# CONTENTS



## LIST OF TABLES



## LIST OF FIGURES

# SECTION 1.0

# INTRODUCTION

## REPORT ORGANIZATION

This report is divided into nine sections, including: 1) Introduction, 2) Hydraulic Studies, 3) Water Quality, 4) Sediment Quality, 5) Vegetation, 6) Wetland Biota, 7) Mosquitoes, 8) Metals Mass Balance, and 9) CWFATE Model.

The introduction provides an overview of the wetland project. Project goals and objectives are enumerated. The physical layout of the wetlands is described and the experimental strategy and methods of monitoring at the wetlands are given.

Hydraulic data collected at the wetlands site are summarized and discussed in Section 2. Each of the hydraulic components of the wetland, including inflow, outflow, precipitation, evaporation, transpiration, and infiltration is described. The measured hydraulic data are used to develop a water balance. An evaluation of flow-measuring devices employed during the project is given. Additionally, the results of two investigations, a tracer study and a Manning's "n" flow study, are presented.

Water quality data collected at the wetlands facility are addressed in Section 3. The performance of the wetlands with respect to the removal of conventional water quality constituents (e.g., $BOD_5$, TSS, $NH_4$, TP) and priority pollutants (e.g., metals) is described. Cell by cell comparisons of treatment performance are made. The effluent constituent concentrations from the wetlands are compared to existing and proposed numeric criteria. The performance of the Sacramento wetlands is also compared to other wetlands used for wastewater treatment. Lastly, results of a groundwater monitoring program are examined to assess the impact of the wetlands on the underlying aquifer.

Changes in sediment quality in the wetland project over the five years of operation are examined in Section 4. Specifically, the soil quality data are examined for evidence of metals and nutrients accumulation. Metals concentrations are examined with respect to distance along the wetlands profile as well as soil depth. Observed metals concentrations are also compared to EPA limits for land application of biosolids and National Oceanic and Atmospheric Administration toxicity values.

Wetland vegetation is addressed in Section 5. Dominant wetland plant species are identified and their relative growth rates and densities presented. The effect of varying hydraulic regimes on plant growth and density is presented. Vegetation management and harvesting methods are described. Metal and nutrient levels in above-ground and below-ground biomass are presented. The influence of water depth on wetland plant species is also covered. Lastly, a tree-growth study that compares the use of wetland effluent versus groundwater is presented.

The results of invertebrate, fish, and wildlife monitoring studies are summarized in the wetland biota chapter, Section 6. Biotic indices of invertebrate species collected in the control, treatment, and adjacent riparian wetlands are presented. An assessment of the indices to examine changes over time and between the different wetland regimes is given. A summary of metals concentration levels found in the invertebrates is presented. A description of the mosquito fish tissue sampling and metals analysis results is also included in Section 6. A discussion of bird use at the wetlands facility is presented along with a list of all the bird species observed over the five-year project. Lastly, problems associated with burrowing muskrats and the results of a trapping and relocation program are presented.

Monitoring and management of mosquitoes was an essential component of the wetland facility project. The methods and results of an integrated mosquito control program are presented in Section 7. The effectiveness of both biological control measures (e.g., application of mosquito larvicides and stocking of predator fish) and physical source manipulation (e.g., vegetation thinning, sprinkler irrigation, water depth control) are discussed. Lastly, an economic comparison of the use of two commercially available larvicides is made.

Data from the water quality, sediment quality, vegetation, and biota sections are analyzed in an attempt to develop a metals mass balance in the wetlands in Section 8. The derivation of a simple mass balance equation is presented. The results of the mass balance equation are given, indicating the relative fraction of each metal exiting in the wetland effluent, infiltrating to groundwater, adsorbed in the wetland sediment, accumulated in wetland plant biomass, and removed with harvested vegetation.

Lastly, in Section 9, the Constructed Wetland Fate and Aquatic Transport Evaluation (CWFATE) model is presented. The objectives, concept and formulation of the model are given. Elements to be included in an updated version of the model are also discussed.

