrimental effect on the environment. The best design will take into account the suggestions mentioned previously.

Size

Evaporation ponds should have enough capacity to satisfy the maximum storage expected or total inflow minus the total outflow.

Total inflow = drainage from the field
+ rainfall
+ perimeter drainage (drainage collected by interceptor drain)

Total outflow = evaporation + seepage

In the San Joaquin Valley, water levels in evaporation ponds change seasonally. They are typically high in winter and low in summer (Tanji and Grismer, 1989). Since the capacity of the evaporation ponds have to satisfy the highest water level to avoid overflow to adjacent areas, pond capacity has to be determined using the highest water inflow rather than the yearly averaged value. Pond volume must also be calculated to deal with major storm events and prolonged high rainfall years.

Shape

The major factor influencing the shape of an evaporation pond is the environmental impact. Since wildlife are attracted to evaporation ponds, the reduction of shoreline (the reduction of access to contaminated water) is desirable. Although the circular shape poses the least shoreline per unit area compared to square and rectangular shapes, the circular shape would not make efficient use of land because most fields are rectangular in shape. If land wasted is not a constraint, the circular shape is the best option environmentally. Otherwise, the square shape is recommended since the shoreline per unit area is less than that of rectangular shapes (Department of Water Resources, 1988).

Depth

According to the Department of Fish and Game the recommended minimum depth is 2 feet to discourage wildlife use. Bonython (1965) found that the variation with depth can be virtually neglected evaluating the result of Ferguson (1952) and Block et al., (1951). Ferguson has shown that evaporation in a pond with a depth of 40 inches is 4 % less than a 6 inch deep pond, and the evaporation from a 1 inch deep pond is 4 % greater than a 6 inch deep pond. Thus, the influence of depth on evaporation may be largely ignored.

Cells

As explained in the previous sections, cells contribute to maximizing evaporation and salt precipitation by allowing mixing of waters to control solute concentrations. Cells with gates are essential for regulating solute concentrations and thus maximizing efficiency of evaporation ponds.

Embankment

The current design based on the specification of the Department of Agriculture-Soil Conservation Service is adequate relative to evaporation but not to discourage wildlife usage. The current design criteria include:

Top width	At least 14 feet
Freeboard	1.6 feet or the maximum wave ramp
Inside Slope	6:1
Outside Slope	2:1

Lining and Interceptor Drain

Impermeable linings such as concrete and asphalt are not economically feasible for evaporation ponds. Tanji and Grismer (1989) estimated that seepage from a typical San Joaquin Valley evaporation pond is approximately 1 foot per year using existing soil materials for a pond bottom. Interceptor drains would be desirable to reduce contamination of groundwater from seepage. Tanji et al. (1985) suggested installation of tile drains underneath ponds instead of around the perimeter and pumping seepage back into evaporation ponds.

Best Management Options

Possible management options to sustain evaporation and precipitation rates include:

1. Use of green dyes to increase evaporation.
2. Monitor the salinity of effluent to each cell to determine when effluent should be transferred to a higher concentration cell.

3. Remove salt crusts periodically.
4. Prevent the complete drying out of evaporation ponds or pond cells. As there is some uncertainty as to whether the periodic drying out of ponds reduces biota and hazards to wildlife, further research needs to be carried out. Until these uncertainties are addressed, evaporation ponds should not be dried out (Department of Water Resources, 1988). Also, during the drying phase, more wildlife may have access to contaminated water.
5. Use blue-green algae to seal the pond bottoms instead of interceptor drains to minimize seepage. It has been reported that 3–12 months after applying blue-green algae, complete sealing occurs in salt- producing ponds. Although the cost of algae treatment is less than interceptor drains, the effectiveness is still undetermined (Department of Water Resources, 1988).
6. Consider ORMAT, an evaporation enhancement system. ORMAT is designed to increase the evaporation rate of water by reducing the water to fine droplets. The total surface area of droplets is greater than a surface water body of the same volume of water. This, in turn, leads to an increase in the rate of evaporation. Since a higher rate of evaporation is achieved, smaller ponds would be required. ORMAT is commercially used in Israel and has been utilized in the U. S. (Bradford et al., 1989b). Since performance information concerning ORMAT is limited, the efficiency in increasing evaporation rates of water is not known. In addition, a high cost of set-up and operation could hinder widespread application.
7. Use Iron Sulfide (FeS_2) Sealing. Paul and Clark (1989) stated that Soviet workers found that a buried layer of straw approximately 15 cm thick covered with another 15 cm of soil results in the sealing of soils under ponds by means of a gleying reaction (decay of organic matter resulting in the reduction of Fe^{3+} to Fe^{2+} and SO_4^{2-} to S^{2-}. As a result of that reaction, FeS_2 is precipitated and soil colloids peptize. This procedure is inexpensive, and might be used in reducing or preventing seepage leading to contamination of groundwater.

Constraints

The above best management options and design features may be overridden by considerations to make evaporation ponds least attractive to wildlife and reduce potential contaminant hazards to wildlife.

