MULTIPURPOSE WETLANDS

PHASE II/III REPORT

FINAL

FINAL DESIGN AND ONGOING RESEARCH INVESTIGATIONS

BUREAU OF RELCAMATION

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SEPTEMBER 1994

FINAL

MULTIPURPOSE WETLANDS

Phase II/III Report

Final Design and Ongoing Research Investigations

Eastern Municipal Water District
Bureau of Reclamation
National Biological Survey

September 1994

ACKNOWLEDGEMENTS

The Multipurpose Wetlands Research and Demonstration Project represents a comprehensive effort to evaluate the feasibility and effectiveness of integrating wetlands with advanced water treatment, environmental enhancement, and the ultimate reuse of reclaimed water in arid areas of the United States. This program was originally initiated as a cooperative effort between the Eastern Municipal Water District (EMWD) and the Bureau of Reclamation (USBR). In the fall of 1993, the National Biological Survey (NBS) joined the coordinated research and demonstration team.

Because this opportunity for wetlands research has national significance, not only in terms of its objectives but also in advancing wetland habitat and treatment technology, experts within the field were engaged to assist with this study and provide peer review. To achieve the desired level of expertise, EMWD, USBR, and NBS assembled a diverse group of technical experts from governmental agencies, the academic community, and environmental organizations.

Technical Advisory Committee: The following agencies and individuals are members of the Technical Advisory Committee.

Federal Agencies

Environmental Protection Agency
    Dr. Robert K. Bastian
Fish and Wildlife Service
    Mr. Bob James
National Biological Survey
    Mr. Lee S. Ischinger

State of California and Local Agencies

Department of Fish and Game
    Mr. John W. Anderson
    Mr. Tom Paulek
    Mr. Fred Worthley
Regional Water Quality Control Board
    Ms. Linda Garcia
Riverside County Flood Control and Water Conservation District
    Mr. Ken Edwards
Riverside County Health Department
    Mr. Hugh Murray
    Mr. David Richardson

Water Resources Control Board
Mr. Tom Inouye

Academic Community

Humboldt State University
Dr. Robert A. Gearheart
San Diego State University
Dr. Richard Gersberg
University of California at Riverside
Mr. Jewell L. Meyer, P.E.
Dr. Mir S. Mulla
Dr. Marilynn V. Yates

Environmental Groups

Ducks Unlimited
Mr. John Nagel

Consultants to Eastern Municipal Water District

CH2M Hill

Executive Committee: An Executive Committee was also formed to direct the study. This committee is the core management team, assembled periodically to resolve the important issues regarding policy decisions and administrative coordination as required to accomplish the objectives of the Multipurpose Wetlands Research and Demonstration Project. Members include the following:

Eastern Municipal Water District

Mr. Michael Garner	Program Manager; Resource Development Administrator
Ms. LeAnne Hamilton	Project Manager; Research Coordinator
Mr. P. Ravishanker	Assistant General Manager

Bureau of Reclamation

Mr. Bill Boegli	Chemical Engineering Leader
Dr. Jim LaBounty	Environmental Sciences Leader
Ms. Jean Shepherd	Project Manager
Mr. Tim Ulrich	Temecula Area Office Manager; EC Chair

Mr. Ron Willhite	Denver Loan Program Manager (retired)
Mr. Doug Yoder	Denver Wetlands Program Manager

National Biological Survey

Mr. Jim Sartoris	Research Coordinator

Additionally, recognition and thanks are extended to those who worked together in team efforts to accomplish the many tasks involved in bringing the final design to completion and to undertake the research activities that are described in this report. These individuals and respective activities are as follows:

Final Design Team: A technical team was assembled to coordinate the final design effort and to effectively transfer design concepts and preliminary design information into the preparation of plans and specifications for construction, planting, and landscaping of the multipurpose wetlands demonstration system at the Hemet/San Jacinto site. This team consisted of staff from EMWD, USBR, NBS, and final design consultants as follows:

Eastern Municipal Water District

Ms. Christie Moon Crother	Project Coordinator
Mr. Michael Garner	Program Manager; Resource Development Administrator
Ms. LeAnne Hamilton	Project Manager; Research Coordinator
Mr. Bob Page	Hemet/San Jacinto Regional Water Reclamation Facility Plant Manager
Mr. John Ward	Project Engineer

Bureau of Reclamation

Ms. Mary Lou Pierce	Landscape Architect
Mr. Eric Stiles	Design Coordinator
Mr. Richard Straubinger	Technical Review
Ms. Bernice Sullivan	Activity Manager
Mr. Ron Willhite	Loan Program Oversight

National Biological Survey

Dr. Doug Andersen	Wildlife Biology
Ms. Joan Thullen	Wetlands Vegetation

CH2M Hill

Ms. Michelle Girts	Wetlands Specialist
Mr. Christopher Poli	Project Engineer
Mr. Jagdish Salgaonkar	Project Manager

Research Investigations: Various research investigations concerning the test wetland cells, the pilot reverse osmosis system, and the saline marsh have been conducted by the following group of dedicated scientists with enthusiastic assistance provided by laboratory and field support staff members. The collaborative research investigation and technical support team include the following members:

Principal Investigators:

Eastern Municipal Water District

Mr. Steve Crombie	Water Quality; Reverse Osmosis Operation
Ms. Stella Denison	Biology; Public Education

Bureau of Reclamation

Mr. Bill Boegli	Reverse Osmosis Process
Ms. Joy Gober	Soils Chemistry
Ms. Judy Hamilton	Geohydrology

National Biological Survey

Dr. Doug Andersen	Wildlife Biology
Mr. Jim Sartoris	Wetlands Water Quality
Ms. Joan Thullen	Wetlands Vegetation

Wetlands Planting and Landscape Team: This technical team was responsible for preparation of landscaping plans, planting guidelines, and contract specifications for planting of the wetland and upland areas of the Hemet/San Jacinto multipurpose wetlands demonstration site. This small team consisted of staff from EMWD, USBR, and NBS as follows:

Eastern Municipal Water District

Mr. Michael Garner	Program Manager
Ms. LeAnne Hamilton	Research Coordinator
Mr. John Ward	Project Engineer

Bureau of Reclamation

Ms. Mary Lou Pierce	Landscape Architect
Mr. Eric Stiles	Design Coordinator
Mr. Richard Straubinger	Technical Review
Ms. Bernice Sullivan	Activity Manager

National Biological Survey

Ms. Joan Thullen	Wetlands Vegetation

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Eastern Municipal Water District

Mr. Steve Crombie	Water Quality
Ms. Stella Denison	Biology
Mr. Jeff Hale	Special Services
Ms. LeAnne Hamilton	Research Coordinator
Mr. Al Javier	Biologist
Mr. Steve Shockey	Field Services Assistant
Ms. Joanna Tewksbury	Water Quality Specialist

Bureau of Reclamation

Mr. Bill Boegli	Reverse Osmosis Process
Ms. Joy Gober	Soils Chemistry
Ms. Judy Hamilton	Geohydrology
Mr. S. Mark Nelson	Aquatic Biologist
Mr. Rick Wydoski	Biological Technician

National Biological Survey

Dr. Doug Andersen	Wildlife Biology
Mr. Jim Sartoris	Wetlands Water Quality
Ms. Joan Thullen	Wetlands Vegetation

Other Participants: Special thanks is also offered to the following individuals for their efforts and assistance:

Eastern Municipal Water District

Mr. Mike Creighton
Dr. John Crossman
Ms. Betty Gibbel
Ms. Arlene Gomez
Dr. Behrooz Mortazavi

Bureau of Reclamation

Mr. Ed Beddow
Mr. Keith Copeland
Mr. Russ Dodge
Ms. Amy Porter
Ms. Christina Robinson
Ms. Suzanne Sikora
Mr. Mike Walker

State of California and Local Agencies

City of Hemet
Mr. Mark Goldberg
City of San Jacinto
Mr. Mike Chestnut

Academic Community

California State Polytechnic University-Pomona
Ms. April Sleigh
Dr. Laszlo J. Szijj

Our sincere thanks and appreciation is extended to all for their expert counsel, participation, and support.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The Eastern Municipal Water District (EMWD), the Bureau of Reclamation (USBR), and the National Biological Survey (NBS), in consultation with other governmental agencies, the academic community, and environmental groups, are involved in a cooperative wetlands research and demonstration effort. This report reflects progress through the first 3 years of a 5-year program. The goal of the Multipurpose Wetlands Research and Demonstration Project is to evaluate and expand the use of reclaimed water and contaminated ground water through the incorporation of multipurpose constructed wetlands into EMWD's total water resources management program. The focus of the wetlands is the development of design, construction, and operational criteria that will provide a cost-effective and innovative alternative for managing water resources and provide other public benefits in arid areas. The program also recognizes the fact that naturally-occurring wetlands, both coastal and inland, have been disappearing at an alarming rate.

Millions of migratory birds funnel through the Pacific Flyway each winter on their annual flight from Alaska and Canada to Latin America. California, a critical 1130-kilometer (km) (700-mile (mi)) link on this corridor, has lost over 90 percent of its natural wetlands since the 1700's, resulting in the loss of habitat for resting, feeding, breeding, and the rearing of young. This project will provide vital habitat in a portion of the corridor as well as valuable information on the use of reclaimed water. Ninety-two different species of birds have already been identified utilizing the Hemet/San Jacinto Research and Demonstration Facility. Threatened and endangered species and species of special concern which have visited the site include the bald eagle, peregrine falcon, American white pelican, double-crested cormorant, white-faced ibis, northern harrier, golden eagle, prairie falcon, burrowing owl, and bank swallow.

Reclaimed water is a vital element in water resources management, especially in arid areas. Its use can minimize the strain on existing water delivery facilities and local water resources. Constructed wetlands designed to treat secondary effluent will directly affect the reclaimed water supply as a functional equivalent of advanced treatment. Concurrently, diminishing ground-water resources could be supplemented or, in some areas, additional recharge water could be provided as part of a comprehensive ground-water remediation program. The net result will be the maximum utilization of local water resources, thereby reducing the dependence on imported water supplies.

The success of the project is demonstrated by the many national and international visitors that have toured the research and demonstration site to date, including two groups from Australia, representatives from Taiwan and the People's Republic of China, and a delegation from 14 Middle Eastern countries. In addition, local school

PHOTO 1. SAN JACINTO WILDLIFE AREA

children utilize the wetlands as an environmental science laboratory, learning about wetlands ecology, the value of reclaimed water and its reuse, and developing an awareness of water as a finite and precious resource. The site is well-known among bird watchers and is one of the locations used by the Audubon Society for its annual Christmas Bird Count. In contrast to its arid surroundings, the facility provides green space and habitat appealing to both people and wildlife.

National, State, and regional awards that the project has received include the Association of Metropolitan Sewerage Agencies (AMSA) Research and Technology Award for 1994; California's Local Government Commission 1992 Award for Innovation in Water Conservation, Reclamation, and Management; and the Inland Empire West Resource Conservation District 1993 Conservation Partnership Award for Water Quality.

The 5-year study began in December 1990 with the signing of a Memorandum of Agreement. Phase I of the study established specific goals and objectives and developed conceptual designs for multipurpose wetlands at three separate sites comprising up to 243 hectares (ha) (600 acres (ac)). The objective of these demonstration projects was to allow the development of information on wetlands design features that could ultimately be used as guidance for the development of similar projects across the nation. The Phase I Report (November 1991) provided background information and preliminary design concepts for wetlands at the Hemet/San Jacinto Regional Water Reclamation Facility (RWRF), Little Valley, and a site in the vicinity of the San Jacinto Wildlife Area. It contained information on soil characteristics, fauna and flora, and hydrology for each site.

The wetlands which are being developed as part of this project are truly multipurpose in nature, providing water treatment, public education, wildlife habitat, open space, recreation, and other public benefits. In addition, each site has specific water resources objectives. For example, tertiary treatment and nutrient removal are the primary objectives at Hemet/San Jacinto; ground-water remediation and nitrate removal are the focus for Little Valley; and ground-water recharge and remediation of brackish ground water are the main objectives for the San Jacinto Wildlife Area site.

This Phase II/III Report covers the activities which have taken place since the Phase I Report was completed in November 1991. The major accomplishments were the design, construction, and monitoring of the wetlands research facility and final design of the 19-ha (47-ac) Hemet/San Jacinto demonstration wetlands. Work at Little Valley and the San Jacinto Wildlife Area sites has progressed more slowly due to the need to conduct more extensive hydrogeological and environmental investigations.

The EMWD/USBR/NBS Wetlands Research Facility was constructed at EMWD's Hemet/San Jacinto RWRF. This 3.2-ha (7.8-ac) site includes two 0.2-ha (0.5-ac) nursery cells and eight pilot research cells. The nursery cells were constructed first to propagate bulrush for later transplant to research and demonstration projects and determine the most efficient harvesting and planting techniques. The research cells are being used for ongoing research to monitor plant growth and establishment, water quality dynamics, sediment quality, and benthic invertebrates. The first year of monitoring has provided data on baseline conditions and seasonal and long-term variability and trends. The next phase of monitoring (Series 2) will look more closely at nutrient dynamics, nutrient input from wildlife, the significance of open water versus vegetated zones, and other topics.

The research facility also includes a pilot reverse osmosis (RO) desalination unit, saline vegetated marshes, and evaporation cells. The RO/saline marsh project involves studying the feasibility of supporting saline vegetated marshes with the reject stream of the desalter. If successful, the use of desalters and saline marshes will become part of EMWD's total water resources management program, allowing EMWD to reclaim brackish ground water and address the salt balance issue associated with reclaimed water. Brine disposal is a major cost element in the use of desalters in inland areas. The success of the saline marsh effort could result in an additional use of brackish water for the development of habitat, greenbelts, and open space and reduce brine disposal costs. A monitoring program has been initiated to assess bioproductivity, toxic accumulation, and habitat value.

In addition to the research program, EMWD secured a Federal loan through the Small Reclamation Projects Act (SRPA) loan program to develop an extensive reclaimed water distribution system which included construction and enhancement of up to 243 ha (600 ac) of wetlands. The loan program was created in 1956 to stimulate local economies and benefit the nation by extending, reclaiming, and recycling local water supplies. The loan program gives special consideration to wetlands enhancement opportunities in conjunction with local water management techniques.

The original wetlands as envisioned in the loan application were much less sophisticated and beneficial than the wetlands now being constructed. These wetlands were single-purpose in nature, thus requiring minimum grading for shallow ponds and indigenous shoreline vegetation. However, subsequent to the preliminary research effort by EMWD and USBR, it was cooperatively agreed to pursue the development of multipurpose wetlands. This resulted in the development of highly-engineered wetlands to support multipurpose objectives, including control features to enhance water quality, wildlife habitat, and other public benefits.

Design of the 19-ha (47-ac) Hemet/San Jacinto Multipurpose Constructed Wetlands was accomplished in stages with input from EMWD, USBR, NBS, CH2M Hill, and the Technical Advisory Committee (TAC). First, baseline and planning investigations were conducted by USBR and NBS to identify conditions and issues which could affect the design development. The next stage, the wetlands preliminary design investigations, provided critical information pertaining to site engineering, wetlands system design, and landscape and planting features. This resulted in the Design Concepts and Criteria Report, prepared by EMWD and USBR in June 1993. The final stage of design, preparation of construction drawings, specifications, and contract documents, took place between June and November 1993, with engineering consulting services provided by CH2M Hill. This Phase II/III Report covers activities through the final design. A Phase IV report will be prepared after the completion of construction of the Hemet/San Jacinto wetlands.

Construction of the Hemet/San Jacinto wetlands, funded with SRPA loan funds, began in January 1994. Located at the northwest corner of the Hemet/San Jacinto RWRF, the site is well-suited for the evaluation of water treatment efficiency under varying loadings. Being situated within the Pacific Flyway, it is also an excellent location to promote waterfowl diversity and provide public education benefits. This project was designed in collaboration with the USBR and NBS technical team. Several design features are included specifically to enhance habitat and allow public viewing. Planting and upland landscaping began in mid-August and will continue in phases until the end of December 1994. The first phase will involve transplanting of bulrush from the nursery cells. A monitoring program will begin shortly after planting to assess plant establishment, wildlife use, and water quality.

The Hemet/San Jacinto wetlands design is already serving as a model for other cities. The City of Phoenix has proposed a similar conceptual design for the Tres Rios Demonstration Wetlands Project that is currently underway. Constructed wetlands have great public appeal and offer significant advantages in terms of cost over conventional wastewater treatment. The type of information and experience which is being generated by the EMWD/USBR/NBS effort is essential to further the state of the art of constructed wetlands application and design.

Many aspects of the EMWD/USBR/NBS Multipurpose Wetlands Research and Demonstration Project are ongoing. In particular, the research and monitoring efforts up to this point have been devoted largely to gaining data on baseline conditions or conditions during establishment of a mature wetlands system. Therefore, this report presents discussion and recommendations rather than final study conclusions. One of the purposes of the report is to allow input from the Technical Advisory Committee on the interim results and recommendations for further research.

Based on experiences thus far, the creation of a wetlands nursery is recommended to provide adequate plant material when building a large wetland. Establishment of the nursery cells at the Hemet/San Jacinto research facility was very successful. Within 3 months (July to October 1991), the original plant density increased, on average, about 16 times. There was enough plant material in the southwest corner of the north cell to vegetate the eight research cells successfully. The 0.4 ha (1 ac) of material in both nursery cells is expected to be sufficient to vegetate the 8 ha (20 ac) of marsh area in the demonstration wetlands.

Various methods of transplanting bulrush were evaluated. When removing bulrush from the donor site, it was found that there was no difference between the use of a backhoe versus hand-digging with a shovel; however, use of a backhoe may cut labor costs. When planting at the new site, staking the bulrush root clumps on top of the dry substrate, then flooding, is recommended as the best technique. This technique produced the most rapid propagation, which, in turn, provided the shortest time to total coverage. It was also the least labor-intensive and, therefore, the most cost-effective.

The research cells were constructed of two types to allow comparison of water treatment performance. Four of the cells have open water areas in the middle (three-phase), while the other four are fully vegetated (one-phase). Based on preliminary water quality monitoring, the most significant difference between the two types of cells was the performance in reducing nitrogen. The difference may be attributed both to nitrogen input from blackbirds inhabiting the bulrush and to better nitrification in the cells with open water. Further experiments are proposed to study these possibilities.

CHAPTER 1
INTRODUCTION

CHAPTER 1

INTRODUCTION

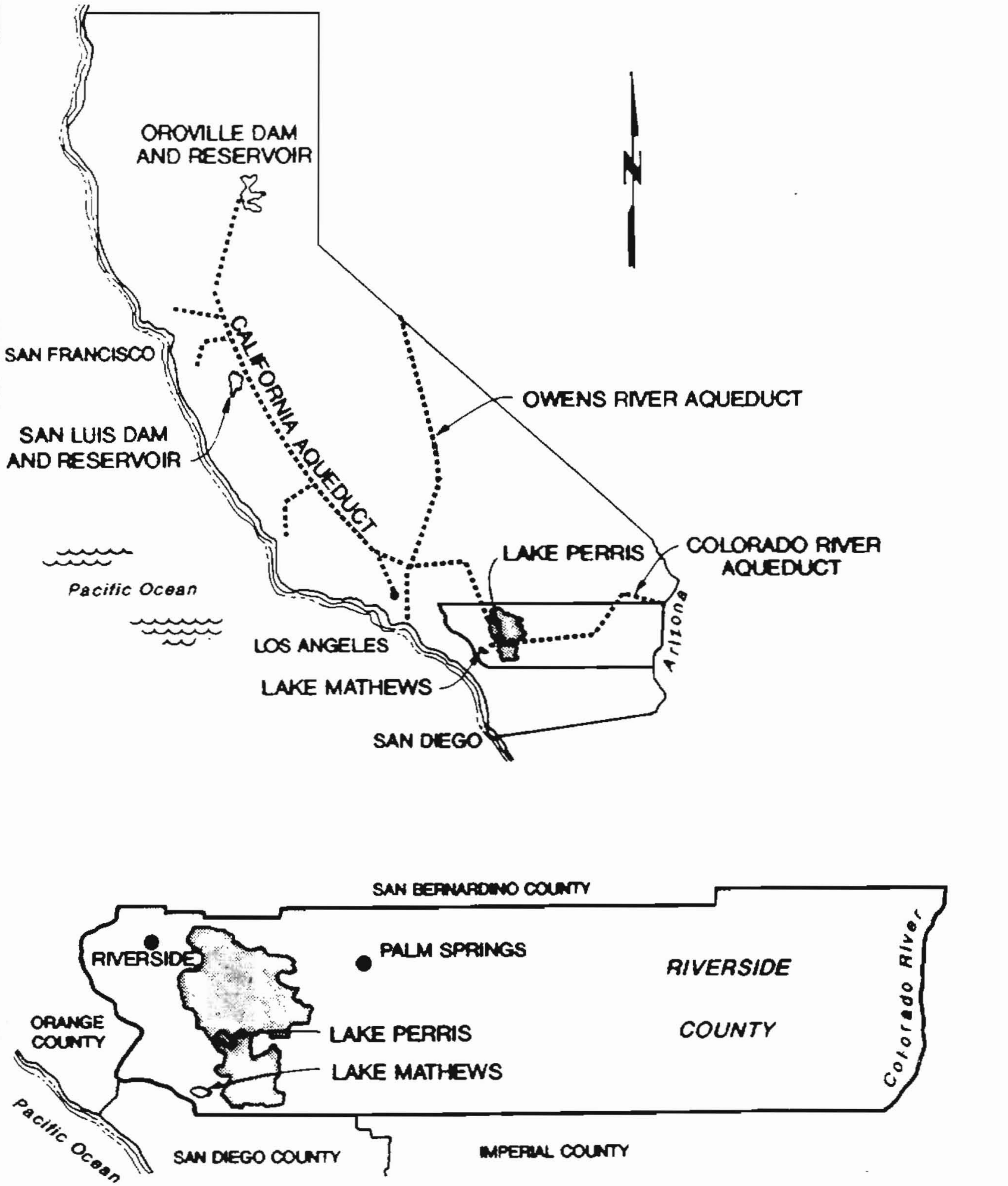
The Multipurpose Wetlands Research and Demonstration Project is examining the role of wetlands in conjunctive management of water, land, and environmental resources. The project is a cooperative effort among EMWD, USBR, and NBS. This wetlands demonstration program and related studies will evaluate and expand the use of reclaimed water and ground-water resources through the incorporation of multipurpose constructed wetlands into comprehensive plans for water resources management.

The focus of the wetlands component of the reclaimed water resources management program is the development of design, construction, and operational criteria that will provide a cost-effective and innovative alternative for managing water resources and provide other public benefits in arid areas. The program recognizes that scarce water resources place increased emphasis on integrated approaches to utilize water resources while protecting valuable ecosystem functions. It is also responsive to indications that naturally-occurring wetlands have been disappearing at an alarming rate, a problem of nationwide concern given the potential implications of losing a highly-productive food base and an extraordinarily dynamic ecosystem resource.

The cost of the wetlands research program has been shared by EMWD, USBR, and NBS through a combination of in-kind services and direct funding. The costs of design and construction of the full-scale demonstration facilities are being funded by a Federal loan and grant under Public Law 84-984. EMWD secured an SRPA loan to develop an extensive reclaimed water distribution system to serve its customers and to build up to 243 ha (600 ac) of wetlands to provide multiple environmental and public benefits.

PROJECT HISTORY

In the early planning stages of the project, a five-phase plan was formulated as a basis to establish full-scale wetland demonstration facilities at three selected sites. Upon completion of the first phase, a project report was prepared to delineate project goals, objectives, and principal research issues for the Multipurpose Wetlands Research and Demonstration Project. The Phase I Report also presented conceptual-level design plans for wetland systems to be established at each of the three sites, along with general information on soils, fauna and flora, and hydrologic characteristics associated with each site.



LOCATION MAP
EASTERN MUNICIPAL WATER DISTRICT

FIGURE I-1

EASTERN MUNICIPAL WATER DISTRICT

RIVERSIDE COUNTY, CALIFORNIA

RECLAIMED WATER FACILITIES

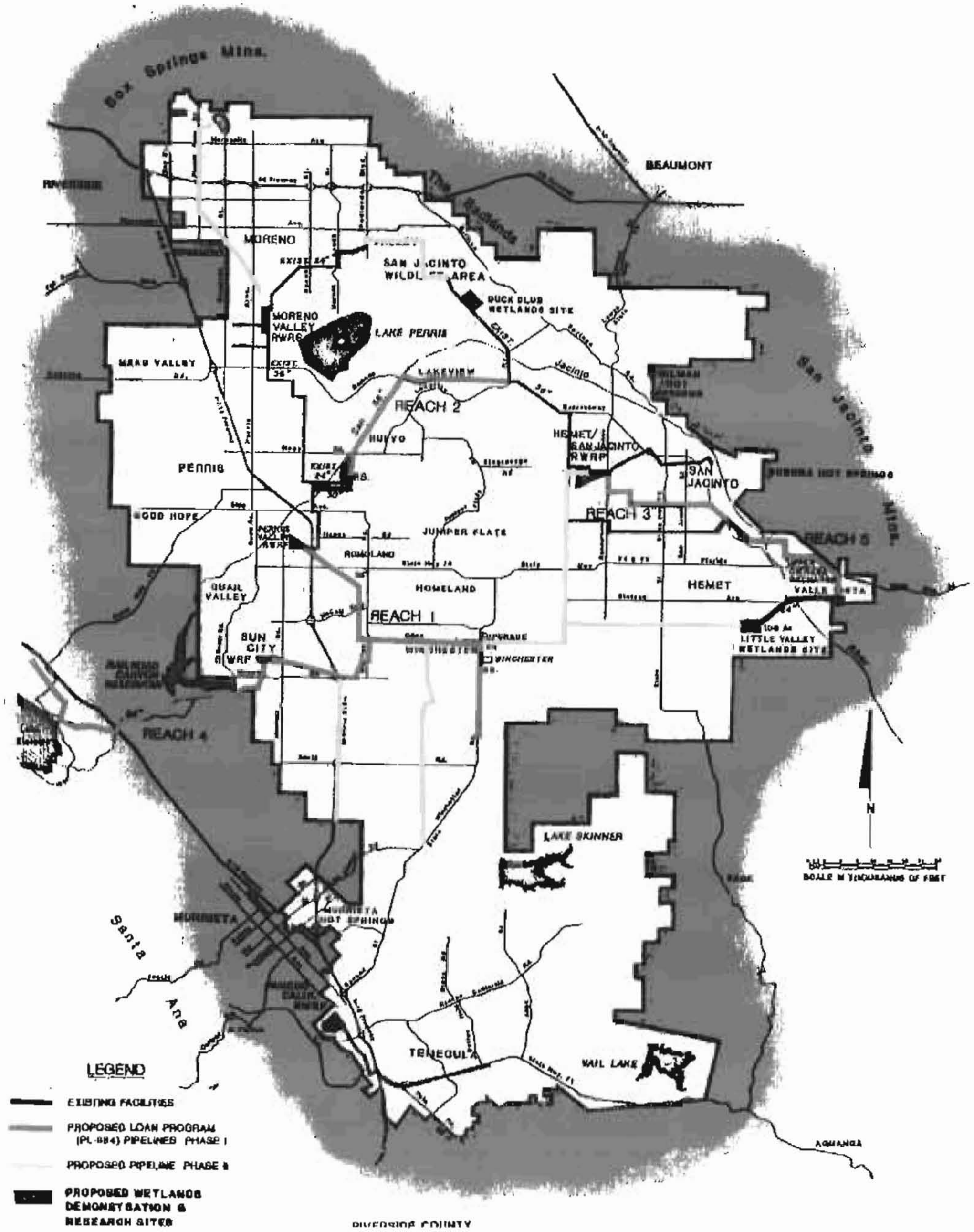


FIGURE 1-2

The five phases identified correspond to a discrete sequence of activities envisioned for each of the wetland demonstration sites as follows:

Phase I	Conceptual Design
Phase II	Predesign Investigations (and Environmental Assessment/Environmental Impact Statement work)
Phase III	Final Design (and permitting)
Phase IV	Construction of Demonstration Facilities
Phase V	Operations and Monitoring.

The five phases pertain to the conventional engineering development stages rather than distinct types of research studies. The project was initially conceived as a combined research and demonstration effort. As such, the project is comprised of applied science and engineering principles as required to construct wetland facilities while attributes are incorporated to increase the value of the wetland facilities by allowing investigations into the principal topics of interest.

Although three sites were identified in the Phase I Report, most of the subsequent investigation and design efforts have been focused at the Hemet/San Jacinto site. Work at Little Valley and the San Jacinto Wildlife Area sites has progressed more slowly due to the need to conduct more extensive hydrogeological and environmental investigations and to expand the water resource management objective for these areas.

Plans for the Hemet/San Jacinto RWRF site have progressed through the Phase II preliminary design investigations and the Phase III final design. Construction plans and specifications have been completed, and construction began during the winter of 1993. Planting of the wetlands vegetation began in mid-August and will be complete in December 1994. Planting plans for the terrestrial areas of the site are currently in preparation and will likely be implemented in late 1994.

Phases II and III also marked the construction of two wetland nursery cells, which were built and planted for the purpose of providing plant stock for the pilot- and full-scale wetland demonstration facilities. Eight research cells have been fully established, and the first series of pilot-scale research investigations was initiated. Both of these facilities were constructed at the Hemet/San Jacinto site. A pilot-scale RO system and saline marshes and evaporation cells to utilize the RO reject water were built at this site to allow research into ground-water remediation feasibility.

PURPOSE OF REPORT

This Phase II/III Report covers the activities which have taken place since completion of the Phase I Report, dated November 1991. Although several papers have been written and presented on the work which has occurred since then (see Appendix H), the major report which has been issued as part of the study is the Design Concepts and Criteria Report, dated 1993, which served as guidance and direction for final design of the Hemet/San Jacinto demonstration wetlands.

As a result, this Phase II/III Report covers a relatively long period of activity, and it serves several purposes. It is acting as a status report for the EMWD/USBR/NBS cooperative study, a scientific report on the preliminary research results, and a documentary report on the final design and public involvement activities.

The Multipurpose Wetlands Research and Demonstration Project will be completed in September 1995. A Phase IV Report will document the project activities and events through the construction of the demonstration facilities at the Hemet/San Jacinto site. A final report will present findings of the research investigations and the conclusions pertaining to demonstration issues such as the overall feasibility and cost effectiveness of multipurpose constructed wetlands, a summary of what was learned, and recommendations for project planning, design, construction, and operations of wetlands as part of water resources management.

One of the objectives of this study is to provide useful information on the costs to design, build, operate, and maintain the wetland facilities. Financial information will be included in the final report. By that time, the Series 2 monitoring at the research facility will be complete as well as construction and planting of the Hemet/San Jacinto Multipurpose Constructed Wetlands demonstration system. In addition, a monitoring program for the demonstration system will have been implemented.

Once the present study is complete, there will still be many opportunities for further investigations at both the research facility and the demonstration facilities. This may occur through cooperative research agreements between EMWD and other agencies or universities or through grants, loans, or volunteer programs. For example, EMWD, USBR, and the United States Geological Survey (USGS) are cooperating in an effort to characterize the total organic carbon entering and leaving the wetlands. Other areas of interest are virus removal, toxicity reduction, biodiversity, nutrient removal, nonpoint source treatment, habitat enhancement, and public recreation and education. Many other possibilities exist which can be pursued as funds become available.

This report presents activities undertaken in the Phase II task orders, status of final design for the Hemet/San Jacinto site demonstration wetlands, and results of ongoing research investigations at the joint wetlands research facility. Also included are activities related to public involvement and other pertinent information concerning this project.

CHAPTER 2
SUMMARY OF PROGRES

CHAPTER 2

SUMMARY OF PROGRESS

TASK ORDER NUMBER 1

Most activities comprising Phases II and III were completed through an agreement and two task orders among EMWD, USBR, and NBS. The task orders established a means for accomplishing items necessary to the multiple objectives of the program. The status of each task item included in the first two task orders is briefly described in this section.

Not all project activities were accomplished through these task orders. For example, the final design work was completed by the design consultants, and the design review and coordination was accomplished directly without task orders. The results of these efforts are presented in the summary of the Hemet/San Jacinto site final design in Chapter 3.

Task No. 1.1, Wetlands Nursery Cells

As the initial stage in the EMWD/USBR/NBS Multipurpose Wetlands Research and Demonstration Project, two 0.2-ha (0.5-ac) nursery, or plant propagation, cells were constructed during the first half of 1991. These cells provided a facility for propagating bulrush for later use in research and demonstration projects and for determining effective and practical planting techniques. Secondary-treated reclaimed water from the Hemet/San Jacinto RWRF was piped into the nursery cells at an average flow rate of approximately 56.8 liters per minute (L/min) (15 gallons per minute (gal/min)) per cell.

Between July 1 and 10, 1991, California bulrush and hardstem bulrush were harvested from four local donor marshes, and some bulrush were also purchased from a native plant nursery for the establishment of the nursery cells. Several methods were utilized in planting the bulrush to determine the best methods for later harvesting and transplanting. One objective was to generate enough plant material in the nursery cells to later vegetate the larger-scale demonstration wetlands. The staking of bulrush clumps to the soil surface followed by immediate flooding was determined to be the best method of transplant, the least labor-intensive, and the most cost-effective, while achieving a high survival rate and rapid propagation. In addition, other wetland plants and indigenous riparian plants were introduced into the nursery cells to test their adaptability and survivability.

Water quality within the nursery was monitored for 8 months to gain an early indication of how effectively the planned wetland system would improve the quality of

EMWD's reclaimed wastewater. Additionally, samples of benthic invertebrates were collected to obtain basic information on development of the invertebrate community in the system. These data can give an indication of system developmental rate and status as well as food availability for wildlife that might be expected to use the demonstration wetlands. Mosquito larvae production was also monitored in the nursery; the resulting data will have public health implications for all future wetlands development.

California bulrush taken from the southwest corner of the north nursery cell was used to plant the eight research cells from September 2 to 9, 1992. Since then, that area of the nursery has completely revegetated itself. During the summer of 1994, plant material in the nursery will be used to vegetate the full-scale demonstration wetlands.

Task No 1.2, Research Cells

EMWD/USBR/NBS personnel designed eight wetlands pilot cells for the joint research facility during the spring of 1992. Construction began on June 24, 1992, and the completed cells were planted with California bulrush from the nursery cells from September 2 to 9, 1992. The Series 1 monitoring program began 6 weeks after planting, on October 20, 1992.

The objectives of the Series 1 monitoring program were to document the processes by which the research cells became established as operational water treatment/habitat units and to determine the degree of variability between the three-phase and one-phase cells and among the cells within each type. Monitoring activities were focused on four aspects of cell establishment: vegetation establishment, sediment-water interactions, development of the macroinvertebrate communities, and water treatment functioning.

Initial plans called for the Series 1 monitoring program to continue through April 1993, but heavy winter rains and flooding of the cells forced the suspension of all monitoring activities from February 11 to May 5, 1993. The Series 1 monitoring program was extended, as Series 1A, from May through October 1993 in an effort to compensate for the data lost during the rainy season.

The Series 2 monitoring program is currently under development and will be included in Task Order Number 3 between EMWD, USBR, and NBS. Recommendations for Task Order Number 3 are contained in Chapter 4.

Task No. 2.1, Wetlands Baseline and Planning Investigations

Baseline investigations were undertaken to establish initial conditions for use as a reference in future research at demonstration wetlands. In addition, planning investigations addressed topics which affected the design development, such as

PHOTO 2. HARVESTING CALIFORNIA BULRUSH FROM DeVUYST DRAIN FOR PROPAGATION (NURSERY) CELLS

PHOTO 3. PLANTING THE NURSERY CELLS WITH TLC

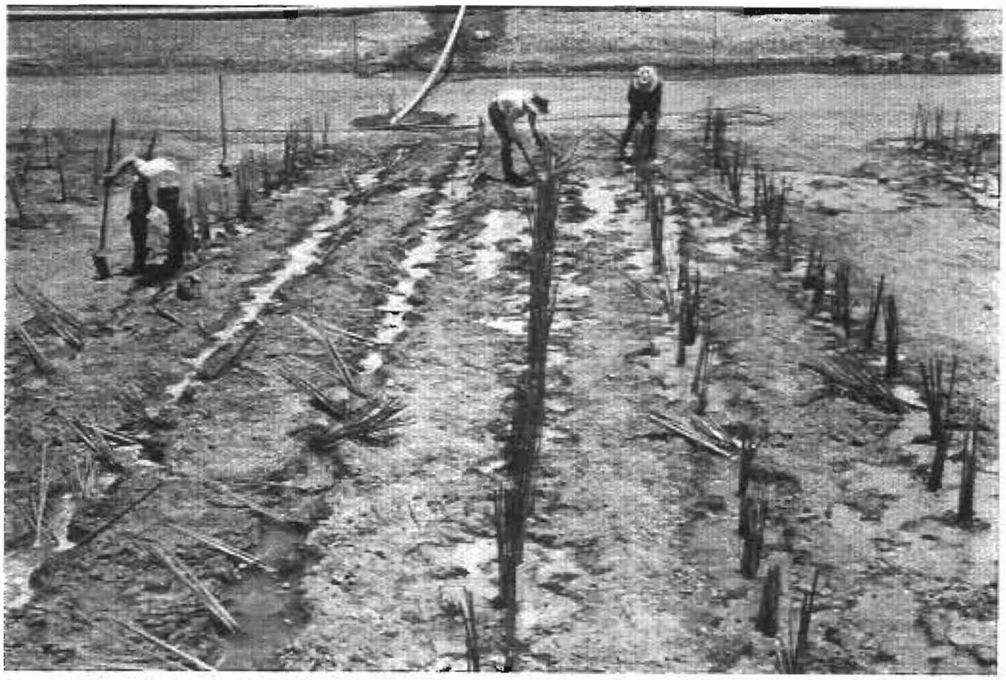


PHOTO 4. PLANTING NATIONAL CITY'S BARE ROOT UNITS IN NURSERY CELL

PHOTO 5. PLANTING RESEARCH CELLS; CALIFORNIA BULRUSH STAKED CLUMPS

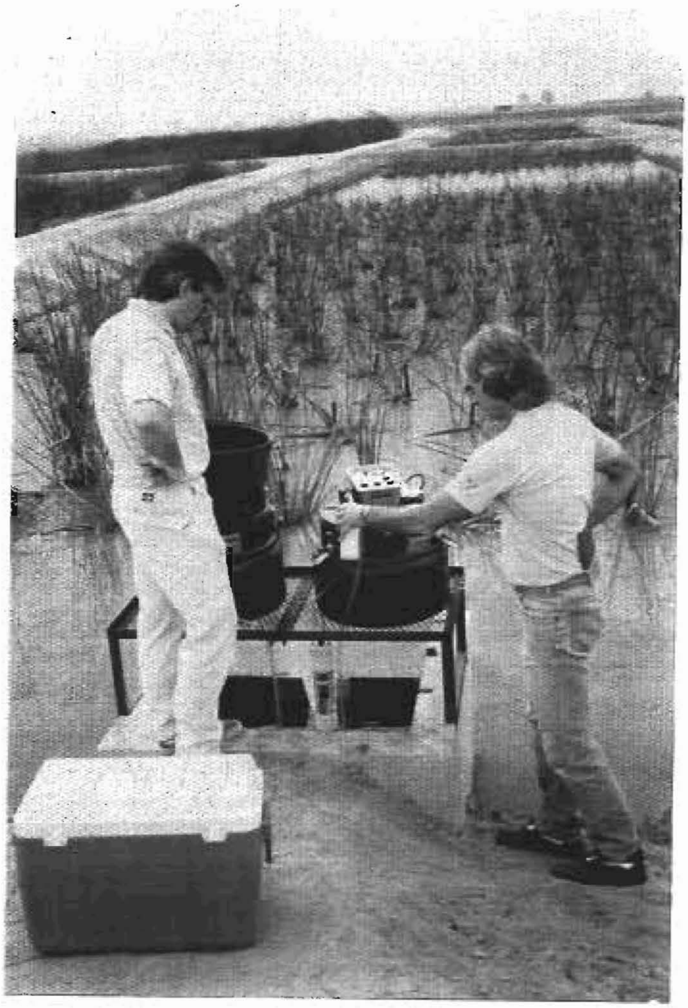


PHOTO 6. SETTING UP WATER QUALITY SAMPLES IN RESEARCH CELLS

PHOTO 7. COLLECTING PLANT GROWTH DATA IN RESEARCH CELL

defining planting, landscaping, and monitoring/testing needs. As such, these activities directly supported the planning of wetland facilities to achieve fundamental wetland system functions, while allowing specific features to be adjusted or integrated for research purposes. Four subtasks were identified to accomplish these tasks:

1. *Wetlands Study and Monitoring Program:* The intent of this task was to identify critical research and demonstration issues as they might affect the incorporation of distinct facilities or features into the demonstration system design. Consideration also included a determination of which types of wetland issues should be investigated at the demonstration sites and the research cells. These issues were presented to the TAC to gain a broad-based perspective of critical issues concerning constructed wetlands. This effort helped to delineate the types of studies appropriate for different facilities, to establish an experimental plan for the initial stages of research, and to answer critical issues regarding preliminary design development of the Hemet/San Jacinto site demonstration facilities. A monitoring and research program will be developed for the Hemet/San Jacinto site within the next year.

2. *Soils Investigations:* These specific investigations were intended to examine and evaluate the potential interactions of the Hemet/San Jacinto site soils with the reclaimed water supply for the wetlands system. Some initial field testing was completed using the nursery and pilot wetland facilities for these studies. There was no indication that wetlands could not be sustained by using reclaimed water at the site, or that constructed wetlands would pose harmful consequences to wildlife that would exceed ambient conditions associated with the supply water and site soils. Transformations and soils characteristics may be researched through ongoing studies; however, the feasibility issues associated with water and soils were considered to be addressed through these investigations.

3. *Vegetation and Propagation Studies:* These studies were intended to determine the appropriate and desirable plant communities for use within the Hemet/San Jacinto wetlands and on the surrounding terrain. The effort also included examination of different methods to propagate large quantities of emergent vegetation as required to initiate vegetation growth in full-scale wetland systems and assessment of the methods to transplant plant materials. Seed germination experiments were conducted, and the growth of plants established by various techniques was monitored in the nursery facilities. A determination was made that staking bulrush clumps prior to flooding is the most effective method of establishing the bulrush communities in the marsh areas. Other plants can be established according to individual needs. A tentative planting plan was developed for both the

terrestrial and wetlands plant varieties to be used in the Hemet/San Jacinto wetlands facilities.

4. *Wetlands Preconstruction Investigations:* The major objective of this task was to identify baseline studies which were needed before proceeding with final design and construction of the wetlands system at the Hemet/San Jacinto site. Included was a review of the wetlands conceptual design in relation to site plans, to evaluate any site characteristics which might be affected by the proposed wetlands system, and to determine a course of action for initiating studies or establishing interim plans to coincide with the ongoing final construction planning. The review of site conditions was simplified by the decision to build the wetlands system within a 19-ha (47-ac) site area that had been used previously as a reclaimed water storage facility. The baseline investigations were largely restricted to consideration of converting open storage ponds and surrounding berms and roads to a constructed wetlands with multipurpose attributes. Existing wildlife use of the proposed site was considered moderate and was predominantly identified with waterfowl using the adjacent duck-hunting club ponds, migrating shorebirds, or songbirds primarily attracted to other parts of the RWRF, or small mammals immigrating onto the site from surrounding agricultural land and fence row habitat.

Research and wetlands system issues will be reviewed during the next year to assemble more detailed plans for monitoring and research to be undertaken at the Hemet/San Jacinto site. As the demonstration program progresses, studies are likely to be continually reviewed and adjusted, as appropriate, to address important objectives within research funding capabilities.

Task No. 2.2, Wetlands Preliminary Design Engineering

This task consisted of preliminary design engineering investigations as required to proceed with final design and preparation of the construction plans, specifications, and contract documents for the Hemet/San Jacinto Multipurpose Constructed Wetlands. Five subtasks were identified to complete the preliminary design engineering:

1. *Engineering Review of Wetlands Systems:* This subtask included review of the wetlands conceptual design and additional information available to ensure that the design direction remained consistent with the full-scale demonstration project objectives. Once the overall constraints to design were established, specific engineering issues were resolved pertaining to the hydraulic systems, site earthwork, and ancillary features comprising the complete multipurpose wetlands system. The intent was to compile all information and findings necessary to allow preparation of final design plans for the construction of all wetlands system components and features.

2. *Geotechnical Investigations:* Site-specific engineering issues pertaining to the properties of site soils were addressed by completing field and laboratory geotechnical investigations. Due to the specialized nature of these investigations and logistical considerations, these investigations were accomplished by contract to a certified professional geotechnical engineering firm. The results and findings of these investigations are presented in a report prepared by Inland Foundation Engineering, Inc., in 1993. The contract was completed, and results of these investigations were used to evaluate two major wetlands engineering issues, namely: (a) the suitability of site soils for earthwork construction, including creating designed slopes, grades, and structural backfill considering the implications of wetlands development; and (b) the ability of site soils to retain water within the wetlands system considering operational objectives and relevant regulatory constraints. These results were used in final design and in consideration of site monitoring wells.

3. *Preliminary Design of Wildlife Features:* Development to a preliminary design level was required due to the specific nature of these features and the potential need to convert biological requirements into distinct engineering terms for use in final design construction plans. The majority of this work centered on details for features that were added to the basic wetlands design. For example, the size, shape, grade, and location of islands, shallow pond zones, and moist-soil areas were all defined to an appropriate level of detail. Design requirements to achieve specific conditions, the practical constructibility, and cost factors were considered in each case. Results were incorporated into the final design criteria and recommendations.

4. *Surveying and Mapping:* Site surveying and preparation of base topographical maps were both accomplished by EMWD. Site surveys were delayed for some time due to water on the site area following the heavy rains during the winter of 1993. Surveys were completed, and base sheets were prepared in digital form for transfer to the final design team.