## BACKGROUND

The Sacramento Regional County Sanitation District (District) is the public agency responsible for the collection, treatment, and disposal of wastewater generated in the cities of Sacramento, Folsom, and Citrus Heights, as well as the unicorporated areas of Sacramento County, California; a service area of over 250 square miles serving more than one million people (see Figure 1-1). Wastewater is treated at the District's Regional Wastewater Treatment Plant (SRWTP) located in Elk Grove, California. Effluent from the pure oxygen activated-sludge treatment facility is currently disinfected with chlorine, dechlorinated, and discharged to the Sacramento River. With an average daily flow of over 150 Mgal/d, the SRWTP is the State's largest discharger to inland surface waters.

In 1992, the SRWTP developed the Sacramento Constructed Wetlands Demonstration Project (SCWDP). The development of the wetlands project was primarily motivated by the then impending requirements of the California Inland Surface Waters Plan (ISWP). The ISWP, which was California's attempt to comply with the Clean Water Act Amendments of 1987, attempted to establish effluent discharge limits on a number of previously unregulated water quality constituents (priority pollutants), including toxic organic compounds and metals. The cost of upgrading the SRWTP to meet the ISWP was seen as significant. The use of constructed wetlands was viewed by the District as a potentially cost-effective alternative to the more conventional methods of reducing effluent toxicity and metals concentrations such as chemical precipitation, membrane filtration, or reverse osmosis.

Additional reasons for the development of the wetland project were the perceived need in the wastewater industry for a model on the fate and transport of metals in constructed wetlands, and the interest of the United States Environmental Protection Agency (EPA) in funding a demonstration wetlands with a fate and transport model.

The objectives of the SCWDP were threefold:

1. To characterize constructed wetlands treatment performance.
2. To identify the fate of specific constituents of concern in wetlands such as metals.
3. To develop and evaluate constructed wetlands management procedures.

Design and construction of the wetland facility took place in 1992 and 1993. Operation of the SCWDP began in November of 1993 continued through December of 1998.

## PURPOSE

The purpose of this Five-Year Summary Report is to provide a comprehensive overview of the operations and monitoring results collected at the wetlands facility through 1998. For additional information, the reader is directed to detailed annual reports prepared following each of the first four years of facility operation (Nolte, 1995; Nolte, 1996; Nolte, 1997; Nolte, 1998).

## FACILITIES DESCRIPTION

The SCWDP is situated on 22 acres to the northeast of the SRWTP as presented in Figure 1-2. A site plan and process flow diagram of the facility are presented in Figures 1-3 and 1-4, respectively. Design criteria are presented in Table 1-1. System components included the following:

- A 1.7 Mgal/d pump system located at the SRWTP water recycling plant filter feed pump station.
- An ultraviolet light disinfection system designed for a maximum flow rate of 1.7 Mgal/d. Flows in excess of those required at the wetlands automatically overflow back to the SRWTP secondary effluent channel.

- A wetland supply pump station with a maximum flow rate of 1.2 Mgal/d.
- A wetland distribution influent control structure (standpipe) 4 ft in diameter and 11 ft high.
- Ten similar wetland treatment cells each covering approximately 1.5 acres.
- One wetland treatment cell to be used as a project control cell.
- A 2.0-acre habitat wetland to be used as a large scale bioassay.

Each of the treatment cells was approximately 1,260 feet in total length and 50 feet in width. The treatment cells were constructed in two halves (A and B), each half being about 630 feet in length. The wetland inlet was located on the B-half and wetland effluent leaves the outlet located in the A-half on the same end of the cell as the inlet. The aspect ratio (length to width) for the cells was about 25:1 to minimize short-circuiting. Common features of each treatment cell were 5-foot deep mosquito fish pools located at both ends and the midpoint of each half-cell.

A 2.0-acre habitat cell received effluent from the treatment cells prior to return to the treatment plant for discharge. The habitat cell had a maximum depth of 7 feet with some shallow areas provided for emergent vegetation and two islands.

**Treatment Processes**

The ten treatment wetlands were used to examine five treatment processes, including: 1) plug flow, 2) plug flow with recycle, 3) fill and draw, 4) a combination of plug and overland flow, and 5) subsurface flow. One plug flow cell was operated as a project control and received groundwater. The control cell was initially designed to receive supplemental ammonia at a level similar to the cells receiving wastewater; however, ammonia supplementation was found to be unnecessary to support plant growth.