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SECTION 11
APPENDICES

APPENDIX A: Evaporation Pond Diurnal Monitoring Data

Table A.1 Weather Conditions During First Diurnal Study: Pryse Pond

Date	Time	t hrs	Temp °C	Solar Radiation	RH %	Wind Direction, °	Wind Speed m/s
3/26/89	10:00 AM	0.0	11.5	64.80	67	354	0.540
	10:30 AM	0.5	11.4	16.92	69	288	0.646
	11:00 AM	1.0	12.5	71.50	65	16	0.606
	11:00 AM	1.5	12.8	31.80	65	50	0.566
	11:30 AM	2.0	13.6	72.40	63	315	0.619
	12:00 N	2.5	13.6	40.80	58	350	0.606
	12:30 PM	3.0	13.5	14.76	56	277	0.566
	1:00 PM	3.5	13.9	10.02	56	121	0.540
	1:30 PM	4.0	14.0	9.24	59	301	0.480
	2:00 PM	4.5	14.8	46.32	49	47	0.486
	2:30 PM	5.0	15.6	47.40	51	285	0.580
	3:00 PM	5.5	15.2	25.26	50	250	0.460
	3:30 PM	6.0	14.9	27.66	51	63	0.460
	4:00 PM	6.5	14.7	8.40	52	341	0.500
	4:30 PM	7.0	14.3	4.74	59	106	0.500
	5:00 PM	7.5	13.6	0.72	65	126	0.513
	5:30 PM	8.0	13.3	0.24	72	108	0.633
	6:00 PM	8.5	13.1	0.12	75	138	0.526
	6:30 PM	9.0	12.9	0.30	77	150	0.540
	7:00 PM	9.5	12.9	-0.30	74	147	0.553
	7:30 PM	10.0	12.8	-0.06	78	174	0.460
	8:00 PM	10.5	12.7	-0.30	76	197	0.447
	8:30 PM	11.0	12.1	0.30	75	220	0.580
	9:00 PM	11.5	10.8	0.06	88	60	0.540
	9:30 PM	12.0	9.8	-0.12	96	41	0.619
	10:00 PM	12.5	11.0	-0.72	96	130	0.566
	10:30 PM	13.0	10.7	0.00	94	112	0.460
	11:00 PM	13.5	10.5	0.12	95	116	0.500
	11:30 PM	14.0	10.1	0.03	93	154	0.606
3/27/89	12:00 M	14.5	9.5	-0.06	94	109	0.646
	12:30 AM	15.0	8.1	-0.42	97	86	0.526
	1:00 AM	15.5	8.5	0.18	98	153	0.646
	1:30 AM	16.0	7.4	0.06	99	102	0.553
	2:00 AM	16.5	7.4	-0.06	100	104	0.580
	2:30 AM	17.0	7.1	0.12	101	143	0.566
	3:00 AM	17.5	5.5	-0.24	100	213	0.447
	3:30 AM	18.0	4.7	0.06	102	63	0.606
	4:00 AM	18.5	4.9	-0.06	102	264	0.513
	4:30 AM	19.0	5.5	-0.18	103	114	0.606
	5:00 AM	19.5	4.9	0.48	103	255	0.447
	5:30 AM	20.0	•	•	•	•	•
	6:00 AM	20.5	•	•	•	•	•
	6:30 AM	21.0	•	•	•	•	•
	7:00 AM	21.5	•	•	•	•	•
	7:30 AM	22.0	•	•	•	•	•
	8:00 AM	22.5	•	•	•	•	•
	8:30 AM	23.0	•	•	•	•	•
	9:00 AM	23.5	•	•	•	•	•
	9:30 AM	24.0	•	•	•	•	•

• = na data

Table A.2 Pond Water Conditions During First Diurnal Study: Pryse Pond

Cell	Date	Time	time hrs	Temp °C	EC(25°C) dS/m	pH	DO mg/L	Eh mV	Density
1	3/26/89	10:00 AM	0	16.2	51.58	8.06	8.2	536	1.035
		12:00 N	2	17.3	52.60	8.49	9.4	465	1.035
		2:00 PM	4	18.1	50.93	8.42	11.2	492	1.035
		4:00 PM	6	17.6	51.88	8.36	9.0	484	1.035
		6:00 PM	8	17.7	50.59	8.55	14.2	419	1.035
		8:00 PM	10	17.3	50.71	8.57	17.8	419	1.030
		10:00 PM	12	17.8	50.00	8.6	17.8	420	1.030
	3/27/89	12:00 M	14	16	50.73	8.53	16.0	415	1.030
		2:00 AM	16	14.7	51.51	8.6	15.6	419	1.030
		4:00 AM	18	15	50.63	8.57	13.6	403	1.030
		6:00 AM	20	13.3	52.48	8.59	12.8	396	1.030
		8:00 AM	22	14	52.56	8.62	13.4	375	1.035
		10:00 AM	24	16.3	52.66	8.49	10.4	384	1.035

Table A.3 Weather Conditions During First Diurnal Study: Peck Pond

Date	Time	t hrs	Temp °C	Solar Radiation	RH %	Wind Direction, °	Wind Speed m/s
3/29/89	10:00 AM	0.0	16.0	53.34	53	319	0.553
	10:30 AM	0.5	16.9	57.78	51	329	0.593
	11:00 AM	1.0	17.3	60.42	52	339	0.486
	11:30 AM	1.5	17.8	61.04	52	330	0.593
	12:00 N	2.0	18.4	63.18	54	311	0.606
	12:30 PM	2.5	19.4	63.00	52	337	0.540
	1:00 PM	3.0	19.4	61.62	50	317	0.447
	1:30 PM	3.5	20.1	59.28	51	303	0.553
	2:00 PM	4.0	21.5	55.98	48	316	0.593
	2:30 PM	4.5	21.1	51.48	43	310	0.553
	3:00 PM	5.0	21.3	46.14	43	336	0.606
	3:30 PM	5.5	21.6	38.88	50	328	0.606
	4:00 PM	6.0	21.7	32.52	40	326	0.460
	4:30 PM	6.5	21.4	24.84	39	344	0.500
	5:00 PM	7.0	21.1	17.34	43	327	0.480
	5:30 PM	7.5	21.6	10.02	43	335	0.447
	6:00 PM	8.0	19.6	28.80	47	348	0.633
	6:30 PM	8.5	17.5	0.12	50	330	0.526
	7:00 PM	9.0	15.9	0.00	55	316	0.646
	7:30 PM	9.5	15.6	-0.18	56	267	0.593
	8:00 PM	10.0	14.6	0.00	55	304	0.473
	8:30 PM	10.5	14.4	0.00	60	293	0.500
	9:00 PM	11.0	14.1	0.00	62	296	0.513
	9:30 PM	11.5	13.4	-0.06	62	265	0.540
	10:00 PM	12.0	13.3	-0.06	61	266	0.553
	10:30 PM	12.5	13.1	0.00	62	269	0.553
	11:00 PM	13.0	14.1	-0.12	62	253	0.486
	11:30 PM	13.5	13.6	-0.06	64	246	0.526
3/30/89	12:00 M	14.0	13.5	0.00	64	261	0.566
	12:30 AM	14.5	12.9	0.00	65	264	0.473
	1:00 AM	15.0	12.8	-0.06	66	255	0.646
	1:30 AM	15.5	12.0	-0.06	70	252	0.566
	2:00 AM	16.0	12.3	0.00	71	262	0.473
	2:30 AM	16.5	8.0	0.00	73	22	0.513
	3:00 AM	17.0	6.0	-0.12	82	13	0.486
	3:30 AM	17.5	7.2	-0.12	84	355	0.606
	4:00 AM	18.0	8.0	0.00	84	331	0.580
	4:30 AM	18.5	8.2	-0.06	84	292	0.500
	5:00 AM	19.0	8.1	0.00	84	267	0.580
	5:30 AM	19.5	8.5	-0.06	85	257	0.633
	6:00 AM	20.0	8.4	0.66	85	251	0.460
	6:30 AM	20.5	9.0	5.34	79	264	0.540
	7:00 AM	21.0	10.1	12.60	76	257	0.580
	7:30 AM	21.5	11.8	17.58	75	269	0.593
	8:00 AM	22.0	13.2	27.72	74	274	0.580
	8:30 AM	22.5	14.7	33.42	68	302	0.540
	9:00 AM	23.0	16.0	41.82	65	278	0.519
	9:30 AM	23.5	16.8	58.95	59	358	0.526
	10:00 AM	24.0	17.3	55.91	56	310	0.593