5. *Preliminary Site Engineering:* This subtask included identification of all remaining concerns to be addressed prior to proceeding with final design. Specific items identified were: (a) location and assessment of utilities that would be affected by the wetlands project; (b) review and assessment of applicable land ownership and right-of-way considerations; and (c) consideration of a land-use master plan for the entire Hemet/San Jacinto RWRF property with respect to the possibility of integrating the wetlands demonstration project with other facilities on the property. All potential utility and ownership issues were resolved and recorded for reference in final design. Development of a master plan was considered;

however, existing site constraints and future needs for storage of reclaimed water within the property precluded development of a master plan within the timeframe of this wetlands demonstration project.

The major product of this subtask was a report entitled Design Concepts and Criteria Report, prepared by EMWD and USBR, June 1993. It includes the critical design information pertaining to site engineering, wetlands system design, and landscape and planting features. The geotechnical investigations report, certification of property ownership, and draft instructions for planting wetland vegetation are included as appendices to the report. For purposes of this project, this report serves as the preliminary design engineering report to provide design constraints and criteria to guide final design. It was transferred to the final design team as a basis for preparing construction plans and specifications for the Hemet/San Jacinto site wetlands demonstration system.

Task No. 2.3, Preliminary Environmental Regulatory Review

Task No. 2.3 consisted of a preliminary review of National Environmental Policy Act and California Environmental Quality Act (CEQA) requirements for demonstration wetlands at three sites.

An initial study and CEQA negative declaration for the Hemet/San Jacinto wetlands facility was adopted by EMWD's Board of Directors on April 7, 1993. The analysis was simplified by the fact that the site had previously served as a reclaimed water storage pond.

Biological and archeological field surveys for the Little Valley site have been completed. The biological survey of Little Valley found that the 12.4 ha (30.6 ac) in the central floodplain portion of the property is relatively constraint-free except for the small amount of existing wet habitat (recharge area). In contrast, the surrounding uplands support primarily coastal sage scrub, a plant community recognized as highly sensitive by local, State, and Federal resource agencies. Any impacts to coastal sage scrub may require mitigation in the form of revegetation or off-site habitat acquisition coupled with the dedication of that habitat to open space. Potential impacts to the limited amount of wet habitat in the center of the site could be mitigated by the creation of wetland habitat associated with the project and yield a net benefit for wetlands.

The cultural resource assessment of Little Valley found a large archeological site in the southwestern corner of the property which would not be impacted directly by the wetlands. However, the site is vulnerable to indirect impacts such as erosion and unauthorized collection of artifacts. These could be mitigated by restricted public access, fencing, and erosion control measures. A Phase II cultural resource assessment is planned to collect more information.

A CEQA Notice of Exemption was obtained for the performance of predesign investigations at Little Valley on August 6, 1993. It covers geophysical and geohydrological studies at the site. These studies will provide scientific information needed to design the wetlands and recharge areas.

Discussion of a potential wetlands location in the San Jacinto Wildlife Area was included in an Environmental Impact Report/Environmental Assessment prepared by K. S. Dunbar and Associates in September 1990.

Further environmental regulatory review work is necessary for both the Little Valley and San Jacinto Wildlife Area sites. However, these sites are no longer part of the EMWD/USBR/NBS Cooperative Research and Demonstration Study, and they will be addressed separately by EMWD.

Task No. 3.1, Investigations and Planning of Ground-water Recharge

This task included examination of factors concerning the feasibility of recharging ground-water aquifers, especially with respect to the use of wetlands-treated reclaimed wastewater. The investigations considered the use of several different ground-water formations in the area, including recharge of water to augment local ground-water resources and the potential for remediation of poor quality ground-water supplies within the EMWD area. This included a review of data and information available pertaining to the major ground-water basins, characteristics of selected recharge sites for either passive percolation or injection recharge, and the prevalent regulatory and public health implications. Also included was an evaluation of current information and the application of computer modeling to address the recharge and aquifer characteristics.

Application of specialized computer models was deferred due to the limited information available to address the complex geohydrology over relatively extensive and undefined aquifer formations in the area. The selection of an appropriate model may depend on the quality of recharge water sources. As a result of early investigations, the focus of this task shifted to evaluation of distinct feasibility issues concerning recharge of wetland-treated water in general and to examine the potential for recharge of alternate fresh and reclaimed water sources at Little Valley.

Investigations of the Little Valley site were to consider the subsurface characteristics which could affect the ability to recharge defined aquifer basins of interest. Recommendations for a geophysical testing program were prepared to guide the collection of information required to address unknown aspects of the Little Valley site. While these specific geophysical investigations were not undertaken as part of this task, a seismic reflection survey of the site was completed by the USGS in August 1993. Preliminary results indicated that the direction of subsurface water flow may be toward a less desirable ground-water basin than was expected. Specific field exploration testing is planned to confirm these initial findings. A cost estimate and specifications for these field tests were also submitted as part of this task. Further geophysical/geohydrologic investigations are beginning in June 1994 under an agreement between EMWD and USGS.

California has produced draft guidelines for recharge of reclaimed water at the time of this task. The draft guidance provides specific criteria for recharge effects on ground-water resources and blending requirements in proportion with the organic carbon content of the water source. As written, the organic carbon issue may have strong implications on the feasibility of recharge with wetland-treated water. These topics will warrant close attention as the final regulations are established.

Task No. 3.2, Wetlands Impacts on Ground-water Aquifers

A topic related to ground-water recharge is the impact of wetlands development on ground water and geologic formations. This includes the effects of seepage losses from wetlands, inadvertent recharge, chemical interactions with ground water, and the potential for seismotectonic damage from either injection or percolation. The emphasis here was on the Hemet/San Jacinto site since this site will be the first to have a full-scale wetlands demonstration system established. The major objective of this task was to evaluate the issues concerning seepage from the wetlands and the possible interactions of wetland water with ground water. Issues related to injection technology were not considered in detail as part of this task. These issues warrant specialized investigations in the event that injection operations are considered for any application.

However, the Hemet/San Jacinto wetlands site has been permitted for several years by the California Regional Water Quality Control Board for storage of reclaimed water. Reports from EMWD and the May 1993 geotechnical investigations by Inland Foundation Engineering, Inc., have indicated that seepage is negligible. USBR recommended that monitoring wells be installed at the Hemet/San Jacinto site to provide information for analysis of effect of the wetland pilot plant on ground-water conditions. Based on the assumption that the demonstration wetlands would not be likely to exhibit effects on the ground-water resources that would be appreciably different from those associated with storage of reclaimed water, and since the volume of water in the wetlands would be considerably less than was historically stored, plans for construction of the wetlands were finalized without inclusion of ground-water monitoring wells.

Task No. 4.1, Saline Marsh System

A pilot study was undertaken at the wetlands research facility to evaluate the use of RO desalting for improving the quality of brackish ground water in the Lower San Jacinto Ground-water Basin to potable standards and also to evaluate the use of RO

PHOTO 8. REVERSE OSMOSIS UNIT

PHOTO 9. SALINE VEGETATED MARSHES AND NONVEGETATED EVAPORATION PONDS

reject brine for the support of salt-tolerant emergent vegetation. The benefits derived from the successful demonstration of these goals would include the reduction of RO reject brine volume through plant transpiration and evaporation (evapotranspiration) and the creation of irrigated greenbelts, open spaces, and habitat areas.

The pilot facility consists of an RO treatment unit, two saline vegetated marshes, and two non-vegetated evaporation cells.

Task No. 4.1 dealt with the saline marshes and evaporation cells. (Task No. 4.2 dealt with the RO system). Task No. 4.1 consisted of four parts: (1) research and design; (2) construction; (3) planting; and (4) monitoring. Parts 1, 2, and 3 have been completed. Monitoring will continue for at least one more year to measure the long-term effects of saline marsh operation on the biota. This will be done as part of the cooperative research and demonstration program under a future task order (Task Order Number 3) or independently by EMWD.

Two 12.2-meter (m) by 24.4-m (40-foot (ft) by 80-ft), lined vegetated cells (saline marshes) and similarly-sized, lined, non-vegetated evaporation cells were constructed in April 1993 under the same construction contract as the wetland research cells. The piping system for the saline marshes and evaporation cells were installed by EMWD crews. The marshes were planted with four salt-tolerant species on April 27 and 28, 1993, by EMWD/USBR/NBS staff. The plants received fresh water to promote establishment for 6 weeks; reject brine from the RO unit was first added June 7, 1993.

During peak evapotranspiration periods in the summer of 1993, the addition of 4.7 cubic meters (m^3) (1250 gal) of reject brine each weekday was insufficient to keep both saline marsh cells continuously wet. Therefore, beginning on September 20, 1993, 9.4 m^3 (2500 gal) of potable water from a local fire hydrant was added weekly to the north cell. The south cell continued to receive the reject brine through February 1994.

Operation of the RO unit for 2 weeks at the beginning of February 1994 was hindered by rain, making the road to the RO unit inaccessible to the water hauling truck. After the rains, road regrading work was performed by EMWD crews. An electrical failure at the well supplying the RO unit also caused a brief shutdown while EMWD electricians made repairs. The ownership of the well supplying water to the RO unit suddenly changed in February 1994, and water could not be pumped from the well after February 23, 1994. Negotiations to form a license agreement with the attorney for the new owner have taken longer than anticipated. From approximately February 24, 1994, until the present (June 1994), the RO system has been shut down, and both saline vegetated marshes are being supplied by the winter rains or fresh water from a nearby fire hydrant. At the time of this writing, the trustee for the new owner of the well is reportedly close to signing the new license agreement.

Task No. 4.2, Reverse Osmosis Water System

Twelve subtasks were associated with Task No. 4.2, as follows:

a. Design RO pilot plant; select membrane elements to be tested;
b. Conduct bench-scale tests to evaluate pretreatment alternatives;
c. Procure process equipment, instrumentation, and membrane elements;
d. Fabricate RO test skids and assemble pilot plant;
e. Document operation and maintenance (O&M) procedures; prepare test plan and data sheets;
f. Perform shakedown testing at the Denver laboratories;
g. Complete test site preparation;
h. Ship pilot plant to test site;
i. Installation at the site, plant start-up, and operator training;
j. Complete testing and evaluation of RO membranes; lab analyses;
k. Prepare final report;
l. Continue operation in support of saline marshes; and lab analyses.

Of the 12 subtasks listed above, the first nine have been completed. The first five were accomplished at USBR's Denver laboratories. Site preparation (concrete slab and shade structure) was performed by EMWD personnel. The shipment, installation, and start-up of the pilot plant equipment and training of an EMWD operator were completed by the end of April 1993. Subtask 4.2(j) began on May 3, 1993, and is within 4 months of completion. Subtask 4.2(k) will be accomplished following the completion of membrane testing. Subtask 4.2(l) will continue for approximately another year.

Operators from EMWD are charged with the day-to-day operation of the RO pilot plant. They operate and maintain the system, in accordance with the system O&M manual, and collect data. Overall direction for the RO test program is provided by USBR's Denver Office.

Subtask 4.2(b), "bench-scale testing", was conducted in anticipation that RO operations were to be performed using the Walker Duck Club well water. It consisted of laboratory experiments to evaluate brine-regenerated ion exchange as a pretreatment process. Because of the high concentrations of calcium and bicarbonate in the Walker Duck Club well water, it would have been necessary to add a considerable amount of acid plus anti-scalant to avoid the precipitation of calcium carbonate in the RO membranes. Ion exchange experiments were conducted using a strong acid cation exchange resin operated in a sodium cycle to remove calcium. Regeneration of the resin was attempted using a brine solution synthesized to duplicate the anticipated RO reject brine. These experiments were completed in April 1992, and the results were documented in a May 1992 memorandum report to EMWD from USBR. Subsequent to these experiments, the Walker Duck Club well was abandoned as a potential RO feedwater source because of severe flooding and access problems.

EMWD located another well known as the Moreno Highlands well. This well was determined to have acceptable water chemistry. It is located in the lower San Jacinto Ground-water Basin, as was the Walker Well, but it is more accessible.

TASK ORDER NUMBER 2

Task No. 1.1, Hemet Invertebrate Sampling

The primary objective of the invertebrate sampling program was to provide evidence of the establishment of equilibrium conditions within the research cells. This information would support or refute the water quality and plant establishment studies. Secondary objectives were to: (1) document the pattern and pace of development of the invertebrate communities in order to gain insight into the invertebrate communities likely to develop within the demonstration wetland; (2) to develop or refine invertebrate sampling procedures for experimental work in the research cells; and (3) to develop procedures for monitoring the demonstration unit.

Samples of benthic macroinvertebrates were collected on three occasions during 1993 using two different methods. There was no evidence of equilibrium establishment within the sampled community, and the sampling problems encountered have led to significant revisions in proposed methods to be employed in the demonstration wetlands.

Task No. 1.2, Electrical for Reverse Osmosis Pilot Plant

Installation of electrical service for the RO pilot plant was successfully completed in April 1993. This service will also serve the pumping plant for the Hemet/San Jacinto RWRF site demonstration wetlands in the future. To provide the 1200-volt, 200-amp service, EMWD dug a 975-m (3200-ft) trench from Sanderson Road to the RO facility, and Southern California Edison laid the cable.

Task No. 1.3, Hemet/San Jacinto Site Geotechnical Investigations

This task was a continuation of the geotechnical investigations undertaken in the first task order. Task No. 1.3 consisted of coordination with the geotechnical subcontractor, a review of the results and findings for incorporation into the final design, and in consideration of the need for site monitoring wells.

The geotechnical investigations were conducted by Inland Foundation Engineering. They included five borings between April 5 and 7, 1993. The borings were made to depths ranging from 15.7 to 16.9 m (51.5 to 55.5 ft). Standard penetration tests were conducted during drilling at approximate 1.5-m (5-ft) intervals, and selected samples were tested to determine moisture content and dry unit weight. Ground-water levels determined during drilling ranged from 3.8 to 6.6 m (12.5 to 21.5 ft). The report prepared by Inland Foundation Engineering, Inc., Geotechnical Testing, Wetlands Demonstration Unit, Hemet/San Jacinto Treatment Plant, San Jacinto Area, Riverside County, CA, dated May 21, 1993, was reviewed and evaluated by USBR staff (Appendix A). The report indicated that seepage losses from the ponds were expected to be minimal and that the proposed facility would not be expected to have any significant effect on underlying ground water. Absent concerns on seepage from the ponds, no additional geotechnical activities are being considered for the site.

Task No. 1.4, Hemet/San Jacinto Site Final Landscape Design

Landscape design plans were prepared by USBR personnel for the upland site areas outside of the main wetlands system footprint. Originally, the landscape design included both the landform contours for the upland areas and the vegetation planting and seeding plans for the area. The decision was made to separate the contract for this landscape work from the construction contract for the wetlands system. The conceptual landscape grading plan was incorporated into the final design for site earthwork construction, and plans for the landscape planting, the public overlook area, and other site amenities were developed separately. USBR's landscape architect has completed final landscape plans. The landscape features will be installed after the wetlands system construction is completed. The upland planting plan consists primarily of seeding native, drought-tolerant varieties over most of the site land area, with more intensive planting of selected shrubs and trees in areas near the public overlook and riparian areas. This plan is being revised and finalized. Provisions required for temporary or permanent irrigation systems will have to be developed prior to installation of the upland planting.

Task No. 2.1, Little Valley Pilot Wetlands

The 43.7-ha (108-ac) Little Valley site is located southeast of the City of Hemet. The site is well-suited for a constructed wetlands demonstration project related to ground-water remediation and recharge while fulfilling the multipurpose objectives of the cooperative study. An excellent opportunity exists for using wetlands to treat nitrate-contaminated ground water collected from adjacent agricultural (citrus) areas and then percolate the denitrified water into local aquifers. The natural setting and ease of public access also provide an ideal opportunity for integrating park, open space, and public education/passive recreation elements with wetlands development to achieve water resource management objectives.

A preliminary conceptual design for a pilot wetlands at Little Valley was included in the Phase I Report. This concept has been revised, resulting in several possible variations of water treatment wetlands which would blend more with the natural environment. The two main proposals were to use either upflow gravel filters or horizontal subsurface flow plant beds to achieve a cienega effect while providing denitrification. Either the filters or the submerged beds would create a zone of saturated soil and allow an upwelling effect similar to that found in a natural cienega. The water would surface and flow through a riparian zone and a recharge zone.

Since ground-water recharge with wetlands-treated water is envisioned at Little Valley, detailed ground-water investigations are necessary. To enable evaluation of recharge characteristics and ground-water flow, a geophysical investigation was performed consisting of running several seismic lines across the valley. It yielded information on depth to bedrock and slope of bedrock, which was used to determine ground-water flow direction. An agreement has been developed with the USGS to perform additional geophysical and geotechnical work, including drilling several test holes and monitoring wells. With this information, a site plan can be developed.

The EMWD/USBR/NBS Cooperative Research and Demonstration Study Executive Committee determined that time and funding constraints made it necessary to put the Little Valley Project on hold while concentrating on the successful completion of the Hemet/San Jacinto Multipurpose Constructed Wetlands. In the interim, EMWD is continuing with the hydrogeological work and environmental compliance documentation.

Task No. 3.1, Hemet/San Jacinto Site Demonstration Wetlands Development

The purpose of this task was to assemble technical information for use as a guide in the final design of the Hemet/San Jacinto Multipurpose Constructed Wetlands. Activities centered on the gathering of information to produce a set of instructions, criteria, and constraints, as a basis for writing the contract specifications, rather than the actual writing of the contract documents. This task was a follow-up to the preliminary design activities cited previously in Task No. 2.2 of the Task Order Number 1 summary. The activities also included initial coordination with the final design engineering consultant in preparation for proceeding with the final design process. The two subtasks identified are briefly described as follows:

1. *Construction Specifications:* Materials compiled to define the final design construction plans and specifications were presented in the Design Concepts and Criteria Report previously cited. The reader is referred to this report for specific details regarding the criteria imposed on the final design process. Upon completion of final design, the construction plans and specifications were reviewed and approved by EMWD and USBR staff prior to release for competitive bidding and contracting procedures.

2. *Planting Specifications:* Technical information regarding planting of the wetlands vegetation was compiled as a basis for preparing contract documents for this work. The decision was made to separate the construction work from the planting contract, due to significant differences in the nature of the work, and to simplify the scheduling and coordination of site work activities. Draft specifications, prepared by EMWD and USBR, have been completed. Final specification and contract documents were completed in July 1994.

CHAPTER 3
SUMMARY OF FINAL DEMONSTRATION WETLANDS DESIGN

CHAPTER 3

SUMMARY OF FINAL DEMONSTRATION WETLANDS DESIGN

HEMET/SAN JACINTO SITE FINAL DESIGN

Description

The 19-ha (47-ac) Hemet/San Jacinto Multipurpose Constructed Wetlands site, located at the northwest corner of the Hemet/San Jacinto RWRF, will focus on reclaimed water treatment, migratory and resident waterfowl and shorebird habitat enhancement and wildlife diversity, and public education and recreation. Funded with SRPA (Public Law 84-984) loan funds, this cooperative effort among EMWD, USBR, and NBS is an innovative use of multipurpose constructed wetlands in a comprehensive water resources management program which will greatly benefit the local area as well as other regions of the country.

Final Design Process

The design is a three-phase integrated system consisting of five separate wetlands treatment units, a combined open water and marsh habitat area, and a final polishing wetland. The basic 3785 m^3/d (1 Mgal/d) integrated system occupies approximately 10 ha (25 ac) of the site. The system concept is based on marsh and pond areas sized to achieve certain retention times within the desired water depth and configuration. Secondary reclaimed water from the Hemet/San Jacinto RWRF will be distributed to the five wetland treatment units, or arms, then will be recombined in the central area to flow through the open pond prior to flowing through the final polishing wetland. The larger final wetlands will combine all flows to remove biological input produced in the open water habitat area. From the air, the system is "amoeba-shaped" and, on the ground, the curved lines give the appearance of a natural system.

Wetlands for wastewater treatment have received widespread interest as communities nationwide attempt to solve water and wastewater management problems. In existing treatment wetlands, the final step in the treatment process is disposal, and the wetland is designed with the single purpose of treatment in mind. This project introduces a new application; it is truly multipurpose--incorporating water treatment, recovery, and reuse with wildlife values, public education and recreation, and enhancement of environmental resources.

Wildlife Features

Included in the design are as follows:

1. A habitat-intensive central pond isolated from operational activities at the inlets;

2. Two types of moist soil areas to evaluate feasibility and wildlife values;

3. Islands to provide habitat and assess the wildlife value and constructibility;

4. Pond bench and riparian areas to increase shoreline habitat and allow for specialized vegetation studies;

5. Public amenities and access features designed to minimize interference with wildlife while allowing viewing, public education, and recreational opportunities; and

6. A landscape plan, including seeding with native grasses and selective planting of trees and shrubs.

Water Resources Design Considerations

Included to improve water quality performance of the system are the following:

1. A three-phase, marsh-pond-marsh system with directly-connected components;

2. Inlet marshes sized according to process functions and having an elongated shape to promote even flow and localize intensive treatment near the inlets;

3. Faster flow rates in the open pond and outlet marsh areas, relative to the inlet marshes, to reduce internal production and evaporation effects;

4. Arrangement of islands and planting scheme to induce even flow distribution through the marsh; and

5. Subdivision of inlet and outlet marshes to allow periodic maintenance of component areas without requiring shutdown of the entire wetlands system.

Public benefits also include education and recreation opportunities. Trails for walking and hiking, picnic areas, and areas for wildlife viewing and bird watching are planned. Interpretive centers, displays, and guided tours are included to increase public awareness of the environment, the value of reclaimed water, and respect for water as a precious and finite resource. Use of the wetlands by school children as an environmental science laboratory for the study of wetlands ecology, the local environment, and water resources is also of great importance and another public benefit.

The final design and preparation of construction plans and specifications for the Hemet/San Jacinto Multipurpose Constructed Wetlands was completed by CH2M Hill, Santa Ana, California, as consultants to EMWD. An initial meeting and two progress meetings were held to coordinate the major final design topics concerning EMWD, USBR, NBS, and the consultant. Design submittals were prepared for review at the 50 percent and 90 percent completion points, and the final product consisted of construction drawings and specifications for incorporation into EMWD contracting procedures. A fourth project-end meeting was held to resolve certain design issues remaining at the 99 percent completion stage.

Coordination of final design consisted primarily of ensuring that critical design features were correctly interpreted and translated into practical construction plans. Other site-related engineering problems were also resolved through the final design collaboration. Development and coordination of final design was accomplished separately from the task items described previously. Completion of final design constitutes Phase III of the Multipurpose Wetlands Research and Demonstration Project.

It is important to note that the conceptual design development focused on functional aspects of the wetlands; consequently, water supply and conveyance facilities were defined in terms of operational constraints, from a biological perspective, rather than engineering design. The Design Concepts and Criteria Report served as the preliminary document used to translate the operational constraints and objectives into engineering terms and functions. The construction plans and specifications were prepared by CH2M Hill.

At the onset of final design, the consultants were requested to review the conceptual design plans and the results of preliminary design investigations to assess the overall engineering feasibility and the practicality of constructing the wetland features. They also employed their environmental experience when reviewing the conceptual plan. No significant flaws were identified at that time. Any issues regarding site features or system components which were not clear were addressed and resolved through the final design engineering process.

The final site plan for the Hemet/San Jacinto demonstration wetlands is shown in Figure 3-1. This figure includes refinements and adjustments made during final design and is a graphical representation of the features included in the construction plans. Note that this site plan indicates considerable modification and refinement from that illustrated in the Phase I conceptual design report, but the major conceptual design elements remain intact.

HEMET /SAN JACINTO REGIONAL WATER RECLAMATION FACILITY
MULTIPURPOSE CONSTRUCTED WETLANDS GRADING

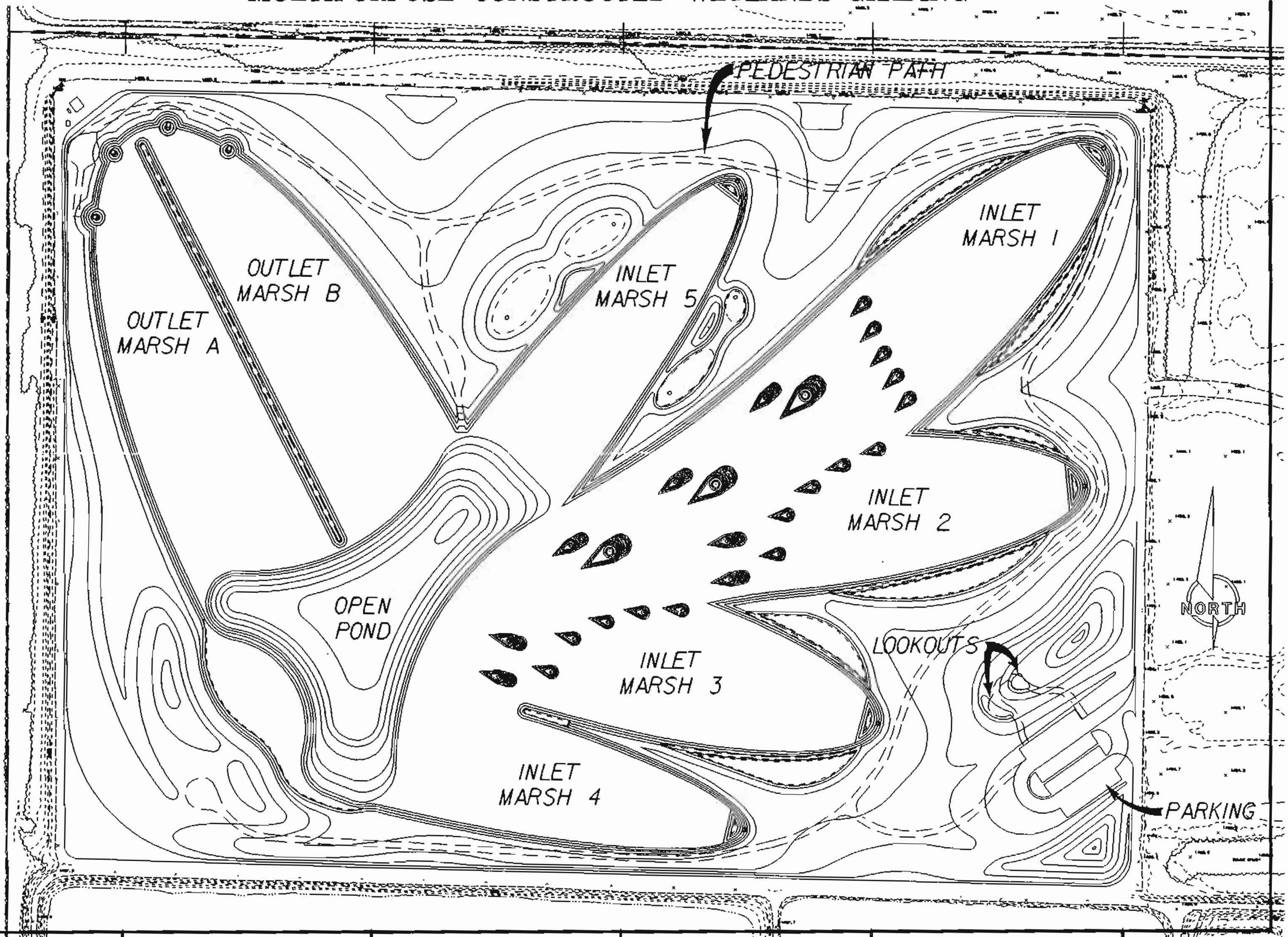


FIGURE 3-1

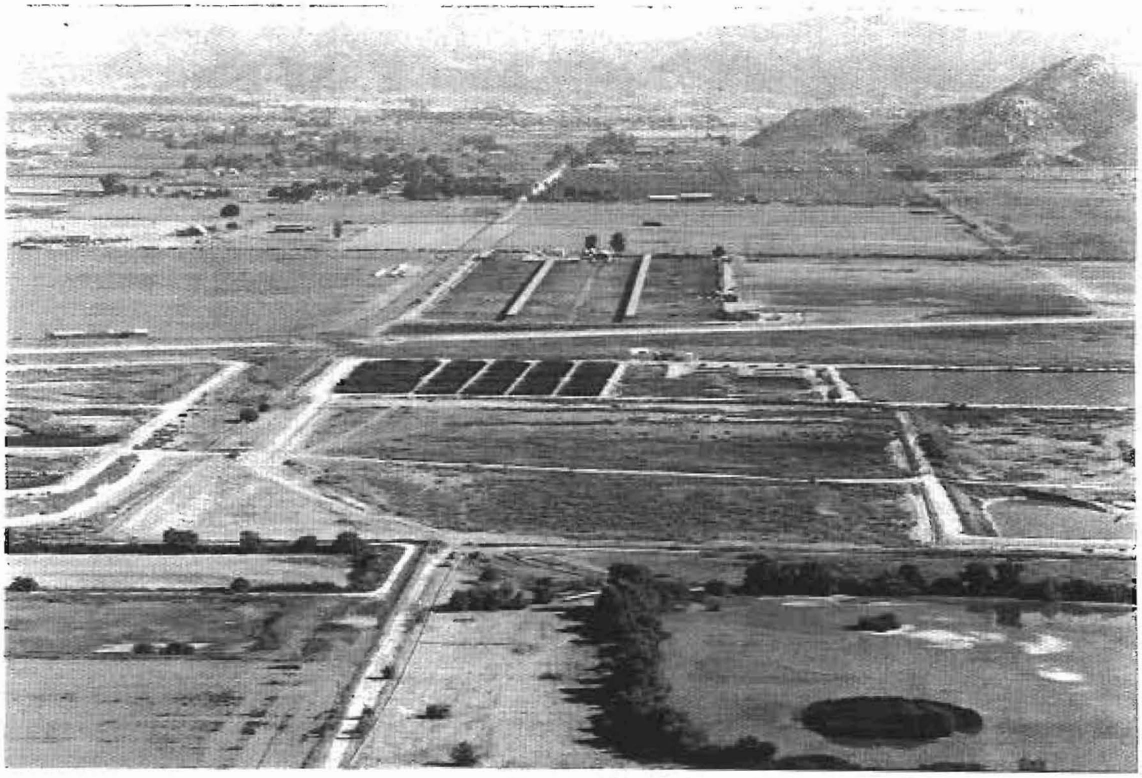
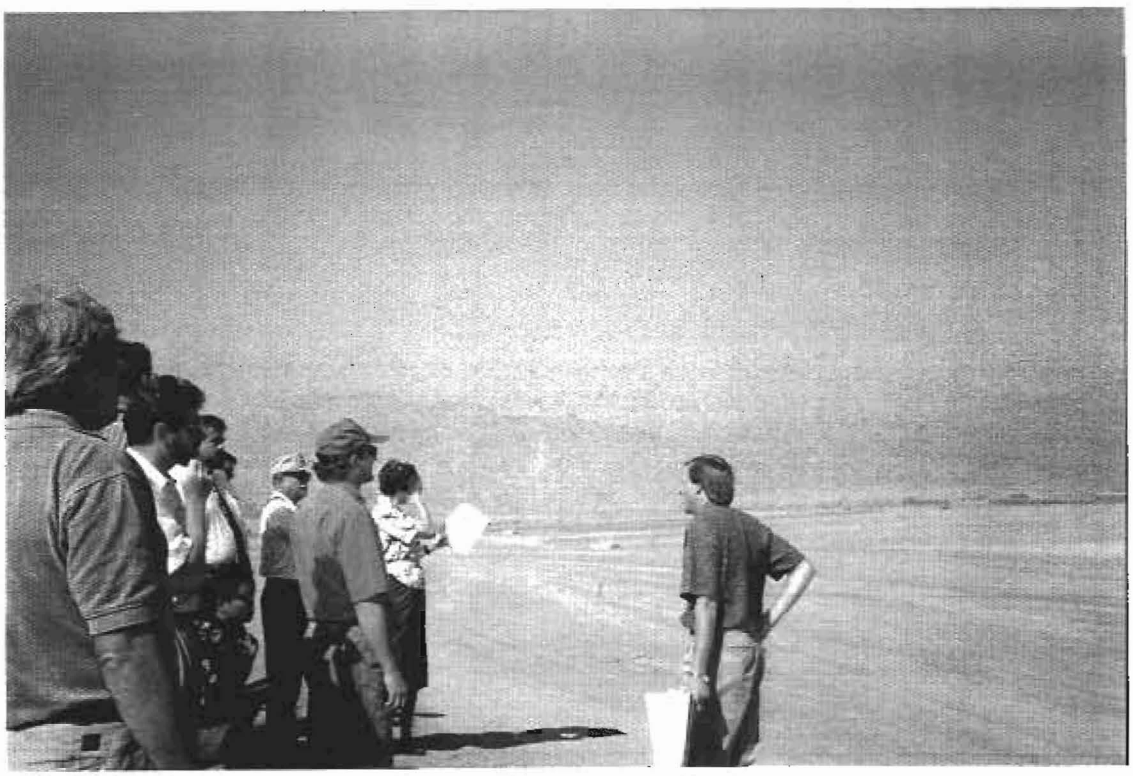


PHOTO 10. AERIAL VIEW OF HEMET/SAN JACINTO REGIONAL WATER RECLAMATION FACILITY WETLANDS RESEARCH FACILITY

PHOTO 11. CONSTRUCTION OF DEMONSTRATION WETLANDS



PHOTOS 12 AND 13. TECHNICAL ADVISORY COMMITTEE AND EXECUTIVE COMMITTEE VISIT DEMONSTRATION WETLANDS SITE

Operational parameters and design constraints described in the Design Concepts and Criteria Report are not restated here. Significant results, changes in the wetlands design elements, and events that transpired throughout the course of the wetlands design development stages are summarized as follows:

Wetlands Configuration and Site Grading

Prior to the development of the Design Concepts and Criteria Report, a decision was made to locate the wetlands demonstration site within a specific 19-ha (47-ac) portion of the Hemet/San Jacinto RWRF site. This decision created some constraints unique to this site and not necessarily typical of future wetland sites. The earthen foundation of the site provided in situ seepage control at no additional cost, whereas other wetland sites may require the addition of a liner system, such as geomembranes, to provide seepage control. This site consisted of two abandoned, rectangular, water storage ponds, bounded on all sides by low earthen berms. The earthen site had been excavated, backfilled, and reworked many times prior to the construction of this project. Therefore, a major portion of the cost of the construction earthwork was due to the need to level, import fill, and compact the site. The size and shape of this site required a reconfiguration of the original overall wetlands system design to fit within the designated area. The final design consultants noted that the reconfiguration had resulted in changes to the size of the wetland compartments comprising the three-phase large compartment process design. This effect on fundamental process functions was considered to be within the defined range of operational control for the system.

Wetlands Base Elevation. The design elevation for the bottom of the wetlands system was a key issue since the site area was to be leveled and compacted to restore flat grades, within ± 0.03 m (± 0.1 ft), across the bottom of the wetland marsh areas. This was considered essential to promote even distribution of water flow throughout the wetlands and, thereby, enhance the effective area and volume relationships that influence the water quality transformation processes. All of the surface grades at the site, from the pond invert to the uplands contours, were tied to the base elevation of the inlet and outlet marshes invert. Thus, revisions in the base elevation caused changes in the amount of earthwork required at the site or affected the net balance between the amount of earth being imported or removed from the site. In the initial final design workshop, a final base elevation of 453.5 m (1488.0 ft) was established. It was concluded that a net import of material, from some concurrent excavation work at some of EMWD's holding ponds a short distance southeast of the site, would optimize the amount of earthwork being done in total by EMWD.

Slope Grades and Drainage. To minimize erosion of the fine soils, site slopes were held to 4 horizontal to 1 vertical (4:1) or flatter slopes. For the most part, the final site grading plans were able to accommodate this objective except in local areas where moderately steeper slopes were required to allow for access and drainage around the northeastern and western corners of the site area.

A deeper pool was added to the grading plan in the vicinity of each inlet and outlet control structure to reduce problems with plant encroachment and to allow some access space around the structures. Each control box will have an excavated zone of 1.2 m (4 ft) deep, 0.76 m (2.5 ft) below the base elevation, for a distance of 7.62 m (25 ft) from each of the inlet or outlet control structures.

Design of Marsh Areas. The overall dimensions and shape of the inlet marsh areas were retained from the conceptual design. Of the five inlet marsh compartments, the three connected inlet marsh units have 2:1 length to width aspect ratios, and the other two inlet marshes each have 3:1 aspect ratios. The designated site required that the length of the outlet marsh be shorter than the original design. The outlet marsh was split along the centerline by incorporating a dividing berm. This was done to maintain a minimum aspect ratio of 2:1 within each half of the 2.43-ha (6-ac) total area. The shape of the connecting marsh area was adjusted slightly; however, the overall size and configuration were not greatly affected.

Open Pond Design. The shape of the open pond was revised and the size increased to accommodate the site configuration. This change did not appear to compromise the functional attributes intended for the pond. The capability of draining the open pond by an installed drain and sump pipe was eliminated due to the relatively high cost and low probability of need. If the pond did need to be drained, portable pumps could handle the task.

Special Emergent Test Area. This feature was moved to the shallow bench area on the southwest bank of the open pond from its original location at the outlet end of the connecting marsh. The raised test plot posed some construction problems and concerns regarding the potential effects on water flow within the wetlands system. As a result, the new position and implementation of this feature allowed for a simpler grading plan. The planting plans were also modified accordingly. This area is currently identified on the construction plans as a "shallow bench" or "shallow emergent test area".

Island Location and Details. Spatial relationships and orientation of all islands were delineated, and coordinates were determined for construction. The height, shape, and earthwork tolerances for the islands were also reviewed and details adjusted to clarify the construction plans.

Moist Soil Test Areas. The water supply systems for the moist soil test areas were revised to better handle the proposed seasonal hydrograph for the wetlands. Some refinements were made to the dividing berms due to freeboard and earthwork geometry considerations. The berm heights were modified by dropping the heights to

76.2 centimeters (cm) (30 inches (in)) above the base elevation, which would then provide 30.5 cm (12 in) of freeboard at the design water surface, 15.2 cm (6 in) of freeboard above the design high water (winter) condition, and 7.6 cm (3 in) of freeboard above the peak operational inundation level. The type 2 moist soil test areas adjacent to inlet marsh 5 have low saddle zones between the inlet marsh and the moist soil test area. This feature allows for a different way of flooding the moist soil test area during high water times.

Permanent Location Markers. Permanent site markers will be installed to serve as reference points for use in research studies, O&M work, and to allow for visual orientation once the wetlands are fully established. A location plan was prepared to indicate the installation of markers at 30.48-m (100-ft) intervals as projected and offset perpendicularly from the centerline of each marsh area and around the remaining perimeter of the wetlands system. The exact type of marker remains to be determined. The permanent marker should be constructed out of a durable material; however, light duty or temporary markers may be used initially to lay out the planting work or for specific research studies. The permanent markers will be installed by a survey contractor upon completion of the main site construction contract.

Tie Down Posts. This refers to posts that will be installed at 15.24-m (50-ft) intervals around the margins of the open pond or marsh/pond interface. The intent of these posts is to provide a mechanism for anchoring floating features and to form a point of reference similar to the permanent markers installed around the wetlands perimeter. Since these structures need to be installed before the wetlands area is flooded, they were included in the site construction plans. The final design consists of 10.2- by 10.2-cm (4- by 4-in) wooden posts, 2.4 m (8 ft) in length, to be set upright, with 0.91 m (3 ft) buried below the base elevation.

Monitoring Wells. No ground-water monitoring wells will be installed as part of the initial site construction and development. This decision was based on the previous use of the site for storage of reclaimed water, as permitted by the State of California. This issue is also discussed in the task summary for the preliminary geohydrology investigations.

Related Site Work and Features

Several site features related to public use amenities and wildlife habitat that were indicated in the original concept design were excepted from the main site construction contract. This was done because their construction is substantially different from the type of work being done in the construction contract and the deletion of these relatively minor features would not interfere with completion of the major construction work. Only the items that had to be installed along with the construction or prior to flooding were included in the construction plans. Construction of these features will be done later by others.

Most of these features are optional, although they will enhance and contribute to the multipurpose attributes of the site. Installation of some features will be fairly simple and could present an opportunity for public and educational participation. Typical features are briefly described as follows:

Public Amenities. These could include pathways, trails, interpretive signs, displays, shade structures, viewing platforms, or other features that would enhance the public recreation, safety, and educational values of the site.

Site Facilities. A parking area, overlook, and grading to allow for access paths are already in the construction plans. Additional facilities could be installed, particularly for use in research, operational monitoring, and maintenance (for example, a portable building for equipment storage or work area). Other items might include electrical and phone lines, more lighting, or restrooms. All of these items may be installed by EMWD according to future needs and funding availability.

Wildlife Features. An initial set of wildlife features was suggested for installation at the completion of wetlands construction and planting. Only the base set of features needed to establish suitable wildlife habitat were included in the final design. As the wetlands become established, it is likely that additional features could be identified and added in support of the wildlife response to actual site characteristics.
A description of wildlife features under consideration for the site upland and wetland is summarized below.

Suggested Wildlife Amenities. The following wetland amenities are recommended for consideration, subject to availability of funding.

1. *Floating Platforms (Islands).* Thirty-five small, floating platforms, linked to form an elongated island, to be anchored in the northern portion of the open water pond.

2. *Bat Boxes.* Four bat boxes are to be placed on poles at appropriate locations. Boxes are to be mounted 3.6 to 4.6 m (12 to 15 ft) above the ground and below a horizontally-placed shading platform (sized to ensure shading occurs and topped with gravel so that it can also serve as a Lesser Nighthawk/Common Poorwill/White-throated Swift Roosting and/or nesting platform).

3. *Cliff Swallow Boxes.* Three swallow shelters are to be placed on poles at appropriate locations. Shelters are open "boxes" intended to provide protection for nests and birds from sun, wind, and precipitation. At least one artificial Cliff Swallow nest should be attached to the back of each shelter near the junction of the back and top.

4. *Shorebird Beaches.* Two areas, about 3- by 10-m (9.8- by 32.8-ft) each, are to be located at the edge of the open water pond covered with sand and/or gravel to a depth of 10 to 15.2 cm (4 to 6 in) (i.e., adequate depth to ensure it will remain a "beach" and not revert to "rocky soil"). The purpose is to attract shorebirds and provide a source of grit for waterfowl.

5. *Viewing Blinds.* Three blinds are to be constructed, two southwest of and overlooking open water pond and one at the research boat access point on the north end of the open water pond.

Suggested Upland Features. The following features are suggested for review and consideration as possible amenities to include in the site at a later date.

1. *Aesthetic Features.* Visually and spatially appropriate arrangements of trees, shrubs, and herbaceous plants that provide seasonal interest and some level of solitude for the observer, linking him/her to nature; paths for viewing plant arrangements; benches for contemplating arrangements. Other features that might be included are ordinary or man-made objects, e.g., sculpture, placed to enhance their aesthetic value.

2. *Wildlife Habitat Features.* Vegetation of various kinds and amounts planted in spatial patterns to directly or indirectly furnish food and/or shelter cover and concealment cover for waterfowl, shorebirds, songbirds, small mammals, reptiles, and amphibians; habitat structural features, such as rock piles, standing and down large woody litter (tree trunks), and running water.

3. *Educational Features.* Trails and viewing stands and/or blinds providing opportunities to view wildlife, the wetlands' structure, or specific kinds of wildlife habitat; signs depicting species-specific natural history and general ecological information (or numbers coordinated with pamphlet).

4. *Recreational Features.* Paths for wildlife viewing; viewing stands and/or blinds.

Water Supply Systems and Hydraulic Controls

The Design Concepts and Criteria Report indicated that the main water supply system to the site should be capable of delivering 11,355 m^3/d (3 Mgal/d) total flow, based on having at least two times the design flow, plus an excess to allow for raising the system water surface rapidly. The criteria for the five separate inlet controls was to allow up to 3785 m^3/d (1 Mgal/d) flow to each, thereby ensuring the inlets did not restrict the capacity of the total system and placing maximum flow well within the range of the inlet measurement capabilities. The ability to provide a constant, steady flow and the ability to measure flows were also specified as design criteria.

While preliminary design established the operational constraints for the wetlands system, specific design details were not developed. As a result, final design included a complete design of the water supply systems, hydraulic controls, and design of water connections to and from the wetlands site. The major components of these systems and conclusions of the final design process can be broken into the following topics.

Chlorination of the Water Supply. The plant is now chlorinating year-round. EMWD is considering whether or not to dechlorinate, or whether to use unchlorinated water.

Main Water Supply System. The water supply to the wetlands system is limited by the capacity of existing pipes, pumps, and treatment facilities. Currently, this is estimated to be about 11,355 m^3/d (3 Mgal/d) to the Buena Vida pipeline, which will supply the wetlands. To help maintain steady flows, the pipe system to the inlet controls was designed for low pressures by using fairly large-diameter piping. The result of this is that the entire water supply manifold and inlet controls can handle a total flow rate of 18,925 m^3/d (5 Mgal/d). Although this is in excess of the operating design criteria, it required only a minor increase in pipe size, and this excess flow capacity could be beneficial in the future.

Inlet Controls. Each of the five inlet controls consists of a concrete box that is fitted with an adjustable sliding weir gate for fine control. The boxes are connected to the water supply manifold with piping sized to reduce the water pressure of from approximately 207 kiloPascals (kPa) (30 pounds per square in (lb/in^2)) at the manifold down to 34.5 kPa (5 lb/in^2) at the entrance to each inlet box. Coarse flow control is provided by a butterfly valve upstream of each box. Slots are formed into the sides of the boxes to allow stop logs to be installed as baffles to reduce inflow turbulence, as required. The adjustable weir has a 60 degree V-notch to allow for calibration of flow rates.

Each box is sized to accommodate 3785 m^3/d (1 Mgal/d) maximum flow. This is done so that the maximum flow rate of 2271 m^3/d (0.6 Mgal/d) lies within the range of control and measurement devices.

Outlet Controls. Final design of outlet controls consists of four concrete box structures similar to the inlet controls. These boxes are also fitted with an adjustable weir to provide depth control, flow measurement, and allow changes in depth to be done more easily than by fixed controls such as stop logs. Each box will accommodate installation of a "skimmer" board across the front to reduce floating debris from entering the outflow systems.