The ten wetland cells and one control cell were numbered sequentially from one to eleven from west to east. Cell numbers and their associated flow regime are indicated below:

| | |
|---|---|
| • Cells 1 and 2 | Fill and Draw |
| • Cells 3 and 4 | Plug Flow with Recycle |
| • Cell 5 | Project Control – Groundwater Supply |
| • Cell 6 | Overland Flow/Wetland |
| • Cells 7, 8, 9, and 10 | Plug Flow |
| • Cell 11 | Subsurface Flow/Plug Flow |

The project was designed to compare the performance of the wetland cells on two levels; intra-process and inter-process. The objective of the intra-process experiments was to observe the effect of changes in operational parameters on treatment performance. The availability of two cells per process type allows adjustments to be made to a process variable cell, which could then be compared with a process control cell.

Inter-process comparisons were designed to determine the most efficient process type (e.g., batch, plug, recycle) for polishing treatment of wastewater. Each of the process control cells (Cells 1, 3, 5, 6A, 7, and 9) were to be operated over the five-year period at the same flow, depth, and detention time and evaluated to identify treatment performance differences.

## Monitoring Program

A five-year monitoring program was conducted from December 1993 through December 1998. The wetland treatment cells, control cell, and habitat cell were closely monitored for water quality, sediment character, vegetation types and growth, and wildlife quantity and diversity.

Baseline monitoring was conducted during the establishment, initial and start-up periods. The results of the baseline monitoring program are presented in the Initial and Start-Up Monitoring Summary Report (Nolte, 1995), and are referenced throughout this report for comparison purposes.

Ongoing monitoring of water quality, sediment, vegetation, and wildlife tissues and evaluations of vegetation and wildlife was performed for the entire five-year demonstration period. The primary focus of the ongoing monitoring program was to measure the pollutant removal ability of the treatment cells and indicate pollutant concentration trends. The main focus of the water quality sampling was on Cells 7 and 9, the plug flow process control cells. The intensive sampling of these two cells in lieu of all eleven cells reduced the program cost and provided a database sufficient for the comparison of water quality trends in other wetland cells.

An additional level of monitoring consisted of special experiments to provide insight into treatment mechanisms and characteristics of constructed wetlands. Special monitoring requirements were identified on an ongoing basis throughout the project and are covered in the individual sections.

## Monitoring Procedures

Water quality, sediment, vegetation, and biota monitoring was performed by SRWTP staff associated with the demonstration wetlands program. A monitoring training program was conducted at the commencement of the project to familiarize the wetlands staff with wetlands monitoring procedures. Procedures for collection of water quality samples were those used by the SRWTP laboratory. Laboratory analytical procedures used by the SRWTP laboratory are those in Standards Methods (17$^{th}$ Edition or later). Analytical procedures not able to be performed at the SRWTP laboratory were sent offsite to a certified laboratory. Procedures for the collection and analysis of vegetation samples were those used by R. Post and are described in Section 5 of this report.

## ABBREVIATIONS

A list of abbreviations commonly used in this report is presented in Table 1-2. Common names for vegetation species referred to frequently in this report are also presented.

## ACKNOWLEDGEMENTS

The information presented in this report represents the efforts and collaboration of numerous participants. The individuals responsible for staffing the monitoring program deserve particular appreciation, for without their efforts and hours of dedication, the data presented in this report would not be available. The following individuals and organizations have been instrumental in the development of this project:

**Sacramento Regional County Sanitation District**

| | |
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| Wendell Kido | District Manager |
| Stan Dean | Plant Superintendent |
| Mary James | Senior Engineer |
| Chuck Williams | Associate Engineer, Project Manager |
| Mark Perry | Project Engineer |
| Craig Lekven | Project Engineer |
| Kevin Cassady | Natural Resource Specialist |
| Rebecca Post | Natural Resource Specialist |
| Shannon Brown | Natural Resource Specialist |
| Scott Miller | Natural Resource Specialist |
| Roger Jones | Natural Resource Specialist |
| Jennifer Albright | Natural Resource Specialist |
| Steve Scott | Bufferlands |
| Rocco Leighton | Bufferlands |
| Hakim Hamid | Laboratory |

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**Jones and Stokes Associates, Inc.**

| | |
|---|---|
| Garrett Platenkamp | Biological and Mosquito Management Analyst |
| Russ Brown | CWFATE Model Development |
| Steve Chainey | Biologist |

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Smith, G.S., "New Combinations in North American Schoenoplectus, Bulboschoenus, Isolepis and Trichophorum (Cyperaceae)," NOVON 5:97-102, 1995.