Table A.4 Pond Water Conditions During First Diurnal Study: Peck Pond

Cell	Date	Time	time hrs	Temp °C	EC(25°C) dS/m	pH	DO mg/L	Eh mV	Density
3	3/29/89	10:00 AM	0	17.3	70.80	8.59	9.5	385	1.070
		12:00 N	2	18.9	74.26	8.69	9.8	434	1.070
		2:00 PM	4	21.7	72.38	8.64	9.8	356	1.070
		4:00 PM	6	22.3	73.33	8.63	10.0	387	1.070
		6:00 PM	8	21.1	73.54	8.61	10.4	372	1.070
		8:00 PM	10	19.5	73.82	8.58	10.2	377	1.070
		10:00 PM	12	18.2	72.34	8.66	9.6		1.070
	3/30/89	12:00 M	14	16.7	73.14	8.6	9.8	*	1.070
		2:00 AM	16	16	72.44	8.62	9.4	*	1.070
		4:00 AM	18	13.5	73.12	8.64	9.3	*	1.070
		6:00 AM	20	13.4	73.70	8.57	9.6	*	1.070
		8:00 AM	22	13.5	75.32	8.66	9.0	*	1.070
		10:00 AM	24	16.4	73.79	8.57	9.4	*	1.070
5	3/29/89	10:00 AM	0	18.3	61.66	8.71	10.0	391	1.060
		12:00 N	2	20.3	64.90	8.73	10.0	419	1.060
		2:00 PM	4	22.5	62.91	8.7	9.6	348	1.060
		4:00 PM	6	21.5	64.62	8.72	9.9	380	1.060
		6:00 PM	8	19.1	63.83	8.69	9.4	364	1.060
		8:00 PM	10	16.6	63.70	8.65	9.4	*	1.060
		10:00 PM	12	16.5	61.45	8.69	9.2	*	1.060
	3/30/89	12:00 M	14	14.4	62.44	8.64	9.4	*	1.060
		2:00 AM	16	14.6	62.25	8.66	9.6	*	1.060
		4:00 AM	18	11.9	63.82	8.58	9.6	*	1.065
		6:00 AM	20	12.4	62.97	8.7	9.4	*	1.060
		8:00 AM	22	13.8	65.98	8.73	10.8	*	1.065
		10:00 AM	24	19.8	64.29	8.69	11.6	*	1.060

* = no data

Table A.5 Weather Conditions During First Diurnal Study: Barbizon Pond

Date	Time	t hrs	Temp °C	Solar Radiation	RH %	Wind Direction, °	Wind Speed m/s
3/27/89	1:00 PM	0.0	19.8	57.36	22	3	0.447
	1:30 PM	0.5	20.0	53.34	21	183	0.566
	2:00 PM	1.0	19.9	48.78	22	329	0.513
	2:30 PM	1.5	20.2	43.20	22	7	0.513
	3:00 PM	2.0	20.3	36.54	23	33	0.513
	3:30 PM	2.5	19.5	29.88	23	339	0.593
	4:00 PM	3.0	19.2	22.14	22	357	0.646
	4:30 PM	3.5	18.9	14.88	22	16	0.513
	5:00 PM	4.0	18.1	7.74	22	363	0.566
	5:30 PM	4.5	16.4	1.44	22	27	0.619
	6:00 PM	5.0	15.4	0.00	22	31	0.540
	6:30 PM	5.5	14.8	0.00	22	42	0.619
	7:00 PM	6.0	14.4	-0.06	22	339	0.513
	7:30 PM	6.5	14.3	-0.06	21	351	0.619
	8:00 PM	7.0	13.6	-0.06	22	326	0.447
	8:30 PM	7.5	13.5	-0.06	21	325	0.593
	9:00 PM	8.0	13.4	-0.06	21	174	0.500
	9:30 PM	8.5	11.2	0.00	22	345	0.553
	10:00 PM	9.0	13.3	-0.06	21	162	0.513
	10:30 PM	9.5	12.6	-0.06	21	214	0.540
	11:00 PM	10.0	11.5	-0.12	21	284	0.593
	11:30 PM	10.5	9.5	-0.06	21	298	0.513
3/28/89	12:00 M	11.0	9.4	-0.06	21	343	0.447
	12:30 AM	11.5	8.9	0.00	21	45	0.447
	1:00 AM	12.0	8.0	-0.06	21	98	0.566
	1:30 AM	12.5	6.8	-0.06	21	67	0.606
	2:00 AM	13.0	8.1	-0.06	21	162	0.540
	2:30 AM	13.5	9.6	0.00	21	163	0.500
	3:00 AM	14.0	9.3	-0.06	21	178	0.447
	3:30 AM	14.5	9.1	0.00	21	205	0.460
	4:00 AM	15.0	9.0	-0.06	21	116	0.473
	4:30 AM	15.5	7.9	-0.06	21	90	0.460
	5:00 AM	16.0	8.4	0.00	21	80	0.593
	5:30 AM	16.5	8.0	0.72	21	86	0.580
	6:00 AM	17.0	9.7	6.48	21	106	0.553
	6:30 AM	17.5	12.1	3.54	21	133	0.566
	7:00 AM	18.0	14.1	21.18	21	153	0.633
	7:30 AM	18.5	14.5	27.72	21	157	0.486
	8:00 AM	19.0	16.6	34.80	21	154	0.486
	8:30 AM	19.5	17.0	41.10	21	157	0.447
	9:00 AM	20.0	18.7	46.92	21	228	0.500
	9:30 AM	20.5	20.1	52.02	21	165	0.580
	10:00 AM	21.0	20.7	54.92	21	169	0.486
	10:30 AM	21.5	22.2	59.22	21	283	0.566
	11:00 AM	22.0	21.2	60.78	21	98	0.606
	11:00 AM	22.5	23.4	60.96	21	140	0.500
	11:30 AM	23.0	23.8	60.60	21	100	0.460
	12:00 N	23.5	23.9	60.30	21	226	0.500
	12:30 PM	24.0	24.6	57.90	21	319	0.553