Outlet boxes are sized to handle the design flow range of up to 18,925 m^3/d (5 Mgal/d) based on the 11,355 m^3/d (3 Mgal/d) operating flows and an allowance to evacuate storm flows or to increase the outflow rate to lower the wetlands water surface.

Outflow Pump Station. A concrete wet well structure will collect flows from the four individual outlet boxes. The installed pumping capacity will accommodate up to 11,355 m^3/d (3 Mgal/d). This is sufficient for an operating flow of 7570 m^3/d (2 Mgal/d), plus an excess capacity to drain the system down, or to handle moderate storm flows. The well box is designed to accommodate a total outflow of 11,355 m^3/d (5 Mgal/d), although extending the pump capacity to 11,355 m^3/d (5 Mgal/d) would require additional pumps to be installed either on a temporary or permanent basis. If it becomes desirable to extend the pumping capacity to 11,355 m^3/d (5 Mgal/d) permanently, the wet well has two empty bays designed into the structure to allow pumps to be added to the pump station systems. The main outflow pipe will have a continuous flow counter installed for use in recording the total outflow removed from the system.

At the normal operating flow of 3785 m^3/d (1 Mgal/d), the three pumps installed with initial construction will operate in a cycle pattern to distribute wear. This design also allows for complete shutdown of a single pump for periodic maintenance or repairs without altering the outflow pump rate. Space is available in the concrete well box to install additional pumps for either temporary or permanent operations. Each pump will have screens installed to reduce overheating problems caused by debris. The control system is designed to shut down the pumps and turn on a warning light when pump pressures exceed a certain limit.

Flow Measurement. Facilities to be constructed will allow inflow and outflow rates to be recorded by visual readings of the V-Notch weir scales on each box. The inflow system is designed to allow flow adjustment at each inlet such that, once set, the inflow does not vary with upstream pressure fluctuations in main water supply pipe. Continuous flow monitoring or the ability to send signals by radiotelemetry were both discussed but not included in the design plans due to the expense. These systems could be installed at a later date, as appropriate.

Wetlands Planting

Planting of wetland vegetation in the marsh and pond areas will be accomplished under separate contract from the site construction work. Draft specifications for the planting work were prepared for incorporation into contract documents to be administered by EMWD. This contract is scheduled to be awarded after the site construction is complete in the summer of 1994.

A related topic addressed in the final design was the need for features to allow access into the dense marsh areas of the wetlands. Structural methods such as hardened pathways or over-excavated zones were considered. The decision was made to accomplish this by leaving unplanted areas at regular intervals, transverse to flow, in the main marsh areas. The intent is to allow access for monitoring and possibly to improve the function of the wetlands system by inhibiting extensive short circuit flow routes.

These open zones and other features of the planting plan are shown in Figure 3-2. Further discussion of plant propagation and transplanting studies is provided in Chapter 4.

Landscape Vegetation and Irrigation

Planting of upland areas and any corresponding irrigation systems was separated from the main site construction contract. This, again, was considered as a type of work that is distinctly different from the construction and can be installed at any time after the wetlands system is established. Draft landscape planting plans and specifications were prepared by USBR for use by EMWD. Perhaps the most important component identified in the upland landscaping plan concerns getting some type of vegetation cover over the surrounding site areas to reduce erosion of site soils. Similar concerns have surfaced with respect to the riparian areas along the margins of the wetlands system. Experience gained at the pilot facility has indicated noxious weeds can become a significant problem due to the abundant water in these areas. A recommendation was made to seed with native grasses and other drought-tolerant species soon after the wetlands work is completed.

A related issue concerns irrigation of the upland areas. Even though the upland vegetation plans have been directed primarily toward drought-tolerant species as appropriate to the region, some temporary irrigation may be required to establish the vegetation from seed. Without temporary irrigation systems, invasive weeds are likely to grow and could exceed desired varieties or retard the rate of establishing desirable vegetation at the site. Permanent irrigation was considered as a possibility to serve about 0.4 to 0.8 ha (1 to 2 ac) near the public viewing area. In all areas, the need for and design of irrigation systems was deferred until plans for installing the landscaping can be confirmed.

Cost Estimates

The final contract award amount was $942,000 for construction of the demonstration wetland facilities. The construction bids probably came in lower than the estimate due to local economic conditions at the time of construction.

As expected, the construction cost estimates indicated that earthwork is the predominant cost for wetlands development at this site. This conclusion has important implications regarding selection of future sites for constructed wetland systems. Based on the final design, it is evident that the components that control costs for

HEMET /SAN JACINTO REGIONAL WATER RECLAMATION FACILITY
MULTIPURPOSE CONSTRUCTED WETLANDS PLANTING

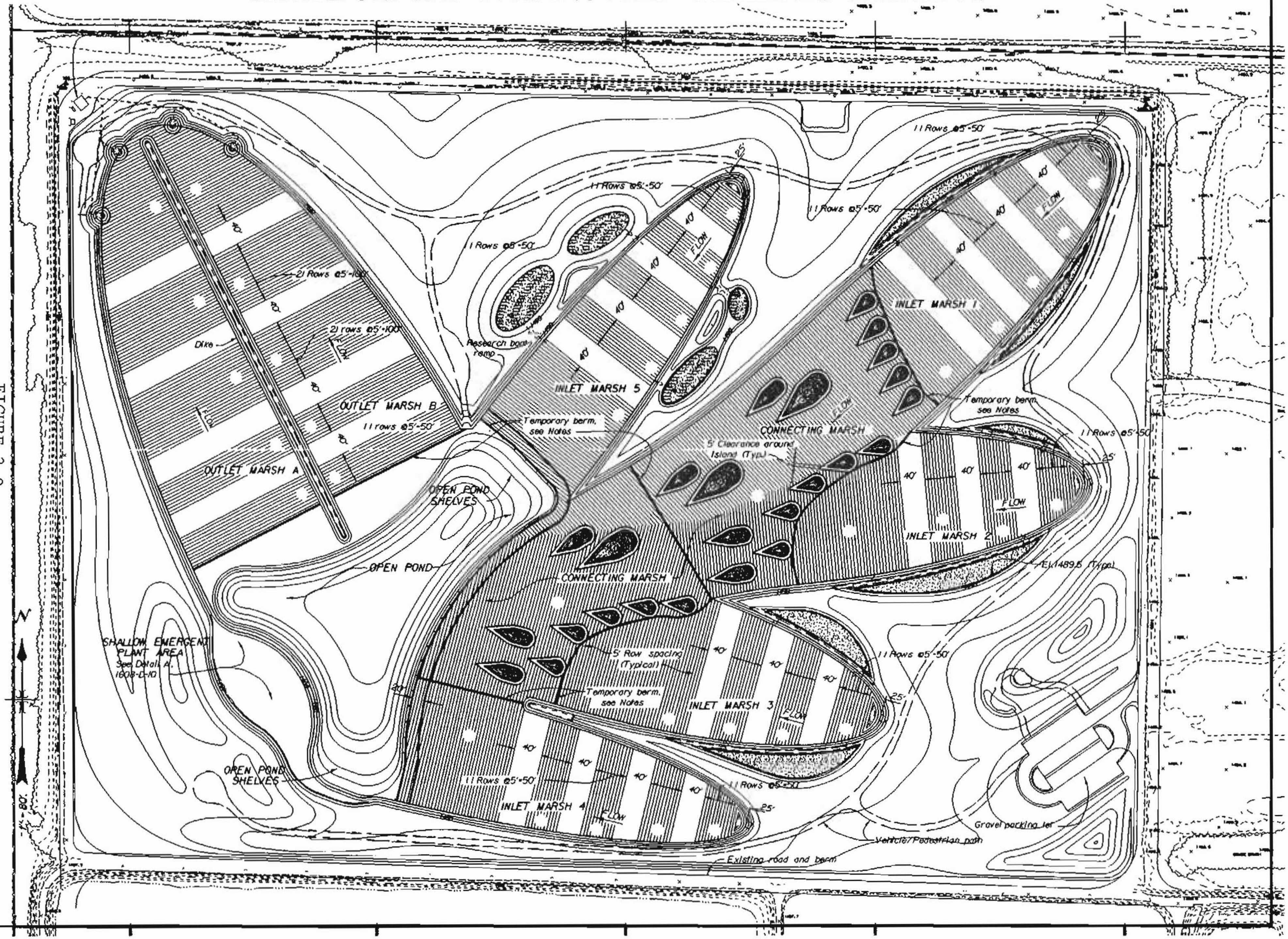


FIGURE 3-2

wetlands construction are the earthwork requirements, permeability of site soils as they could affect the need for impervious liners, land acquisition costs, and the extent of water supply pumping and conveyance systems required.

The total costs associated with final design, construction, planting, and landscaping for the Hemet/San Jacinto demonstration wetlands are as follows:

Final Design

Engineering Consulting Services:	$75,000
Geotechnical Investigation and Report:	8,000
EMWD Planning and Engineering Costs:	13,000
USBR Planning and Engineering Costs:	30,000

Construction Costs
Excavation, earthwork, grading, pump station, inlet and outlet structures, and yard piping: $942,000.

Wetlands Vegetation Planting
Planting of bulrush, moist soil test areas, shallow emergent test area, pond shelves, seed islands, and revegetation of nursery cells: $98,000.

Landscape Planting and Site Amenities (Estimated Costs)
Seeding of upland areas, trees and shrubs, shade shelter and bench in visitor overlook area, riparian trees and willows in riparian area, duck blind, irrigation and initial maintenance: $109,000.

CHAPTER 4
ONGOING RESEARCH INVESTIGATIONS

CHAPTER 4

ONGOING RESEARCH INVESTIGATIONS

PART 1: METHODS

Prior to construction of the large-scale multipurpose constructed wetlands, the EMWD/USBR Wetlands Research Facility was developed. The research facility is used for ongoing wetlands research, focusing on the ability of a wetlands system to polish and remove nutrients from secondary-treated wastewater. Evaluation of marsh habitat for wildlife diversity (migratory and resident waterfowl and shorebirds) as well as educational opportunities and other public benefits are also being studied. Located at the northwest corner of EMWD's Hemet/San Jacinto RWRF, this 3.16-ha (7.8-ac) facility was begun in 1991. It consists of the following (Figure 4-1):

1. Two 0.2-ha (0.5-ac) nursery cells for wetland plant propagation;
2. Eight research cells (approximately 13.7- by 69.2-m (45- by 227-ft)); and
3. An RO desalination unit, two saline marshes, and two evaporation cells.

Nursery Cells

Design and Construction. Two nursery, or plant propagation, cells were constructed to propagate bulrush for later transplant to research and demonstration projects and to determine the most efficient planting techniques. Design of the nursery cells was performed by EMWD, USBR, and NBS personnel. They were constructed in an old, effluent storage pond by constructing separating berms. The berms were graded by taking soil from the west end of the site and placing it along the berm alignments. A pressurized supply system to transport secondary reclaimed water from the Hemet/San Jacinto RWRF was constructed, and a gravity collection pipeline was installed. The water enters each cell by way of three inlets, flows through the cells, exits through three outlets in each cell, and flows to a sump. The sump is pumped into a reclaimed water distribution system for downstream use. The flow rate through each of the cells is approximately 37 to 57 L/min (10 to 15 gal/min).

Planting. The two nursery cells were planted from July 1 through 10, 1991, with California bulrush and hardstem bulrush. These species were selected because they are native to the area; they thrive in water up to 91 cm (3 ft) deep; they provide an excellent substrate for wastewater treatment; they provide excellent wildlife food and habitat; and their growth habit enables mosquito larvae-eating fish access through the marsh. Additional species planted in or around the nursery included a rush,

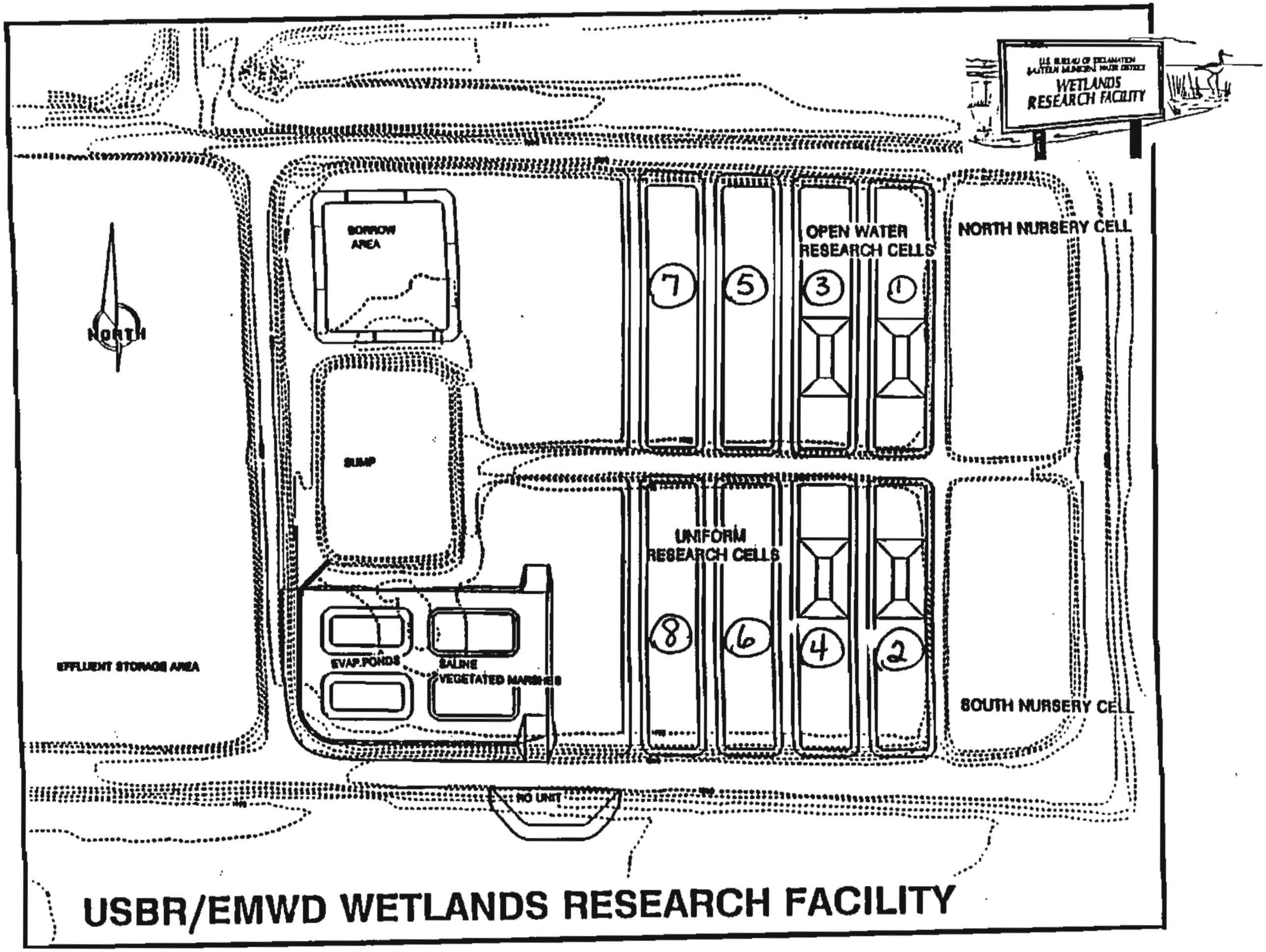

WETLANDS RESEARCH FACILITY
NORTH
BORROW AREA
SUMP
OPEN WATER RESEARCH CELLS
NORTH NURSERY CELL
7
5
3
1
UNIFORM RESEARCH CELLS
8
6
4
2
EVAP.PONDS
SALINE VEGETATED MARSHES
EFFLUENT STORAGE AREA
SOUTH NURSERY CELL
RO UNIT
USBR/EMWD WETLANDS RESEARCH FACILITY

FIGURE 4-1

duckweed, marsh pennywort, and seepwillow. These plants were introduced because such species may be utilized later in the demonstration wetlands, and their survivability as transplants was unclear. The bulrush plant material came from five donor marshes: the San Jacinto Wildlife Refuge (SJWR) where the San Jacinto River crosses Davis Road (hardstem bulrush); Sanderson Road (SR) north of Ramona Expressway (hardstem bulrush); DeVuyst's cornfield drain (DV) west of Bridge Street (California bulrush); Walker Canyon (WC) along Interstate Highway 15 (hardstem bulrush); and a donor marsh used by Pacific Southwest Biological Services, Inc., in National City (NC), California (California bulrush). The soil substrates of the SJWR and SR donor marshes were very dry during the harvest period while plants were removed from standing water in DeVuyst's drain and Walker Canyon.

Forty-four plots were created in the two nursery cells. The plots represented separate harvesting or planting treatments. Many of the plots were replicates of each other. The holes were dug (unless stated otherwise) to depths of 20 to 30 cm (8 to 12 in) using a gas-powered auger. Ninety-one-cm (3 ft) lath stakes were used to stake the bulrush plant clumps to the soil surface to prevent them from floating away with the rising water. Once a treatment plot was completed, a small soil berm was built around the perimeter and the area flooded with water from the reclaimed water pipeline until the entire cell was completed. The various treatments were:

1. Clumps dug by backhoe planted in holes with tops trimmed to 61 to 91 cm (2 to 3 ft);
2. Hand-dug clumps planted in holes with tops not trimmed;
3. Hand-dug clumps planted in holes with tops trimmed to 91 to 122 cm (3 to 4 ft);
4. Bare root plants from Pacific Southwest Nursery, National City, California, planted in holes with tops trimmed to 61 to 76 cm (2 to 2 1/2 ft);
5. Hand-dug clumps planted in holes (hand-dug) with tops not trimmed and tied up with special care[1] (TLC);
6. Hand-dug clumps staked onto the soil surface with tops not trimmed;
7. Hand-dug clumps staked onto the soil surface with tops trimmed to 92 to 122 cm (3 to 4 ft);
8. Hand-dug clumps placed on a plastic sheet with tops not trimmed;
9. Hand-dug clumps placed on and in between the planks of wooden pallets with tops trimmed to 91 to 122 cm (3 to 4 ft);

[1] The special care consisted of holding up the bulrush culms by hand during transit, carrying each plant to its position in the nursery so that no culms would bend or touch the ground, and tying the culms up to laths once the plant clumps were placed gently in their holes. The culms were left tied up when the planting was completed.

10. Hand-dug clumps placed on chain-link fence with tops trimmed to 91 to 122 cm (3 to 4 ft); and
11. "Junk tubers" (bare rhizomes with no shoot attached) pushed gently into the wet soil.

Most plants from the four local donor marshes were planted on 112-cm (44-in) centers in the various treatments. However, the 1500 bare root units from the nursery in National City, California, were planted only in holes with spacings of 56 by 112 cm (22 by 44 in).

Monitoring. USBR personnel monitored the nursery cells on August 15, 1991 (6 weeks after planting), October 8, 1991 (3 months after planting), and February 26, 1992 (almost 8 months after planting).

Plant Growth and Establishment. Two techniques were used for monitoring the bulrush growth and establishment in the nursery cells. The first technique focused on 19 plant clumps which were subjectively selected immediately following the planting. For easy access, all are located close to the perimeter of the marsh. Weekly, for the next 9 weeks, the total number of new shoots (the culms, or above-ground stems, put out by the plant since being transplanted into the nursery cells) from each of the 19 selected plants were counted and recorded. A final count was made approximately 3 1/2 months (on October 24, 1991) after planting; the bulrush culm density was so great after that time that accurate individual plant culm counts were no longer practical. New culms arising from the horizontally-growing rhizomes emerged between the original plant clumps, and it was impossible to tell which culm came from which plant by visual inspection alone.

The second technique used for evaluating the bulrush growth involved monitoring each of the 44 plots in the two nursery cells. The entire area of each plot was carefully surveyed to determine a representative plant clump for that plot (avoiding the largest and smallest clumps in the plot). That representative clump could change between sample dates. The new shoots were counted and recorded. Likewise, the largest plant clump in the plot was determined, and its new shoots were counted and recorded. The average height for the plants in each plot and the maximum height for the plants in each plot were estimated by inspection and recorded to the nearest 0.15 m (0.5 ft).

Additional indicators of condition, such as phenology (i.e., flowering or seeding), general health of the plants, presence of fungi or insect pests, and presence of other plant species were also noted within each plot. Photographs were taken during each of the monitoring trips to document appearance.

The data from each treatment replicate (similarly planted plots) were averaged to obtain a value for that planting technique. The data were compared, and planting

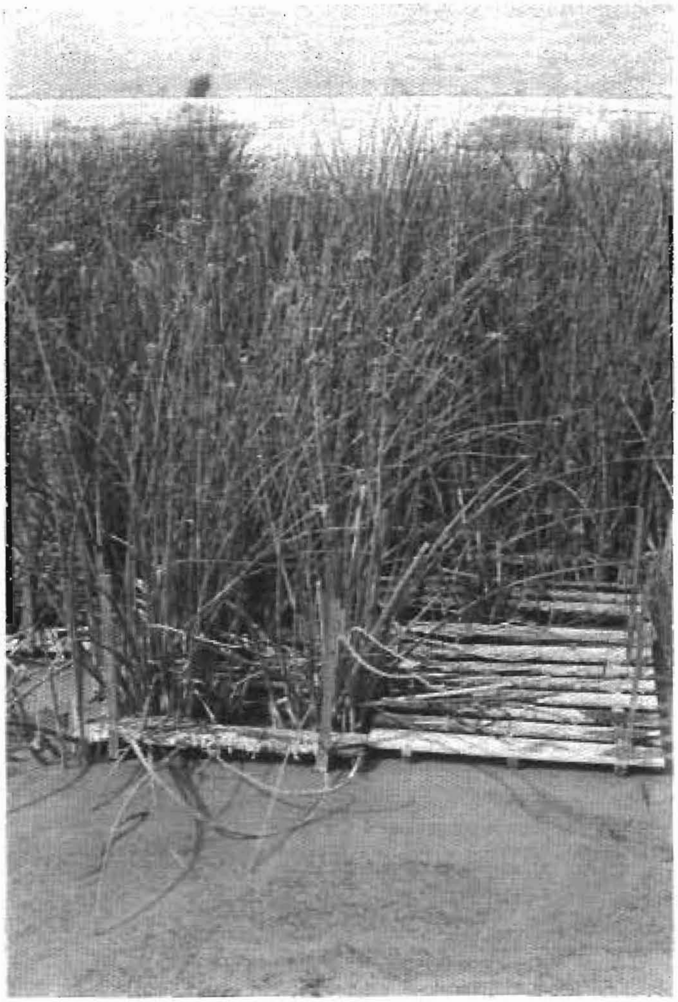


PHOTO 14. NURSERY PLOT; PLANTING ON AND IN WOODEN PALLETS

PHOTO 15. HORIZONTAL RHIZOME GROWTH. NOTE HOW CULMS ARE IN LINES RADIATING OUT FROM ORIGINAL CLUMP

PHOTO 16. MONITORING GROWTH IN NURSERY CELL

techniques were evaluated. Evaluations and planting technique recommendations are reported in the conclusions section below.

Water Quality and Invertebrates. Water quality and benthic invertebrate data were collected by members of the USBR technical team during site visits in August and October 1992 and February 1993. In each case, the water quality monitoring effort consisted of in situ measurements of water temperature, pH, conductivity, dissolved oxygen concentration, and oxidation-reduction potential at nine points within each cell and collection of inflow and outflow water samples for laboratory analyses. The inflow water samples were collected from the inlets of each cell, and the outflow sample was collected from the combined outflow of the two cells. Major analyses performed on each sample included determinations of ammonia and nitrate nitrogen, orthophosphate phosphorus, total dissolved solids (TDS), and total suspended solids concentrations.

Sediment samples for identification and counting of benthic macroinvertebrates were collected with a 5-cm (2-in) coring tube and screened through a No. 30-mesh littoral bucket. Composite samples, consisting of five individual core samples each, were collected on three transects perpendicular to the flow in each of the two cells.

Mosquito Larvae. Mosquito larvae were sampled at four points on each of three transects in each nursery cell. The three transects were located perpendicular to the direction of flow at points approximately 9 m (30 ft) downstream of the inlets, across the middle of the cell, and approximately 9 m (30 ft) upstream of the outlets.

At each sampling point, the mosquito larvae sampling cup was dipped smoothly and quickly into previously undisturbed water to remove a sampler-full (400 ml) (24 cubic inches (in^3)) of the surface water. The number of mosquito larvae in the cup was counted and recorded, then the cup contents were discarded. The floating vegetation types or other relevant observations at each sampling site were also recorded.

Research Cells

Design and Construction. In the fall of 1992, eight research pilot cells were constructed and planted with California bulrush transplanted from the nursery cells. The research cells were designed by EMWD, USBR, and NBS staff, plans were compiled by EMWD, and earthwork grading was performed by an EMWD contractor. The pressurized supply and gravity collection systems, including concrete inlet and outlet boxes, were installed by EMWD. The cells are of two types: four cells with inlet and outlet emergent marshes separated by an open area, 1.2 m (4 ft) deeper than the surrounding marshes (three-phase cells), and four cells which are uniform emergent marshes with no open pools (one-phase cells). These cells were designed to be experimental mesocosms in which researchers can perform various wetland loading and treatment process studies with a high degree of control over external variables.

Planting. The eight research cells were planted from September 2 to 9, 1992. California bulrush plants with 30.5-cm (12-in) diameter root clumps were dug out of the southwest corner of the north nursery cell with shovels. The clumps were carried up the berm, their culms (the above-ground stems) cut to about 91.4 cm (3 ft), then carried to the appropriate research cell. Once the clumps were put in place on 121.9-cm (4-ft) centers in the cells, they were staked in place with 91.4-cm (3-ft) wooden laths. The cells were flooded at different times. The deep water pools were pre-flooded; staked plants were sprayed by an EMWD water truck to keep them moist prior to flooding.

Monitoring.

Plant Growth. Plant growth monitoring was initiated 6 weeks after planting. Bulrush growth, vigor, and establishment were evaluated on October 20 and 21, 1992; April 28 and 29, 1993; July 27 and 28, 1993; and November 2, 1993. The quarterly sampling planned for the end of January 1993 was missed due to torrential winter rains and unseasonably cooler temperatures in the area. Plant growth during that time was minimal.

Plant growth monitoring consisted of recording several parameters during the October 1992 and April 1993 sample. The new shoots (culms put out by the plant since being transplanted into the research cells) of 10 sample plant clumps distributed throughout each cell were counted and recorded. The maximum culm height and the mean culm height were measured and recorded for each sample plant. Means are presented in the results section as the mean plus or minus the standard deviation. The general health of the plants in each cell was recorded as well as the range in the culms' width (measured as the length of one side of the triangular culms). Survival percentage was also noted throughout the evaluation periods.

At the time of the July 1993 samples, the bulrush culm density was so great that accurate individual plant culm counts were no longer possible. New culms arising from the horizontally-growing rhizomes emerged between the original plant clumps, and it was impossible to tell which culm came from which plant. Maximum and mean heights of the plants, culm widths, and the general health of the plant communities in each of the eight cells were measured and recorded. Additionally, many photographs were taken during each of the monitoring trips.

Water Quality and Inflow Rates. Series 1 of the monitoring program was originally intended to last 6 months, from October 1992 until March 1993. However, heavy rains and flooding forced suspension of all monitoring activities from February 11 to May 5, 1993. The Series 1 monitoring was extended as Series 1A for

PHOTO 17. COLLECTION OF HYDROLAB MEASUREMENTS IN OPEN WATER OF RESEARCH CELL

PHOTO 18. COLLECTION OF BENTHIC INVERTEBRATE SUBSTRATES FROM BULRUSH IN RESEARCH CELL

6 months to allow the cells to reach maturity and allow a distinct baseline condition to be established.

In the following, Series 1 refers to the period from October 20, 1992, to May 5, 1993 (weeks 1 to 30), and includes the 15-week period (weeks 16 to 30) when monitoring was suspended. Series 1A refers to the period from May 5 through November 10, 1993 (weeks 30 through 56).

Weekly Monitoring. Paired three-phase and one-phase cells were monitored in weekly rotation throughout Series 1/1A. For example, cell 1 (three-phase) and cell 5 (one-phase) would be monitored for 1 week, followed by cell 2 (three-phase) and cell 6 (one-phase) the next week, then cell 3 (three-phase) and cell 7 (one-phase) for another week, and finally cell 4 (three-phase) and cell 8 (one-phase), after which the weekly paired cell cycle would begin again with cells 1 and 5. This paired cell rotation was developed in response to equipment and funding limitations.

The typical weekly monitoring consisted of three components:

1. Three Hydrolab Corporation DataSonde 3 water quality data loggers were used to make hourly measurements of water temperature, pH, conductivity, dissolved oxygen concentration, and dissolved oxygen saturation in the outlet of each cell and in the inlet of one of the pairs of cells. This arrangement was necessitated by the fact that only three data loggers were available for the Series 1 and 1A program, but it was assumed that, since the inflow to all eight cells came from the same pipeline, the water quality at all eight inlets should be essentially the same.

2. Water samples were collected weekly from one inlet and both outlets for laboratory chemical and biological analyses. The sample collection was usually done about midway through the weekly cycle. The specific analyses performed varied from week to week because the sampling schedule was different for different parameters. For example, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, orthophosphate phosphorus, and turbidity analyses were performed weekly, while total Kjeldahl nitrogen, total phosphorus, biochemical oxygen demand, total suspended solids, total organic carbon, and total and fecal coliform bacteria analyses were performed every third week.

3. Two ultrasonic flowmeters became available during Series 1A, and these were used to record total and average daily flows on the inlets of the paired cells. Cell outflows were not measured during the Series 1/1A monitoring program.

Quarterly Surveys. Quarterly surveys of the research cells were carried out on April 28 and 29, July 27 to 29, and November 3, 1993. The objectives of these surveys were to evaluate vegetation condition and growth, sample the macroinvertebrate communities, and document variations in water quality conditions within and among the research cells. The water quality component of these quarterly surveys consisted of taking Hydrolab measurements of water temperature, pH, conductivity, and dissolved oxygen in the inlet, middle, and outlet of each cell. Chlorophyll-a concentrations were also measured in the inlet and outlet of each cell.

Invertebrates.

Artificial Substrate Design and Installation. Artificial substrates were used to sample benthic macroinvertebrates resident within the research cells. Three groups of nine substrate assemblies (27 per cell total) were placed in each of three-phase ("open water area") cells 1 and 2, and one-phase ("uniform marsh") cells 5 and 6 on February 12, 1993 (total of 108 assemblies). Each assembly consisted of six 5.12-cm (2-in) Tri-pack spheres in a 0.47 L (1-pint) plastic container (with lid) that had eight 3.2-cm (1.25-in) holes punched in its wall, and one 3.2-cm (1.25-in) hole punched through the lid. Approximately 190 cm^3 (11.59 in^3) of soil was placed in the container bottom (below the lowest holes). A plastic electrical tie threaded through the upper wall holes served as a handle for the container; a nylon fishing line "lead line" connected the handle to a 2.5-cm (1-in) plastic bobber. Soil for the containers was obtained from a 0.5-m^2 (1.64-ft^2) area of the berm separating cells 3 and 4; the soil was friable and mixed well before placement into the containers and, once filled, containers were selected from the total pool available in a manner to further ensure that any variations in soil quantity or quality was distributed among the 12 groups. EMWD assisted with assembly, and NBS added all soil to containers and placed all assemblies into cells.

The containers were arranged in three groups of nine containers each, with groups placed to sample the inlet, middle (or open water area), and outlet portions of the planted section of each cell. Assemblies were placed in the cells by hand, using positions of bulrush plants as reference points (i.e., no distances were measured): the approximate center point of the groups were (1) 13 rows from inlet; (2) 30 rows from inlet or center of open water; and (3) five rows from outlet. Each assembly was slowly lowered via the lead line at a position within the cell where it was believed the container would rest on the flat cell bottom. In no case was the assembly, once lowered, visible. Thus, it is possible that some are actually resting in a tipped position due to placement in a depression (e.g., footprint), on a root, or (in the open water) on the cell sideslope. Open water groups were installed from a small (one- to two-person) inflatable boat. Because of the inability to maintain the boat in a stationary position, the assembly placement in the open water is rather spread out but centered to the degree possible on the flat-bottomed portion of the deep water area. Lead lines varied in length, resulting in some bobbers remaining a few cm below the

PHOTO 19. COLLECTION OF MACROINVERTEBRATES IN RESEARCH CELL; SWEEP NET METHOD

PHOTO 20. TRICOLORED BLACKBIRDS USING RESEARCH CELL

water surface and others drifting perhaps as much as 1.5 m (4.92 ft) off the vertical position above the container in the deep water. Within the marsh portions, assemblies were placed in a grid to the degree possible, with 0.5 to 1.0 m (1.64 to 3.28 ft) separating assemblies; the offset rows of bulrush and their variable size made a more regular placement impossible. Bobbers may be up to 15 cm (5.86 in) off the vertical position due to drift and lead line length. Specific locations of all assemblies were mapped.

At the time of installation, the bulrush within cells 1 and 2 appeared similar in stature; plants in either of these cells appeared fuller than those in cell 6, however, and plants in cell 6 appeared fuller than those in cell 5. In all cases, individual transplants and planting rows were easily discernable. Cell 5 was the only one that contained an algal mat on the water surface. No water was flowing into the cells (due to an inability to handle outflow in the flooded sump); all cells appeared to have water levels slightly below the nominal 0.46-m (1.5-ft) depth.

Collection Procedures. The following procedure was used for collecting the artificial substrate samples. The substrate assembly was slowly lifted from the bottom using the nylon line and placed in a soil sieve (250 micron mesh size was desired, but mesh size as large as No. 30 (600 micron openings) was used for July 28, 1993, collections). The six spheres were put into two containers containing 10 percent formalin solution along with any invertebrates noted on the container surface. The container was then inverted and sediment dumped into the sieve. This material was "panned" for invertebrates using the pond water to flush sediment out of the sieve. A squirt bottle filled with RO unit product water was used to concentrate the remaining material and organisms within the sieve, and then a flexible pocket ruler or other "spoon" was used to transfer the matter out of the sieve and into the formalin bottles.

Samples were sorted and invertebrates identified by USBR's Denver Office personnel. Personnel corroborated identifications made by others. Rose bengal stain was used in some cases to aid in differentiating animals and plant debris. Many, but not all, sorted samples have been retained.

Sweep Net Sampling. By November, many substrates were inaccessible because of the combination of effectively complete closure of bulrush transplants to form a uniformly dense stand without access channels and the falling over and "lodging" of bulrush stems due to wind or other factors. Retrieval of the substrates would have required cutting a path through the bulrush, and the associated level of disturbance to the cells was deemed undesirable. In place of the substrate samples, samples were collected using a custom, fine-screen dip net (use of the net was initiated during July sampling). The following procedure was used: a point close to the location of artificial substrates was sampled by dipping the net into the water and, if possible, substrate three times in rapid succession. All invertebrates collected in the net were preserved in the same manner as artificial substrate samples (10 percent Formalin solution). Actual sites sampled varied from 1 to 5 m (3.28 to 16.4 ft) from edge of cell, depending upon degree to which entry into the cell was possible. Sweep net samples were sorted and invertebrates identified in Denver by USBR personnel in the same manner as noted for samples from artificial substrates.

Sediments. Monitoring of bottom sediments has been conducted since initial flood-up in September 1992. The objective of monitoring was to identify substrate influences upon (1) the fate of toxic constituents; (2) nutrient availability; (3) denitrification; and (4) phosphorus removal. The following parameters were monitored in research cells 1 and 2 in an effort to characterize substrate impacts:

• pH	monthly
• redox potential	monthly
• electrical conductivity	monthly
• nitrate nitrogen	monthly
• phosphorus (total and orthophosphate)	monthly
• trace elements	yearly
• particle-size analysis	yearly
• organic carbon	yearly
• calcium carbonate	yearly
• cation exchange capacity	yearly

Four sampling sites were selected (cell 1 - inflow, cell 1 - outflow, cell 2 - inflow, and cell 2 - outflow). Each site sample was a surface composite 0.0- to 7.5-cm (0.0- to 3-in depth) obtained along a transect at six equally spaced points. The transects crossed the cells perpendicular to the flow approximately 3 m (10 ft) from inlet and outlet points. Data for pH, redox potential, and electrical conductivity (EC) were obtained from in situ readings at these points. The remaining parameters were measured through laboratory analysis on collected samples. Composites were placed in ziploc bags, refrigerated, and delivered to the laboratory the same day. At the laboratory, samples were air-dried, thoroughly mixed, and analyzed according to standard Environmental Protection Agency (EPA) methodology.

Reverse Osmosis System, Saline Marshes, and Evaporation Cells

Design and Construction. The RO treatment/saline marsh study is being conducted at the Hemet/San Jacinto RWRF to investigate the potential for using the reject stream of the RO desalting process in vegetated saline marshes to reduce brine volume and provide an additional use of brackish water in arid areas while providing much-needed habitat, greenbelts, and open space. The research site is comprised of a 22.7 L/min (6 gal/min) RO pilot system, designed and built at USBR's Denver Office laboratories, two 12- by 24- by 0.6-m (40- by 80- by 2-ft) deep, lined saline vegetated marshes, and two similarly-sized lined evaporation cells.

PHOTO 21. REVERSE OSMOSIS UNIT AND SALINE MARSHES

PHOTO 22. EXECUTIVE COMMITTEE MEMBERS VISIT REVERSE OSMOSIS UNIT

Installation of the pilot RO system was accomplished during the month of April 1993. The reject line from the RO system was plumbed such that flows of brine could be directed to either or both of the saline marsh cells. Initially, the two saline marshes were operated in parallel. Outflows from each vegetated marsh went into evaporation cell number one and then into evaporation cell number two in series. Due to lack of sufficient brine from the RO unit to meet the demands of the saline marshes during peak evapotranspiration periods, the underground piping and valve system was modified in September 1993 to allow the south pond to receive all of the brine and the north pond to receive RO product water as a control (Figure 4-2). Plumbing modifications were also made to allow the overflow from the north pond to flow into a sump instead of into the evaporation cells.

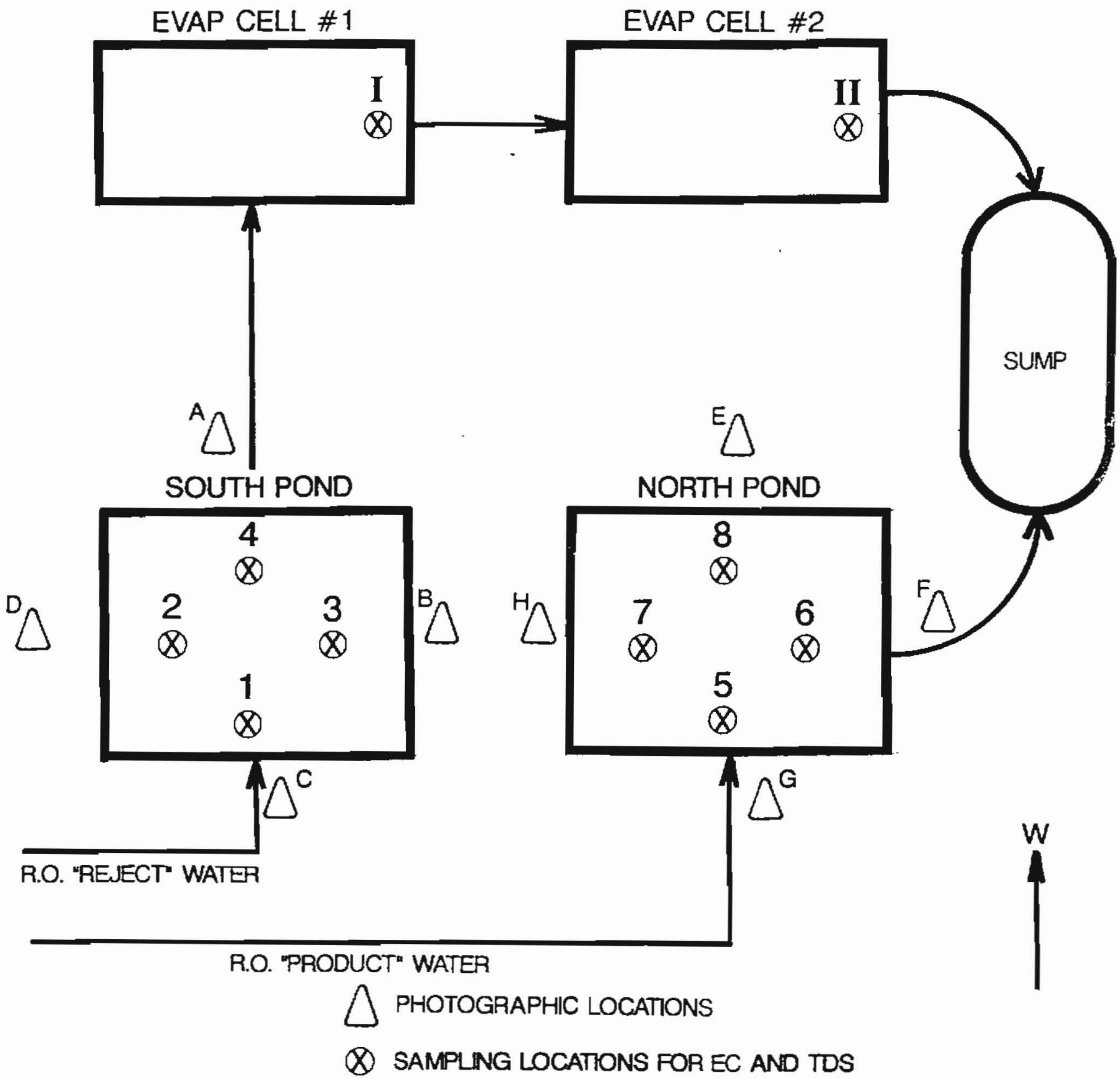
The evaporation cells are nonvegetated. They were designed to be as unattractive to wildlife as possible because of concern that some constituents in the brine could be concentrated to toxic levels. They were constructed with steep sides so that no food, shelter, or nesting areas would be available to wildlife.

To prevent seepage of concentrated brine into ground water, the evaporation cells were lined with a high-density polyethylene liner of relatively high thickness (0.08 m) (0.26 ft). In April 1994, a leak formed in the north evaporation cell and, a short time later, the south cell appeared to be leaking. Both cells were drained. It was determined that the north cell was leaking because a weld along the liner seam had failed. The south cell leaked through the inlet pipe penetration. The manufacturer of the lining was called to repair the leaks. All of the seams on the linings of both cells were resealed to prevent future leaks. This work was performed under warranty by the manufacturer.

About 19 m^3 (5000 gal) of RO feedwater is trucked to the site each weekday from a nearby well (presently from the Moreno Highlands well). This water is first pretreated: (1) to remove suspended materials (i.e., silts and clays); (2) to kill microbial organisms to prevent biofouling of the membranes; and (3) to suppress the scaling tendencies of selected minerals. The unit processes involved in pretreatment include: polymer addition, two-stage pressure filtration, ultraviolet disinfection, acid addition, anti-scalant addition, and cartridge filtration. The RO system then desalts the feedwater using thin-film composite (TFC) membrane elements at an operating pressure of about 1555 kPa (225 lb/in^2). Operating at 75 percent recovery, the RO system yields 17.0 L/min (4.5 gal/min) of product water and 5.7 L/min (1.5 gal/min) of reject brine. A total of about 4.7 m^3 (1250 gal) of brine is produced and stored each weekday to support the saline marshes.

Figure 4-2

FLOW SCHEMATIC OF SALINE VEGETATED PONDS AND EVAPORATION CELLS



Planting of Saline Marshes. Alkali bulrush, creeping spikerush, marsh smartweed, and Pennsylvania smartweed were planted in the two saline marshes. The plants were chosen because they tolerate high brine ion concentrations, 15 cm (6 in) of water depth, are plants which wildlife use, and are native to the area.

The species were planted in horizontal bands, and each species band was repeated three times per marsh to expose the plants to different positions along the salinity gradient expected to develop as brine moved from inlet to outlet within the cell. Seed was broadcast, but plants and rhizomes were planted in offset rows on about 46-cm (18-in) centers. Alkali bulrush and creeping spikerush plants were collected from local donor marshes; Pennsylvania smartweed seeds and marsh smartweed rhizomes were purchased from a Wisconsin wetland plant nursery. Three additional species were suggested for the plant palette but were not available.

Monitoring. The "Saline Marsh Research Program and Proposed Monitoring Program" are contained in Appendix E. The overall objective of the research is to determine the feasibility of using the reject stream of the desalting process in vegetated saline marshes to provide an additional use of brackish water in arid areas through the irrigation of amenities such as greenbelts, open space, and habitat areas. Specific areas of research include plant survival, water and soil analysis, plant and benthic tissue analysis, and wildlife use.

Plant Growth and Survival. Plant growth and survival are monitored weekly by EMWD personnel utilizing general observations and a photographic record (Appendix D). Plant growth, establishment, and health are also evaluated during quarterly trips by USBR personnel. The main objective has been to determine plant survivability based on the color of the vegetation and presence of new shoots. During the late winter, when vegetation had turned completely brown, survival was determined by digging up several rhizomes and cutting them open. If root buds were present on the outside of the rhizomes and the insides were firm and fleshy, with no presence of rot, the plants were determined to be alive. As confirmation, several plants were transplanted into a glass aquarium and kept indoors in water from the saline marsh. Production of new shoots was used as an indicator of plant survival.

In Situ Water Analyses. EC and temperature data were collected weekly at four sampling points in each marsh between July 13 and August 18, 1993, and at one location in each evaporation cell using a hand-held meter. The EC readings are converted to an estimated TDS concentration using an empirically-derived conversion factor. Spot collections were made thereafter. Hydrolab data were collected on July 28 and November 3, 1993, during quarterly sampling tests.

Water Quality Analyses. One RO reject sample was taken on August 13, 1993, and analyzed by Associated Laboratories of Orange, California, for metals using EPA methods. The RO reject sample also served as the "inflow" sample for the saline marsh. There was no outflow from the saline marsh into the first evaporation cell until it began to rain in later November. Overflow into the second evaporation cell from the first did not occur until mid-January.

Water quality samples will be taken at five locations: inflow (RO reject); in front of the outlets of the saline marshes; and in front of the outlets of each evaporation cell.