State of California Water Resources Control Board, April 1991. California Inland Surface Waters Plan; Water Quality Control Plan for Inland Surface Waters of California 91-12WQ.

FIGURE 1–1

## SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT SERVICE AREA

SACRAMENTO CONSTRUCTED WETLAND DEMONSTRATION PROJECT

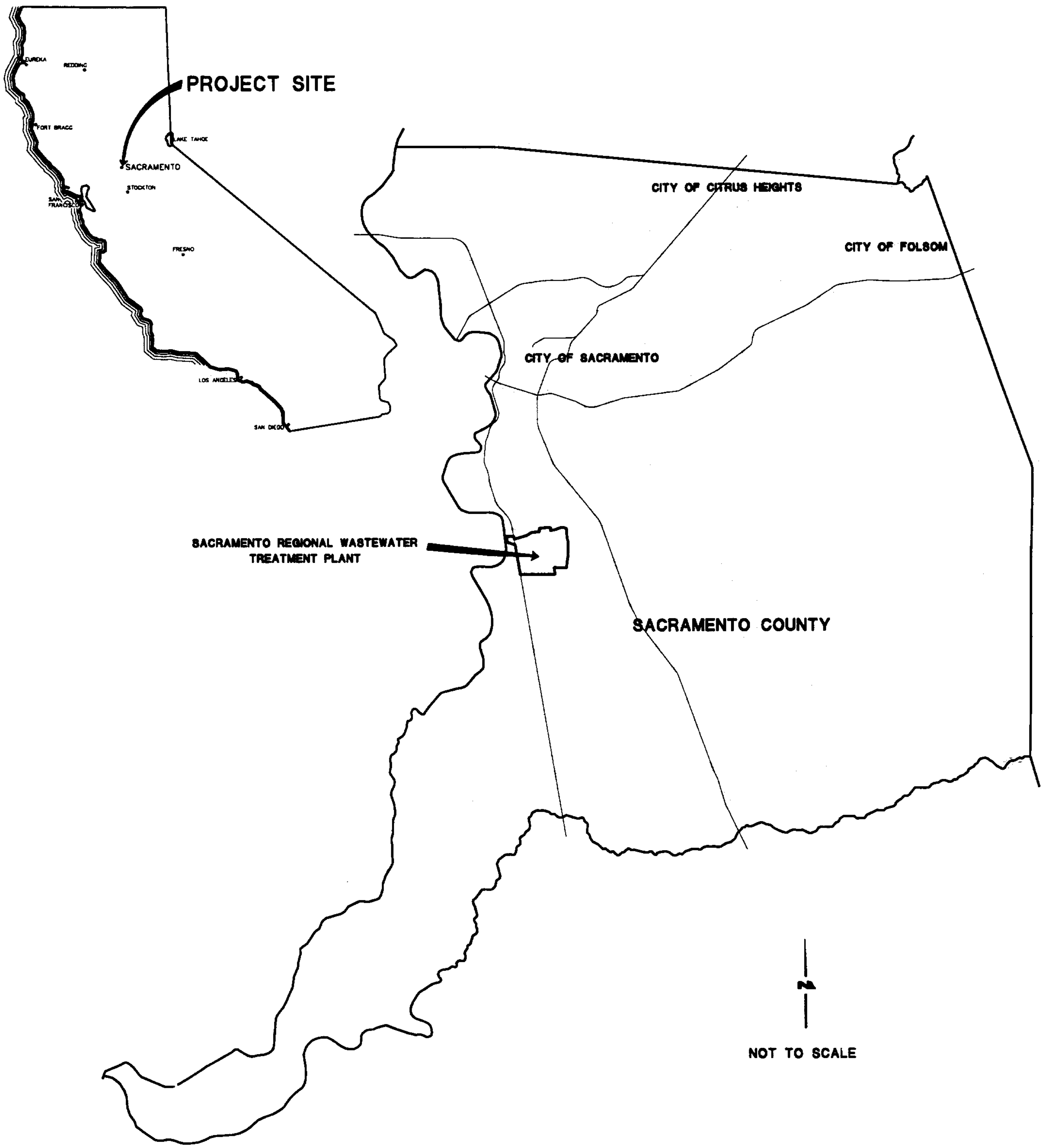

FIGURE 1–2

# SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT SITE MAP

SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

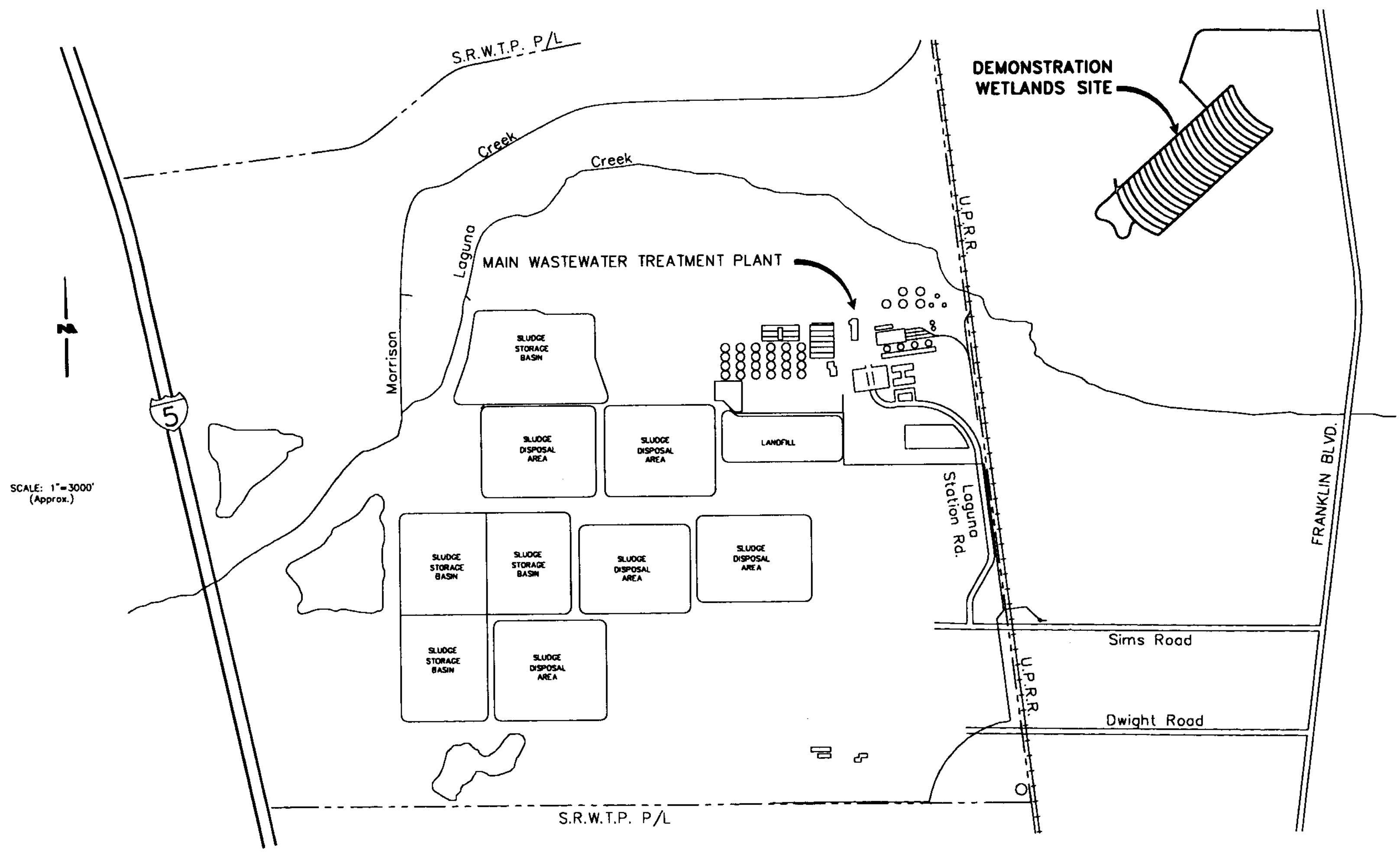

FIGURE 1–3

## CONSTRUCTED WETLANDS SITE PLAN

SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

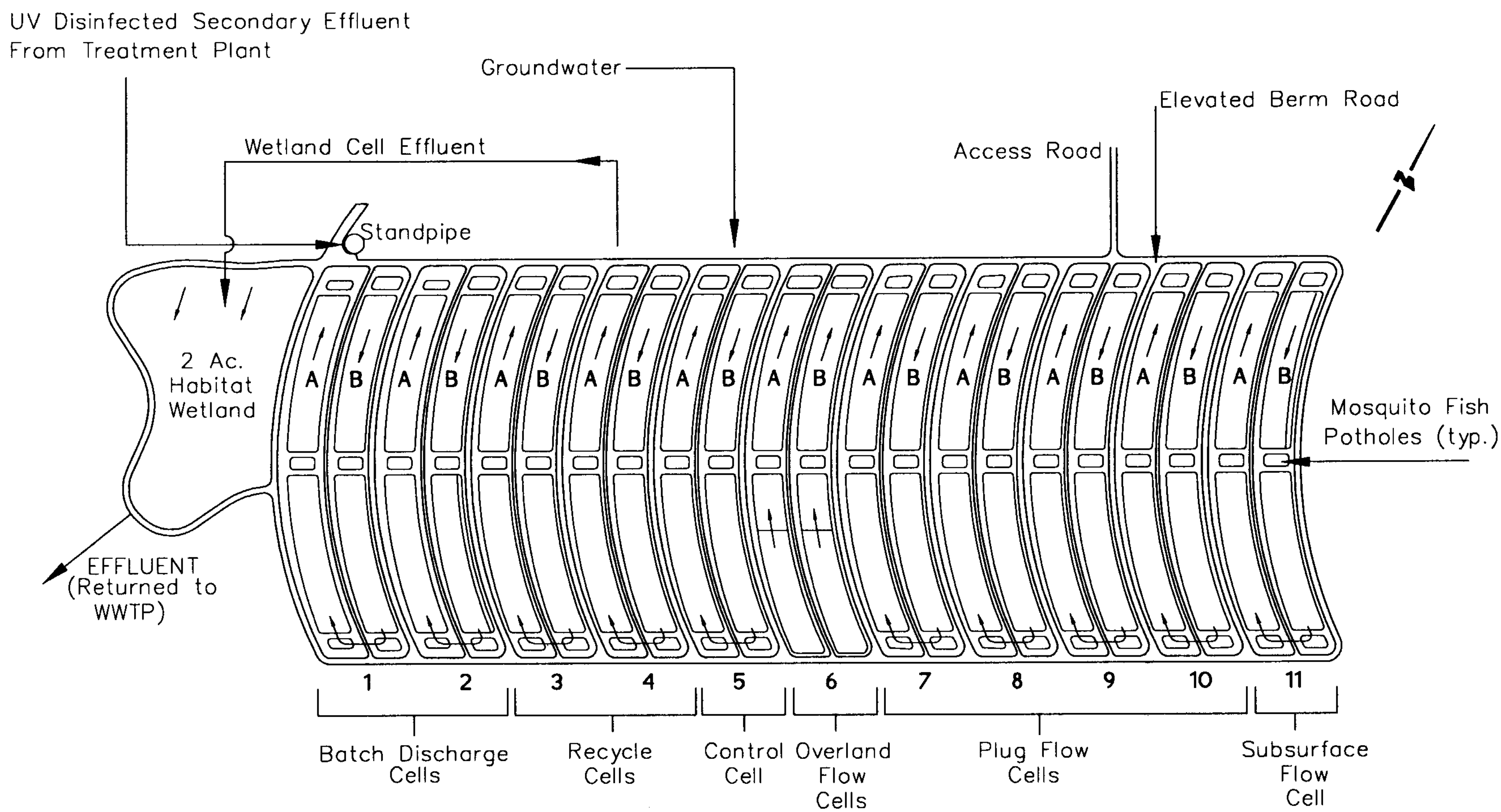

FIGURE 1-4

# PROCESS FLOW DIAGRAM

SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

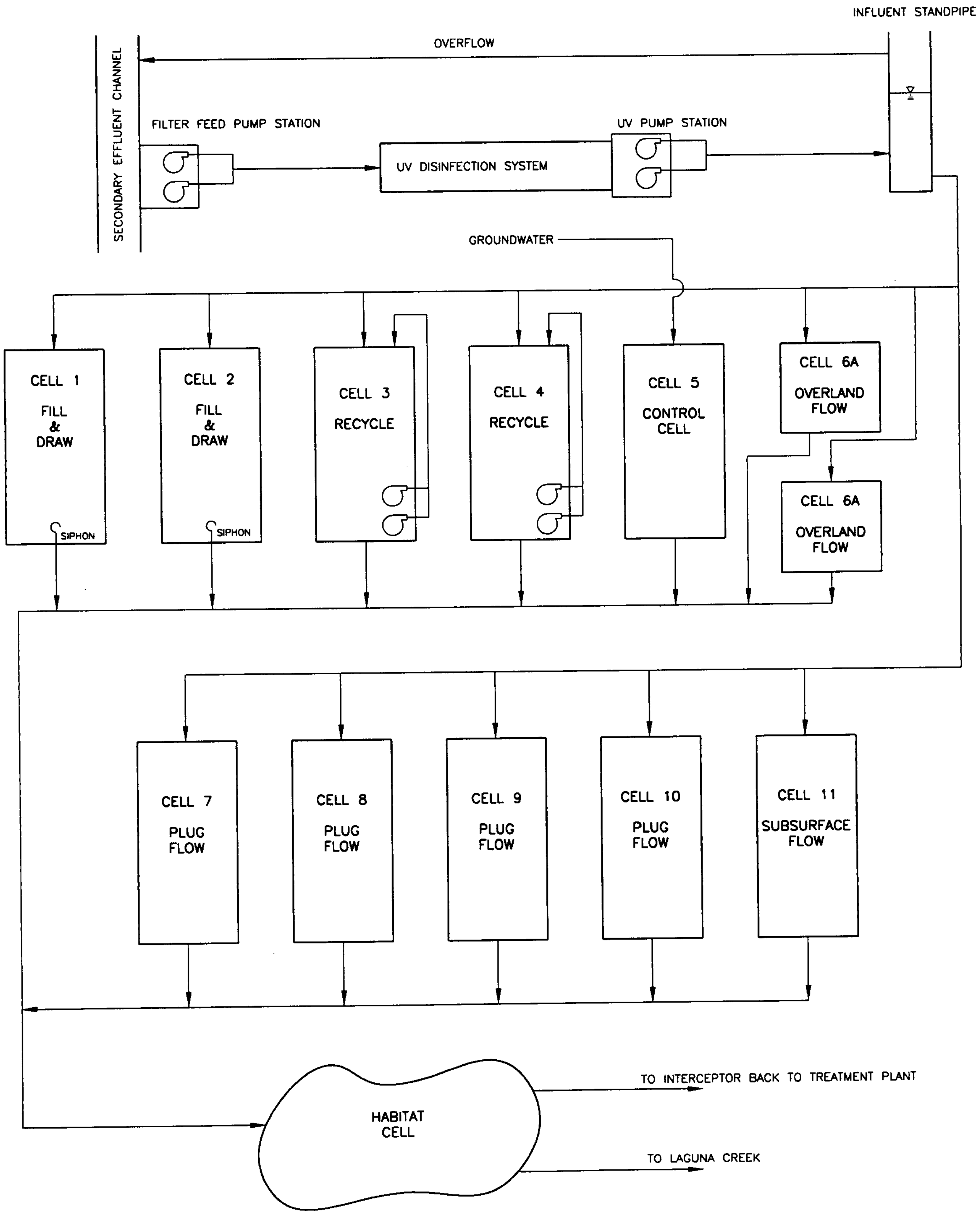