Table A.6 Pond Water Conditions During First Diurnal Study: Barbizon Pond

Cell	Date	Time	time hrs	Temp °C	EC(25°C) dS/m	pH	DO mg/L	Eh mV	Density
C	3/27/89	1:00 PM	0	21.2	21.75	8.70	348.7	15	1.010
		3:00 PM	2	24.6	21.57	9.01	381.7	18	1.010
		5:00 PM	4	23.5	20.41	8.94	54.7	19	1.010
		7:00 PM	6	20.7	21.12	9.06	117.7	15	1.010
		9:00 PM	8	19.4	20.95	8.82	196.7	11	1.015
		11:00 PM	10	17.9	20.40	8.72	172.7	10	1.010
	3/28/89	1:00 AM	12	15.5	21.11	8.83	407.7	8	1.010
		3:00 AM	14	14.6	20.68	8.48	476.7	6	1.010
		5:00 AM	16	14	20.45	8.60	491.7	5	1.010
		7:00 AM	18	13.9	21.22	8.72	478.7	5	1.010
		9:00 AM	20	19.5	20.03	9.70	457.7	10	1.010
		11:00 AM	22	23.8	21.21	8.96	447.7	14	1.010
		1:00 PM	24	26.2	21.48	9.00	423.7	16	1.010

Table A.7 Weather Conditions During Second Diurnal Study: Pryse Pond

Date	Time	t hrs	Temp °C	Solar Radiation	RH %	Wind Direction, °	Wind Speed m/s
8/15/89	11:00 AM	0.0	32.7	59.22	35	199	0.593
	11:30 AM	0.5	33.5	16.14	40	176	0.486
	12:00 PM	1.0	35.3	65.04	34	113	0.593
	12:30 PM	1.5	35.3	67.20	33	153	0.513
	1:00 PM	2.0	37.1	67.26	28	127	0.566
	1:30 PM	2.5	38.6	66.24	28	221	0.486
	2:00 PM	3.0	37.7	65.10	26	167	0.553
	2:30 PM	3.5	39.1	62.52	24	203	0.619
	3:00 PM	4.0	39.5	57.96	25	176	0.580
	3:30 PM	4.5	39.0	53.70	24	347	0.646
	4:00 PM	5.0	38.5	49.38	23	362	0.606
	4:30 PM	5.5	38.5	43.56	23	57	0.566
	5:00 PM	6.0	38.3	36.36	24	33	0.473
	5:30 PM	6.5	38.0	30.00	23	17	0.553
	6:00 PM	7.0	37.7	22.44	23	354	0.593
	6:30 PM	7.5	36.7	14.94	23	22	0.540
	7:00 PM	8.0	34.9	8.04	26	34	0.606
	7:30 PM	8.5	31.4	1.26	29	37	0.486
	8:00 PM	9.0	30.8	0.18	34	299	0.526
	8:30 PM	9.5	27.4	-0.06	35	235	0.540
	9:00 PM	10.0	24.3	-0.06	39	237	0.540
	9:30 PM	10.5	23.0	-0.12	42	230	0.526
	10:00 PM	11.0	21.5	-0.06	43	239	0.566
	10:30 PM	11.5	21.6	-0.06	44	238	0.486
	11:00 PM	12.0	20.5	0.00	47	237	0.500
	11:30 PM	12.5	20.4	0.06	46	236	0.593
8/16/89	12:00 AM	13.0	20.7	0.00	47	271	0.580
	12:30 AM	13.5	20.3	0.00	47	256	0.593
	1:00 AM	14.0	20.5	0.00	49	279	0.553
	1:30 AM	14.5	20.7	0.00	52	286	0.553
	2:00 AM	15.0	19.1	0.06	56	269	0.447
	2:30 AM	15.5	18.1	0.00	54	266	0.540
	3:00 AM	16.0	17.0	-0.12	63	248	0.633
	3:30 AM	16.5	17.8	-0.06	54	255	0.460
	4:00 AM	17.0	17.7	0.00	56	256	0.500
	4:30 AM	17.5	17.1	0.12	56	255	0.606
	5:00 AM	18.0	16.1	-0.06	66	242	0.526
	5:30 AM	18.5	16.8	-0.06	67	82	0.553
	6:00 AM	19.0	15.6	0.00	68	120	0.513
	6:30 AM	19.5	16.9	1.14	78	145	0.566
	7:00 AM	20.0	20.6	6.72	70	152	0.606
	7:30 AM	20.5	21.0	13.62	59	141	0.593
	8:00 AM	21.0	22.9	21.06	55	153	0.633
	8:30 AM	21.5	23.2	3.36	53	130	0.553
	9:00 AM	22.0	25.3	36.00	49	131	0.447
	9:30 AM	22.5	27.2	42.66	46	126	0.447
	10:00 AM	23.0	29.7	48.18	45	126	0.646
	10:30 AM	23.5	32.2	54.12	32	226	0.526
	11:00 AM	24.0	33.0	58.68	29	262	0.500