Plant and Benthic Invertebrate Tissue Analyses. The research program calls for tissues to be analyzed annually to determine the long-term bioaccumulation of toxics. The proposed monitoring program calls for the primary species of plants (stems, tubers, and leaves) to be collected, marked, and analyzed by an outside contract laboratory for toxic accumulation, specifically metals and nonmetal analytes. A minimum of two grams (dry weight) of plants will be needed for analysis. In addition, benthic invertebrates will be sampled by removing some sediment substrate, placing in a pan, and removing 100 individual organisms at random. Sample locations will be immediately in front of the influent and effluent areas of each vegetated marsh.

Soil and Sediment Analyses. The baseline soil sampling was performed on April 28, 1993, just before initial flooding of the marshes. Samples were collected near the inlet, middle, and outlet of each marsh by USBR personnel. The six samples were stored at 4° C (39.2° F) for 9 months before being analyzed by a contract laboratory for metals, ions, particle size, and organochlorine pesticides and polychlorinated biphenyls. The lab was requested to use the lowest possible detection limits.

The proposed monitoring program calls for sediment samples to be collected on June 30 and December 30 of each year. Sample locations will be along two transects in front of the inlet and outlet areas of each vegetated marsh. Several grab samples from each transect will be composited by mixing in a glass bowl.

Wildlife Use. General observations of wildlife use are made by EMWD personnel during weekly visits. Signs of wildlife use, such as tracks and droppings, are noted, and a carcass log is used to record findings of any dead animals in or around the marshes.

PART 2: RESULTS

Nursery Cells

Plant Growth and Establishment. The data from the 19 selected plants, evaluated weekly, illustrate the rate of growth and differences in the average number of new shoots per plant between the donor marshes (Figure 4-3). After 3 1/2 months, the

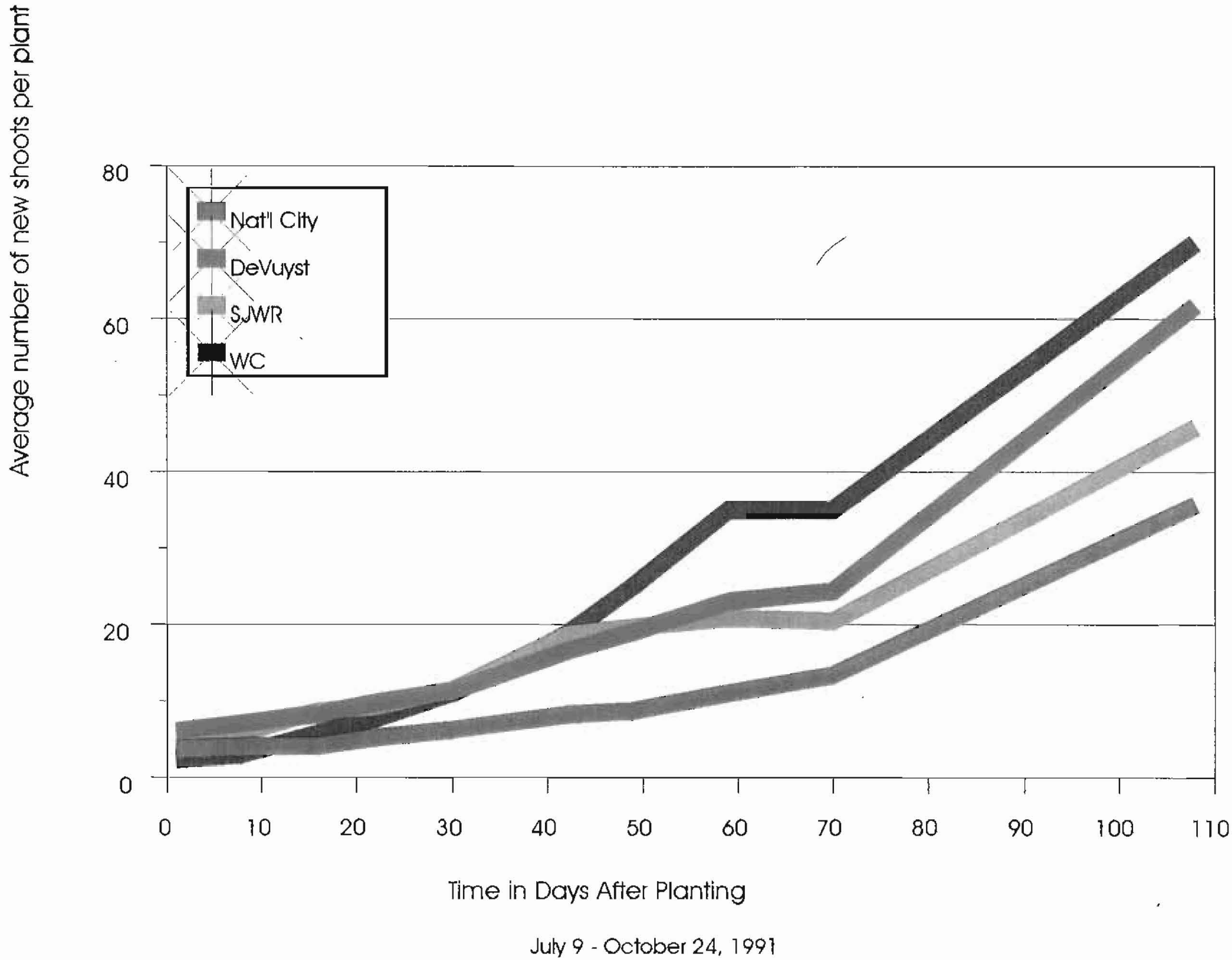


FIGURE 4-3. Scirpus growth data by donor marsh location, technique 1.

PHOTO 23. STAKED CALIFORNIA BULRUSH IN CENTER COMPARED TO NATIONAL CITY'S CALIFORNIA BULRUSH ON EITHER SIDE (3 MONTHS AFTER PLANTING)

average number of new shoots per plant harvested from the Walker Canyon donor marsh was 70; from DeVuyst's cornfield drain, 62; from the SJWR, 46; and from the Pacific Southwest Nursery, 36. Growth increased steadily with time.

The data from the second monitoring technique illustrate similar results; however, the average number of new shoots per plant differs considerably. The average number of new shoots per plant in October was 117 for Walker Canyon plants, 97 for DeVuyst's drain, 63 for SJWR, 22 for Pacific Southwest Nursery, and 83 for Sanderson Road (Figure 4-4).

The likely reason for the difference was that the 19 subjectively-selected plants were not necessarily representative of their donor marsh group. Nevertheless, the growth trends for each of the donor marshes were similar.

Plant source and harvesting technique affected subsequent transplant growth. There were virtually no differences in new growth and establishment between the harvesting of plants by hand or by a skilled backhoe operator. On the other hand, the plants purchased from the nursery in National City grew much slower than any of the other plants (Figures 4-3 through 4-6). There were several reasons for this. The harvested plant culms were cut to 61 to 76 cm (2 to 2 1/2 ft), their roots washed of all soil and microorganisms, then they were put into wet burlap bags and transported for 3 hours in an open truck in temperatures near 38° C (100° F). Their cut culms appeared dry when they arrived. They were obviously stressed. Mortality would have been higher if each bare root unit was planted in an individual hole, but planting one large to several small units (3 to 10 shoots) in each hole maintained the overall survival over 80 percent. By February 1992, when many of the other plants were growing together, open areas still existed between the National City plants (Photo 23).

Planting technique affected how fast the plants put out new shoots. In Figure 4-5, the data are separated by donor marshes but also by whether those plants were planted into holes, staked to the soil surface, given special care, planted on pallets, planted on plastic, or planted as "junk tubers". It was fairly obvious that the plants which produced new culms most rapidly were those that were staked to the soil surface and, thus, not restricted by the hard clay substrate that surrounded the plants in holes. The plants staked on top of the substrate with their roots bathed in nutrient-rich water, so that they were essentially being grown hydroponically, were unconstrained and, therefore, had the ability to expand horizontally.

The plants from the two donor marshes that were moisture-stressed (SJWR and Sanderson Road) produced about twice as many new shoots when staked to the soil surface or set on plastic than when planted in holes. An average of 38 new shoots per plant planted in holes versus 85 staked for SJWR, and 50 versus 100 for Sanderson Road in October 1993 (Figure 4-5). The stressed plants were probably not as robust and, therefore, their new horizontal roots and rhizomes were less able to

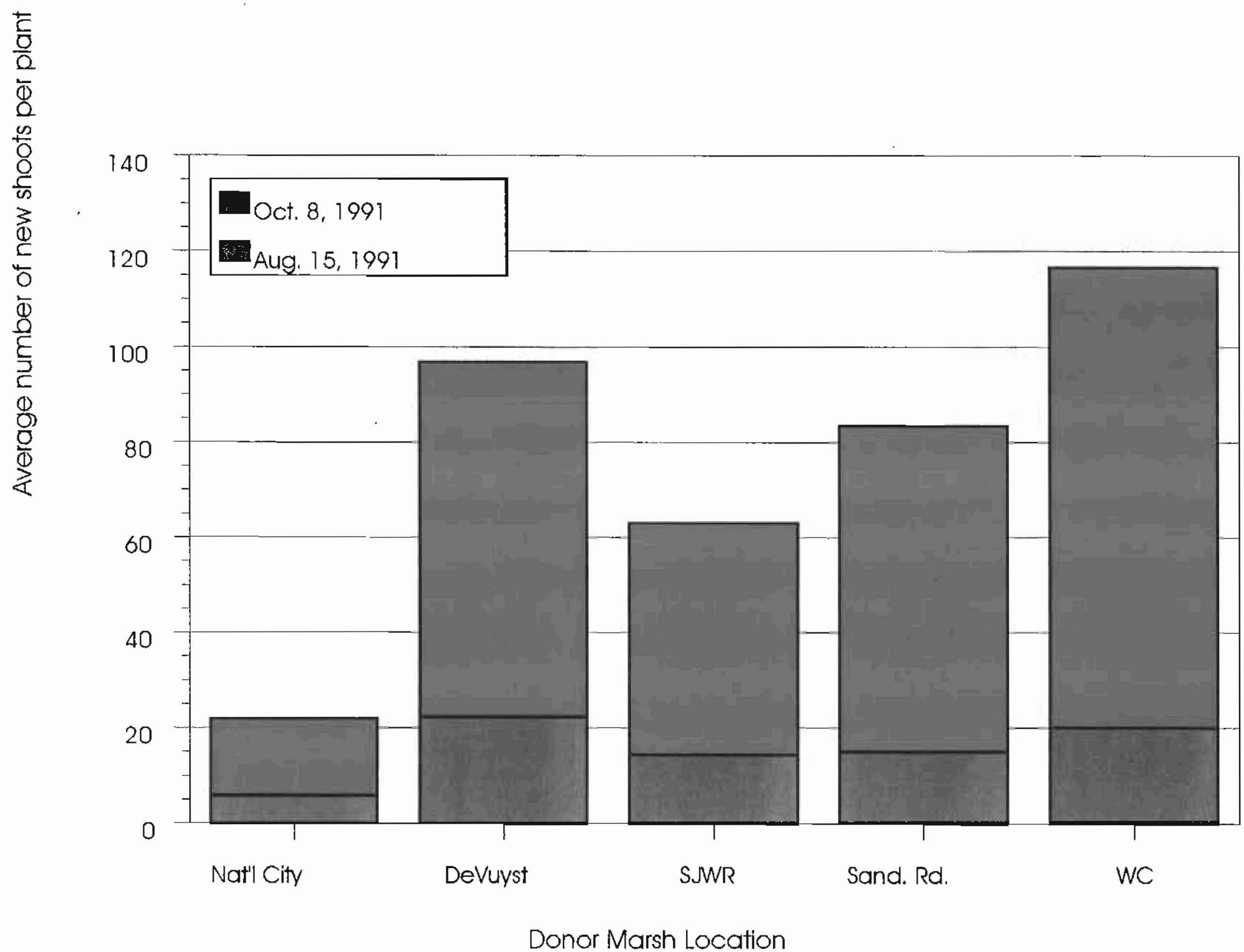


FIGURE 4-4. Scirpus growth data by donor marsh location, technique 2.

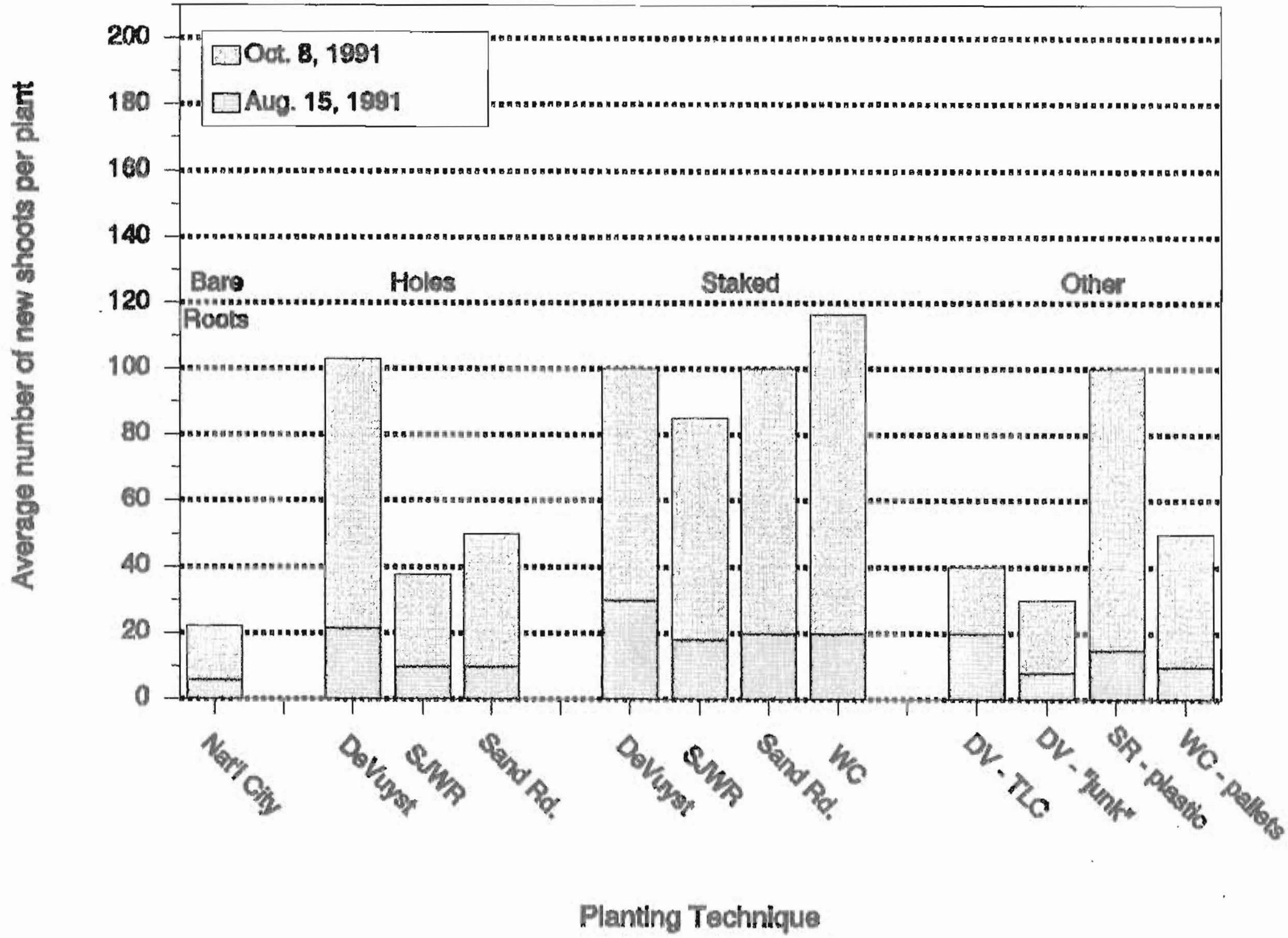


FIGURE 4-5. Average Scirpus growth data by planting technique and donor marsh.

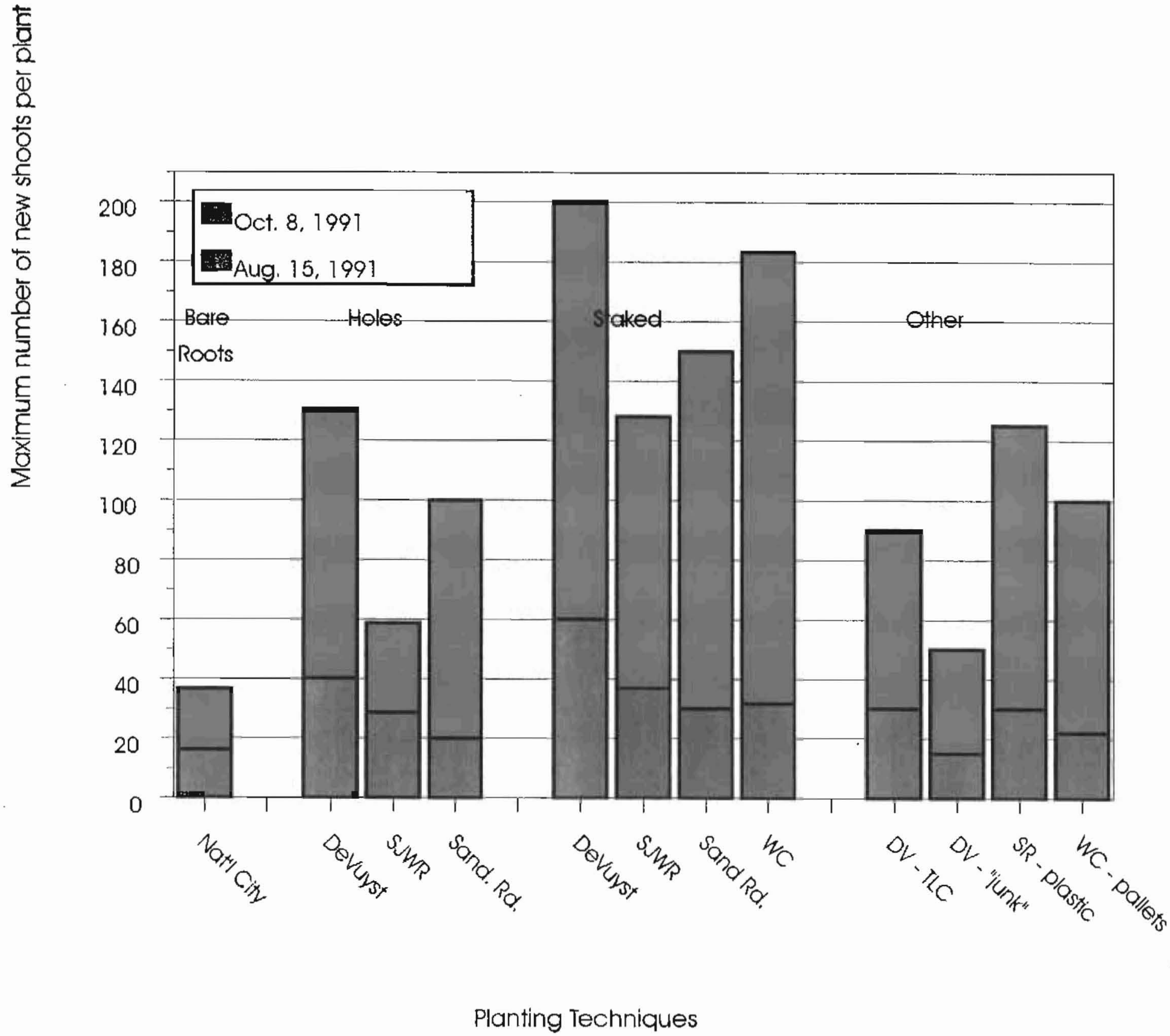


FIGURE 4-6. Maximum Scirpus growth data by planting technique and donor marsh.

penetrate the hard clay substrate that surrounded them. Stressed plants that were staked on top of the hard clay surface were in an ideal situation and were able to grow unrestricted. The plants from the DeVuyst drain grew equally well in either planting technique, with the exception of the plants treated with special care, probably because they were so healthy and were little stressed during transport (the site was only 11.3 km (7 mi) away). Their rhizomes remained robust and, thus, were able to penetrate the clay substrate.

Healthy plants from DeVuyst's drain given special care were planted in holes, but their growth was limited compared to the other DeVuyst plants. Similarly, the Walker Canyon plants placed on and in the wooden pallets, although healthy going in, were restricted by the pallets. The "junk tubers" from DeVuyst's drain, always behind in growth, produced new shoots faster on average than the National City plants (30 versus 22 in October, respectively). Therefore, the plants set on top of the soil surface had a more ideal situation in which to expand unhindered. In addition to being the least labor-intensive of the planting techniques and, therefore, the most cost-effective, the staked plants provided the shortest time to full coverage of the area.

Special handling of the bulrush plants did not enhance the rate of growth after transplanting. The slower growth of the plants given special care, compared to the other DeVuyst plants, implies that damage to the culms (by trimming or breaking) seemed to encourage the rhizomes to produce new shoots more rapidly. In fact, trimming or not trimming the tops (but allowing them inadvertently to bend or break during transport) made no difference in the subsequent growth of the plant. Trimming the culms beforehand, however, makes transport easier.

In comparing the differences in growth between the two marshes with the fastest growth, the only discernable difference is the plant species. The plants from DeVuyst's drain were California bulrush; the plants from Walker Canyon were hardstem bulrush. When healthy and staked, both species were very prolific.

The height of the plants increased with time, but it was not a good measurement for comparing the different harvesting and planting techniques. For example, the plants from National City had average and maximum heights similar to the others although their shoot numbers were much fewer (Figures 4-6 through 4-8). On average, the staked plants were about 30 cm (1 ft) taller than their counterparts planted in holes with the exception of the DeVuyst plants. Three months after planting, the maximum heights of the bulrush from DeVuyst's drain and Walker Canyon were 2.7 to 3.0 m (9 to 10 ft) tall.

Experiments to examine ease of subsequent harvesting included the use of plastic, wooden pallets, and chain-link fencing. The plants planted on plastic lacked soil for support and fell over when growth became tall and high winds occurred. The wooden pallets restricted horizontal and basal plant growth and interfered with hydraulic flow.

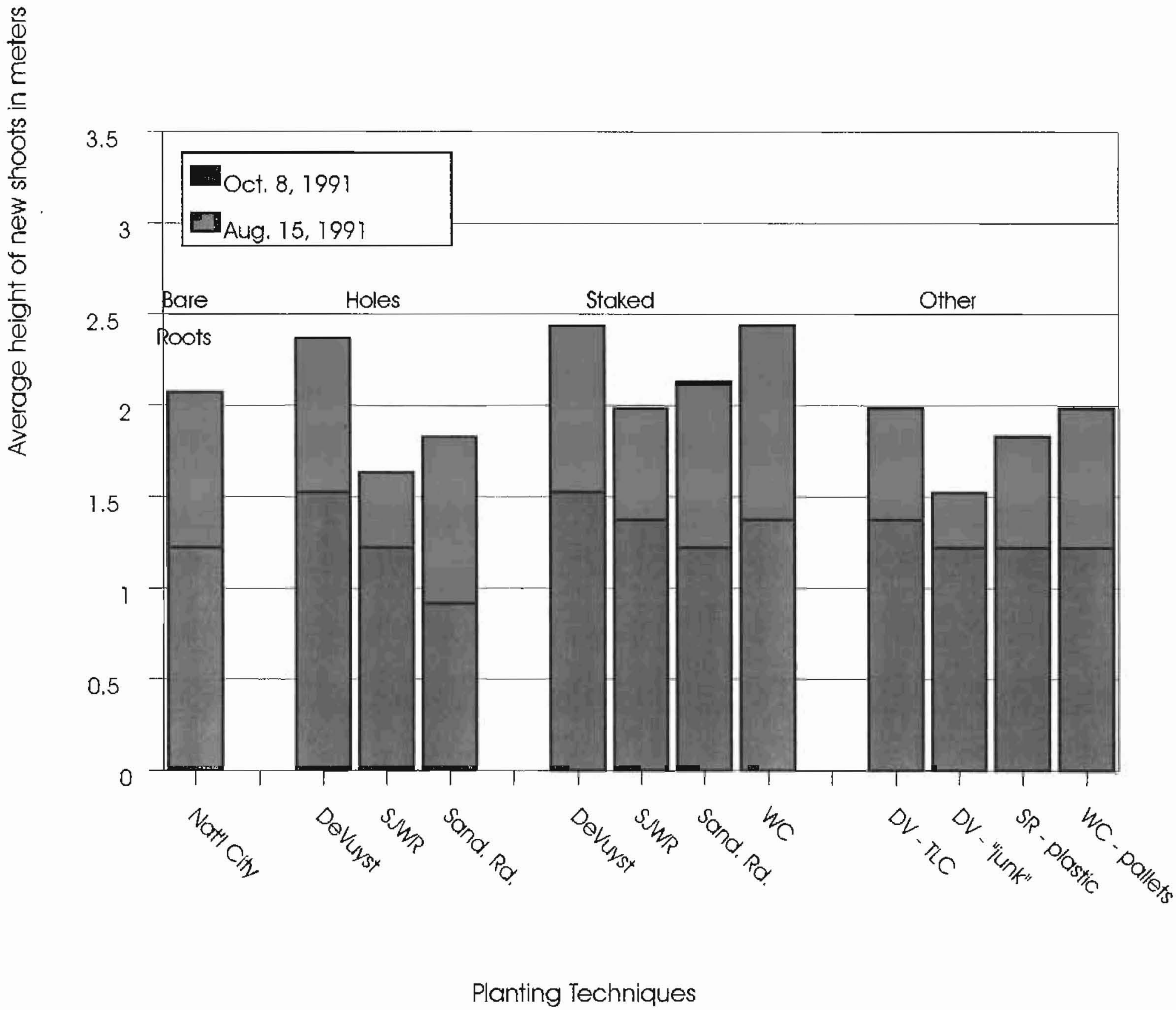


FIGURE 4-7. Average height of new Scirpus shoots by planting technique and donor marsh.

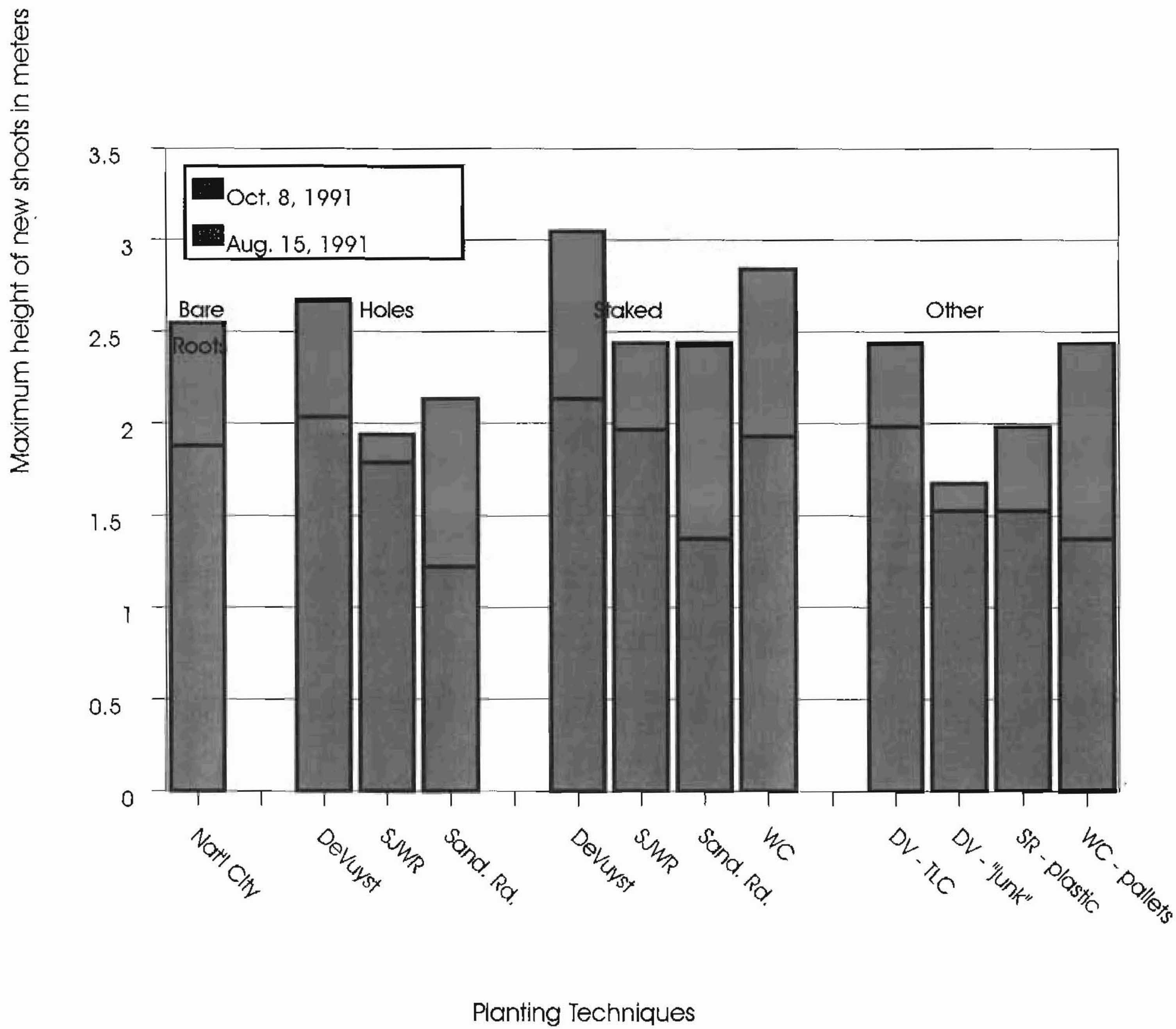


FIGURE 4-8. Maximum height of new Scirpus shoots by planting technique and donor marsh.

Plants planted on chain-link have put extensive roots in and around the fencing. Damage to the plants is probable when they are harvested. Therefore, these planting techniques, designed to make later harvesting easier, were mostly unsuccessful and may prove to be just the opposite.

Additional observations during the August 1991 monitoring trip indicated that most of the plants were healthy and actively growing. Some of the plants from DeVuyst's drain were flowering, while the plants from National City were spindly and had a white fungus growing on their culms. In October, the fungus was gone, and some of the plants had formed seed heads. The other plants were generally healthy with some seed heads (most flowering had already passed). A variety of other organisms was observed using the plants, including insects, spiders, small frogs, and birds.

During the winter, the hardstem bulrush culms senesced and, by the February 1992 monitoring trip, many had bent over and were lying in the water. The California bulrush culm tops turned brown, but most of the plant remained green and upright. In February, new shoots were beginning to come up through the older material of both species, marking the first of the new spring growth.

Chlorine was added to the reclaimed water supply from early October 1992 into January 1993. It was noted during the October sampling that the duckweed around the inlets was bleached white. By January 1993, the duckweed had disappeared in both cells. The chlorine did not appear to damage the other plant species. By April 1993, some duckweed had reappeared.

Marsh pennywort tended to wilt or die back when temperatures were too hot or too cold. The rush survived and flourished along the eastern edge of the north nursery. The seepwillow survived the transplanting but was pulled out because it would be in the way of harvesting activities. A few additional species came in naturally when the water levels were low in October, including alkali bulrush and several grass species. Once the colder temperatures arrived and water depths increased, these species died out for the winter. In the spring, the species did not reappear due to the water depths and lack of available light and space between the larger bulrushes.

Predation, or the eating, of new shoots by American Coots, a small black waterbird, was initially a concern. The coots require "runways" for takeoff and landing. Therefore, immediately after planting, some nylon netting was erected to provide a visual barrier to the birds. As the new culms shot upwards and filled in the bare areas, predation was no longer a threat, so the netting was removed. Very little predation occurred anywhere in the nursery.

Water Quality. Mean inflow to each nursery cell was about 57 L/min (15 gal/min), which resulted in an average hydraulic loading rate of 4 cm/d (1.56 in/d) and an average retention time of 5 days.

Table 4-1 summarizes the results of the in situ water quality measurements of water temperature, dissolved oxygen saturation, pH, and conductivity taken at nine points within each nursery cell on each of the three survey dates. Water temperature in the cells basically reflected ambient air temperatures on the survey dates. Dissolved oxygen saturation percentages and pH's, however, reflected the shift from algae-dominated, sparsely-vegetated cells, in August, to established emergent marshes by October. Supersaturated dissolved oxygen levels and basic pH's, in August, are the result of algal photosynthesis under highly eutrophic conditions. By October, the emergent vegetation had become dense enough to shade out the algae, leaving dissolved oxygen levels below saturation and nearly neutral pH's, which are more typical of a marsh environment. The rise in conductivity from August to February may have been due to evapotranspiration, but, given the range of error in these measurements, the rise is probably not significant.

TABLE 4-1. NURSERY CELL WATER QUALITY COMPARISON
North and South Cell Mean Constituent Values

	AUG 1991		OCT 1991		FEB 1992	
	S	N	S	N	S	N
Water Temperature (°C)	30.5	31.2	20.5	25.1	16.5	14.4
Dissolved Oxygen (% sat)	133.0	173.0	28.0	37.0	82.0	55.0
pH	8.8	9.2	7.4	7.6	7.6	7.5
Conductivity (μS/cm)	1060.0	957.0	1076.0	1015.0	1135.0	1131.0

Table 4-2 summarizes the results of the laboratory analyses of the water samples collected from the cell inlets and the combined outlet of the two cells on each survey date. Because the outlet sample represents the combined outflows of the two nursery cells, the removal efficiencies shown in Table 4-2 were estimated using the average of the two cell inlet concentrations.

TABLE 4-2. NURSERY CELL WATER TREATMENT
Estimated Mean Constituent Removal Efficiencies

	AUG 1991	OCT 1991	FEB 1992
AMMONIA NITROGEN	26%	38%	-58%
NITRATE NITROGEN	75%	90%	-20%
ORTHOPHOSPHATE PHOSPHORUS	-145%	-85%	-77%
TOTAL ORGANIC CARBON	0%	-56%	NO DATA
TOTAL SUSPENDED SOLIDS	38%	0%	-157%
TOTAL DISSOLVED SOLIDS	-22%	-7%	-9%

Ammonia and nitrate nitrogen removal efficiencies in August probably reflected uptake by the algae that dominated the cells at that time (Table 4-2). By October, however, the emergent vegetation was well enough established to have shaded out the algae, so removal efficiencies at that time most likely reflected nitrification-denitrification transformations in the marsh environment. It appeared that the chlorination of the nursery cells from October to January severely impacted the microbial biofilm on the stems of the emergent vegetation as well as killing the floating duckweed, so rather than removing nitrogen from the water, the dead organic material actually increased ammonia and nitrate nitrogen concentrations.

Orthophosphate phosphorus was added to the wastewater within the cells from August through February, although the amount added declined steadily throughout this period (Table 4-2). The pattern of declining orthophosphate phosphorus additions suggests that leaching from the newly inundated soils may have been the main source of the added phosphorus.

The last three constituents shown in Table 4-2--total organic carbon, total suspended solids, and TDS--are difficult to interpret with the available data. The downward trend in TDS additions may, however, reflect a decrease in evapotranspiration as the emergent vegetation began to shade the water surface and air temperatures declined with the passing season.

Invertebrates. Table 4-3 summarizes the results of the benthic invertebrate sampling on the three survey dates. In August, the benthos were almost entirely composed of chironomids, non-biting midge larvae, often called "blood worms". Such a benthic community is typical of a wastewater oxidation pond, which is essentially what the nursery cells were at that time. By October, the benthic community had increased in numbers of organisms and in the number of taxa present. The predominance of chironomids had declined somewhat, and oligochaetes, or aquatic earthworms, had begun to appear, reflecting the shift toward a more typical marsh benthic community. The shift from a benthic community completely dominated by chironomids to one with a higher percentage of oligochaetes continued into February, although both numbers of organisms and number of taxa had declined sharply since the October survey, perhaps as a result of the chlorination of the cells in the interim period.

TABLE 4-3. NURSERY CELL BENTHIC COMMUNITY COMPARISON

	AUG 1991		OCT 1991		FEB 1992	
	S	N	S	N	S	N
Number of taxa present	6	6	16	13	4	3
Total number of organisms	448	551	753	1176	241	94
% Chironomids	97	97	81	82	75	73
% Oligochaetes	0	0	3	11	24	26

Mosquito Larvae. Mean mosquito larvae counts were 0.83 larvae per sample in the north cell during August 1991. In October, the mean data were 0.83 larvae per sample in the north cell and 1.1 in the south cell. The larvae were more dense under the marsh pennywort than under duckweed or algae. In February, no mosquito larvae samples were collected due to high winds.

Research Cells

Plant Growth and Establishment. Six weeks after planting, the bulrush plants were actively growing with a 99.97 percent survival rate (one out of 3652 clumps died). A few clumps had floated away from their staked positions but were found growing along a nearby shoreline. Since that time, no plants have died.

The mean number of new bulrush shoots per sampled clump was 21.4 in October 1992. The mean illustrates how quickly the bulrush proliferated in the research cells in just 6 weeks. The actual number of new shoots per sampled clump ranged from 2 to 80 throughout the cells (Figure 4-9). Major differences in development of new shoots between cells were probably due to the hydraulic problems of the cells. During planting, the water to each of the research cells was delivered at various times so the transplanted clumps were exposed to differing periods of drying out, causing a

PHOTO 24. RESEARCH CELLS (14 MONTHS AFTER PLANTING)

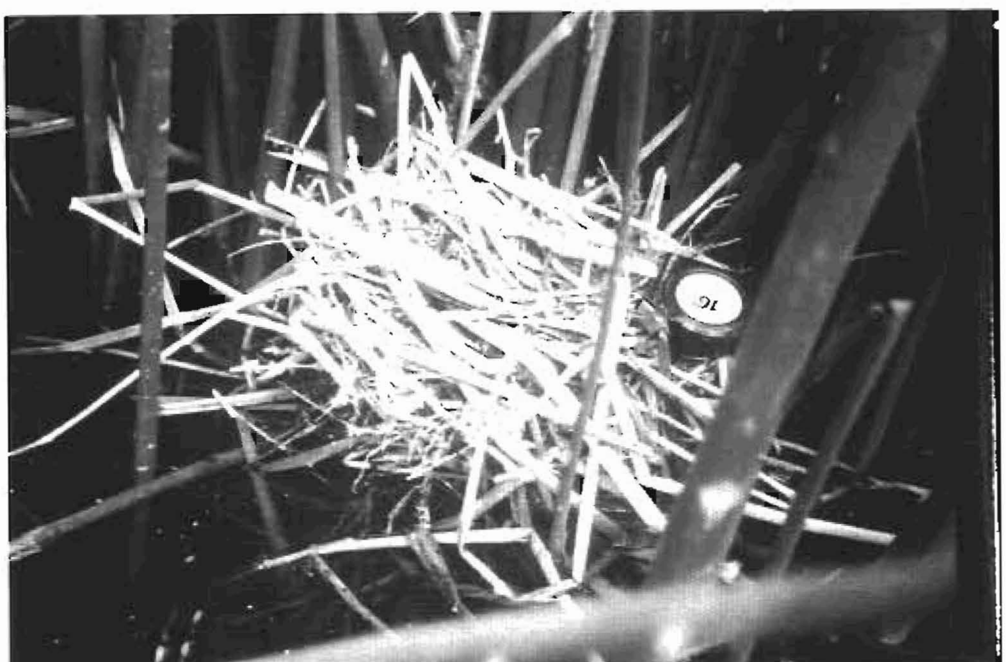


PHOTO 25. NEST MADE OF BULRUSH CULMS IN RESEARCH CELL

FIGURE 4-9

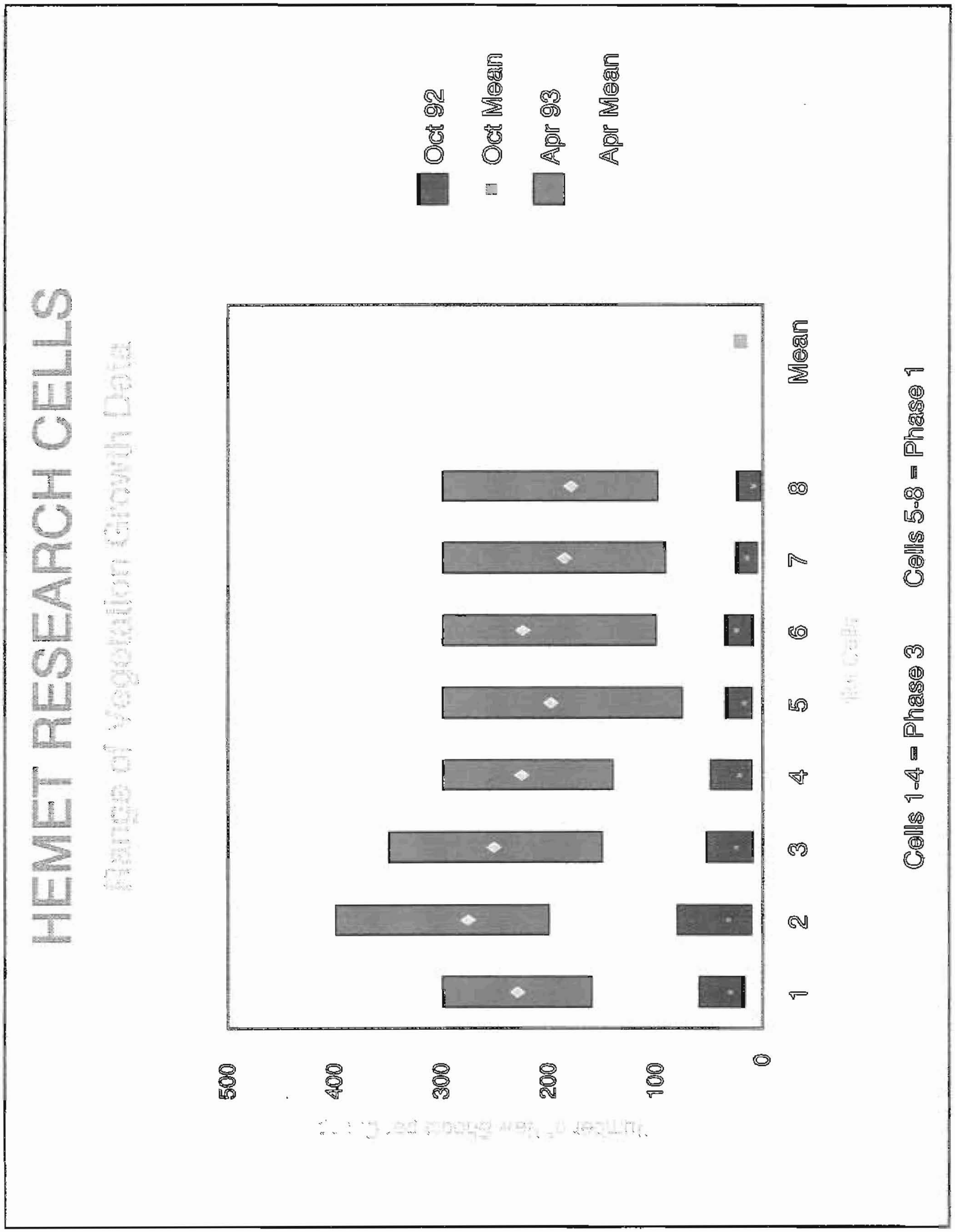

HEMET RESEARCH CELLS
Range of Vegetation Growth Data
Oct 92
Oct Mean
Apr 93
Apr Mean
500
400
300
200
100
0
1
2
3
4
5
6
7
8
Mean
Cells 1-4 = Phase 3
Cells 5-8 = Phase 1

FIGURE 4-10

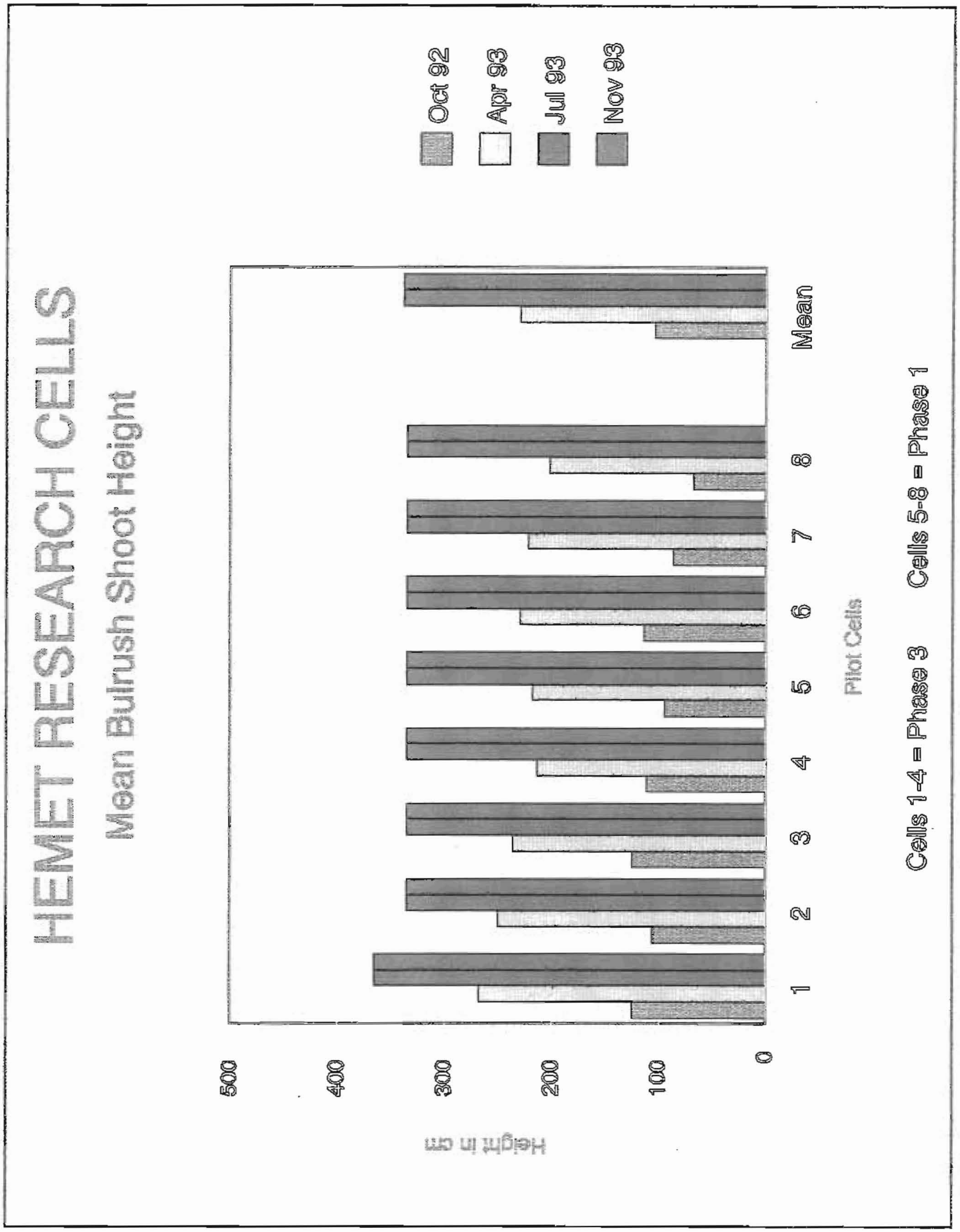
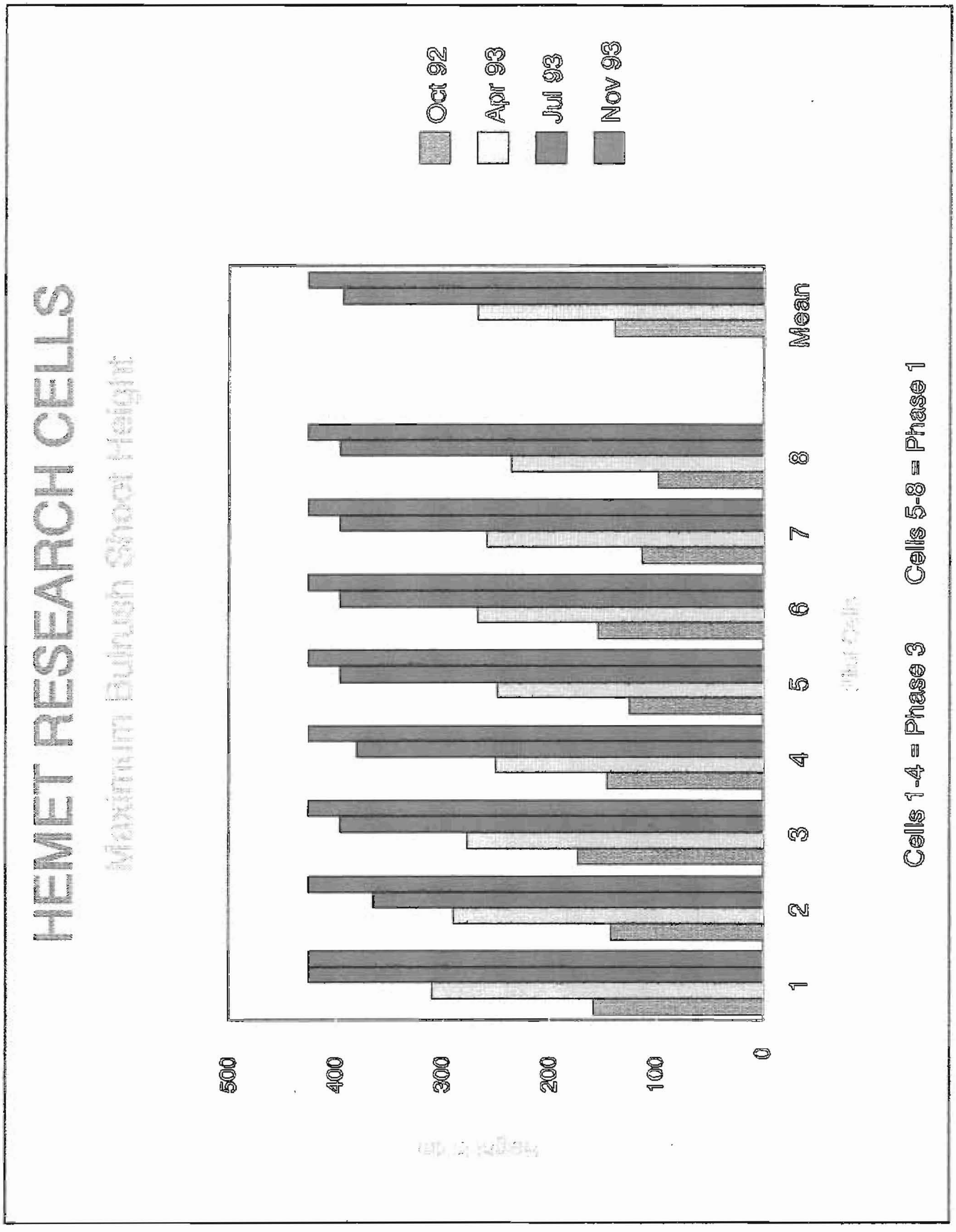

HEMET RESEARCH CELLS
Mean Bulrush Shoot Height
Oct 92
Apr 93
Jul 93
Nov 93
Height in cm
500
400
300
200
100
0
1
2
3
4
5
6
7
8
Mean
Pilot Cells
Cells 1-4 = Phase 3
Cells 5-8 = Phase 1

FIGURE 4-11


HEMET RESEARCH CELLS
Maximum Bulrush Shoot Height
Oct 92
Apr 93
Jul 93
Nov 93
500
400
300
200
100
0
1
2
3
4
5
6
7
8
Mean
Cells 1-4 = Phase 3
Cells 5-8 = Phase 1

variation in initial conditions. The research cells were engineered to be level; however, before planting, fill dirt was deposited in each of the cells to provide loose soil for rhizome penetration. The soil was not re-leveled in order to avoid compaction. This created an unevenness in the bottom of the cells, and some cells contained high spots which were above the water level 6 weeks after planting. Additionally, daily water flow into each of the cells was erratic, and each cell's daily flow was different from the others.