**TABLE 1-1**
**DESIGN CRITERIA AND CHARACTERISTICS OF**
**SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT**

| Criteria | Units | Value |
|---|---|---|
| Number of Wetland Cells | each | 11 |
| Number of Treatment Cells | each | 10 |
| Number of Control Cells | each | 1 |
| Cell Length | ft | 1,260 |
| Cell Width | ft | 50 |
| Average Depth | ft | 0.5 to 2 |
| Aspect Ratio (L:W) | ratio | 25 to 1 |
| Mosquitofish Potholes per Cell | number | 6 |
| Mosquitofish Pothole Size (L x W x D) | ft | 40 x 50 x 5 |
| Influent to Treatment Cells | Source | Disinfection Secondary Effluent |
| Influent to Control Cell | Source | Groundwater |
| Average Influent Flow Rate per Cell | gal/min | 70 |
| Average Influent Flow Rate, Overland Flow (Cell 6B) | gal/min | 40 |
| Maximum Total Project Flow Rate | Mgal/d | 1.2 |
| Hydraulic Loading (Cells 1-5, 7-11) | Mgal/ac·d | 0.07 |
| Hydraulic Loading (Overland Flow Cell 6B) | Mgal/ac·d | 0.1 |
| Typical Plug Flow Cell Nominal Detention Time | d | 10 to 12 |
| Number of Habitat Cells | each | 1 |
| Area of Habitat Cell | acre | 2 |
| Habitat Cell Depth | ft | 0 to 7 |
| Dominant Vegetation | Genus species | *Scirpus acutus* |
| | | *Typha latifolia* |
| | | *Typha domingensis* |

**TABLE 1-2**
**ABBREVIATIONS USED IN FIVE YEAR SUMMARY REPORT**
**SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT**

| Abbreviation | Term |
|---|---|
| Ag | Silver |
| anova | Analysis of Variation |
| As | Arsenic |
| Bs | Bacillus sphaericus |
| Bti | Bacillus thuringensis var. israelensis |
| Be | Beryllium |
| BOD | Biological Oxygen Demand |
| Cd | Cadmium |
| CEC | Cation Exchange Capacity |
| Cr | Chromium |
| Cu | Copper |
| CTR | California Toxics Rule |
| CWFATE | Constructed Wetland Fate and Aquatic Transport Evaluation model |