Table A.8 Pond Water Conditions During Second Diurnal Study: Pryse Pond

Cell	Date	Time	time hrs	Temp °C	EC(25°C) dS/m	pH	DO mg/L	Eh mV	Density
1 NW	8/15/89	11:00 AM	0	29.2	56.09	8.62	3.6	477	1.040
		1:00 PM	2	31.8	56.87	8.79	20.0	470	1.040
		3:00 PM	4	35.1	59.65	8.82	6.7	434	1.040
		5:00 PM	6	31.1	65.69	8.79	18.6	380	1.050
		7:00 PM	8	26.9	65.61	8.32	7.2	356	1.050
		9:00 PM	10	26.3	65.59	8.53	6.4	318	1.050
		11:00 PM	12	25.8	65.45	8.58	13.8	340	1.050
	8/16/89	1:00 AM	14	26.2	67.19	8.68	11.8	338	1.050
		3:00 AM	16	24.6	67.44	5.47	8.0	326	1.045
		5:00 AM	18	23.8	65.88	8.54	3.2	358	1.050
		7:00 AM	20	19.3	61.85	8.55	6.0	373	1.050
		9:00 AM	22	22.8	54.92	8.52	18.8	377	1.040
		11:00 AM	24	28.7	54.10	8.61	20.0	353	1.035

Table A.9 Weather Conditions During Second Diurnal Study: Peck Pond

Date	Time	t hrs	Temp °C	Solar Radiation	RH %	Wind Direction, °	Wind Speed m/s
8/19/89	10:30 AM	0.5	25.2	50.82	56	14	0.460
	11:00 AM	1.0	27.3	55.50	58	265	0.447
	11:30 AM	1.5	29.0	59.46	55	273	0.629
	12:00 PM	2.0	28.9	62.28	57	261	0.512
	12:30 PM	2.5	32.1	64.56	50	256	0.538
	1:00 PM	3.0	31.8	64.86	48	76	0.551
	1:30 PM	3.5	33.3	63.96	45	355	0.460
	2:00 PM	4.0	30.6	5.34	41	83	0.603
	2:30 PM	4.5	34.2	60.18	40	322	0.447
	3:00 PM	5.0	35.2	56.58	40	354	0.486
	3:30 PM	5.5	34.0	52.02	39	217	0.616
	4:00 PM	6.0	33.1	47.10	40	289	0.499
	4:30 PM	6.5	32.9	41.22	38	293	0.447
	5:00 PM	7.0	32.9	34.86	38	273	0.590
	5:30 PM	7.5	32.9	27.84	31	341	0.525
	6:00 PM	8.0	31.6	20.46	42	348	0.590
	6:30 PM	8.5	31.0	13.26	42	355	0.460
	7:00 PM	9.0	29.4	6.78	43	355	0.603
	7:30 PM	9.5	27.5	1.80	47	264	0.499
	8:00 PM	10.0	25.2	0.06	61	283	0.460
	8:30 PM	10.5	24.7	-0.06	62	283	0.486
	9:00 PM	11.0	23.2	0.00	66	73	0.642
	9:30 PM	11.5	21.4	0.06	62	269	0.499
	10:00 PM	12.0	22.6	0.06	63	257	0.538
	10:30 PM	12.5	21.3	0.00	60	281	0.512
	11:00 PM	13.0	20.8	0.00	66	263	0.447
	11:30 PM	13.5	19.0	-0.06	71	299	0.577
8/20/89	12:00 AM	14.0	18.5	0.06	70	84	0.629
	12:30 AM	14.5	18.3	-0.06	71	358	0.551
	1:00 AM	15.0	18.5	0.06	67	350	0.525
	1:30 AM	15.5	18.3	0.00	76	300	0.616
	2:00 AM	16.0	17.7	0.00	82	279	0.512
	2:30 AM	16.5	16.9	-0.12	82	268	0.603
	3:00 AM	17.0	16.7	0.06	82	295	0.538
	3:30 AM	17.5	16.6	-0.06	84	324	0.616
	4:00 AM	18.0	16.7	0.00	83	308	0.512
	4:30 AM	18.5	15.7	-0.06	85	287	0.577
	5:00 AM	19.0	15.7	-0.06	82	273	0.564
	5:30 AM	19.5	16.1	0.00	82	335	0.564
	6:00 AM	20.0	15.0	-0.06	87	333	0.616
	6:30 AM	20.5	14.5	0.36	90	298	0.577
	7:00 AM	21.0	14.4	1.56	90	270	0.525
	7:30 AM	21.5	16.4	8.42	80	358	0.499
	8:00 AM	22.0	18.8	18.48	76	279	0.499
	8:30 AM	22.5	19.7	25.56	74	298	0.460
	9:00 AM	23.0	21.2	4.38	71	284	0.538
	9:30 AM	23.5	23.2	39 18	71	296	0.525
	10:00 AM	24.0	23.2	46.02	66	308	0.551

Table A.10 Pond Water Conditions During Second Diurnal Study: Peck Pond

Cell	Date	Time	time hrs	Temp °C	EC(25°C) dS/m	pH	DO mg/L	Eh mV	Density
1NW	8/19/89	10:00 AM	0	24.9	12.80	7.5	8.8	375	1.010
		12:00 N	2	2.62	24.08	7.82	9.8	367	1.010
		2:00 PM	4	26.4	12.35	7.33	9.0	383	1.010
		4:00 PM	6	27.8	12.50	7.59	9.2	362	1.010
		6:00 PM	8	27.4	12.90	7.83	9.6	373	1.010
		8:00 PM	10	24.8	12.65	7.82	9.4	370	1.010
		10:00 PM	12	23.5	12.78	7.72	9.0	357	1.005
	8/20/89	12:00 M	14	23	13.21	7.86	8.8	392	1.005
		2:00 AM	16	22.2	13.88	8.37	9.0	432	1.010
		4:00 AM	18	22.2	14.62	8.81	9.0	375	1.010
		6:00 AM	20	21.8	14.63	9.1	9.2	392	1.010
		8:00 AM	22	21.2	14.94	8.86	9.4	373	1.010
		10:00 AM	24	23.4	14.88	8.81	10.1	389	1.010
3 SW Brine Shrimp	8/19/89	10:00 AM	0	24.5	98.38	8.32	8.2	372	1.120
		12:00 N	2	27.9	101.61	8.41	12.4	362	1.115
		2:00 PM	4	31.6	101.24	8.43	14.4	364	1.115
		4:00 PM	6	33.2	99.48	8.79	12.0	364	1.115
		6:00 PM	8	30.9	101.34	8.73	7.6	347	1.120
		8:00 PM	10	27.5	124.67	8.81	2.4	341	1.120
		10:00 PM	12	25	98.00	8.55	4.4	322	1.115
	8/20/89	12:00 M	14	22	99.57	8.28	2.4	308	1.115
		2:00 AM	16	20.1	100.22	8.28	2.2	377	1.120
		4:00 AM	18	19.2	99.77	8.38	4.4	331	1.115
		6:00 AM	20	17.7	99.77	8.35	3.2	345	1.115
		8:00 AM	22	17.3	101.30	8.32	3.8	342	1.120
		10:00 AM	24	22.4	99.05	8.25	5.0	349	1.120
3 W Salt Crusts	8/19/89	10:00 AM	0	27.4	144.47	7.8	2.4	373	1.235
		12:00 N	2	32.2	140.56	7.76	1.6	361	1.250
		2:00 PM	4	35.1	150.75	7.9	1.6	349	1.250
		4:00 PM	6	36.2	147.88	8.07	1.4	367	1.250
		6:00 PM	8	33.8	143.54	8	1.6	345	1.300
		8:00 PM	10	33	135.78	8.04	1.8	369	1.300
		10:00 PM	12	26.3	139.86	7.94	2.0	333	1.300
	8/20/89	12:00 M	14	23.6	139.71	7.67	1.6	323	1.300
		2:00 AM	16	21.3	139.74	7.68	1.8	357	1.300
		4:00 AM	18	28	117.45	7.8	2.6	319	1.300
		6:00 AM	20	19.9	137.08	7.82	2.0	330	1.300
		8:00 AM	22	18.8	140.75	7.73	2.4	329	1.300
		10:00 AM	24	22.8	132.11	7.66	2.6	331	1.300