By April 1993, the number of new shoots had increased dramatically in each cell; most of the increase occurred during the previous month. The mean number of new shoots per sample clump throughout the cells jumped to 220, an increase of over 10 times per October's mean. The range of new shoots per sample clump was 91 to 400, with variation both between and within the cells. All of the plants were healthy. The horizontal growth of the rhizomes was causing the plants to grow toward each other, filling in the spaces between the plants. By July 1993, the new shoots along the new rhizomes had increased in number so much that it was impossible to determine which clump the new shoots came from without digging the plants out. The variation within the cells was not as apparent as in the previous months. Cells 7 and 8 were visually not as dense with new culms as cells 1 through 6, but the plants were still very healthy and robust. By November 1993, the plants were so dense throughout all of the cells that the use of a machete was necessary to walk through them. Visual variations between or within the cells in regard to bulrush growth could not be discerned. The research cells had reached 100 percent plant coverage.

The mean bulrush culm height of all the sampled plants throughout the research cells was 104 cm (± 25 cm) (41 in) in October 1992, 230 cm (± 31 cm) (90 in) in April 1993, and 339 cm (± 10 cm) (132 in) in July and November 1993 (Figure 4-10). Maximum culm heights of the bulrush plants averaged 140 cm (± 34 cm) (55 in), 268 cm (± 36 cm) (105 in), 394 cm (± 16 cm) (154 in), and 427 cm (± 0.0 cm) (167 in), respectively (Figure 4-11). Initially, bulrush culm height also varied within and between the research cells, but by July and through November 1993, culm heights became more uniform. It appeared the 427-cm (167-in) height was maximum for this species, and the 339-cm (132-in) height was typical under Hemet/San Jacinto conditions.

The maximum culm width (the length of one of the three sides of the largest culm) sampled in October 1992 was 1.9 cm (0.75 in). The maximum culm width sampled in April, July, and November 1993 was 3.2 cm (1.25 in). Although 3.2 cm (1.25 in) appeared to be the maximum culm size in this system, few were noted in April and, as time went on, progressively larger culms were noted.

The research cells were designed to be as similar to each other as possible in order to serve as replicates in specific studies; therefore, only one plant species, California bulrush, was intentionally planted. One hardstem bulrush plant was inadvertently planted along the eastern edge of cell 1. No other species were deliberately planted. However, many other plant species have appeared in and around the research cells, presumably introduced by natural means (wildlife or wind) or unavoidable contamination during planting. Duckweed and water pennywort were observed growing on the water surface in many of the cells by July 1993. Cattail were growing in the north end of cell 5 by November 1993. Many other plant species have established themselves around the perimeter of each of the research cells on the 4:1 sloped berms. The first plant to establish itself was swamp timothy, which was noted during the April 1993 sampling trip. By July, more swamp timothy, two species of smartweed, willow, seepwillow, and a mallow were observed. In November, prickly lettuce, and a brown surface algae were observed in addition to the other species.

To date, the additional plant species have not impacted the California bulrush community and, therefore, are not considered a cause of any variation in water quality.

In Situ Water Analyses.

Hydrolab DataSonde Measurements. Mean water temperature, conductivity, pH, and dissolved oxygen saturation measured on the inflows and outflows of both types of cells during Series 1 and Series 1A are shown in Figures 4-12 through 4-19. The mean parameter values were calculated on the basis of over 1680 hourly measurements during Series 1 and over 1100 hourly measurements during Series 1A. Figures 4-12 through 4-19 show mean parameter values along with their plus and minus one standard deviation ranges.

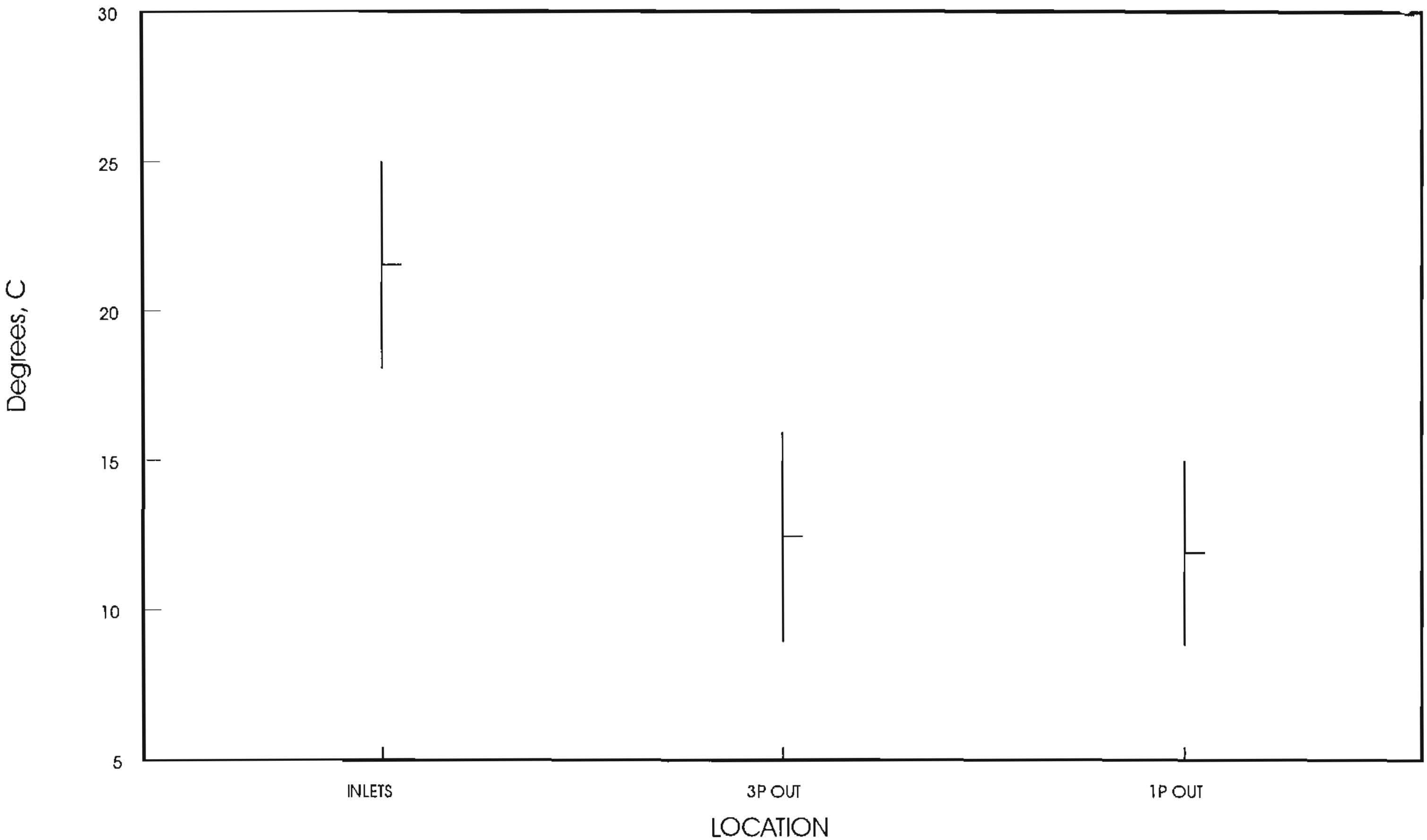
Water Temperature. Figures 4-12 and 4-13 indicate that the water cooled as it flowed through both types of cells during both Series 1 and Series 1A. This cooling averaged about 9° C during Series 1 and about 7° to 8° C during Series 1A. There does not appear to have been any significant difference between the two types of cells in the degree of cooling during either Series 1 or 1A.

Conductivity. Figures 4-14 and 4-15 indicate no significant change in the conductivity of the water as it flowed through either type of cell during either Series.

pH. Figures 4-16 and 4-17 show generally neutral to slightly basic pH's in the inflow and outflow of both types of cells throughout Series 1 and 1A. During Series 1, both the three-phase and one-phase cells exhibited a slight increase in pH from the inflow to the outflow, perhaps as a result of photosynthesis by the algae that predominated in the open water of the still sparsely vegetated cells. During Series 1A, neither type of cell exhibited a significant difference in pH between inflow and outflow.

WATER TEMPERATURE

EMWD WETLAND RESEARCH CELLS: SERIES 1

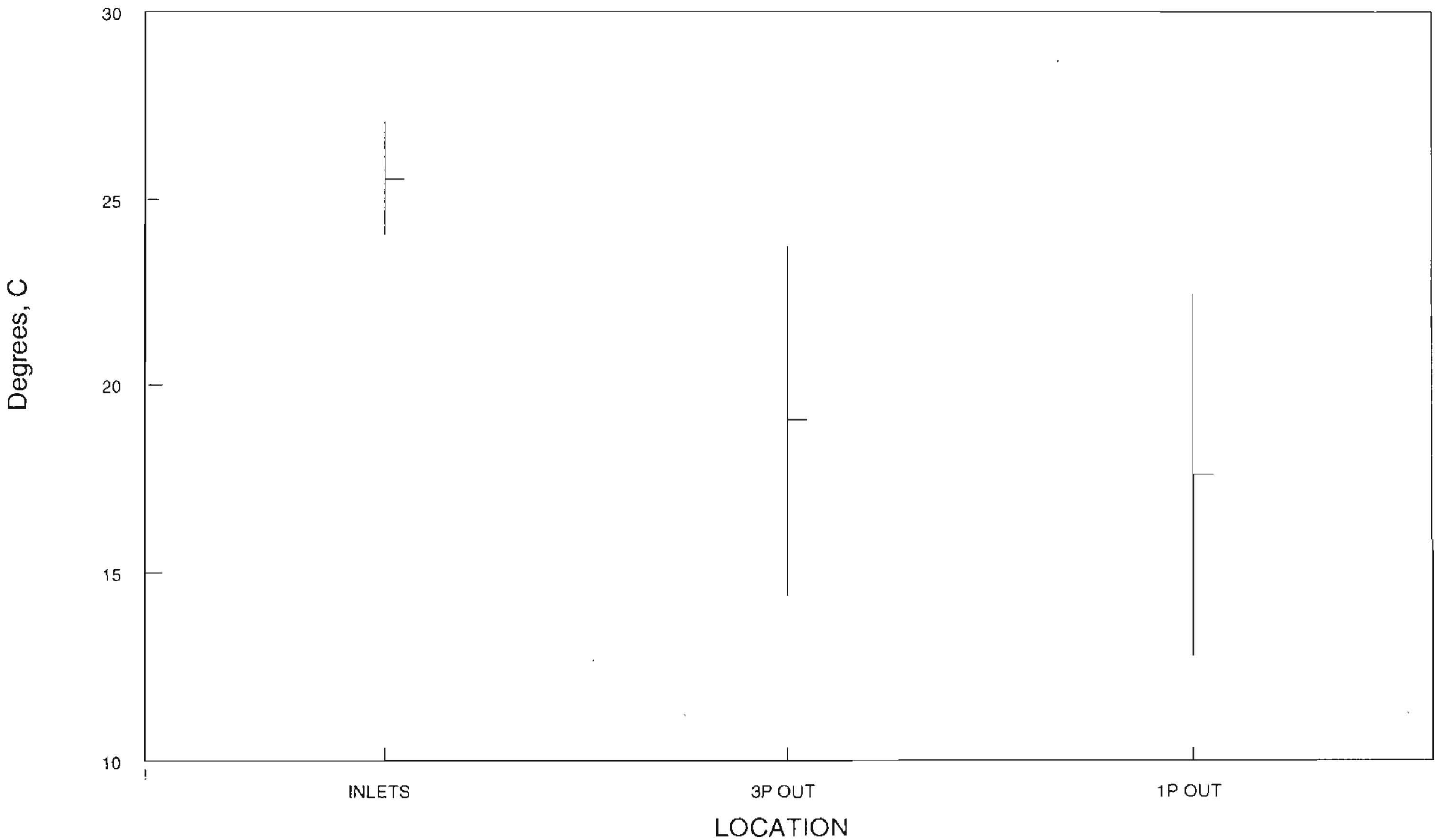


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-12

WATER TEMPERATURE

EMWD WETLAND RESEARCH CELLS: SERIES 1A

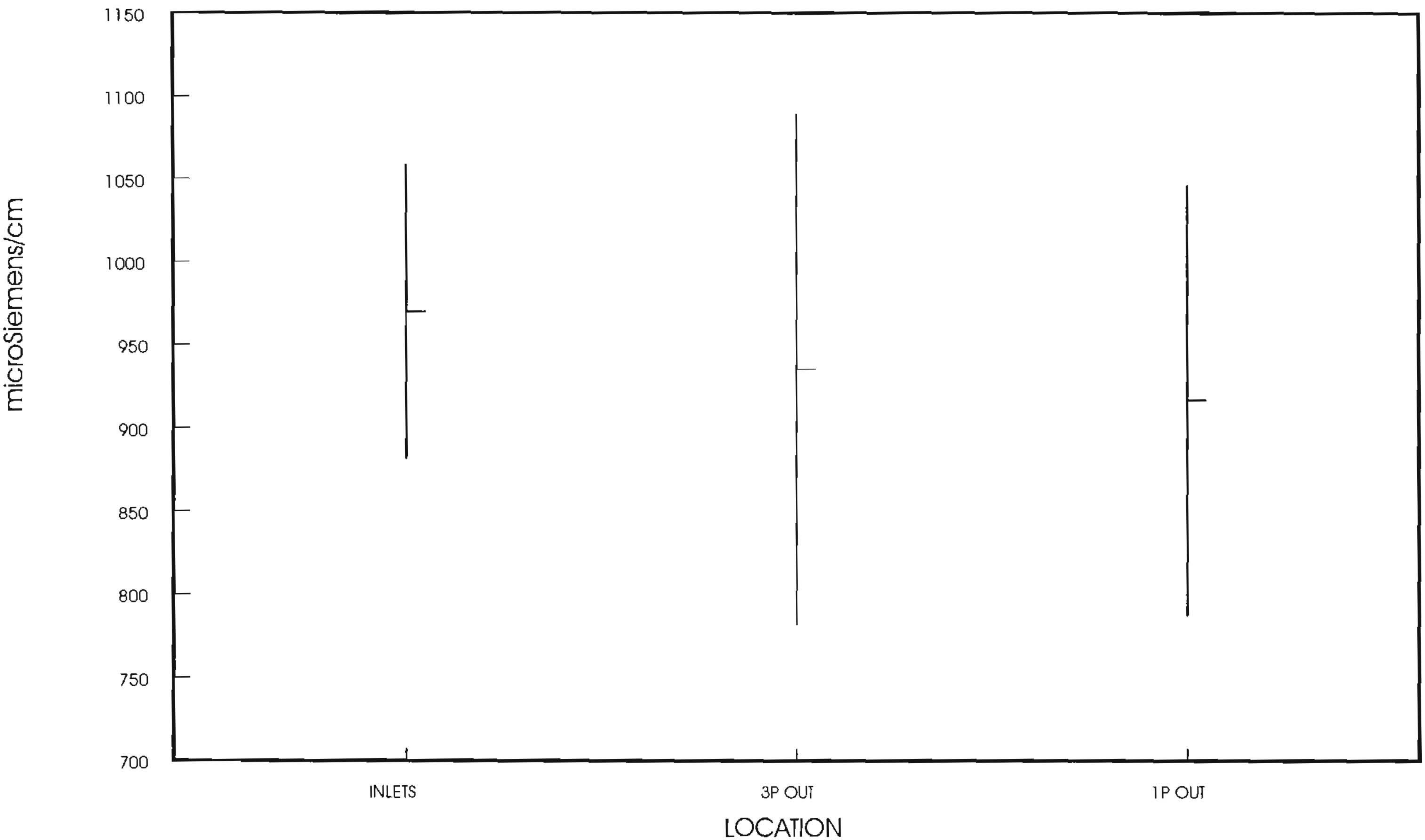


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-13

CONDUCTIVITY

EMWD WETLAND RESEARCH CELLS: SERIES 1

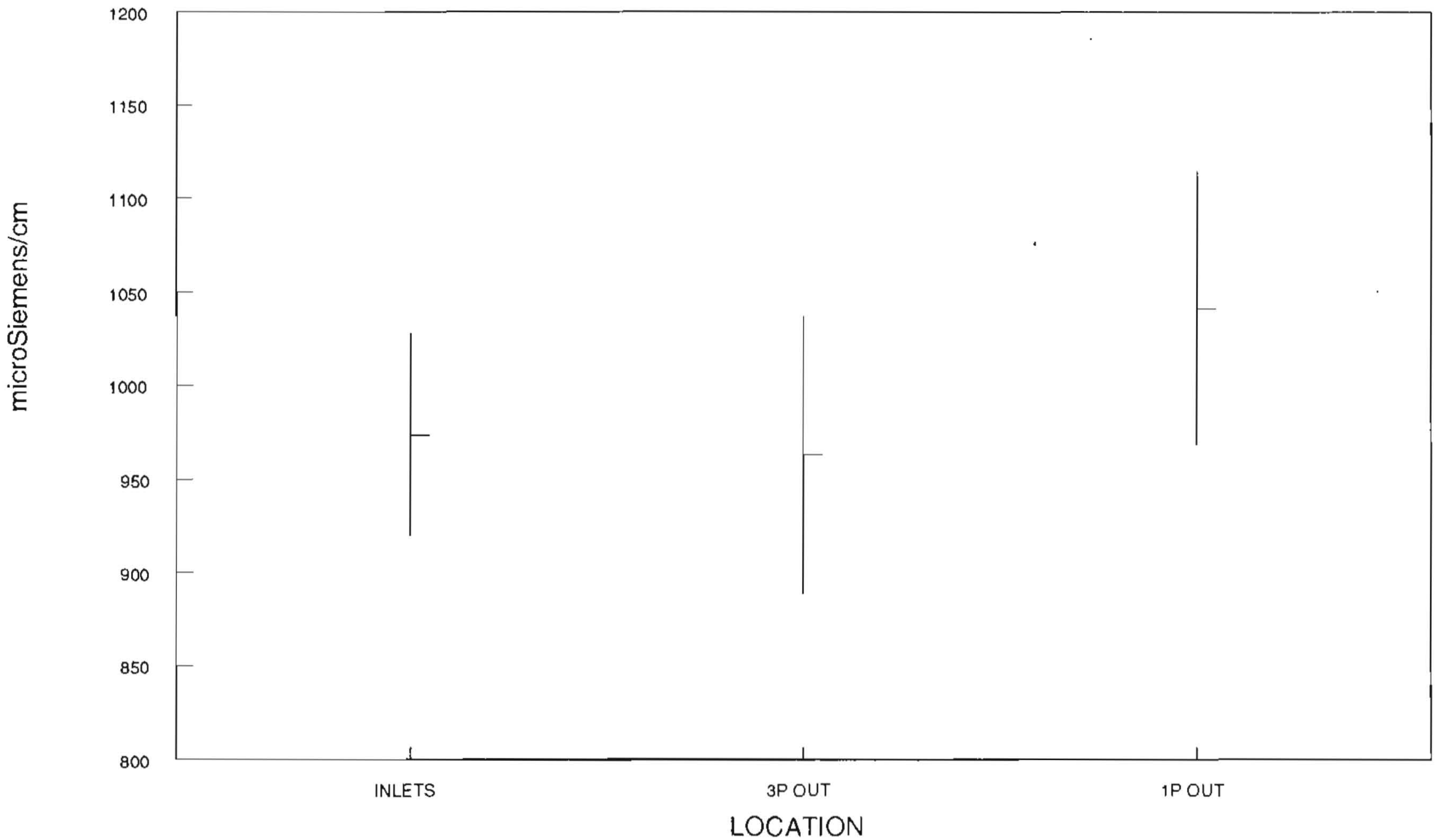


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-14

CONDUCTIVITY

EMWD WETLAND RESEARCH CELLS: SERIES 1A

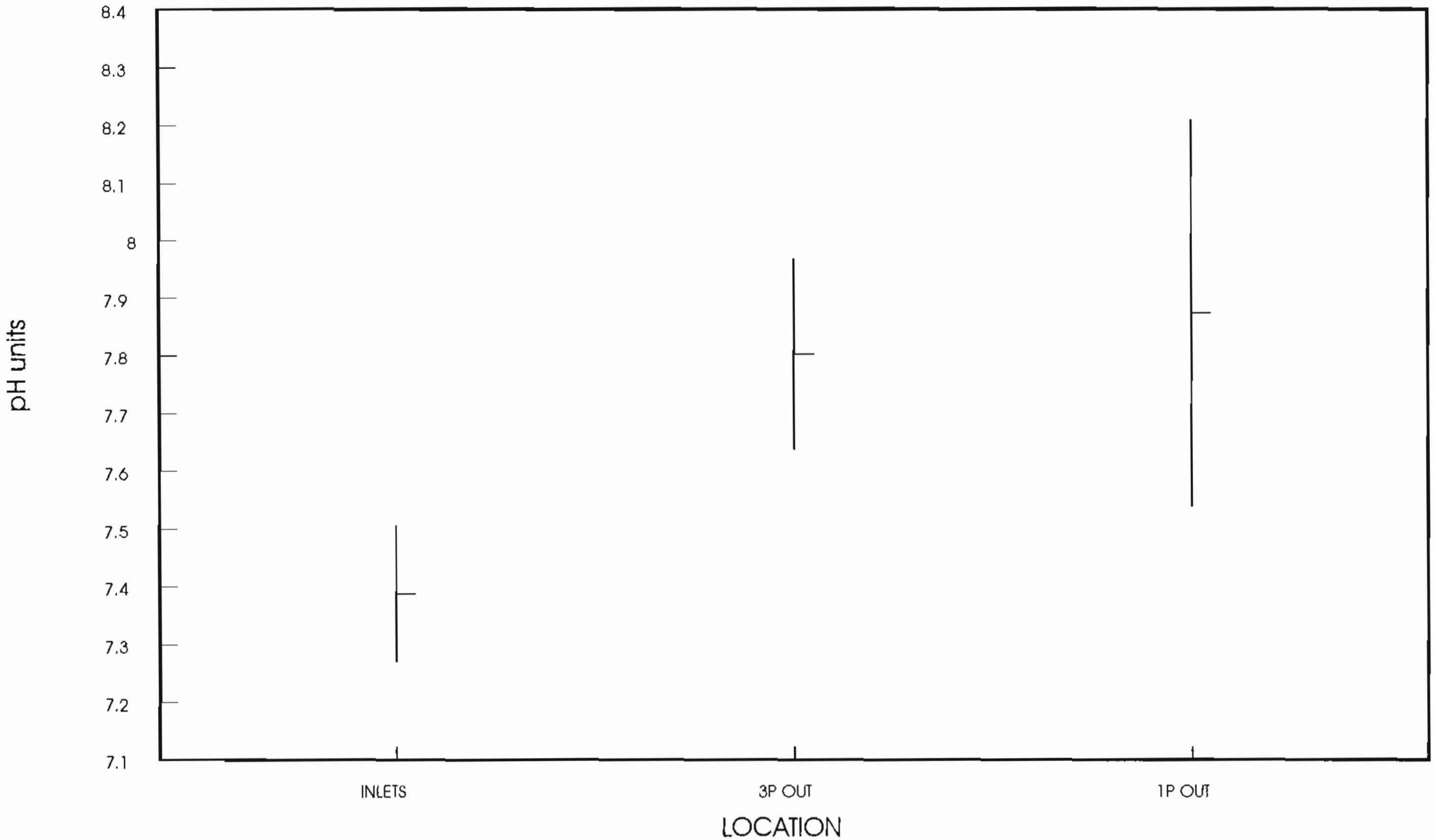


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-15

pH

EMWD WETLAND RESEARCH CELLS: SERIES 1

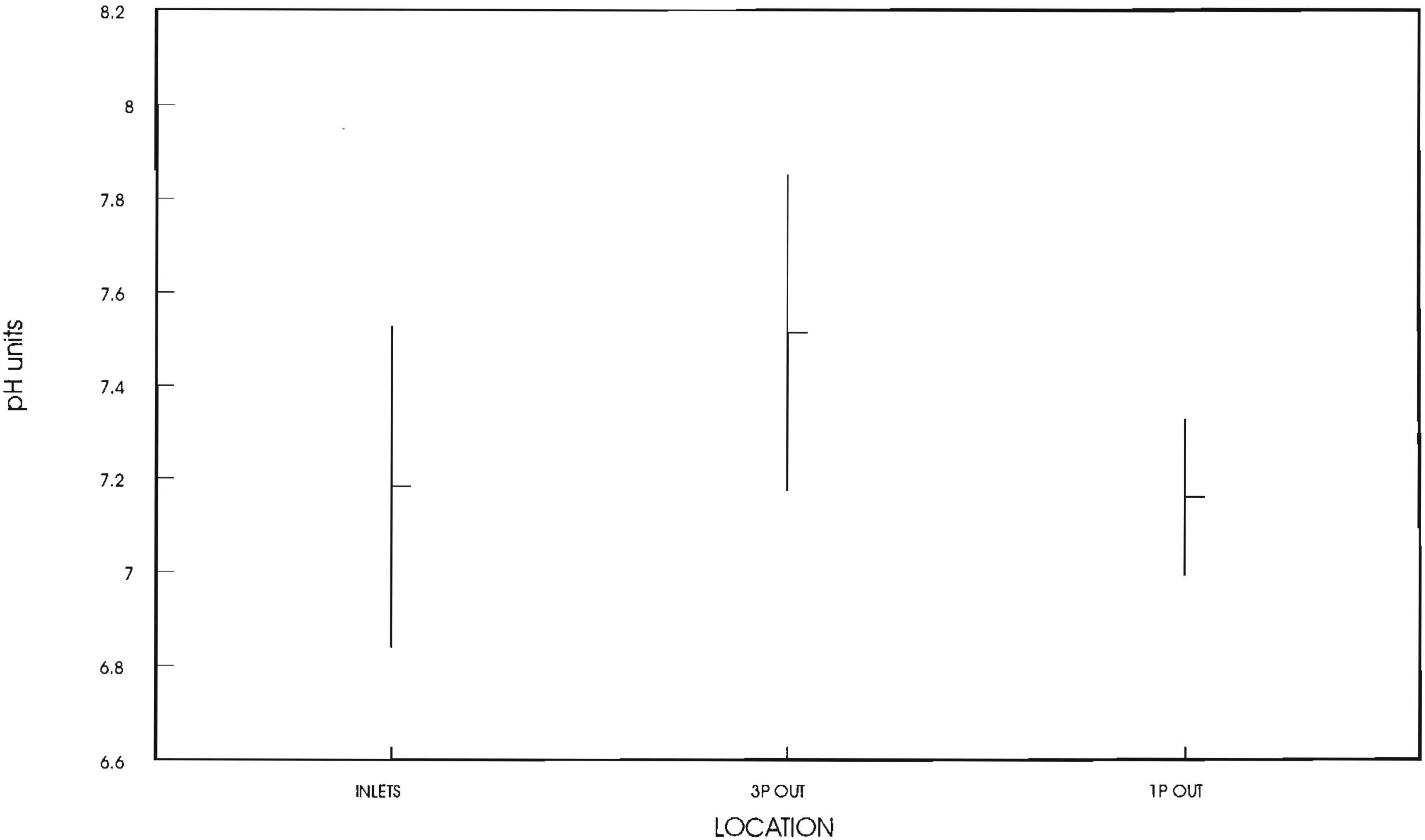


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-16

pH

EMWD WETLAND RESEARCH CELLS: SERIES 1A

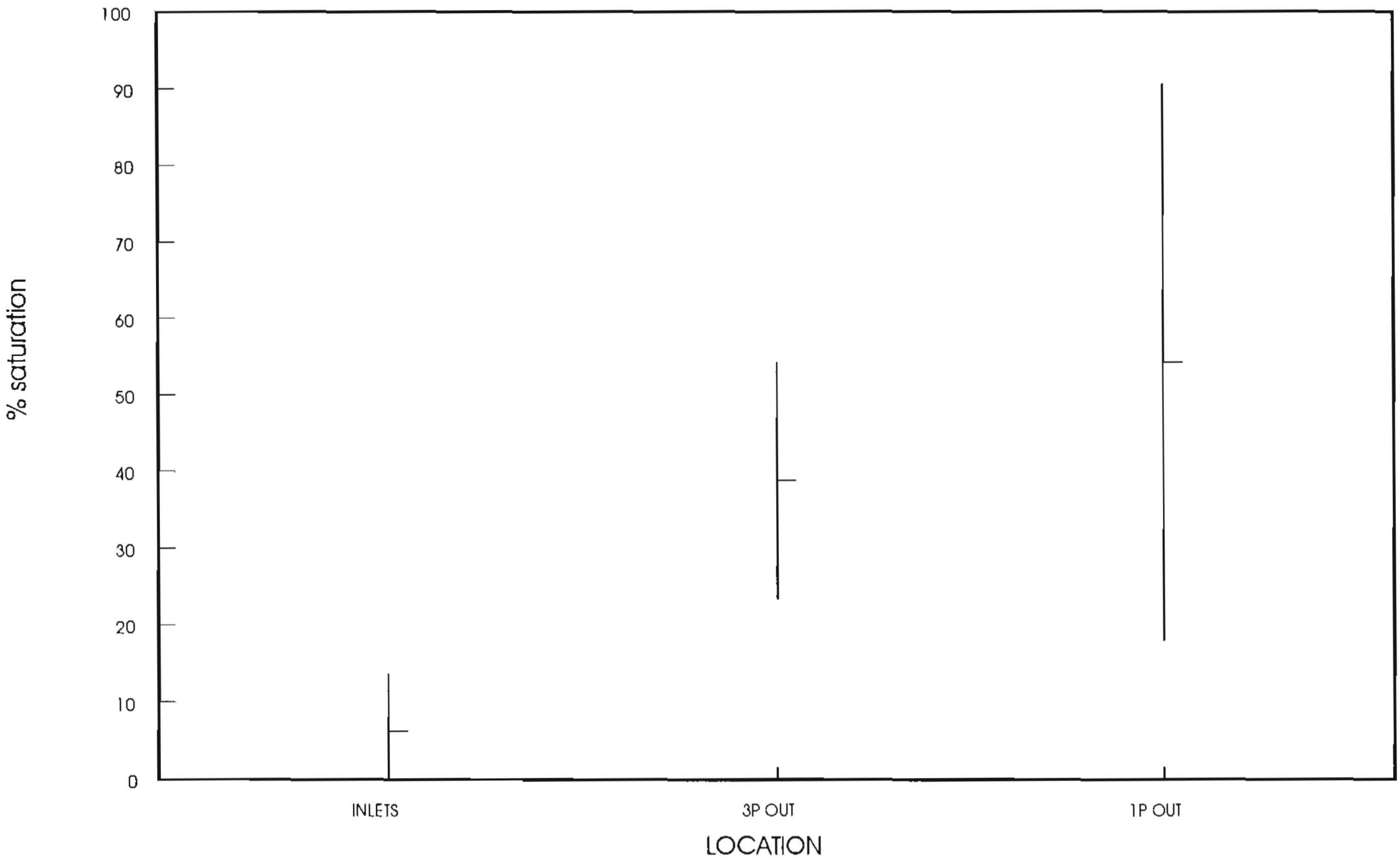


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-17

DISSOLVED OXYGEN SATURATION

EMWD WETLAND RESEARCH CELLS: SERIES 1

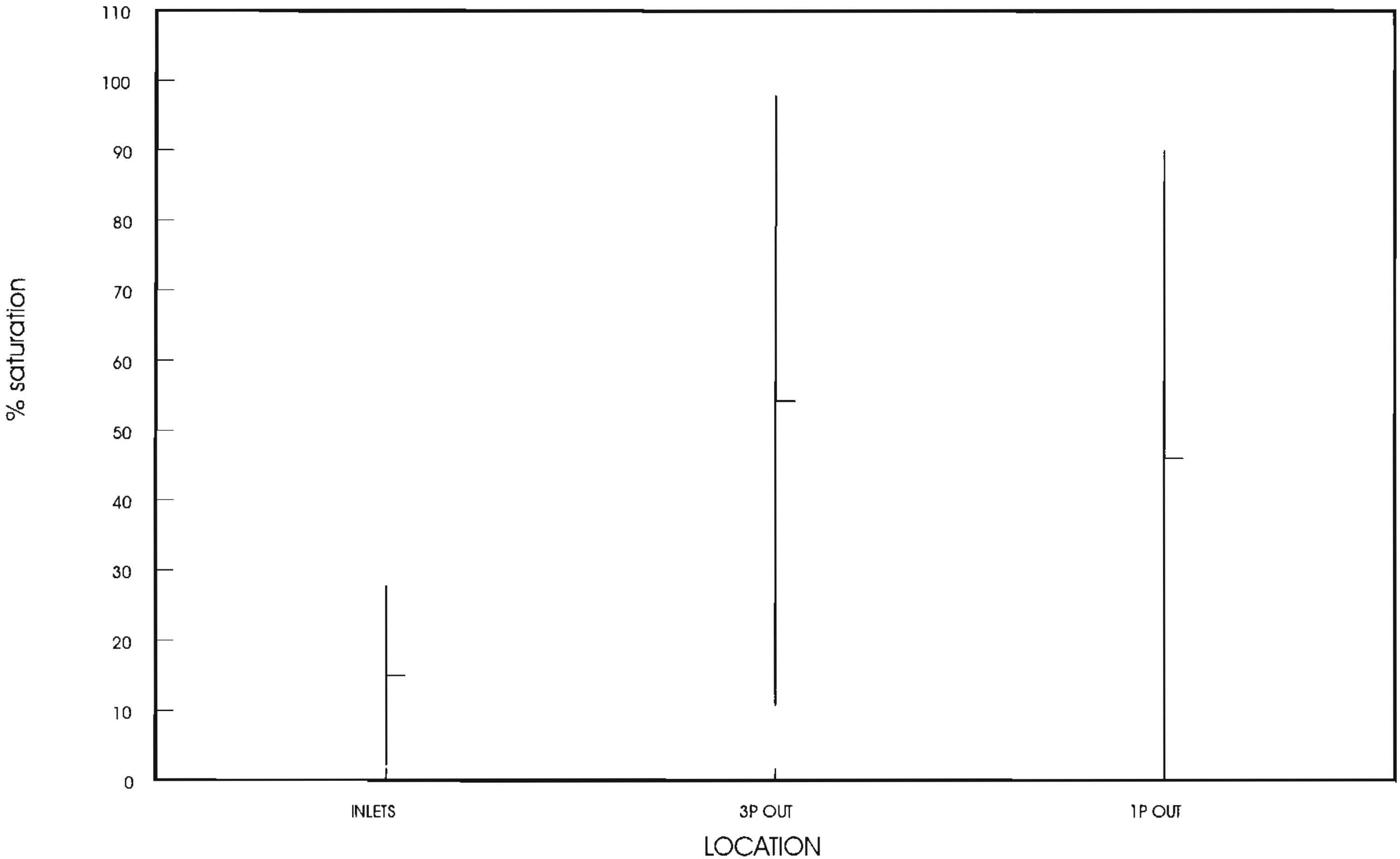


NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-18

DISSOLVED OXYGEN SATURATION

EMWD WETLAND RESEARCH CELLS: SERIES 1A



NOTE: DATA PLOTTED AS MEANS +/- 1 STANDARD DEVIATION.

FIGURE 4-19

Dissolved Oxygen Saturation. Figures 4-18 and 4-19 show that the reclaimed water enters the research cells at a consistently low percentage of dissolved oxygen saturation. (This low dissolved oxygen content accounts for the fact that nitrite is an important component of the total nitrogen concentration of the cell inflows.) The outlets of both types of cells exhibit a significant increase in mean dissolved oxygen saturation. A marked diurnal cycle of high daylight and low nighttime dissolved oxygen saturation accounts for the wide variation about the means. This diurnal cycle is mainly the result of algal photosynthesis and respiration.

NOTE: The fact that the DataSondes were suspended in wells within the inlet and outlet structures of the cells may sometimes have affected the data, especially the pH and dissolved oxygen saturation data. Very low, slow flows, at times, allowed thick algal scums to build up on the water surface within the wells; pH and dissolved oxygen variations at such times could have been exaggerated by the photosynthesis and respiration of the algae within the wells.

Inflow Rates. Two flowmeters became available during the Series 1A monitoring program, and both of them were used to monitor inflows on the paired three-phase and one-phase cells. Monitoring of inflow rates to the three-phase and one-phase cells began on June 5 and July 6, respectively. Figure 4-20 shows the mean daily inflows to the three-phase cells, and Figure 4-21 shows the same data for the one-phase cells. The Series 1A average daily inflow to the three-phase cells was 32.2 L/min (8.5 gal/min), which resulted in an average retention time of 13.21 days. Corresponding series averages for the one-phase cells were an inflow rate of 23.1 L/min (6.1 gal/min) and a retention time of 13.05 days.

Using an average daily inflow rate of 32.2 L/min (8.5 gal/min) for the three-phase cells during Series 1A, average retention times were estimated for each of the three components of the marsh-pool-marsh system:

Inlet marsh component = 4.7 days (36 percent of total cell retention time)
Pool component = 6.6 days (50 percent of total cell retention time)
Outlet marsh component = 1.9 days (14 percent of total cell retention time).

Although the Series 1A average retention times in both types of cells were roughly equal, there was an important difference in the fact that 50 percent of the time, the water in the three-phase cells was residing in an open, relatively deep pool and was not exposed to marsh conditions.