| DO | Dissolved Oxygen |
| EDL | Elevated Data Level |
| Fe | Iron |
| gpm | Gallons Per Minute |
| Hg | Mercury |
| ISWP | California Inland Surface Waters Plan |
| kg | Kilogram |
| L | liter |
| Lemna | Commonly referred to as Duckweed |
| LiCl | Lithium Chloride |
| mg | Milligram |
| mgd | Million Gallons Per Day |
| MOEE | Canadian Ministry of Environment and Energy |
| NA | Not Available, Not Applicable |
| $NH_3$ | Un-ionized Ammonia |
| $NH_4^+$ | Ammonium Ion |
| Ni | Nickel |
| ng | Nanogram |
| $NO_3$ | Nitrate |
| NOAA | National Oceanic and Atmospheric Administration |
| NS | Not Sampled |
| MW | Monitoring Well |
| Pb | Lead |
| PVC | Polyvinyl Chloride Pipe |
| redox | Oxidation-Reduction |
| Sb | Antimony |
| Scirpus | Commonly referred to as Tule or Bulrush |
| SDWDS | Sacramento Demonstration Wetland Database System |
| Se | Selenium |
| spp. | Species |

**TABLE 1-2 (continued)**
**ABBREVIATIONS USED IN FIVE YEAR SUMMARY REPORT**
**SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT**

| Abbreviation | Term |
|---|---|
| SCWDP | Sacramento Constructed Wetlands Demonstration Project |
| SQG | Sediment quality guideline |
| SRCSD | Sacramento Regional County Sanitation District |
| SRWTP | Sacramento Regional Wastewater Treatment Plant |
| SWRCB | California State Water Resources Control Board |
| SYMVCD | Sacramento-Yolo Mosquito and Vector Control District |
| TDS | Total Dissolved Solids |
| TKN | Total Kjeldahl Nitrogen |
| Tl | Thallium |
| TN | Total Nitrogen |
| TOC | Total Organic Carbon |
| TP | Total Phosphorous |
| TSS | Total Suspended Solids |
| Typha | Commonly referred to as Cattail |
| μg | Microgram |
| Zn | Zinc |