Table A.11 Pond Water Conditions During Second Diurnal Study: Barbizon Pond

Date	Time	t hrs	Temp °C	Solar Radiation	RH %	Wind Direction, °	Wind Speed m/s
8/17/89	11:00 AM	0.0	23.9	56.82	55	246	0.526
	11:30 AM	0.5	25.3	9.72	51	224	0.553
	12:00 PM	1.0	26.4	58.80	51	221	0.580
	12:30 PM	1.5	26.5	65.58	47	105	0.486
	1:00 PM	2.0	29.2	66.66	46	186	0.606
	1:30 PM	2.5	28.2	66.24	47	218	0.473
	2:00 PM	3.0	28.8	64.74	44	235	0.526
	2:30 PM	3.5	30.0	62.10	38	53	0.486
	3:00 PM	4.0	31.4	58.86	35	2	0.513
	3:30 PM	4.5	31.4	54.66	32	312	0.619
	4:00 PM	5.0	31.5	49.20	3	306	0.513
	4:30 PM	5.5	31.8	43.32	28	336	0.580
	5:00 PM	6.0	32.3	37.02	27	317	0.460
	5:30 PM	6.5	31.5	29.46	26	288	0.619
	6:00 PM	7.0	31.1	22.14	27	4	0.619
	6:30 PM	7.5	30.5	14.46	30	341	0.566
	7:00 PM	8.0	29.9	7.50	31	341	0.500
	7:30 PM	8.5	28.2	1.38	42	3	0.553
	8:00 PM	9.0	26.4	0.06	46	8	0.526
	8:30 PM	9.5	24.7	-0.06	48	325	0.447
	9:00 PM	10.0	23.5	0.00	54	312	0.646
	9:30 PM	10.5	22.0	-0.06	59	284	0.473
	10:00 PM	11.0	22.1	0.00	58	311	0.513
	10:30 PM	11.5	20.9	0.06	63	307	0.566
	11:00 PM	12.0	19.9	0.00	67	309	0.513
	11:30 PM	12.5	19.5	0.00	71	303	0.633
8/18/89	12:00 AM	13.0	18.9	-0.06	73	316	0.447
	12:30 AM	13.5	18.1	-0.60	77	324	0.619
	1:00 AM	14.0	17.9	0.06	78	306	0.553
	1:30 AM	14.5	18.1	-0.06	79	296	0.486
	2:00 AM	15.0	18.0	0.00	78	297	0.553
	2:30 AM	15.5	17.6	0.00	79	293	0.540
	3:00 AM	16.0	17.3	0.06	81	301	0.526
	3:30 AM	16.5	16.5	0.06	85	320	0.566
	4:00 AM	17.0	15.5	0.00	87	359	0.460
	4:30 AM	17.5	14.8	0.00	94	67	0.566
	5:00 AM	18.0	14.2	0.00	97	53	0.593
	5:30 AM	18.5	14.3	0.06	96	291	0.566
	6:00 AM	19.0	14.4	0.00	97	264	0.619
	6:30 AM	19.5	14.2	0.78	94	275	0.486
	7:00 AM	20.0	16.3	4.86	90	292	0.447
	7:30 AM	20.5	18.3	11.10	84	293	0.526
	8:00 AM	21.0	19.3	17.94	80	300	0.553
	8:30 AM	21.5	20.3	25.26	77	307	0.619
	9:00 AM	22.0	21.5	32.58	74	306	0.447
	9:30 AM	22.5	23.8	15.84	70	312	0.460
	10:00 AM	23.0	24.5	45.78	68	313	0.593
	10:30 AM	23.5	26.5	51.18	64	348	0.593
	11:00 AM	24.0	25.6	55.98	63	329	0.566

Table A.12 Pond Water Conditions During Second Diurnal Study: Barbizon Pond

Cell	Date	Time	time hrs	Temp °C	EC(25°C) dS/m	pH	DO mg/L	Eh mV	Density
C	8/17/89	11:00 AM	0	24.9	11.87	8.18	20.0	340	1.005
		1:00 PM	2	27.4	11.77	8.5	20.0	348	1.005
		3:00 PM	4	28.6	11.87	8.73	20.0	355	1.005
		5:00 PM	6	27.6	12.19	8.27	17.6	321	1.005
		7:00 PM	8	24.6	12.00	7.85	11.0	311	1.005
		9:00 PM	10	24.3	11.76	7.44	5.2	411	1.005
		11:00 PM	12	21.2	12.31	7.24	5.2	420	1.005
	8/18/89	1:00 AM	14	18.8	12.29	7.55	5.0	400	1.005
		3:00 AM	16	17.5	12.48	7.57	5.4	325	1.005
		5:00 AM	18	19.3	14.70	7.47	5.6	112	1.005
		7:00 AM	20	18.9	14.69	7.49	7.8	375	1.005
		9:00 AM	22	21.5	13.23	8.12	17.6	365	1.005
		11:00 AM	24	25.4	13.00	8.46	20.0	370	1.005