The pool component of the three-phase cells, thus, has the potential of affecting the water treatment process in at least two major ways:

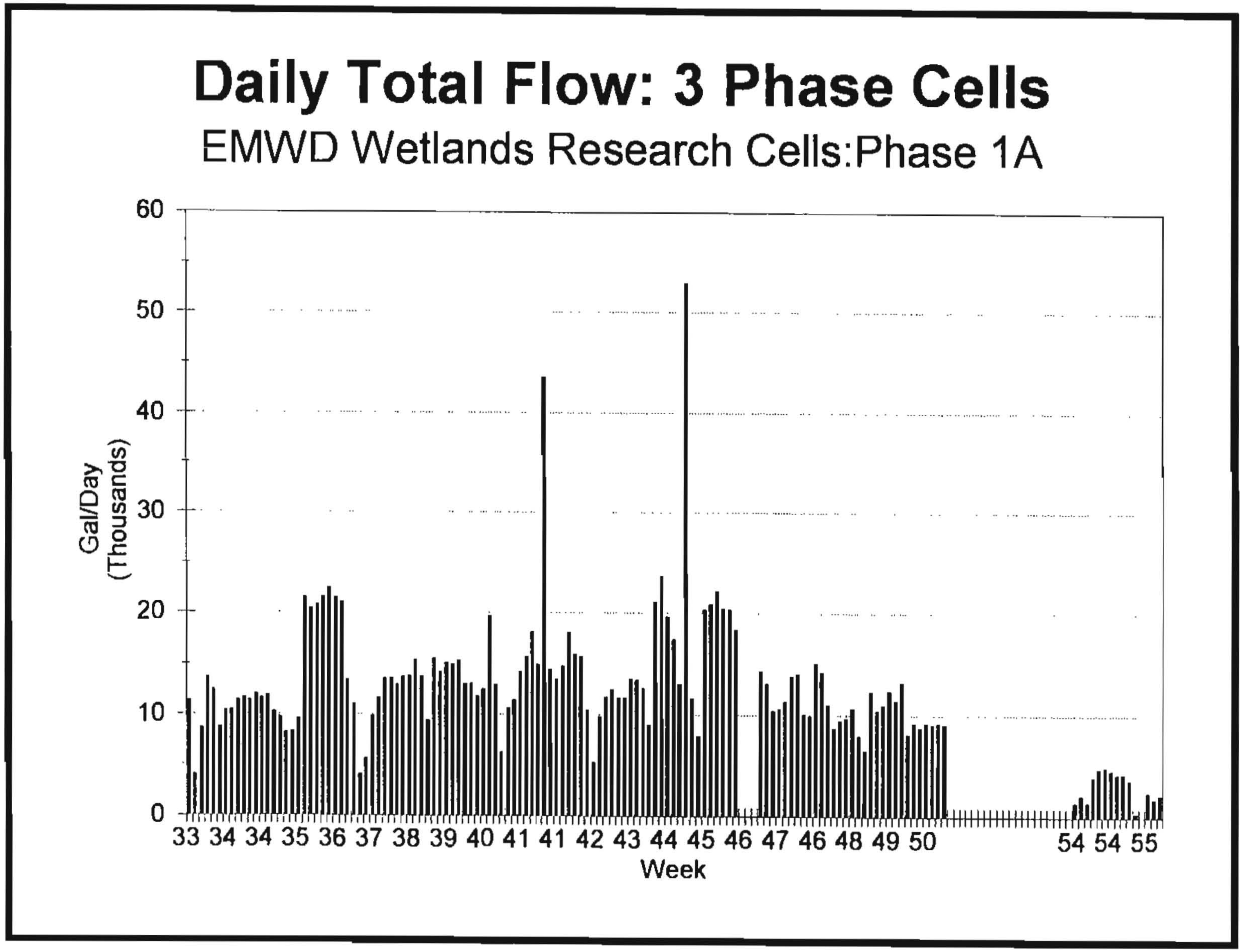

Daily Total Flow: 3 Phase Cells
EMWD Wetlands Research Cells:Phase 1A
Gal/Day
(Thousands)
0
10
20
30
40
50
60
33 34 34 35 36 37 38 39 40 41 41 42 43 44 45 46 47 46 48 49 50
54 54 55
Week

FIGURE 4-20

Daily Total Flow: 1 Phase Cells

EMWD Wetlands Research Cells:Phase 1A

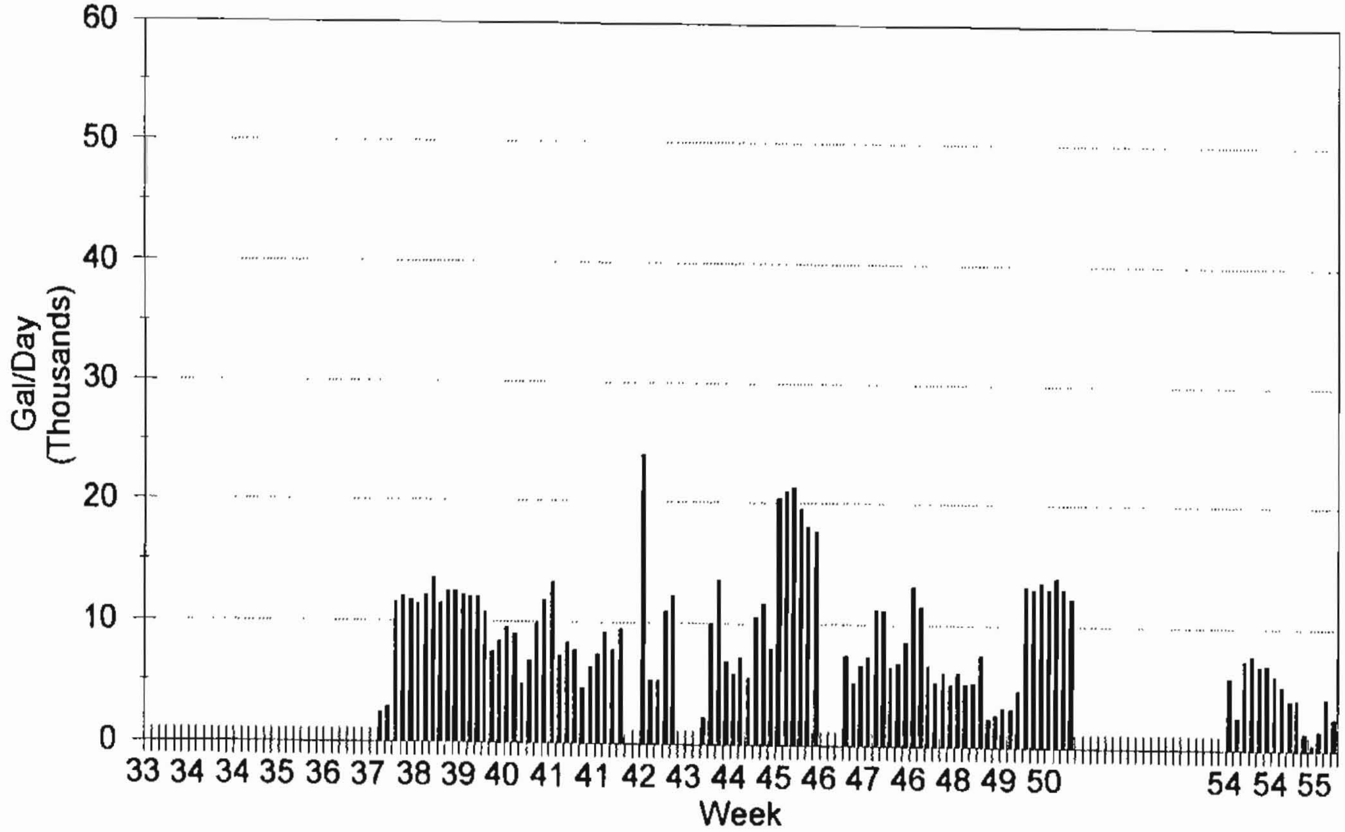


FIGURE 4-21

1. It could act as a facultative wastewater treatment lagoon within the emergent marsh system, which would enhance the efficiency of the nitrogen transformation in particular.

2. Given equal retention times, it would reduce by half the amount of time the water is exposed to organic loading by nesting and perching birds in the emergent marsh vegetation of the one-phase system.

Laboratory Water Quality Analyses. The following data analysis and discussion is limited to those data collected during Series 1A (i.e., during the period from May 5, 1993, when monitoring was resumed after the winter rains and flooding, through November 10, 1993, when all initial research cell monitoring was terminated). Series 1 data are not included because of the sparsity of the data and the long hiatus between Series 1 and 1A.

The paired sample t-test was selected as the statistical method for evaluating the water quality data and determining if there were significant differences between the laboratory chemical data for the three-phase and one-phase systems. Simply averaging the data for each system and comparing means would not take into account either the variance of the measurements or the number of samples used. The paired sample t-test takes these factors into consideration and can be used to determine if the differences between two sets of data, taken in pairs, are significant.

In the paired sample test, the "t" factor is calculated as the average of the differences between the pairs of measurements divided by the standard error of that set of differences. The "t" factor is then compared to the critical value of "t" for the degrees of freedom in the set and the desired level of significance. If the absolute value of a computed "t" value is found to be greater than the critical value, then the hypothesis is rejected. For the present analysis, the difference between the sets of paired data was hypothesized to be null, and the level of significance was set at 0.05, which means that rejecting the premise that the two data sets are the same would have less than 5 percent probability of being in error. The two-tailed critical "t" value was used in this analysis because a difference in either direction was considered to be grounds for rejecting the null hypothesis.

Summary tables of the Series 1A data, general statistics, and paired t-test results, for each of the following parameters, are included in Appendix A of this report.

Biochemical Oxygen Demand (BOD). BOD increased slightly in both the three-phase and the one-phase cells when outlet concentrations were compared with inlet concentrations (Figure 4-22). The average BOD for the inlet, three-phase outlets, and one-phase outlets were 4.9, 5.7, and 5.1 milligrams per liter (mg/L), respectively. The highest BOD concentration was 15 mg/L, observed in a three-phase outlet; the lowest BOD concentration was 1 mg/L, measured in the inlet. For the

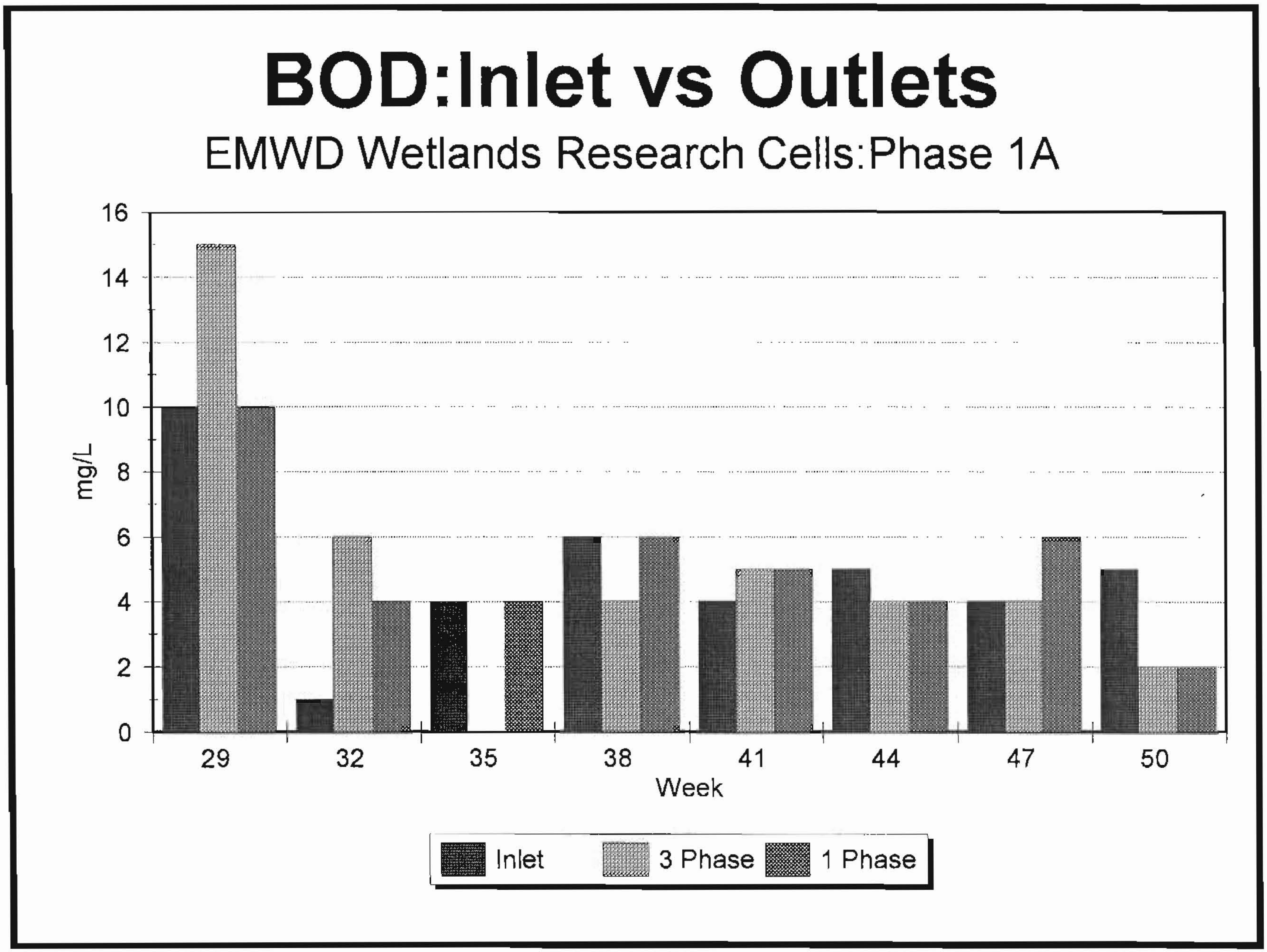

BOD:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
mg/L
16
14
12
10
8
6
4
2
0
29
32
35
38
41
44
47
50
Week
Inlet
3 Phase
1 Phase

FIGURE 4-22

three-phase cells, the increase in BOD over inlet concentrations amounted to 17.2 percent; for the one-phase cells, the corresponding increase was 5.1 percent.

The paired sample t-test, however, did not show either of these differences to be significant, due mainly to the small number of samples and the large variance in their values.

Considering the low BOD concentrations coming into the wetlands, it is not surprising that the outlet concentrations are somewhat higher. The increase in outlet BOD concentrations probably reflects organic production (i.e., assimilation of nutrients and shedding of organic material) within the wetlands. A "background" BOD of approximately 5 mg/L is probably the lower limit that can be expected from a wastewater treatment wetland.

Total Organic Carbon (TOC). TOC concentrations in the inlet, three-phase outlets, and one-phase outlets averaged 10.4, 11.7, and 11.1 mg/L, respectively (Figure 4-23). The highest concentration recorded was 17 mg/L, in a one-phase outlet, and the lowest was 5.2 mg/L, also in a one-phase outlet. As with BOD, average TOC concentrations showed a slight increase in the outlets of both types of cells compared with the inlet. The average TOC increase was 12.4 percent in the three-phase systems and 6.4 percent in the one-phase, neither of which the paired sample t-test indicated to be statistically significant. The slight apparent increase in TOC concentrations in the research cell outlets probably reflects the same internal production noted in the previous discussion of BOD.

Total Suspended Solids (TSS). TSS results were skewed by one inlet sample that contained a very high concentration (25 mg/L) compared with the average concentration of 10 mg/L (Figure 4-24). Without that one sample, the results would have shown an increase in TSS concentrations in the three-phase cells. The highest TSS was 25 mg/L, in an inlet, and the lowest was 3 mg/L, in a one-phase cell outlet. Average TSS concentrations for the inlet, three-phase outlets, and one-phase outlets were 10, 8.4, and 4.6 mg/L, respectively. The paired t-test did not indicate any significant differences between inlet and outlet TSS concentrations, once again because of high variance in the inlet samples and the small total number of samples. There was, however, a significant difference between the three-phase and one-phase outlets, but this result does not take into consideration the poor accuracy of the TSS analytical method at these low concentrations.

Visual inspection of the graphed data suggests that there may have been a decline in TSS during Series 1A. It is interesting that the graphed turbidity data also suggest a decline. If such declines actually occurred, they may have been due to seasonal phenomena or due to conditions in the research cells stabilizing. More monitoring of

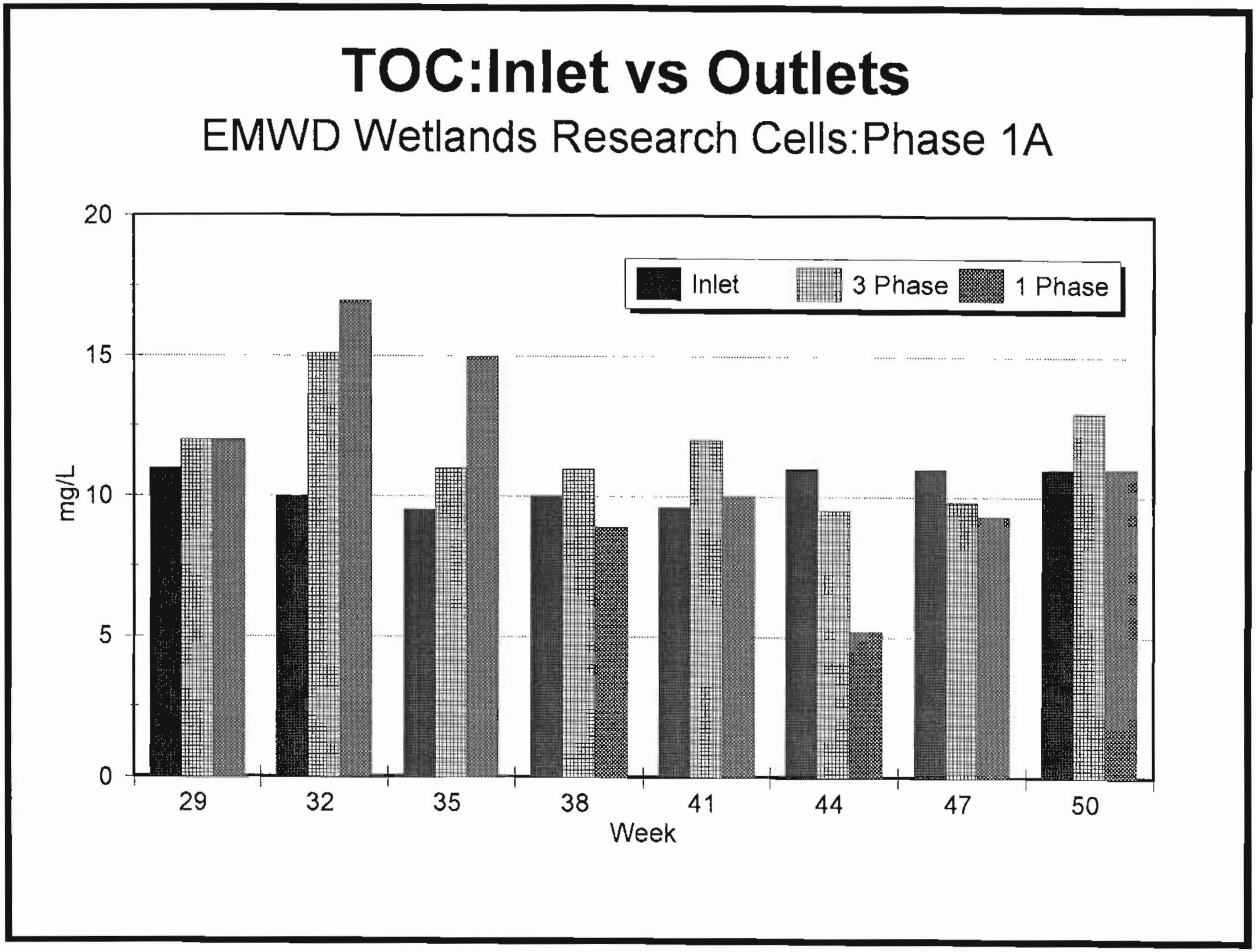

TOC:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
Inlet
3 Phase
1 Phase
20
15
10
5
0
mg/L
29
32
35
38
41
44
47
50
Week

FIGURE 4-23

TSS:Inlet vs Outlets

EMWD Wetlands Research Cells:Phase 1A

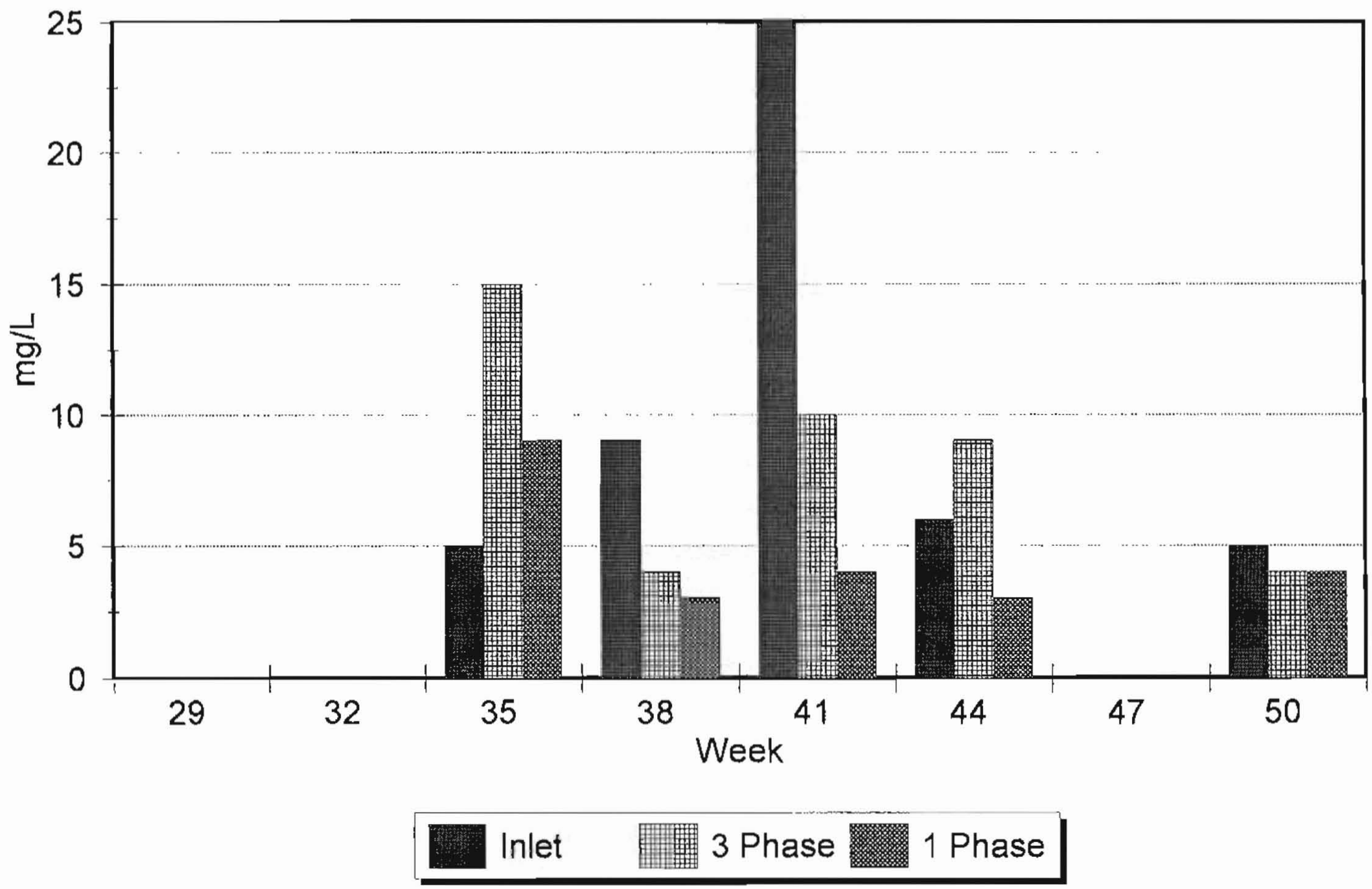


FIGURE 4-24

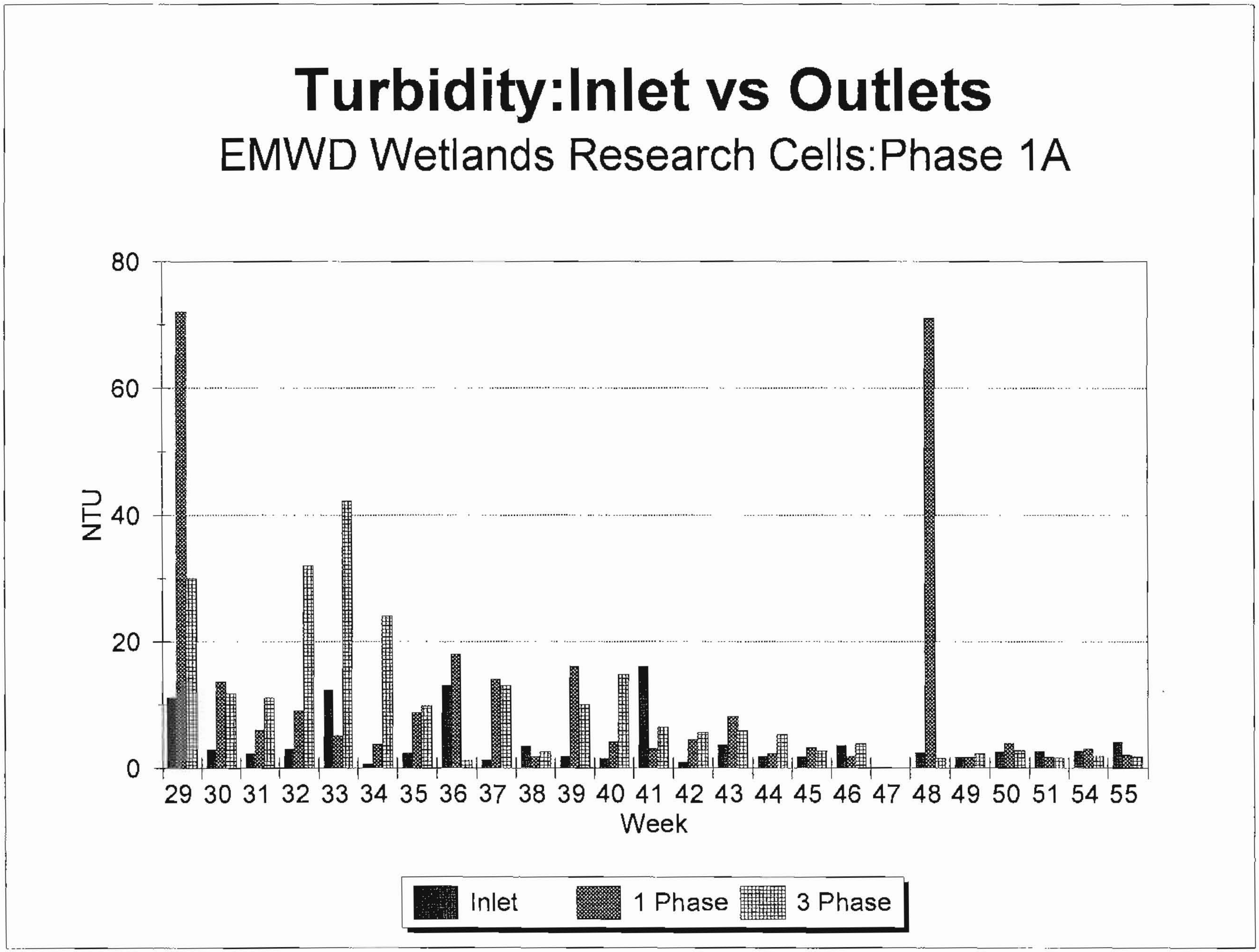
effluent suspended solids is needed before any definite conclusions can be reached in a comparison between the three-phase and one-phase systems or between the inlet and outlets.

Turbidity. Turbidity increased in both the three-phase and one-phase outlets compared with inlet turbidity levels (Figure 4-25). The average increase over inlet values was 148 percent for the three-phase system and 183 percent for the one-phase system. Turbidity averaged 4.1, 10.2, and 11.6 nephelometric turbidity units in the inlet, three-phase, and one-phase systems, respectively. The difference between the three-phase and one-phase systems was not significant. Three-phase outlet turbidity did differ significantly from the inlet turbidity, and, although the t-test did not show a significant difference for the one-phase outlets compared with the inlet, the computed "t" value was nearly equal to the critical value.

Graphed turbidity data for the outlets suggest a general trend toward lower turbidities during Series 1A, but this trend was punctuated, at times, with very high values, mostly in the one-phase cells. Speculation as to the cause of the various high turbidity readings has included algae, chemical leachate from the soil reacting with something in the water, decaying plant matter, bacteria, fungus, bird droppings, and/or any combination of these. Microscopic examination for algae, which was suspected because the gray-green color of the water, showed that not only was algae not a factor but that there was a conspicuous absence of algae in the samples. Further microscopic examination, involving fixing and staining a slide, revealed a preponderance of filamentous bacteria resembling varieties commonly found in the treatment plant (e.g., Beggiotoa and Sphaerotilus). This suggested a highly eutrophic environment.

In later January 1994, a white slime was observed on the weirs and outlet boxes of the one-phase cells, and turbidity in these cells was also observed to be much higher than usual. It was hypothesized that the source of the white slime might be the large number of birds producing fecal matter, coupled with recent rains that washed it off the bulrush and into the water. This could have been exacerbated by recent cold weather which may have lowered microbial activity enough so that the uric acid in the fecal matter was not decomposed. If this were the case, the white slime should have had a high nitrogen content. A sample of the slime was taken to the EMWD lab and analyzed for total Kjeldahl nitrogen (TKN). The slime sample was found to have a TKN of 2800 mg/L, compared to an inlet TKN of 24 mg/L, 32 mg/L at the midpoint of the cell, and 36 mg/L at the outlet. The hypothesis that the white slime was uric acid seemed to be supported by the laboratory analytical results.

Total and Fecal Coliforms. During duck hunting season, which usually spans the period from October to January, reclaimed water sold to the neighboring duck clubs must be disinfected so all secondary effluent from the treatment plant is chlorinated before it is released. To protect the wetland research cells from being



Turbidity:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
NTU
80
60
40
20
0
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 54 55
Week
Inlet
1 Phase
3 Phase

FIGURE 4-25

directly chlorinated during this period, secondary effluent being sent to the facility was dechlorinated with sodium bisulfite. A dechlorination unit was installed which could handle residual chlorine levels of up to 10 mg/L. When the residual chlorine level was expected to rise above the 10 mg/L level, flow into the research cells was halted until chlorination returned to a level the dechlorination unit could handle. Fecal and total coliform samples collected from the inlets during this period, which coincided with the later part of Series 1A, were not comparable to the earlier undisinfected samples.

A total of eight samples were analyzed for total and fecal coliforms during Series 1A (Figures 4-26 and 4-27, respectively); two of these samples had been chlorinated and then dechlorinated. Included in the graphs and analyses are two sets of data: one with the chlorinated samples included and one without them. Total coliform counts in the three-phase outlets averaged 97.7 percent less than inlet counts when the chlorinated samples were not included. Fecal coliform counts in the three-phase outlets averaged 98.6 percent less than inlet counts with the chlorinated samples included and 99.3 percent less without them. The one-phase outlet total coliform counts averaged 83.4 percent less than inlet counts when the chlorinated samples were included (93.0 percent less than inlet counts overall) and 92.5 percent less when the chlorinated samples were excluded. The small number of samples and the high variability of the results cast some doubt on any conclusions that might be drawn from these data. Despite the high average differences between inlet and outlet coliform counts, paired t-tests indicated only marginal significance.

Nitrogen.

Ammonium Nitrogen (NH_4-N). Twenty-five samples were analyzed for ammonium nitrogen concentrations (Figure 4-28). Ammonium is the major form of nitrogen in the reclaimed water coming into the wetland research facility, with an average inlet concentration during Series 1A of 11.7 mg/L. Mean outlet concentrations were 5.7 mg/L for the three-phase systems and 13.4 mg/L for the one-phase systems. Compared with the inflow concentrations, then, the three-phase systems decreased NH_4-N by an average of 51.6 percent, while the one-phase systems actually increased NH_4-N by 14.6 percent on average. Paired t-tests indicated that the differences between the three-phase outlets and the inlet and between the outlets of the two types of cells were statistically significant; however, the outlet concentrations of the one-phase systems were not found to be significantly different from the inlet concentrations.

Nitrite Nitrogen (NO_2-N). Due to the dynamic nature of this form of nitrogen and its rapid oxidation to nitrate under aerobic conditions, it would be incorrect to talk about "removal" of nitrite. Nitrite nitrogen concentrations in the inlet samples were relatively high (Figure 4-29) because the reclaimed water was relatively anoxic when it entered the research cells. The inlets averaged

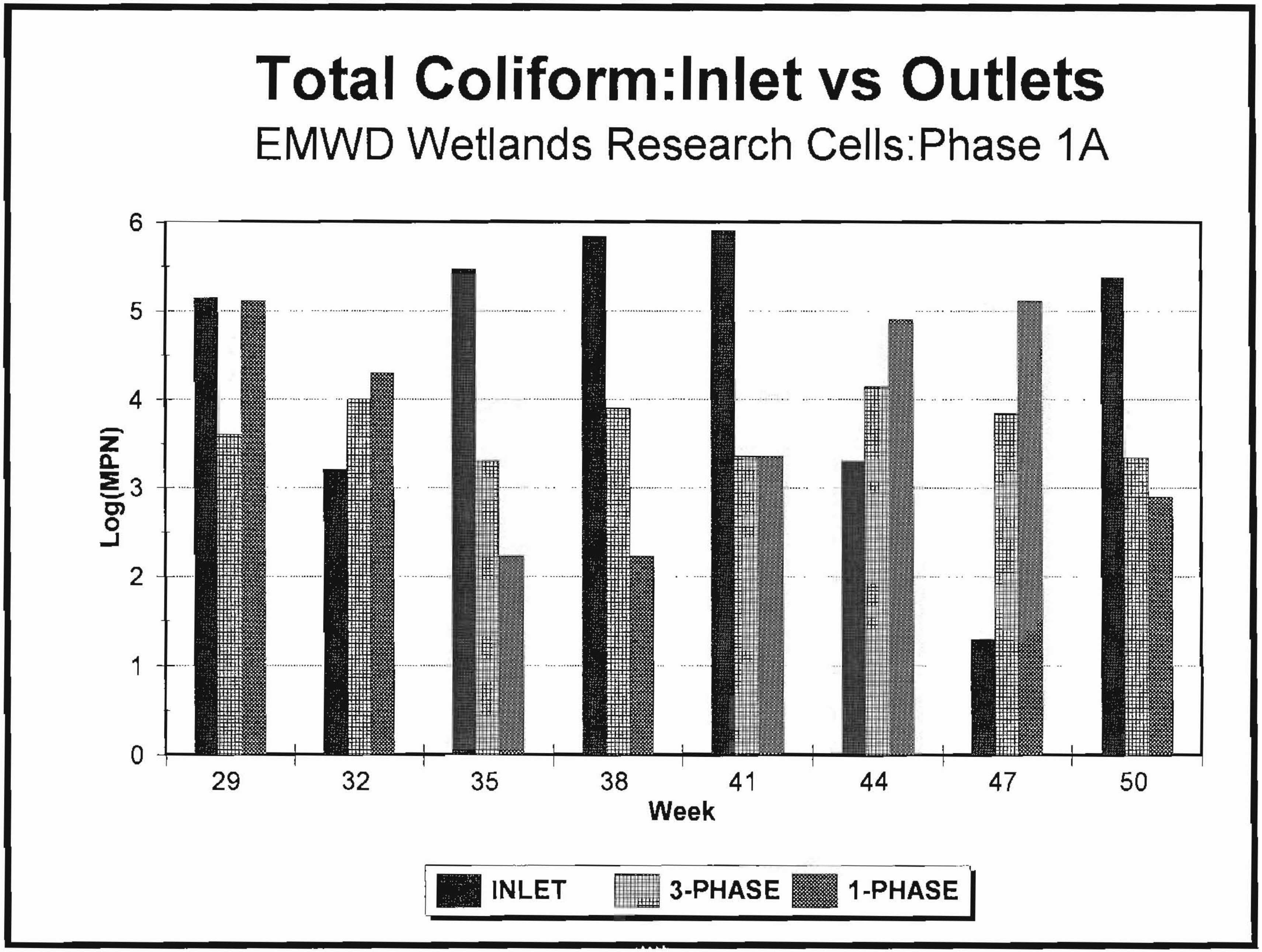
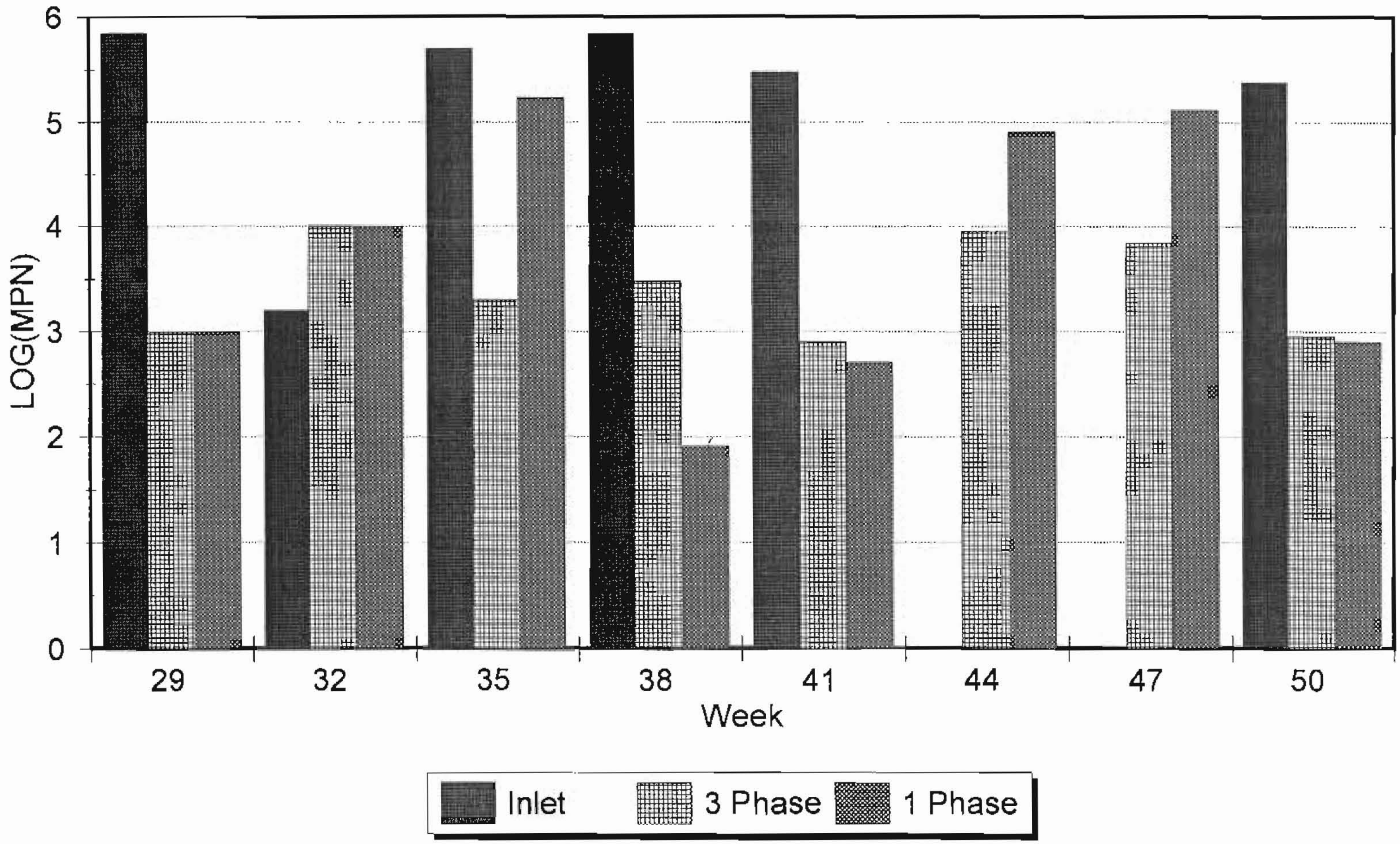

Total Coliform:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
Log(MPN)
0
1
2
3
4
5
6
29
32
35
38
41
44
47
50
Week
INLET
3-PHASE
1-PHASE

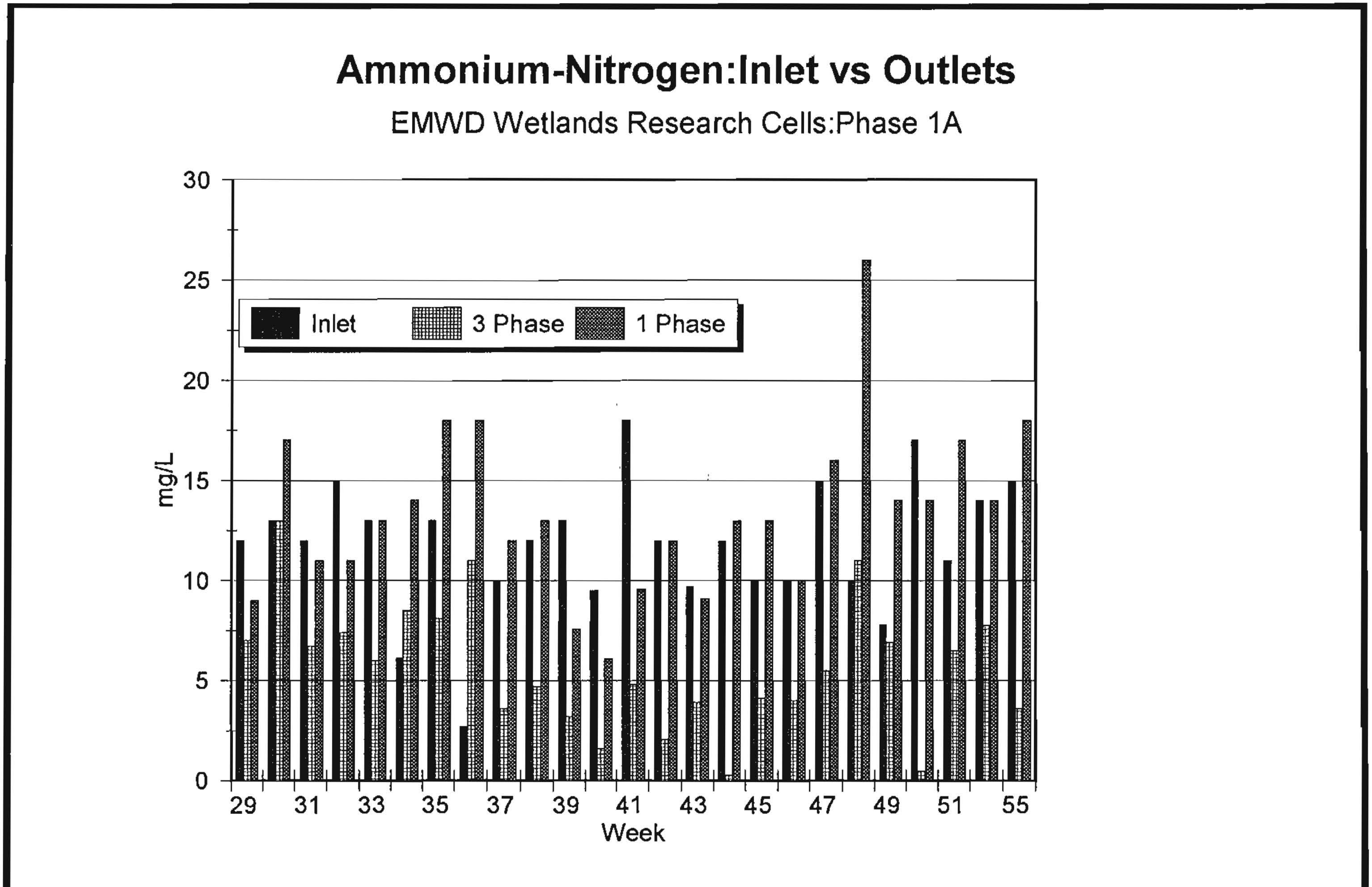
FIGURE 4-26

FIGURE 4-27

Fecal Coliform:Inlet vs Outlets

EMWD Wetlands Research Cells:Series 1A





Ammonium-Nitrogen:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
Inlet
3 Phase
1 Phase
mg/L
30
25
20
15
10
5
0
29
31
33
35
37
39
41
43
45
47
49
51
55
Week

FIGURE 4-28

Nitrite-Nitrogen:Inlet vs Outlets

EMWD Wetlands Research Cells:Phase 1A

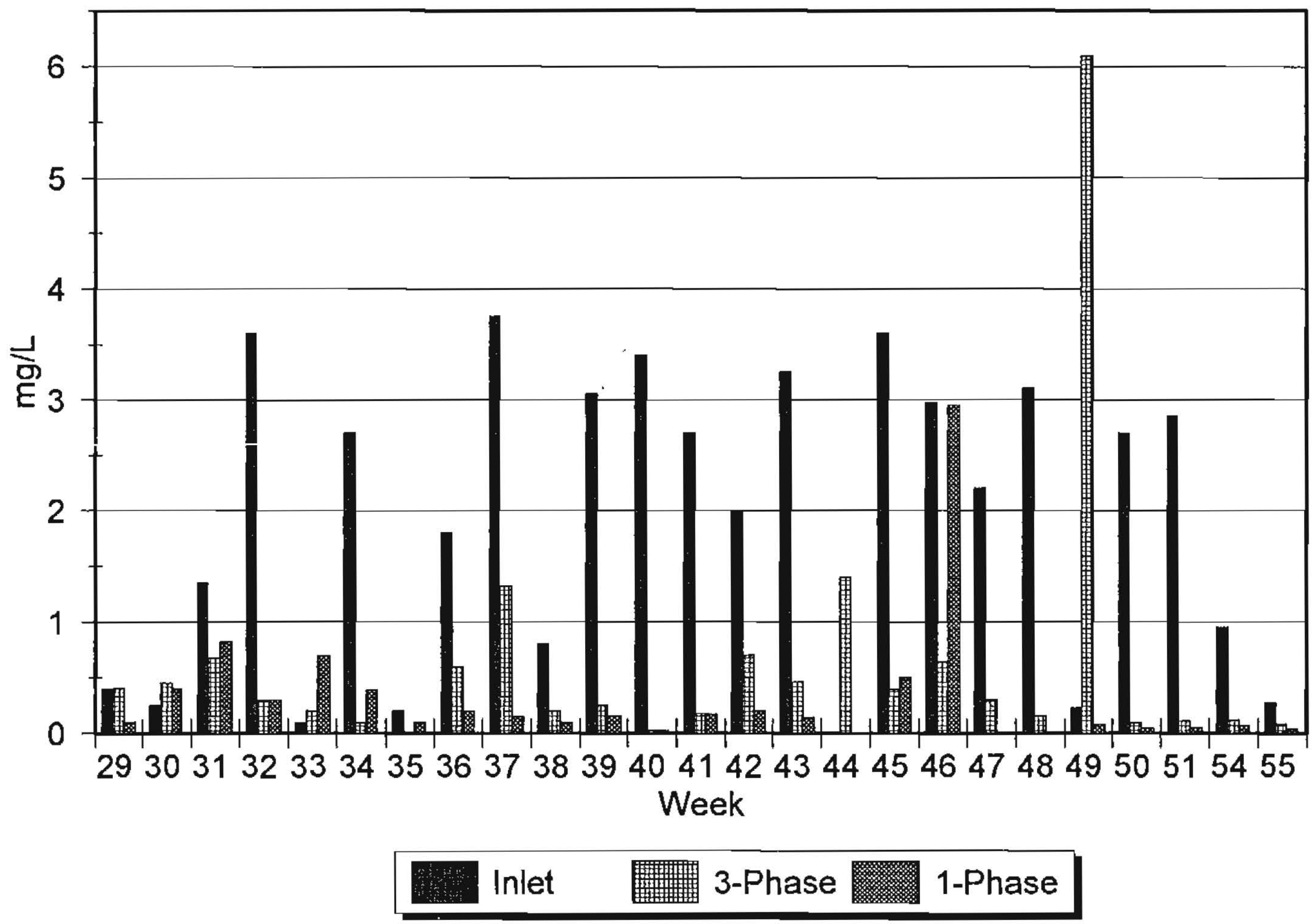


FIGURE 4-29

1.93 NO_2-N mg/L, the three-phase outlets averaged 0.61 mg/L, and the one-phase outlets averaged 0.31 mg/L. The three-phase and one-phase outlet concentrations were not significantly different from each other, but the differences between the outlet and inlet concentrations in both systems were statistically significant.

Nitrate Nitrogen (NO_3-N). Nitrate nitrogen concentrations averaged 0.8 mg/L in the inlet samples, 0.8 mg/L in the three-phase outlets, and 0.6 mg/L in the one-phase outlets (Figure 4-30).