APPENDIX B: CIMIS Weather Data from Stations Near To Evaporation Ponds

Table B.1 Hourly CIMIS weather data for McFarland station near to Pryse pond for March 26-27, 1989

Time	Elapsed Hrs	Air Temp. (°C)	Solar Rad. (W/sq.m)	Rel. Humid. %	Wind Direction (0-360°)	Wind speed (m/s)	Vapor Press. (mbars)	ETo (mm/hr)
1000	0	11.2	550	74	331	2.4	9.9	0.29
1100	1	12.3	697	67	328	2.3	9.6	0.4
1200	2	13.1	710	61	332	1.8	9.2	0.42
1300	3	13.8	690	55	305	2.1	8.7	0.42
1400	4	14.5	691	51	314	2.0	8.4	0.43
1500	5	14.6	682	48	293	2.1	8.0	0.41
1600	6	14.7	323	46	304	1.7	7.7	0.2
1700	7	14.5	225	45	302	1.8	7.5	0.14
1800	8	13.4	53	49	297	1.3	7.5	0.05
1900	9	12.1	0	65	119	1.1	9.5	0.02
2000	10	11.5	-2	80	116	0.8	10.9	0
2100	11	11.0	-2	87	102	0.7	11.5	0
2200	12	10.6	-2	88	89	1.1	11.3	0
2300	13	9.2	-2	92	95	1.4	10.7	-0.01
2400	14	7.7	-2	93	105	1.7	9.8	-0.01
100	15	6.8	-2	91	101	2.0	9.0	-0.01
200	16	6.5	-2	91	98	2.1	8.8	-0.01
300	17	6.0	-2	92	103	1.8	8.6	-0.01
400	18	5.7	-2	92	98	1.9	8.4	-0.01
500	19	5.8	-2	92	92	2.0	8.4	-0.01
600	20	5.4	-1	92	98	1.7	8.3	-0.01
700	21	5.6	49	84	151	1.2	8.6	0
800	22	8.1	190	89	189	1.6	9.7	0.08
900	23	10.9	423	81	212	1.8	10.5	0.21

Table B.2 Hourly CIMIS weather data for Stratford station near to Barbizon pond for March 27-28, 1989

Time	Elapsed Hrs	Air Temp. (°C)	Solar Rad. (W/sq.m)	Rel. Humid. %	Wind Direction (0-360°)	Wind speed (m/s)	Vapor Press. (mbars)	ETo (mm/hr)
1300	0	18.2	887	43	58	1.9	8.9	0.65
1400	1	18.7	817	40	54	2.1	8.6	0.62
1500	2	19.3	687	39	42	2.7	8.8	0.55
1600	3	19.6	513	40	40	3.2	9.0	0.43
1700	4	19.6	305	40	36	3.3	9.2	0.26
1800	5	18.3	103	42	33	2.5	8.9	0.07
1900	6	15.6	2	49	29	1.2	8.7	0.03
2000	7	13.7	-2	54	5	1.0	8.6	0.02
2100	8	12.3	-2	66	47	0.9	9.4	0.01
2200	9	11.5	-2	68	320	0.6	9.2	0.00
2300	10	10.4	-2	67	249	1.2	8.4	0.01
2400	11	10.1	-2	66	267	1.0	8.2	0.01
100	12	9.0	-2	73	279	0.5	8.4	0.00
200	13	8.3	-2	84	19	0.5	9.2	-0.01
300	14	8.0	-2	84	57	0.9	9.0	0.00
400	15	8.4	-2	84	175	1.0	9.2	0.00
500	16	8.7	-2	88	170	0.6	9.9	0.00
600	17	7.8	0	91	104	1.0	9.7	-0.01
700	18	9.0	84	91	108	1.5	10.5	0.01
800	19	11.8	276	82	128	2.4	11.3	0.12
900	20	15.5	488	65	133	2.6	11.4	0.30
1000	21	18.3	665	54	132	2.4	11.4	0.47
1100	22	20.4	794	45	141	2.4	10.8	0.60
1200	23	21.5	865	44	107	1.9	11.2	0.66

Table B.3 Hourly CIMIS weather data for Mendota/Murietta station near to Peck pond for March 29-30, 1989

Time	Elapsed Hrs	Air Temp. (°C)	Solar Rad. (W/sq.m)	Rel. Humid. %	Wind Direction (0-360°)	Wind speed (m/s)	Vapor Press. (mbars)	ETo (mm/hr)
1100	0	16.2	690	42	322	5.7	7.7	0.49
1200	1	17.8	802	37	328	6.3	7.6	0.63
1300	2	19.0	853	37	324	5.3	8.1	0.68
1400	3	20.5	839	33	322	5.5	7.9	0.72
1500	4	21.6	771	25	320	5.0	6.5	0.71
1600	5	22.3	645	18	319	4.9	4.8	0.66
1700	6	22.3	473	16	330	5.1	4.4	0.55
1800	7	21.8	274	15	331	5.3	4.0	0.41
1900	8	20.3	79	18	335	4.4	4.4	0.21
2000	9	16.9	1	25	336	2.1	4.9	0.07
2100	10	12.8	-1	45	265	2.1	6.7	0.05
2200	11	11.8	-1	48	282	2.1	6.6	0.04
2300	12	10.2	-1	56	249	2.0	7.0	0.03
2400	13	9.5	-1	57	251	2.2	6.8	0.03
100	14	9.3	-1	58	260	2.3	6.8	0.03
200	15	8.2	-1	60	258	1.9	6.5	0.02
300	16	7.6	-1	61	270	1.8	6.4	0.02
400	17	7.9	-1	61	326	1.8	6.5	0.02
500	18	6.5	-1	61	317	1.8	6.0	0.02
600	19	5.3	-1	69	280	1.5	6.1	0.01
700	20	4.0	5	74	261	1.9	6.0	0.01
800	21	7.1	128	71	259	2.6	7.2	0.03
900	22	12.6	320	62	279	3.6	9.1	0.14
1000	23	15.8	530	48	300	3.5	8.6	0.30
1100	24	17.6	693	41	340	3.0	8.3	0.43