Total Inorganic Nitrogen (TIN). There were 25 samples that could be analyzed as TIN (i.e., NH_4-N + NO_2-N + NO_3-N) (Figure 4-31). When total inorganic nitrogen concentrations are considered, the data show an average increase of 1.2 percent in the one-phase outlets and an average decrease of 60.6 percent in the three-phase outlets, compared with the inlet concentration. It is clear that these TIN removal efficiencies are largely influenced by the difference in the ability of the two systems to decrease ammonium nitrogen concentrations relative to inlet concentrations.

Total Kjeldahl Nitrogen (TKN). Seven samples were analyzed for TKN (Figure 4-32). The three-phase outlet concentrations averaged 58.5 percent less and the one-phase outlet concentrations 3.5 percent less than inlet concentrations. When TKN is broken down into organic-N and NH_4-N, it is apparent that the difference between the two systems is in NH_4-N concentrations. Outlet organic-N concentrations in both systems showed small average increases compared with the inlet concentrations. While this apparent increase in organic-N may reflect a variety of internal and/or external nitrogen sources, it may also reflect assimilation of inorganic nitrogen and subsequent shedding of organic material by the biotic communities within the cells.

Total Nitrogen. The seven samples that were analyzed for TKN were also used to calculate total nitrogen concentrations (i.e., total inorganic nitrogen plus organic nitrogen) (Figure 4-33). For these samples, the three-phase outlet concentrations averaged 57.7 percent less than inlet concentrations, while the one-phase outlet concentrations averaged 11.1 percent less than inlet concentrations. The paired t-test results indicated no significant difference between the one-phase outlet and inlet concentrations. Three-phase outlet and inlet concentrations, however, were significantly different. Once again, it is clear that it was the differing ability of the two systems to handle ammonium nitrogen that accounted for the difference in total nitrogen concentrations in the outlets relative to the inlet.

The sequence of bacterially-mediated nitrogen transformations is as follows:

$$\text{Organic-N} \rightarrow NH_4 \rightarrow NO_2 \rightarrow NO_3 \rightarrow N_2O\uparrow \rightarrow N_2\uparrow$$

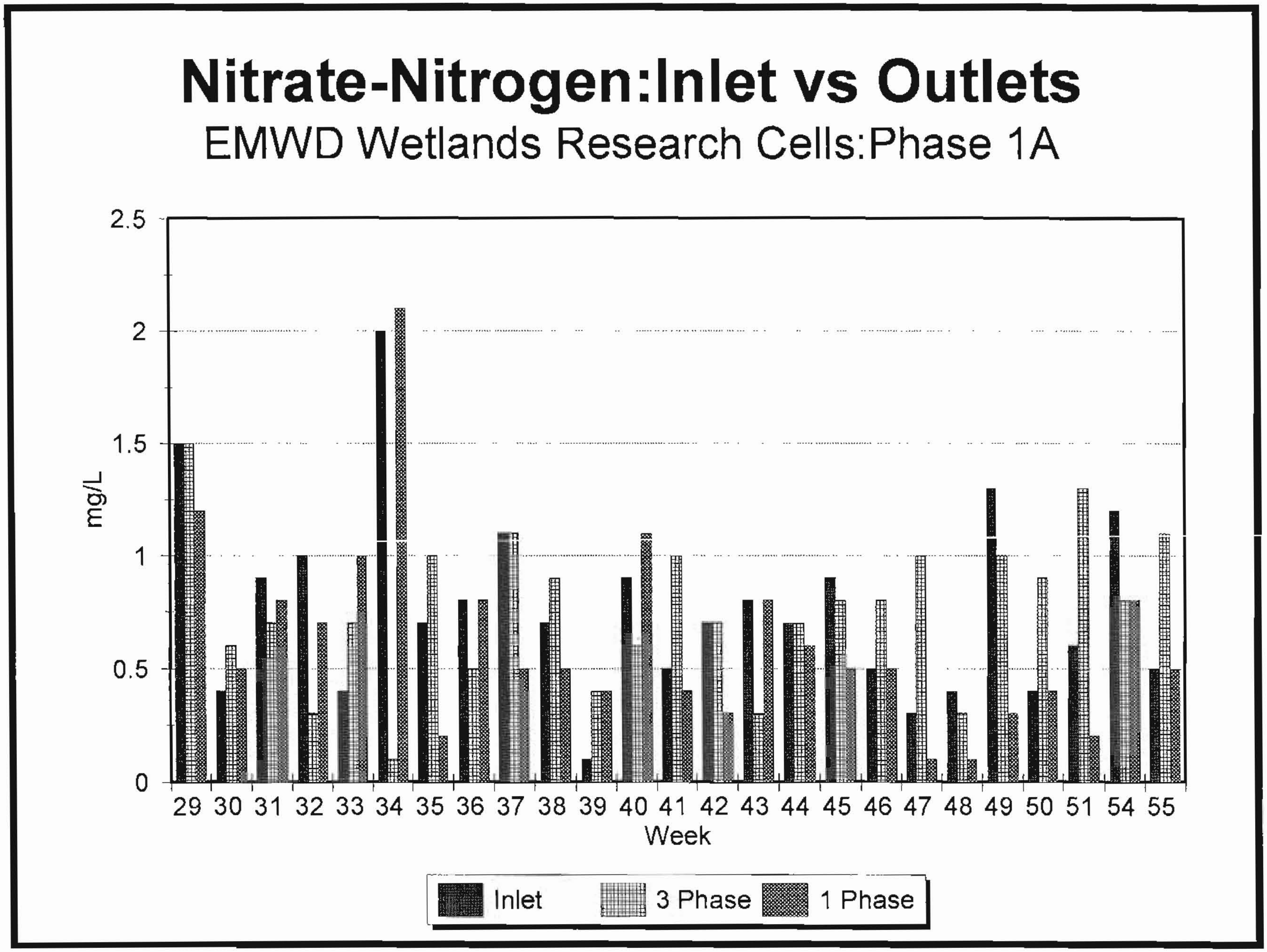

Nitrate-Nitrogen:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
mg/L
2.5
2
1.5
1
0.5
0
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 54 55
Week
Inlet
3 Phase
1 Phase

FIGURE 4-30

The first step is the "ammonification", or reduction, of nitrogenous organic material to ammonium nitrogen. This process involves both aerobic and anaerobic bacteria. Organic nitrogen material added to a wetland, from whatever source, will eventually break down and contribute to the ammonium load of the wetland and, thus, affect the ammonium concentrations in the wetland.

The next two steps are the "nitrification", or oxidation, of ammonium to nitrite and then to nitrate. This process requires free oxygen and, therefore, takes place under aerobic conditions. It appears that the pool component is the key factor in the three-phase systems' demonstrated ability to decrease ammonium nitrogen concentrations relative to the inlet concentrations.

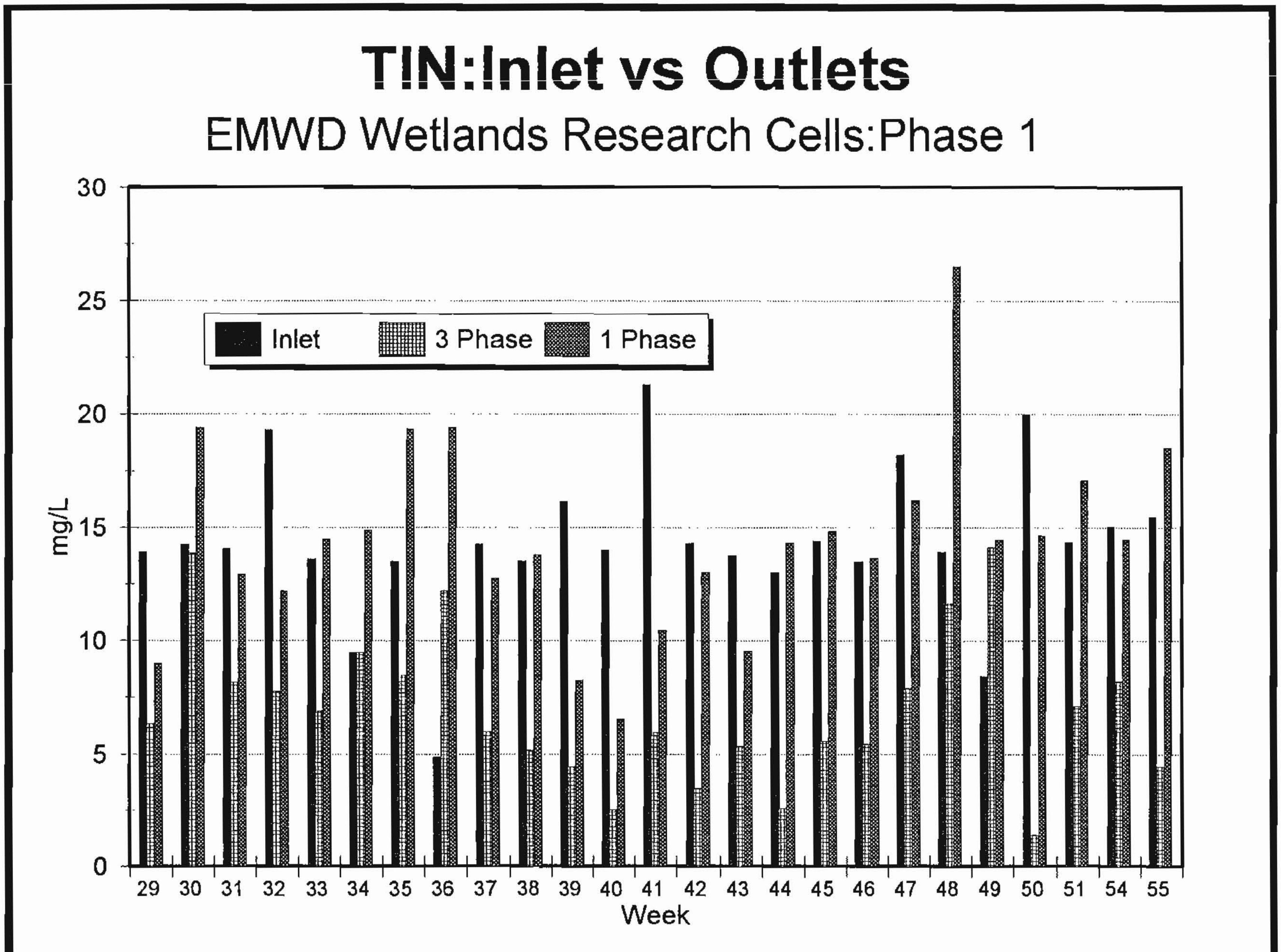
The last two steps in the sequence are the "denitrification", or reduction, of nitrate to nitrogen oxide and elemental nitrogen gases. This process takes place under anaerobic conditions and requires the simultaneous oxidation of carbon to remove the oxygen from the nitrogen ions. Denitrification is the ultimate step in removing nitrogen from the reclaimed water into the atmosphere. It is likely that most denitrification in both systems takes place in the anoxic to anaerobic areas of the marsh components. The longer marsh retention time in the one-phase systems could account for the apparent greater decrease in nitrate in the one-phase versus the three-phase systems.

It is important to note, however, that it will be necessary to use flow-weighted nitrogen budgets, taking into account retention times, to adequately address the questions of how much nitrogen is actually being removed and whether or not nitrogen loading other than that through the inlets is having a significant impact on the nitrogen dynamics of the two types of wetland systems. Bird exclusion experiments might also be useful in determining the impact of bird usage of marshes on nitrogen budgets.

Phosphorus.

Total Phosphorus (TP). Eight samples were analyzed for TP during Series 1A (Figure 4-34). Average concentrations were 4.0 mg/L in the inlet, 5.4 mg/L in the three-phase outlets, and 4.9 mg/L in the one-phase outlets. The three-phase systems averaged a 33.8 percent increase and the one-phase systems a 23.1 percent increase in TP concentration relative to the inlet concentration. Both system outlet concentrations were significantly greater than the inlet concentrations, but the outlet concentrations did not differ significantly from each other.

The significant increase in TP concentrations from inlet to outlet in each of the wetland systems suggests that phosphorus is being added to the systems from some source other than the inflow. Two likely candidates for this source during Series 1A are leaching from the sediments and bird droppings, which contain relatively high



TIN:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1
Inlet
3 Phase
1 Phase
mg/L
30
25
20
15
10
5
0
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 54 55
Week

FIGURE 4-31

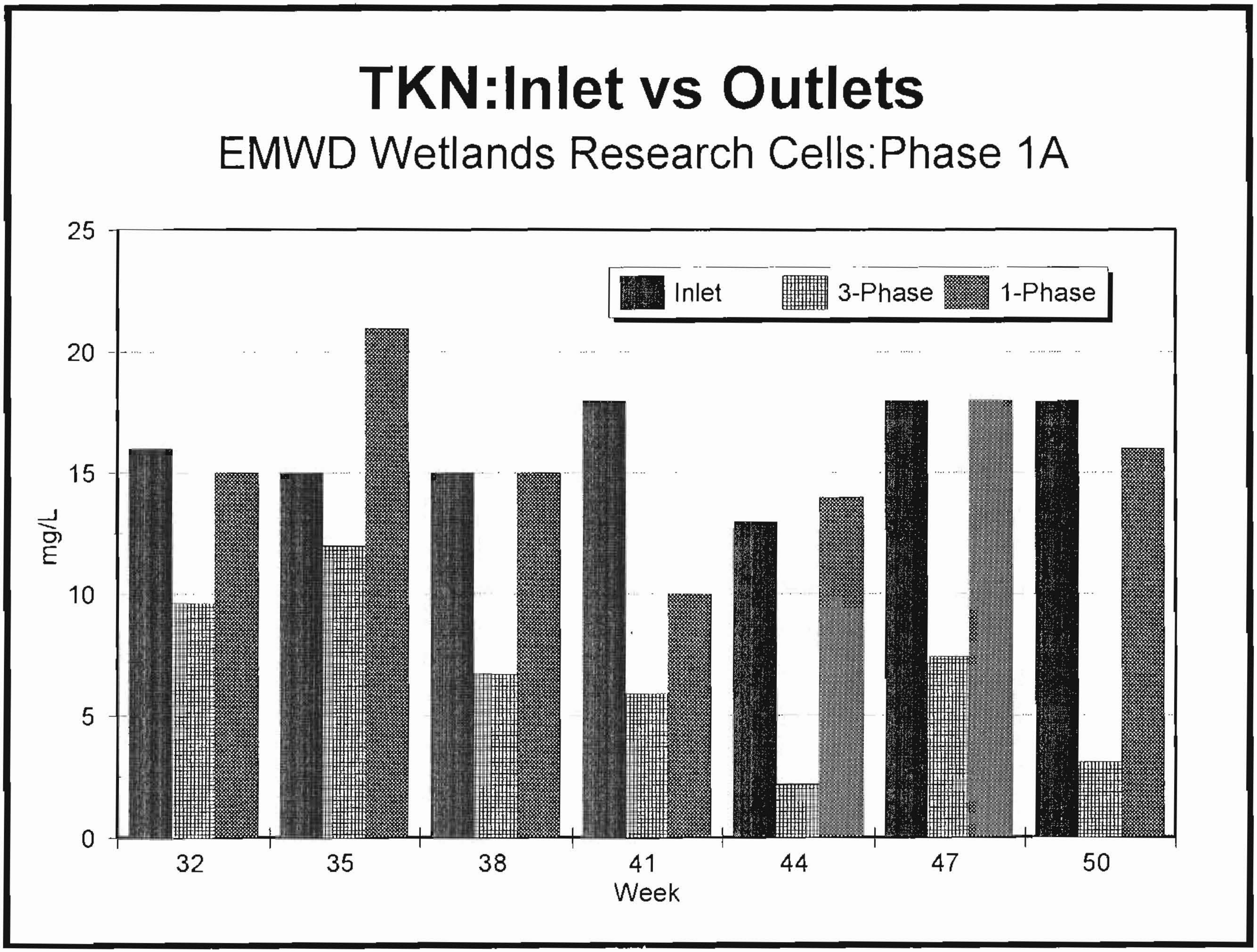

TKN:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
Inlet
3-Phase
1-Phase
mg/L
0
5
10
15
20
25
32
35
38
41
44
47
50
Week

FIGURE 4-32

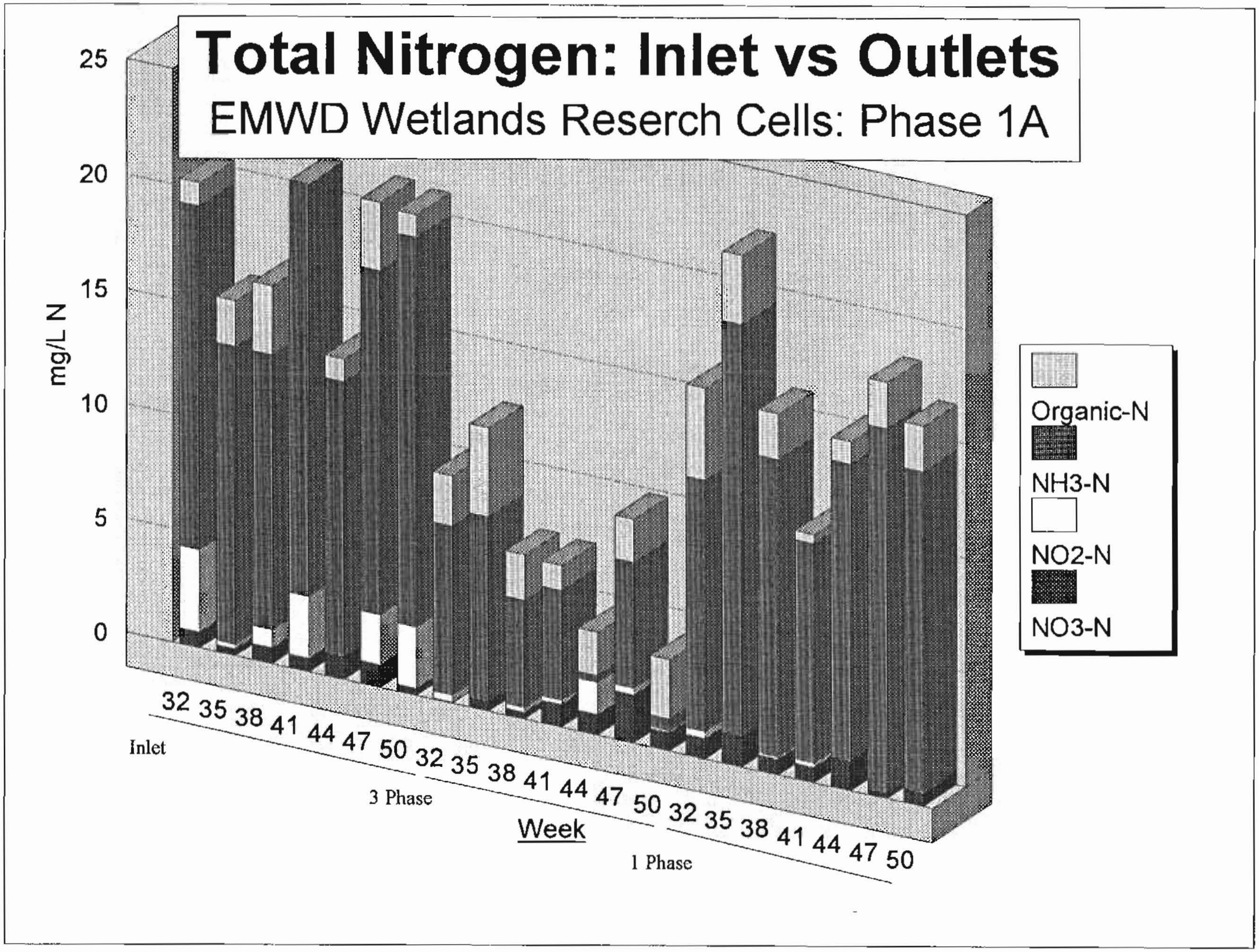

Total Nitrogen: Inlet vs Outlets
EMWD Wetlands Reserch Cells: Phase 1A
mg/L N
25
20
15
10
5
0
32 35 38 41 44 47 50 32 35 38 41 44 47 50 32 35 38 41 44 47 50
Inlet
3 Phase
1 Phase
Week
Organic-N
NH3-N
NO2-N
NO3-N

FIGURE 4-33

Total Phosphorus:Inlet vs Outlets

EMWD Wetlands Research Cells:Phase 1A

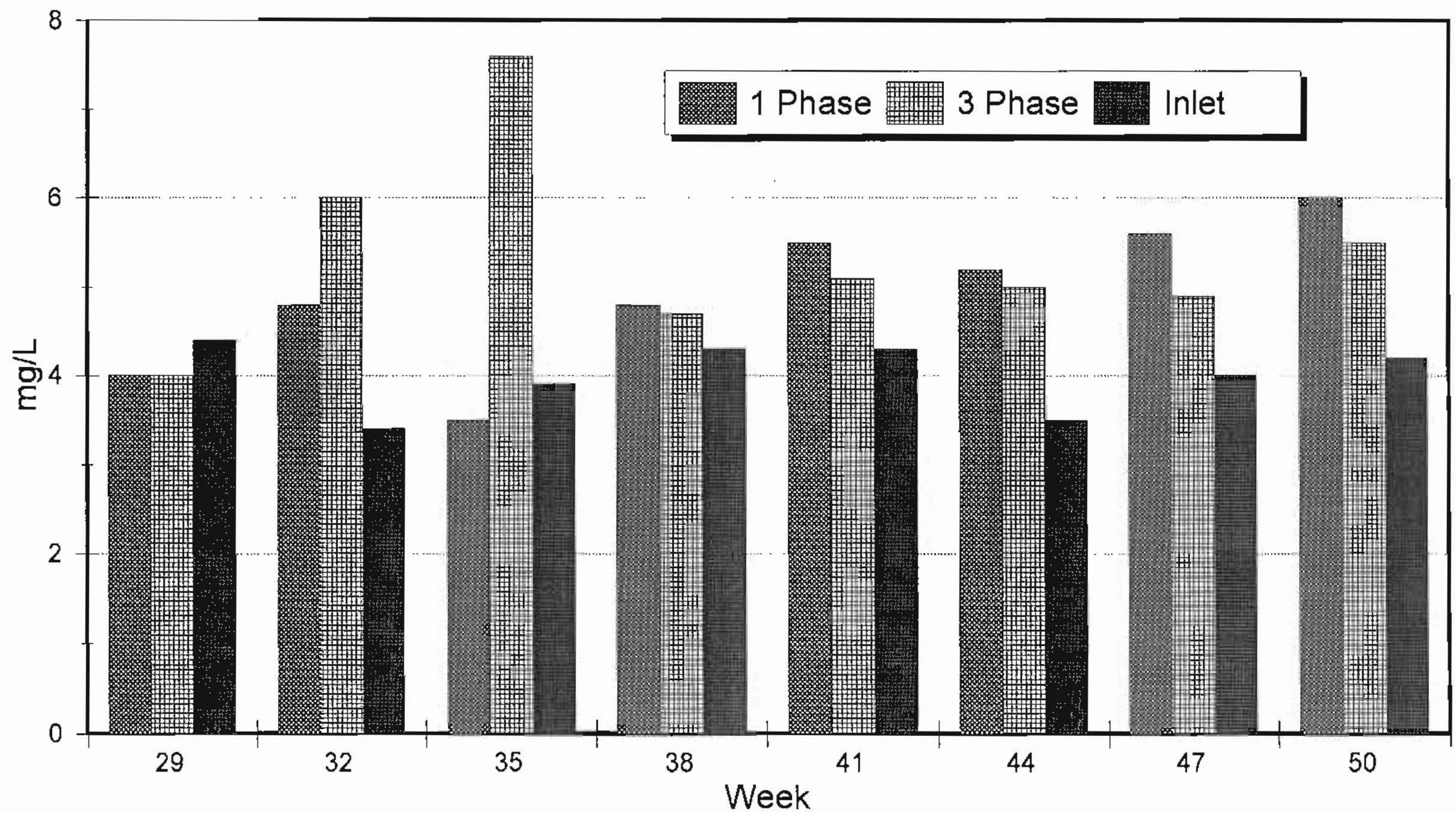


FIGURE 4-34

amounts of phosphorus. The rather consistent difference between inlet and outlet concentrations (Figure 4-34) and the long period of time that the cells were flooded before Series 1A sampling began would favor bird droppings as the source. Comparing observations of bird usage of the marshes to flow-weighted TP budgets and/or bird exclusion experiments would go far toward resolving the question of bird impact on wetland phosphorus dynamics.

Orthophosphate Phosphorus (PO_4-P). Twenty-five samples were analyzed for PO_4-P during Series 1A (Figure 4-35). For these 25 samples, the PO_4-P concentrations averaged 3.3 mg/L in the inlet, 4.3 mg/L in the three-phase outlets, and 5.3 mg/L in the one-phase outlets. The 30.9 percent increase in three-phase outlet concentrations and the 62.3 percent increase in one-phase outlet concentrations, relative to the inlet concentrations, were both statistically significant. Three-phase and one-phase outlet concentrations were also significantly different.

Orthophosphate is the inorganic phosphorus form that is most readily available for plant uptake. This fraction of the TP concentration would be expected to increase under anoxic conditions. Eight of the 25 samples were also analyzed for TP, and, for these eight samples, the PO_4-P concentrations averaged 3.3 mg/L in the inlet, 4.4 mg/L in the three-phase outlets, and 4.5 mg/L in the one-phase outlets. As percentages of the mean TP concentrations, these average PO_4-P concentrations become 83.4 percent of TP in the inlet, 81.8 percent of TP in the three-phase outlets, and 92.1 percent of TP in the one-phase outlets. The high percentage of the TP concentration in the orthophosphate form suggests relatively anoxic conditions in the one-phase systems; this observation seems consistent with the previous discussion of greater apparent nitrate removal in these same systems.

Invertebrates. Invertebrates were sampled within the research cells in April, July, and November 1993. It was intended that artificial substrates would be retrieved from inlet, middle, and outlet portions of each of cells 1, 2, 5, and 6. However, substrates were successfully retrieved only from some locations within both sets of cells, and sweep net samples were taken in place of collection of artificial substrates. The sampling schedule is presented in Table 4-4.

TABLE 4-4. SAMPLING DATES FOR BENTHIC MACROINVERTEBRATES
Samples were collected from the Hemet research cells via artificial substrates (AS) and via use of a sweep net (SN). Note that during July sampling, both methods were used at four sampling locations.

Sampling Date	One-phase system						Three-phase system					
	Cell 5			Cell 6			Cell 1			Cell 2		
	I	M	O	I	M	O	I	M	O	I	M	O
April 1993	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS	AS
July 1993	AS		AS SN	AS		AS SN	AS	AS SN	AS	AS	AS SN	AS
November 1993	SN	SN	AS	SN	SN	AS	SN	AS	SN	SN	AS	SN

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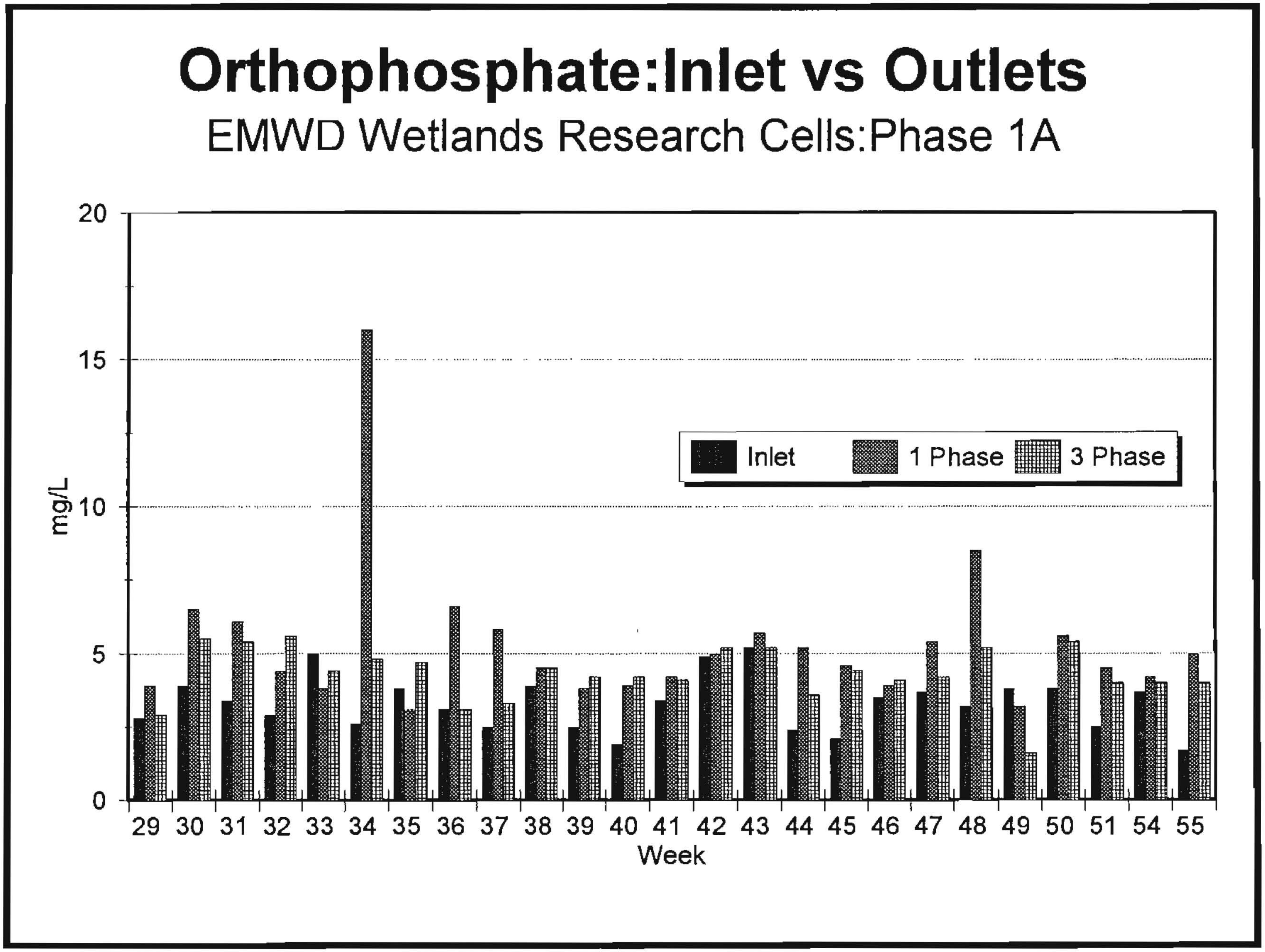

Orthophosphate:Inlet vs Outlets
EMWD Wetlands Research Cells:Phase 1A
mg/L
0
5
10
15
20
Inlet
1 Phase
3 Phase
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 54 55
Week

FIGURE 4-35

A total of 24 taxa were identified from the artificial substrate and sweep net samples (Table 4-5). The highest number recorded in any type of cell during a particular sampling period was 15. Eight taxa were relatively common in the artificial substrates. These included aquatic earthworms, snails, midges, and ostracods (seed shrimp). Representative count data for two of these species are shown in Figures 4-36 and 4-37. Predaceous diving beetles, water fleas, biting midges, and mosquitos were less common. Mean counts of mosquito larvae within the research cells on each quarterly sampling visit are shown in Table 4-6. The complete set of research cell invertebrate data is presented in Appendix A.

In all cases where the July sampling included both collection of an artificial substrate and use of the sweep net, the sweep net collections contained more taxa (cell 5: 13 vs. 7; cell 6: 10 vs. 4; cell 1: 12 vs. 4; cell 2: 11 vs. 3). Because of the poor ability to quantify the sweep net sampling compared to the artificial substrate sampling, plus the great likelihood that different portions of the system were being sampled, comparison across methods should generally be avoided. For example, the abundances of taxa common to both collections were usually greater in the sweep net samples, but actual densities may be more accurately reflected in the artificial substrate samples.

The total number of benthic macroinvertebrate species collected within the cells (richness) showed a continuous decline between the first sample in April and the last in November, whether based on artificial substrates or on sweep net samples (Figure 4-38).

The number of invertebrate species that were present in the research cells but escaped collection is unknown. Flatworms were noted during the November mosquito sampling in cells 2 and 4 (outlet area). None were collected in the artificial substrate or sweep net samples. Aquatic vertebrates were present in the cells, but no attempt was made to sample them in even a qualitative manner. At least one species of frog was noted present in one cell, and small fish were noted present in several cells. These two species are likely present in all eight research cells, but their distribution has not yet been confirmed. Fish, probably Gambusia sp., were added to some or all research cells by EMWD personnel.

Sediments. A complete year of data has been collected, including the second set of annually-monitored parameters. The trends and potential concerns which have been observed regarding (1) the fate of toxic constituents; (2) nutrient availability; (3) denitrification; and (4) phosphorus removal are described. Tables 4-7 and 4-8 summarize the results of sediment sampling, and additional new data are on file at EMWD offices in San Jacinto, California.

Fate of Toxic Constituents. Baseline sampling indicated that all trace elements in the substrate were well within acceptable limits. Therefore, it was considered

TABLE 4-5

Invertebrates collected at EMWD constructed wetland research sites during 1993 by sampling via artificial substrates and sweep net.

TAXON ID NO.	TAXONOMIC GROUP			COMMON NAME
1	ANNELIDA	OLIGOCHAETA		Aquatic earthworm
2	ANNELIDA	HIRUDINEA		Leech
3	ARACHNDIDEA	HYDRACARINA		Mite
4	COLEOPTERA	DYTISCIDAE		Predaceous diving beetle
5	COLEOPTERA	HYDROPHILIDAE		Water scavenger beetle
6	COLEOPTERA	STAPHYLINIDAE		Aquatic rove beetle
15	COLLEMBOLA			Springtail
20	CRUSTACEA	CLADOCERA		Water flea
21	CRUSTACEA	COPEPODA		Copepod
22	CRUSTACEA	AMPHIPODA	Gammarus	Scud
30	DIPTERA	CERATAPOGONIDAE		Biting midge
31	DIPTERA	CHIRONOMIDAE		Midge
34	DIPTERA	CULICIDAE	Culex	Mosquito
35	DIPTERA	CULICIDAE	Anopheles	Mosquito
40	EPHEMEROPTERA	BAETIDAE		Mayfly
50	GASTROPODA			Snail
60	HEMIPTERA	CORIXIDAE		Water boatman
61	HEMIPTERA	NAUCORIDAE		Creeping water bug
62	HEMIPTERA	NOTONECTIDAE		Back swimmer
70	LEPIDOPTERA			Aquatic caterpillar
80	ODONATA	ANISOPTERA		Dragonfly
81	ODONATA	ZYGOPTERA		Damselfly
90	OSTRACODA			Seed shrimp
99	PELECYPODA			Bivalve clam

TABLE 4-6

Sampling Date	Mean count of mosquito larvae									
	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 6	CELL 7	CELL 8	Mean for all cells	Comments
20 Oct 92	0	0	0	0	0	0	0	0	0	North nursery cell loaded with mosquito larvae
29 Apr 93	0	0	0	0	0	0	0	0	0	
3 Nov 93	0.4	1.2	1.0	0	0.2	7.8	0.6	1.4	1.6	

Mean count of mosquito larvae within Research Cells on the three quarterly sampling visits. Each cell was sampled in five locations with a standard sampling cup during each visit.

FIGURE 4-36

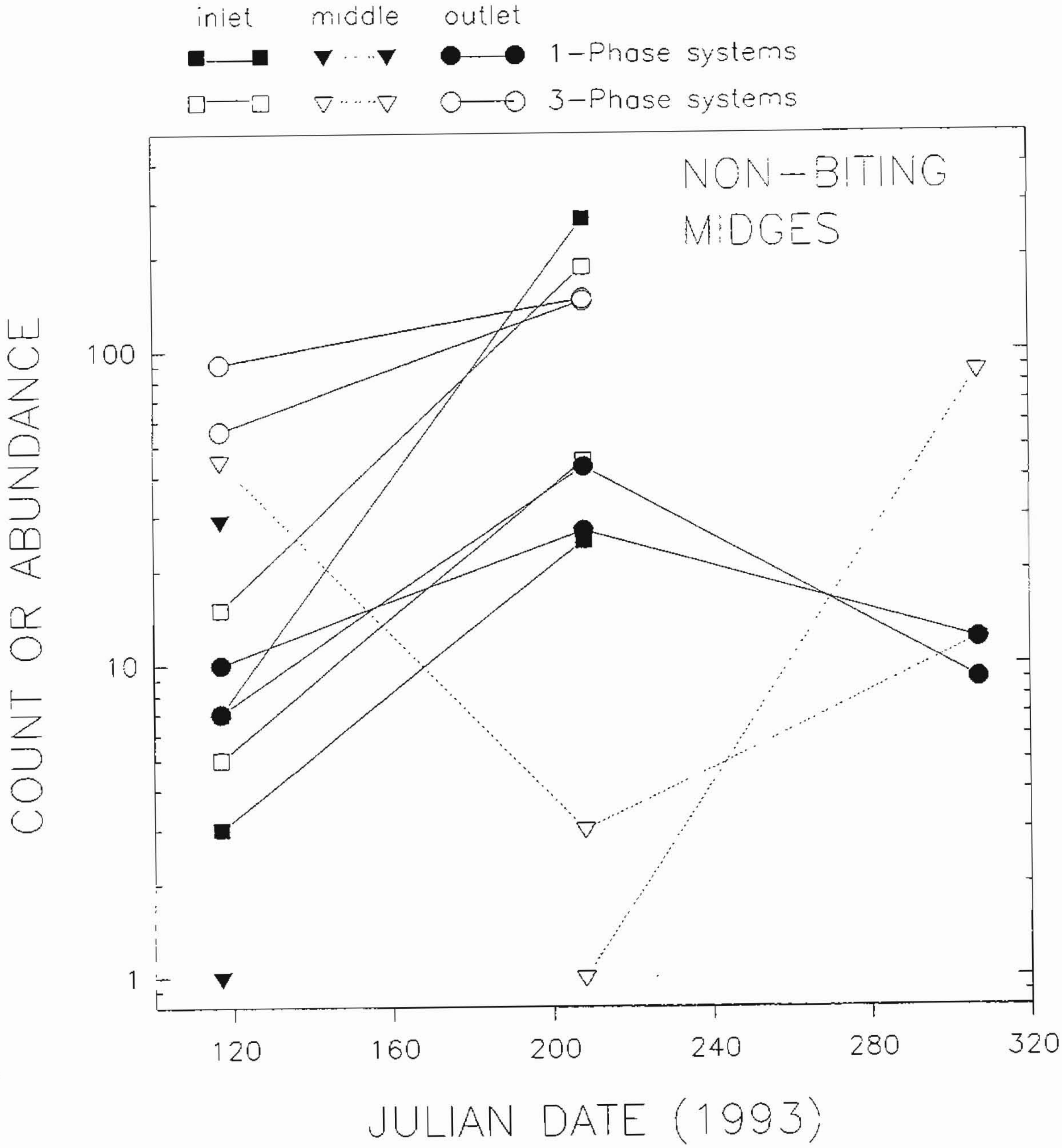


Fig. 4-36. Temporal change in counts of non-biting midge larvae (Chironomidae) associated with artificial substrates installed at inlet, middle, and outlet positions within 1-Phase research cells (cells 5 and 6) and 3-Phase cells (1 and 2) at the Hemet site in 1993 (Julian Date 44). Lines link counts from the same location (cell and position). Counts of zero are not shown due to the log scale, but all occurred during the first sampling (Julian Day 119), the only date when substrates from all cell/position combinations were collected (see Table 4-4).

FIGURE 4-37

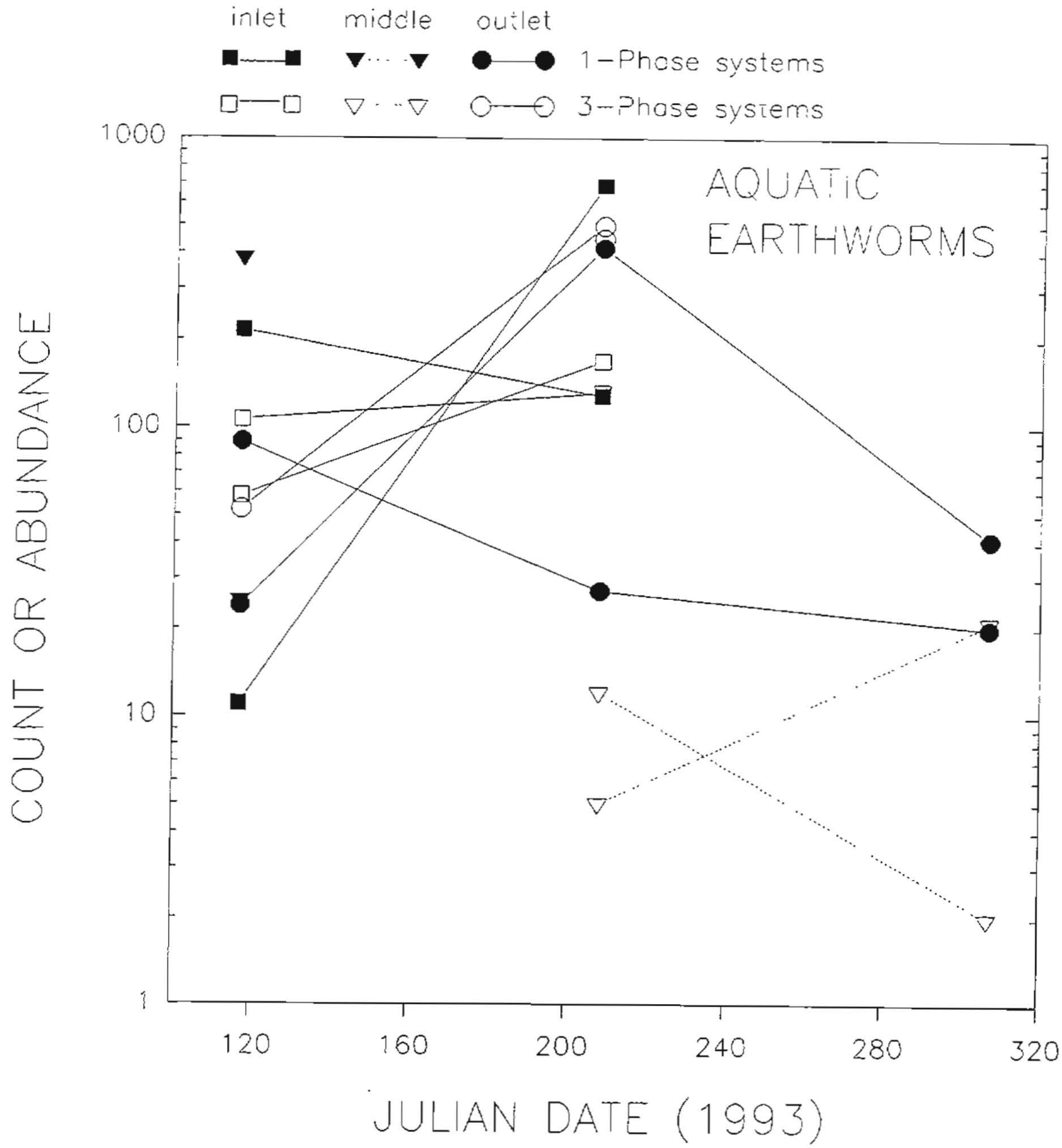


Fig. 4-37. Temporal change in counts of aquatic earthworms (Oligochaeta) associated with artificial substrates installed at inlet, middle, and outlet positions within 1-Phase research cells (cells 5 and 6) and 3-Phase cells (1 and 2) at the Hemet site in 1993 (Julian Day 44). Lines link counts from the same location (cell and position). Counts of zero are not shown due to the log scale, but all occurred during the first sampling (Julian Day 119), the only date when substrates from all cell/position combinations were collected (see Table 4-4).

FIGURE 4-38

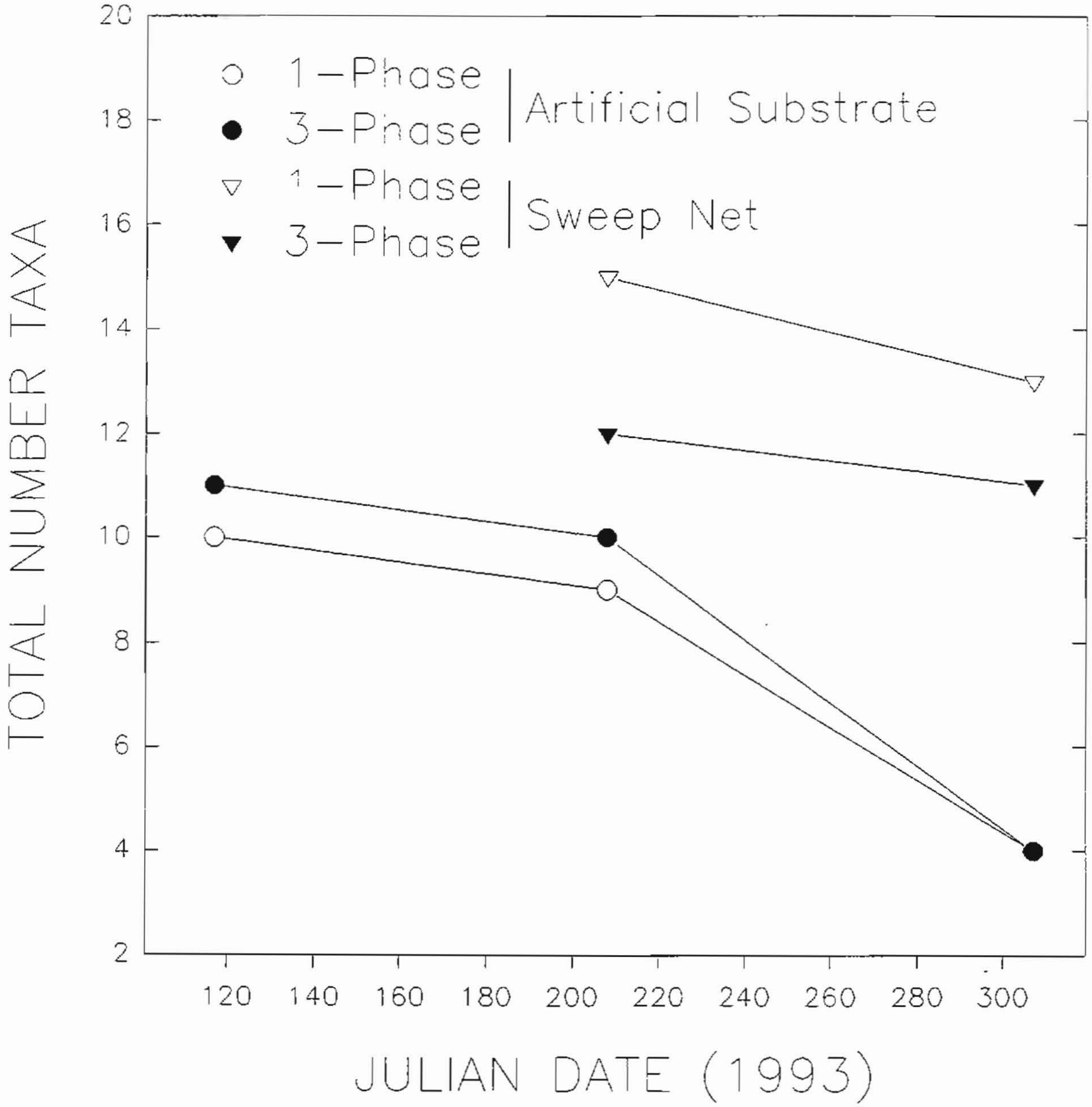


Fig. 4-38. Changes in total number of macroinvertebrate taxa collected (an estimate of biodiversity) in 1-Phase research cells (cells 5 and 6) and 3-Phase research cells (cells 1 and 2) at the Hemet site during 1993.