Table B.4 Hourly CIMIS weather data for McFarland station near to Pryse pond for August 15-16, 1989

Time	Elapsed Hrs	Air Temp. (°C)	Solar Rad. (W/sq.m)	Rel. Humid. %	Wind Direction (0-360°)	Wind speed (m/s)	Vapor Press. (mbars)	ETo (mm/hr)
1100	0	33.5	861	30	264	1.8	15.5	0.71
1200	1	35.4	916	24	298	2.0	13.8	0.79
1300	2	36.2	932	16	282	2.0	9.6	0.80
1400	3	37.9	977	11	310	2.1	7.4	0.79
1500	4	38.7	760	10	316	2.0	6.9	0.71
1600	5	39.0	603	9	337	2.1	6.6	0.58
1700	6	39.3	399	9	332	2.1	6.6	0.42
1800	7	37.6	196	13	345	2.3	8.5	0.27
1900	8	31.8	31	26	61	1.4	12.1	0.11
2000	9	27.2	0	35	261	1.6	12.8	0.07
2100	10	24.3	0	34	248	1.1	10.2	0.05
2200	11	22.6	0	35	335	1.0	9.5	0.05
2300	12	21.5	0	41	82	1.3	10.4	0.04
2400	13	19.5	0	49	100	1.4	11.2	0.03
100	14	17.4	0	72	142	1.4	14.2	-0.02
200	15	17.4	0	66	126	1.4	13.0	-0.01
300	16	16.9	0	67	115	1.3	12.9	-0.01
400	17	16.6	0	64	94	1.5	12.0	-0.01
500	18	16.1	0	64	94	1.5	11.7	-0.01
600	19	15.7	28	70	87	1.6	12.6	0.01
700	20	21.8	190	57	104	0.8	14.8	0.11
800	21	26.9	390	38	288	0.9	13.5	0.27
900	22	29.2	584	33	296	1.3	13.2	0.43
1000	23	31.5	748	23	335	1.7	10.5	0.59
1100	24	32.7	863	21	304	1.7	10.2	0.70

Table B.5 Hourly CIMIS weather data for Stratford station near to Barbizon pond for August 17-18, 1989

Time	Elapsed Hrs	Air Temp. (°C)	Solar Rad. (W/sq.m)	Rel. Humid. %	Wind Direction (0-360°)	Wind speed (m/s)	Vapor Press. (mbars)	ETo (mm/hr)
1100	0	24.1	861	40	279	1.2	12.0	0.59
1200	1	26.3	930	33	198	1.1	11.4	0.67
1300	2	27.8	931	26	199	1.2	9.9	0.69
1400	3	28.6	867	24	0	1.7	9.4	0.69
1500	4	29.8	747	18	22	1.8	7.5	0.62
1600	5	30.3	586	14	12	1.7	6.1	0.49
1700	6	30.5	392	14	23	1.6	5.9	0.34
1800	7	29.9	188	15	15	1.6	6.4	0.20
1900	8	27.8	27	22	6	1.6	8.3	0.11
2000	9	25.5	-2	32	6	1.4	10.3	0.07
2100	10	23.3	-2	38	308	1.2	10.8	0.05
2200	11	22.2	-2	40	322	1.8	10.8	0.06
2300	12	20.8	-2	45	338	2.0	11.2	0.05
2400	13	19.5	-2	53	329	1.5	11.9	0.03
100	14	18.6	-2	60	320	1.6	13.0	0.01
200	15	18.2	-2	67	313	1.6	14.0	0.00
300	16	18.0	-1	70	327	1.9	14.3	0.00
400	17	17.0	-2	76	348	1.1	14.6	-0.01
500	18	15.7	-2	82	331	1.2	14.6	-0.02
600	19	14.6	18	89	277	1.5	14.8	-0.01
700	20	16.5	162	86	304	1.5	16.1	0.09
800	21	18.7	362	76	334	2.0	16.3	0.22
900	22	20.7	558	65	337	1.9	15.8	0.37
1000	23	22.9	723	54	347	1.8	15.1	0.51
1100	24	25.2	847	43	311	1.6	13.8	0.60

Table B.6 Hourly CIMIS weather data for Mendota/Murietta station near to Peck pond for August 19-20, 1989

Time	Elapsed Hrs	Air Temp. (°C)	Solar Rad. (W/sq.m)	Rel. Humid. %	Wind Direction (0-360°)	Wind speed (m/s)	Vapor Press. (mbars)	ETo (mm/hr)
1100	0	26.7	850	59	311	1.7	20.7	1.7
1200	1	28.5	707	55	312	2.1	21.4	2.1
1300	2	30.3	908	50	7	1.7	21.6	1.7
1400	3	31.5	843	48	332	3.4	22.2	3.4
1500	4	31.8	733	43	299	3.5	20.1	3.5
1600	5	32.0	563	42	315	2.3	20.0	2.8
1700	6	31.9	366	43	349	3.4	20.1	3.4
1800	7	31.3	171	41	331	3.9	19.0	3.9
1900	8	28.3	23	47	318	3.1	18.1	3.1
2000	9	25.1	0	52	310	2.6	16.5	3.6
2100	10	22.5	0	59	274	1.7	16.1	1.7
2200	11	21.2	0	60	284	1.6	15.1	1.6
2300	12	20.0	-1	60	313	2.2	14.3	2.2
2400	13	19.0	-1	66	310	2.4	14.5	2.4
100	14	18.3	-1	72	294	3.9	15.2	3.9
200	15	17.3	-1	77	277	3.1	15.3	3.1
300	16	17.1	-1	76	285	2.5	14.9	2.5
400	17	16.0	-1	78	306	2.2	14.2	2.2
500	18	15.2	-1	81	318	2.4	14.0	2.4
600	19	14.6	13	82	325	2.5	13.6	2.5
700	20	15.1	151	83	314	2.8	14.2	2.8
800	21	19.1	378	79	314	3.3	16.3	3.3
900	22	20.4	571	73	337	2.5	17.6	2.5
1000	23	22.9	523	67	342	2.6	18.4	2.6