TABLE 4-7

ANALYSIS OF PARAMETERS SAMPLED YEARLY
IN SEDIMENT OF RESEARCH CELLS

Parameter (units)	Cell 1 - in 92/93	Cell 1 - out 92/93	Cell 2 - in 92/93	Cell 2 - out 92/93
Arsenic (ppm)	1.27/17	<1/21	<1/18	1.07/20
Selenium (ppm)	<1/<0.5	<1/<0.5	<1/<0.5	<1/<0.5
Mercury (ppm)	<0.07/<0.1	<0.07/<0.1	0.07/<0.1	0.10/<0.1
Boron (ppm)	16/5	14/6	14/5	19/6
Silver (ppm)	<0.1/<1	<0.1/<1	0.98/<1	1.11/<1
Aluminum (%)	1.4/1.1	1.3/1.3	1.3/1.1	1.35/1.2
Barium (ppm)	190/150	181/160	198/150	193/170
Beryllium (ppm)	0.73/<0.5	0.68/<0.5	0.66/<0.5	0.70/<0.5
Cadmium (ppm)	<0.2/2.4	<0.2/2.7	<0.2/2.4	0.22/2.7
Calcium (%)	0.96/0.67	0.85/0.79	0.84/0.64	0.87/0.87
Cobalt (ppm)	8.56/6	8.39/7	8.41/6	8.19/7
Chromium (ppm)	10.7/8	10.4/9	11.1/8	11.2/9
Copper (ppm)	7.81/8	7.59/9	18.9/14	20.2/13
Iron (%)	1.7/1.6	1.6/1.7	1.6/1.5	1.6/1.7
Potassium (%)	0.65/0.50	0.63/0.55	0.61/0.45	0.61/0.53
Magnesium (ppm)	7070/5400	6800/6000	6600/4900	6700/6100
Manganese (ppm)	281/250	268/270	269/230	264/270
Sodium (ppm)	2260/1000	2070/1300	2030/970	2500/960
Nickel (ppm)	6/4	5/5	6/4	6/5
Antimony (ppm)	6/2	6/3	4/2	5/2
Vanadium (ppm)	31.7/25	30.6/28	30.5/23	30.6/26
Zinc (ppm)	57.3/51	57.0/58	89.3/90	92.1/70
Molybdenum (ppm)	<0.5/<1	<0.5/<1	<0.5/<1	<0.5/<1
Lead (ppm)	-/<1	-/<1	-/9	-/3
Thallium (ppm)	-/<5	-/<5	-/<5	-/<5
$CaCO_3$ (%)	2.39/2.16	2.13/2.30	2.09/1.45	2.18/2.23
Organic C (%)	1.20/0.16	0.07/0.08	0.35/0.24	0.31/0.08
Clay Content (%)	18/1	4/1	10/<1	9/<1
CEL (meq/100g soil)	11/2.5	16/10.0	20/2.5	24/8.8

TABLE 4-8

NUTRIENT CONCENTRATION IN
SEDIMENT OF RESEARCH CELLS

Date	Nitrate (mg/kg dry wt.) Cell #1 in/out	Nitrate (mg/kg dry wt.) Cell #2 in/out	Total P (mg/kg dry wt.) Cell #1 in/out	Total P (mg/kg dry wt.) Cell #2 in/out	Ortho P (mg/kg dry wt.) Cell #1 in/out	Ortho P (mg/kg dry wt.) Cell #2 in/out
9/4/92	22/6	100/507	22/75	107/61		
10/6/92			Equipment Breakdown			
11/19/92	12/13	9/22	1351/1017	1669/1489	509/485	1229/1088
12/18/92	49/37	17/19	947/955	1501/2179	540/477	1033/1350
1/13/93	18/15	8/11	1012/1080	1575/1620	891/926	1225/1239
2/5/93	2/2	3/3	931/887	1581/1882	501/494	960/1013
			Spring Floods			
5/14/93	2/2	3/3	848/983	1433/1449	364/356	328/391
6/17/93	1/2	1/1	1667/3284	1516/2344	985/791	859/1078
7/30/93	13/14	11/11	957/972	1338/2029	449/338	779/797
8/17/93	10/11	9/12	843/914	1271/1406	457/457	757/797
9/14/93	>.5/>.5	>.5/>.5	791/705	1007/1151	4/4	5/5
10/21/93	>1/>1	>1/>1	837/727	884/1046	3/6	6/6

unlikely that the substrate would serve as a source for any toxic constituents. Instead, it was anticipated that the substrate would act as a sink, potentially removing certain constituents from the water through adsorption and precipitation processes. Little information is available regarding toxic concentrations in substrate. However, arsenic and cadmium have shown a considerable increase. It would appear that significant quantities of arsenic and cadmium are being brought into the wetlands via the treated wastewater. Both elements are common waste products. Arsenic is a component of many pesticides, wood treatment processes, and swine and poultry feed supplements. Cadmium is a by-product in the manufacture of paint, batteries, and textiles.

Arsenic and/or cadmium could have adverse impacts to wetland plants and animals if the lab data are correct and if the trend continues. Arsenic concentrations greater than 25 mg/L in the sediment may cause adverse impacts to sensitive plant species (Eisler, 1988). Initial symptoms include wilting, then decreased root and top growth. Precipitation is the primary removal mechanism for arsenic (McLean and Bledsoe, 1992). Little information is available regarding toxic concentrations substrate. However, cadmium concentrations from 0.8 to 9.9 micrograms per liter (μg/L) in water are lethal to several species of insects, crustaceans, and teleosts (Eisler, 1985). Adsorption mechanisms may be the primary source of cadmium removal (Dudley et al., 1991). Sediments may, therefore, reach a maximum capacity with regard to cadmium. At this point, cadmium concentration in the water would begin to increase.

Nutrient Availability. Nutrient availability is usually not critical in wetlands constructed for wastewater treatment. Inputs of nitrogen and phosphorus are generally considerable. Potassium levels in the bottom sediment of the research cells are low but still within the range of what would normally be considered adequate. However, it is possible that potassium might become a limiting factor in plant productivity.

Denitrification. Nitrate levels in the soil showed a sharp decline following the initial flood-up and have remained fairly stable since. This would indicate that nitrogen loss through volatilization during denitrification is occurring.

Phosphorus Removal. The effect of sediments upon phosphorus removal in the research cells remains unclear. No discernable trend is evident. The substrate can act as a source or sink for phosphorus. If the sediments were acting as a sink, as expected, a gradual increase in concentration should be evident.

Reverse Osmosis and Saline Marshes

Reverse Osmosis Unit Operations. Operation of the RO system began on May 3, 1993, using feedwater trucked in daily from the nearby Moreno Highlands well.

Initially, only a partial complement of six Filmtec BW30-2540 membrane elements was tested. This was done to observe the performance of the newly-constructed system without risking too many elements. On June 6, 1993, after a month of successful operation (i.e., without noticeable degradation in performance), the initial six elements were removed and replaced with a full load of 18. During the following 8 months of testing, a total of 1860 hours of RO operations were logged. In that time, 2.53×10^6 L (6.70×10^5 gal) of Moreno Highlands well water was processed yielding 1.90×10^6 L (5.02×10^5 gal) of product water and 6.34×10^5 L (1.67×10^5 gal) of reject brine. RO feed pressure averaged 1267 kPa (184 lb/in^2) during the 8 months. Average feed and product concentrations were 988 and 14.2 mg/L TDS, respectively. Given these concentrations, a 50:50 blend of the two would yield an effective total recovery of nearly 86 percent (RO system recovery was 75 percent) and a blended TDS of about 500 mg/L (California's secondary drinking water standard).

Except as noted below, the pilot plant performed as anticipated with minimal interruption caused by equipment or operational difficulties. Midway through the test period, some early signs of membrane degradation were observed, which was suspected of occurring from the weekly use of biocide Minncare™. Because the system operates intermittently (nightly and weekend shutdowns), which is uncharacteristic of most RO plants, the membrane elements have required periodic disinfection to avoid biofouling. The biocide Minncare was selected for this purpose because of its advertised compatibility with TFC membranes. During the first 1400 hours of operation, membrane salt rejection dropped slightly, by 0.35 percent, and normalized permeate flow increased by about 8 percent. Since Minncare contains hydrogen peroxide, a strong oxidant, as a principal constituent, it is suspected of causing some degradation of the membrane surface. To combat or slow down this degradation, the disinfection protocol was changed to include less frequent disinfection and weekend storage of the elements in dilute sodium bisulfite solution to inhibit microbial growth. Based on the last 200 hours of operational data (i.e., since the change in disinfection procedures), it appears that the salt rejection and normalized permeate flow values have leveled out.

Saline Marsh Plant Survival. Appendix D contains a representative selection of photographs of the vegetation in the saline marshes, showing the progression of growth. By July 1993 (3 months after planting), the alkali bulrush had spread to every available area in each cell except for the six bands where the spikerush were planted and at the inflow ends. Most of the original alkali bulrush plants had turned brown, but the plants were green, robust, and taller than the original plants. The spikerush were healthy and spreading, but flower and seed production was less than normal. Both smartweed species had been completely eliminated due to a combination of insufficient water (drying out some seedlings), too much water (drowning some seedlings), and bird predation. A few cattail plants, which came in on their own, were growing in both cells, and a few watergrass plants also began to grow. Although the cattails and watergrass appeared to be healthy, neither species spread a great deal, and cattail flower production was minimal.

Because the smartweed failed to survive, USBR personnel suggested in July 1993 that mature smartweed plants be transplanted from along the sides of the research cells into two bands in the saline marshes where smartweed seed and rhizomes had originally been planted. On August 25, 1993, EMWD personnel transplanted the smartweed and began making evaluations. Prior to transplanting, it was observed that the smartweed had set seed, and the plants lacked luster and vitality. Within 2 weeks, the plants appeared dead to the casual observer. The smartweed were removed, thus, no conclusions can be made regarding these species.

Throughout the first growing season, the plants appeared to be thriving, but, to the trained observer, some plants of each species exhibited stress (i.e., some browning, slower growth, less seed production). Both higher salinity and lack of water may have been contributing factors.

As of November 2, 1993, it was evident that the alkali bulrush, spikerush, cattail, and watergrass had survived in both cells, although plants were mostly brown due to the colder winter temperatures. A quillwort mat had formed in the inflow end of the north cell and appeared to be very healthy. Alkali bulrush seed was floating over the water surface in both cells.

The plants were brown throughout the winter because of normal seasonal dormancy. In the spring of 1994, plants regenerated by producing new growth from their rootstock. Although alkali bulrush seed was floating over the water surface in both marshes in the fall of 1993, no evidence of seed germination appeared in the spring. The new growth is very lush and tall, and all plants appear healthy. Cattails have expanded in the north marsh to about three times the area they covered in the fall. It is possible that, in addition to the change in seasons, the lush growth reflects the fact that brine flow into the marshes has been interrupted since February 4, 1994. Long-term evaluation using the appropriate water is, therefore, very important to accurately assess the final outcome of this pilot study.

Saline Marsh Water Analyses. The EC and TDS data are summarized in Appendix C. The mean (average of four sample sites) EC values for each saline marsh are listed in Table 4-9. The salt concentrations in the saline marshes were influenced by the occasional addition of fresh water, which was necessary to keep the marshes from drying out during peak summer evapotranspiration periods. The RO facility produces about 14.7×10^3 to 18.4×10^3 L (3880 to 4850 gal) of brine per week. Using data from the evaporation pan at the site to calculate water losses, evaporation from both marshes is between 15.9×10^3 and 21.2×10^3 L/week (4200 and 5600 gal/week). Thus, it was necessary to make up the shortfall by adding fresh water from the fire hydrant in front of the RWRF. Approximately 2500 gal of fresh water were added to each marsh on July 21, 1993, and again on August 13, 1993. In September, EMWD decided that, rather than continue adding fresh water to both marshes, all of the brine would be fed to the south marsh, and the north marsh would receive 100 percent fresh water. Thus, the south cell would not be diluted, and the north cell would act as a sort of "control".

The data in Table 4-9 show how the saline marshes gradually became more saline until the fresh water was added. Measurements taken immediately after the addition of fresh water to the north marsh on November 3, 1993, showed that the inflow end experienced an EC of 2070 μS/cm. The inflow sampling site on the south marsh was 6200 μS/cm at the same time.

Laboratory Water Quality Analyses. The analysis of the marsh influent (RO reject) on August 17, 1993, is contained in Appendix C. The constituents present above detection levels in mg/L were: arsenic (0.006), barium (0.22), copper (0.01), molybdenum (0.15), selenium (0.007), vanadium (0.02), zinc (0.05), iron (0.03), manganese (0.05), silicon (40.1), and boron (0.66).

Wildlife Observations. Wildlife usage of the saline vegetated marshes was documented on several occasions in 1993. Actual sightings, prints, scat, or sounds have provided evidence of usage. Raccoon and rabbit prints were observed as well as evidence that waterfowl usage occurred (e.g., paths and tunnels through the spikerush). Predaceous diving beetle larvae, beetles, and snails were also observed in the marshes.

During 1994, the usage has increased with the sprouting of the plants. Numerous tadpoles have been observed. Ducks, blackbirds, and a variety of invertebrates have also been observed in and around the vegetated marshes.

TABLE 4-9

The Mean EC (Electrical Conductivity) Data (in μS/cm) for Each Saline Vegetated Marsh by Sample Date

Date	MARSH South	MARSH North
7/13/93	7,123	6,543
7/14	7,125	6,670
7/21	7,708	6,895
7/23		(18.8 m^3 (5000 gal) of fresh water added each marsh)
7/23	2,985	3,083
7/28	6,495	5,230**taken by USBR Hydrolab
7/29	6,015	5,203
8/02	6,500	5,478
8/04	6,963	5,473
8/09	8,628	7,100
8/12	8,225	7,483
8/13		(18.8 m^3 (5000 gal) of fresh water added each marsh)
8/18	6,173	4,808
9/01	8,833	6,968
		beginning 9/20/93, 9.4 m^3 (2500 gal) of potable water was added about weekly to the North marsh
11/03	6,680	3,790**taken by USBR Hydrolab
12/02	5,095	no data *determined by EMWD lab
1/18/94	6,113	3,875
1/21	6,438	4,275
1/26	5,525	no data
2/24	2,525	1,350
3/03	2,900	1,625
3/11	3,150	1,813
3/18	4,075	2,375
3/28	2,275	1,675
4/04	2,900	2,125
4/19	2,725	1,913
4/27	1,988	1,575

Observations have confirmed the original assumption that wildlife would not be attracted to the evaporation cells. Because of their steep, nonvegetated sides and plastic lining, the evaporation cells provide no food, shelter, or nesting areas. Without those attractions, transient waterfowl do not linger around the cells, limiting their exposure to any concentrated constituents. Usage by waterfowl has been brief and transient. Two ducks were observed on different days in the evaporation cells, but they did not stay for more than 3 days. It has been observed that small mammals cannot get out of the evaporation cells once they get in due to the steep sides and smooth lining.

PART 3: CONCLUSIONS AND RECOMMENDATIONS

Many aspects of the EMWD/USBR/NBS Multipurpose Wetlands Research and Demonstration Project are ongoing. In particular, the research and monitoring efforts up to this point have been devoted largely to gaining data on baseline conditions or conditions during establishment of a mature wetlands system. Therefore, this section presents discussion and recommendations rather than final study conclusions.

Nursery Cells

The creation of a wetland nursery is recommended to provide adequate plant material for building large wetlands. The spacing of the plants in the nursery cells (112- by 112-cm (44- by 44-inch) intervals) produced dense vegetation in the 90 days from July 10 to October 8, 1991. The original plant material increased, on average, about 16 times during that period.

In September of 1992, the plant material in the southwest corner of the north nursery cell was used to vegetate the eight research cells. The one corner of material was sufficient to plant an area approximately 20 times its size. The 20:1 ratio will be tested again when the 0.4 ha (1 ac) of material in the two nursery cells is used to vegetate the 8 ha (20 ac) of marsh area in the demonstration wetland.

Various methods of removing bulrush from the donor sites and transplanting at the new site were evaluated. It was found that there was no difference between the use of a backhoe versus hand-digging with a shovel; however, use of a backhoe may cut labor costs. Trimming the plant tops made transport easier and appeared to stimulate new shoots.

Staking the bulrush root clumps on top of the dry substrate, then flooding, is recommended as the best planting technique. This technique produced the most rapid propagation, which, in turn, provided the shortest time to total coverage. This method proved to be the least labor-intensive and, therefore, the most cost-effective.

The addition of chlorine to the reclaimed water supply from October 1991 through January 1992 adversely affected the duckweed. The chlorine was added during this period to meet the regulatory requirements for use of reclaimed water by local duck clubs during the hunting season. The marsh was no longer improving the quality of the reclaimed water. The addition of chlorine may have been one of the causes. It was noted by January that the duckweed had disappeared in both cells. None of the other plant species appeared to be affected by chlorination. By April 1992, some duckweed had reappeared.

To prevent reoccurrence of this problem, a ratio-feeder dechlorination system was installed by EMWD in early 1993 specifically for the wetlands. Problems with clogging of the ratio-feeder screen by algae have made it very difficult to operate. As a consequence, EMWD is planning to construct a separate pipeline to the wetland cells in 1994 that will bypass the chlorination system.

Research Cells

Plant Growth. Rapid growth and establishment of bulrush, in terms of both new shoot numbers and culm height, was documented. This suggests that the combination of Hemet/San Jacinto climate and the soil and water constituents at this site created optimum conditions for bulrush propagation. New shoots per bulrush clump increased from an overall mean of 21.4 in October 1992 to 220.7 in April 1993 (over 10 times in 6 months). By July 1993, they were too dense to count accurately. Likewise, overall mean culm height had increased from 104 cm to 339 cm (3.4 to 11 ft) in 9 months. By November 1993 (14 months after planting), the bulrush culms were sufficiently dense and robust that the research cells were considered to be completely vegetated and established.

By November 1993, a great deal of lodging of plants had occurred probably due to their height and the strength of the Santa Ana winds, which were heavy at that time. Some bulrush plants showed chlorotic spots which were identified as fungus under the microscope. There was a question as to whether the spots could indicate a potassium deficiency. Since the soils data indicated that potassium levels in the sediments at the bottom of the research cells were slightly low, this is recommended as a subject of future research.

Wildlife Usage. Habitat creation, environmental enhancement, and wildlife usage were not design objectives for either the nursery or research cells. However, use by various forms of wildlife at the facility has been surprisingly intense. American coots and common moorhen were among the first to take up residence. Various ducks, herons, and other birds are frequently observed feeding or resting in the cells. Coots, moorhen, and mallard ducks have used the cells for nesting and rearing of

PHOTO 26. HABITAT CREATION; RUDDY DUCKS IN RESEARCH CELL

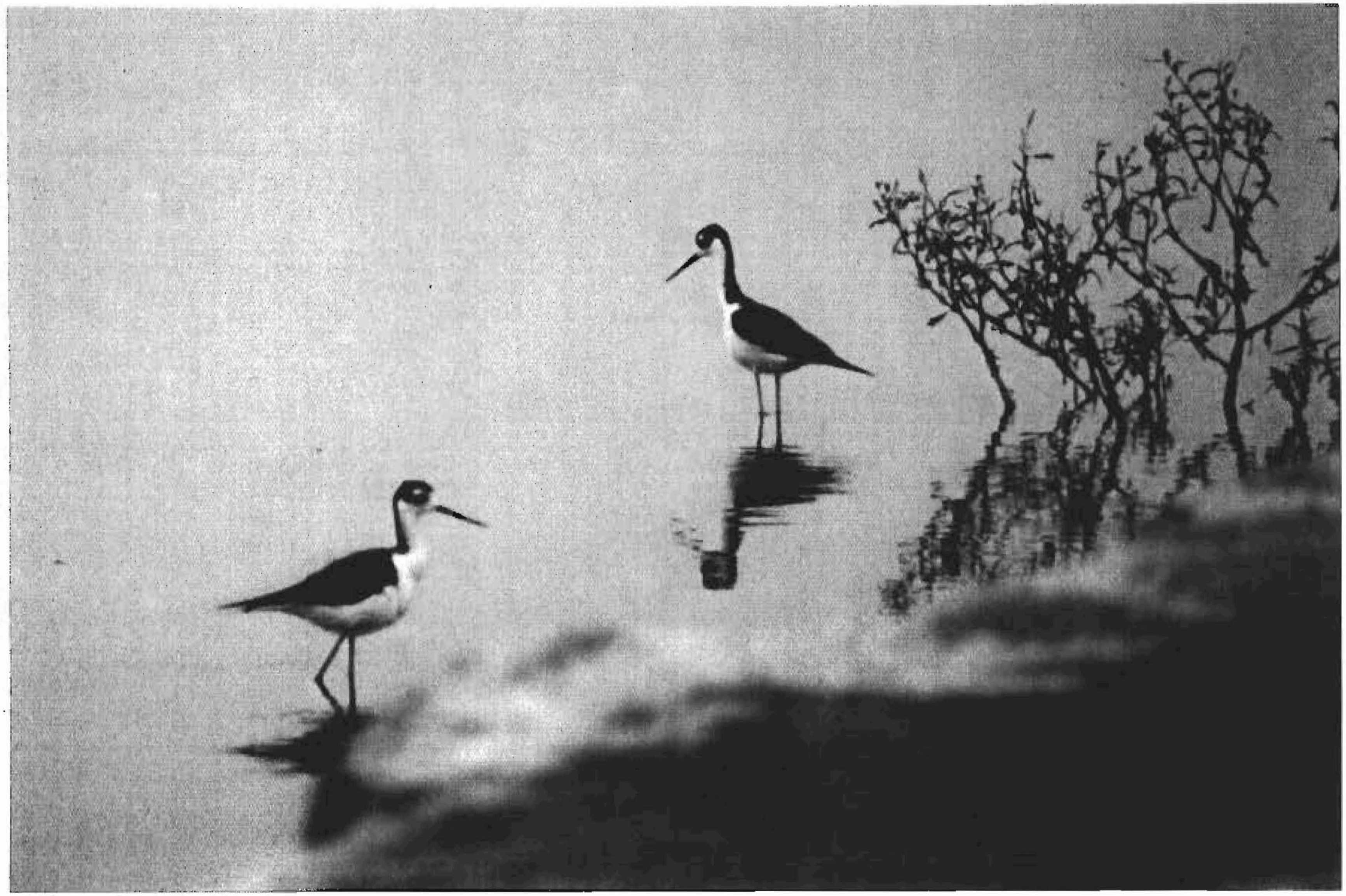
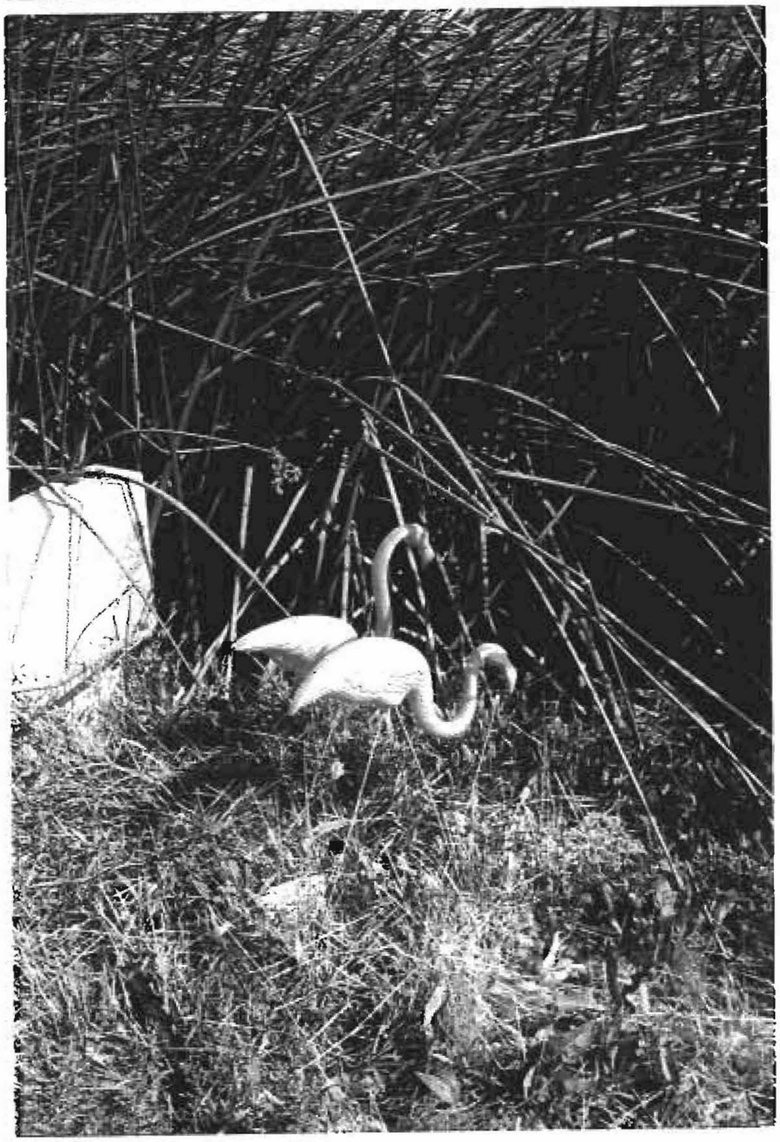


PHOTO 27. BLACK-NECKED STILTS AT HEMET/SAN JACINTO REGIONAL WATER RECLAMATION FACILITY



PHOTOS 28 AND 29.
RARE FLAMINGO PLASTICUS
SPOTTED IN RESEARCH CELL
DURING TECHNICAL ADVISORY
COMMITTEE'S VISIT

young. Ruddy ducks have bred, nested, and raised young in the three-phase cells for the last 2 years, but they have not been observed in the single-phase, fully vegetated cells.

Mammals that have either been directly observed by EMWD personnel or identified by prints or tracks include raccoon, skunk, coyote, mice, bobcat, opossum, cottontail and jack rabbits, and California ground squirrel. Some domestic cogs and cats from nearby farms have also visited the site. Gopher and garter snakes have been seen in and around the cells. Gambusia, or mosquito fish, appeared in the nursery cells, probably carried in by birds. They were then intentionally introduced into the research cells by EMWD personnel as a means of controlling mosquitos. They, along with frogs, tadpoles, and arthropods, provide food for many of the visiting and resident waterfowl.

The bird population at the Hemet/San Jacinto RWRF has been documented for 1 year by two graduate students from California Polytechnic University, Pomona, California. Their data are included in Appendix J. Approximately 100 species of birds are listed with dates and numbers of individuals indicated.

Weed Abatement. Weed growth along the banks of the research cells has become an O&M problem. Tumbleweeds, thistles, and other weeds as well as willow trees grew aggressively to such size and density that access to the inlet and outlet structures was restricted, roads along the berms were blocked, and the appearance of the cells was negatively affected. Various methods of weed control were attempted in an effort to remove undesirable species while allowing more desirable plants to remain--plants which provide ground cover, prevent erosion, and provide food for waterfowl.

It is recommended that the banks of future full-scale wetlands be seeded immediately after construction with desirable low-growing ground cover before weeds have a chance to become established. Plants that have value as a waterfowl food source are preferred. In addition, banks should be constructed with 4:1 side slopes to allow maintenance vehicles to get close to the water's edge, especially around inlet and outlet structures.

Water Quality Monitoring. The data indicate that the three-phase (marsh-pool-marsh system) cells are doing a better job of removing inorganic nitrogen from the treatment plant effluent than are the one-phase (uniform marsh system) cells. This may be due to better nitrification of the ammonia-dominated effluent in the pools of the three-phase cells. The data also suggest that a net loading of organic nitrogen may be occurring in both the three-phase and one-phase cells, perhaps from birds perching and nesting in the emergent vegetation of the marsh sections. This organic nitrogen load may account for the increase in ammonia nitrogen concentrations that has been observed at times in the outlets of both types of cells relative to the inflow concentrations.

It is impossible to be more specific in identifying the nitrogen transformation and removal mechanisms operating in the cells or to draw conclusions as to loading rates, retention times, and operating criteria because there was insufficient hydraulic control during the monitoring and because the data are not sufficiently detailed. The data collection program focused on the inlets and outlets of the cells and assumed a relatively steady inflow and outflow rate. As it transpired, the flow through the cells was highly erratic, and two flow meters were not enough to adequately monitor the flow variations.

In general, the research to date has raised questions about how much data is adequate to allow statistically-valid conclusions about wetland water quality dynamics. This question is important to answer before beginning the Series 2 research program. The paired sample t-test failed to show any significant differences in many of the water quality parameters measured when comparing influent and effluent samples or when comparing three-phase versus one-phase cells. This was attributed to the small number of samples and the large variance in their values.

How much data necessary is an interesting question because wetlands change in response to a variety of natural factors, such as weather and climate. Changes in the quality of the influent reclaimed water may also perturb the system. Both the invertebrate data and TSS data seemed to show trends that may have been seasonal in nature, but more data are needed to know whether the trends were seasonal or whether they simply indicated the trend toward establishment of an equilibrium condition as the wetlands became established.

The value of the Series 1 water quality data from the research cells is limited due to problems which were experienced with the control of inflow rates. While the average retention times in the three-phase and one-phase cells were roughly equal, there were nonetheless wide day-to-day fluctuations in influent flow rates. The original intent was to maintain a retention time of approximately 8 days in both the three-phase and one-phase cells, which required inflows of about 53 L/min (14 gal/min) and 37.5 L/min (9.9 gal/min), respectively. Mean daily inflows to the three-phase and one-phase cells during Series 1A averaged 32.2 L/min (8.5 gal/min) and 23.1 L/min (6.1 gal/min), respectively, and ranged from 0.0 to 139 L/min (0.0 to 36.7 gal/min). Average Series 1A retention times, based on the average of the mean daily inflow rates, were slightly more than 13 days for both the three-phase and one-phase cells. Longer than optimum retention times can lead to secondary effects within the cells that interfere with the treatment process and result in increases in some water quality constituents, such as BOD and organic nitrogen.

The fluctuations in inflow resulted from the fact that the water supply line for the research facility was tied into the main supply line serving reclaimed water to agricultural users. In the summer, the demand for reclaimed water was very high and also very variable based on the patterns of a few large agricultural users. When agricultural demand suddenly increased, the RWRF operators did not always respond to ensure that there was not a pressure drop in the supply line to the wetlands. EMWD is designing a new supply line for the research facility to solve that problem; completion is expected in September 1994. Since the Series 2 monitoring program is expected to begin in July 1994, an interim solution is also under investigation.

Another factor which may have affected the flow variability was the use of a portable, manually-operated pump in the collection sump for the effluent from the research cells and nursery cells. The collection sump had to be periodically emptied into a larger reclaimed water storage pond. The pump was a problem for the RWRF operators because it had to be manually turned on and off and sometimes moved to other locations. To correct this problem, in April 1993, an automatic floating submersible pump was designed, fabricated, and installed by EMWD.

A third modification has recently been made to improve the distribution of flow to the research cells. A pipeline was installed along the west end of the research facility that ties together the influent supply lines running along the north and south sides. This completes a circuit around the facility rather than having dead-end supply lines.

Invertebrate Monitoring. The results of the benthic macroinvertebrate monitoring were unexpected in that a decline in species richness over time was observed. Further, there was no pattern in abundance or richness of benthic invertebrates that could be interpreted as indicating that an "equilibrium" condition had been attained within either the one-phase or the three-phase research cells. The data collected to date suggest that the invertebrate assemblages within the cells are undergoing either seasonal shifts that mask equilibrium or a general shift in composition toward an equilibrium that has yet to be attained.

It is recommended that the benthic macroinvertebrate sampling be continued in the Series 2 monitoring program. The original objectives remain appropriate and should be pursued. More data are needed in order to be able to distinguish between annual cycles and long-term trends. Identification of seasonal and long-term cycles will have implications for the frequency of monitoring in the Hemet/San Jacinto demonstration wetlands, which is under construction.

The main problem which was encountered in the invertebrate monitoring was placement and retrieval of artificial substrates in the dense bulrush. At the time of the July 1993 sampling, bulrush density was high, and the normal intertwining of the plants' drooping stems made travel through the stand extremely difficult in some areas. The original planting rows had grown together so that the rows, used to identify locations of the clusters of artificial substrates at the time of their installation, were no longer discernable. Some of the artificial substrates could not be located or retrieved.

Based on these problems, future research will require creating a means to ensure collection of all substrates. It is recommended that a path leading to substrate locations be created and maintained by cutting of vegetation at or below the waterline. Each path should be marked at its origin and at about 1-m intervals with brightly-colored stakes that extend at least 15 cm above the waterline. The positions of substrates should be marked with flagging on overhead vegetation or by other means. In addition, anchoring points for research boats are recommended in open water areas to allow more accurate placement of sampling materials.

Saline Vegetated Marshes

The amount of brine produced by the RO was insufficient to supply both the north and south marshes during the first year because evaporation rates exceeded inflow during the hot summer months. During the second year of operations, all of the brine will be fed to the south marsh, and fresh water will be fed to the north marsh as a control. Both the brine and fresh water flows will be kept at a constant rate as nearly as possible, and the flows will be recorded. Rainfall and evaporation rates will continue to be recorded.

Detailed protocols for all of the types of analyses that are called for in the research program were not available in 1993. A proposed Saline Marsh Monitoring Program (dated July 5, 1994) is contained in Appendix E. It contains more specific protocols for performing the types of analyses that are outlined in the Research Program. It explains record-keeping procedures and provides monitoring frequencies and dates.

Soil, plant, and benthic invertebrate tissues will be collected from both marshes and analyzed for trace elements. If funds are obtained, benthic samples will be split, and the organisms in one split will be counted and identified to determine diversity while the other split is analyzed for trace elements. Water samples will be collected and analyzed annually for specific ions, trace elements, and other constituents. Trace elements will be analyzed more frequently (e.g., monthly) if funds are available. In situ EC, temperature, and TDS measurements will be continued on a weekly basis. Data will be provided to experts in wildlife toxicology.

CHAPTER 5
PUBLIC INVOLVEMENT

CHAPTER 5

PUBLIC INVOLVEMENT

INTRODUCTION

Public involvement is a process, or processes, by which interested and affected individuals, organizations, agencies, and governmental entities are consulted and included in decision-making. In addition to informing the public, public involvement programs solicit public response regarding the public's needs, values, and evaluations of proposed solutions. Before the public can become involved, they must be informed. Therefore, education is a critical element of any public involvement program.

The shifts in social values by which governmental actions are measured and the loss of governmental credibility have affected all aspects of government at all levels. Many agencies, which once considered themselves to be "the good guys", now find themselves being challenged, questioned, and criticized. The benefits of a public involvement program can far surpass the particular project for which the program was designed. The overall image of an agency can be positively affected and the program originator viewed as an environmentally aware, concerned, and responsible agency. Public input can provide unanticipated perspectives and information which can greatly enhance any project.

The use of a public involvement program is analogous to preventive medicine. If any proposed project is controversial or contains potentially misunderstood or controversial elements, the use of a public involvement program can redirect opposition into positive participation. Through the development and implementation of a good public program, the Multipurpose Wetlands Research and Demonstration Project will, hopefully, be received favorably by the general public and the environmental community. By informing and involving the public, support for the Multipurpose Wetlands Research and Demonstration Project, districtwide water resource management plans and perception of EMWD itself as a trustworthy, environmentally-aware, and concerned service agency can be achieved.

MAJOR ISSUES

The major informational issue is the feasibility of using multipurpose constructed wetlands incorporating wastewater treatment, recovery, and reuse with wildlife values, public education and recreation opportunities, and other public benefits as part of a total water resources management plan.

Potential issues of concern include the use of reclaimed water, mosquitoes, proximity of duck hunting clubs to bird watching areas, and/or cost to the consumer.

PUBLIC INVOLVEMENT PROGRAM GOAL AND OBJECTIVES

Goal: To develop acceptance of the Multipurpose Wetlands Research and Demonstration Project with the resultant acceptance of the use of reclaimed water.

Objectives:

1. Inform public of the Multipurpose Wetlands Research and Demonstration Project;
2. Identify public concerns and values; assess levels of interest in projects; and address concerns, if any;
3. Develop a consensus on the value of the project and the use of reclaimed water to the region;
4. Promote participation in the project by diverse groups and interests; and
5. Encourage public input as to the amenities to be included at constructed wetland sites with regard to the locations of future wetlands sites.

TARGET GROUPS

1. Local Groups. Citizen groups comprise the arena most commonly thought of as "the public", though there may be overlap within groups. In any area with a large population of retirees, senior citizen groups are very aware, interested, and active in community affairs. Members of civic and service groups are interested and involved in their community and provide an organized forum for the dissemination of information and opinion-gathering. Service organizations such as Rotary, Lions, or American Business Women's Association provide ideal forums for educating the public. In addition, they frequently contain the "movers and shakers" and are, consequently, important advocates.

Schools/Colleges. This project offers a natural opportunity and vehicle to educate young people about water and, in the process of establishing rapport with school systems, to also extend that element to the staff and parents. We do not want our young people to have misconceptions about reclaimed water, its reuse, or water quality in general. These are our future voters and home owners; educating them and including them in the process can be of great benefit to EMWD. In addition to educating students about water, we can raise their level of awareness of the variety of potential work opportunities in resources management and the need for the appropriate education to qualify for such opportunities.

EMWD Employees. A major opportunity for public information is education of employees. Although an employee may know his/her job and do it well, he/she does not automatically know what is happening outside his/her immediate area of activity. Employees who are kept informed of EMWD's policies and programs will improve performance and have job satisfaction because they have a common goal and a feeling of being valued. These same employees "represent" EMWD in their personal contacts throughout the community; therefore, having well-informed employees is important for effective management and for improving community relations. Employee education activities can include employee newsletters, tours, and briefings or presentations. A brochure about the project containing facts and figures for the employee to refer to and share with friends, relatives, and neighbors provides an inexpensive means of disseminating information. Responsibility for operation of the constructed wetlands will be turned over to the Operations Branch; therefore, it is important to include them early in the process.

2. Regional Groups. The Planning Task Force (PTF) is comprised of elected representatives of the cites of Hemet, Moreno Valley, Murrieta, Perris, San Jacinto, and Temecula; the Riverside County Board of Supervisors; and water agencies, including Lake Hemet Municipal Water District, Murrieta County Water District, Rancho California Water District, and EMWD. The PTF provides a forum for inter-agency collaboration to ensure long-term availability of water resources and to develop planning and finance strategies which integrate water and environmental resources to formulate programs that are cost-effective while addressing environmental issues and meeting societal needs.

EMWD also participates in quarterly planning meetings with the Directors of Public Works and Directors of Planning with the Cities of Hemet, Moreno Valley, Murrieta, Perris, San Jacinto, and Temecula. The purpose of these meetings is to share information, coordinate planning efforts, and avoid duplication of services.

Involving and informing the above entities with regard to the multipurpose constructed wetlands is an ongoing effort consisting of written materials, presentations, site tours, and briefings, and serves as a mechanism for providing information to and receiving input from a broad public base.

3. Regulatory/Governmental Agencies. Other governmental agencies should be thought of as "public" just as various interest groups or individuals are. Like any public, they are likely to feel resentful and put upon if not consulted, or if included too late, in the decision-making process. Of primary value in working with other governmental agencies is that they are an important source of information on both technical matters and public preferences.

Various Federal, State, and local governmental agencies were included in the review of the Multipurpose Wetlands Phase I Report and will continue to be consulted and asked for input. Governmental agencies are well-represented on the Technical Advisory and Technical Review Committees or are included on an informal basis.

They include the State Water Resources Control Board and Regional Water Quality Control Board; Departments of Health Services: State, County, and local; State of California Department of Fish and Game and the United States Fish and Wildlife Service; local units of government: cities, county; PTF members; and the United States EPA.

4. The Environmental Community. These are the very groups that frequently find themselves in adversarial positions with respect to water purveyors and public agencies. The study is an ideal project with which to build rapport with these groups due to the habitat creation, environmental enhancement, and educational elements of the project. Environmental groups active in the area include the Audubon Society, Sierra Club, Friends of Northern San Jacinto Valley, Moreno Valley Ecological Protection Committee, California Waterfowl Association, and Ducks Unlimited, Inc.

A representative from Ducks Unlimited, Inc. serves on the TAC and various environmental groups were asked to review and comment upon the Phase I Report. The Hemet/San Jacinto site is a favorite with local bird watchers and is one of the locations made available to and used by the Audubon Society for its Annual Christmas Bird Count. The California Waterfowl Association is interested in putting wood duck nesting boxes at the constructed wetlands and is willing to provide advice and assistance.

PUBLIC INVOLVEMENT TECHNIQUES AND STRATEGIES

1. TAC and Technical Review Committee (TRC). The TAC and TRC reviewed and commented upon the Phase I Report. This process will continue with subsequent documents. Individuals and organizations are frequently added to the review process. In addition to the regulatory and governmental agencies listed above, the TAC includes representatives from Humboldt State University; the Graduate School of Public Health, San Diego State University; the University of California, Riverside; and Ducks Unlimited, Inc. The TRC is even broader, including additional representatives of governmental and regulatory agencies, local entities, and environmental groups.

2. Presentations/Briefings/Promotional Materials. Numerous presentations have been given and will continue on an ongoing basis. Diverse groups have shown great interest in the project. Presentations have been made in-house and/or on-site, to visiting dignitaries and international visitors, to local groups and schools, to academicians and water industry technicians, to EMWD/USBR/NBS staff, and to representatives of environmental interests.

USBR, Lower Colorado Region, produced a 9 1/2 minute video which has been shown and distributed with very positive results. Constructed Wetlands: Helping Man

PHOTO 30. MEMBERS OF THE TECHNICAL ADVISORY COMMITTEE AND EXECUTIVE COMMITTEE

and Nature provides an overview of the project, discusses goals and objectives, and reports preliminary research results. It is suitable for all segments of the population.

An extensive collection of color 35 mm slides has been developed for use in presentations, publications, and promotional materials. An informative newsletter is produced and distributed to interested individuals and groups as well as brochures, booklets, and other descriptive materials.

Technical papers and conference presentations have been made by both EMWD and USBR staff. A listing of papers and publications is included in Appendix H.

3. Site Tours. The Hemet/San Jacinto RWRF sites, the EMWD/USBR/NBS Wetlands Research Facility and the Multipurpose Constructed Wetlands, are visited by a wide range of groups. Local elementary and high schools utilize the site for environmental science field trips to learn about wetlands ecology, the local environment, the value of reclaimed water, and the importance of water as a precious and finite resource. EMWD staff have developed educational resource materials for use with school children at the wetlands and by teachers in the classroom.

A graduate student from California Polytechnic University, Pomona, is compiling a species list and bird census at the Hemet/San Jacinto site and has introduced banded, juvenile burrowing owls at the site as part of a research project.

International interest in the project is evidenced by the number of foreign visitors who have toured the site including two groups from Australia, one from Taiwan, another from the Peoples Republic of China, and participants from 14 countries as part of the Middle East Peace Process, sponsored by the United States Department of State and the Agency for International Development.

National, Federal, regional, and local visitors also frequent the site. It is anticipated that the public will provide input and some assistance with regard to the type of amenities (walking/jogging/bike riding trails, bird/wildlife watching points, and other) to be incorporated into the large-scale constructed wetlands. In the future, the public could suggest sites for wetlands in the PTF Multipurpose Corridor.

EVALUATION

The success or effectiveness of a public involvement program cannot always allow for quantifiable, objective measurement. However, it is not difficult to determine the general level of acceptance and interest in the project based on requests for information and tours, the tone of newspaper articles or stories, the use of the site by educational groups, and cooperation by environmental groups. Effectiveness can also be measured by volunteer hours or monies contributed to the project for such diverse items as docents, interpretive guides and signs, or wildlife-watching platforms; letters of endorsement, praise, or awards; participation from environmental or governmental groups; or utilization of facilities by the public for passive recreational activities.

Awards presented to the project include:

- AMSA Research and Technology Award for 1994;
- California's Local Government Commission 1992 Award for Innovation in Water Conservation, Reclamation, and Management; and
- Inland Empire West Resource Conservation District, 1993 Conservation Partnership Award for Water Quality.

A chronological listing of presentations, tours, awards, visitors, newspaper articles, and other pertinent events is included Appendices F through I.

PHOTO 31. PUBLIC BENEFIT: SCHOOL CHILDREN STUDYING WETLANDS ECOLOGY AND RECLAIMED WATER REUSE

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